MICROBIAL CONTRIBUTION TO VOLATILE CYCLING IN POLAR ENVIRONMENTS: COMPLEX DYNAMICS AND ECOSYSTEM ROLE

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GIOVANNELLI LAB

DIPARTIMENTO DI BIOLOGIA

CNR IRBIM
ISTITUTO PER LE RISORSE BIOLOGICHE E LE BIOTECNOLOGIE MARINE

RUTGERS
THE STATE UNIVERSITY OF NEW JERSEY

EBSI
EARTH - LIFE SCIENCE INSTITUTE

WOODS HOLE OCEANOGRAPHIC INSTITUTION
1930

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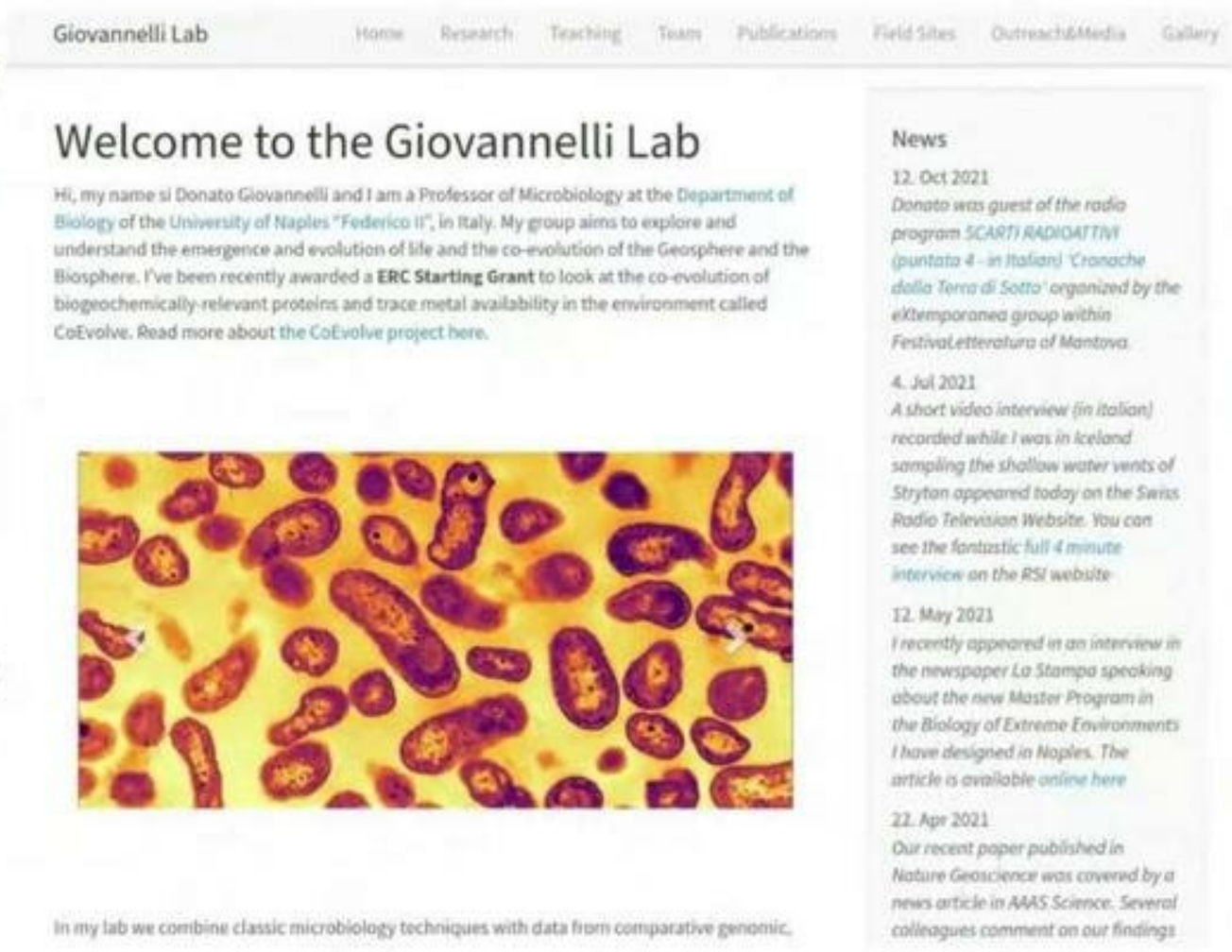
Giovannelli Lab - Our group Interest

We are interested in the planetary effects of microbial metabolism, and its role in geosphere biosphere coevolution

The majority of our work is carried out in extreme environments, where we combine classic microbiology techniques with data from comparative genomic, phylogenetic, geochemistry, environmental surveys and computational approaches to reconstruct geo-bio interactions



In my lab we combine classic microbiology techniques with data from comparative genomic,

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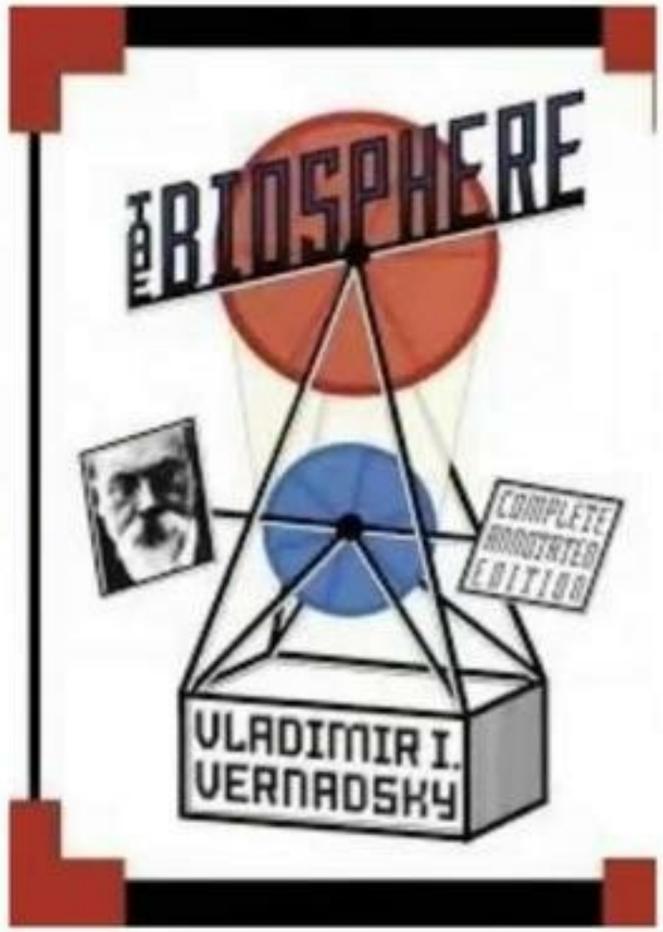
What microbes do best: gas exchange with the environment

Published in 1926 book The Biosphere, by hypothesizing that life is the geological force that shapes the Earth

He was one of the first scientists to recognize that the oxygen, nitrogen and carbon dioxide in the Earth's atmosphere result from biological processes, and proposing that one of the fundamental properties of life is to exchange gases with the environment

Vladimir Vernadsky
1863 - 1945



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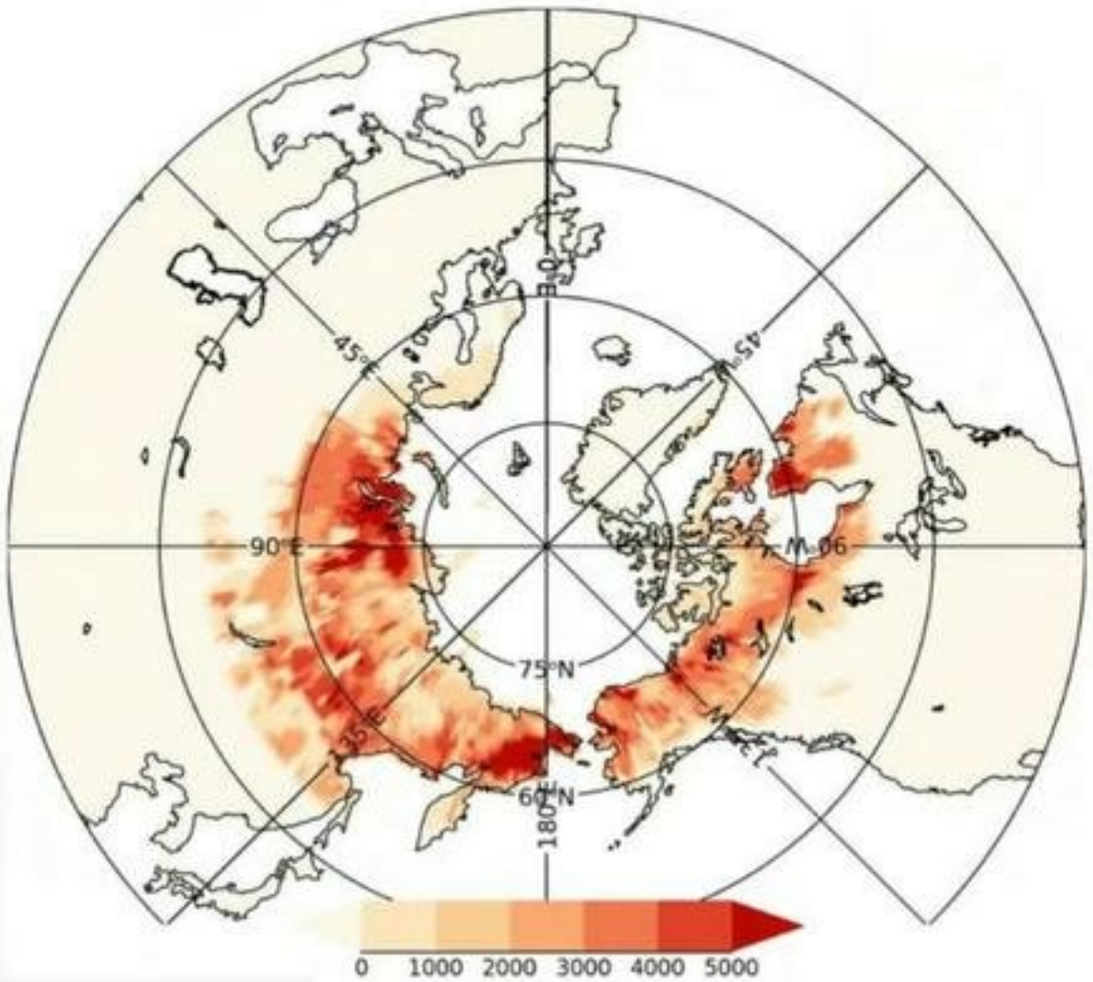
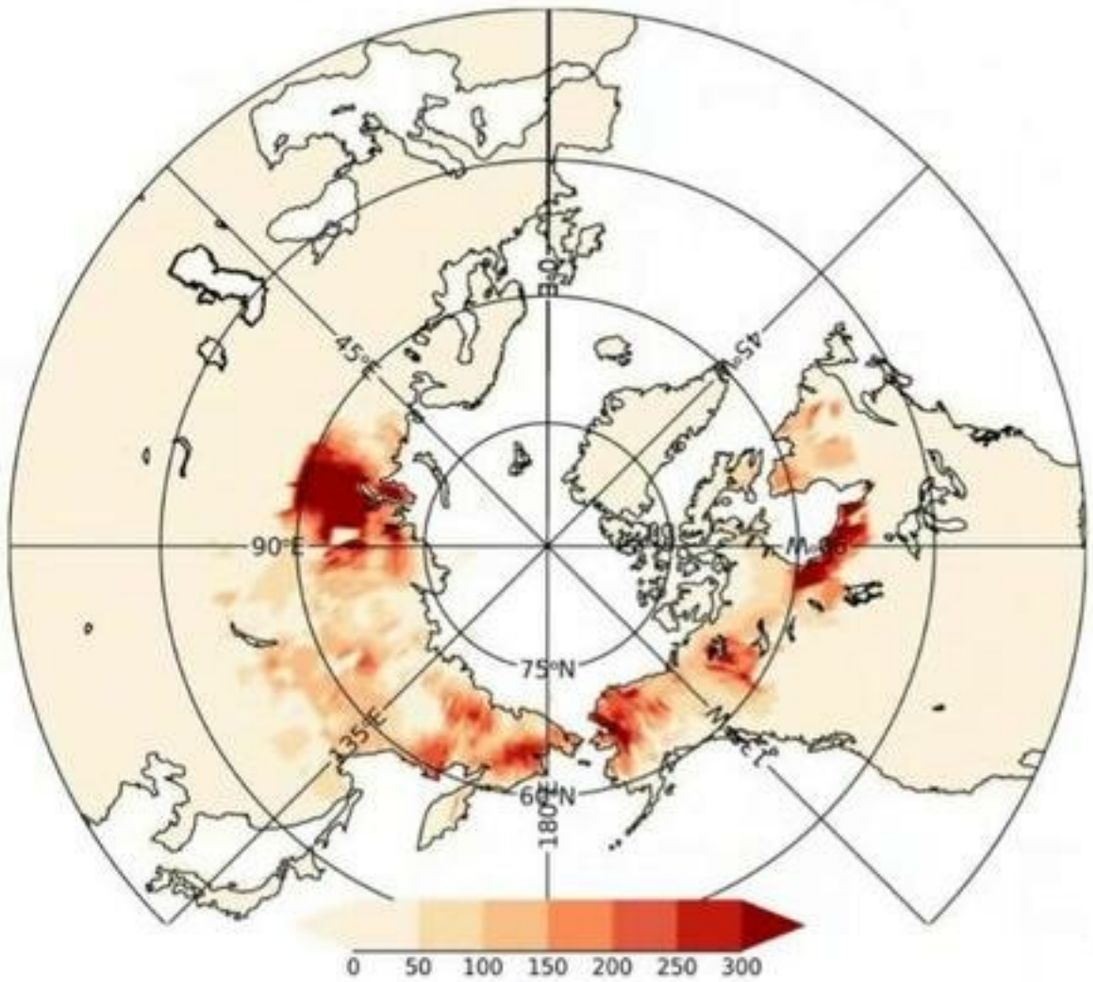
What microbes do best: gas exchange with the environment

CO2 cumulative flux [kgC/m2/year], RCP8.5



CH4 cumulative flux [kgCH4/m2/year], RCP8.5



Yokohata et al. 2020 Progr Earth Plan Sci

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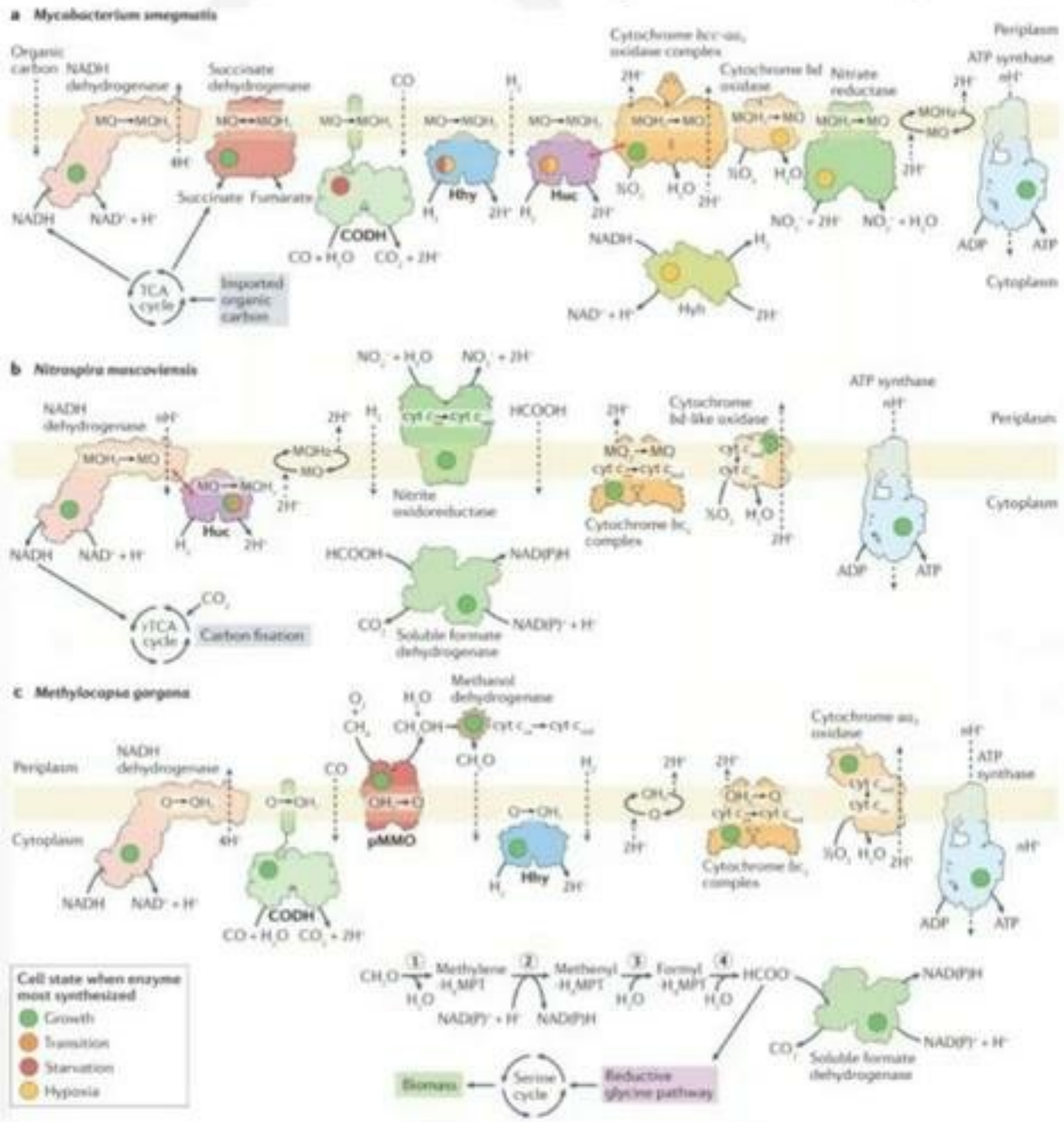
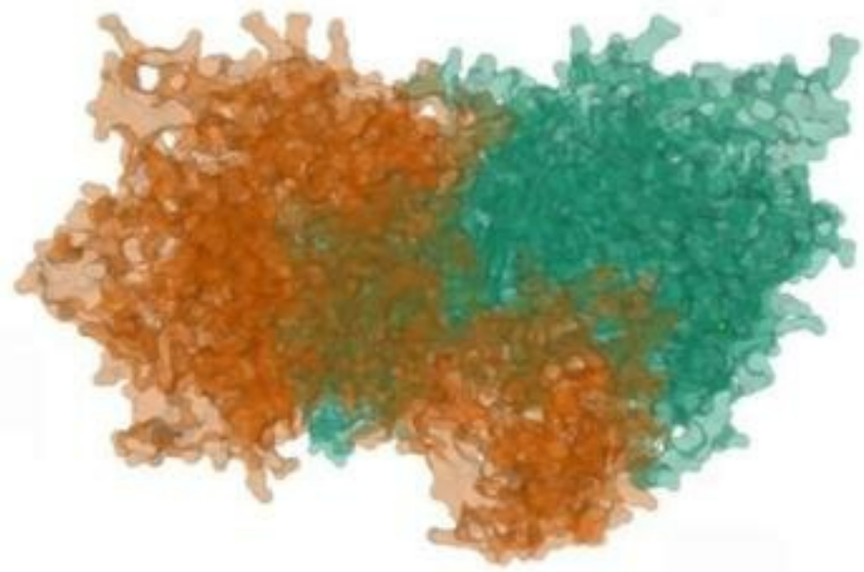
What microbes do best: gas exchange with the environment





nitrous oxide reductase

Greening and Grinter, 2022 Nat Rev Microbiol

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How microbes interact with volatiles: the role of metals

CH_4 N_2O CO_2

How microbes interact with volatiles: the role of metals

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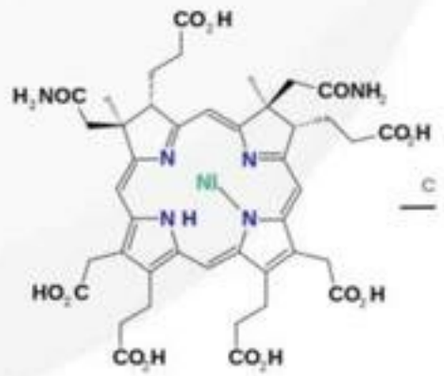
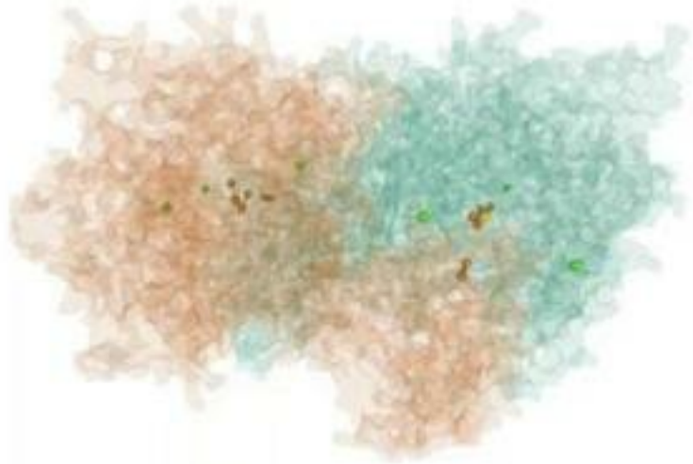
CH_4

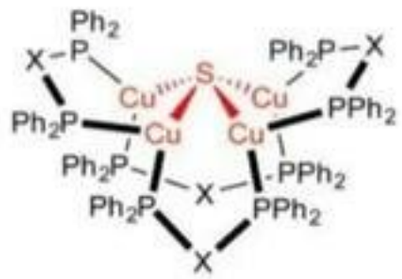
methyl coenzyme M reductase



N_2O

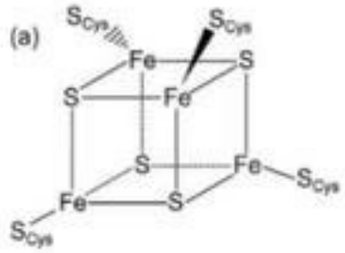


nitrous oxide reductase



CO_2

fumarate reductase



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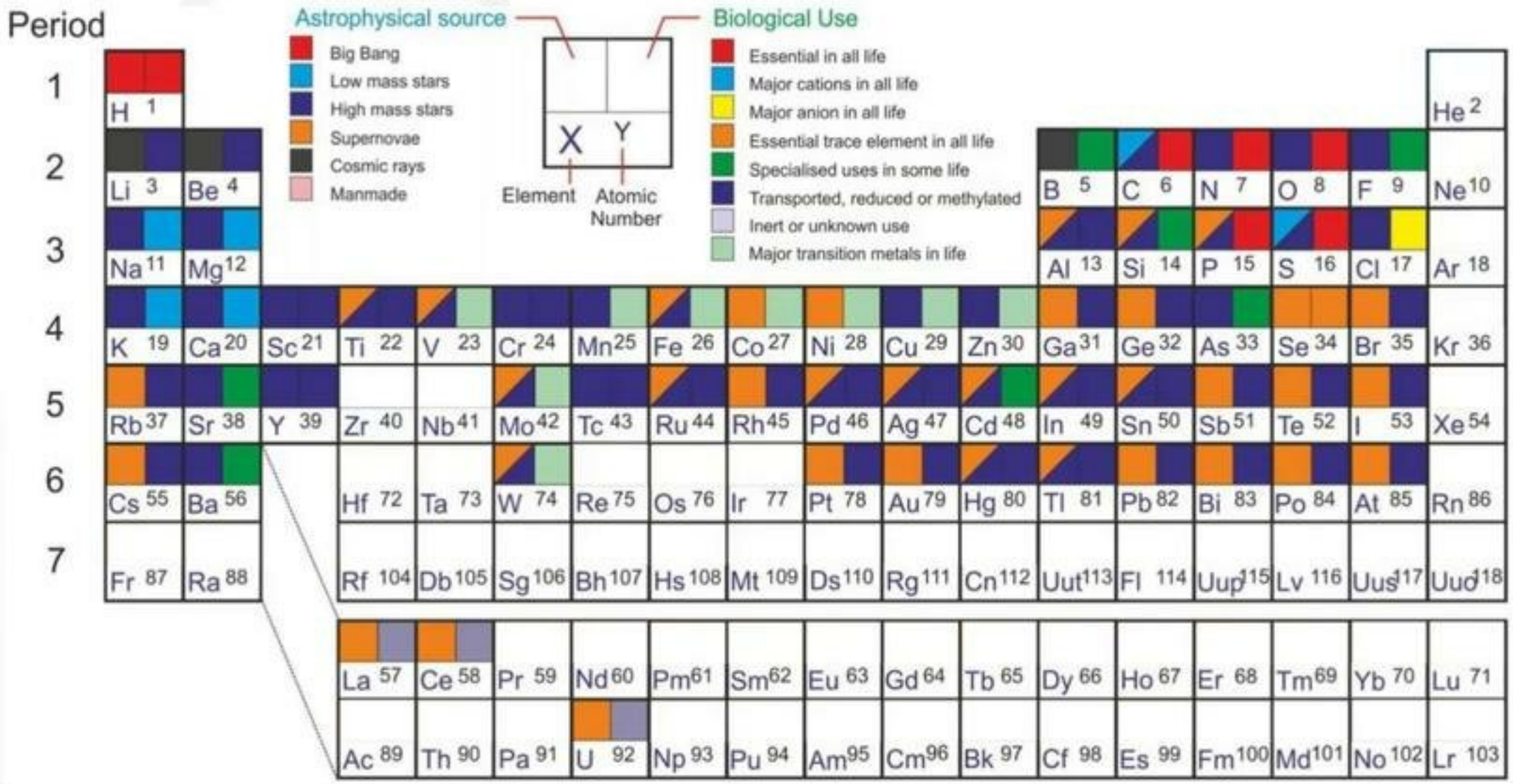
How microbes interact with volatiles: the role of metals



Biological data from Wackett, L.P., Dodge, A.G., Ellis, L.B.M. (2004) *Applied and Environmental Microbiology* **70**, 647-655.

erc

ERC StG CoEvolve

www.coevolve.eu

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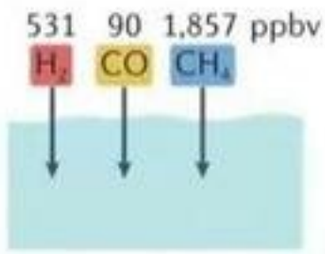
modified after Cockel 2015

What microbes do best: gas exchange with the environment

Marine waters (copiotrophic or oligotrophic)

Atmospheric sources



Trace gas oxidizer abundance

H_2 2%
CO 21%
CH_4 0.04%

Marine sources

Photochemical degradation
DOC → CO

Nitrogen fixation
→ H_2

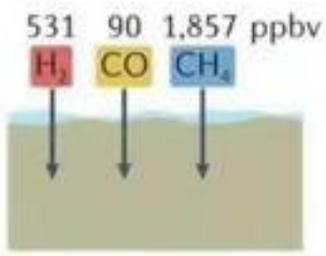
Methylphosphate degradation
→ CH_4

Key microbial mediators

Acidobacteriota
Actinobacteriota
Bacteroidota
Chloroflexota
Proteobacteria
SAR324
Verrucomicrobiota
Halobacteria

Antarctic soils (oligotrophic)

Atmospheric sources



Trace gas oxidizer abundance

H_2 90%
CO 32%
CH_4 1.5%

Key microbial mediators

Acidobacteriota
Gemmatimonadota
Actinobacteriota
Myxococcota
Armatimonadota
Proteobacteria
Bacteroidota
Verrucomicrobiota
Chloroflexota

Greening and Grinter, 2022 Nat Rev Microbiol

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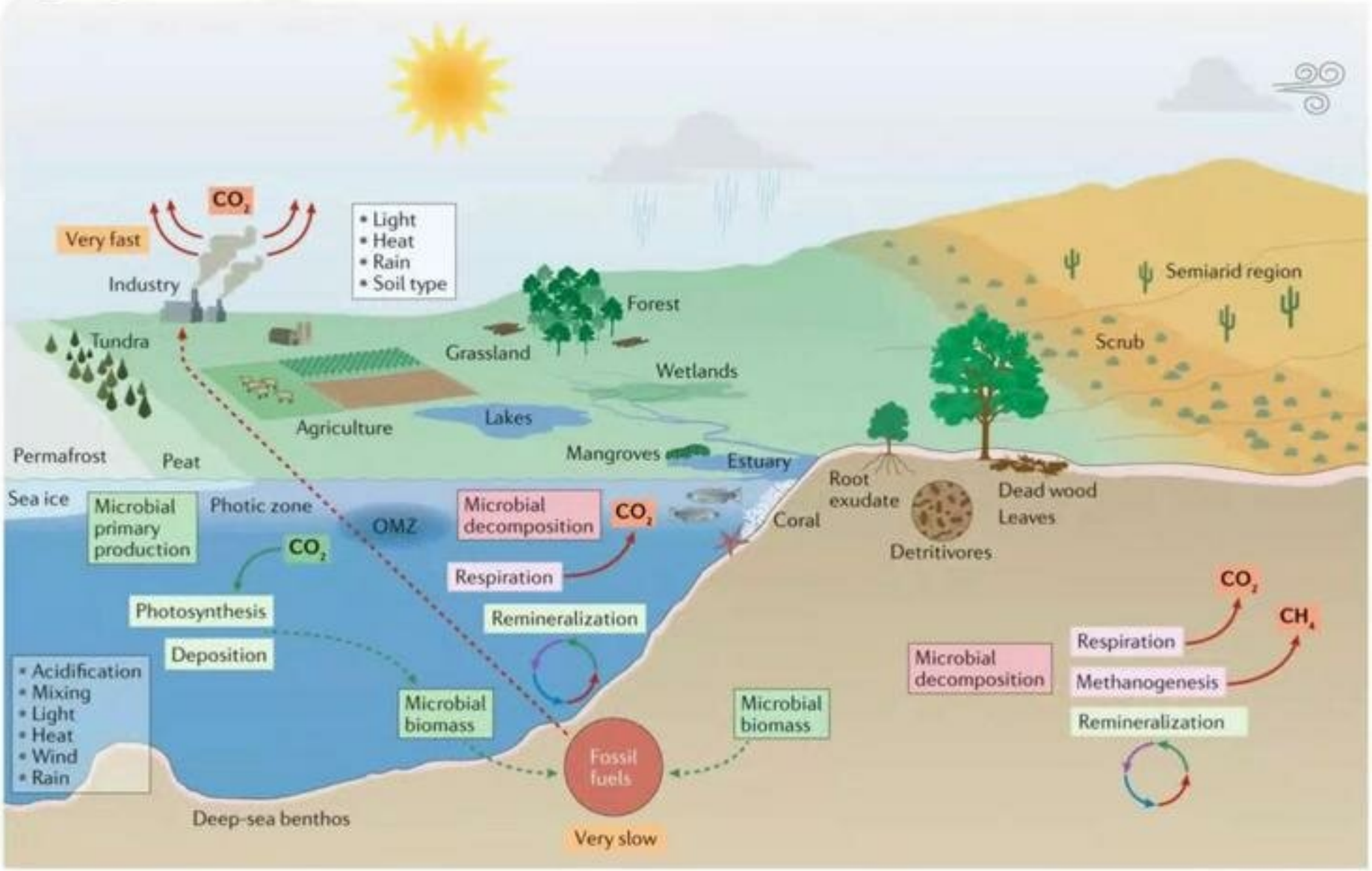
Gas cycling by microbes and climate



Cavicchioli et al. 2019 Nat rev Microbiol

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Example of unexpected impacts of microbes on volatiles

Example of unexpected impacts of microbes on volatiles

Barry et al 2019 Nature; Fullerton et al. 2021 Nat Geosci

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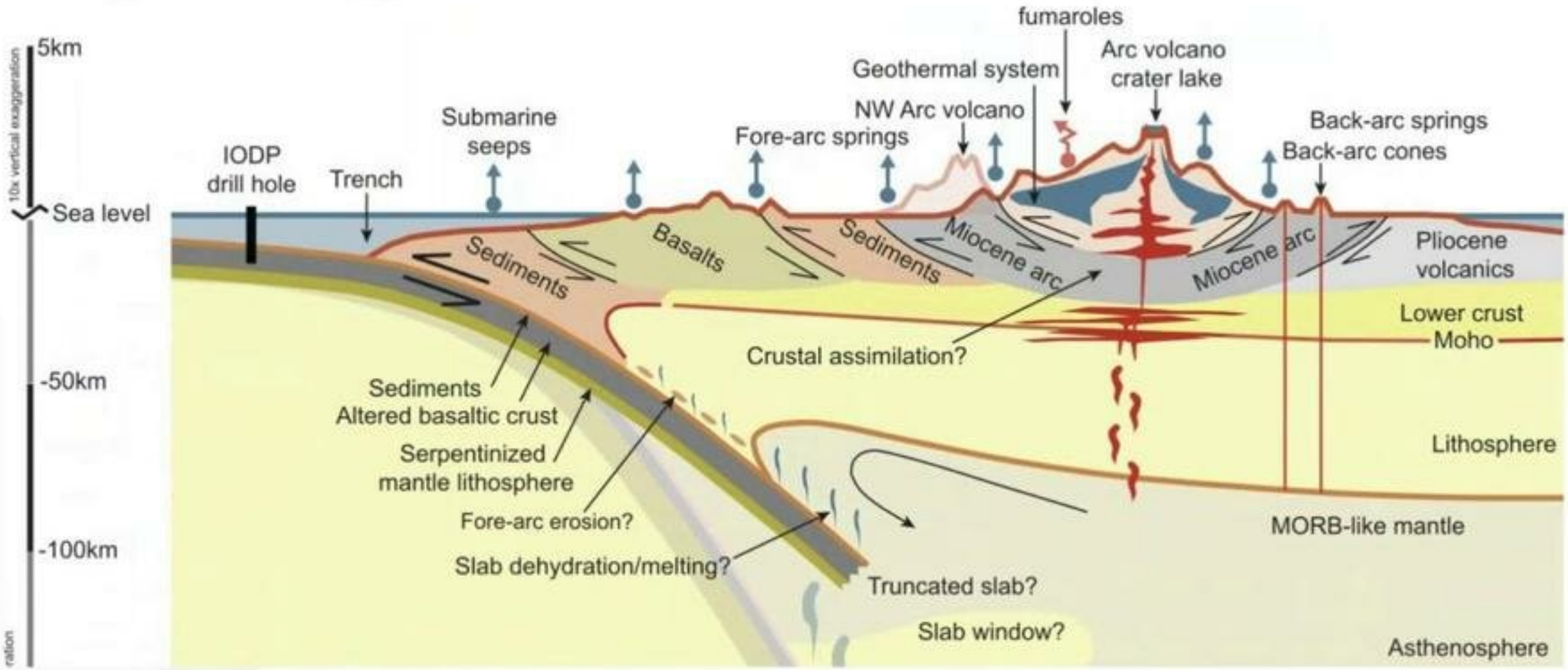

Giovannelli et al. Eos, 101

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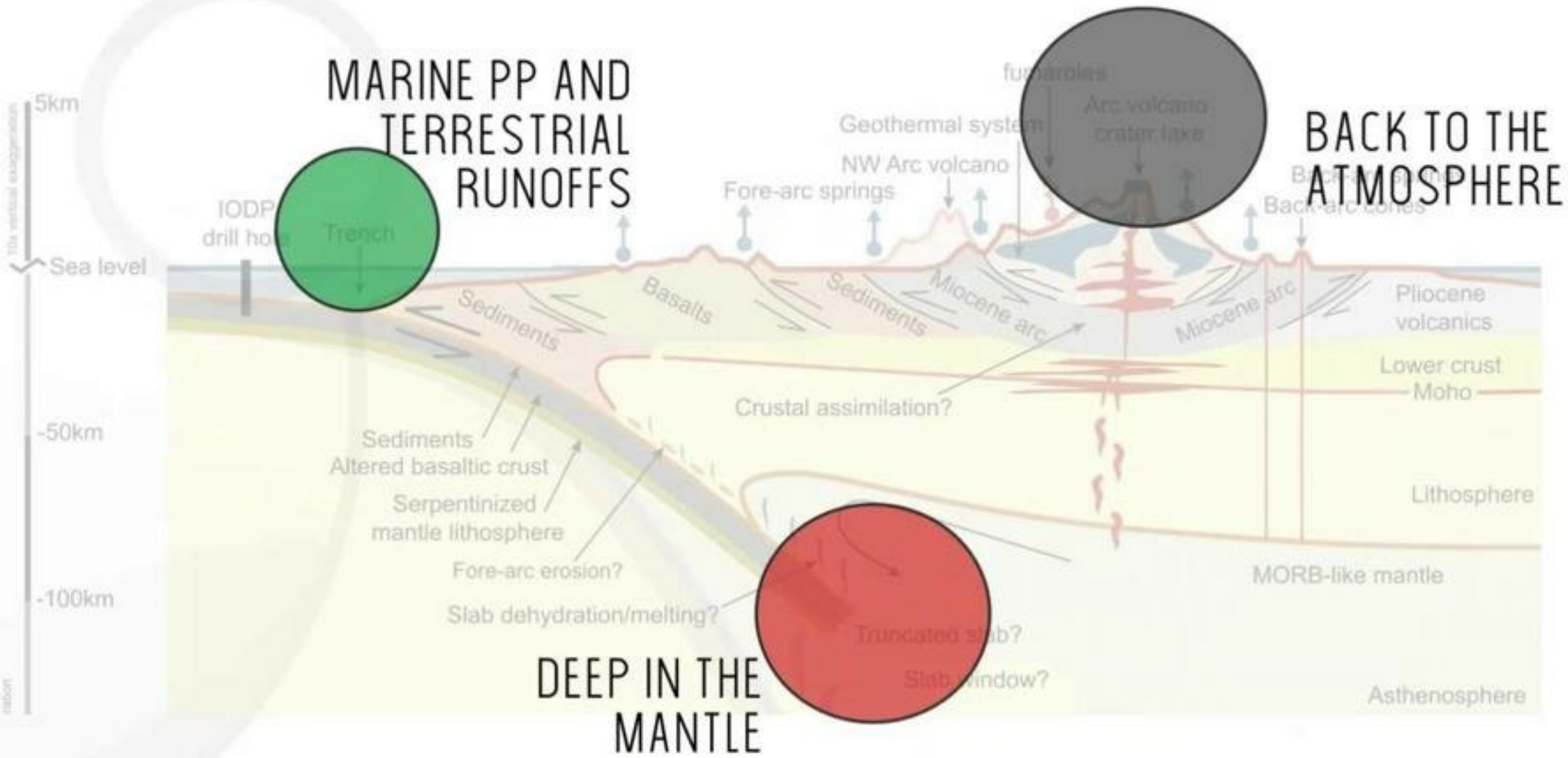
MARINE PP AND TERRESTRIAL RUNOFFS

BACK TO THE ATMOSPHERE

DEEP IN THE MANTLE



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Giovannelli et al. Eos, 101

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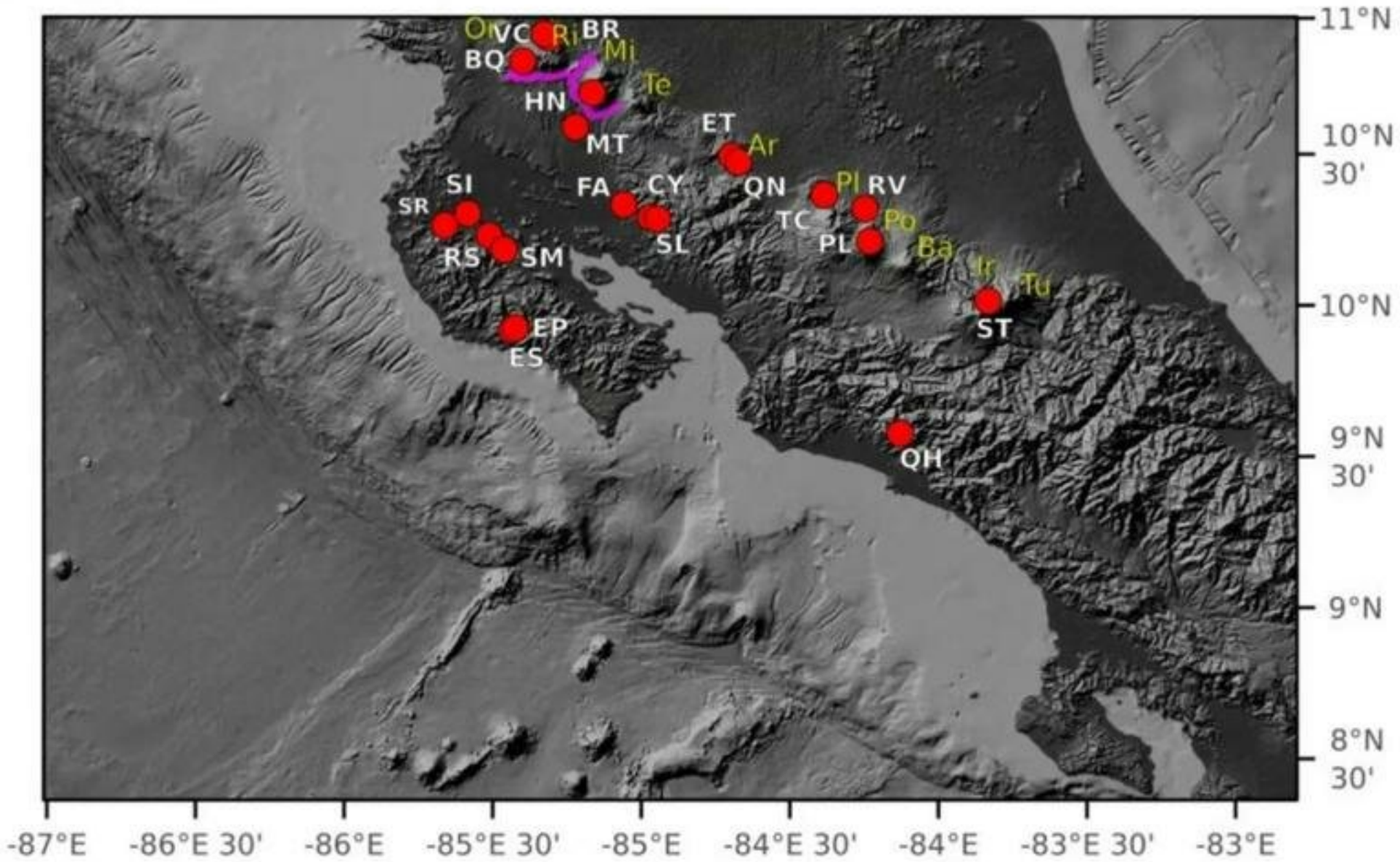

Barry et al 2019 Nature; Fullerton et al. 2021 Nat Geosci

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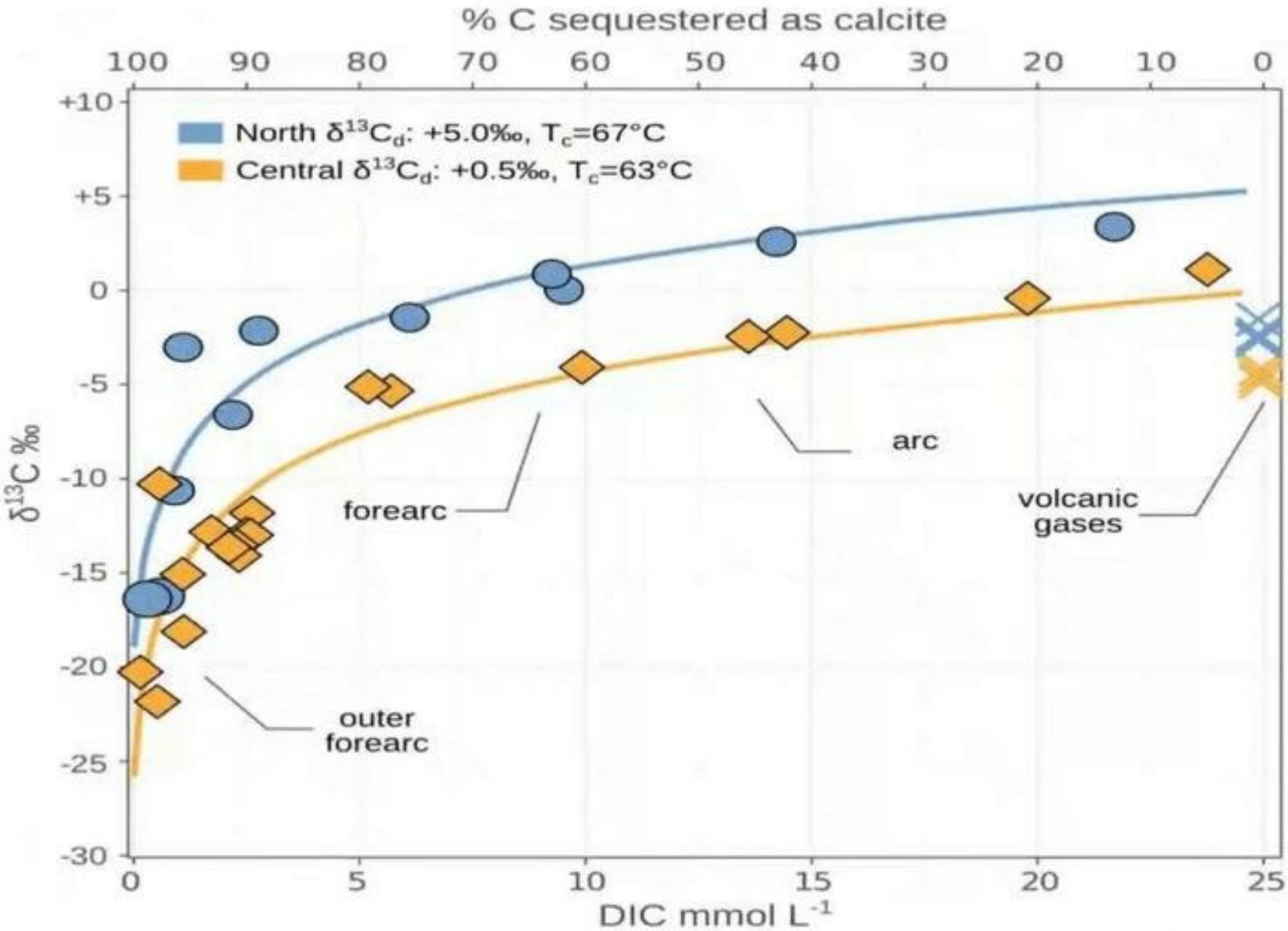

Barry et al 2019 Nature

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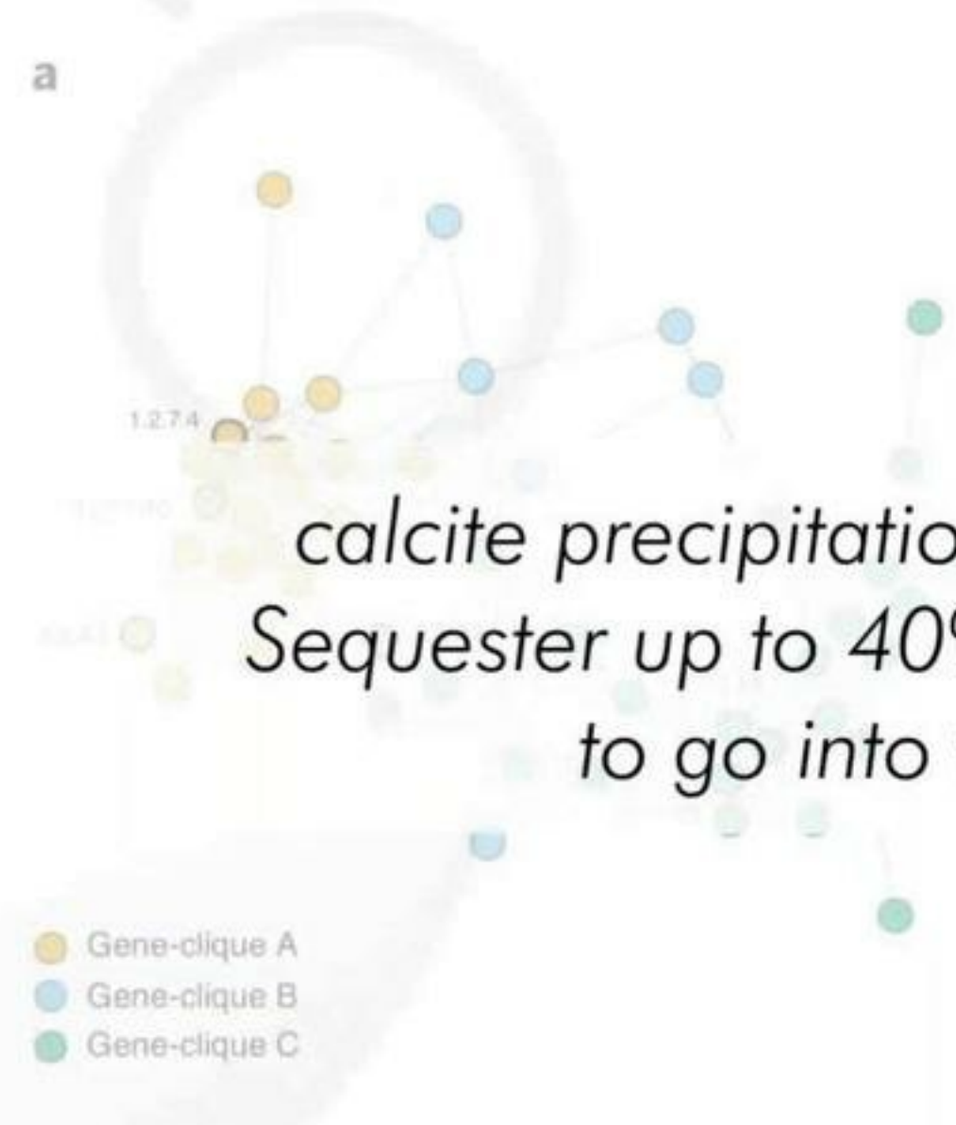

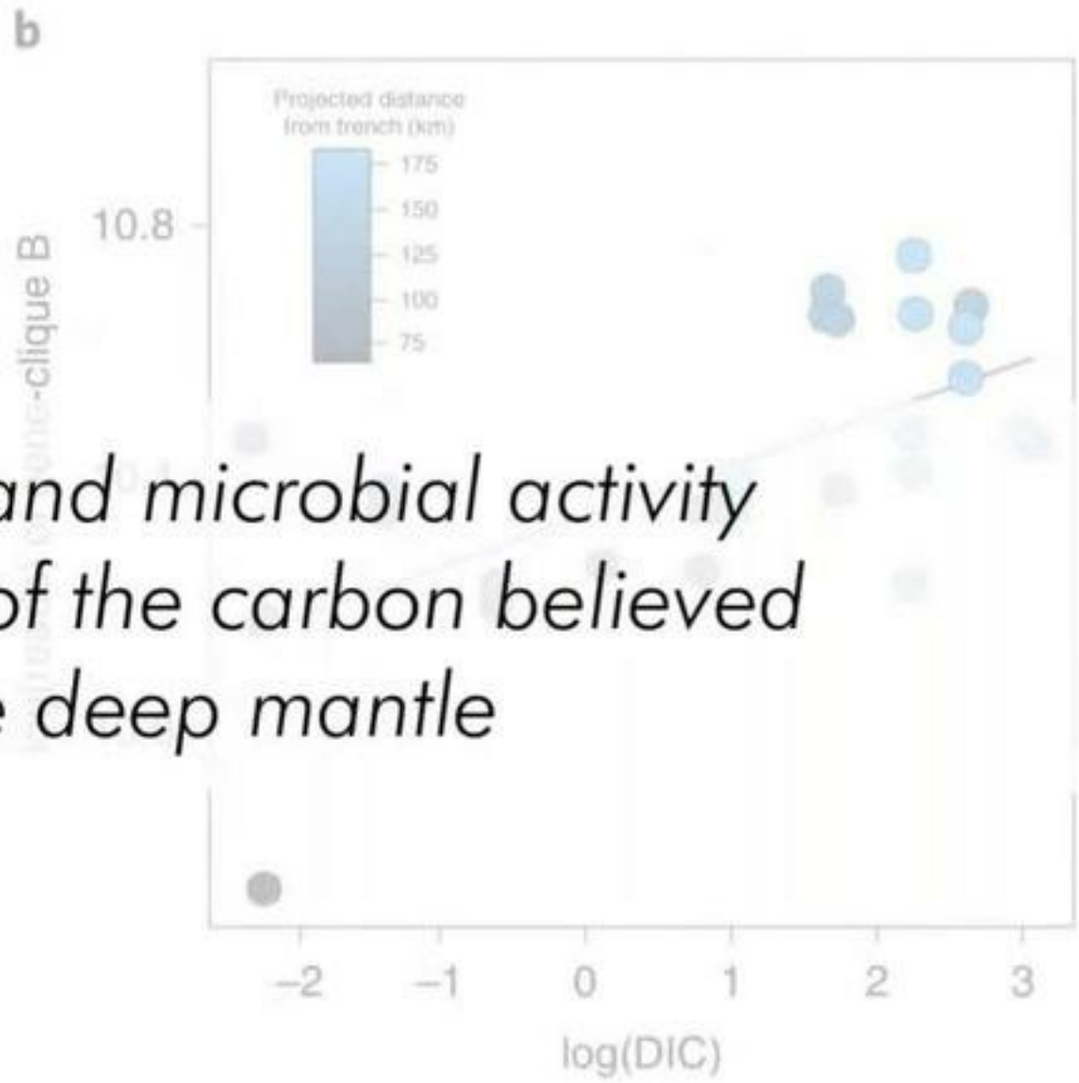

calcite precipitation and microbial activity
Sequester up to 40% of the carbon believed to go into the deep mantle

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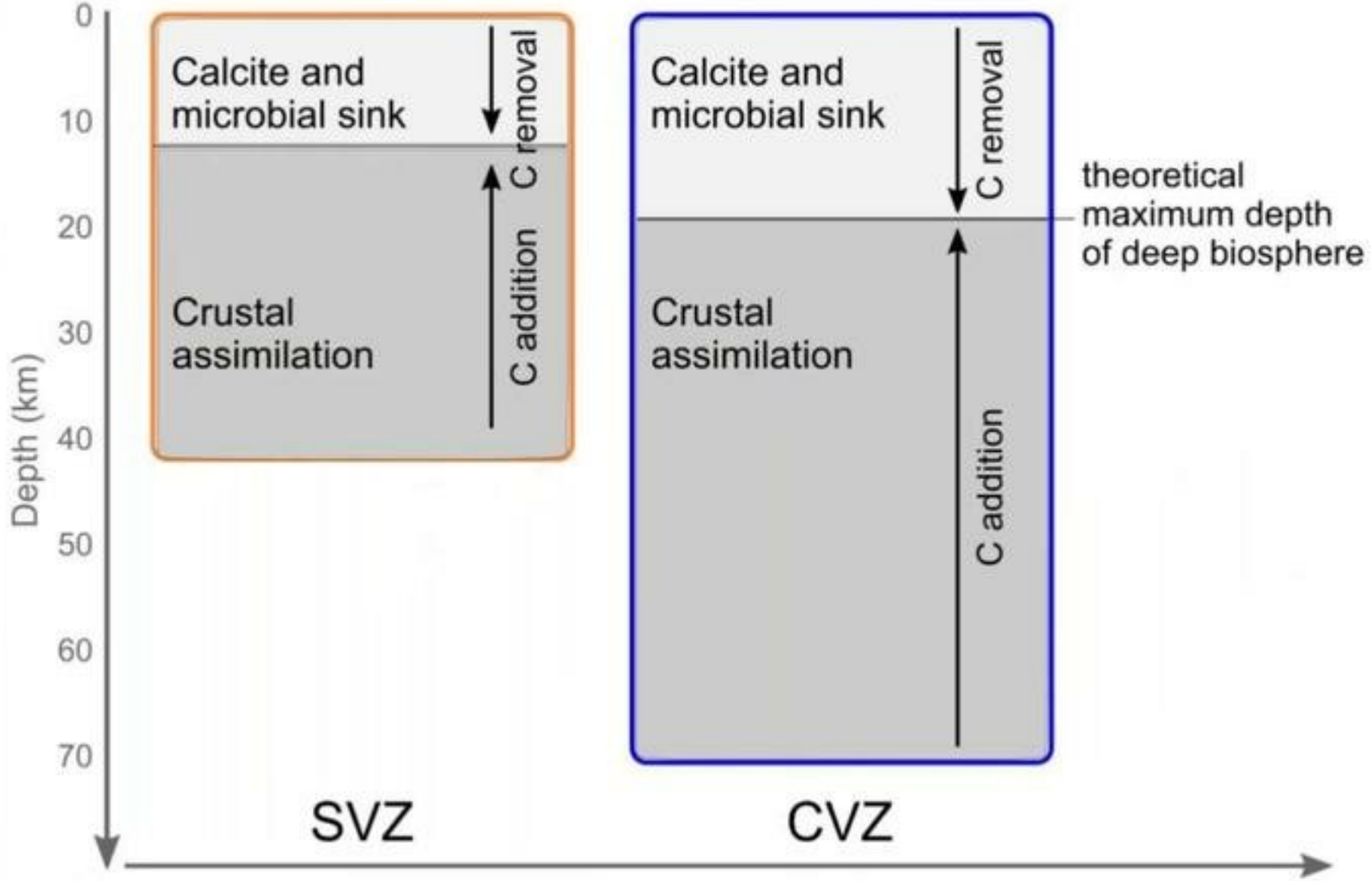
Fullerton et al. 2021 Nat Geosci



Barry et al 2022 Front Earth Sci

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Microbial role in permafrost thawing

The ISME Journal
Multidisciplinary Journal of Microbial Ecology

Published: 17 November 2011

Microbes in thawing permafrost: the unknown variable in the climate change equation

David E Graham ✉, Matthew D Wallenstein, Tatiana A Vishnivetskaya, Mark P Waldrop, Tommy J Phelps, Susan M Pfiffner, Tullis C Onstott, Lyle G Whyte, Elizaveta M Rivkina, David A Gilichinsky, Dwayne A Elias, Rachel Mackelprang, Nathan C VerBerkmoes, Robert L Hettich, Dirk Wagner, Stan D Wullschleger & Janet K Jansson

The ISME Journal **6**, 709–712 (2012) | Cite this article

Graham et al. 2012 ISMEJ

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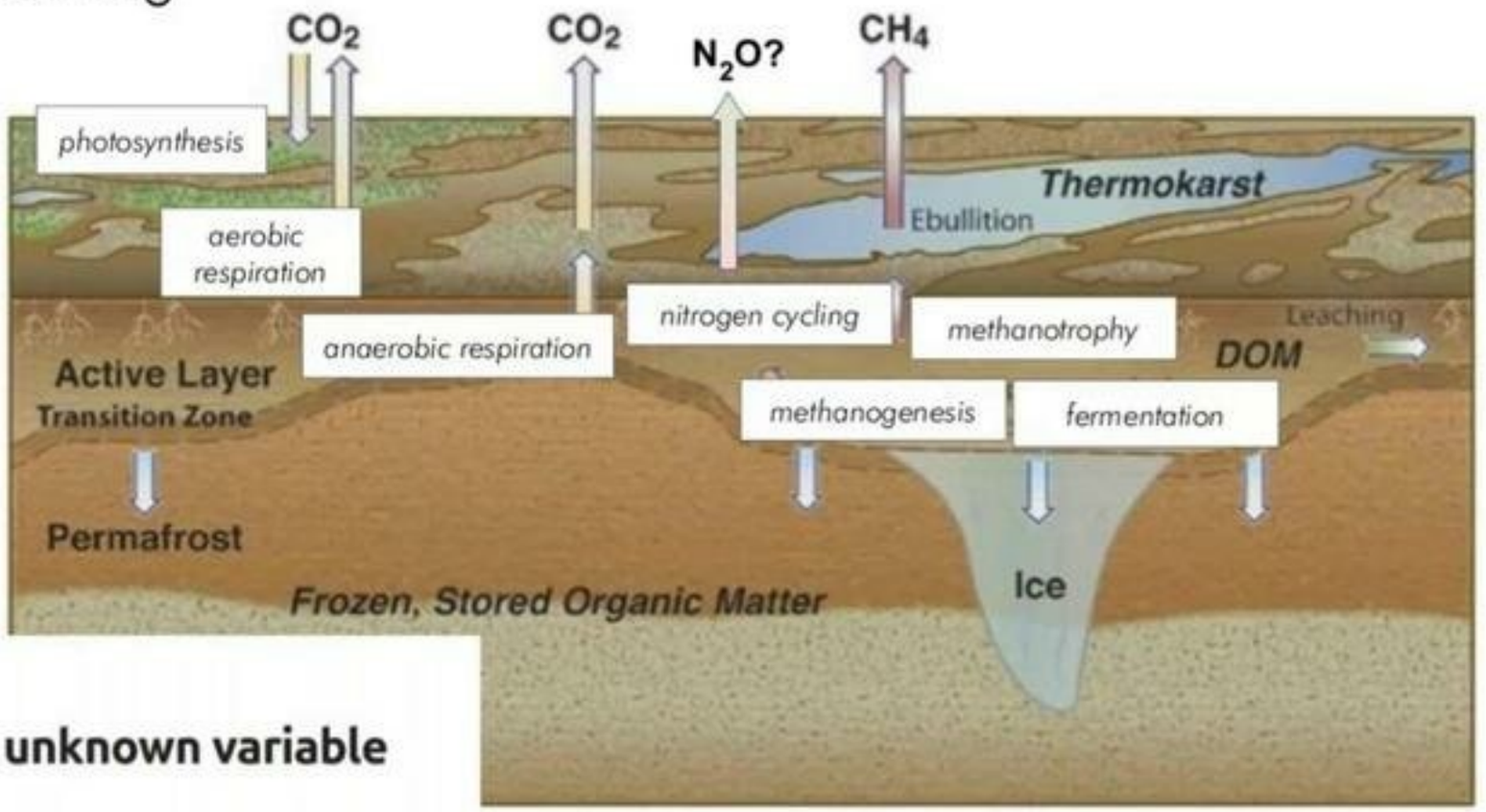

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ESD11-015

Graham et al. 2012 ISMEJ

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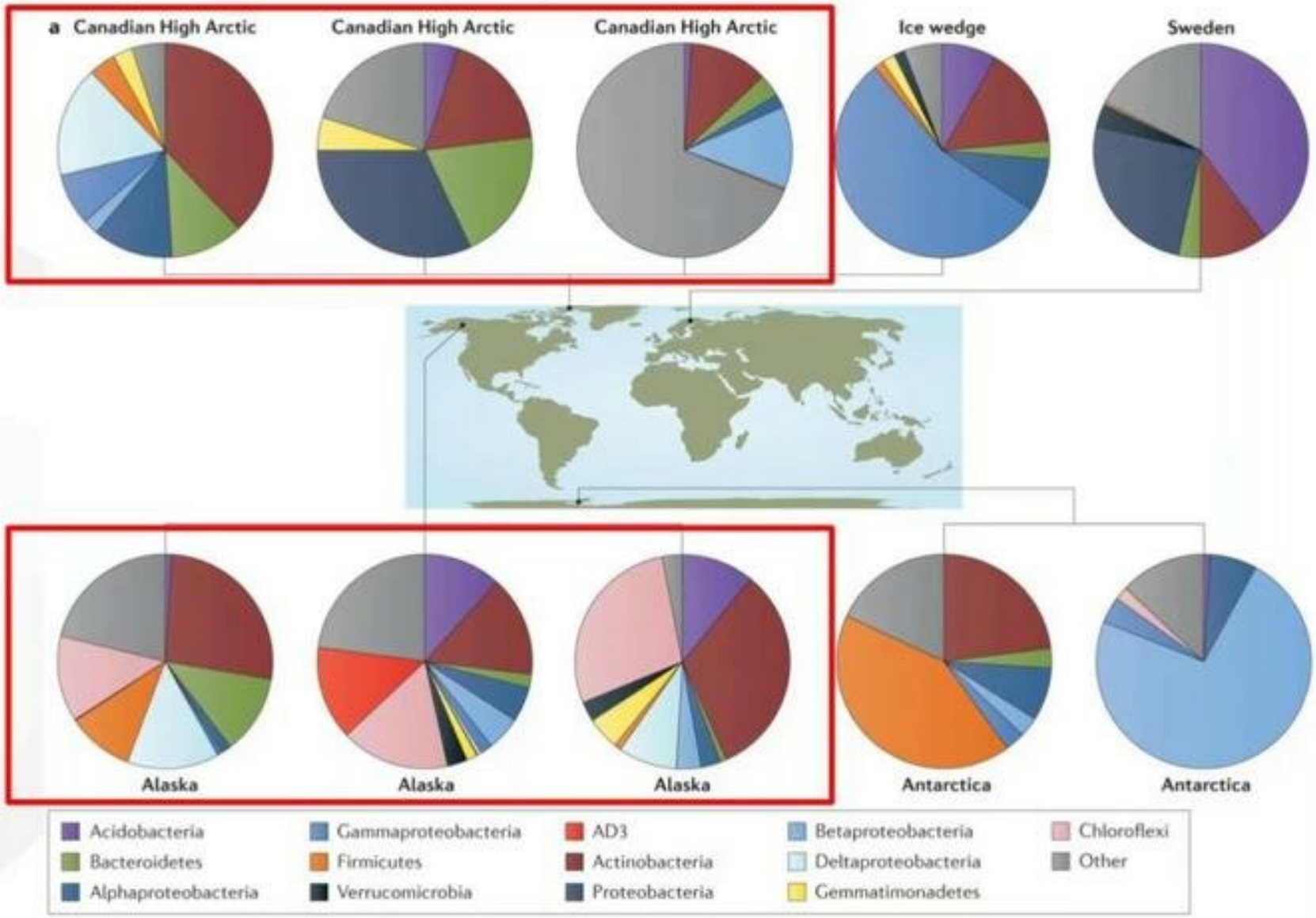

Jasson and Taş 2014 Nat Rev Microbiol

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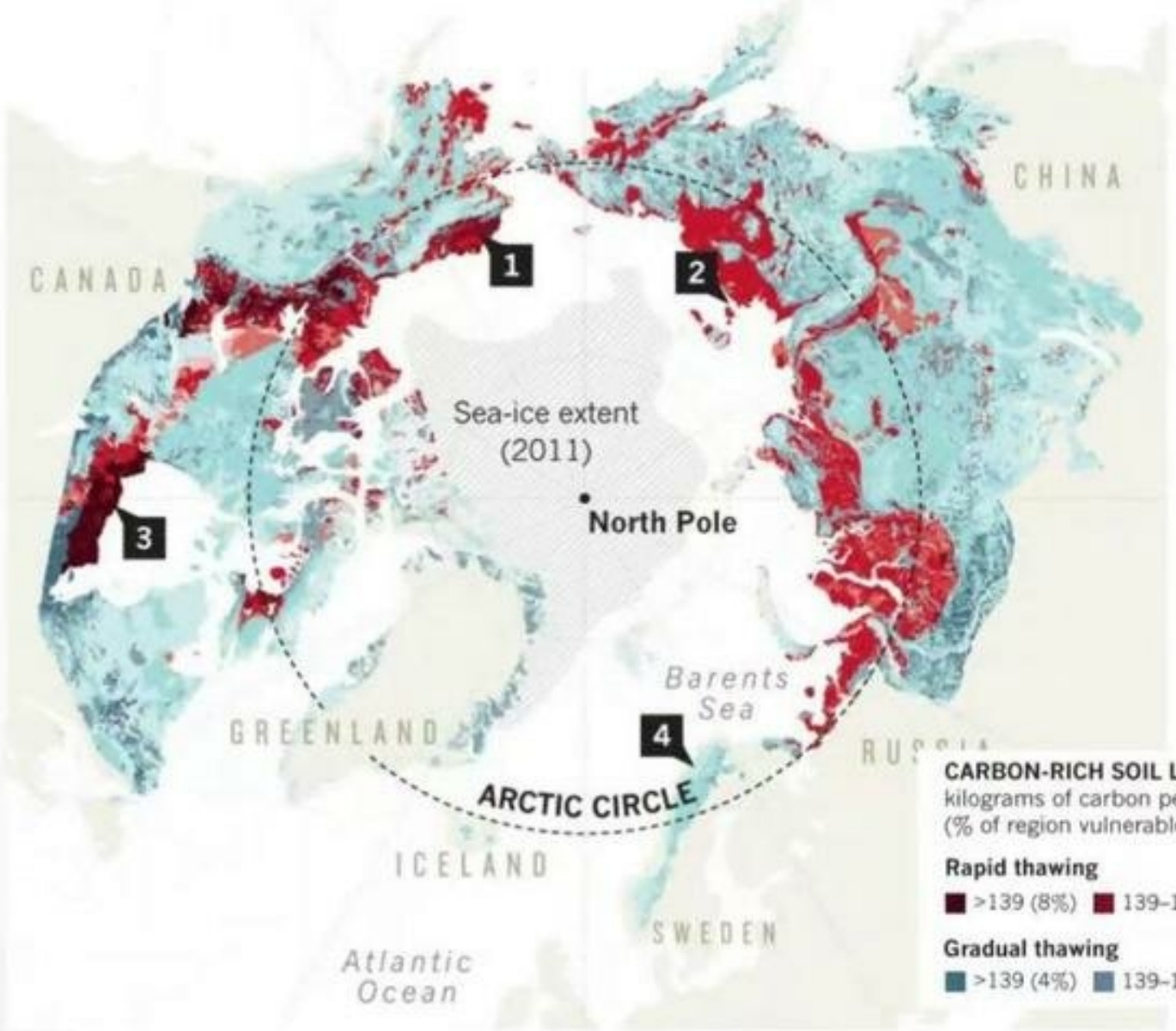
Permafrost and Glacier melting is not just about carbon



nature
COMMENT | 30 April 2019

Permafrost collapse is accelerating carbon release

The sudden collapse of thawing soils in the Arctic might double the warming from greenhouse gases released from tundra, warn Merritt R. Turetsky and colleagues.

Merritt R. Turetsky ✉, Benjamin W. Abbott, Miriam C. Jones, Katey Walter Anthony, David Olefeldt, Edward A. G. Schuur, Charles Koven, A. David McGuire, Guido Grosse, Peter Kuhry, Gustaf Hugelius, David M. Lawrence, Carolyn Gibson & A. Britta K. Sannel

CARBON-RICH SOIL LEVELS
kilograms of carbon per square metre
(% of region vulnerable to type of thawing)

Rapid thawing
>139 (8%) 139–105 (10%) 104–70 (60%) 69–36 (19%) 35–0 (3%)

Gradual thawing
>139 (4%) 139–105 (3%) 104–70 (26%) 69–36 (39%) 35–0 (28%)

Turetsky et al. 2019 Nature

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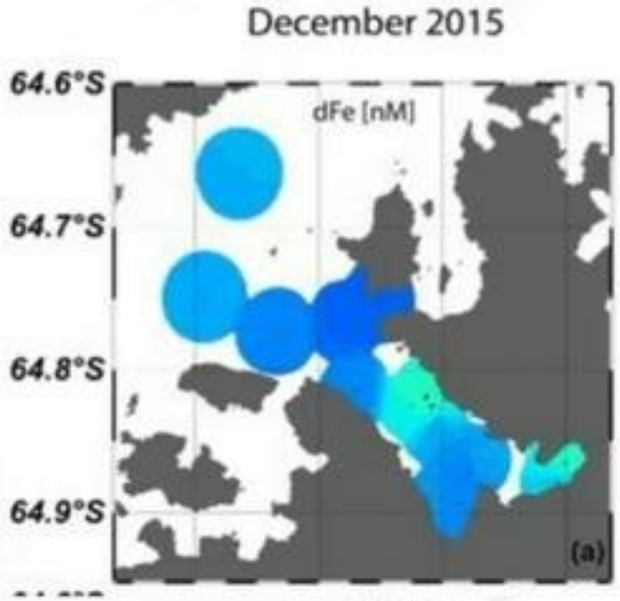
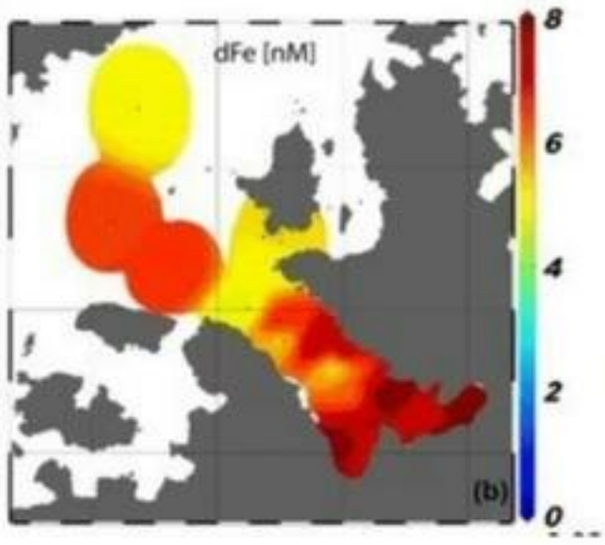
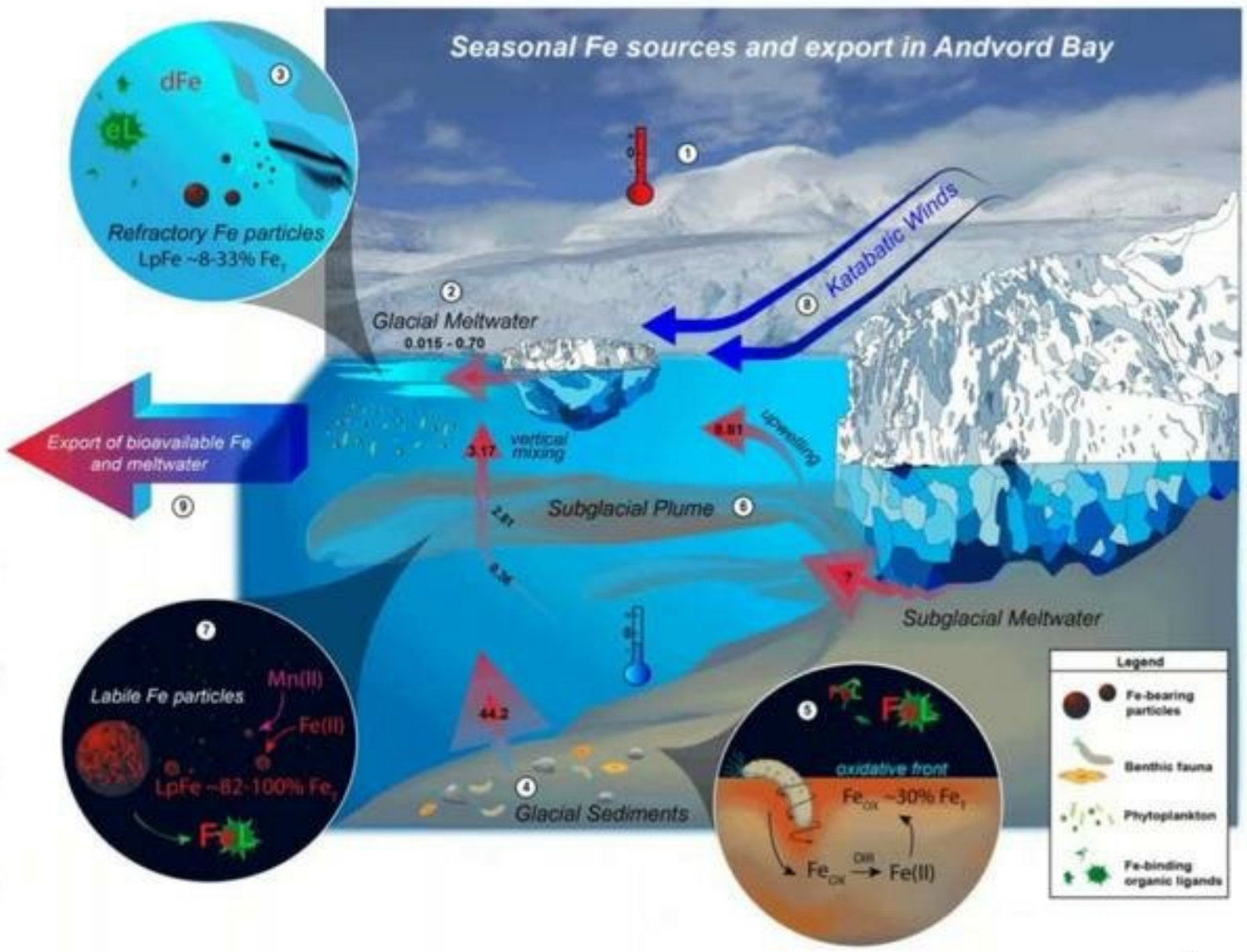
Permafrost and Glacier melting is not just about carbon, but also metals







Forsch et al. 2021 Biogeosciences

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Melting glaciers: a key component of warming polar regions

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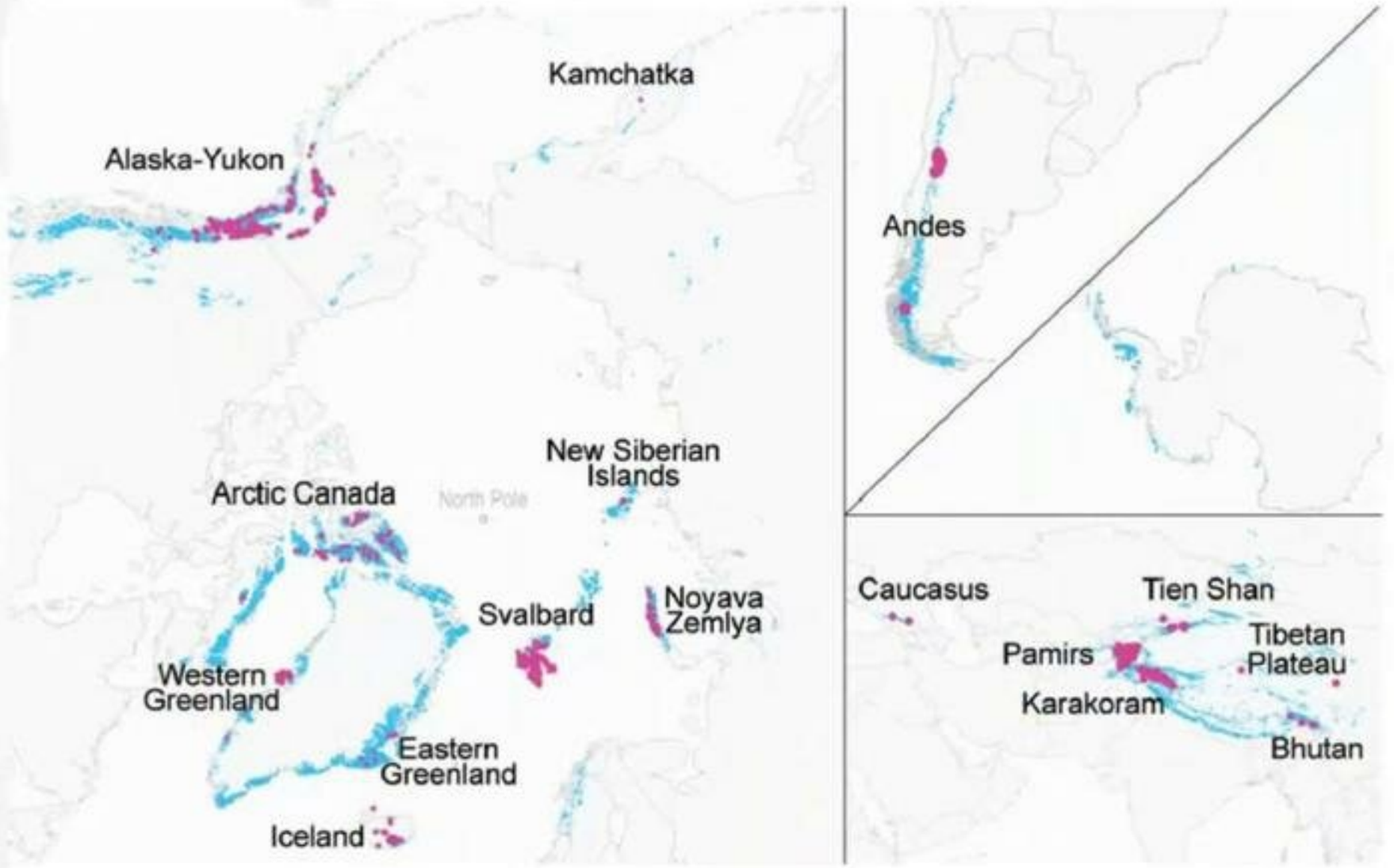

Pasotti et al. 2013 Mar Ecol; Correggia et al. 2022 in prep

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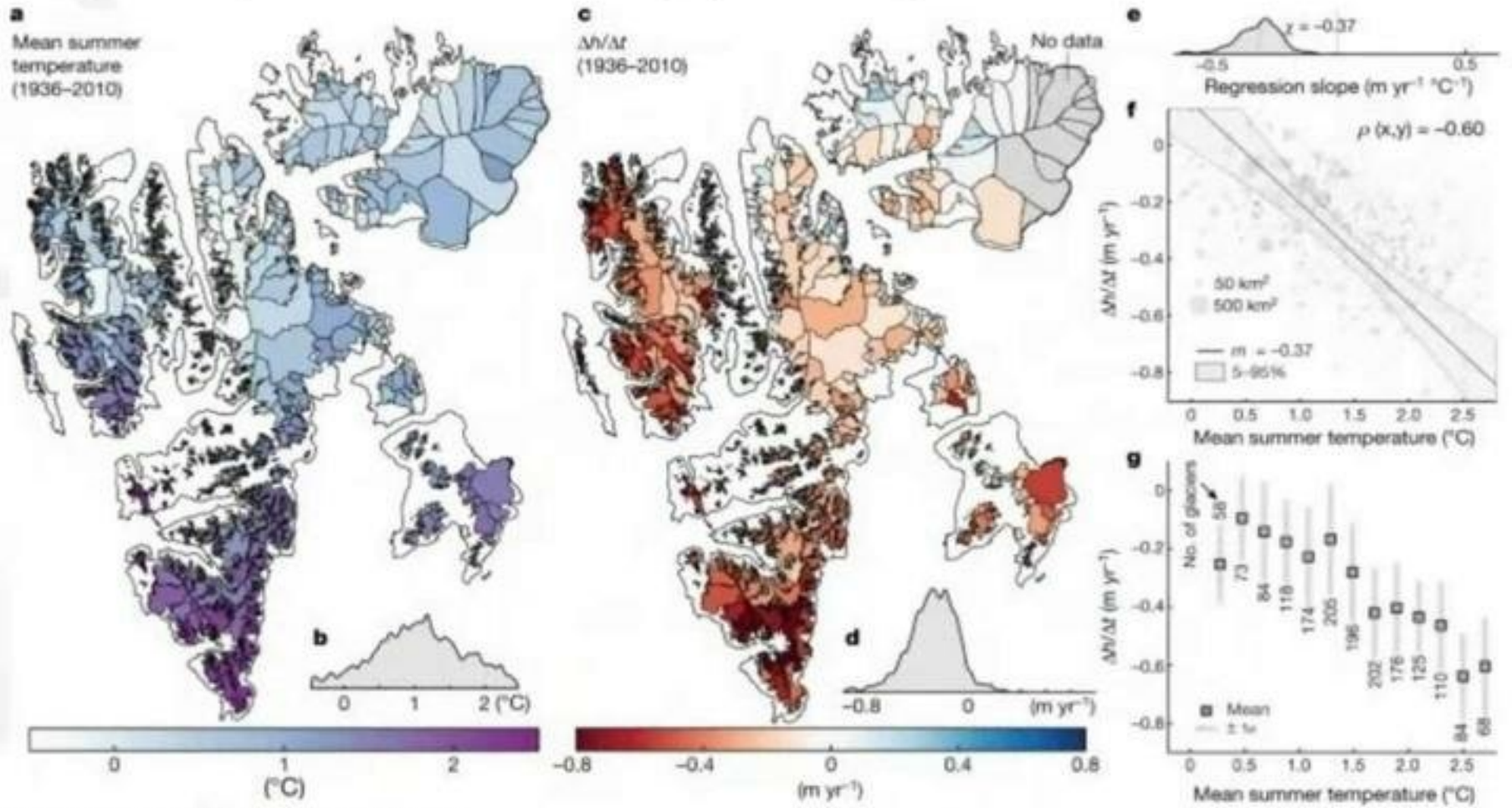

nature

Historical glacier change on Svalbard predicts doubling of mass loss by 2100

Emily C. Geyman ✉, Ward J. J. van Pelt, Adam C. Maloof, Harald Faste Aas & Jack Kohler

Nature **601**, 374–379 (2022) | Cite this article

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Melting glaciers: a key component of warming polar regions

Aerial pictures by Karen Lloyd/UTK, USA

West Antarctic Peninsula: Sampling microbial diversity and glacier retreat

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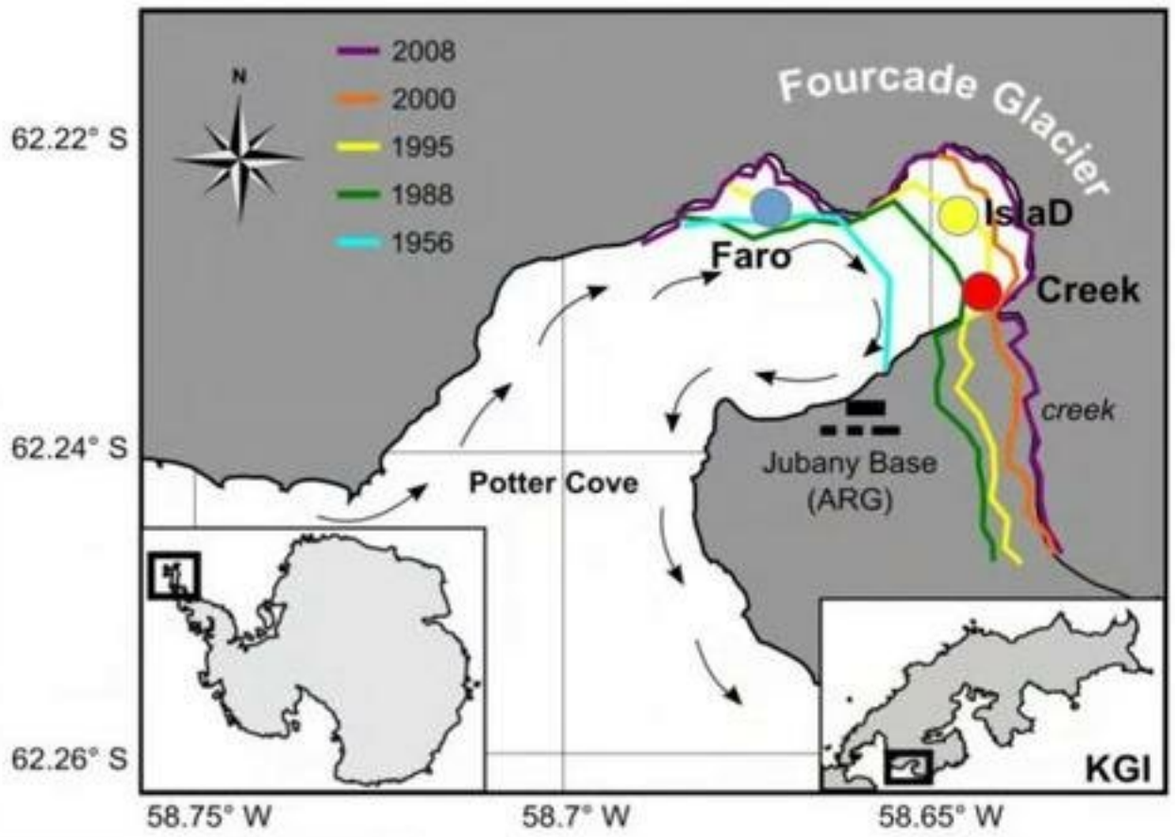

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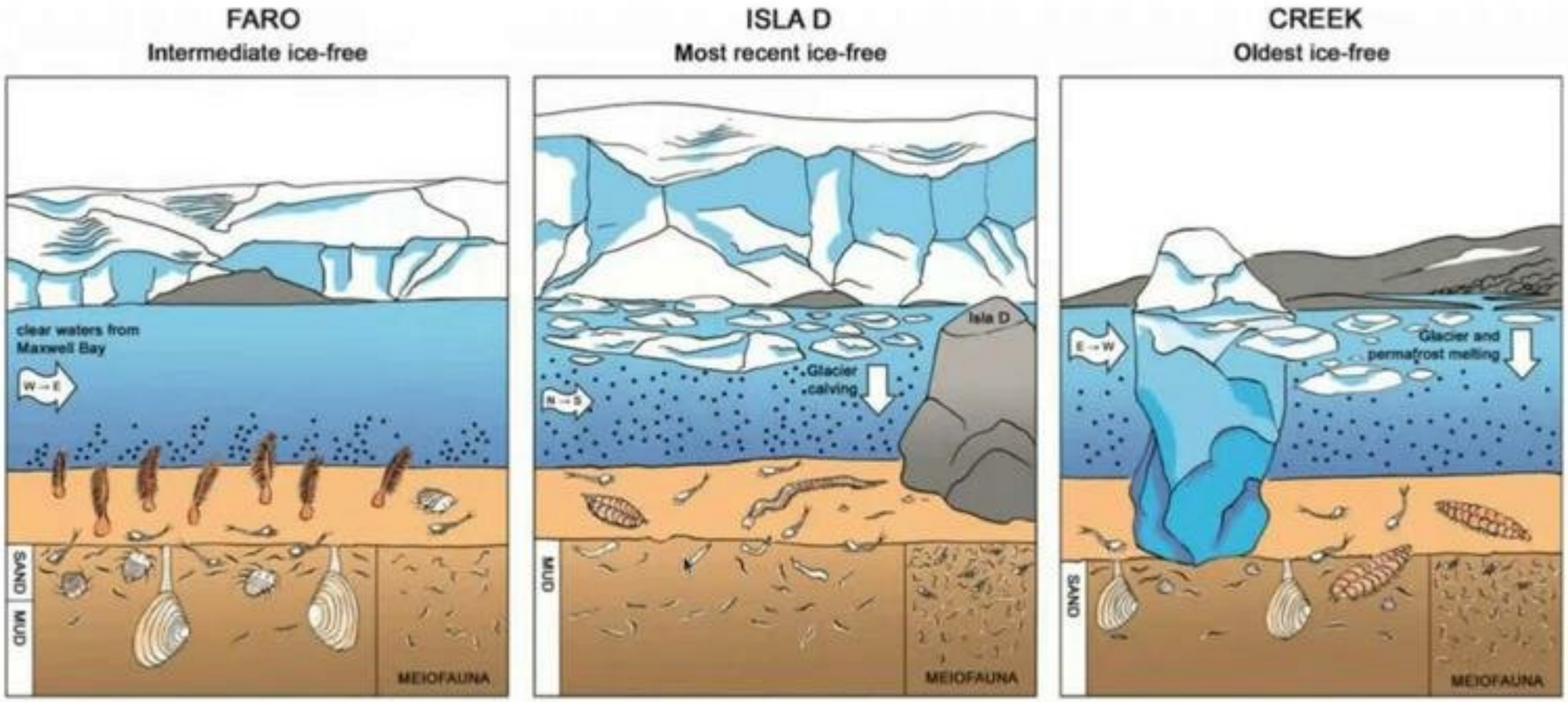

Pasotti et al. 2013 Mar Ecol; Correggia et al. 2022 in prep

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The role of microbes in producing gas in summer

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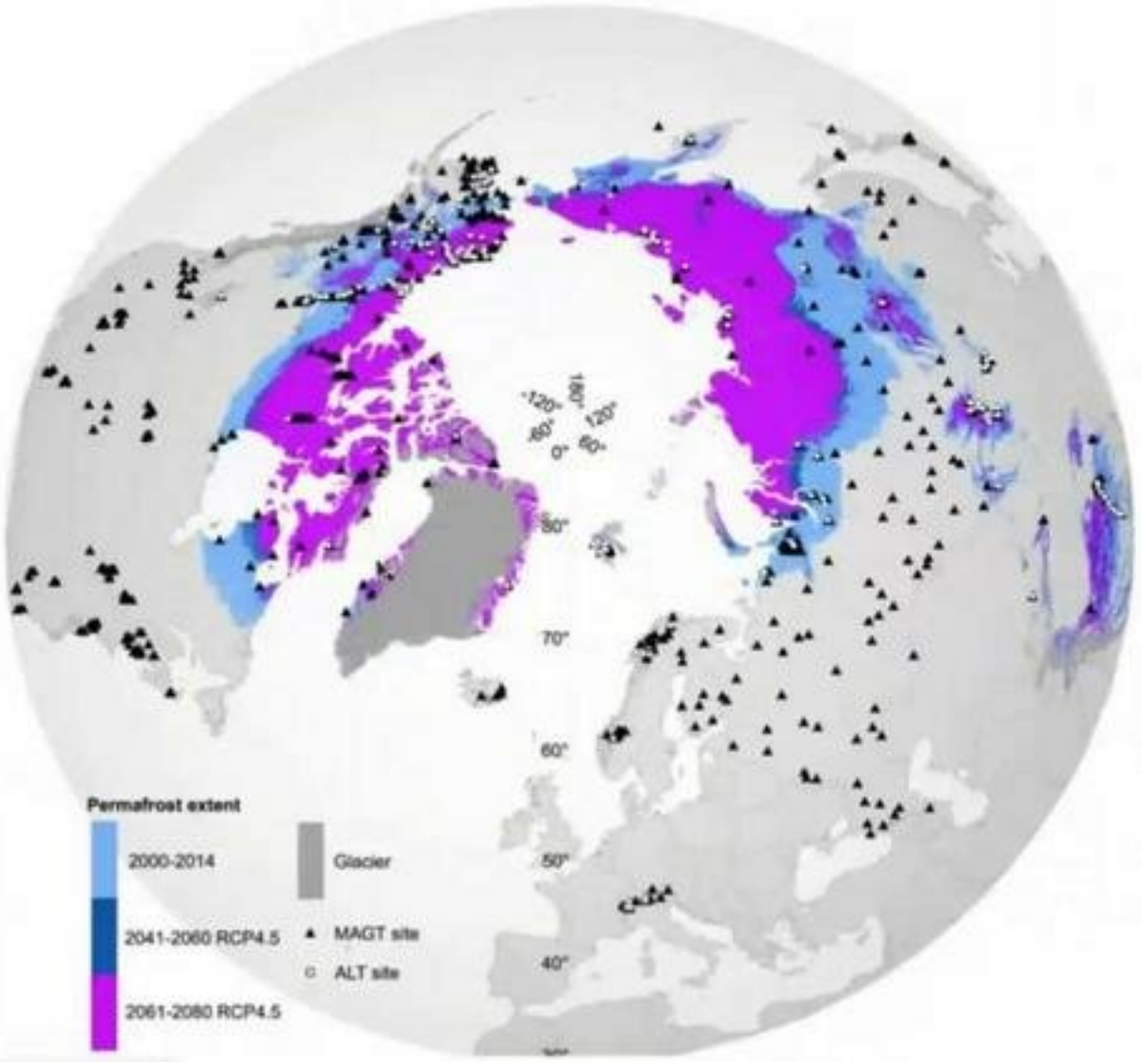

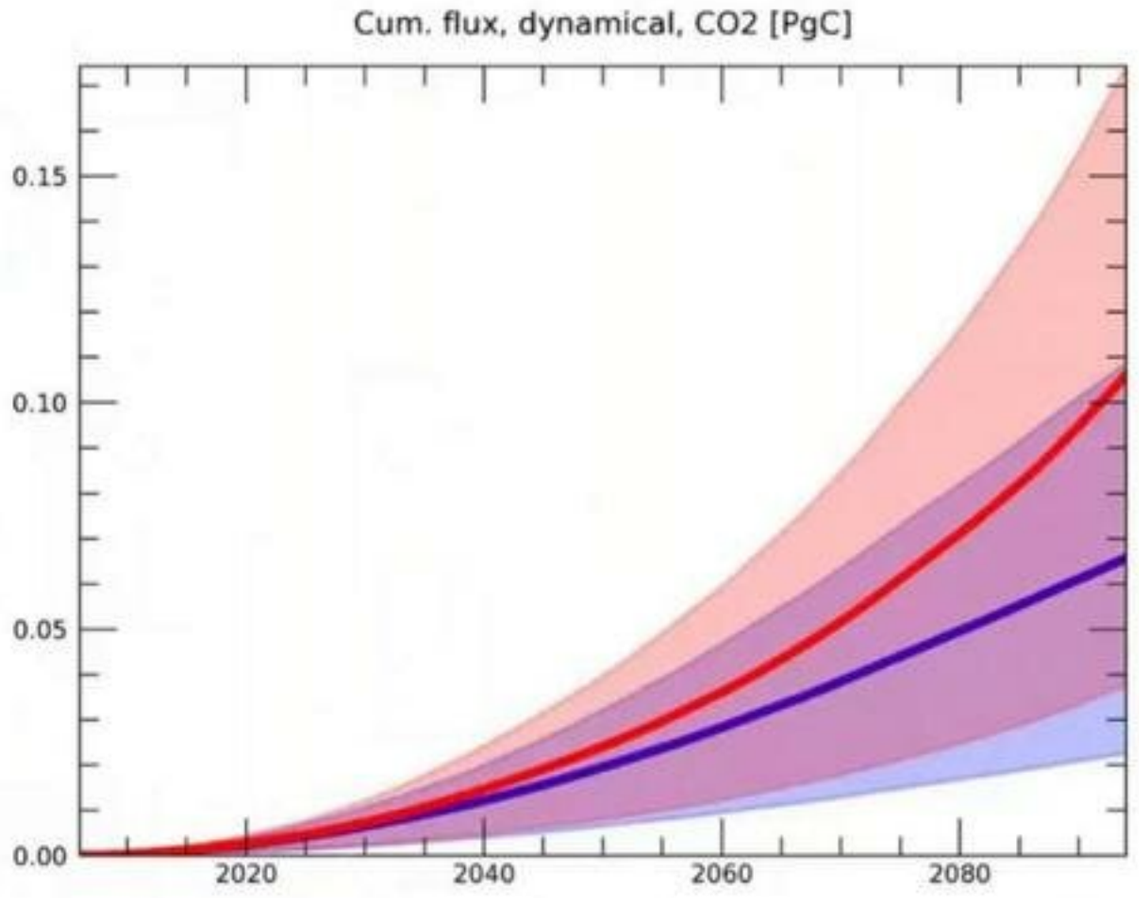

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Yokohata et al. 2020 Progr Earth Plan Sci

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What about winter?

The subzero microbiome: microbial activity in frozen and thawing soils

Mrinalini P. Nikrad, Lee J. Kerkhof, Max M. Häggblom

FEMS Microbiology Ecology, Volume 92, Issue 6, June 2016, fiw081,
https://doi.org/10.1093/femsec/fiw081
Published: 21 April 2016 **Article history**

Nikrad et al. 2016 FEMS Microbiol Ecol; Merino et al. 2019 Front Microbiol

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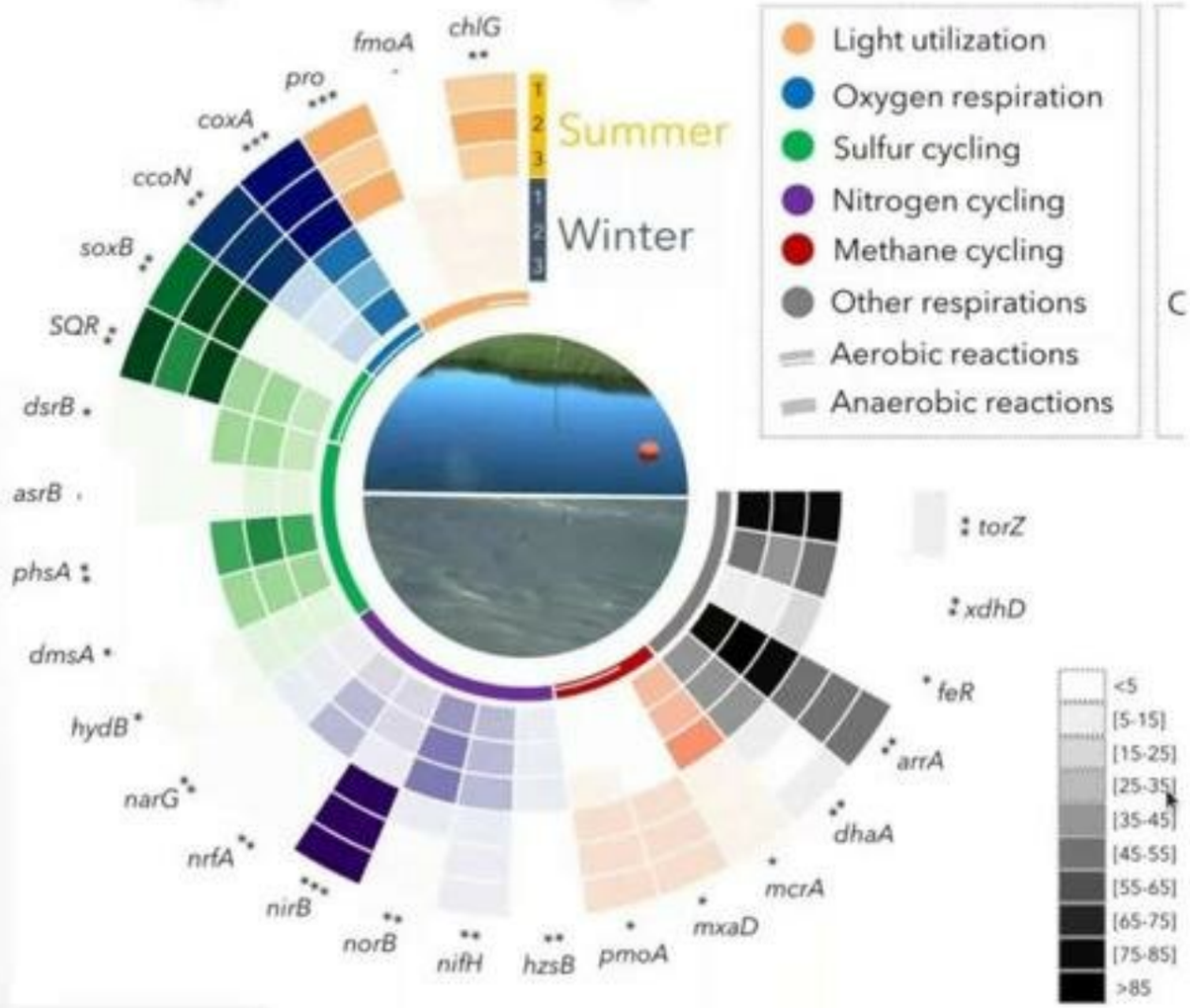
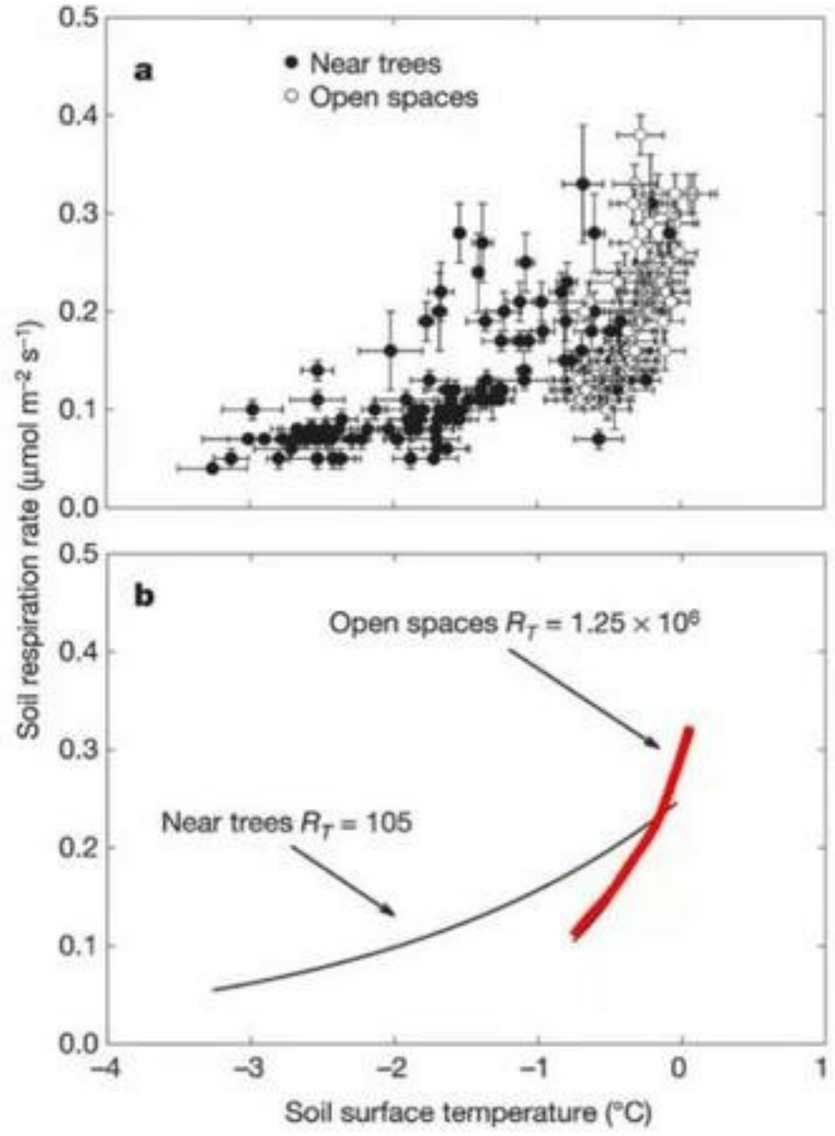
What about winter?





Vigneron et al 2019 Front Microbiol; Monson et al. 2006 Nature

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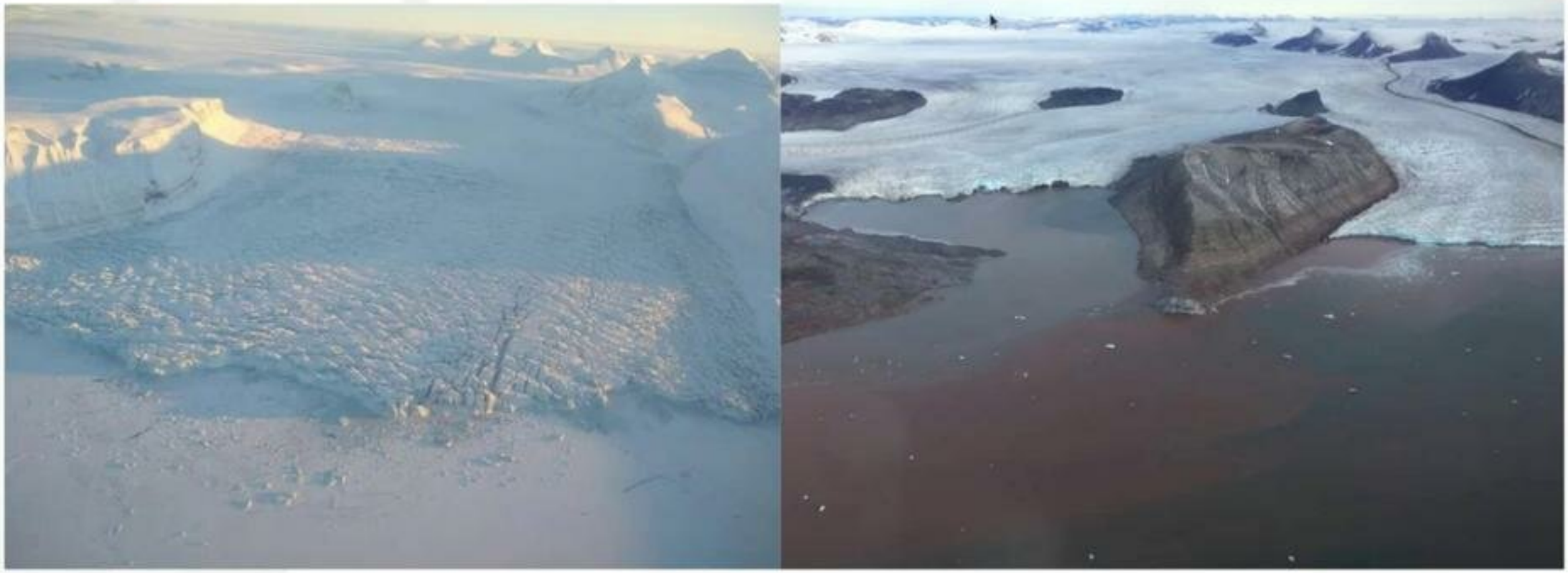
The PRA MeltingICE project



Aerial pictures by D Giovannelli/UNINA and K Lloyd/UTK

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The PRA MeltingICE project

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The PRA MeltingICE project

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The PRA MeltingICE project: preliminary data

Cardellini et al, 2022 unpublished / PRA MeltingICE

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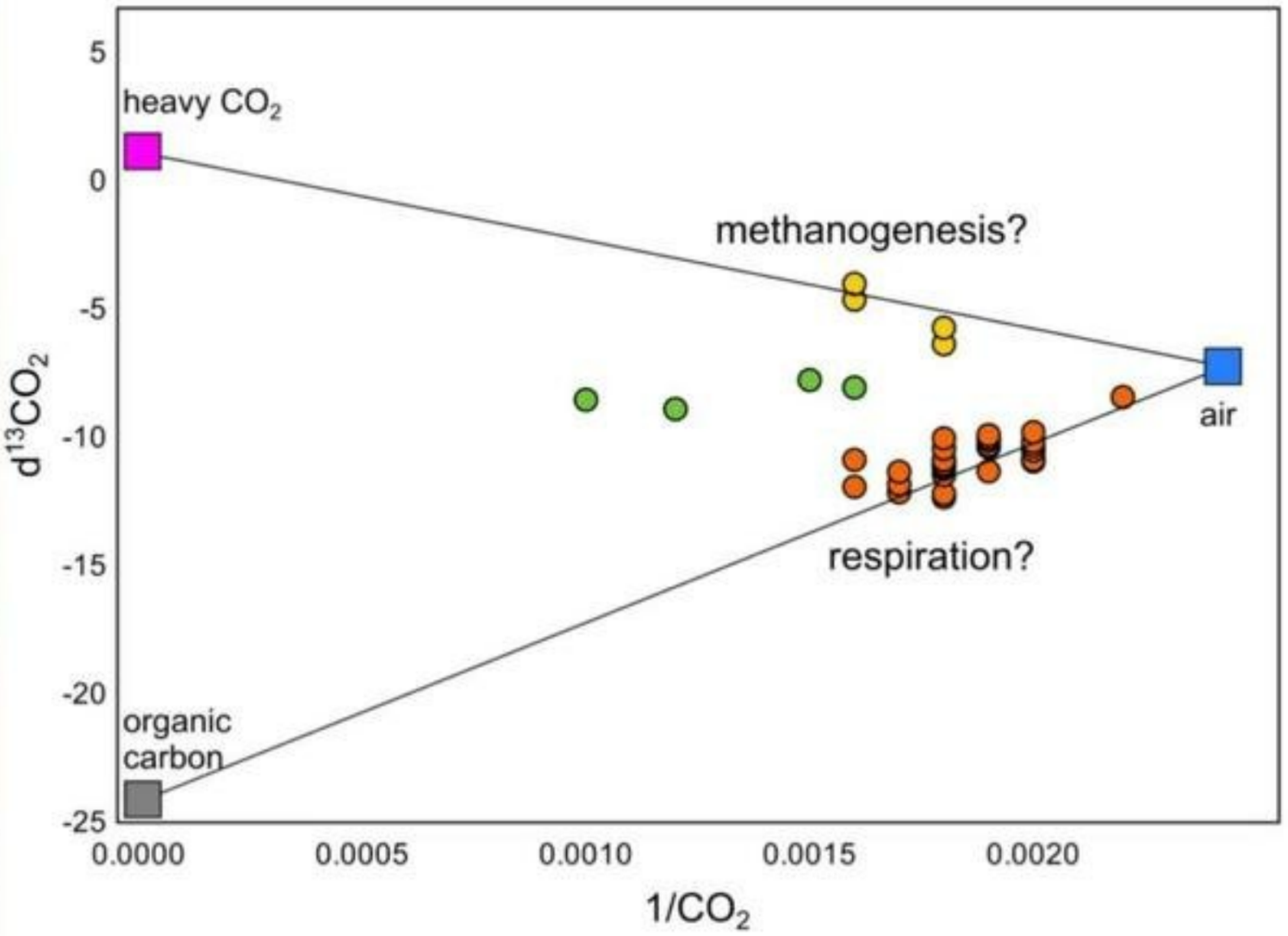
The PRA MeltingICE project: preliminary data



Cardellini et al, 2022 unpublished / PRA MeltingICE

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What's ahead?

Microbial DNA analysis is ongoing

Summer field campaign planned in June 2022

Biology Meets Subduction project

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Whats ahead?

Trace metal and carbon addition microcosm experiments

Fe
Mn
Cu
Ni
Co
Mo
Zn
W

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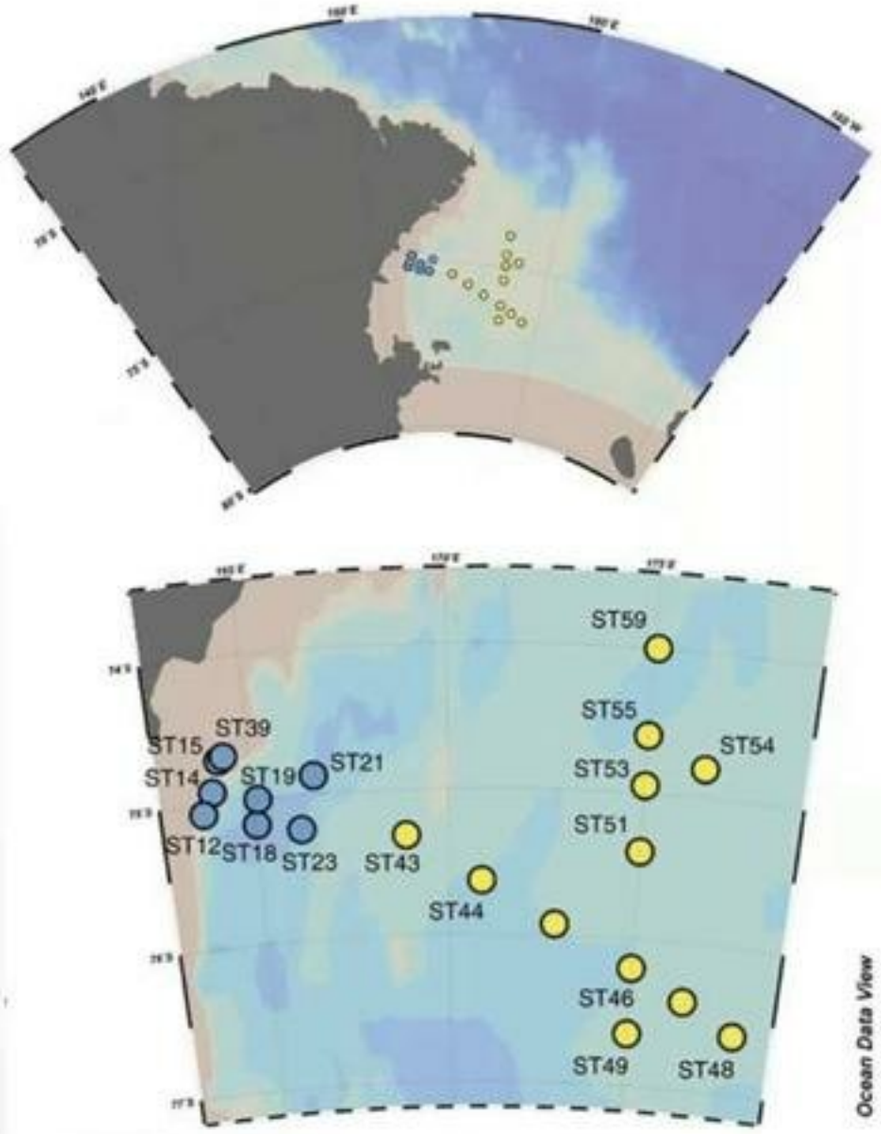
What is the role of microbe-microbe interactions?



Cordone et al. 2022 Fornt. Microbiol.

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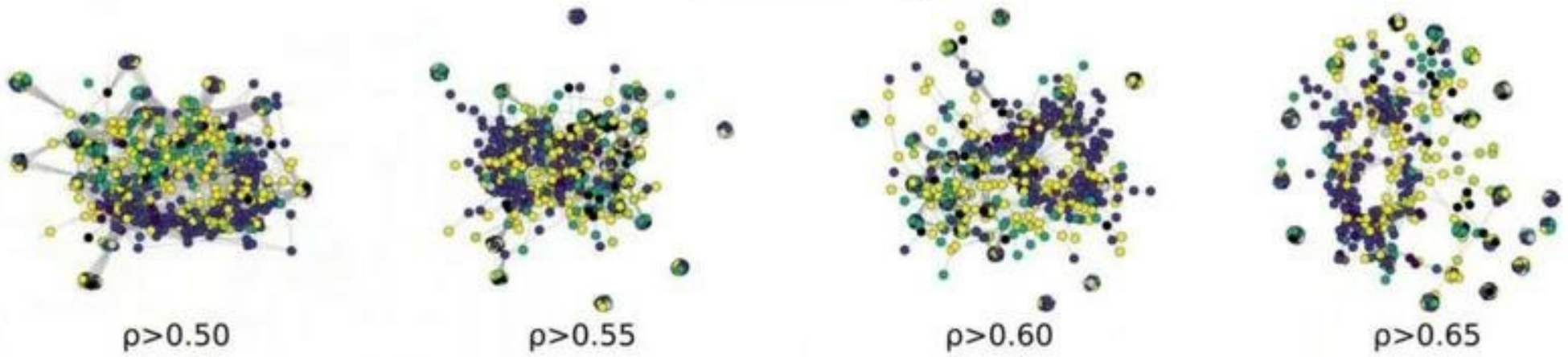
What is the role of microbe-microbe interactions?

Increeasing co-occurrence cut-off



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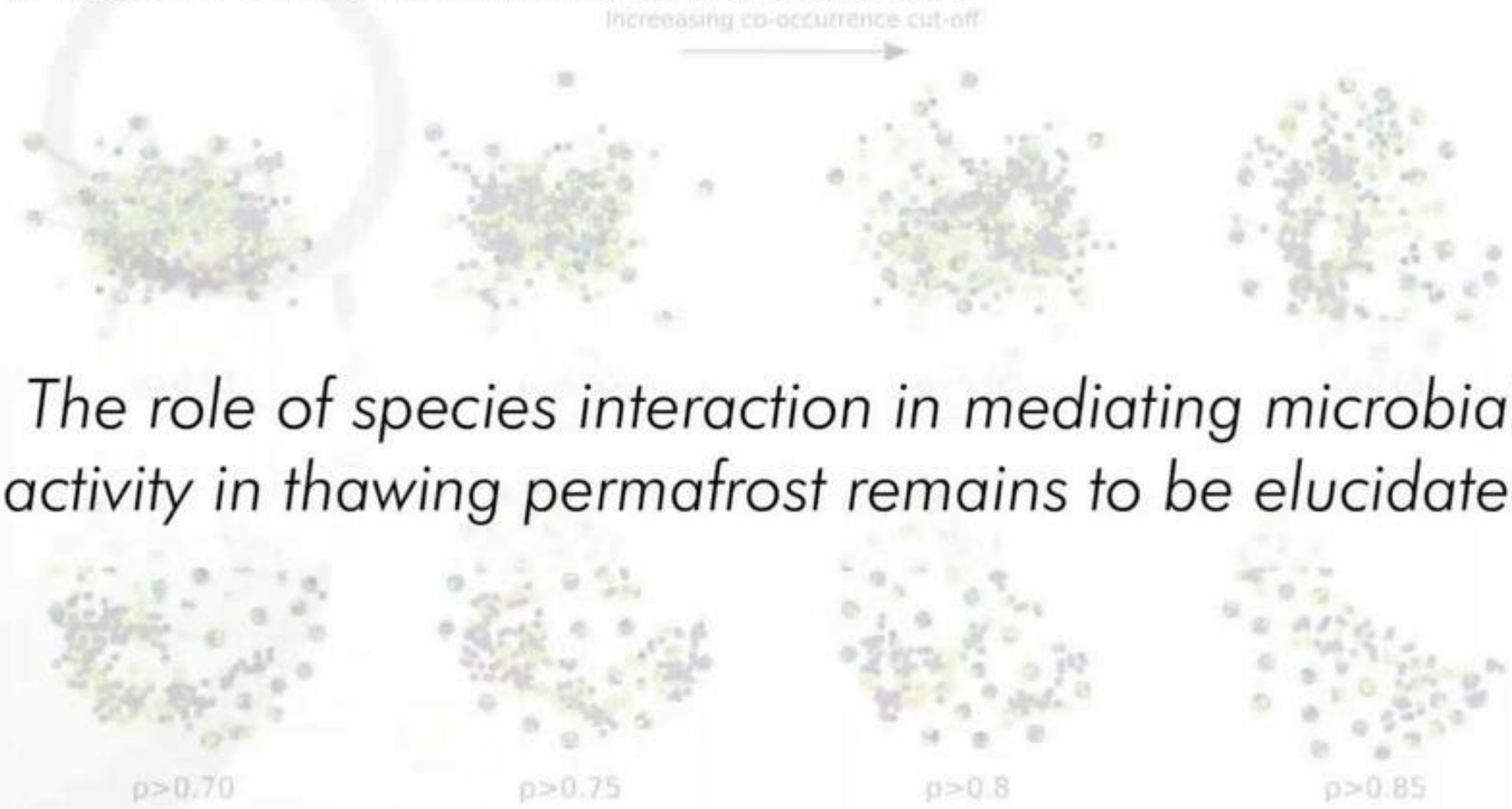
What is the role of microbe-microbe interactions?



The role of species interaction in mediating microbial activity in thawing permafrost remains to be elucidated

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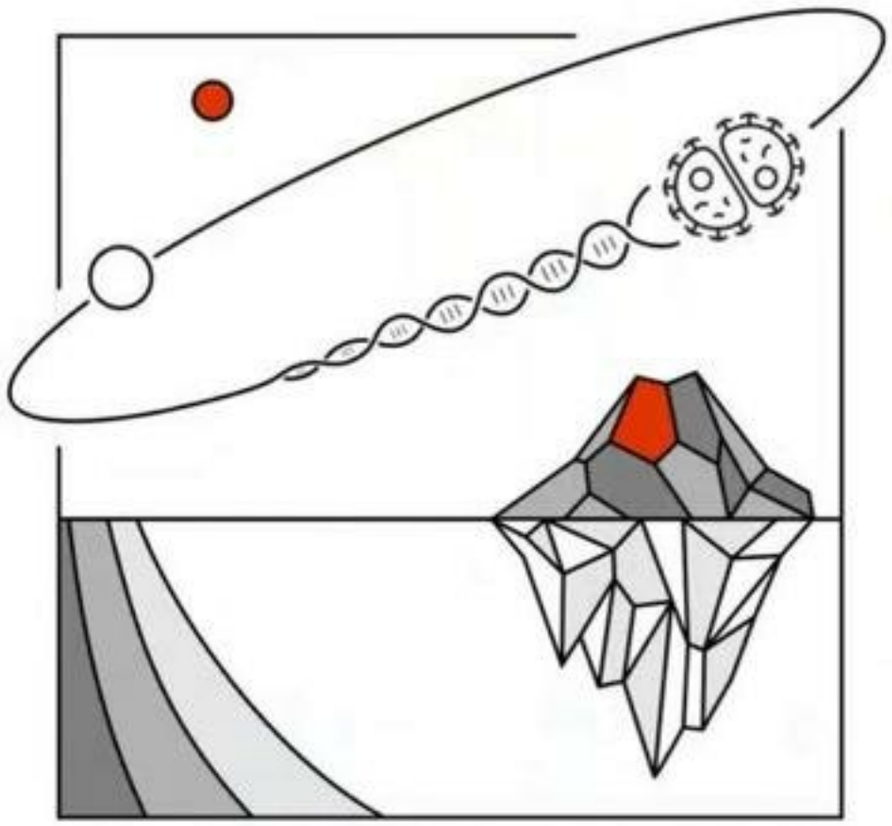

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