Science Strategy for Space Exploration of the Outer Solar System
Icy Moons Oceans

Life in marine extreme environments

examples from geological record

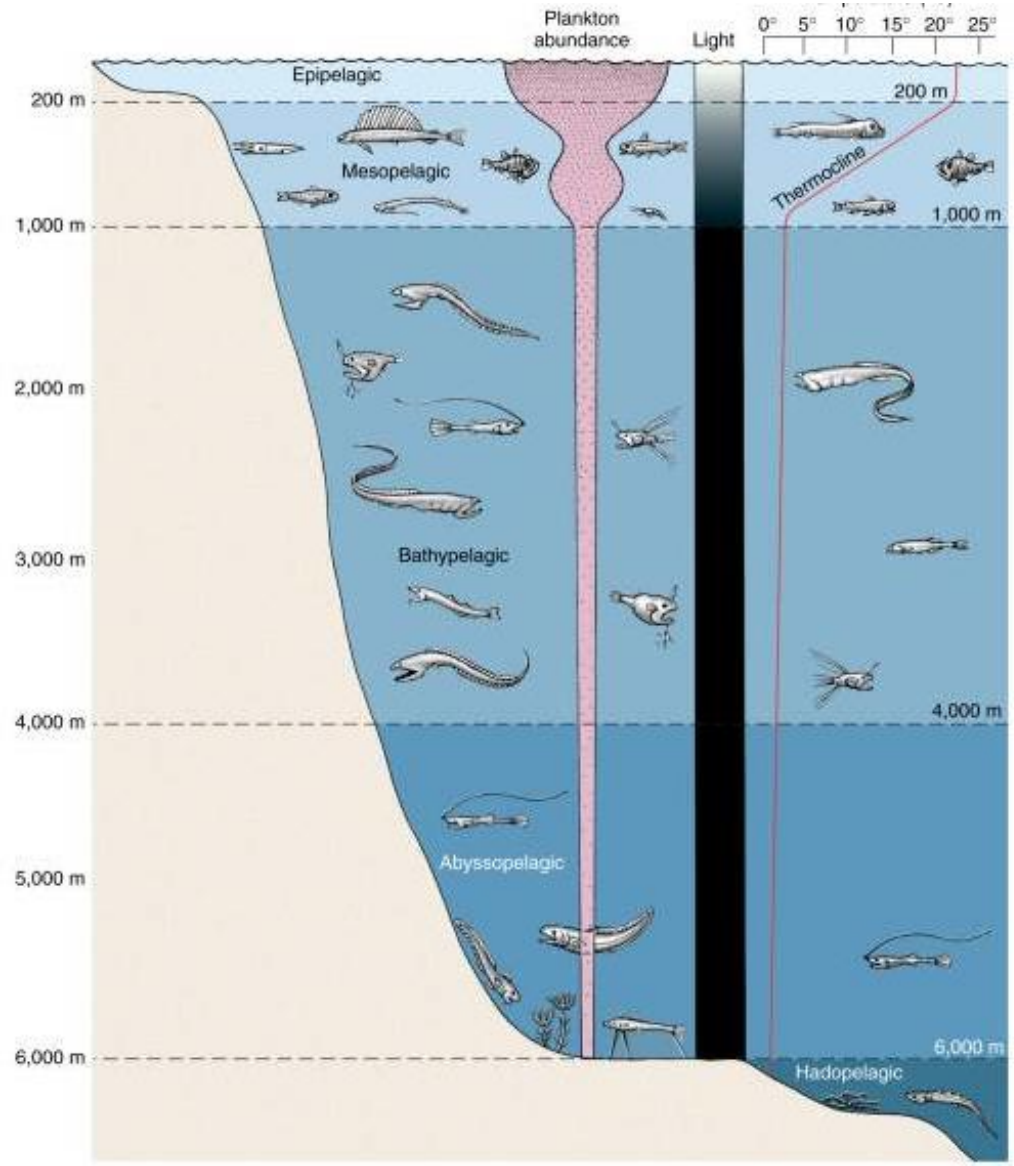
Barbara CAVALAZZI

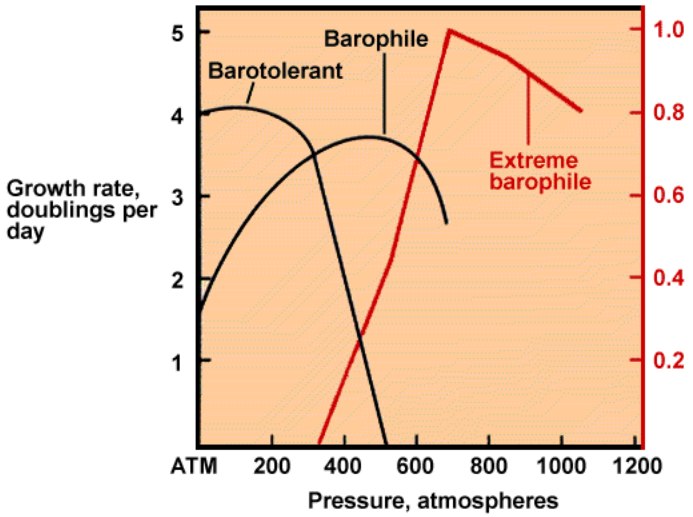
13-14 November 2017 - Observatoire de Paris - France

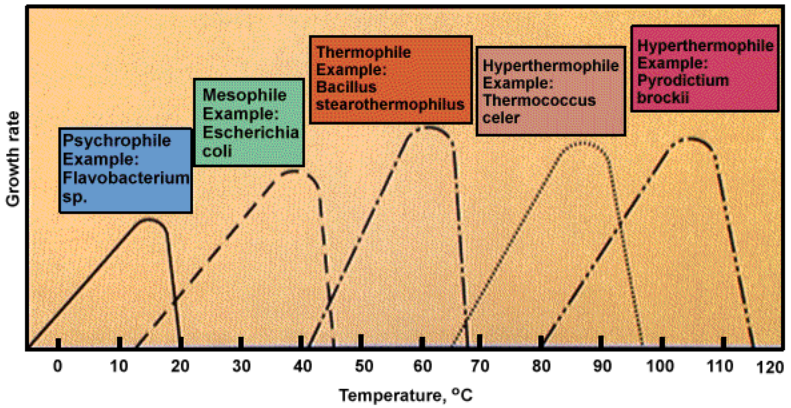
Earth’s Oceans

today

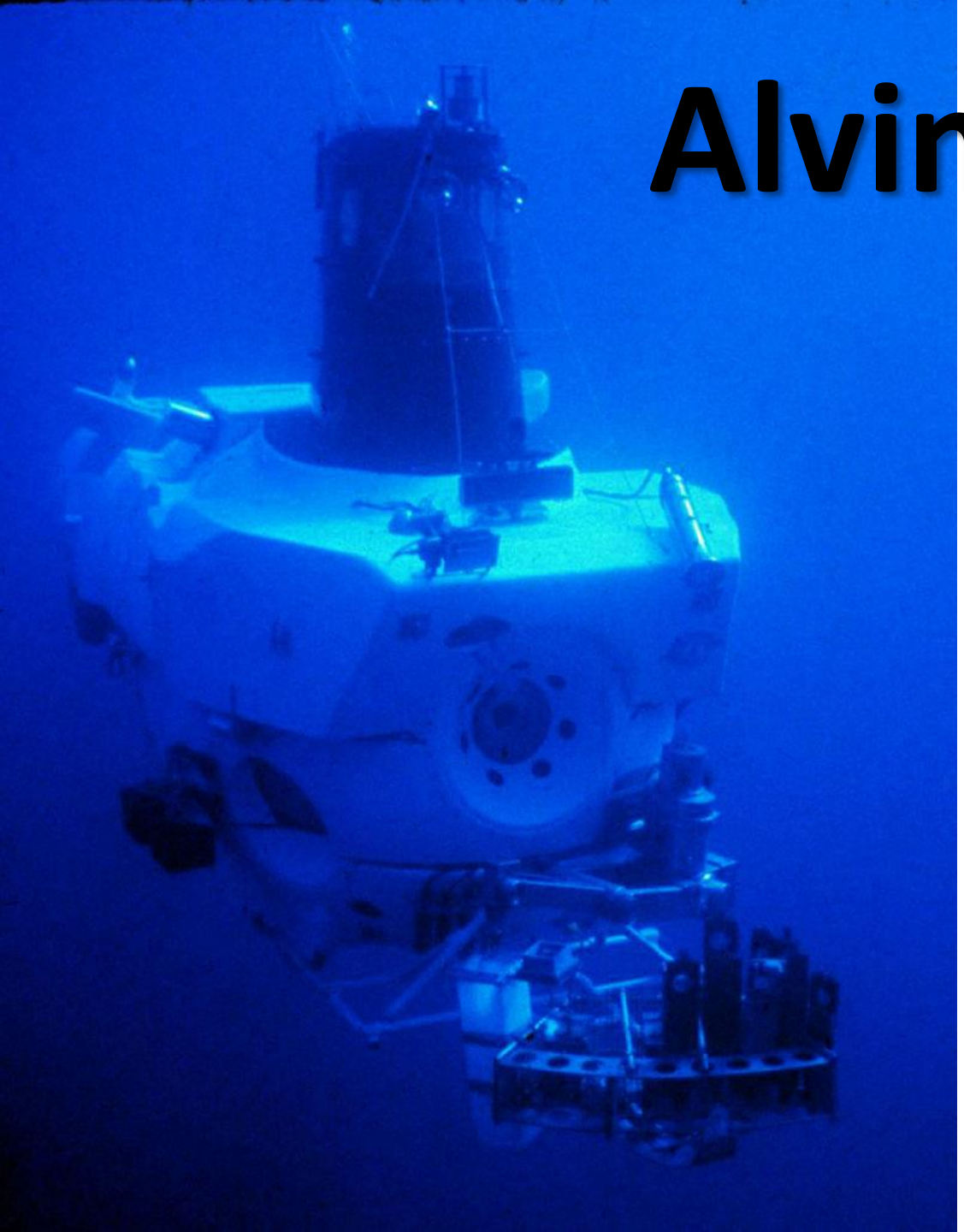
Earth's Oceans







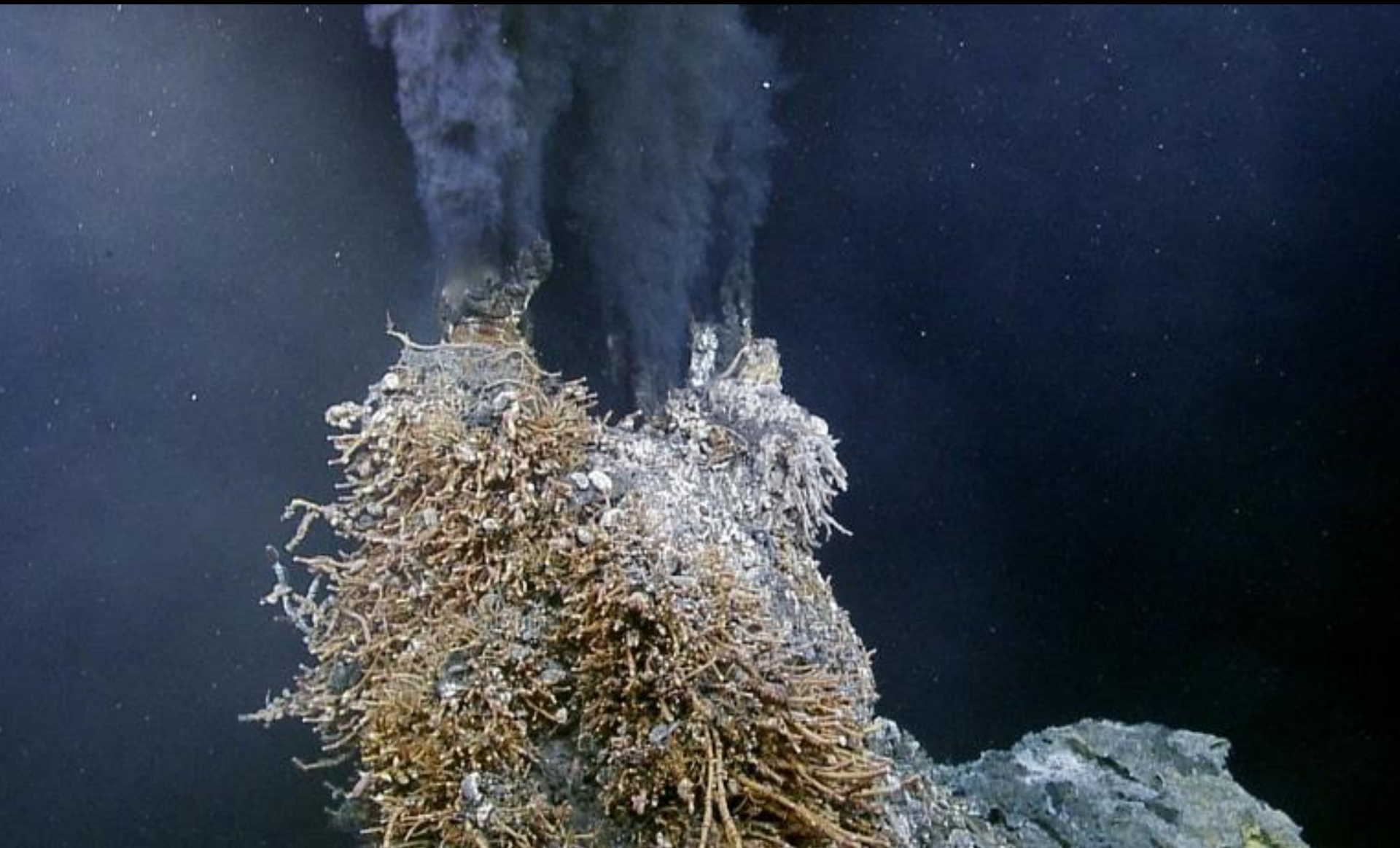
Alvin



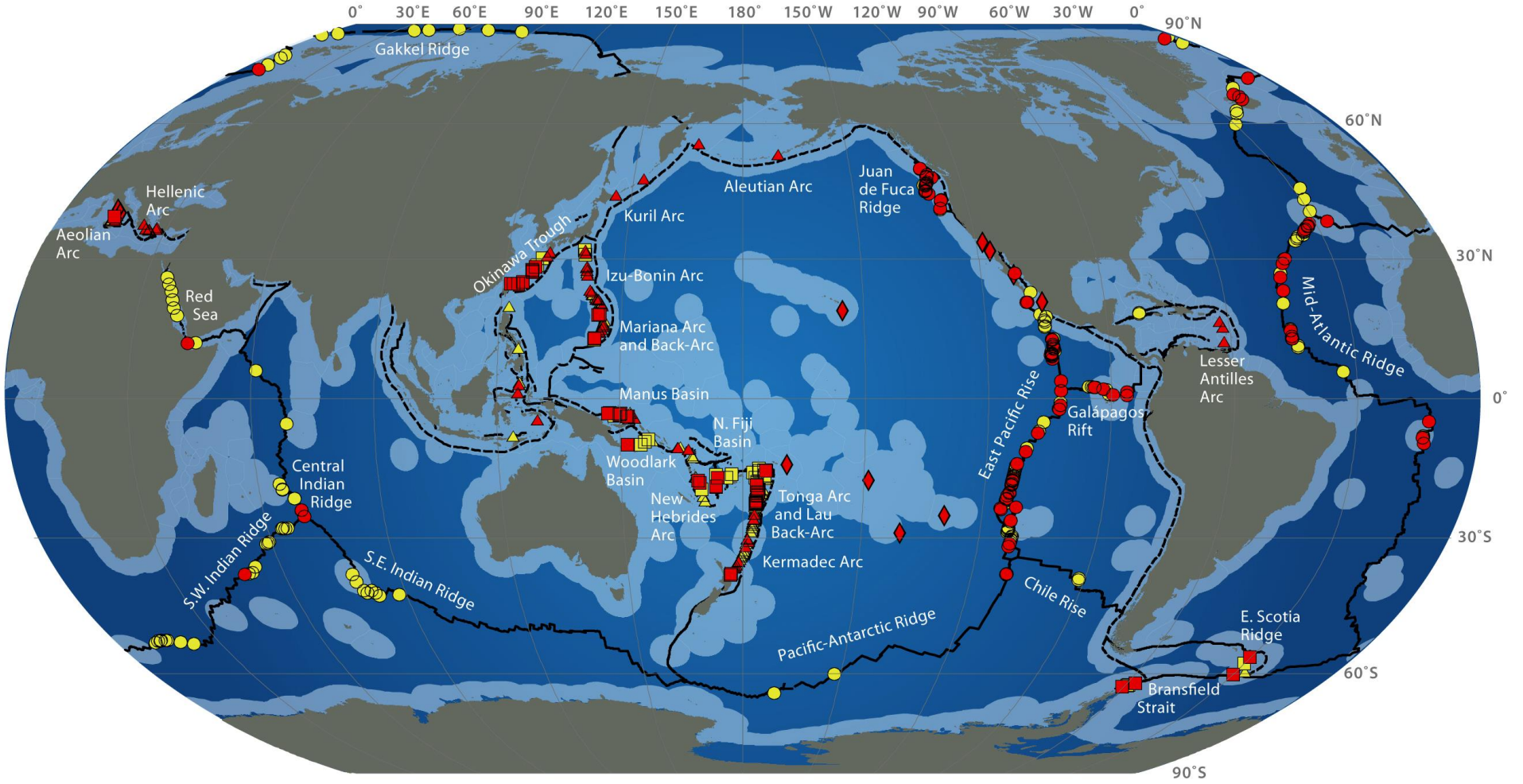
1977: diffuse vents, Galapagos Spreading Center (Corliss et al. 1979)
1979: black smokers, East Pacific Rise (Spiess et al., 1980)

Alvin in 1978, a year after first exploring hydrothermal vents. The rack hanging at the bow holds sample containers.

Earth's Oceans

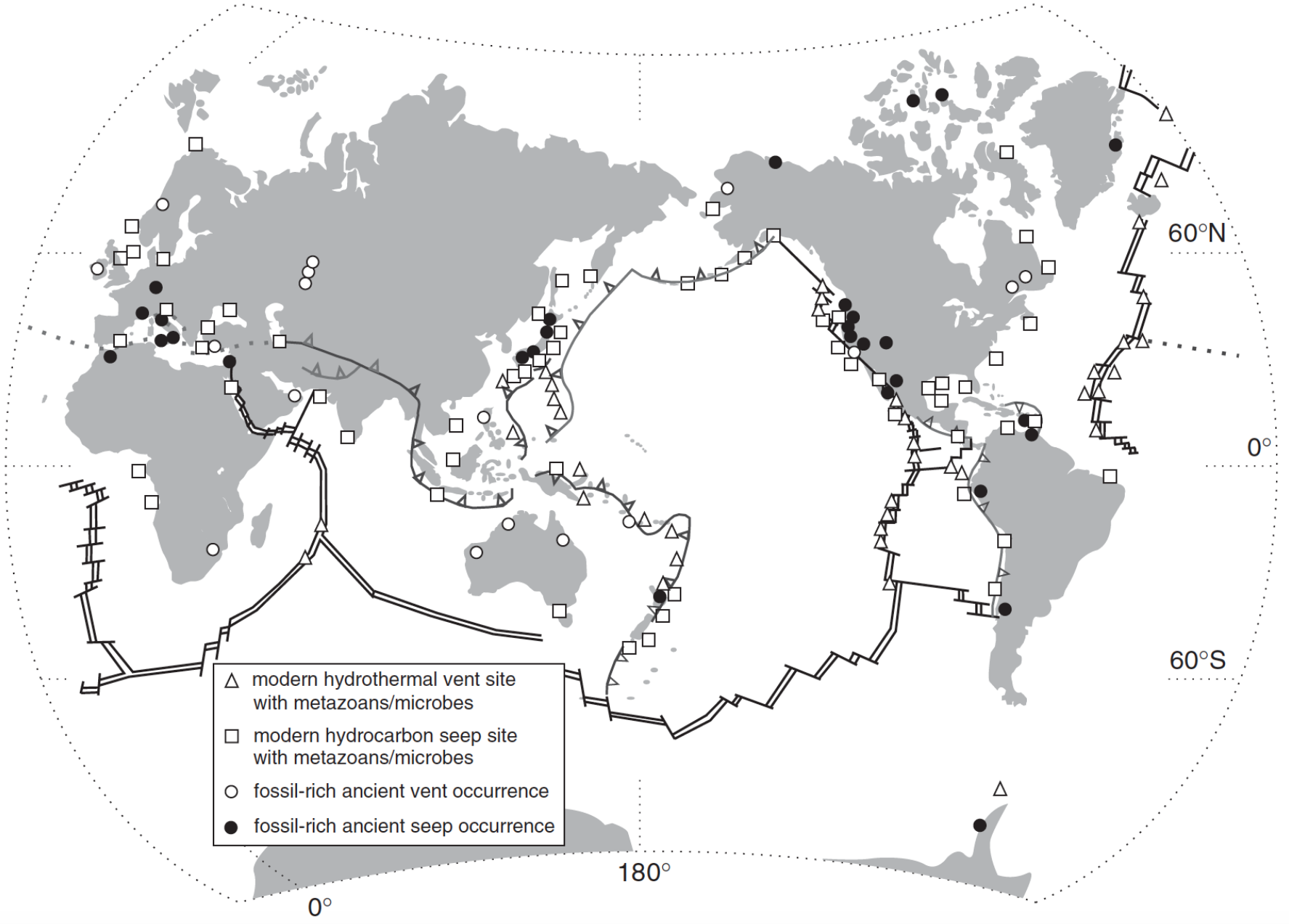


Global Distribution of Hydrothermal Vent Fields



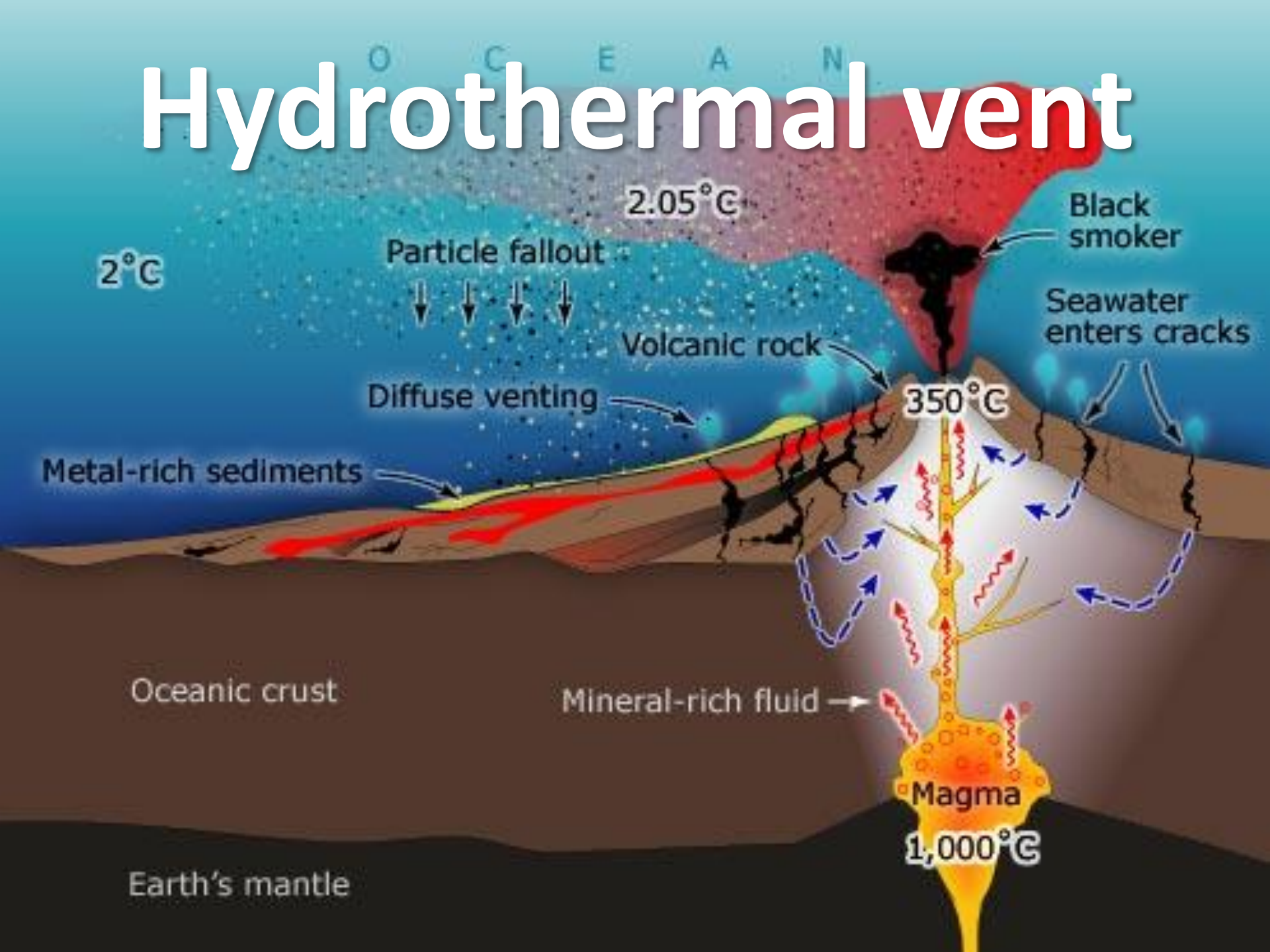
Mid-ocean ridge	Arc volcano	Back-arc spreading center	Intra-plate volcano & Other	
Active	Active	Active	Active	Ridge & Transform
Unconfirmed	Unconfirmed	Unconfirmed		Trench
				Exclusive Economic Zones

http://vents-data.interridge.org/maps

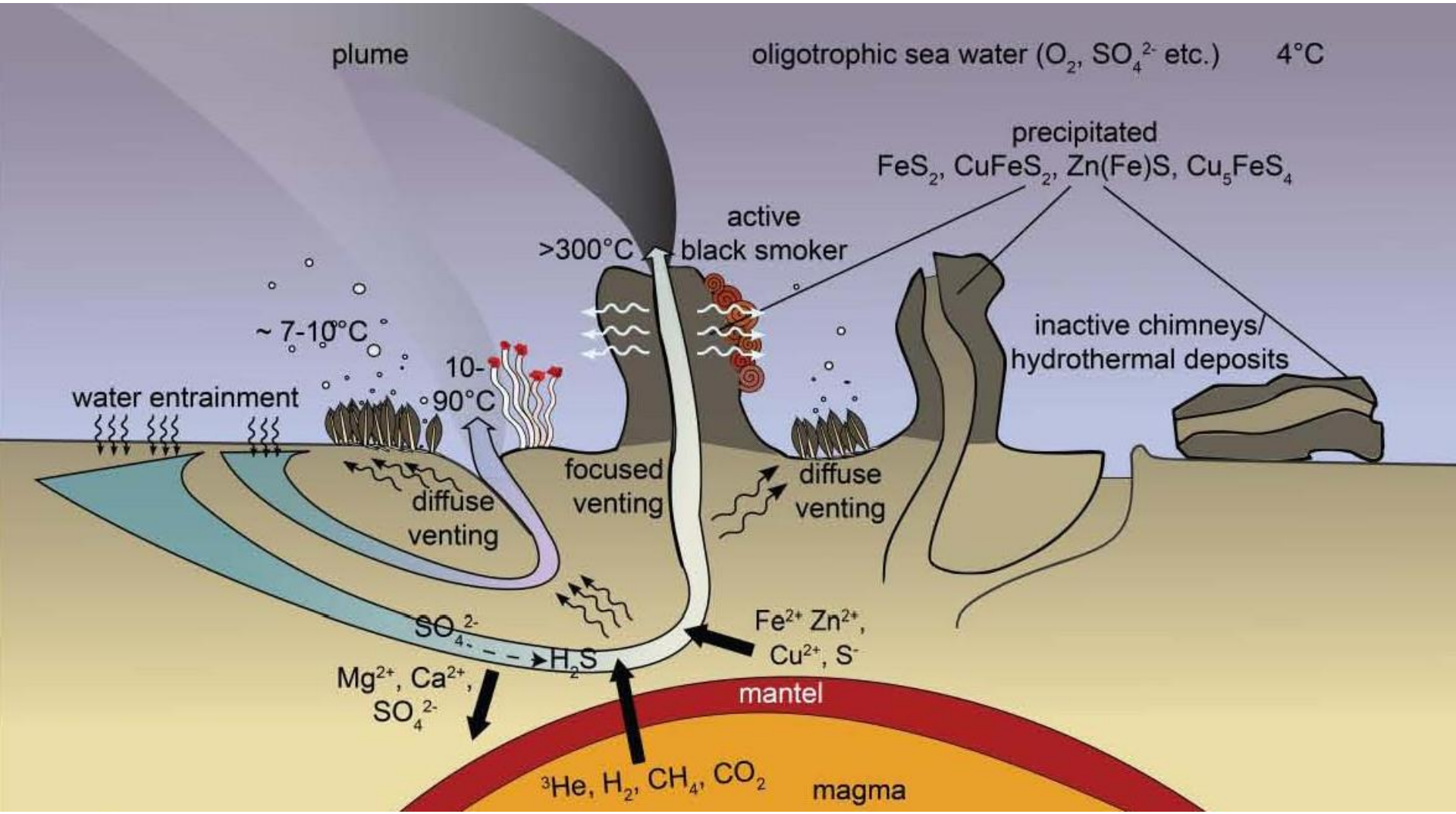


Campbell, 2006

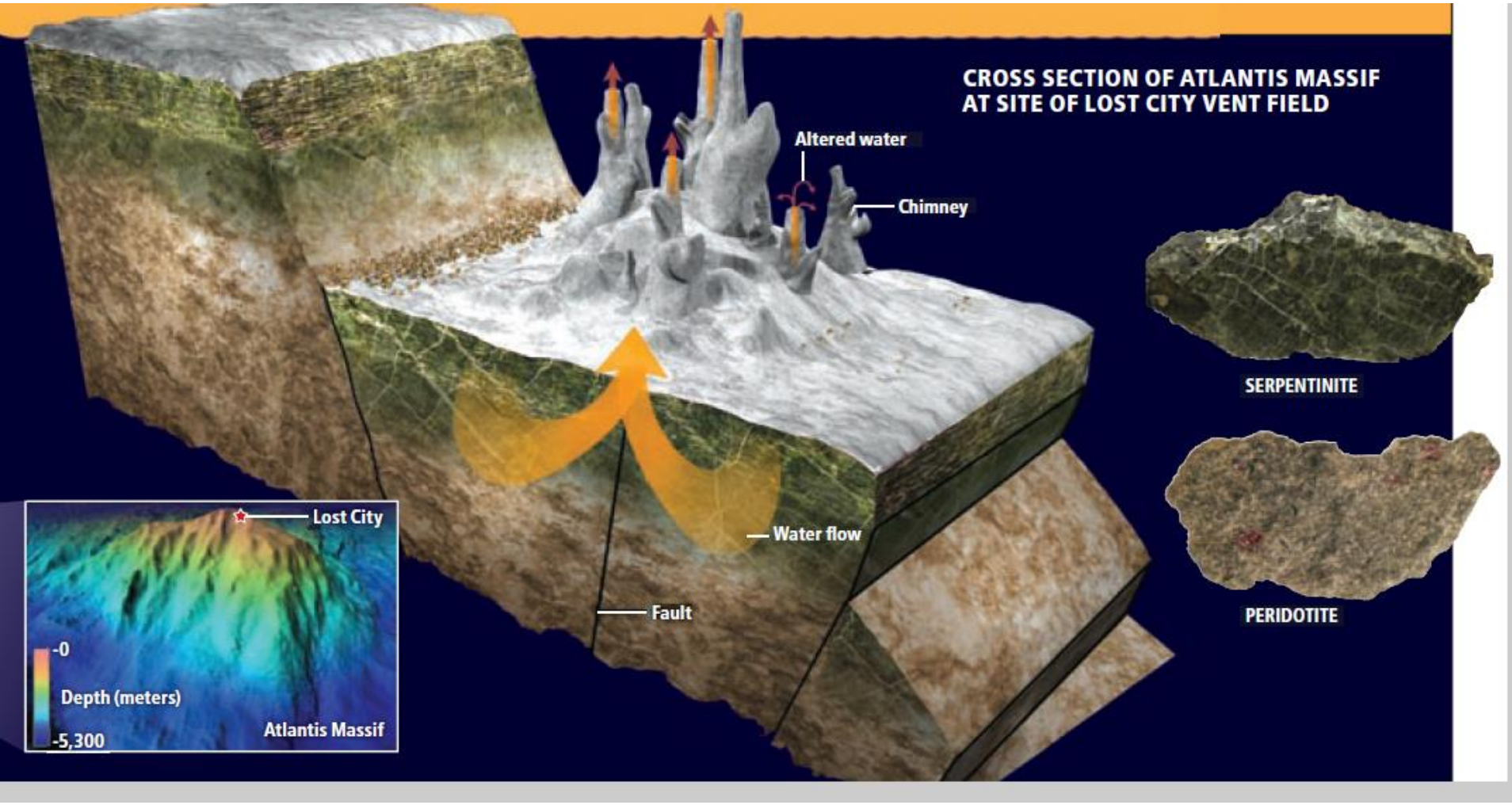
Hydrothermal vent

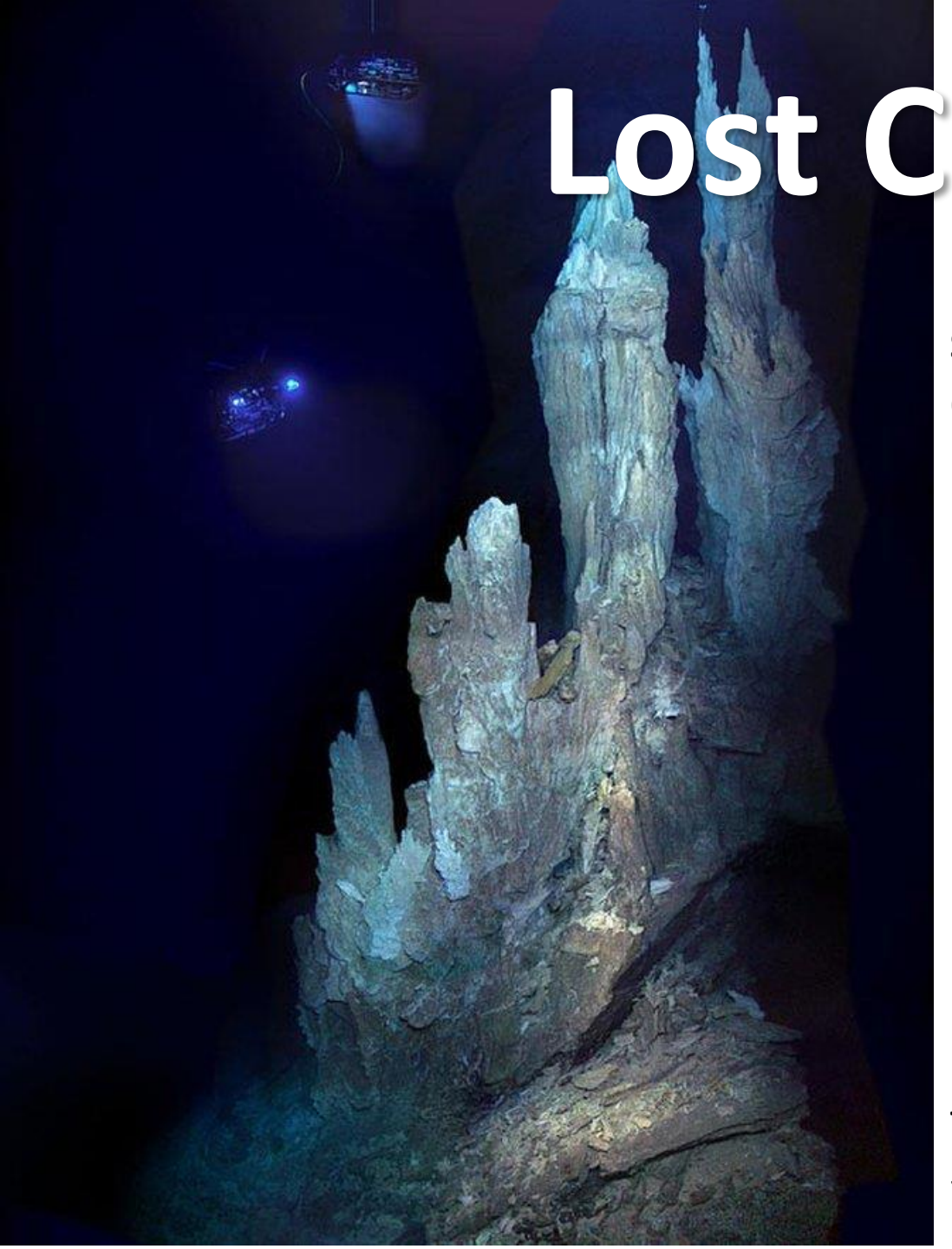


Chemo-ecosystem



Hydrothermal system





Lost City

Serpentinization

Olivine → Serpentine (hydration)

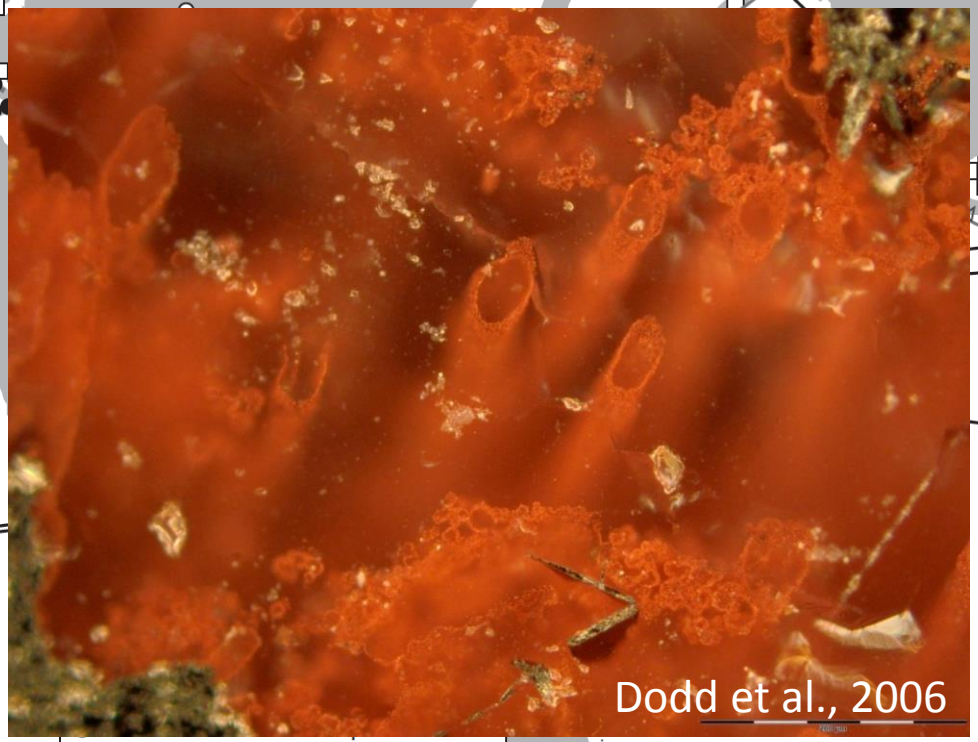
Exothermic reaction 260°C

Basic fluids pH 9-10 ($CaCO_3$ precipitate)

Fluids contain high CH_4 and H_2

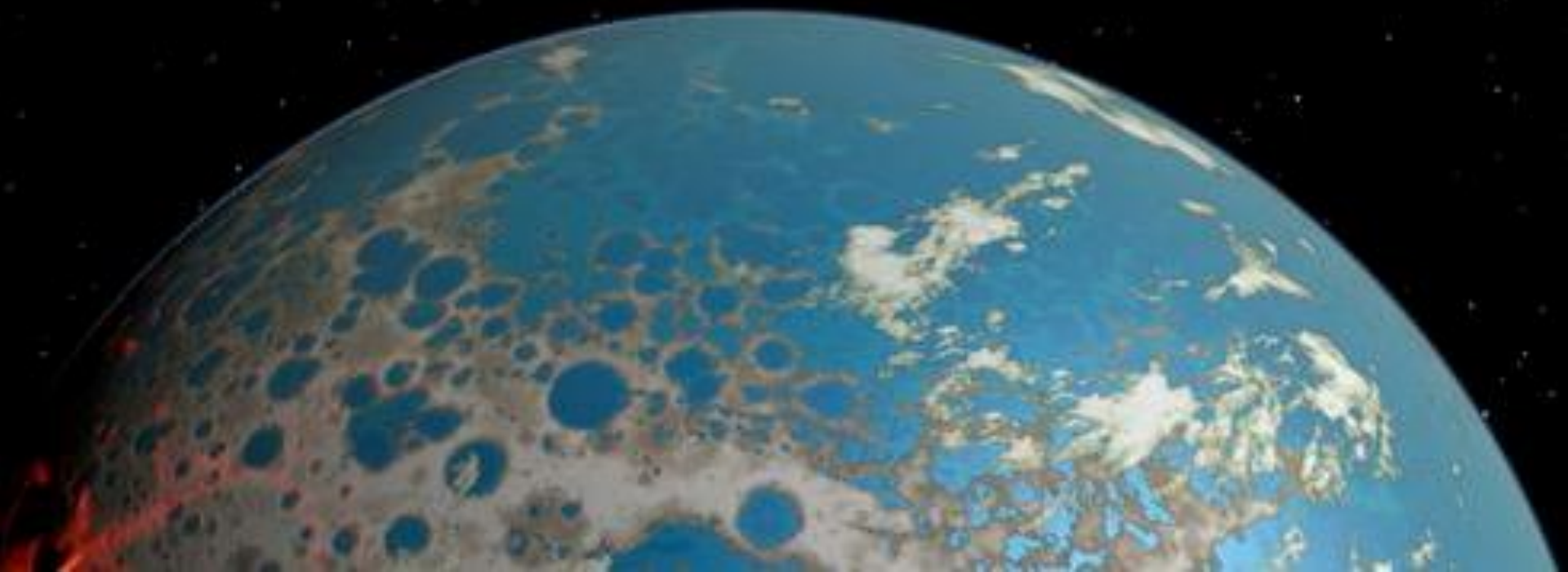
The Lost City Field include these white columns.

Hydrothermal systems have prevailed throughout geological history on Earth



Campbell, 2006

Earth's Oceans



Early Oceans

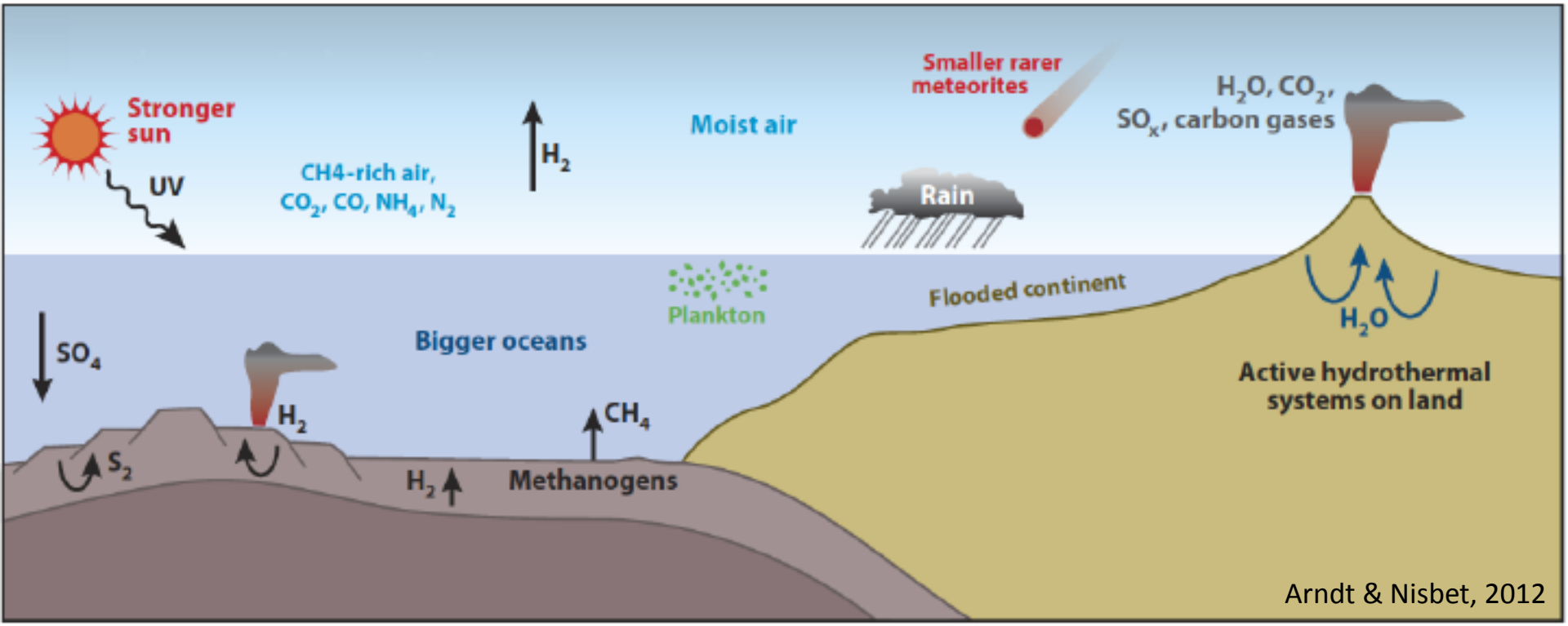
4.4 Ga old zircon

Hadean Earth


T (°C): ~ 23
pH: ~ 8
S (‰): 35
Eons
Hadean: 4.56-4.0 Ga
Archean: 4.0-2.5 Ga

Early Oceans - T

Early Oceans – pH & S

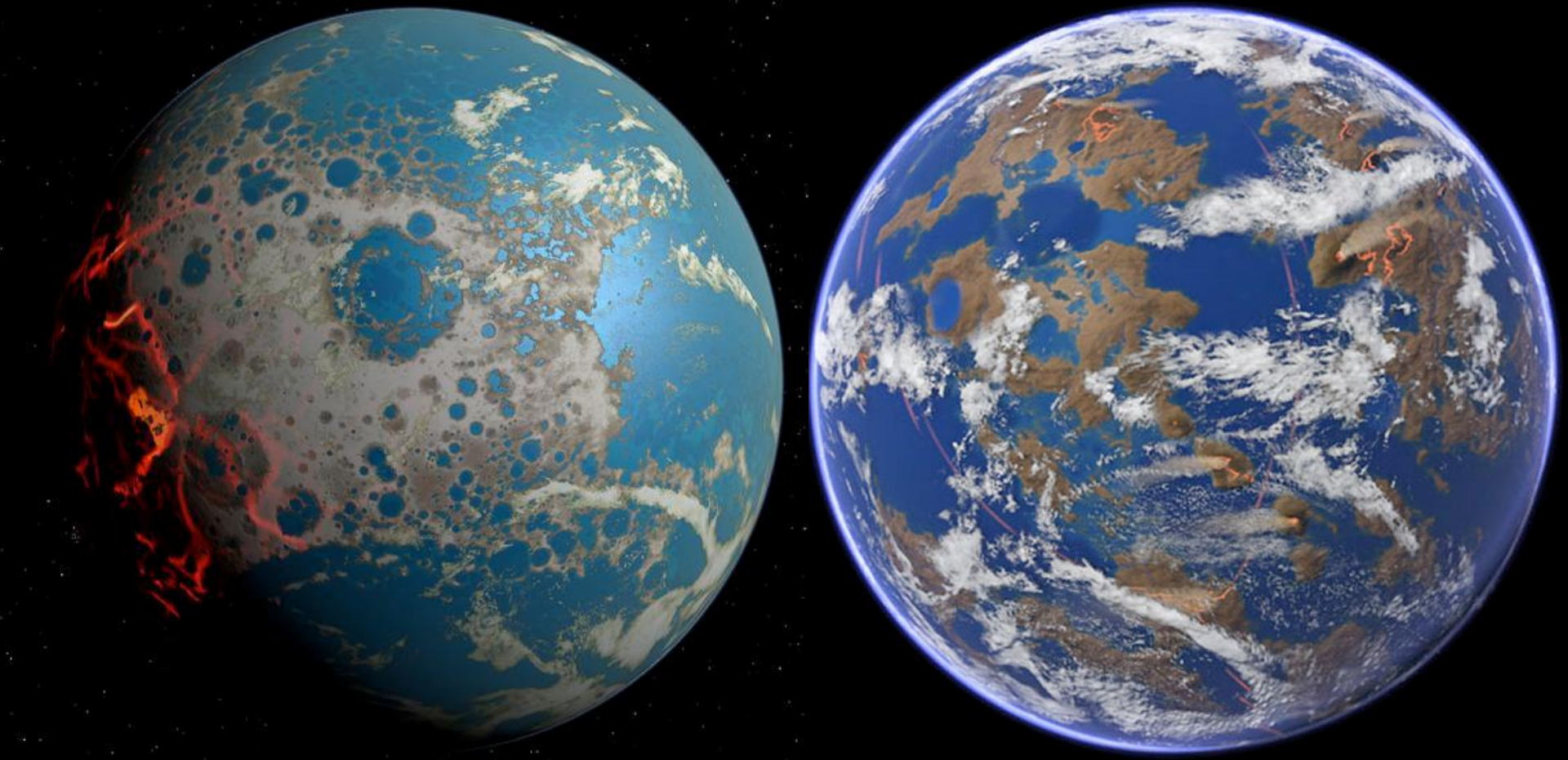


T (°C): ~ 50-80 or 26-35

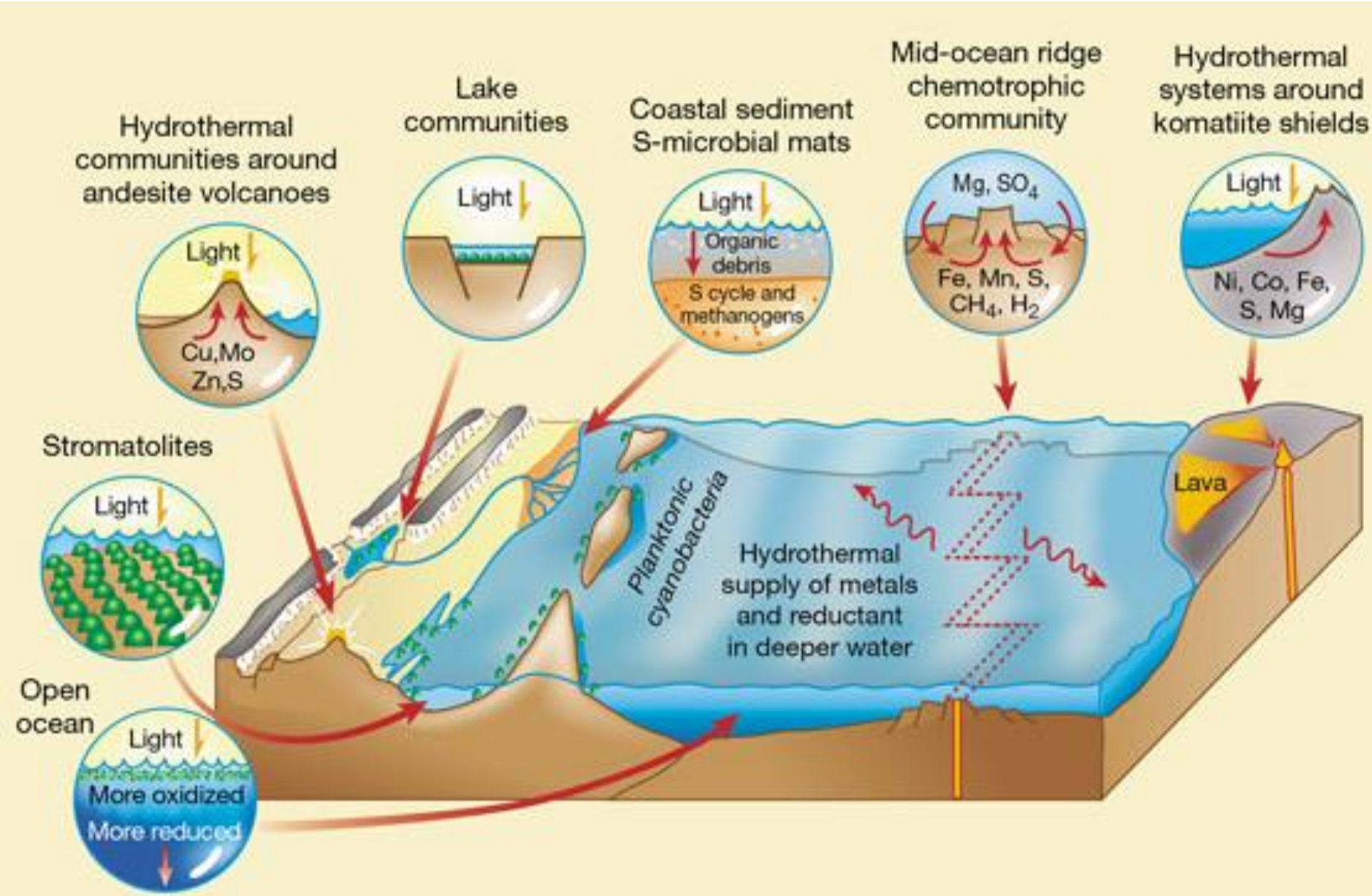
pH: ~ 5.5

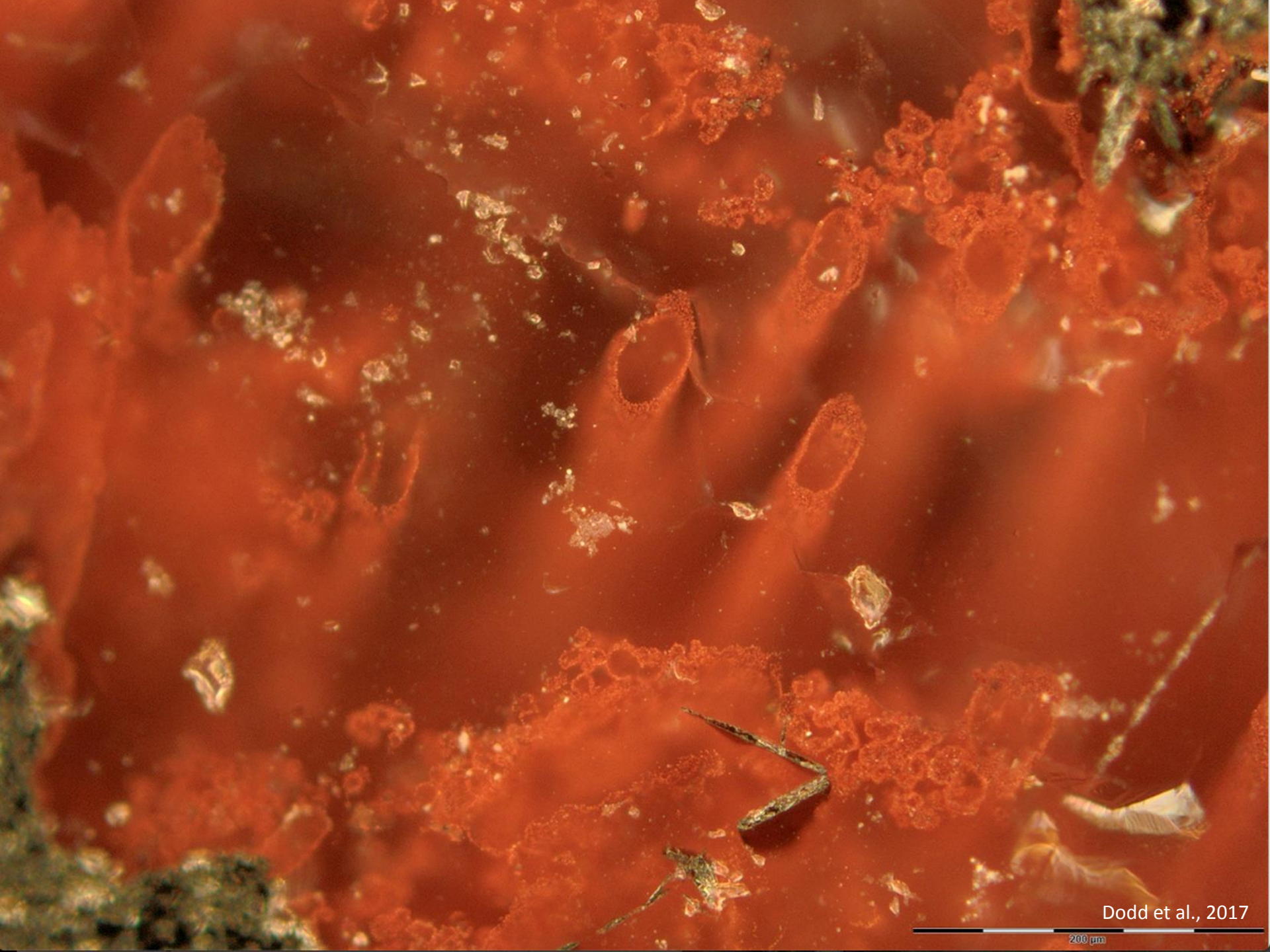
S (‰): salty (Na, Cl, Br, Ca)

Early Oceans



Early Oceans: niches for life

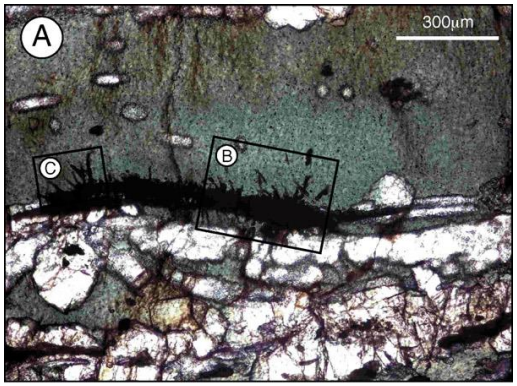


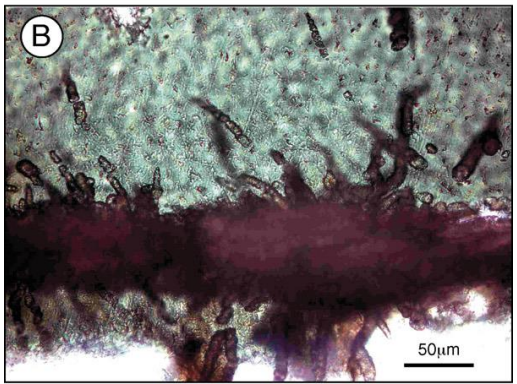


Dodd et al., 2017

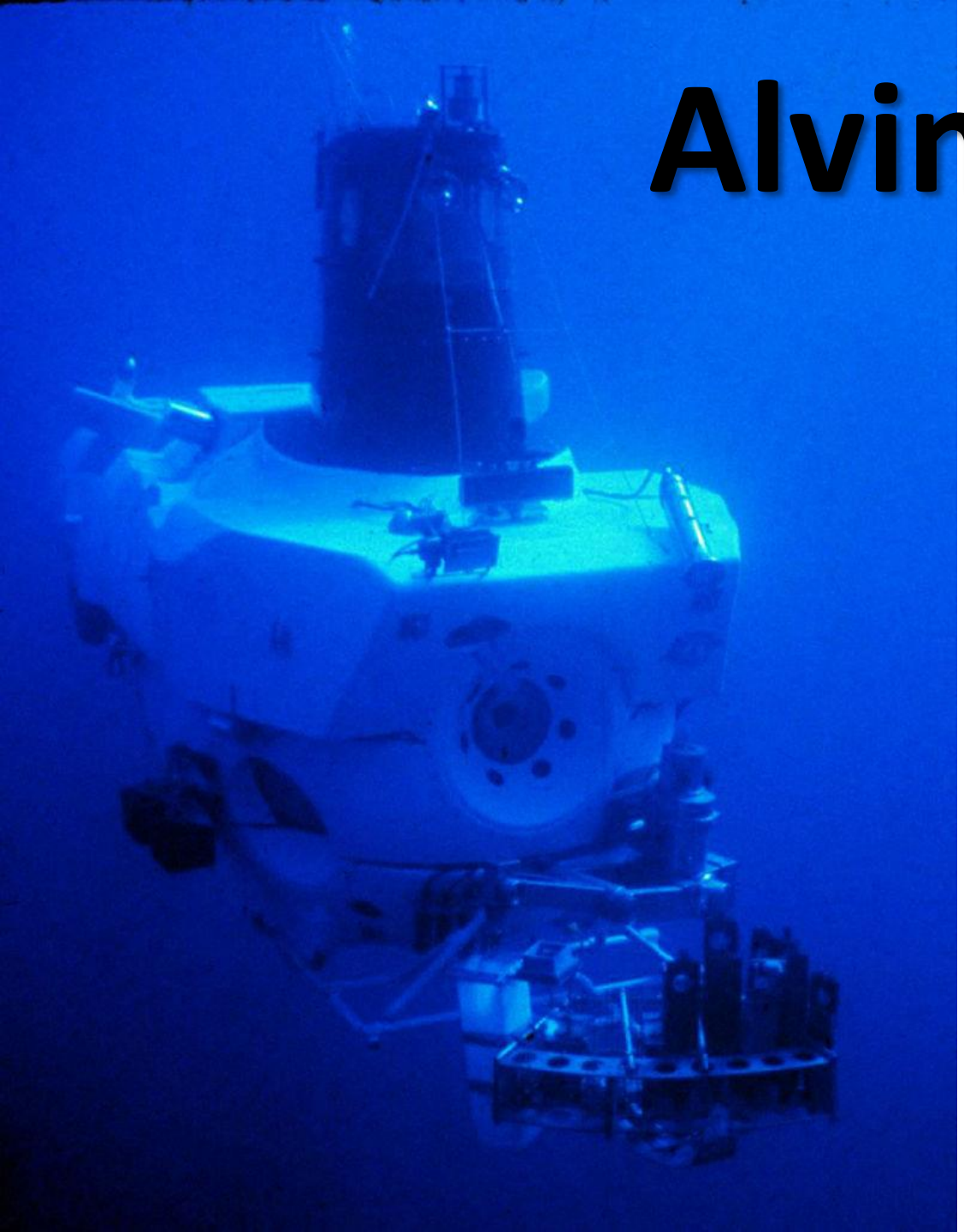
BIOALTERATION

preserved remains of microbial remineralization





Barberton Greenstone Belt Hooggenoeg Fm South Africa



Alvin

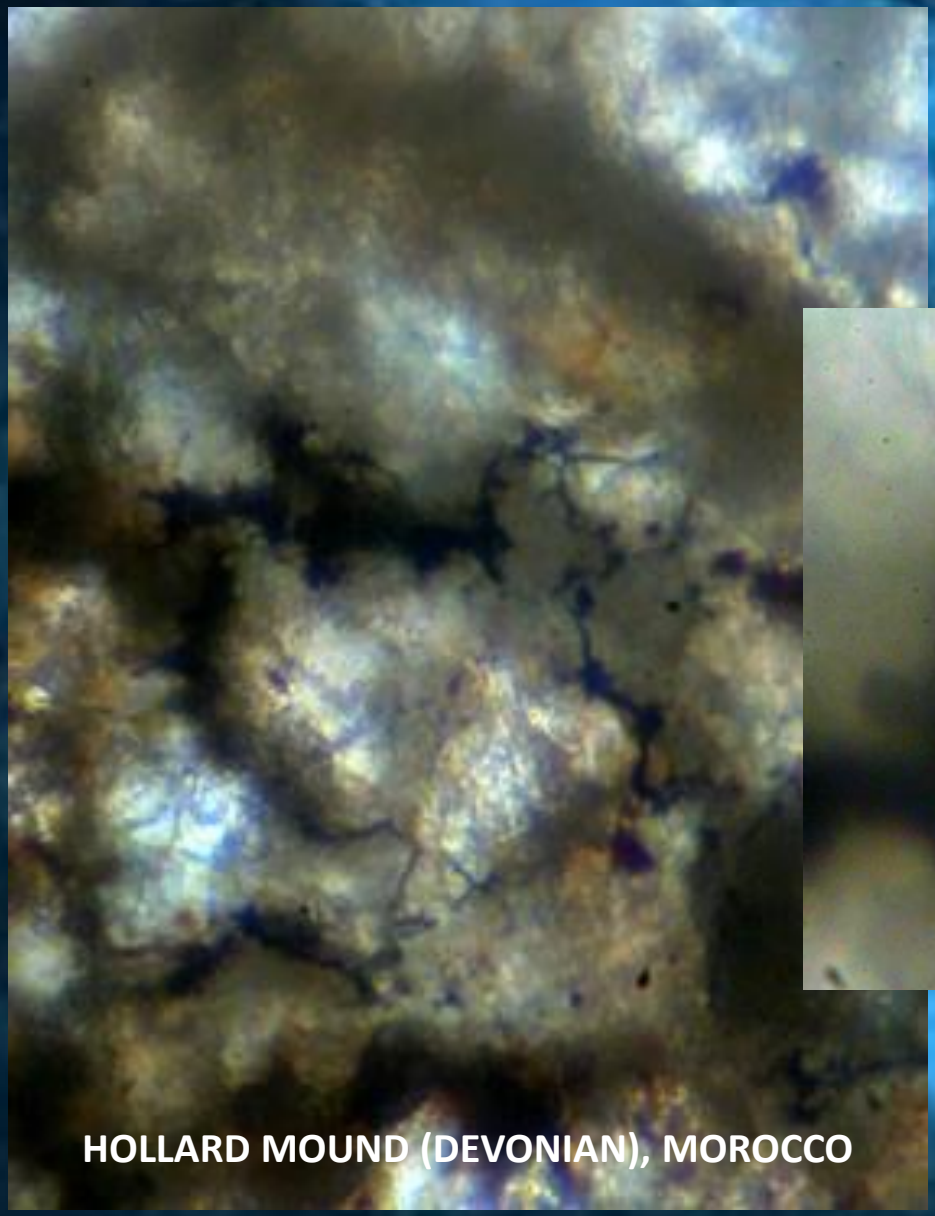
1984: cold seeps, base of the Florida escarpment in the Gulf of Mexico (Paull et al., 1984).

Alvin in 1978, a year after first exploring hydrothermal vents. The rack hanging at the bow holds sample containers.

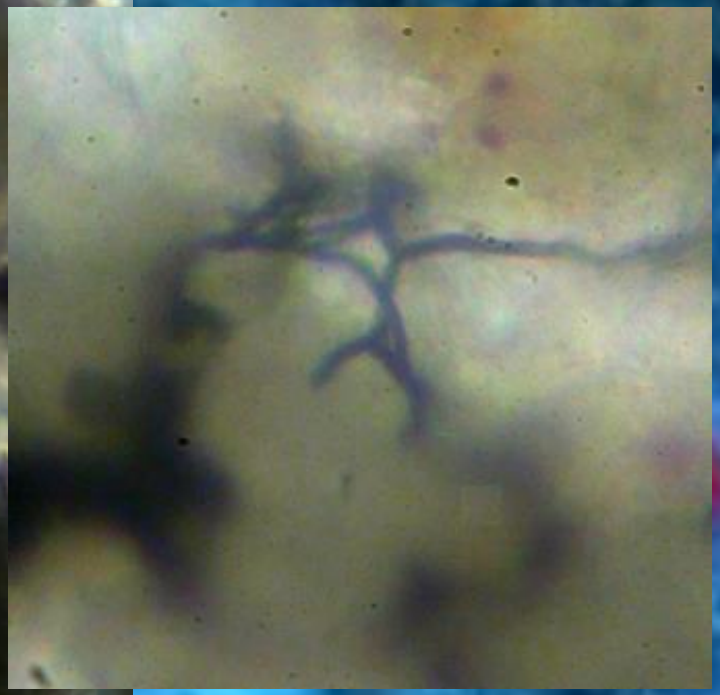
GAS HYDRATE MOUND (~2m across) AT BUSH HILL (27°45.7`N, 91°30.5`W, Green Canyon, Gulf of Mexico

CALCARI A LUCINA, ITALY

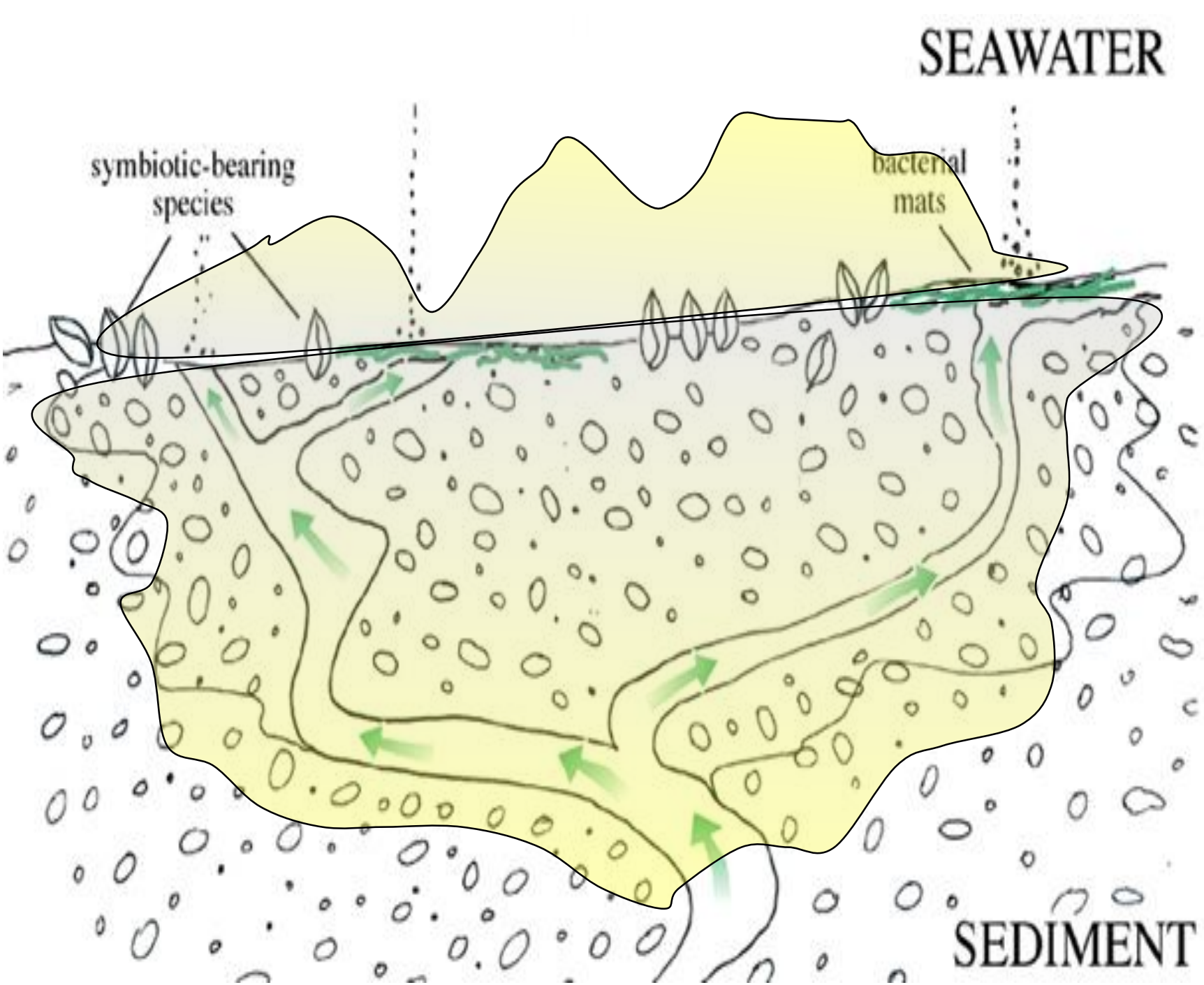
DEEP METHANE-SEEP, CALIFORNIA

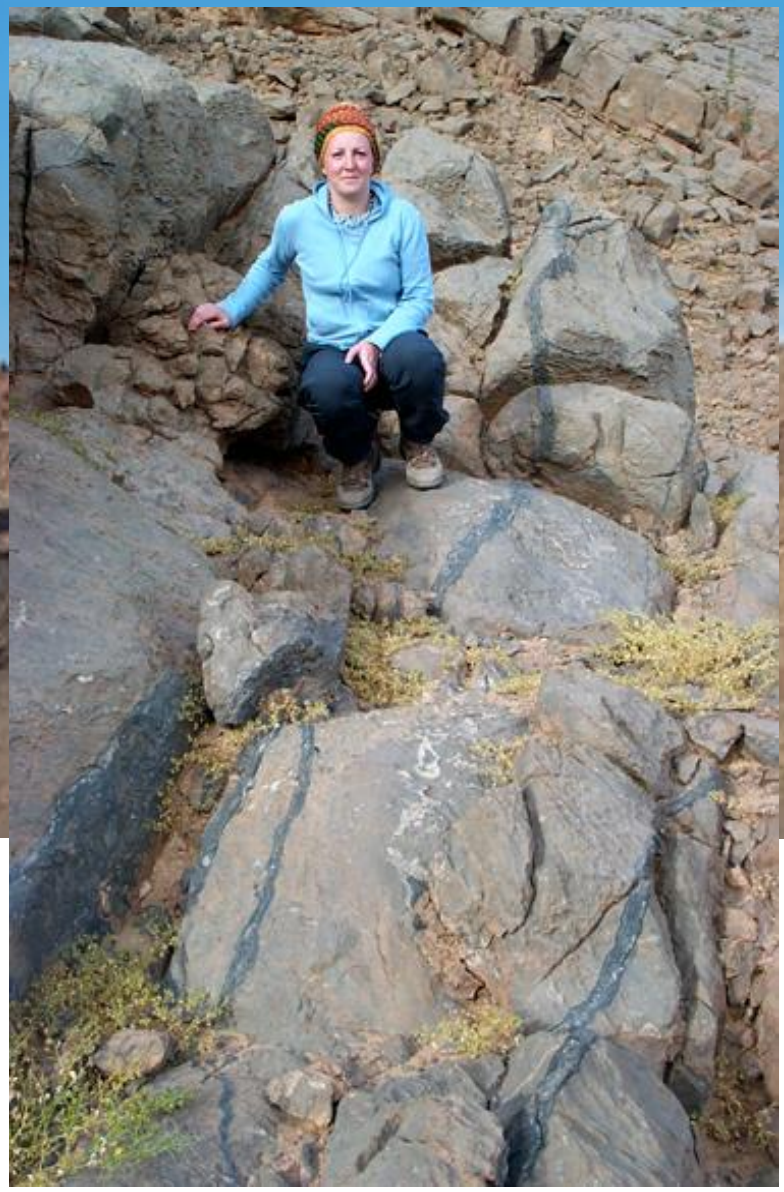


HOLLARD MOUND (DEVONIAN), MOROCCO

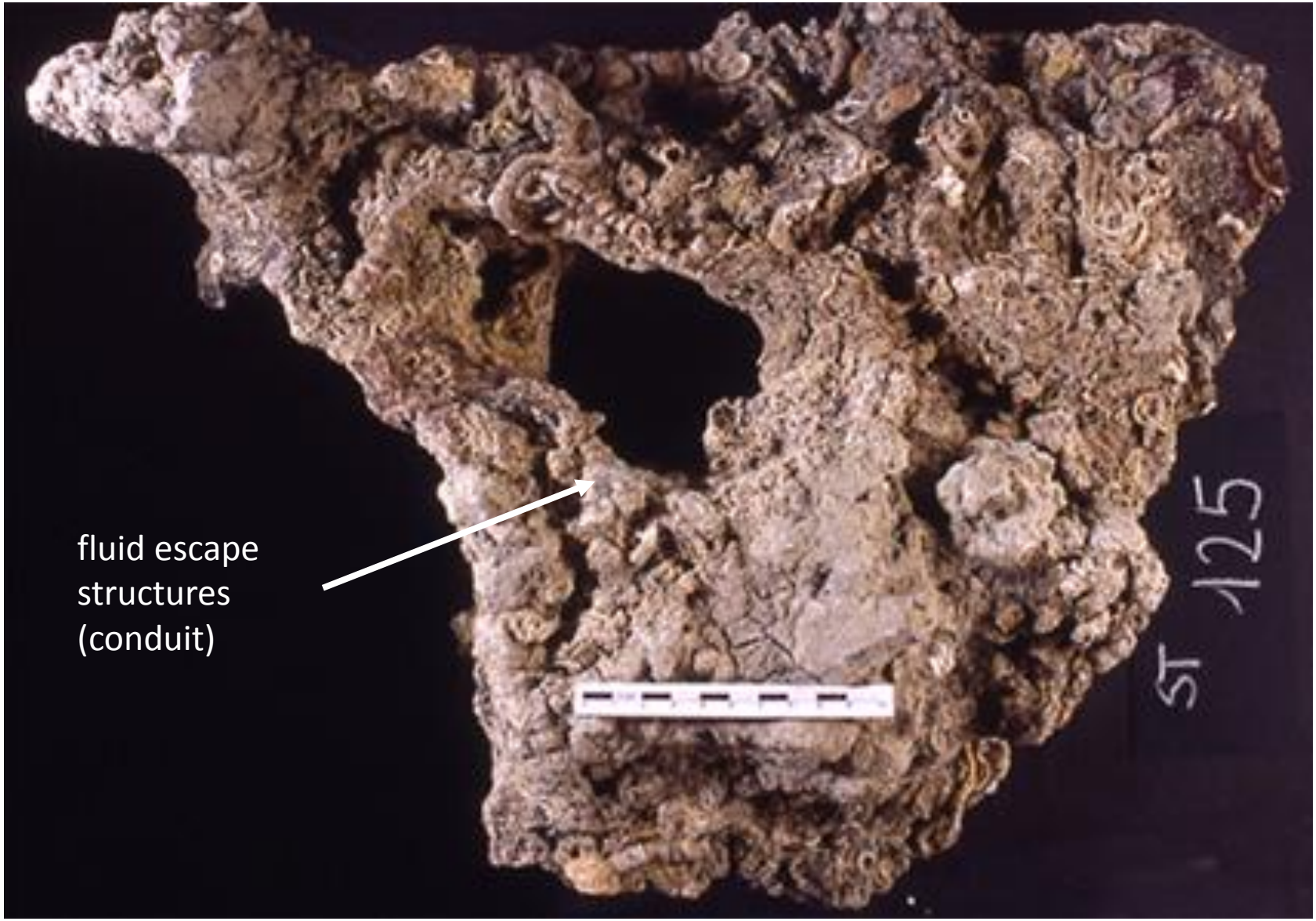


SOBs BEGGIATOA MAT (~600m deep), active CH_4-seep, Black Ridge, S-Carolina


SEAWATER
symbiotic-bearing species
bacterial mats
SEDIMENT



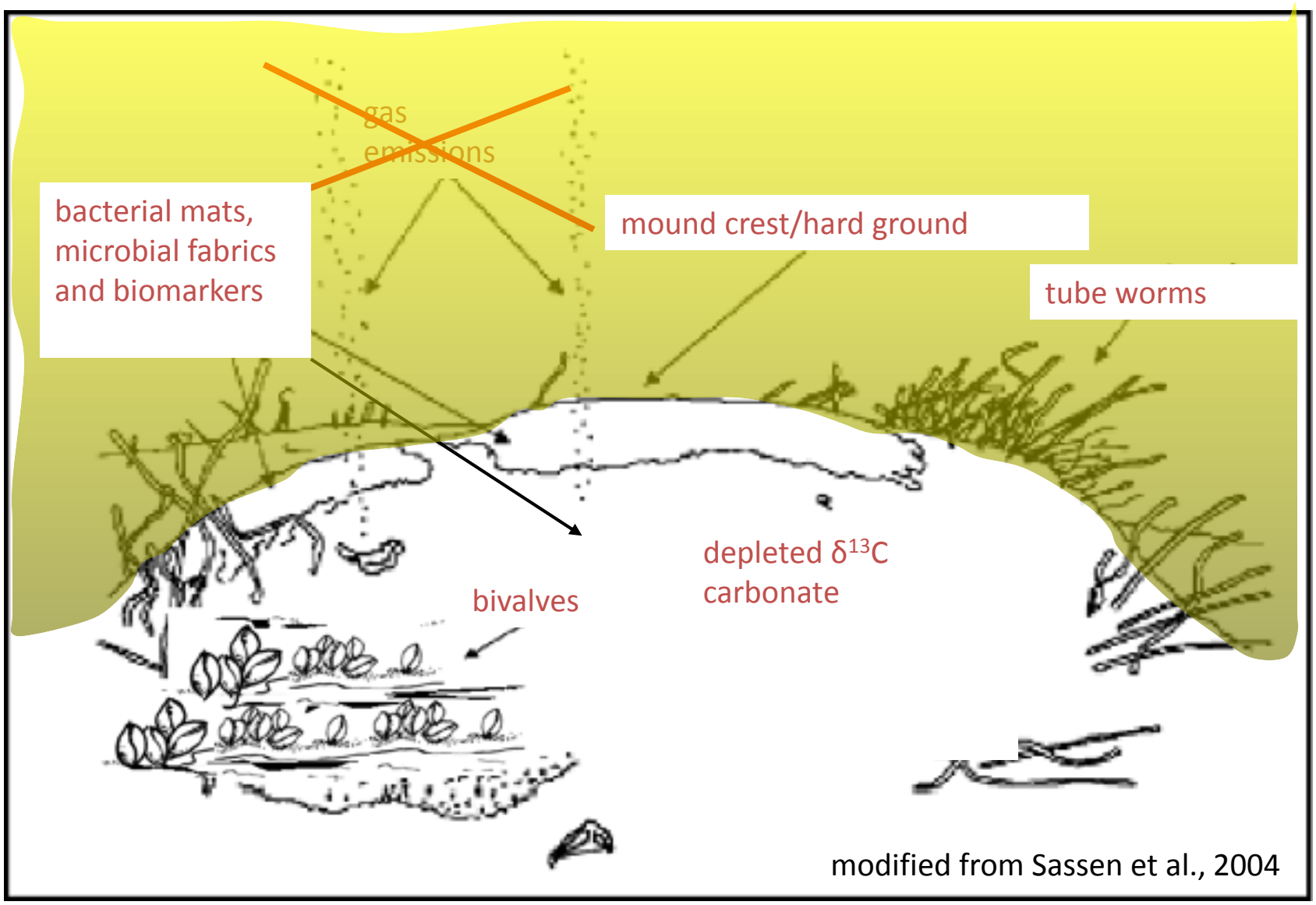
Middle Devonian (hydrocarbon) seep, Hollard Mound
eastern Anti-Atlas, Morocco



Authigenic carbonate crust with serpulids active hydrocarbon seep, North Adriatic Sea

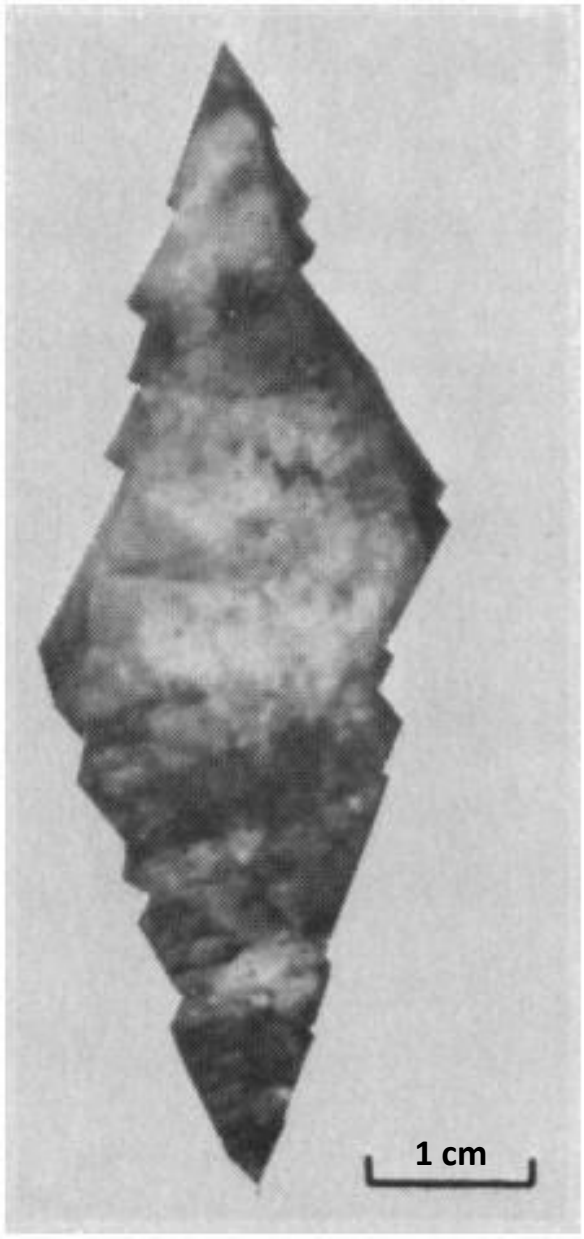
VENT AND SEEP SEARCH-STRATEGY based on typical features recognized in (modern and fossil) ore deposit and vulcanogenic massive sulfide deposits, and carbonates:

- GEOLOGICAL SETTING
- SEDIMENT ACCUMULATIONS (ISOLATED) IN DEEP WATHER/SILICICLASTIC SEDIMENTS
- GEOMETRIES, MORPHOLOGIES AND STRUCTURES
- MONOSPECIFIC CHEMOSIMBIOTIC BENTONIC MEGAFAUNA ACCUMULATIONS (IN LIVE POSITIONS)
- GEOCHEMICAL SIGNATURES
- SEDIMENTARY FABRICS
- BIOCHEMICAL SIGNATURES/BIOMARKERS
- FLUID INCLUSIONS



modified from Sassen et al., 2004

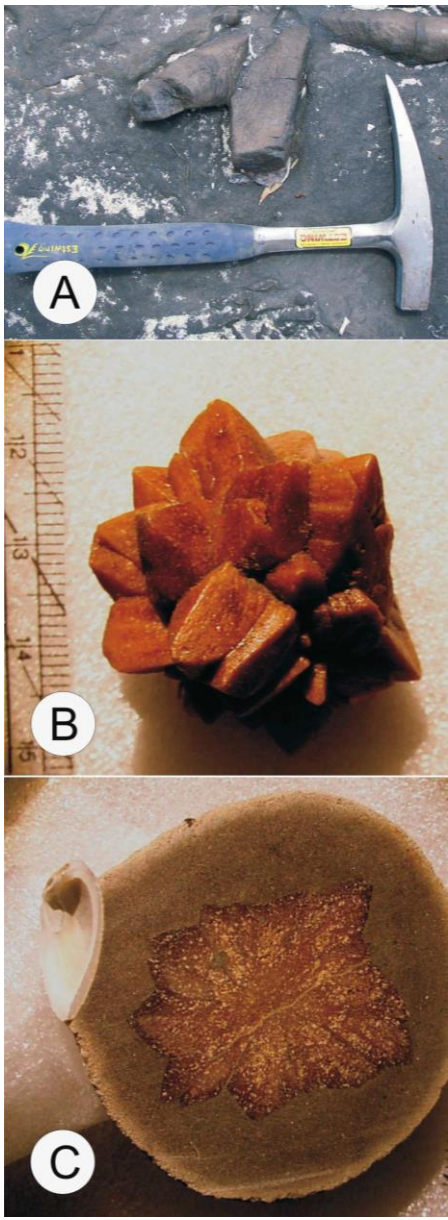
IKAITE: $CaCO_3$ $6H_3O$



(Sedimentary) Ikaite forms in marine setting:

- near-freezing temperature (between -2 and 4°C)
- decompose as the water temperature rises (up to 5-6°C)
- ikaite loose 68.6% of its volume when convert to calcite and water
- grow displacively near the sediment-water interface
- geochemical and biogeochemical processes
- large blade-, stellate- or pine apple-shaped crystals are often encased in nodules/concretions

Single crystal of ikaite from Antarctic Peninsula.
Suess et al, 1992



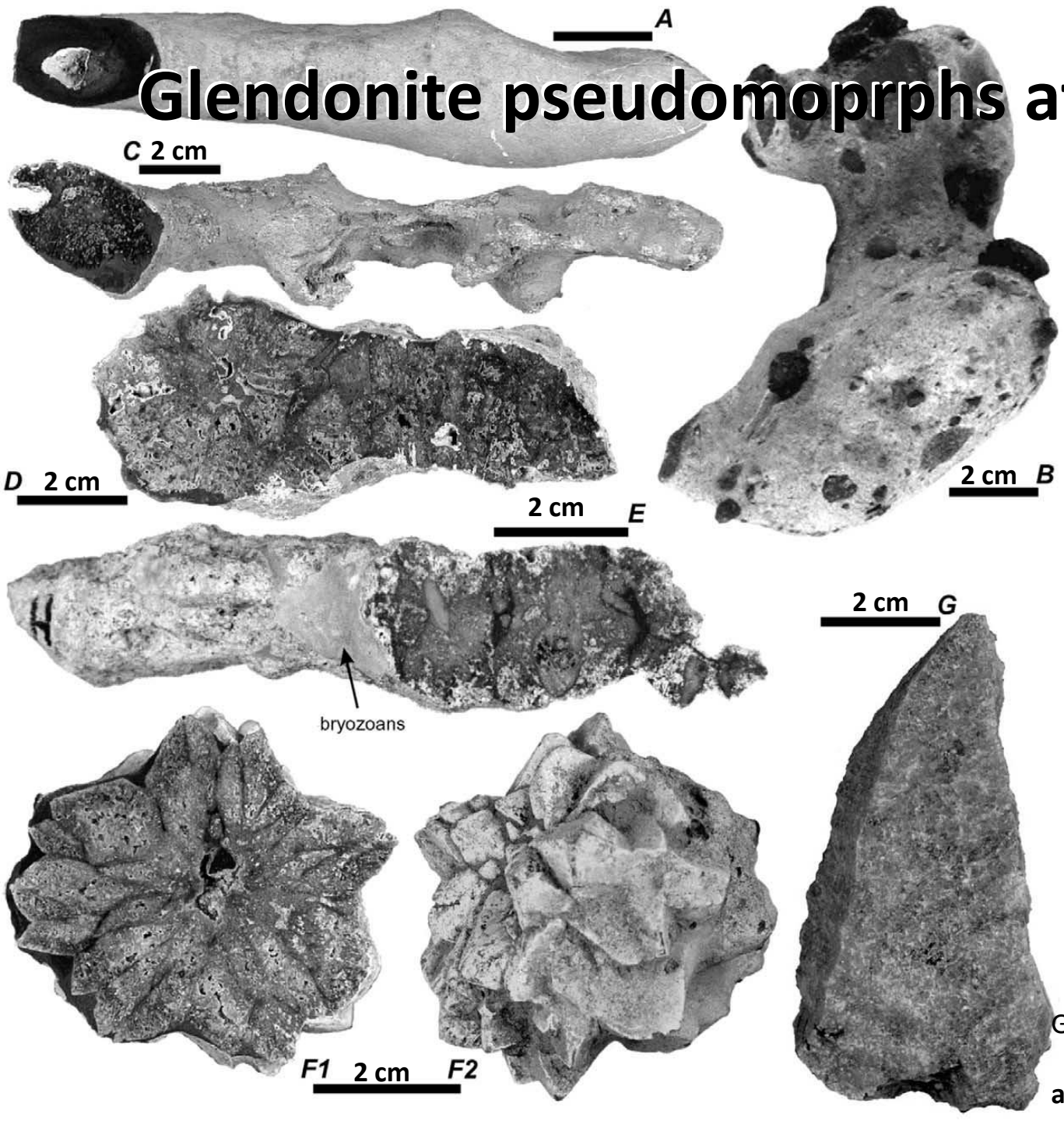
IKAITE: $CaCO_3$ $6H_3O$

Recent ikaite occurrences in the marine environment are typically linked to low temperatures below 6 C

Ikaite has been a common mineral in cold-water environments throughout the geological record as glendonites are known from deposits of Carboniferous to Recent age from high latitudes of the northern and southern hemispheres

Ikaite columns below the surface of Ikka Fjord, SW Greenland. Photo@ P. Martin.

Glendonite pseudomoprphs after ikaite

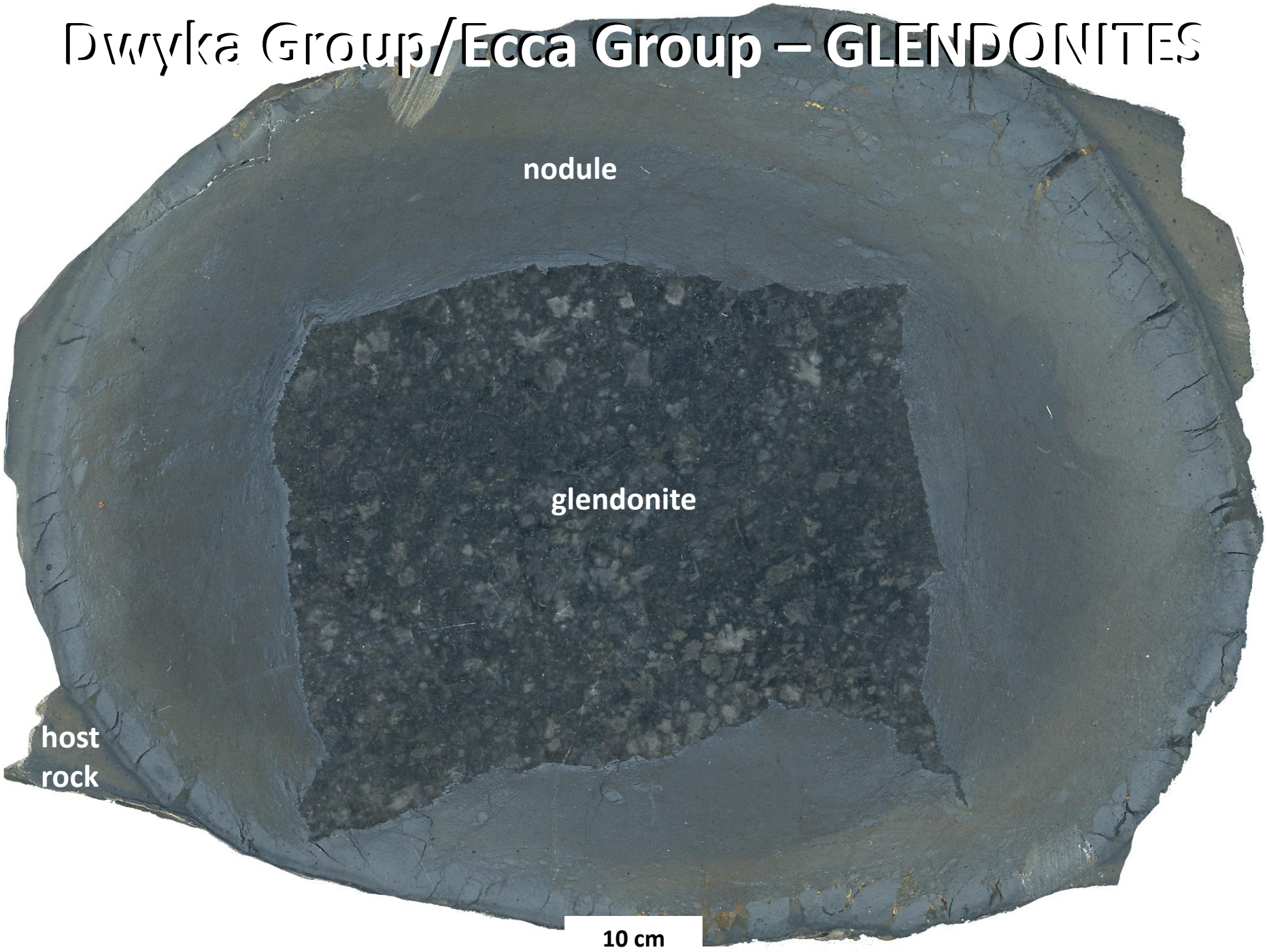


… cold fluid venting of reduced geochemical species coupled with the AOM via SR could constitues another mechanism that might be involved in the ikaite formation

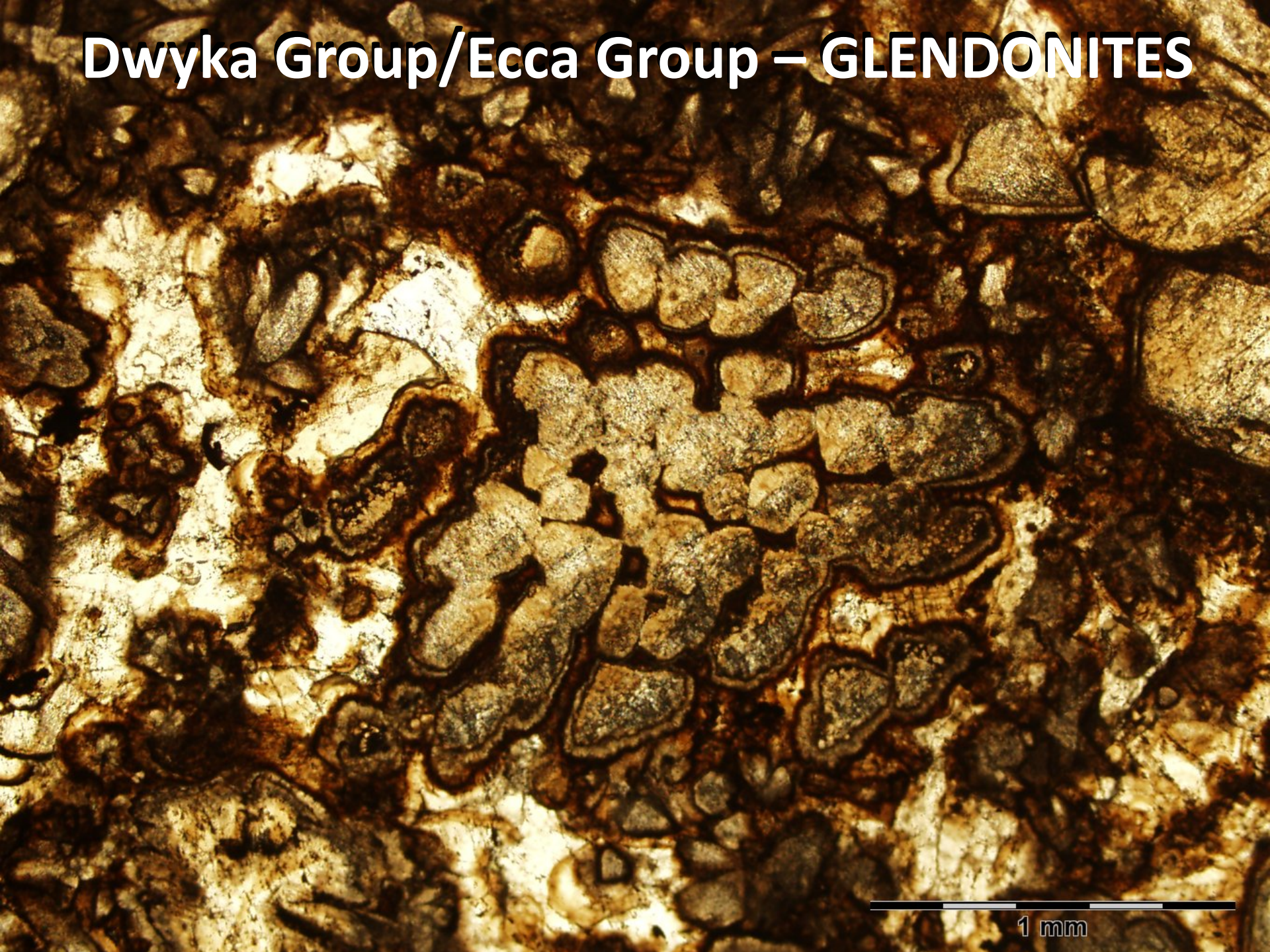
Glendonites from northern Sakhalin Slope, Sea of Okhotsk.
after Greinert and Derkachev , 2004

Dwyka Group/Ecca Group – GLENDONITES

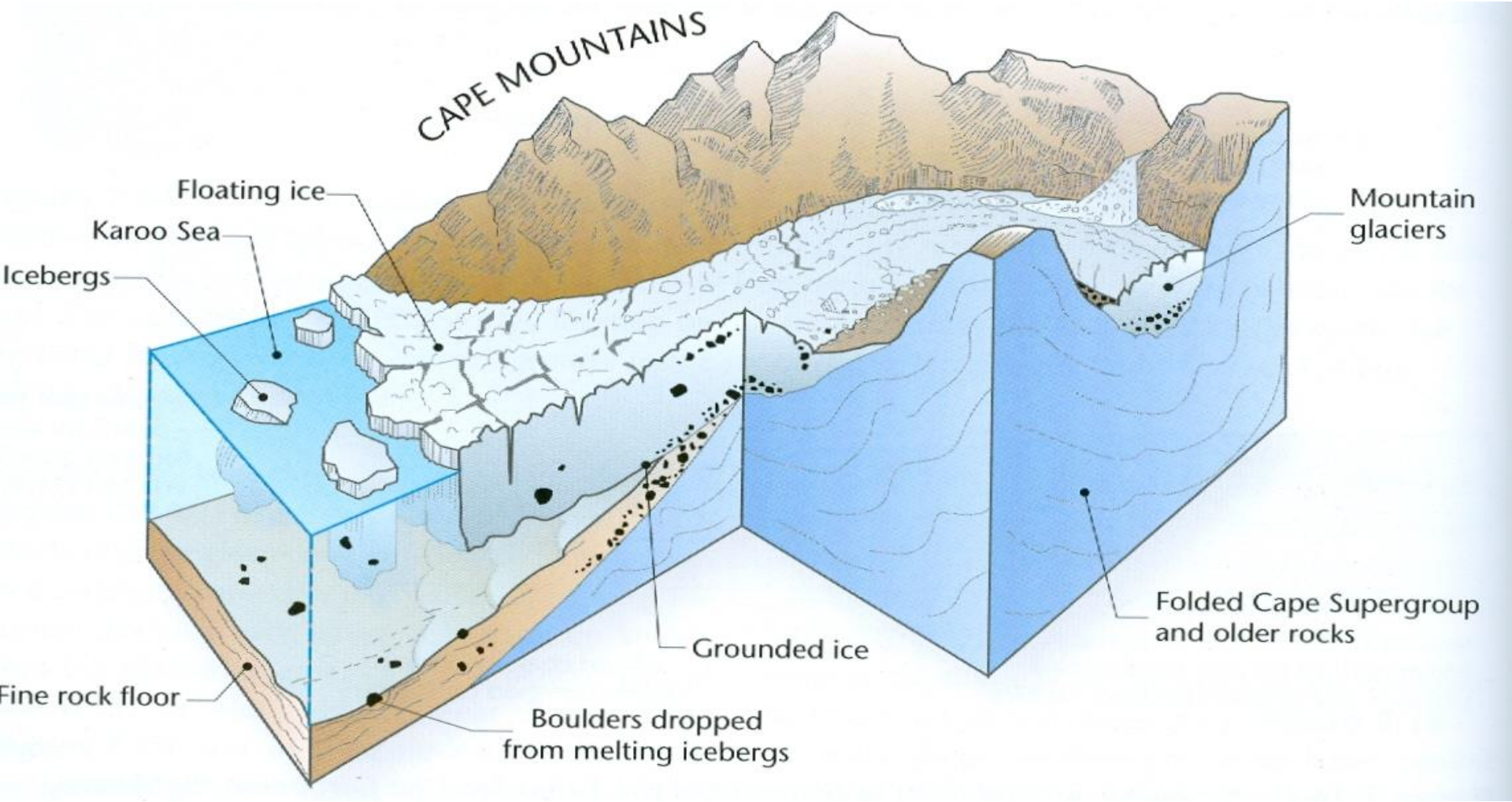
Dwyka Group/Ecca Group – GLENDONITES



Dwyka Group/Ecca Group – GLENDONITES




Ecca G
Collingham & Whitehill F
Prince Albert F
Dwyka G


CAPE MOUNTAINS
Floating ice
Karoo Sea
Icebergs
Mountain glaciers
Grounded ice
Folded Cape Supergroup and older rocks
Fine rock floor
Boulders dropped from melting icebergs


Grazie!