

# **Paleoenvironmental Application of Calcareous Nannofossils\***

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Search and Discovery Article #50189 (2009)

Posted May 14, 2009

\*Adapted from oral presentation at AAPG International Conference and Exhibition, Cape Town, South Africa, October 26-29, 2008

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## **Abstract**

Biostratigraphers primarily use benthic foraminifera and palynological assemblages for paleoenvironmental reconstruction; calcareous nannofossils and planktonic foraminifera for detailed age dates. Preliminary research comparing modern to Miocene coccoliths indicates that broader application of calcareous nannofossils may be possible. Ocean depth preferences of the modern calcareous nannoplankton can be extrapolated to the fossil record, if we assume that morphological variability can imply habitat.

Intraspecific variability in the modern calcareous nannoplankton contrasts markedly from the shallow to the deep photic zone. Considerable intra- and interspecific variability in coccolith and coccosphere morphology characterizes the shallow photic zone, whereas low intraspecific variability distinguishes the deep photic zone. It is this juxtaposition in variability that we can use in examining the fossil record.

I present a quantitative comparison of the morphological variability between coccoliths of extant calcareous nannoplankton species and the Miocene species, *Minylitha convallis*. The morphology of the coccoliths of *M. convallis* remains constant through time, with overall low intraspecific variability in all samples, indicating that it may have lived in the deep photic zone. Following this assumption, greater relative abundance of *M. convallis*, like that of the modern deep photic zone species, should indicate a highly stratified paleo-ocean, deep nutricline, and warmer climate, whereas reduced abundance relative to other calcareous nannoplankton species should indicate a cooler climate and shallow nutricline.





# Paleoenvironmental applications of calcareous nannofossils:

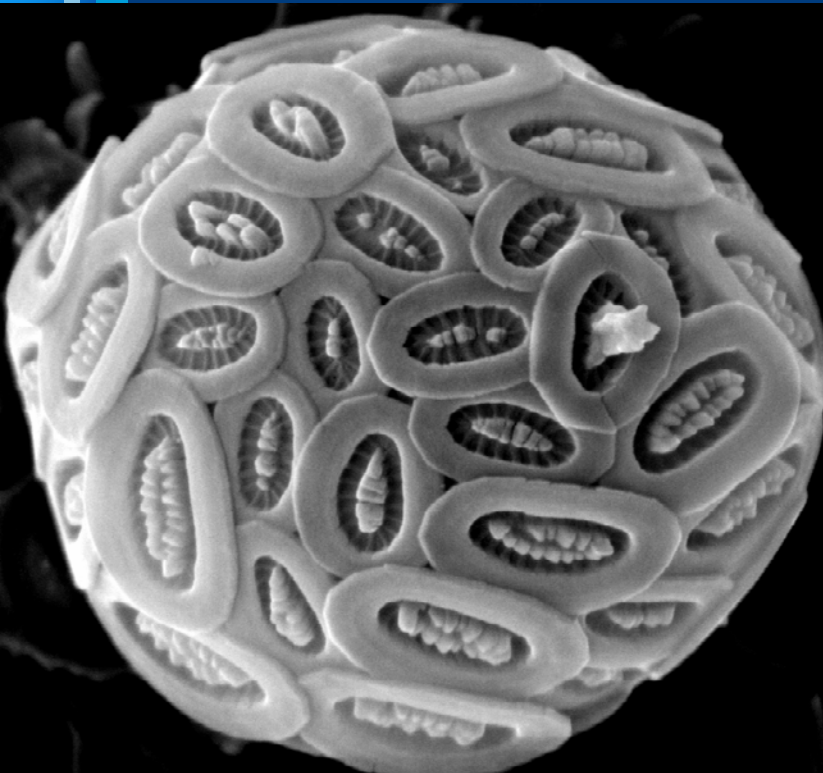
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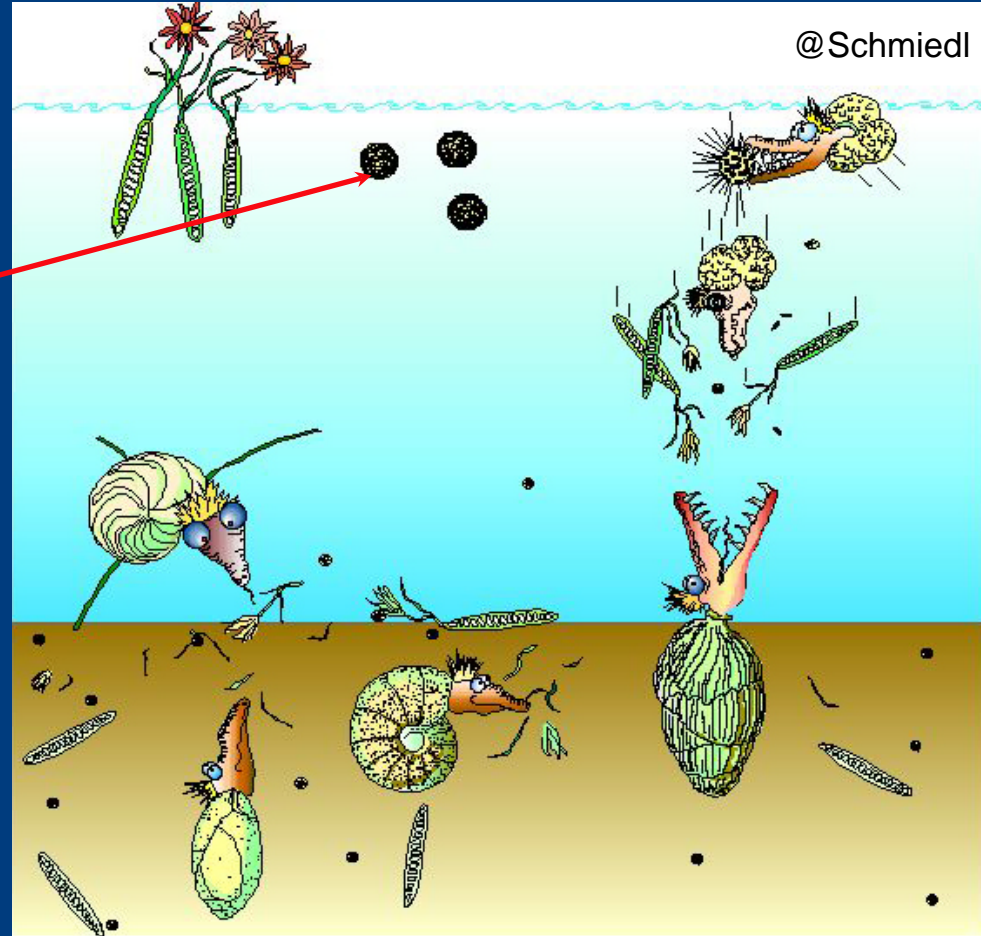


# What are calcareous nannoplankton?

Calcareous nannoplankton = unicellular, marine gold brown algae (phytoplankton)



*Syracosphaera molischii*





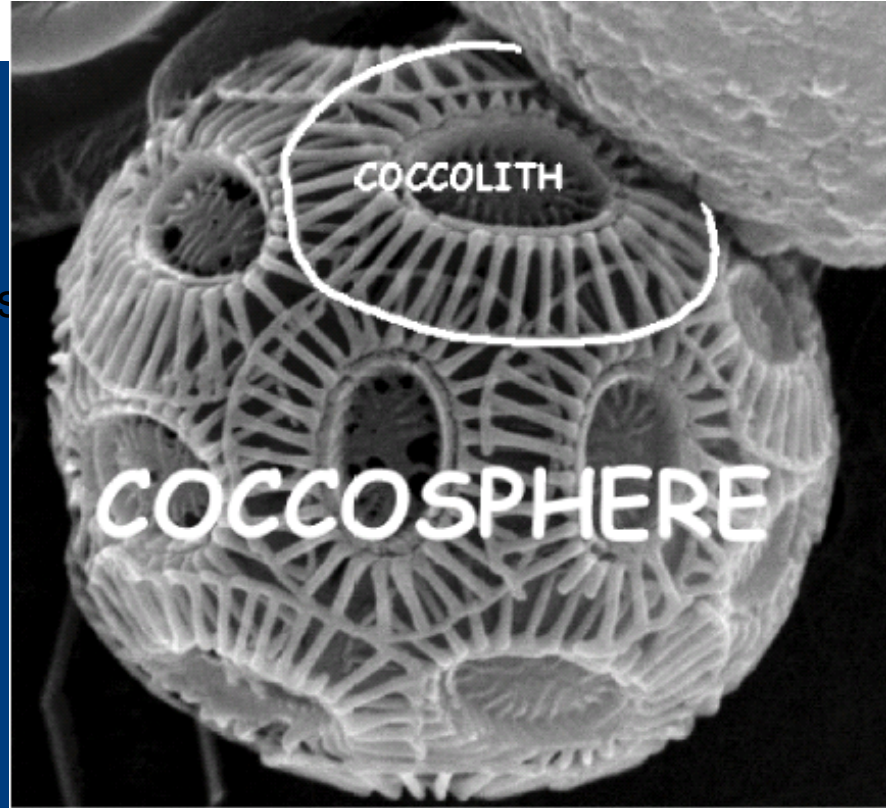
# Calcareous nannoplankton overview



**Coccolithophore** - the organism, including the cell and external coccoliths (living cell).

**Coccosphere** - ~ spherical layer of coccoliths surrounding the cell.

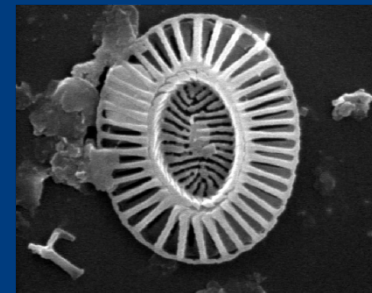
**Coccolith** - the individual calcareous plate ( $\text{CaCO}_3$ ).



After death coccospheres collapse and the coccoliths contribute substantially to sediments, e.g., Upper Cretaceous calks.



Coccosphere



Coccolith



# Coccolithophore morphostructure

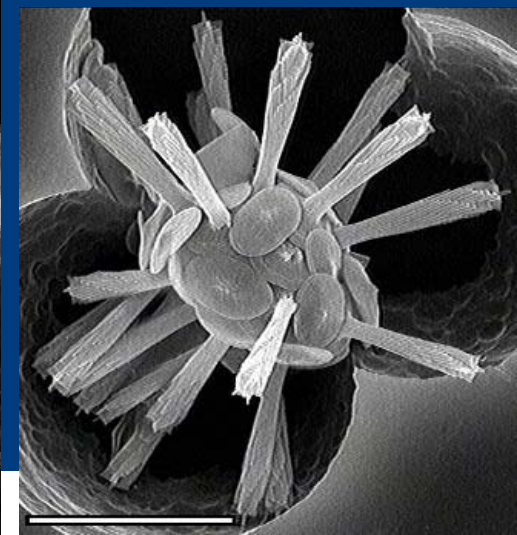
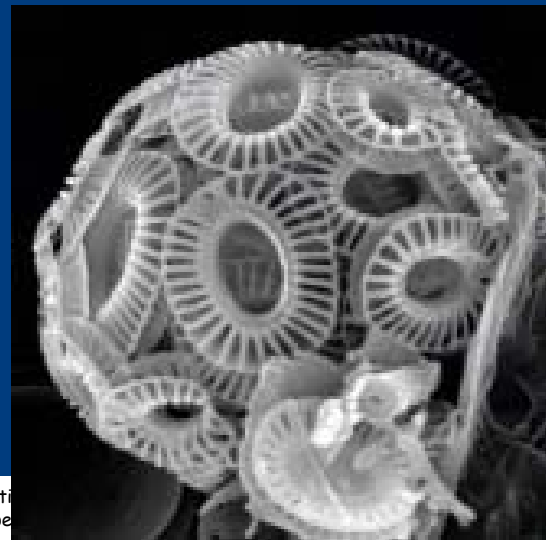
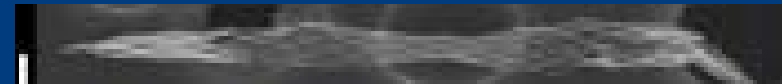
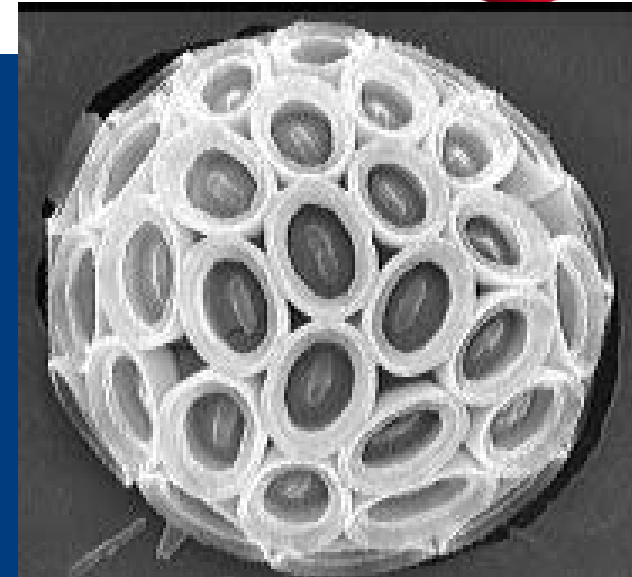


Secreted coccoliths composed of calcium carbonate

Function unknown/unconfirmed

Sound taxonomy based on the morphostructure of the coccoliths

Here use structure, morphology to extract information (from extant to fossil)





# Present is the key to the past – applicability of extant coccolithophores to fossil record



## Biostratigraphy

### \*Paleoceanographic interpretation

- Stratification
- Depth (shelf, open water, within water column)

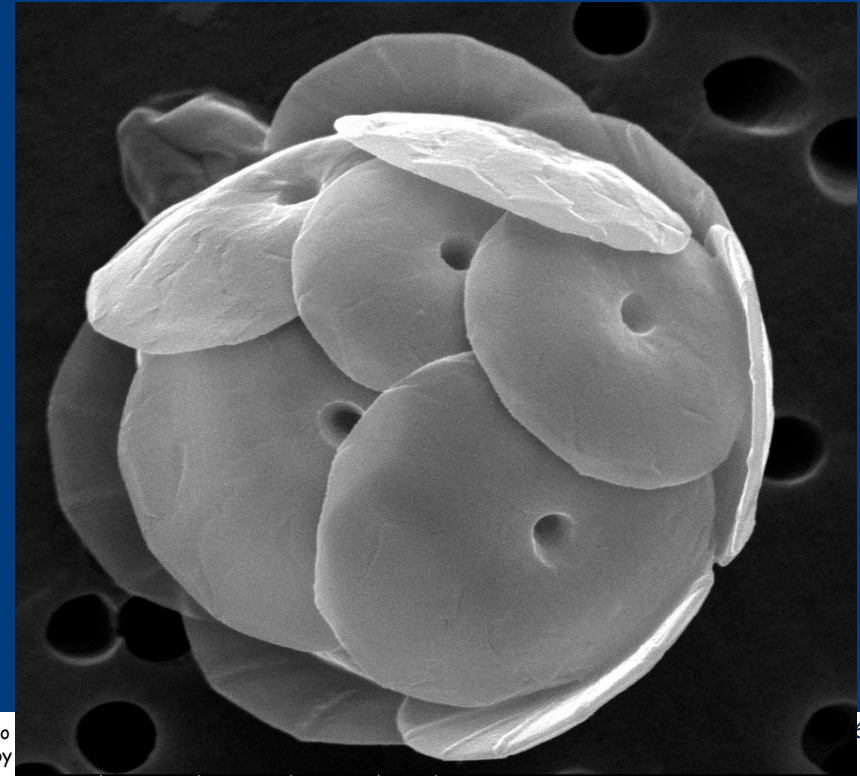


# Stratification of modern coccolithophores in the photic zone



Okada & Honjo (1973) discovered the deep dwelling community (~120-200m)

- e.g., *F. profunda*, *O. antillarum*, *G. flabellatus*, *A. robusta*
- Live in nutrient-rich environment at the thermo/nutricline





## Purpose/Methodology

Document intra- and interspecific variability in the coccolithophores from the shallow and deep photic zone in the southern Indian Ocean

- Quantitative measurements
- Morphological analysis

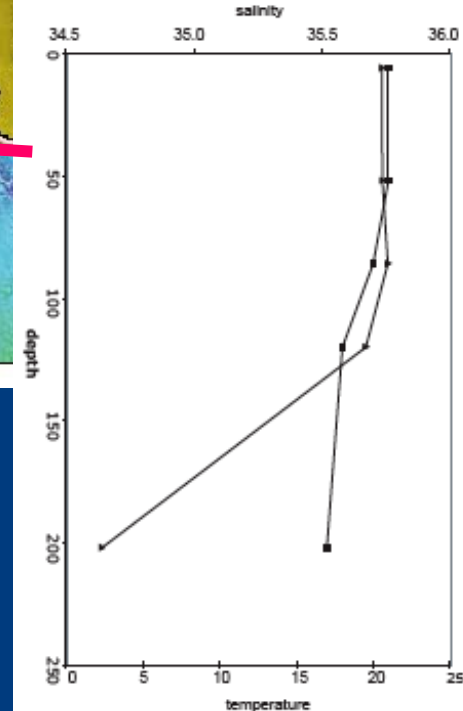
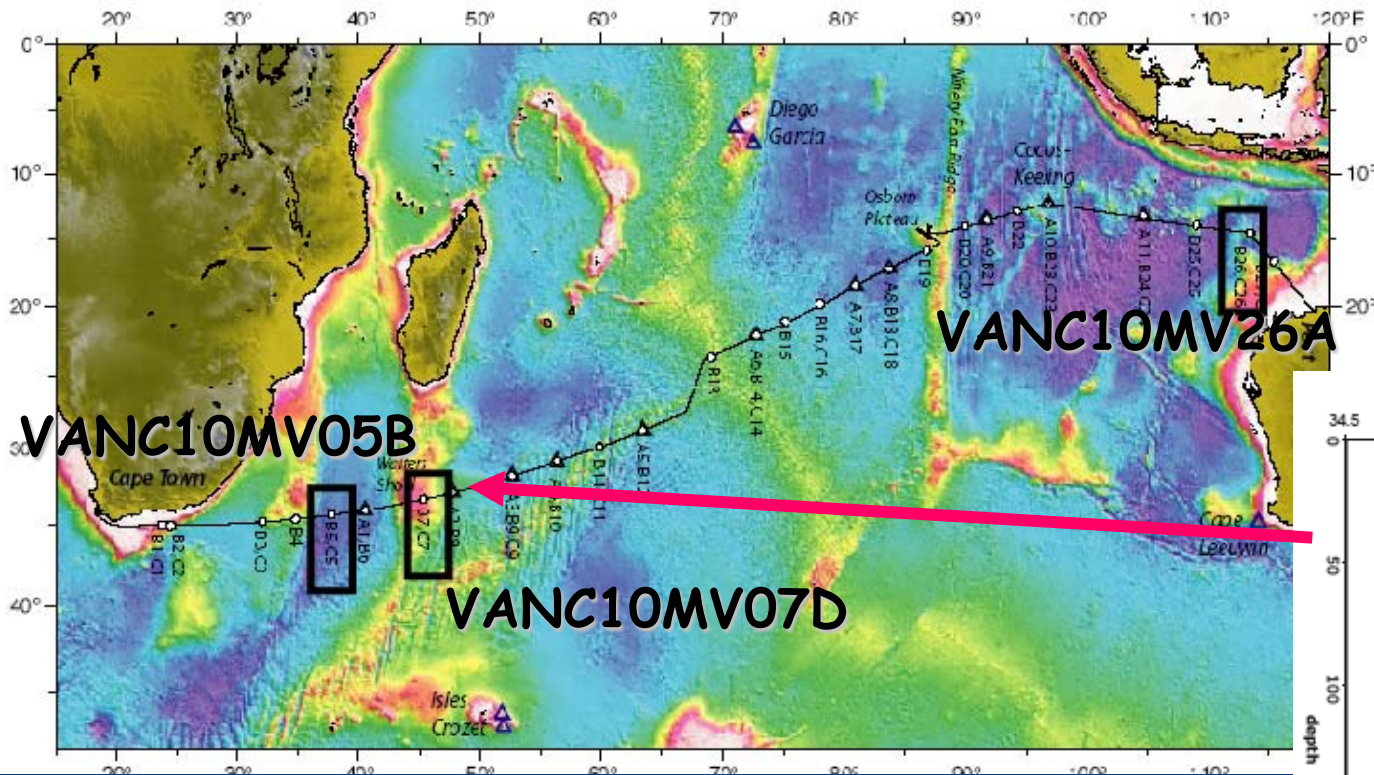
Apply model to fossil record by establishing intraspecific variability in fossil record

- Interpret paleo-habitat of species
- Extrapolate paleoceanographic conditions



# Indian Ocean modern photic zone

VANC10MV Hydroacoustic & Biological Sampling Cruise May/June 2003



Sample VANC10MV05B

49 m depth, 21°C

Sample VANC10MV07D

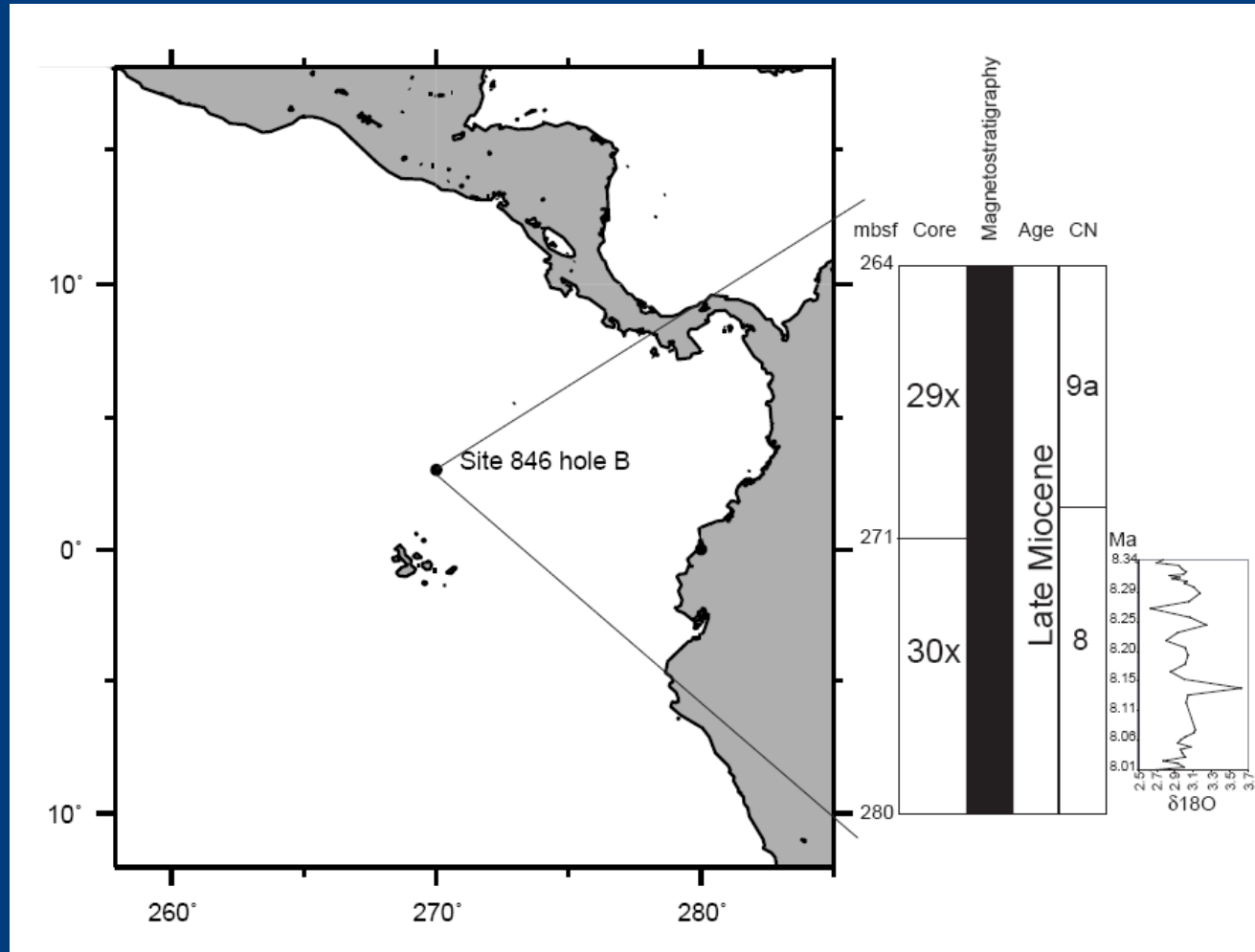
120m depth, 18°C

Sample VANC10MV26A

unknown depth/temperature



# ODP Site 846, hole B



Samples from: Zone CN8 to CN9a, upper Miocene (~10.6 - 7.0 Ma)



## ODP samples (*Miocene M. convallis*)

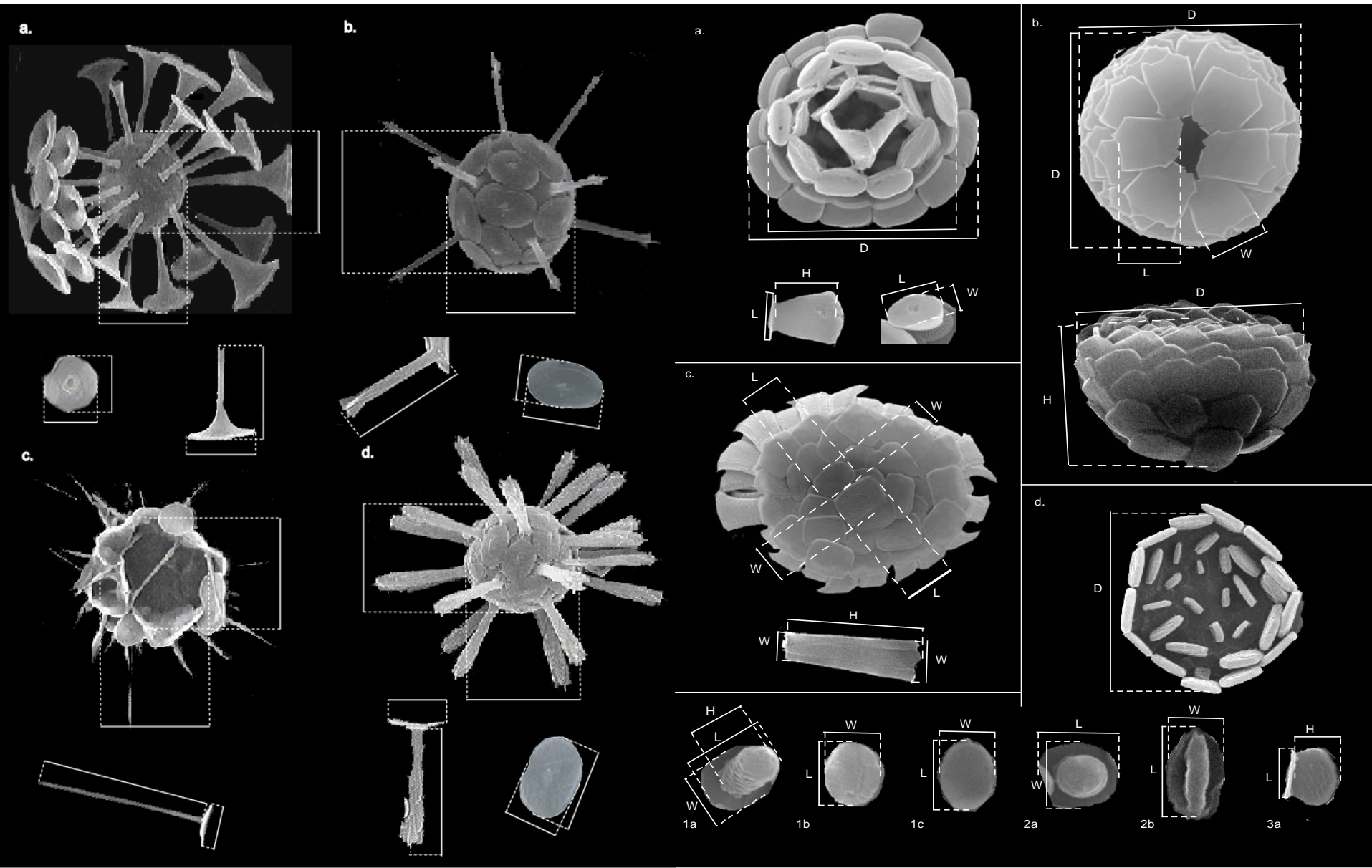
- Core sampled at 20 cm resolution from 264-280 mbsf
- 75 smear slides prepared on cover slip, heated to 175°C and adhered to slide with Ayac
- 40 smear slides analyzed in plain light on Zeiss Axiovision microscope
  - ~1000x
- Photographed and measured 50 nannoliths of *M. convallis* per sample

## Filter samples (extant coccolithophores)

- 5L water vacuum-filtered for sample VANC10MV07D in Indian Ocean
- Cut ~8mm<sup>2</sup> piece of filter, mounted on stub, and coated with gold and palladium
- Photographed and measured all coccospheres and constituent coccoliths across filter on FEI Quanta 400 ESEM
  - 4000-120,000x

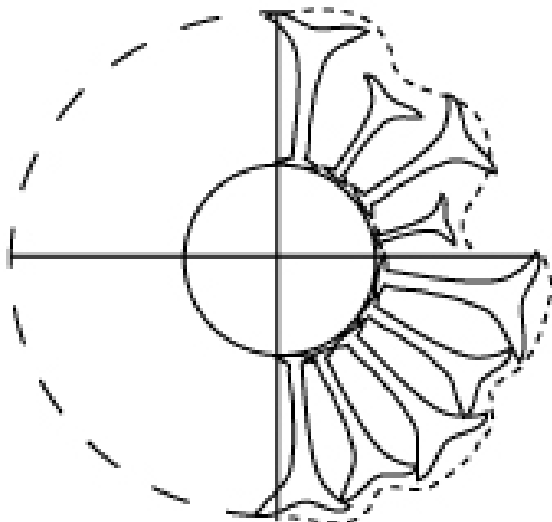
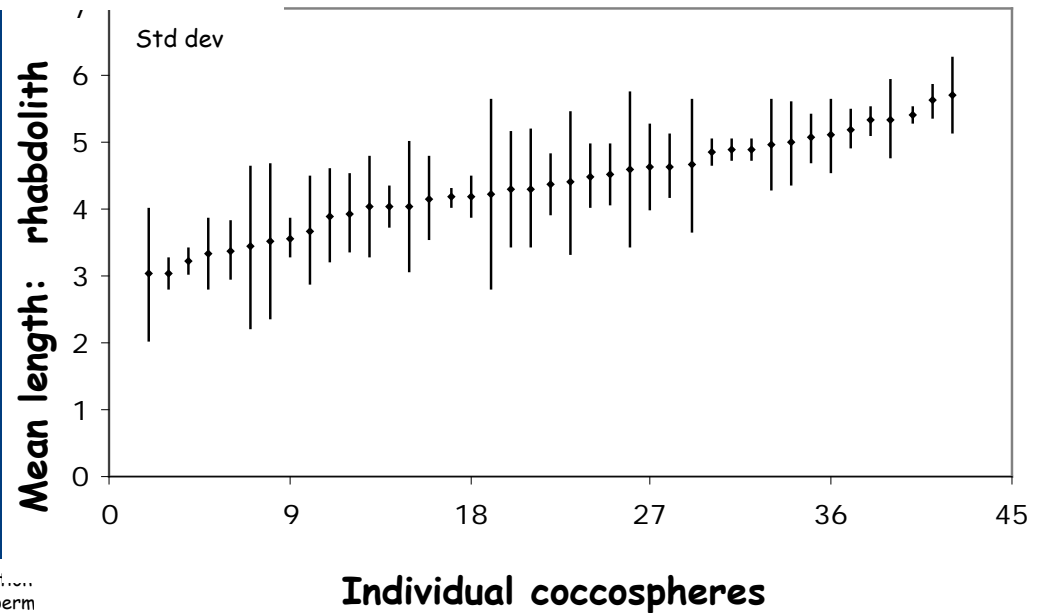
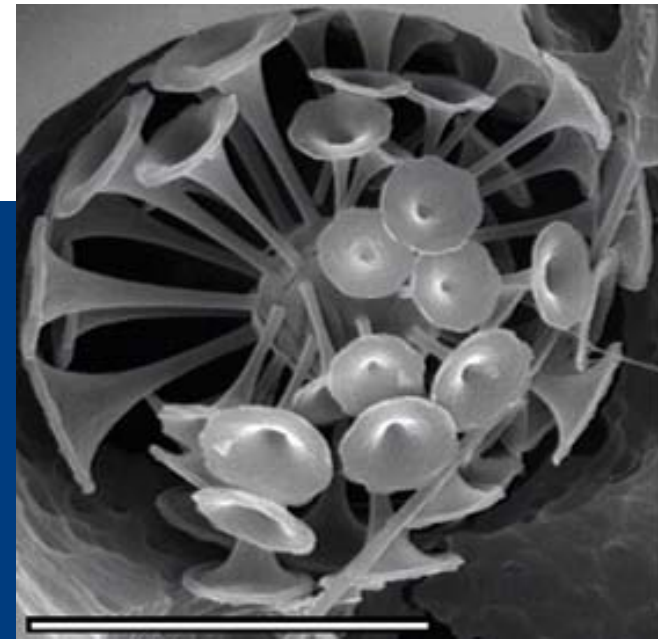
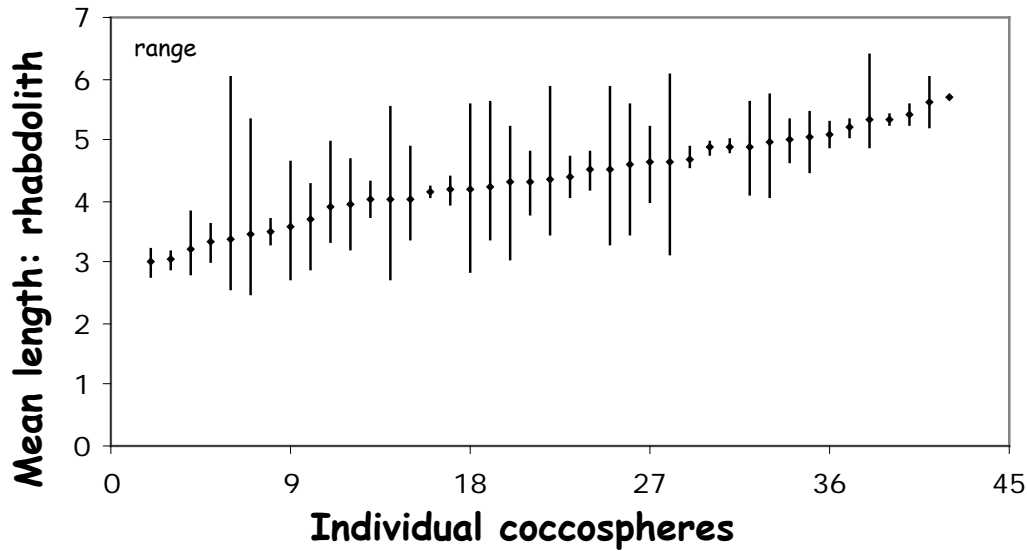


# Quantitative measurements of extant coccolithophores



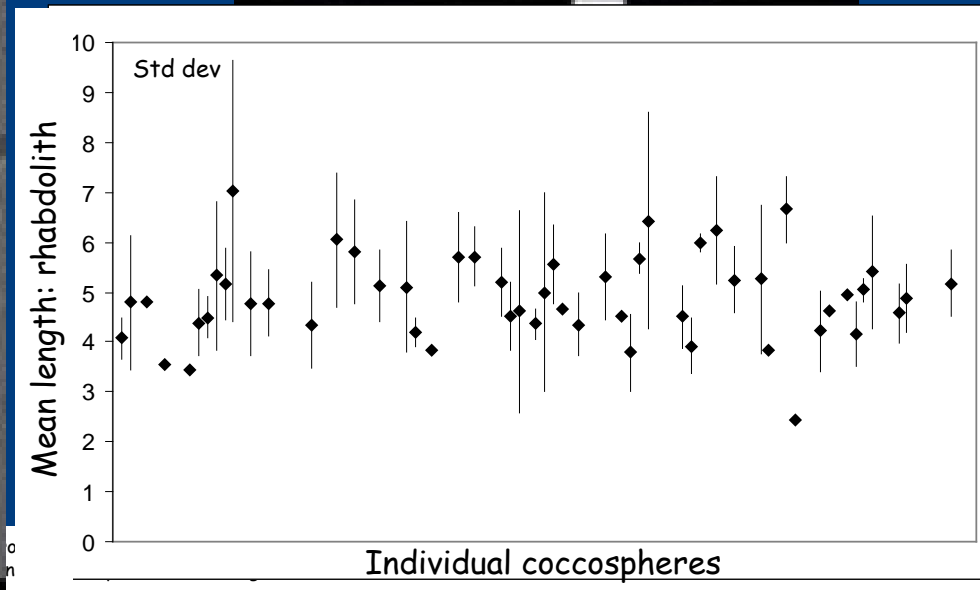
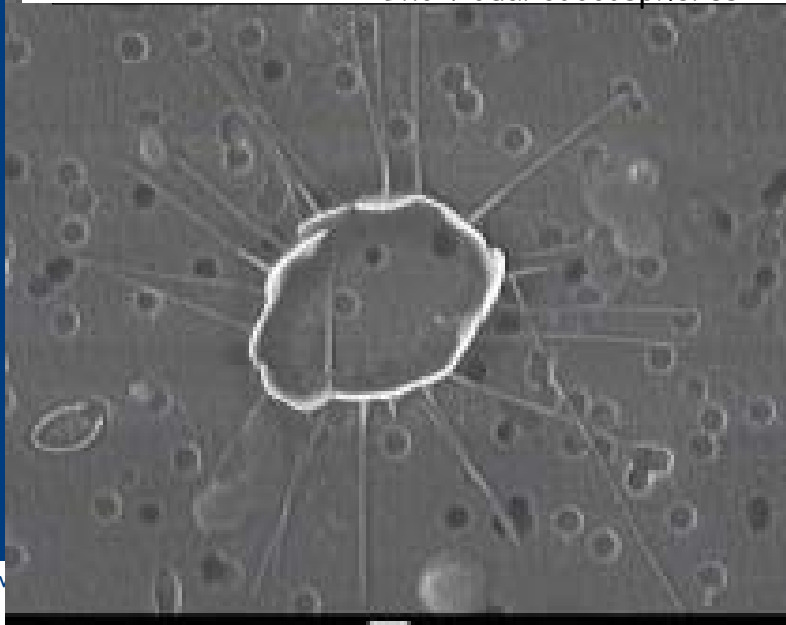
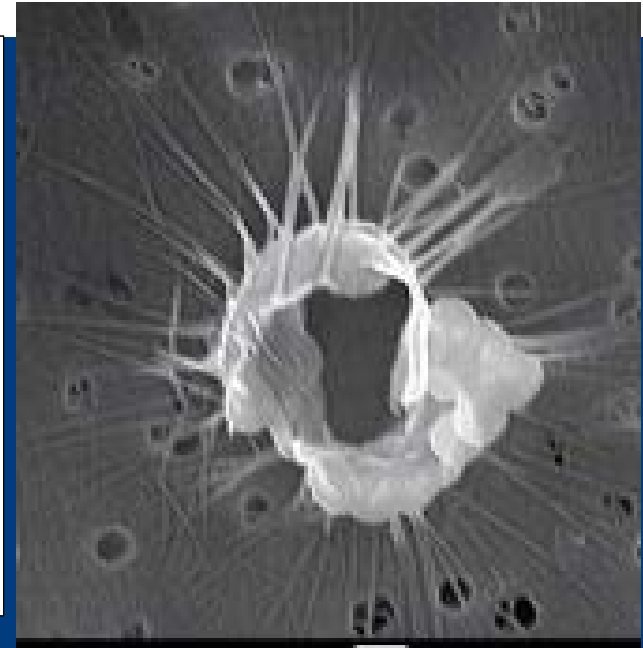
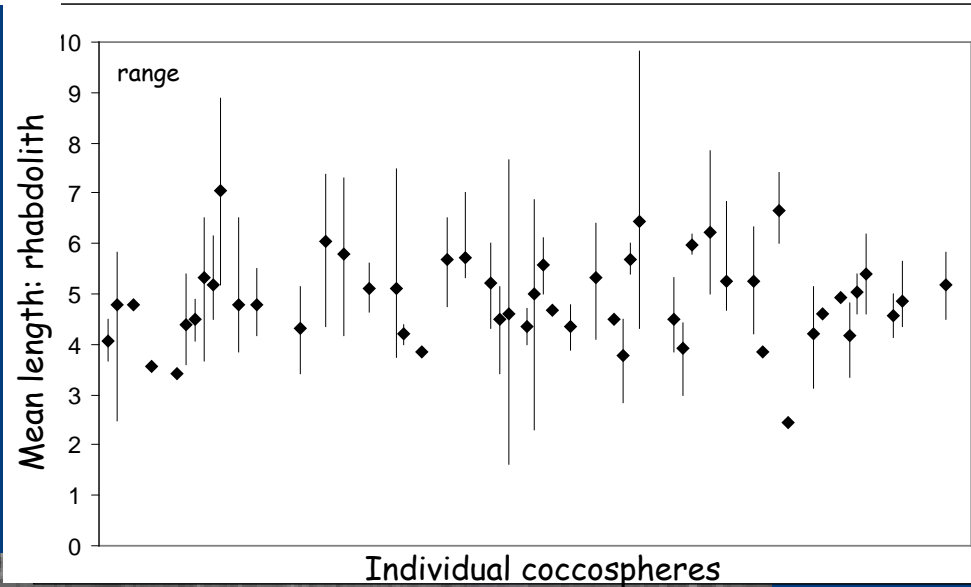


# *Discosphaera tubifera* - SPZ





# *Palusphaera vandelli* - SPZ





## Morphologic observations

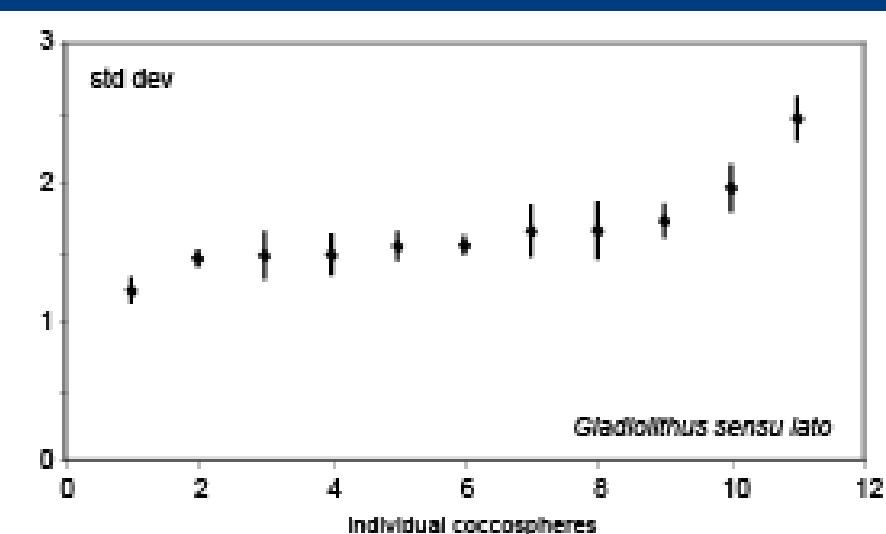
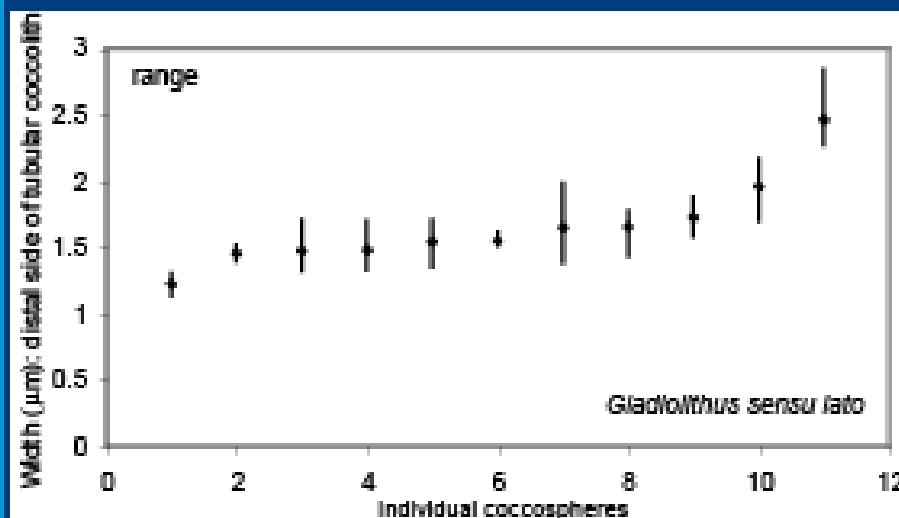
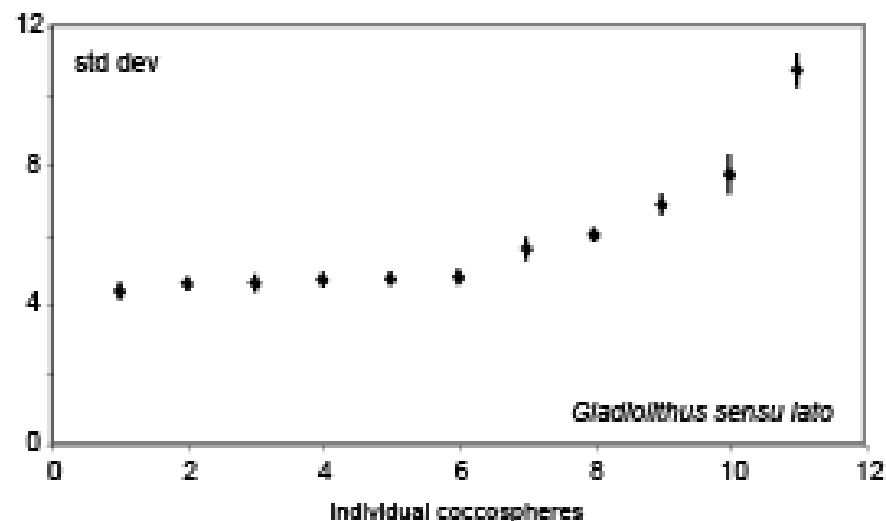
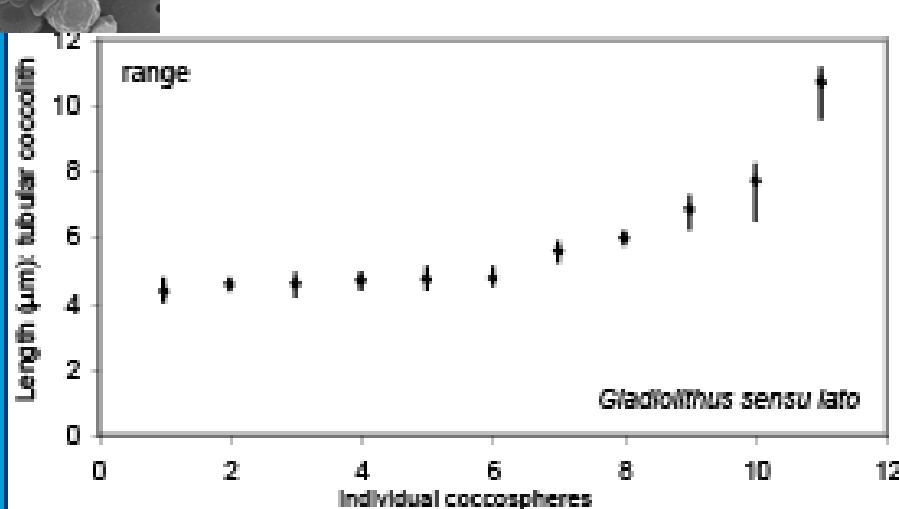
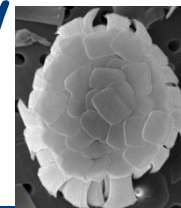
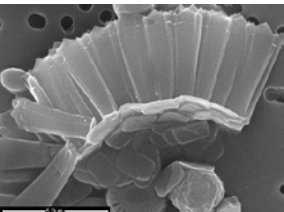
High variability in all measurements

- *D. tubifera*, *P. vandellii*, (*R. clavigera*, *R. stylifera*)

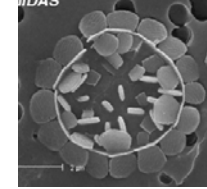
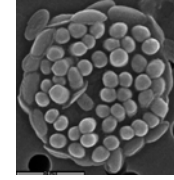
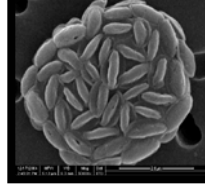
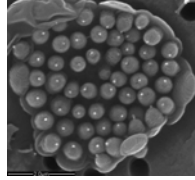
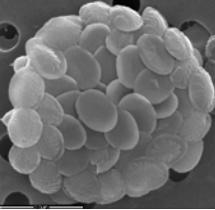
No clear pattern emerged among measurements



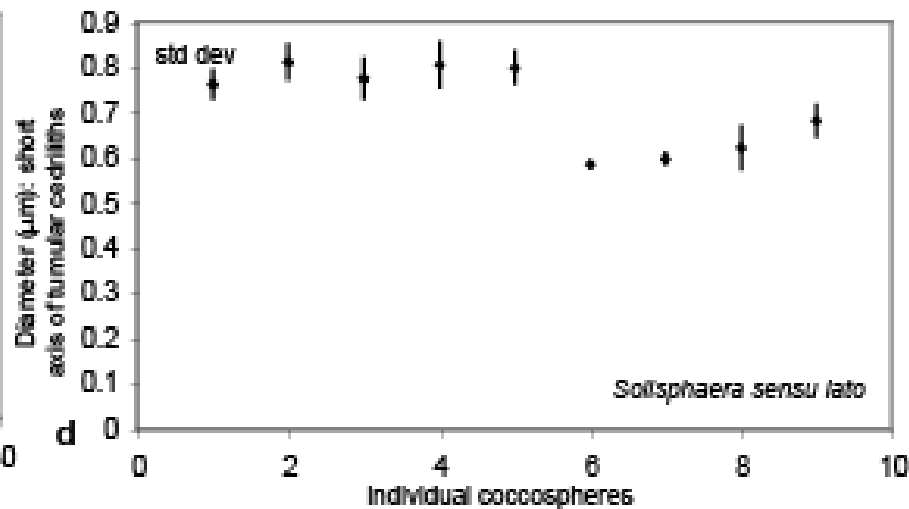
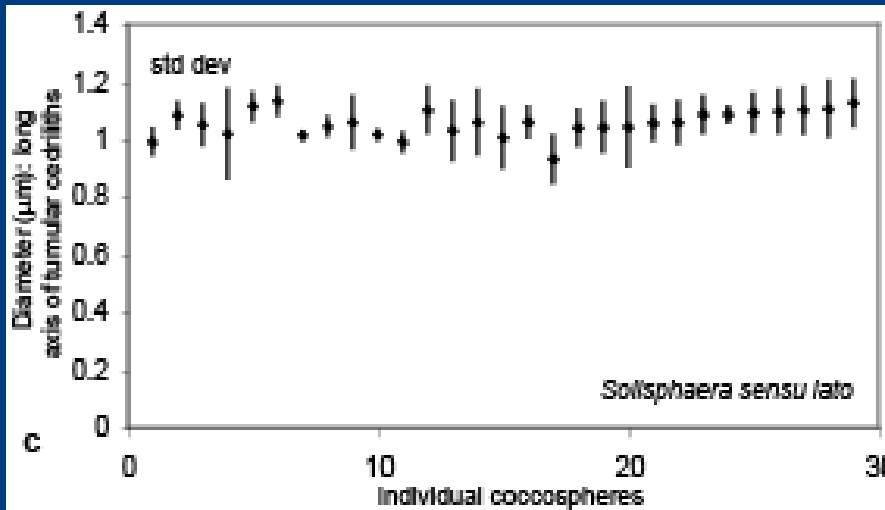
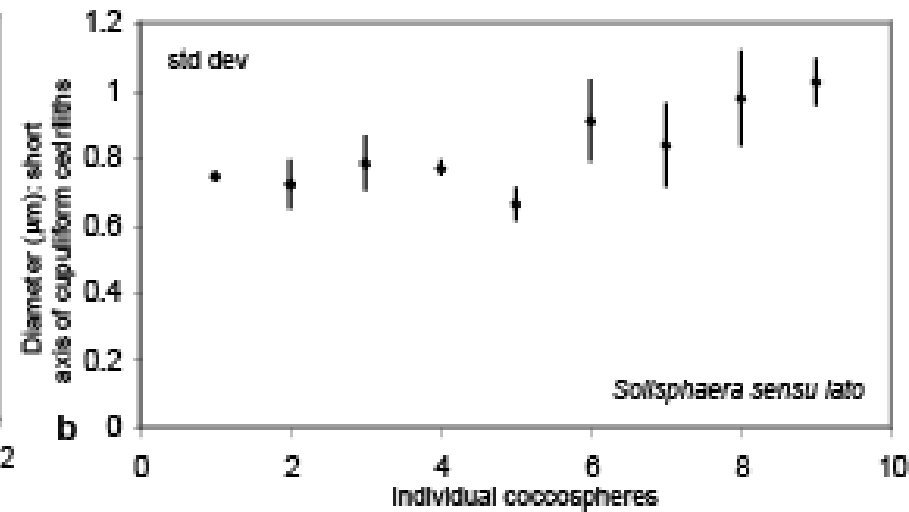
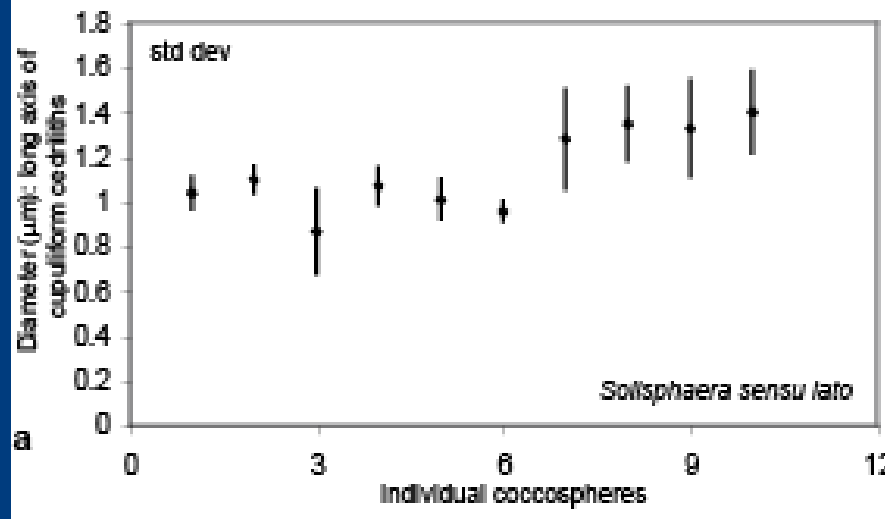
# Intraspecific variability in *Gladiolithus sensu lato* -DPZ



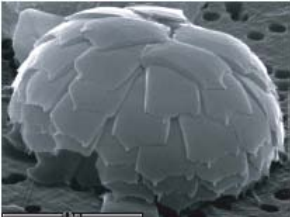




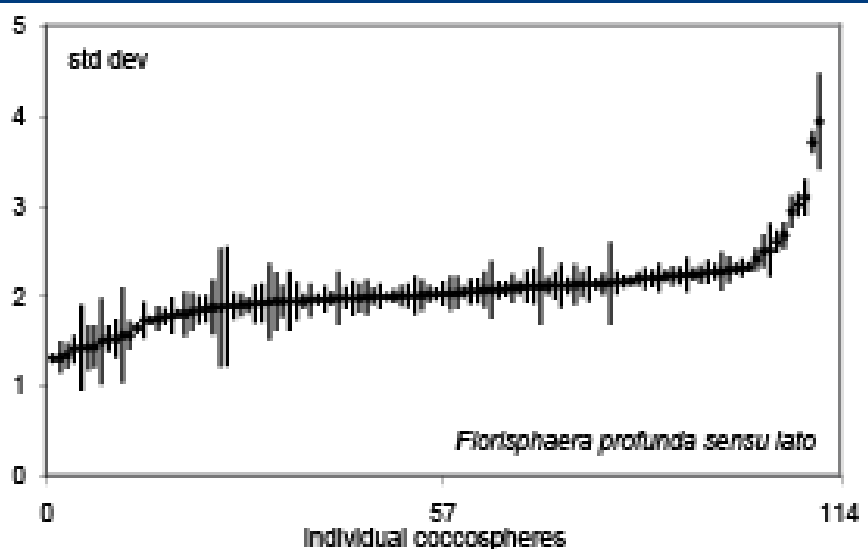
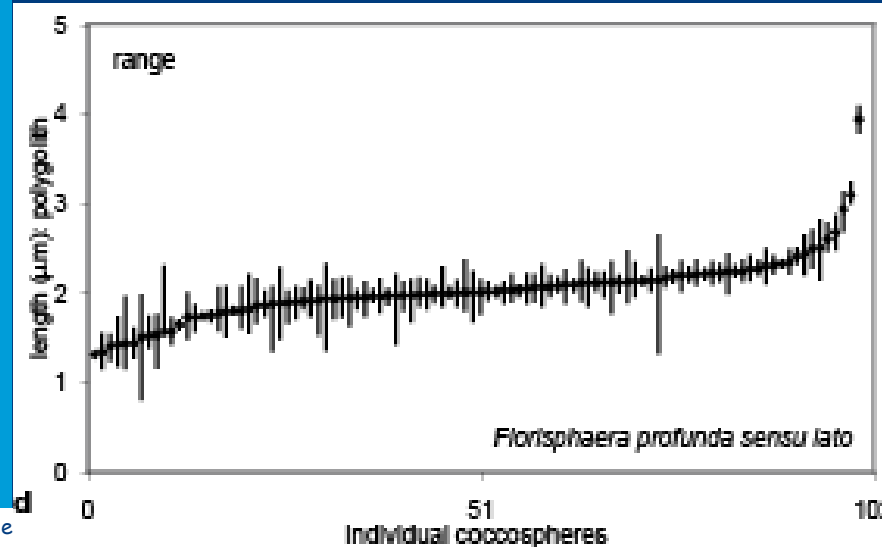
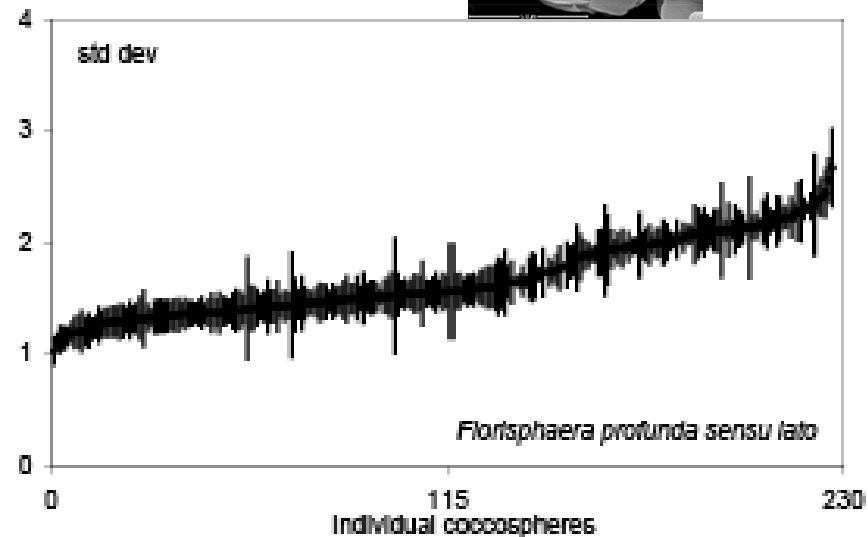
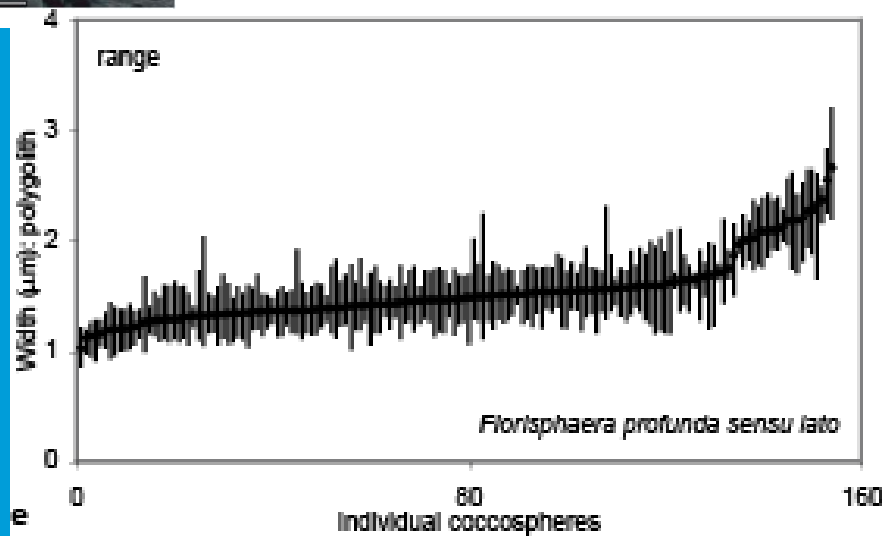
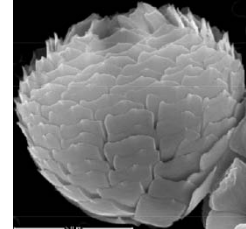
## Intraspecific variability in *Solisphaera sensu lato* - DPZ







# Intraspecific variability in *F. profunda*





## Morphologic observations

Low variability in all measurements, both among species and genera

- *Florisphaera, Gladiolithus, Solisphaera, Algirosphaera*



# Hypothesis

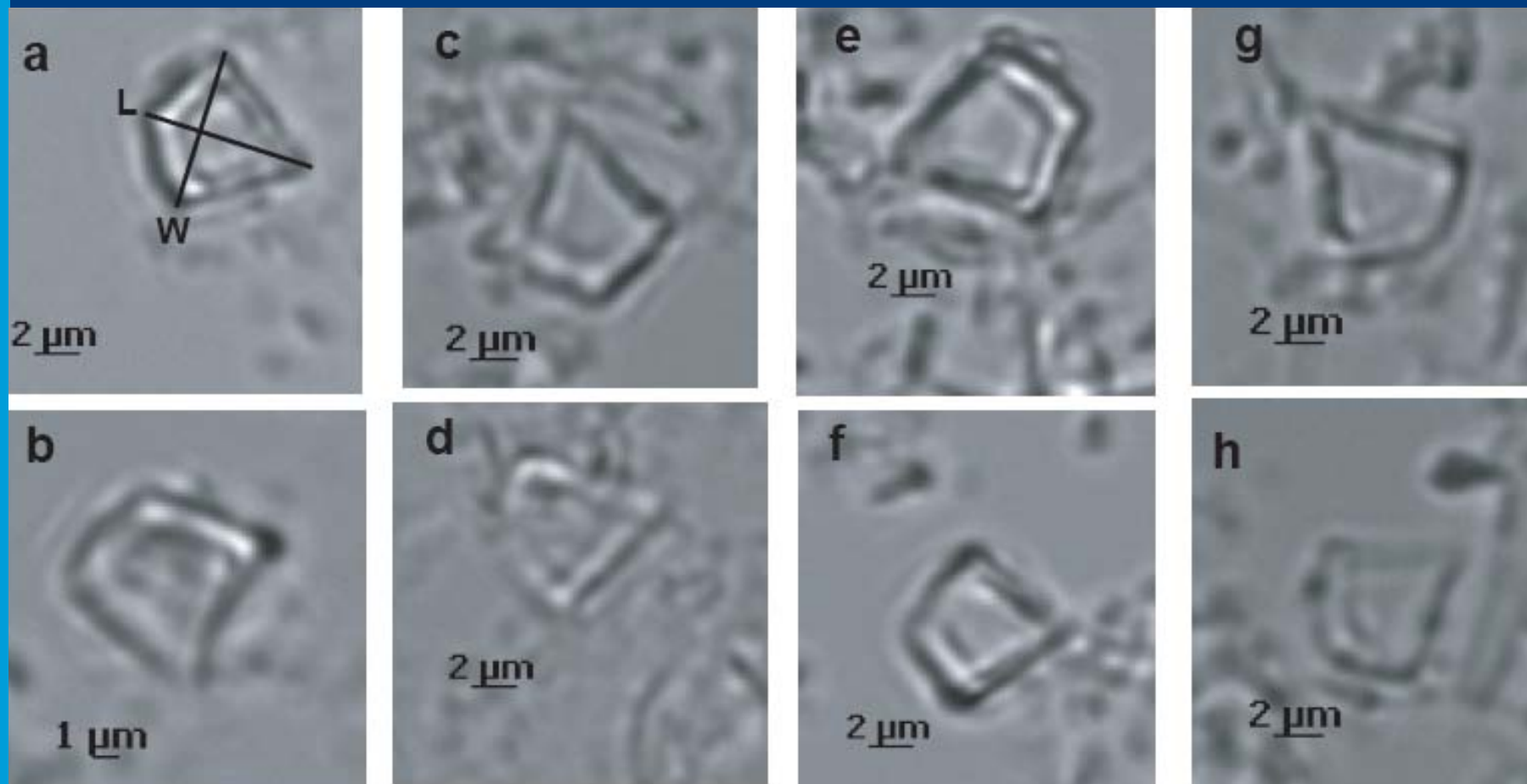
Miocene *M. convallis* is deep photic zone dweller

Why?

- Unique geometry, classified as nannolith
- Proposed to be ancestral to *F. profunda* (Gartner 1992)
  - Stratigraphic range:
    - ▶ *M. convallis* ~11.2-7.2 Ma
    - ▶ *F. profunda* ~7 Ma - today
  - Polygonal plates

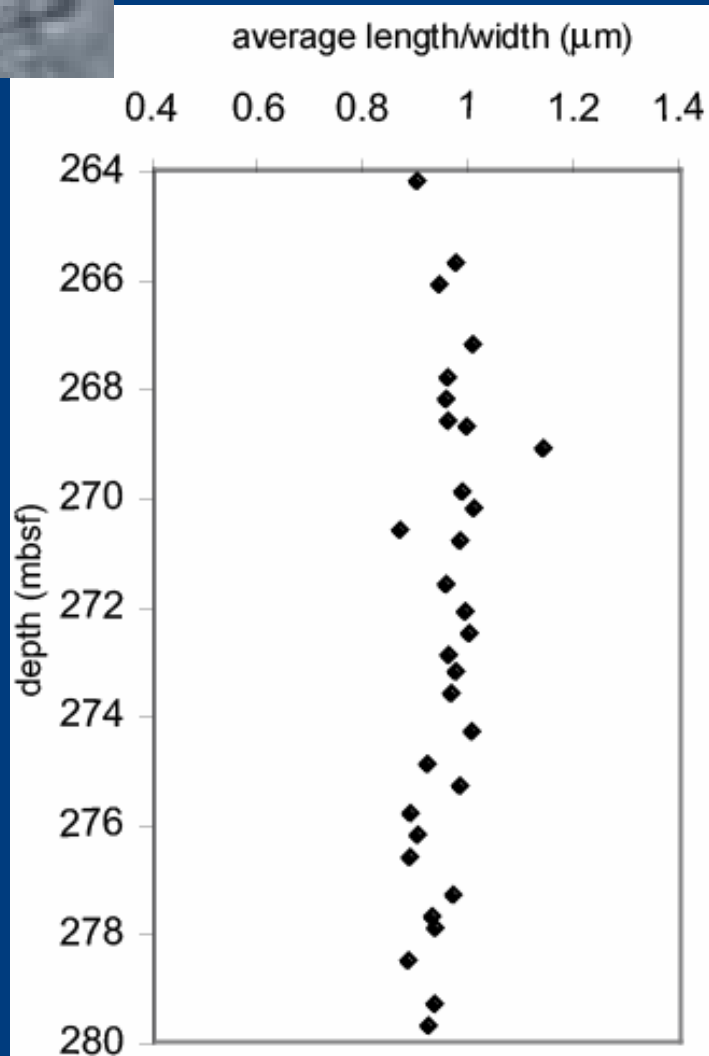
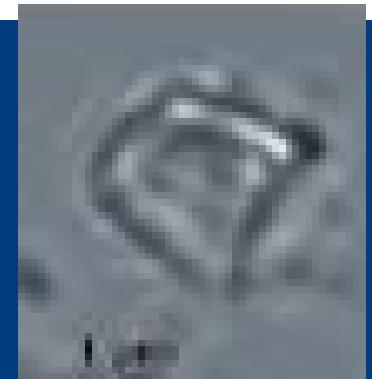


# *Minylitha convallis*

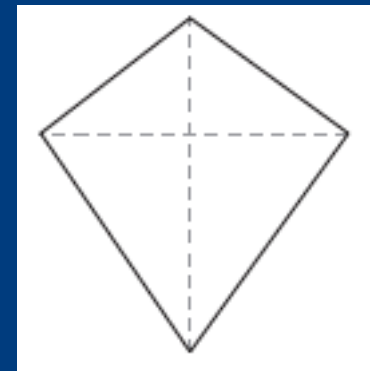
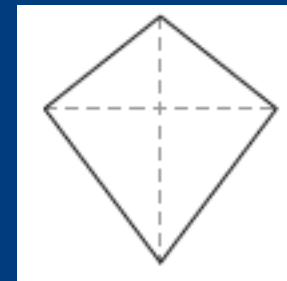
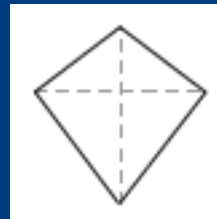




# Intraspecific variability through time in *Minylitha convallis*

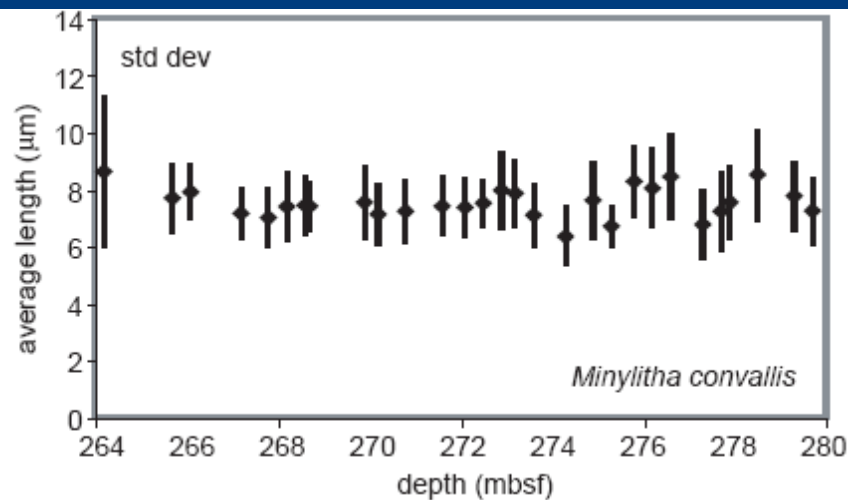
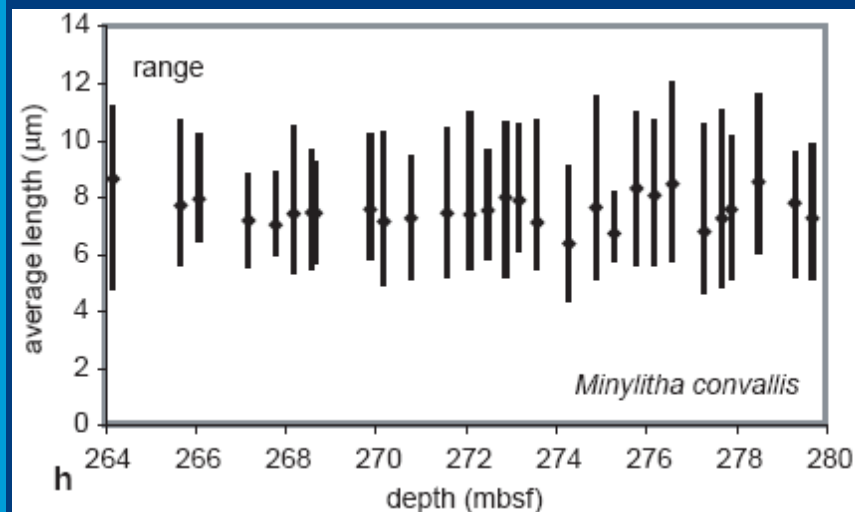
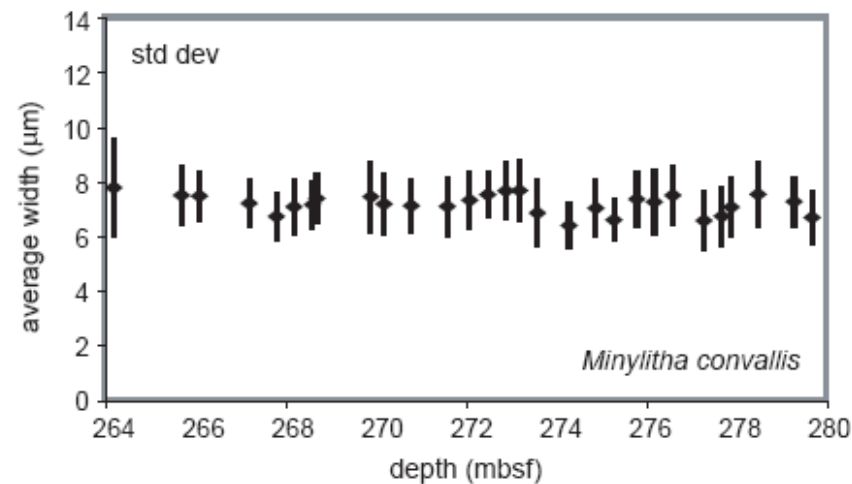
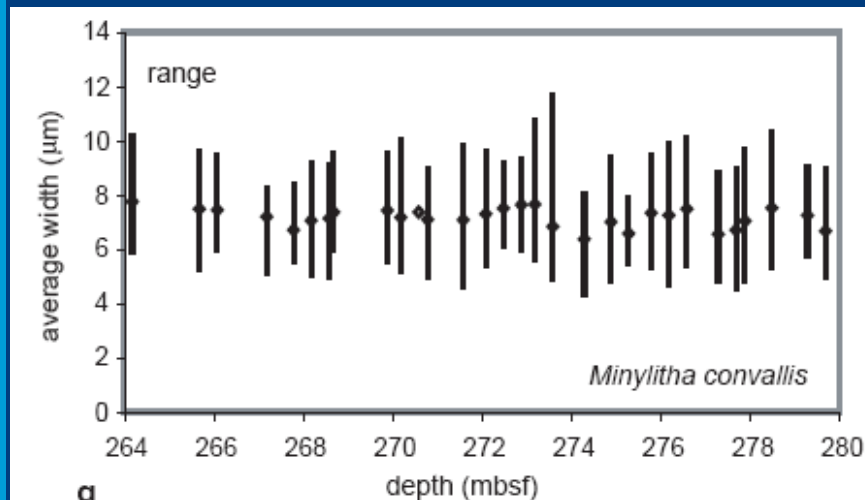


Total variability over 3.6 m.y.:  
63% average length  
58% average width





# Intraspecific variability in *Minylitha convallis*



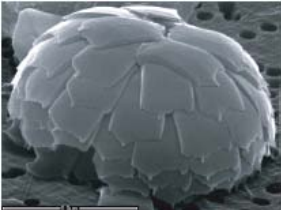


## Morphologic observations

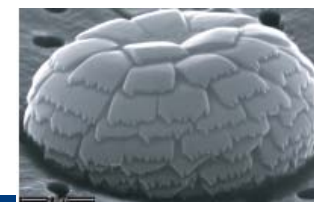
Low variability in all measurements both in individual samples and through stratigraphic range

*Minylitha convallis*





# A closer look: Inter- and intraspecific variability in *F. profunda sensu lato*



Variability per single coccospheres:

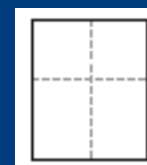
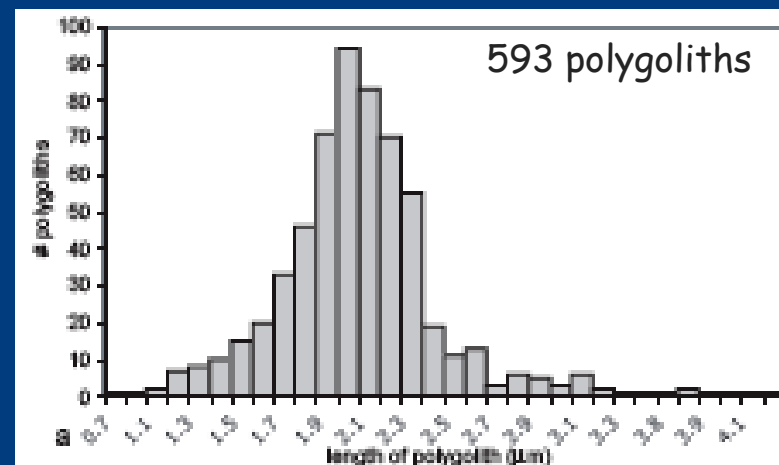
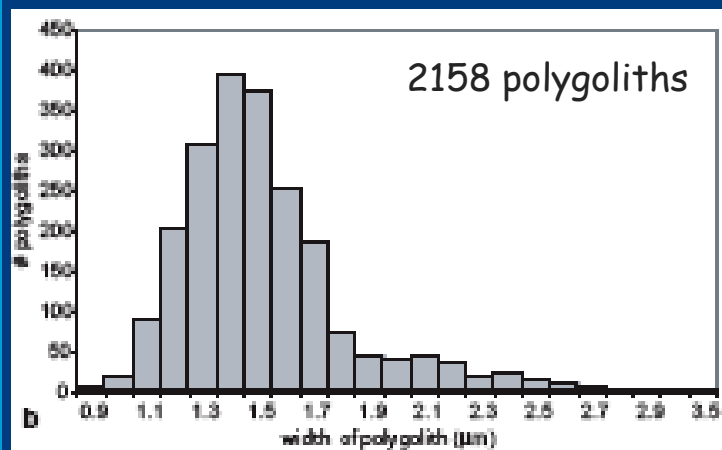
17% in average length

30% in width

Total variability (all morphotypes):

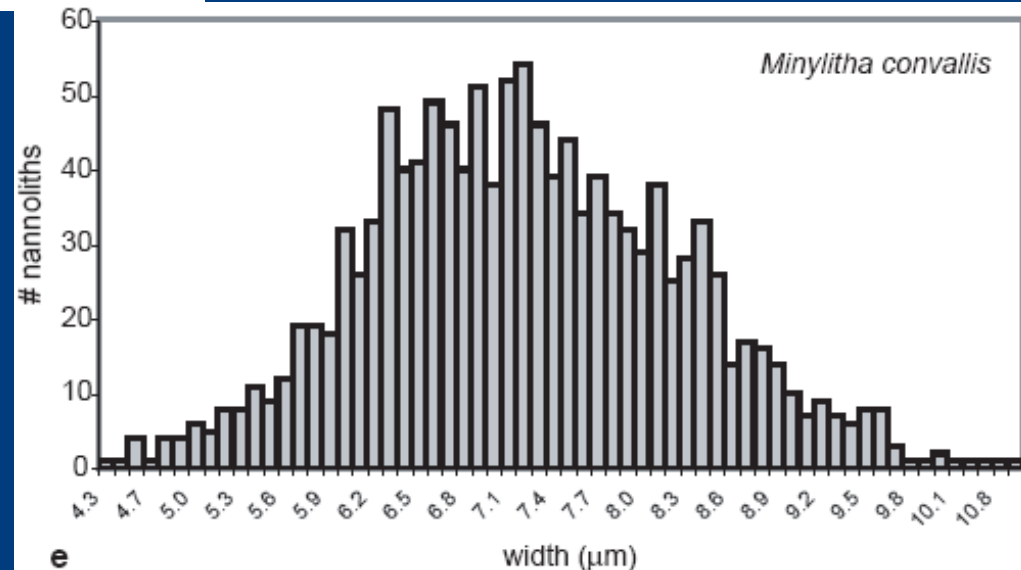
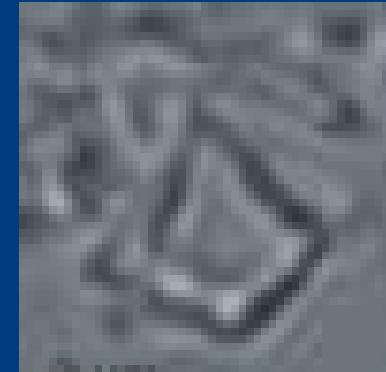
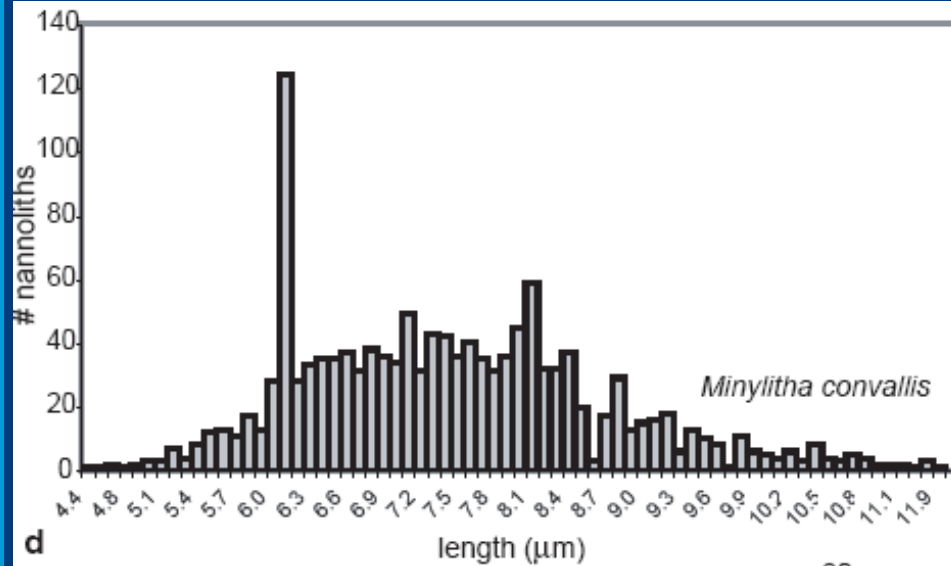
167% in average length

173% in width





# Distribution of all measurements of *M. convallis*





# Implications of low variability of *M. convallis*

Parallels in low intraspecific morphologic variability in both *M. convallis* and DPZ genera

Indication:

*M. convallis* was a deep photic zone dweller

Therefore:

High relative abundance indicates:

- Stratified water column
- Deepened nutricline
- (warmer climate)



# Acknowledgements

Marie-Pierre Aubry

Colomban de Vargas

Christopher Daniel

DSDP (now IODP) repository at Lamont Doherty  
Oceanographic Institute