LATE-STAGE WEATHERING AND CHLORAPATITE DISSOLUTION AS A POSSIBLE SOURCE FOR CHLORIDES ON THE MARTIAN SURFACE

M. Melwani Daswani* and E. S. Kite
Department of the Geophysical Sciences, University of Chicago
melwani@uchicago.edu

Chloride-bearing deposits occur widely on Mars [1]. Where did the components to form them come from? We use geochemical models, geomorphological evidence and mass balance calculations to place constraints on their origin.

Why study chlorides? Their presence can be used to quantify past aqueous activity. Salts could potentially preserve biosignatures [e.g. 2], and they remain important targets for current and future biosignature detection missions [e.g. 3].

Possible sources of chlorine
1) Weathering of primary igneous minerals in basalts — namely chlorapatite (Ca$_5$(PO$_4$_2)Cl) [e.g. 4].
2) A worked, ancient evaporite deposit [e.g. 5].
3) Cl-bearing components (e.g. HCl and perchlorates) in the soil and atmosphere resulting from volcanic degassing [e.g. 6].

Weathering of near-surface basalts
We used a 1D reaction-transport thermodynamic geochemical model (CHIM-XPT [7]) to weather basalts (Fig. 1) and compute:
- chemical equilibria
- precipitated minerals
- ion activities

Assumptions:
- pCO$_2$ = 60 mbar
- T = 273.15 K
- Host rock composition based on the basaltic clasts of martian meteorite NWA 7034 (Fig. 2) adjusted for the incongruent dissolution behavior of different minerals (Fig 3).

Volcanic degassing as a source of Cl?
- Volcanic degassing rate of Cl estimated at: 1.1 × 10$^{-7}$ kg m$^{-2}$ year$^{-1}$ to 1.1 × 10$^{-9}$ kg m$^{-2}$ year$^{-1}$ on Mars over time [6].
- Concentrating Cl on the surface to the same order as the basalt clasts of NWA 7034 (~ 0.3 wt. %; [8]) would require > 400 Ma of degassing at the highest degassing rate.
- pHCl = 1.2 × 10$^{-4}$ bar at its height, in the early Hesperian atmosphere (from volumes of volcanic extrusions [11]).
- Liquid water in equilibrium with this atmosphere would contain ~ 4 × 10$^{-3}$ g Cl L$^{-1}$, i.e. lower than the Cl concentration in NWA 7034 basalt clasts (~ 3 g kg$^{-1}$), and the Cl concentration in basin leachates at W/R > 5000 (Fig. 5).

Conclusions
Dissolution of igneous chlorapatite could have leached sufficient Cl to form the chlorides. Volcanic degassing of Cl compounds occurred too slowly to account for the observed masses of chlorides, and reworking of ancient evaporite deposits is an unlikely origin based on geomorphology. Seasonal melting cannot explain the observed mass of chlorides at the deposit near Miyamoto crater.

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References