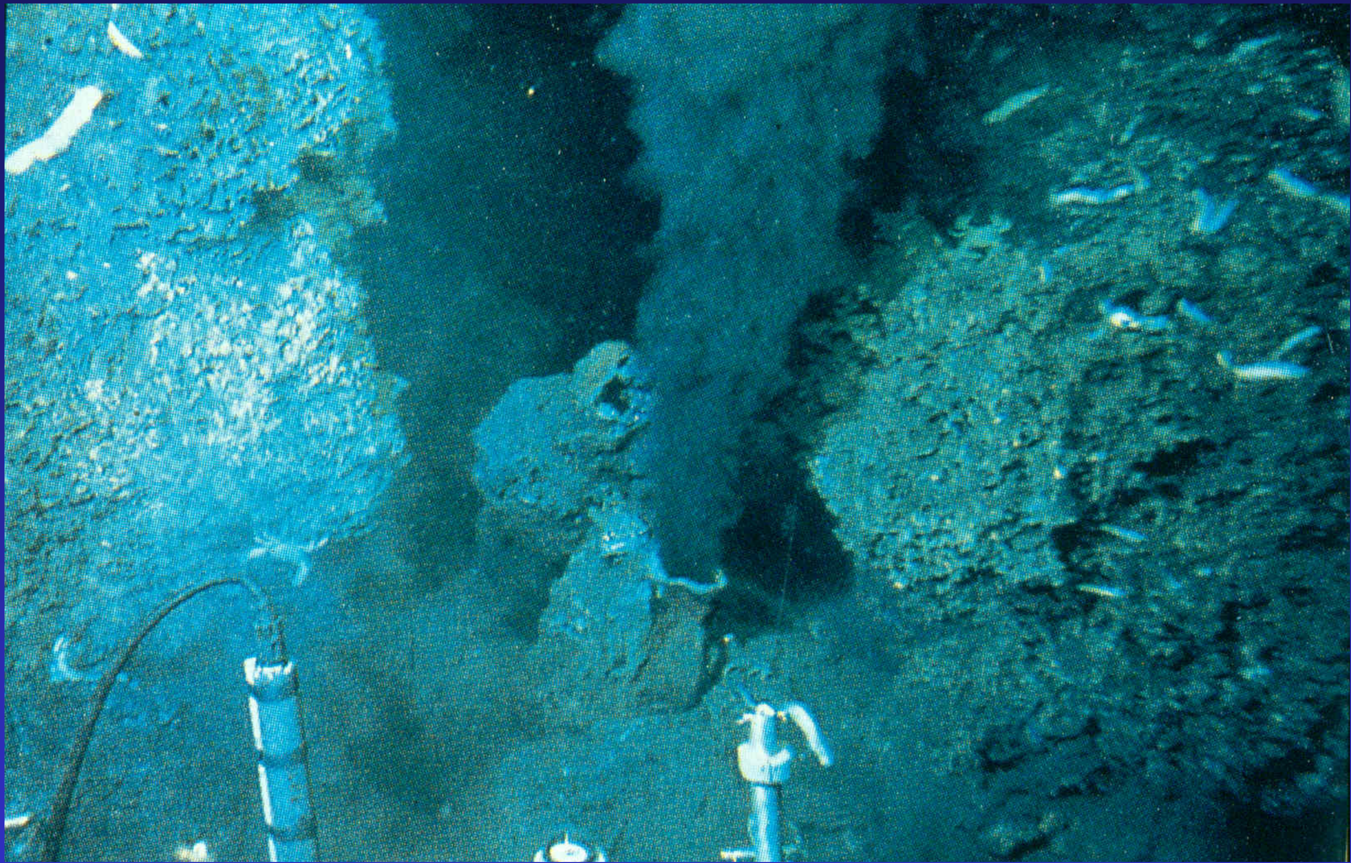
Deep sea hot vents - oases under water



Prof. Dr. Johannes F. Imhoff
Marine Mikrobiologie
Leibniz-Institut für Meereswissenschaften,
IFM-GEOMAR Kiel

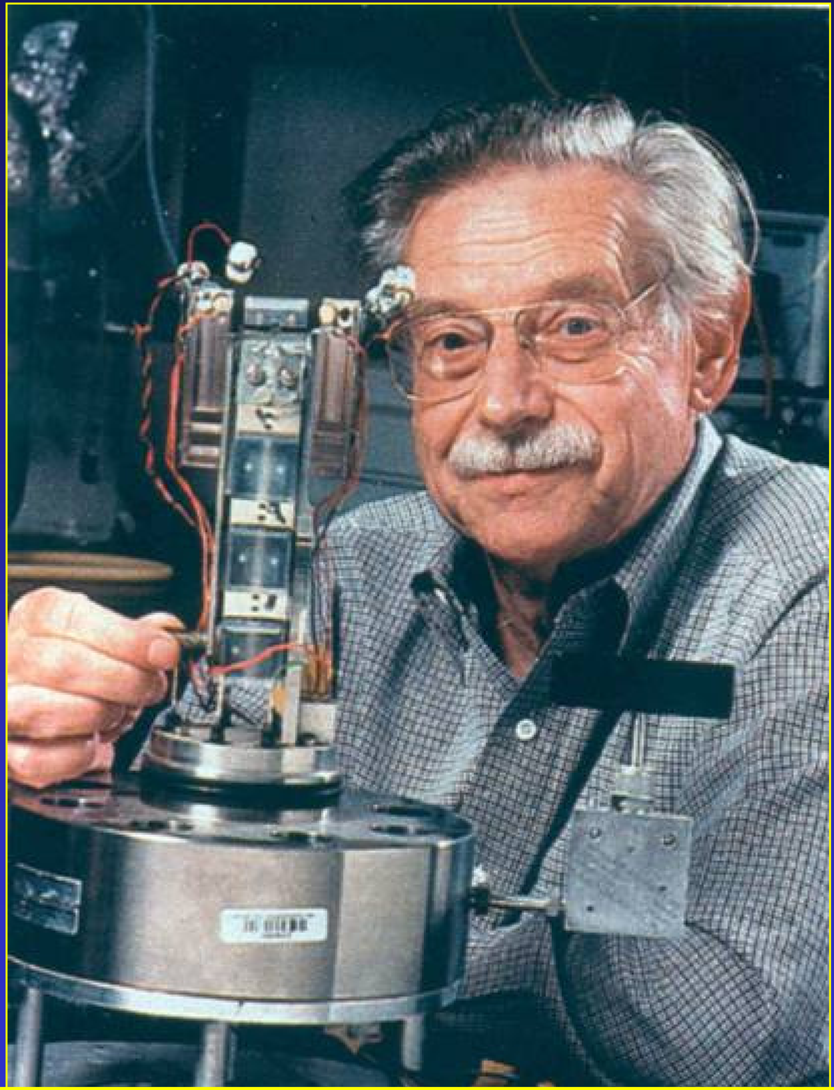
ATLANTIS II with Alvin

courtesy H.W. Jannasch

The deep sea submersible Alvin

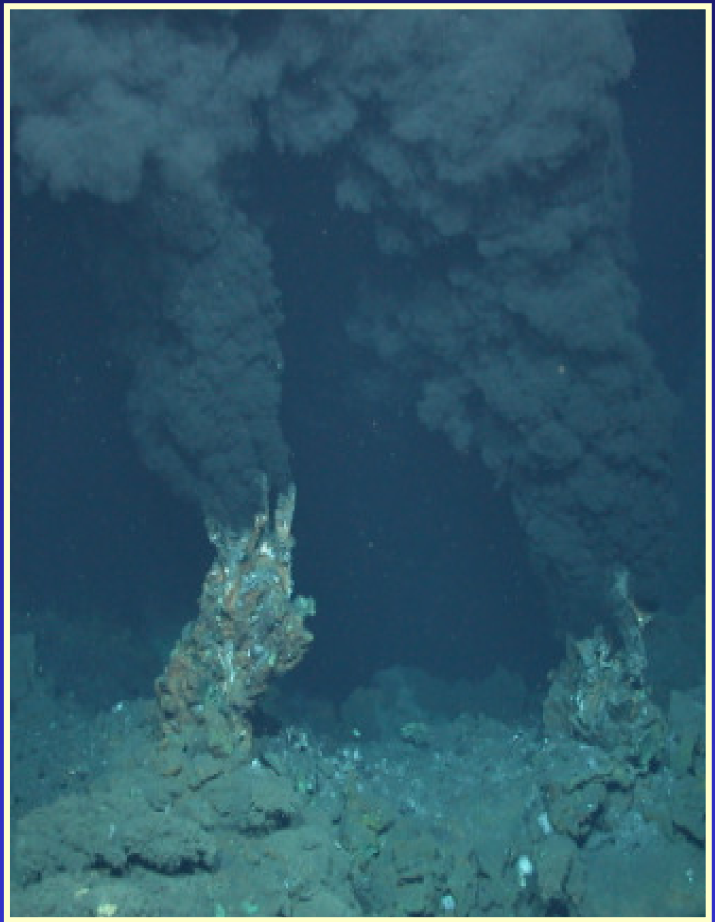
courtesy H.W. Jannasch

The German Microbiologist Holger W. Jannasch



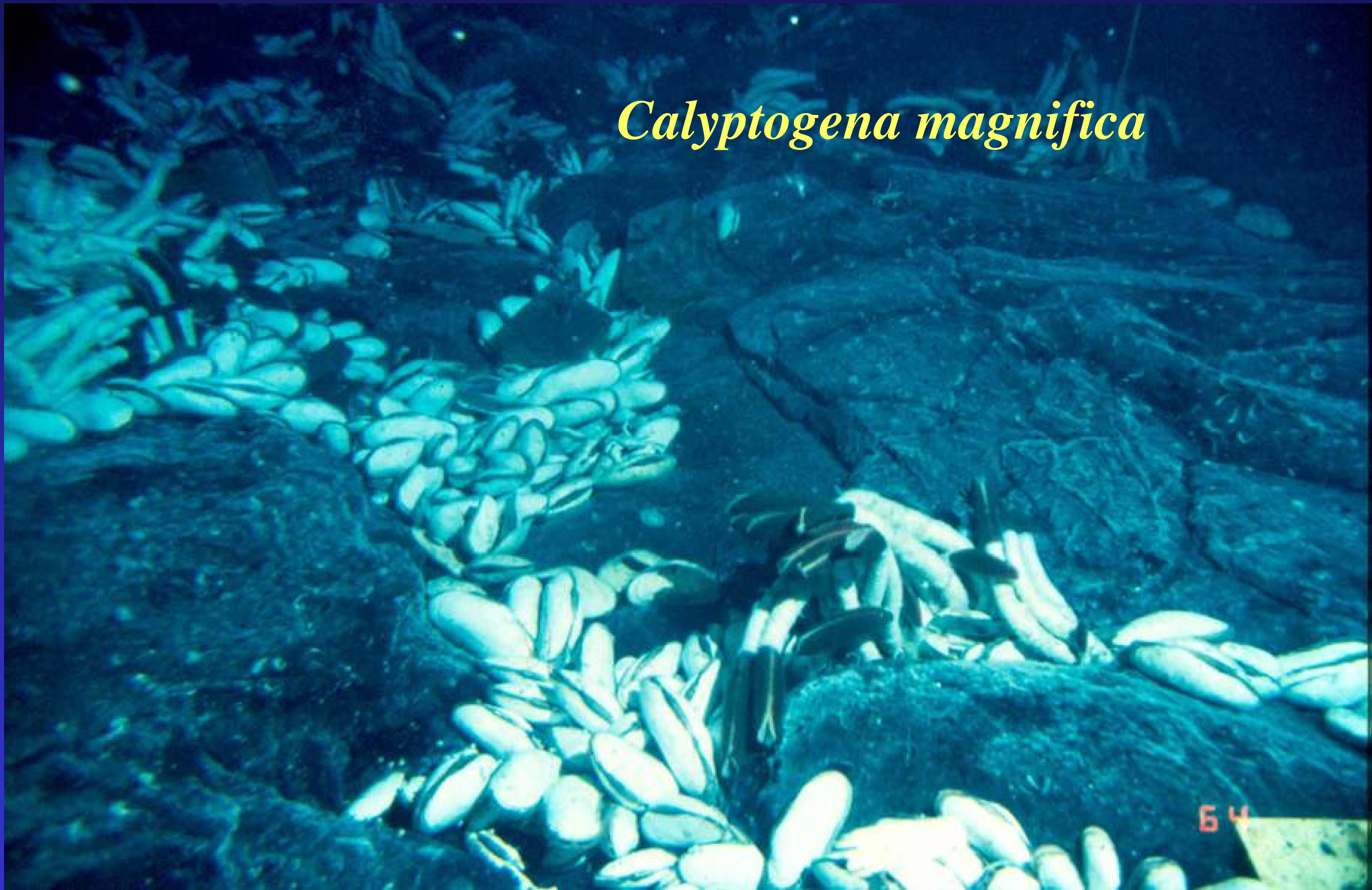
A pioneer in deep sea hot vent biology working at
Woods Hole Oceanographic Institution (USA)

“Black Smoker”

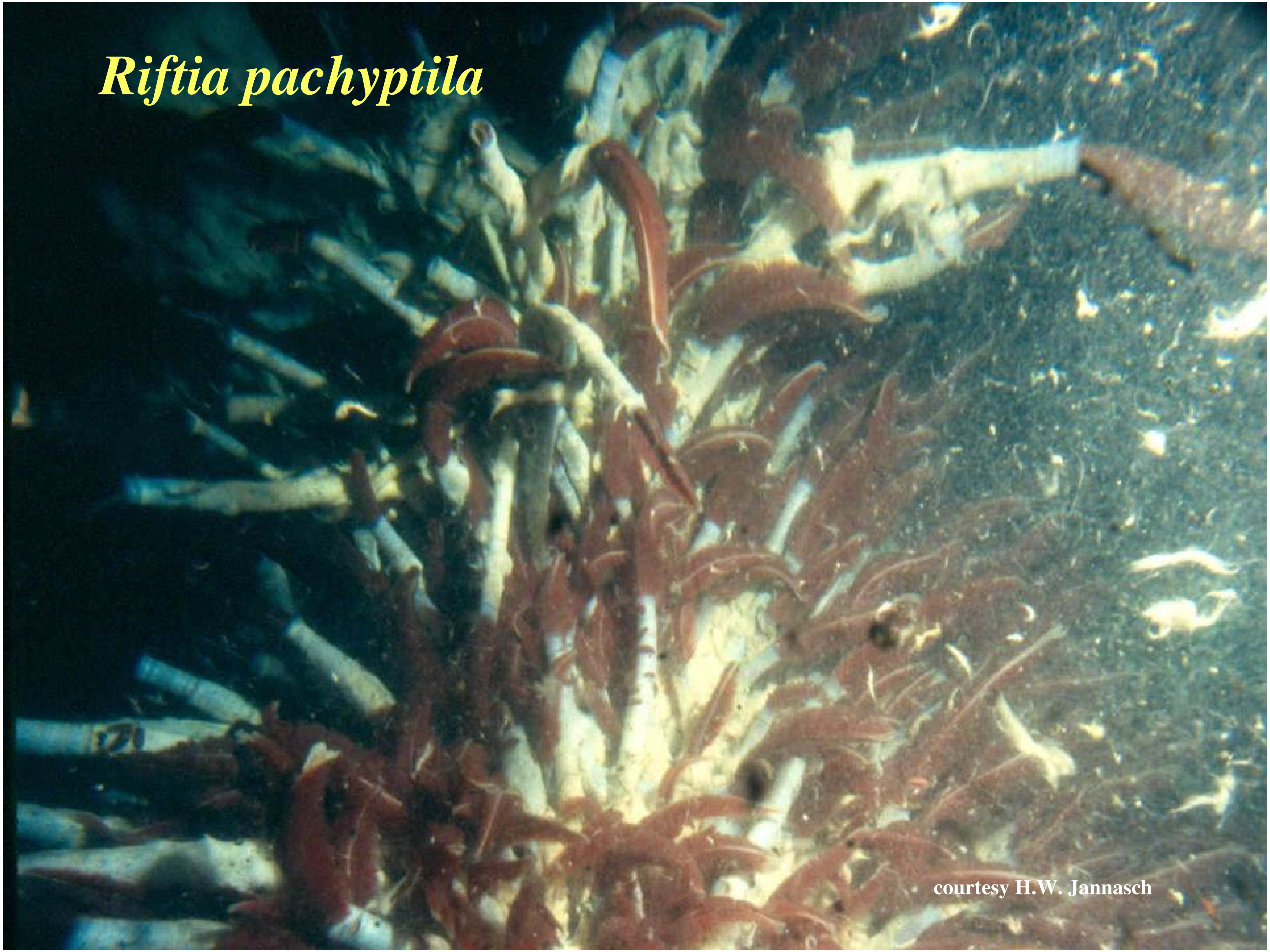


- **The impressive black smokers are found alongside the oceanic spreading axes.**
- **The outflow of hydrothermal fluid has temperatures up to 350^{o}C**
- **The fluids are enriched in reduced chemical compounds, which can serve the chemolithotrophic life style of bacteria and archaea**
- **Especially adapted microorganisms like hyperthermophilic archaea can live at temperatues of 113^{o}C but can not survive below 80^{o}C.**

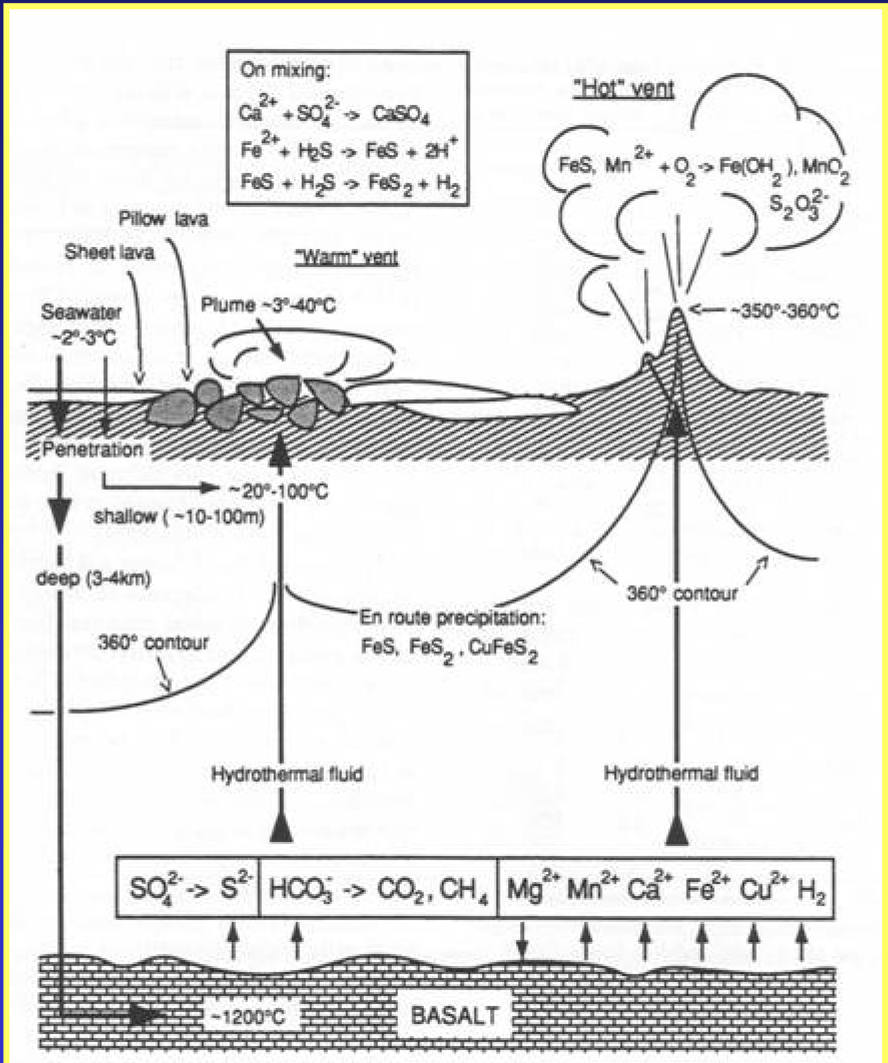
courtesy H.W. Jannasch



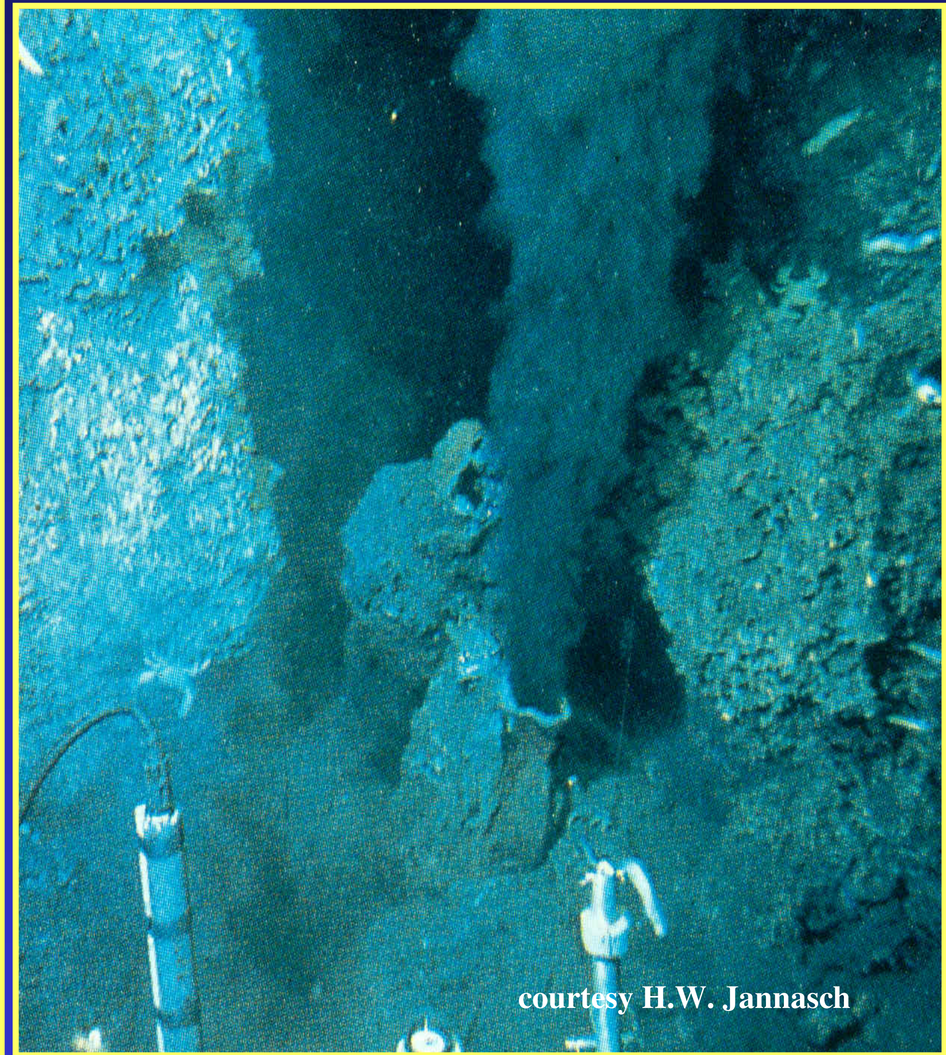
courtesy H.W. Jannasch


Riftia pachyptila
courtesy H.W. Jannasch

Important geochemical processes during hydrothermal circulation



from H.W. Jannasch (1995)



Concentration of chemical ions in hydrothermal fluids

CS	molar level	GB	21°N	SW
Fe	(μM)	56	1664	0.001
Mn	(μM)	139	960	0.001
Co	(nM)	5	213	0.03
Cu	(μM)	1	35	0.007
Zn	(μM)	4	106	0.01
Ag	(nM)	230	38	0.02
Pb	(nM)	265	308	0.01
Mg	(mM)	29	0	52.7
Ca	(μM)	29	15.6	10.2
Na	(mM)	489	432	464
K	(mM)	48	28	9.79
Sr	(μM)	202	81	87
Ba	(μM)	12	7	0.14
Cl	(mM)	601	489	541
$SO_4^{=}$	(mM)	0	0	27.9
Si	(mM)	13	18	0.16
Al	(μM)	1	5	0.01
H_2S	(mM)	5.8	7.3	0
NH_4^+	(mM)	15	0	0
H_2	(mM)	8	50	0.001
CH_4	(mM)	1	1.6	0.001
[pH		5.9	3.4	8.1]

from H.W. Jannasch (1995)

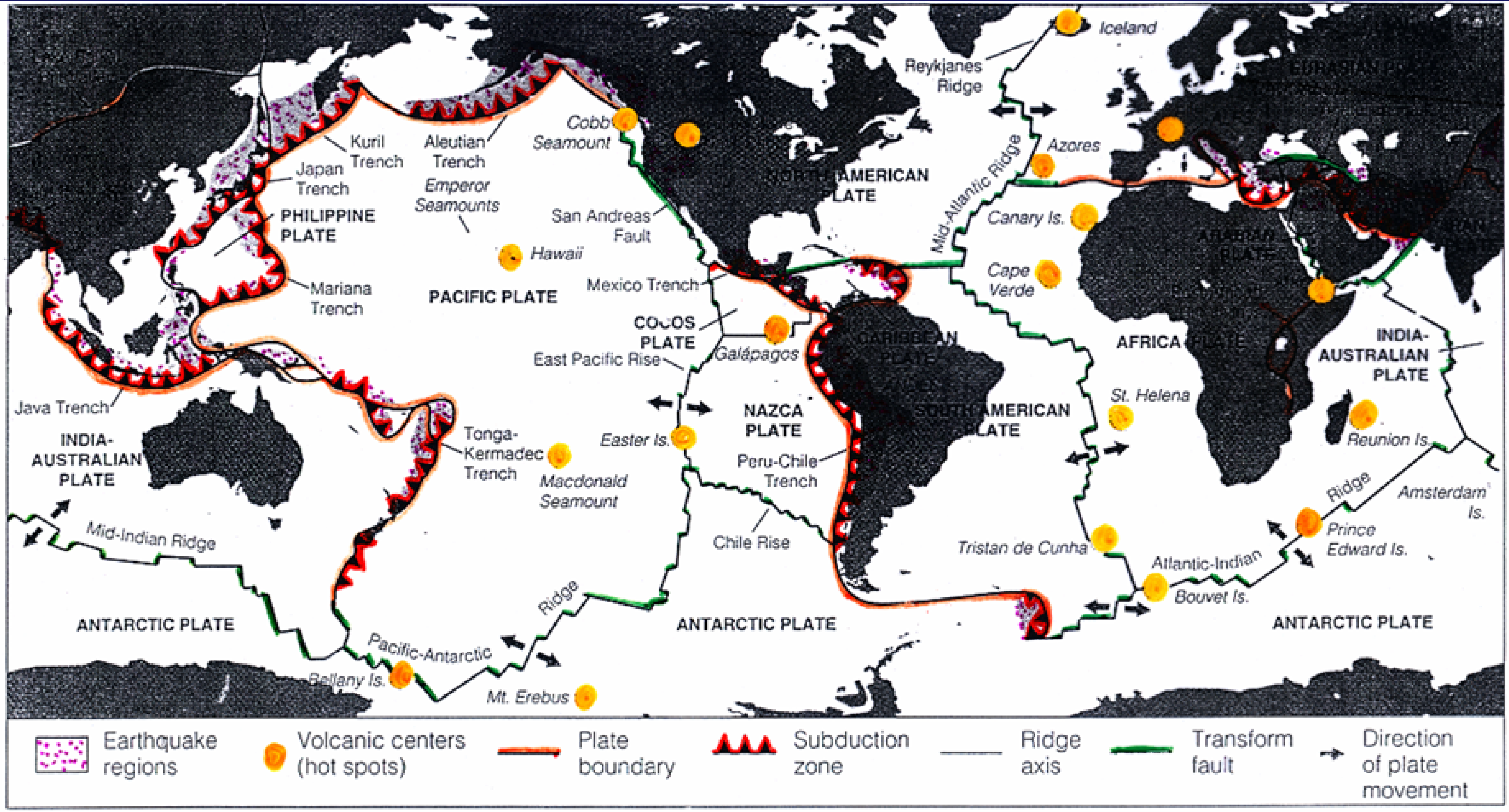


Figure 3.14 The major lithospheric plates, showing their directions of relative movement and the location of the principal hot spots. Note the correspondence of plate boundaries and earthquake locations.

Energy yielding reactions of major genera of lithoautotrophic hyperthermophilic vent isolates

Electron-donor	Electron-acceptor	Reaction	Organisms
H_2	CO_2	$4H_2+CO_2 \longrightarrow CH_4+2H_2O$	Methanopyrus Methanococcus
H_2	S^o	$H_2+S^o \longrightarrow H_2S$	Pyrodictium*
H_2	SO_4^{2}; $S_2O_3^{2+}$	$4H_2+H_2SO_4 \longrightarrow H_2S+4H_2O$	Archaeoglobus*
H_2 S^o; S^{2-}	O_2	$H_2+1/2O_2 \longrightarrow H_2O$ $2S^o+3O_2+H_20 \longrightarrow 2H_2SO_4$	Aquifex Sulfolobus**

* facultatively heterotrophic, ** not yet isolated from marine hydrothermal sources

from H.W. Jannasch (1995)

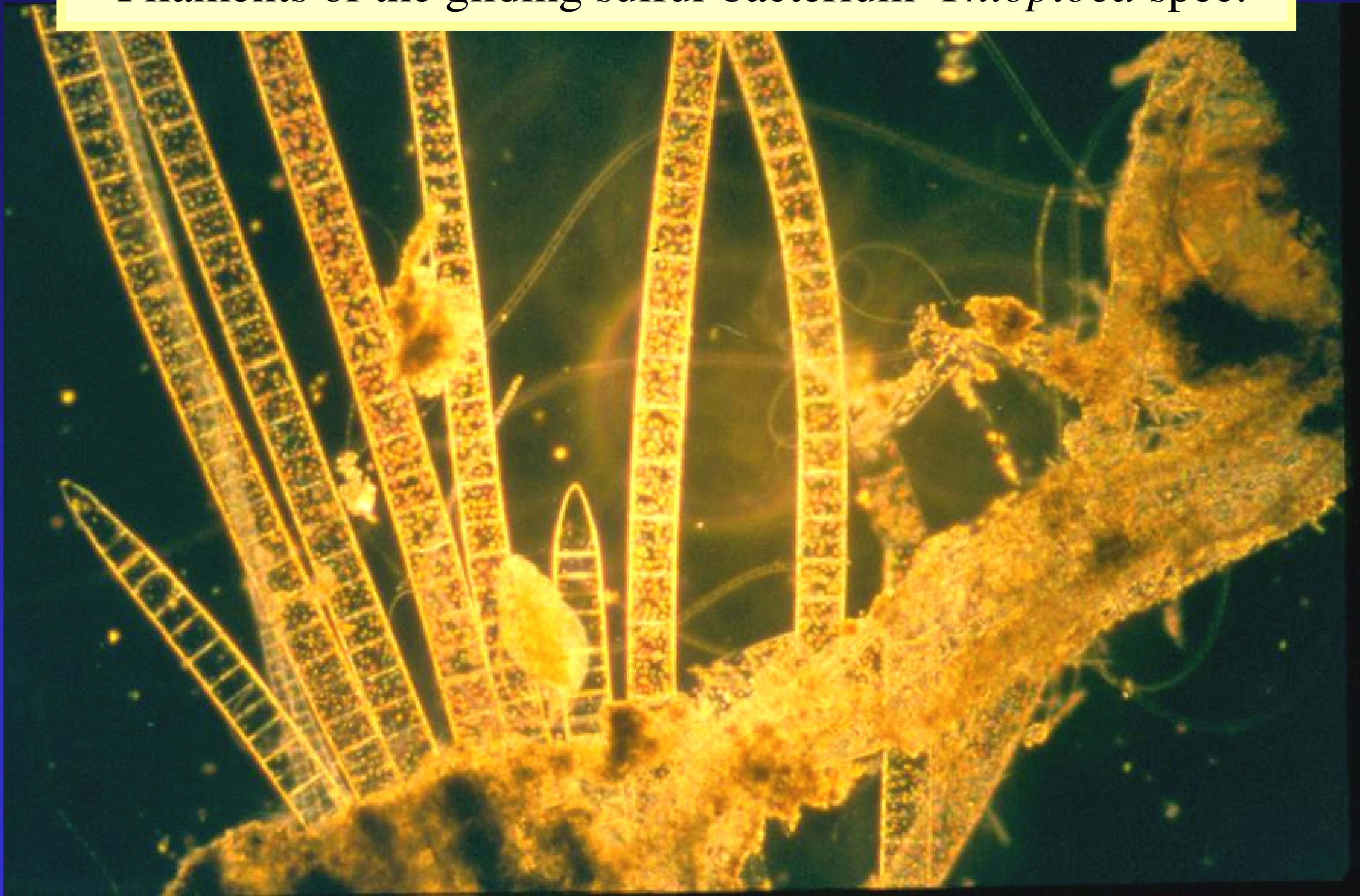
Life with reduced sulfur compounds as energy source

- Sulfur bacteria are chemolithoautotrophic bacteria
- They gain energy by oxidising reduced sulfur compounds using oxygen

$$CO_2 + H_2S + H_2O + O_2 \longrightarrow [CH_2O] + H_2SO_4$$

- These bacteria are able to use inorganic carbon dioxide as a sole source of cellular carbon
- Thus, they can live exclusively from inorganic substances

Filaments of the gliding sulfur bacterium *Thioploca* spec.



Microbial processes observed in hot vent Prokaryotes

Electron donor	Electron acceptor	Free energy ΔG° [a]	Temperature response[b]	Process
$S^{=}$	O_2	-797	m., hyp.	sulfide oxidation
S^{o}	O_2	-585	m., hyp.	sulfur oxidation
$S_2O_3^{=}$	O_2	-952	m., hyp.	thiosulfate oxidation
Fe^{++}	O_2	-44.3	m.	iron oxidation
Mn^{++}	O_2	-68.2	m.	manganese oxidation
NH_4^{+}	O_2	-275	m.	nitrification
CH_4	O_2	-810	m.	methane oxidation
$[CH_2O]$	O_2	-477	m., hyp.	org.C oxidation
H_2	O_2	-237	m., hyp.	hydrogen oxidation
H_2	$NO_3^{=}$	-239	m., hyp.	denitrification[c]
H_2	S^{o}	-98.3	hyp.	sulfur reduction
H_2	$SO_4^{=}$	-38.1	m., hyp.	sulfate reduction
H_2	CO_2	-34.7	m., hyp.	methanogenesis
$[CH_2O]$	S^{o}	-25.1	hyp.	heter. sulfur reduction
$[CH_2O]$	$SO_4^{=}$	-40.6	m., hyp.	heter. sulfate red.
$[CH_2O]$	$[CH_2O]$	-38.5	m., hyp.	fermentation[d]

aerobic
anaerobic

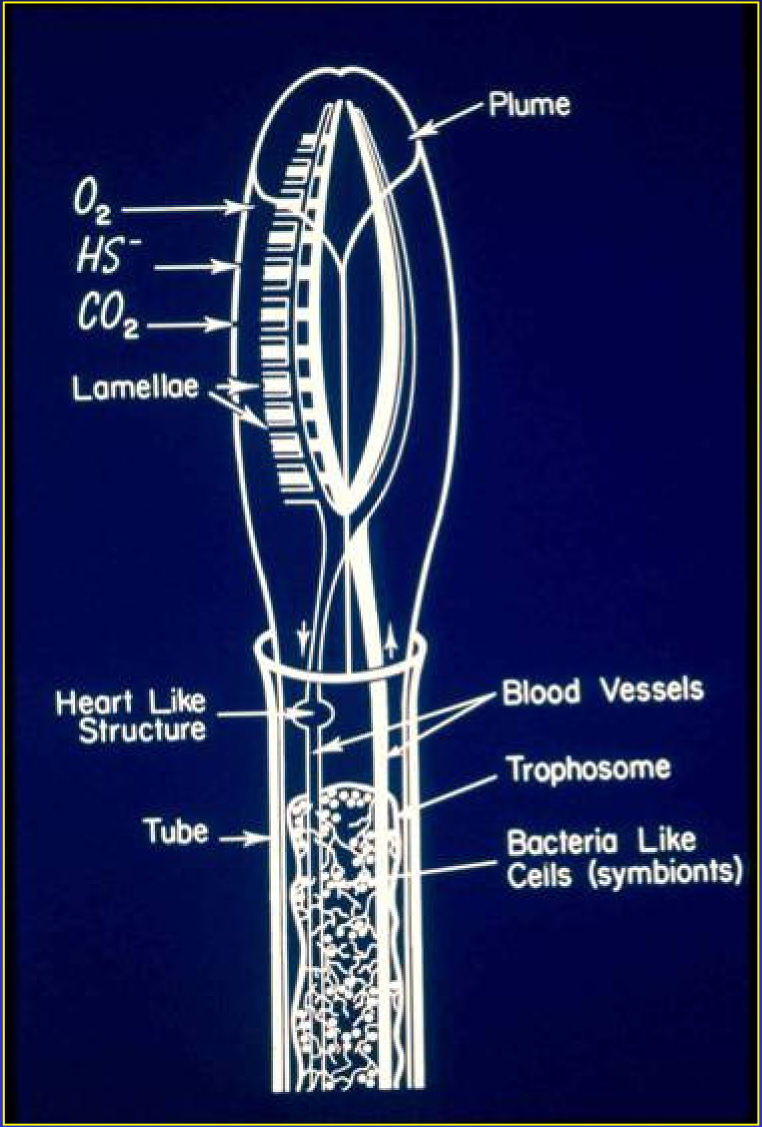
from H.W. Jannasch (1995)

Presently known upper temperature limits for growth of living organisms

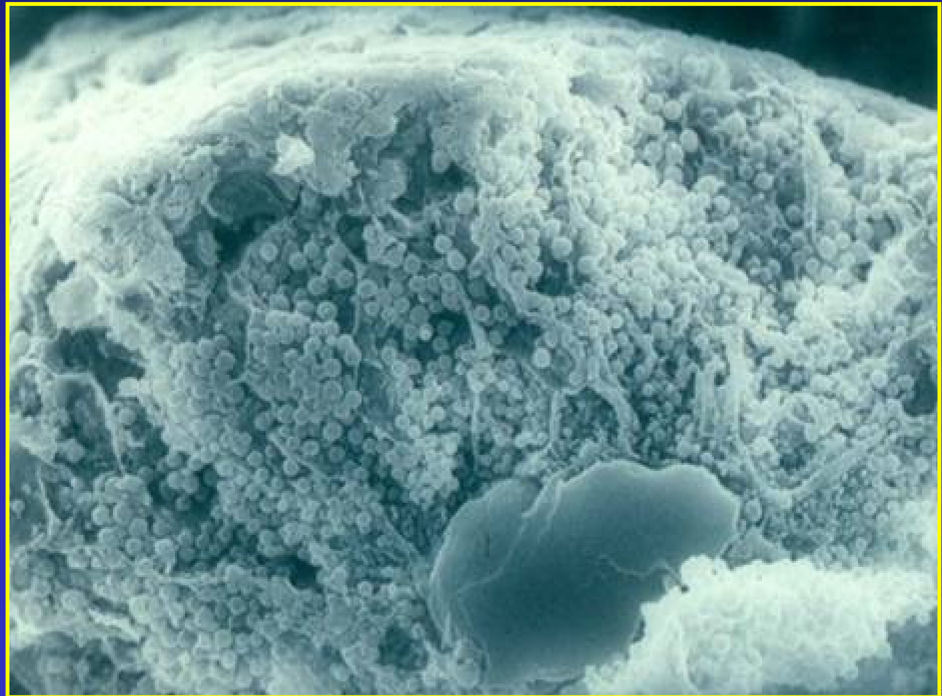
Group	Upper temperature limits (°C)
Animals	
Fish and other aquatic vertebrates	38
Insects	45-90
Ostracods (crustaceans)	49-50
Plants	
Vascular plants	45
Mosses	50
Eukaryotic Microorganisms	
Protozoa	56
Algae	55-60
Fungi	60-62
Prokaryotes	
Bacteria	
Cyanobacteria	70-74
Anoxygenic phototrophic bacteria	70-73
Chemoorganotrophic bacteria	90
Archaea	
Hyperthermophilic methanogens	110
Sulfur-dependent hyperthermophiles	113

Life at hydrothermal vents in the deep sea

- Hydrothermal vents are oases in the deep ocean desert
- Life is dependent on chemolithotrophic bacteria
- The vents harbor copious communities of organisms
- These are characterised by various symbiotic associations

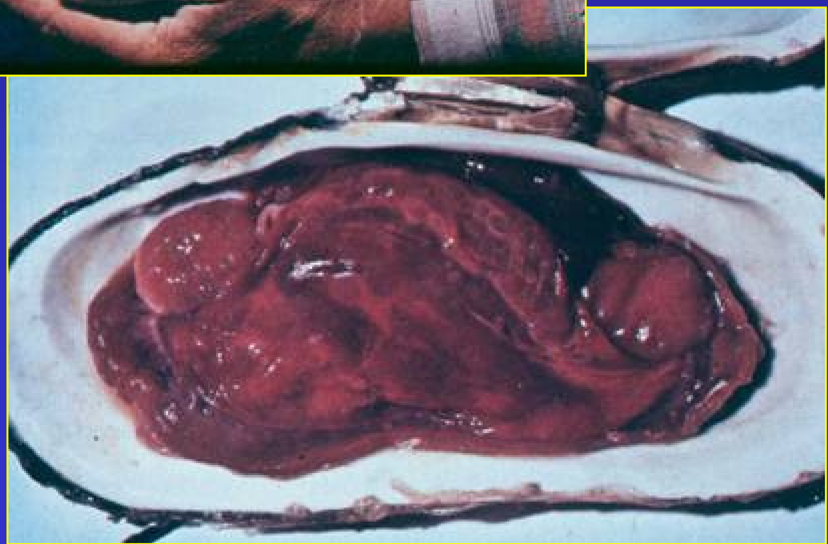


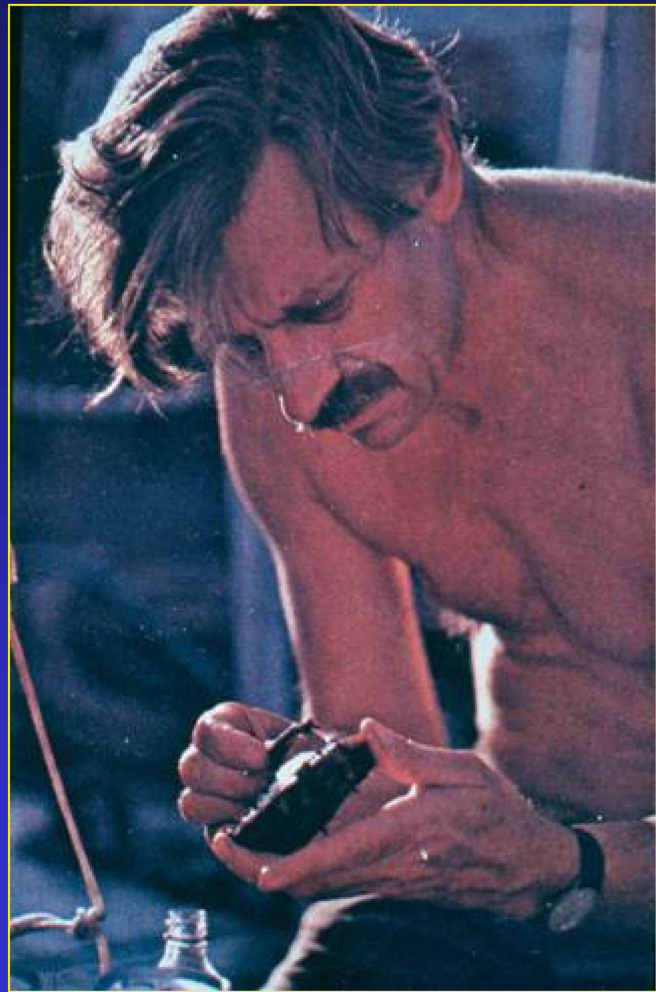
The tube worm *Riftia pachyptila*

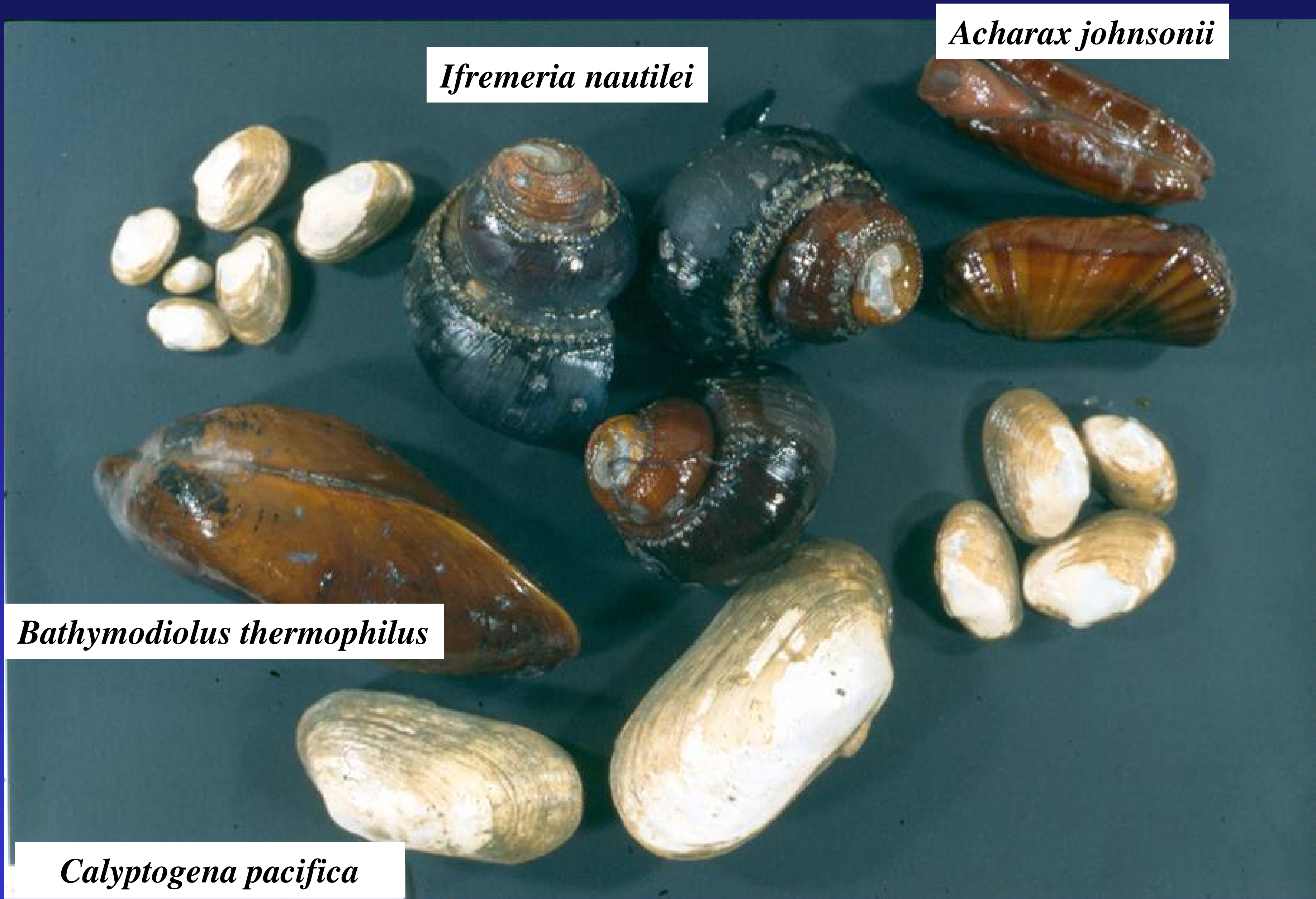


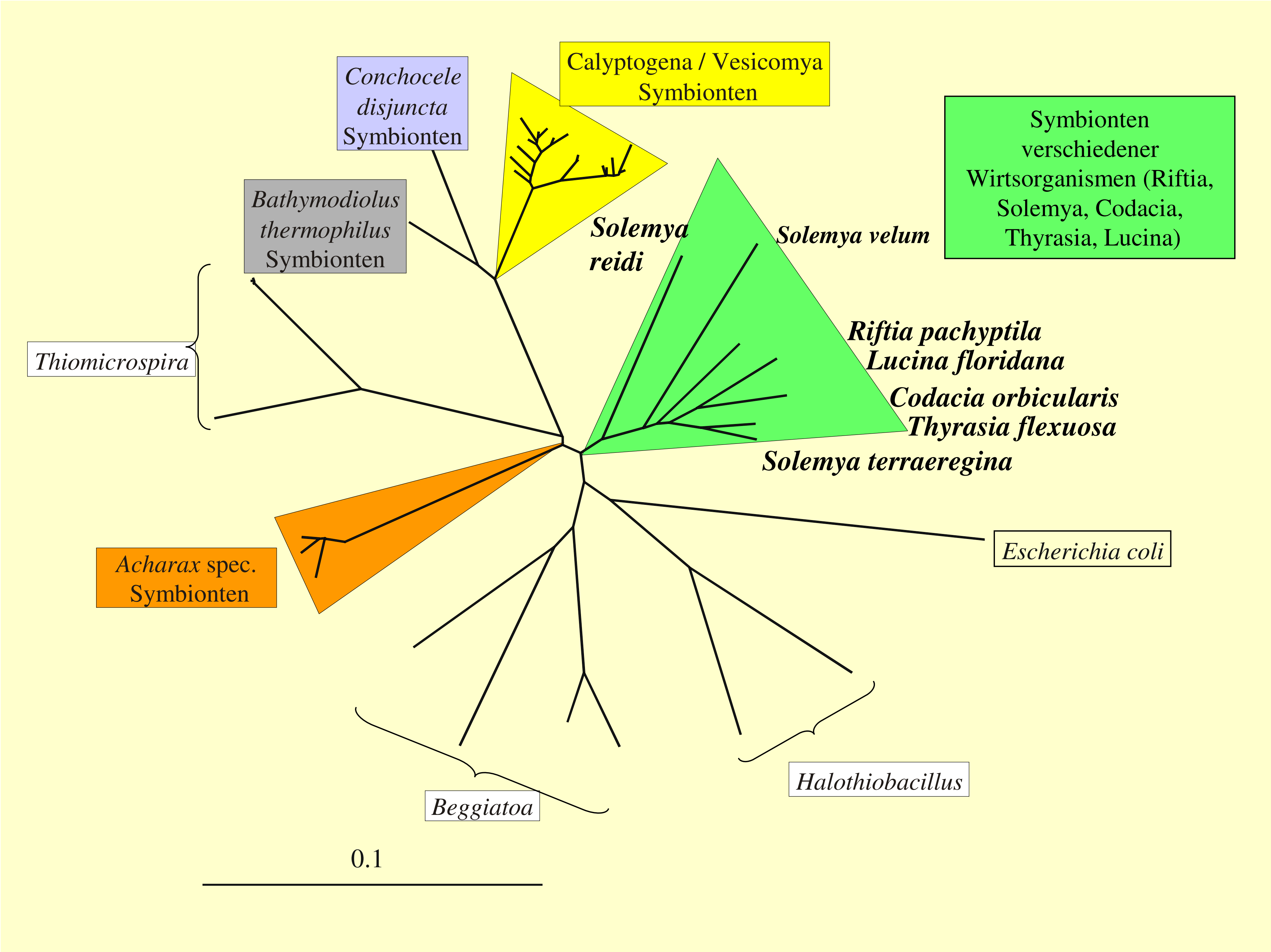
courtesy H.W. Jannasch

Calyptogena magnifica






Ifremeria nautilei
Acharax johnsonii
Bathymodiolus thermophilus
Calyptogena pacifica

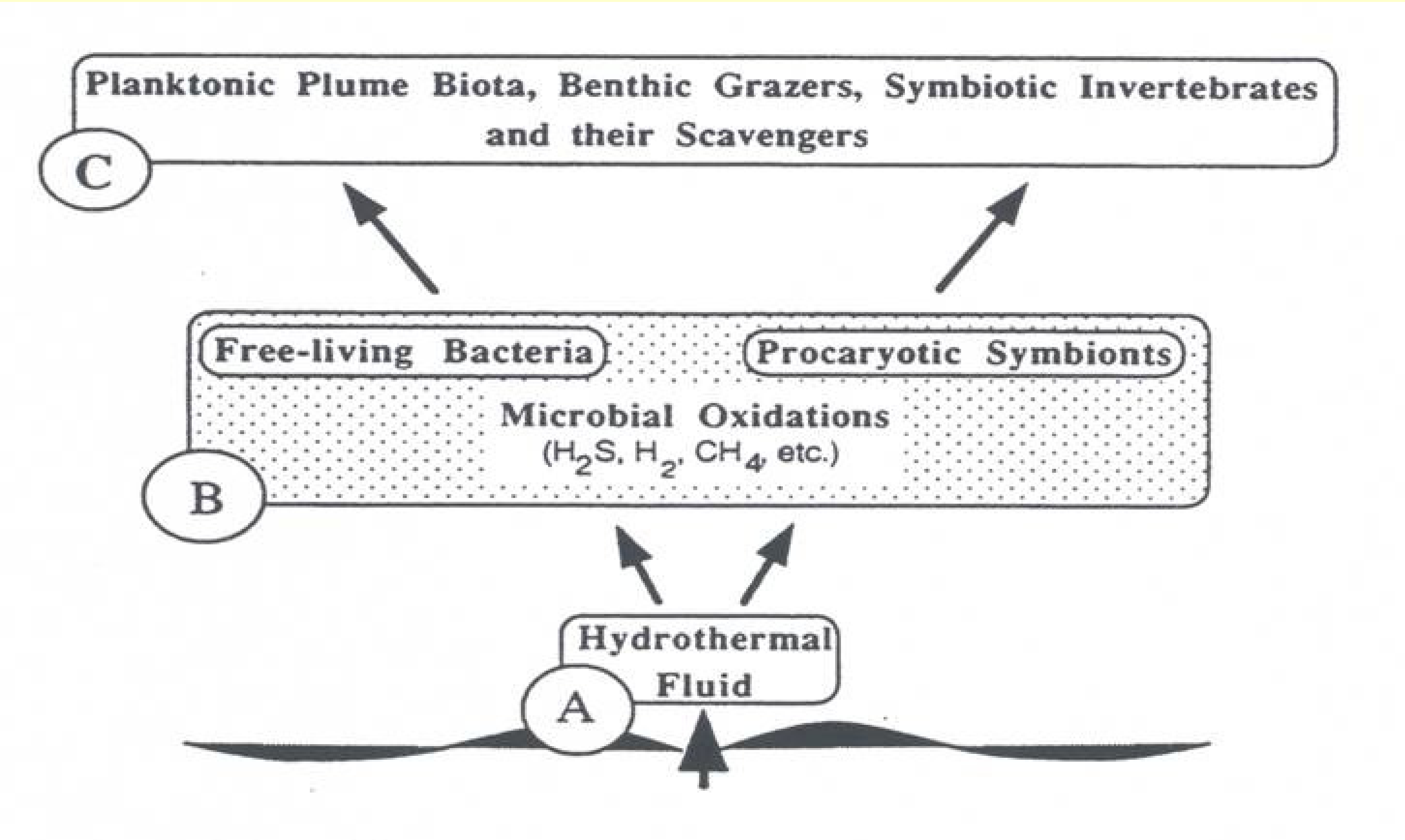


Conchocele disjuncta Symbionten
Calyptogena / Vesicomya Symbionten
Symbionten verschiedener Wirtsorganismen (Riftia, Solemya, Codacia, Thyrasia, Lucina)
Bathymodiolus thermophilus Symbionten
Solemya reidi
Solemya velum
Thiomicrospira
Riftia pachyptila
Lucina floridana
Codacia orbicularis
Thyrasia flexuosa
Solemya terraeregina
Escherichia coli
Acharax spec. Symbionten
Halothiobacillus
Beggiatoa
0.1

Endosymbioses of hydrothermal vents in the deep sea

- **Symbiotic associations represent approx. 90% of the animal biomass**
- **The symbiotic associations are species specific (Each host harbors a single specific bacterial species)**
- **Symbioses between sulfur bacteria and animals have been invented several times**
- **Also methylotrophic symbionts are found in hydrothermal vents systemes**
- **The distribution of animals arround hydrothermal vents indicates their strict dependency from this source of energy**

Deep-sea food chain based on microbial transformations of geothermal energy



from H.W. Jannasch (1995)

Forschungsfahrt Meteor 60/3

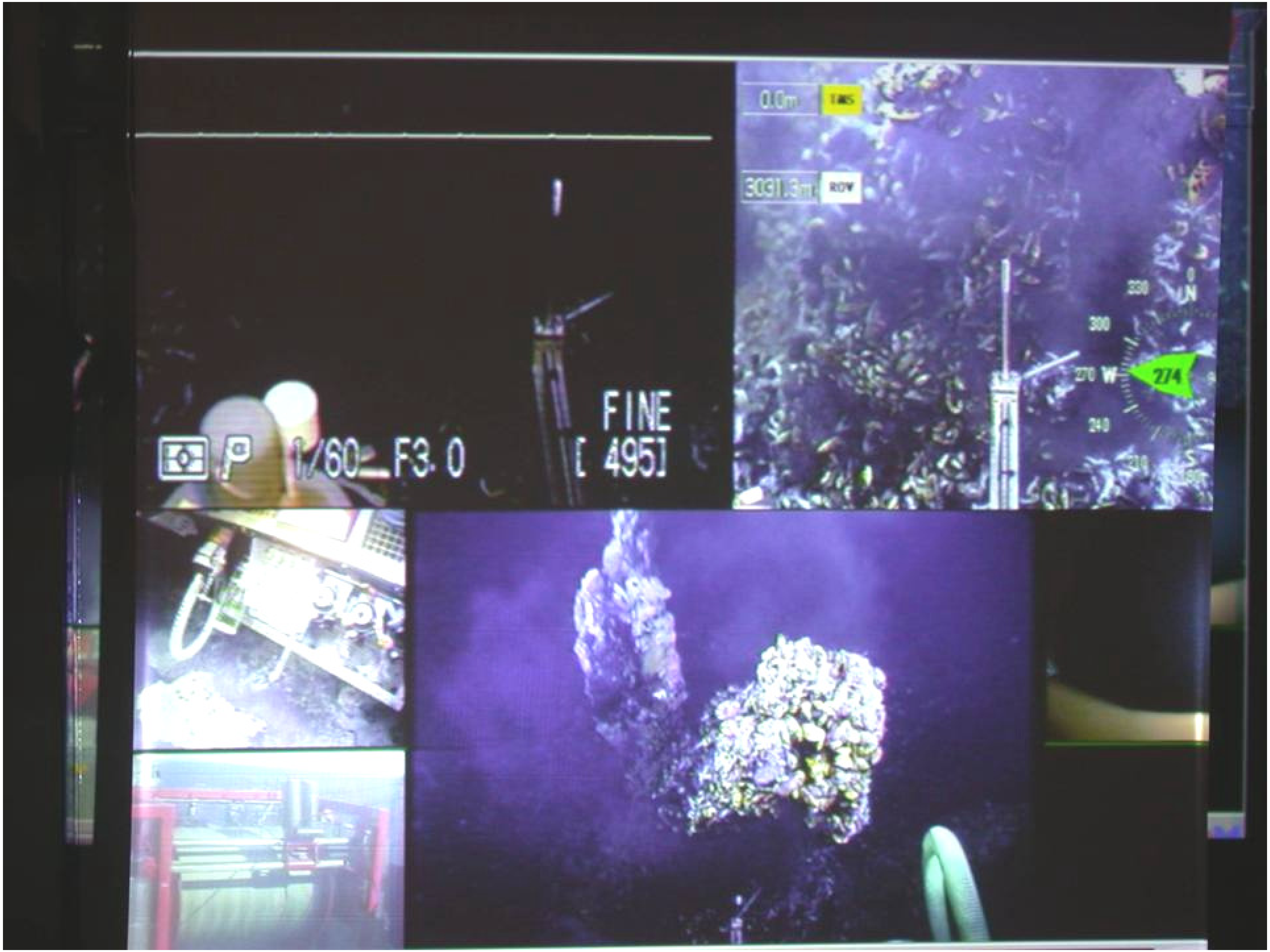
mit dem Tauchboot Quest auf Entdeckungsfahrt

Januar/Februar 2004

Meteor in Kiel am 7.11.2003


marum
QUEST
4000 METER


GEOU 1000200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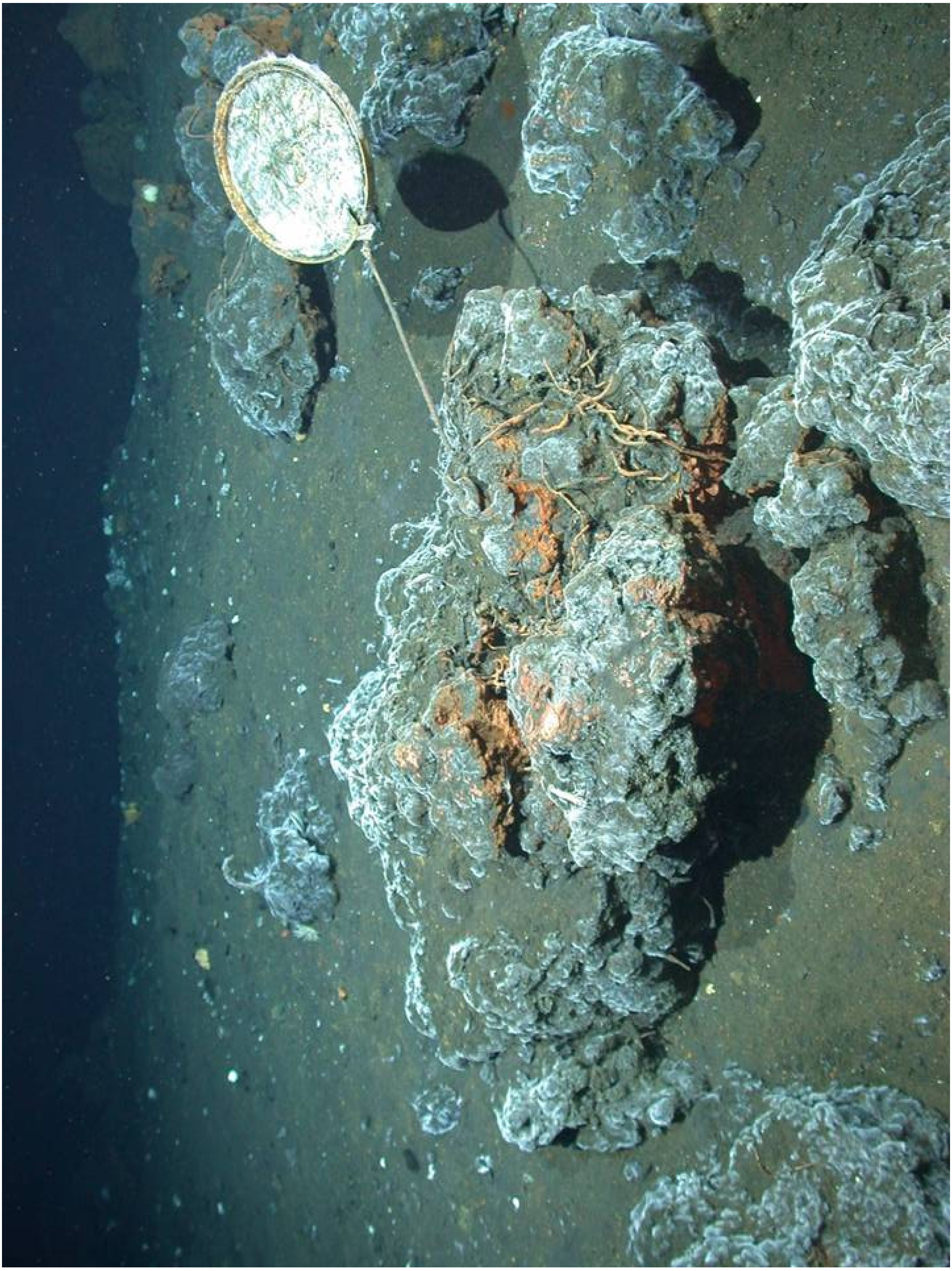
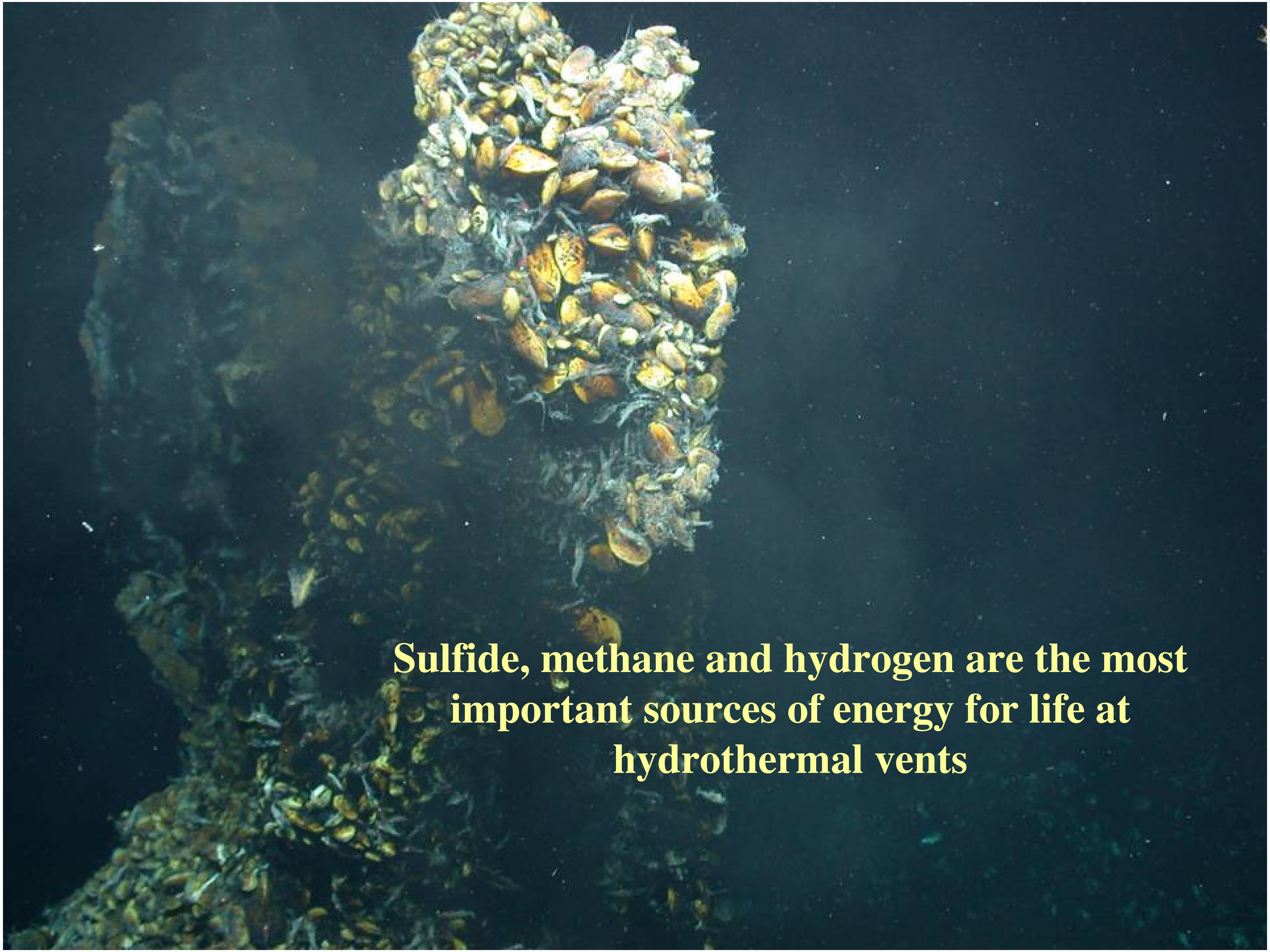



Sulfide, methane and hydrogen are the most
important sources of energy for life at
hydrothermal vents

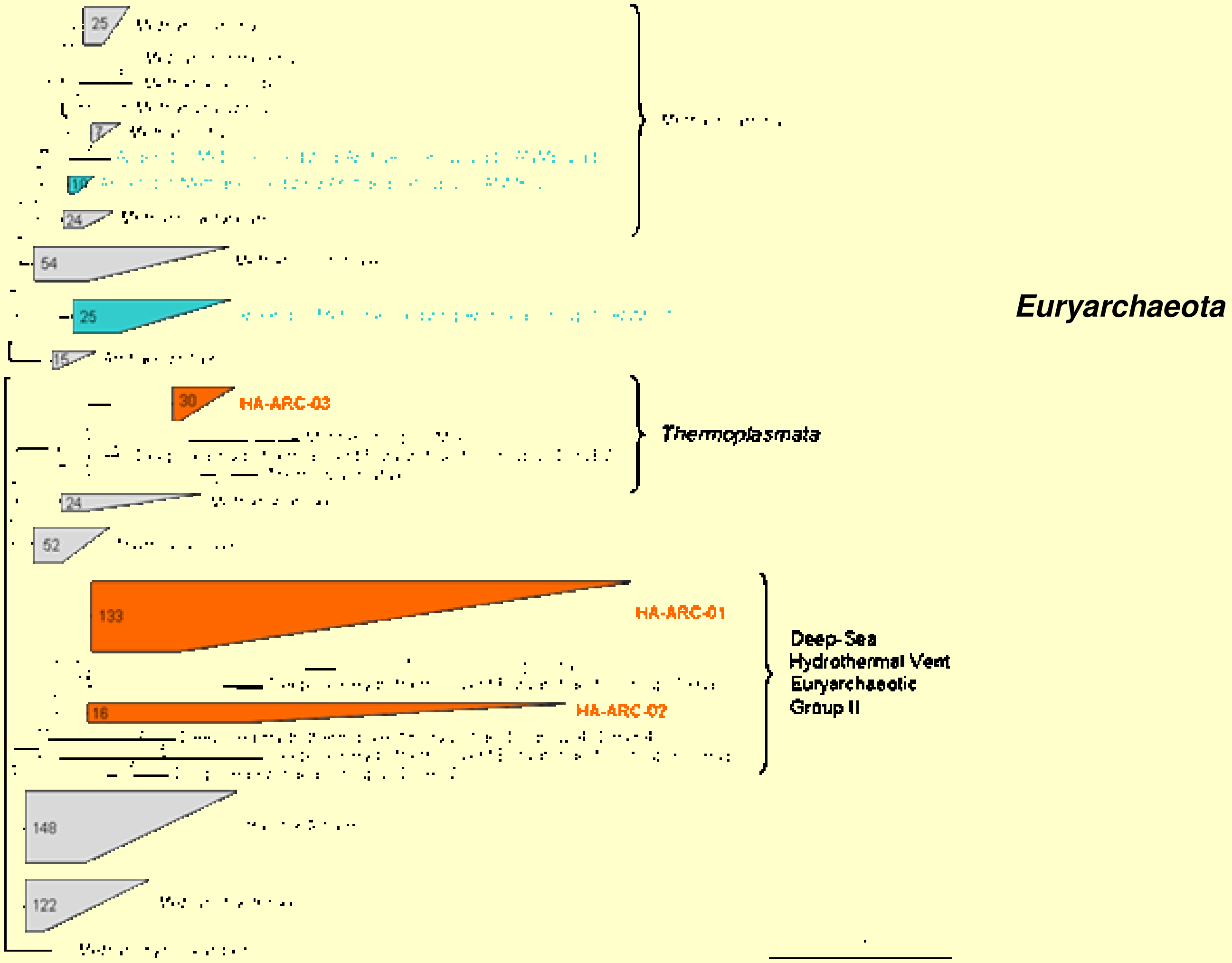
Selection of animals found in the Logatchev vent field

Bathymodiolus thermophilus

Rimicaris exoculata

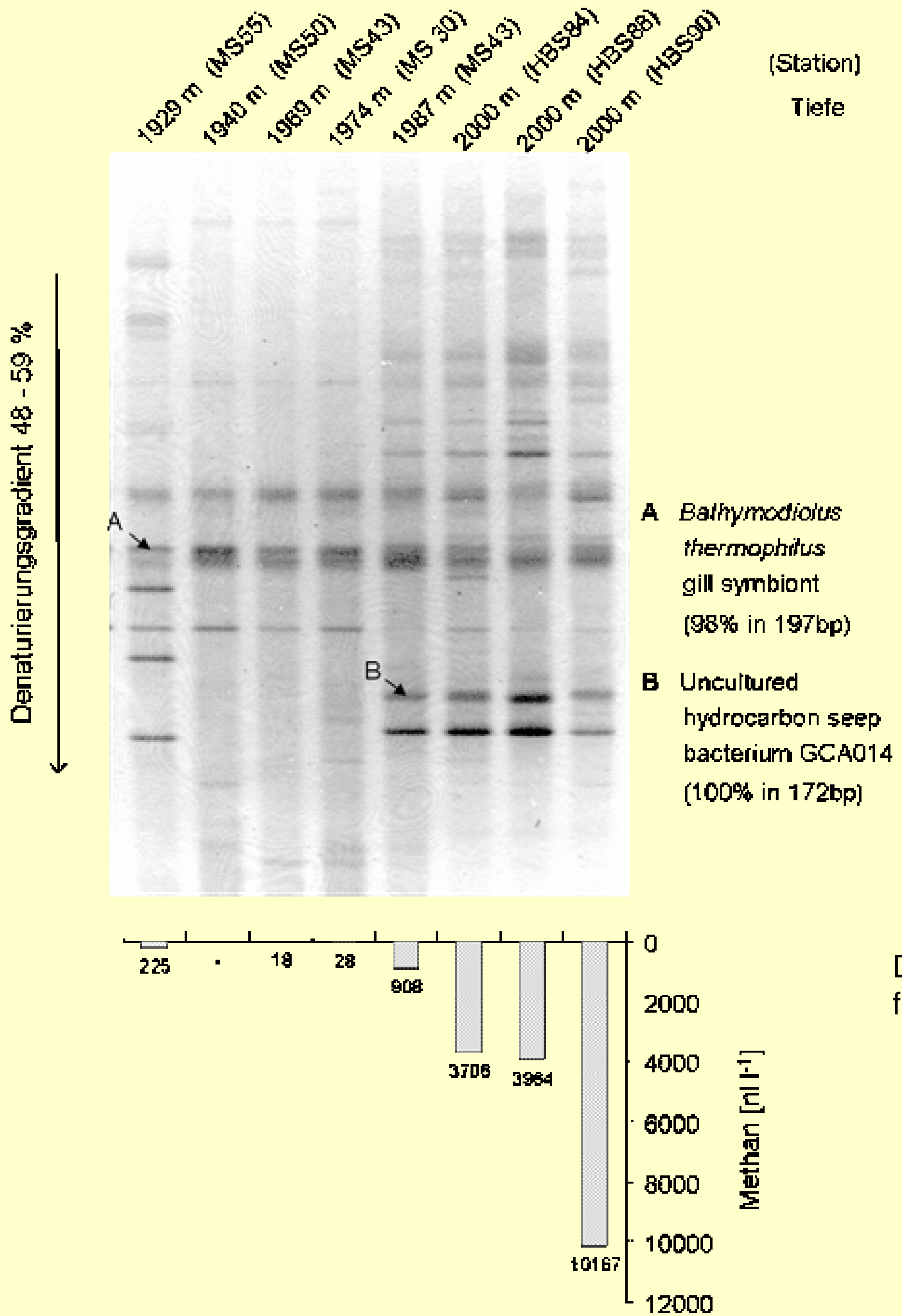
„The vent crab“

New euryarchaeota from hydrothermal sediments in the Arctic Ocean



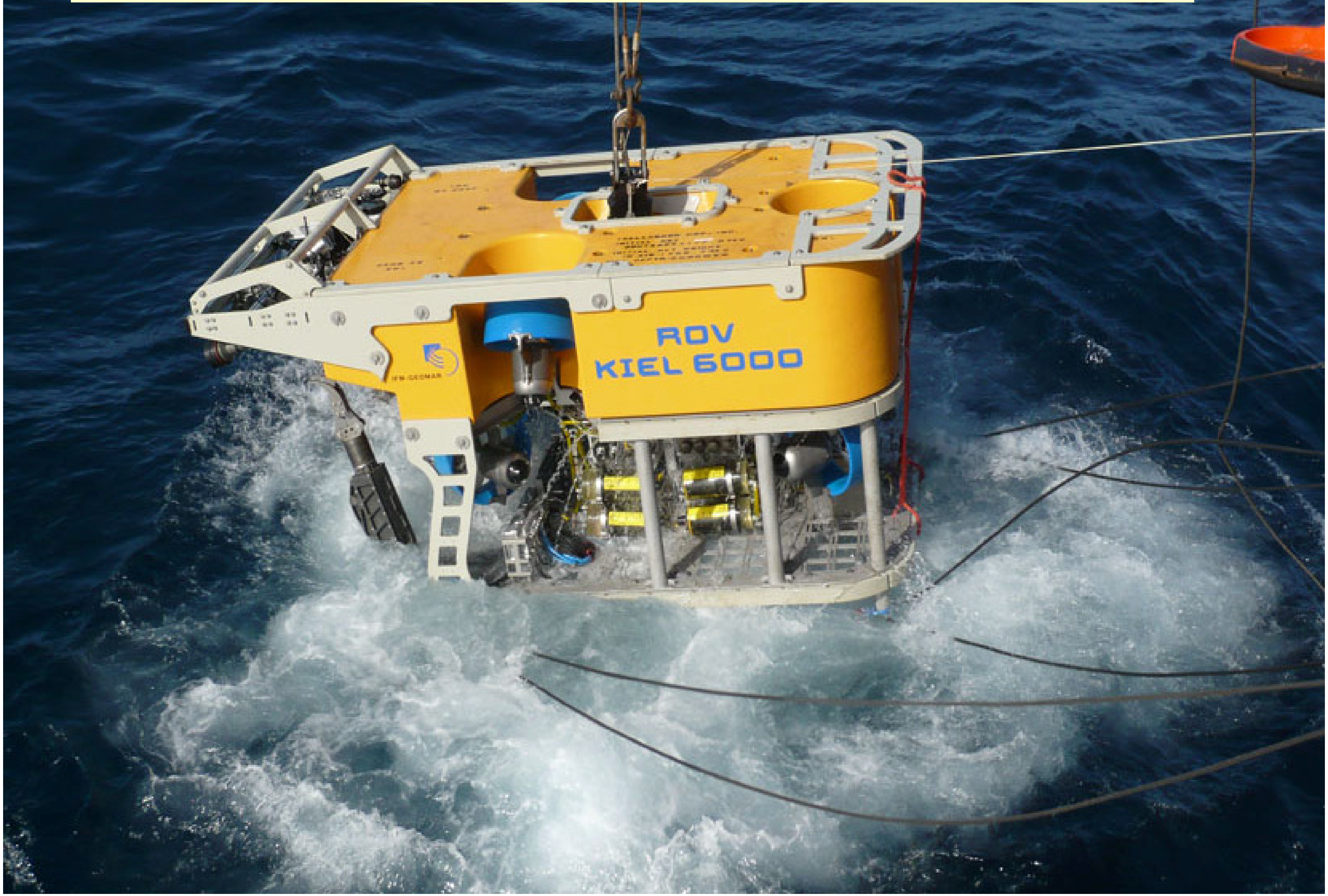
Clone sequences of 16S rDNA from the sediment at site 32-MUC (Imhoff et al. unpublished data)

Gradient gel separation of bands from hydrothermal waters in the Fiji-Basin



DGGE-band pattern and methane concentrations from different sites. (Imhoff et al., unpubl. Data)

The new ROV of IFM-GEOMAR

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an der Universität Kiel
Thank you for your attention