Foraminifera: a Tool for Dating and Assessing Climatic and Ecosystem Change in Estuarine and Marine Environments

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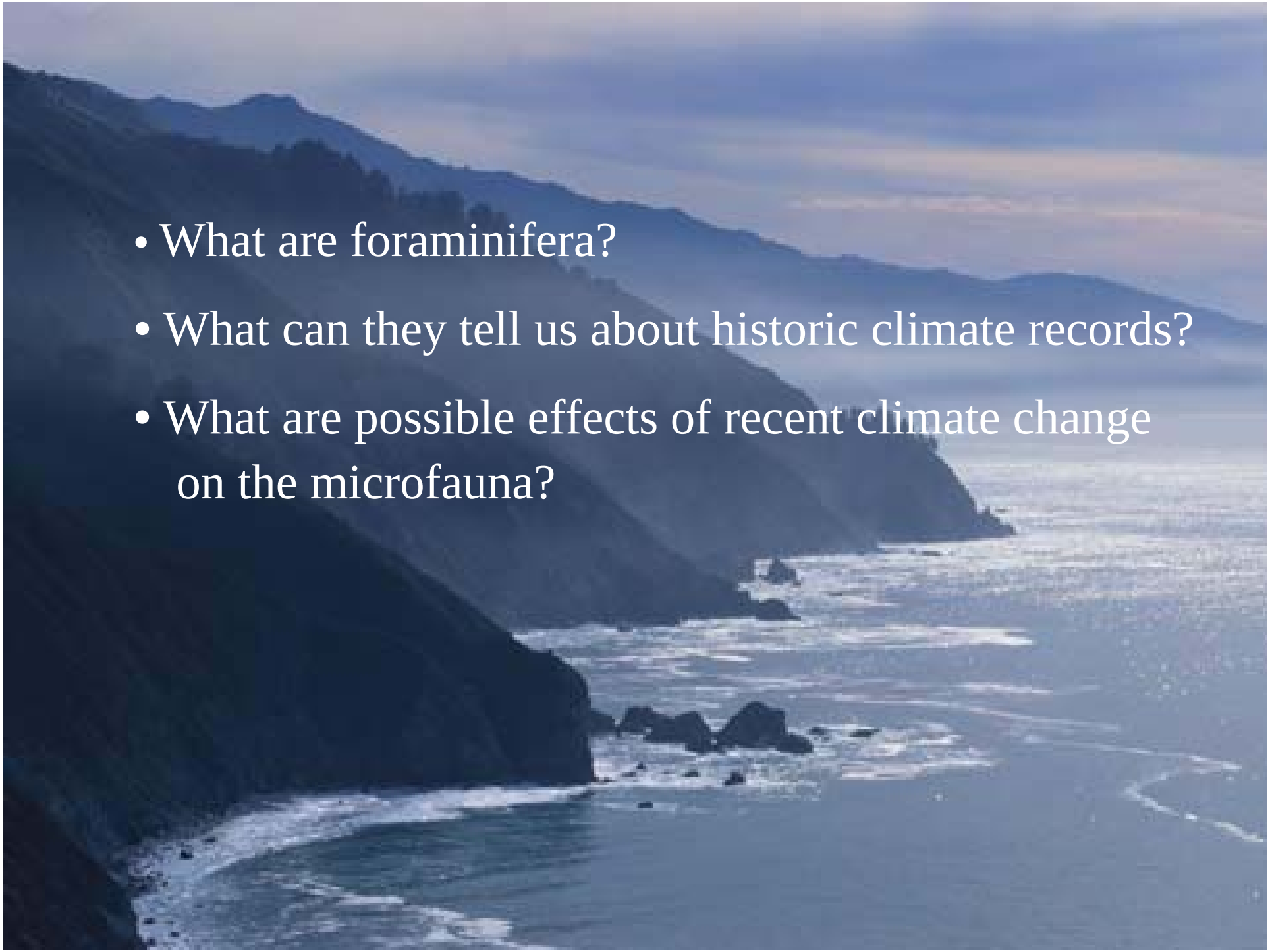
USGS
science for a changing world

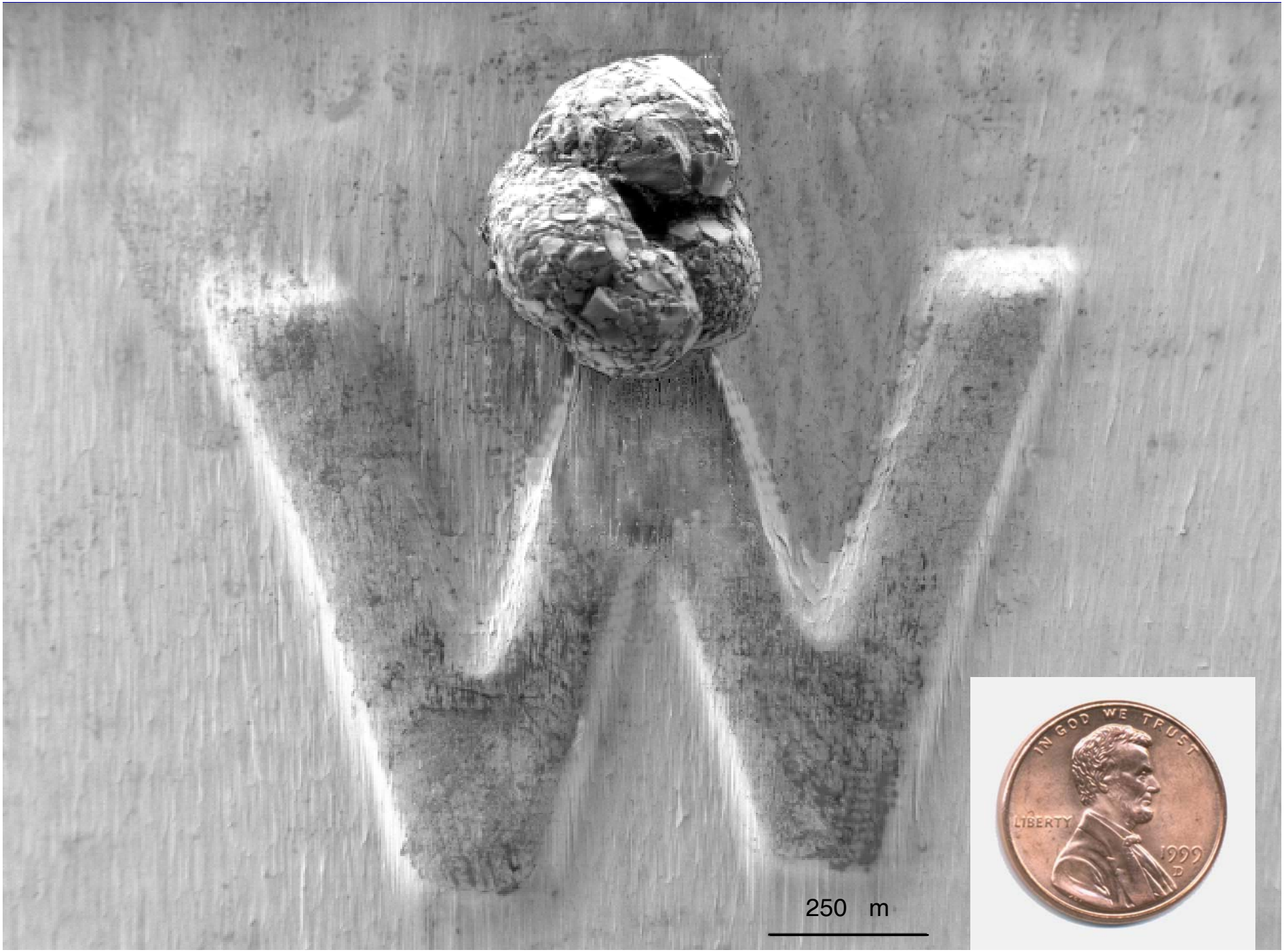


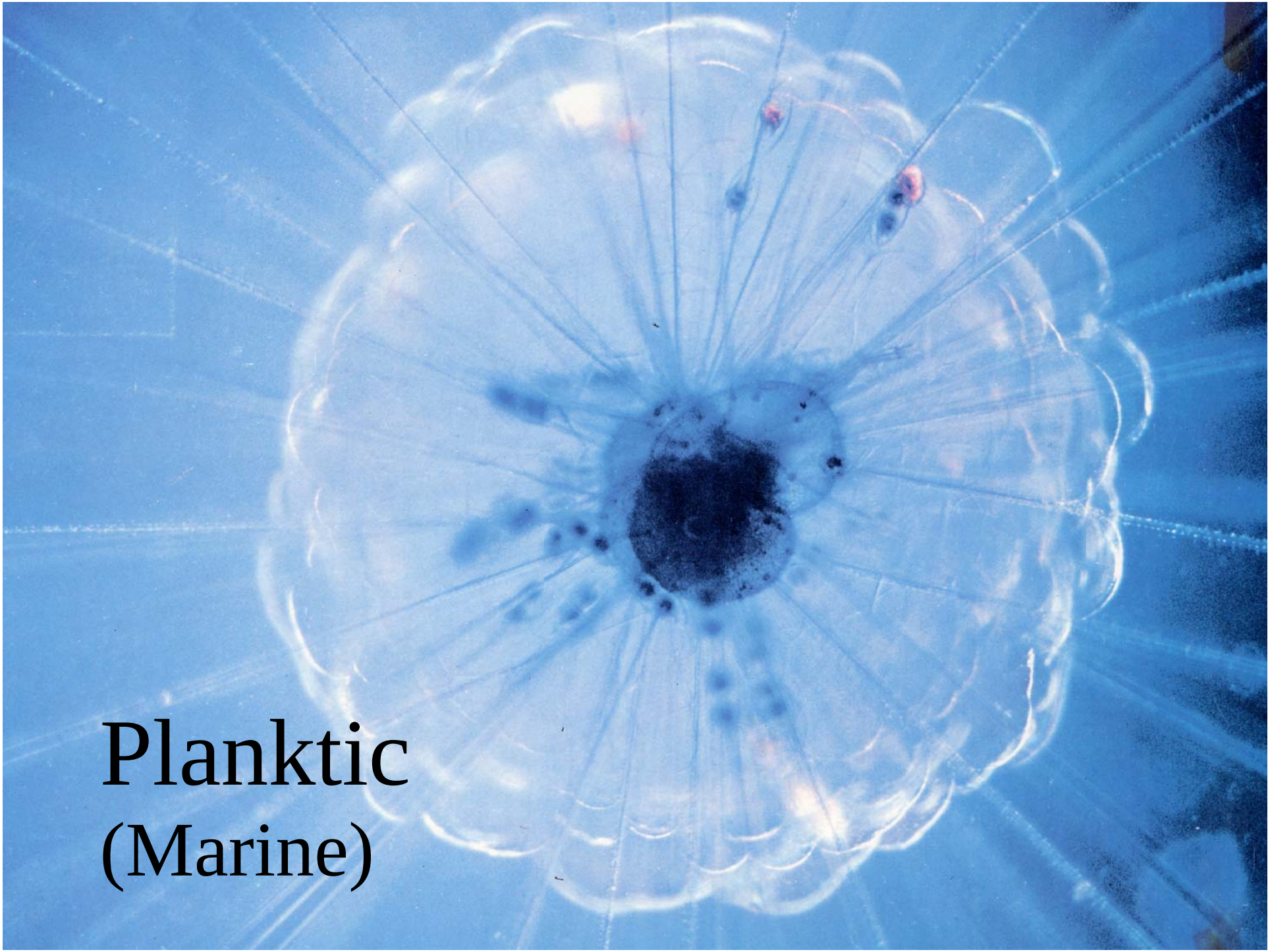
- What are foraminifera?
- What can they tell us about historic climate records?
- What are possible effects of recent climate change on the microfauna?

FORAMINIFERA

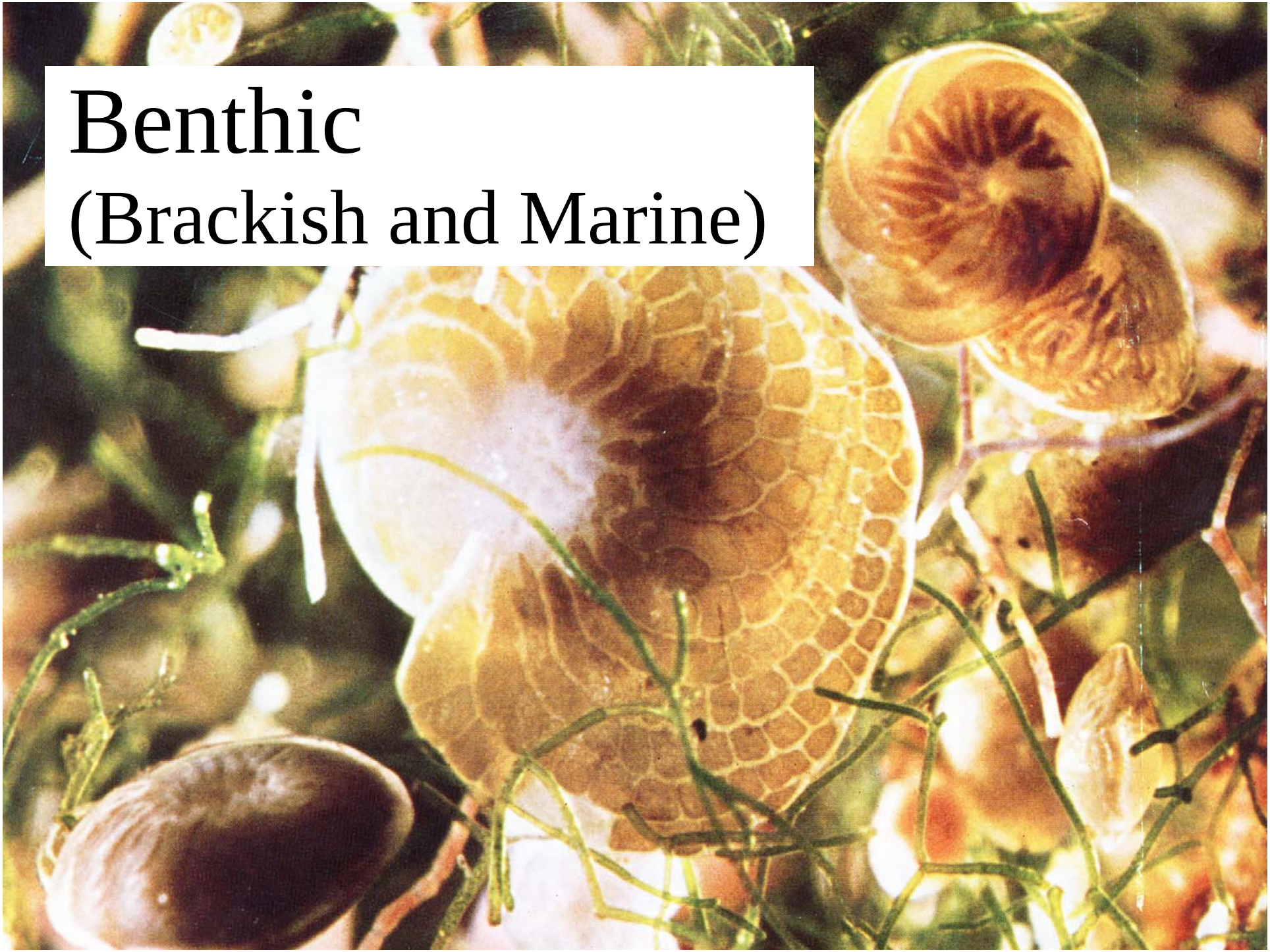
1. Protozoans
2. Pseudopodia
3. Sensitive to environmental change
4. Micro- and meio-faunal size (63-500 microns)
5. Form hard external skeleton (test)
6. Brackish and marine

TRUST
1983
D

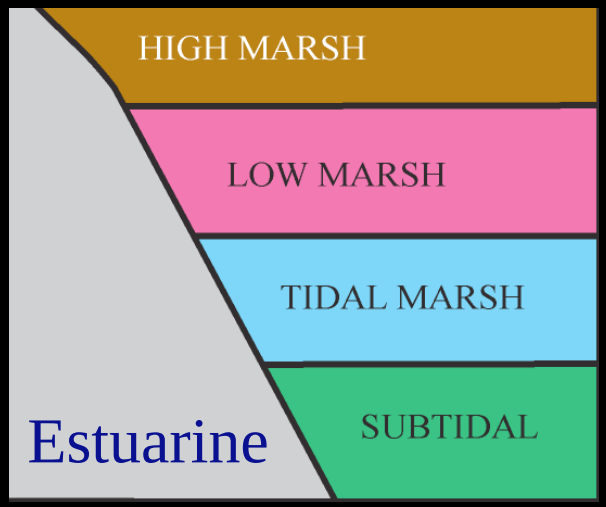

250 m
IN GOD WE TRUST
LIBERTY
1999
D

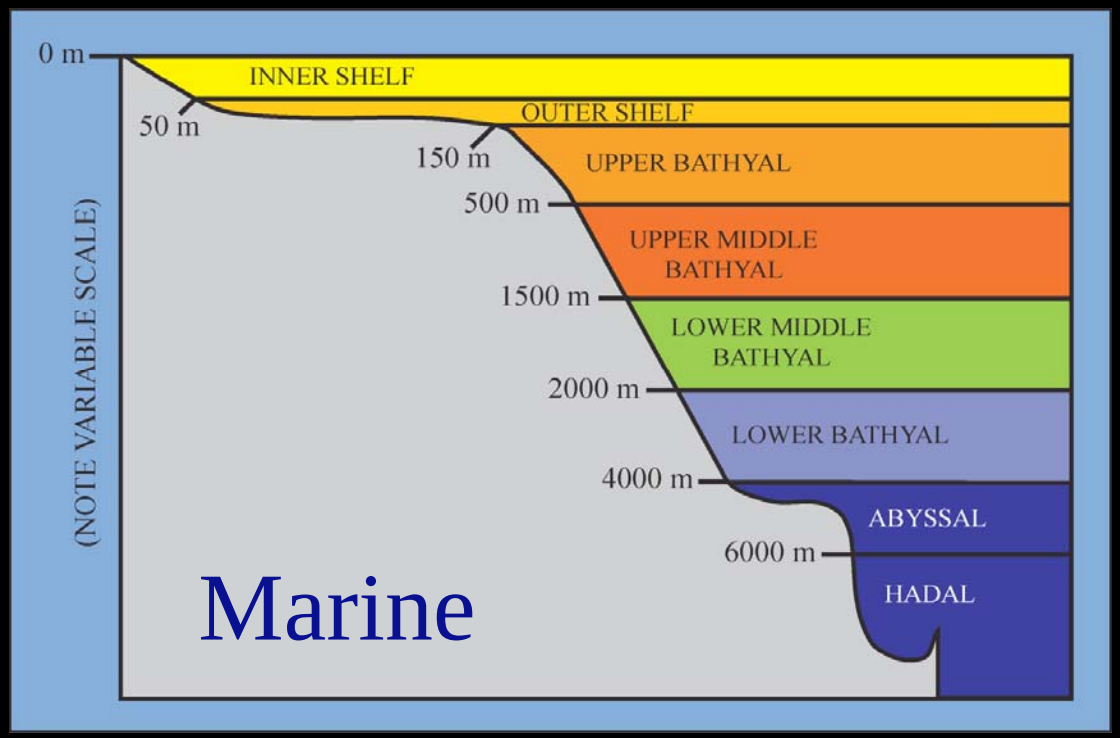

Planktic
(Marine)

Benthic
(Brackish and Marine)



60,000 Species: Numerous Biofacies

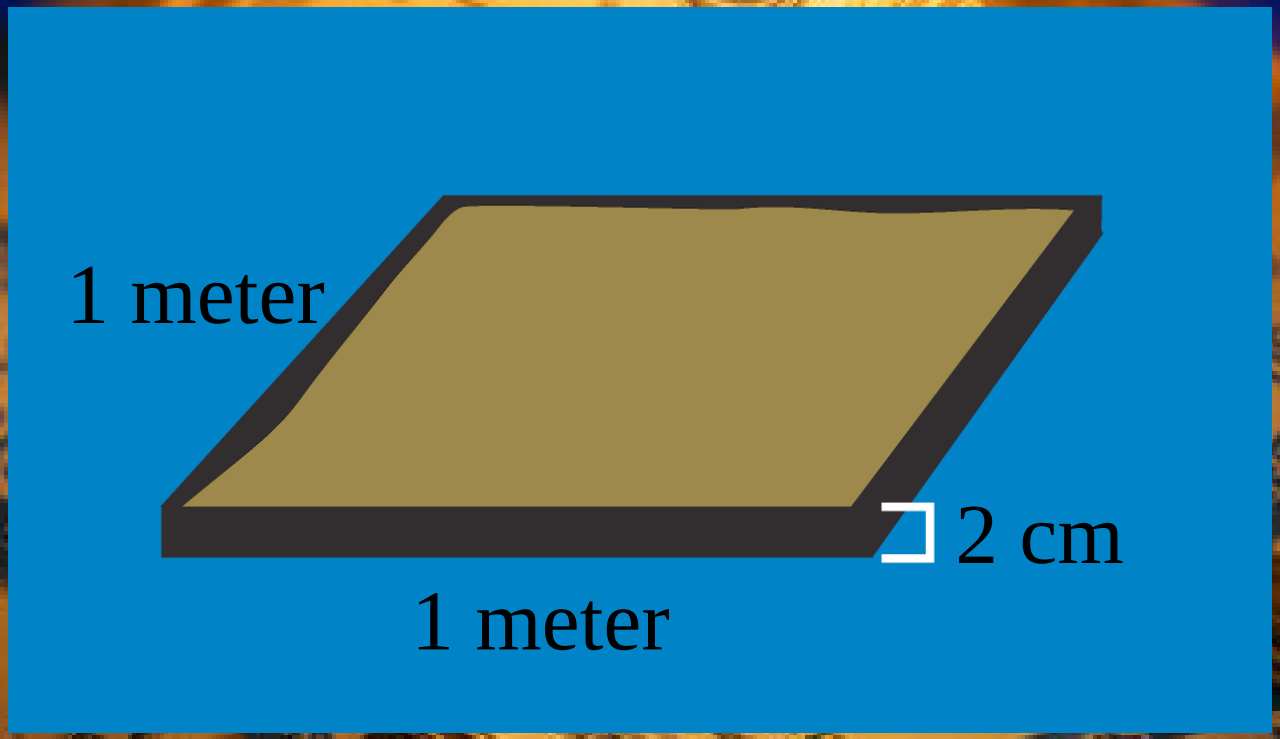




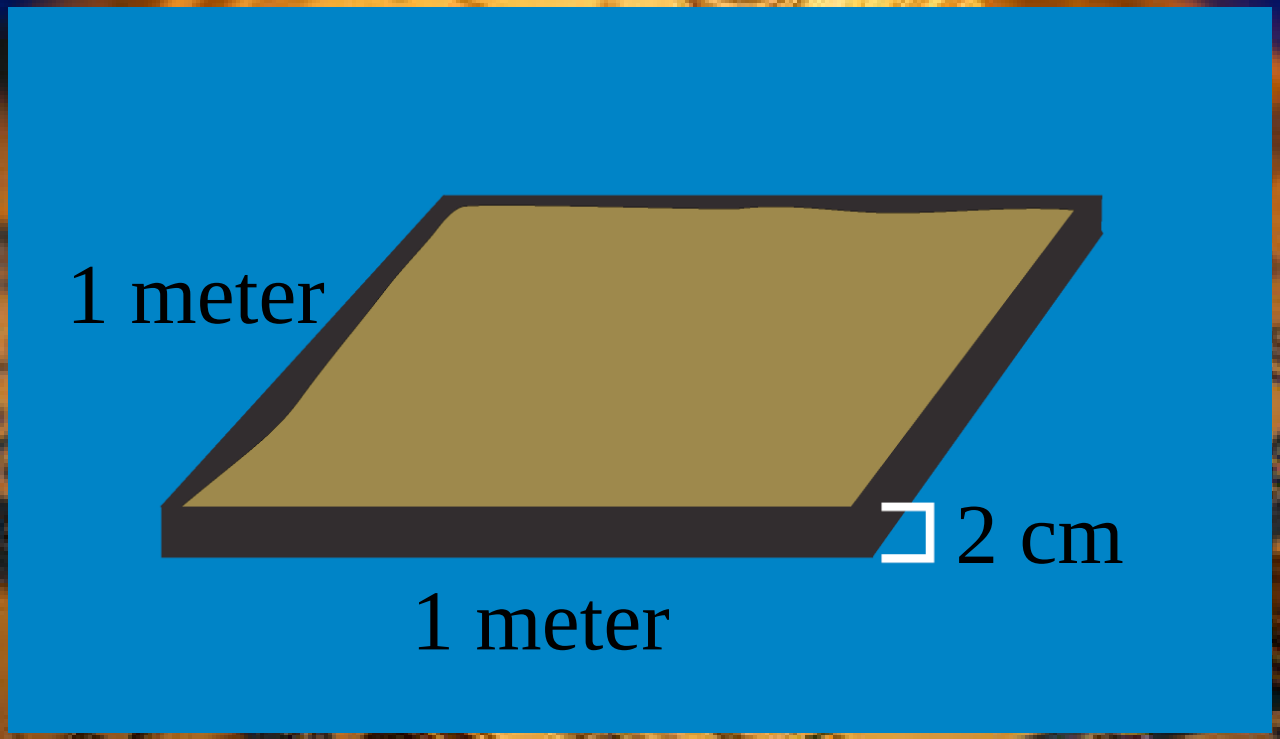
Foraminiferal Reproduction

$100
ONES
THE UNITED

How Many Foraminifera?

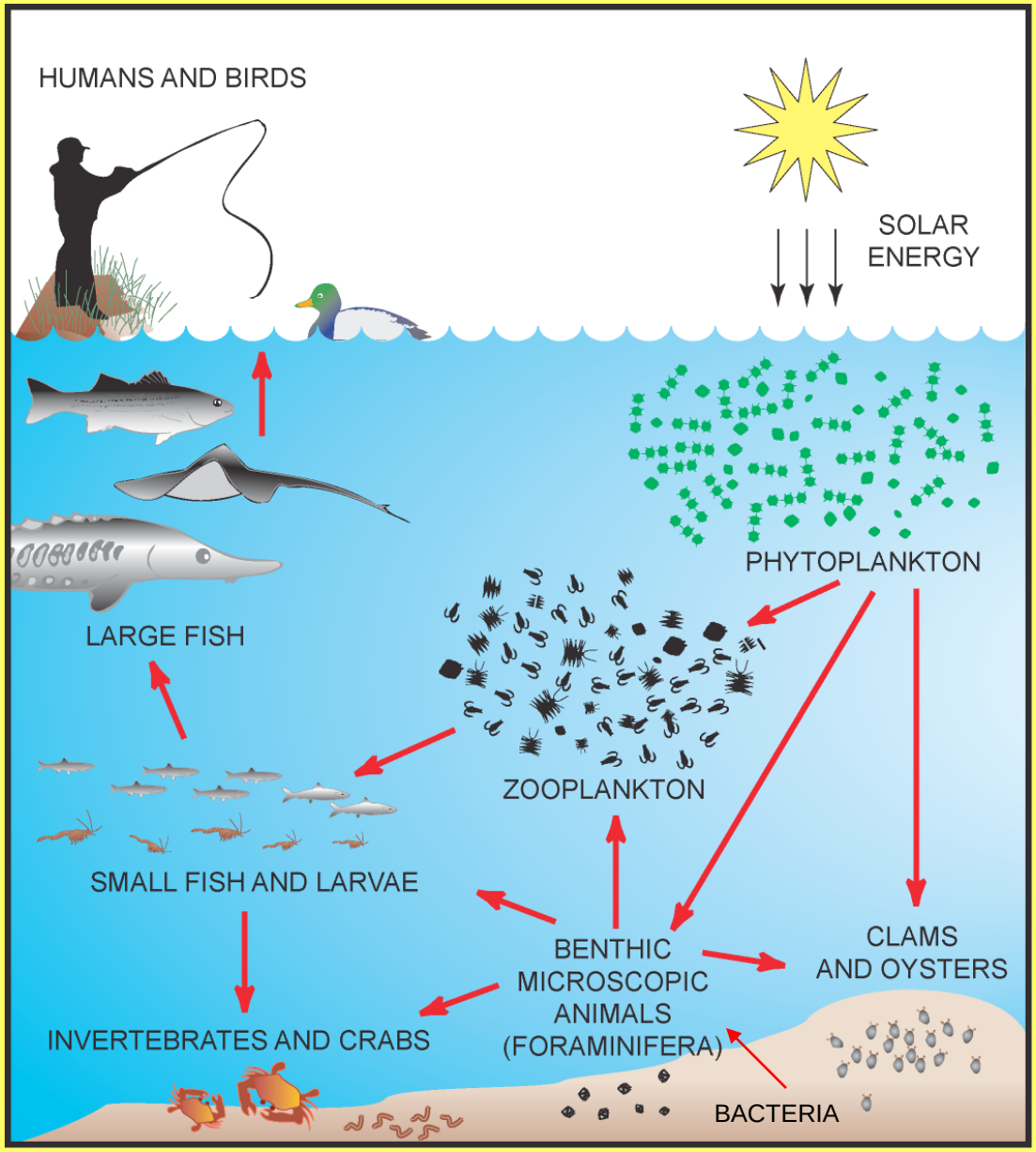


How Many Foraminifera?



4 MILLION!

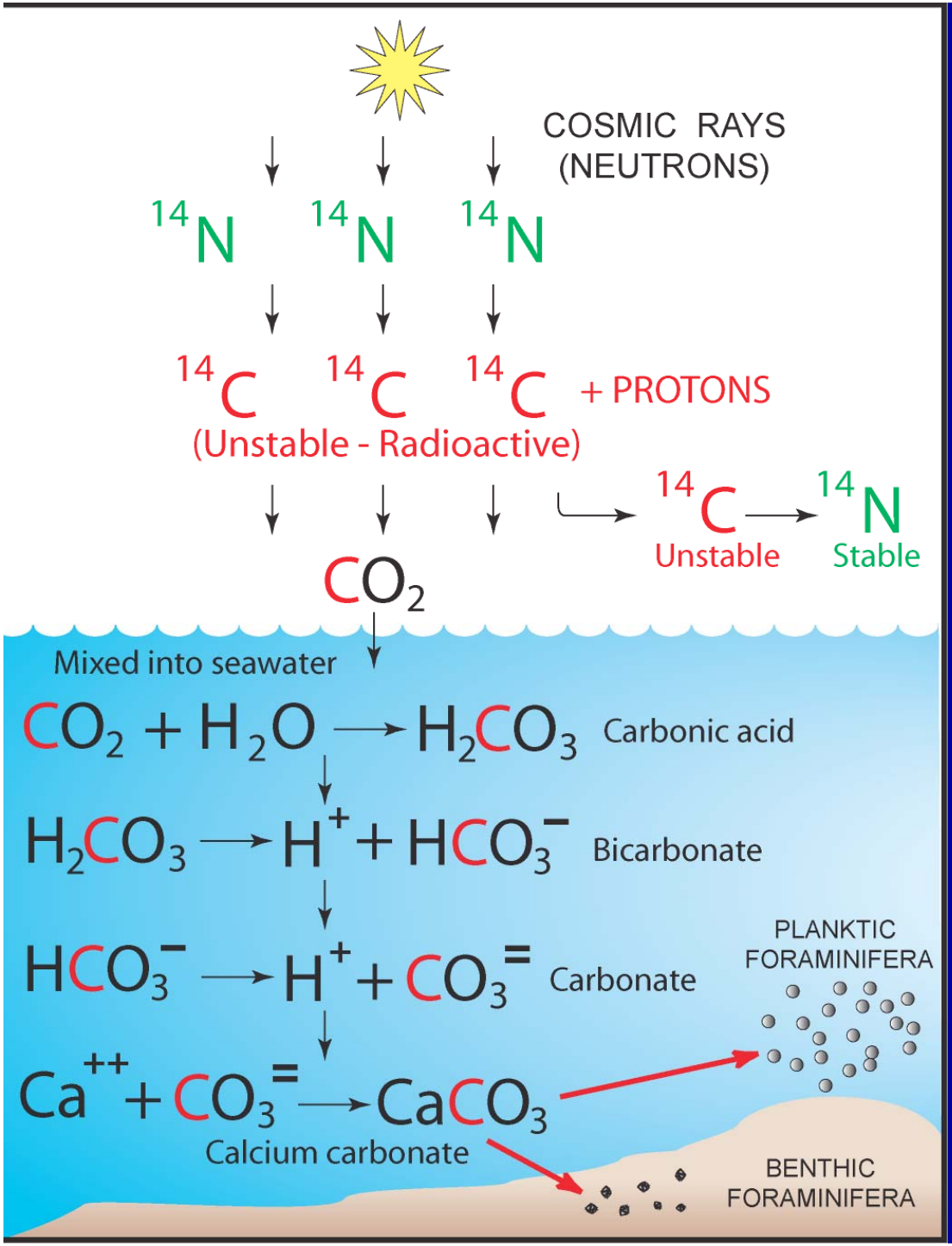
Marine and Estuarine Food Web



What can foraminifera tell us about historic climate records?

Sediment Age

Paleoclimatology

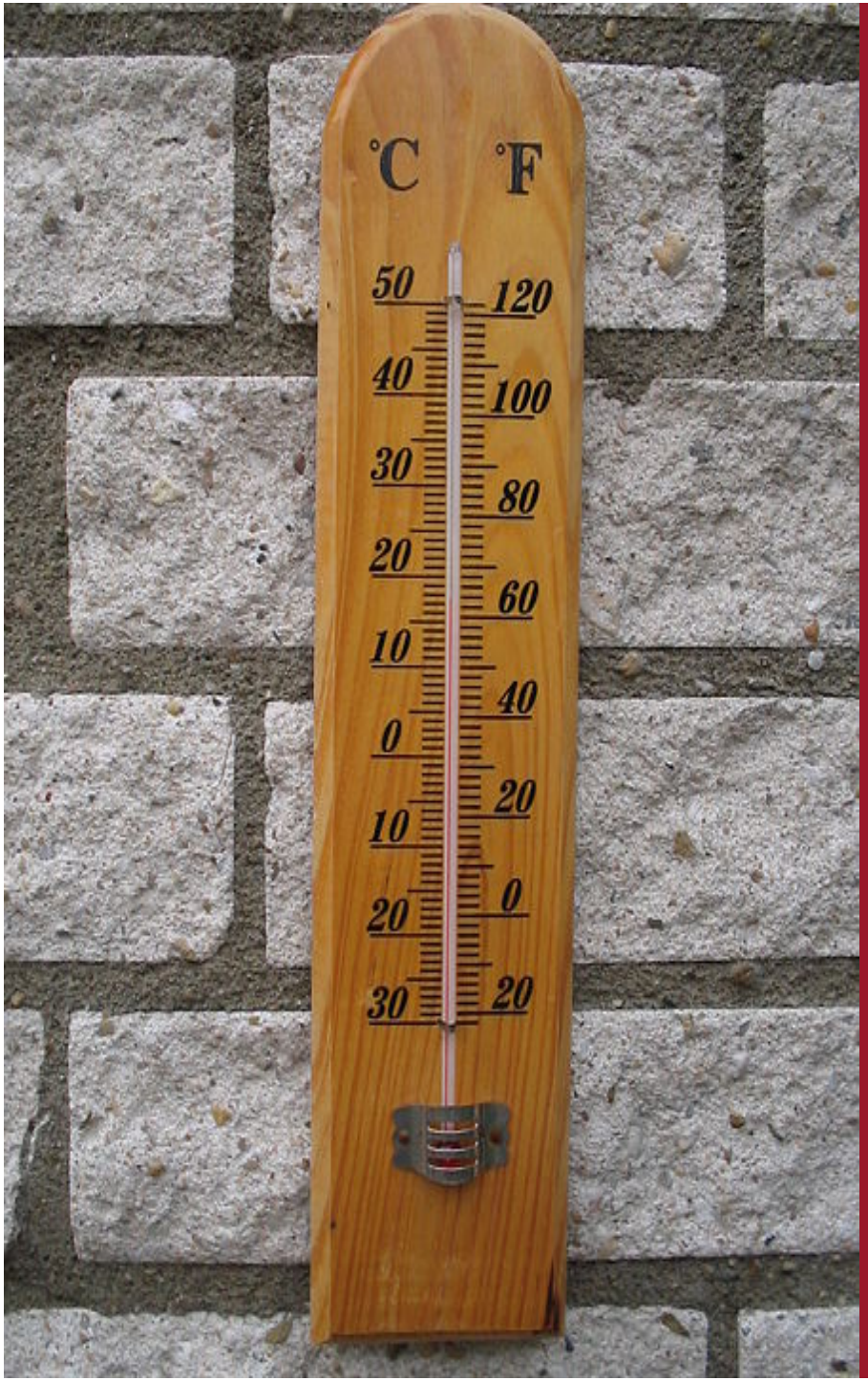


CARBON 14 DATING

- Half-life of carbon is 5720 years

- Useful back to ~ 40,000 years ago

(Estuarine and Marine)



WATER TEMPERATURE

ELEMENTAL RATIOS:

Mg/Ca
Sr/Ca

(Estuarine and Marine)

Mg/Ca and Water Temperature

Species Specific Equations

Estuaries: *Elphidum excavatum*

$y = 4.4289 \text{ Ln } (x) = 11.682$

y = water temperature (^{o}C)
x = Mg/Ca

Mg/Ca and Water Temperature

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Marine: *Uvigerina peregrina*

Mg/Ca and Water Temperature

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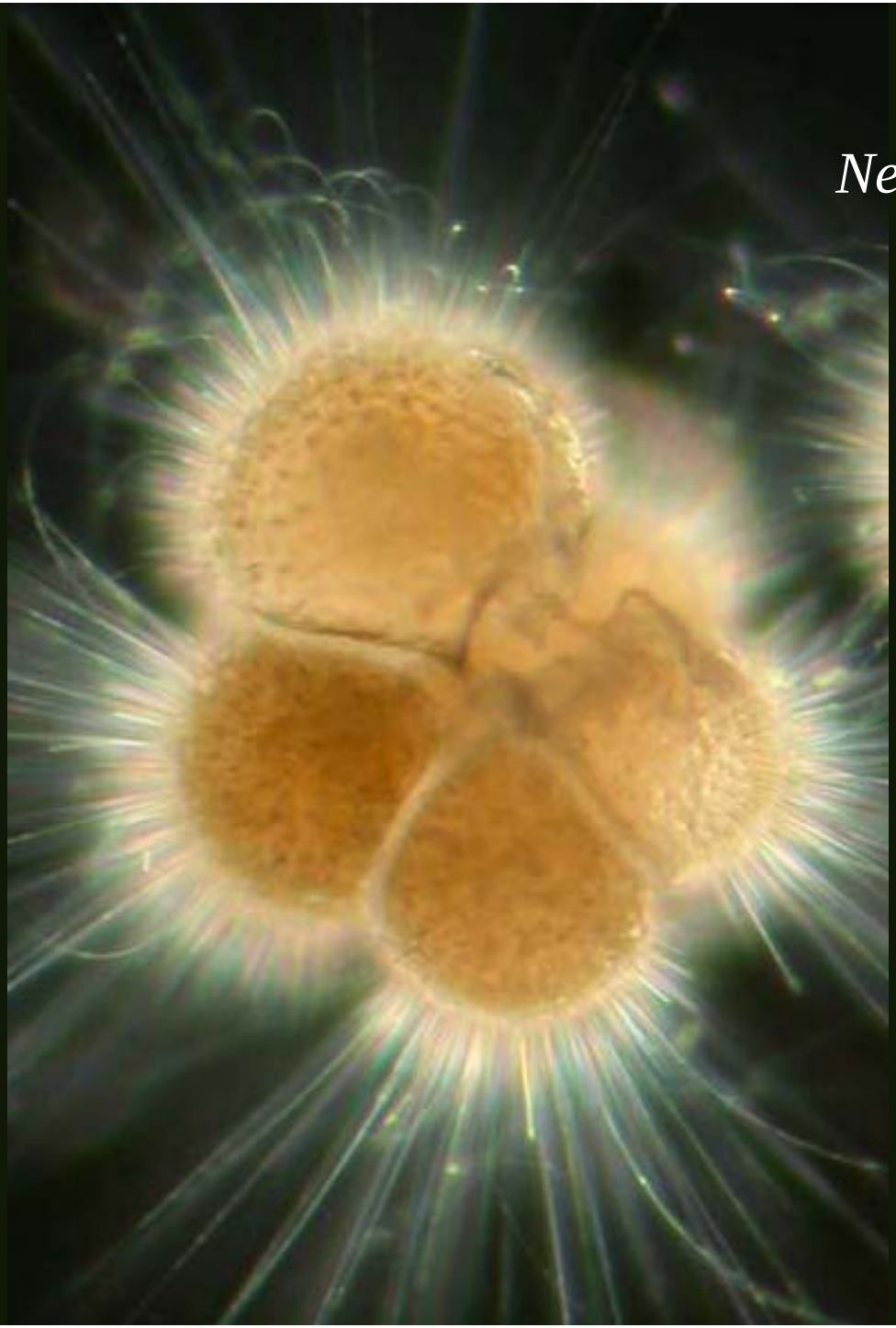
Cibicides wullerstorfi

COIL



Neogloboquadrina pachyderma

COLD ←

WARM →

(Marine)

SALINITY
(and ice volume)

ISOTOPES:

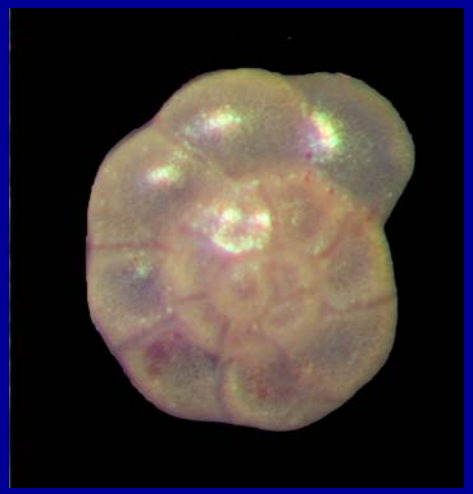
^{18}O, ^{13}C

ELEMENTAL RATIOS:

Sr/Ca

(Estuarine and Marine)

Ammonia-Elphidium (A-E) Index and Hypoxia



Ammonia beccarii
Abundant in oxygen-depleted environments

$$\frac{A}{E} \uparrow$$

Lower Oxygen Conditions

Elphidium excavatum
Abundant in oxygen-rich environments

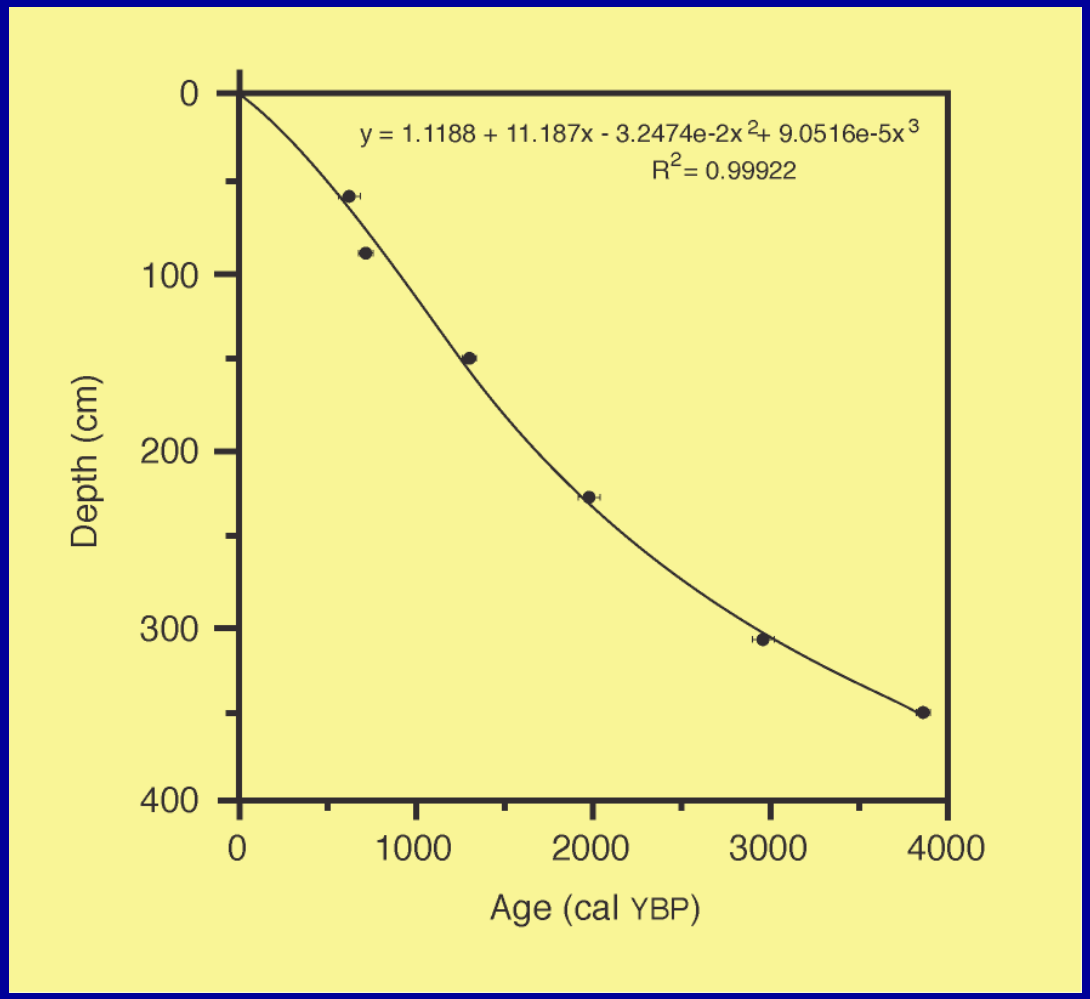
$$\frac{A}{E} \downarrow$$

Higher Oxygen Conditions

(Estuarine)

Core DJ-6

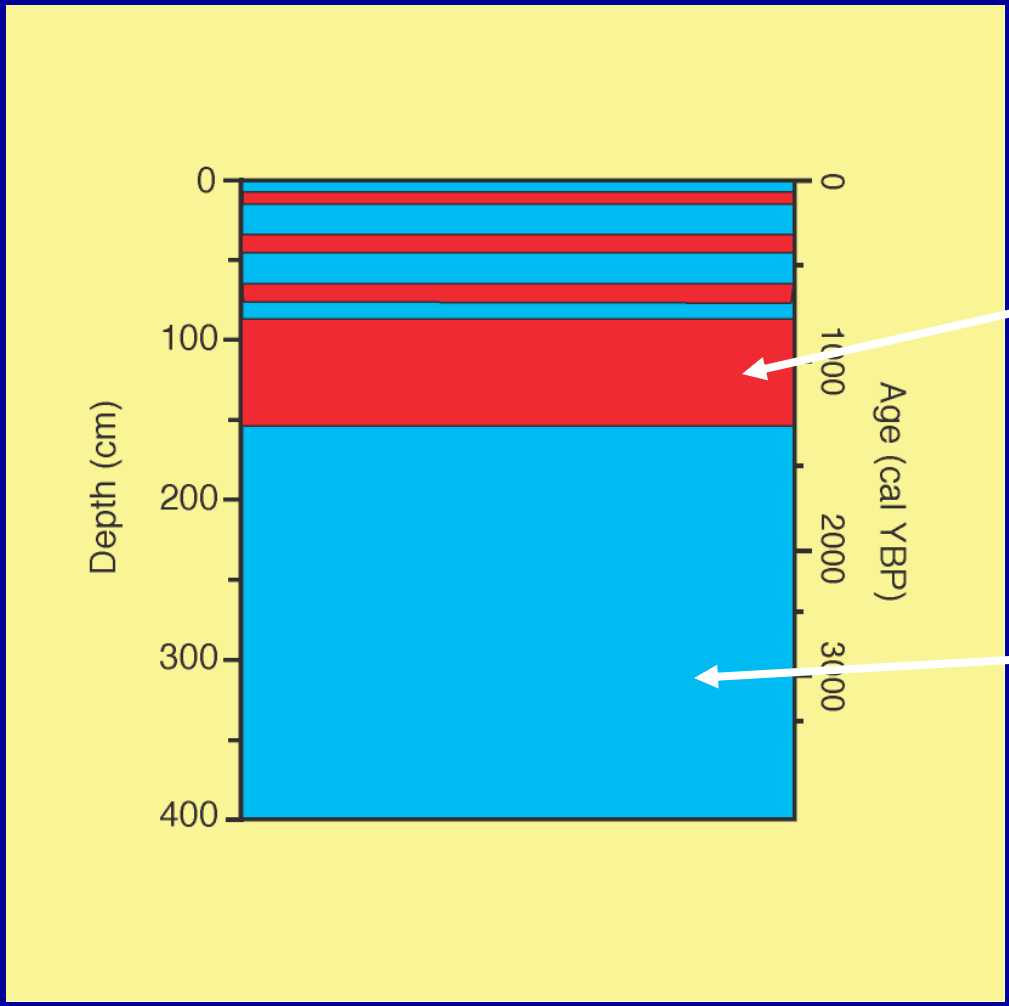
6 ^{14}C Measurements

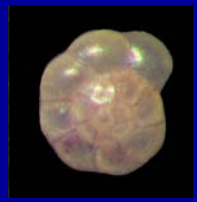


Age-Depth Model

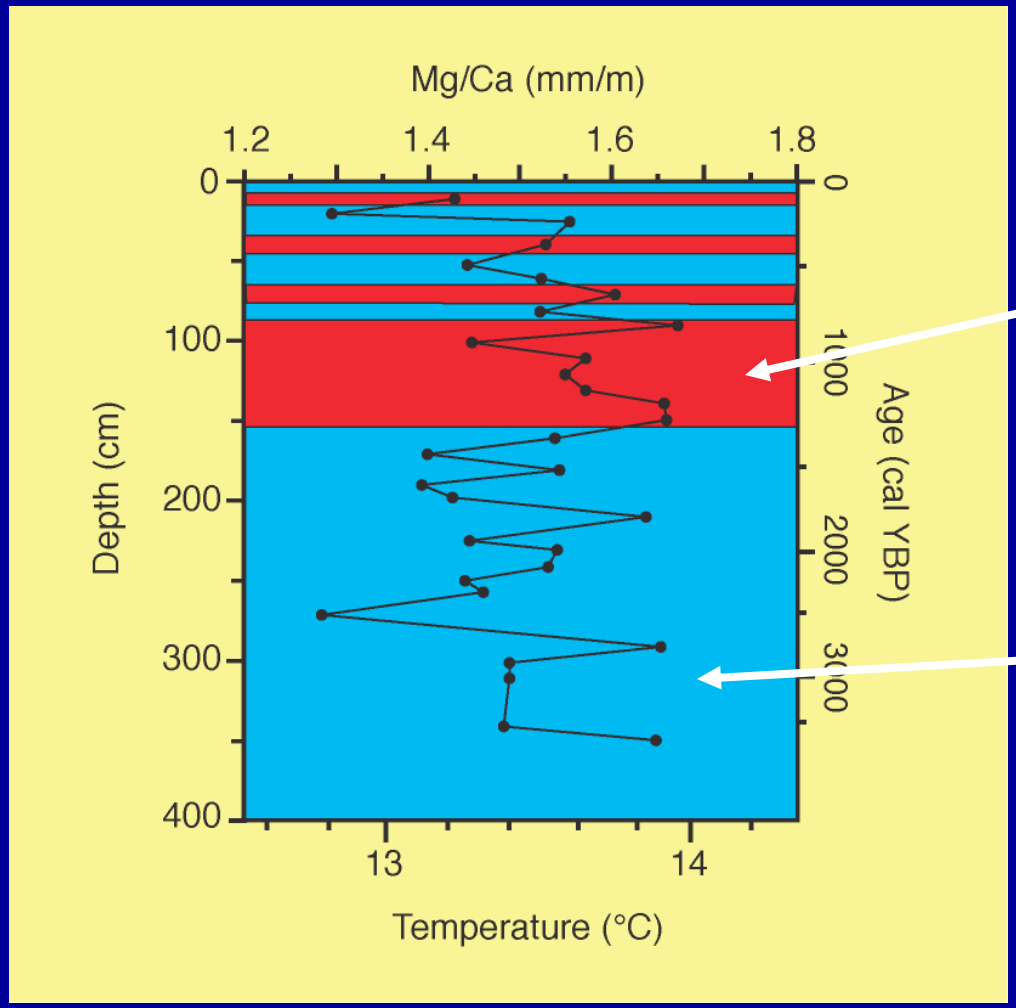
3900 years

Cluster Analysis of the Fauna





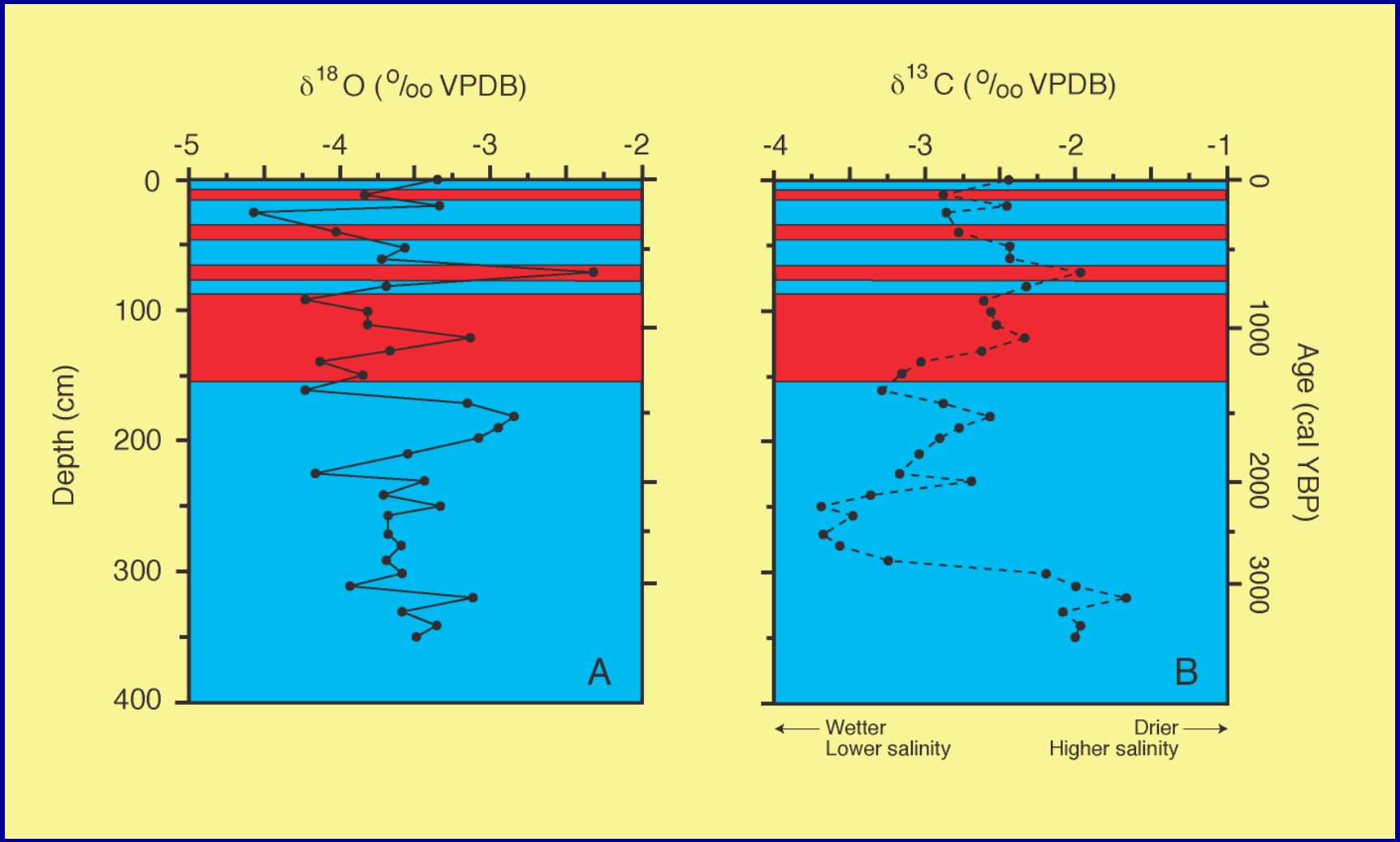
Mg/Ca and Temperature



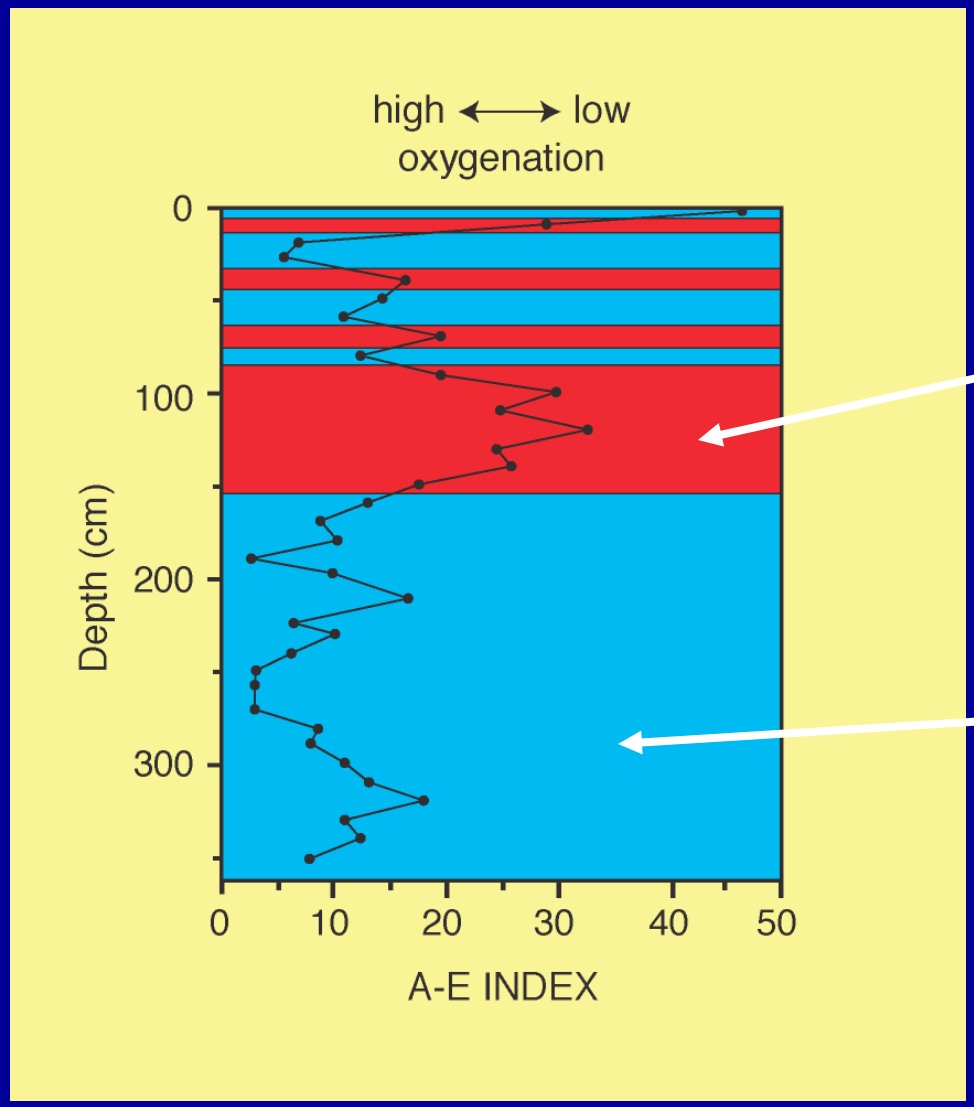
Warm

Cold

Isotopes and Salinity



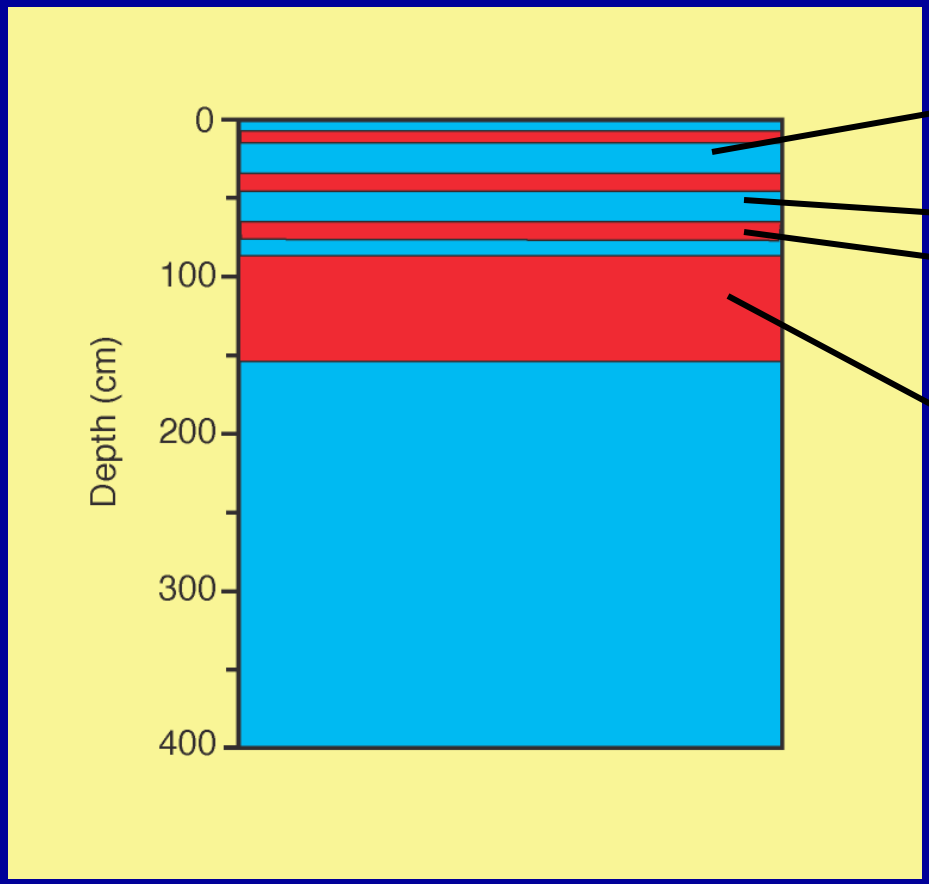
Ammonia-Elphidium Index



Low O_2

High O_2

San Francisco Bay Airport Core
3,900 year record



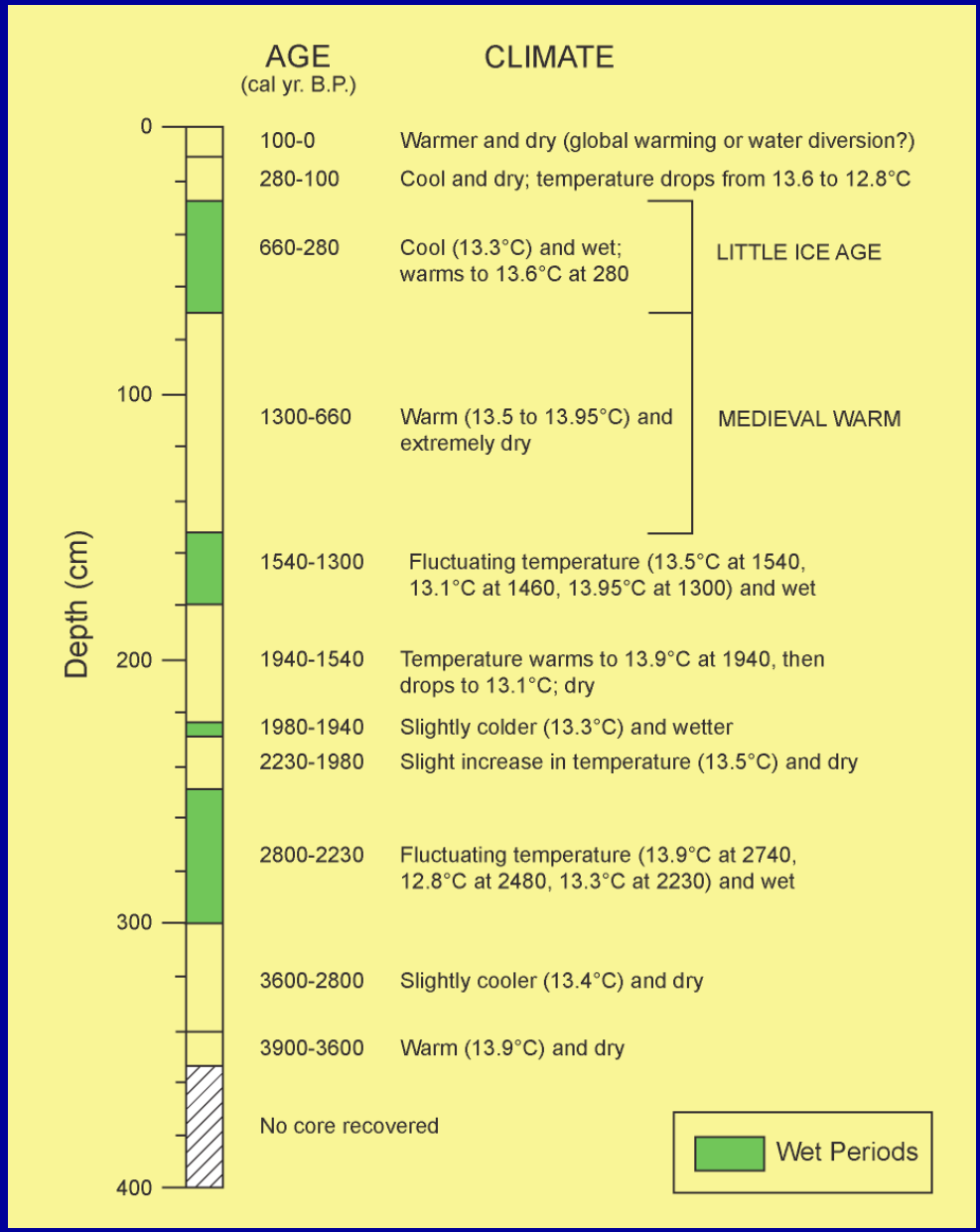
Late Little Ice Age (1760-1880)

Early Little Ice Age (1490-1570)

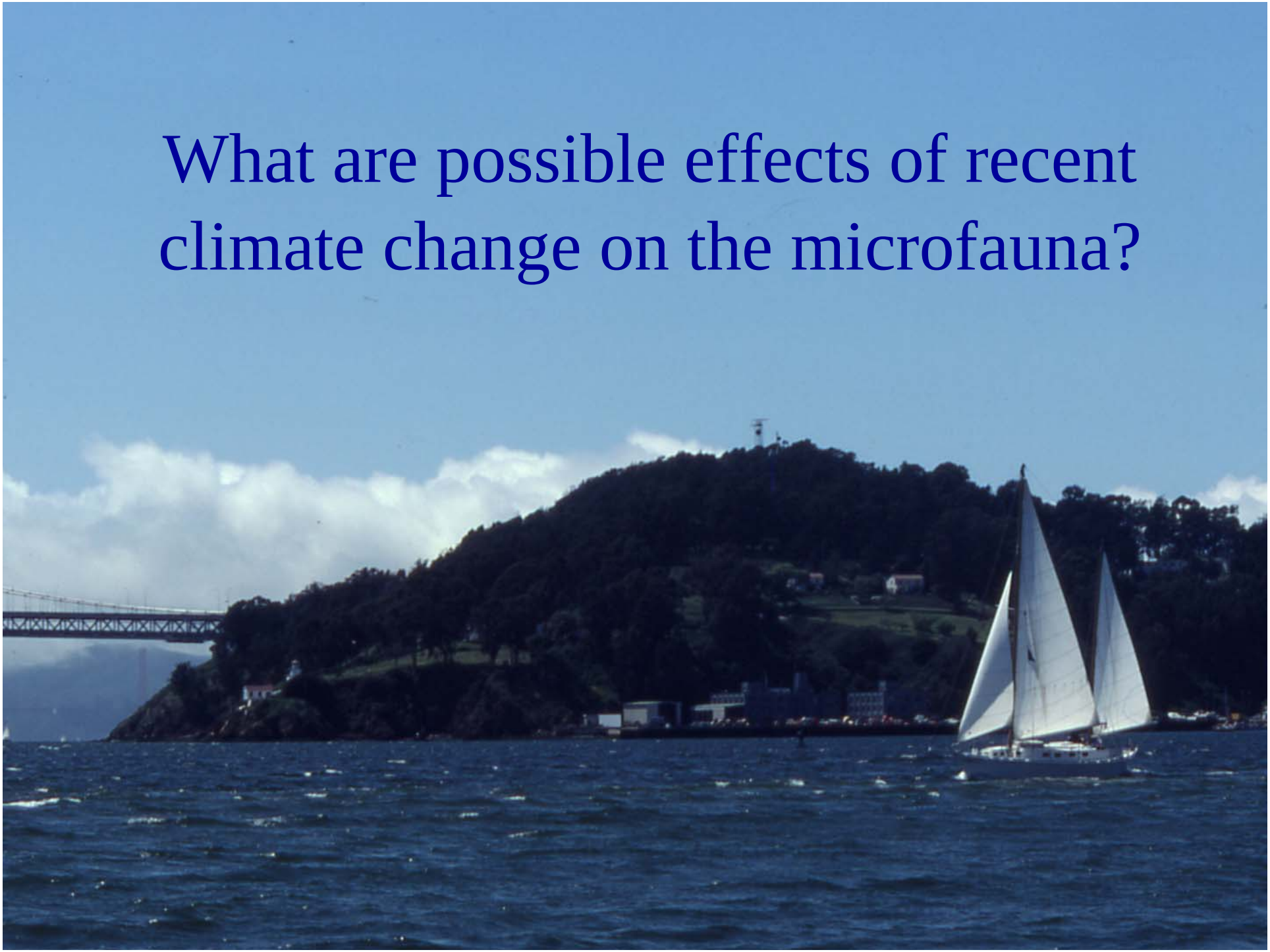
Conventional Medieval Warm Period (1040-1340)

Early Medieval Warm Period (490-940)

Detailed Summary of San Francisco Bay Climate



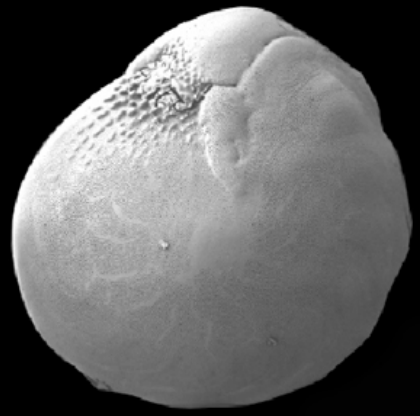
What are possible effects of recent climate change on the microfauna?

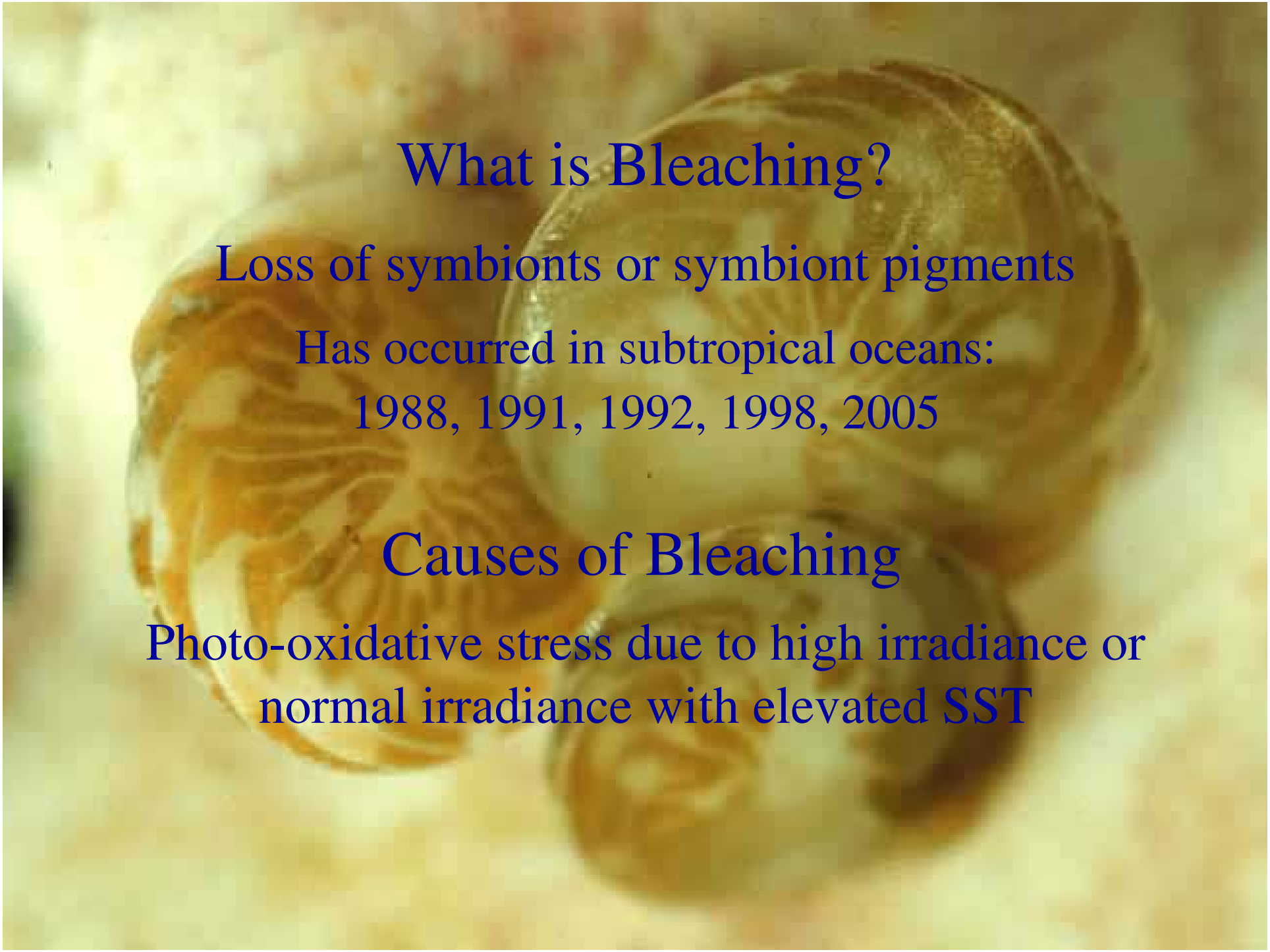


Tropics: foraminifera are often large and commonly have symbiotic algae

Tropical Foraminifera With Symbiotic Algae

Amphisorus
Amphistegina
Borelis
Heterostegina
Peneroplis





What is Bleaching?

Loss of symbionts or symbiont pigments

Has occurred in subtropical oceans:
1988, 1991, 1992, 1998, 2005

Causes of Bleaching

Photo-oxidative stress due to high irradiance or normal irradiance with elevated SST

Bleaching in the Foraminifera *Amphistegina*

Coral Reefs: bleaching in forams first, then corals

Photo: Hallock, Univ. of South Florida

In conjuction with global temperature monitoring, bleaching in foraminifera can forecast mass coral-bleaching events and their susceptibility to disease

BLEACHING

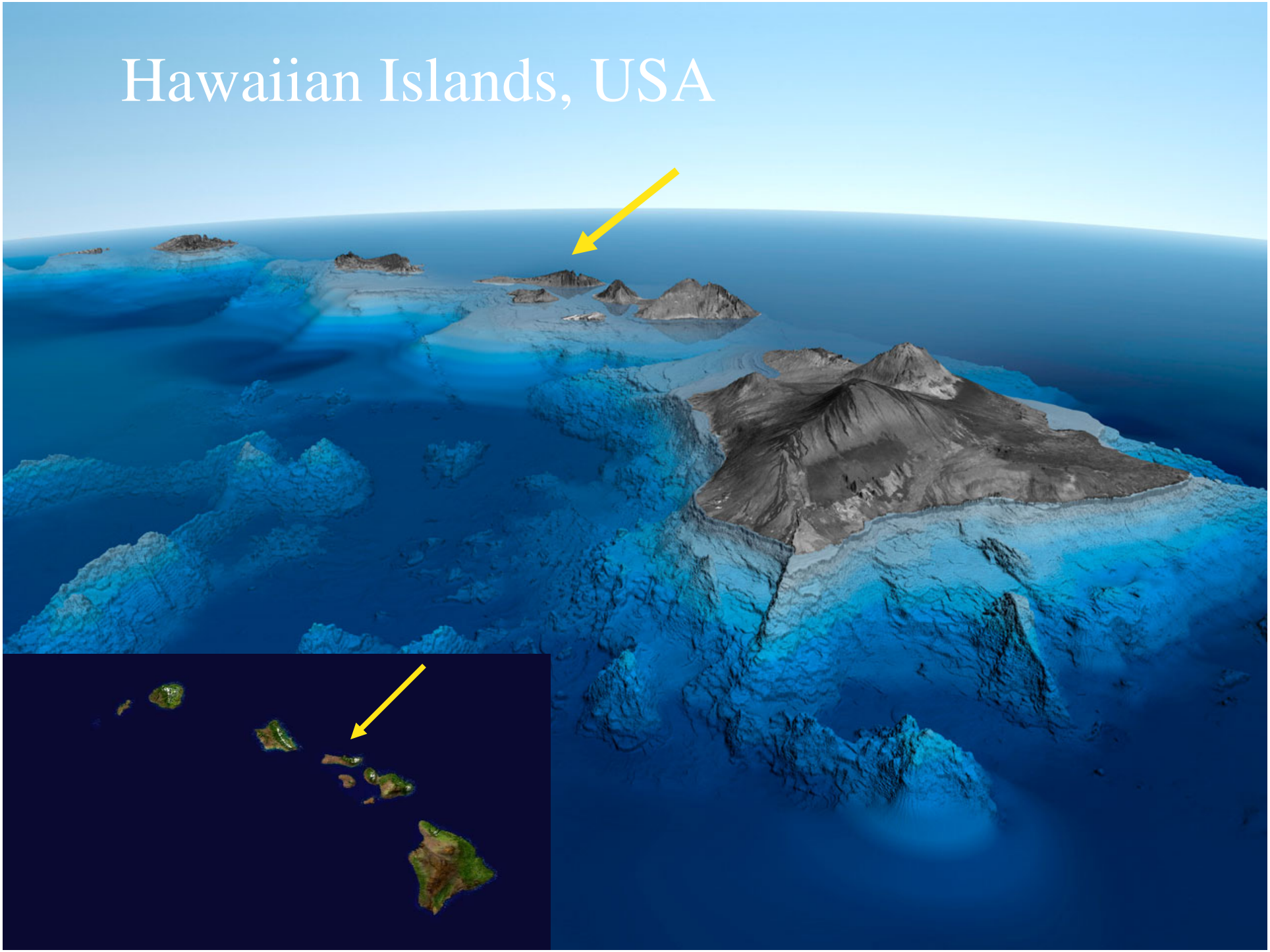
IS a concern at sites in the Atlantic Ocean

Is NOT presently a concern in Hawaii

SLR - Shoreline Transgression and Sediment Resuspension = Turbidity

Hawaiian Islands, USA

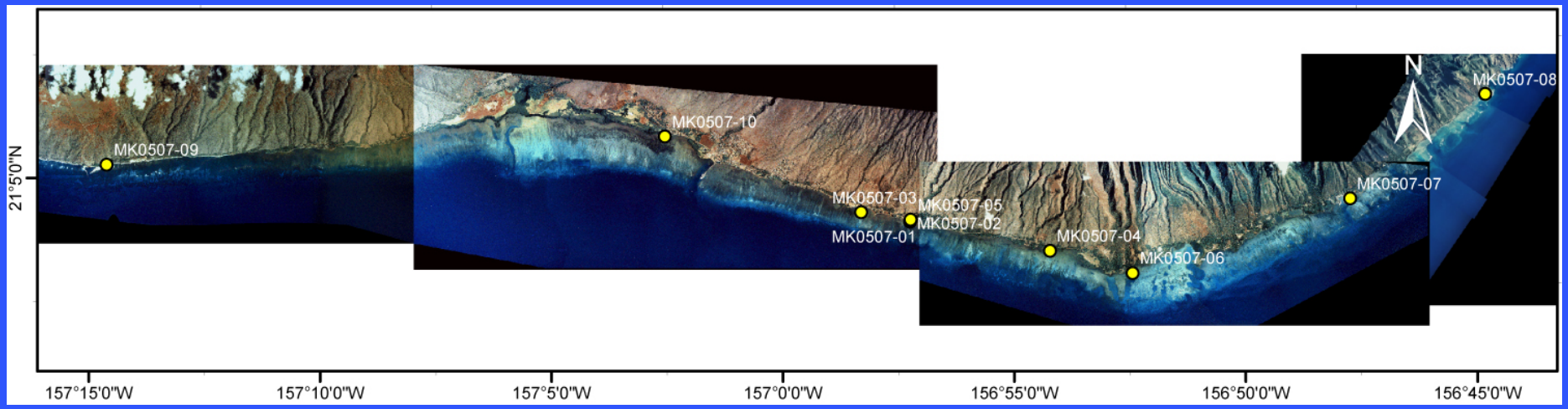
Hawaiian Islands, USA

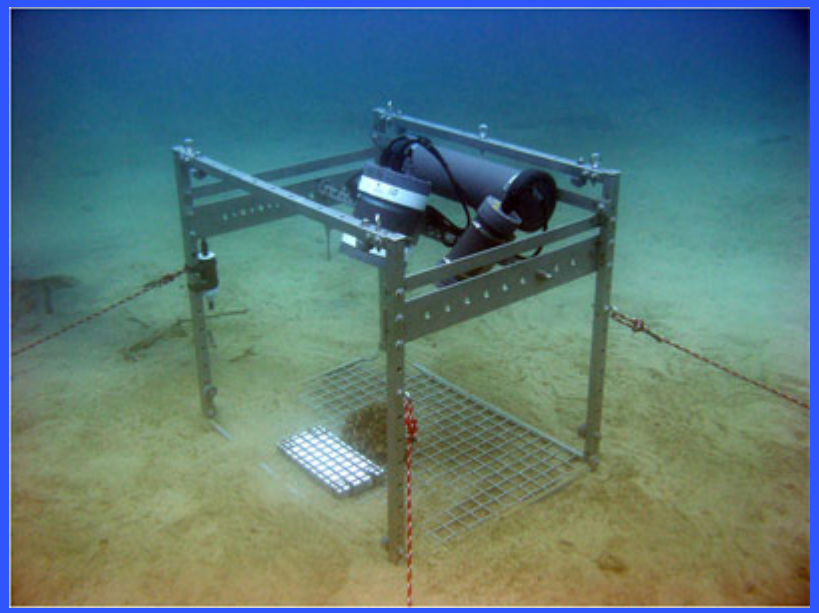


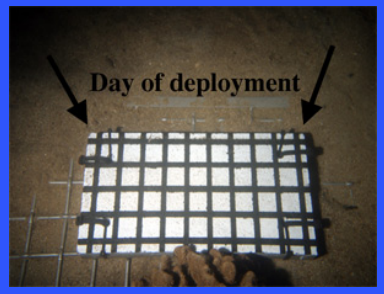
MOLOKA'I

673 sq km (260 sq miles)
S shore - longest continuous fringing reef of the USA
N & W coasts little coral growth due to NW swells

Watershed Degradation







Abundance of Specimens with Symbiotic Algae

92%

Coarse Sediment
Clear Water

69%

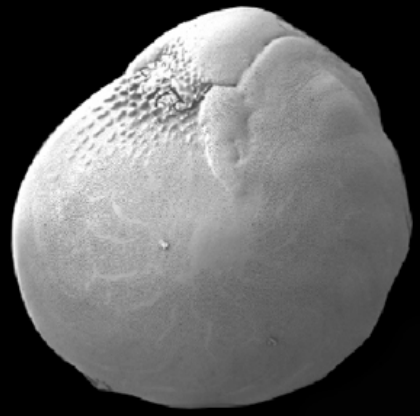
Muddy Sediment
Turbid Water

0-1%

5%

Tropical Foraminifera With Symbiotic Algae

Amphisorus
Amphistegina
Borelis
Heterostegina
Peneroplis



Tropical Foraminifera With Symbiotic Algae

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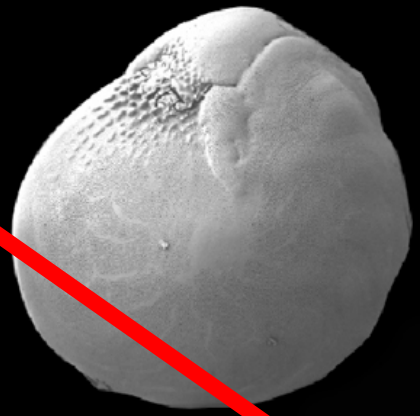
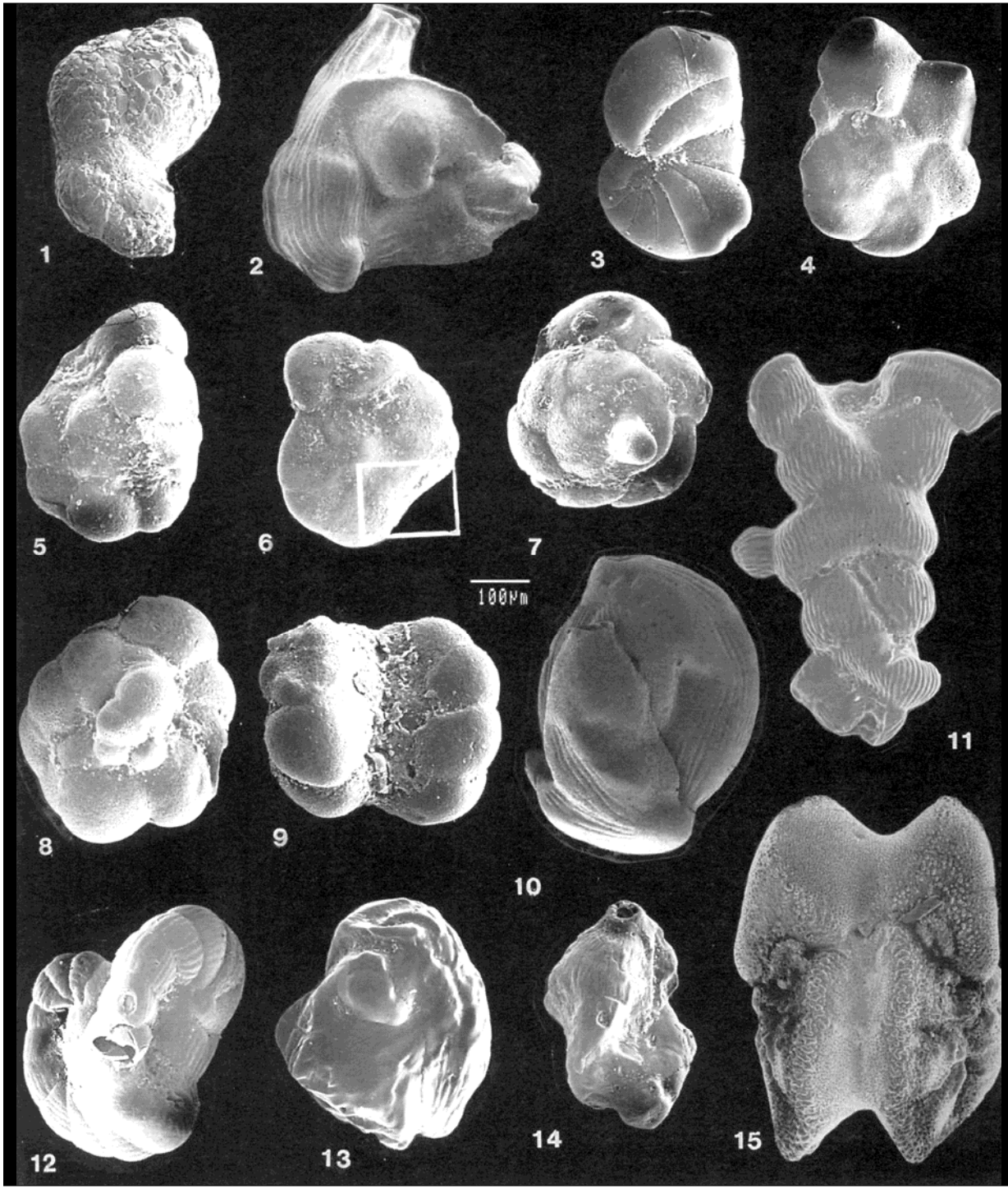


Tropical Foraminifera Without Symbiotic Algae

Ammonia
Ammotium
Bolivina
Buliminella
Eggerella
Elphidium
Fissurina
Miliammina
Nonionella
Quinqueloculina
Rosalina
Spirillina

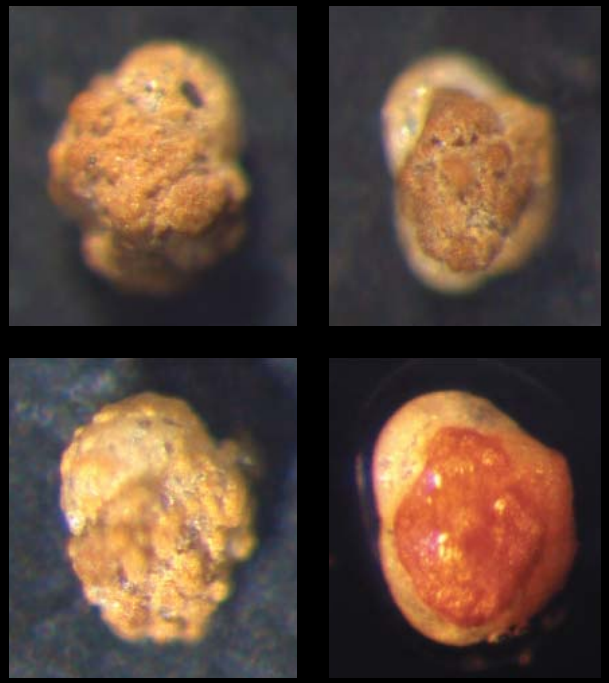
Hunters Point Super Fund Site



MORPHOLOGIC DEFORMITIES

↓

DEAD ZONES



SST Predicted ↑ 2-3°C

= Thermal Pollution Present Today Near Some Power Plants → Deformed Foraminifera

CO^2 Increases:
Ocean Acidification
$CaCO_3$ dissolves

Marine and Open Bay Foraminifera

Calcium Carbonate

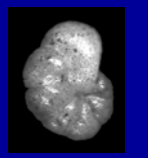
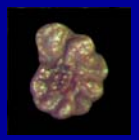
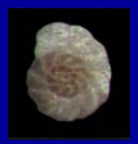
Marsh & Mudflats

Sand Grains

Marine and Open Bay Foraminifera

Calcium Carbonate

Marsh & Mudflats

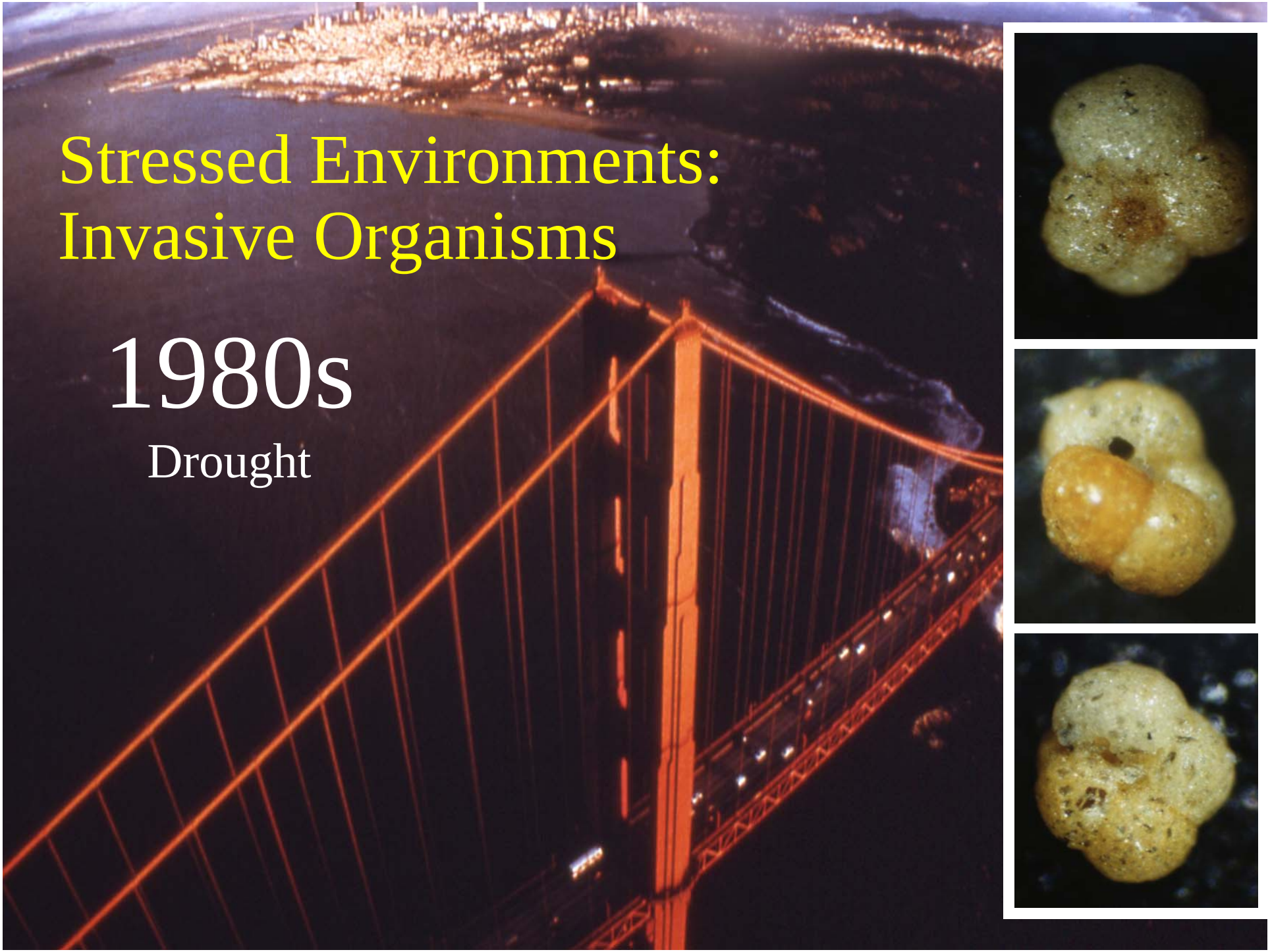




Sand Grains

Stressed Environments: Invasive Organisms

1980s

Drought



Foraminifera

- Provide paleoclimatic record - age dating, temperature, salinity, oxygen
- Increased SST and irradiance - can forecast mass bleaching events in corals
- SLR - increased turbidity, loss of symbionts, faunal alteration
- SLR - sediment resuspension, release of toxins, deformed shells, dead zones
- Increased SST and SLR - faunal spatial ranges alterated
- Ocean acidification - loss of calcareous shells
- Stressed environments - increase in invasive species
- Food web - change fauna near the base affects all organisms above it

Thank you!