Supporting Information for "Anaerobic microbial metabolisms as a link between carbonate platform drowning and Ocean Anoxic Events"

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Introduction

This file gives a more detailed overview of how the model was constructed as well as sources for constants and starting variables from the literature.

Text S1: Steady state solutions. Unique steady state solutions for Eqns. 3-6 require starting values for Δ_{alk}, A_i, C_i, and ∇C. The remaining parameters F_{prod}, F_{diss}, J, ∇A, and F_o can be solved algebraically or scaled using relationships from the modern ocean.

The initial carbonate flux out of the surface ocean (F_{prod}) is related to the weathering input of alkalinity by a constant R_x, which represents carbonate overproduction in the surface ocean:

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$$F_{prod} = \frac{R_x A_i}{2} \tag{S1}$$

Here the factor of $1/2$ is needed because F_{prod} is written in moles of carbon and carbonate production consumes alkalinity in a 2:1 ratio. Combining Eqns. 3 and 4 and substituting in Eqn. S1, the dissolution flux can be re-written as:

$$F_{diss} = \frac{(R_x - 1)A_i}{2} \tag{S2}$$

The organic flux, F_o, is scaled as a multiple of the carbonate flux. Note that the scaling factor (R_{org}) tracks fluxes at the base of the photic zone; it is not equivalent to the rain ratio, which tracks preservation of carbonate and organic matter at the seafloor.

The remaining steady state parameters can now be solved algebraically. The exchange flux, J, is given by re-arranging Eqn. 6:

$$J = \frac{F_{prod} - F_{diss}}{\nabla C} \tag{S3}$$

The initial alkalinity gradient is given by re-arranging Eqn. 4:

$$\nabla A = \frac{2F_{diss} + F_o \Delta_{alk}}{J} \tag{S4}$$

And the initial DIC flux from weathering can be found from Eqn. 5:

$$C_i = F_{prod} + F_o - J\nabla C \tag{S5}$$

Text S2: Calculating saturation states.

After the initial steady state is calculated for $\Delta_{alk} = 0$, the relative fluxes of carbonate production are depicted as power laws of the saturation state in each box:

$$F_{prod} = \frac{(\Omega_{surface} - 1)^2}{(\Omega_{surface|t=0} - 1)^2} F_{prod|t=0} \tag{S6}$$

$$F_{diss} \propto \frac{(1 - \Omega_{deep})^2}{(1 - \Omega_{deep|t=0})^2} F_{diss|t=0} \tag{S7}$$

The saturation state is defined as:

$$\Omega = \frac{[Ca^{2+}][CO_3^{2-}]}{K_{sp}} \tag{S8}$$

Where K_{sp} is a constant that depends on salinity, pressure and temperature. Saturation states were calculates using a version of CO2sys implemented under the 'seacarb' package in R (Gattuso et al., 2019) with the following settings: calcium concentrations fixed at modern values, temperature dependencies for K1 and K2 from Lueker, Dickson, and Keeling (2000), pressure corrections from Millero (1995). Conditions for the surface ocean were modeled as T = 17.5°C, S = 35 ppt, and P = 0 bars and the deep ocean was modeled as T = 2.5°C, S = 35 ppt, and P = 350 bars. for the deep ocean. These values were held constant for all runs; considering changes (e.g., warming) during OAEs is beyond the scope of the current work.

Table S1. Independant model parameters with units and sources. Sources are (Amante & Eakins, n.d.), 2–(Ridgwell, 2005), 3–(Higgins et al., 2009), 4–(Broecker & Peng, 1982), 5–(Munhoven, 2002), 6–(Li et al., 1969)

parameter	description	value	units	source
V	total ocean volume	1.32e21	kg	1
f	volume fraction in surface ocean	0.029	-	2
C_1	initial surface DIC	2.1e-3	moles	3
C_2	initial deep DIC	2.35e-3	moles	3,4
A_1	initial surface alkalinity	2.3e-3	terramoles	3
A_i	weathering flux of alkalinity	30	terramoles	2,5
R_x	starting overproduction	4	-	4
R_o	Ratio of organic flux/carbonate flux	4	-	6

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