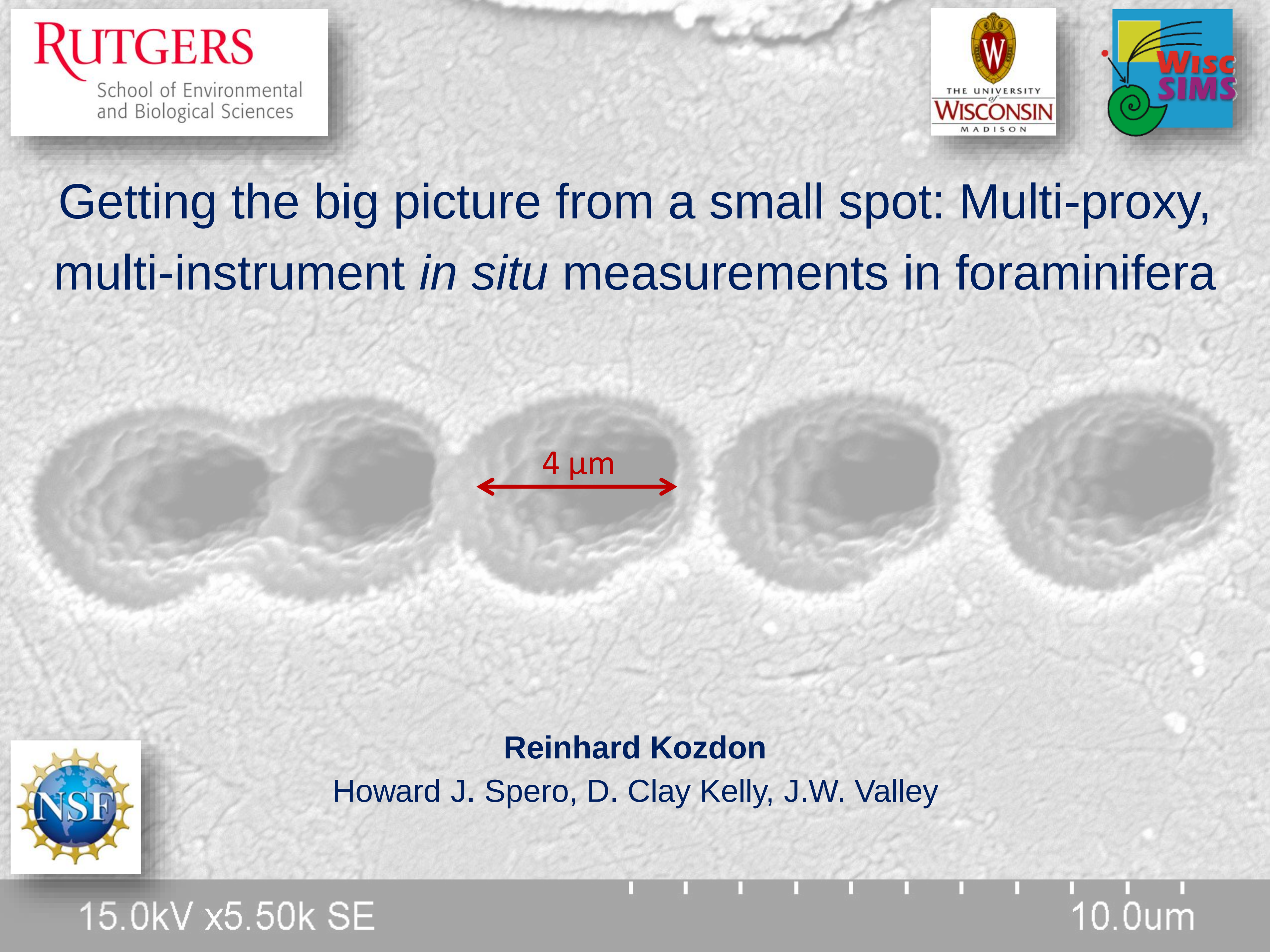
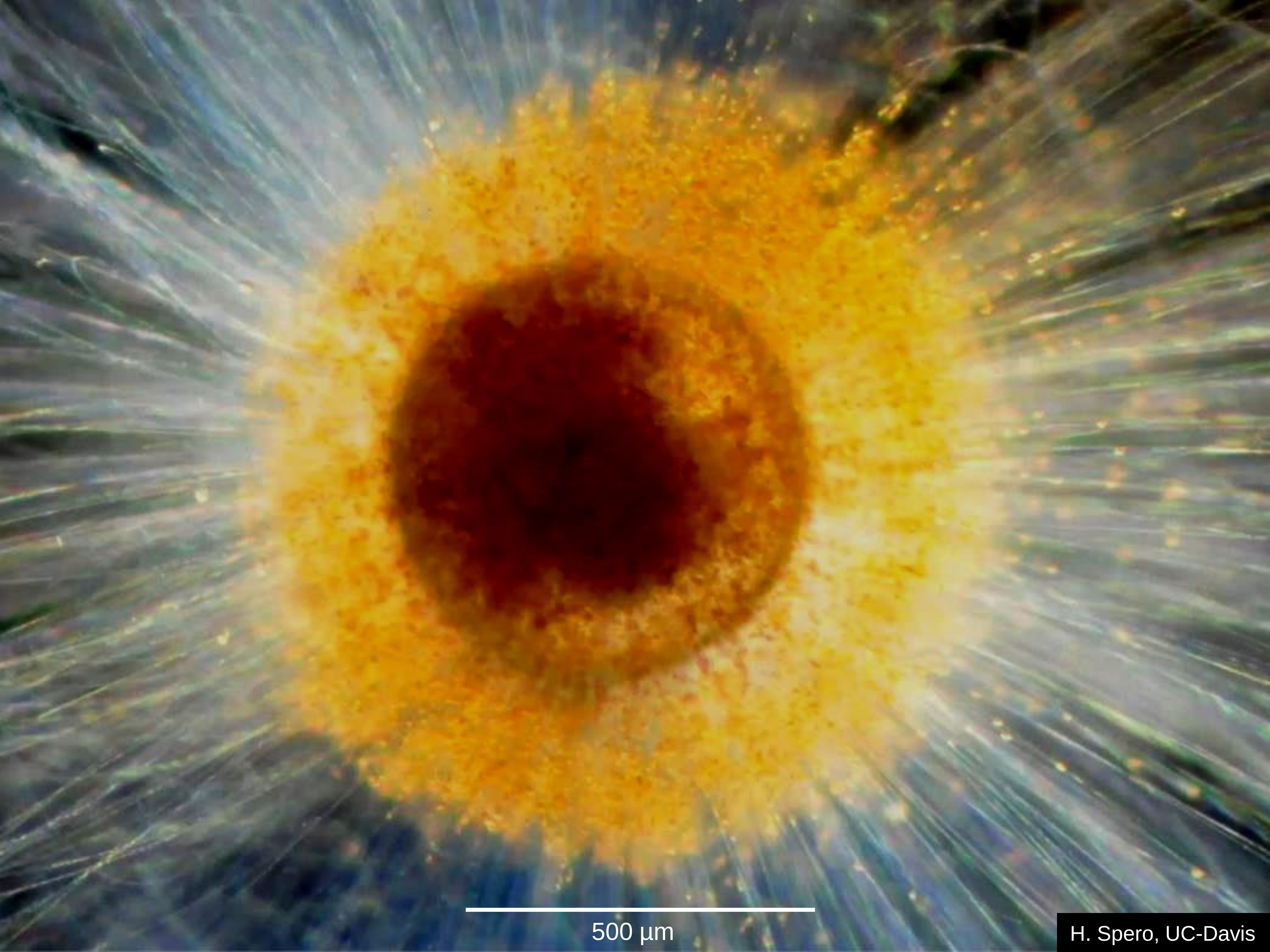
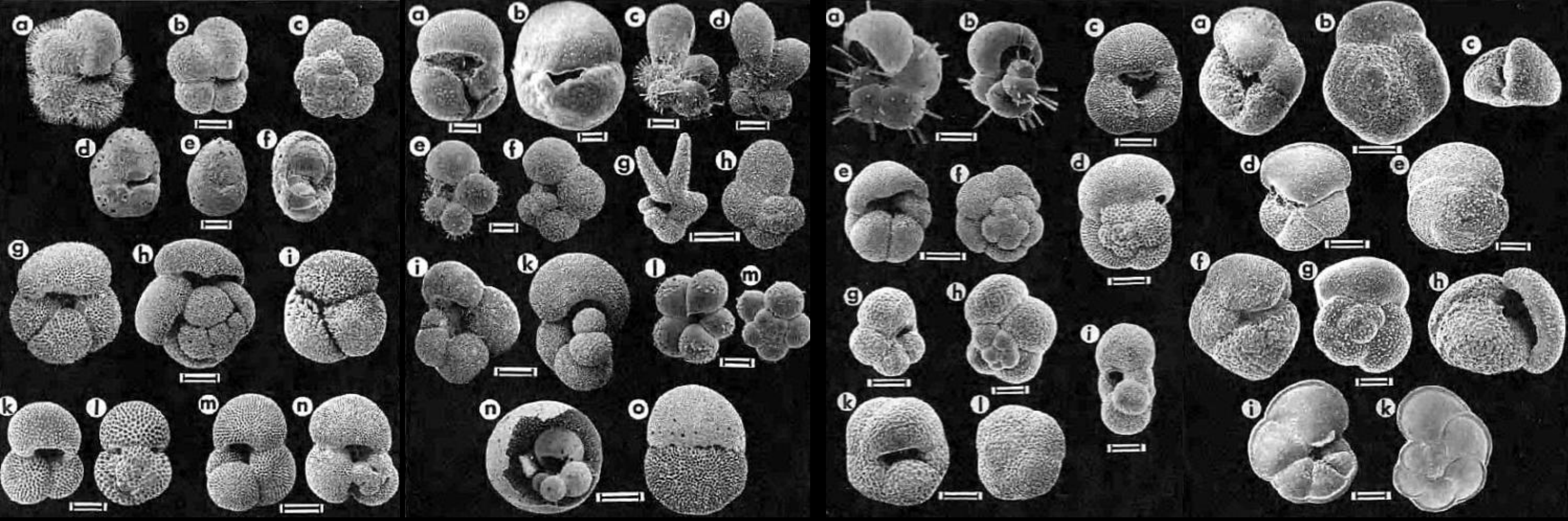
Getting the big picture from a small spot: Multi-proxy, multi-instrument *in situ* measurements in foraminifera

Reinhard Kozdon

Howard J. Spero, D. Clay Kelly, J.W. Valley

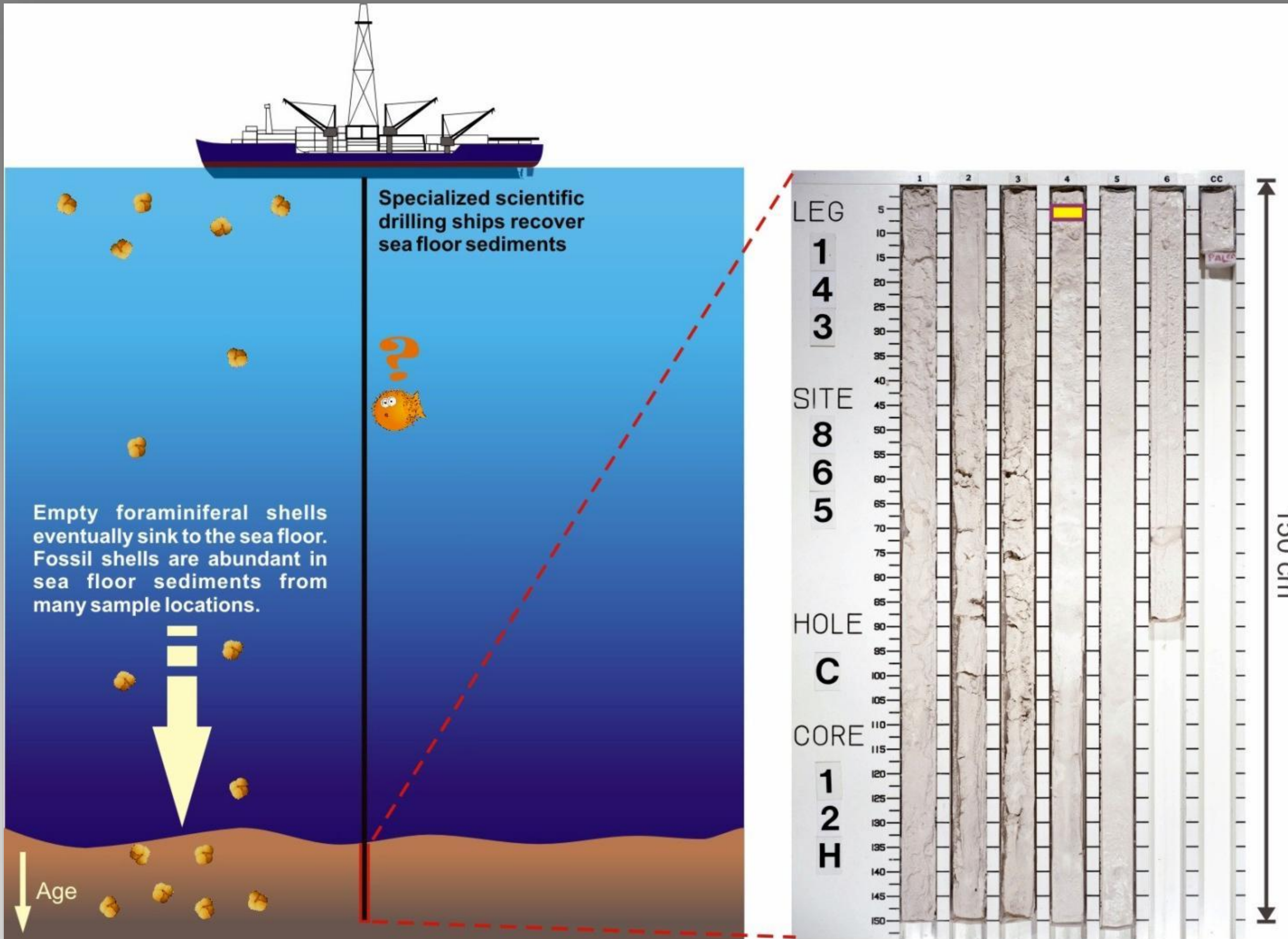



500 µm
H. Spero, UC-Davis



Modern planktonic foraminifera (~70 modern species)

Hemleben et al., 1989



Specialized scientific drilling ships recover sea floor sediments
Empty foraminiferal shells eventually sink to the sea floor. Fossil shells are abundant in sea floor sediments from many sample locations.
Age
LEG
143
SITE
865
HOLE
C
CORE
12H
1
2
3
4
5
6
CC
150 cm

Foraminifera – recorder of past climate conditions

- analyses of stable oxygen isotopes ($\delta^{18}O$) from fossil foraminiferal shells is arguably the most powerful proxy to assess the climate history of Earth
- Emiliani (1955) was the first to measure the $\delta^{18}O$ in foraminiferal shells (as proposed by Epstein and Mayeda, 1953)

Published 60 years ago!

PLEISTOCENE TEMPERATURES[1]

CESARE EMILIANI
University of Chicago

ABSTRACT

Oxygen isotopic analyses of pelagic Foraminifera from Atlantic, Caribbean, and Pacific deep-sea cores indicate that the temperature of superficial waters in the equatorial Atlantic and Caribbean underwent periodic oscillations during the Pleistocene with an amplitude of about 6° C. The temperature record of the Pacific cores was much affected by local oceanographic conditions.

Seven complete temperature cycles are shown by a Caribbean core. By extrapolating rates of sedimentation based on radiocarbon data, an age of about 280,000 years is obtained for the earliest temperature minimum. Correlation with continental events suggests that the earliest temperature minimum corresponds to the first major glaciation.

The chronology of Pacific cores proposed by Arrhenius (1952) must be modified if correspondence with the chronology of Atlantic and Caribbean cores is desired.

In one Pacific core which extends to the Pliocene, the 610-cm. level below top is believed to represent the Plio-Pleistocene boundary. About fifteen complete temperature cycles occur above this level, and the length of Pleistocene time is estimated at about 600,000 years. The so-called pre-Günzian stages appear to span a time interval about as long as the Günz and post-Günzian stages. A glacial lowering of sea-level of about 100 m. is indicated.

Foraminifera – recorder of past climate conditions

Published 60 years ago!

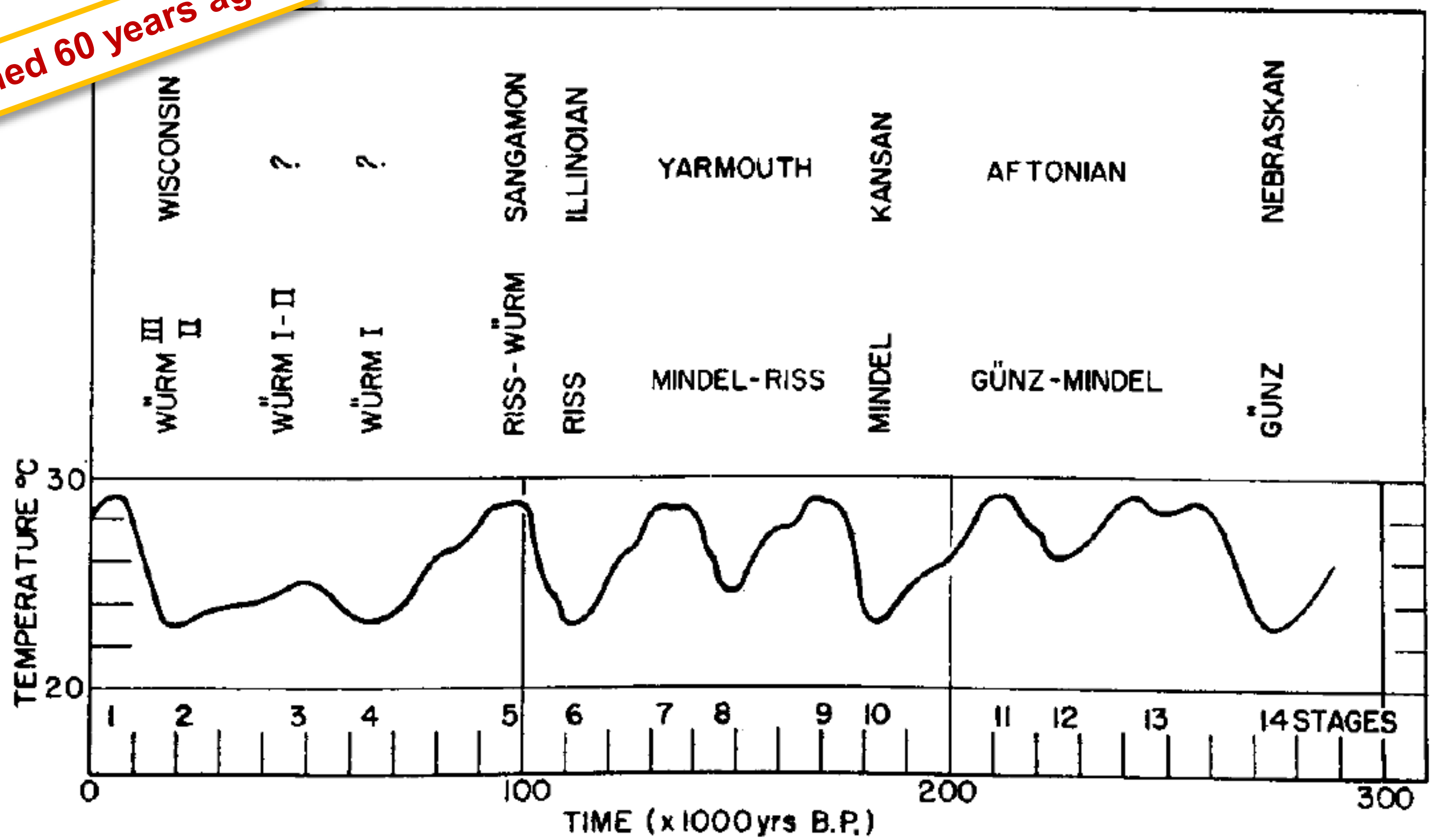


FIG. 15.—Generalized temperature variation, based on the temperature graphs of the cores and on the astronomical time scale.

Emiliani, 1955

Conventional analytical approach

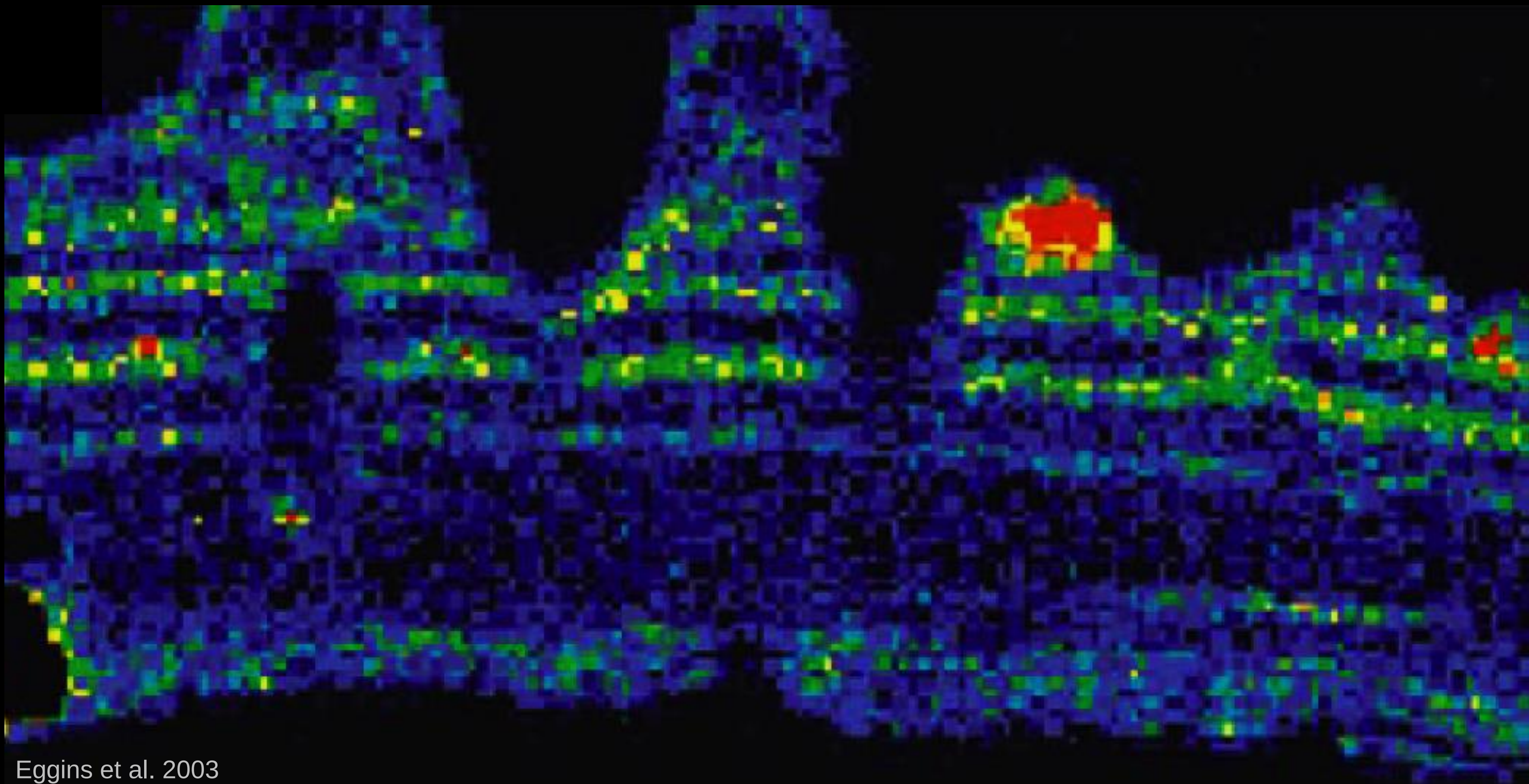
www.microscopy-uk.org.uk

www.whoi.edu

www.thermoscientific.com

Foraminiferal shells are isotopically and chemically zoned

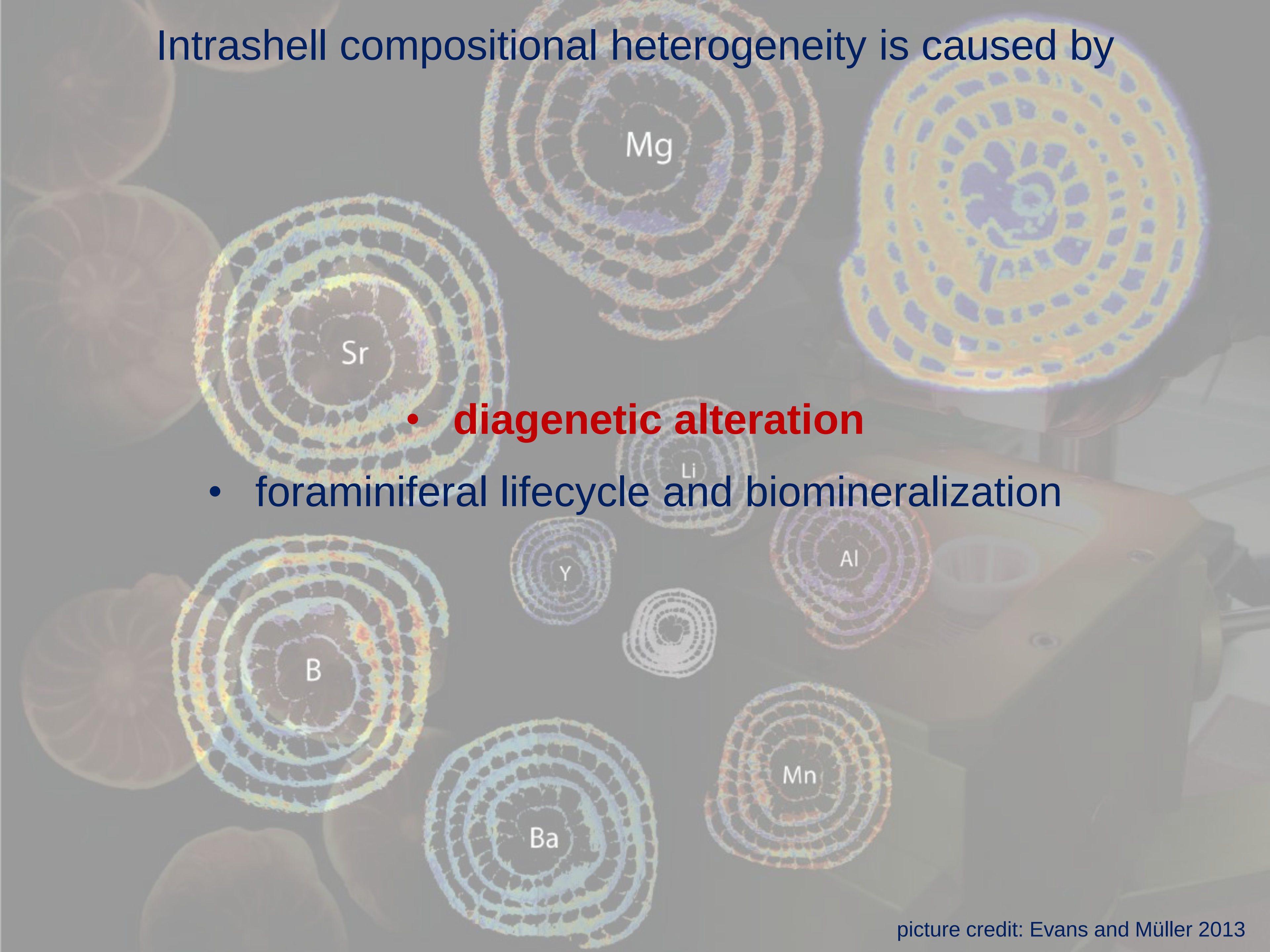
- conventional acid digestion measurements homogenize shell composition!



Eggins et al. 2003

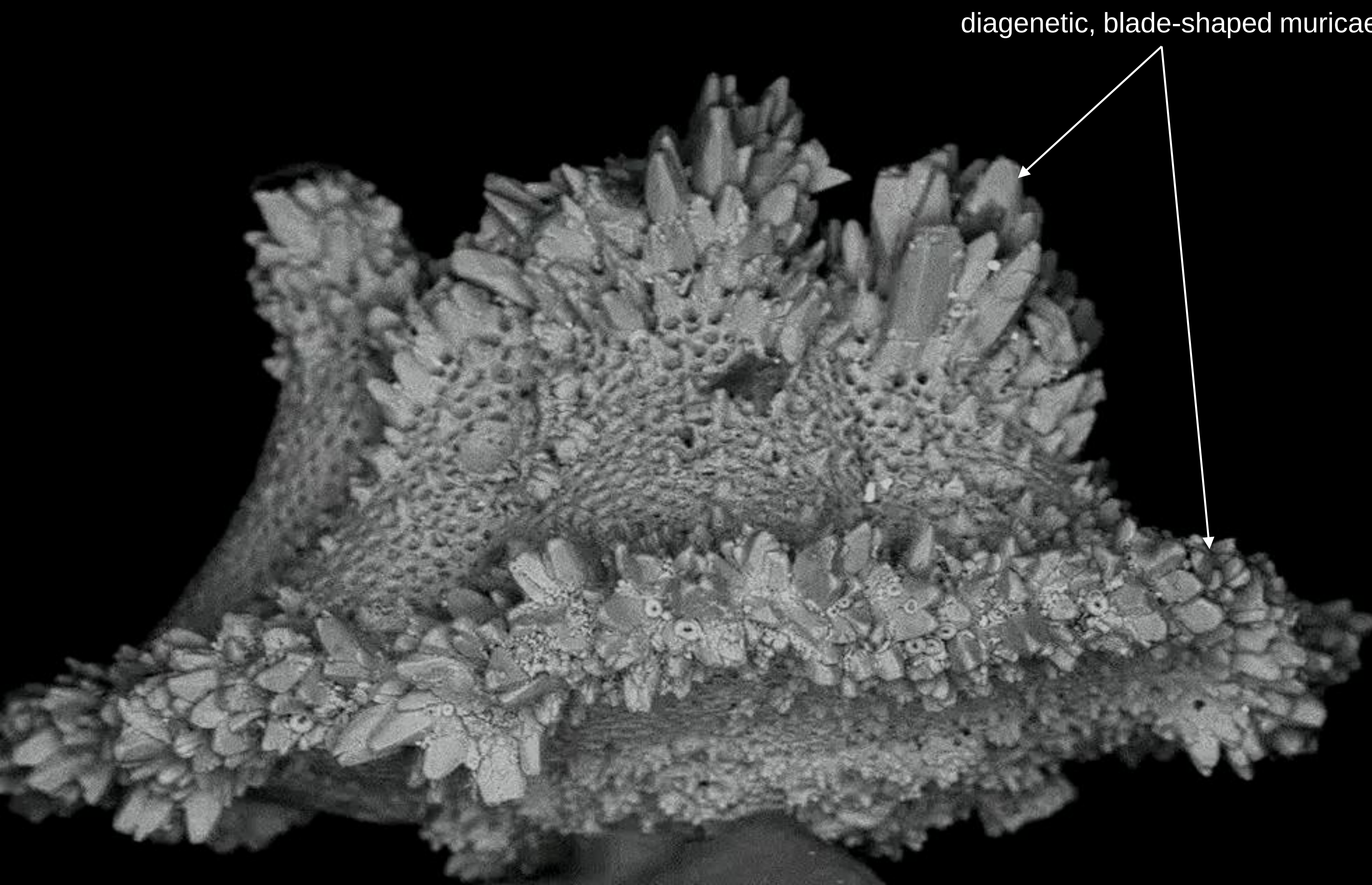
Intrashell compositional heterogeneity is caused by

- **diagenetic alteration**
- foraminiferal lifecycle and biomineralization

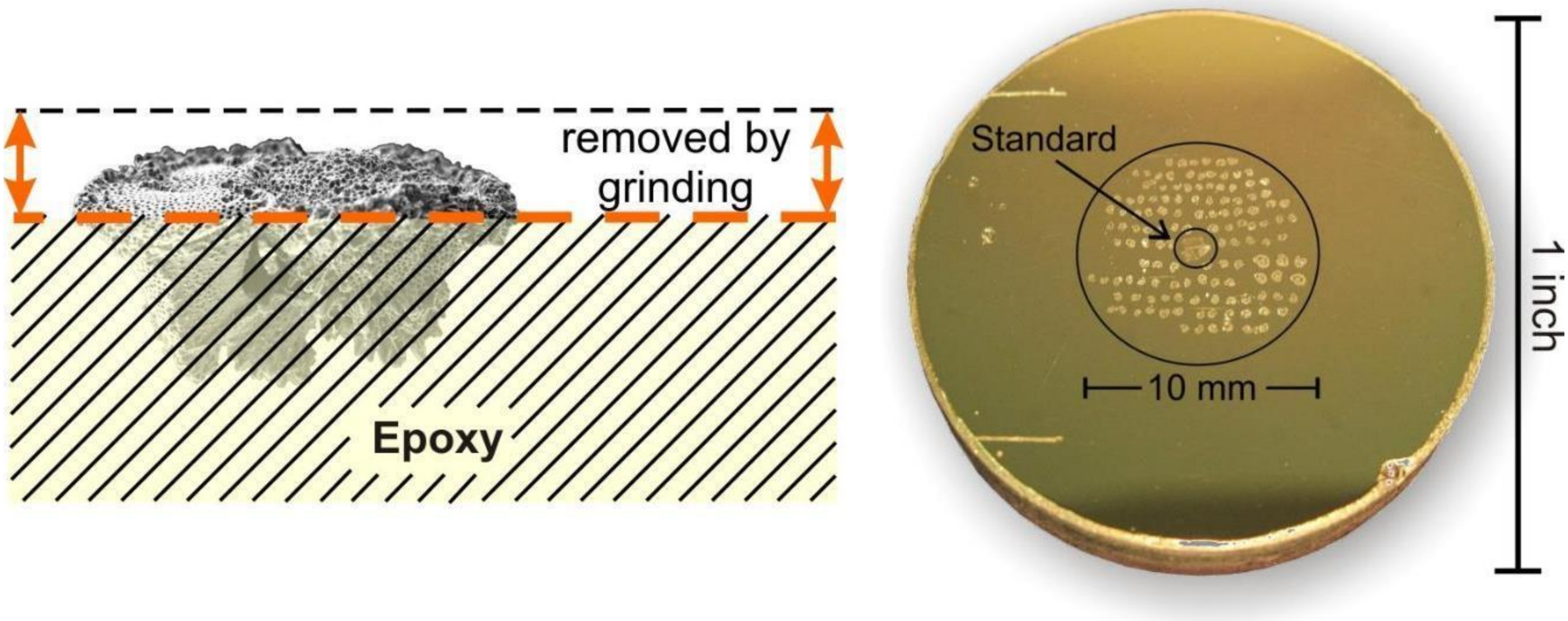


picture credit: Evans and Müller 2013

M. velascoensis from ODP Site 865 (PETM, 56 Ma)



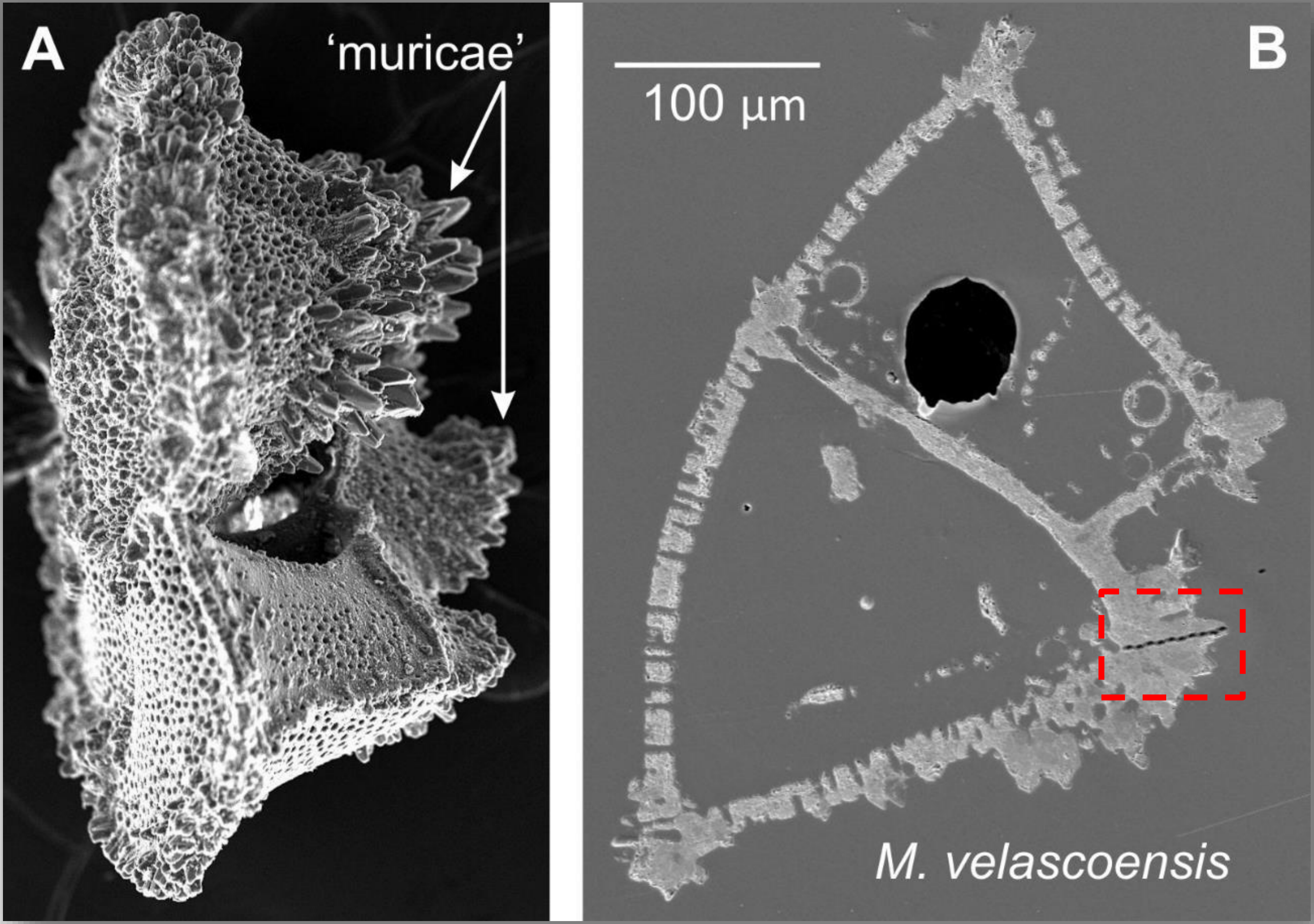
Sample preparation for *in situ* $\delta^{18}O$ analyses by SIMS



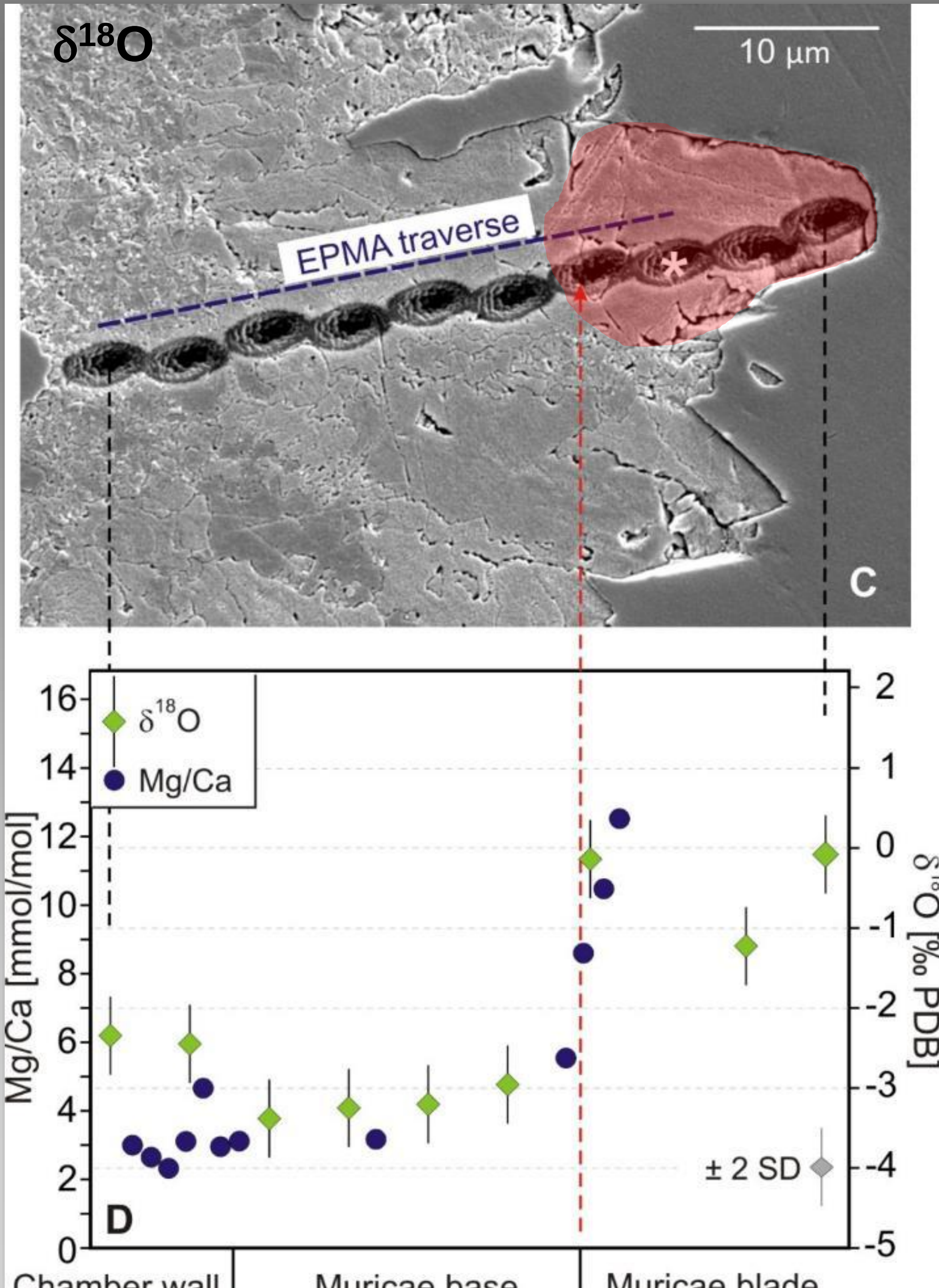
BSE image of polished shells for *in situ* SIMS analyses

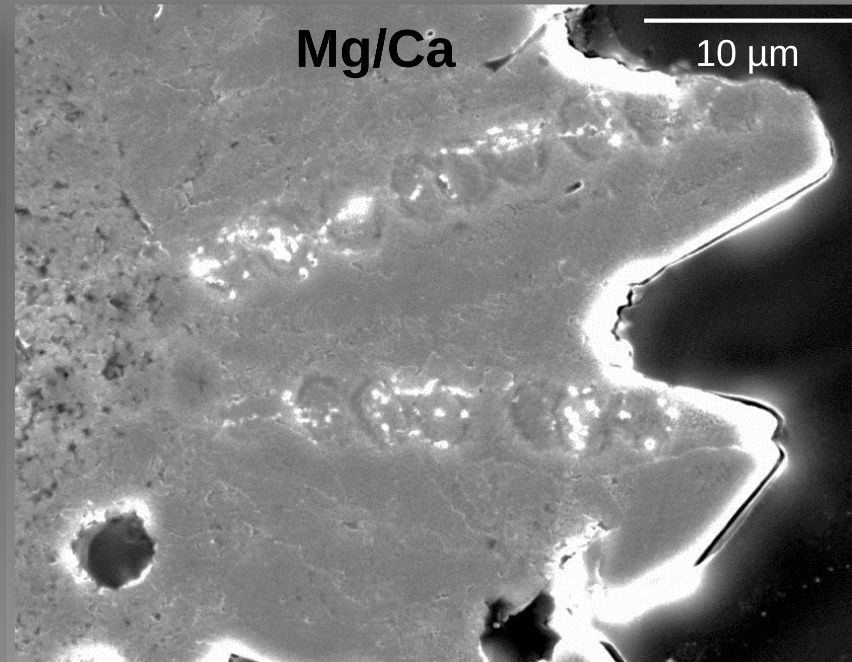
10 mm

Assessing the $\delta^{18}O$ and Mg/Ca of biogenic and diagenetic calcite



Kozdon et al. 2013

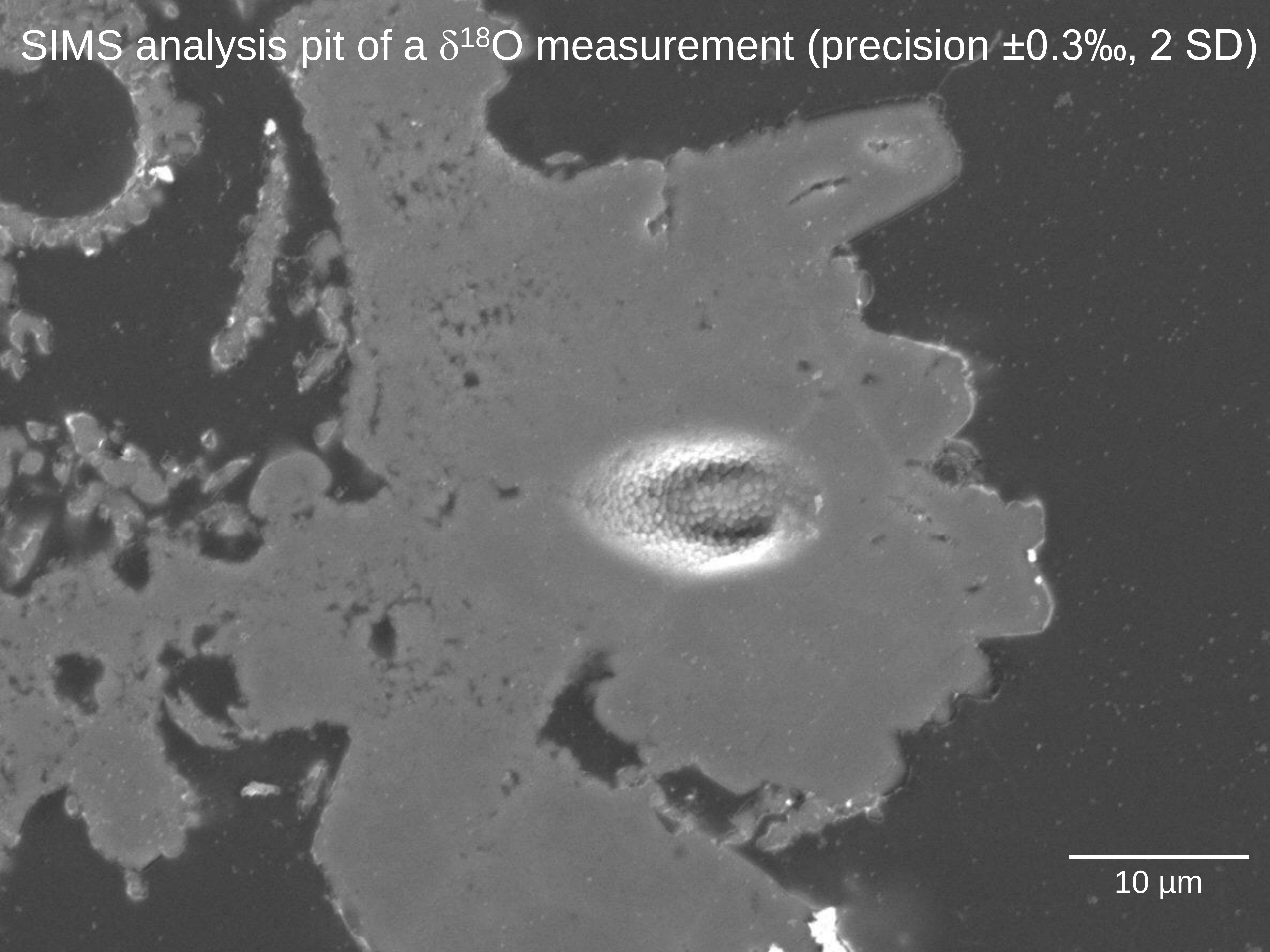




multi-instrument *in situ* approach

- SIMS ($\delta^{18}O$)
- EPMA (Mg/Ca)

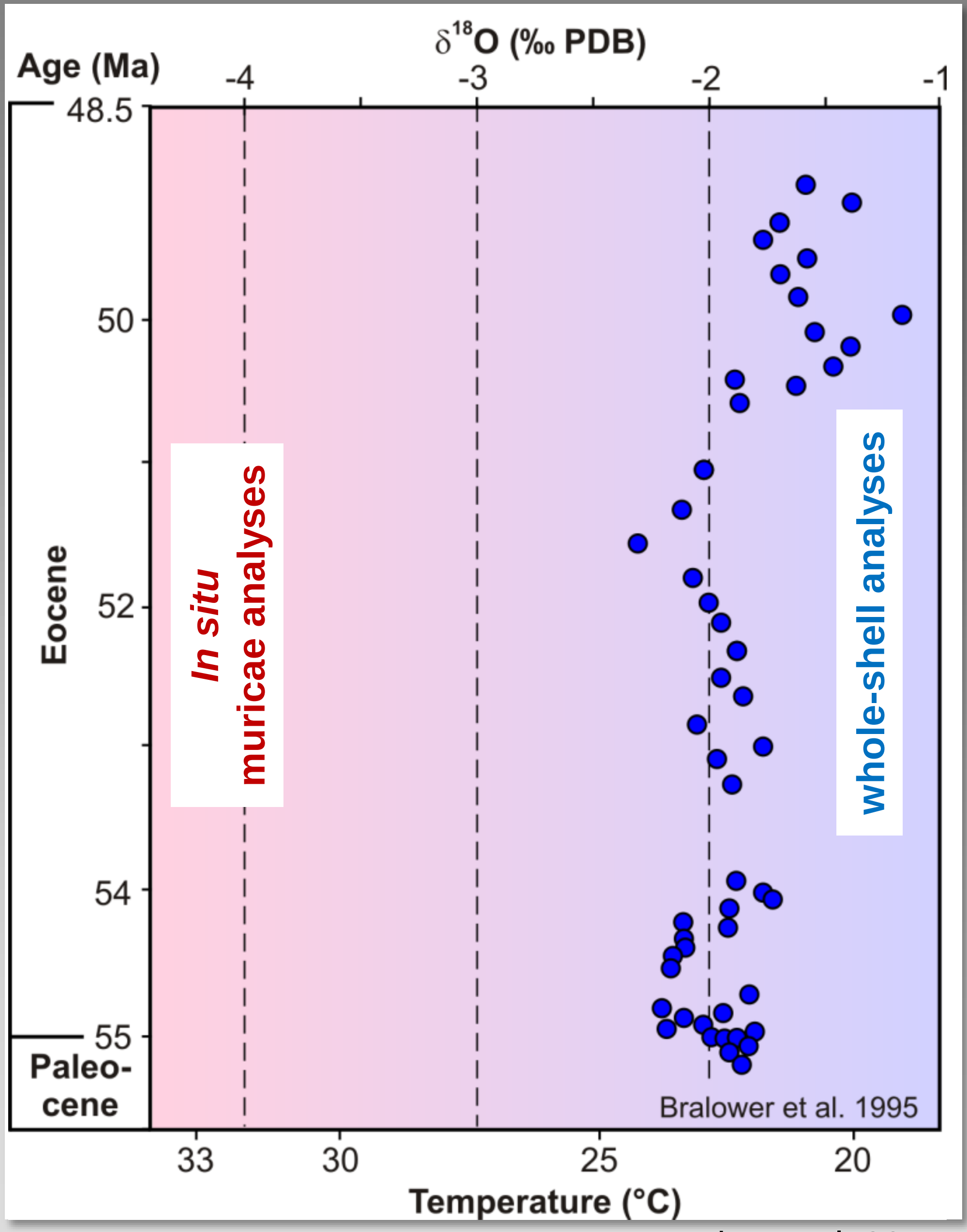
Kozdon et al. 2013

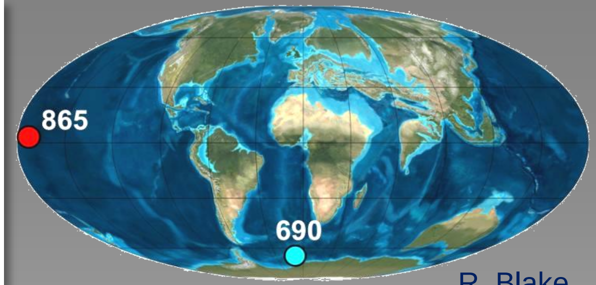

SIMS analysis pit of a δ18O measurement (precision ±0.3‰, 2 SD)
10 µm

δ^{18}O-inferred temperatures, whole-shell measurements, ODP Site 865

Tropical

Pacific





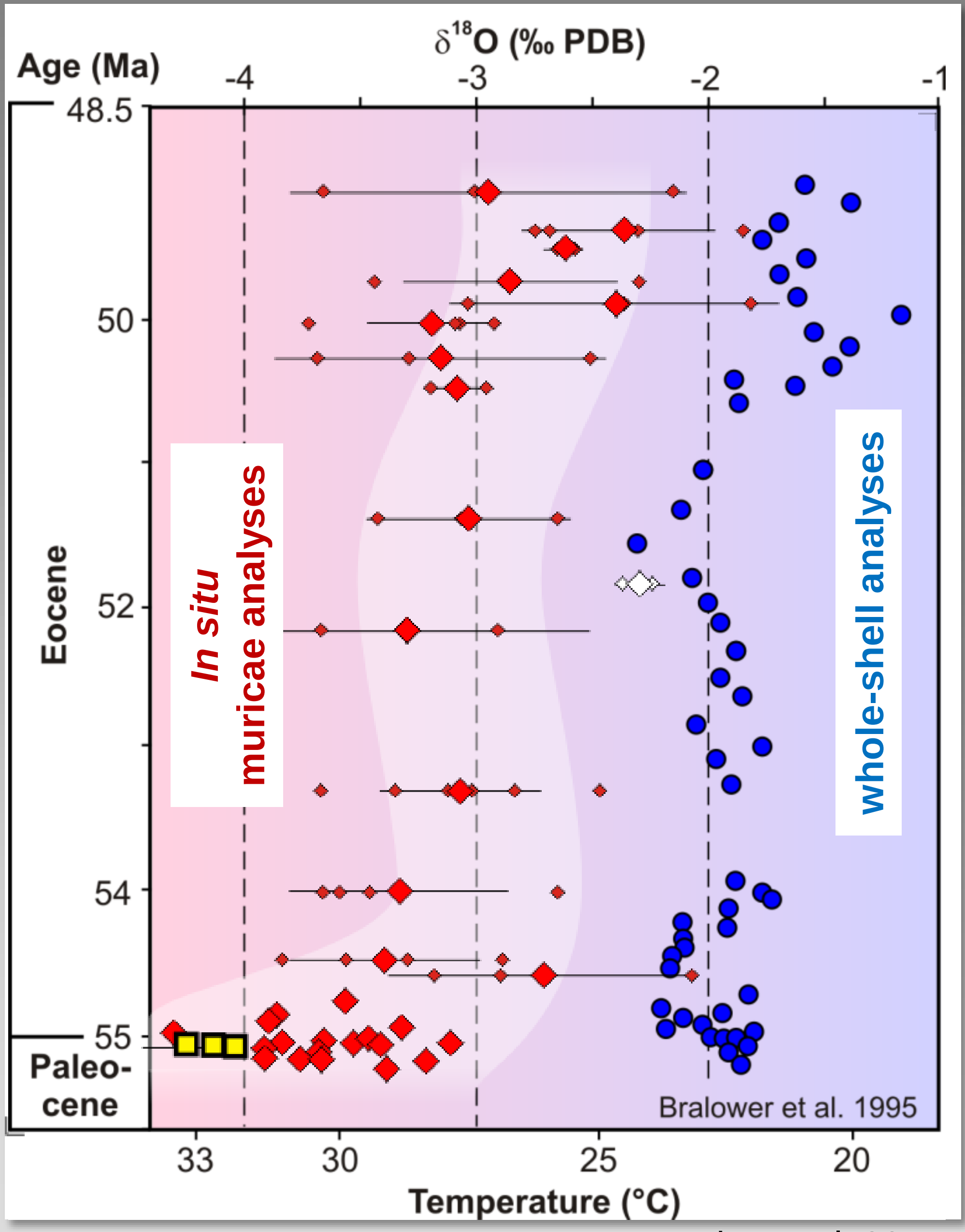
R. Blake

Whole shell measurements of δ^{18}O represent a mixture of biogenic and diagenetic calcite.

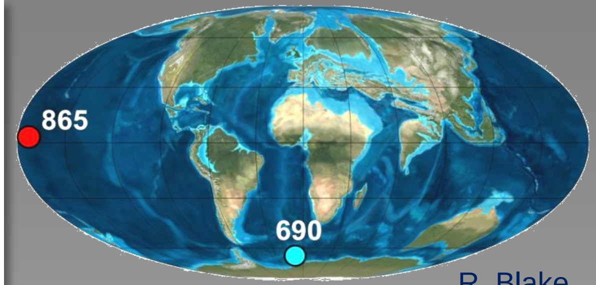
Kozdon et al. 2011

Temperatures calculated from *in situ* $\delta^{18}O$, ODP Site 865

Tropical Pacific



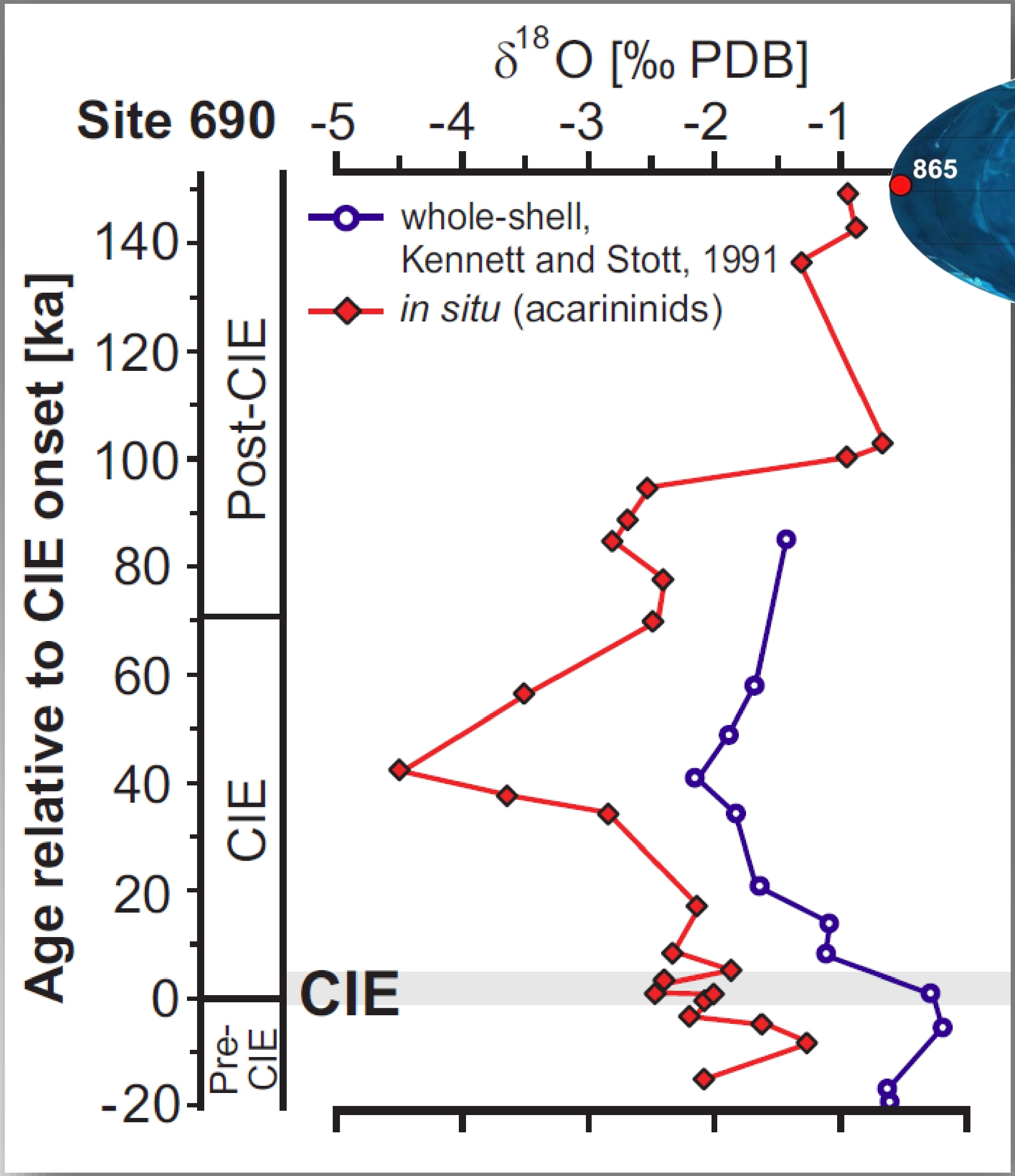
Kozdon et al. 2011

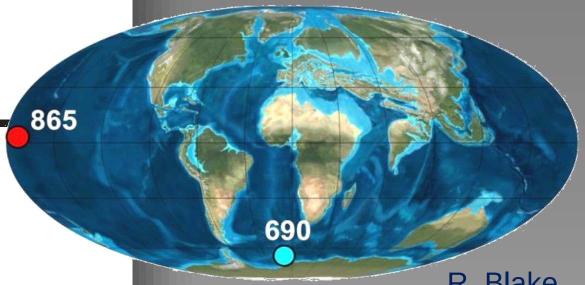


R. Blake

In situ $\delta^{18}O$ measurements in largely unaltered domains are in agreement with climate model simulations for the PETM.

High Latitudes (Weddell Sea)





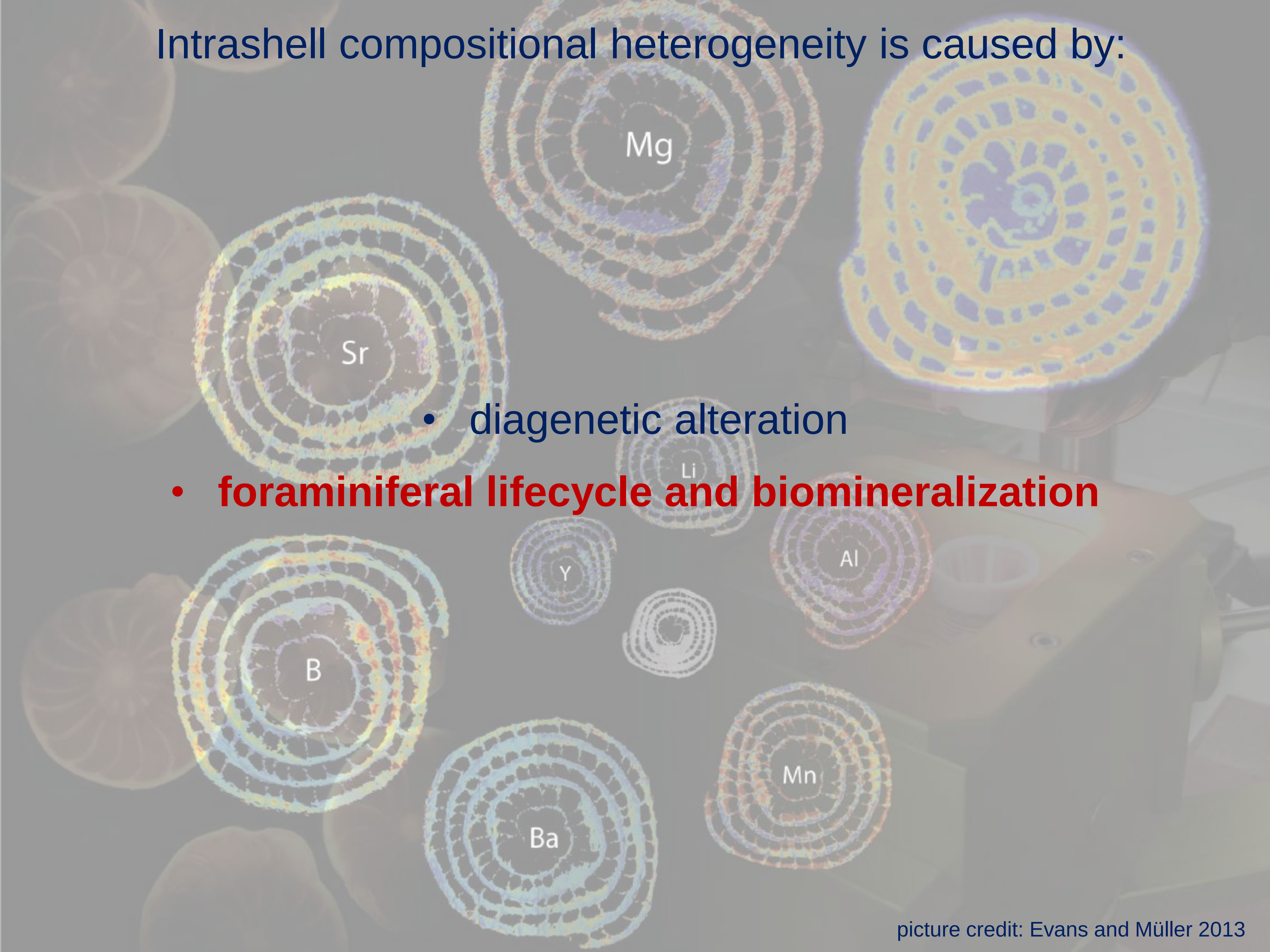
R. Blake

The whole-shell $\delta^{18}O$ record from Site 690, Weddell Sea, is also significantly biased by diagenesis.

Kozdon et al. in prep.

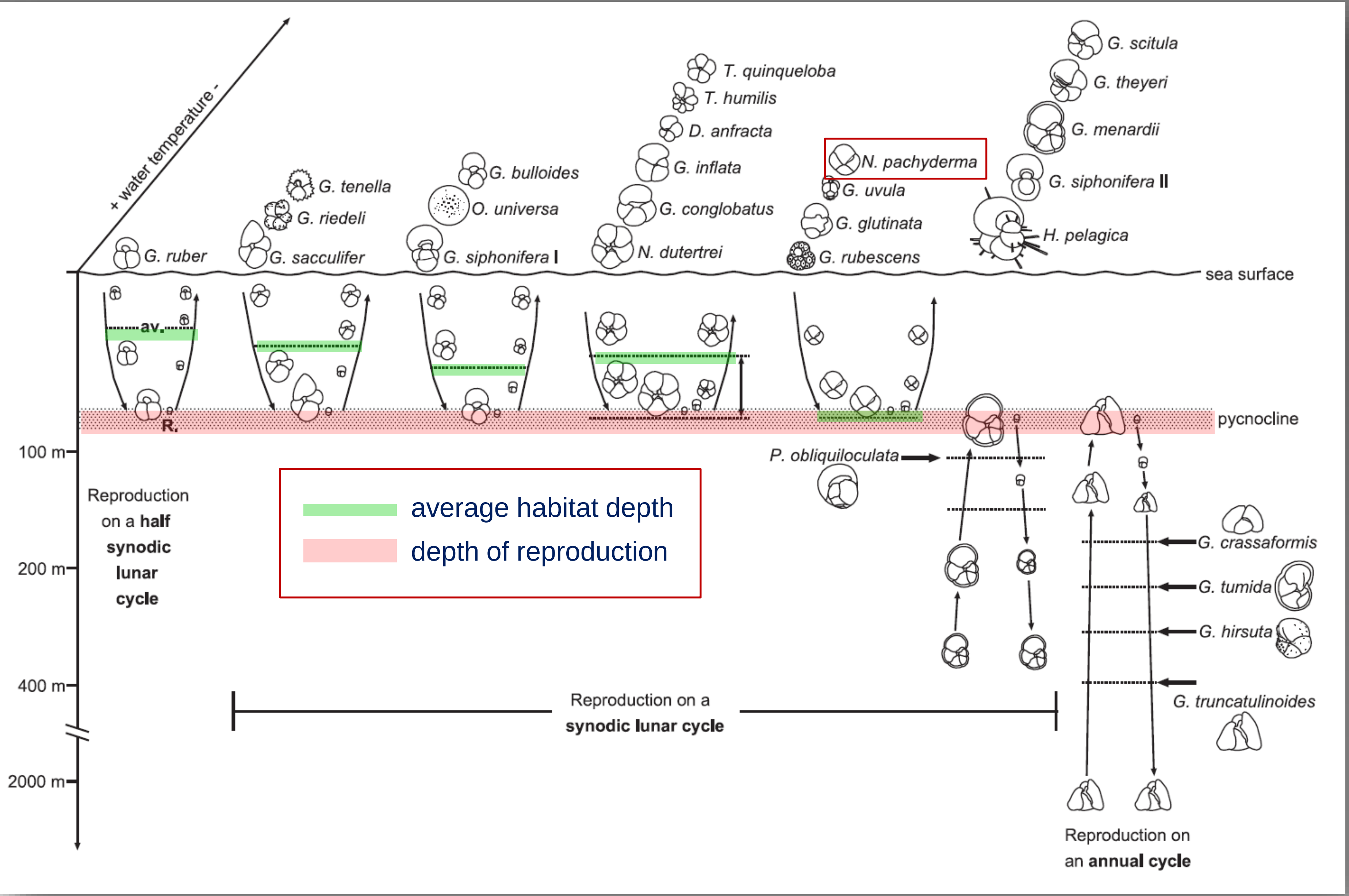
Intrashell compositional heterogeneity is caused by:

- diagenetic alteration
- **foraminiferal lifecycle and biomineralization**



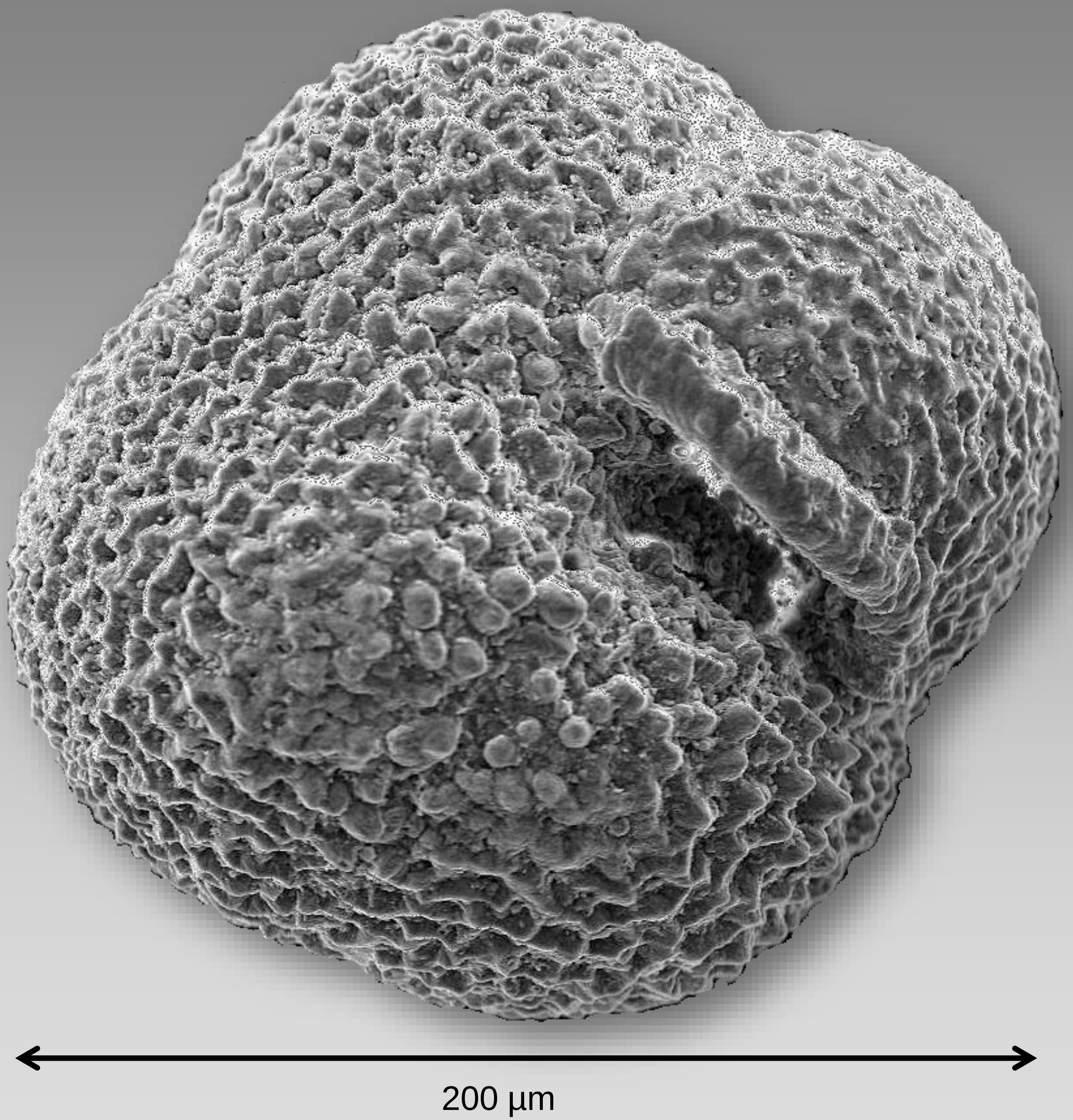
picture credit: Evans and Müller 2013

Depth migration of planktonic foraminifera

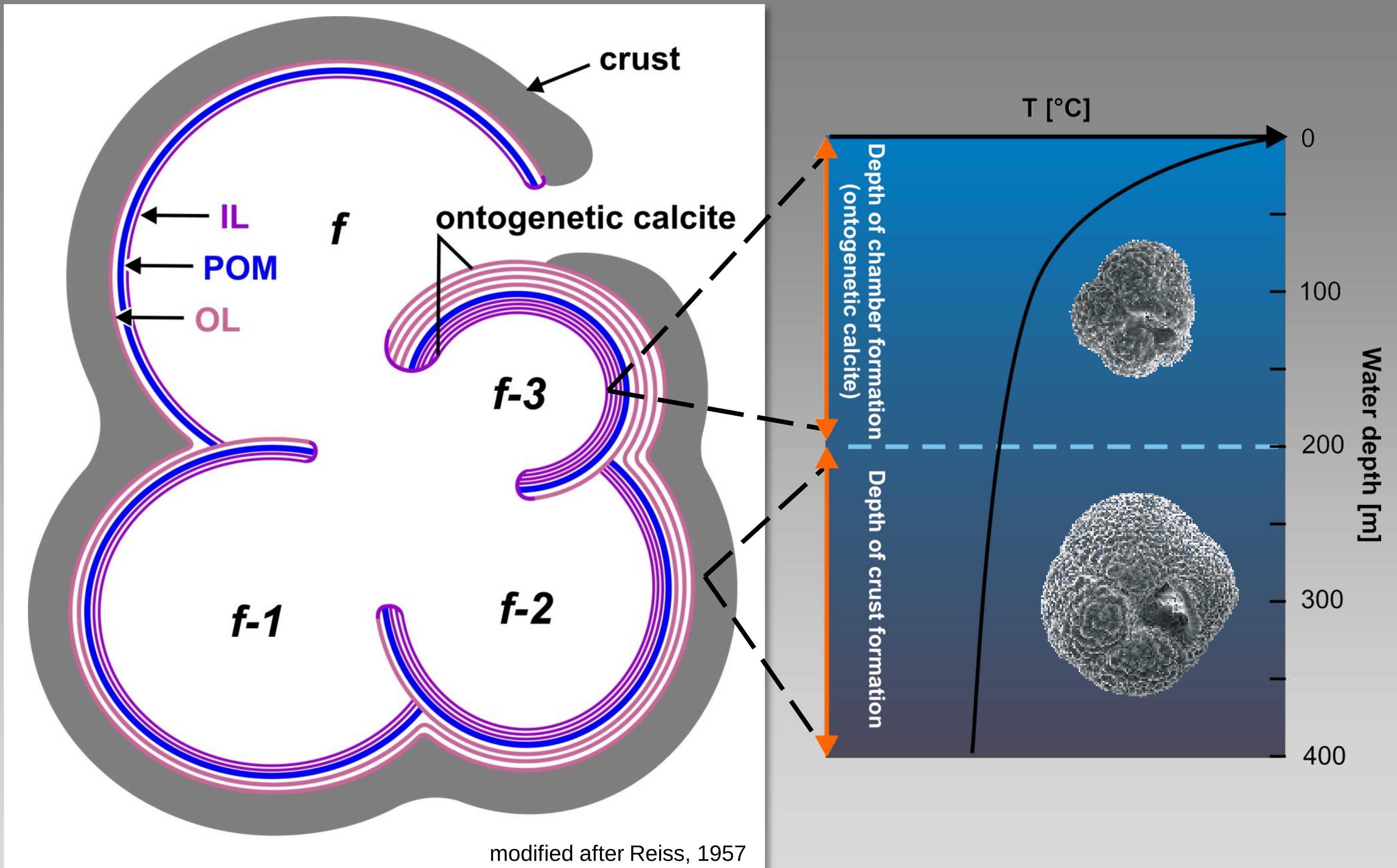


Schiebel and Hemleben, 2005

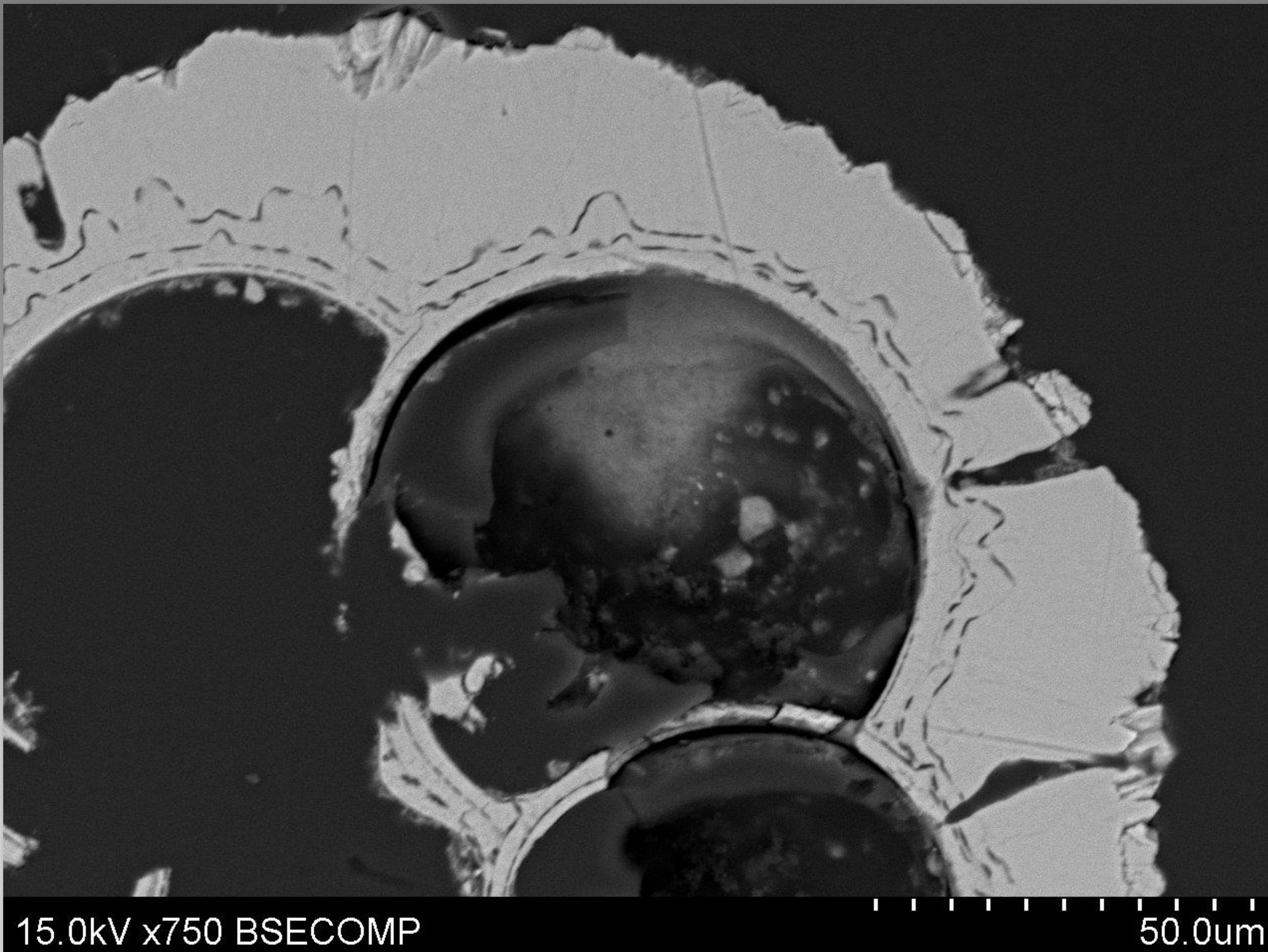
Neogloboquadrina pachyderma sinistral

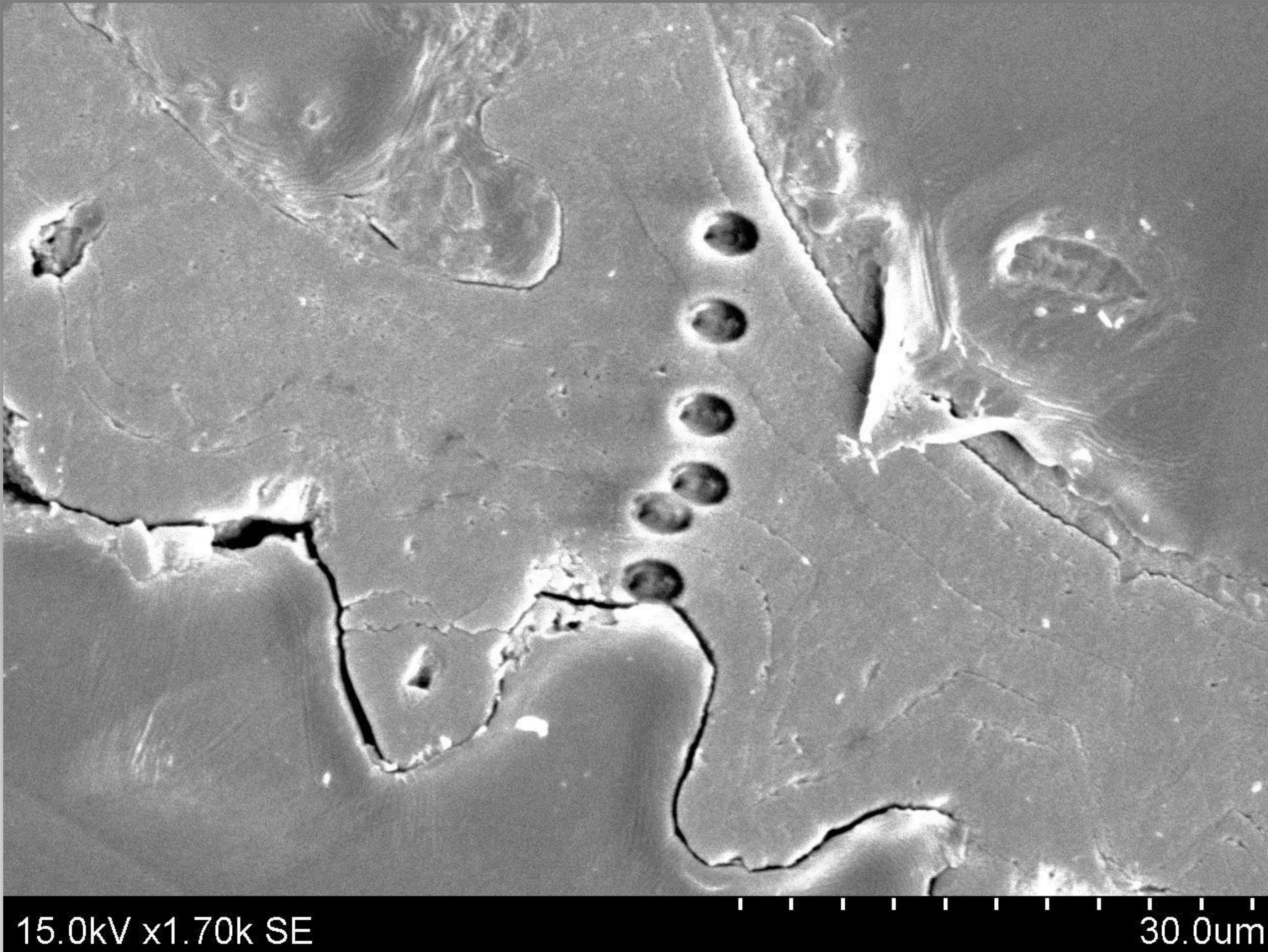


The layers record signals from different water depths

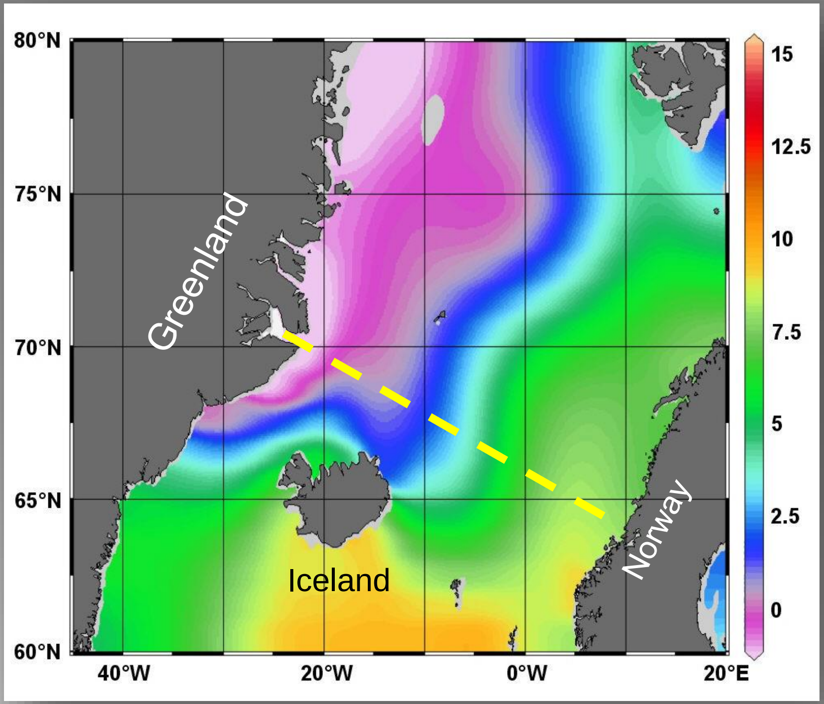



15.0kV x400 BSECOMP
100um

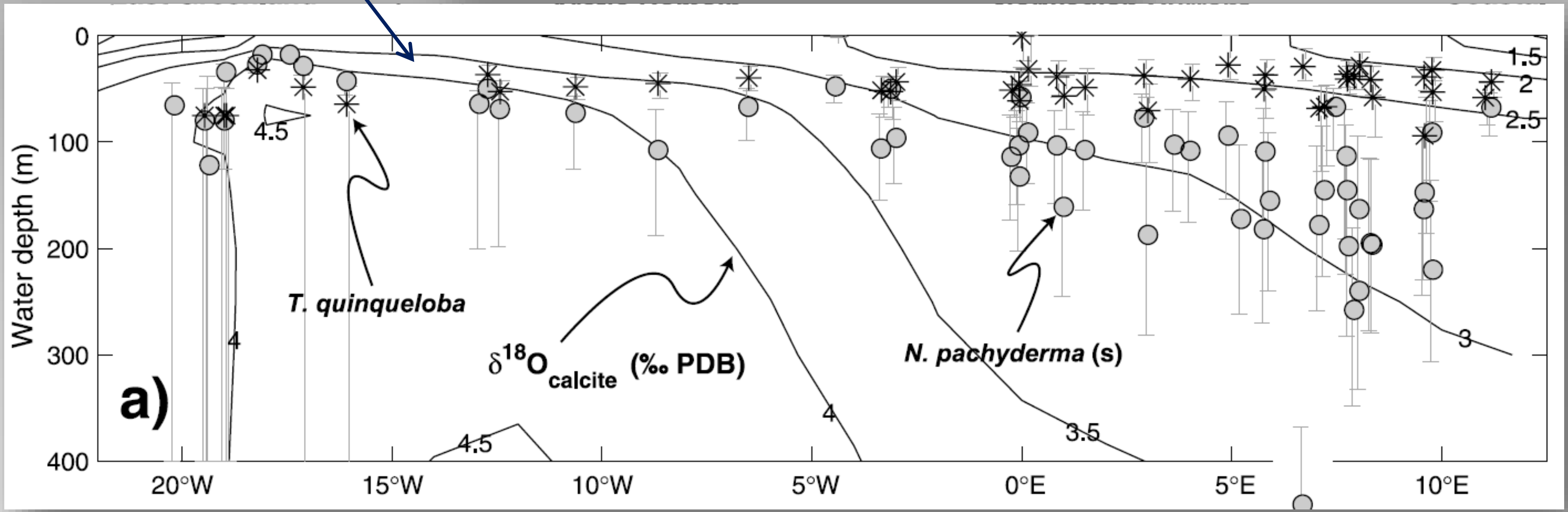

15.0kV x750 BSECOMP
50.0um


15.0kV x1.70k SE
30.0um

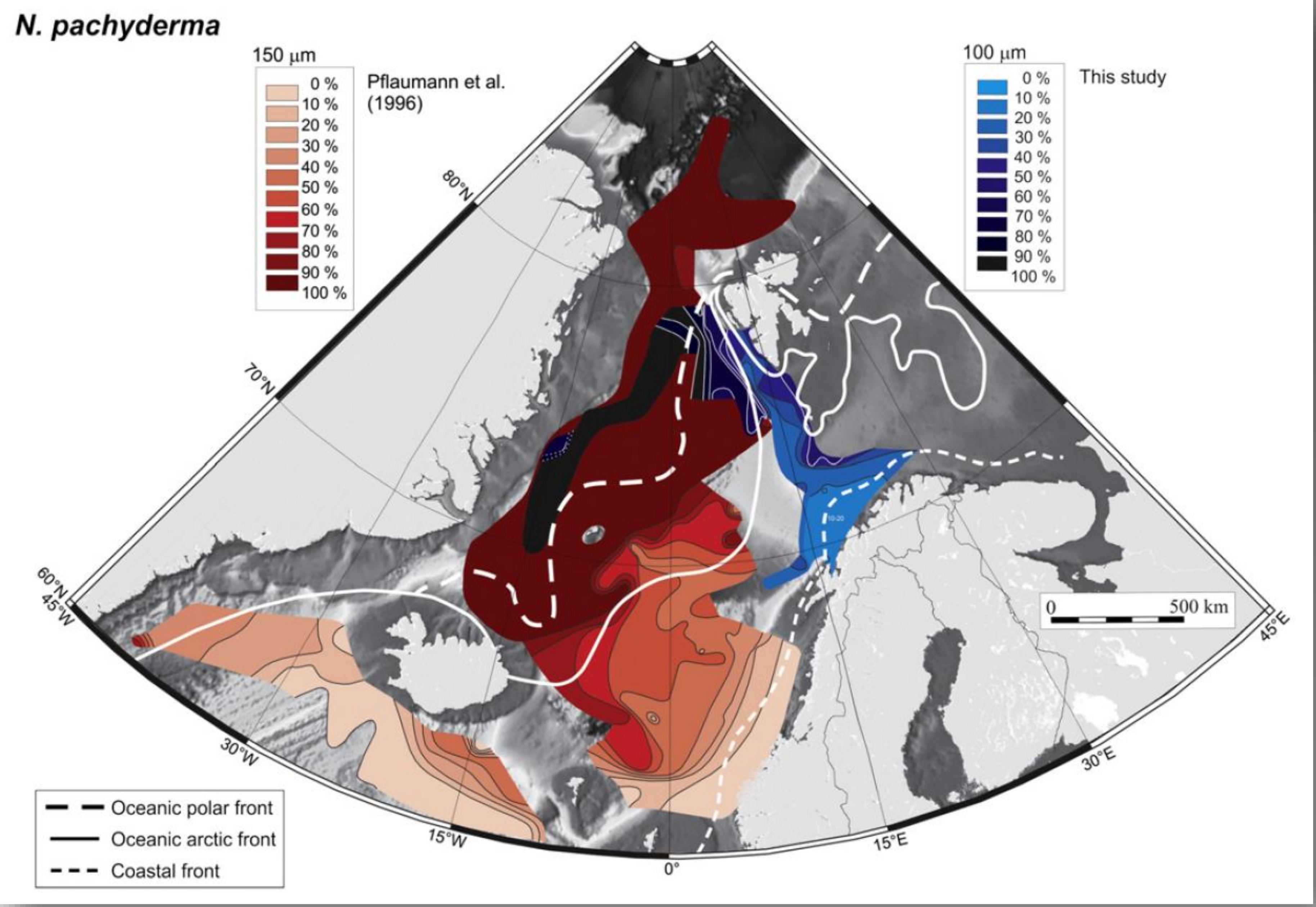
In the Nordic Seas, stratification of the water column can be reconstructed by comparing chemical data from planktonic foraminiferal species with different habitat preferences. However, *Nps* is the only abundant foraminifera in polar regions.



$\delta^{18}O$ calcite isolines (equilibrium with seawater $\delta^{18}O$ and T)

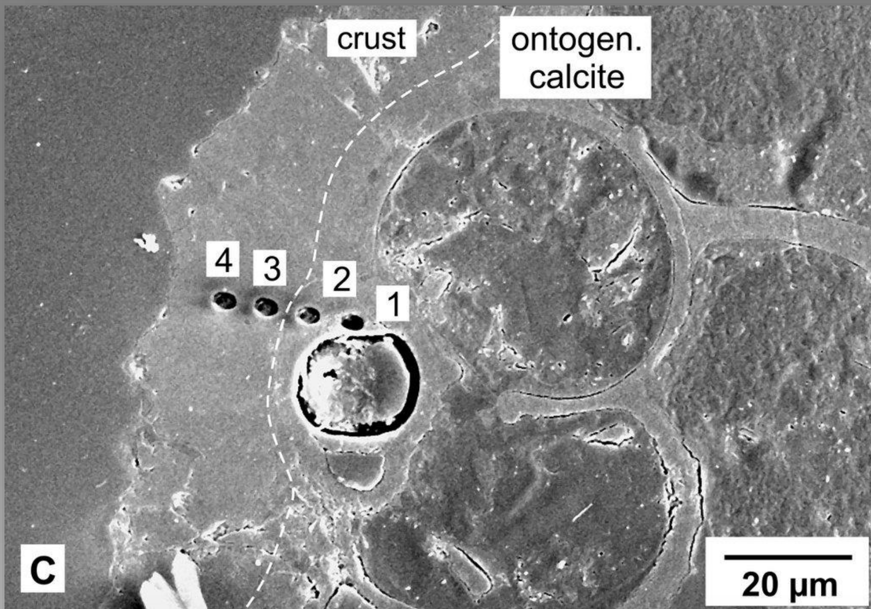


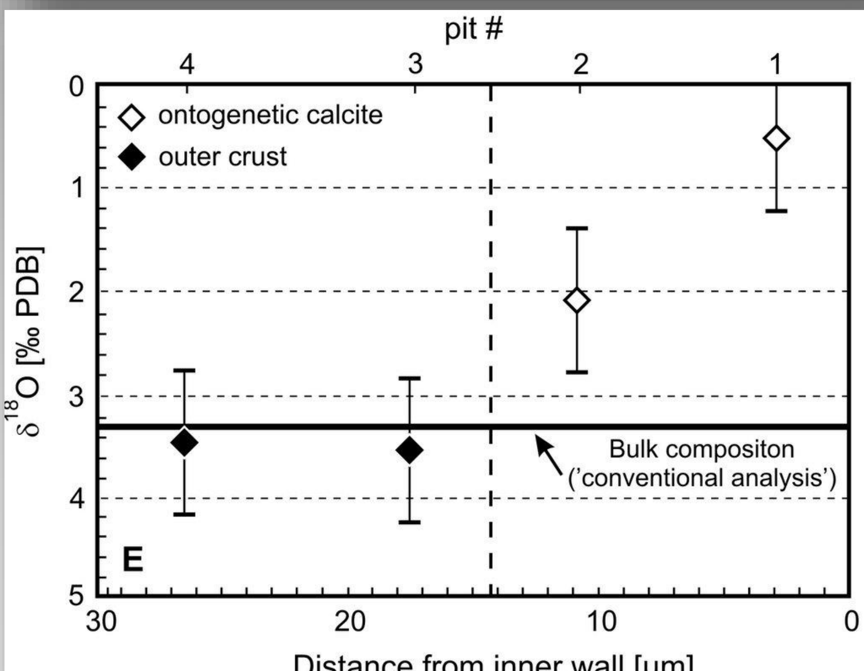
Simstich et al. 2003

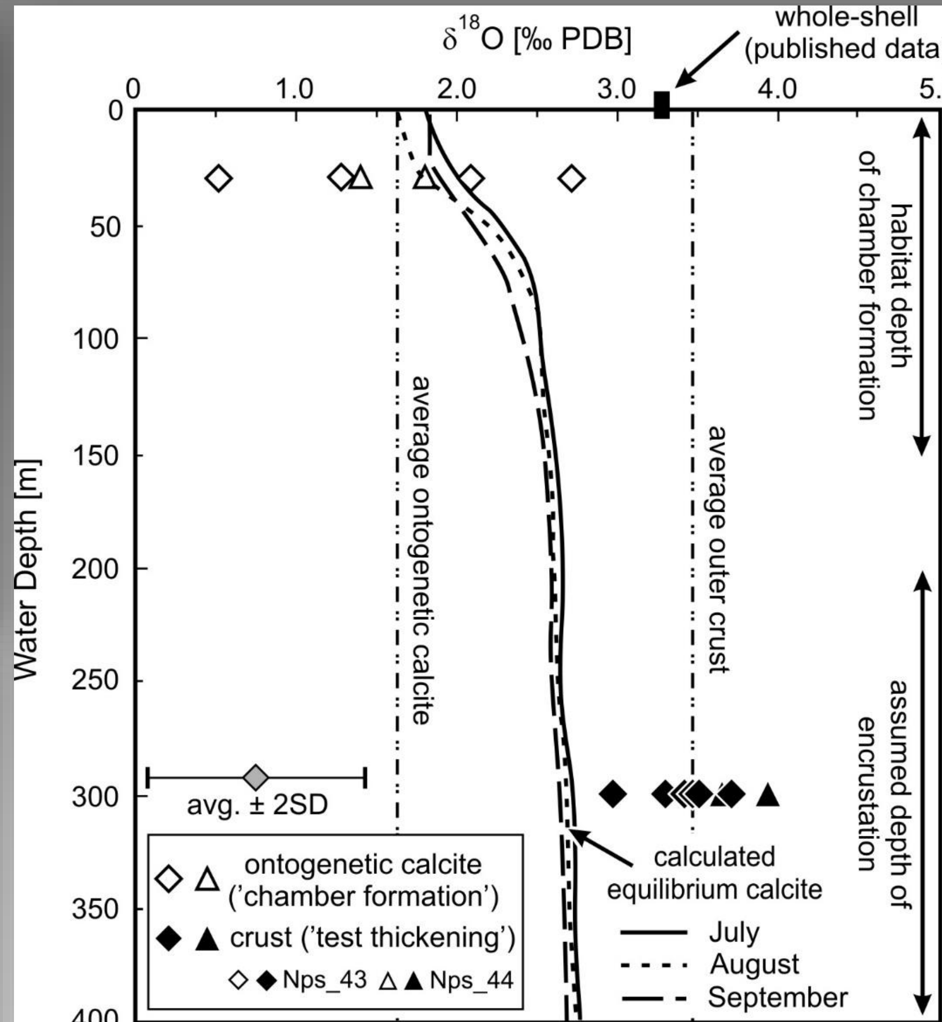


Schiebel and Hemleben, 2005

Reconstruction of water mass stratification from single shells

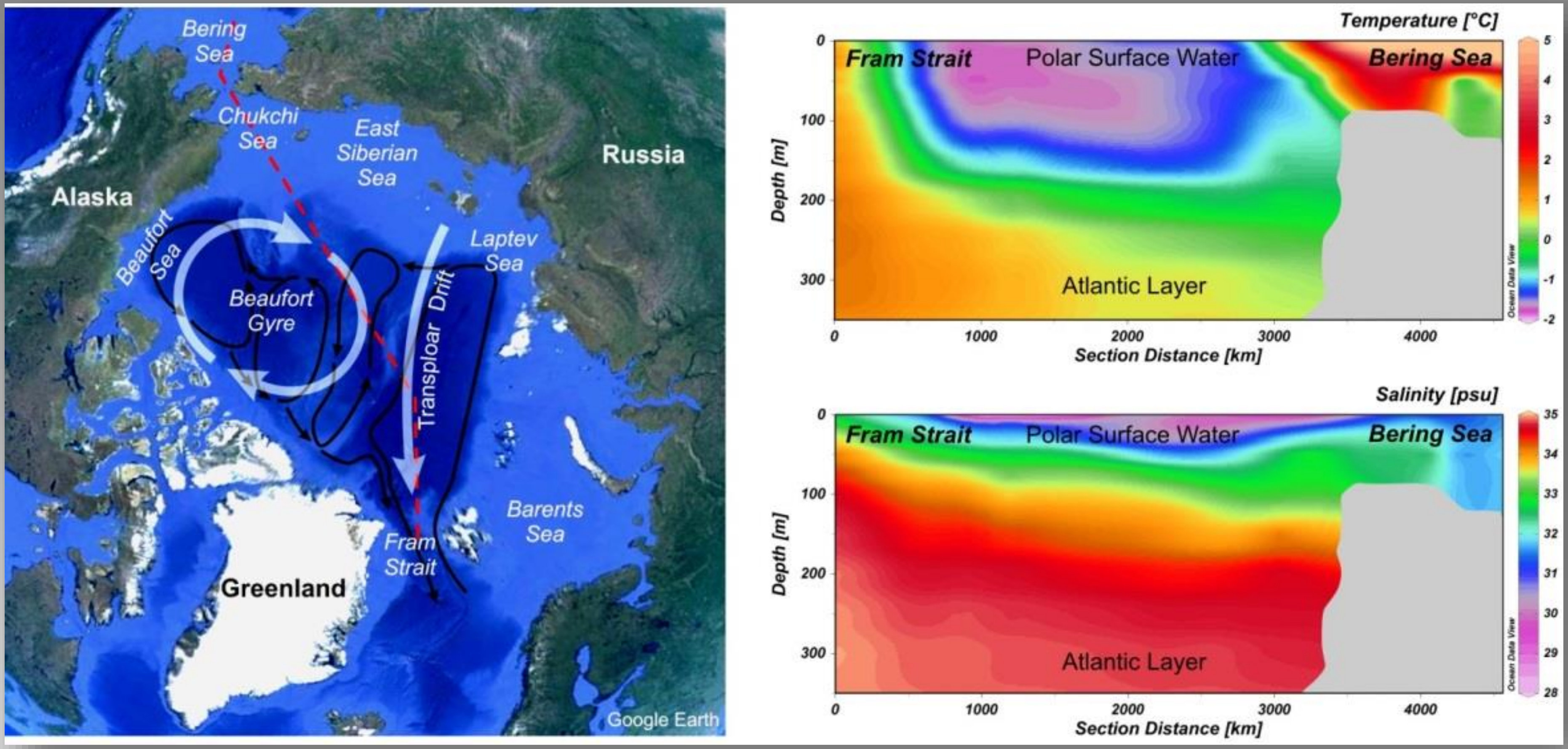




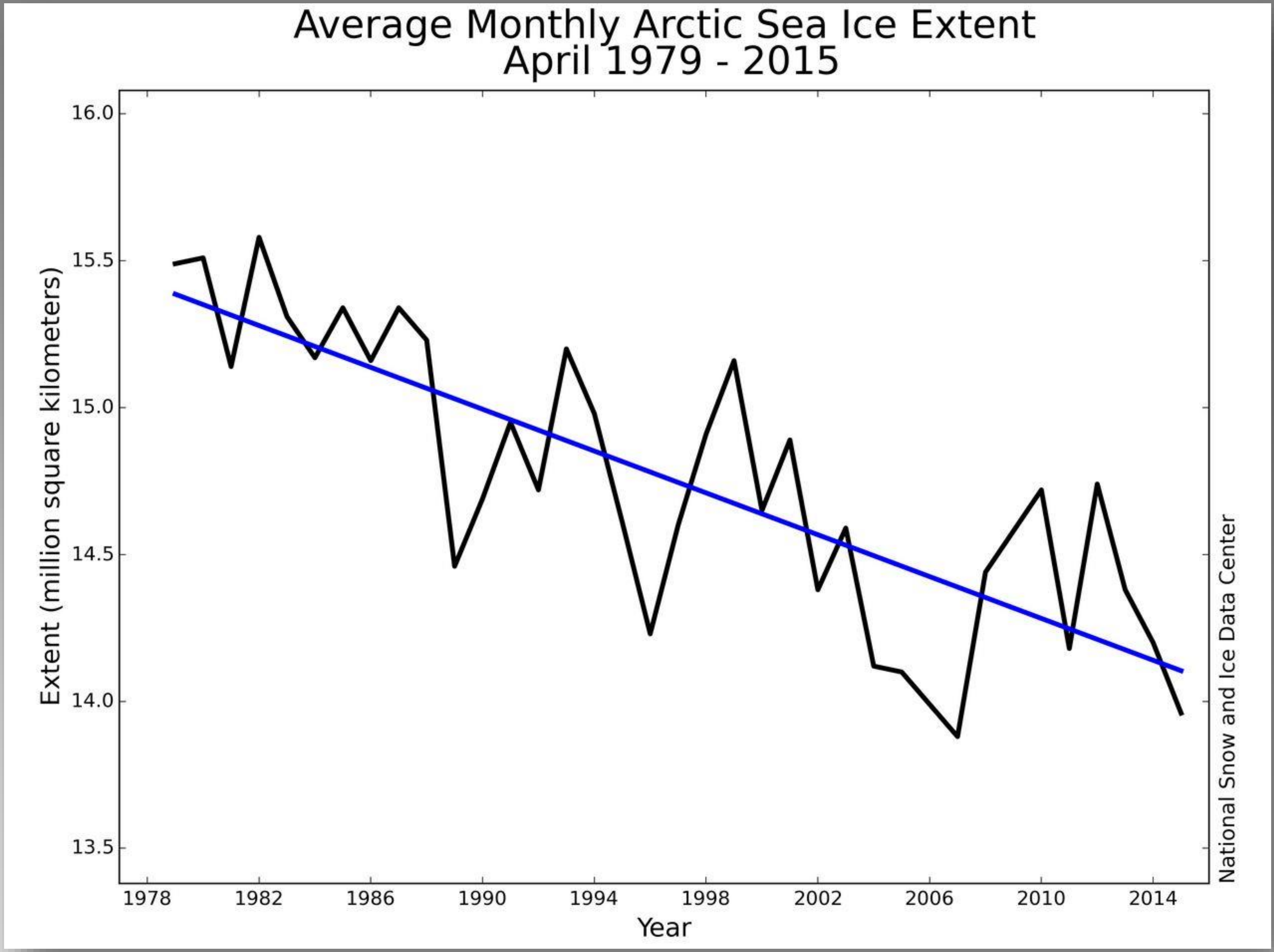


Kozdon et al. 2009

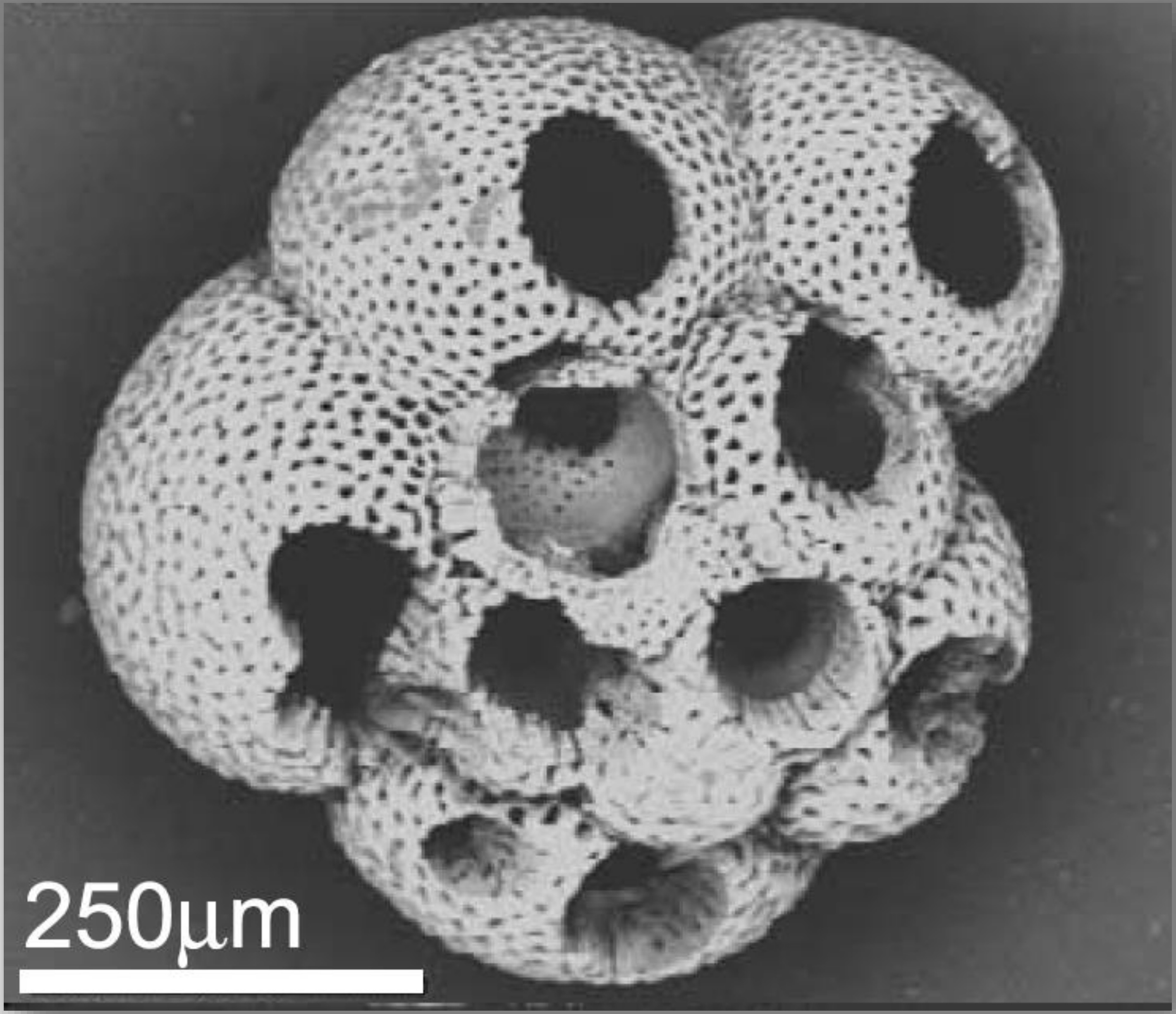
Modern water mass stratification of the Arctic Ocean



Climate change is most dramatic in the Arctic

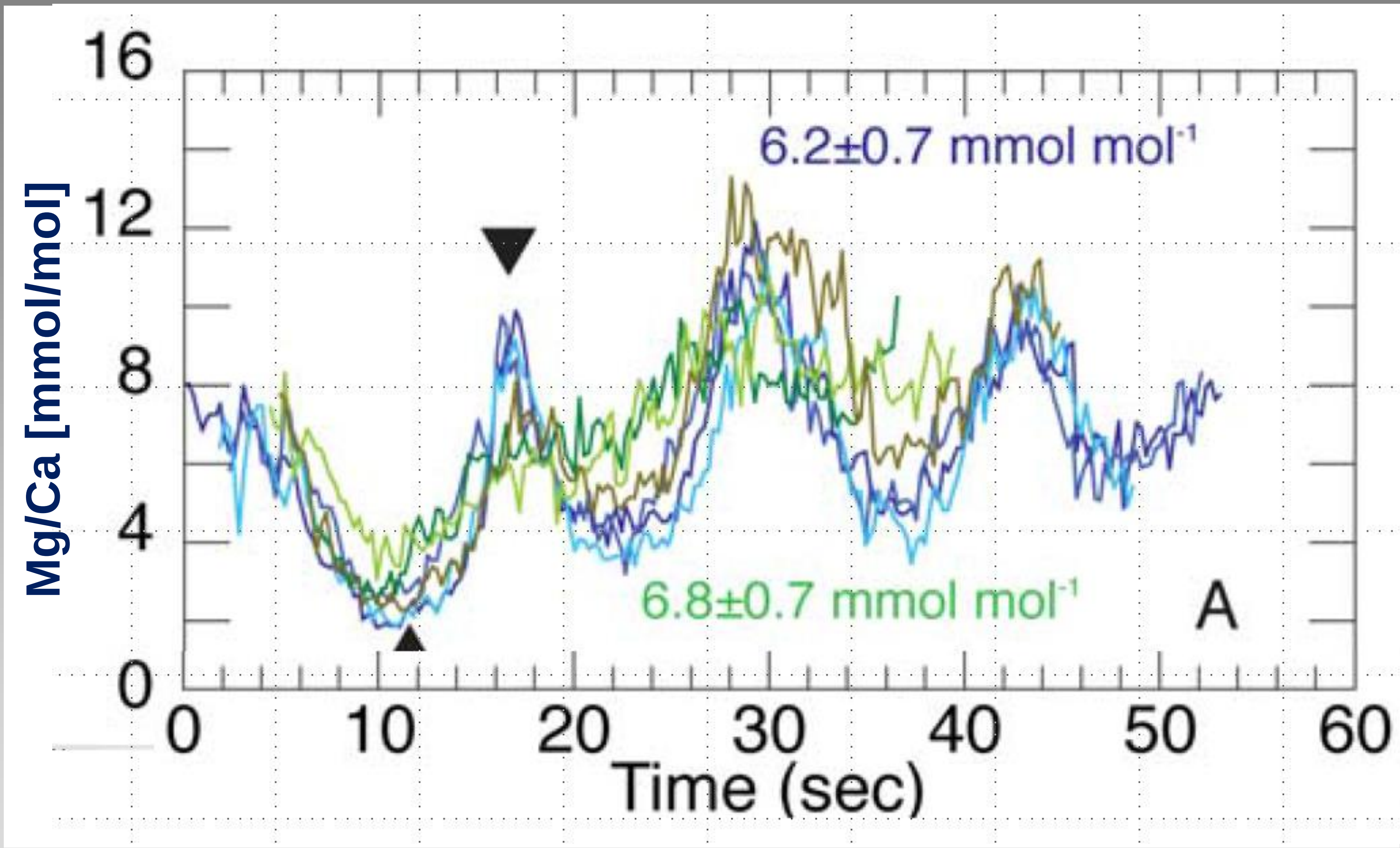


SIMS can be used in concert with laser ablation measurements



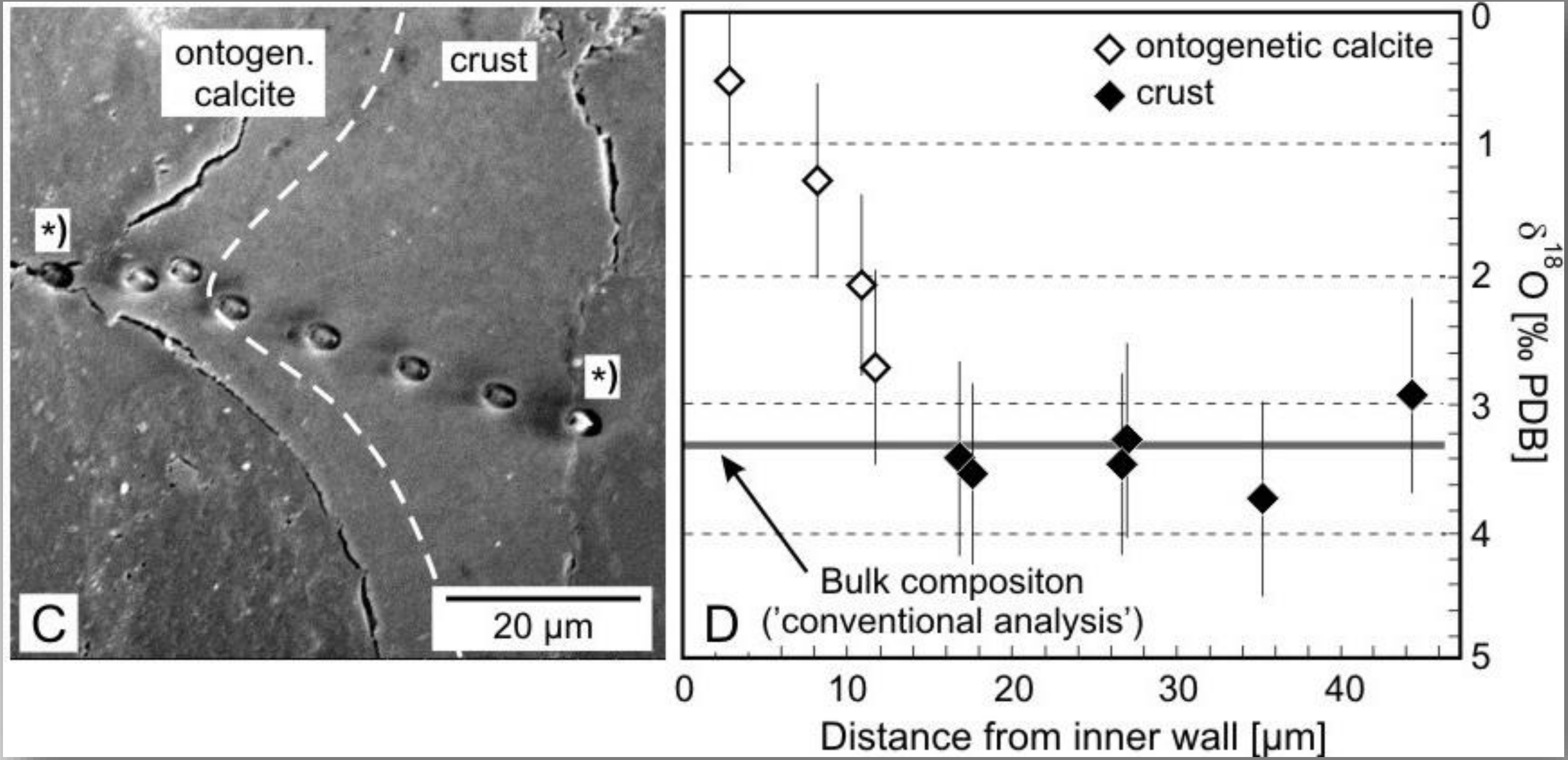
picture credit: Hathorne et al. 2003

Laser ablation reveals El/Ca banding in foraminiferal shells



Vetter et al. 2013

El/Ca profiles by laser ablation will be combined with $\delta^{18}O$ traverses from the same shell



Kozdon et al. 2009

Thank you!