THE MINERALOGICAL EVOLUTION OF SEDIMENTARY SYSTEMS ON MARS. R. E. Milliken[1], [1]Jet Propulsion Lab/Caltech, MS 183-301, 4800 Oak Grove Dr., Pasadena, CA 91109 (Ralph.Milliken@jpl.nasa.gov)

Introduction: A major development in our understanding of Mars geology over the past several decades has been the clear detection and identification of sedimentary systems in the Martian rock record. Stratified deposits are present in terrains of various ages [1], deltas and fans have been observed in both closed and open basins [2-4], and minerals requiring the presence of water have been detected in these environments [3-7]. Of particular interest has been the observation that clay minerals and sulfates are separated in the ancient rock record both in space and time, and this has been used to suggest that Mars experienced a dramatic change in climate and weathering in its early history (>3 Ga) [8]. In order to fully test this hypothesis it is necessary to identify key stratigraphic sections on Mars that record these changes in mineralogy and in which the full mineral assemblages can be identified; thick, intact sedimentary sequences are a natural starting point for defining such 'reference' sections [9].

Clays on Ancient Mars: Phyllosilicates, primarily smectite, chlorite, and kaolin group minerals, have been detected in thousands of outcrops in Noachian-aged terrains on Mars using visible-near infrared reflectance spectra [5-6]. Recent studies have focused on the identification of Fe/Mg smectites in rocks in Mawrth Vallis, Nili Fossae, the southern highlands, and Gale Crater [5,9-12]. However, burial diagenesis on Earth typically results in smectite being converted to mixed-layered clays (e.g., corrensite) and ultimately illite or chlorite. Yet on Mars it is intriguing that some smectites are buried beneath several kilometers of rock and have not experienced this conversion [9], indicating that fluid flow may have been quite limited in some of these sedimentary environments [13]. Alternatively, some clays that have been previously identified as smectites may in fact be mixed-layered smectite-chlorite, which may indicate burial diagenesis [14].

In addition, many sedimentary environments on Mars, including the Eberswalde delta, exhibit only clay minerals as the alteration component. If the parent material is assumed to be basaltic in composition then one would expect smectites to co-exist with complementary salts (e.g., chlorides, sulfates, hydroxides, etc.) due to the excess in cations produced when forming smectite from basalt [7]. Therefore, current orbital data do not always provide the 'full picture' of mineral assemblages in what are otherwise recognizable sedimentary systems from a morphological perspective (e.g., the Eberswalde delta is in a closed basin but exhibits no evidence for evaporites).

These 'missing salts' and the apparent discordance in the rock record may be resolved if we can define stratigraphic sections on Mars that i) are continuous or contain clearly recognizable unconformities, ii) record variations in mineralogy and/or depositional environment with stratigraphic position, iii) are representative of local/regional processes that can be placed in a clear global context, iv) can be linked together in time and space to build a global stratigraphy for Mars. The identification of such reference sections is ultimately necessary to understand and independenty evaluate the climatic and geologic evolution of the red planet on a variety of spatial scales.

Until landers or rovers are capable of absolute age dating of the martian surface, it is reasonable to begin this process by examining thick sequences of sedimentary rocks, which arguably span more time, for which relative ages between units are clear. Gale Crater presents one such example, in which the lowermost strata contain clay minerals (nontronite) and sulfates, the overlying strata are dominated by sulfates, and the uppermost and thus youngest strata lack evidence of hydrated phases [9]. This evolution in the dominant alteration mineral assemblage through time is largely consistent with the hypothesis of Bibring et al. [8], who proposed that Mars transitioned from a climate favorable to clay formation to an acidic environment that favored sulfates, though Mg-sulfates at Gale do not require high levels of acidity to form.

Steps Forward: Determining which minerals and depositional settings (e.g., fluvial, lacustrine, alluvial, etc.) are recorded in martian sedimentary rocks is crucial for understanding climate evolution and identifying the primary volatile involved in crustal weathering on early Mars. As we continue to tackle this matter it is useful to be guided but not blinded by our terrstrial experience. The lack of plate tectonics and crustal recycling on Mars provides a unique opportunity to study the long-term stability of clay minerals and sulfates on timescales not accessible in the terrestrial rock record. In this aspect, ancient sedimentary systems on Mars may have just as much to teach us about evolution of the early Earth as our knowledge of Earth does about the geological evolution of Mars.

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