DEPARTMENT OF OCEAN SCIENCE

Overview:

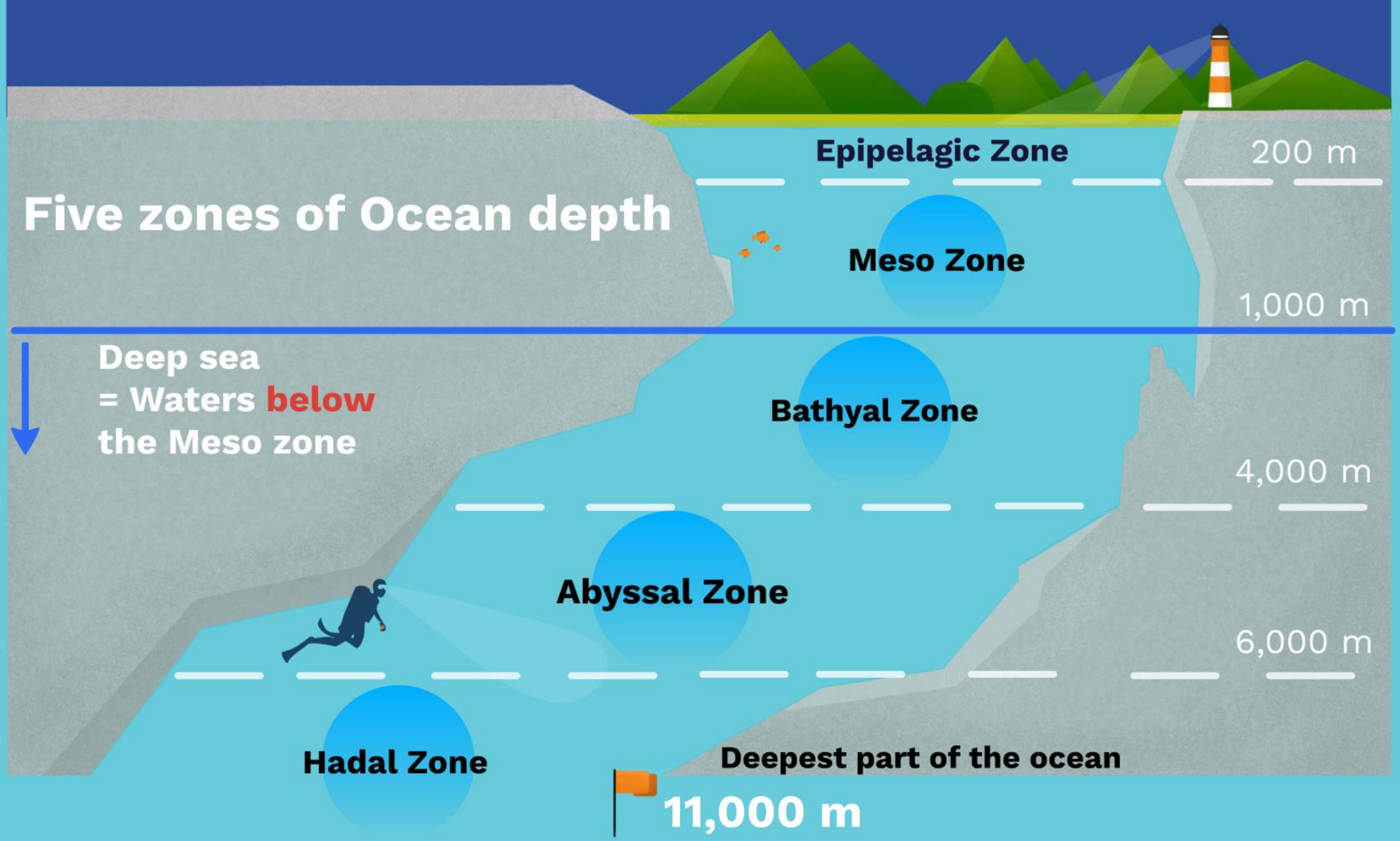
Marine Ecosystems – The Deep Sea

Learning Outcomes

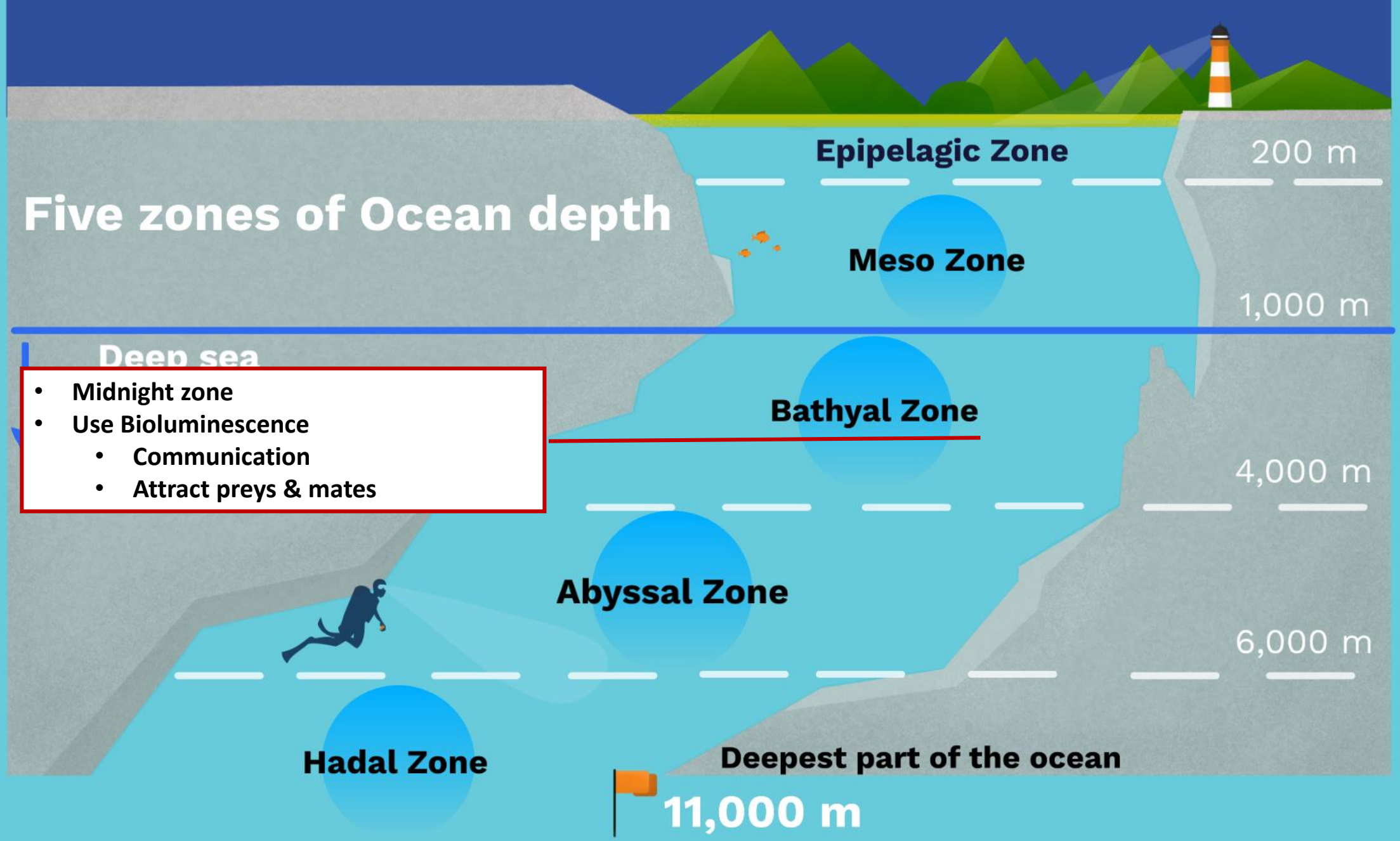
After this part of Module III, students are expected to be able to learn more about the following topics:

- **Deep Sea** – The largest ecosystem but least explored
- **Chemosynthesis in the ecosystem** – Understand how the deep-sea ecosystem functions *without* sunlight
- **Challenges in deep-sea research** – Realize the difficulties for us to investigate the deep-sea habitats
- **Challenges to the deep-sea life** – Understand how deep-sea organisms adapt to the environment
- **Understanding of deep-sea life** – Provide solutions to the future of humankind

Why should I study the Deep Sea?

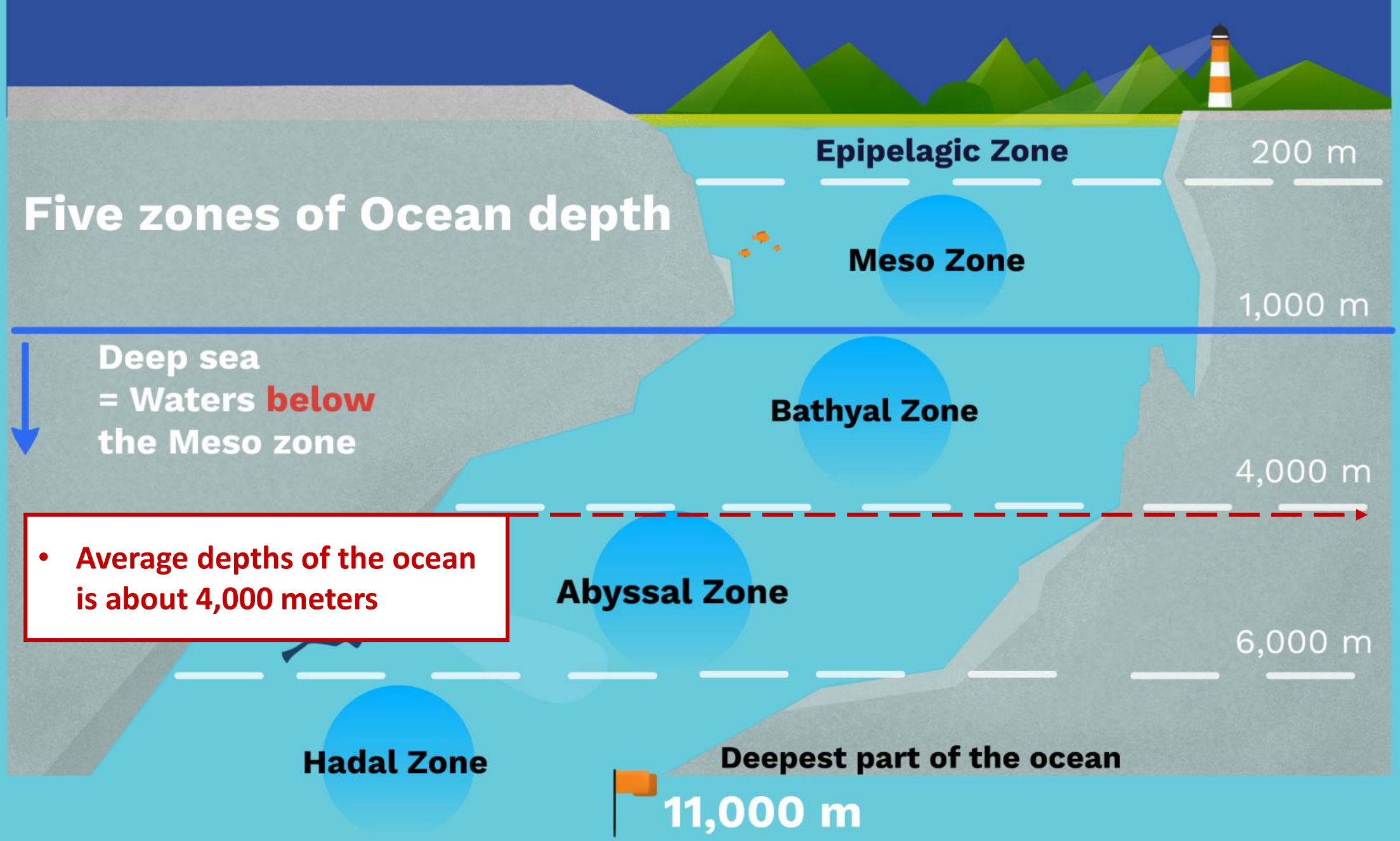


Click to watch: https://prezi.com/p/2h-07rxm5nnu/deep-sea-4-zone/



- Midnight zone
- Use Bioluminescence
  - Communication
  - Attract preys & mates

Click to watch: https://prezi.com/p/2h-07rxm5nnu/deep-sea-4-zone/



Click to watch: https://prezi.com/p/2h-07rxm5nnu/deep-sea-4-zone/

The World's Oceans

Deep-sea Area

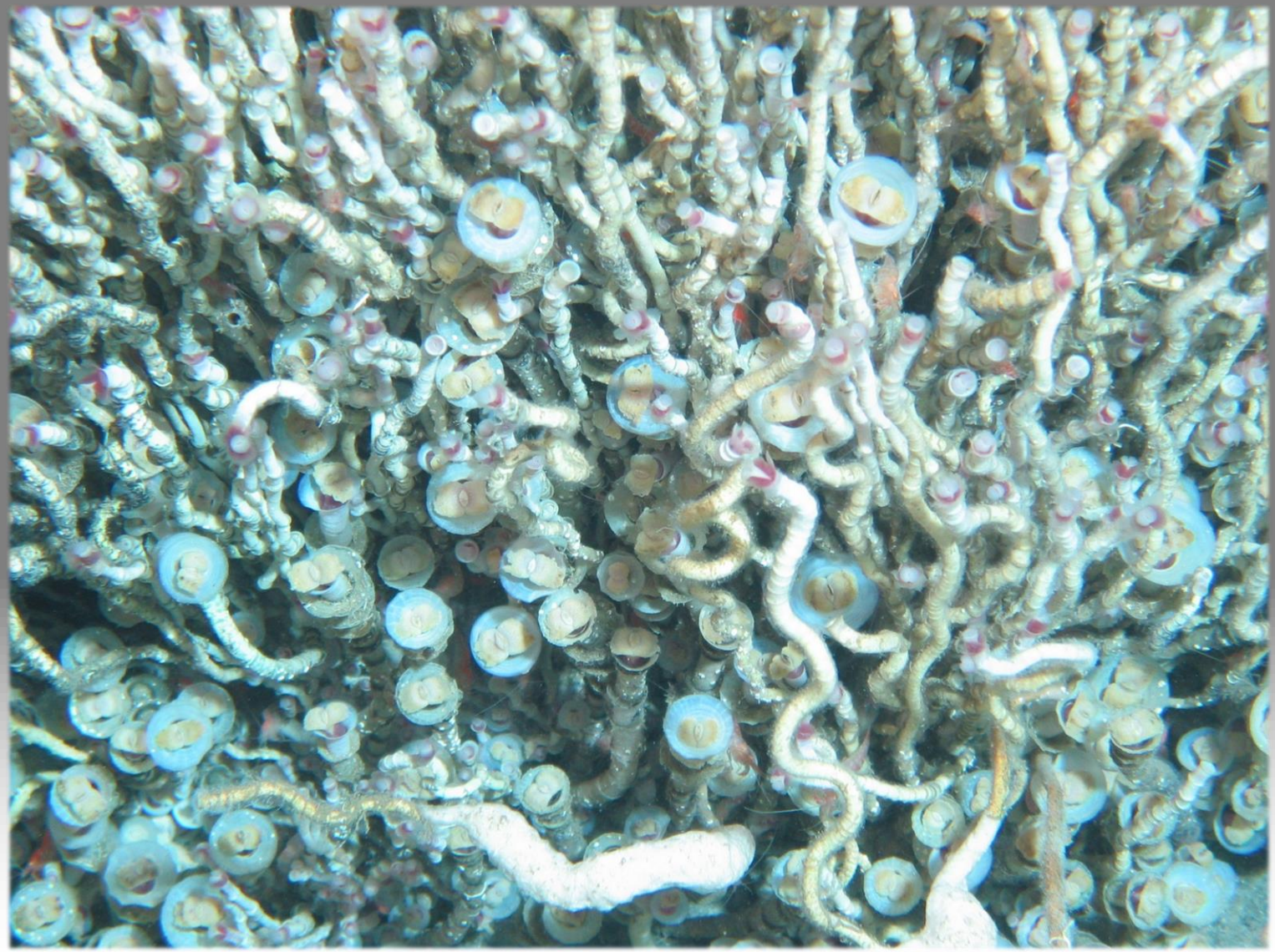
= 300 times larger than the habitable land!

Facts about the Deep Sea

- More people have travelled into outer space (~500 billion meters away) than the depths of our Earth (~11,000 meters away).
- The Deep Sea is in **total darkness and cold**.
- The Deep Sea is **largely unknown** – we have explored **<5%** of the Ocean. We have mostly explored the top 200 meters.
- The bottom of the ocean is the **greatest museum and preserver of history**. The majority of shipwrecks (and sea life) are still **undiscovered**.

Questions

- How do we **define** the Deep Sea?
- **Is there any life** in the Deep Sea?
- What are the **limitations for humans to dive down** to the Deep Sea?



Deep-sea Worms

DEPARTMENT OF OCEAN SCIENCE

The Physical Environment of the Deep Sea

Overview – Challenges at Ocean Depths

1. Low temperature
2. High pressure
3. No light

→ Physiological challenges

Dilute environment (limited food)

→ Nutritional challenges

Overview – Challenges at Ocean Depths

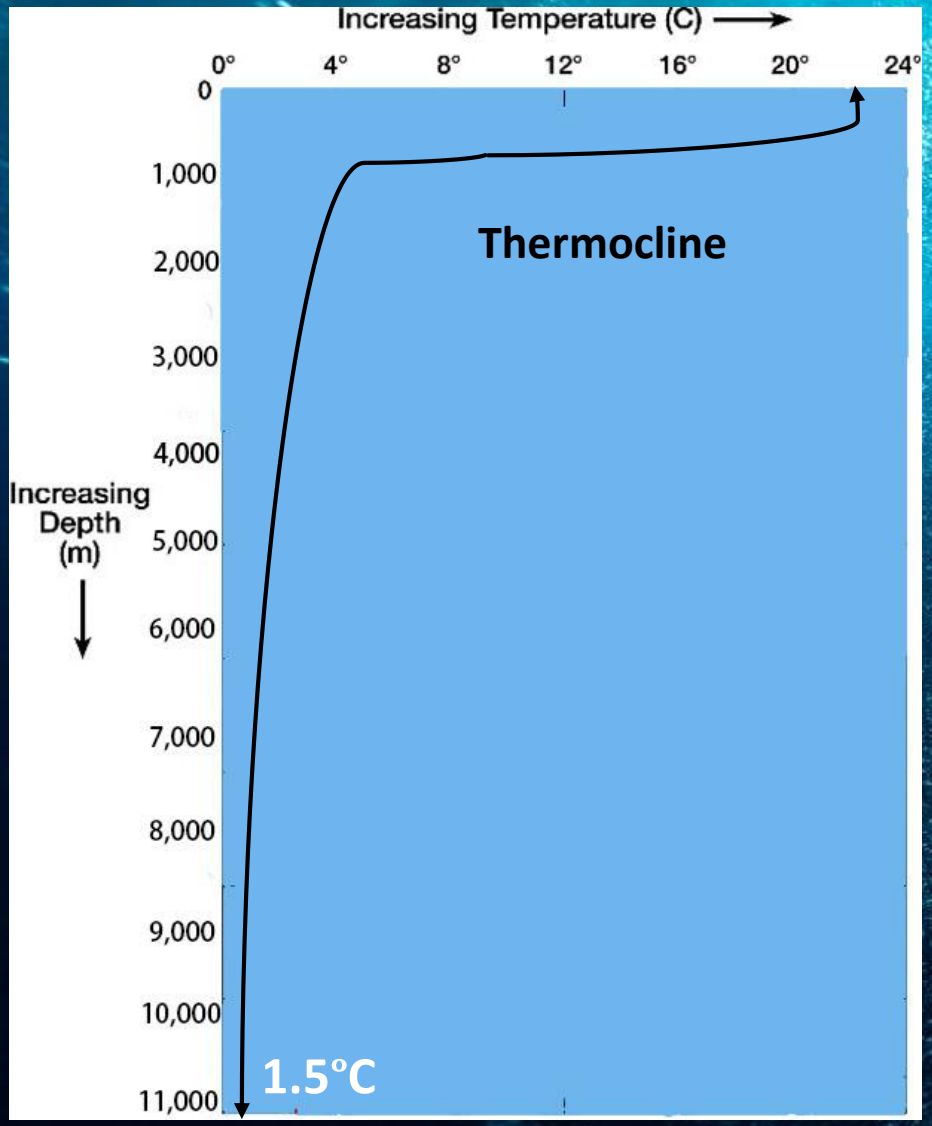
1. **Low temperature**
2. High pressure
3. No light

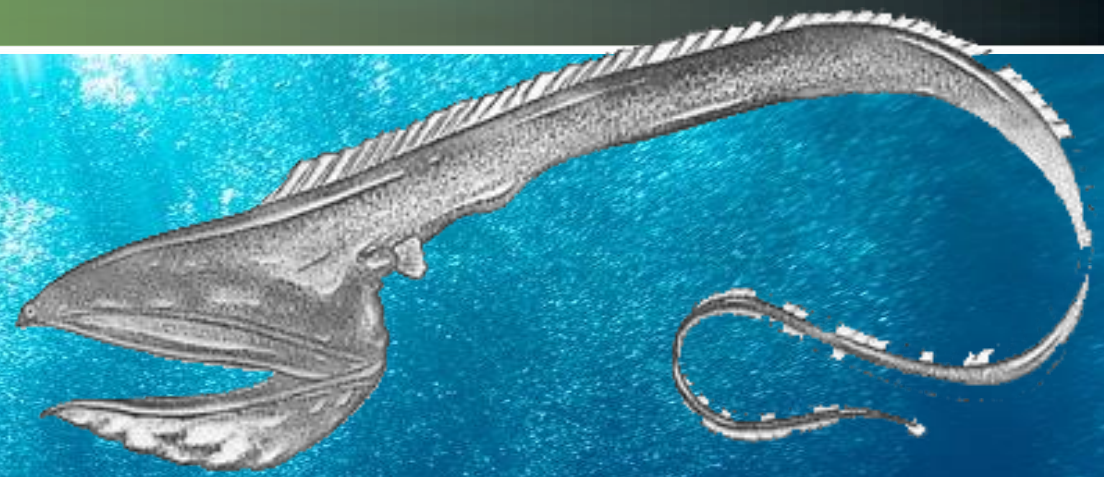
Physiological challenges

Dilute environment (limited food)

Nutritional challenges

Can Organisms Survive under Low Temperatures?



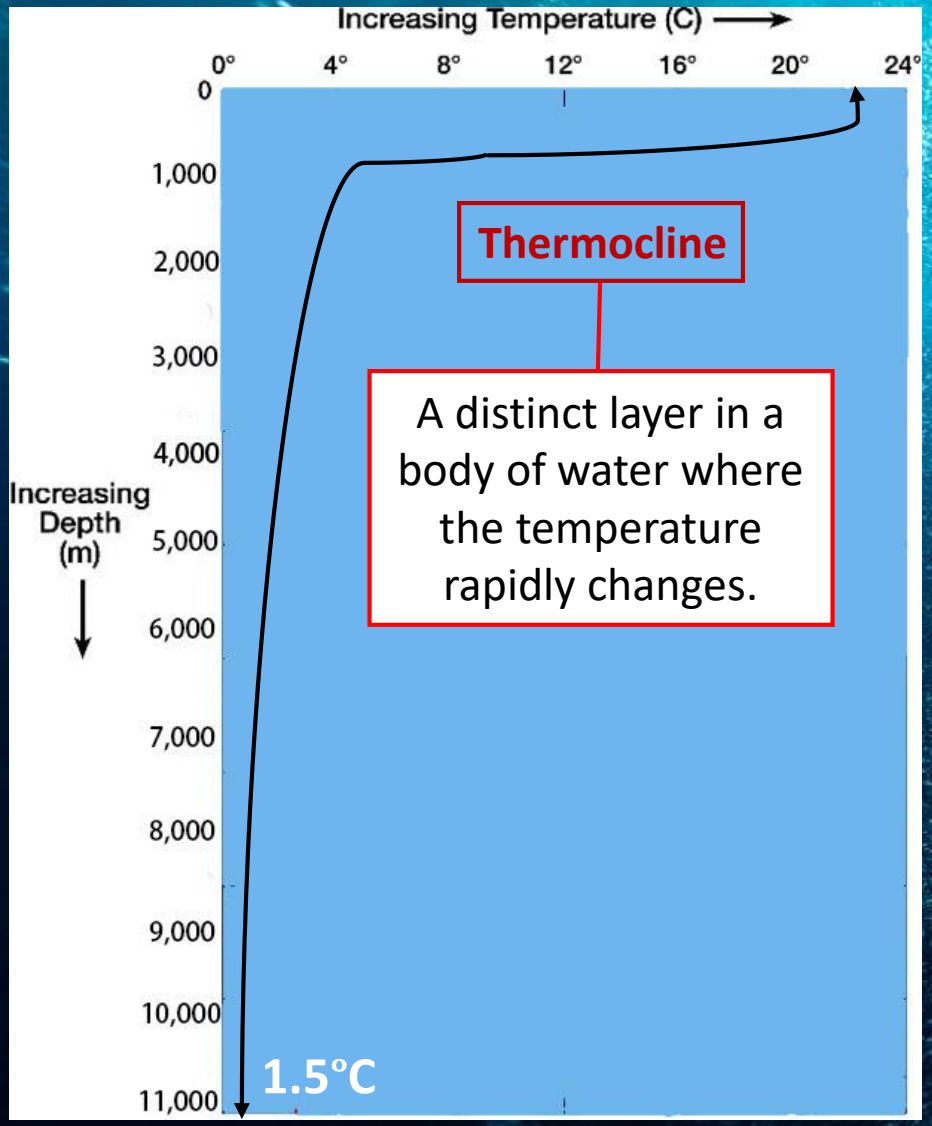


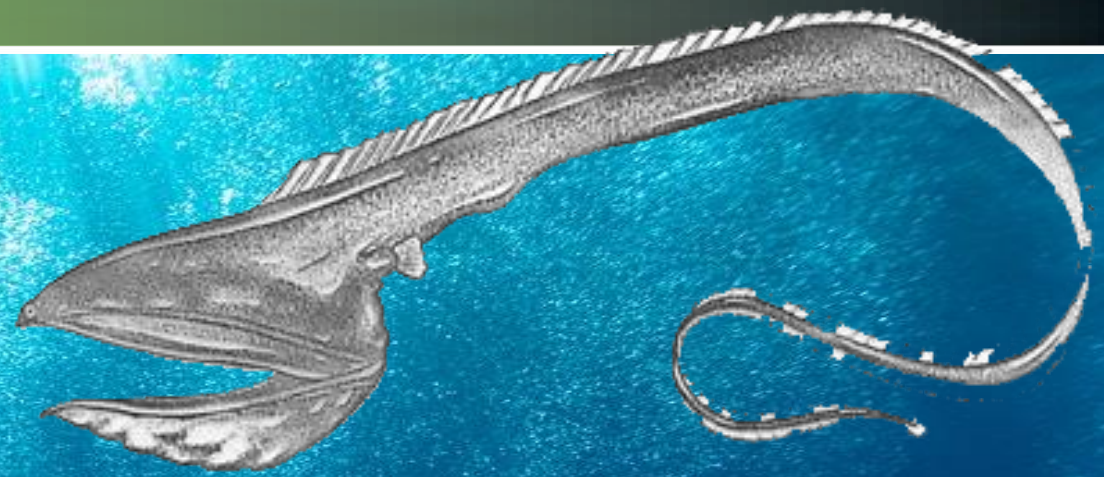
Why is the temperature in the Deep Sea so low? Yet, organisms can thrive in the Deep Sea! **Why?**

Anti-freeze proteins & slow metabolic rate

How can this knowledge help humans in the future?

Can Organisms Survive under Low Temperatures?



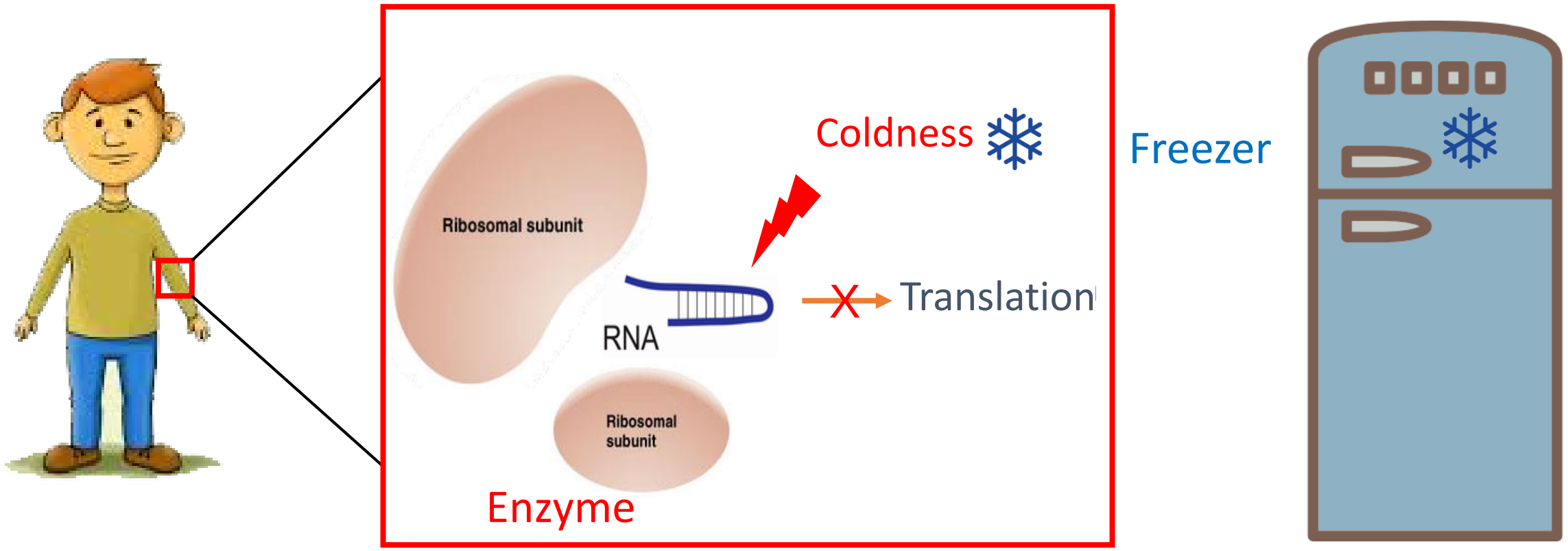


Why is the temperature in the Deep Sea so low? Yet, organisms can thrive in the Deep Sea! Why?

Anti-freeze proteins & slow metabolic rate

How can this knowledge help humans in the future?

Living under Low Temperatures



The deep-sea temperature remains constant, typically at 1-2°C down at ocean trenches.

Living at temperatures <5°C:

- **Metabolism suppressed** (enzyme activities ≈ 0)
- **Processing of genetic information suppressed**

Overview – Challenges at Ocean Depths

1. Low temperature
2. **High pressure**
3. No light

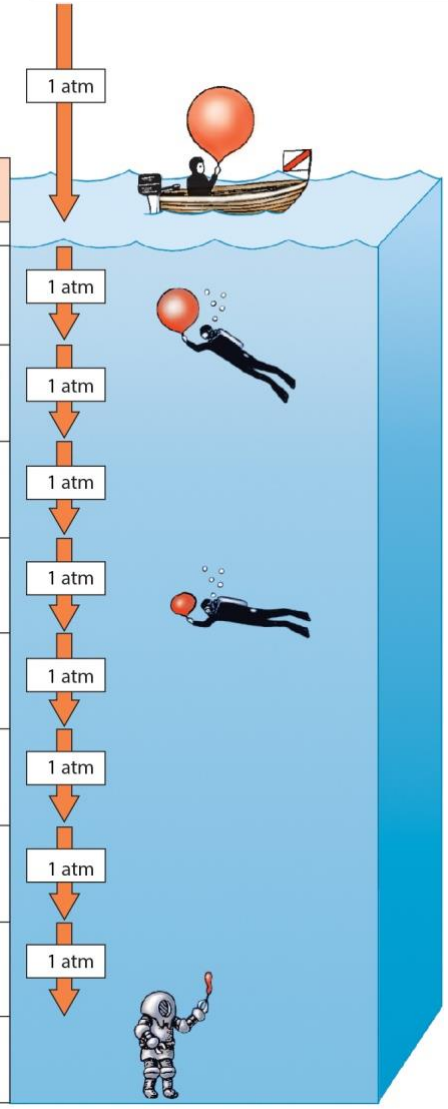
→ **Physiological challenges**

Dilute environment (limited food)

→ **Nutritional challenges**

How Much Pressure as You Go Deeper?

Water depth	Total pressure		
	atm	bar	psi
0	1	1.0	14.7
10 m (33 ft)	2	2.0	29.4
20 m (66 ft)	3	3.0	44.1
30 m (98 ft)	4	4.1	58.8
40 m (131 ft)	5	5.1	73.5
50 m (164 ft)	6	6.1	88.2
60 m (197 ft)	7	7.1	102.9
70 m (230 ft)	8	8.1	117.6
80 m (262 ft)	9	9.1	132.3

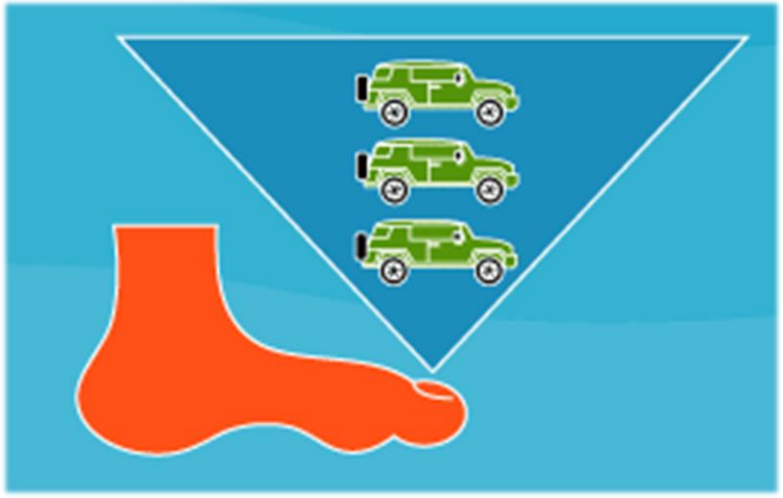


Source: Bill Ober

Hydrostatic pressure increases by 1 atmosphere per 10 m depth increase (or 1 kg cm^{-2}).

At 8,000 m

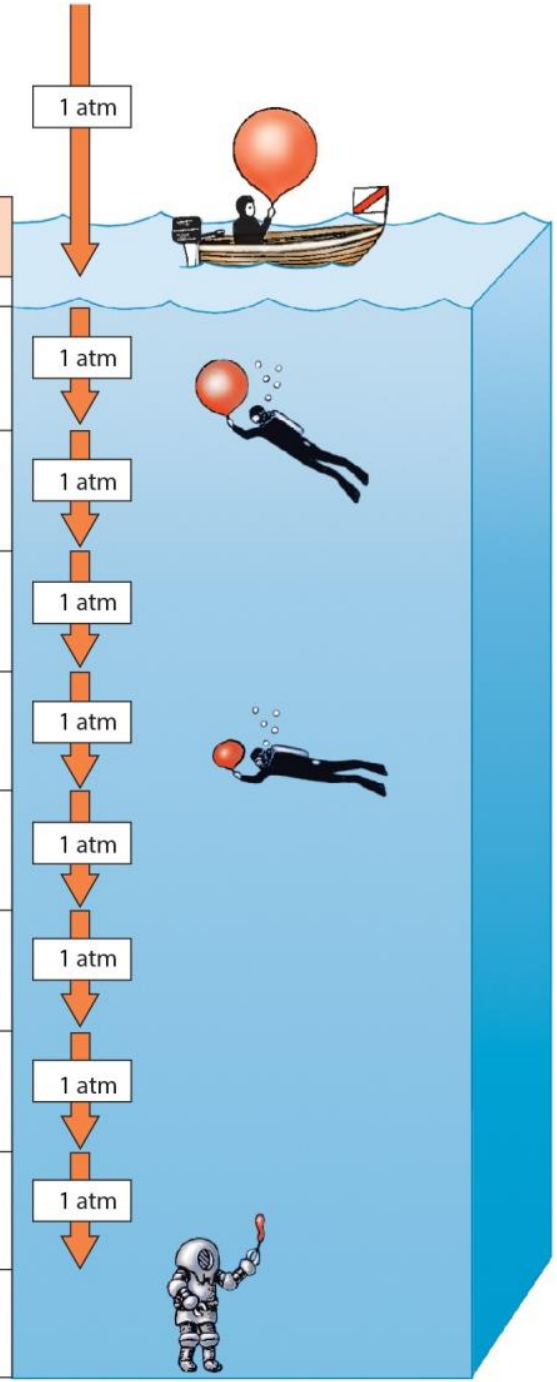
- Pressure = 3 SUVS sitting on your toes



At 11,000 m, what would the hydrostatic pressure be?

= 1,100 atmospheres (atm)

Water depth	Total pressure		
	atm	bar	psi
0	1	1.0	14.7
10 m (33 ft)	2	2.0	29.4
20 m (66 ft)	3	3.0	44.1
30 m (98 ft)	4	4.1	58.8
40 m (131 ft)	5	5.1	73.5
50 m (164 ft)	6	6.1	88.2
60 m (197 ft)	7	7.1	102.9
70 m (230 ft)	8	8.1	117.6
80 m (262 ft)	9	9.1	132.3



Source: Bill Ober

- **The deeper you go, the higher the pressure.**
- **Higher pressure can change the shape or crush solid structures.**

Living under High Pressure

Deep Sea

Living under high pressure:

- **Protein structures damaged**
- **DNA chains broken**

Living under High Pressure

Before

After (Deep Sea)

Adaptation to High Pressure in the Deep Sea

High pressure and low temperature affect **metabolism** of organisms, particularly **enzyme systems**, **protein synthesis**, and **physical properties.**

- ***How deep*** *can humans dive before being crushed?*
- *How do deep-sea animals* ***adapt*** *to high hydrostatic pressure?*
- *How can they live in a* ***large range*** *from 1,000 to 5,000 m?*

Adaptation to High Pressure in the Deep Sea

- Deep-sea fishes: Muscle enzymes less efficient and at low concentrations
  - **Lower metabolic rates, slower movements**
- In contrast to shallow-water organisms, deep-sea organisms have **much more pressure-resistant enzymes**
- Some Deep-sea organisms also have **high concentrations of a chemical that helps stabilize the enzymes**

A challenge to deep-sea research:
Deep-sea fishes usually die when brought to surface water area. ***Why?***

Adaptation to High Pressure in the Deep Sea – *Osmolytes (Biochemical Adaptation)*

Osmolytes

- **Protein stabilizers** in the cells
- An **oil-like fluid**
- Allow species to be **resistant under high pressure**

Balloon filled with air will burst!

Balloon filled with water is more flexible

Species filled with oil-like fluid

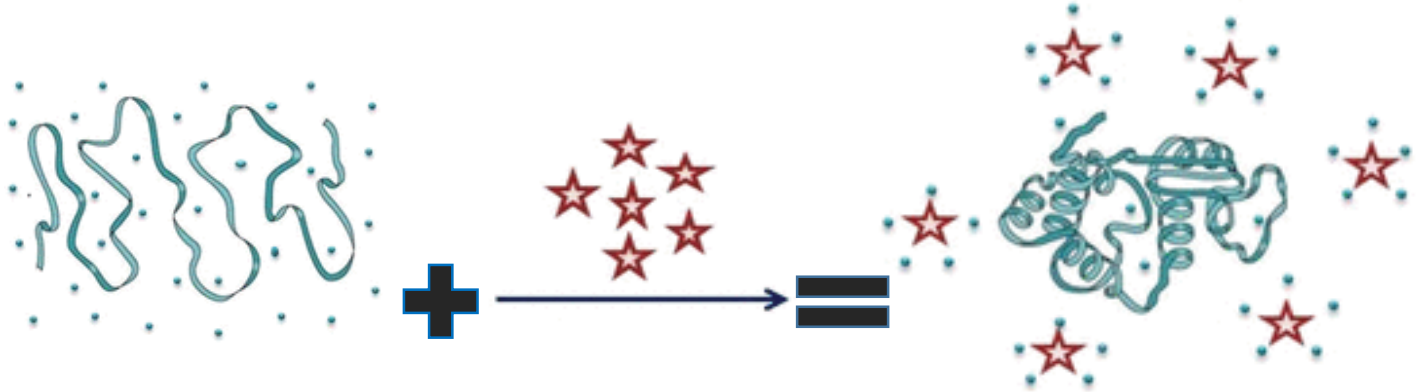
Biochemical Adaptation through Osmolytes – *HOW?*

High pressure

Even higher pressure

Image: Wikipedia

- At deep sea



Under high pressure, proteins become unnatural in shape

Osmolytes can help stabilize protein structure & function

Osmolytes work with protein to maintain natural structure & function

Protein & Osmolyte images: Chandel *et al.* (2017)

Overview – Challenges at Ocean Depths

1. Low temperature
2. High pressure
3. **No light**

Physiological challenges

Dilute environment (limited food)

Nutritional challenges

Is There Any Light in the Deep Sea?

Sunlight cannot penetrate beyond 1,000 m

→ **No photosynthesis in the Deep Sea**

- *If there is no light, do you **need eyes**?*
- *How can deep-sea animals **adapt** to zero light?*
- *How can deep-sea animals identify **friends or foes or food** in total darkness?*

Bioluminescence (video)

https://oceantoday.noaa.gov/bioluminescence/

The only light in the Deep Sea is *Bioluminescence* – *the light produced by an organism using a chemical reaction, sometimes from symbiotic bacteria.*

Overview – Challenges at Ocean Depths

1. Low temperature
2. High pressure
3. No light

Physiological challenges

Dilute environment (limited food)

Nutritional challenges

Deep Sea – Food Availability

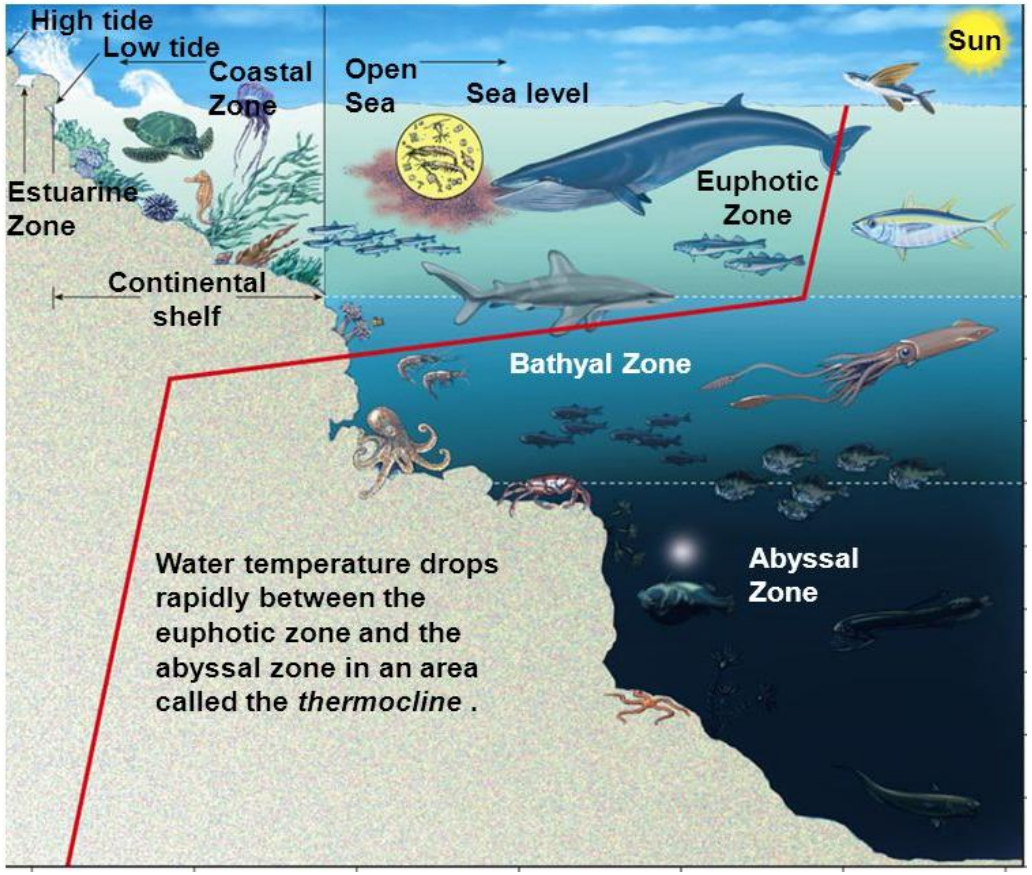
The deeper the depth, the less chance of food reaching the bottom as it gets intercepted.

Problems

- Only **~5%** of the food produced in the epipelagic zone can reach the Deep Sea
- **Low and unpredictable food availability**

Solutions

- Deep-sea animals are **opportunistic**
- **Energy saving adaptations**



More species

Fewer species

Overview – Challenges at Ocean Depths

1. Low temperature
2. High pressure
3. No light

→ Physiological challenges

Dilute environment (limited food)

→ Nutritional challenges

Summary – The Physical Environment of the Deep Sea

How do deep-sea animals adapt to the physical environment of Deep Sea?

- **Low Temperature:** Anti-freeze proteins and slow metabolic rate
- **No Light:** Bioluminescence
- **High Pressure:** With the help of osmolytes
- **Limited Food Source:** Deep-sea animals are opportunistic, they feed on dead species that sink from higher zones

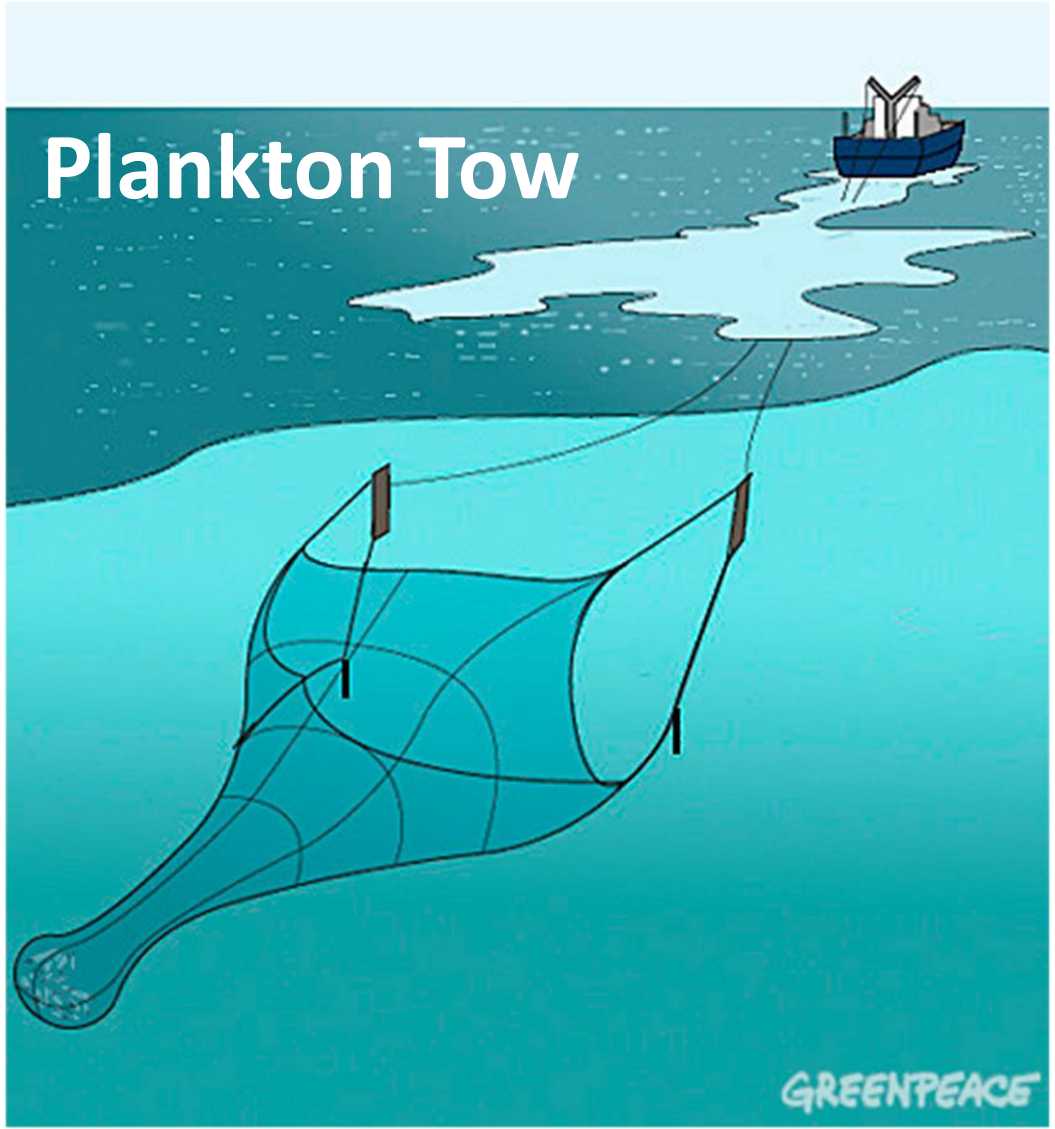
DEPARTMENT OF
OCEAN SCIENCE

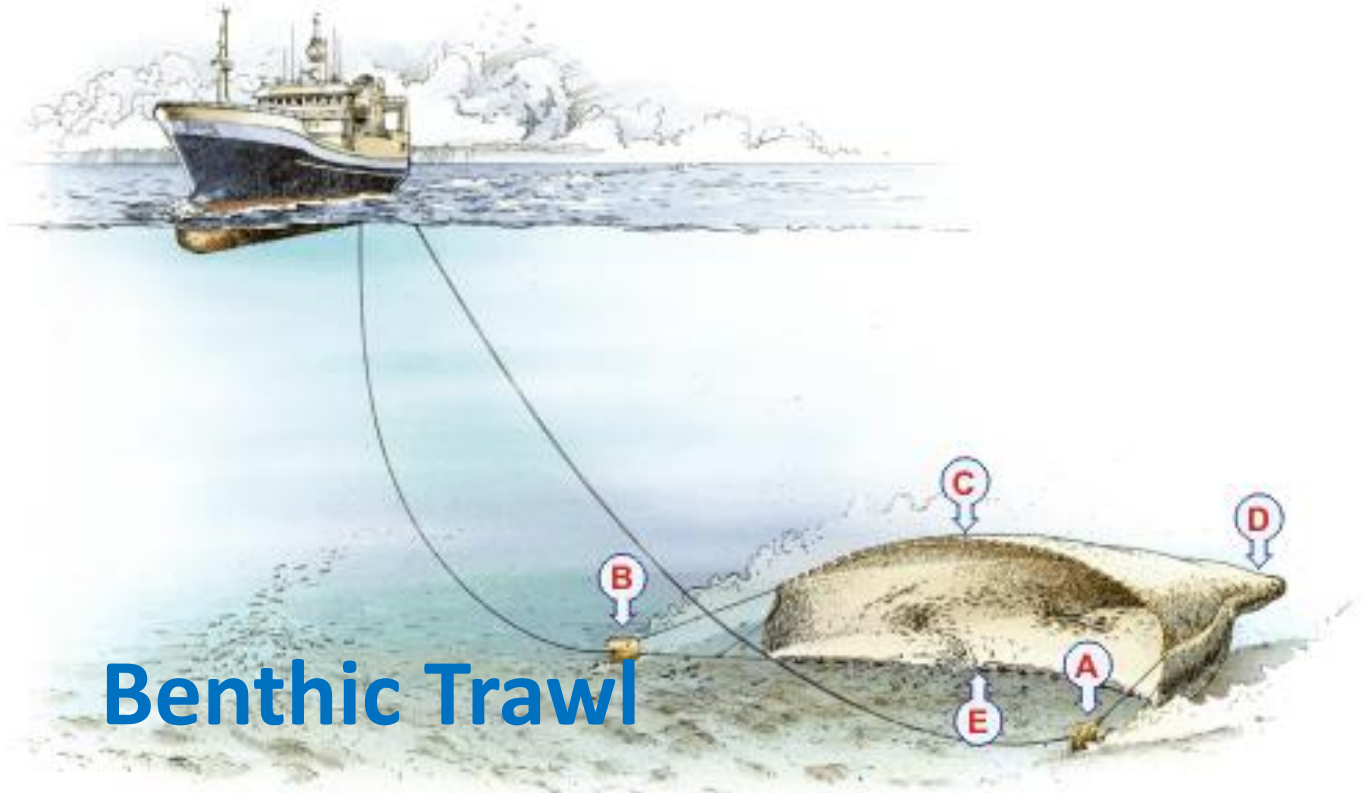
Gears for Deep-Sea Research

Overview – Deep-Sea Research

- **Gear** for deep-sea sampling
  - **Plankton Tow and Benthic Trawl**
  - **Epibenthic Sled**
  - **Box Core and Multiple Core**
- **Underwater Vehicles** to access the Deep Sea
  - **AUV – Autonomous Underwater Vehicle**
  - **ROV – Remotely Operated Vehicle**
  - **HOV – Human Operated Vehicle** (like deep-sea space craft)
- **Cameras** to take records of the deep-sea environments
  - **Lander** (like elevator that collects samples, no cables)

Sampling Nets





Benthic Trawl

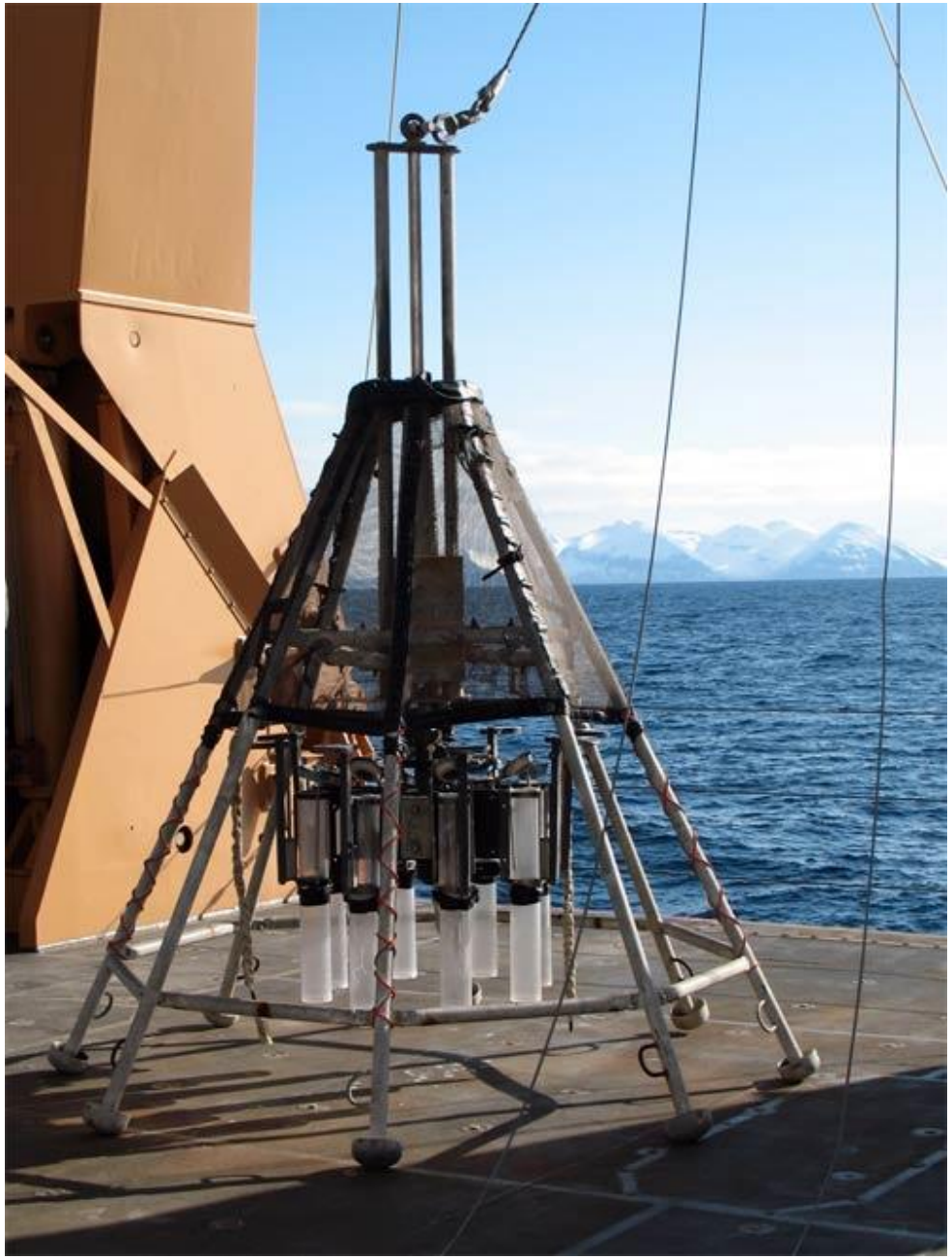
How long do the cables need to be to go down to 3,000 m?

Epibenthic Sled

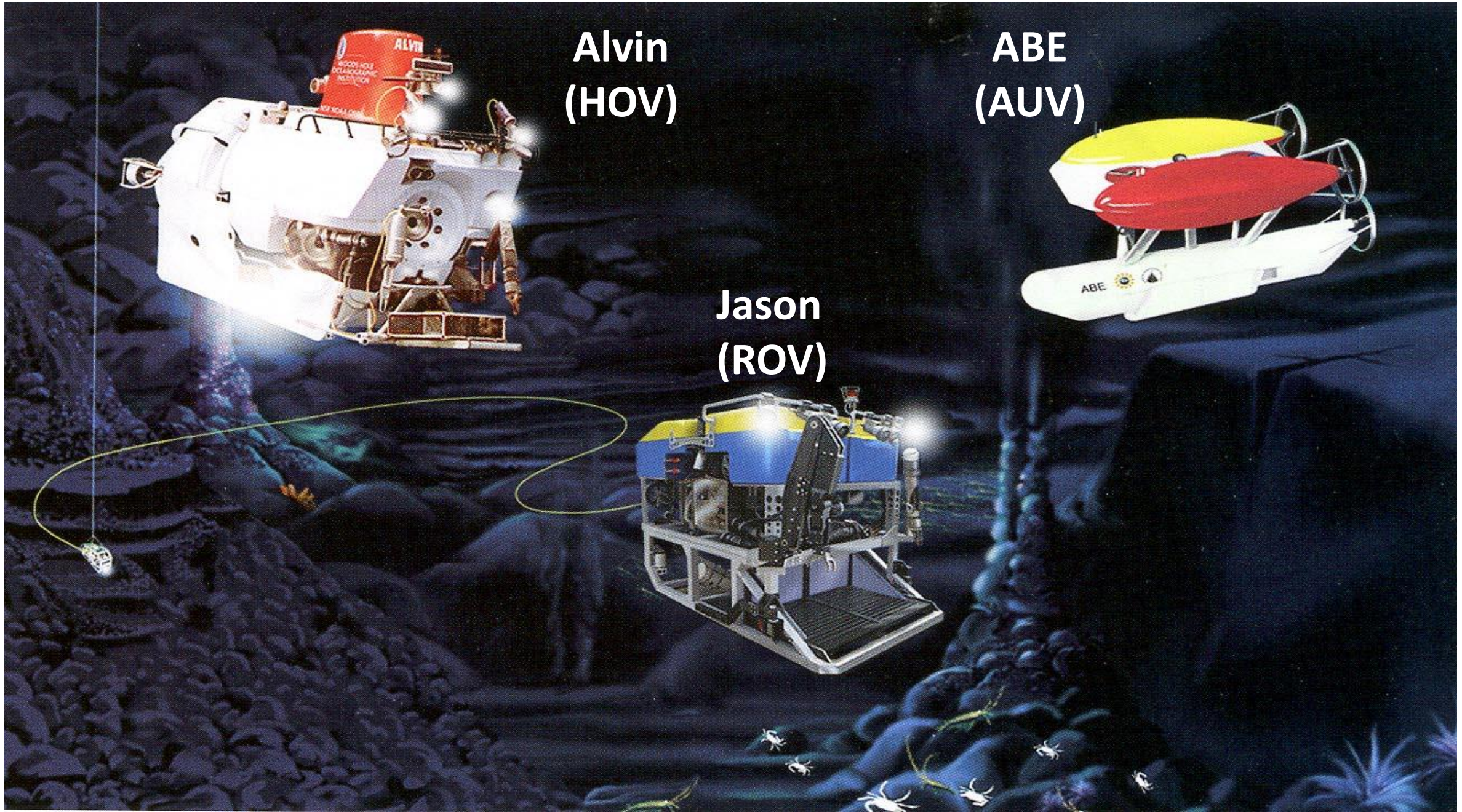
- Captures **smaller, rarer organisms**
- Designed to trawl just above the bottom at the **sediment-water interface** (the epibenthic zone)
- Need to be **strong and heavy** to cut through different features of the seabed (e.g. rocks)

Box Core

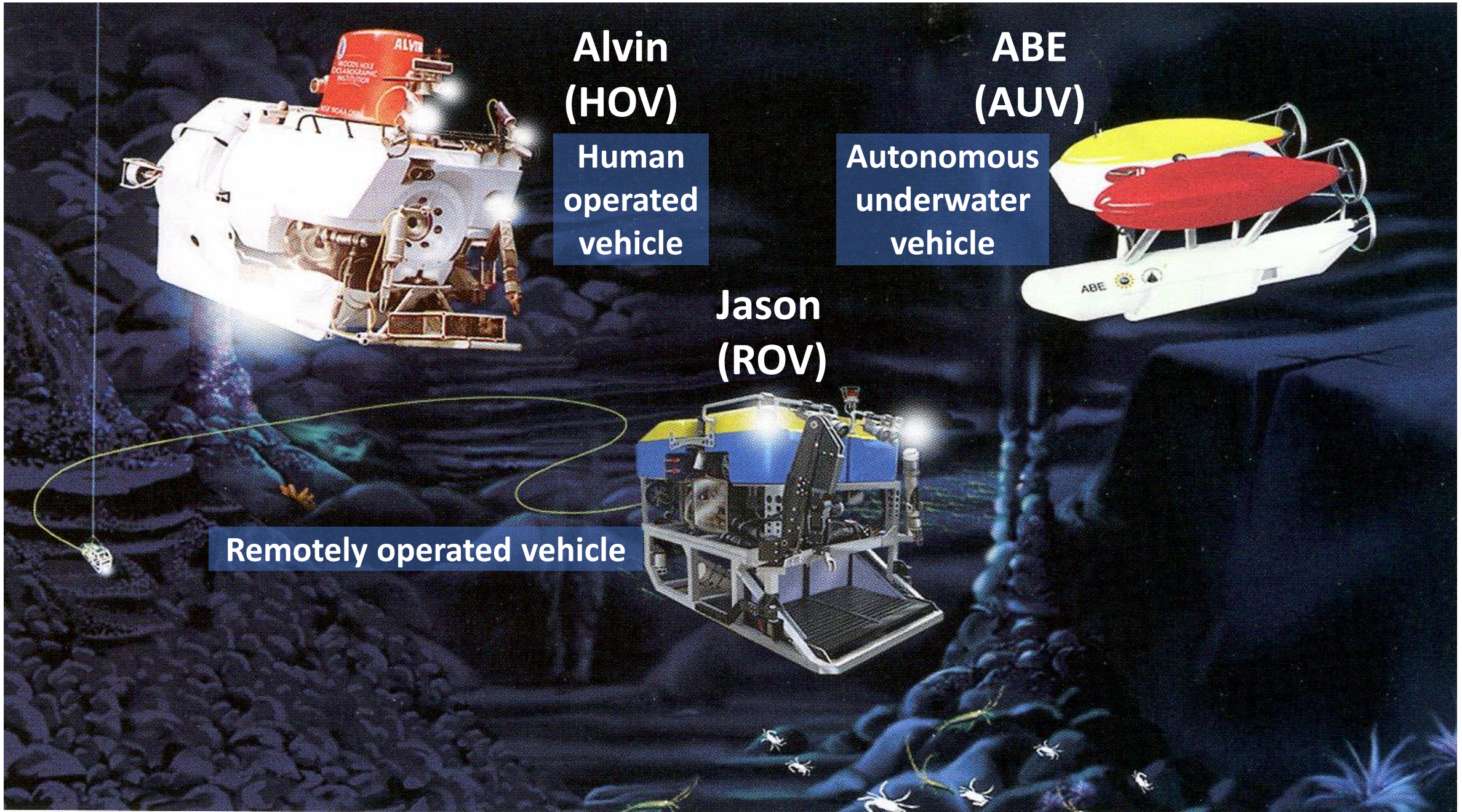
Multiple Core



Underwater Vehicles



Underwater Vehicles



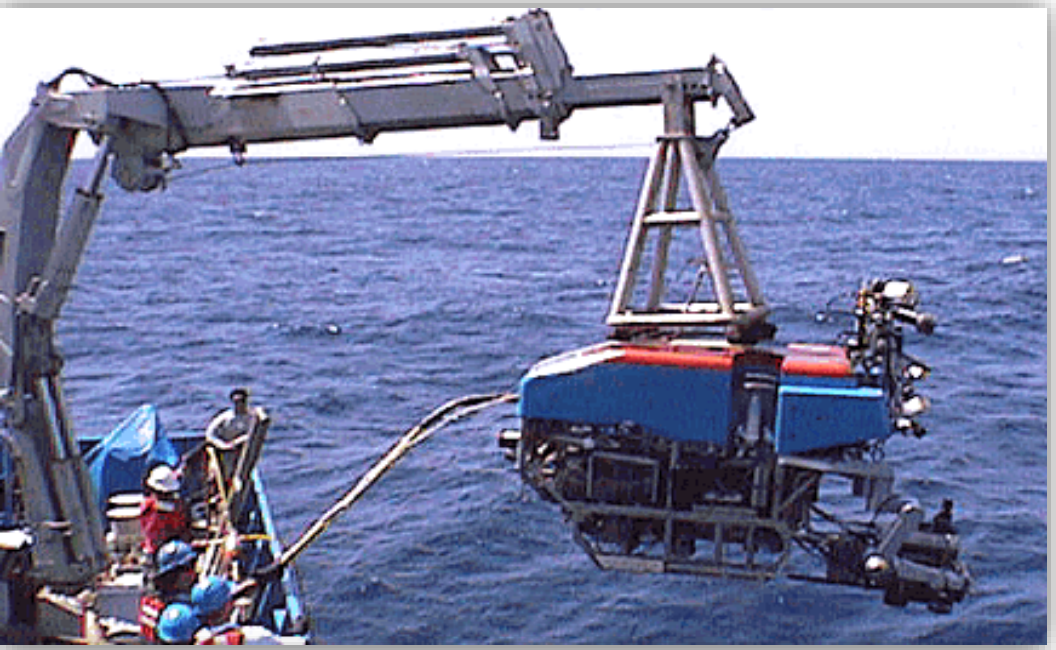
ROV
(1995 – 2003)

ROV
Controls

ROV


ROV Control Room

Remote Operated Vehicles (ROV)



Jason (WHOI),
Isis (NOC, U.K.)

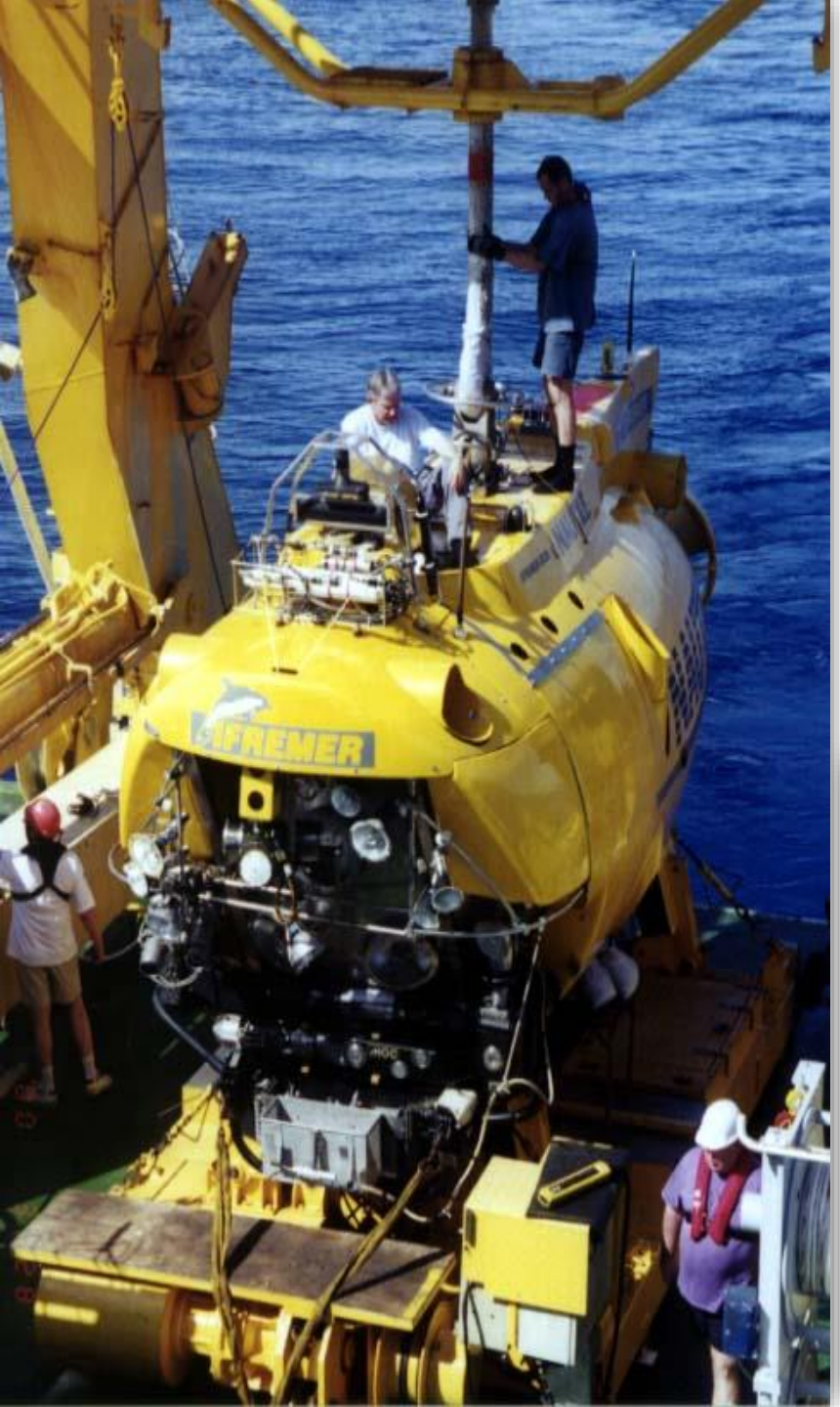
Ropos
(Canada)

Ventana
(MBARI)

Tiburon
(MBARI)

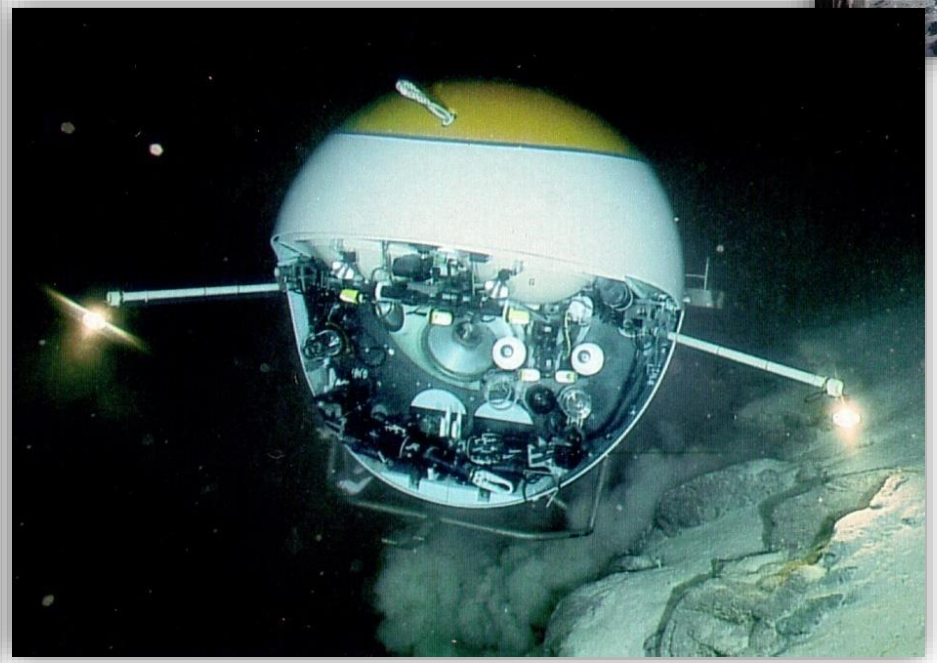
HOV – Jiaolong Submersible 2010 (蛟龍號)

HOV (Manned Submersibles)



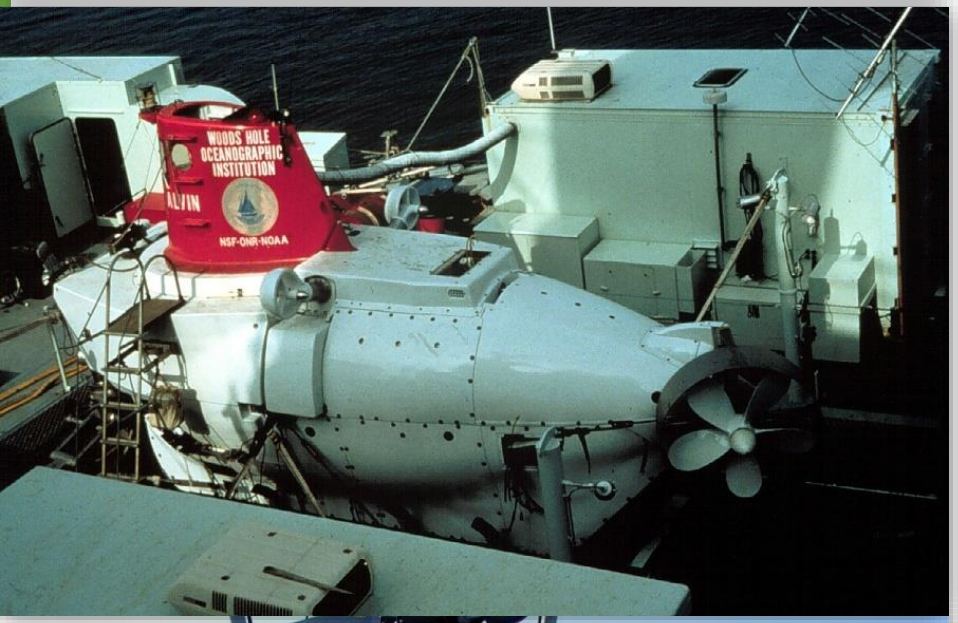
Nautile (France)
(6 km)

Shinkai (Japan)
(6.5 km)



Mir (Russia)
(6 km)

HOV in the U.S. Fleet



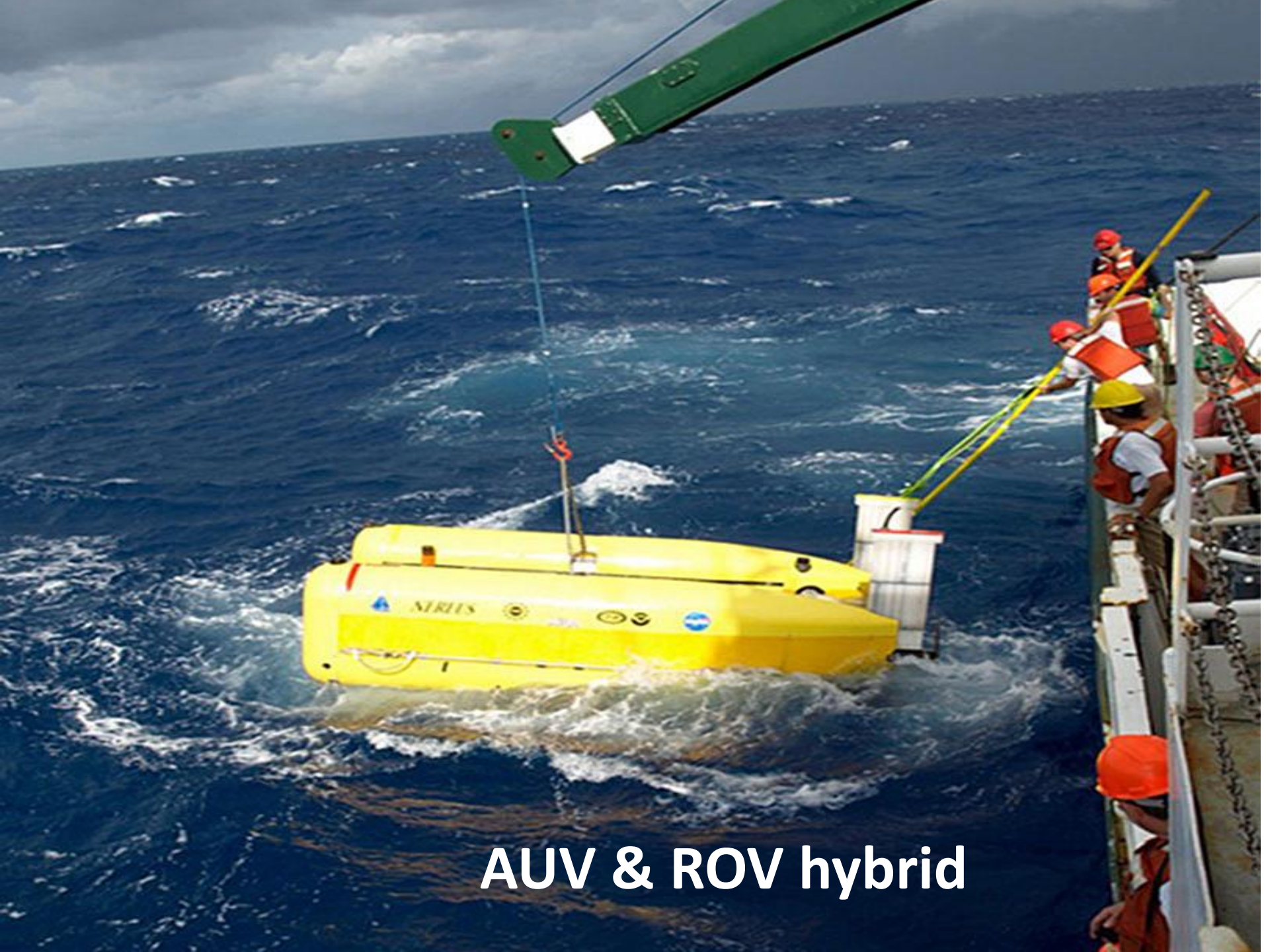
Alvin (WHOI)
(4.5 km)

Delta, Gamma,
Clelia (HBOI)
(300-700 m)

Johnson-Sea-Link
I, II (HBOI)
(915 m)

Pisces IV, V
(NOAA)
(2 km)

HOV
(2013)



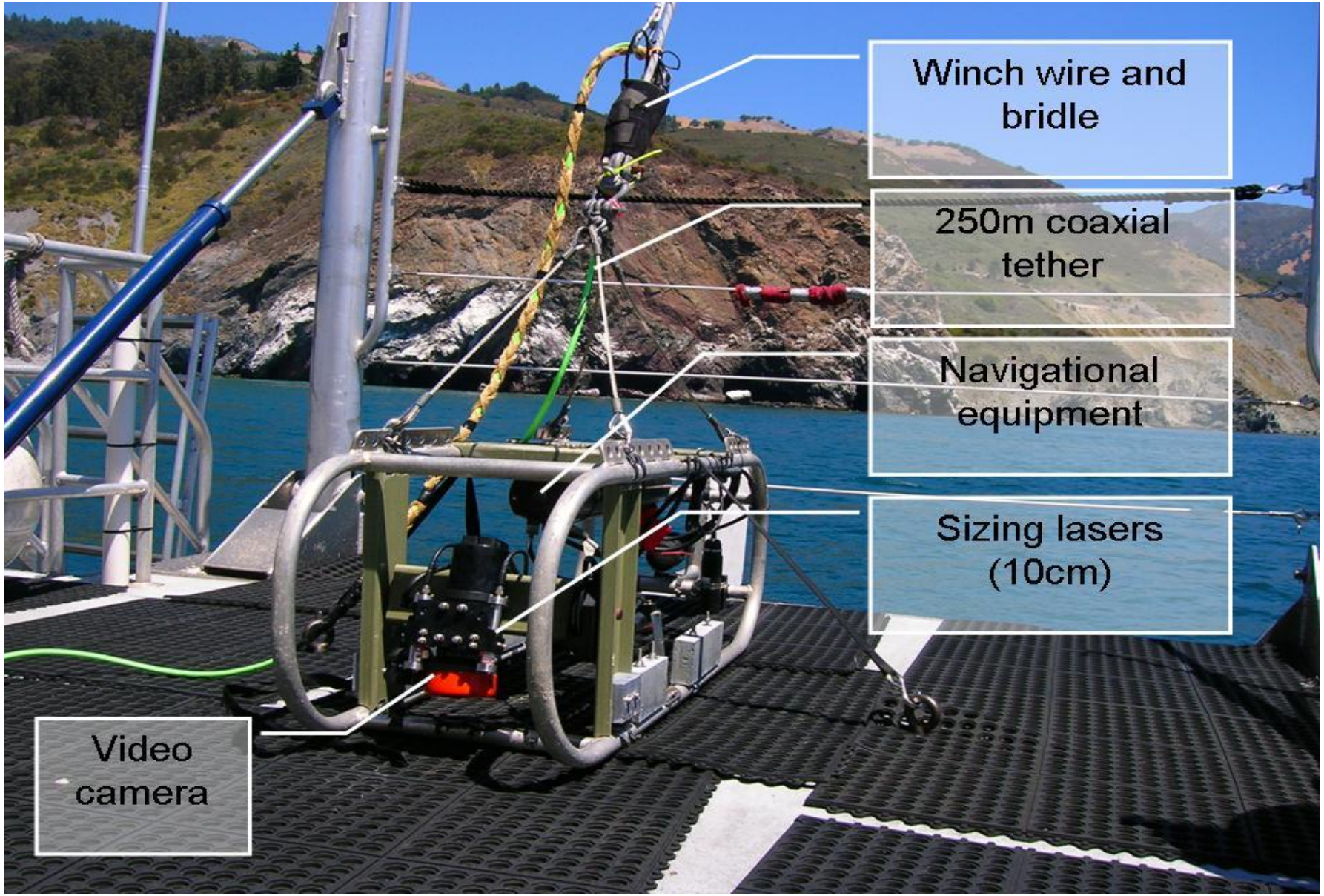
AUV & ROV hybrid

Nereus

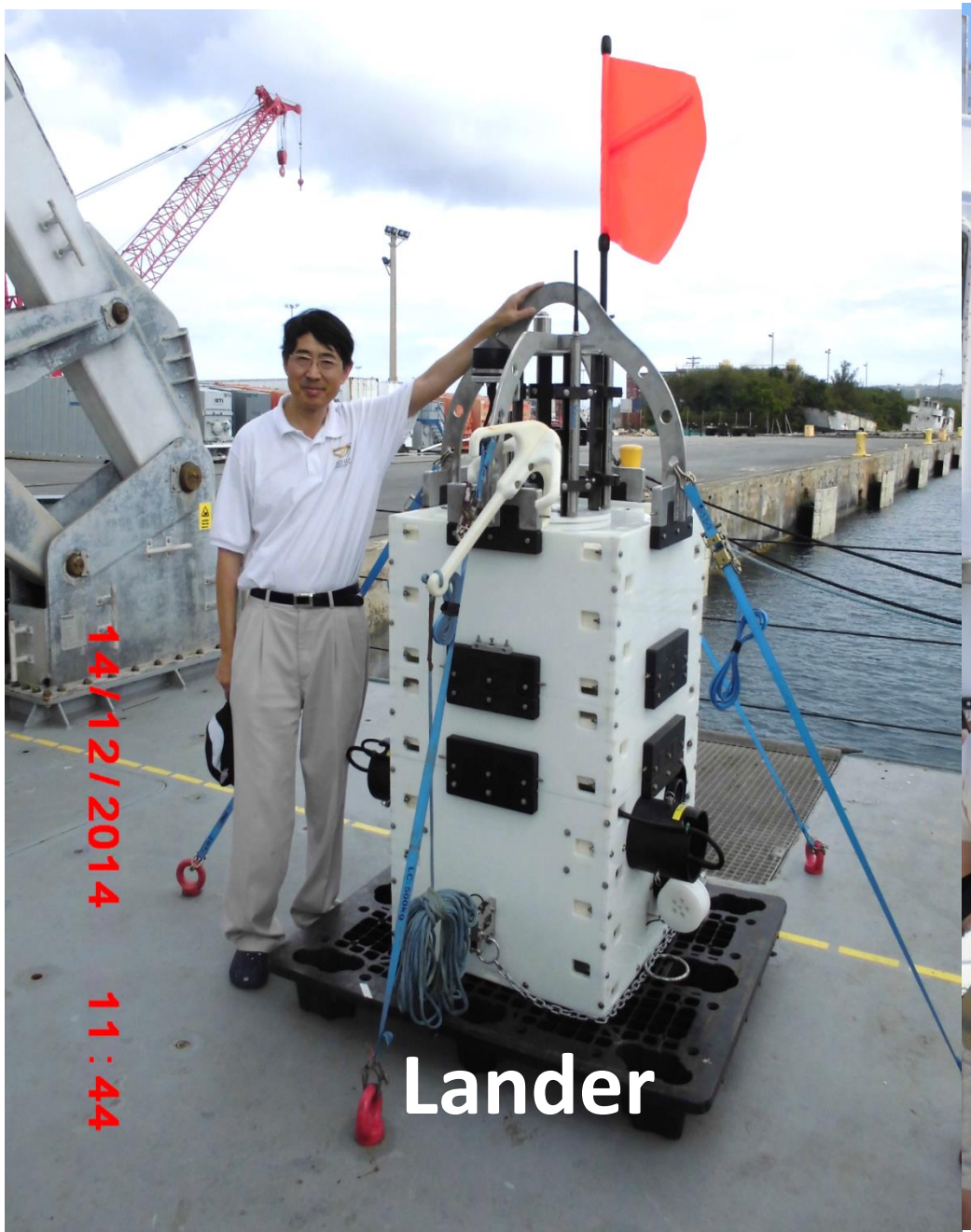
(2009 – 2014)

Exploded

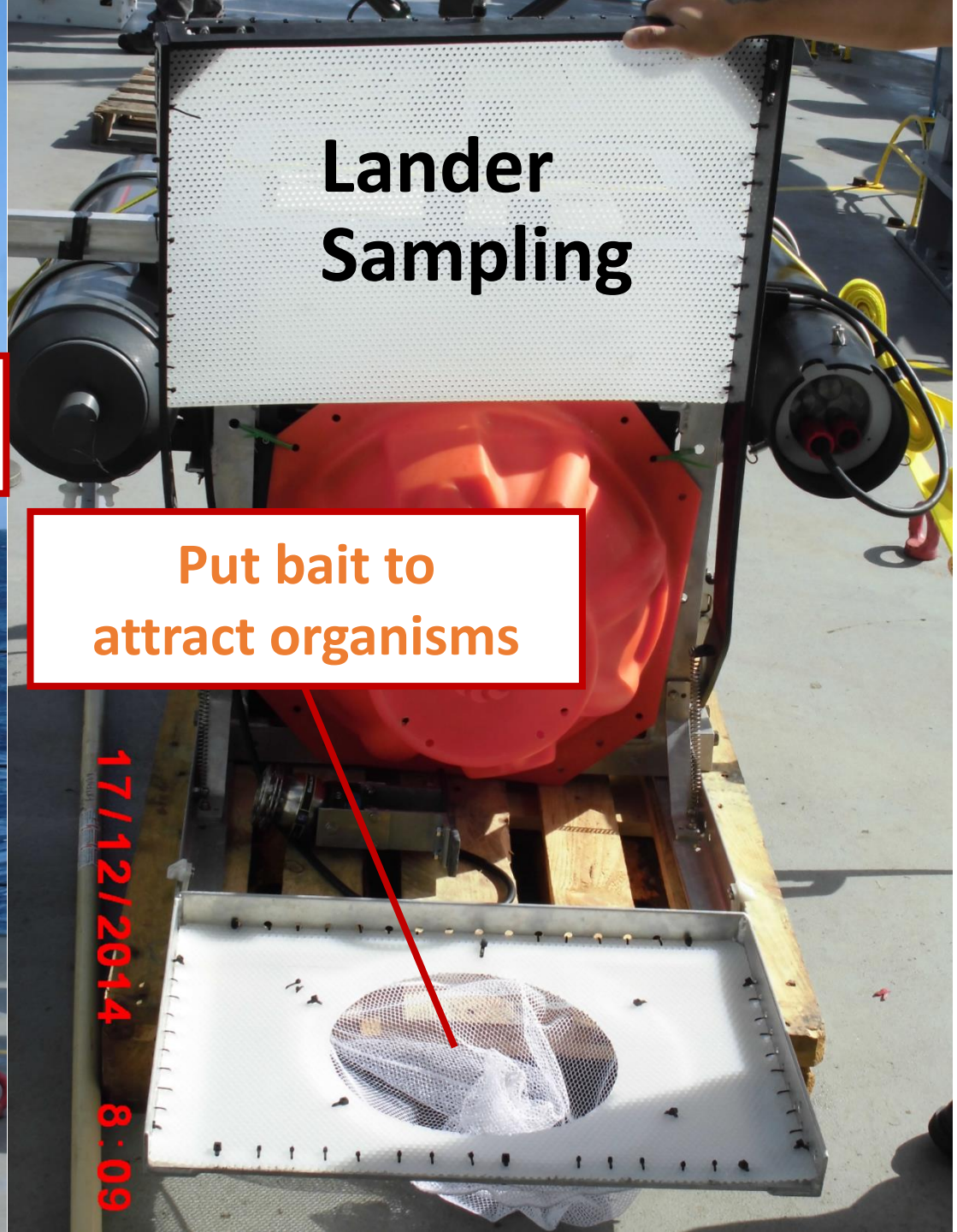
Towed Camera Sled



The *'Challenger Deep'* Expedition

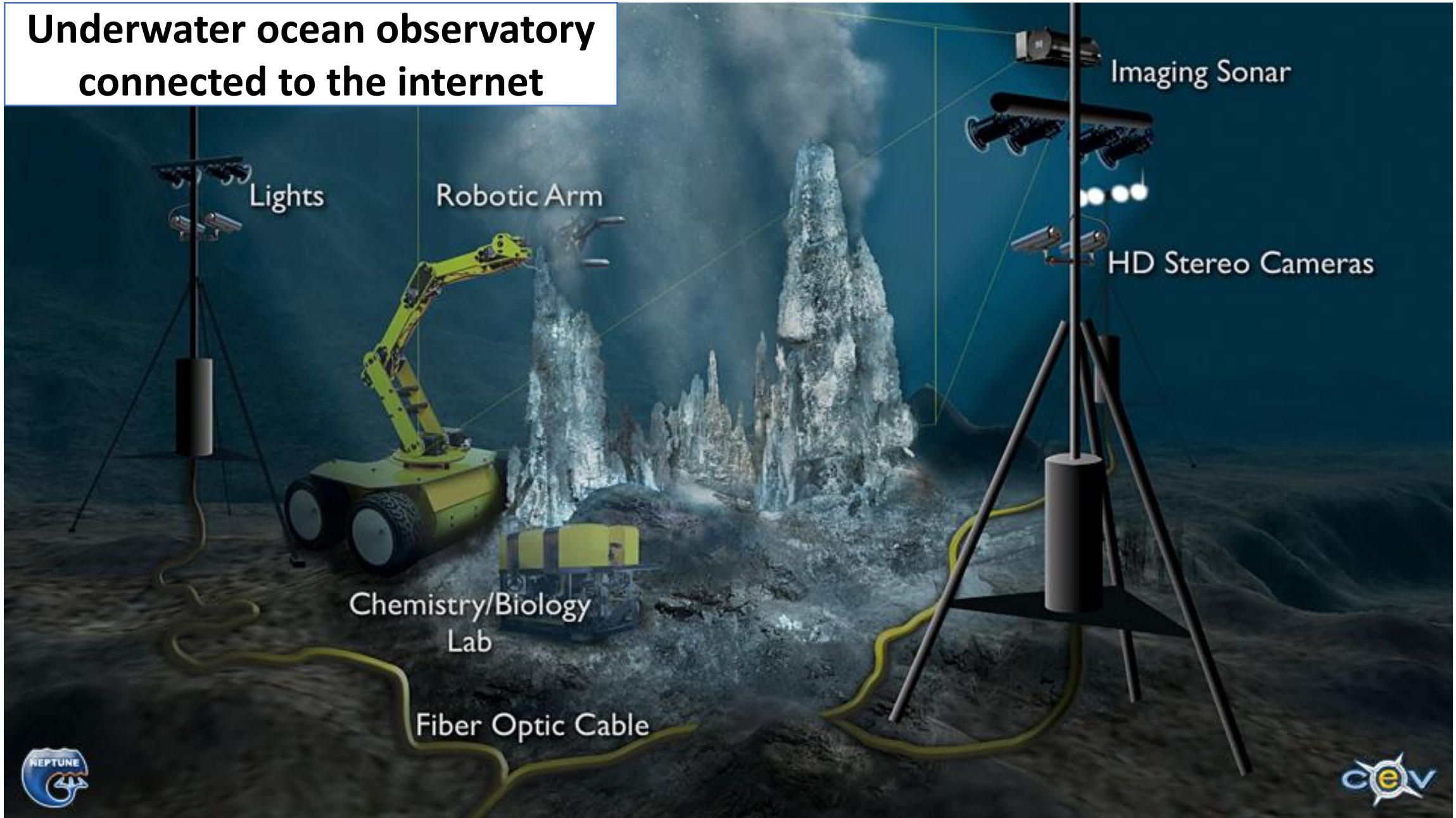



Lander
Camera
Camera
18/12/2014 9:15


Lander
Sampling
Put bait to
attract organisms
17/12/2014 8:09

U.S./Canada Neptune Observatory System

Underwater ocean observatory connected to the internet



Summary – Gears for Deep-Sea Research

Constraints

- **Difficult and expensive** to obtain information about the deep sea.
- Because of **low animal densities**, **large sampling gear** needed.
- The **deeper the sampling depths, the greater the amount of cables** required.
- **The heavier the equipment, the bigger the ship** needed.

Problems in Sampling

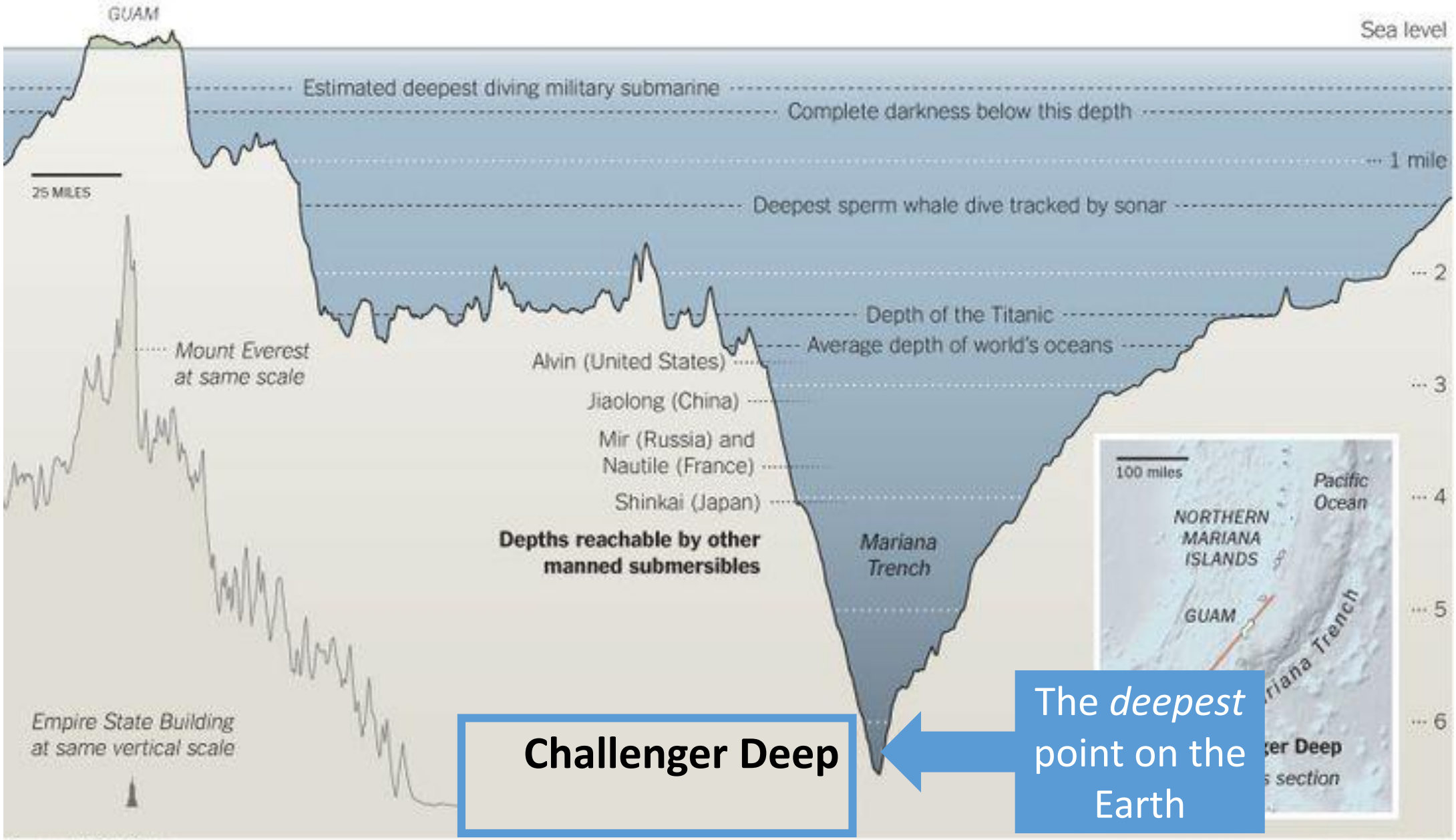
- **Time consuming:** It **takes a long time for the gear to reach the deep-sea bottom**, so sampling is time-consuming (10 - 24 hrs. per haul).
- **Slow and limited catch:** Because of the heavy weight of gear, towing speeds are slow. A lot of **net avoidance by animals**, especially in the mesopelagic zone.

DEPARTMENT OF OCEAN SCIENCE

Challenging the Deepest Point – The Mariana Trench

Deep Dive

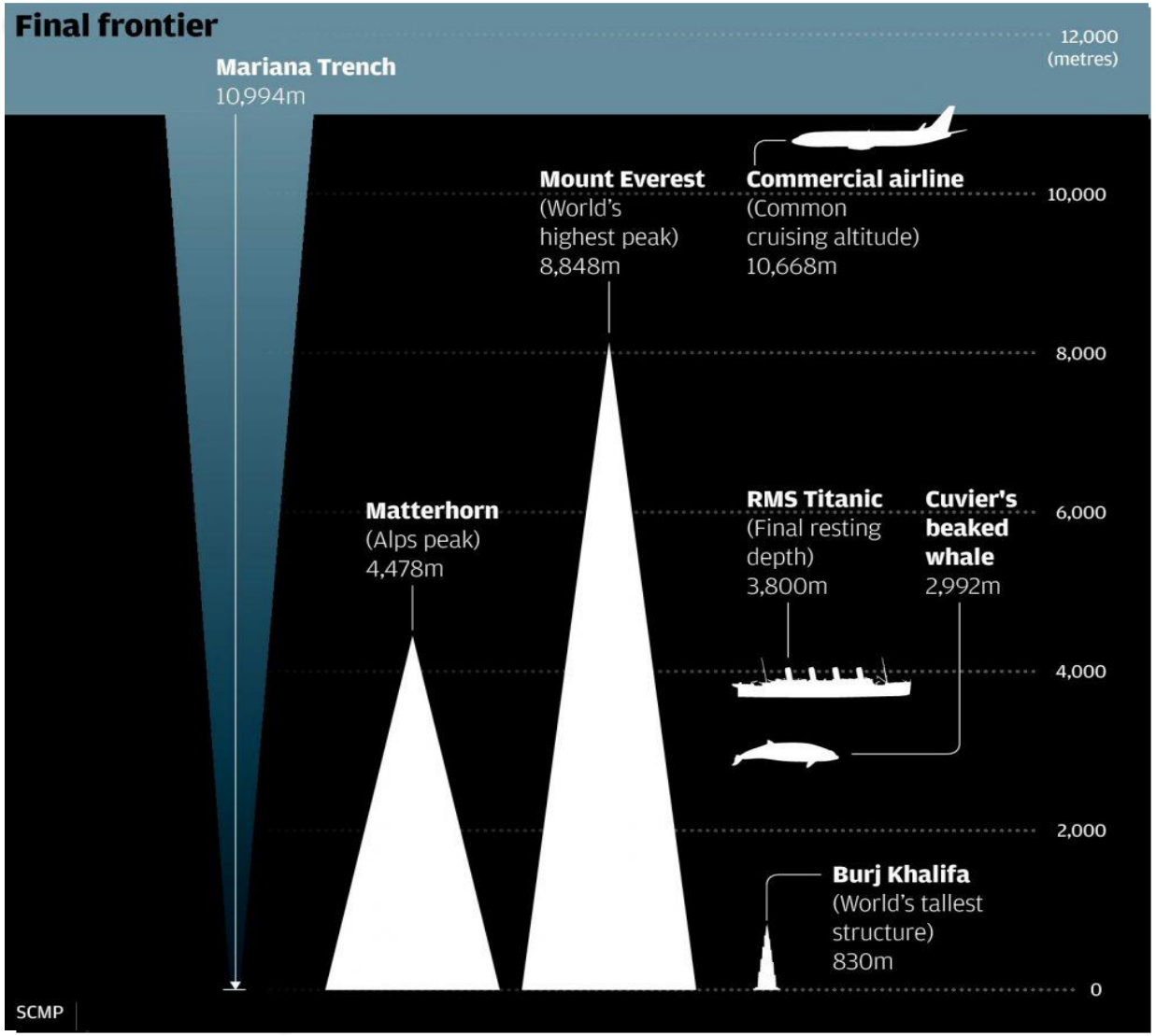
James Cameron succeeded in reaching the Challenger Deep, the deepest part of the ocean, in a mini submarine of his own design.



Sources: NASA; NOAA

THE NEW YORK TIMES

The Deepest Point in the World



The Mariana Trench

Submersible	Bathyscaphe *Trieste*	*Deepsea Challenger*	*DSV Limiting Factor*
Dive	**January 1960** Jaques Pickard Don Walsh	**March 2012** James Cameron	**May 2019** Victor Vescova
Descent	5 hours	2 hours 36 minutes	3.5 hours
Ascent	3.5 hours	1 hour and 7 minutes	3.5 hours
Depth reached	10,916 m	10,898.4 m	10,927 m
Length of time on ocean floor	20 minutes	2 hours 34 minutes	~ 4 hours
Issues	Temperature difference cracked the outer window	Windows cracked	---
Retrieved	None	Amphipods (shrimp-like organisms)	Snails, sea cucumbers, amphipods, rocks, candy wrappings, plastic bags

CHALLENGER DEEP

The Mariana Trench lies in the middle of the ocean, near Guam. This is the deepest point in the ocean and there have only been two manned missions to reach this point. It's no simple task to reach the bottom, but with advances in technology, missions may be more frequent and allow scientists and explorers to spend more time down there.

BATHYSCAPE TRIESTE

January 23, 1960

CREW: Jacques Piccard and U.S. Navy Lieutenant Don Walsh

DEEPSEA CHALLENGER

March 26, 2012

CREW: James Cameron

This vertical shape allowed the vessel to descend quicker, allowing, Cameron to explore the bottom for nearly **9X LONGER** than the Trieste.

SOURCES:
nationalgeographic.com,
deepseachallenge.com

CHALLENGER DEEP

The Mariana Trench lies in the middle of the ocean, near Guam. This is the deepest point in the ocean and there have only been two manned missions to reach this point. It's no simple task to reach the bottom, but with advances in technology, missions may be more frequent and allow scientists and explorers to spend more time down there.

BATHYSCAPE TRIESTE

January 23, 1960

CREW: Jacques Piccard and U.S. Navy Lieutenant Don Walsh

DEEPSEA CHALLENGER

March 26, 2012

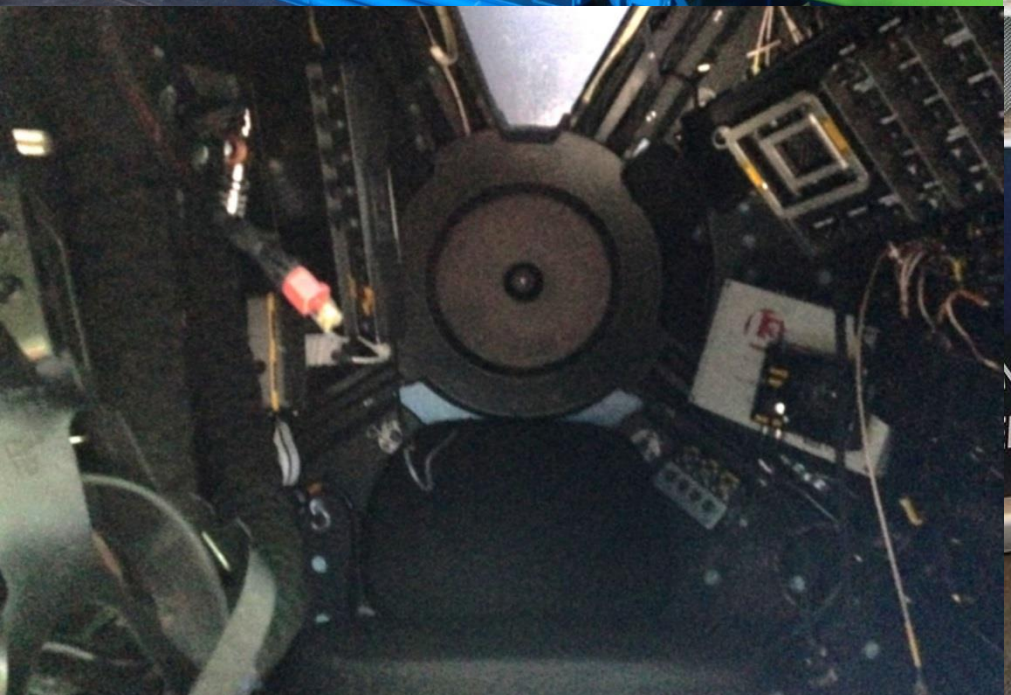
CREW: James Cameron

This vertical shape allowed the vessel to descend quicker, allowing, Cameron to explore the bottom for nearly **9X LONGER** than the Trieste.

SOURCES:
nationalgeographic.com,
deepseachallenge.com

Watch – *The Long Way Down: The Challenger Deep*

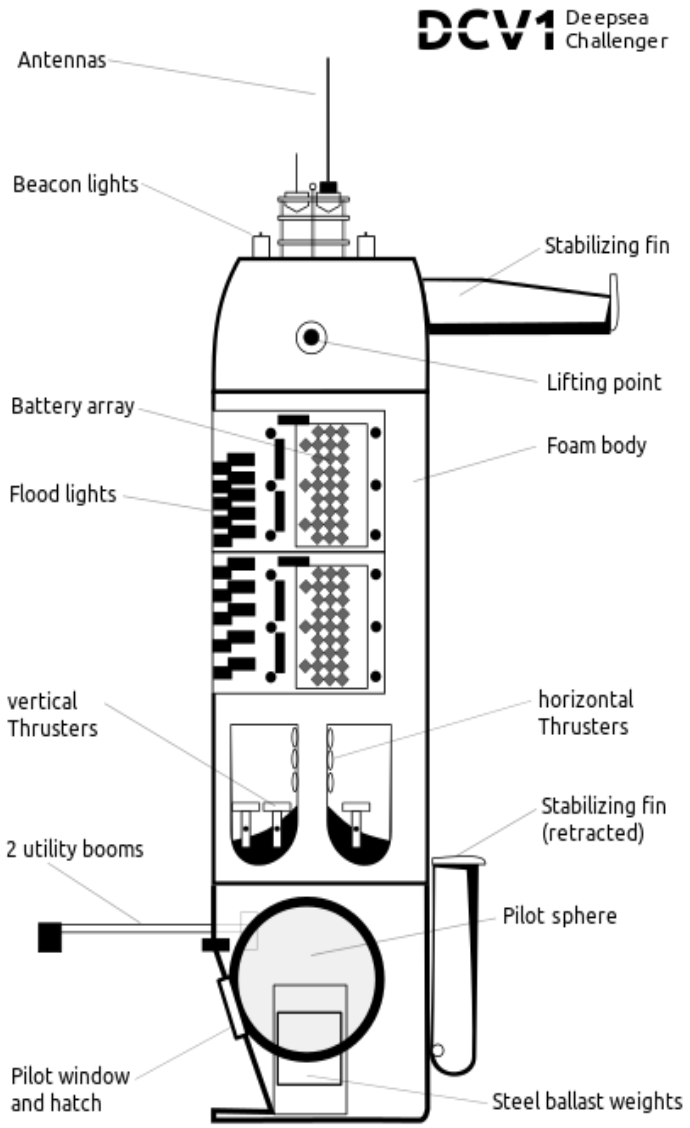
Click to watch: https://www.youtube.com/watch?v=Y2tm40uMhDI

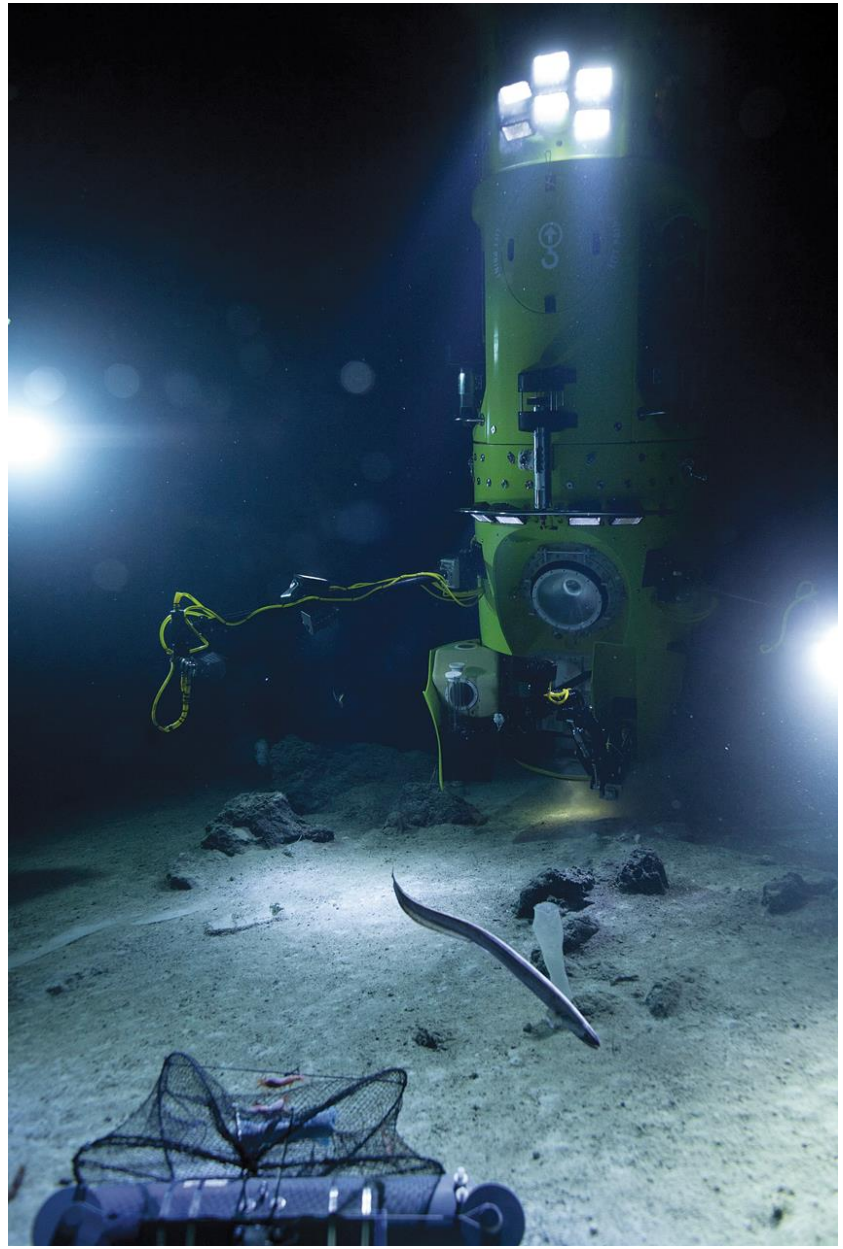


Deepsea Challenger

Built by Rolex,
descended 26 March 2012
with James Cameron
(Film Director of the
movie *Titanic*)

Deepsea Challenger





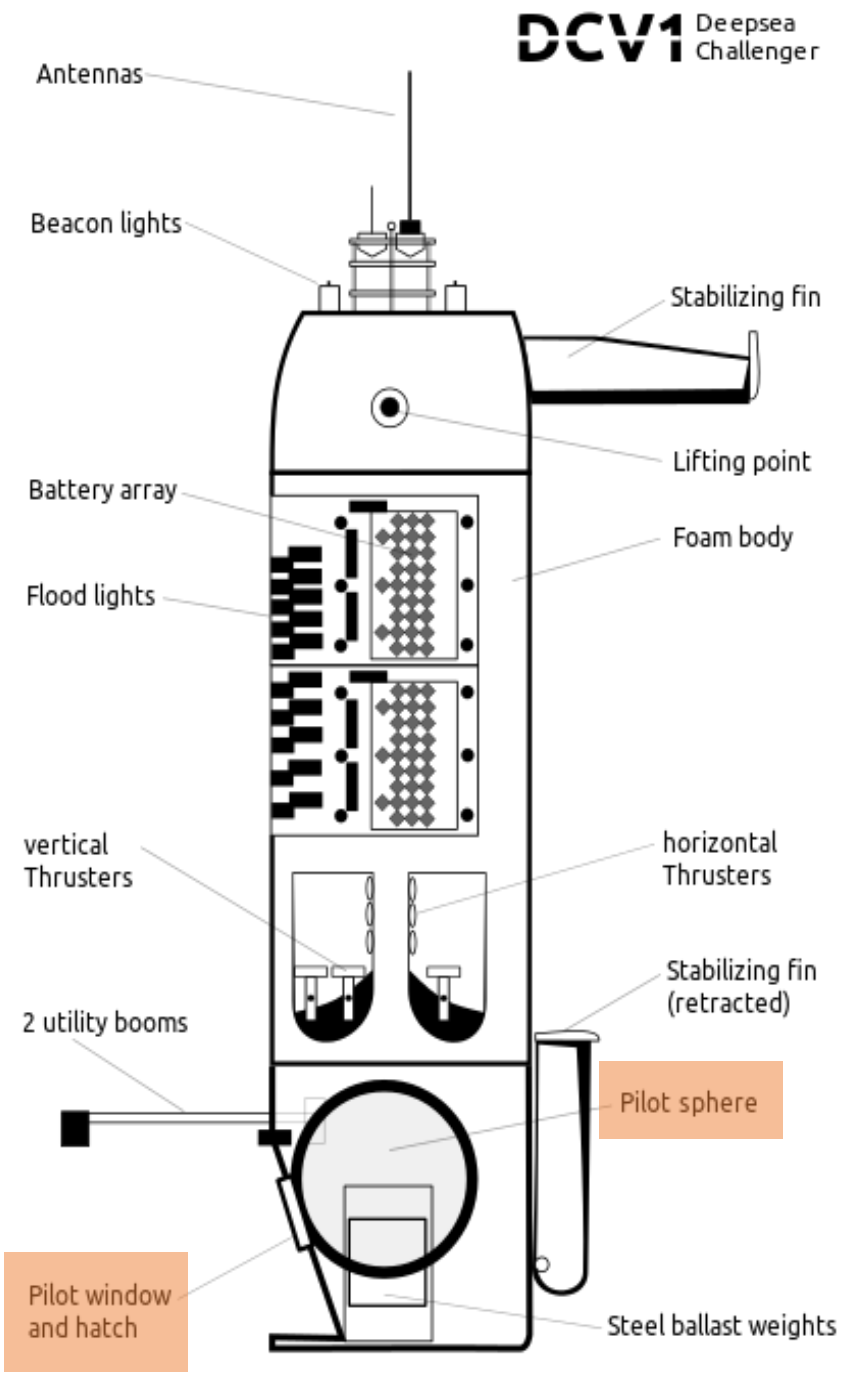


Image from: https://gcaptain.com/james-cameron-donates-deepsea/

Image from: https://www.biznews.com/africa/2014/08/06/james-camerons-deepsea-challenger-voyage-splashes-theatres

Summary – Challenging *the Challenger Deep*

What are the challenges in the Ocean Trenches?

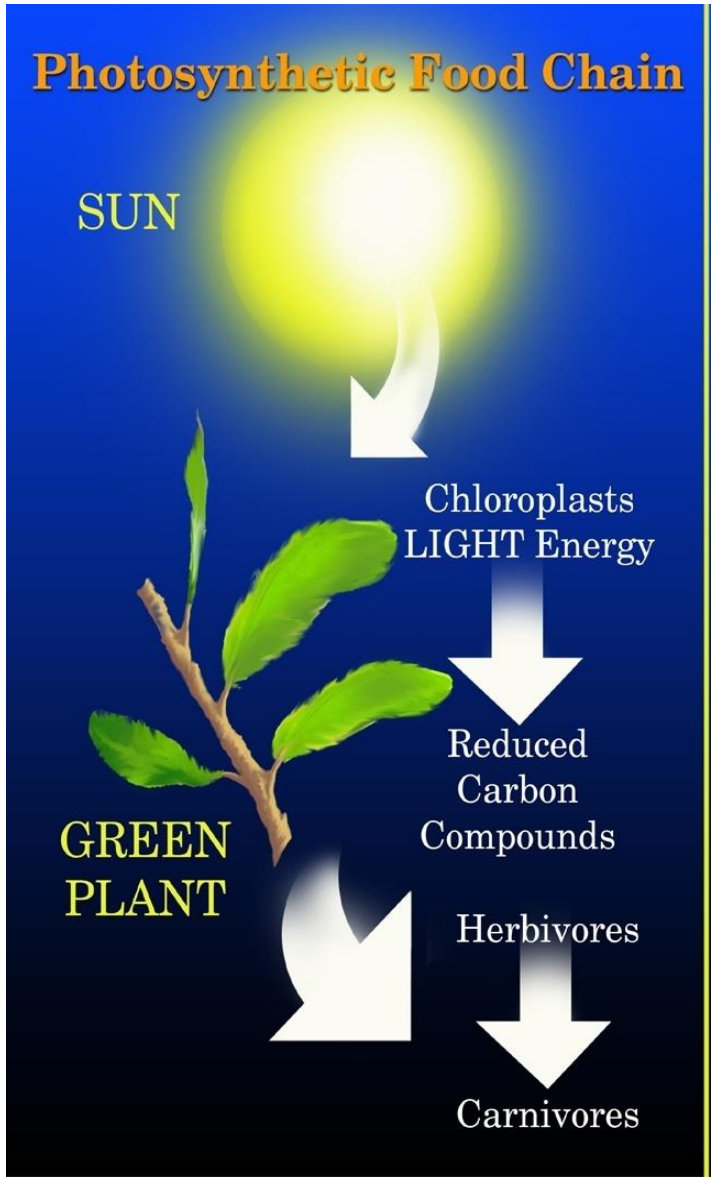
- **Very expensive** for expedition, expensive to build, takes a long time to build and is not used often
- **Very dangerous**
- **Cannot stay on the ocean floor for long**
- **Not many samples** can be retrieved

DEPARTMENT OF OCEAN SCIENCE

Discovery:

Deep-Sea Chemosynthetic Ecosystems

What is Chemosynthesis?

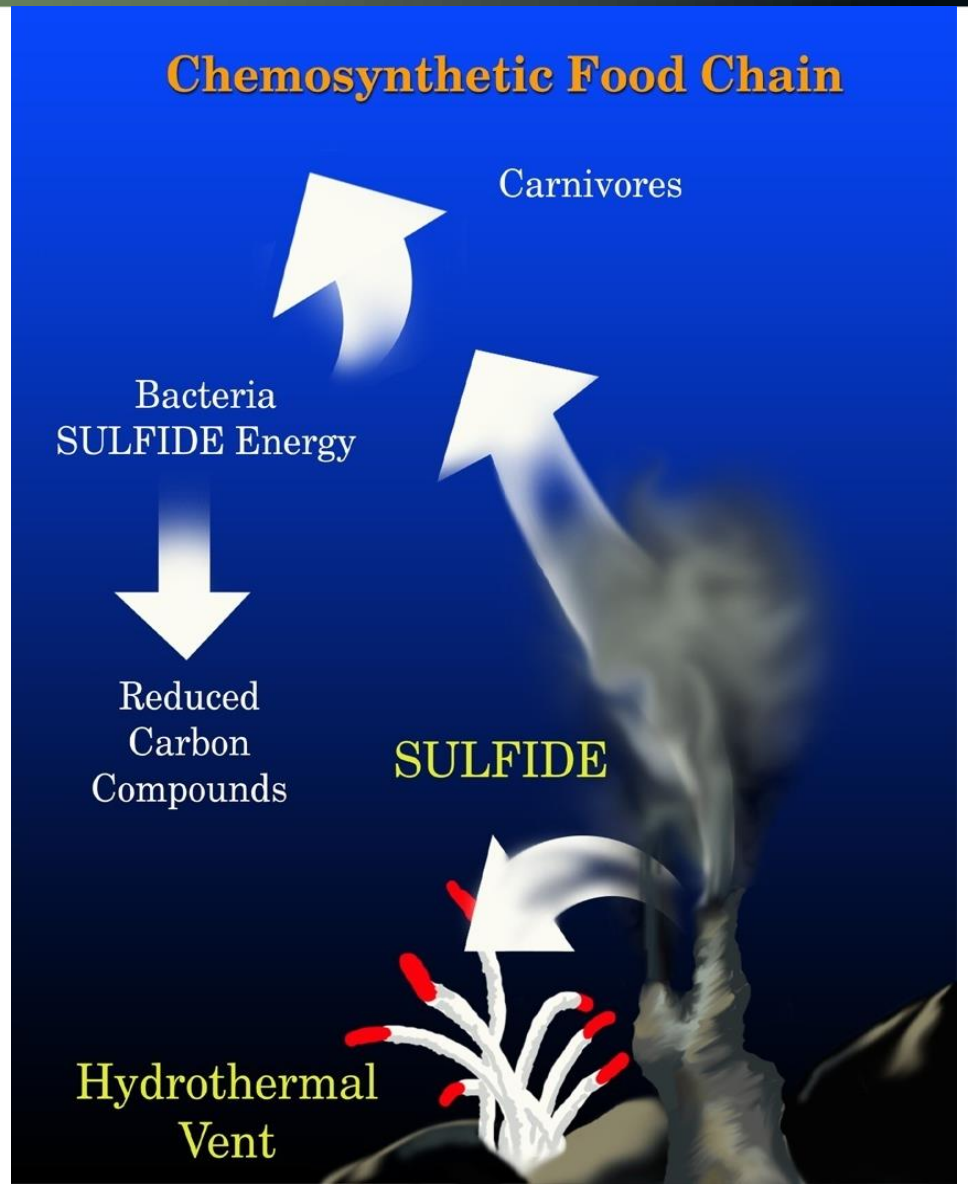


Photosynthesis

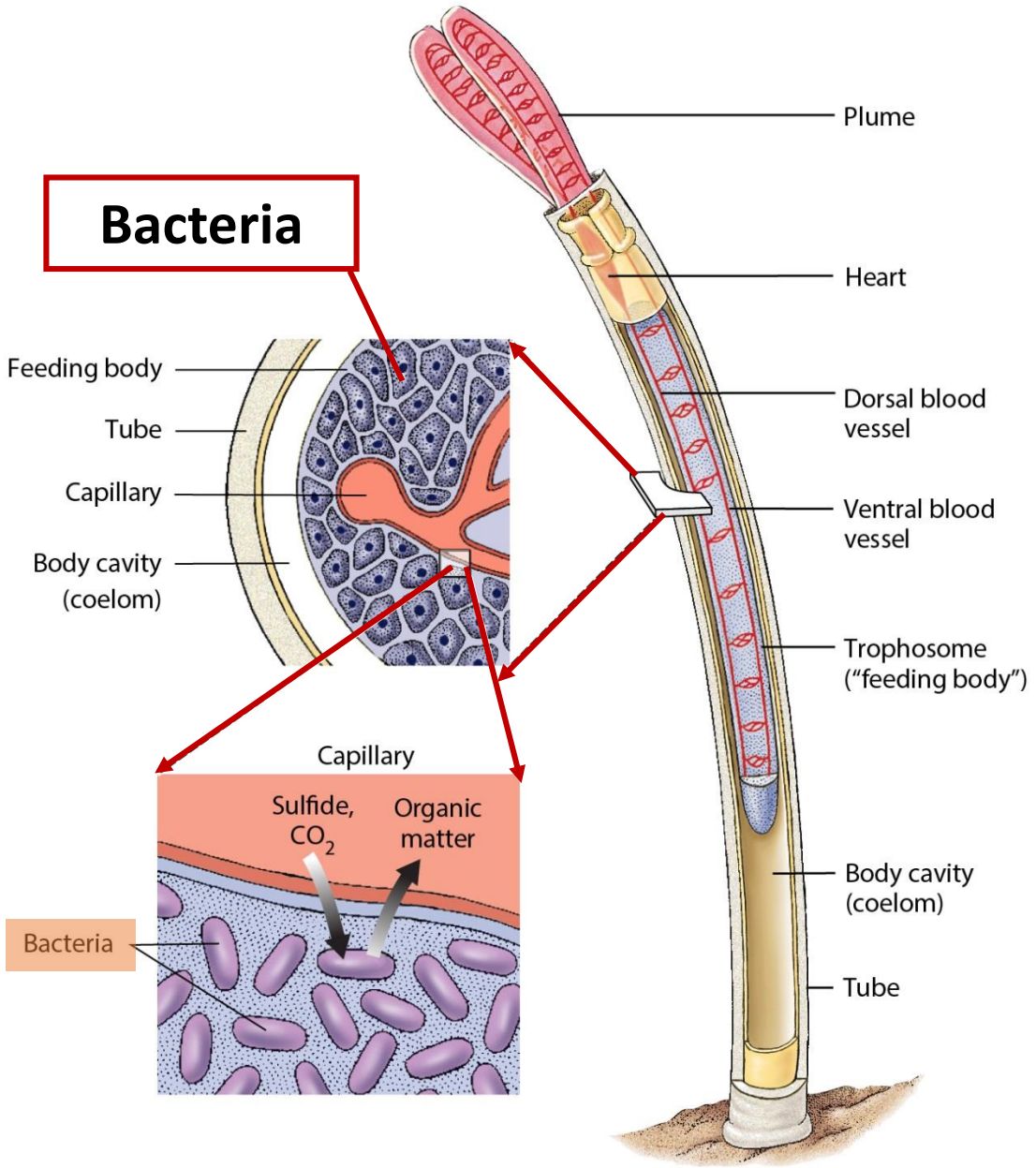
- With sunlight
- Energy from sun

Chemosynthesis

- Without sunlight
- Energy from chemicals



Images from Springfield Central High School



Source: Bill Ober

Copyright © McGraw-Hill Education. All rights reserved. No reproduction or distribution without the prior written consent of McGraw-Hill Education.

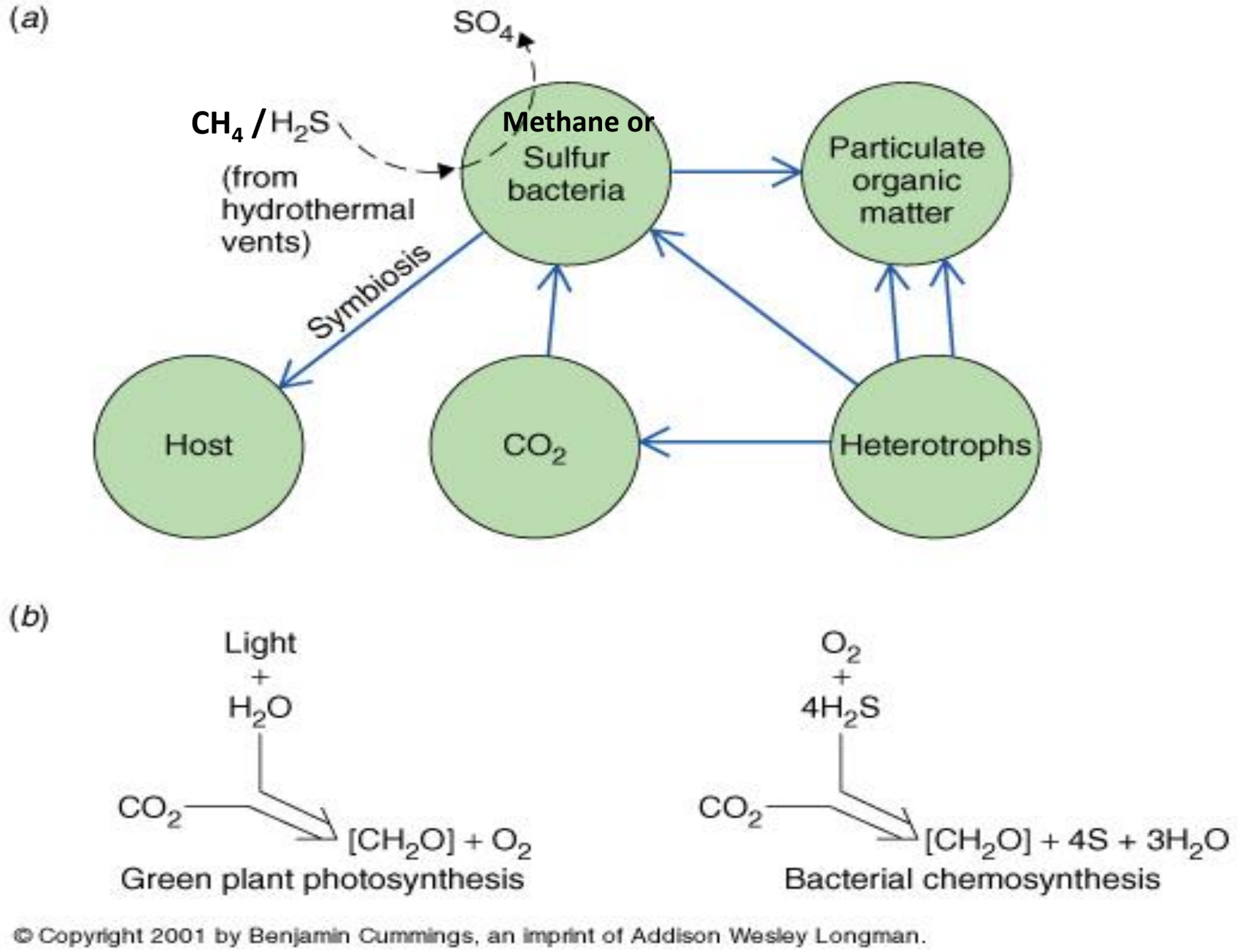
Giant hydrothermal-vent tubeworm, *Riftia*

Red color because of the haemoglobin of the blood.

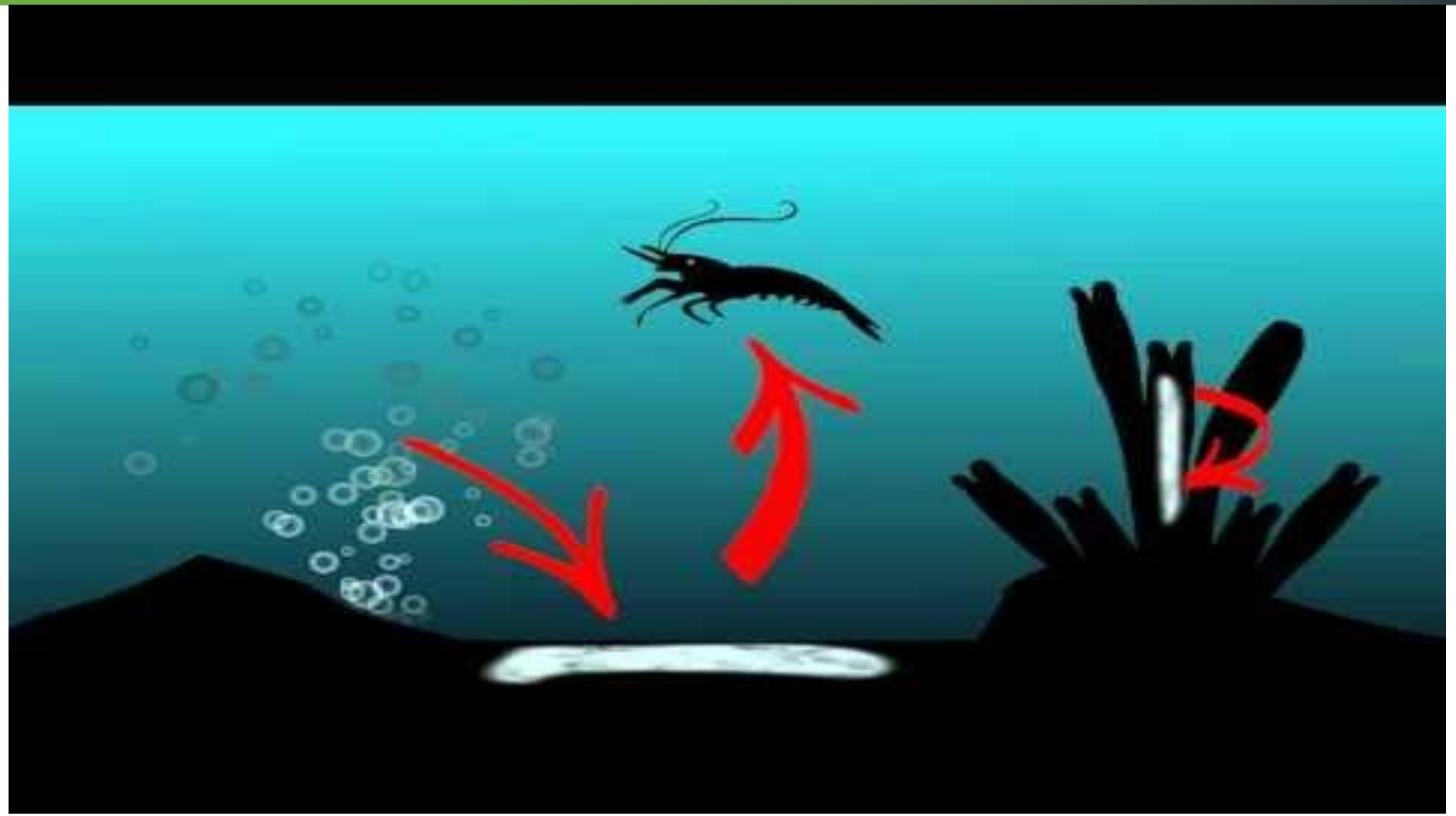
Chemosynthetic ecosystem

- Examples of chemosynthetic organism: bacteria/archaea

- The use of inorganic compounds (e.g. hydrogen sulfide H_2S, methane CH_4) as energy source



Watch – *Behind the Science 2012: Chemosynthesis*



Click to watch: https://www.youtube.com/watch?v=BLOUFrncG7E

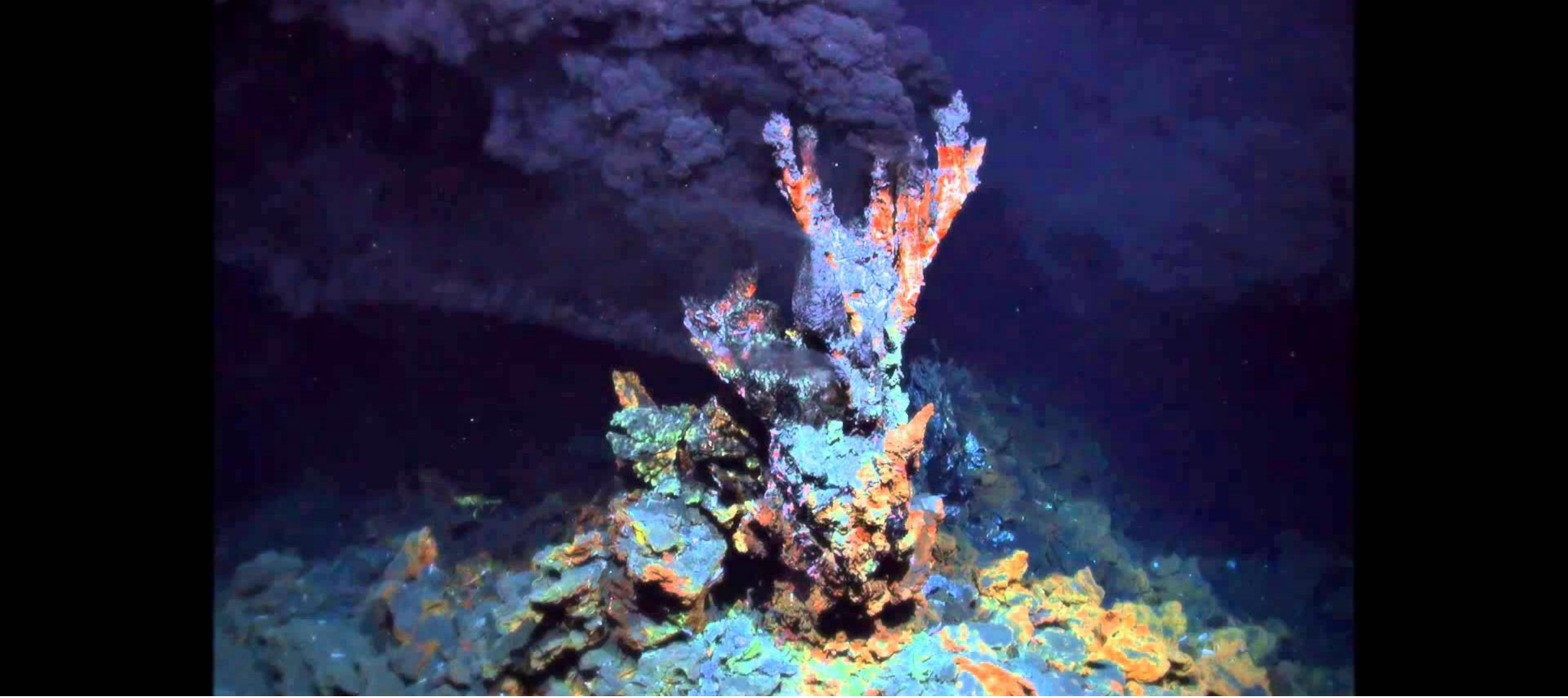
Summary - Chemosynthesis

- **What is chemosynthesis?**
  - The use of **inorganic compounds (e.g. hydrogen sulfide H_2S, methane CH_4)** as energy source

- **Why is chemosynthesis important for deep-sea organisms?**

Total darkness in the deep-sea environment, so they must rely on **chemical energy from bacteria.**

  - Consume bacteria
  - Symbiotic relationship with bacteria



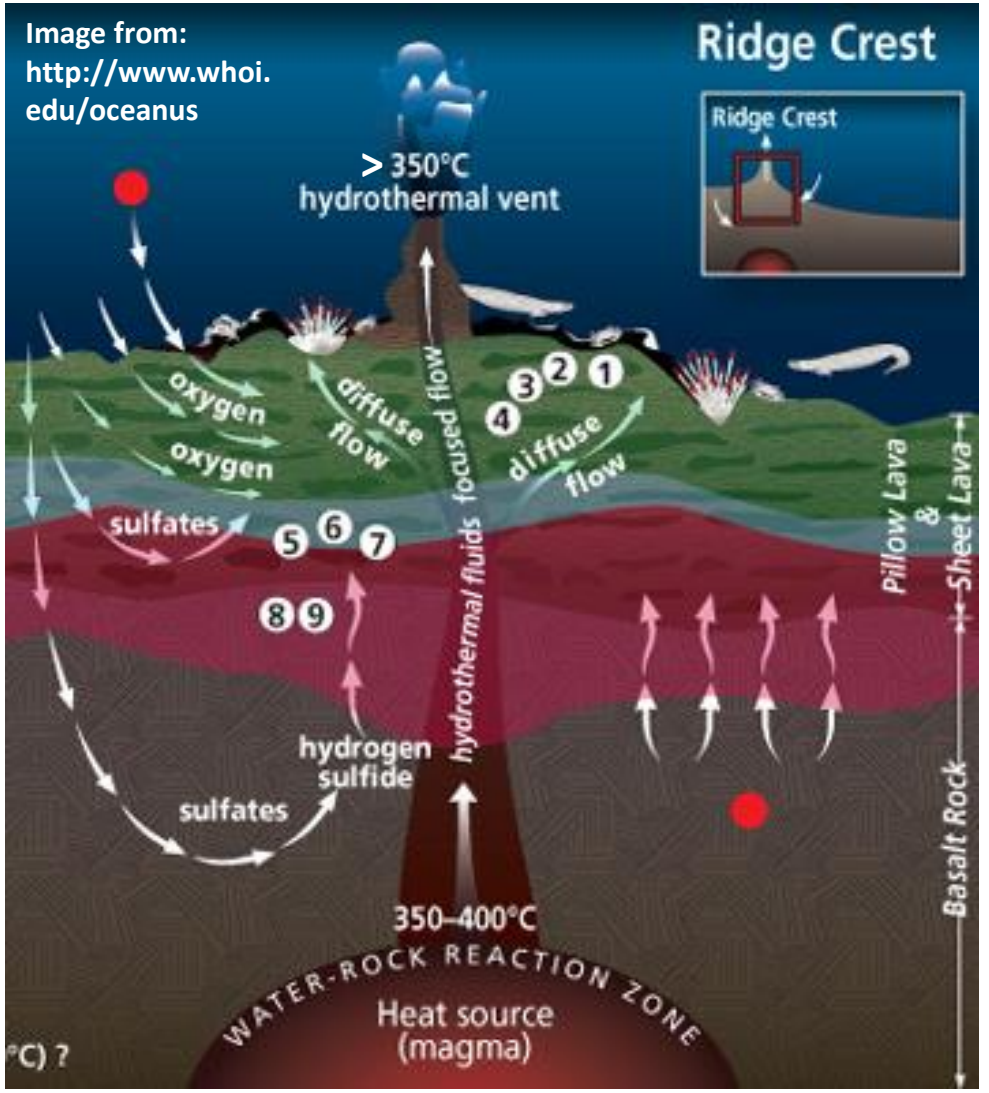
DEPARTMENT OF OCEAN SCIENCE

Hydrothermal Vents

What are Hydrothermal Vents?

High-pressure hot springs

- Located **near deep-sea volcanoes** on the ocean floor
- Water seeps through cracks on the ocean floor
- Water is then heated by molten rock deep below the ocean crust (up to ~400°C)
- Hot fluid rises through rock and bursts out of vent openings and nearby ocean floor
- Hot fluid can crust the rocks and dissolve metals
- This VERY HOT fluid carries dissolved metals and **H_2S gas** (inorganic chemical – like rotten egg gas) from deep beneath the ocean floor



Cracks created from tectonic plate collisions

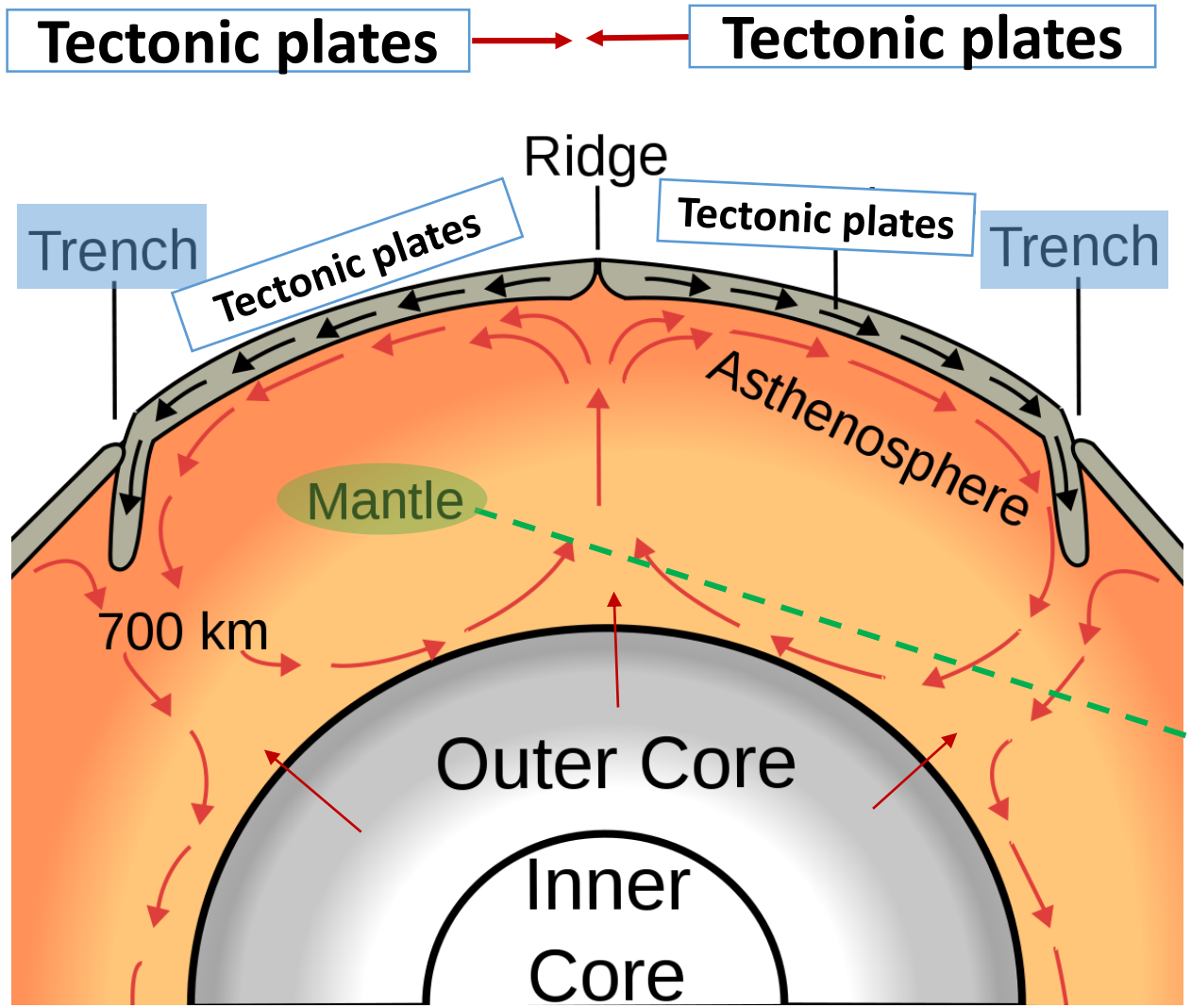
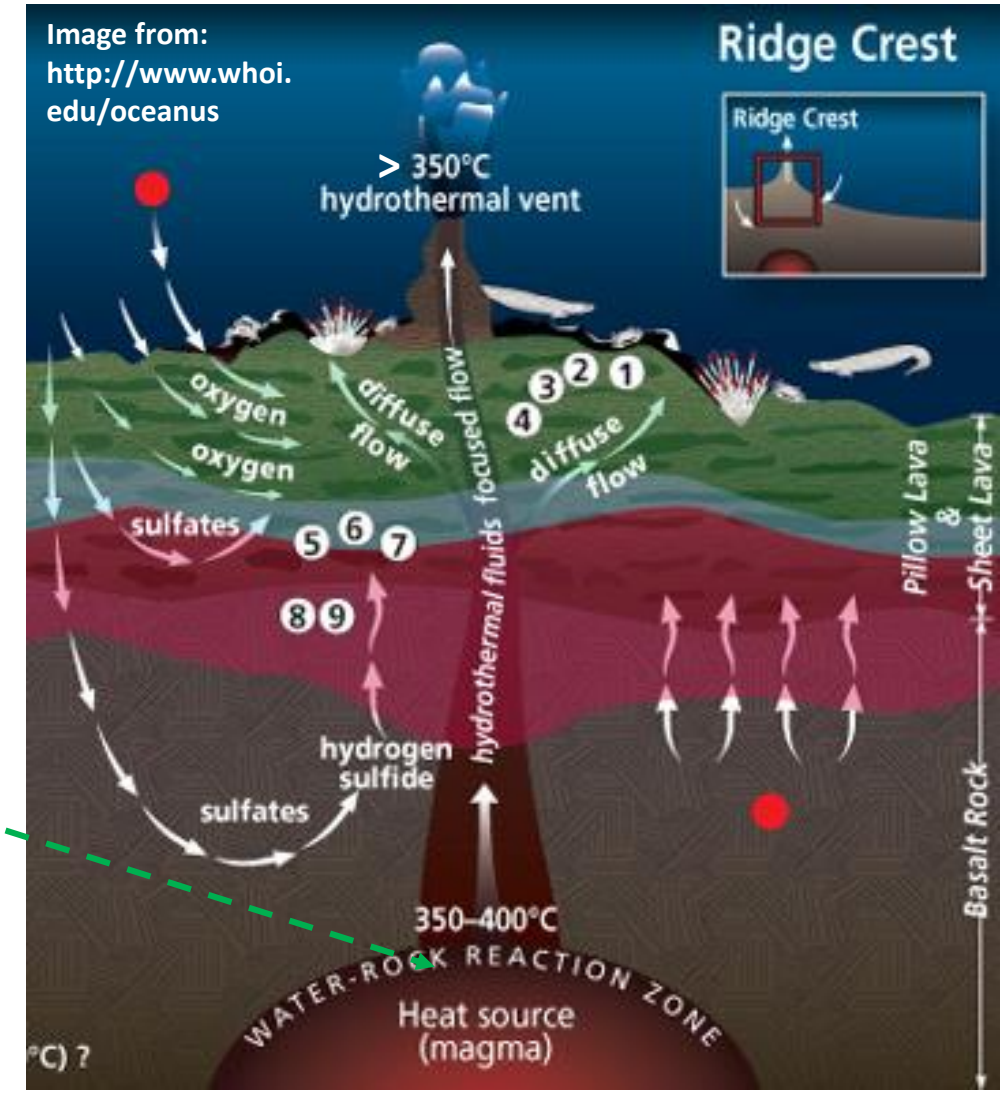
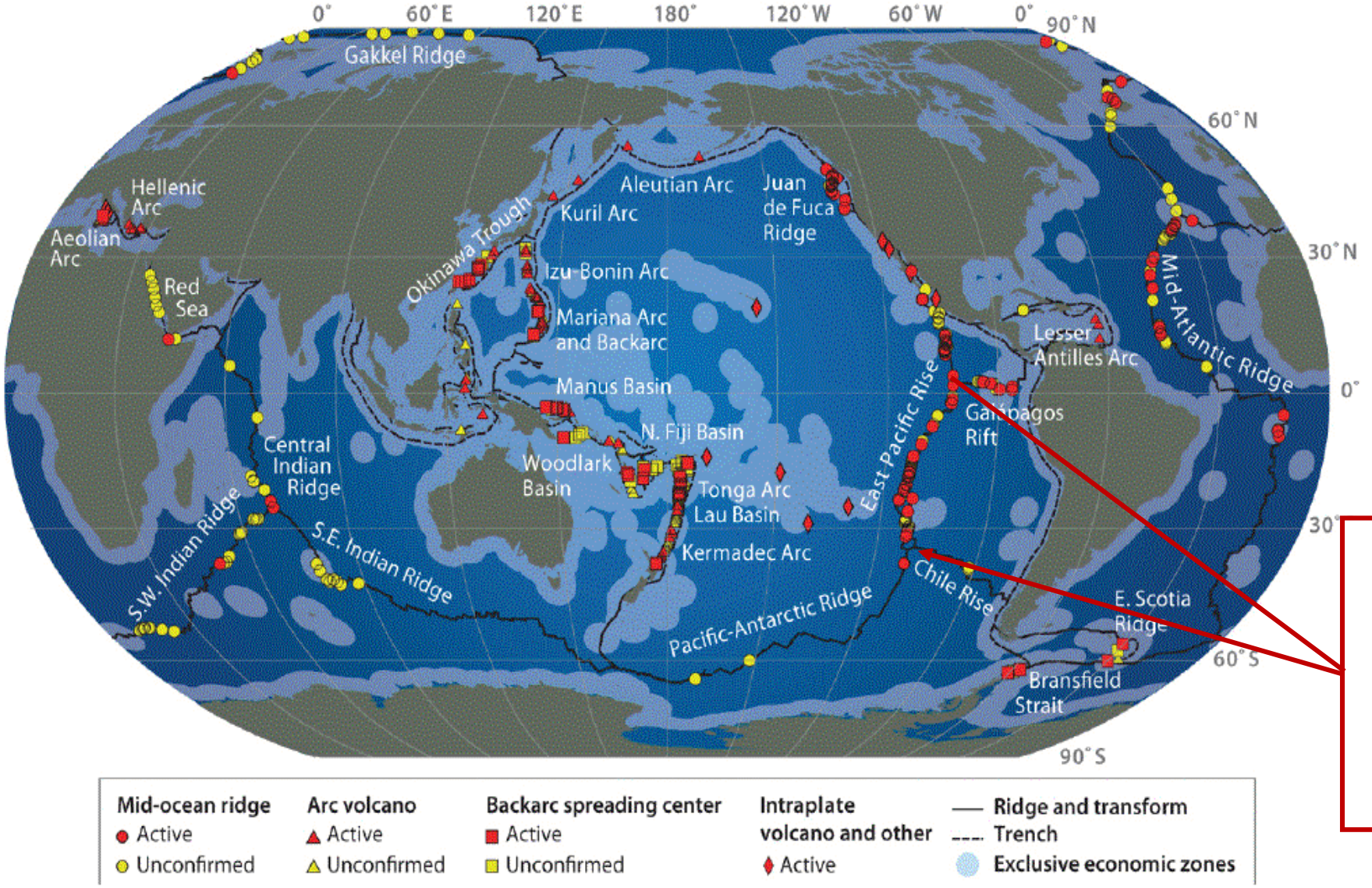


Image from: Wikipedia



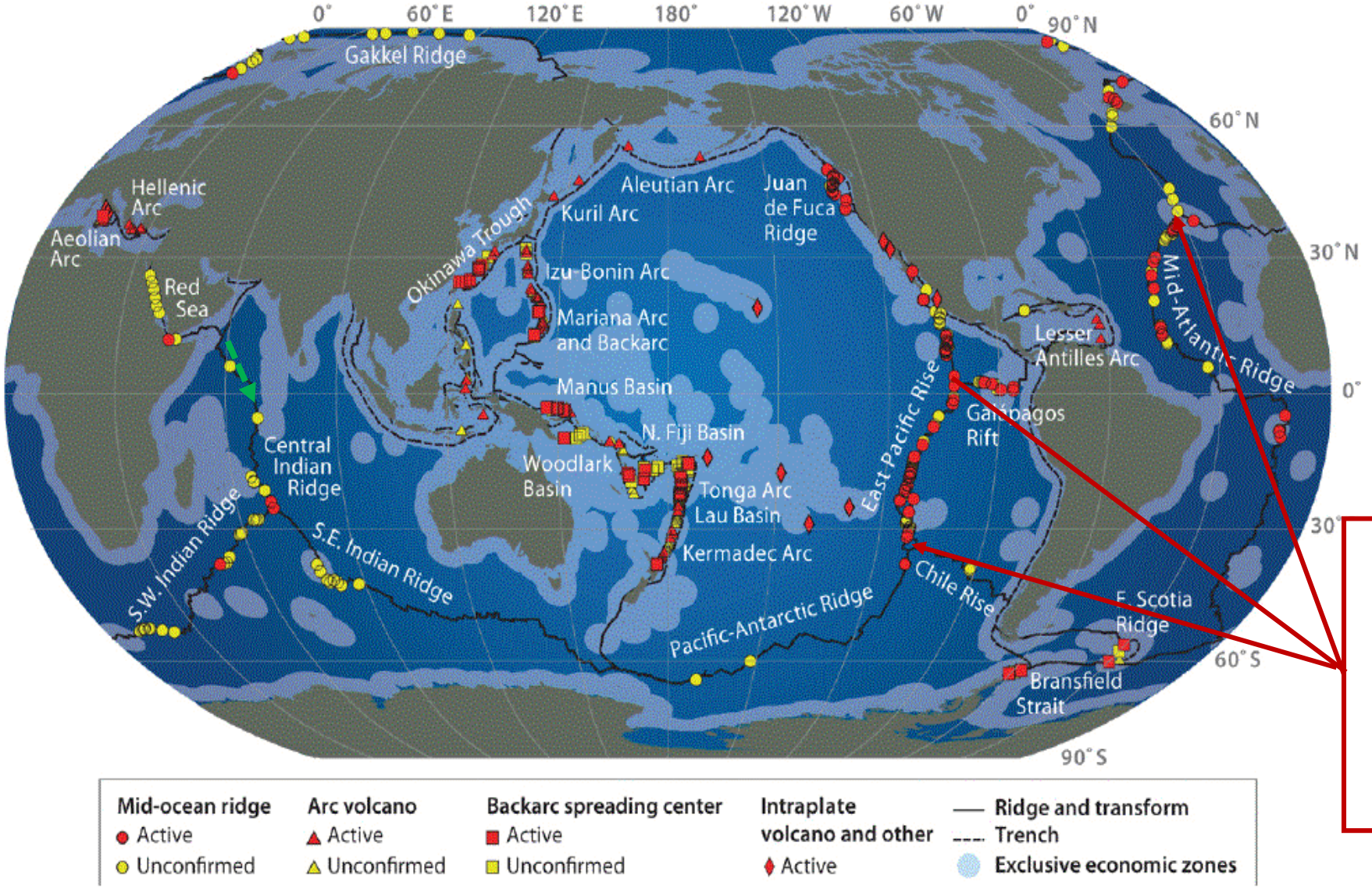
Active Hydrothermal Vents – Global Distribution (544)



Hydrothermal vents are found along areas where tectonic plates meet.

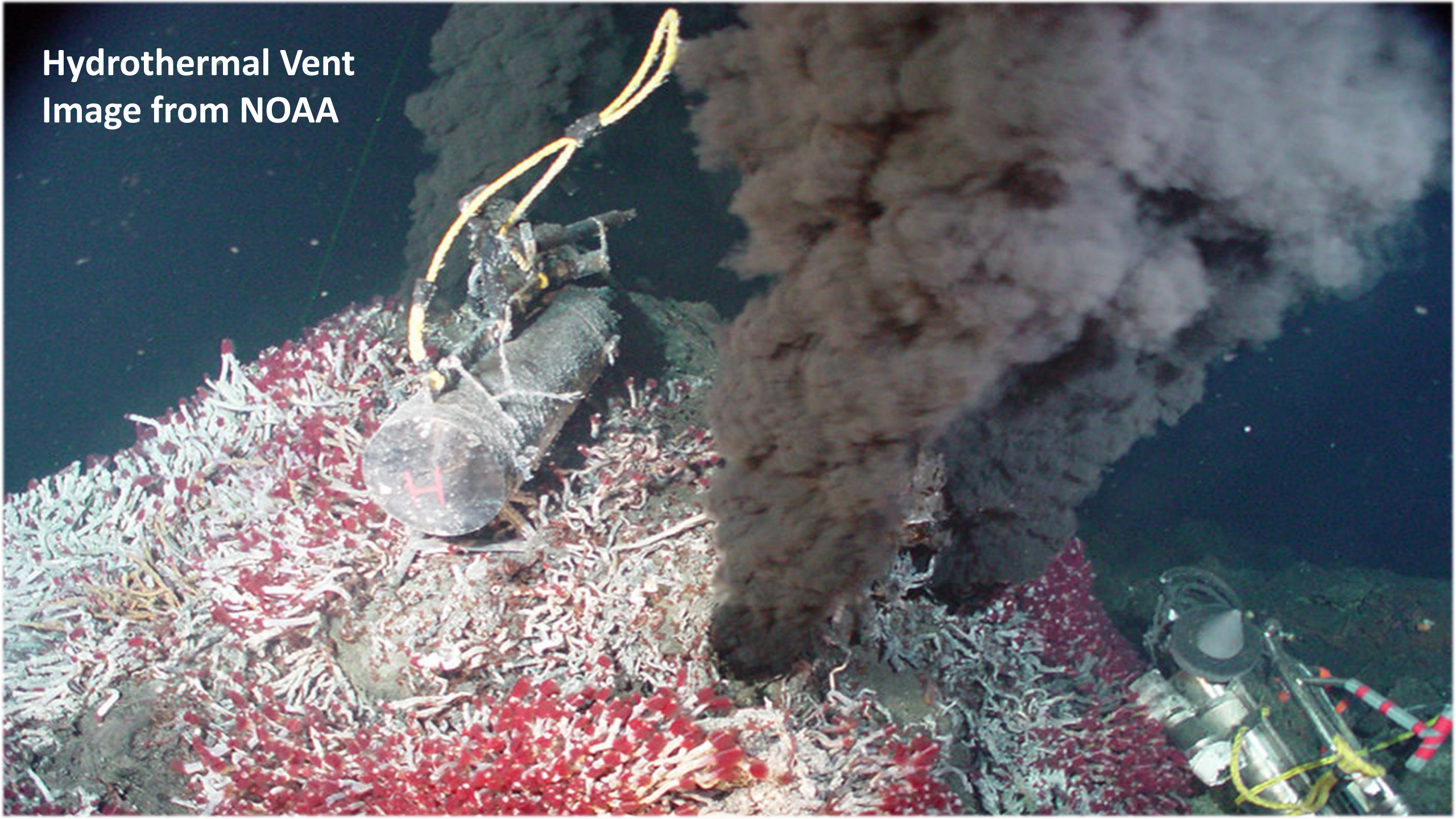
Hannington *et al.* (2011)

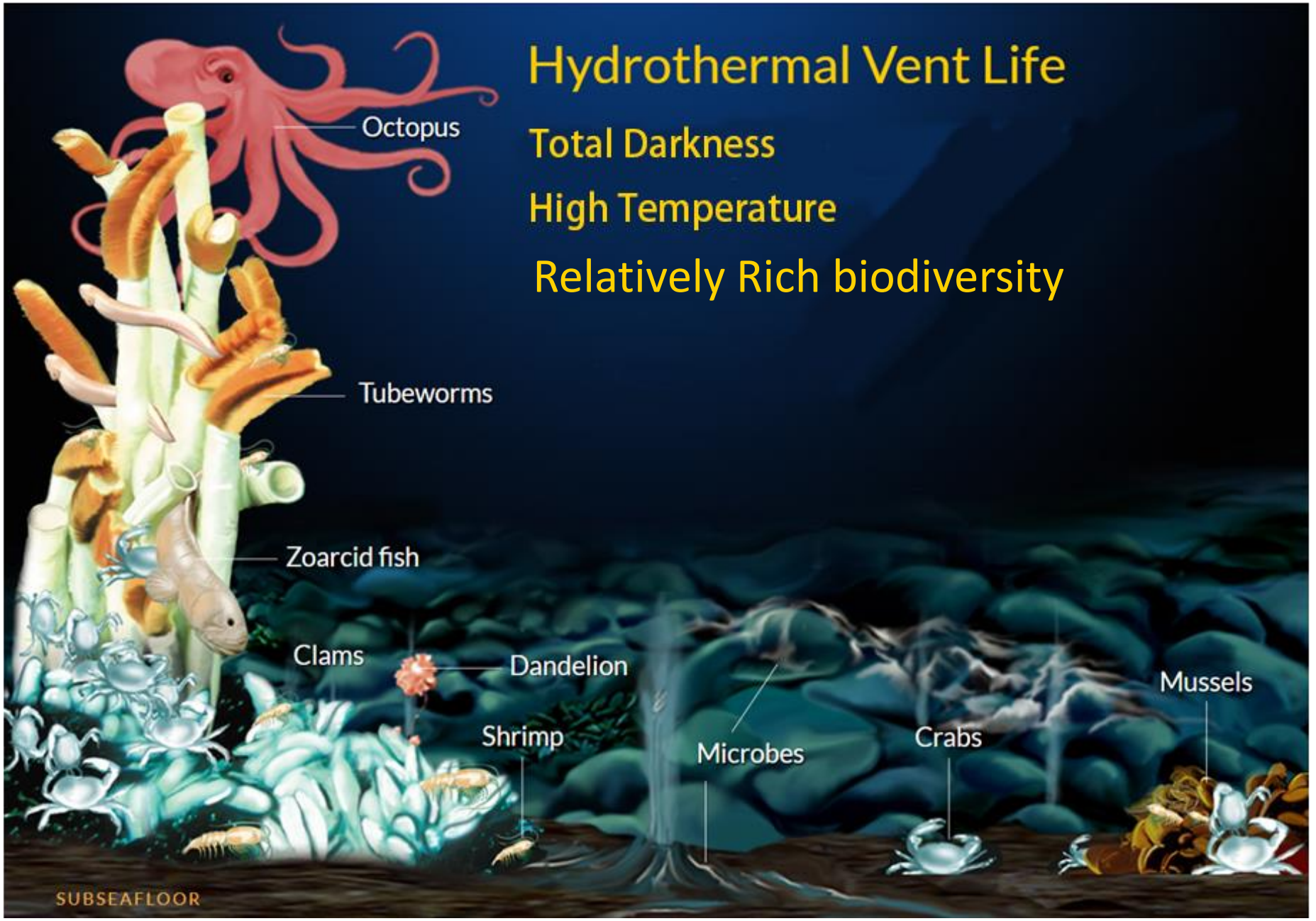
Active Hydrothermal Vents – Global Distribution (544)



Hydrothermal vents are found along areas where tectonic plates meet.

Hannington *et al.* (2011)

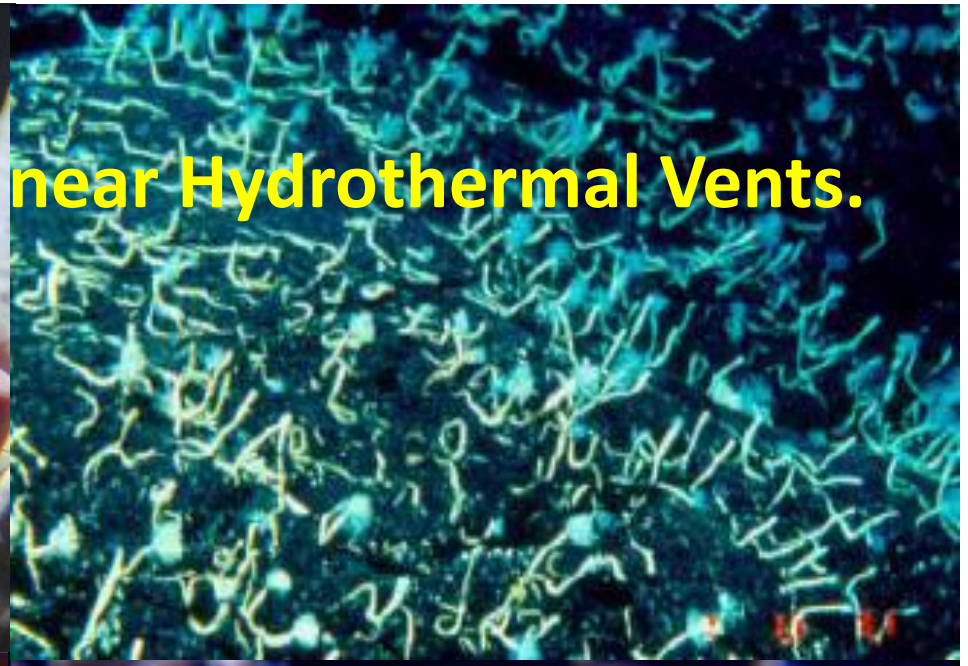

Hydrothermal Vent
Image from NOAA

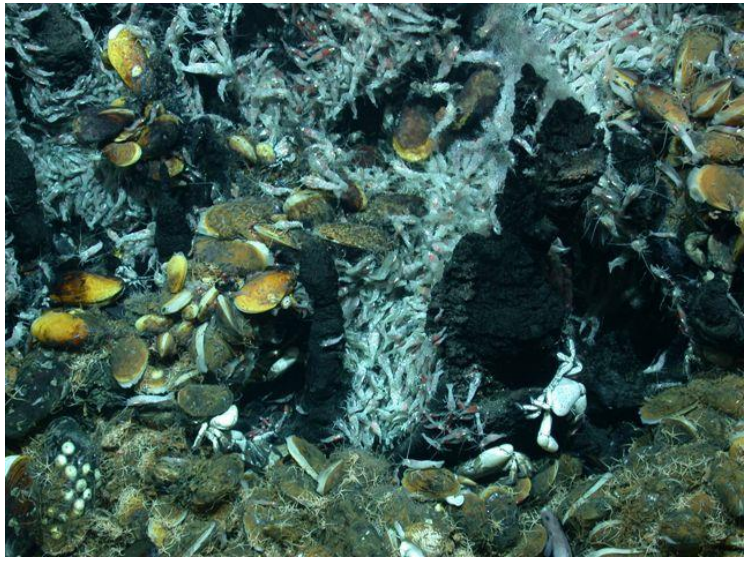


Click to watch: https://prezi.com/p/dvop_jipf4et/trial/

Marine organisms living near Hydrothermal Vents.

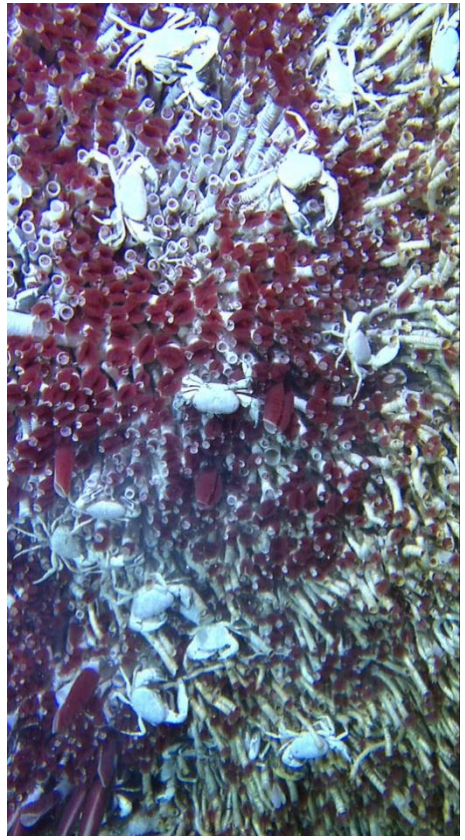
Marine organisms living near Hydrothermal Vents.





Residents of the active Vents.

Huge mussels








Life in the active Vents: Growing under high temperature, resistant to heavy metals; with unusual symbioses.

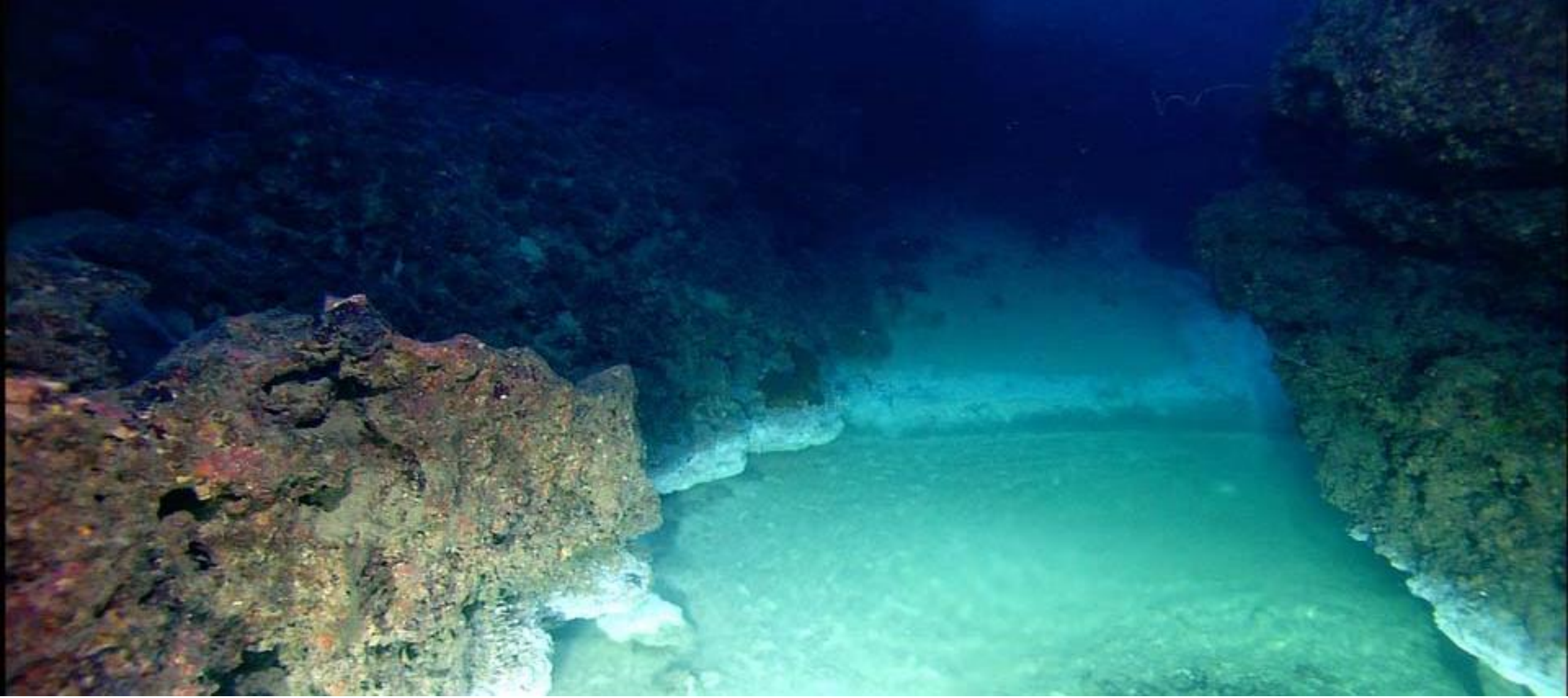
Summary - Hydrothermal Vents

What are hydrothermal vents?

- Like high pressure hot springs – chemosynthetic ecosystem that carries dissolved metals and H_2S gas

What are the environmental conditions around Hydrothermal Vents?

- High temperature
- High pressure
- High concentration of H_2S (hydrogen sulfide)



DEPARTMENT OF OCEAN SCIENCE

Cold Seeps & Gas Hydrates

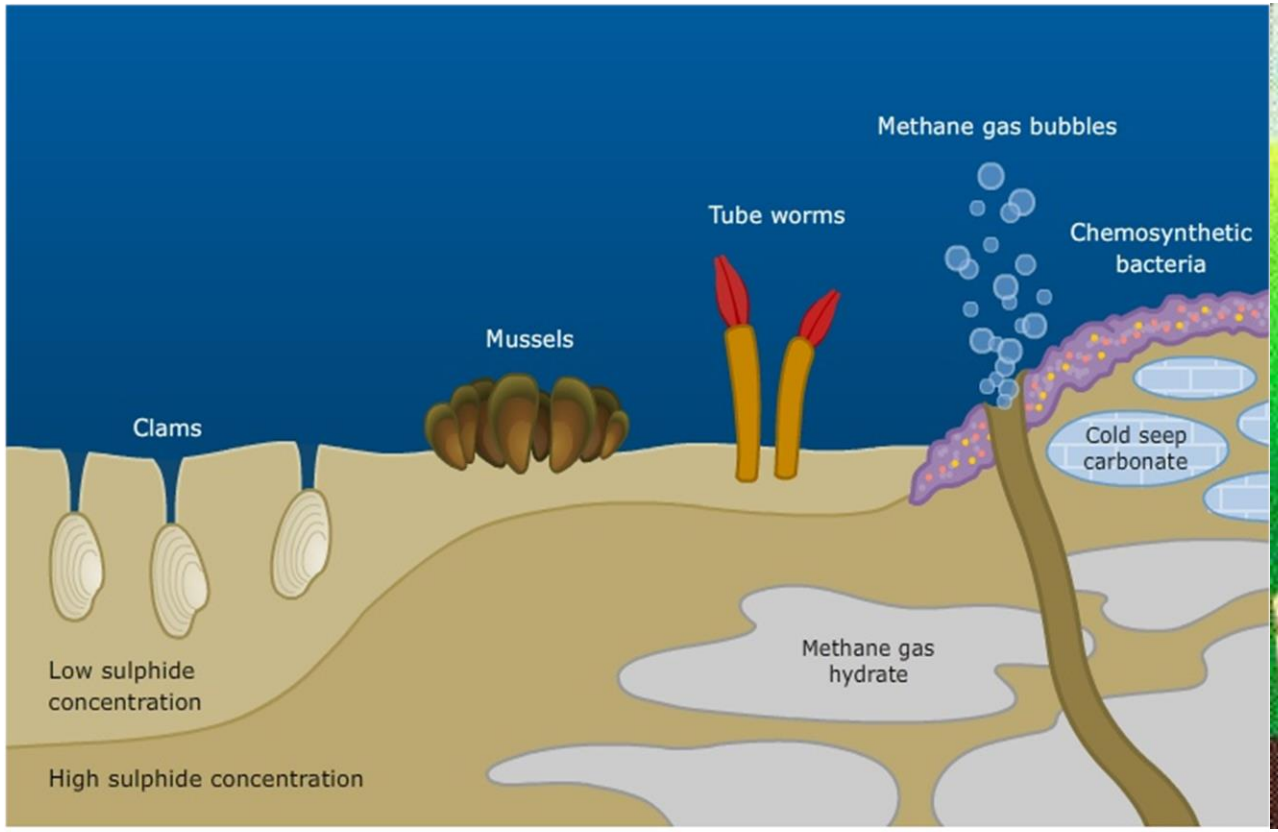
What are Cold Seeps?

Similar to Hydrothermal Vents (Chemosynthetic ecosystem)

- **Chemicals (e.g. H_2S and CH_4)** produced by the decay of organic matter seep out from the sea floor

- These chemicals provide energy to support the ecosystem (i.e. **chemosynthesis**)

Cold Seeps



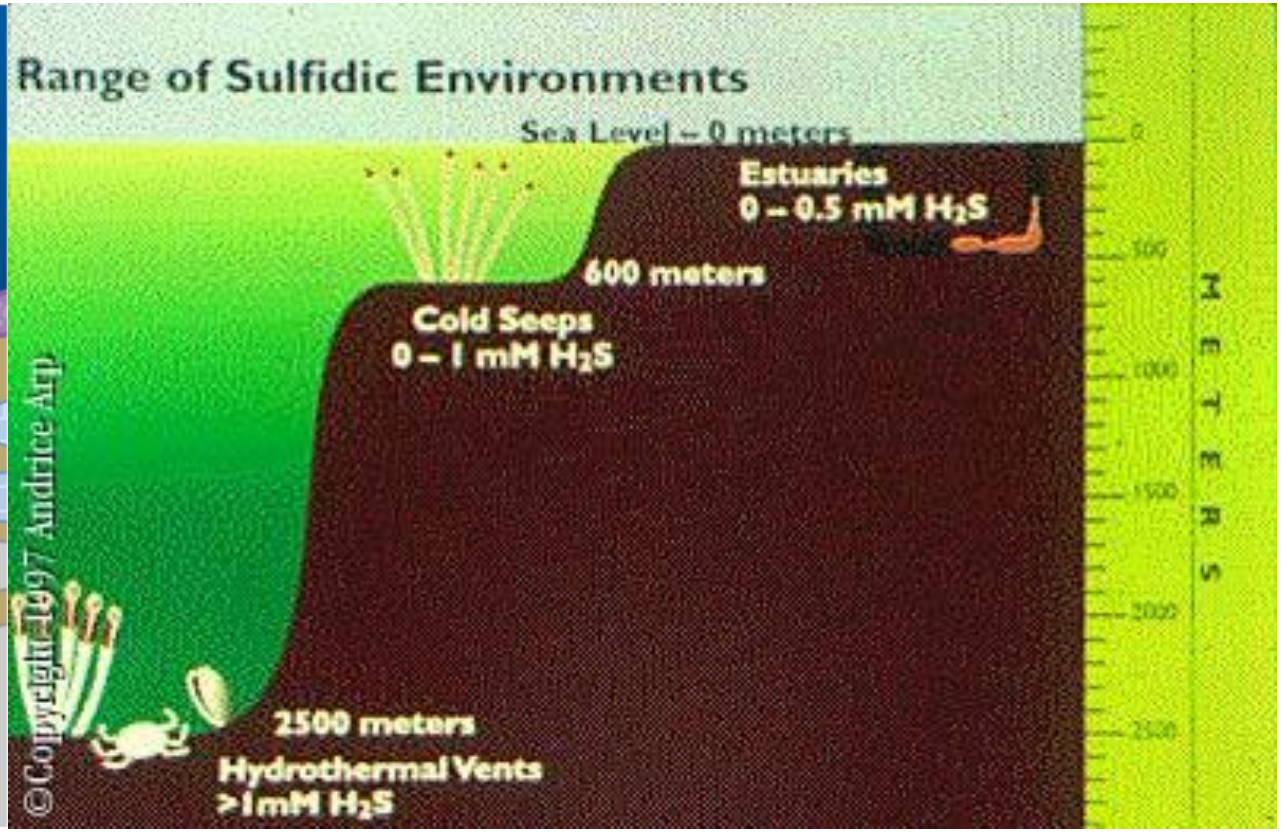
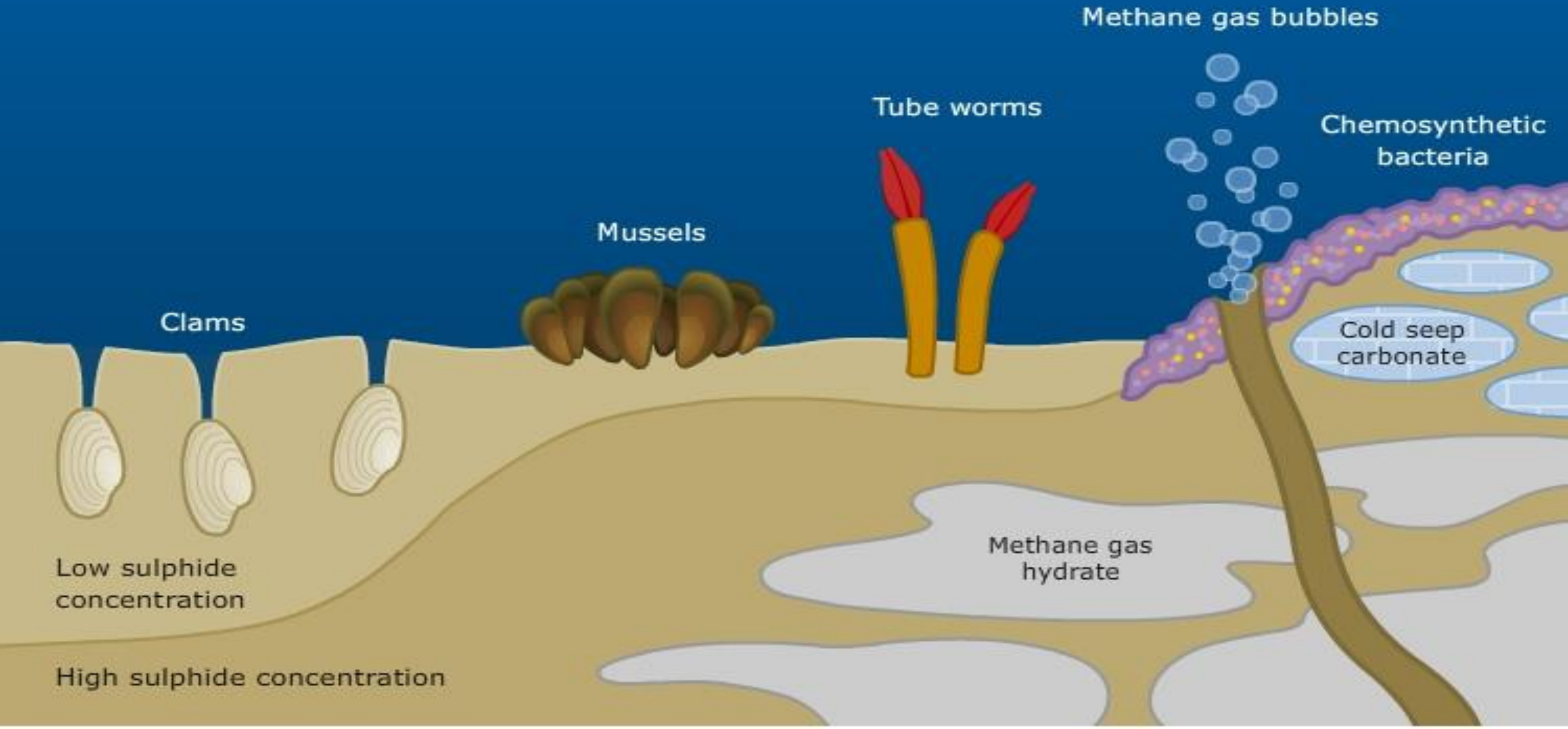


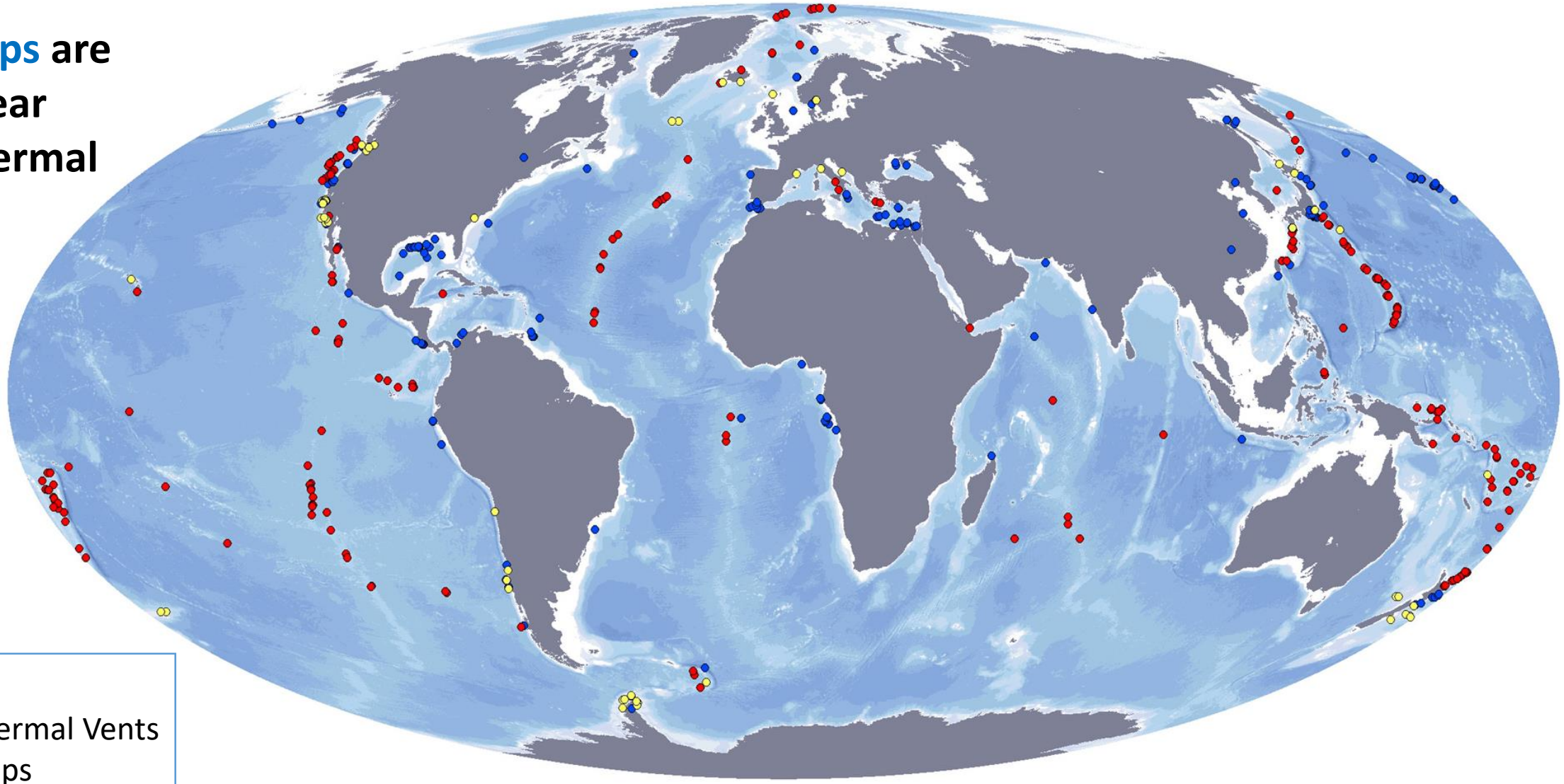
Image from http://www.cas.miamioh.edu/mbiws/ExtremeMicro/coldseeps.htm

Visual reference of Cold Seep environment



Cold Seeps – Global Distribution

Cold seeps are found near hydrothermal vents

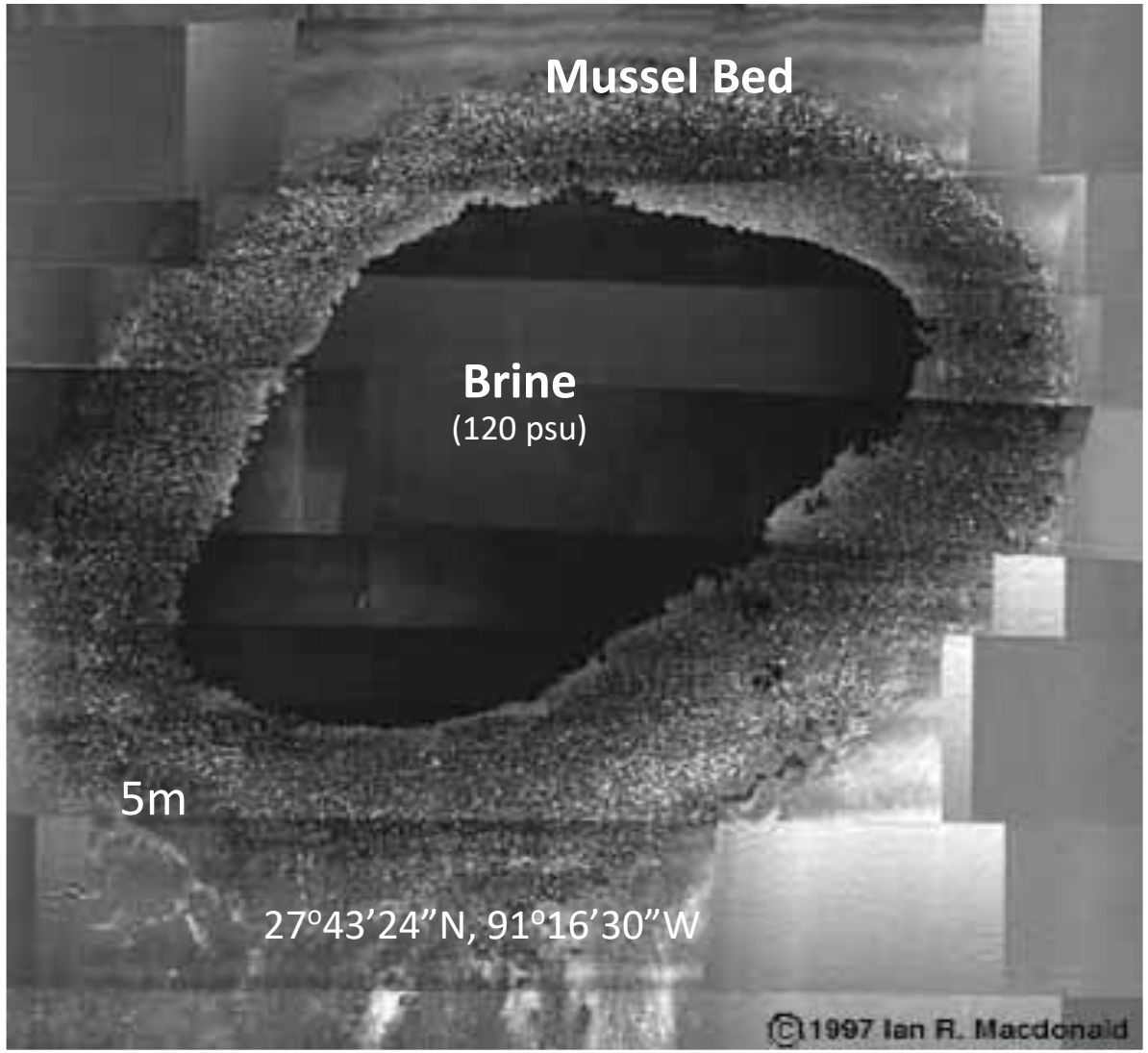


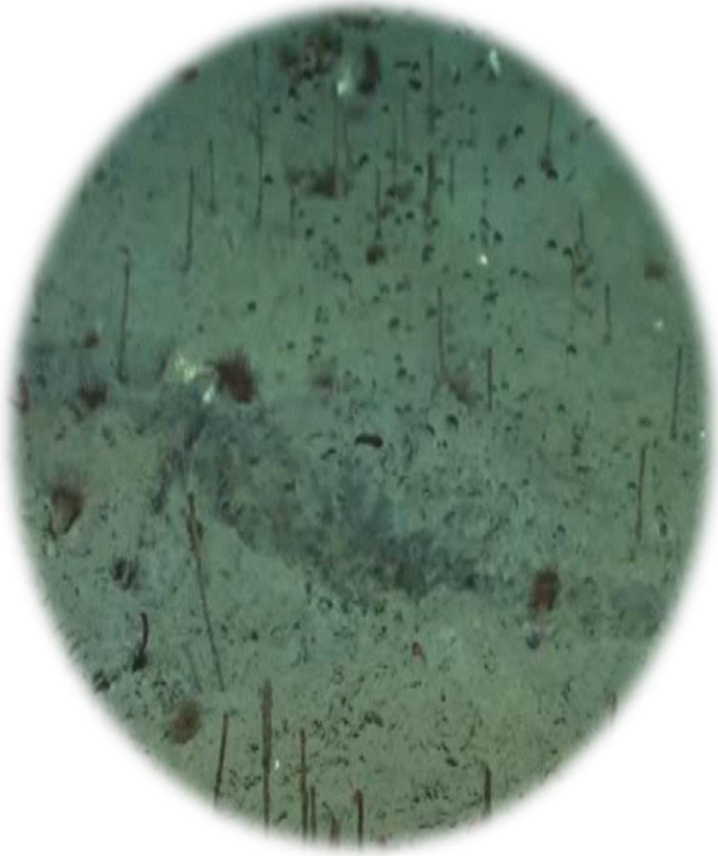
Key

- Hydrothermal Vents
- Cold Seeps

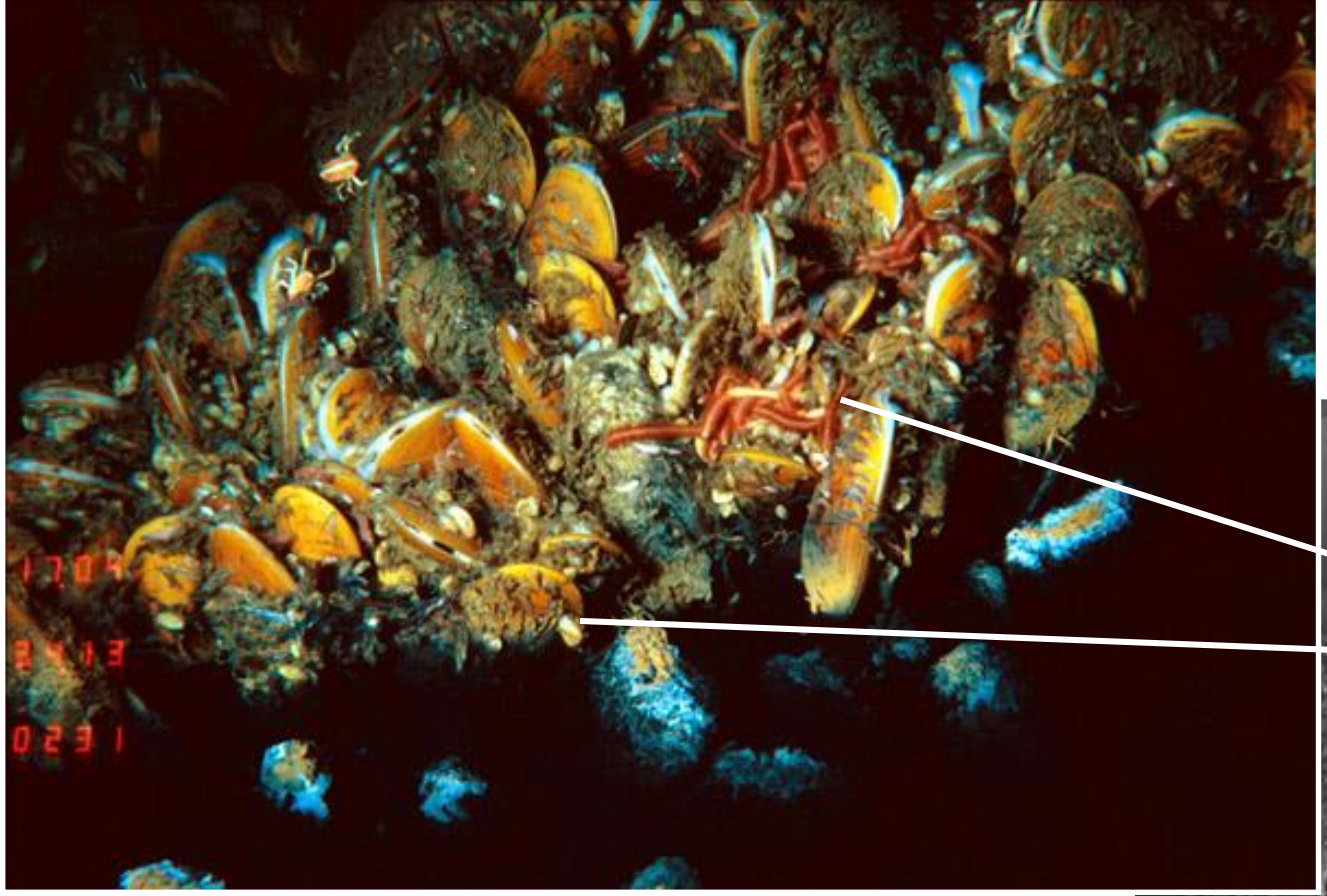
Cold Seeps

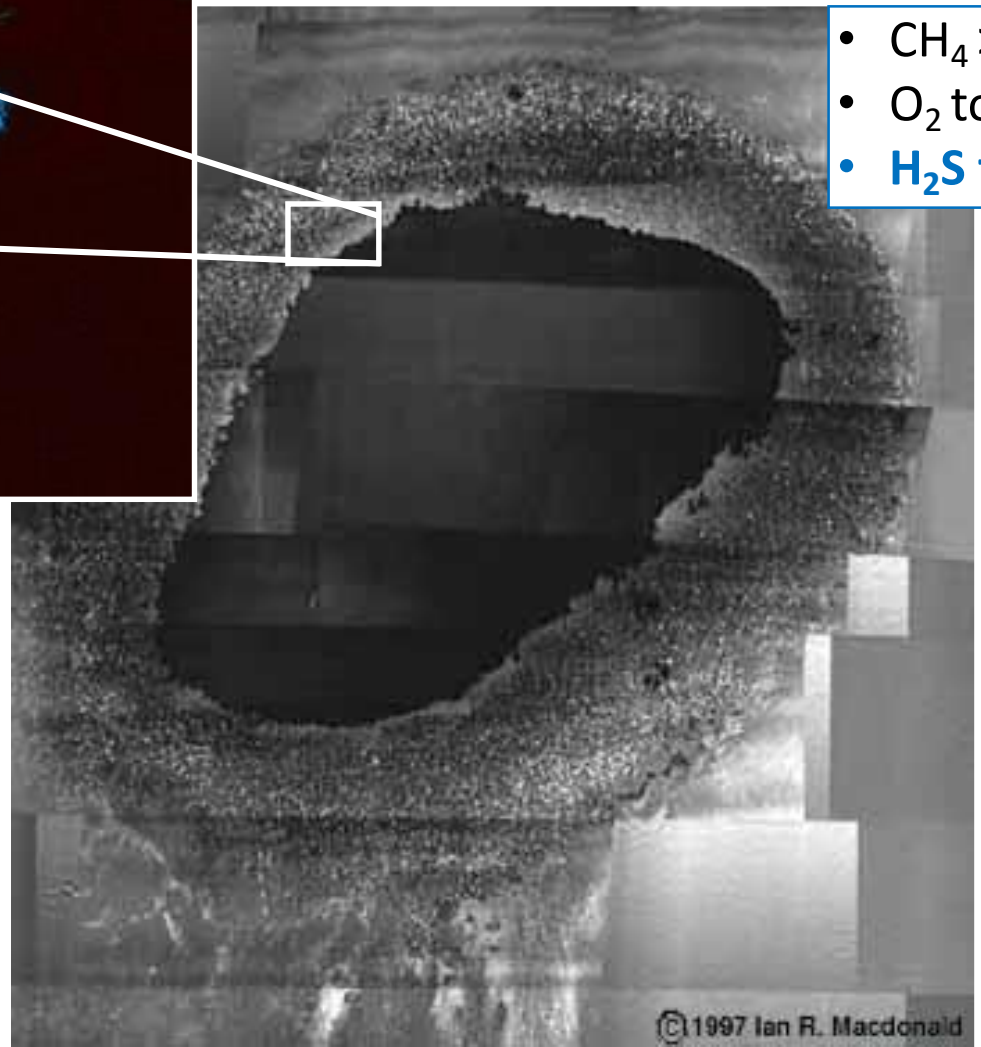
Cold Seeps (Gulf of Mexico)





Cold Seeps (Arabian Sea)





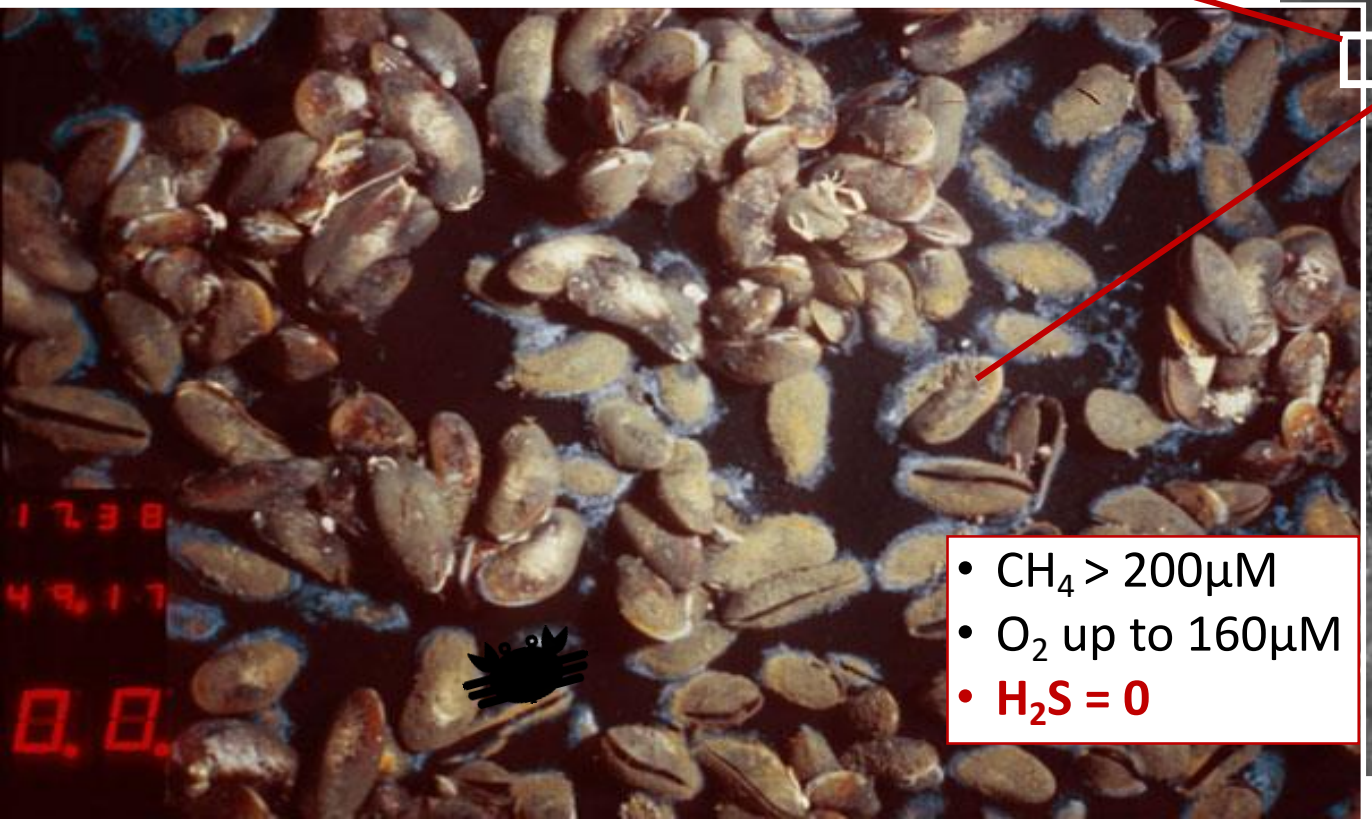
- CH_4 > 200µM
- O_2 to <50µM
- **H_2S to >1000µM**

Near inner edge of brine pool you find lively organisms

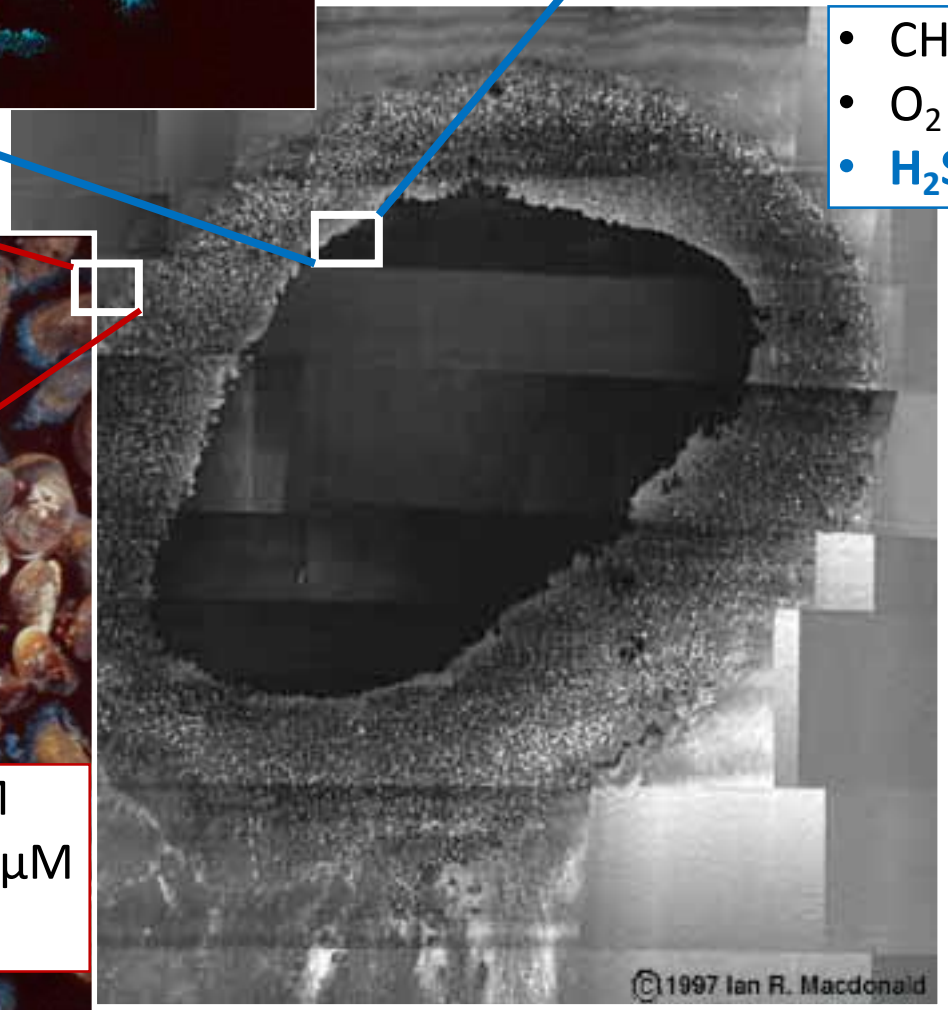
- **Mussels**
- **Worms**
- **Crabs**

Inner edge of brine pool, you find lively organisms because they are near their energy supply

Outer edge of brine pool, you find dead organisms because they are away from their energy supply

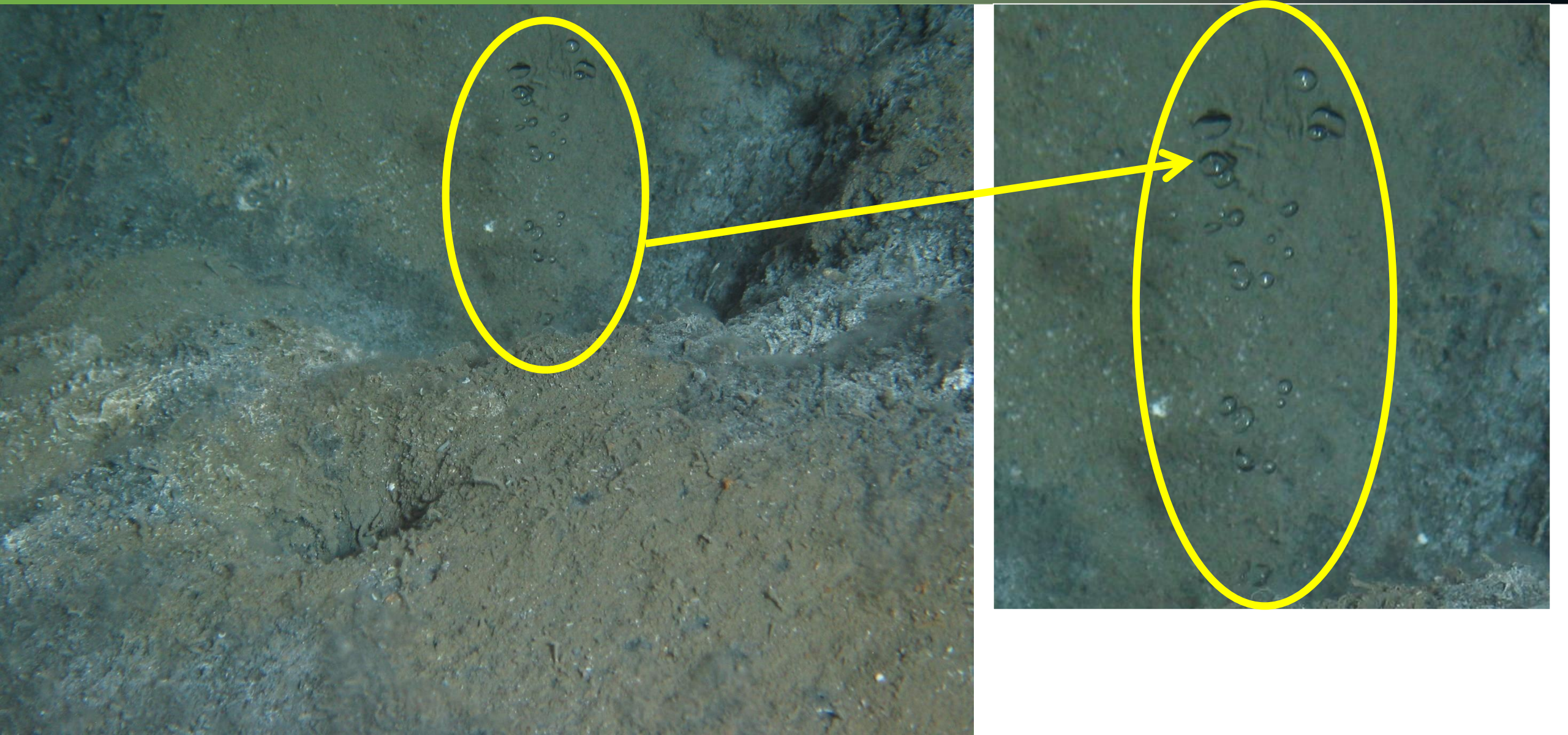


- CH_4 > 200µM
- O_2 up to 160µM
- **H_2S = 0**



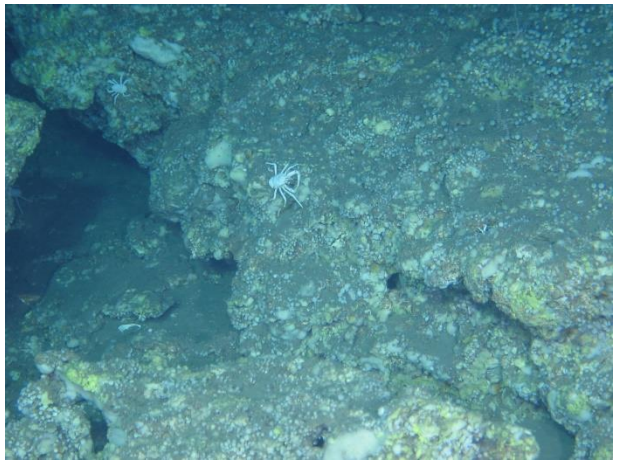
- CH_4 > 200µM
- O_2 to <50µM
- **H_2S to >1000µM**

Cold Seeps – Bubbles

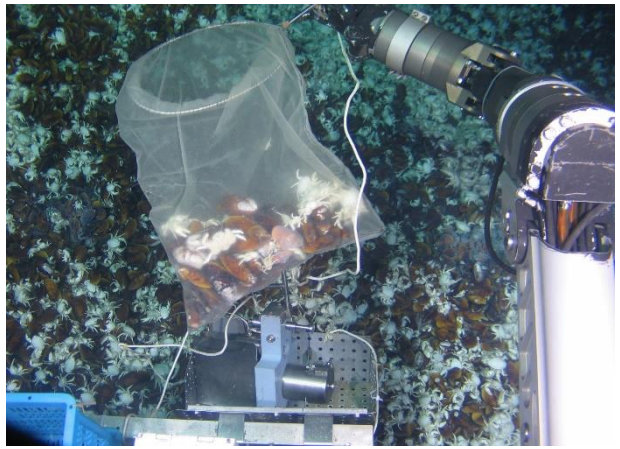


Cold Seeps – Jiaolong Diving @ The South China Sea



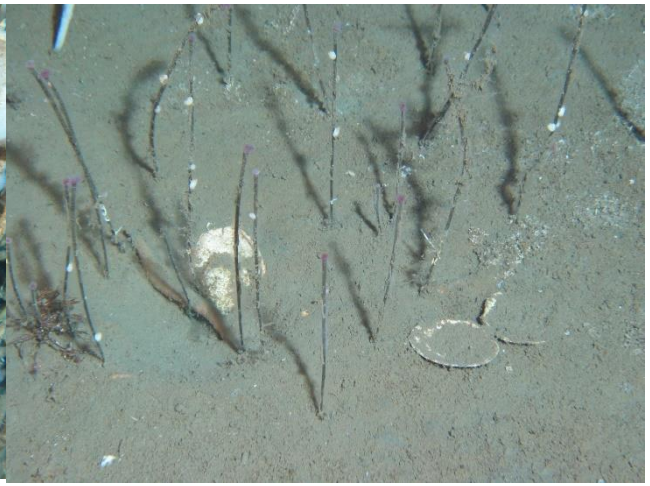







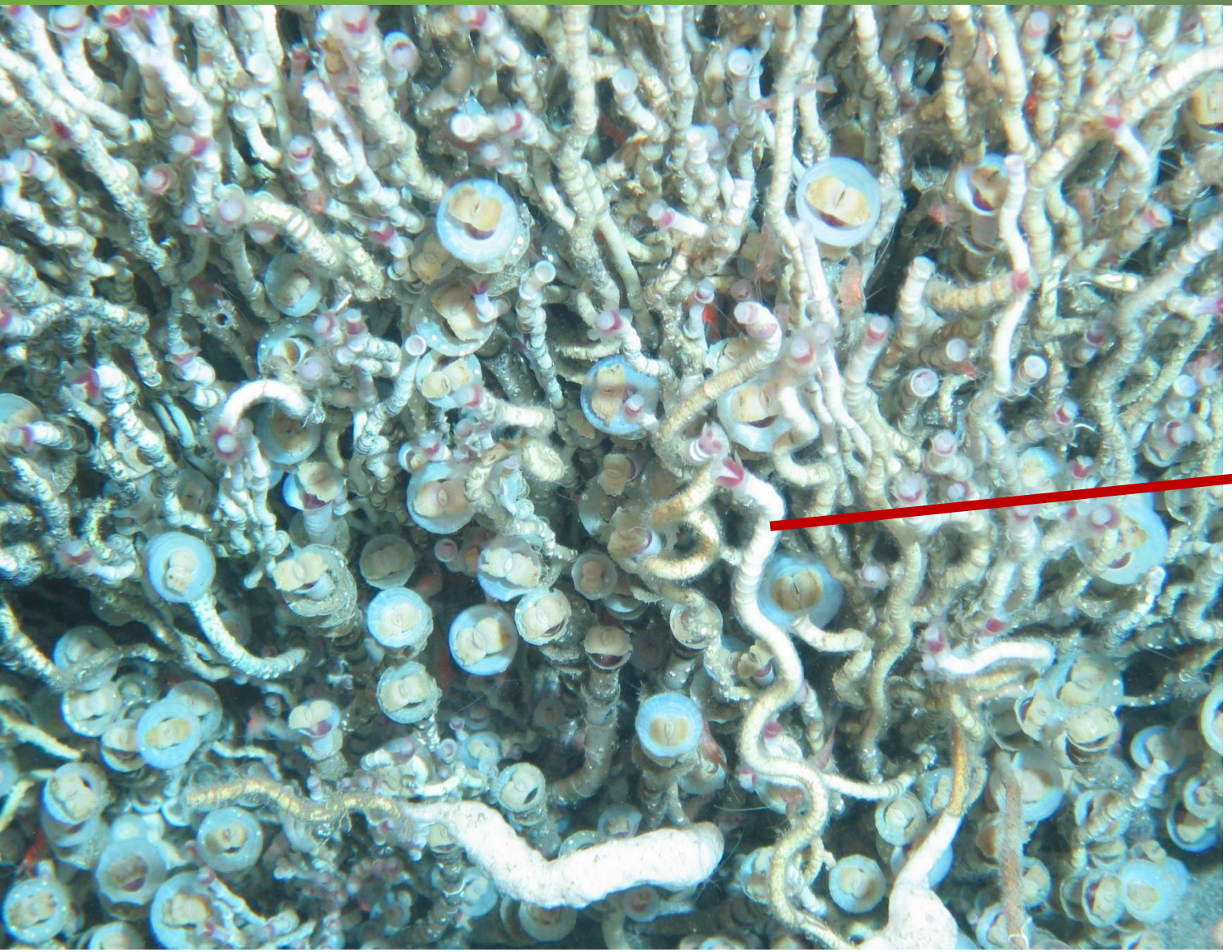
Cold Seeps – The Diversity of Life

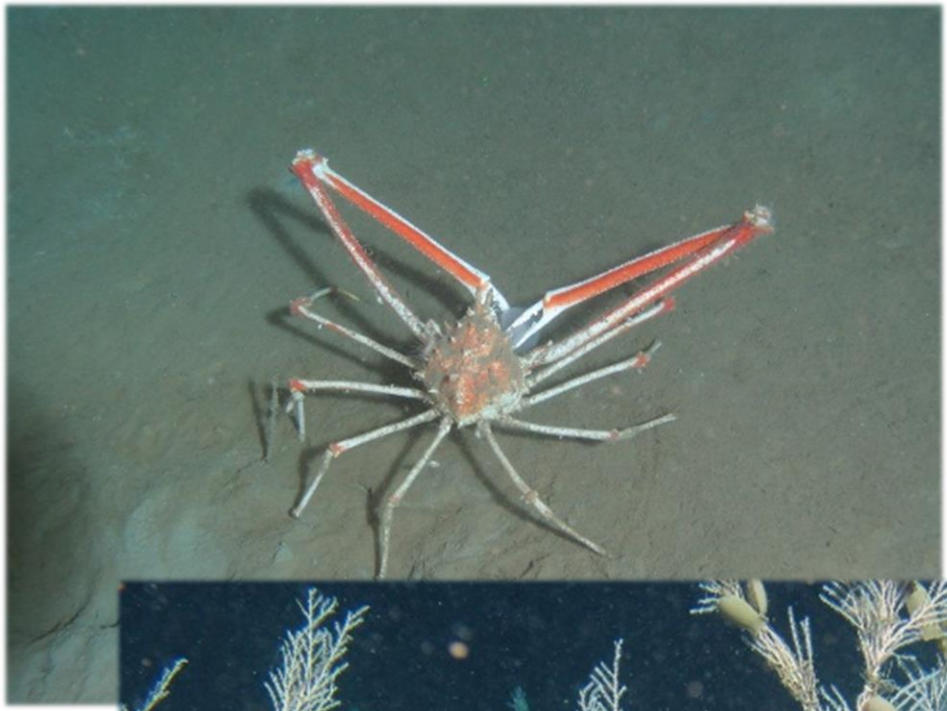


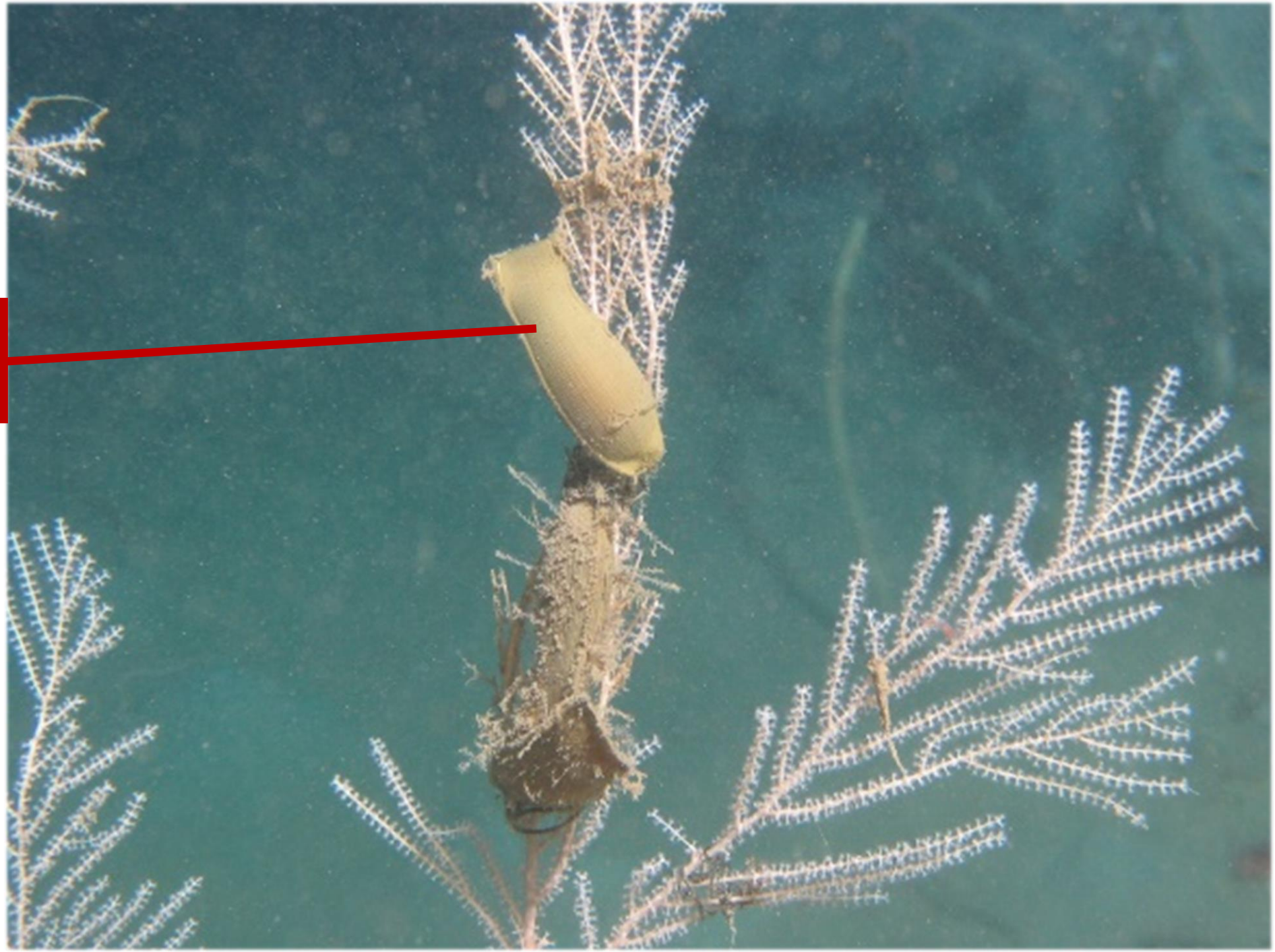


Cold Seeps – The Diversity of Life





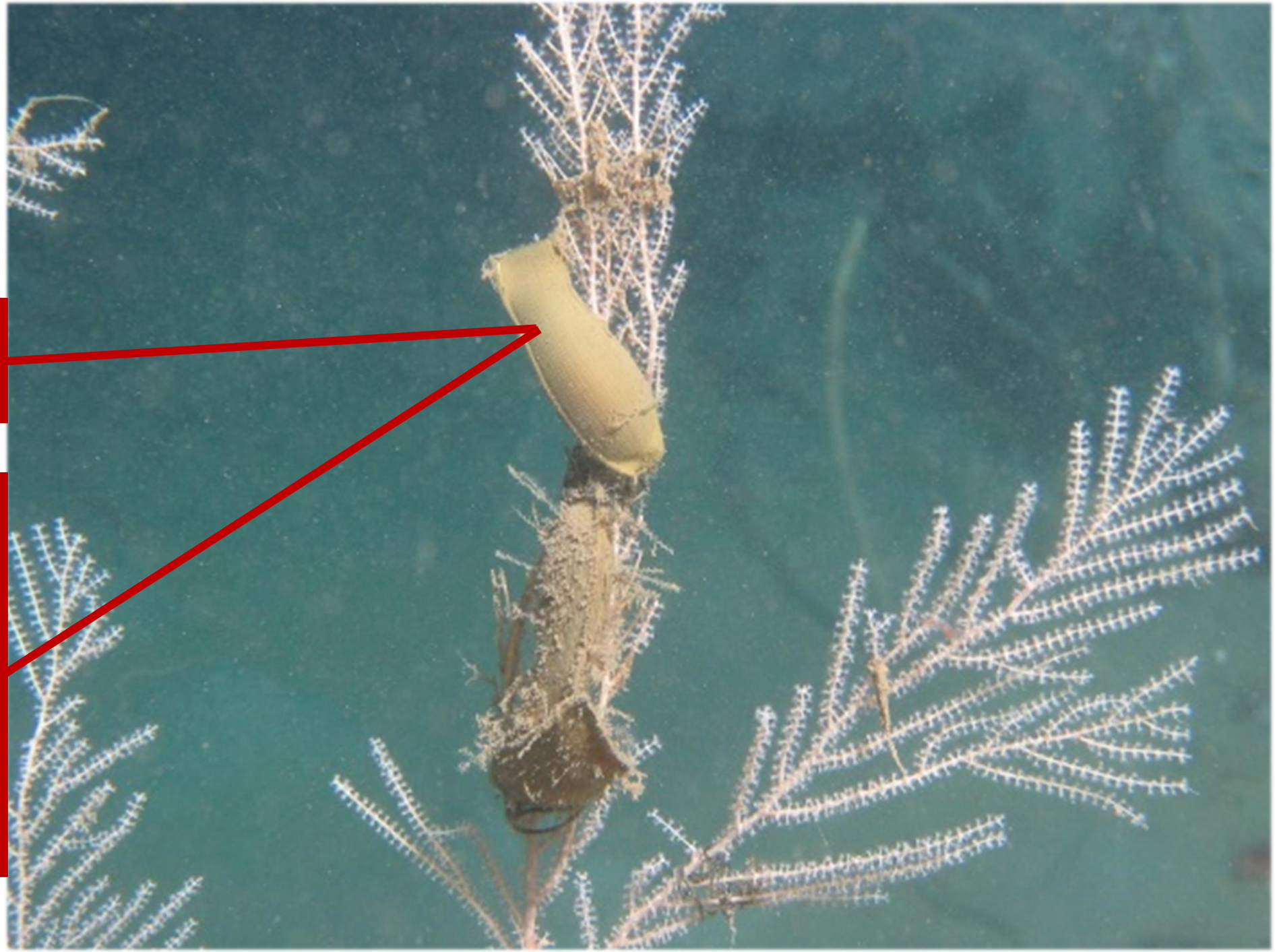
What is this?

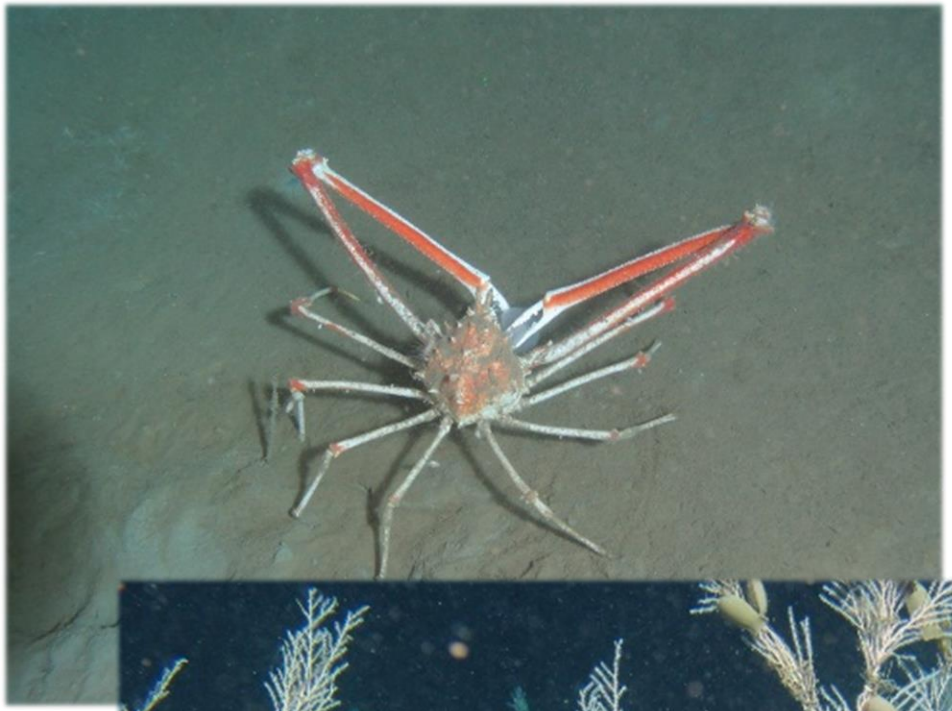


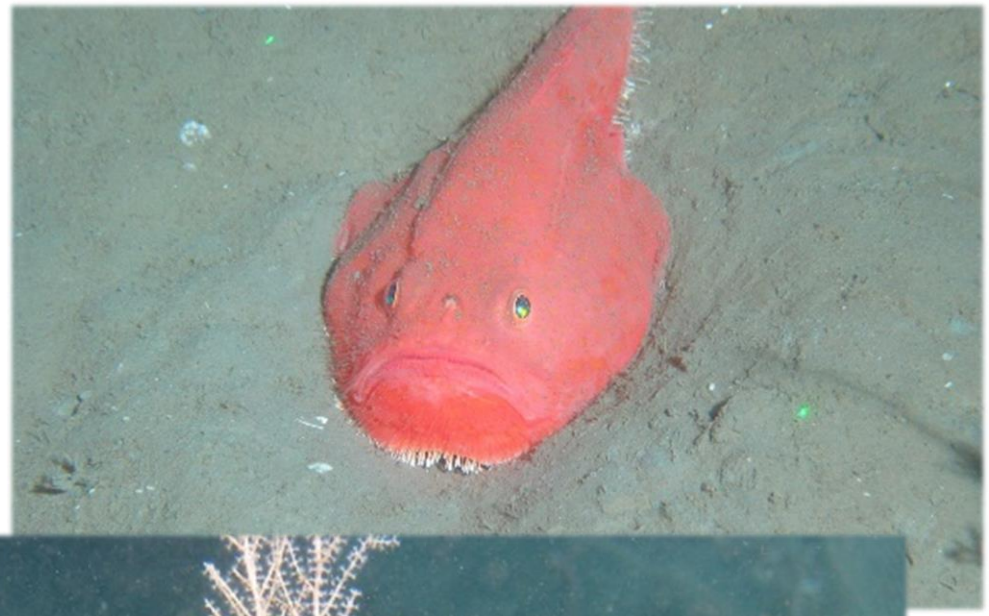
What is this?

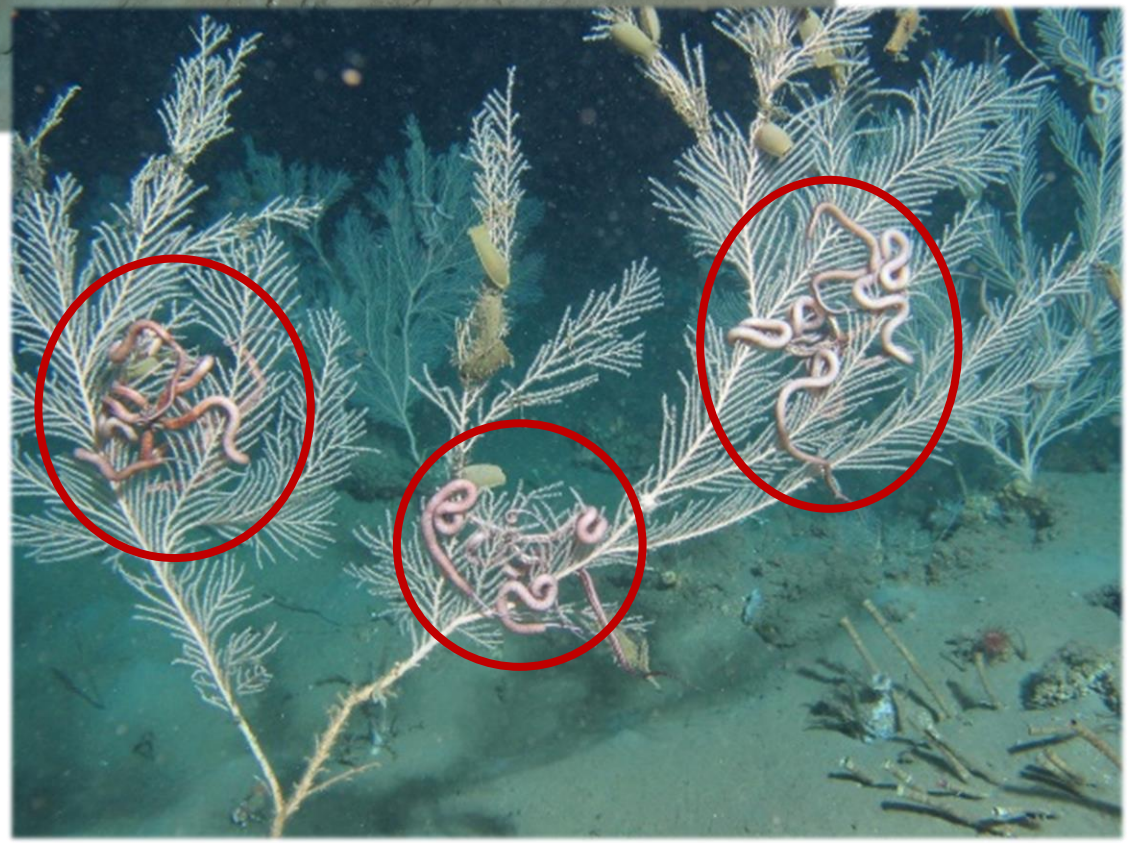
Egg case of sharks

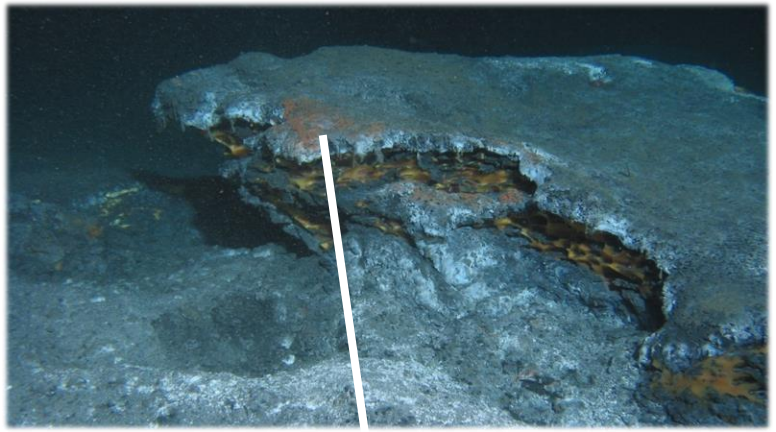
Sharks have laid their eggs here



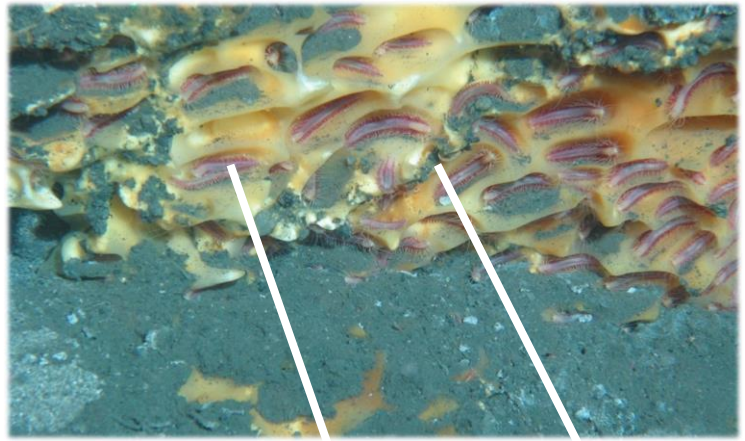




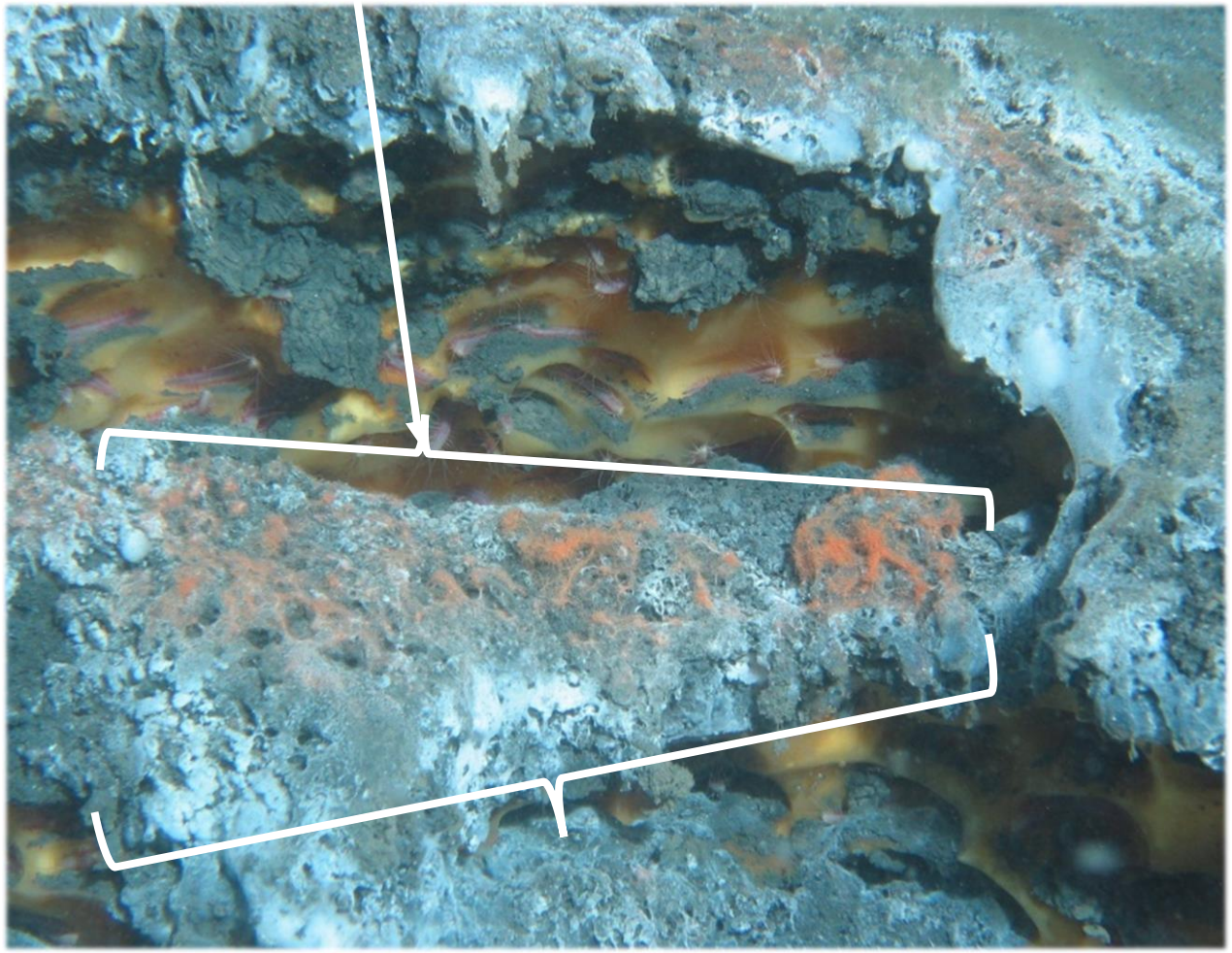


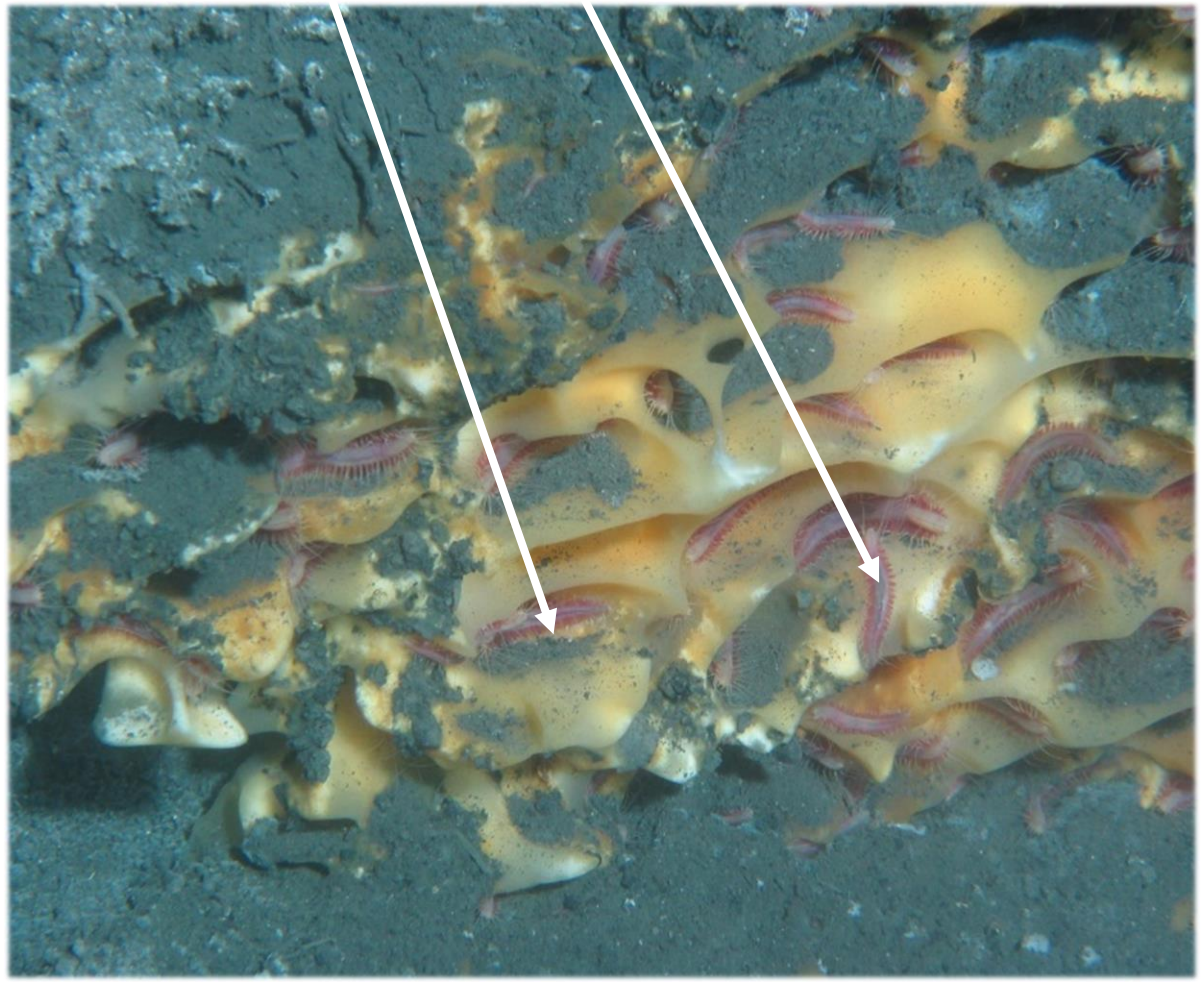


Gas hydrate – clean energy



Worms live on hydrocarbon





Cold Seeps vs. Hydrothermal Vents

	Cold Seeps	Hydrothermal Vents
Water Depth (m)	~200 – 5,000 or more	~500 – 5,000 or more
Temperature	~20 – 140°C	~60 – 550°C
Chemicals Released	• H_2S • CH_4 • Hydrocarbons	• H_2S • Some CH_4 • Heavy metals
Location	Along ocean ridge (where tectonic plates collide or crack) + other areas	Along ocean ridge (where tectonic plates collide or crack)

Summary - Cold Seeps

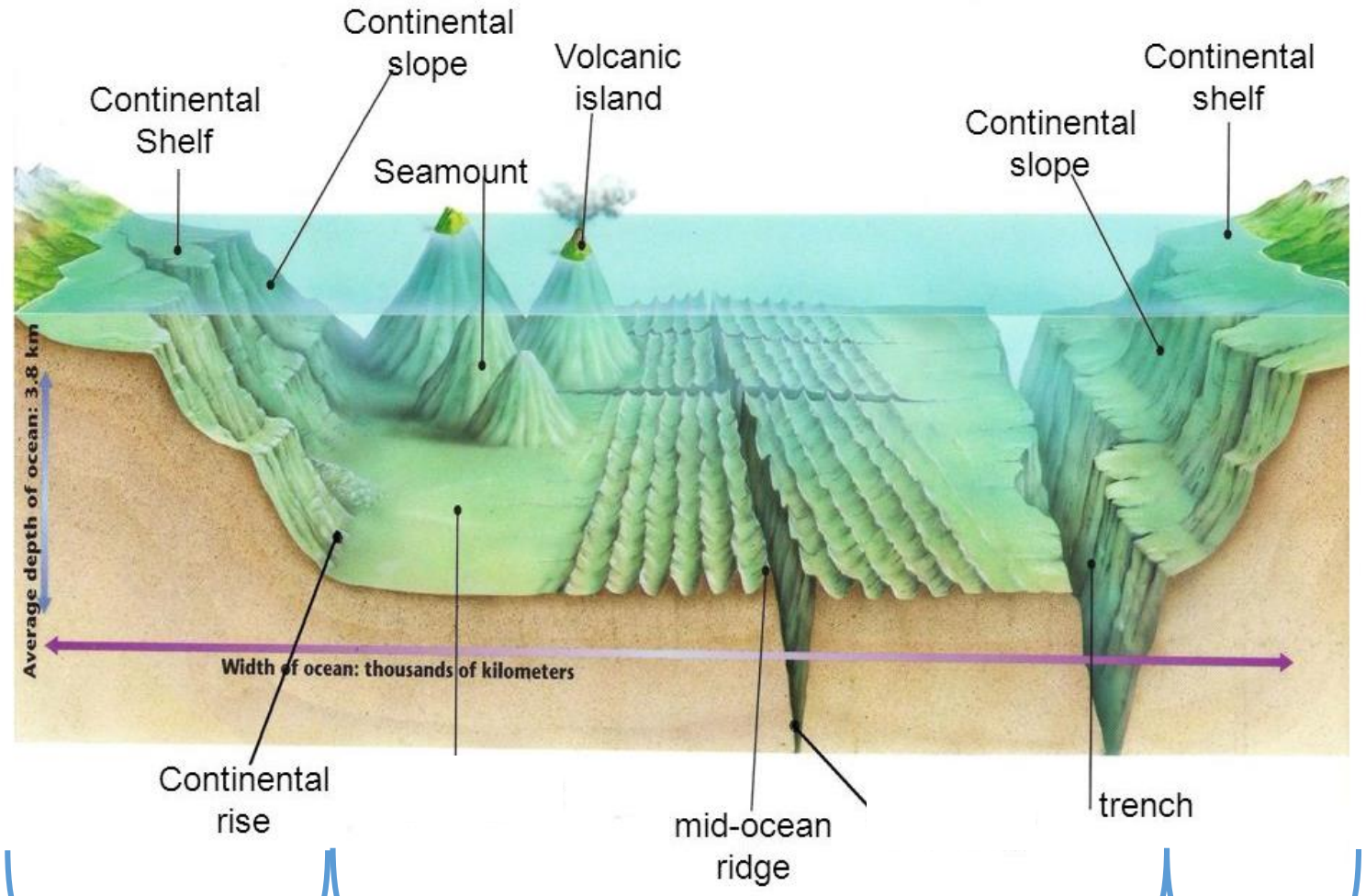
- Another kind of **chemosynthetic** ecosystem

- Why are Cold Seeps important?
  - **Biologically:** **Very rich biodiversity** like Hydrothermal Vents
  - **Ecologically:** **Very dynamic** chemosynthetic ecosystem
  - **Natural Resources:** Gas hydrate and hydrocarbon

DEPARTMENT OF OCEAN SCIENCE

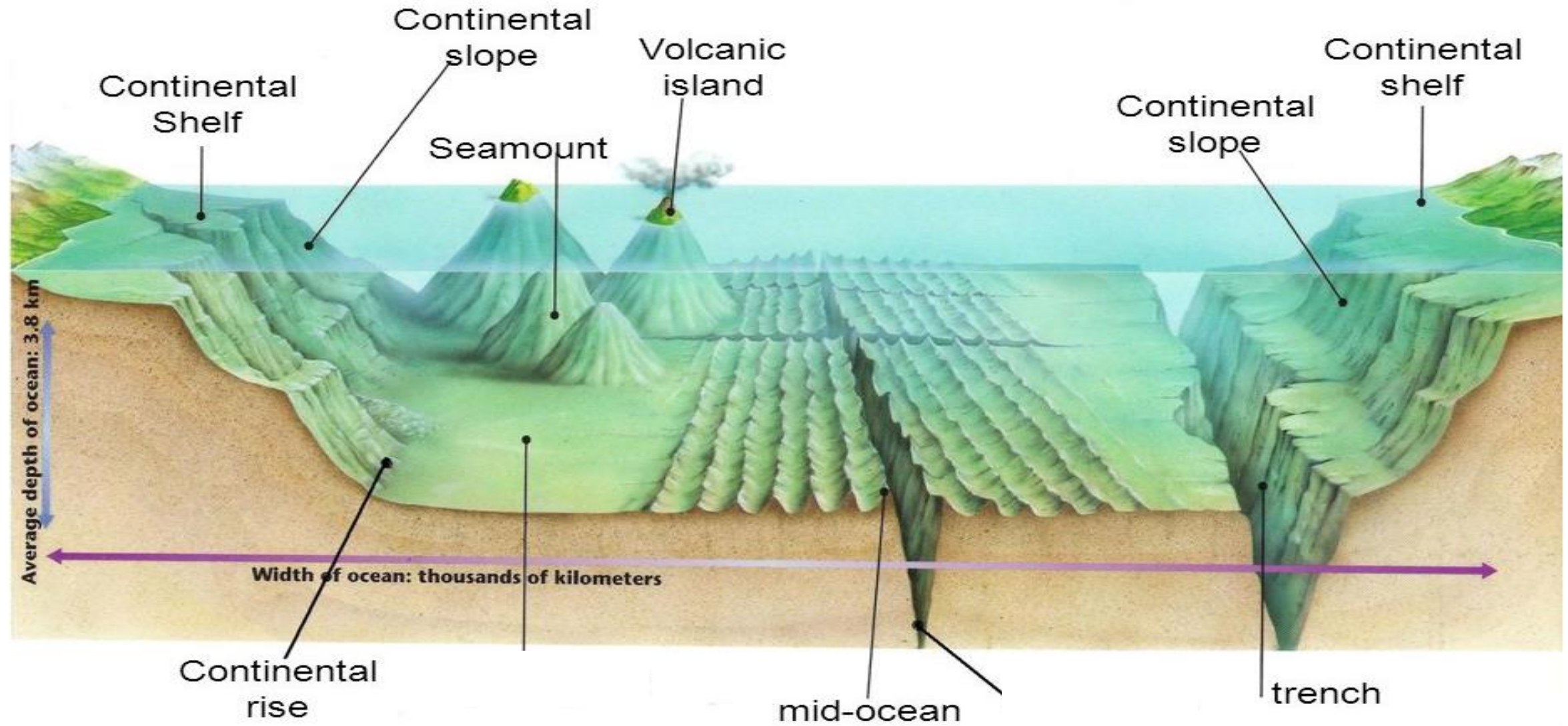
Sea Mounts, Ocean Basins & Ocean Trenches

Features of the Ocean Floor



The ocean floor is not flat

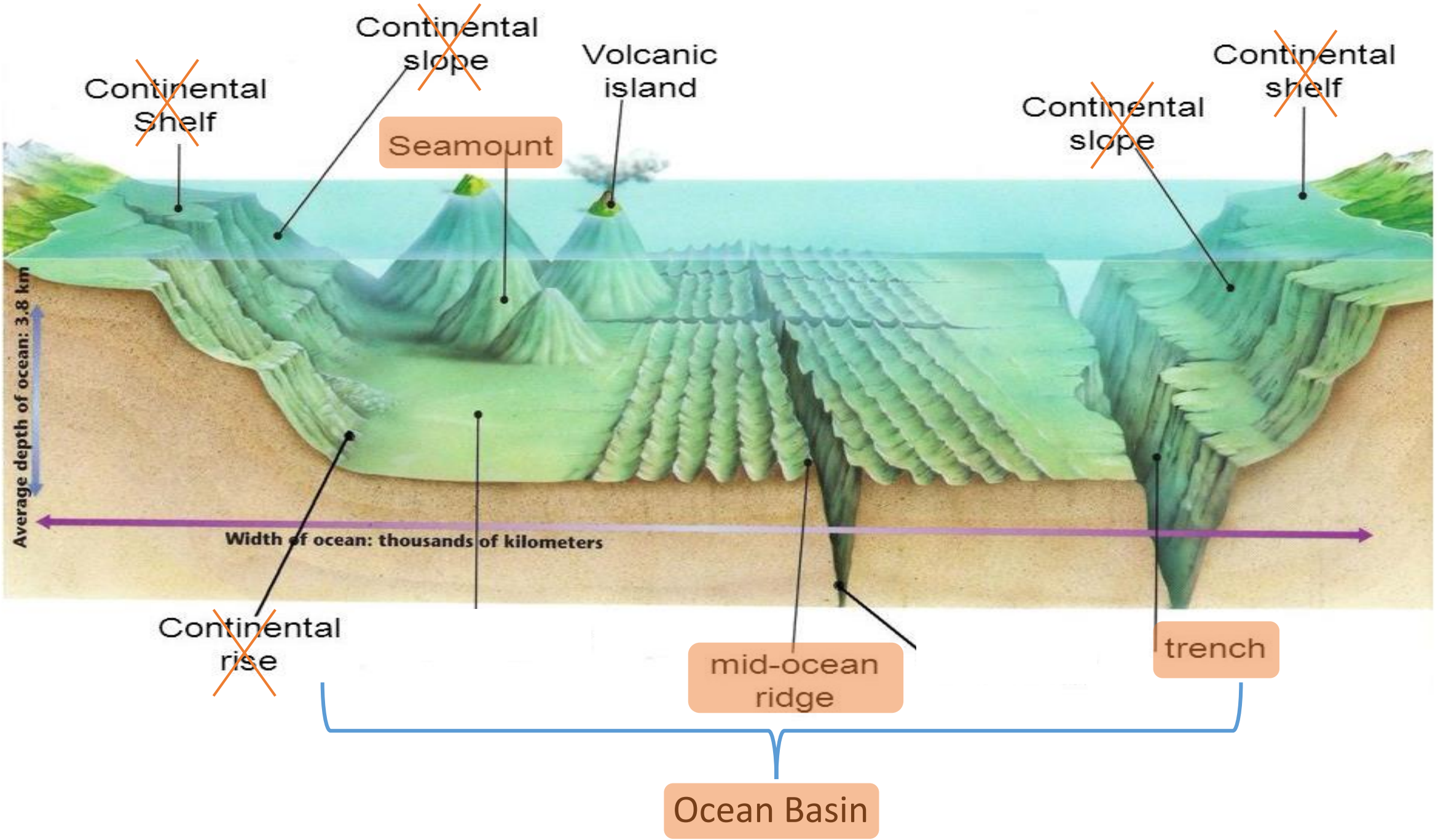
Image from: https://geoteach2017.weebly.com/ocean-morphology.html



Continental Margin

Ocean Basin

Continental Margin


Continental Shelf
Continental slope
Volcanic island
Seamount
Continental slope
Continental shelf
Average depth of ocean: 3.8 km
Width of ocean: thousands of kilometers
Continental rise
mid-ocean ridge
trench
Ocean Basin

Overview – Ecosystems on the Deep-Sea Bed

	Ocean Ridge (active Hydrothermal Vent)	Sea Mount	Ocean Basin	Ocean Trench
Minerals	Sulfide	Crust	Nodule	Unknown
Water Depth (m)	~500 – 5,000 +	~800 – 3,000	~4,000 – 6,000	~6,000 – 11,000
Biodiversity	Low	High	Low	low
Living Conditions	High Temperature High Pressure	---	Low Temperature High Pressure	Low temperature High pressure
Endemicity	High	High	---	High

Overview – Ecosystems on the Deep-Sea Bed

	Ocean Ridge (active Hydrothermal Vent)	Sea Mount	Ocean Basin	Ocean Trench
Minerals	Sulfide	Crust	Nodule	Unknown
Water Depth (m)	~500 – 5,000 +	~800 – 3,000	~4,000 – 6,000	~6,000 – 11,000
Biodiversity	Low	High	Low	low
Living Conditions	High Temperature High Pressure	---	Low Temperature High Pressure	Low temperature High pressure
Endemicity	High	High	---	High

Sulfide deposits found near active hydrothermal vents

Precious metals are associated with sulfide deposits –
Gold, titanium


Image from thirteen.org


Image from Wikipedia

Overview – Ecosystems on the Deep-Sea Bed

	Ocean Ridge (active Hydrothermal Vent)	Sea Mount	Ocean Basin	Ocean Trench
Minerals	Sulfide	Crust	Nodule	Unknown
Water Depth (m)	~500 – 5,000 +	~800 – 3,000	~4,000 – 6,000	~6,000 – 11,000
Biodiversity	Low	High	Low	low
Living Conditions	High Temperature High Pressure	---	Low Temperature High Pressure	Low temperature High pressure
Endemicity	High	High	---	High


(Sea Mount)
Crusts are rich in heavy metal deposits
https://worldoceanreview.com/en/wor-3/mineral-resources/cobalt-crusts/2/

Overview – Ecosystems on the Deep-Sea Bed

	Ocean Ridge (active Hydrothermal Vent)	Sea Mount	Ocean Basin	Ocean Trench
Minerals	Sulfide	Crust	Nodule	Unknown
Water Depth (m)	~500 – 5,000 +	~800 – 3,000	~4,000 – 6,000	~6,000 – 11,000
Biodiversity	Low	High	Low	low
Living Conditions	High Temperature High Pressure	---	Low Temperature High Pressure	Low temperature High pressure
Endemicity	High	High	---	High

Ocean Basin - Nodules

https://worldoceanreview.com/en/wor-3/mineral-resources/manganese-nodules/

Overview – Ecosystems on the Deep-Sea Bed

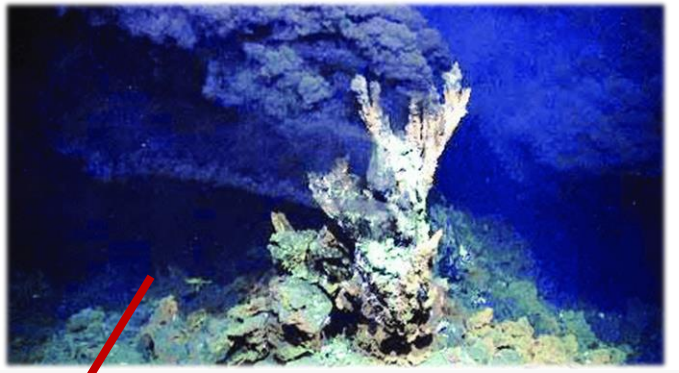
	Ocean Ridge (active Hydrothermal Vent)	Sea Mount	Ocean Basin	Ocean Trench
Minerals	Sulfide	Crust	Nodule	Unknown
Water Depth (m)	~500 – 5,000 +	~800 – 3,000	~4,000 – 6,000	~6,000 – 11,000
Biodiversity	Low	High	Low	low
Living Conditions	High Temperature High Pressure	---	Low Temperature High Pressure	Low temperature High pressure
Endemicity	High	High	---	High

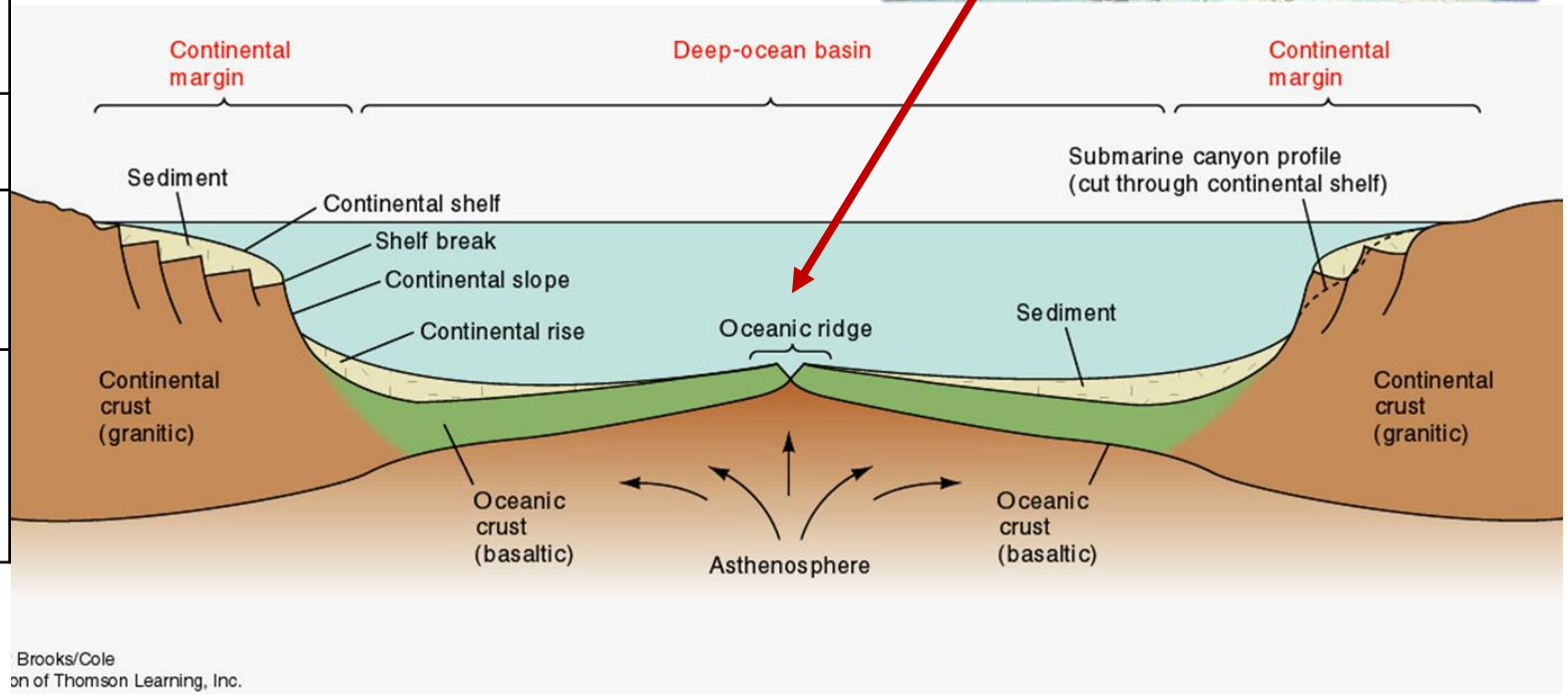
Ecosystems on the Deep-Sea Bed – *Ocean Ridge*

	Ocean Ridge (active Hydrothermal Vent)
Minerals	Sulfide
Water Depth (m)	~500 – 5,000 +
Biodiversity	Low
Living conditions	High Temperature High Pressure
Endemicity	Low

Ocean Ridge:
A mountain-like structure formed under the sea due to volcanic eruptions on the ocean floor

Hydrothermal vents





Ecosystems on Deep-Sea Bed – *Sea Mount*

	Ocean Ridge (active Hydrothermal Vent)	Sea Mount
Minerals	Sulfide	Crust
Water Depth (m)	~500 – 5,000 +	~800 – 3,000
Biodiversity	Low	High
Living Conditions	High Temperature High Pressure	---
Endemicity	Low	---

Sea Mount:
A large underwater mountain that does not reach the water surface

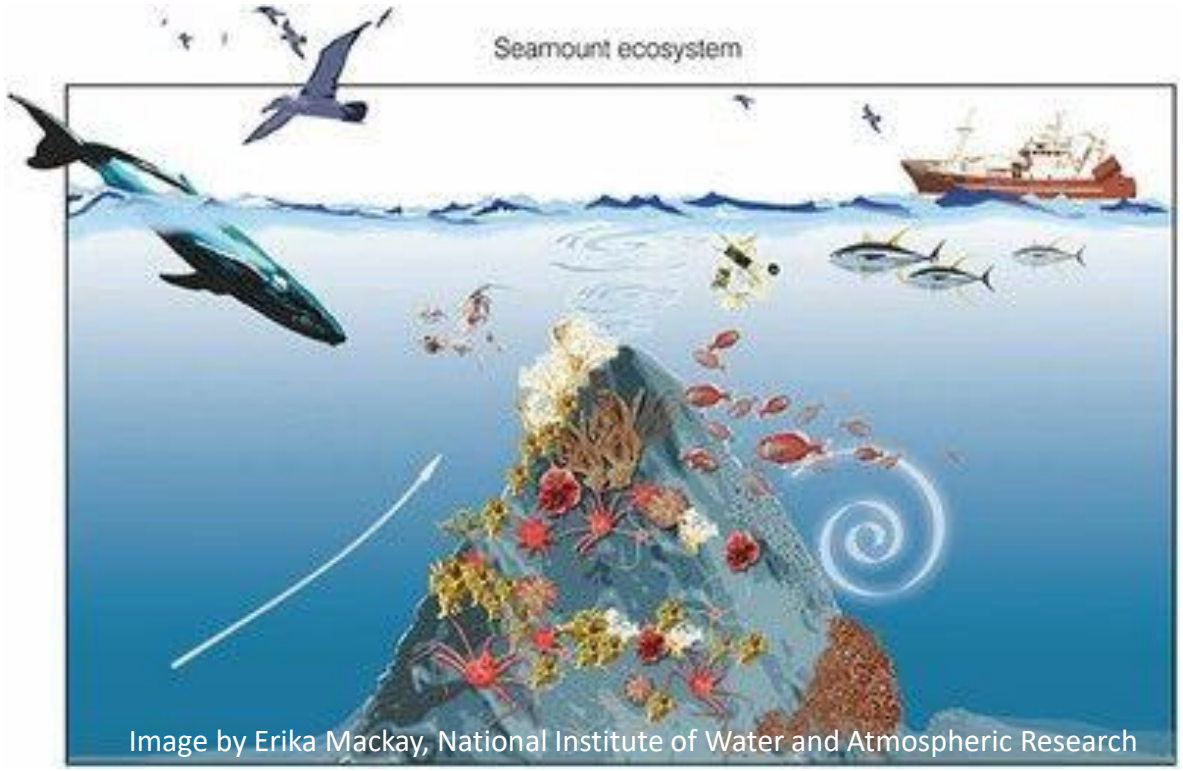
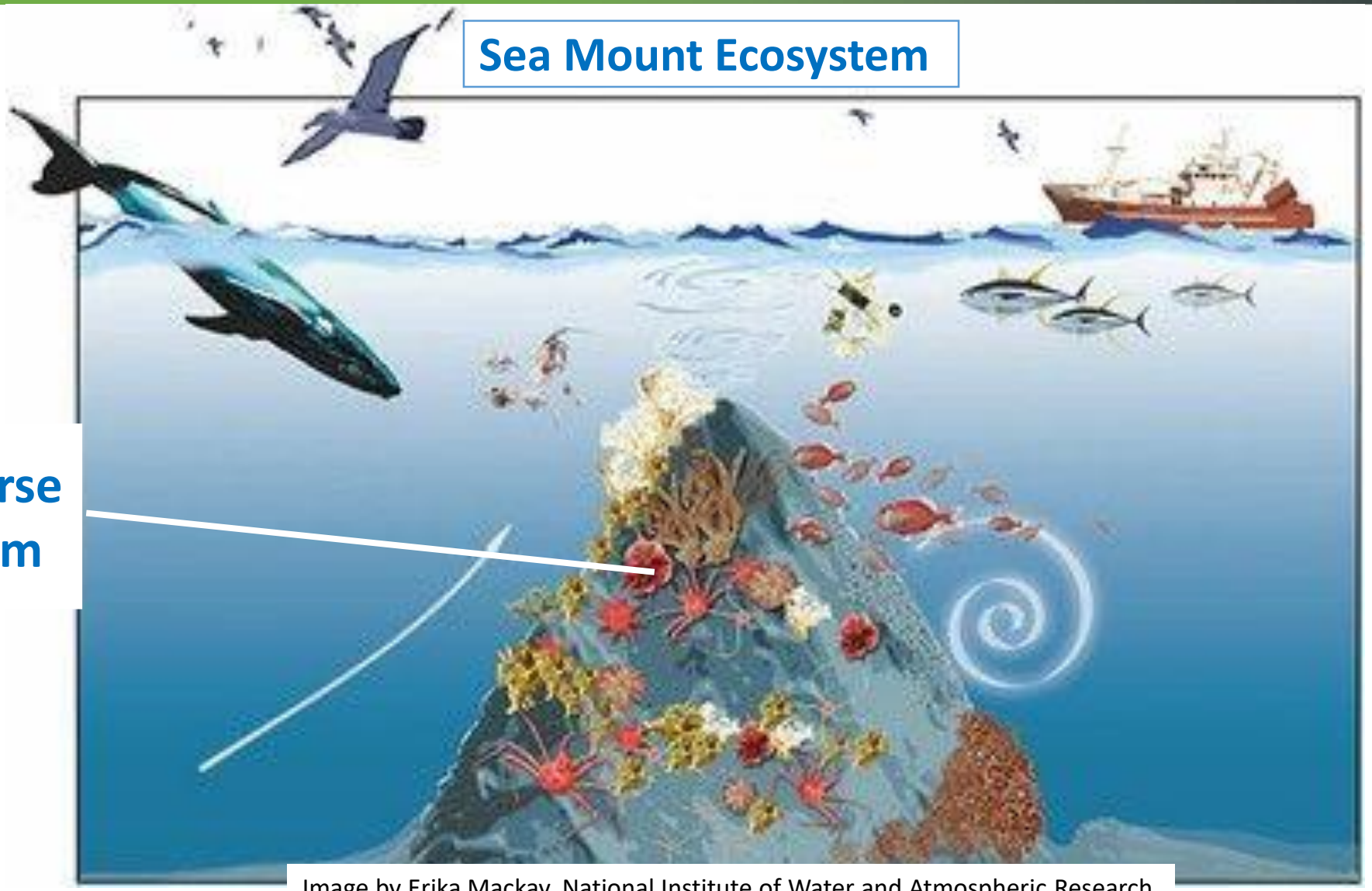


Image by Erika Mackay, National Institute of Water and Atmospheric Research

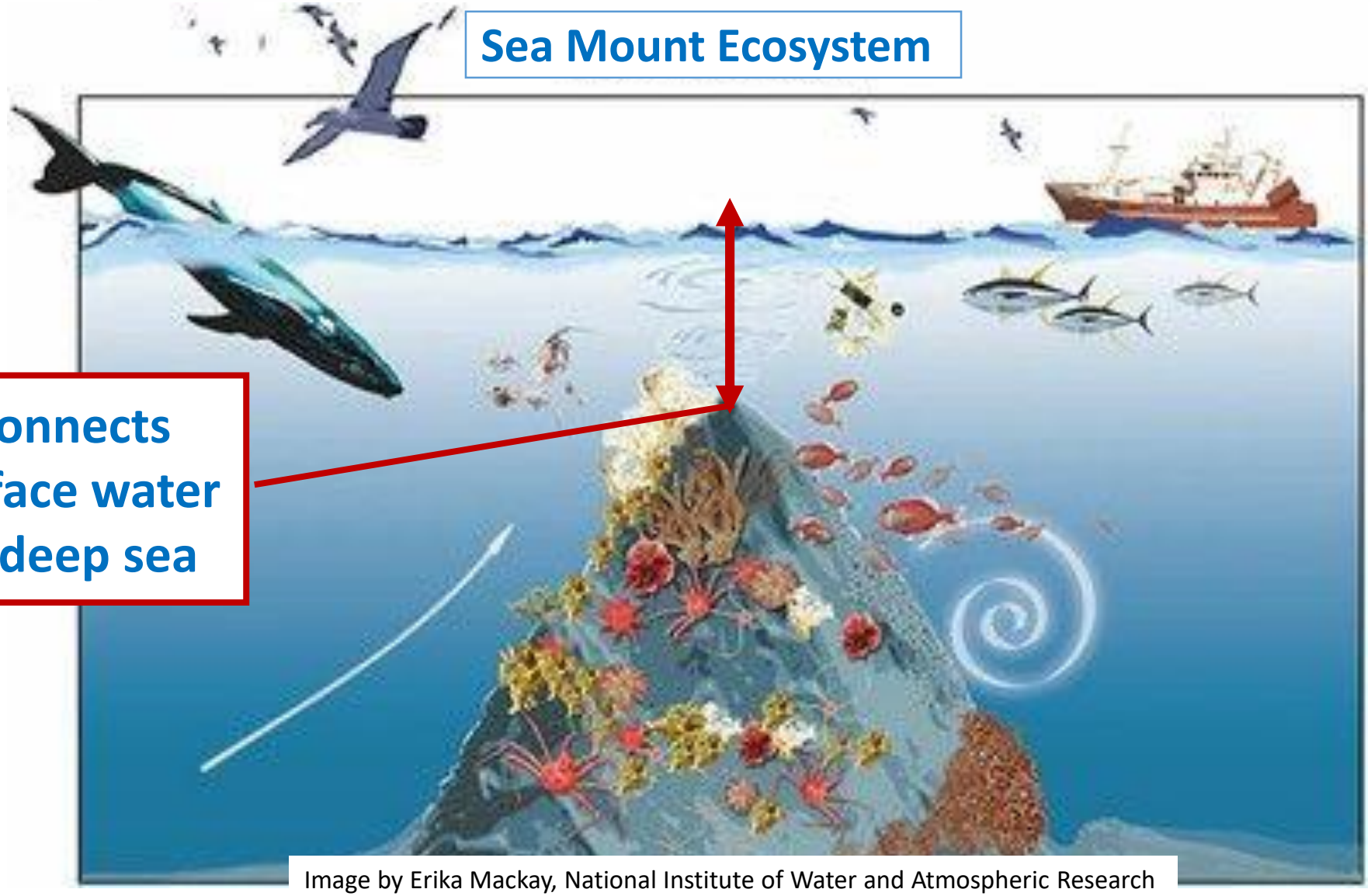
Sea Mount Ecosystem



Very diverse ecosystem

Image by Erika Mackay, National Institute of Water and Atmospheric Research

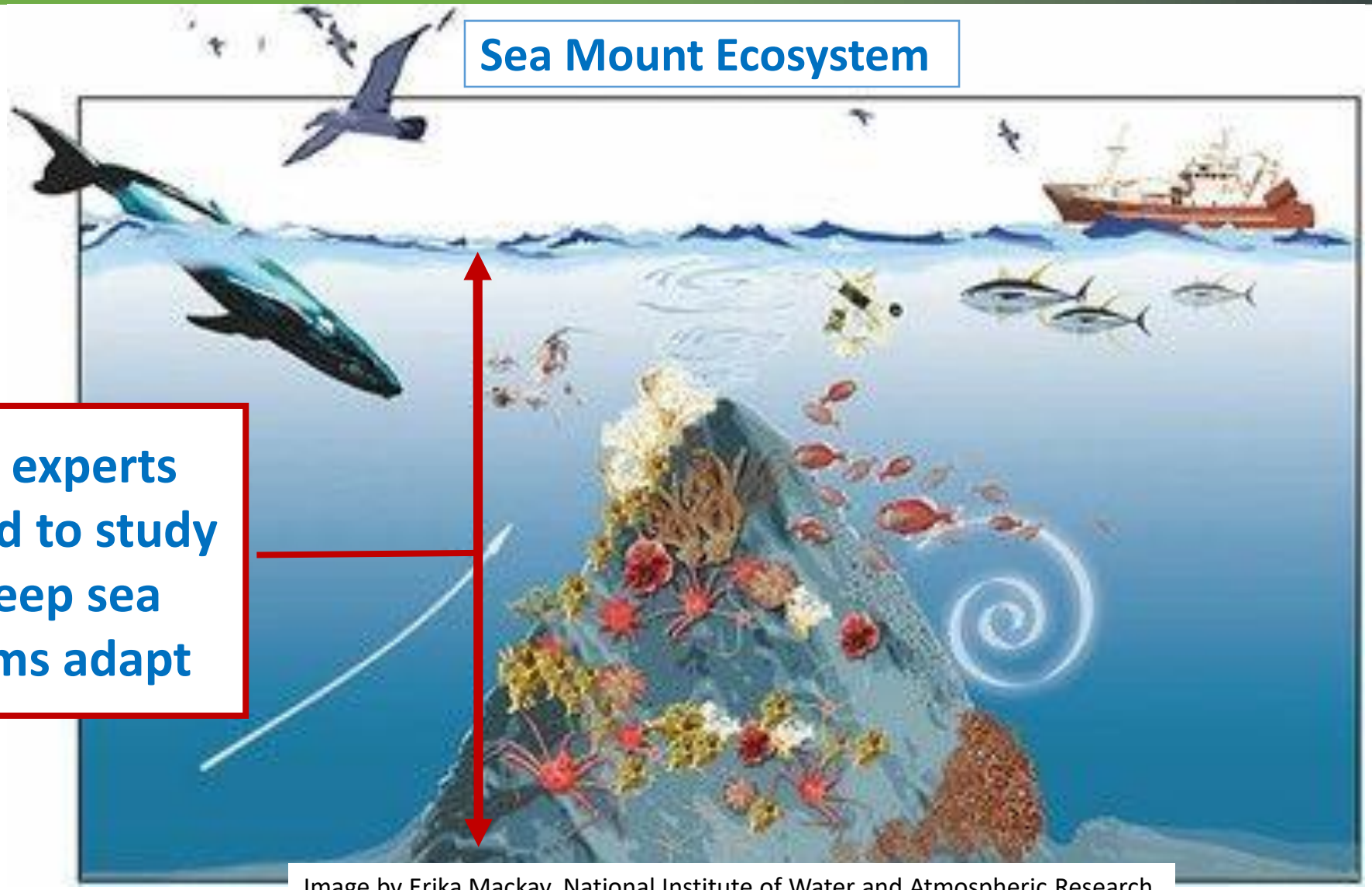
Sea Mount Ecosystem



Connects surface water to deep sea

Image by Erika Mackay, National Institute of Water and Atmospheric Research

Sea Mount Ecosystem



Marine experts interested to study how deep sea organisms adapt

Image by Erika Mackay, National Institute of Water and Atmospheric Research

Ecosystems on the Deep-Sea Bed – *Ocean Basin*

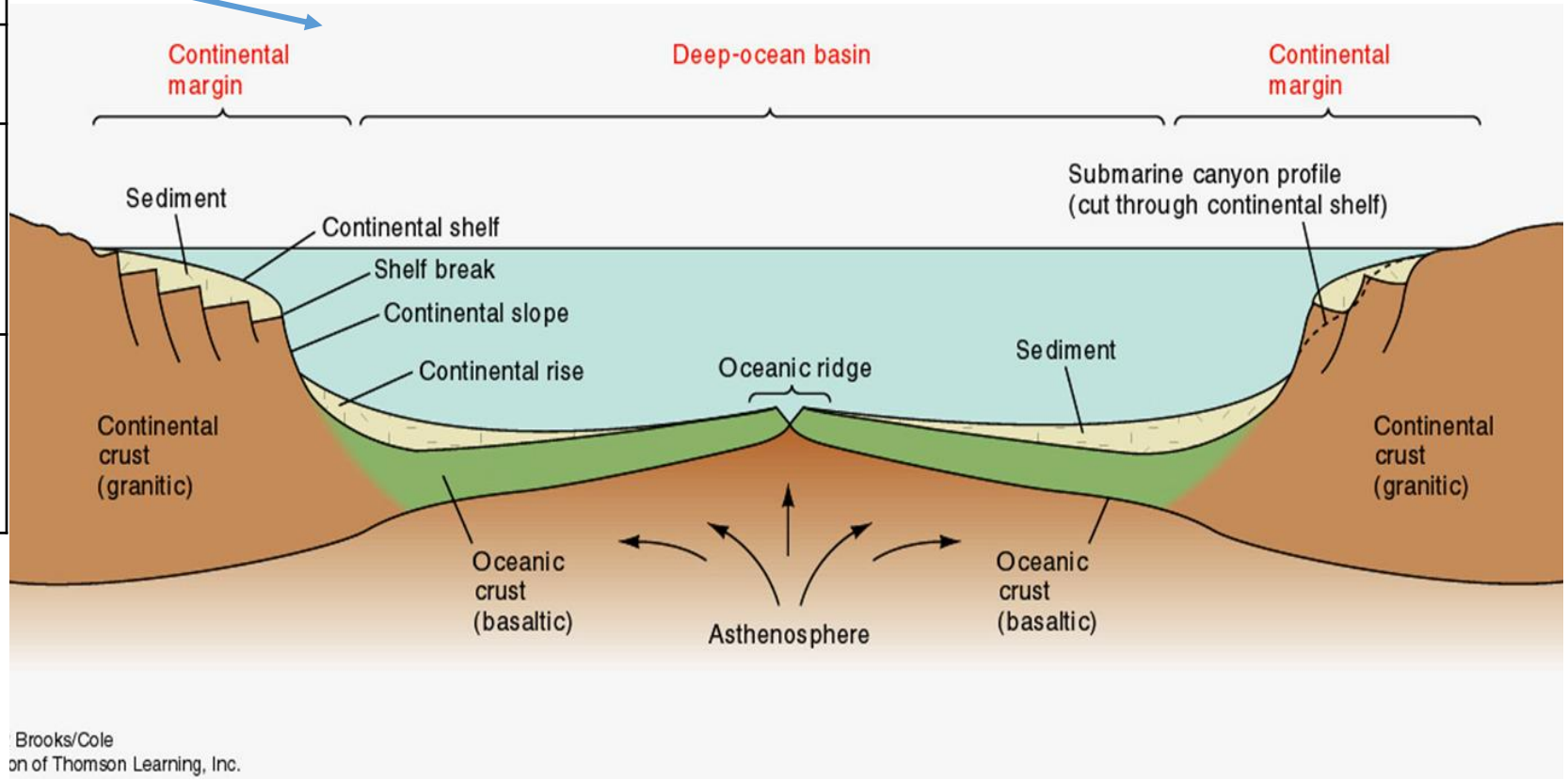
	Ocean Ridge (active Hydrothermal Vent)	Sea Mount	Ocean Basin
Minerals	Sulfide	Crust	Nodule
Water Depth (m)	~500 – 5,000 +	~800 – 3,000	~4,000 – 6,000
Biodiversity	Low	High	Low
Living Conditions	High Temperature High Pressure	---	Low Temperature High Pressure
Endemicity	High	High	---

Ecosystems on the Deep Sea Bed – *Ocean Basin*

	Ocean Basin
Minerals	Nodule
Water Depth (m)	~4,000 – 6,000
Biodiversity	Low
Living Conditions	Low Temperature High Pressure
Endemicity	---

Ocean Basin:

- All land that is covered by sea water
- Includes the Continental Margin



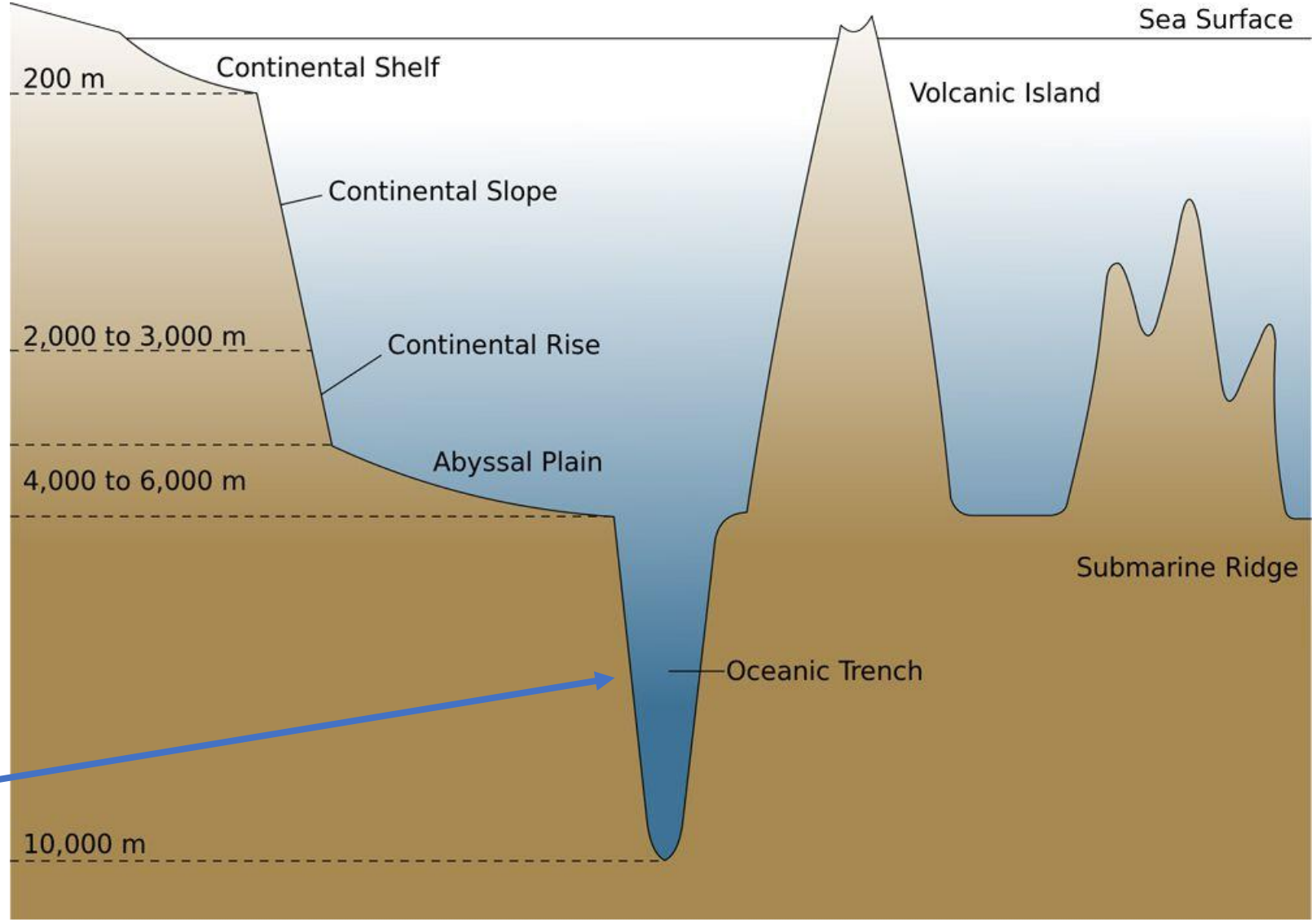
Ecosystems on the Deep-Sea Bed – *Ocean Trench*

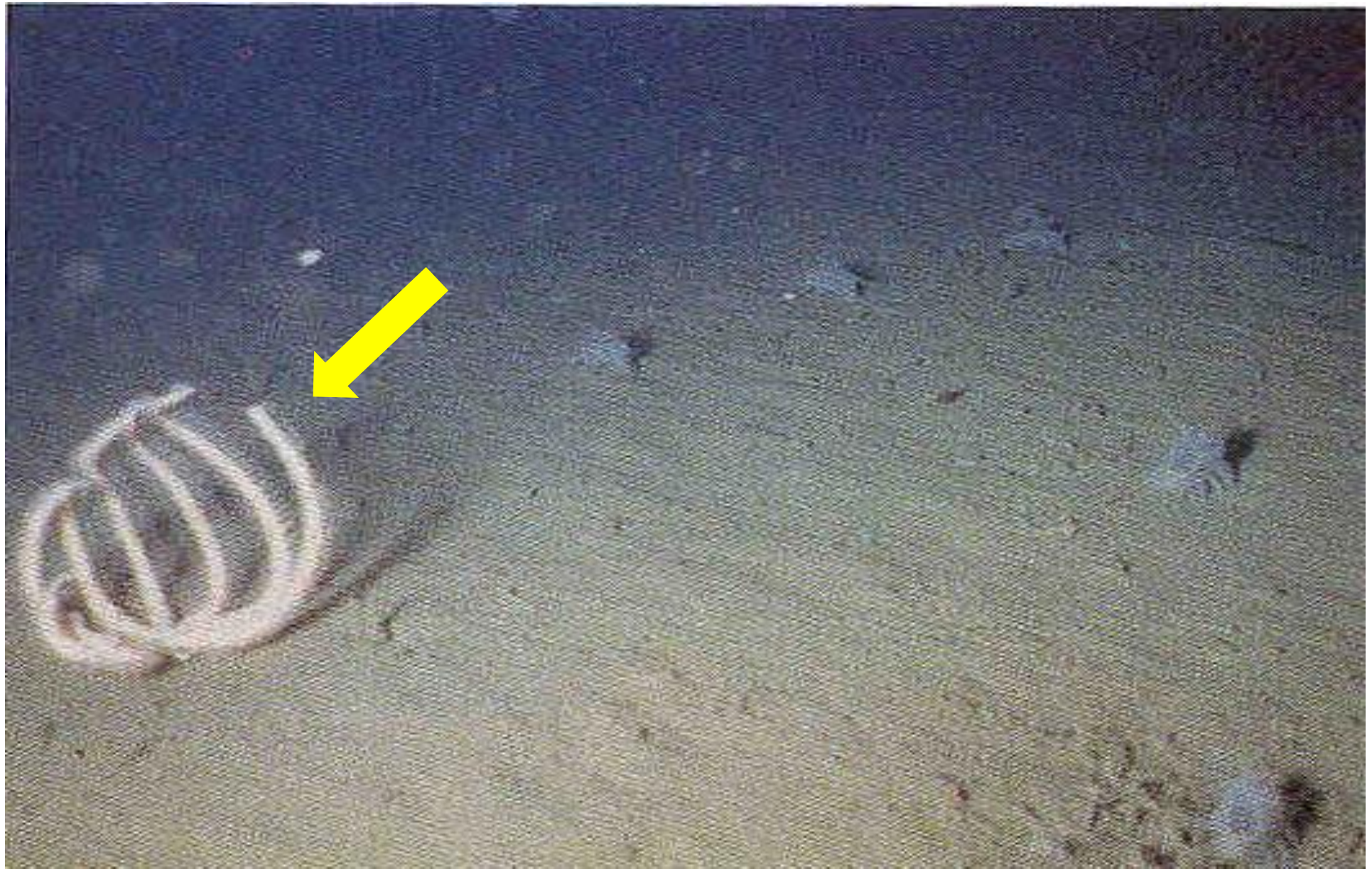
	Ocean Ridge (active Hydrothermal Vent)	Sea Mount	Ocean Basin	Ocean Trench
Minerals	Sulfide	Crust	Nodule	Unknown
Water Depth (m)	~500 – 5,000 +	~800 – 3,000	~4,000 – 6,000	~6,000 – 11,000
Biodiversity	Low	High	Low	Low
Living Conditions	High Temperature High Pressure	---	Low Temperature High Pressure	Low temperature High pressure
Endemicity	High	High	---	High

Ecosystems on the Deep-Sea Bed – *Ocean Trench*

	Ocean Trench
Minerals	Unknown
Water Depth (m)	~6,000 – 11,000
Biodiversity	Low
Living Conditions	Low temperature High pressure
Endemicity	High

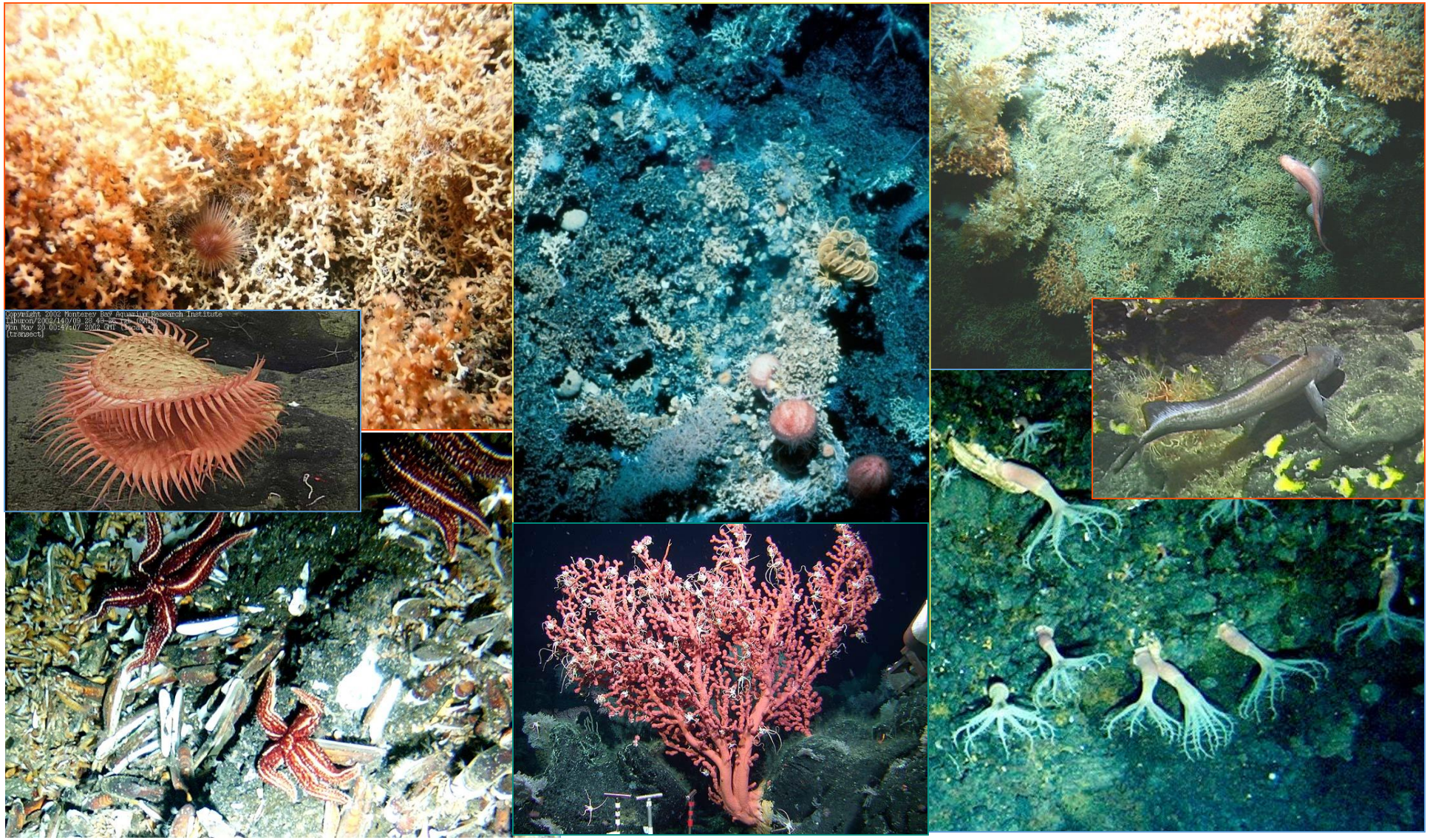
Ocean Trench:
Long, narrow depression on the ocean floor





A typical deep-sea starfish.

Sea Mounts – The Diversity of Life



Summary – Sea Mounts, Ocean Basins & Ocean Trenches

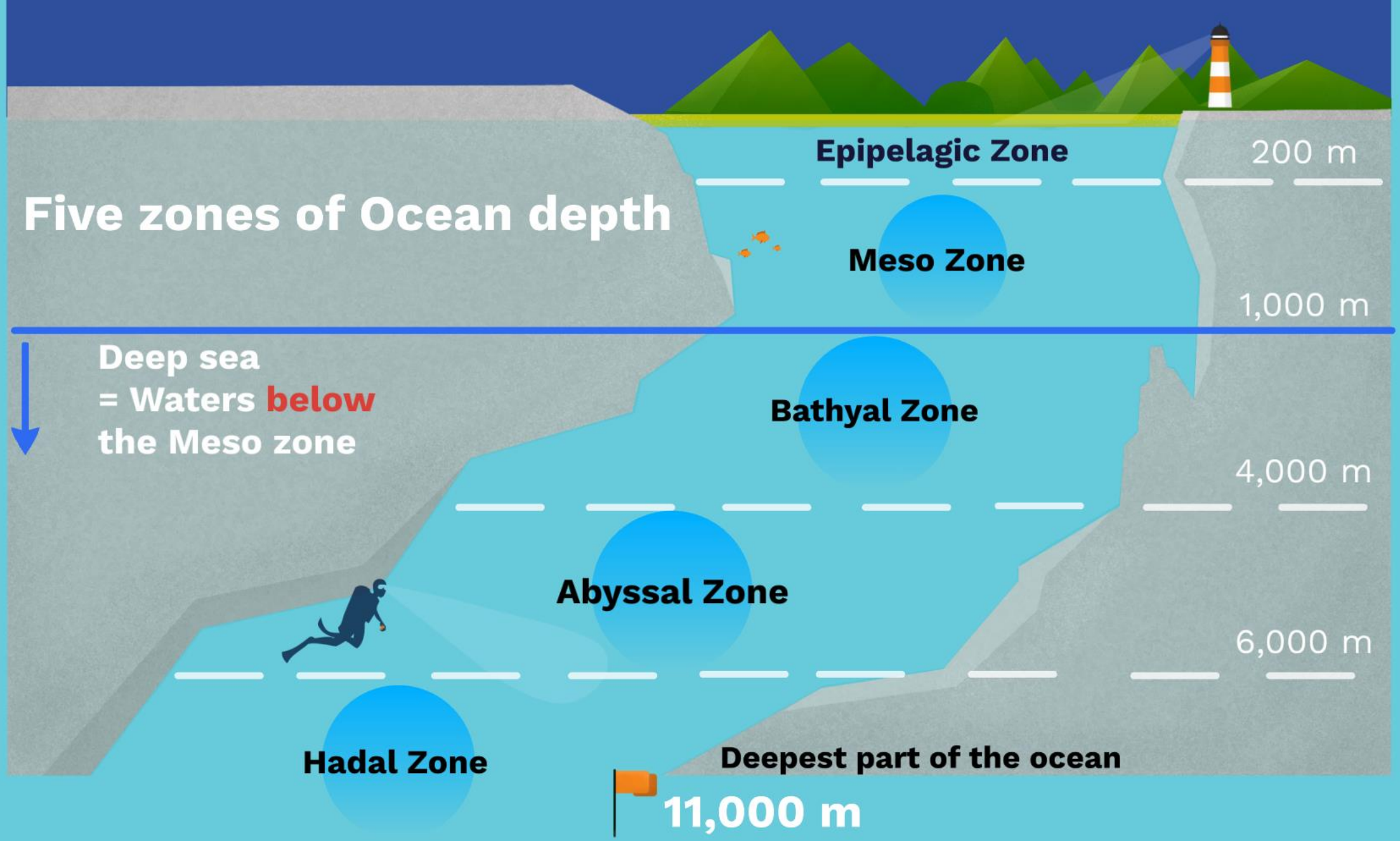
- **Seafloor – Not flat**
  - **Unique ecosystems and resources**

- **Seamounts – More diverse than the other parts of the sea floor**
  - Other parts of the sea floor – more like an *ocean desert*

DEPARTMENT OF OCEAN SCIENCE

Summary:

Marine Ecosystems – The Deep Sea



Click to watch: https://prezi.com/p/2h-07rxm5nnu/deep-sea-4-zone/

Learning Outcomes

After this part of Module III, students are expected to be able to learn more about the following topics:

- **Deep Sea** – The largest ecosystem on our planet but least explored
- **Challenges in deep-sea research** – Realize the difficulties for us to investigate the deep-sea habitats
- **Challenges to the deep-sea life** – Understand how deep-sea organisms adapt to the environment
- **Chemosynthesis in the ecosystem** – Understand how the deep-sea ecosystem functions *without* sunlight
- **Understanding of deep-sea life** – Provide solutions for the future of humankind

Why should I study the Deep Sea?

Learning Outcomes

After this part of Module III, students are expected to be able to learn more about the following topics:

- **Deep Sea** – The largest ecosystem on our planet but least explored

Learning Outcomes

After this part of Module III, students are expected to be able to learn more about the following topics:

- **Deep Sea** – The largest ecosystem on our planet but least explored

- **Challenges in deep-sea research** – Realize the difficulties for us to investigate the deep-sea habitats
  - Physical limitations in the deep sea
  - Limited technology to deal with hydrostatic pressure
  - Very expensive
  - In future, advanced technology will make it easier and cheaper to explore

Learning Outcomes

After this part of Module III, students are expected to be able to learn more about the following topics:

- **Deep Sea** – The largest ecosystem on our planet but least explored
- **Challenges in deep-sea research** – Realize the difficulties for us to investigate the deep-sea habitats
- **Challenges to the deep-sea life** – Understand how deep-sea organisms adapt to the environment
  - How do they survive under high hydrostatic pressure?
  - Under low temperature and darkness
  - With limited food supply

Understanding adaptations in extreme environment can help human civilization

Learning Outcomes

After this part of Module III, students are expected to be able to learn more about the following topics:

- **Deep Sea** – The largest ecosystem on our planet but least explored
- **Challenges in deep-sea research** – Realize the difficulties for us to investigate the deep-sea habitats
- **Challenges to the deep-sea life** – Understand how deep-sea organisms adapt to the environment
- **Chemosynthesis in the ecosystem** – Understand how the deep-sea ecosystem functions *without* sunlight
  - Microbes (bacteria) use chemically rich environment to make energy, in which deep sea organisms feed on, enabling both to live and thrive in such environment
  - Very rich biodiversity and unique interaction in such chemically rich environment

Learning Outcomes

After this part of Module III, students are expected to be able to learn more about the following topics:

- **Deep Sea** – The largest ecosystem on our planet but least explored
- **Challenges in deep-sea research** – Realize the difficulties for us to investigate the deep-sea habitats
- **Challenges to the deep-sea life** – Understand how deep-sea organisms adapt to the environment
- **Chemosynthesis in the ecosystem** – Understand how the deep-sea ecosystem functions *without* sunlight
- **Understanding of deep-sea life & geography** – Understand history and evolution of life to help provide solutions for the future of humankind.
  - Deep Sea environment is not flat with very diverse life found in Sea mounts, ridges, trenches, ocean basins

Learning Outcomes

After this part of Module III, students are expected to be able to learn more about the following topics:

- **Deep Sea** – The largest ecosystem on our planet but least explored
- **Challenges in deep-sea research** – Realize the difficulties for us to investigate the deep-sea habitats
- **Challenges to the deep-sea life** – Understand how deep-sea organisms adapt to the environment
- **Chemosynthesis in the ecosystem** – Understand how the deep-sea ecosystem functions *without* sunlight
- **Understanding of deep-sea life** – Provide solutions to the future of humankind

→ Why should I study the Deep Sea?