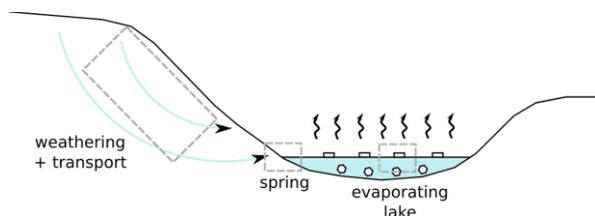


**LATE-STAGE WEATHERING AND CHLORAPATITE DISSOLUTION AS A POSSIBLE SOURCE FOR CHLORIDES ON THE MARTIAN SURFACE.** M. Melwani Daswani<sup>1</sup> and E. S. Kite<sup>1</sup>, Department of the Geophysical Sciences, University of Chicago (5734 S Ellis Ave., Chicago, IL 60637, melwani@uchicago.edu).

**Introduction:** Chlorides could potentially preserve biosignatures, and their presence in sediments indicates past aqueous activity. Local chloride-bearing deposits are widely distributed in the southern highlands on Mars [1]. Their formation is inferred from spectroscopy, topography and geological context to result from ponding surface fluids, and salt concentration by evaporation [e.g., 2]. Assuming the chlorides are NaCl, volumetric calculations of a chloride-bearing deposit and its paleolake near Miyamoto crater in Meridiani Planum were used to estimate a lake salinity of ~ 4 g/kg H<sub>2</sub>O [2]. The source of chlorine for the deposits is unknown, but could be: 1) the martian soil, containing ~ 0.5 wt. % Cl [3] (possibly as perchlorates), 2) subsurface dissolution of previously deposited chlorides, or 3) from Cl-bearing igneous minerals leached by fluids.

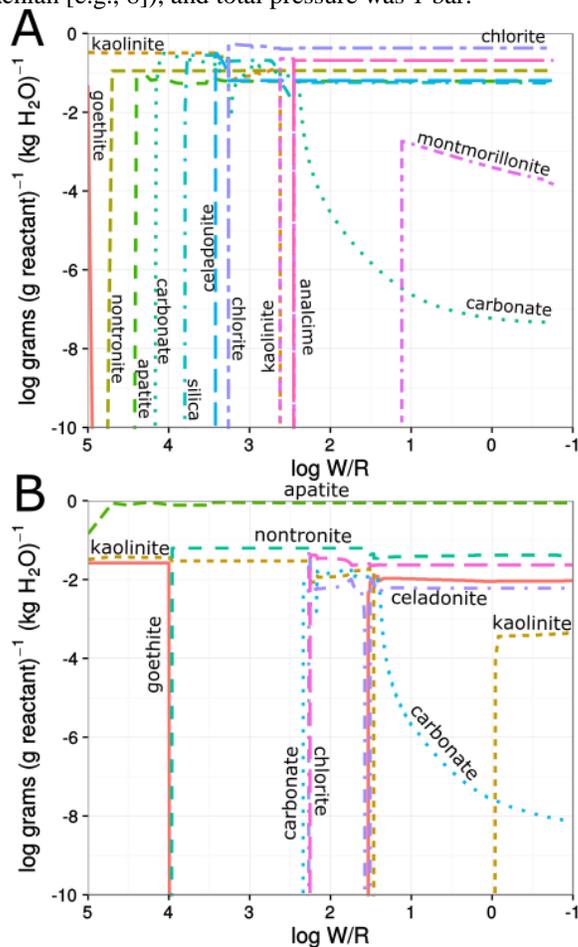
Here we use mass balance calculations and one-dimensional (1D) reaction-transport fluid-rock geochemical modeling to constrain the mass of water and reactant rock required to produce the Meridiani Planum chloride deposit near Miyamoto crater studied by [2]. We also compute the composition of the dissolved reactant rock, secondary mineral precipitates and fluid composition along the reaction path. Fig. 1 represents the geological setting.



**Figure 1** Schematic profile of the geological context of the possible chloride-bearing lake. We hypothesize that fluids permeate and alter the crust, producing secondary minerals (Figure 2), and spring at the lake bearing ions (Figure 3). The lake evaporates, precipitating evaporites.

**Methods:** Geochemical fluid-rock reaction modeling was carried out with CHIM-XPT, using modified Debye-Hückel theory to calculate mass balance, mineral, gas and liquid compositions at varying P-T conditions [4]. The composition of the basaltic clasts in Amazonian martian breccia meteorite Northwest Africa (NWA) 7034 was used as the host reactant rock in the 1D reaction model because of its similarity to martian

surface compositions [e.g., 5, 6]. Temperature was kept at 273 K, pCO<sub>2</sub> was 60 mbar (higher than the current atmosphere [e.g., 7], but lower than estimates for the Noachian [e.g., 8]), and total pressure was 1 bar.

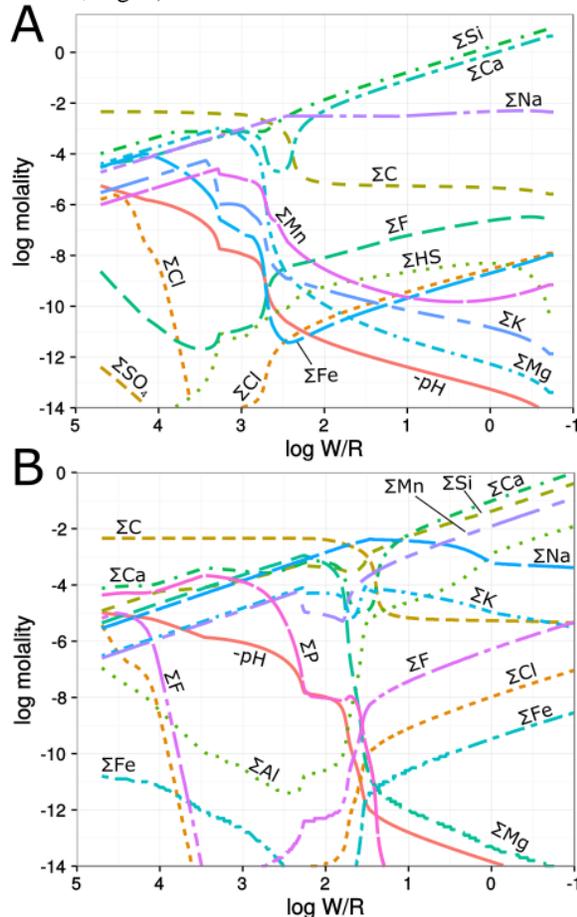


**Figure 2** Secondary minerals precipitated along the weathering path leading to the lake (read from left to right, as fluid infiltrates further). A) Congruent weathering of NWA 7034 basalt clasts, and b) weathering 90 wt. % (F-Cl-OH) apatite + 10 wt. % NWA 7034 basalt clasts.

*Chlorapatite as a reactant.* Apatite in NWA 7034 (~ 6 wt. % of the basaltic clasts) is Cl-rich [e.g., 5], and its abundance in the reactant rock has an impact on the resulting fluid and secondary mineral composition. Apatite also dissolves more quickly than silicates like olivine and pyroxene [e.g., 9] and so the incongruent dissolution of the rock was approached by forward reaction-transport models with different initial apatite

contents, from 1 to 90 wt. % apatite, amounting to 0.05 – 4.1 wt. % Cl in the reactant (here we show 6 and 90 wt. % apatite for simplicity).

**Results:** Dissolution of NWA 7034 leads to different secondary mineral precipitates depending on the water to rock ratio (W/R) and the relative masses of minerals dissolved (i.e., congruent vs. incongruent dissolution, Fig. 2).



**Figure 3** Composition of the water at the spring (sums of aqueous species, note the negative sign for pH), after weathering NWA 7034 basalt clasts a) congruently, and b) with 90 wt. % apatite.

Si-bearing phases dominate the secondary assemblage when NWA 7034 basalt clasts are altered congruently (Fig. 2a), including chlorite and smectites which have been detected on Mars from orbit [e.g., 10]. F-Cl-OH apatite is the most abundant precipitate when accounting for the higher dissolution rate of apatite (Fig. 2b). In both scenarios, pH, Si, Ca and Na increase in the solution as the host rocks dissolve (Fig. 3). Notably, incongruent reaction (with higher amounts of apatite) leads to more oxidized solutions than congruent reaction with the NWA 7034 basalt clasts (Fig.

3). Surprisingly, at  $1000 > W/R > 100$ , Cl in solution is higher under congruent dissolution than incongruent dissolution (Fig. 3). This is because Cl-bearing apatite is a stable secondary mineral which removes Cl from the solution when phosphate is available (Fig. 2b and 3b).

**Discussion:** At  $W/R = 10$ , congruent dissolution releases  $1.3 \times 10^{-11}$  kg Cl/kg  $H_2O$  into solution, while 90 wt. % apatite in the reactant releases  $2.8 \times 10^{-11}$  kg Cl/kg  $H_2O$ . To produce the chloride deposit at Meridiani (a  $\sim 0.12$  km<sup>3</sup> deposit in a  $\sim 35$  km-wide basin[2]),  $\sim 2.5 \times 10^5$  kg rock/m<sup>2</sup> ( $\sim 15$  m depth) were leached if dissolution was congruent, or  $\sim 1.7 \times 10^3$  kg rock/m<sup>2</sup> if the fluid composition was derived mostly from the apatite dissolution. (Assuming the chlorides are NaCl with 45 % porosity, and a reactant rock density of 1650 kg/m<sup>3</sup>.) The required depth of leaching is greater than the annual thermal skin depth, and improbably high volumes of water are needed to leach the Cl in both cases ( $10^{10} - 10^{11}$  km<sup>3</sup>).

Others [2] noted the relationship between chloride deposits in paleolakes and chloride deposits in their feeding valleys, suggesting that the deposits in paleolakes were mobilized from upstream. On Earth, chlorides commonly originate from seawater or are dissolved and re-precipitated from marine deposits [11]. We have shown that preferential dissolution of apatite at low W/R in a single wetting event cannot reasonably account for the inventory of chlorides observed at the deposit studied. Alternatively, multiple dissolution events and kinetic inhibition of apatite re-precipitation may satisfy mass balance. We will carry out further work to constrain the required amounts of rock and water to form other observed chloride deposits, and the fluid and rock composition. We will also compare our results to water volumes independently estimated from geomorphology.

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