Supporting Information for "Calcite dissolution-reprecipitation reactions are a key control on the Sr/Ca, Mg/Ca and $\delta^{88/86}$Sr compositions of Himalayan river waters"

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Contents

S1. References for Figure 1 (see section S6):

Hydrothermal:	Pearce et al. (2015); Krabbenhöft et al. (2010); Andrews & Jacobson (2017).
Soils & Plants:	Halicz et al., 2008; de Souza et al. (2010); Bullen and Chadwick (2016).
Silicates:	Moynier et al. (2010); Charlier et al. (2012); Neymark et al. (2014); Pearce et al., (2015); Stevenson et al. (2016); Andrews et al., (2016), Andrews and Jacobson (2017); Andrews & Jacobson (2018); Amsellem et al. (2018); de Souza et al., 2010
Carbonates:	Fietzke & Eisenhauer (2006); Halicz et al. (2008); Ohno & Hirata (2008); Rüggeberg et al. (2008); Krabbenhöft et al. (2010); Böhm et al. (2012); Raddatz et al. (2013); Neymark et al. (2014); Stevenson et al. (2014); Vollstaedt et al. (2014); Fruchter et al., (2016, 2017); Alkhatib & Eisenhauer (2017a,b); Liu et al. (2017); Shalev et al. (2017), Voigt et al., (2015).
Water:	de Souza et al (2010); Krabbenhöft et al. (2010); Wei et al. (2013); Neymark et al. (2014); Chao et al. (2013, 2015); Pearce et al. (2015); Voigt et al. (2015); Stevenson et al. (2016); Andrews et al. (2016); Fruchter et al. (2016, 2017); Andrews & Jacobson (2017, 2018); Liu et al. (2017); Shalev et al. (2017); Stevenson et al. (2018).

Table S4 Definition of variables (Subscripts *cc* original high Mg, Sr calcite, *F* fluid)

Variable	Definition	Units	Value
Sr_F	Sr in fluid (Sr^0 is fluid Sr at $x = 0$)	$mmol.m^{-3}$	
Sr_{CC}	Sr in calcite	$mmol.m^{-3}$	
Sr_F'	Dimensionless Sr in fluid (eq 6)		
Ca_F	Ca in fluid (Ca^0_F is fluid Ca at $x = 0$)	$mol.m^{-3}$	
Ca_{CC}	Ca in calcite	$mol.m^{-3}$	$2x10^4$
Ca_F'	Dimensionless Ca in fluid (eq 6)		1
t	Time	s	
x	distance along flow path (x' dimensionless distance)	m	
h	Flow path length	m	
$\omega_0\phi$	Fluid flux	$m.s^{-1}$	
$K_D^{Sr/Ca}$	Sr/Ca solid/fluid partition coefficient (eq 1)		
$K_D^{Mg/Ca}$	Mg/Ca solid/fluid partition coefficient		
N_D	Damköhler Number (water) (Equ. 7)		
N_D^{rock}	Damköhler Number (rock) (Equ. 8)		
RCa	Rate of Ca exchange between fluid and calcite	$mol.m^{-3}.s^{-1}$	
$1+\varepsilon$	Rate of precipitation of Ca relative to dissolution		
Γ	Sr/Ca ratio of calcite being dissolved	mmol/mol	
Γ’	Dimensionless Sr/Ca ratio of calcite being dissolved		
$\delta^{88/86}Sr$	$\delta^{88/86}Sr = 10^3\,({}^{88}Sr/{}^{86}Sr_{samp}/{}^{88}Sr/{}^{86}Sr_{SRM987} - 1)$	‰	
$\Delta^{88/86}Sr$	Sr fractionation factor for calcite-water ($\delta_{calcite} - \delta_{water}$)	‰	
$\delta^{44/40}Ca$	$\delta^{44/40}Ca = 10^3\,({}^{44}Ca/{}^{40}Ca_{samp}/{}^{44}Ca/{}^{40}Ca_{SRM915a} - 1)$	‰	
$\Delta^{44/40}Ca$	Fractionation factor for calcite-water ($\delta_{calcite} - \delta_{water}$)	‰	
X^i_{wat}	Concentration of cation, i in water	µmol/L	
X^i_j	Concentration of cation, i in phase j (carbonate or silicate)	mol/kg	
F_j	Weight of phase j (carbonate or silicate) added to the water	kg/L	
E_{Sr}	Enrichment factor for Sr		
E_{Mg}	Enrichment factor for Mg		

S5. Solutions to equations 2 to 5 in the main text

Equation numbers follow from main text. Equation (2) in terms of the dimensionless variables (eq 6) reads

$$\frac{\partial Ca_F'}{\partial x'} = -N_D.\epsilon \tag{S12}$$

and the solution to equation (S12) is

$$Ca_F' = 1 - N_D.\epsilon.x'. \tag{S13}$$

The solution to equation (3), the variation in Ca-isotopic values with reactive transport with Ca_F given by equation (S13), for ε=0 is

$$\delta^{44/40}Ca = \left(\delta^{44/40}Ca_{CC} - \Delta^{44/40}Ca\right) - c4.\,\mathrm{e}^{-N_D.x'} \tag{S14}$$

where

$$\mathrm{c4} = -\Delta^{44/40}Ca, \tag{S15}$$

and the solution when ε≠0

$$\delta^{44/40}Ca = \left(\delta^{44/40}Ca_{CC} - (1+\epsilon).\Delta^{44/40}Ca\right) - c5.\,(1 - N_D.\epsilon.x')^{\frac{1}{\epsilon}} \tag{S16}$$

where the integration constant, c5 is given by

$$\mathrm{c5} = -(1+\epsilon).\,\Delta^{44/40}Ca$$

If ε=0, the solution to equation (4), the variation of Sr concentration with distance, is

$$Sr'_F = \frac{1}{K_D^{Sr/Ca}}\left[\Gamma' - \left(\Gamma' - K_D^{Sr/Ca}\right).\,\mathrm{e}^{-N_D.K_D^{Sr/Ca}.x'}\right] \tag{S17}$$

where Γ’ is the dimensionless Sr/Ca ratio of calcite being dissolved.

If (ε≠0) the solution to equation (4) is

$$Sr'_F = \frac{\Gamma'(1-N_D.\epsilon.x')}{\left[(1+\epsilon).K_D^{Sr/Ca}-\epsilon\right]} + c2.\,(1 - N_D.\epsilon.x')^{(1+\epsilon).K_D^{Sr/Ca}/\epsilon} \tag{S18}$$

where the integration constant c2 for the boundary conditions Ca'^0_F and Sr'^0_F = 1 at *x*’= 0 is given by

$$c2 = 1 - \frac{\Gamma'}{\left[K_D^{Sr/Ca}.(1+\epsilon)-\epsilon\right]}. \tag{S19}$$

*Note equation numbering continues from the main text.

The analytical solution to equation (5) where δ*Sr’F*/δ*x*’ and Sr’F are given by equations (4) & (S17) for the case ε=0 is

$$\delta^{88/86}Sr_F = \frac{\left[\delta^{88/86}Sr_{CC}.\frac{\Gamma'}{K_D^{Sr/Ca}} - N_D.\Delta^{88/86}Sr.\left(\frac{\Gamma'}{N_D.K_D^{Sr/Ca}} - \left(\Gamma' - K_D^{Sr/Ca}\right).x'.\mathrm{e}^{-N_D.K_D^{Sr/Ca}.x'}\right)\right]}{\left(\Gamma'/K_D^{Sr/Ca}\right).\left[1 - \left(1 - K_D^{Sr/Ca}/\Gamma'\right).\mathrm{e}^{-N_D.K_D^{Sr/Ca}.x'}\right]}$$

$$+\frac{c3}{1+{\Gamma'}/{K_D^{Sr/Ca}}\cdot\left(\mathrm{e}^{-N_D\cdot K_D^{Sr/Ca}\cdot x'}-1\right)} \tag{S20}$$

where the integration constant, *C*3, is given by

$$c3 = \delta^{88/86}Sr_{CC} - \frac{\Gamma'}{K_D^{Sr/Ca}}\cdot\left[\delta^{88/86}Sr_{CC} - \Delta^{88/86}Sr\right] \tag{S21}$$

When $\varepsilon \neq 0$ equation (5) has been solved numerically by finite differencing. The numerical solutions reproduce the analytical solutions (eq S20) as $\varepsilon \rightarrow 0$ and Rayleigh fractionation when ε is large.

S6. References

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