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Early Mars habitability and global cooling by H_2-based methanogens

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Supporting Information for “Early Mars’ habitability and global cooling by H_2-based methanogens”

Supplementary Table 1. Ranges of parameter values used in the atmosphere and crust models.

Planetary features	Symbol (units)	Value or Range	Distribution type
Initial atmosphere (ref[14-16])			
Atmospheric pressure	p (bar)	[0.5 – 3]	uniform
H_2 mixing ratio	f_{H_2}	[3.10^{-3} – 0.1]	uniform
CH_4 mixing ratio	f_{CH_4}	10^{-4}	
CO_2 mixing ratio	f_{CO_2}	[1 - (f_{H_2}+f_{CH_4})] × 0.95	
N_2 mixing ratio	f_{N_2}	[1 - (f_{H_2}+f_{CH_4})] × 0.05	
Crust characteristics (ref[6,7])			
Surface pore radius	$r(0)$ (cm)	[10^{-4} – 10^{-3}]	log-uniform
Depth of pore closure	z_{max}(km)	[5 – 20]	uniform
Surface porosity	$\epsilon(0)$	[0.2 – 0.6]	uniform
Surface tortuosity	$\tau(0)$	[1.5 – 2.5]	uniform
Temperature gradient	a_T (K km^{-1})	[10 – 40]	uniform

Supplementary Table 2. Biological parameters.

Parameter	Notation	Value or expression	Unit	References
Cell radius	S_C	$10^{a_r+b_rT}$	µm	ref[12]
	a_r	-13.23	dimensionless	ref[12]
	b_r	0.0431	dimensionless	ref[12]
Cell volume	V_C	$\frac{4}{3}\pi {S_C}^3$	μm^3	
Cellular carbon content	$Q_{C_{org}}$	$18 \times 10^{-15}\ {V_C}^{0.94}$	mol C_{org} $cell^{-1}$	ref[39]
Maximum metabolic rate	q_{max}	$e^{a_q+b_qT}{V_C}^{c_q}$	mol $cell^{-1}$ d^{-1}	
	a_q	- 55.76	dimensionless	Ref[40]
	b_q	0.1	dimensionless	ref[41]
	c_q	0.82	dimensionless	ref[42,43]
Half-saturation constant	K	10^{-8}	mol L^{-1}	ref[44,45]
Maintenance rate	E_m	$e^{a_E+b_ET}{V_C}^{c_E}$	kJ d^{-1}	
	a_E	- 43.54	dimensionless	Ref[40]
	b_E	0.08	dimensionless	ref[46]
	c_E	0.67	dimensionless	ref[47]
Decay rate	k_d	0.5	d^{-1}	
Basal mortality rate	m	0.1	d^{-1}	

Supplementary references

39. S. Menden-Deuer, E. J. Lessard, Carbon to volume relationships for dinoflagellates, diatoms, and other protist plankton, *Limnol. Oceanogr.*, **45**, 569-579 (2000)

40. R. González-Cabaleiro, J. M. Lema, J. Rodríguez, Metabolic energy-based modelling explains product yielding in anaerobic mixed culture fermentations, *Plos one*, **10**, e0126739 (2015)

41. L. Tijhuis, M. C. Van Loosdrecht, J. V. Heijnen, A thermodynamically based correlation for maintenance Gibbs energy requirements in anaerobic and aerobic chemotrophic growth, *Biotechnol. bioengineer.*, **42**, 509-519 (1993)

42. E. Litchman *et al.*, The role of functional traits and trade-offs in structuring phytoplankton communities: scaling from cellular to ecosystem level, *Ecol. lett.*, **10**, 1170-1181 (2007)

43. B. A. Ward *et al.*, The Size Dependence of Phytoplankton Growth Rates: A Trade-Off between Nutrient Uptake and Metabolism, *Am. Nat.*, **189**, 170-177 (2017)

44. D. Canfield, M. Rosing, C. Bjerrum, Early anaerobic metabolisms, *Philos. Trans. R. Soc. B*, **361**, 1819-1836 (2006)

45. K. Ozaki *et al*., *Nat. Geosci.*, **11**, 55-59 (2018)

46. J. F. Gillooly *et al.*, Effects of Size and Temperature on Metabolic Rate, S*cience*, **293**, 2248-2251 (2001)

47. D. L. Aksnes, J. K. Egge, A theoretical model for nutrient uptake in phytoplankton, *Mar. Ecol. Prog. Ser.,* **70**, 65-72 (1991)