

## S1.1 Data collection

Data on olivine dissolution rates ( $k_d$ ) were compiled from Heřmanská et al. (2022) and Rimstidt et al. (2012), adding data from Flipkens et al. (2023), Gerrits et al. (2020), Hausrath and Brantley, (2010), Lunstrum et al. (2023), and Montserrat et al. (2017). In total, 26 papers were analyzed, consisting of 588 data points, of which 463 were used after outlier exclusion. The most common reason for the exclusion of data was an abnormally high grain roughness ( $R_S > 20$ ) (Flipkens et al., 2023; Giammar et al., 2005; Grandstaff, 1986; Hausrath and Brantley, 2010; Montserrat et al., 2017; Siegel and Pfannkuch, 1984; Van Herk et al., 1989). These high  $R_S$  values have previously been attributed to instrumental calibration, reading errors, and the retention of fine material on the grain surfaces (Rimstidt et al., 2012). Additionally, data from Blum and Lasaga (1988) is not included, as there was a preferential release of silicon (Si) at high pH, leading to unusually high dissolution rates estimated from this Si release (Oelkers et al., 2018; Rimstidt et al., 2012). Data from Hänchen et al. (2006) was also not included as high CO<sub>2</sub> levels impacted olivine dissolution rates through a pH change not taken into account. Some data from Pokrovsky and Schott (2000) were excluded for the same reason. Finally,  $R_S$  data from Olsen et al. (2015) was omitted, as they converted  $A_{\text{geo}}$  to  $A_{\text{BET}}$  using an empirical rate equation.

Only BET-based  $k_d$  rates were used in the analysis, as geometric- and BET-based rates cannot be compared without correcting for  $R_S$ . One exception was the inclusion of data from Luce et al. (1972), who derived the grain surface area by Blaine's air permeability method which yields similar results to BET measurements. The  $k_d$  values were mainly calculated from Si release rates, although Mg release rates were used instead in cases where Si release rates could not be determined (Olsen et al., 2015; Pokrovsky and Schott, 2000; Rosso and Rimstidt, 2000; Wogelius and Walther, 1991). This choice is substantiated by the finding that Mg and Si were found to be highly correlated and differ only minimally within the same experiment (Rimstidt et al., 2012).

## S1.2 Calculation of the uncertainty for the intrinsic olivine dissolution rate constant

The parameters used by Rimstidt et al. (2012) in the empiric equation for  $k_d$  were reported with standard errors. Similar to Rimstidt et al. (2012), we used these to derive the standard error for  $k_d$  through forward error propagation. To derive confidence intervals (CI 95 and CI 75), we multiplied the  $k_d$  standard error with the Z-scores from a standard normal distribution (1.96 for CI 95, 1.15 for CI 75) to derive upper and lower confidence intervals around the mean of each parameter. These confidence intervals were then used with Eq. (6) and Eq. (7) to calculate the lower and upper bounds of the dissolution rate. The assumption of normality was based on the parameter distributions shown by Rimstidt et al. (2012), which were obtained by bootstrapping literature data and calculating the slope ( $n_{\text{H}^+}$ ) of  $\log k_d$  with respect to pH and the activation energy ( $E_a$ ). The value of the pre-exponential factor in the Arrhenius equation ( $\log A_0$ ) was not bootstrapped but correlated linearly with  $E_a$ .

**Table S1: Parameters used to calculate the confidence interval of  $\log k_d$ .**

Parameter	Value at pH < 5.6 (standard error)	Value at pH > 5.6 (standard error)
$\log A_0$	5.17 (0.16)	2.34 (0.40)
$-E_a/R$	-3675 (47)	3179 (143)
$n_{H^+}$	-0.44 (0.01)	-0.22 (0.02)

### S1.3 Daily alkalinity production from mERW

35 For the back-of-the-envelope calculation of the alkalinity production from deposition of 15 kg m<sup>-2</sup> of 10 μm olivine grains under a 1 m water column, a water pH of 8 was assumed with a temperature of 15°C. Using Rimstidt et al., (2012) equation Eq. (7) in the main text, these conditions give a  $k_d$  of 3.52x10<sup>-11</sup> mol m<sup>-2</sup> s<sup>-1</sup>. We assume that the olivine used is pure forsterite, so that 4 moles of alkalinity are released upon dissolution of 1 mole olivine ( $\gamma_{A_T} = 1$ ). The reduction in olivine grain diameter during dissolution was calculated with the shrinking core model (Hangx and Spiers, 2009):

$$40 \quad D_t = D_0 - 2k_d R_S \frac{M_{\text{olivine}}}{\rho_{\text{olivine}}} (t - t_0)$$

where  $t$  represents time, and  $\rho_{\text{olivine}}$  represents the specific density of olivine (3.25 g cm<sup>-3</sup>). The reduction in grain diameter  $D$  is then related to a mass change and an areal alkalinity production via:

$$F_{AT} = \frac{D_0^3 - D_t^3}{D_0^3} \cdot \frac{L_{\text{olivine}} 4\gamma_{A_T}}{M_{\text{olivine}} (t - t_0)}$$

These calculations yield an average daily alkalinity release of ~167 μmol m<sup>-2</sup> over the first year after application.

### 45 S1.4 Classification of parameter predictability

We classify the predictability of each parameter based on the current body of research and how well this research is transferable to a coastal setting. As such, parameters with low predictability have received little to no attention in research.  $\Omega$  and  $\gamma_{A_T}$  are classified as having low predictability. In the case of  $\Omega$  only two studies (Flipkens et al., 2023; Montserrat et al., 2017) have acknowledged the effect of saturation during mERW, but no quantification of the potential impact has been done. In recent years,  $\gamma_{A_T}$  has received increasing attention. The potential precipitation reactions are well known (Griffioen, 2017), but results on CaCO<sub>3</sub> formation are mixed (Bach, 2024; Flipkens et al., 2023; Fuhr et al., 2022; Montserrat et al., 2017; Rigopoulos et al., 2018). More importantly, the additionality principle, where mERW may inhibit natural alkalinity production by inhibiting the dissolution of CaCO<sub>3</sub> already present (Bach, 2024), and has only very recently been acknowledged, and therefore received little attention. Furthermore, the extent to which clay formation may play a role in reality is unknown.

55 Moderately predictable parameters have received attention in the literature but are currently difficult to predict in coastal settings. In the case of  $k_d$  and  $A_{\text{surf}}$ , much of the research has been conducted in idealized laboratory settings, meaning that data is not transferable to coastal conditions. The value of  $\eta_{A_r}$  is currently calculable in models when alkalinity is added to the surface, or when coastal waters are permanently mixed. However, in non permanently mixed systems, we do not know how efficiently sediment produced alkalinity can reach the surface. Highly predictable parameters can be calculated or  
60 measured precisely, thereby containing very little uncertainty. Values of  $M_{\text{olivine}}$  and  $x_{\text{inert}}$  can be directly measured from the olivine rock, while  $\rho_{\text{CO}_2}$  can be calculated using programs such as CO2sys (Xu et al., 2017) and AquaEnv (Hofmann et al., 2009).

### S1.5 References

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