Dr. Barbara Donner
Research Center Ocean Margins (RCOM), Bremen

Reconstructing past climate…

Outline

Part A1: Climate archives
Part A2: Marine sediments
(as most important archive)
Practical part: how to investigate a sediment core

Part B: Climate parameters and proxies
Practical part: biostratigraphy

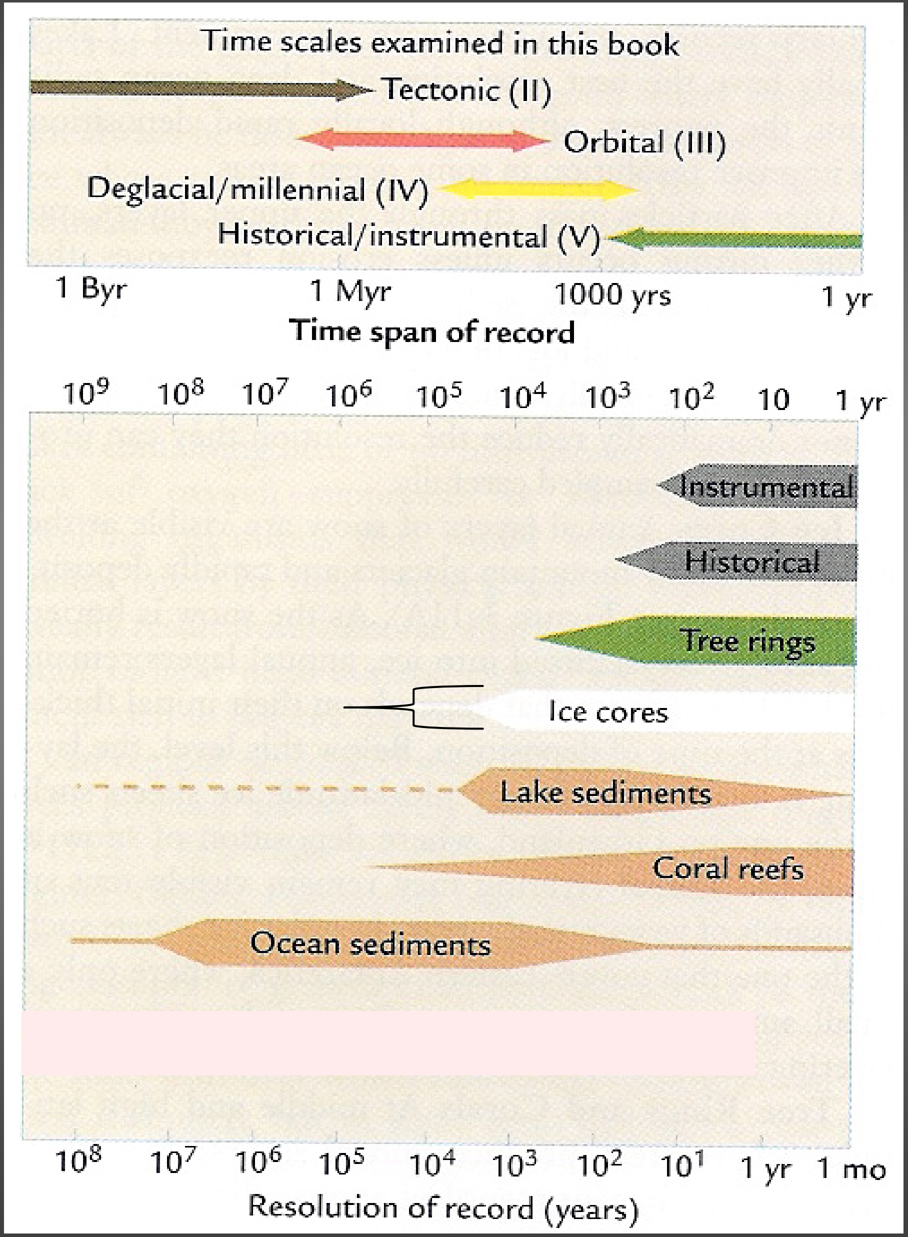
Part C: Evaluation: comparison and discussion of results

A1: Natural climate archives (the best known)

1. tree rings
2. corals
3. lake sediments (varves)
4. ice (drilled ice cores)
5. **marine sediments**

attention:
differences in time interval, time resolution and target parameter!

Climate archives: time span of record



1. Tree rings

(Dendrochronology)

Time interval:
0 – 2 ka bp

Resolution:
(semi-) annual

Target parameters:
precipitation, temperature

Tree Rings

Photos: PAGES Photo archive

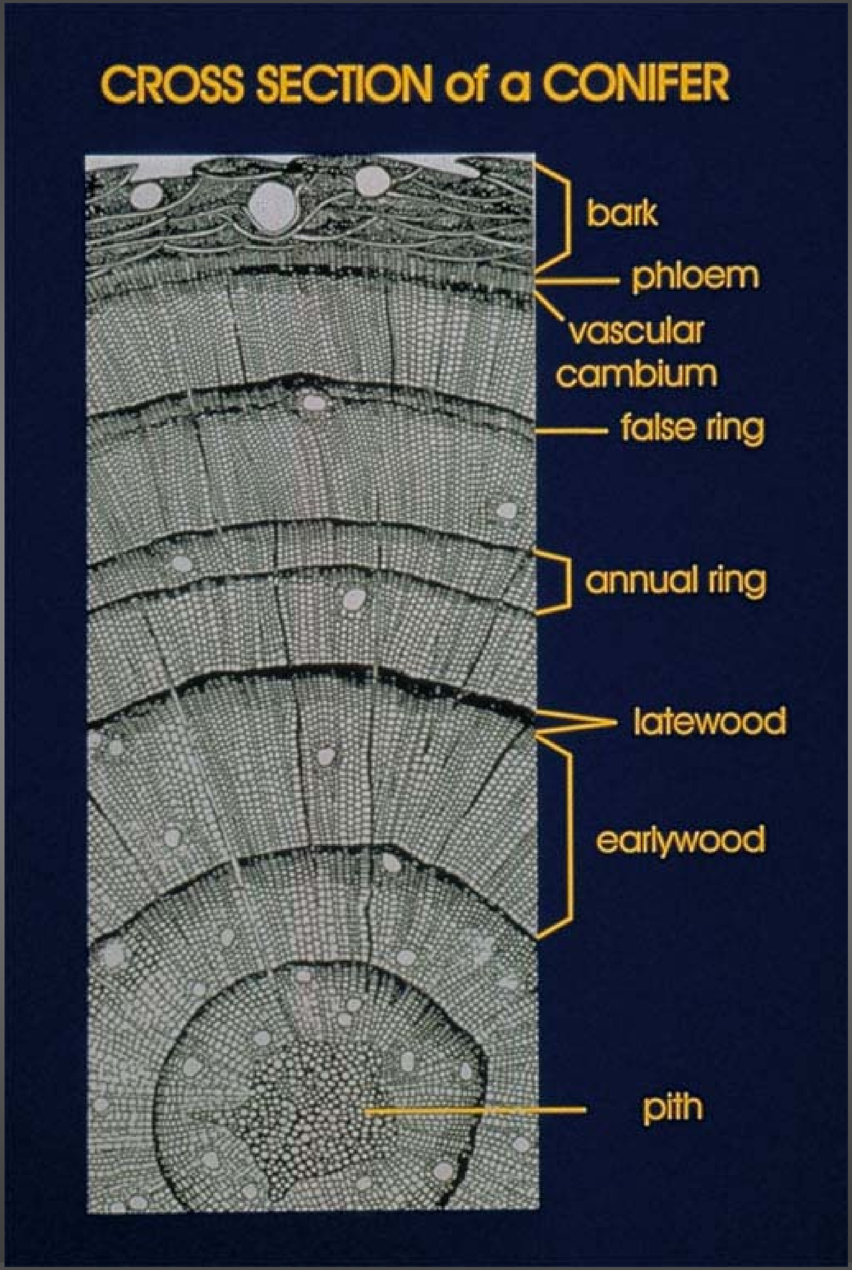
The importance of accurate chronology underlies all efforts to synthesize paleodata across continents and across diverse paleoarchives. One exciting advance has been the discovery of micro-tephras, with chemical fingerprints associated with distinct volcanic eruptions. Such tephras can be found in many paleo-archives, providing an accurate dating constraint. In addition, volcanic eruptions can cause strong global climatic cooling for a period of years, complicating comparisons of temperature change with solar activity or greenhouse gas concentrations.

LB/PAG1/99-4

Tree ring analysis

Conifer
earlywood: cells with thin walls / large diameters, appear bright

latewood: cells with thick walls / small diameters, appear dark



NOAA Paleoclimatology Program

2. Corals

(Sklerochronology)

Time interval:
0 – 8 ka b.p.

Resolution:
seasonal

Target parameters:
SST, precipitation / evaporation, salinity

Corals

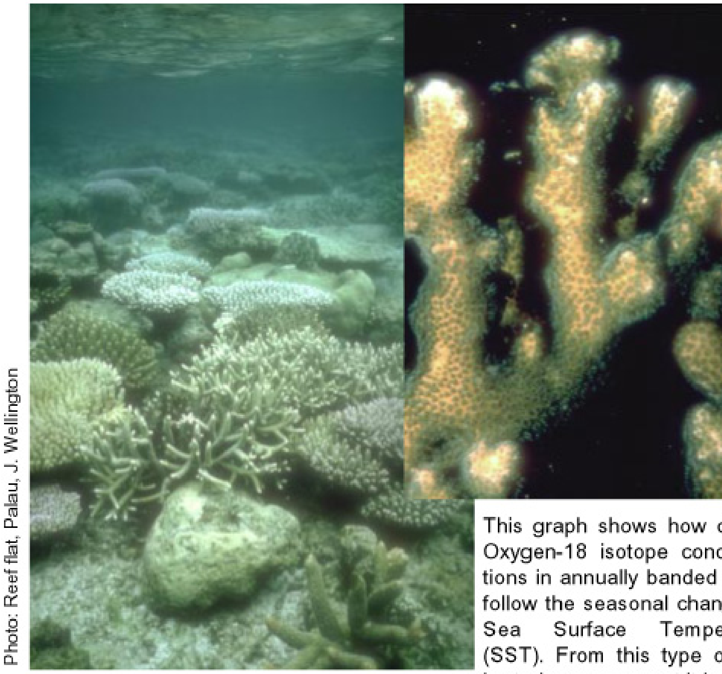
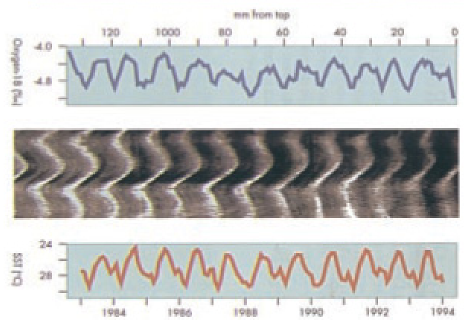


Photo: Reef flat, Palau, J. Wellington

Photo: Branching coral, Panama, J. Wellington



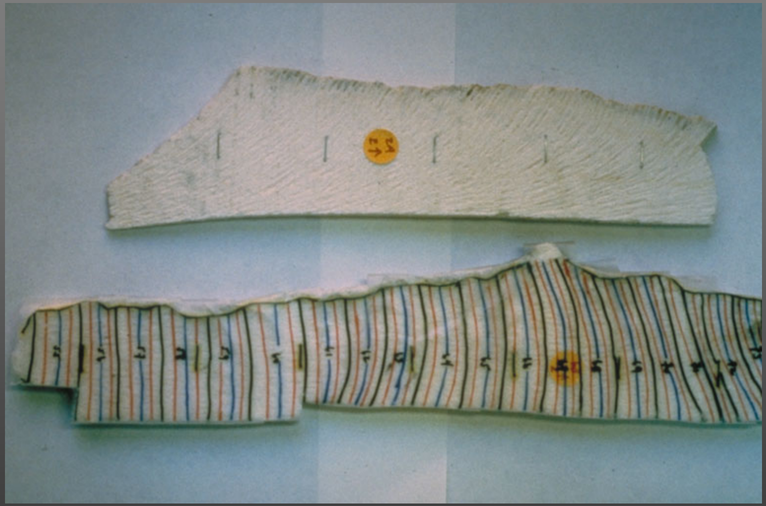
This graph shows how closely Oxygen-18 isotope concentrations in annually banded corals follow the seasonal changes in Sea Surface Temperature (SST). From this type of calibrated measurement it is possible to reconstruct the past periodicity of ENSO events. In some cases precipitation information can also be recovered from banded corals. The existence of fossil corals provides a potential record much longer than the lifespan of individual coral species (R. Dunbar and J. Cole, pers. communication).

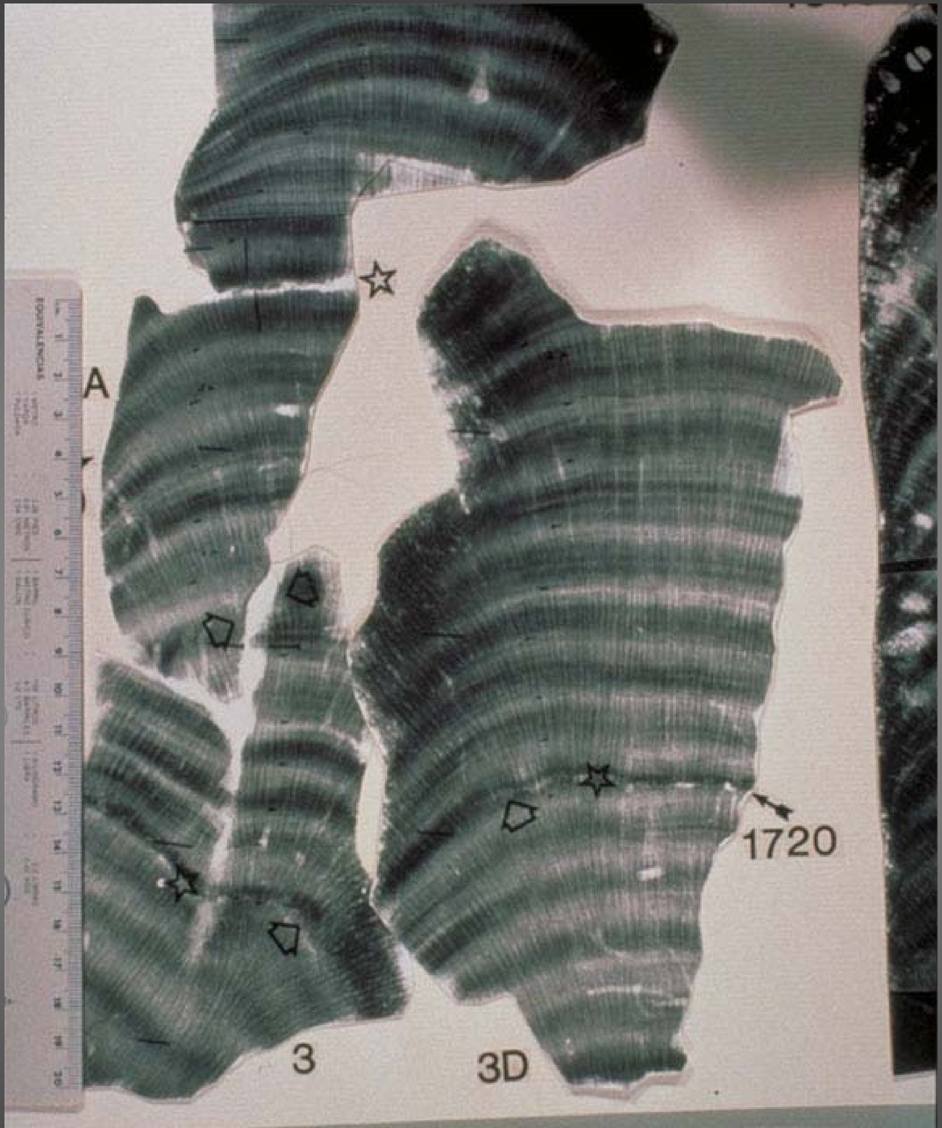
LB/PAG1/99-2

Corals: X ray image

black/white:
annual growth bands

obvious are density changes:
the brighter, the more dense;
more density in times of slow growth =
worse environmental conditions





Jerry Wellington
Department of Biology,
University of Houston

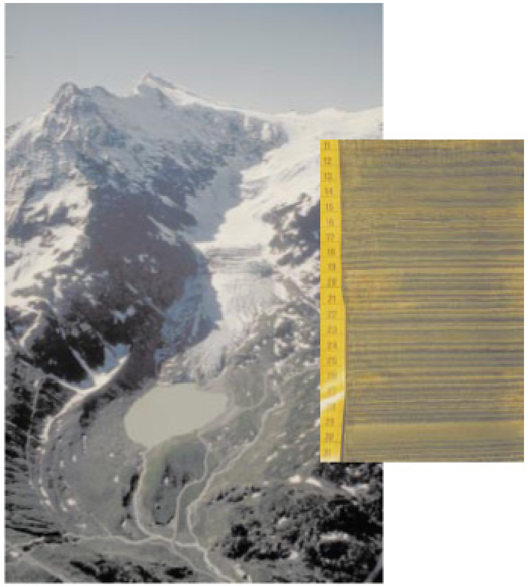
3. Lake sediments
(the memory of the continents)

Time intervall:
0 – about 30 ka bp

Resolution:
annual

Target parameters:
precipitation, temperature

Varved Sediments



Photos: Above: Steinsee, Switzerland, A. Lotter
upper right: annually laminated sediments
from Soppensee, Switzerland, A. Lotter

Lake sediments can provide annually resolved climatic records from continental interiors as a complement to tree ring records. A multiproxy approach allows independent constraints on reconstructed climate variability.

LB/PAG1/99-5

Lake sediments = varves

Varves=

periodically reappearing layers in sediments with biotic and abiotic components

Mike Sturm

4. Ice cores
(the memory of the atmosphere)

Time interval:
0 – 500 ka bp
Dome C: max. about 900 ka

Resolution:
annual or worse

Target parameters:
precipitation, temperature, methane, dust, CO_2

Ice Cores

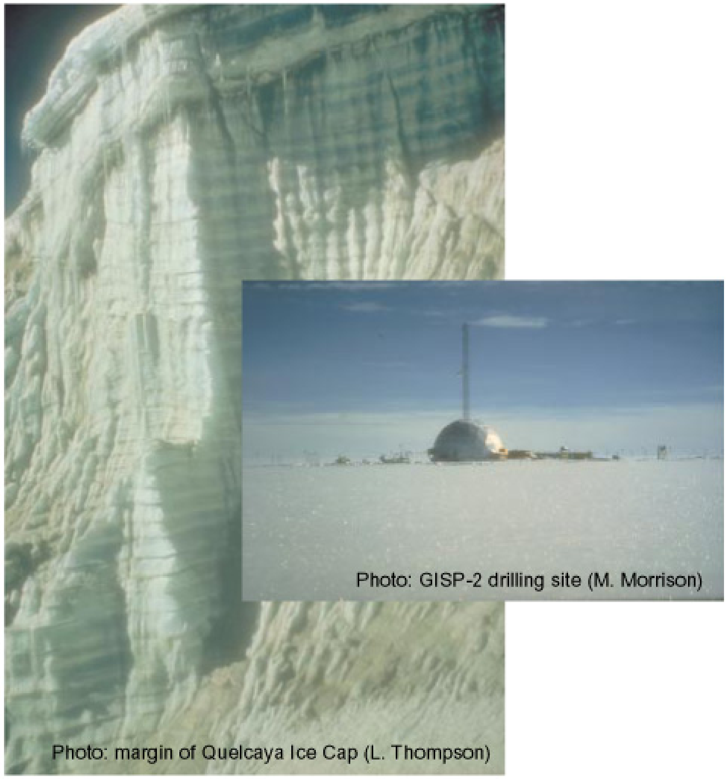


Photo: GISP-2 drilling site (M. Morrison)

Photo: margin of Quelcaya Ice Cap (L. Thompson)

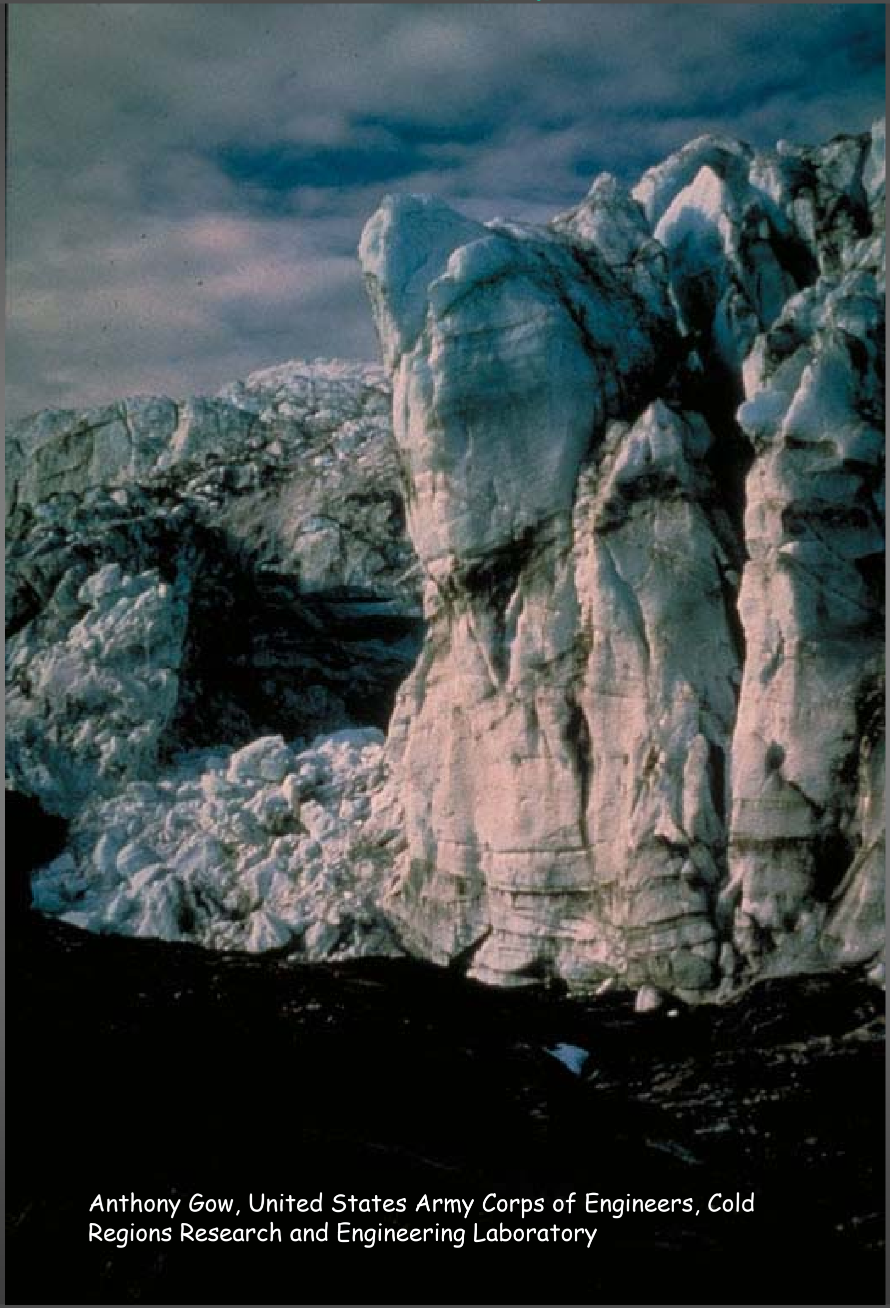
Ice accumulation records from ice sheets and glaciers in polar, mid and tropical latitudes can provide records of climate variability that are resolvable at an annual, sometimes seasonal level. Isotopic signatures in the ice itself yield quantitative information on past temperature and hydrological regimes. This can be set alongside records of changing atmospheric trace gases and dust/aerosol loading from the same core

LB/PAG1/99-1

Ice cores

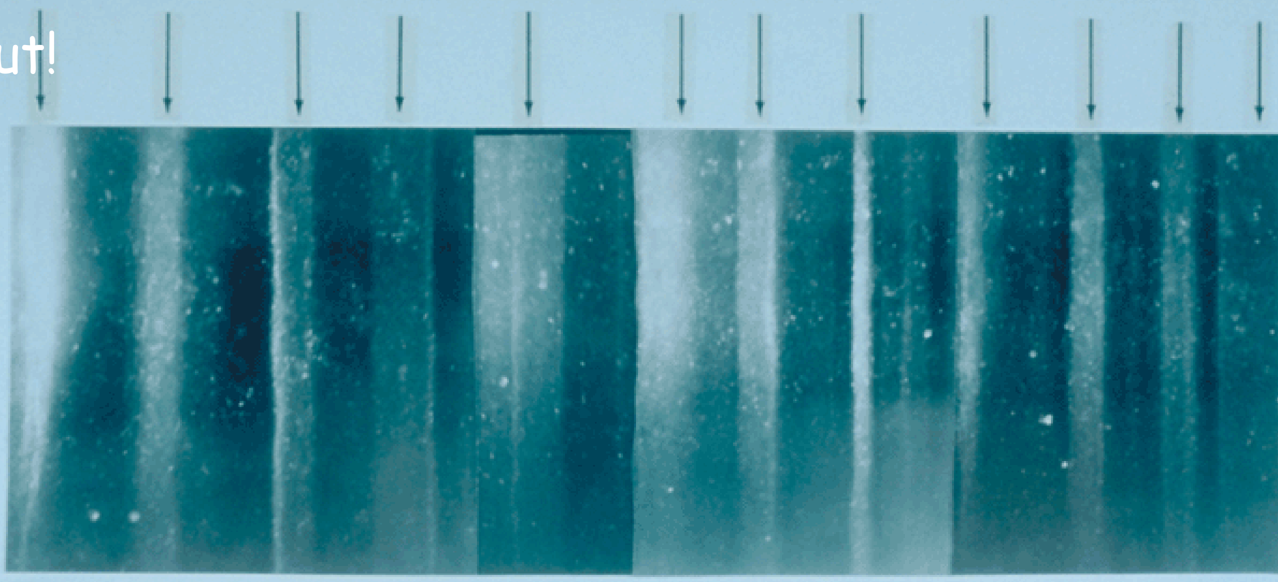
Greenland:
maximal ice thickness: 3.2 km
GRIP (european): 120 ka
GISP (american): 200 ka

Antarctica:
VOSTOK: 500 ka
EPICA/DOME C: 900 ka
accumulation rate slower



Anthony Gow, United States Army Corps of Engineers, Cold Regions Research and Engineering Laboratory

Ice core: summer- and winter layers



19 cm long section of GISP 2 ice core from 1855 m showing annual layer structure illuminated from below by a fiber optic source. Section contains 11 annual layers with summer layers (arrowed) sandwiched between darker winter layers.

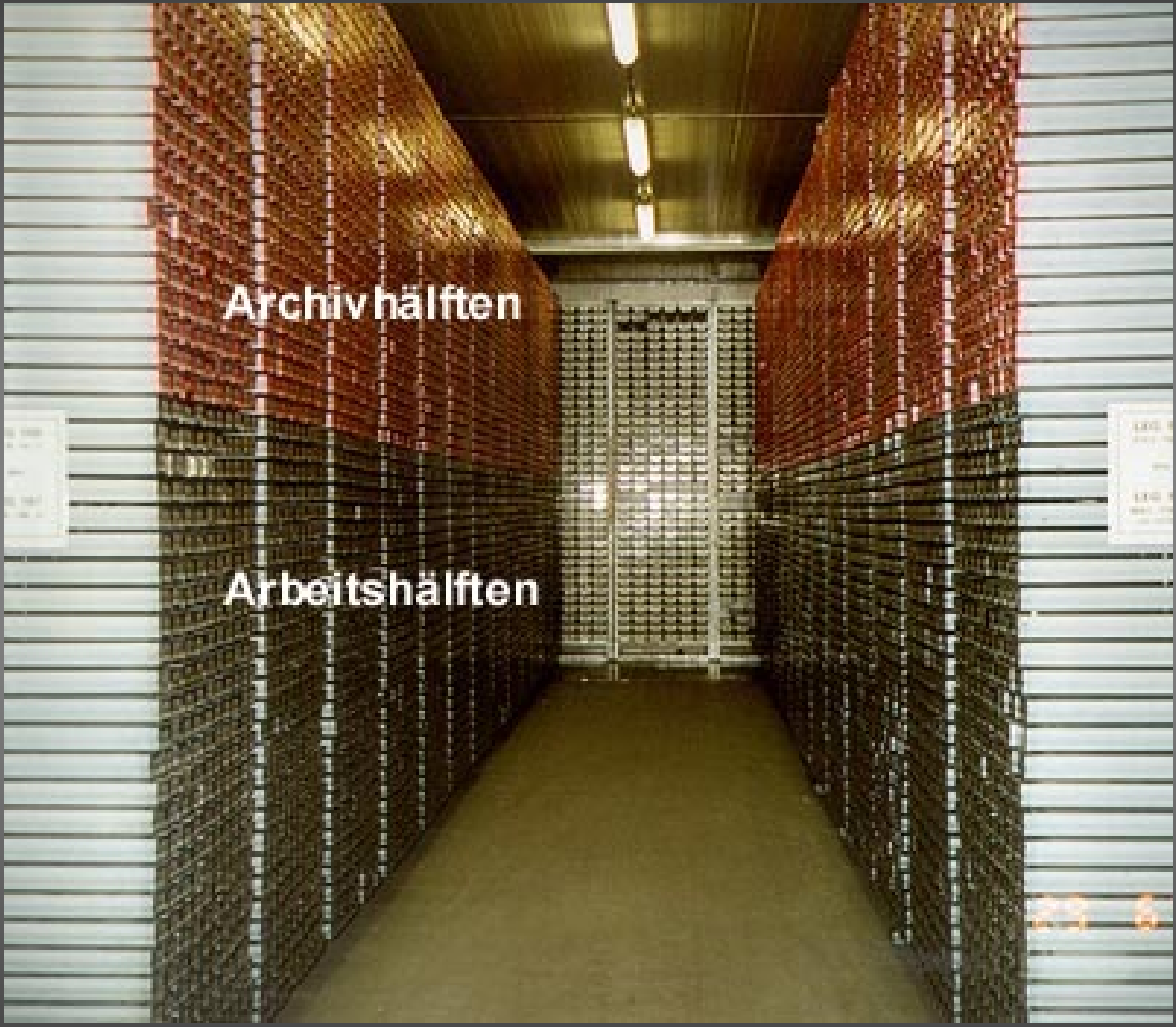
Anthony Gow, United States Army Corps of Engineers, Cold Regions Research and Engineering Laboratory

5. Marine sediments (the memory of the oceans)

Time interval:
0 – several Ma b.p.

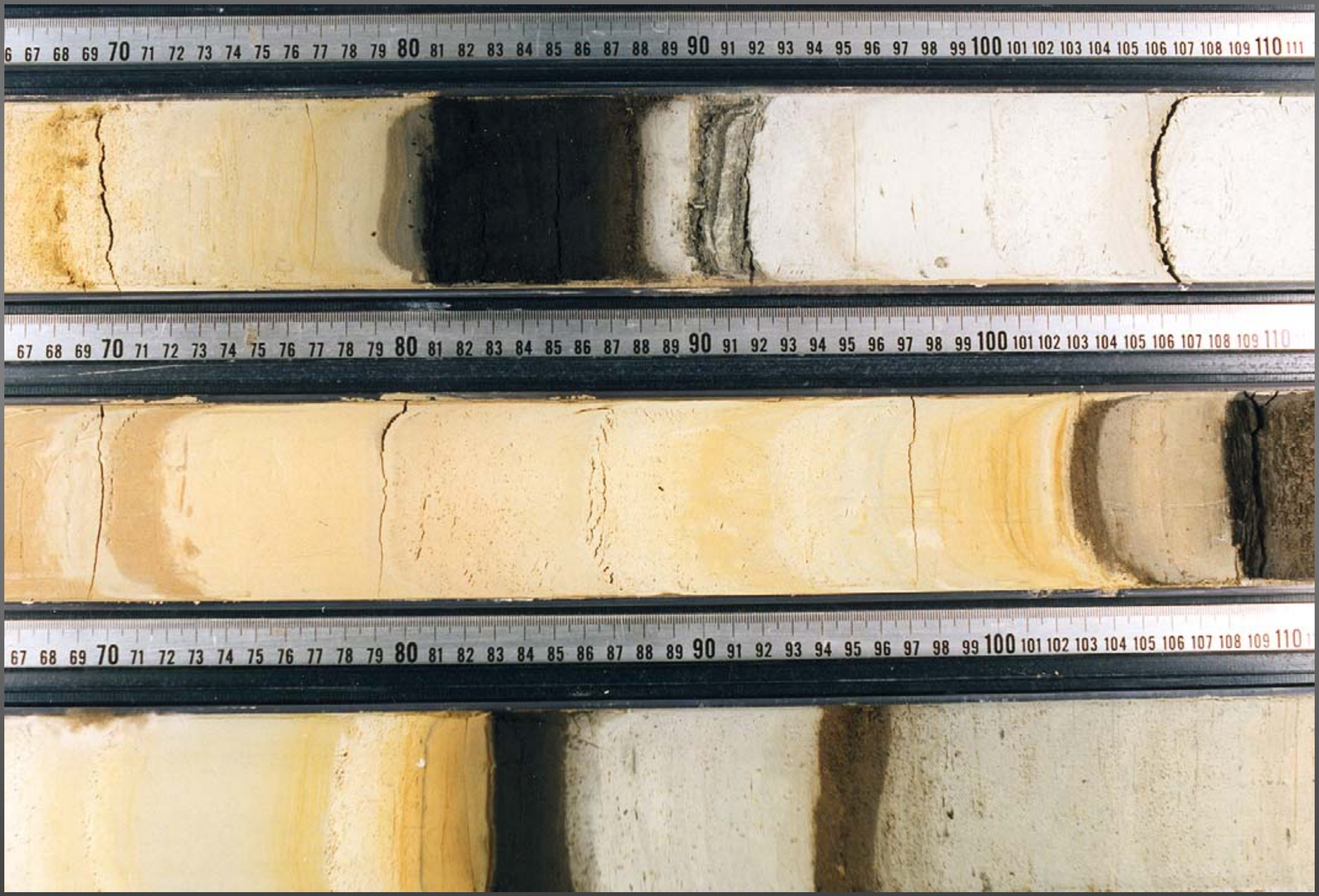
Resolution:
bad: >1000 years

Target parameters:
SST, ice volume, salinity, nutrients, productivity, circulation



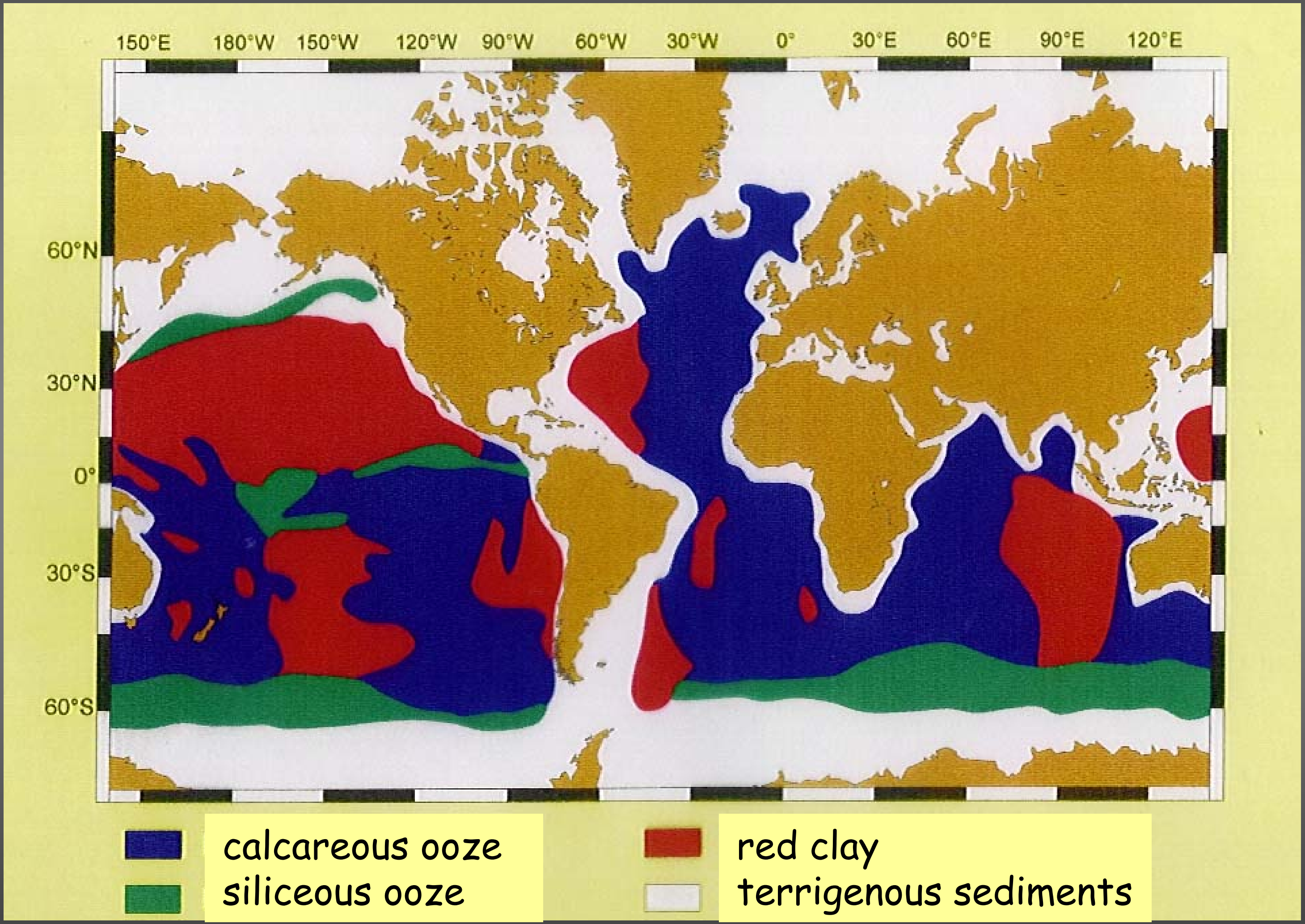
Bremen core repository, IODP

Marine sediments



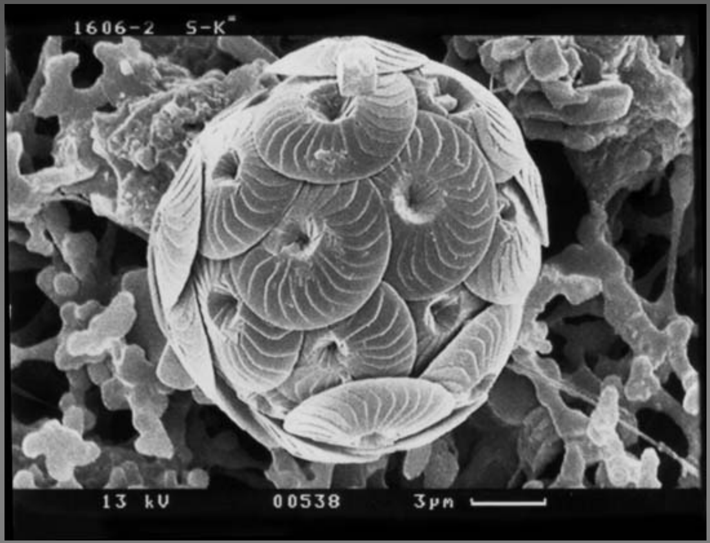
Marum

Marine sediments



Marine sediments: climate indicators

foraminifers



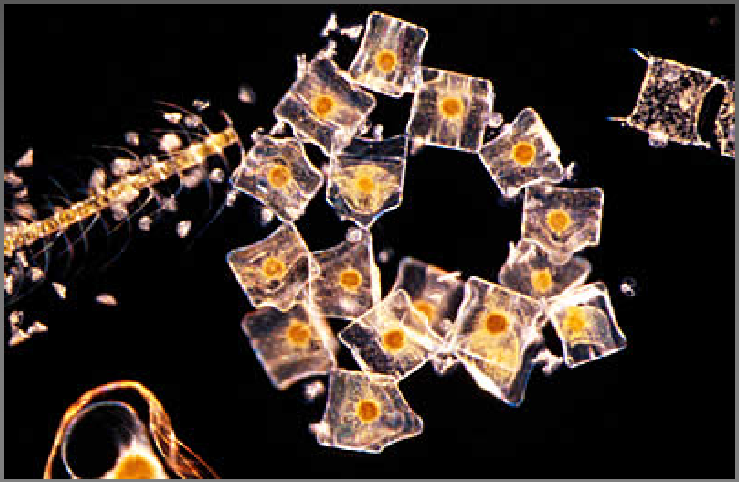
coccolithophorides

calcareous
oozes

pteropods

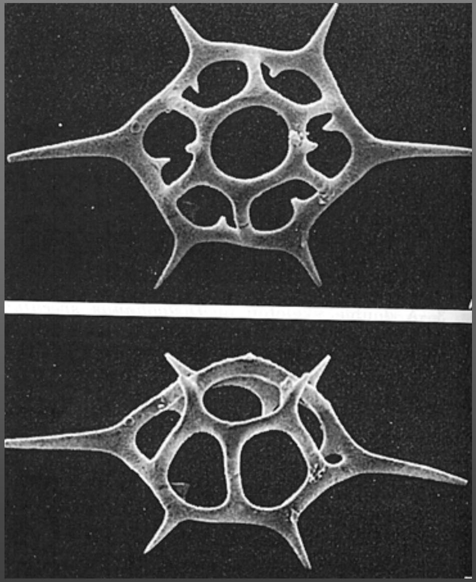
Marine sediments: climate indicators

radiolaria, alive



diatoms, alive

siliceous oozes



silicoflagellates

A2: How to take / to sample marine sediments

Sampling of the seafloor
Research Vessel METEOR

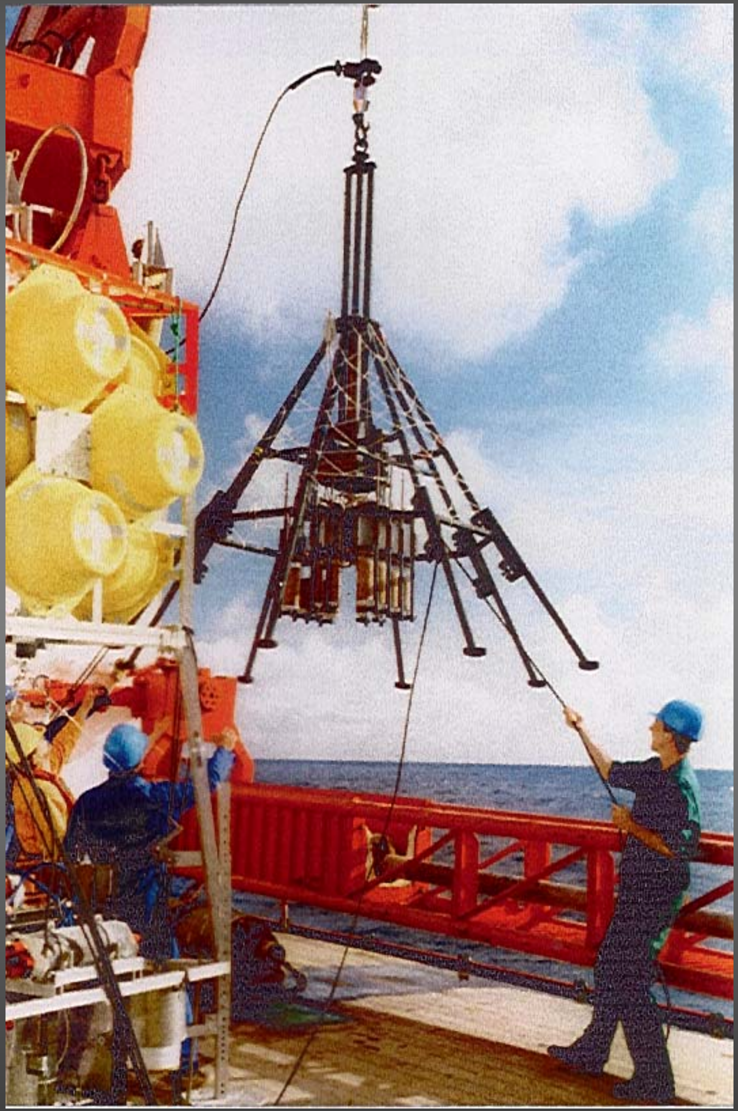
Photo: marum

ROV = remotely operated vehicel „Quest“

advantage: specific sampling

Marum

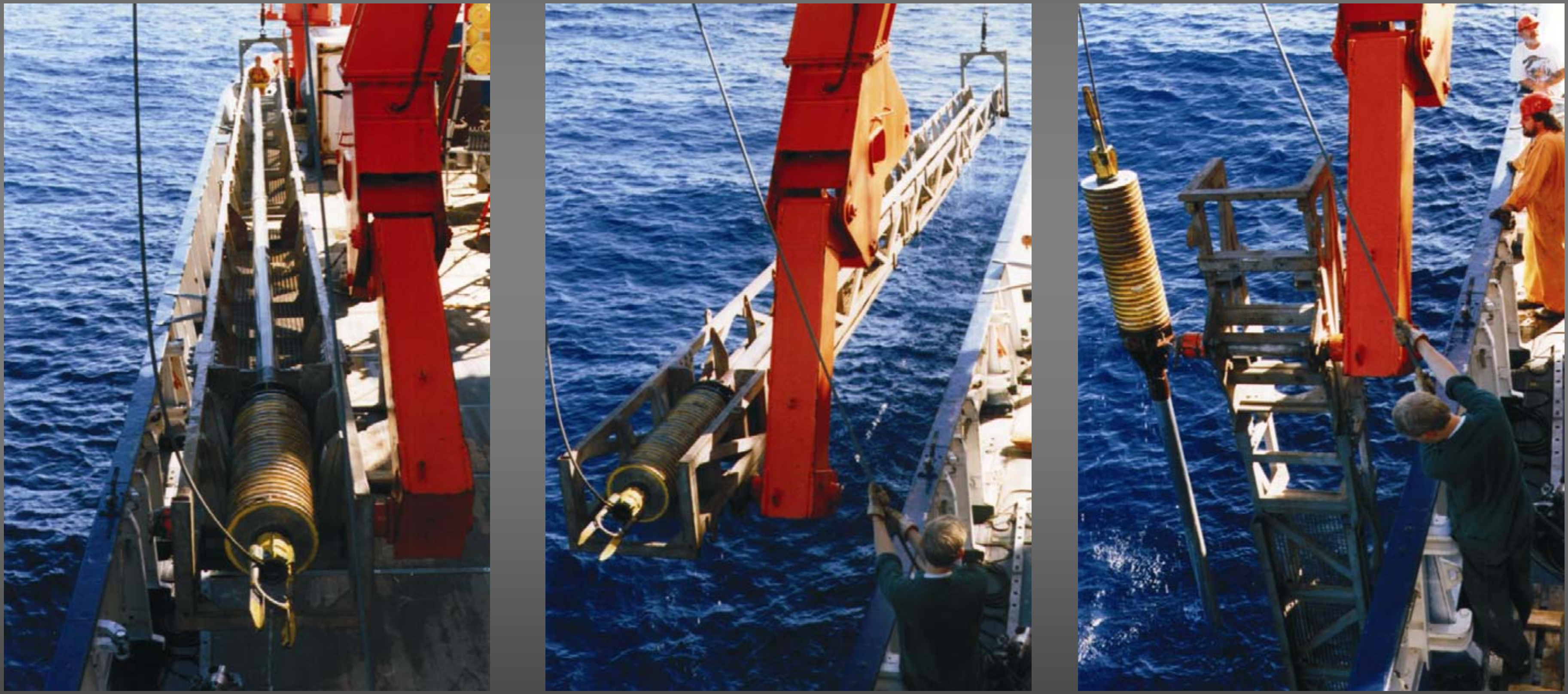
Sampling devices: Multicorer



marum

David M. Anderson, NOAA Paleoclimatology Program and INSTAAR, University of Colorado Boulder

Sampling devices: gravity corer



Marum

Portable remotely operated drill:

still under construction

advantages
- increased recovery
- good quality
- not disturbed
- low in price and available (with respect to drill platforms)

RCOM

IODP-drilling vessel „Joides Resolution“:

ONE of several drilling platforms

IODP

Minolta color scanning

IODP

Faunistic investigations

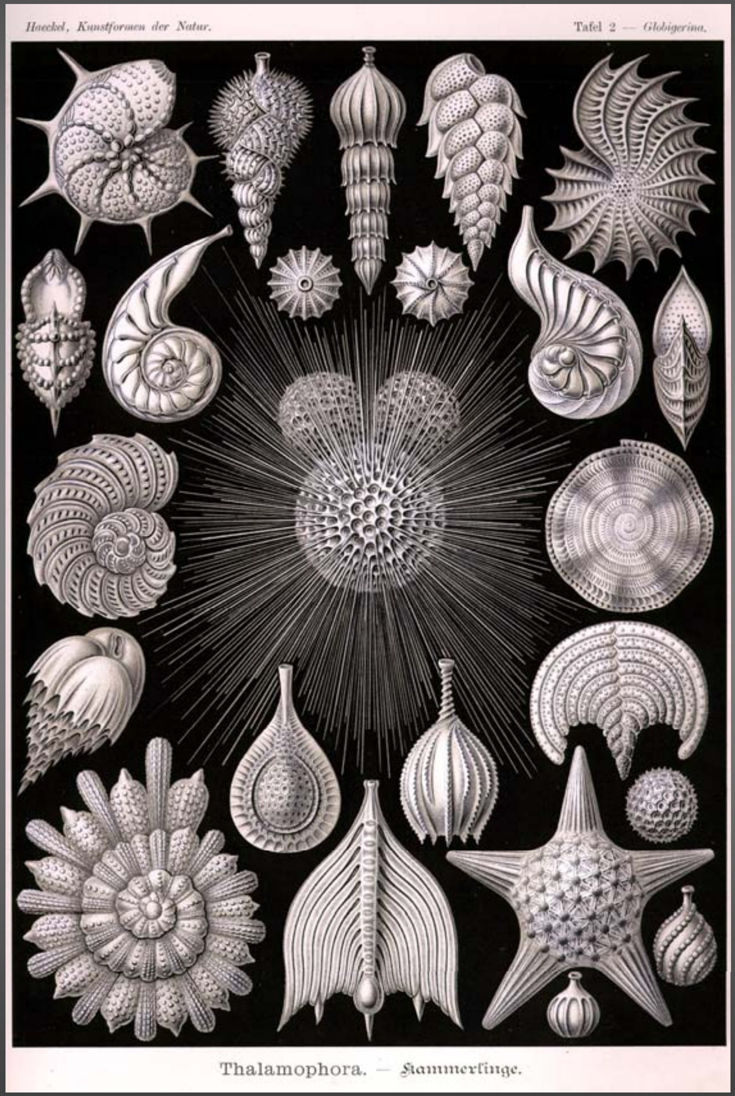
Geolab, onboard RV METEOR

Marum

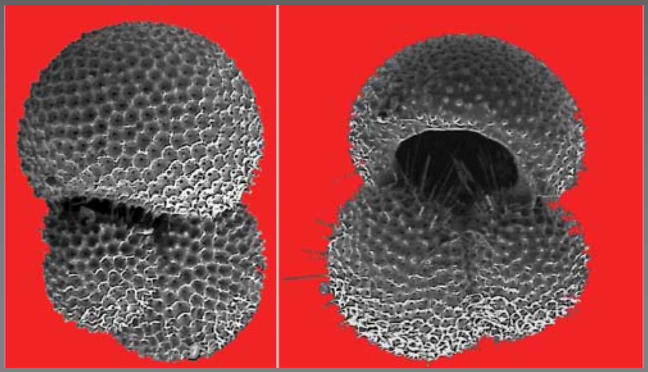
Washing of the samples

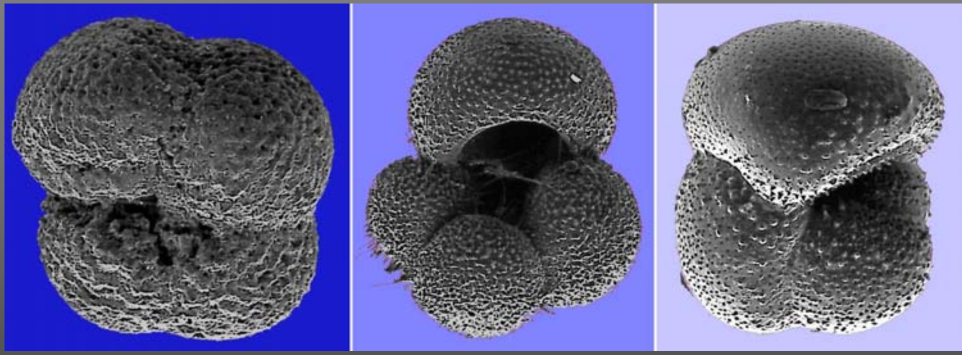
Marum

Climate indicators: foraminifers



drawings: Haeckel





photos: Donner

Part B:
Climate parameters and proxies

How to analyse and reconstruct past climate:

Climate parameters (a few):

- **sea surface temperature (SST)**
- ice volume, sea level, salinity
- productivity
- ocean currents

Proxies to estimate SST

biological proxy

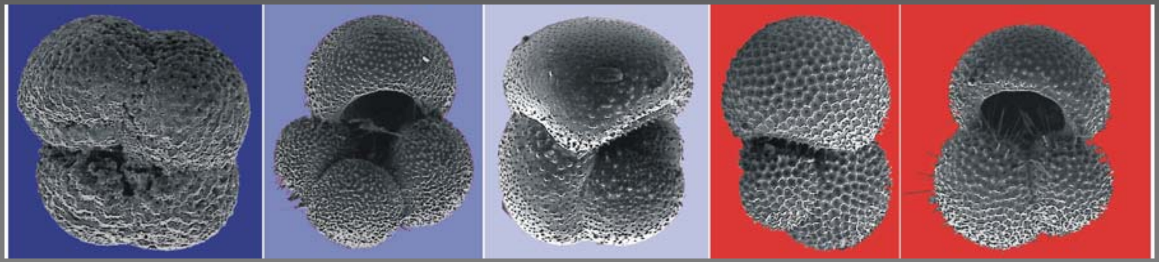
- faunal-/floral assemblages

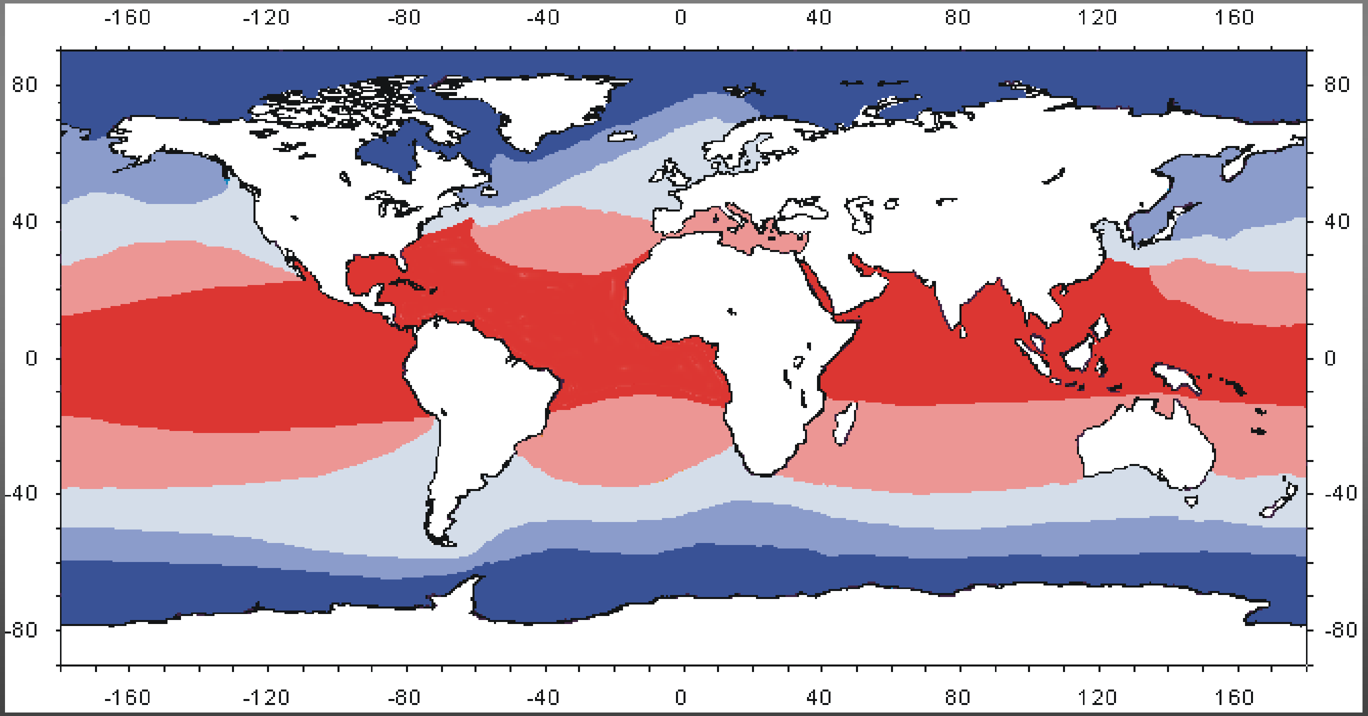
chemical proxies

- alkenones (coccolithophorids)
- oxygen-isotope ratios (calcareous or siliceous shells)
- Mg/Ca ratios (calcareous shells)

1. Assemblage of foraminifers ($CaCO_3$)

recent

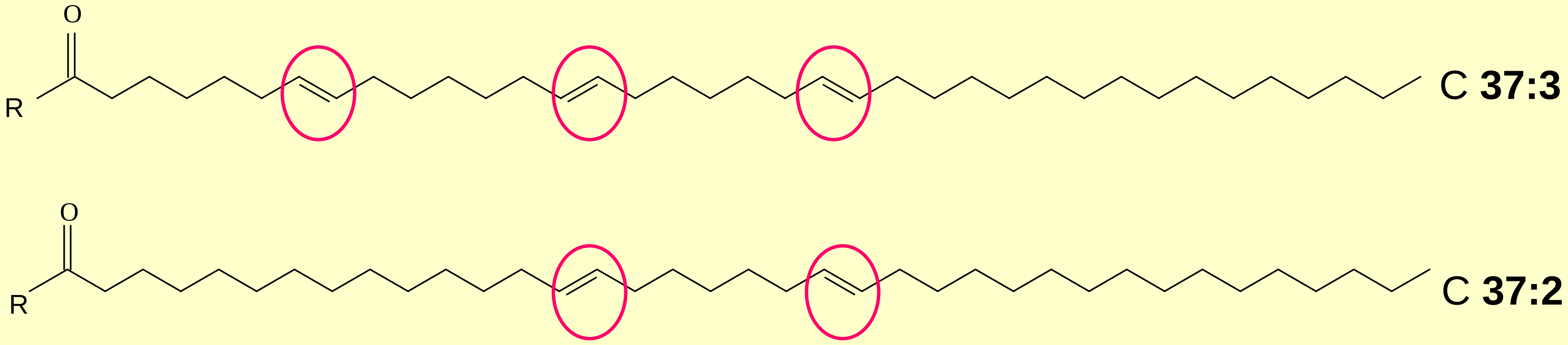




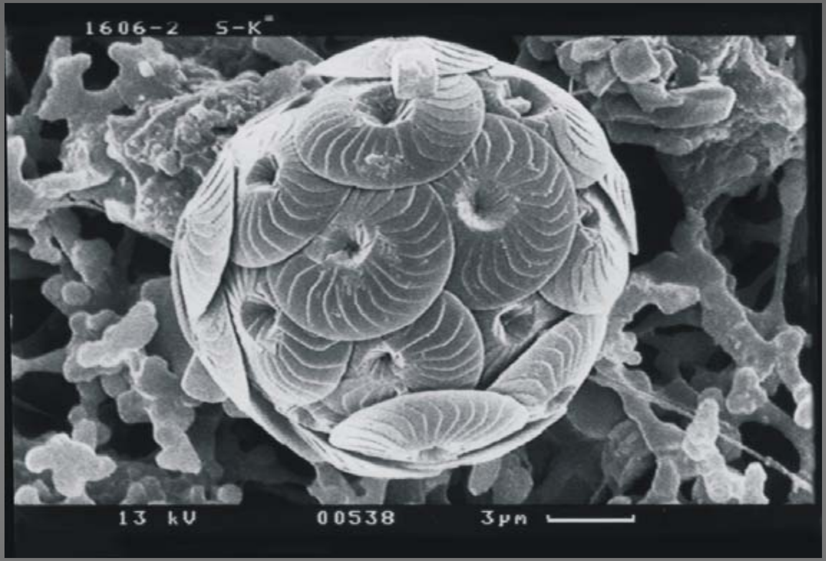
2. Alkenones

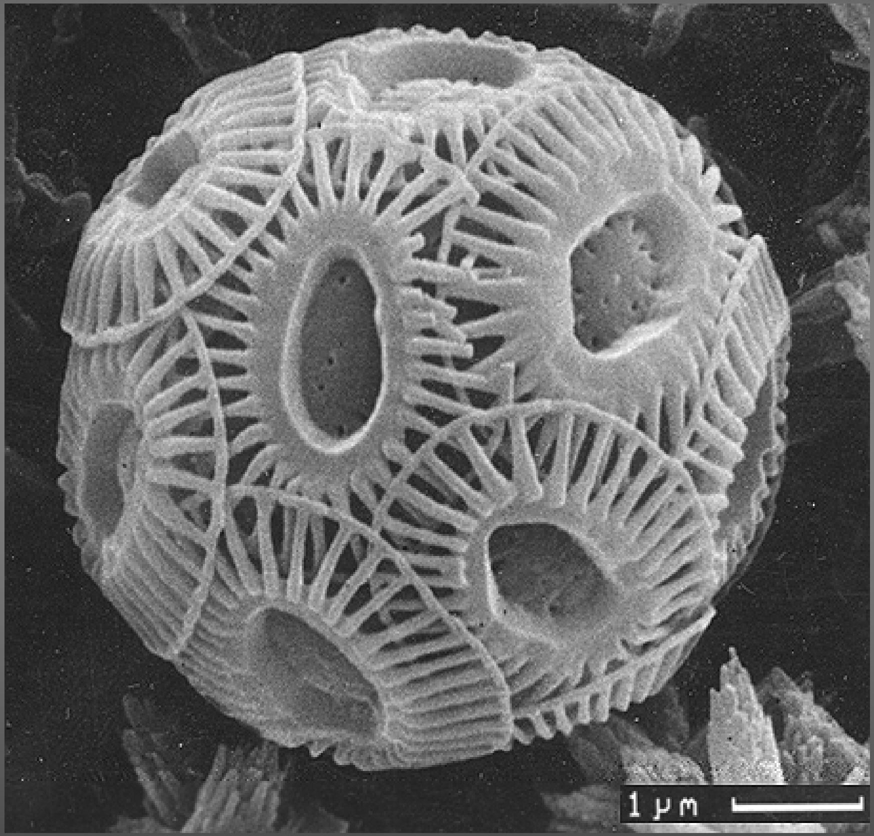
long-chained, 2-, 3-, 4-times unsatturated hydrocarbons (*C* 37, *C* 38, *C* 39)

- produced by coccolithophorids
- remain in sediment
- degree of unsatturation is temperature dependant



Coccolithophorids (calcareous phytoplankton)

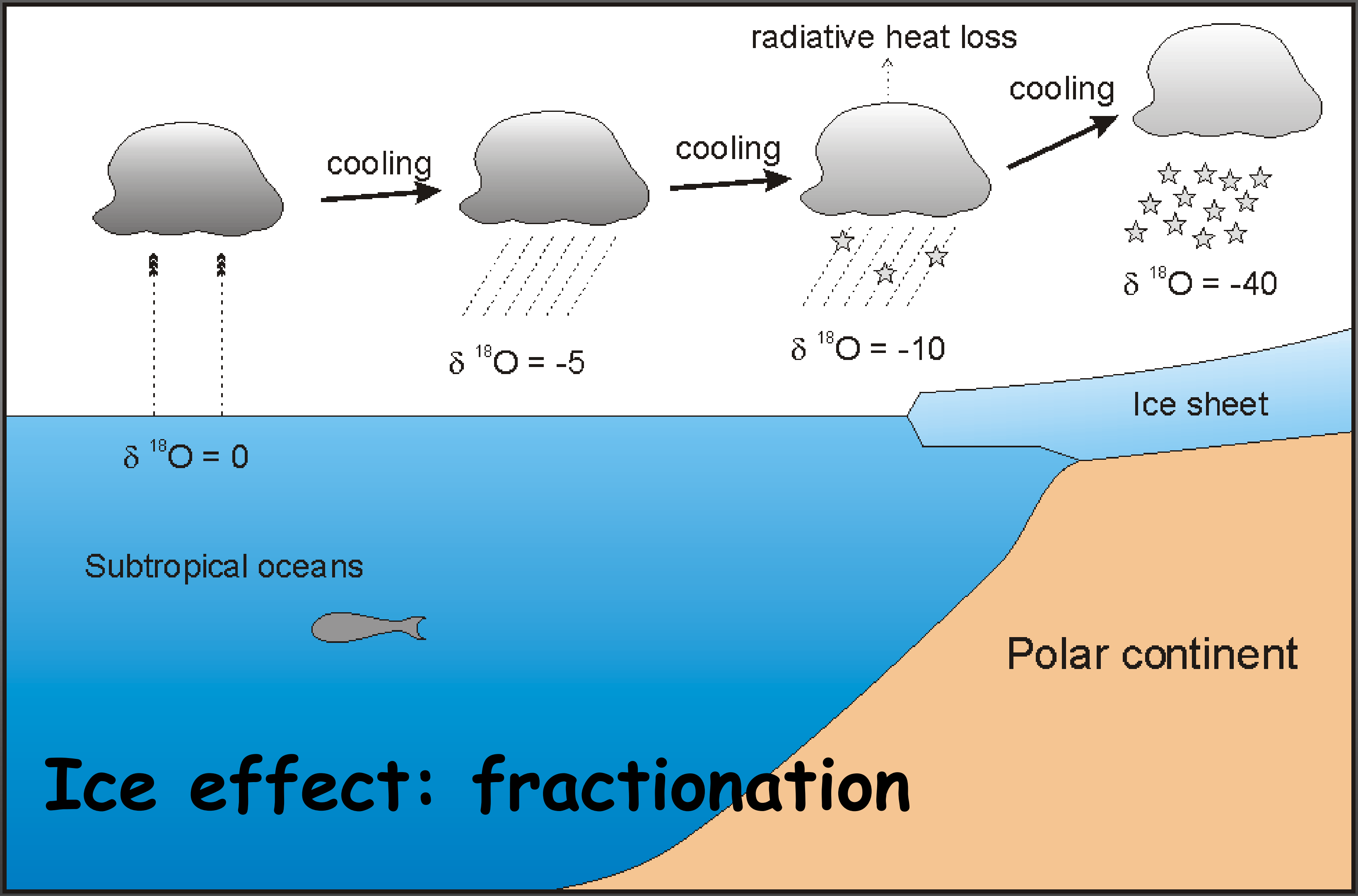




Major producer of alkenones,
recent:
Emiliania huxleyi

Photos:Marum

3. Oxygen isotope ratios ($\delta^{18}O$)



4. Mg/Ca ratios

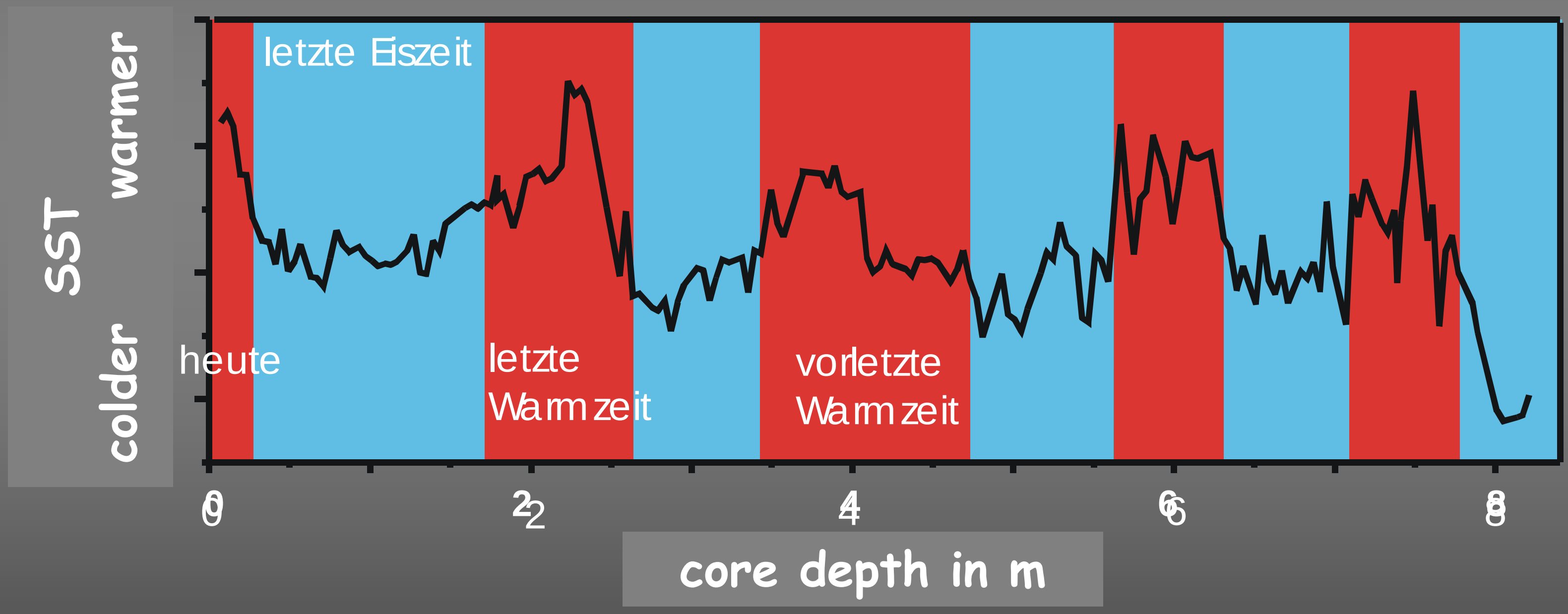
All 3 methods to reconstruct SST have their pros and cons , ultimate method is looked for:

Mg/Ca ratio: Calcareous organisms use Ca to build up their shells. The higher the water temperature, the more Mg instead of Ca.
But this Mg/Ca ratio method showed up only as a forth method, with the same deficiency as the others.

Until now no ultimate method is found !

only solution: the **multi-proxy approach**

Result of reconstruction



Part C: Evaluation

RV METEOR Cruise M16/1: Pointe Noire – Recife

Core GeoB 1403-3:
01°11,9'S   11°52,6'W
Guinea Basin
(equatorial
eastern Atlantic)

water depth: 3692 m
core length: 15,24 m

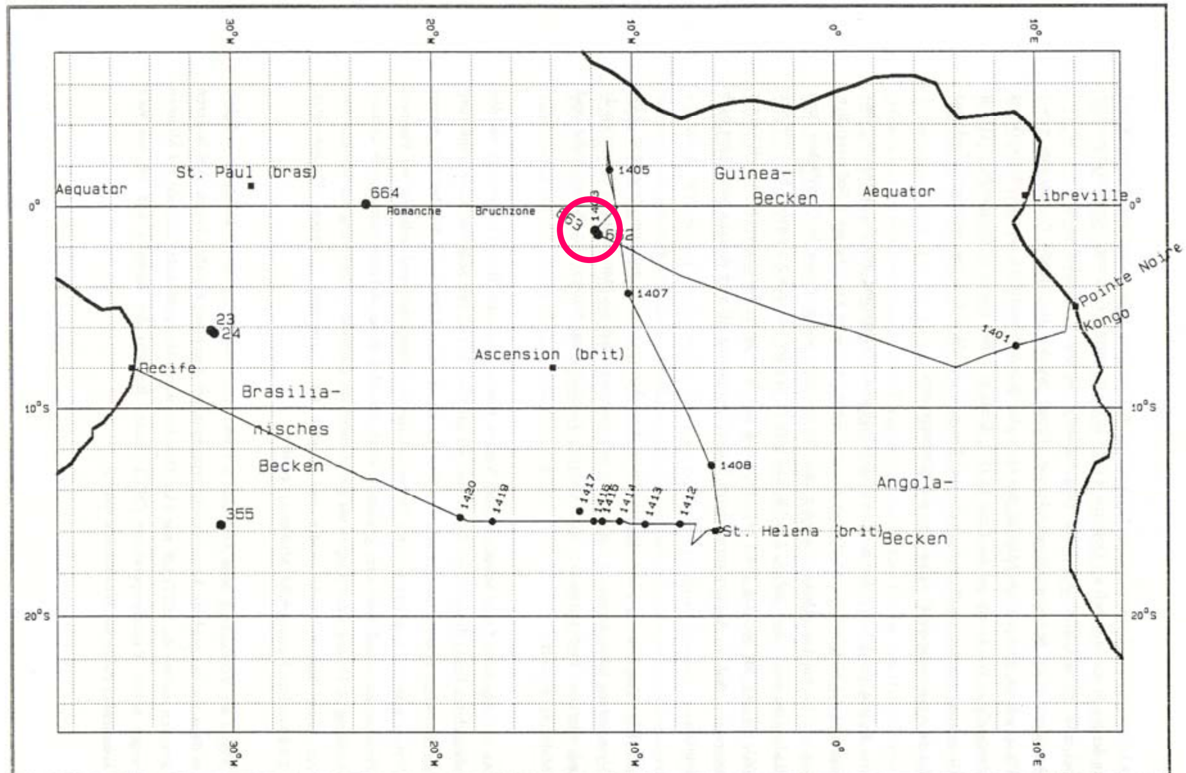
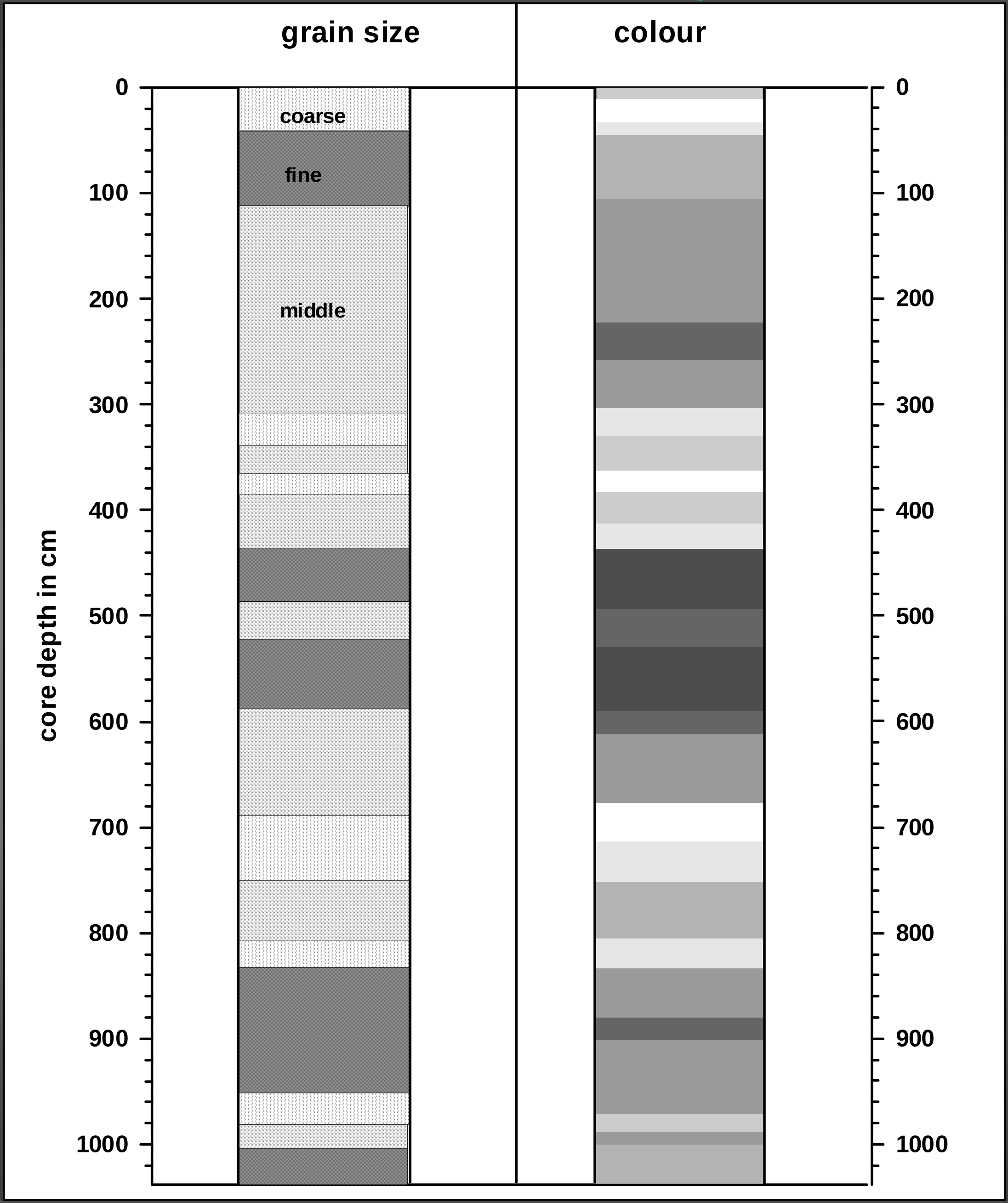


Abb. 1: Fahrtroute der METEOR-Reise M 16/1 (Maßstab 1 : 25 000 000).
Kurs/PARASOUND analog/digital, Schwerelote, F-Tests.

Sedimentechographie
Universitaet Bremen

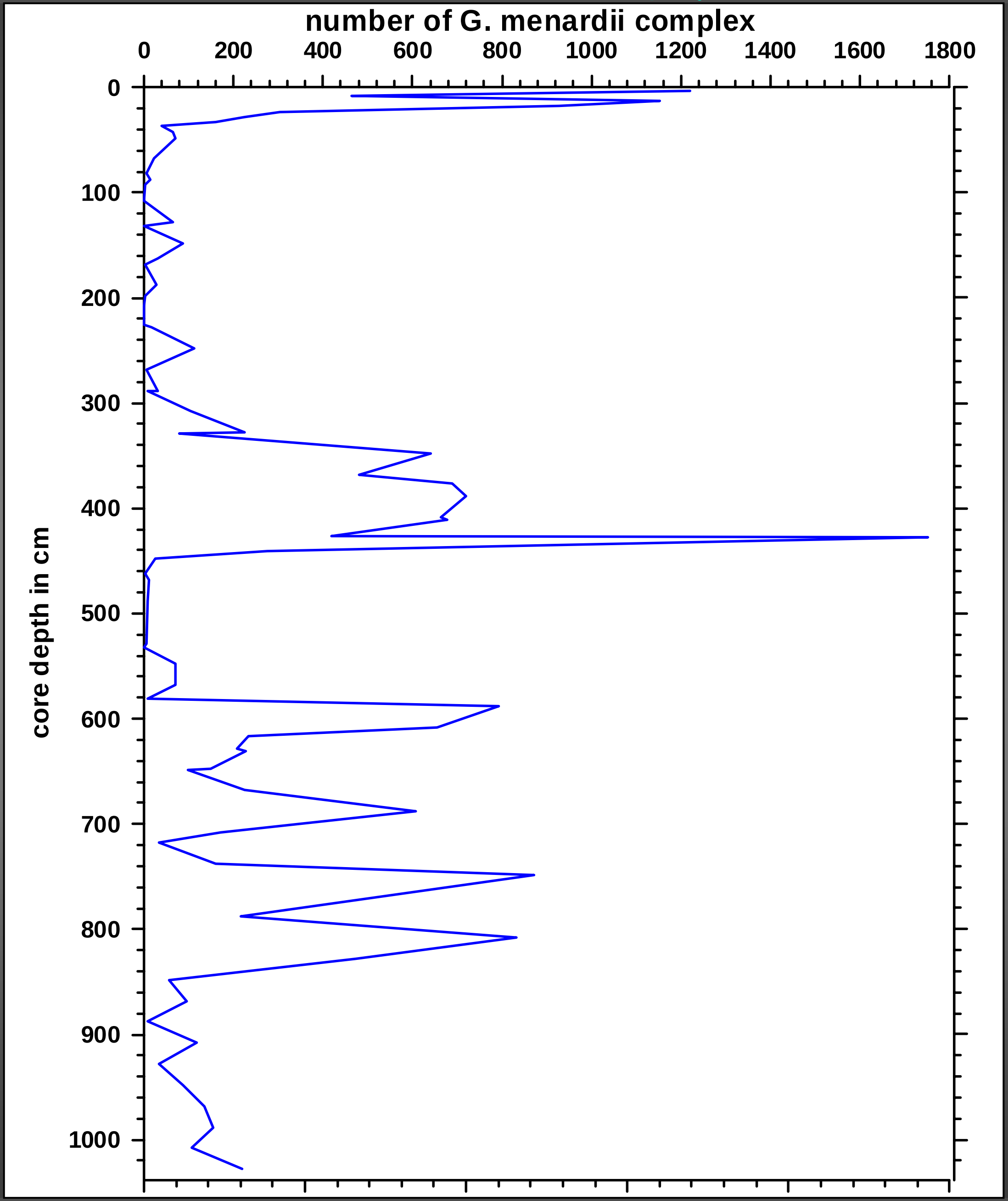
GeoB 1403-3

core description:
grain size,
colour

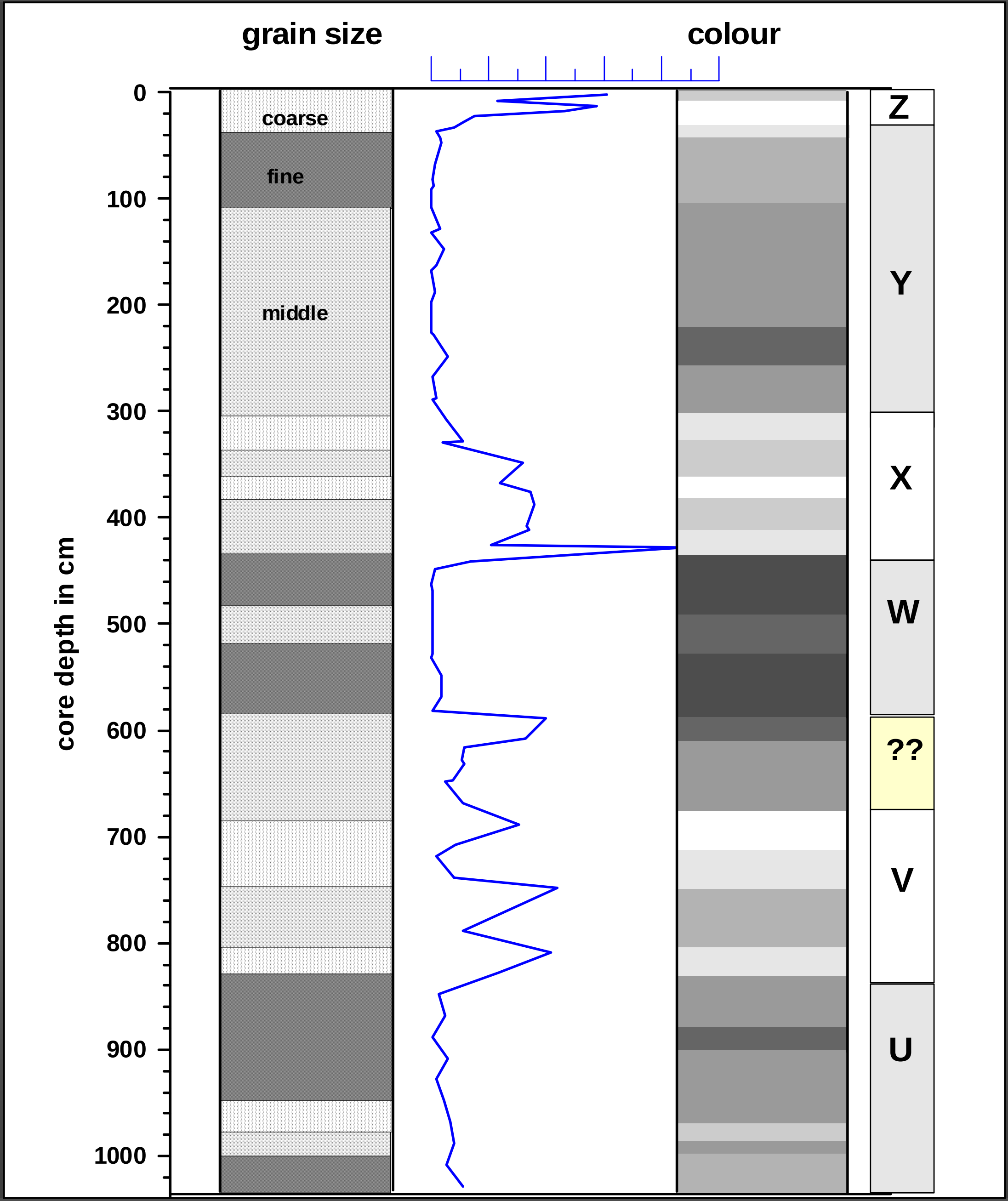


GeoB 1403-3

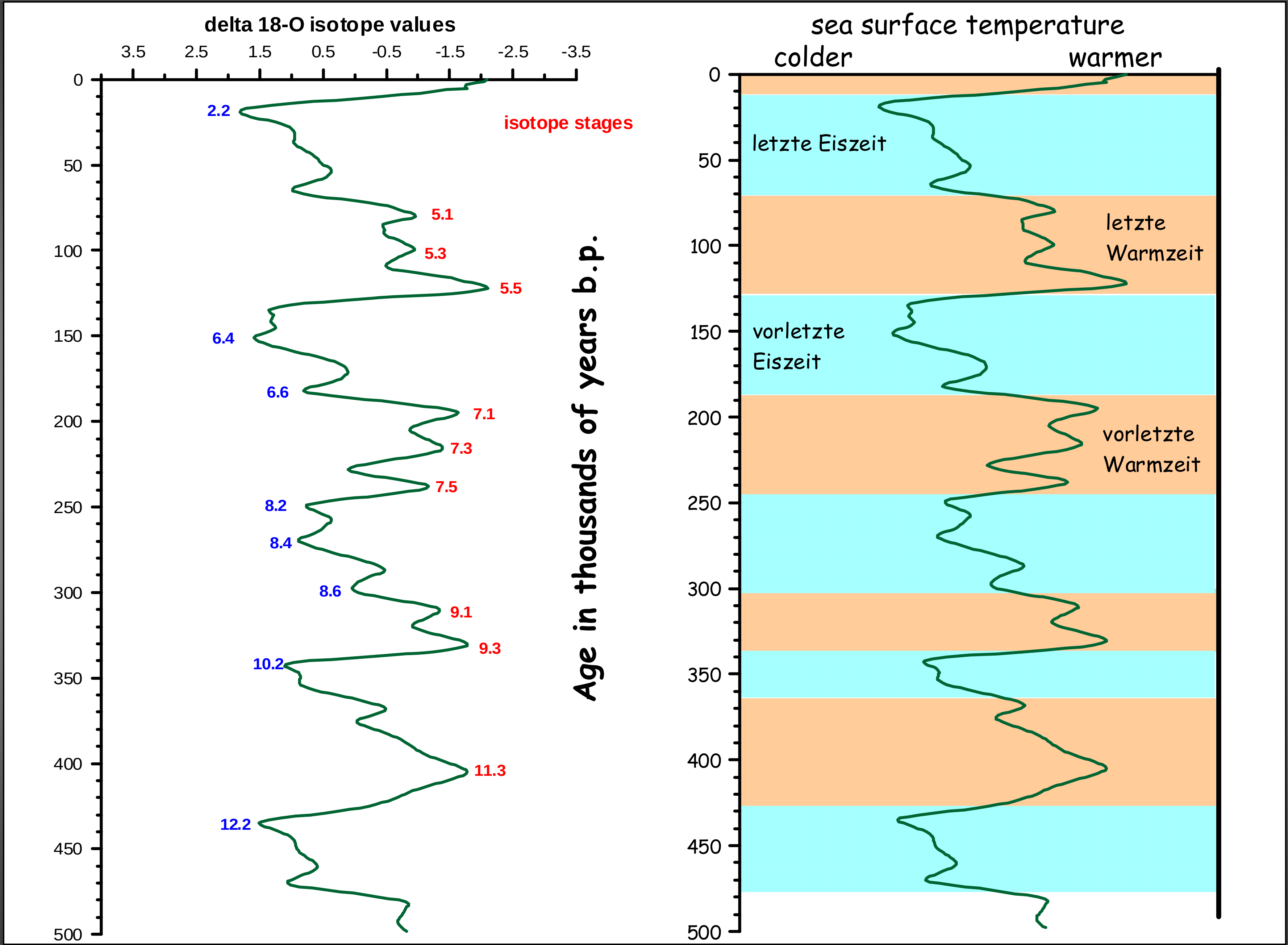
biostratigraphy:
number of
G. menardii



GeoB 1403-3
total

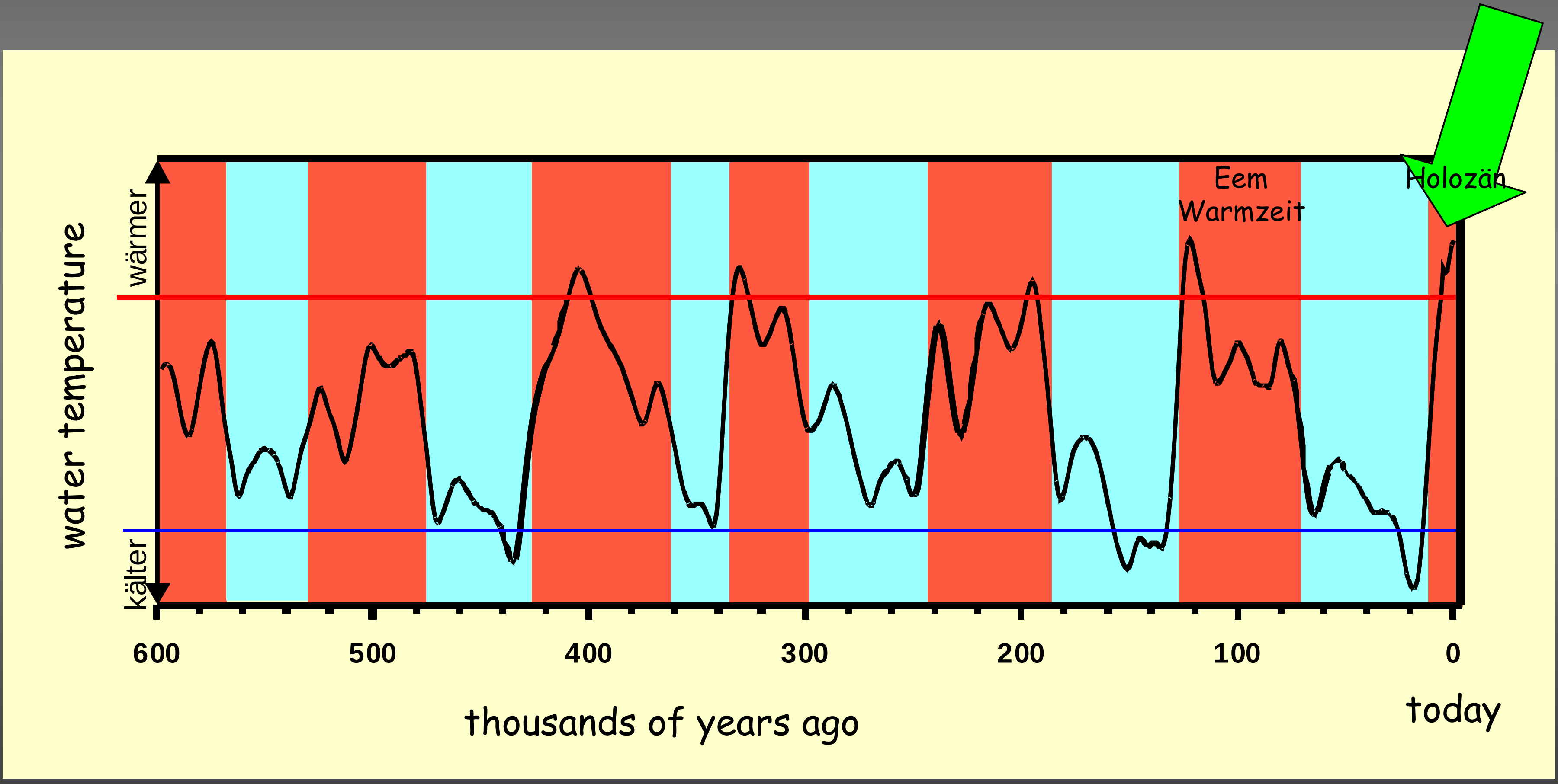


Specmap Eichkurve



Ice age: Pleistocene

cycles of ice- and warmages since 2.75 Ma



(Specmap)