

The climatic history of Antarctica and the Southern Ocean

Peter K. Bijl

Utrecht University – Department of Earth Sciences, The Netherlands



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Southern Ocean, recent changes

Subtropical surface waters warmed

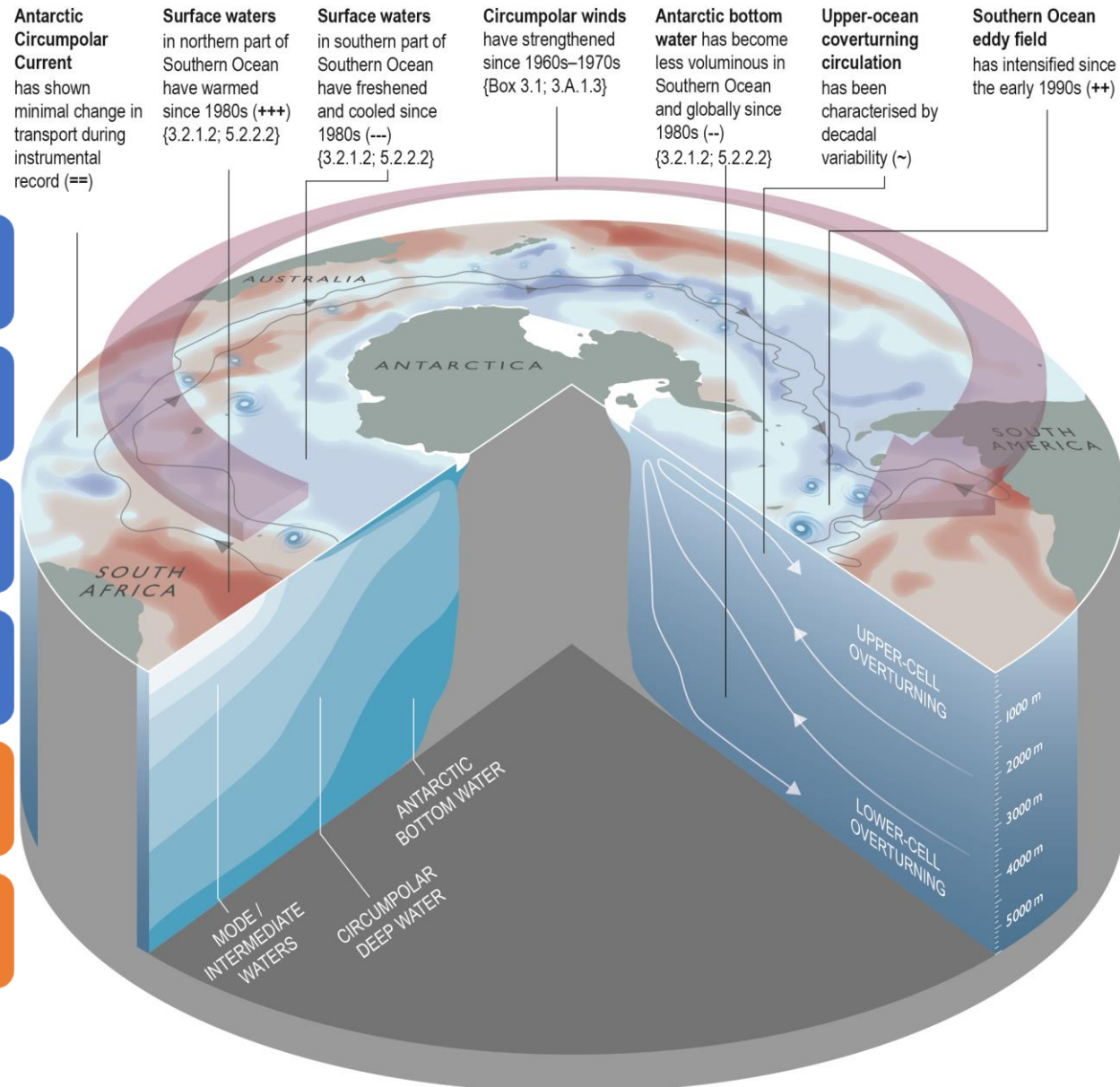
Subpolar surface waters cooled/ freshened

Atmospheric circulation strengthened

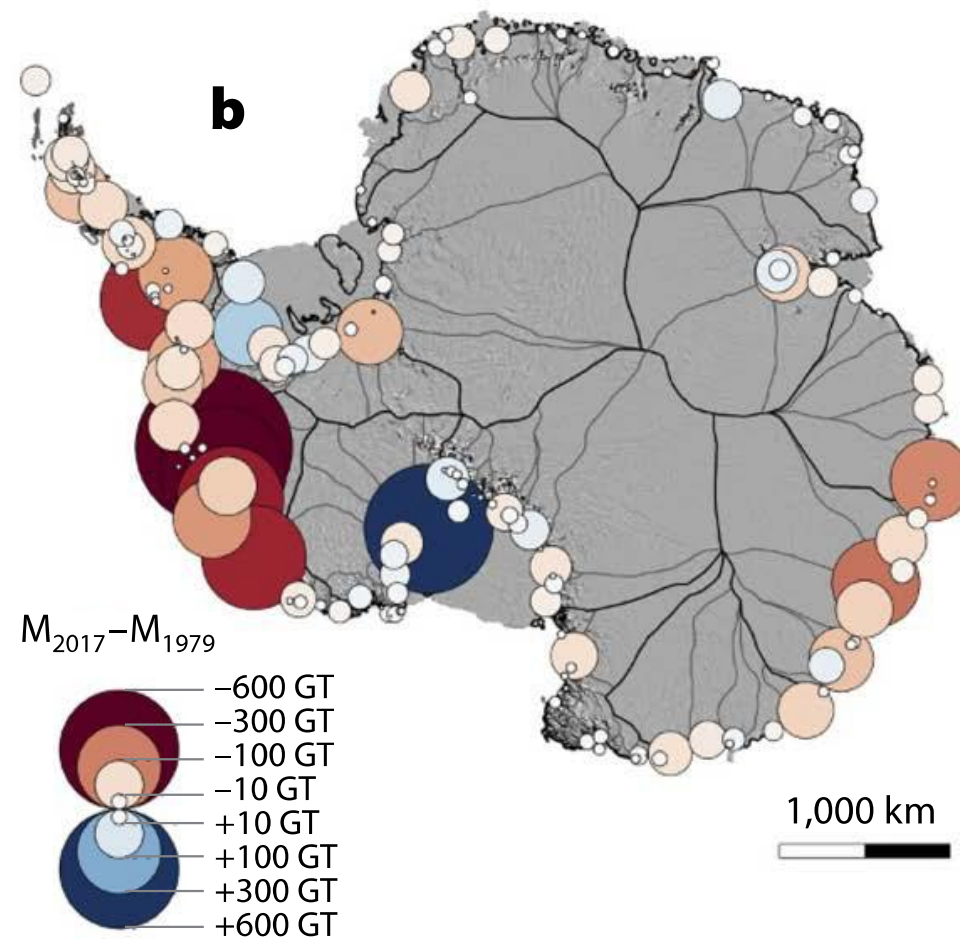
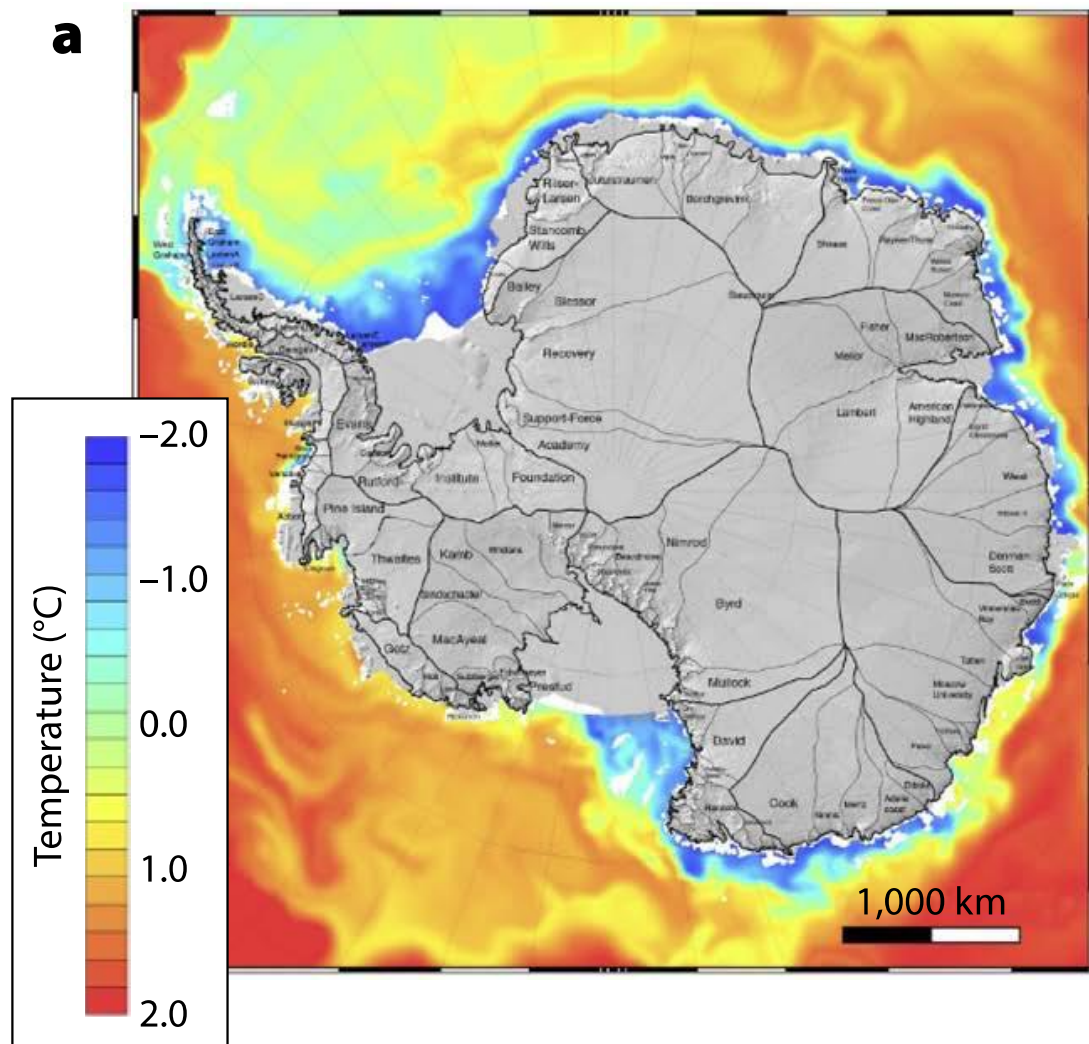
Eddy field increased

Is Southern Ocean CO₂ source or sink?

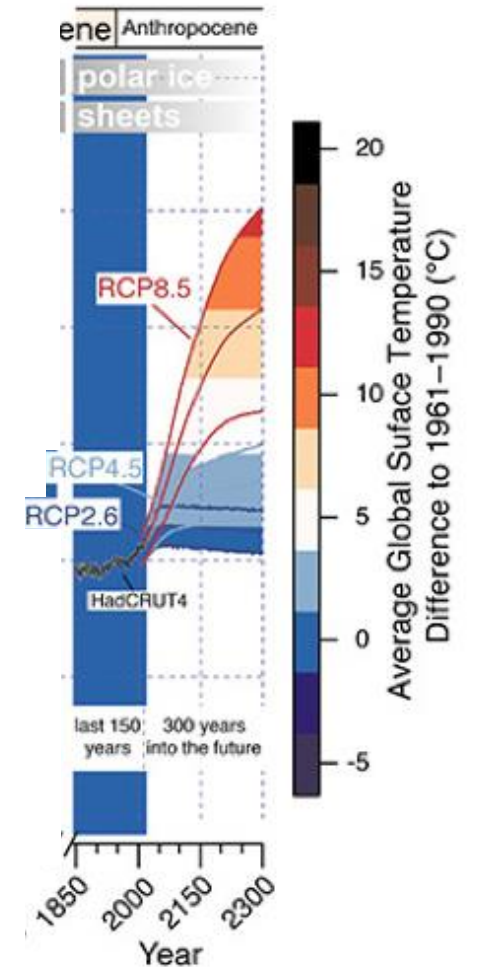
Teleconnections to Antarctic ice sheet?



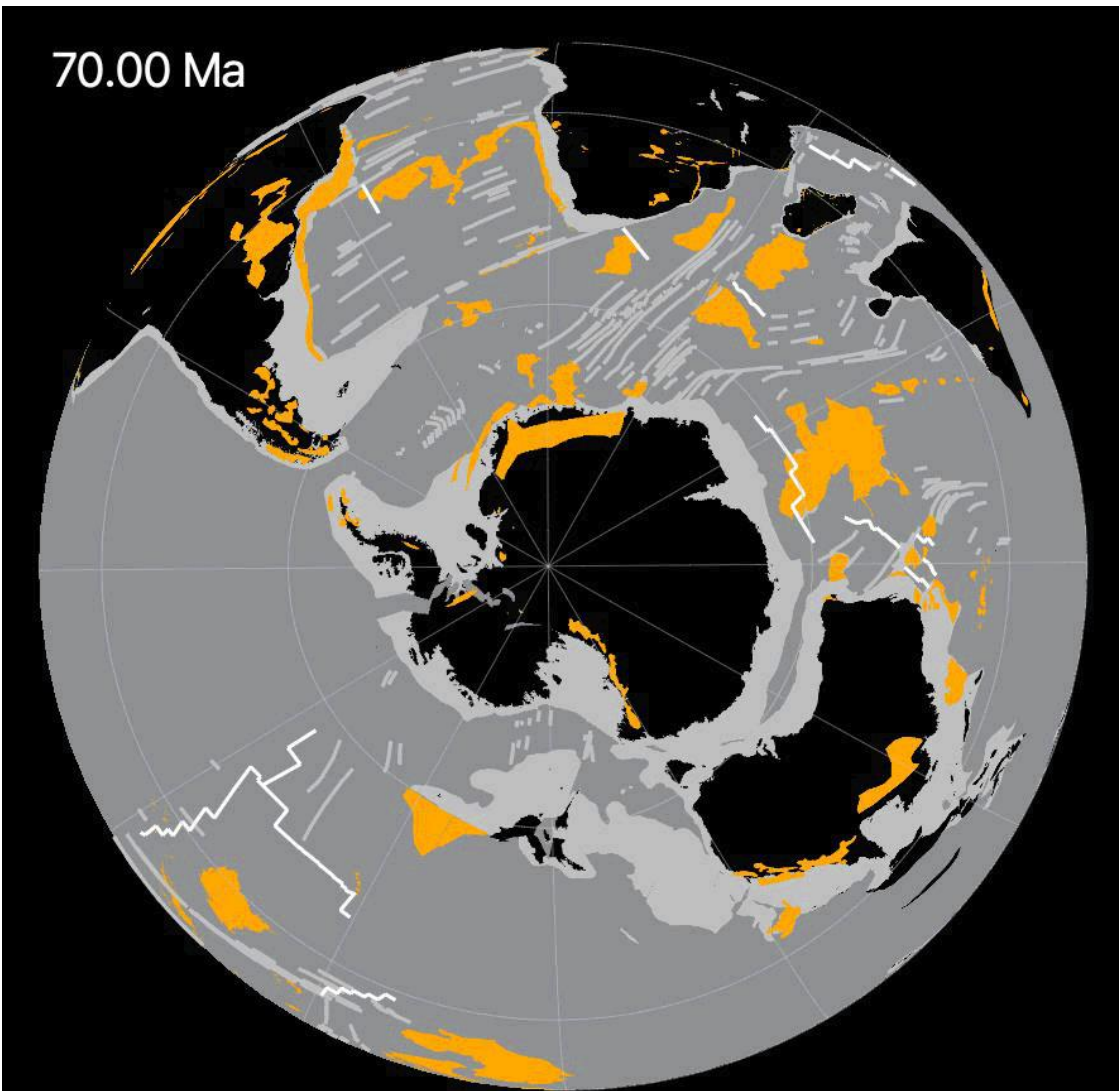
Warm(ish) water lurking nearby...



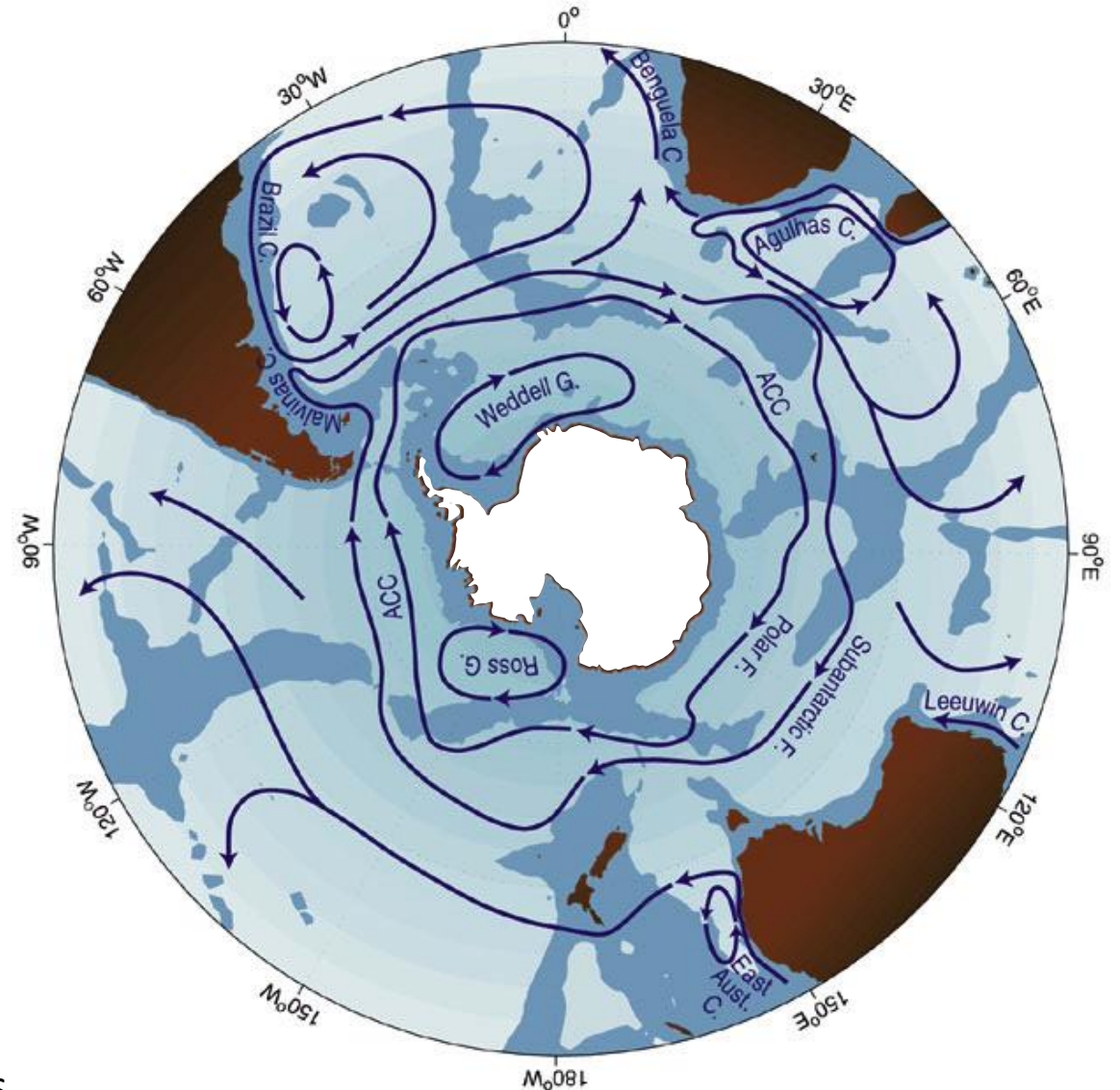
Climate history... with future projections



Tectonic evolution of the Cenozoic Southern Ocean



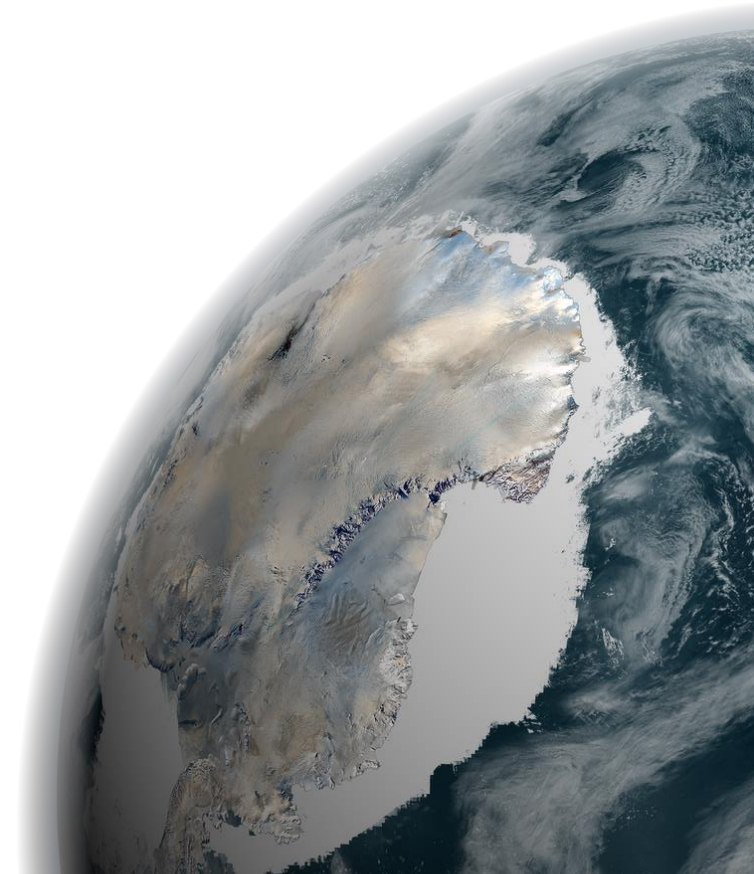
Gplates



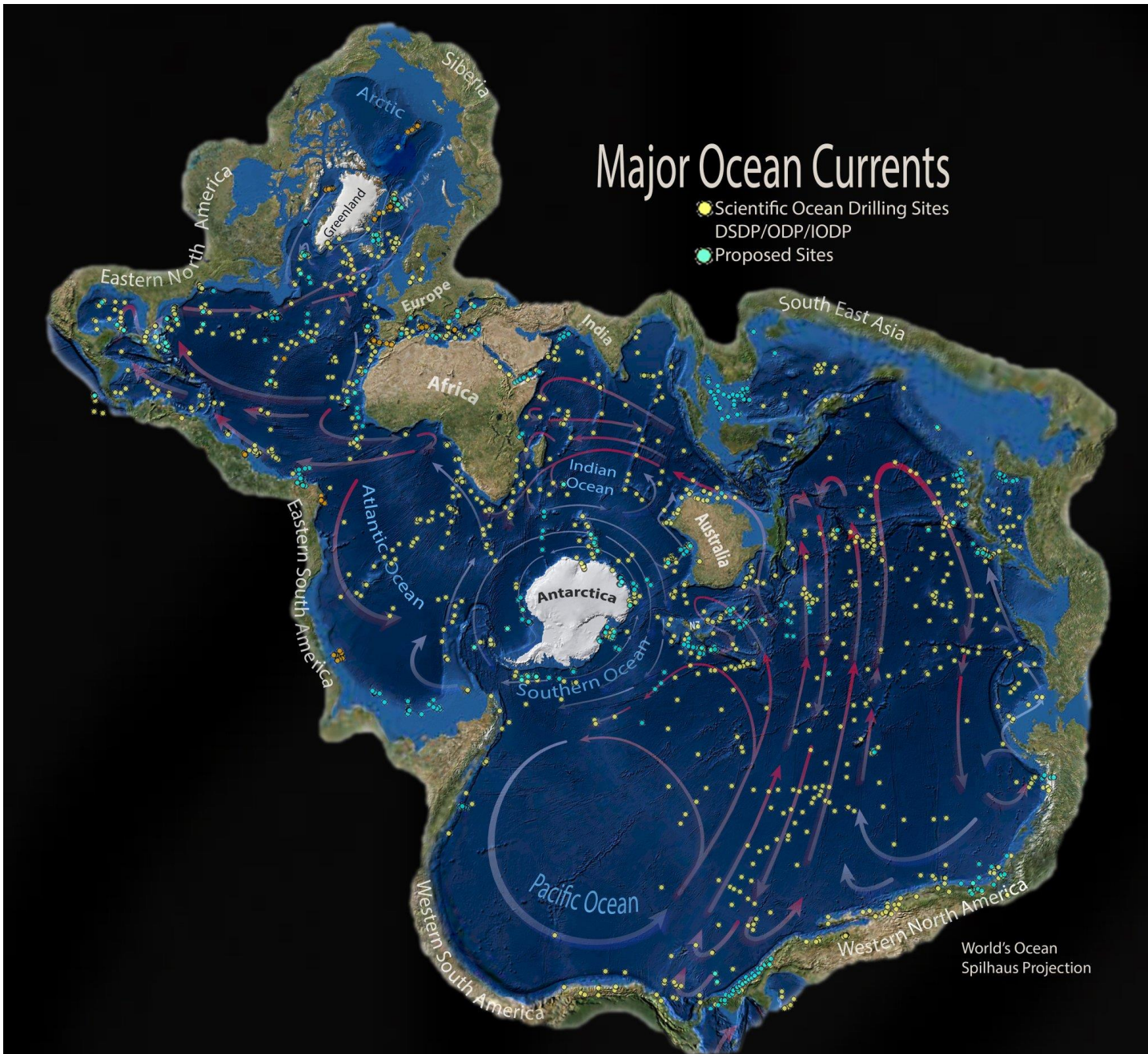
Approach:

- Obtain the sedimentary archive
- Assess time in the sediments
- Analyse the archive and reconstruct past conditions!

It will be fun!



Sedimentary archives

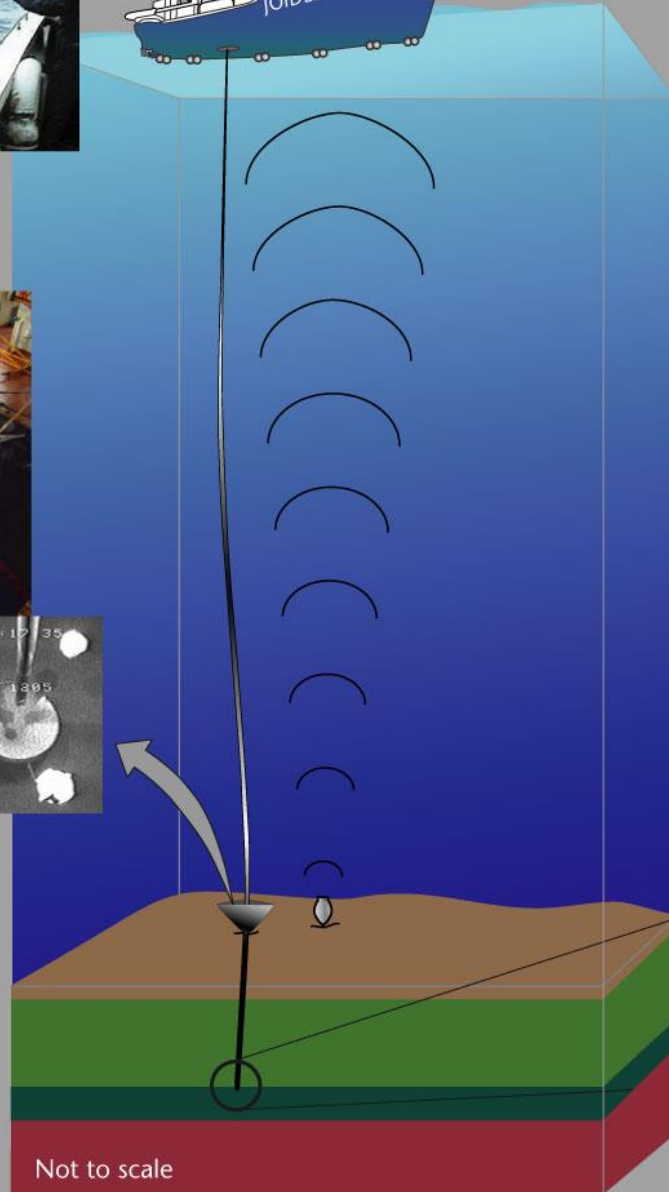


Tools of Exploration

Beacon



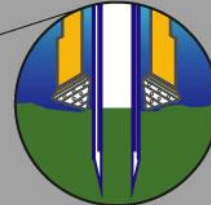
Reentry Cone



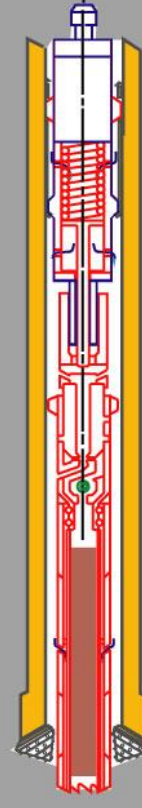
Advanced
Piston
Corer
(APC)



Soft Sediment



Extended
Core
Barrel
(XCB)



Hard Sediment



Rotary
Core
Barrel
(RCB)



Hard Rock



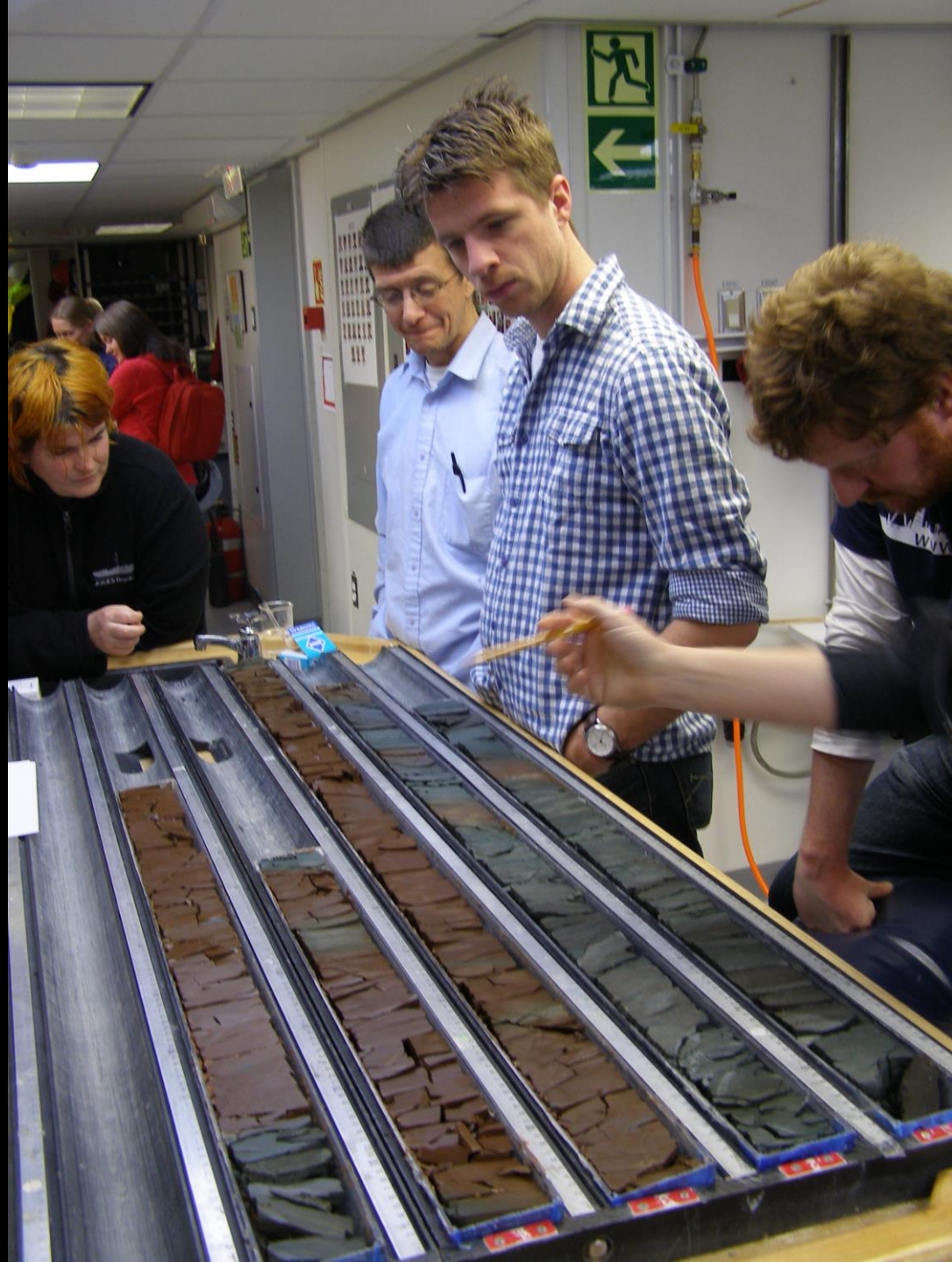
Not to scale



CAUTION
RADIOACTIVE
MATERIAL

CAUTION
RADIOACTIVE
CONTROL OF THE
DOOR

Fisherbrand

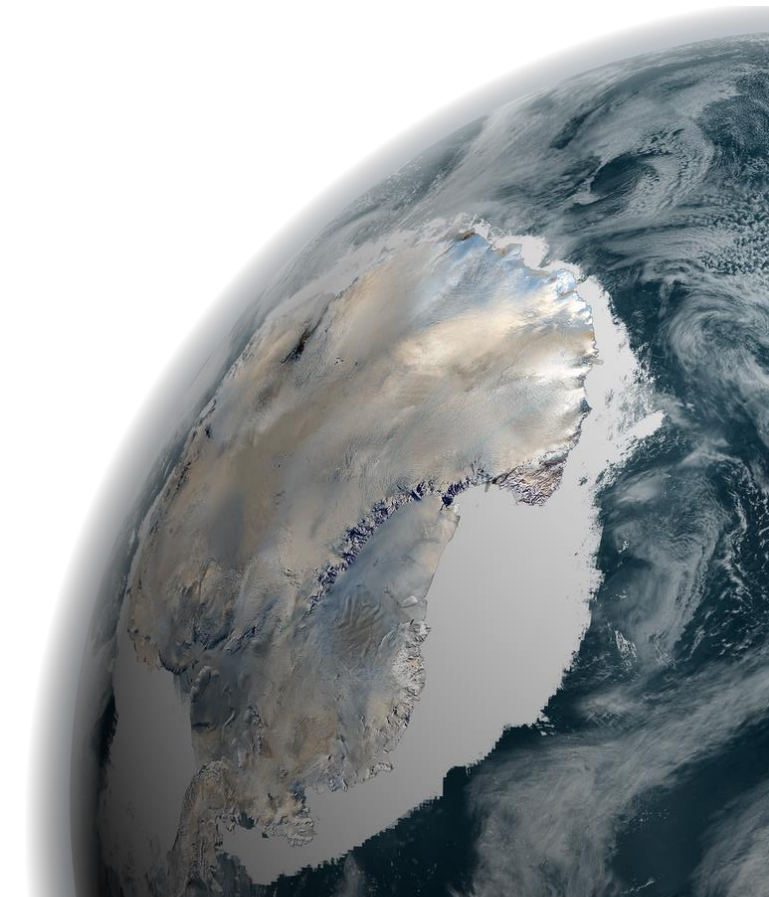




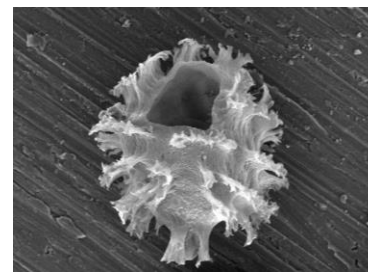
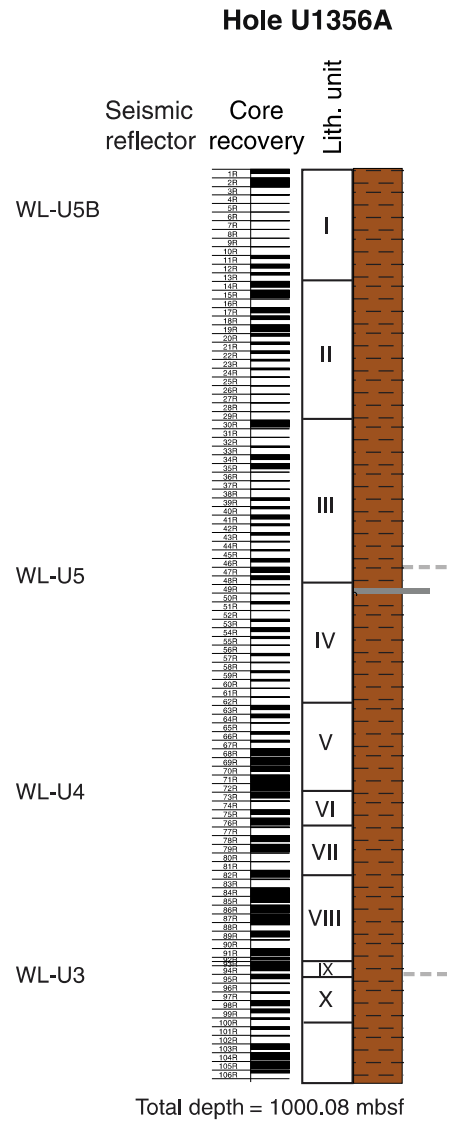
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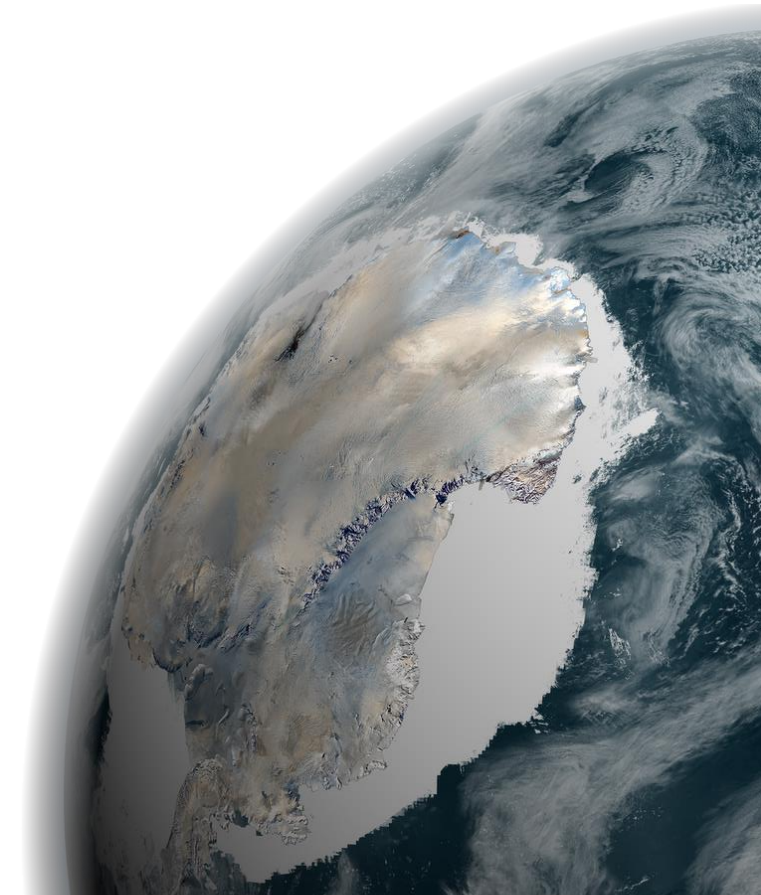
Ages of drill cores offshore Antarctica



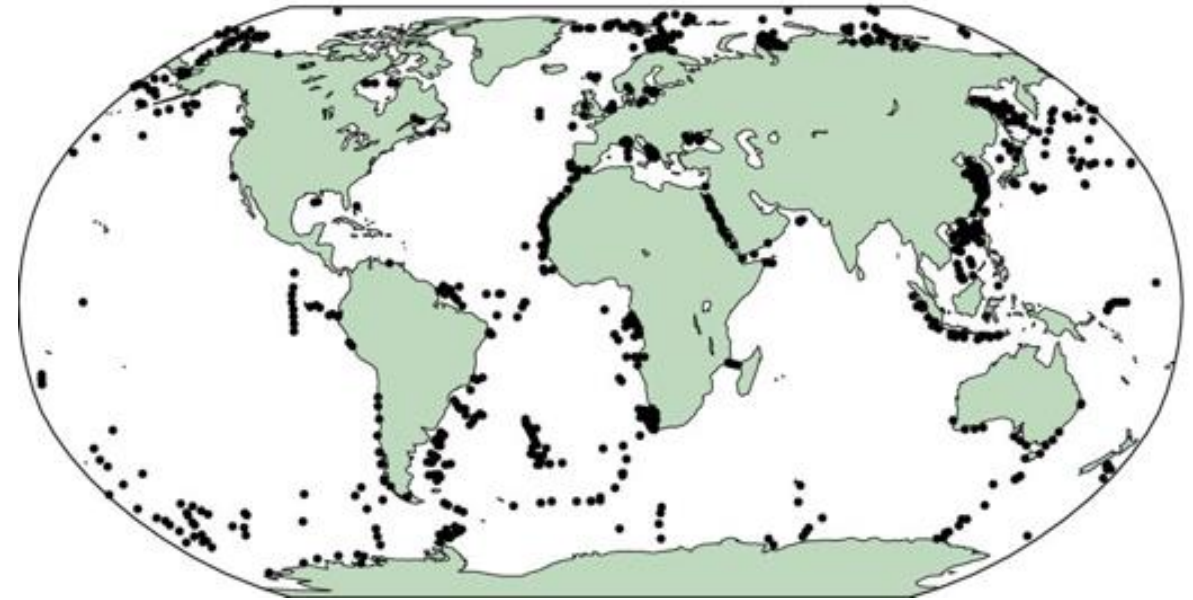
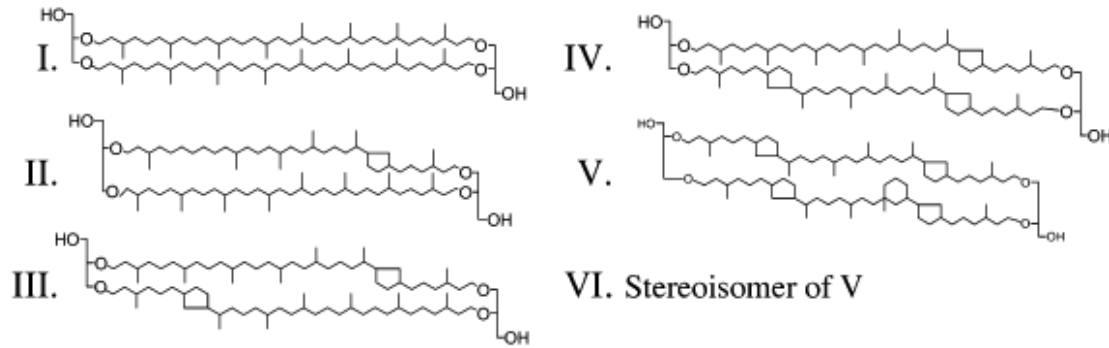
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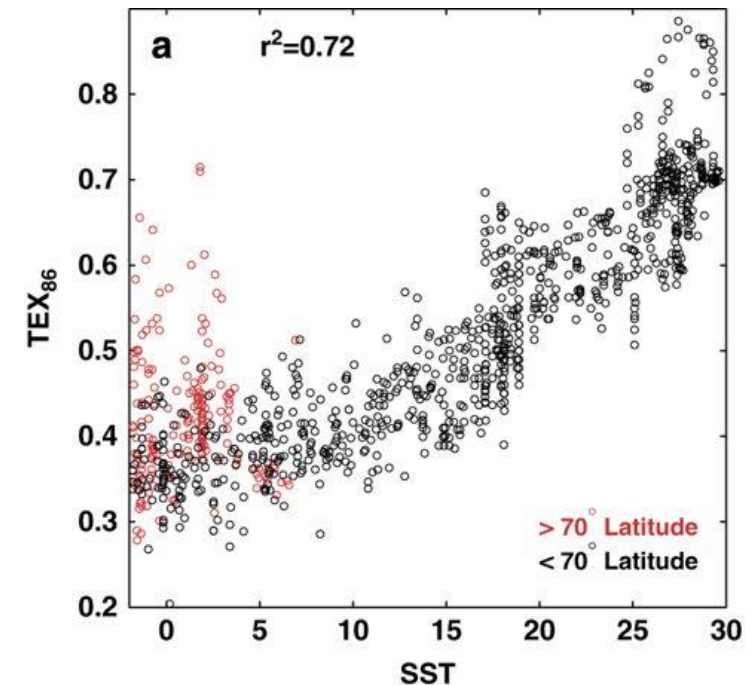
It will be fun!



Tools – quantitative SST



- Biomarker records (TEX_{86} and U^{K}_{37})
- Viscoelastic adaptation of cell membranes to ambient temperatures
- Uses modern core top data to calibrate to mixed layer temperatures (SST)
- Many possible confounding factors, all removed in the data shown



Microplankton as indicator for ocean change

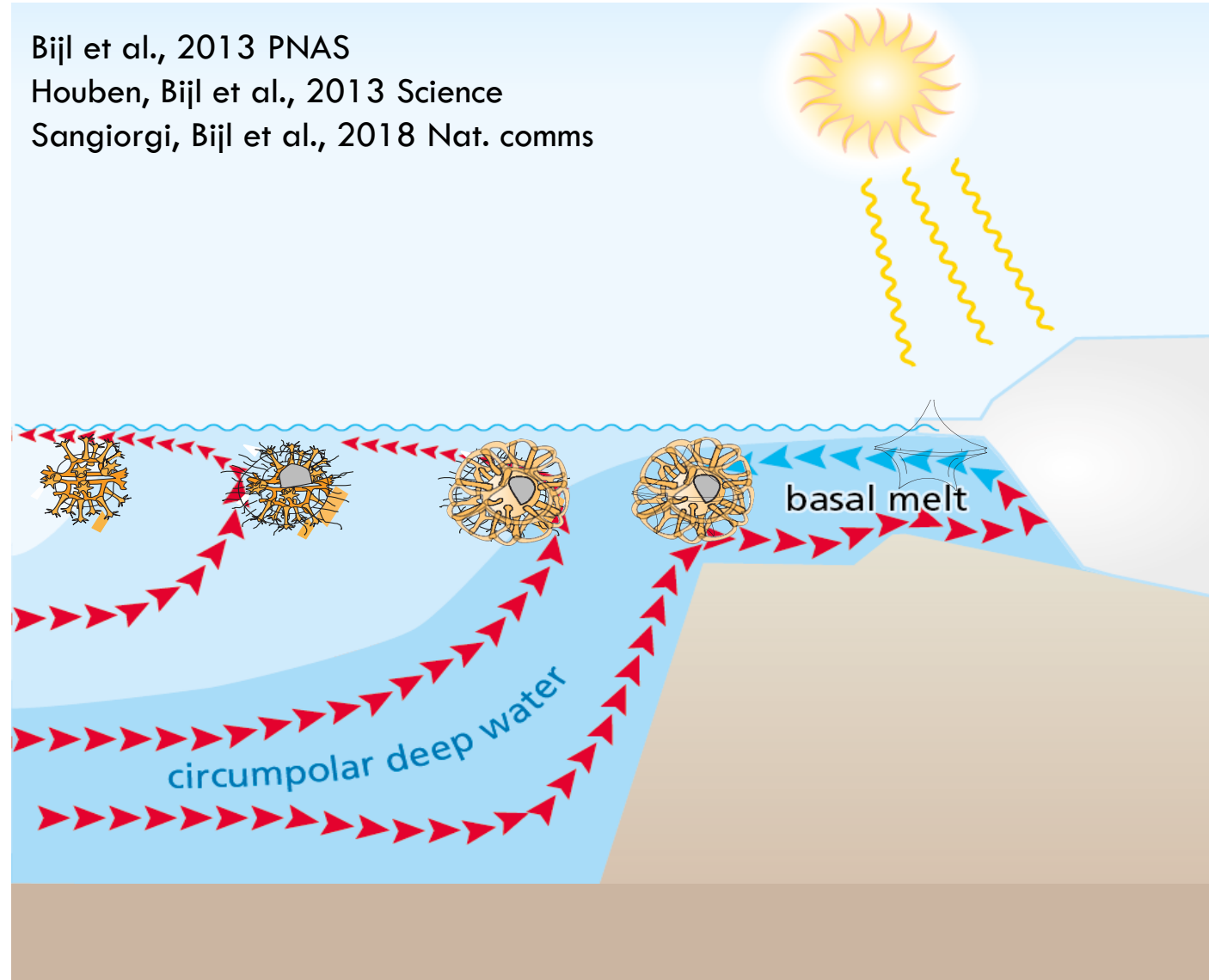
Fingerprints for:

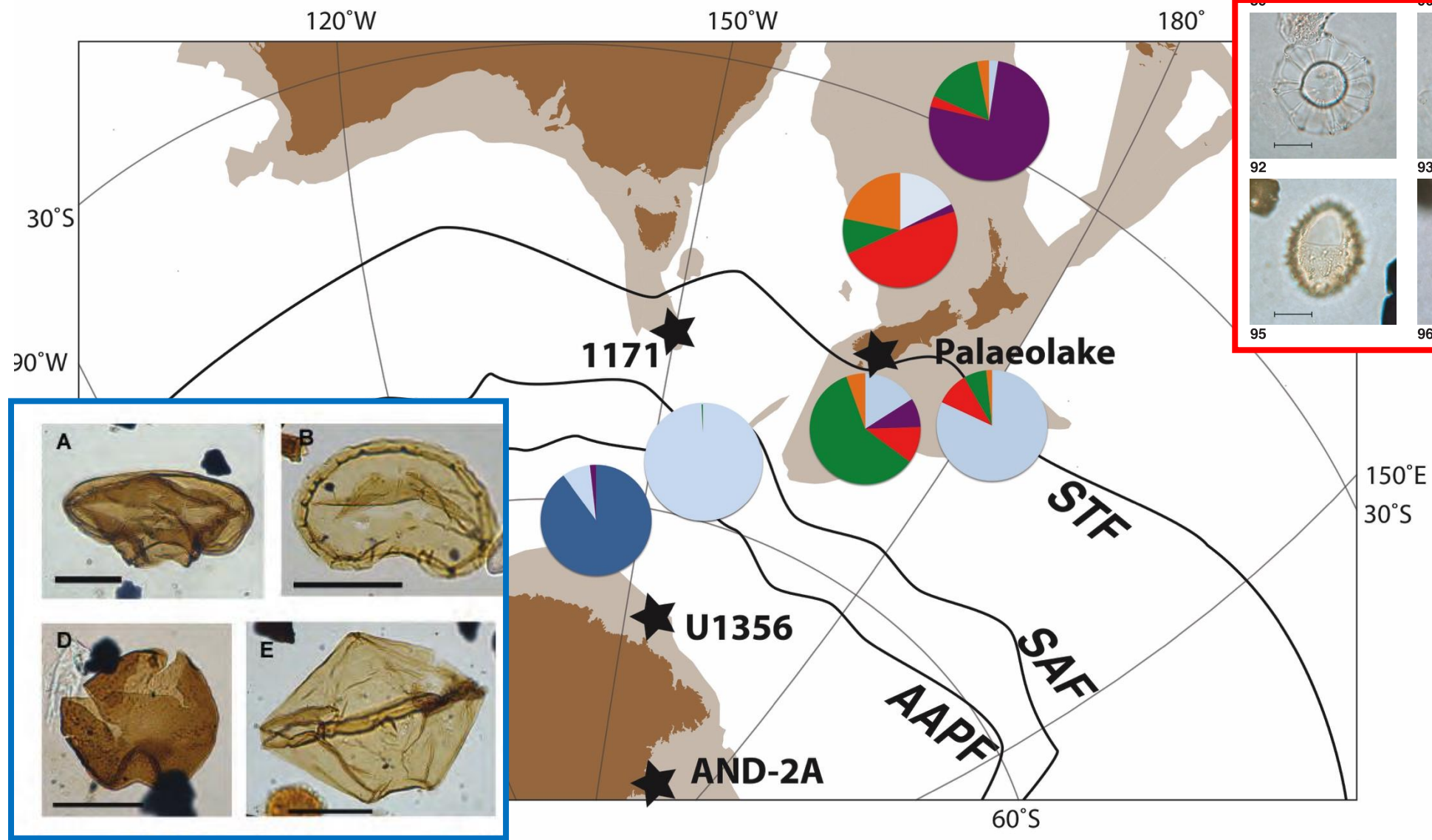
- sea ice cover
- nutrients/upwelling
- ocean temperature

Bijl et al., 2013 PNAS

Houben, Bijl et al., 2013 Science

Sangiorgi, Bijl et al., 2018 Nat. comms





Oceanic fronts

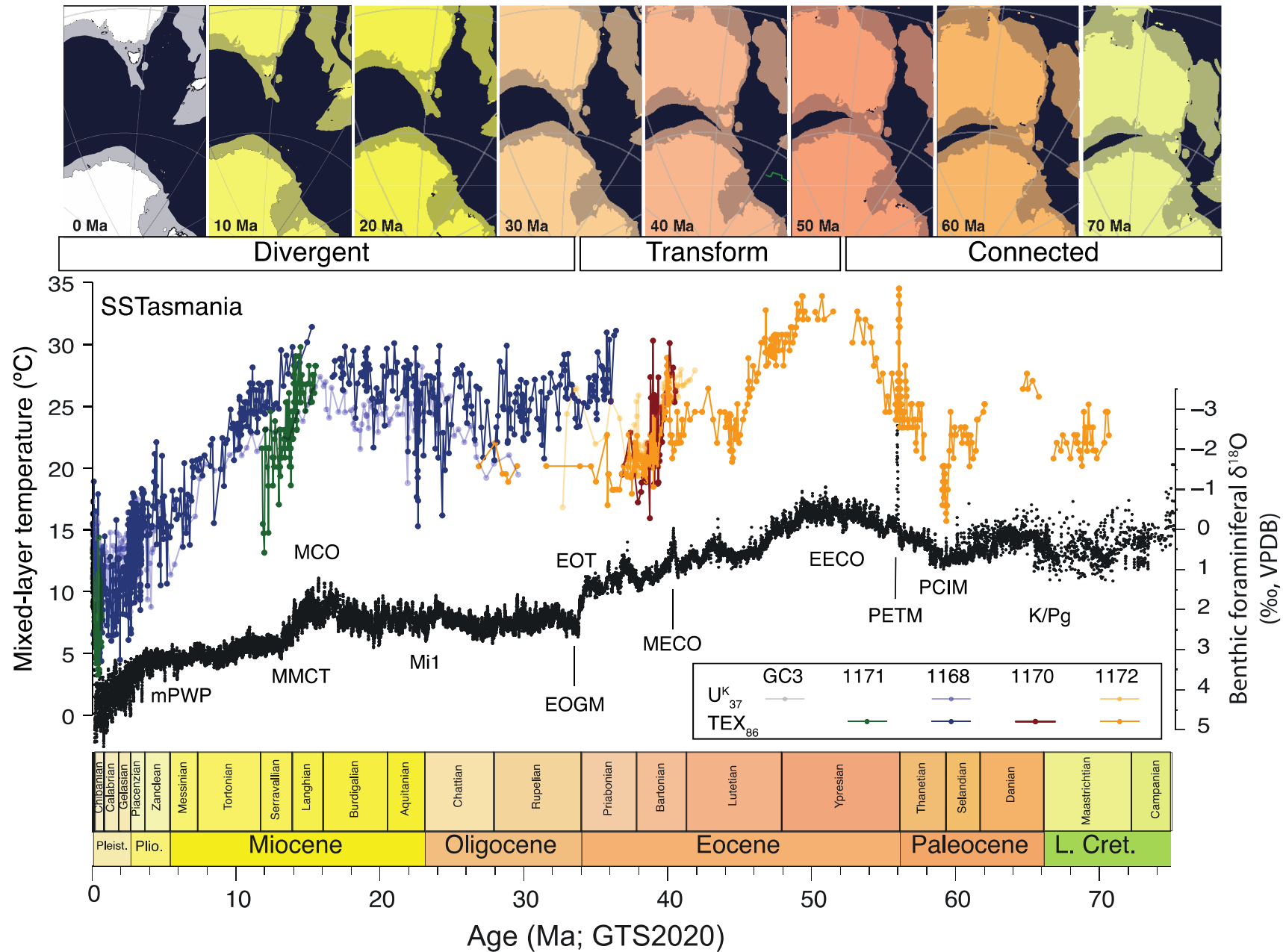
- AAPF Antarctic Polar Front
- SAF SubAntarctic Front
- STF Subtropical Front

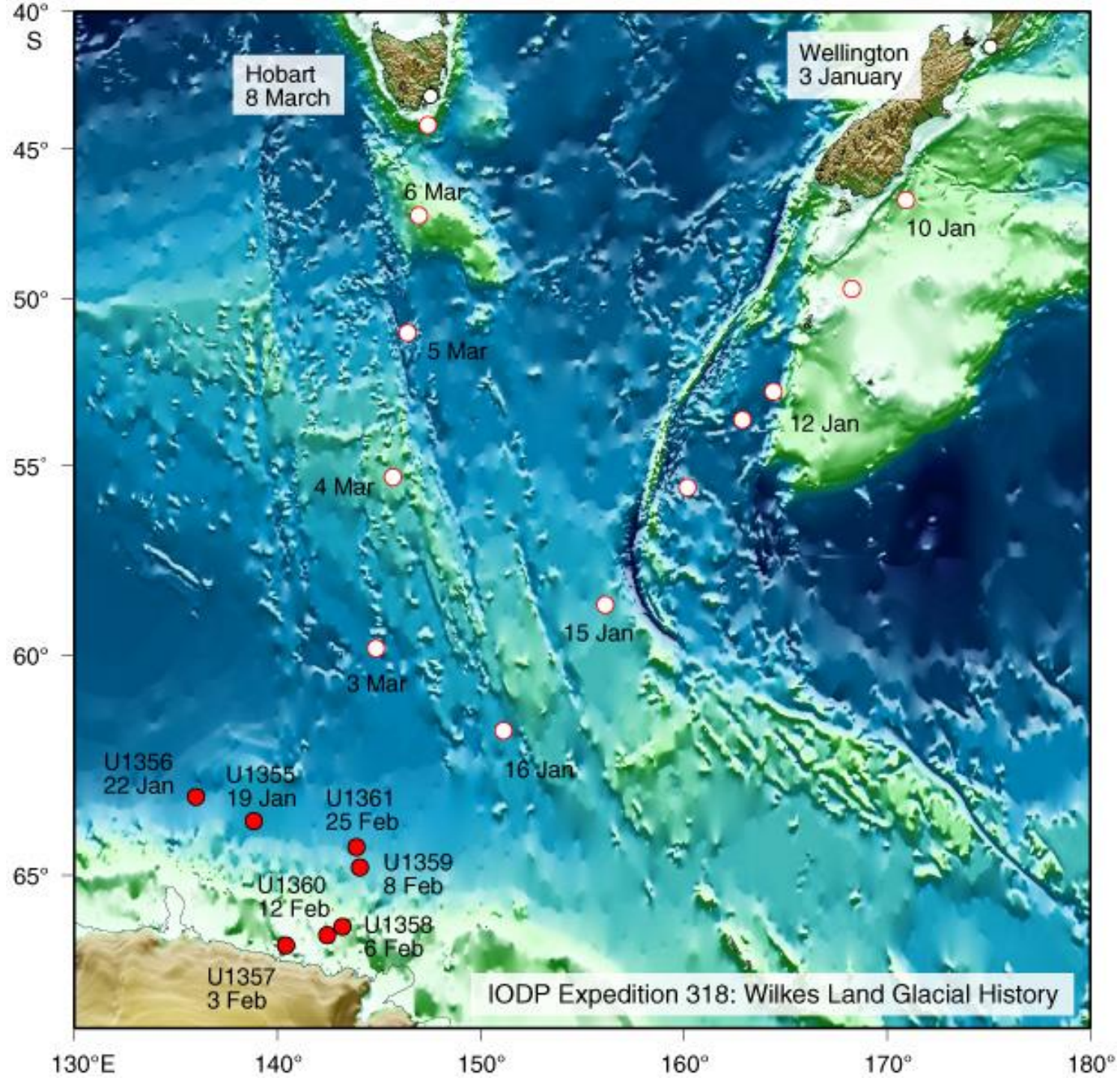
Dinocysts

- Selenopemphix antarctica*
- Other Protoperidinioids
- Impagidinium* spp.

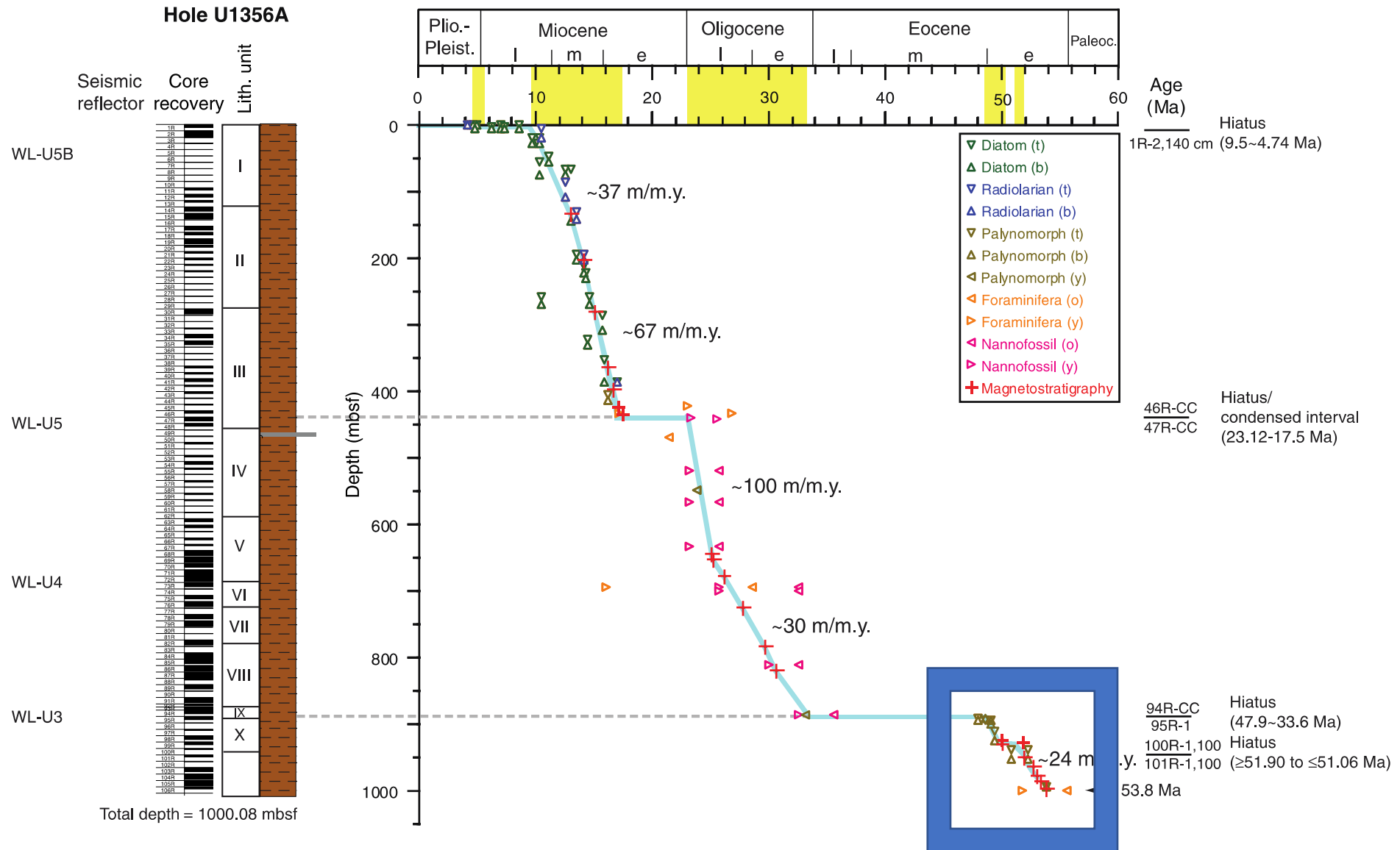
- Nematosphaeropsis labyrinthus*
- Operculodinium* spp.
- Other Gonyaulacoids

Sea surface temperature history of Tasmania



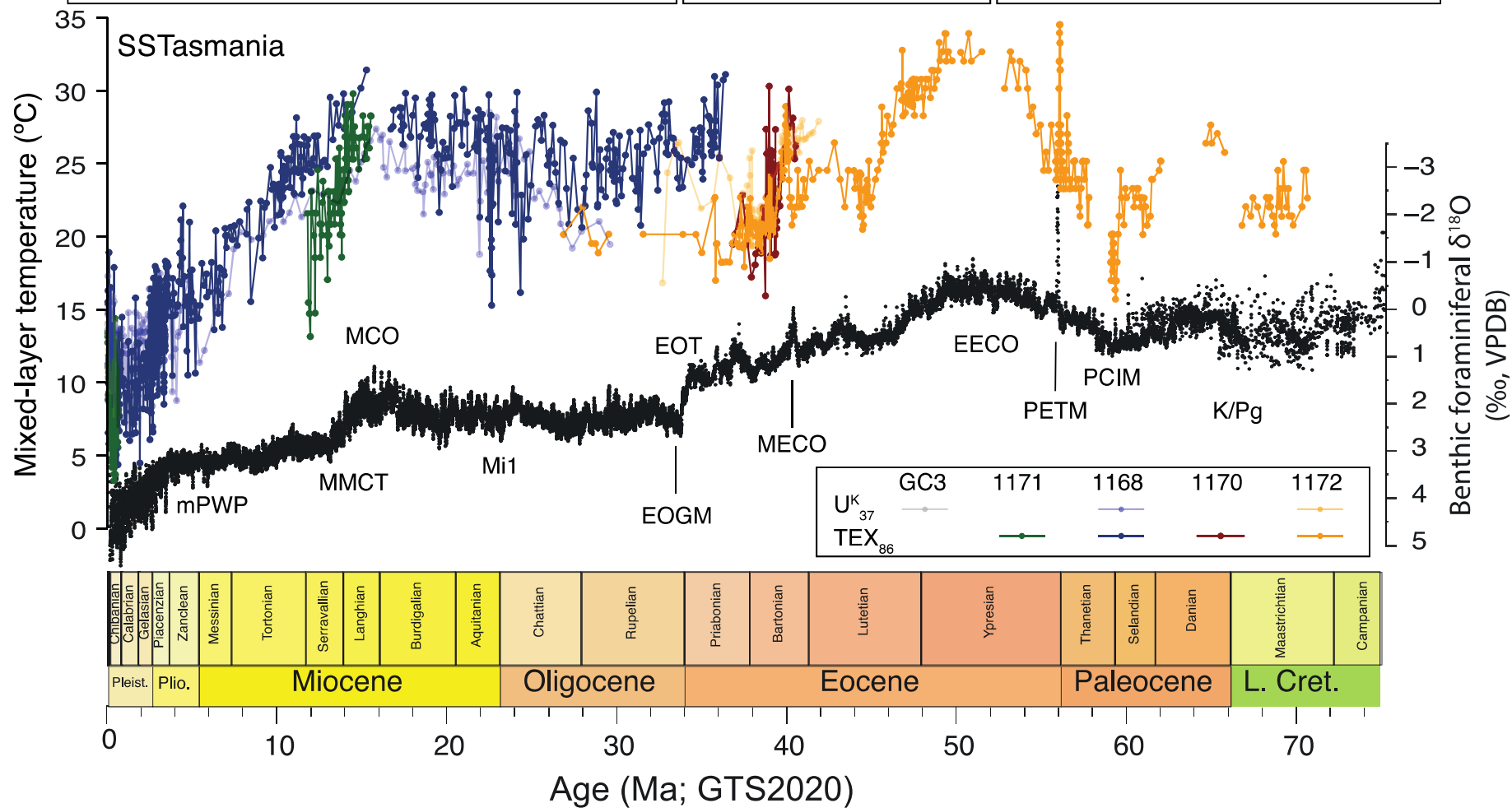
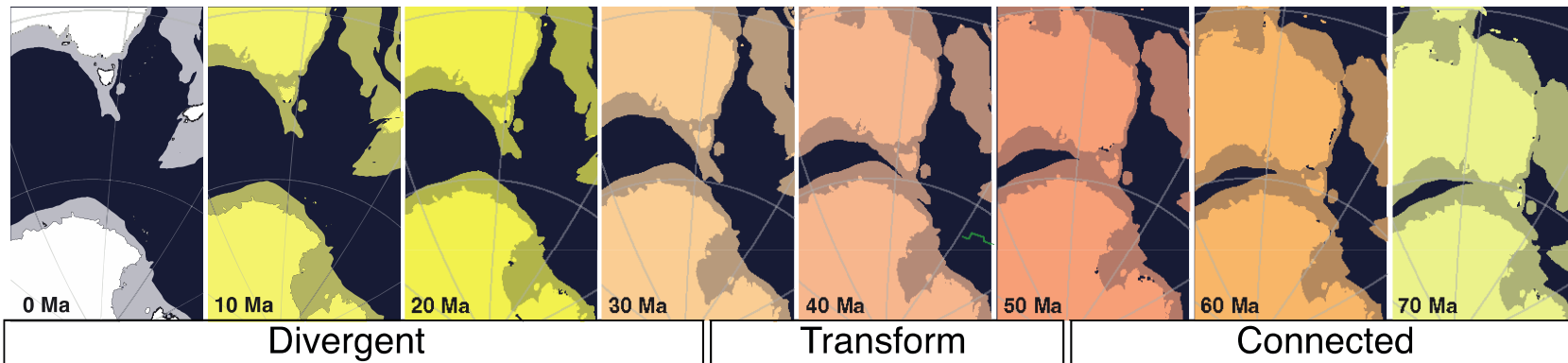


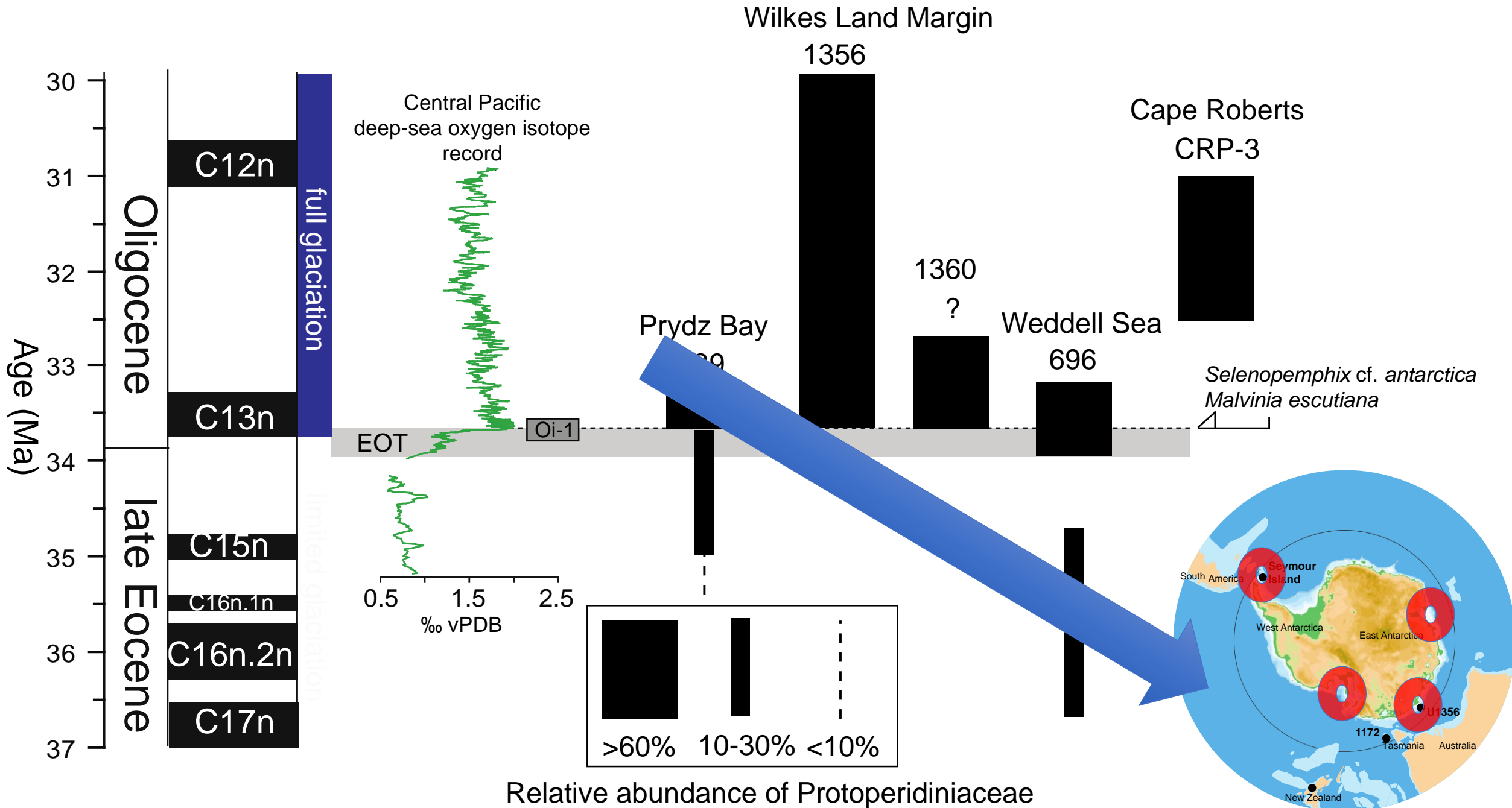
Ages of the drillcores from offshore Antarctica

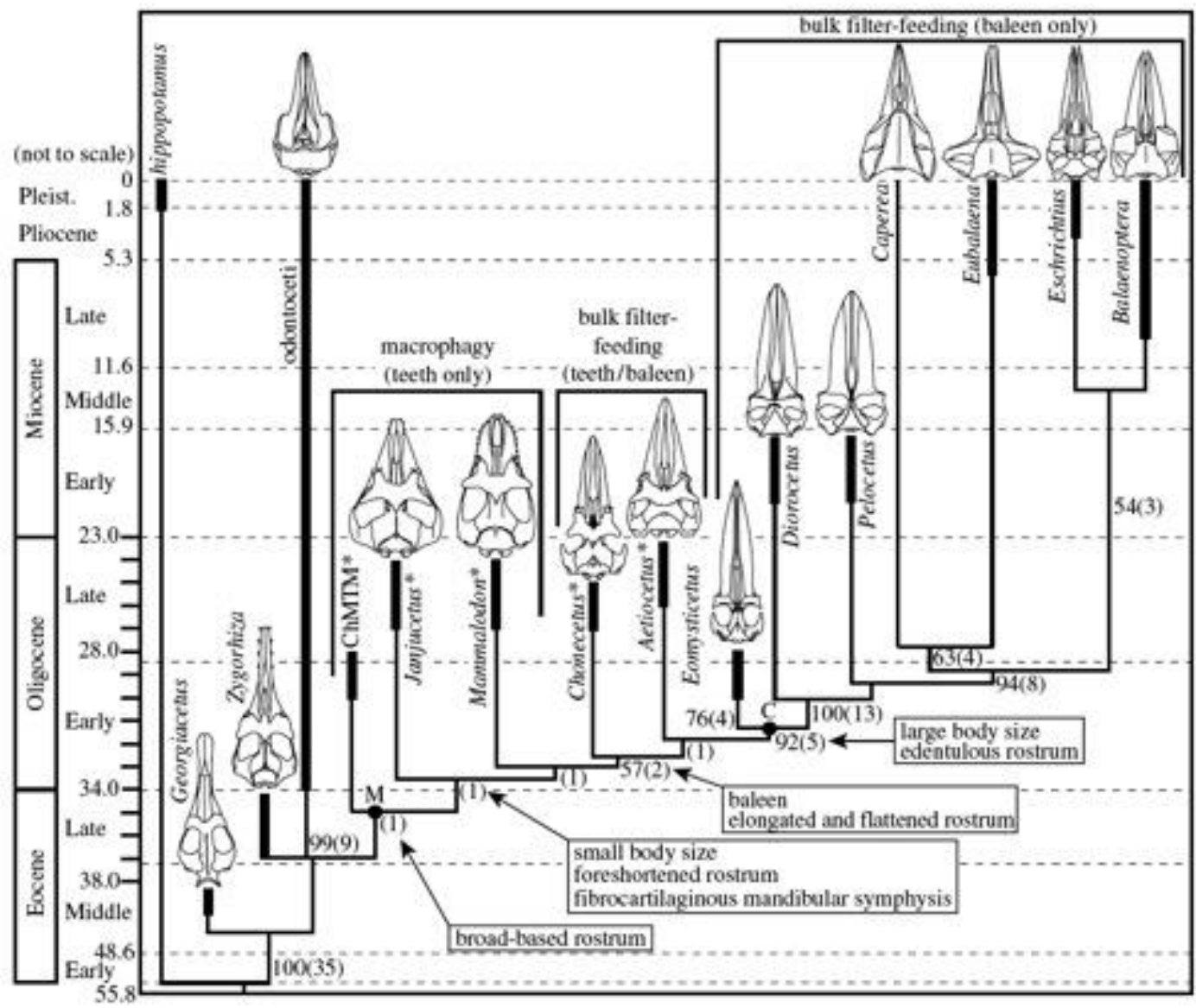


Pollen of the Baobab tree.. from Antarctica







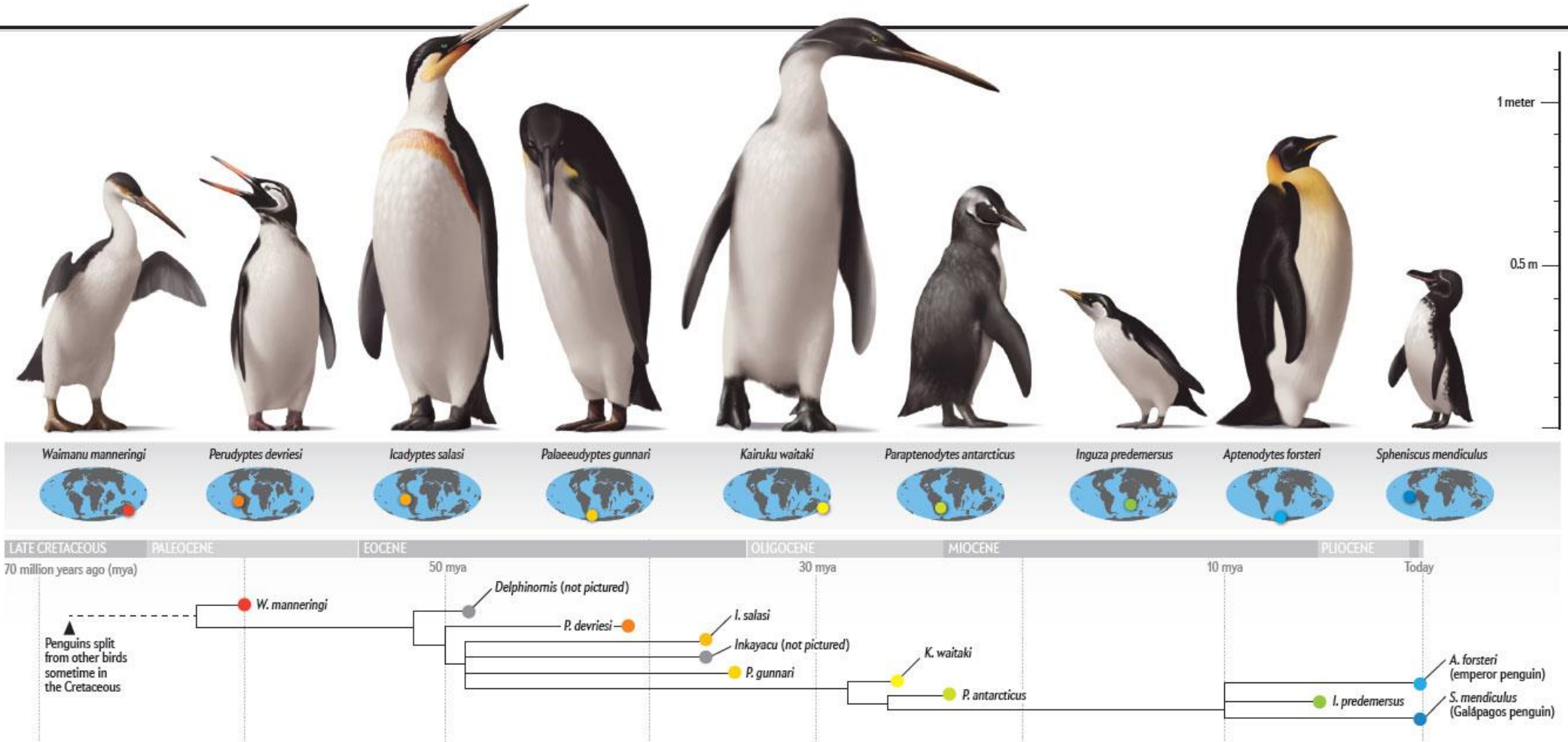


Penguin evolution

FINDINGS

A Panoply of Penguins

Fossil discoveries and analyses of DNA from modern-day penguins suggest that this distinctive group of birds got its start while dinosaurs still roamed the earth. The oldest known fossil penguins hail from what is now New Zealand and date to between 62 million and 58 million years ago. The catastrophic event that extinguished the dinosaurs and other terrestrial and marine predators allowed penguins to thrive in the balmy waters around the submerged mini continent of Zealandia. Then, around 50 million years ago, penguins suddenly started spreading across the Southern Hemisphere, probably thanks to a key evolutionary innovation: a countercurrent heat exchanger called the humeral arterial plexus that helped the birds maintain core body temperature in cool water. As penguins dispersed, they evolved a tremendous diversity of sizes and shapes—much more than modern penguins exhibit. The evolutionary tree at the bottom right shows the relations of a number of penguin species.



Southern Ocean warming and Wilkes Land ice sheet retreat during the mid-Miocene

Francesca Sangiorgi¹, Peter K. Bijl¹, Sandra Passchier², Ulrich Salzmann³, Stefan Schouten^{4,5}, Robert McKay⁶, Rosemary D. Cody⁶, Jörg Pross⁷, Tina van de Flierdt⁸, Steven M. Bohaty⁹, Richard Levy¹⁰, Trevor Williams¹¹, Carlota Escutia¹² & Henk Brinkhuis^{1,4}

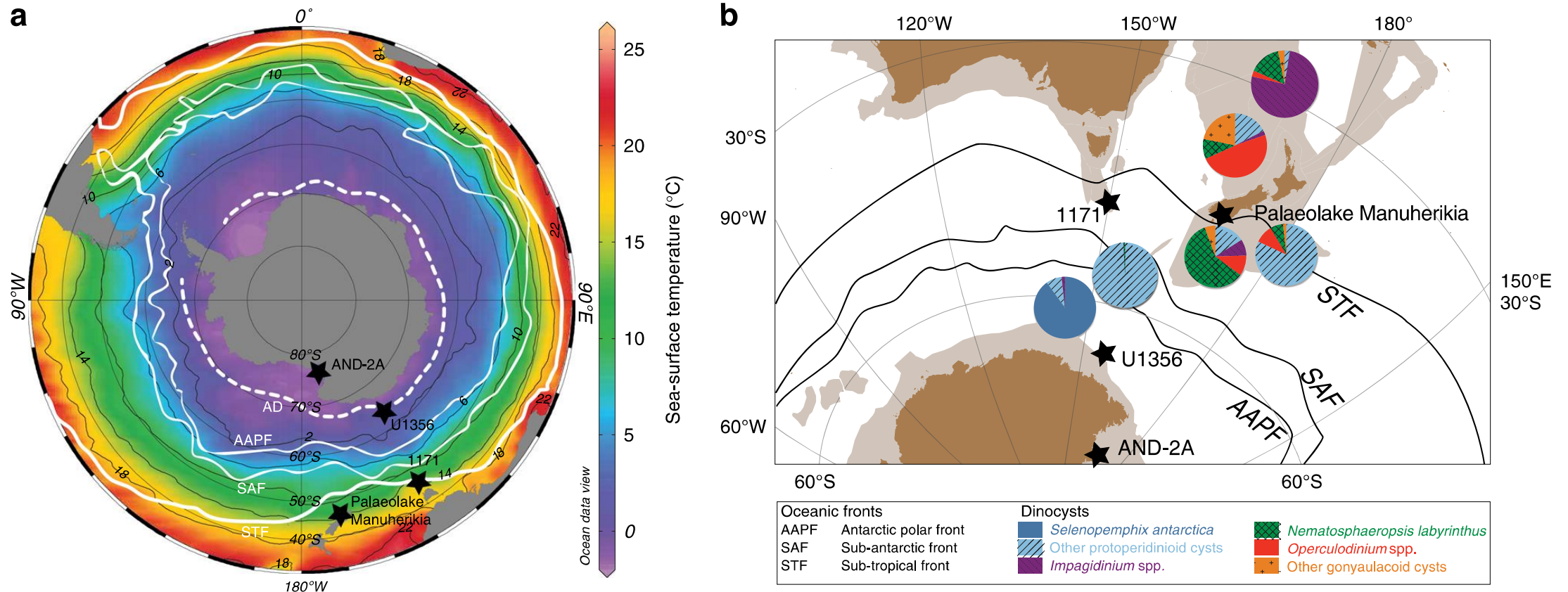
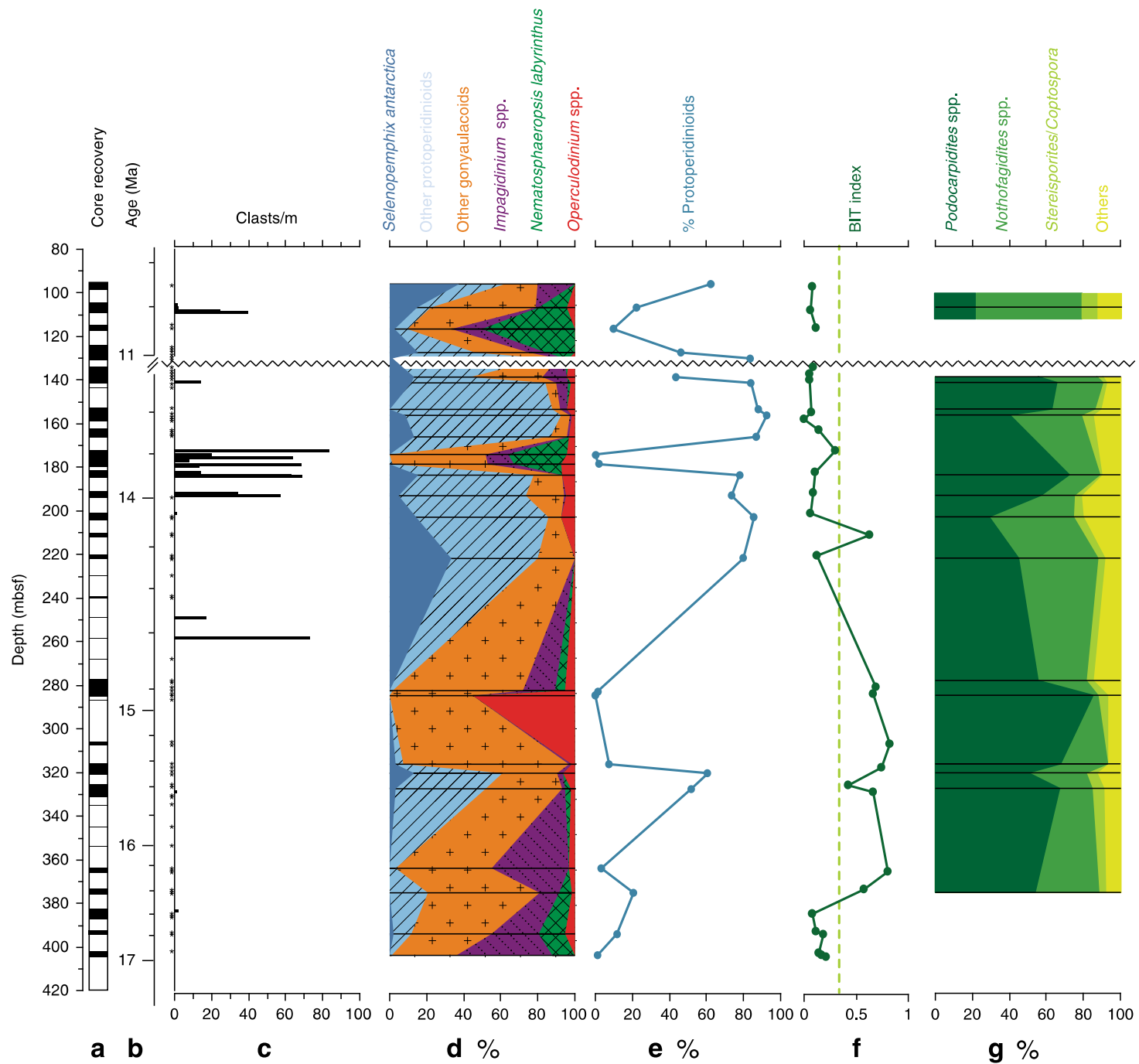
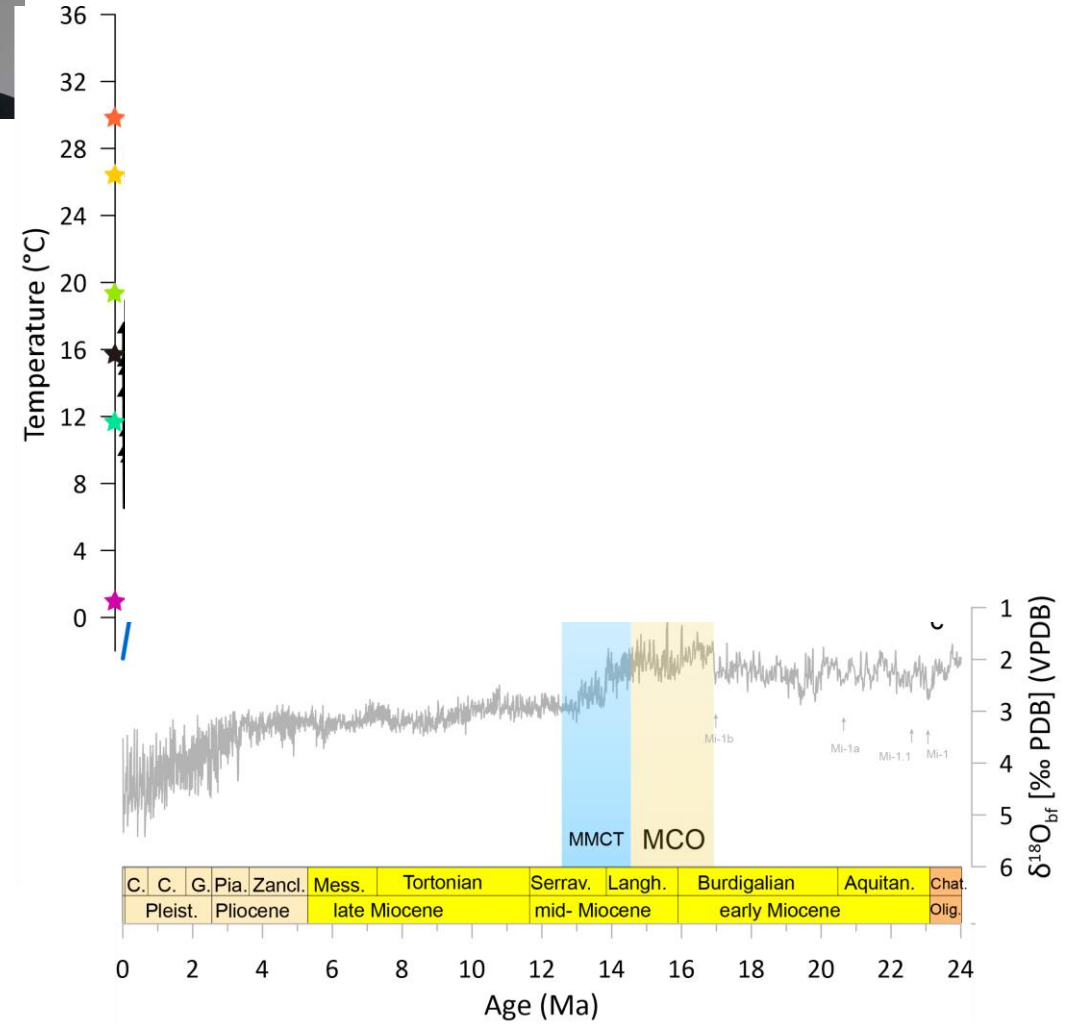
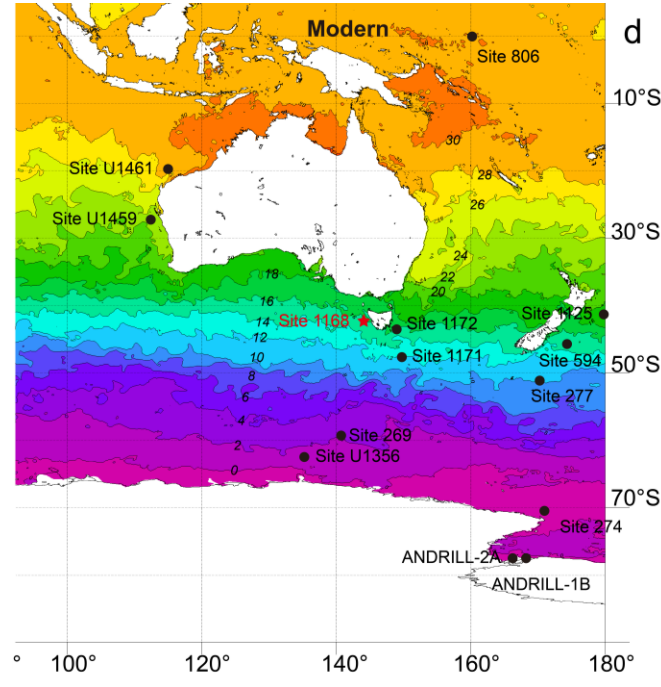


Fig. 1 Mid-Miocene Southern Ocean warming and Wilkes Land ice sheet retreat during the mid-Miocene. **a**, Sea surface temperature (SST) contours of the mid-Miocene Southern Ocean. **b**, SST contours and dinocyst assemblages at the sites AND-2A, U1356, 1171, and Palaeolake Manuherikia. The pie charts show the relative proportions of the different dinocyst species. The oceanic fronts are shown as solid black lines.



Decreasing Neogene SST gradients?



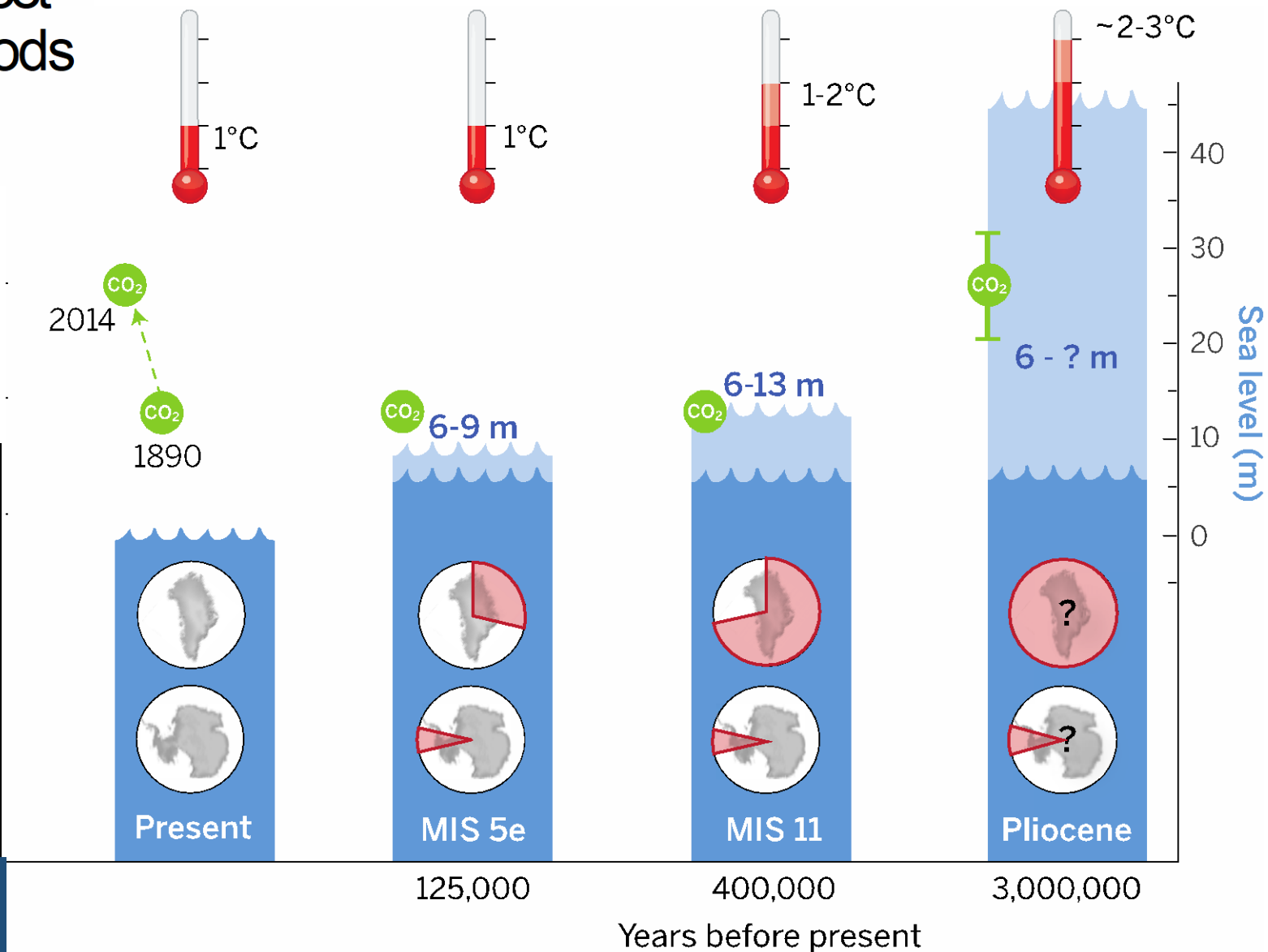
SST gradient in subtropical gyre increases
 SST gradient between STF and AA margin decreases
 due to northward expansion of subpolar conditions?

- Site 806 (Zhang et al., 2014)
- Site 1125 (Herbert et al., 2016)
- U1536 (Sangiorgi et al., 2018)
- δ¹⁸O CENOGRID
- U1461 (He et al., 2021)
- Site 1168 (this study)
- Ross Sea (Duncan et al., 2022)
- ▲ U^K₃₇ SST
- U1459 (De Vleeschouwer et al., 2019)
- Site 1171 (Leutert et al., 2020)
- BWT (Gaskell et al., 2022)
- ★ Modern SST
- Site 594 (Herbert et al., 2016)

SEA-LEVEL RISE

Sea-level rise due to polar ice-sheet mass loss during past warm periods

A. Dutton,* A. E. Carlson, A. J. Long, G. A. Milne, P. U. Clark, R. DeConto, B. P. Horton, S. Rahmstorf, M. E. Raymo



Climate history... with future projections

