THE USE OF MINERAL FACIES MODELS OF TERRESTRIAL SALINE LAKES AS POTENTIAL GUIDES TO THE ORIGIN OF MARTIAN PHYLLOSILICATES. T. F. Bristow[1] and R. E. Milliken[2], [1]NASA Ames Research Center, MS 239-4, Moffett Field, CA 94035 USA (tbristow@jpl.nasa.gov), [2]Department of Civil Engineering and Geological Sciences, University of Notre Dame, Notre Dame, IN 46556 USA.

Introduction: Phyllosilicate minerals provide important constraints on ancient conditions on Mars. The proposed temporal restriction of clay-bearing deposits is used to define an era in Martian history (>3.5 Ga) that was wetter and possibly more hospitable for life [1,2]. However, a barrier to gleaning more specific information from the clay mineral record, regarding spatial and temporal variability of conditions within this period is the fact that specific types of clay minerals are non-unique in terms of their origin [3,4]. For example, Mg-Fe smectites, that are widely distributed on Mars, are typical products of the weathering and hydrothermal alteration of basalts on Earth, but they are also common constituents of modern and ancient terrestrial lake sediments deposited under alkaline/saline conditions, which promote their formation [3,4]. As on Earth, clay formation likely occurs in a variety of settings on Mars.

One possible approach for distinguishing the origin of clay minerals on Mars is to look for spatial and stratigraphic distribution patterns and compare these to models of specific environmental settings. In this contribution, we focus on the spatial and stratigraphic distribution of clays and associated minerals forming *in-situ* in hydrologically closed terrestrial lacustrine systems and restricted marine basins. The goal is to highlight patterns and features that can be integrated with morphological evidence to determine if certain Martian clay deposits may have a lacustrine origin and whether or not any of the observed clay minerals formed *in situ*.

The motivation stems, in part, from the fact that clay-rich lacustrine deposits on Mars are prime targets in the search for organic remnants of ancient life [5]. In addition, if clays can be shown to form *in situ* they can be used as indicators of local environmental conditions and aqueous chemistry at the time of their formation.

Controls on clay minerals in lakes: A wide variety of Mg-Fe-rich clay minerals form in terrestrial saline lakes and restricted marine basins, reflecting the broad range of chemical conditions in these settings [3,4,6]. The most important factors influencing the clay that form are salinity, pH, supply of reactive detritus (often a precursor clay) and redox conditions [4,6,7,8]. Low salinities and near neutral pH tend to favor the formation of fibrous clay minerals like palygorskite and sepiolite, whereas higher salinities or pH (at moderate salinity) tend to favor sheet phyllosilicates, like saponite, that is commonly identified on Mars [8]. In the most concentrated brines the types of clays that form show pronounced pH dependence. Highly alkaline conditions favor the formation of Mg-rich illite at the expense of smectitic clays [9], whereas highly saline but near neutral waters promote chloritization [3].

It is crucial to realize that the change in pH of brines during evaporative concentration is largely governed by the dominant anion in the initial fluid. Carbonate dominated waters will become progressively more alkaline during concentration, whereas chloride and sulfate rich waters remain near neutral [10]. This 'chemical divide' is reflected in different sequences of clay minerals that form; a potentially useful observation for inferring the water chemistry of ancient Martian basins.

Fe-rich clays like nontronite and Fe-illite form in terrestrial lakes over a wide range of salinities and pH values, but typically require local reducing conditions for the mobilization of Fe and incorporation into clays [4, 11].

It should also be noted that authigenic clay minerals are often accompanied by other authigenic phases (e.g. zeolites, evaporates, carbonates, phosphates and silica) that may be indicative of particular conditions. Recognizable assemblages of minerals that are characteristic of a particular depositional setting and conditions are known as mineral facies [12].

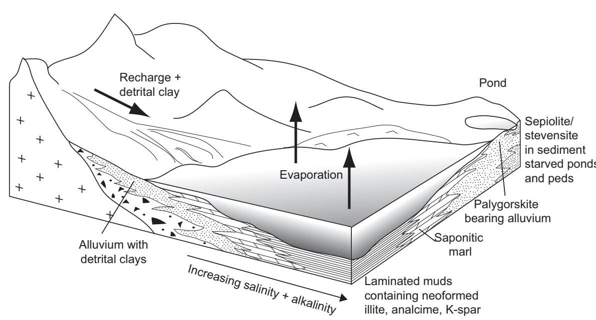

Figure 1. Cartoon showing the distribution of clay minerals (authigenic and detrital) in an idealized alkaline lake (adapted from similar diagrams in refs. 4,6). The types of clays in sediments reflect spatial variability in conditons that characterize these systems.

Spatial and stratigraphic trends: Hydrologically closed lakes and restricted marine basins are dynamic environments that often exhibit considerable spatial and temporal chemical variability. Under the right conditions this diversity is recorded by authigenic mineral assemblages in sediments, giving rise to distinctive spatial and stratigraphic arrangements of mineral facies [4,6,12].

Concentric arrangement of mineral facies. Freshwater recharge at basin margins and evaporation at the basin center often lead to strong lateral chemical gradients in closed lake systems (fig. 1). A number of ancient terrestrial lacustrine deposits (from Spain, SW USA, France and East Africe) exhibit concentric arrangements of mineral facies (including different types of clay minerals) that record chemical gradients, as well as reflecting greater availabity of reactive clay detritus in marginal areas [4,6,9,12]. The Parachute Creek Member of the Eocence Green River Formation is a good example, with; 1) heterogeneous clay mineral mixtures of detrital smectite, kaolinite, and illite in fluvial deposits at the edge of the basin that contrast with, 2) an almost monomineraliac authigenic clay assemblage in lacustrine deposits in marginal areas (the smectite hectorite), and illite in open lacustrine areas [13]. It should be noted, however, that mineral facies are not always arranged in a concentric fashion. For instance, in modern Lake Chad, rivers feed fresher southern waters, therefore authigeneis of Mg-smectites is restricted to the northern evaporative part of the lake [14].

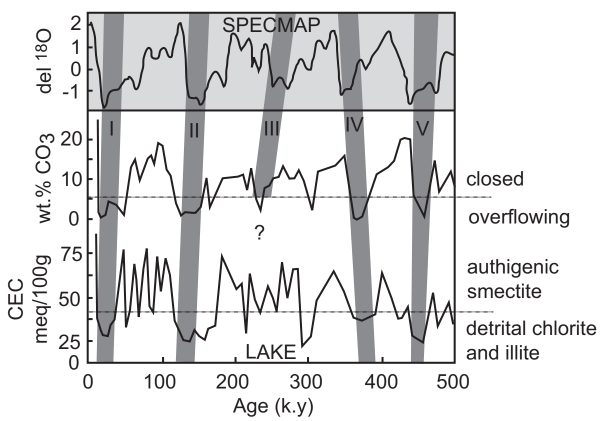

Figure 2. Mineralogical indicators of hydrological change in Owen's Lake corresponding with glacial-interglacial transitions. Sediments deposited during periods of hydrologic closure contain increased carbonate contents and authigenic smectite. Based on ref. 15.

Stratigraphic stacking of mineral facies. Evaporative basins are subject to cyclical changes in hydrological balance driven by climate change and step-changes in hydrology that result from tectonic activity [17]. Therefore the spatial arrangement of mineral facies described above provide temporal snapshots of conditions in a basin that continually evolve through time, producing migration and stacking of various types of clay minerals in response to changing hydrological balance. Variation in the assemblage of clays is observed at at a range of scales, from repetitative m-scale cycles, representing lake-level changes driven by orbital forcing [17], to km-scale packages that record a change in hydrology from an open to a closed system or vice-versa [18].

Owens Lake of California provides an example of a system that has undergone multiple changes in hydrology corresponding to glacial-interglacial intervals over the last 800,000 k.y (fig. 2). The result is that lake sediments contain alternating assemblages of authigenic smectites formed during closed lake periods that alternate with assemblages of detrital illite and chlorite deposited when the lake overflowed [19].

Conclusions: Although there are obvious differences in crustal composition of Earth and Mars, resulting in mineralogical differences on the two planets, the physical processes that ultimately control sedimentation and the hydrology of basins, and therefore distribution of clay minerals, are arguably similar on both planets. Therefore, we conclude that process driven models of clay mineral deposition in lake basins, based on terrestrial systems, may provide additional criteria for determining the origins of martian phyllosilicates. However, mineralogical studies of terretrial saline lakes with analogues basaltic catchments and sulfate/chloride-rich brines would make excellent candidates for future research.

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