Geochemical perspectives on the sedimentary rock cycle of Mars

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Evidence from orbital imaging and spectroscopy, *in situ* study of six landing sites and a variety of experimental and modeling studies indicates that Mars has possessed a dynamic sedimentary rock cycle throughout most of its geological history. Martian crust, much older on average than Earth's continental crust, is dominated by chemically diverse basalts, rather than evolved granitic rocks characteristic of terrestrial upper continental crust. This in turn imposes distinctive chemical and mineralogical compositions onto both clastic and chemical sediments. Accordingly, sedimentary mineral associations on Mars (sands, clays, chemically precipitated constituents) tend to be Fe- and Mg-rich and Na- and K-poor compared to comparable terrestrial settings, and also contain significant amounts of amorphous sedimentary silica.

Surficial processes, including aqueous alteration, chemical sedimentation, diagenesis and sedimentary recycling, commonly are influenced by relatively acidic conditions, with implied pH less than ~4-5. Surface soils and ancient sedimentary rocks commonly are enriched in S in the form of a variety of Ca-, Mg- and Fe (III)-sulfates (Cl is also enriched), ultimately due to the absence of plate tectonic recycling. Accordingly, the sulfur cycle, with strong S-based acids, rather than the carbon cycle, and associated weak C-based acids, dominate most natural waters. Evidence for distinct mineralogical epochs further suggests that the nature of the S-cycle has changed over geological history but details are not yet fully understood. For example, orbital spectral observations suggest that Fe-rich clay-bearing layered deposits may be restricted largely to the early Noachian, possibly suggesting that low pH conditions were less prevalent at that time. During late Hesperian through Amazonian times, the amount of S delivered to the surface by volcanic processes was greatly diminished leading to crustal recycling processes (e.g. impacts, Fe-sulfate oxidation) dominating the S-cycle.

Although evidence for aqueous conditions abound, several lines of evidence suggest that most water-rock interaction took place under water-limited conditions. Thus there was limited plagioclase alteration, absence of expected water mediated diagenetic reactions such as clay transformations and amorphous silica recrystallization and limited lithological differentiation between clastic and chemical constituents.

The role of abyssal ocean circulation in abrupt climate changes in the past

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Numerical and conceptual models invoke a potential role for the ocean's large-scale circulation in past and potential future climate changes. These models may lead to an exaggerated impression that this ocean-climate linkage is well established and understood. Here we focus on specific intervals of past climate change, including a time and a location for which most climate influences were of opposing sign to previously inferred changes in circulation. We discuss new and exisiting geochemical evidence for changes in the Atlantic's meridional overturning circulation (AMOC) and the climate of the North Atlantic region during the last deglaciation and within the last ice age.

At a time when the global and regional climate influences of summer insolation, atmospheric grenhouse gas concentrations, retreating ice sheets and declining albedo all combined for a tendency for warming in the northern hemisphere, our evidence confirms that the deglacial iceberg discharge Heinrich event, H1, was associated with a weakening of the AMOC and a dramatic cooling at sites in the North Atlantic. A particularly strong line of evidence came from sedimentary $^{231}Pa/^{230}Th$ from the Bermuda Rise, and alkenone Uk37' sea-surface temperature estimates from the Iberian Margin, individual records from distant locations with potential competing influences on the respective geochemical signals.

Our results include new $^{231}Pa/^{230}Th$ measurements from the deep western boundary of the Atlantic, along with indicators of particle-scavenging, productivity, and a high-resolution TEX86 sea-surface temperature measured on the same core previously studied on the Bermuda Rise, in addition to physical, isotopic and geochemical for comparable changes within the last ice age. These will be discussed in the context of other sedimentological, faunal, isotopic and elemental data indicating that despite the occasional confluence of multiple warming influences, when the MOC weakened, the North Atlantic region cooled, on millennial timescales, beyond even the conditions of the last glacial maximum.