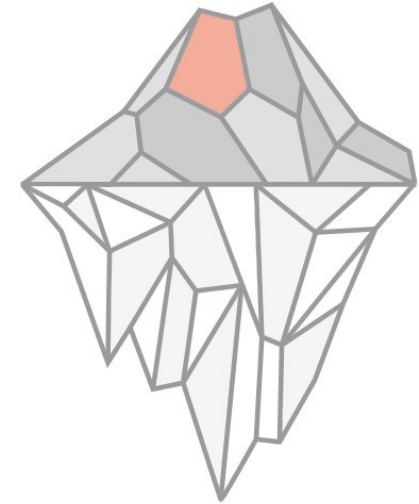


MICROBIOLOGY OF EXTREME ENVIRONMENTS

EXTREMES OF LIFE



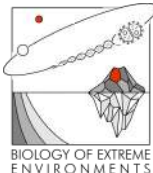
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HOW DO WE DEFINE EXTREME ENVIRONMENTS?



How do we define *Extreme Environments*

Anthropocentric: *An extreme environment is a habitat characterized by harsh environmental conditions, beyond the optimal range for the development and survival of humans*



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Environmental norm: An extreme environment is a habitat characterized by environmental conditions that deviates from average conditions present in common ecosystems



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Limit-of-Life based: An extreme environment a habitat characterized by having one of more of its chemio-physical parameters to be near the limits of Life



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Strongly biased by Human physiology

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Strongly biased by multicellular life

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Strongly limited by our knowledge of Life

How do we define *Extreme Environments*

TABLE 1 | Extremophiles nomenclature and ranges.

Low → High ^a					
pH	Hyperacidophile (<pH 3)	Acidophile (<pH 5)	Neutrophile (pH 5–9)	Alkaliphile (>pH 9)	Hyperalkaliphile (>pH 11)
Temperature		Psychrophile (<20°C)	Mesophile (20–45°C)	Thermophile (45–80°C)	Hyperthermophile (>80°C)
Salinity ^b		Non-halophile (<1.2%)	Halotolerant (1.2–2.9%; tolerate ≤ 14.6%)	Halophile (>8.8%)	Extreme halophile (>14.6%, cannot grow < 8.8%)
Pressure			Piezotolerant or barotolerant (0.1–10 MPa)	Piezophile or barophile (10–50 MPa)	Hyperpiezophile or hyperbarophile (>50 MPa)
Water activity			Xerophile ($a_w < 0.7$)		
Polyextremophile			Tolerance or preference for multiple parameters combined		

^aThe distinction between an extremotolerant microbe and an extremophile is based on the location of the optimum along the specific parameter range. See main text for discussion. ^bSalinity expressed as percent of NaCl (w/v). Specific resistance to more chaotropic salts has been tested for some strains, for instance in the presence of MgCl₂.



SO WHAT DEFINITION SHOULD WE USE?



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ARE EXTREME ENVIRONMENTS
COMMONPLACE ON EARTH?

Are extreme environments commonplace on Earth?

The majority of our planet (surface and subsurface) is extreme, in one or more parameter



Are extreme environments commonplace on Earth?

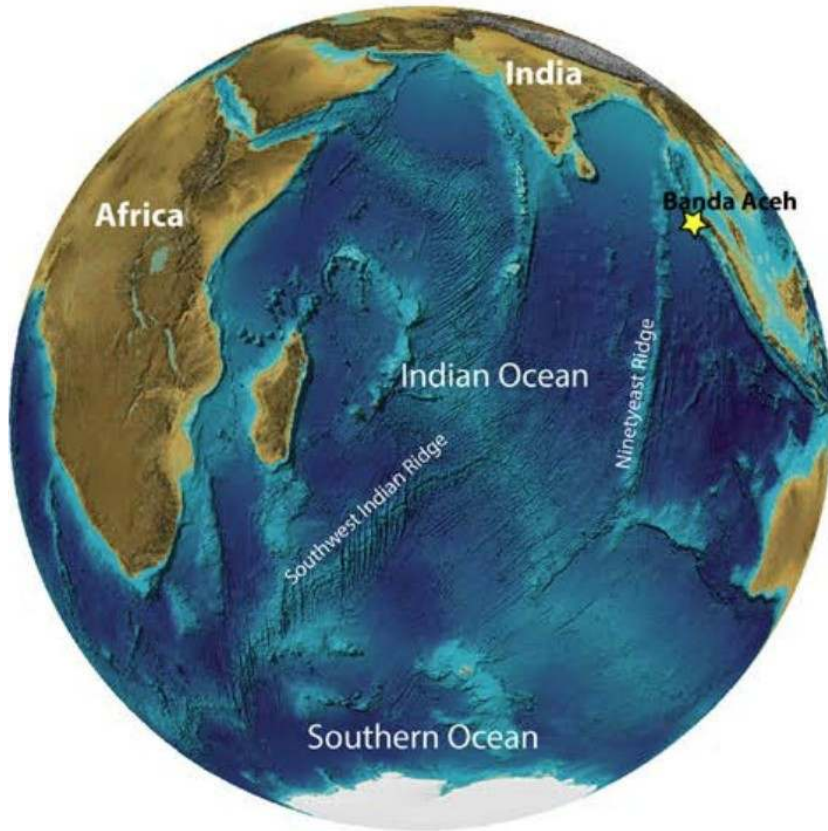
The majority of our planet (surface and subsurface) is extreme, in one or more parameter



70 % of the surface is covered by Oceans, with an average depth of 3,682 meters and an average temperature of 4 °C

Are extreme environments commonplace on Earth?

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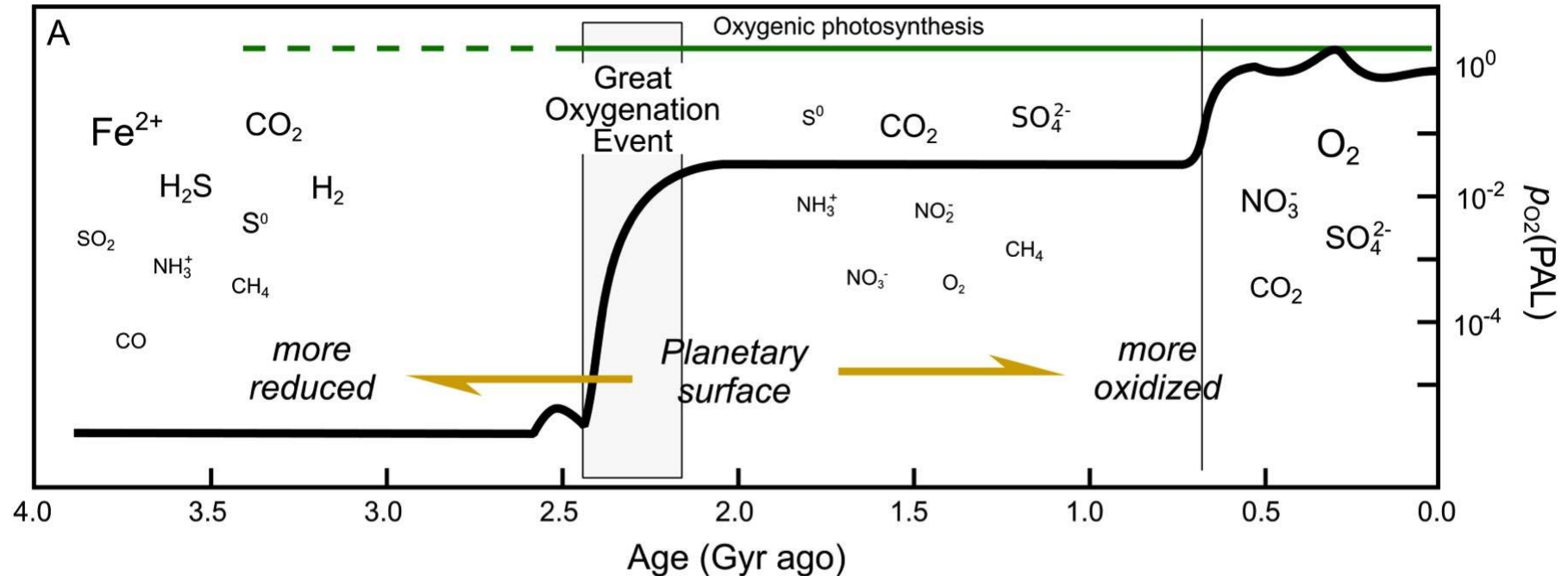


70 % of the surface is covered by Oceans, with an average depth of 3,682 meters and an average temperature of 4 °C

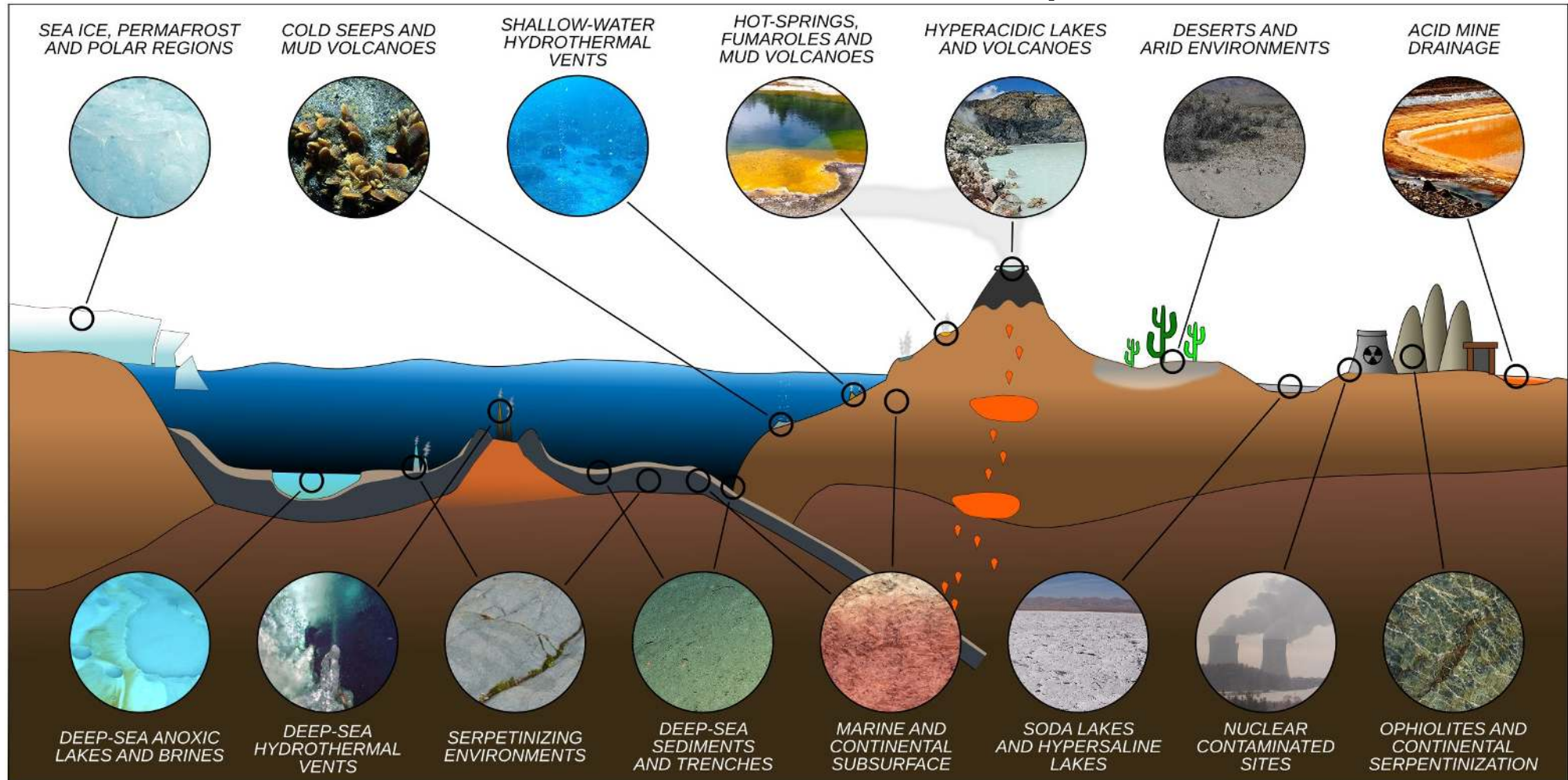
Habitable subsurface environments extend to ~10-20 km depth and to a hypothetical isotherm of 150 °C

Are extreme environments commonplace on Earth?

The majority of the history of our planet the conditions were extreme in one or more parameter



Are extreme environments commonplace on Earth?





WHAT ARE THE LIMITS OF LIFE?

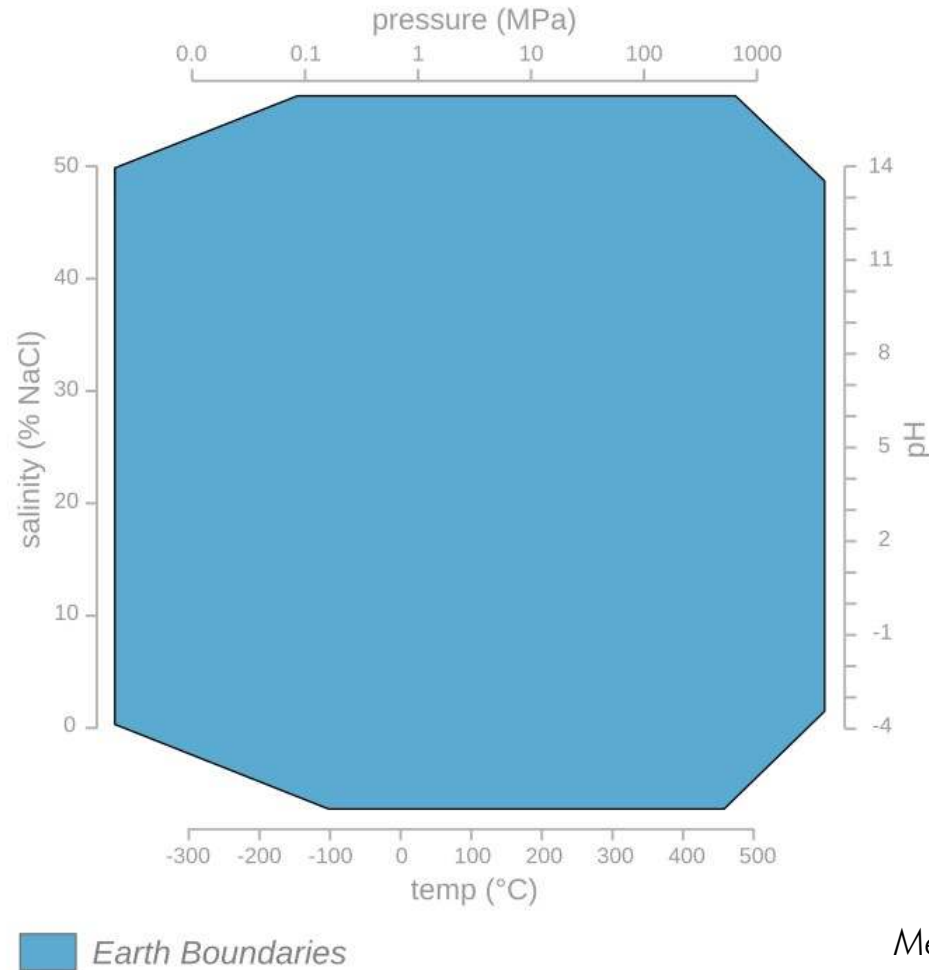
What are the limits of life?

TABLE 3 | Limits of life as identified by (poly)extremophilic organisms in pure cultures.

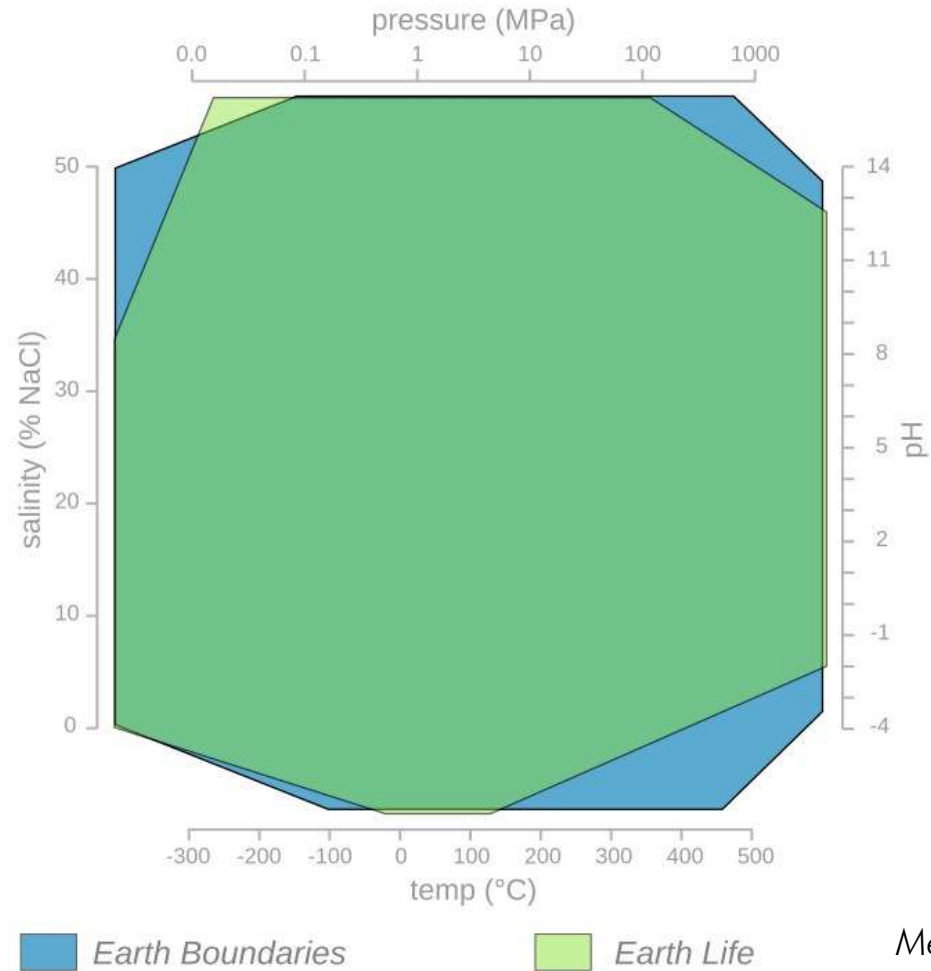
Strain	Domain	Extremophile Type	Isolation ecosystem	Temperature (°C)	pH	Pressure (Mpa)	Salinity (%)	Water activity (a _w)
<i>Picrophilus oshimae</i> KAW 2/2	Archaea	Hypercidophile	Hot springs, Solfataras	47–65 (60) ^a	−0.06 –1.8 (0.7)	nr	0–20	nr
<i>Serpentinomonas</i> sp. B1	Bacteria	Alkaliphile	Serpentinizing system (water)	18–37 (30)	9– 12.5 (11)	nr	0–0.5 (0)	nr
<i>Methanopyrus kandleri</i> 116	Archaea	Hyperthermophile	Deep-sea hydrothermal vent	90– 122 (105)	(6.3–6.6)	0.4–40	0.5–4.5 (3.0)	nr
<i>Planococcus halocryophilus</i> Or1	Bacteria	Halopsychrophile	Sea ice core	−18–37 (25)	nr (7–8)	nr	0–19 (2)	nr
<i>Halarsenatibacter silvermanii</i> SLAS-1	Bacteria	Haloalkaliphile	Soda lake	28–55 (44)	8.7–9.8 (9.4)	nr	20–35 (35)	nr
<i>Thermococcus piezophilus</i> CDGS	Archaea	Piezothermophile	Deep-sea hydrothermal vent	60–95 (75)	5.5–9 (6)	0.1– 125 (50)	2–6 (3)	nr
Haloarchaeal strains GN-2 and GN-5	Archaea	Xerophile	Solar salterns (brine)	nr	nr	nr	nr	0.635

^aData presented as range (optimum) for each parameter. nr, not reported in the original publication. Current limits are highlighted in bold.

What are the limits of life?



What are the limits of life?



Merino et al. 2019 *Front in Microbiol*

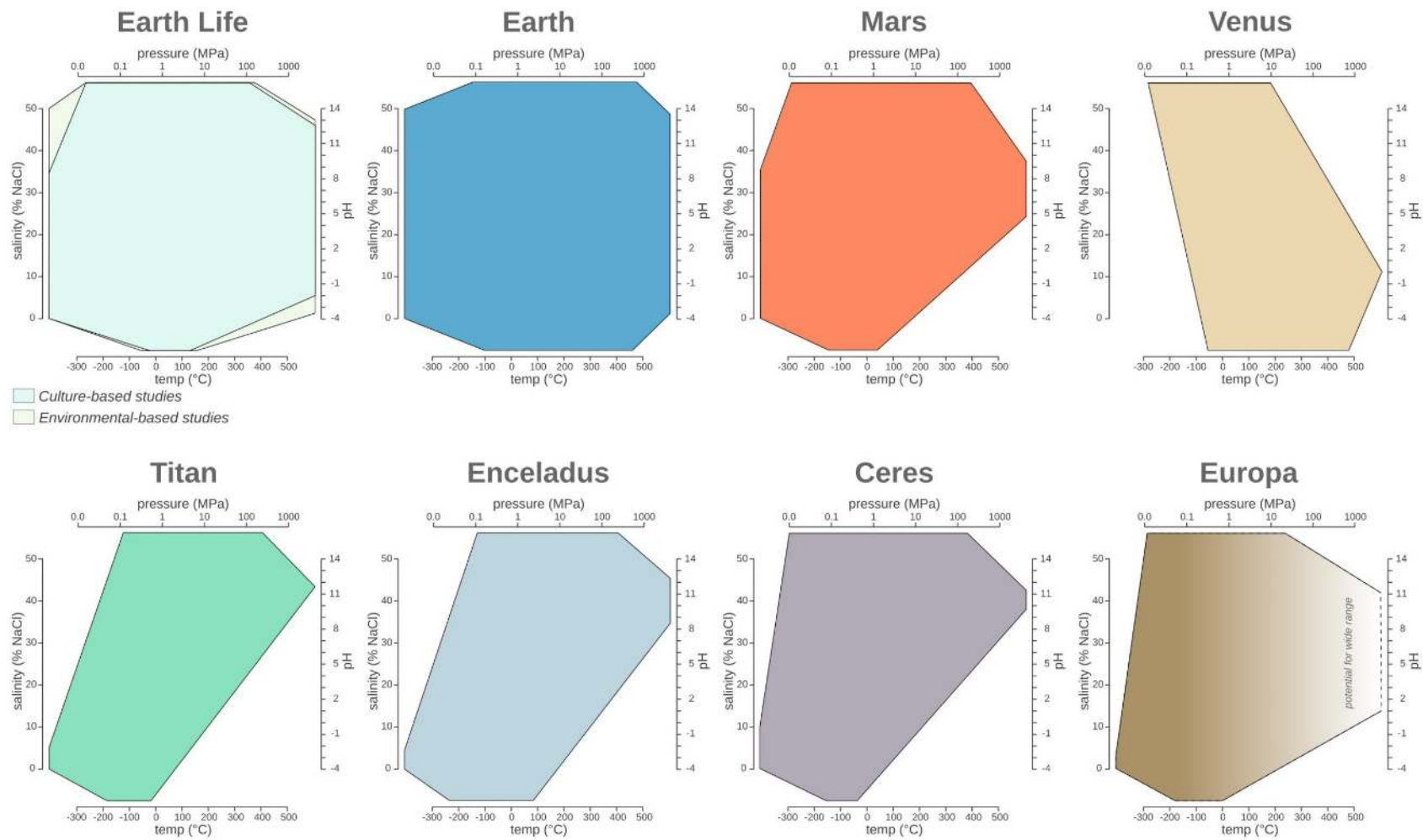


FIGURE 2 | The temperature, pressure, pH, and salinity boundaries observed for life on Earth compared to the phase space observed on planetary bodies discussed in the main text. Polygon charts are designed to represent ranges in multidimensional space. Each edge represents the range for the specific variables. Single values (e.g., when min = max) are represented by a single vertex on an axis, while missing values (e.g., NA or NR) are represented by the absence of the corresponding polygon edge on the corresponding axis.

What are the limits of life?



Expedition 370 will head to the Nankai Trough (latitude/longitude 32.3423, 134.9564) off the coast of Japan to find the temperature limit of Earth-style life. Credit: Deep Carbon Observatory



D/V Chikyu, the world's largest scientific research vessel, at sea during International Ocean Discovery Program (IODP) Expedition 337. Credit: Luc Rolon/JAMSTEC

**HOW
HOT
IS
TOO
HOT?**

Guess the
temperature
limit of
Earth-style
life

What temperature is too hot for life to exist deep beneath the seafloor? **An international research team is answering this question.** What they learn will help define the borders of life inside Earth. Join their scientific mission of discovery by submitting your own guess about the temperature that is too hot for life deep inside Earth. Submit your estimate in degrees Celsius. The winner(s) will receive a Deep Carbon Observatory baseball cap and a sticker commemorating the T-Limit expedition.

<https://www.jamstec.go.jp/chikyu/e/exp370/>



THIS WEEK READ

Merino, N., Aronson, H. S., Bojanova, D. P., Feyhl-Buska, J., Wong, M. L., Zhang, S., et al. (2019). Living at the Extremes: Extremophiles and the Limits of Life in a Planetary Context. Front. Microbiol. 10. doi:10.3389/fmicb.2019.00780.