Table DR1. Transfer Functions used to interpret Martian paleosols

<table>
<thead>
<tr>
<th>Equation</th>
<th>Variables</th>
<th>Coefficient of variation (R²)</th>
<th>Standard error</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \tau_{w,j} = \frac{\rho_w \cdot C_{w,j}}{\rho_p \cdot C_{p,w}} [\varepsilon_{w,i} + 1] - 1 )</td>
<td>( \tau_{w,j} ) (mole fraction) = mass transfer of a specified ( j ) element in a soil horizon ( w ); ( \rho_w ) (g.cm(^{-3})) = bulk density of the soil; ( \rho_p ) (g.cm(^{-3})) = bulk density of parent material; ( C_{p,w} ) (weight %) = chemical concentration of an element ( j ) in the parent material ( p ); ( C_{w,j} ) (weight %) = chemical concentration of an element ( j ) in the soil horizon ( w ); ( \varepsilon_{w,i} ) (mole fraction) = strain due to soil formation</td>
<td>not applicable</td>
<td>Brimhall et al., 1992; Amundson et al., 2008</td>
<td></td>
</tr>
<tr>
<td>( \varepsilon_{w,j} = \frac{\rho_p \cdot C_{j,p}}{\rho_w \cdot C_{w,j}} [\varepsilon_{w,i} - 1] - 1 )</td>
<td>( \varepsilon_{w,j} ) (mole fraction) = strain of a soil horizon ( w ) with respect to a stable chemical constituent ( i ); ( \rho_w ) (g.cm(^{-3})) = bulk density of a soil horizon; ( \rho_p ) (g.cm(^{-3})) = bulk density of parent material; ( C_{w,j} ) (weight %) = chemical concentration of a soil horizon ( w ); ( C_{j,p} ) (weight %) = chemical concentration of a stable element ( i ) in the parent material ( p ); ( \varepsilon_{w,i} ) (mole fraction) = strain due to soil formation</td>
<td>not applicable</td>
<td>Brimhall et al., 1992; Amundson et al., 2008</td>
<td></td>
</tr>
</tbody>
</table>

\[
A = 3.987G + 5.774
\]

\( A \) (kyrs) = duration of soil formation; \( G \) = percent gypsum in gypsic (By) horizon

\[
A = 802468\ln S + 299697
\]

\( A \) (kyrs) = duration of soil formation; \( S \) = Antarctic soil weathering stage of Campbell and Claridge (1987)

\[
B = \frac{-0.62}{0.38 + 1}
\]

\( B \) (fraction) = compaction of Aridisol due to burial; \( k \) (km) = depth of burial

\[
P = 87.593e^{0.0209 \cdot D}
\]

\( P \) (mm) = mean annual precipitation; \( D \) (cm) = compaction-corrected depth to gypsum (By) horizon

\[
T = 0.21I - 8.93
\]

\( T \) (°C) = mean annual paleotemperature; \( I \) (mole fraction) = chemical index of weathering

\[
I = \frac{100 Al_2O_3}{(Al_2O_3 + CaO + Na_2O)}
\]

Gaussian error propagation of molar weathering ratios

Analytical results on the Viking rovers had large error bars (McSween and Keil, 2001), which affect the precision of calculated molar weathering ratios to the extent that they are nearly meaningless. Curiosity rover in contrast has returned high precision analyses (McLennan et al., 2014). Gaussian error propagation of both sets of data have been calculated for comparison using the following partial derivatives.

1. Soda/potash molar ratio (\( F \)) for salinization

\[
F = \frac{Na}{K}
\]

\[
F = \frac{61.98}{94.2}
\]
Gaussian error propagation combining errors of Na, and K

\[ S_F = \sqrt{\left( \frac{\partial F}{\partial Na} \times S_{\text{Na}} \right)^2 + \left( \frac{\partial F}{\partial K} \times S_{\text{K}} \right)^2} \]

\[ \frac{\partial D}{\partial Na} = \frac{1.51985}{K} \]
\[ \frac{\partial D}{\partial K} = -1.51985 \times Na \]

2. Alkaline earths/alumina molar ratio (E) for calcification

\[ E = \frac{\text{Ca}}{56.08} + \frac{\text{Mg}}{40.32} - \frac{\text{Al}}{101.96} \]

Gaussian error propagation combining errors of Ca, Mg and Al

\[ S_E = \sqrt{\left( \frac{\partial E}{\partial Al} \times S_{\text{Al}} \right)^2 + \left( \frac{\partial E}{\partial Ca} \times S_{\text{Ca}} \right)^2 + \left( \frac{\partial E}{\partial Mg} \times S_{\text{Mg}} \right)^2} \]

\[ \frac{\partial E}{\partial Ca} = 1.81812 \]
\[ \frac{\partial E}{\partial Al} = 2.52877 \]
\[ \frac{\partial E}{\partial Mg} = -1.81812 \text{Ca} - 2.52877 \text{Mg} \]
\[ \frac{\partial E}{\partial Al^2} = \text{Al} \]

3. Alumina/silica molar ratio (C) for clayeyness

\[ C = \frac{\text{Al}}{101.96} - \frac{\text{Si}}{60.09} \]

Gaussian error propagation combining errors of Si and Al

\[ S_C = \sqrt{\left( \frac{\partial C}{\partial Al} \times S_{\text{Al}} \right)^2 + \left( \frac{\partial C}{\partial Si} \times S_{\text{Si}} \right)^2} \]

\[ \frac{\partial C}{\partial Al} = 0.589349 \]
\[ \frac{\partial C}{\partial Si} = 0.589349 \text{Al} \]
4. Alumina/bases molar ratio (A) for base loss

\[ A = \frac{Al}{101.96} \]
\[ \frac{Ca}{56.08} + \frac{Mg}{40.32} + \frac{K}{94.2} + \frac{Na}{61.98} \]

Gaussian error propagation combining errors of Ca, Mg, K, Na and Al

\[ S_A = \sqrt{\left( \frac{\partial A}{\partial Ca} \times S_{Ca} \right)^2 + \left( \frac{\partial A}{\partial Mg} \times S_{Mg} \right)^2 + \left( \frac{\partial A}{\partial K} \times S_K \right)^2 + \left( \frac{\partial A}{\partial Na} \times S_{Na} \right)^2 + \left( \frac{\partial A}{\partial Al} \times S_{Al} \right)^2} \]

\[ \frac{\partial A}{\partial Ca} = \frac{1.5519 Al}{(K + 2.33631Mg + 1.51985Na + 1.67974Ca)^2} \]
\[ \frac{\partial A}{\partial Mg} = \frac{0.765007 Al}{(Ca + 0.595329K + 0.904808Na + 1.39087Mg)^2} \]
\[ \frac{\partial A}{\partial K} = \frac{0.337443 Al}{(Ca + 1.39087Mg + 0.904808Na + 0.595329K)^2} \]
\[ \frac{\partial A}{\partial Na} = \frac{0.497662 Al}{(Ca + 0.595329K + 1.39087Mg + 0.904808Na)^2} \]
\[ \frac{\partial A}{\partial Al} = \frac{0.55002}{Ca + 0.595329K + 1.39087Mg + 0.904808Na} \]

5. Sulfite/alumina molar ratio (U) for gypsification

\[ U = \frac{S}{80.07} \]
\[ \frac{S}{101.96} \]

Gaussian error propagation combining errors of S and Al

\[ S_U = \sqrt{\left( \frac{\partial U}{\partial S} \times S_S \right)^2 + \left( \frac{\partial U}{\partial Al} \times S_{Al} \right)^2} \]

\[ \frac{\partial U}{\partial S} = \frac{1.27339}{Al} \]
\[ \frac{\partial U}{\partial Al} = -1.27449S \]
References


