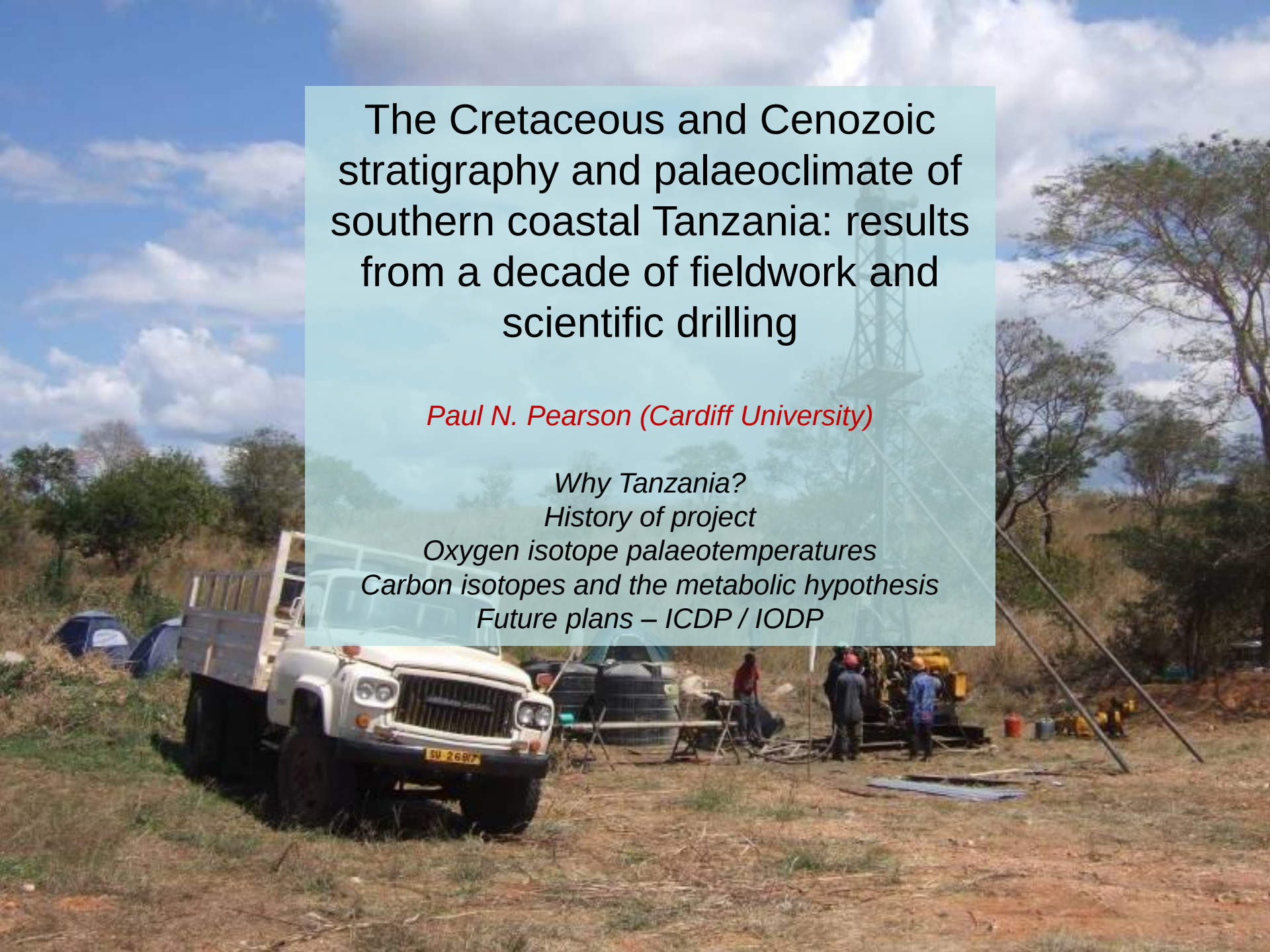


The Cretaceous and Cenozoic stratigraphy and palaeoclimate of southern coastal Tanzania: results from a decade of fieldwork and scientific drilling

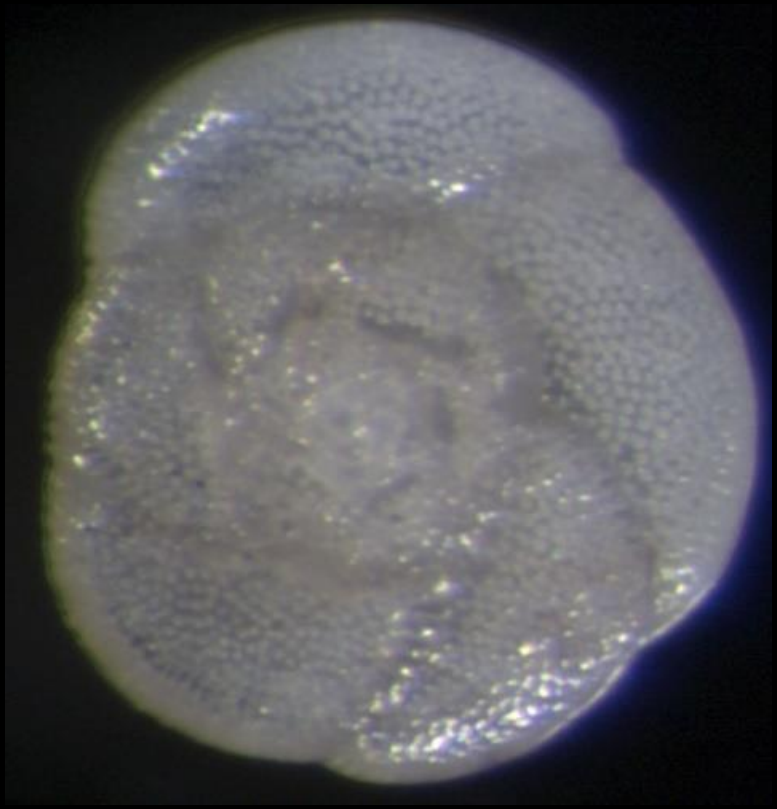
Paul N. Pearson (Cardiff University)

Why Tanzania?
History of project
Oxygen isotope palaeotemperatures
Carbon isotopes and the metabolic hypothesis
Future plans – ICDP / IODP

Onshore Kilwa Group: unique greenhouse tropical climate archive *(mainly Cretaceous and Paleogene)*

Bathyal marine ~ 350-1500 m water. Now emplaced on land

Superb microfossil preservation



Turborotalia cerroazulensis

Fontbotia mkazamboensis

Tanzania Foraminifera

Nannofossils - rock surface SEM

Palaeoclimate proxies

Oxygen isotope palaeotemperatures

Boron isotope palaeo pH / pCO_2

Bacterial lipid biomarkers:
Ocean temperature
Soil temperature

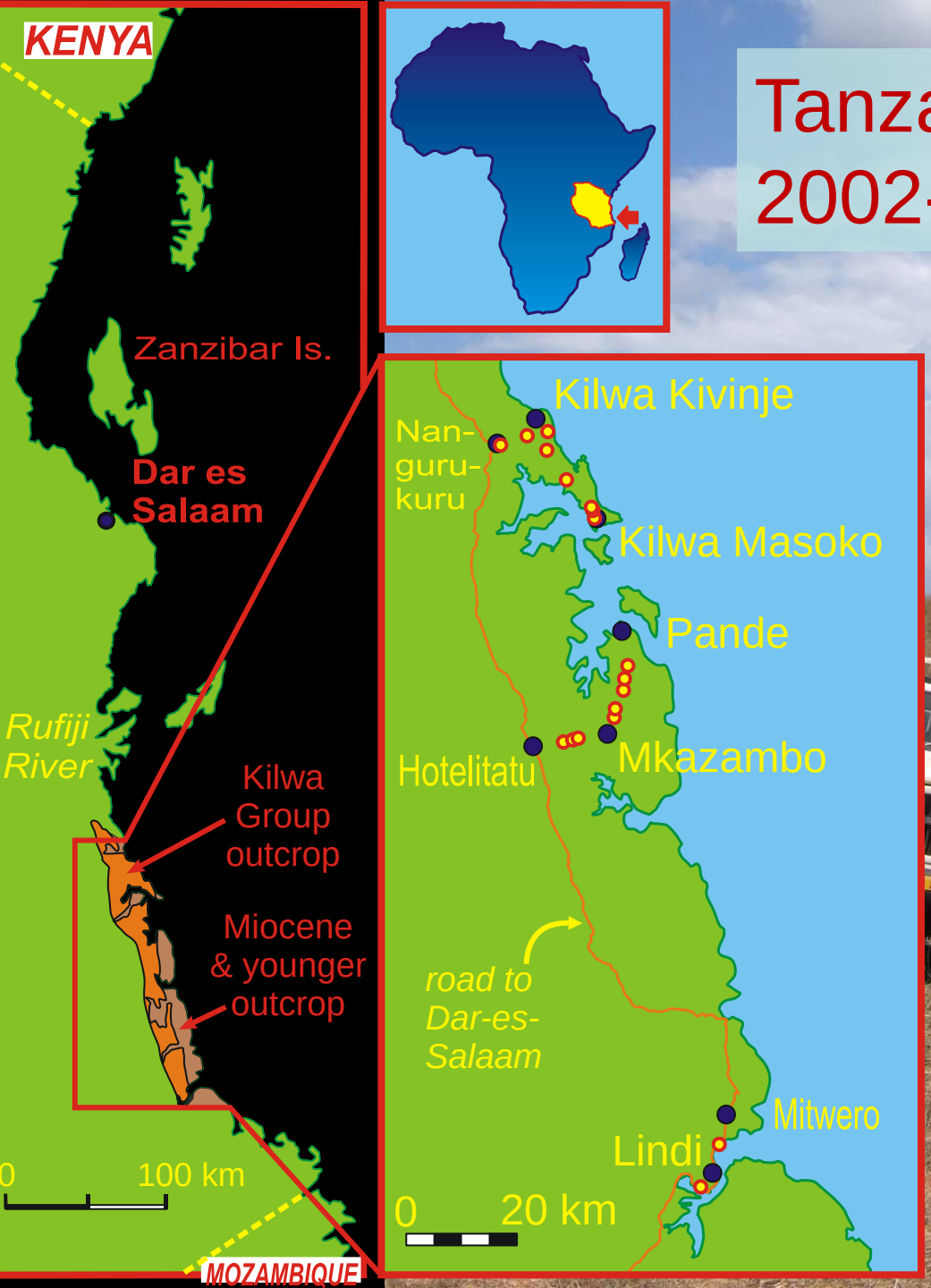
N-alkane biomarkers:
Vegetation chemistry
D/H – evaporation/ precipitation


Hemipelagic clays ~ 3000 m thick
but poorly exposed


Accessory beds: limestones

Cretaceous turbidites with agrichnia Spiroraphe

Tanzania Drilling Project: 2002-2009



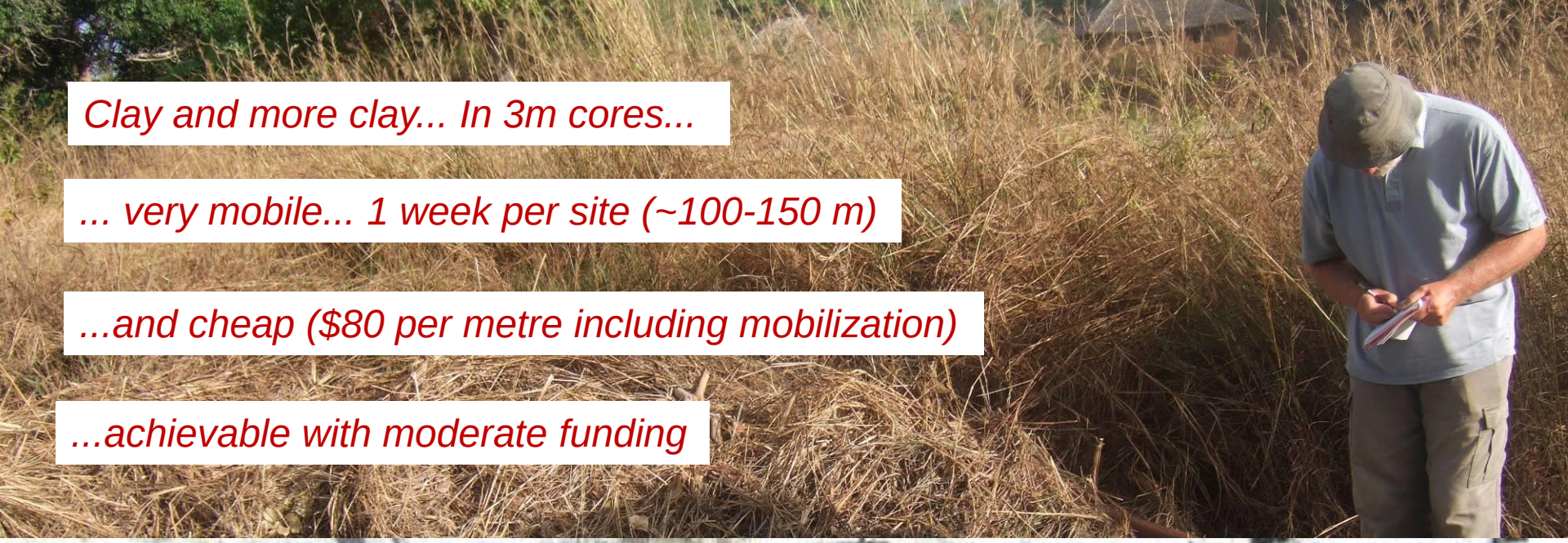
40 sites. Remote locations...

Tanzania Drilling Project

Ya Kale Hadi Yajayo

Narrow diameter cores

On site biostratigraphy



Clay and more clay... In 3m cores...

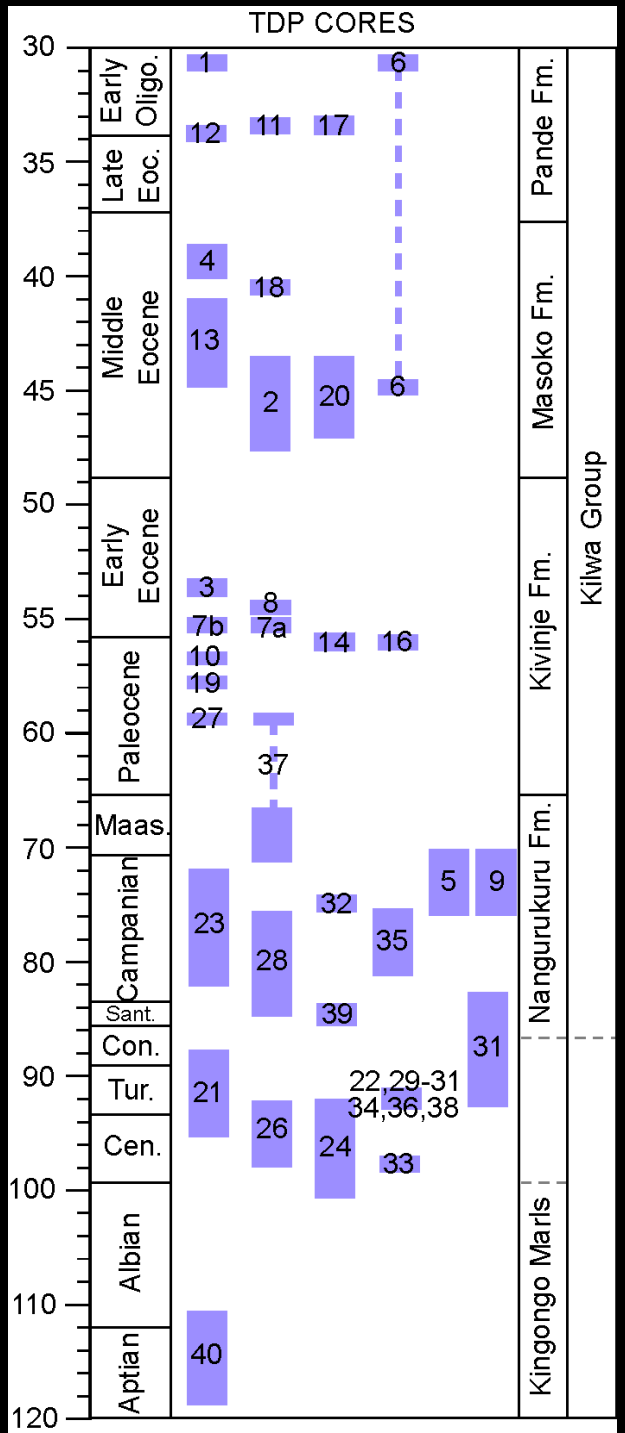
... very mobile... 1 week per site (~100-150 m)

...and cheap ($80 per metre including mobilization)

...achievable with moderate funding

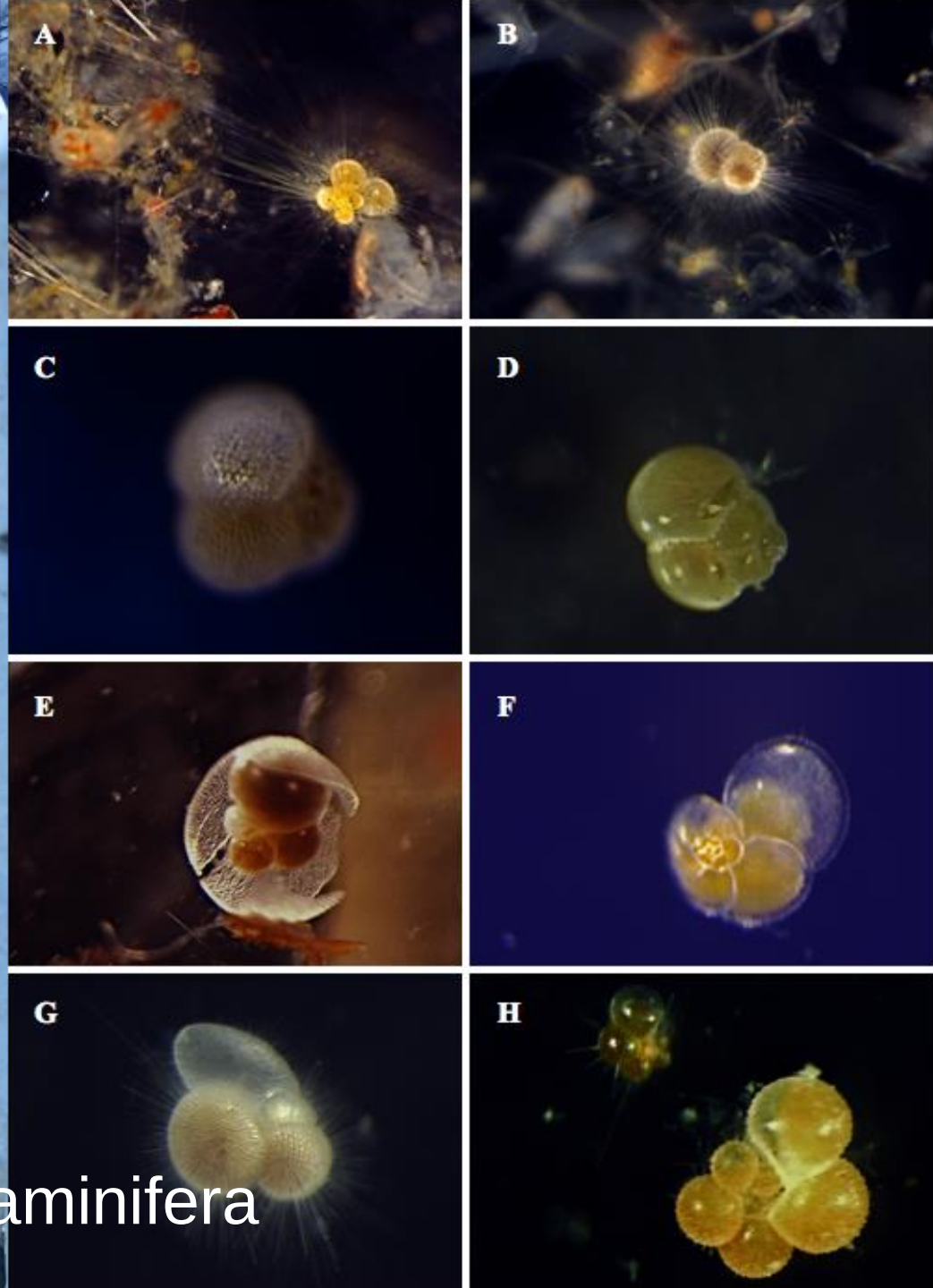
Summary stratigraphy:

- exceptionally well-preserved carbonate and organic carbon throughout
- Key intervals: Paleocene / Eocene, Eocene / Oligocene, Cenomanian / Turonian



38 peer-reviewed papers, and counting

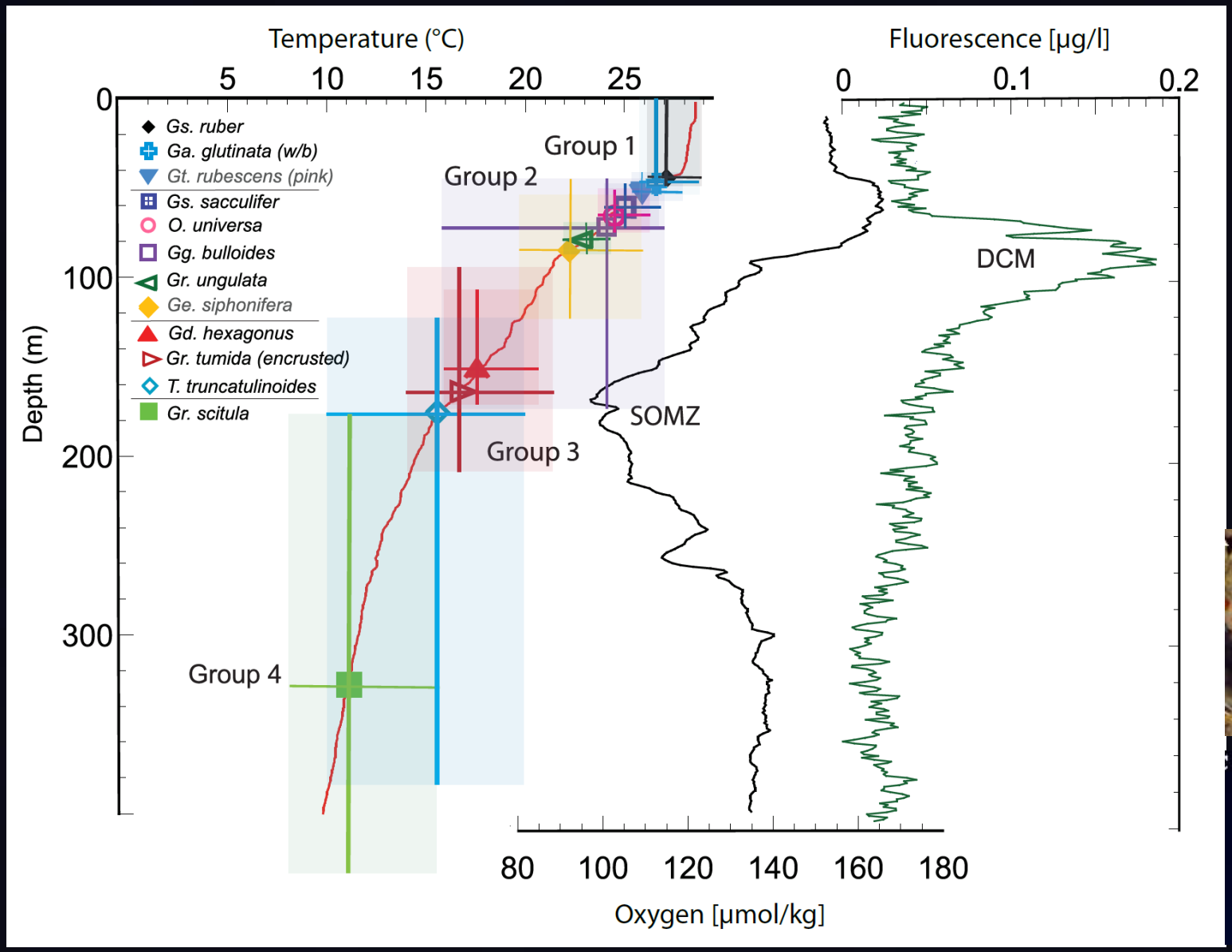
- 1-Pearson P. N., Nicholas C. J., Singano J. M., Bown P. R., Coxall H. K., van Dongen B. E., Huber B.T., Karega A., Lees J. A., Msaky, E., Pancost, R.D., Pearson, M., and Roberts, A. P. 2004. Paleogene and Cretaceous sediment cores from the Kilwa and Lindi areas of coastal Tanzania: Tanzania Drilling Project Sites 1-5, *Journal of African Earth Sciences* **39**, 25-62
- 2-Pearson, P.N., Nicholas, C.J., Singano, J.M., Bown, P.R., Coxall, H.K., van Dongen, B.E., Huber, B.T., Karega, A., Lees, J.A., MacLeoad, K., McMillan, I.K., Pancost, R.D., Pearson, M. and Msaky, E. 2006. Further Paleogene and Cretaceous sediment cores from the Kilwa area of coastal Tanzania: Tanzania Drilling Project Sites 6-10. *Journal of African Earth Sciences*, **45**: 279-317.
- 3-Nicholas, C.J., Pearson, P.N., McMillan, I.K., Ditchfield, P.W., and Singano, J.M. 2007. Structural evolution of southern coastal Tanzania since the Jurassic. *Journal of African Earth Sciences* **48**, 273-297
- 4-Nicholas, C.J., Pearson, P.N., Bown, P.R., Jones, T.D., Huber, B.T., Karega, A., Lees, J.A., McMillan, I.K., O'Halloran, A., Singano, J.M. and Wade, B.S. 2006. Stratigraphy and sedimentology of the Upper Cretaceous to Paleogene Kilwa Group, southern coastal Tanzania. *Journal of African Earth Sciences*, **45**: 431-466.
- 5-Van Dongen, B.E., Talbot, H.M., Schouten, S., Pearson, P.N., and Pancost, R.D., 2006. Well preserved Cretaceous and Paleogene biomarkers from the Kilwa area, Tanzania. *Organic Geochemistry*, **37**: 539-557.
- 6- Jime … 10. Lithost … . Journal of African …
- 7-Pear … sea surface temperatures in the Late Cretaceous and Eocene epochs. *Nature* **413**:481-487.
- 8-Pearson, P.N., Ditchfield, P.W. and Shackleton, N.J. 2002. Tropical temperatures in greenhouse episodes (reply). *Nature* **419**:898.
- 9-Pearson, P.N., van Dongen, B.E., Nicholas, C.J., Pancost, R.D., Schouten, S., Singano, J.M. and Wade, B.S. 2007. Stable warm tropical climate through the Eocene epoch. *Geology* **35**, 211-214.
- 10-Pearson, P.N. and Wade, B.S. 2007. Reply: Stable warm tropical climate through the Eocene epoch. *Geology.* Published Online: November 2007, DOI: 10.1130/G24462Y.1
- 11-Sexton, P.F., Wilson, P.A. and Pearson. P.N. 2006. Microstructural and geochemical perspectives on foraminiferal preservation: "Glassy" versus "Frosty". *Geochemistry, Geophysics, Geosystems*, **7**: Q12P19, doi:10.1029/2006GC001291, 2006
- 12-Stewart D. R. M., Pearson P. N., Ditchfield P. W., Singano J. M. 2004. Miocene tropical Indian Ocean temperatures: evidence from three exceptionally preserved foraminiferal assemblages from Tanzania, *Journal of African Earth Sciences* **40**, 173-190.
- 13-Pearson, P.N., Foster, G.L. and Wade, B.S. 2009. Atmospheric carbon dioxide through the Eocene - Oligocene climate transition. *Nature* **461**: 1110-1113. doi:10.1038/nature 08447
- 14-Bown, P.R. and Pearson, P., 2009. Calcareous plankton evolution and the Paleocene/Eocene thermal maximum event: new evidence from Tanzania. *Marine Micropaleontology*, **71**, 60-70.
- 15-Handley, L., Pearson, P.N., McMillan, I.K., and Pancost, R.D., 2008. Large terrestrial and marine carbon and hydrogen isotope excursions in a new Paleocene / Eocene boundary section from Tanzania. *Earth and Planetary Science Letters* **275**, 17-25.
- 16-Lear, C.H., Bailey, T.R., Pearson, P.N., Coxall, H.K., and Rosenthal, Y., 2008. Cooling and ice growth across the Eocene – Oligocene transition. *Geology* **36**, 251-254. doi: 10.1130/G24584A.1
- 17-Pearson, P.N., McMillan, I., Wade, B.S., Dunkley Jones, T., Coxall, H.K., Bown, P.R. and Lear, C.H., 2008. Extinction and environmental change across the Eocene - Oligocene boundary in Tanzania. *Geology* **36**, 179-182. doi: 10.1130/G24308A.1
- 18-Bown, P.R., 2005. Paleogene calcareous nannofossils from the Kilwa and Lindi areas of coastal Tanzania (Tanzania Drilling Project 2003-2004). *Journal of Nannoplankton Research* **27**, 21-95.
- 19-Bown, P.R. and Dunkley Jones, T., 2006. New Paleogene calcareous nannofossil taxa from coastal Tanzania. Tanzania Drilling Project Sites 11 to 14. *Journal of Nannoplankton Research* **28**, 17-34.
- 20-Bown, P.R., Dunkley Jones, T., Lees, J.A., Randell, R., Mizzi, J., Pearson, P.N., Coxall, H.K., Nicholas, C.J., Karega, A., Singano, J and Wade, B.S. 2008. A Paleogene calcareous microfossil Konservat-Lagerstatte from the Kilwa Group of coastal Tanzania. *GSA Bulletin* **120**, 3-12, doi:10.1130/B26261.1
- 21-Bown, P.R., Dunkley Jones, T., Young, J.R. and Randell, R., 2009. A Paleogene record of extant lower photic zone calcareous nannoplankton. *Palaeontology*, **52**, 457-469.
- 22-Dunkley Jones, T., Bown, P.R., Pearson, P.N., Wade, B.S., Coxall, H.K. and Lear, C.H. 2008. Major shifts in calcareous plankton assemblages through the Eocene – Oligocene transition in Tanzania and their implications for low-latitude primary production. *Paleoceanography*, **23**, PA4202, doi:1029/2008PA001620.
- 23-Dunkley Jones, T. and Bown, P.R. 2007. Post-sampling dissolution and the consistency of nannofossil diversity measures: a case study from freshly cored sediments from Tanzania. *Marine Micropaleontology* **62**, 254-268
- 24-Dunkley Jones, T., Bown, P.R., and Pearson, P.N., in press. Exceptionally well-preserved upper Eocene to lower Oligocene calcareous nannofossils (Prymnesiophycidae) from the Pande Formation (Kilwa Group), Tanzania. *Systematic Paleontology*.
- 25-Lees, J.A., 2007. New and rarely reported calcareous nannofossils from the Late Cretaceous of coastal Tanzania: outcrop samples and Tanzania Drilling Project Sites 5, 9 and 15. *Journal of Nannoplankton Research* **29**, 39-65.
- 26--Wade, B.S. and Pearson, P.N. 2008. Planktonic foraminiferal turnover, diversity fluctuations and geochemical signals across the Eocene/Oligocene boundary in Tanzania. *Marine Micropaleontology*, **68**, 244-255.
- 27-Cotton, L.J. and Pearson, P.N., 2011. Extinction of larger benthic foraminifera at the Eocene/Oligocene boundary. *Palaeogeography, Palaeoclimatology, Palaeoecology*, doi:10.1016/j.palaeo.2011.09.008

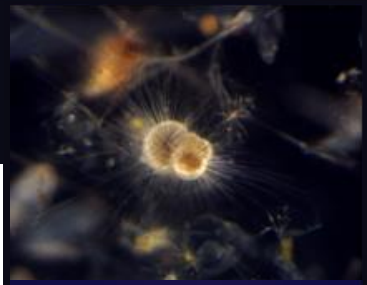


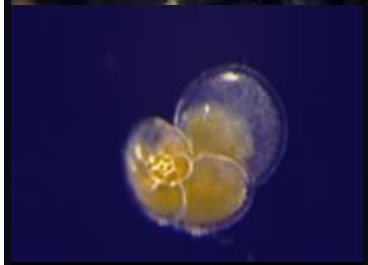
Foraminifera

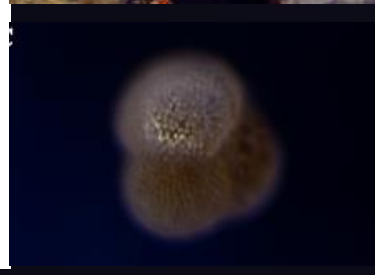
Planktonic depth habitats

(Birch et al., 2013)



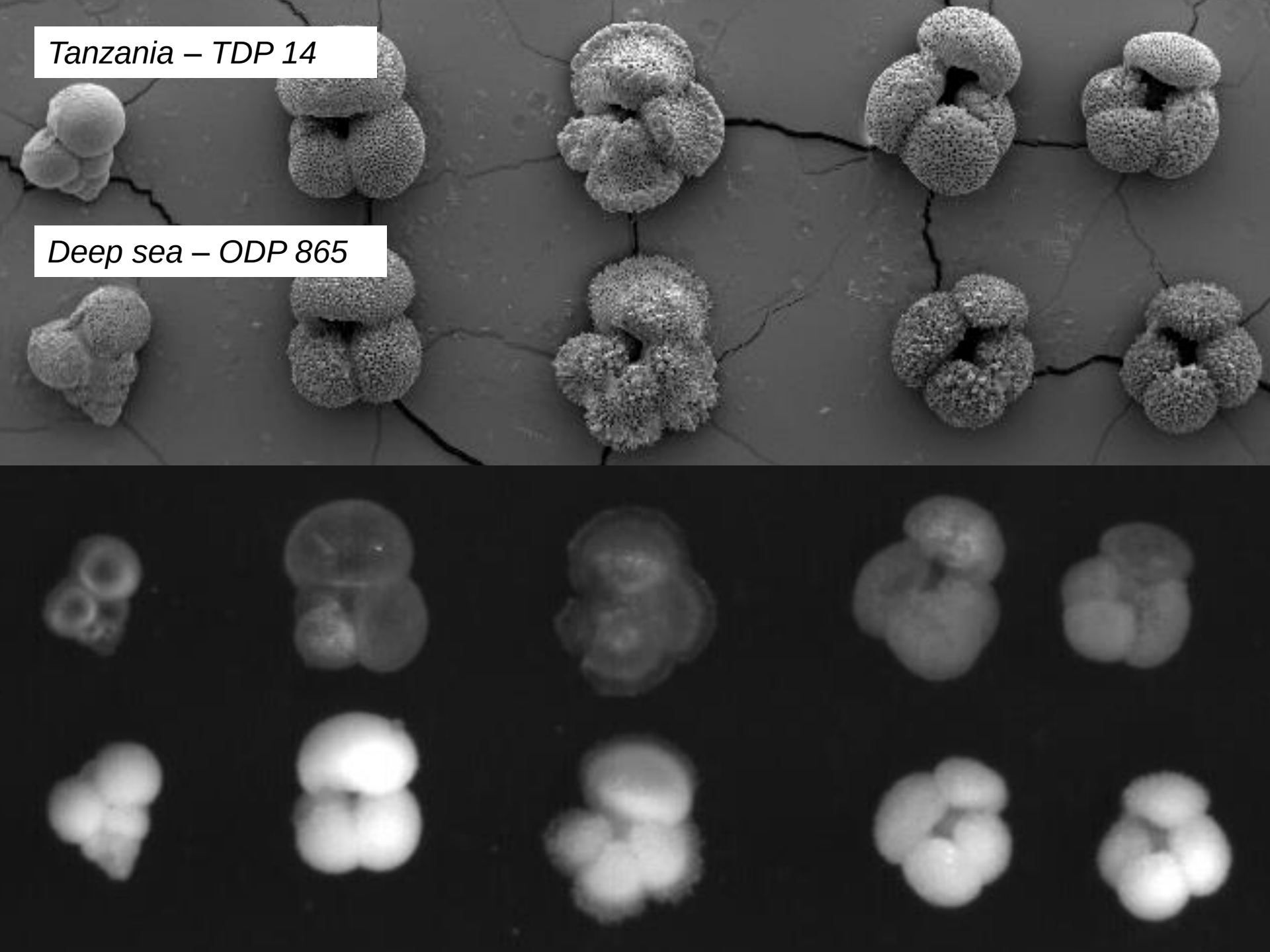


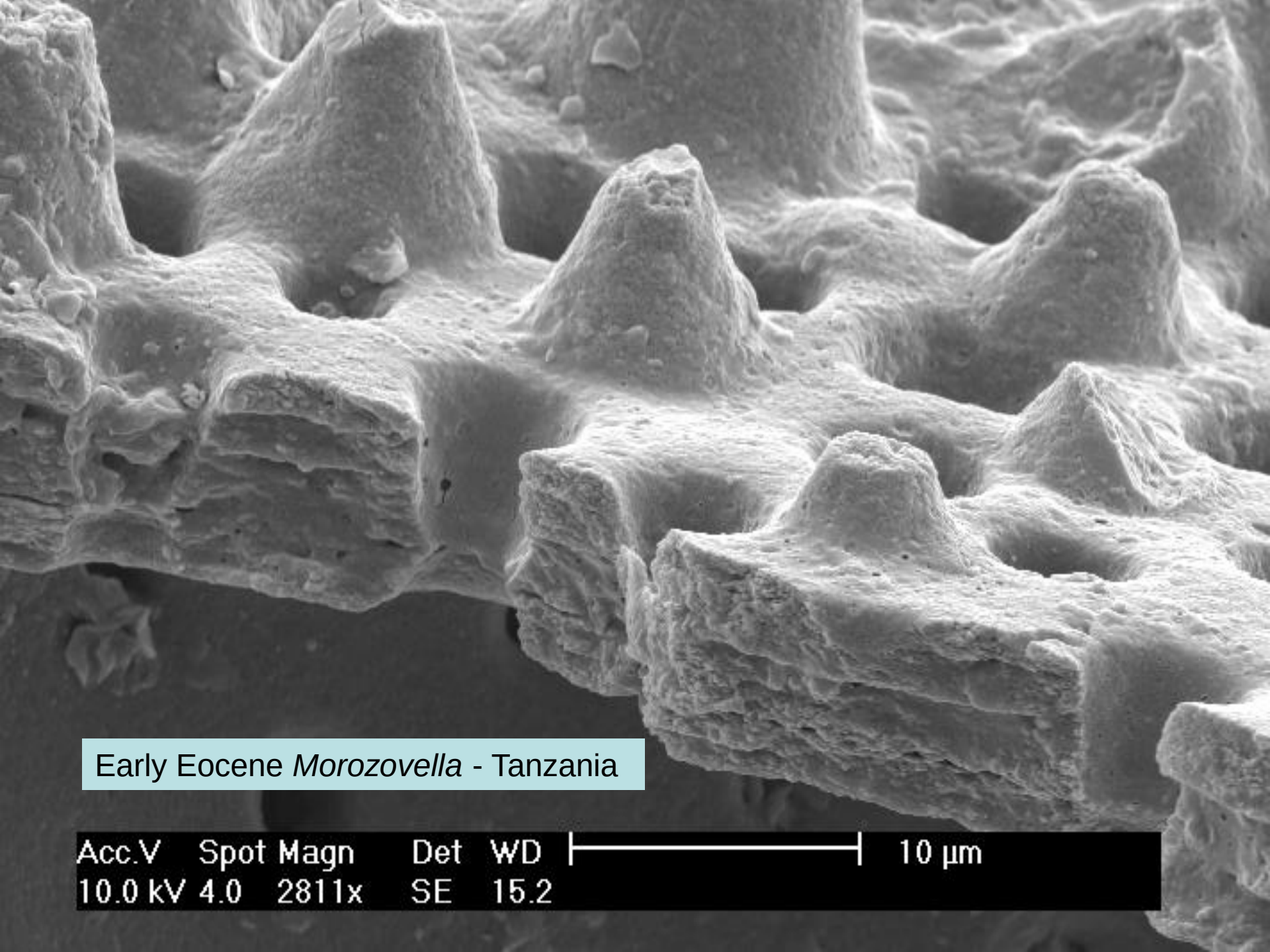


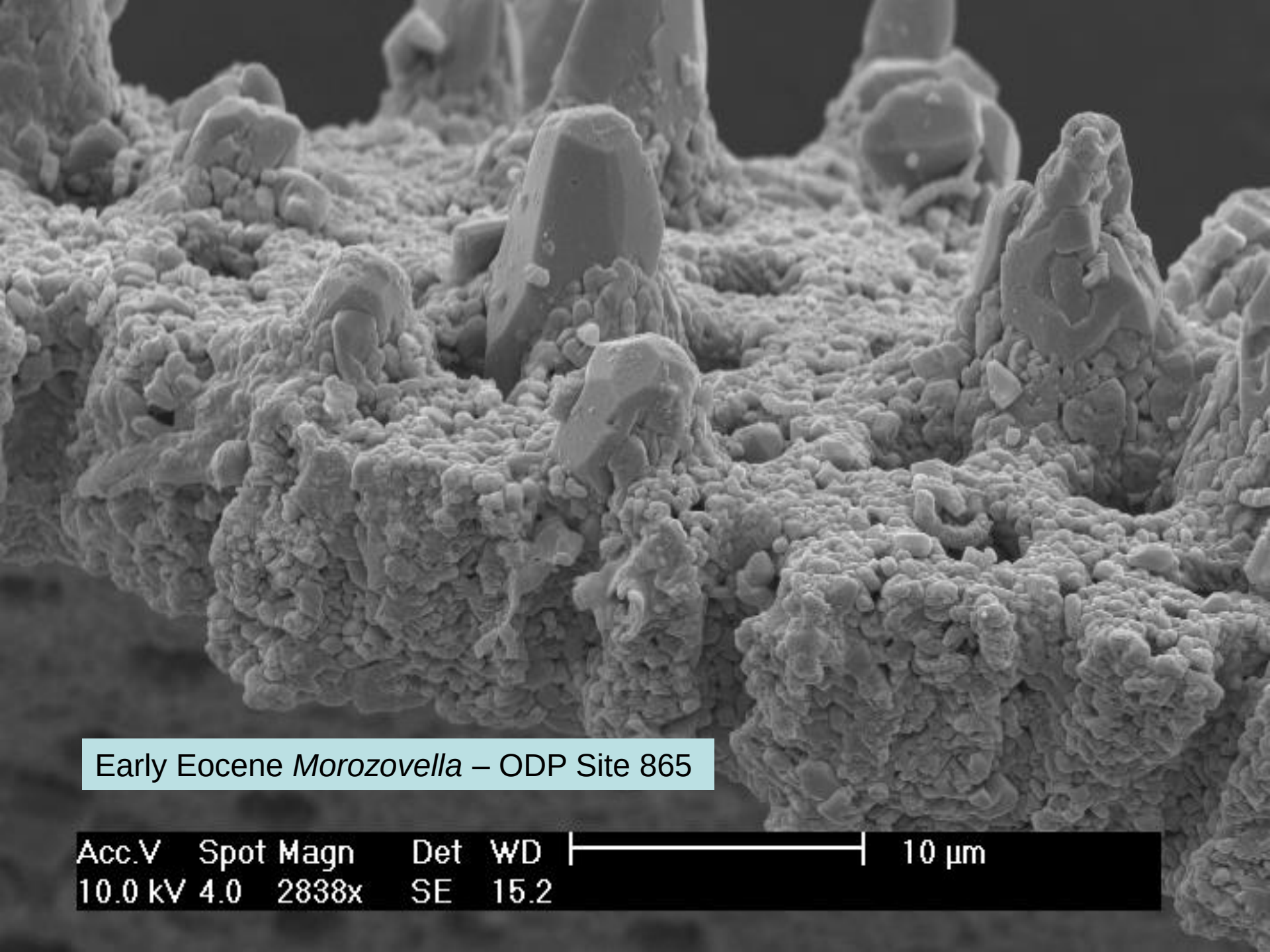


Importance of preservation

Cribrohantkenina inflata
From Tanzania

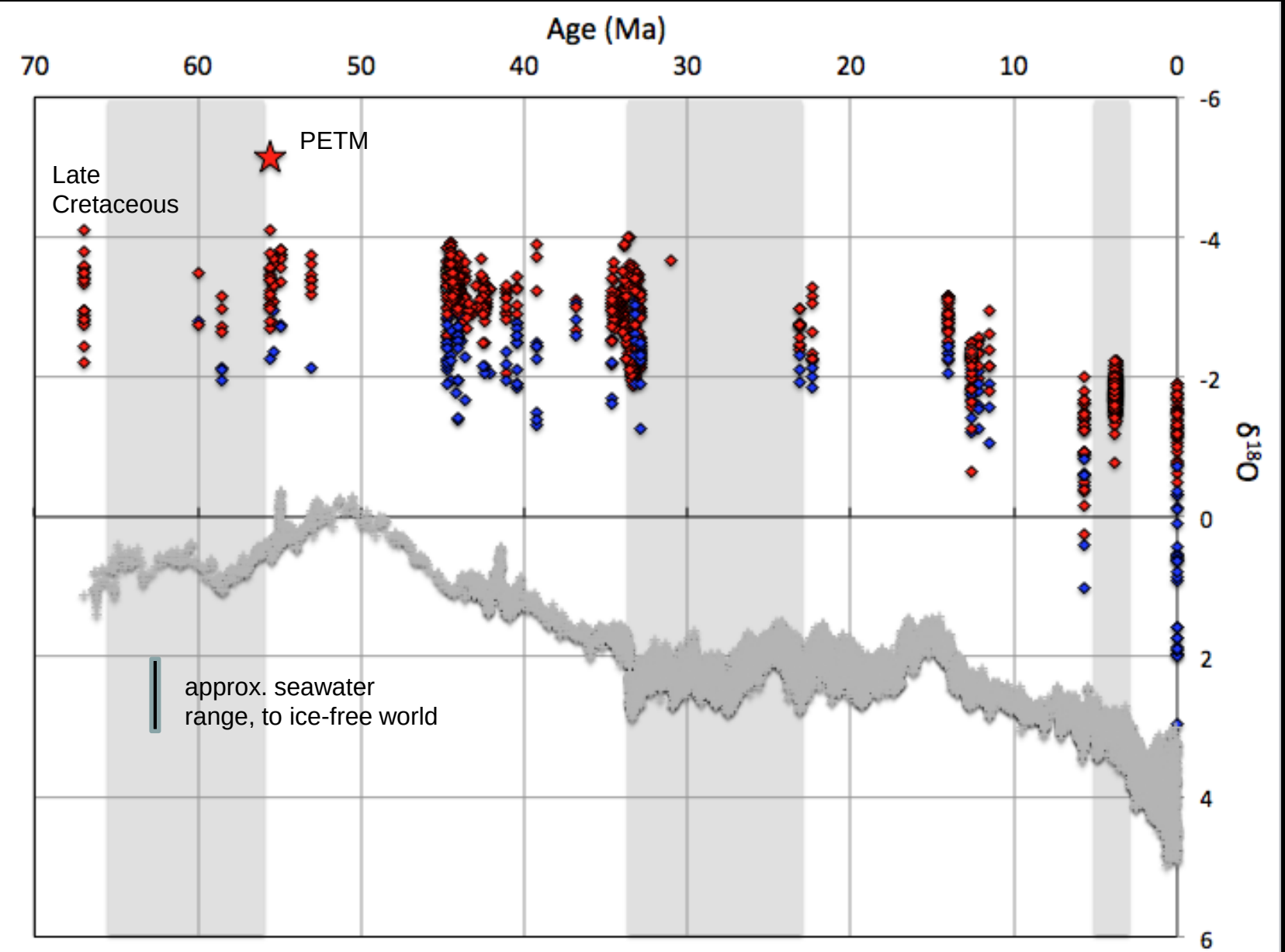

Tanzania – TDP 14
Deep sea – ODP 865


Early Eocene *Morozovella* - Tanzania
Acc.V Spot Magn Det WD
10.0 kV 4.0 2811x SE 15.2
10 µm



Early Eocene *Morozovella* – ODP Site 865

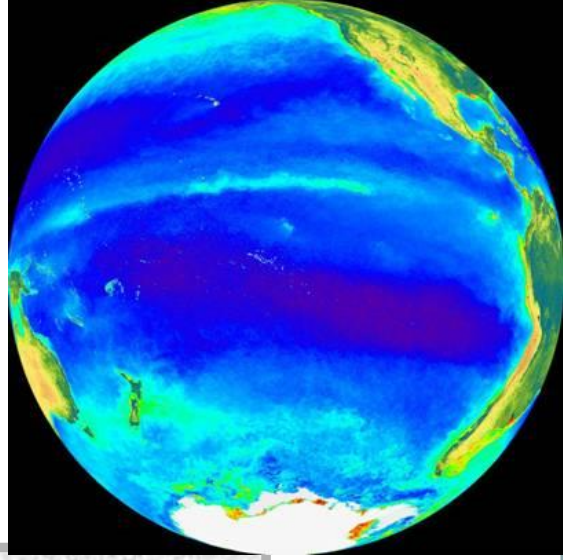
Tanzania planktonic oxygen isotope stack (in prep.)

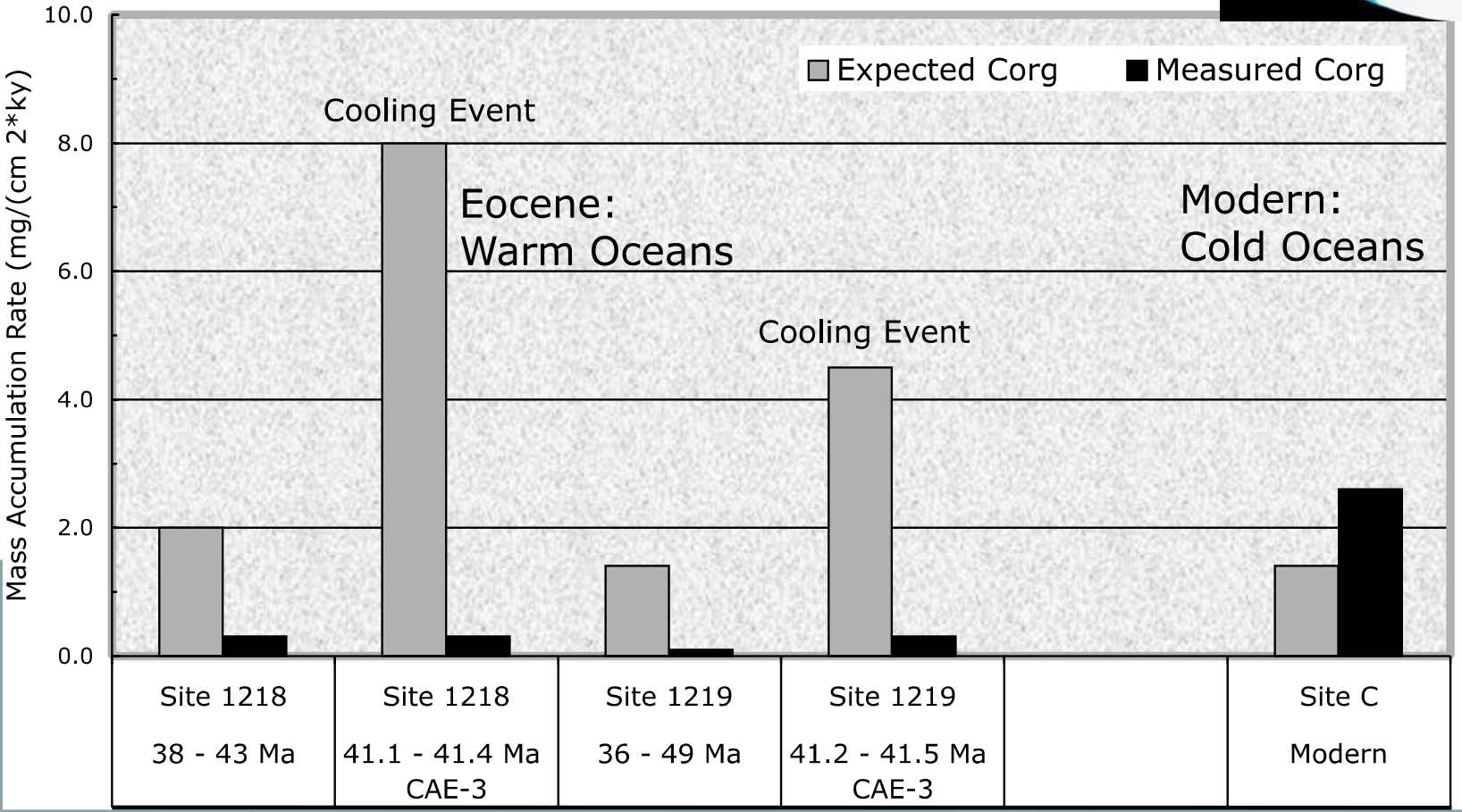


The “metabolic hypothesis”

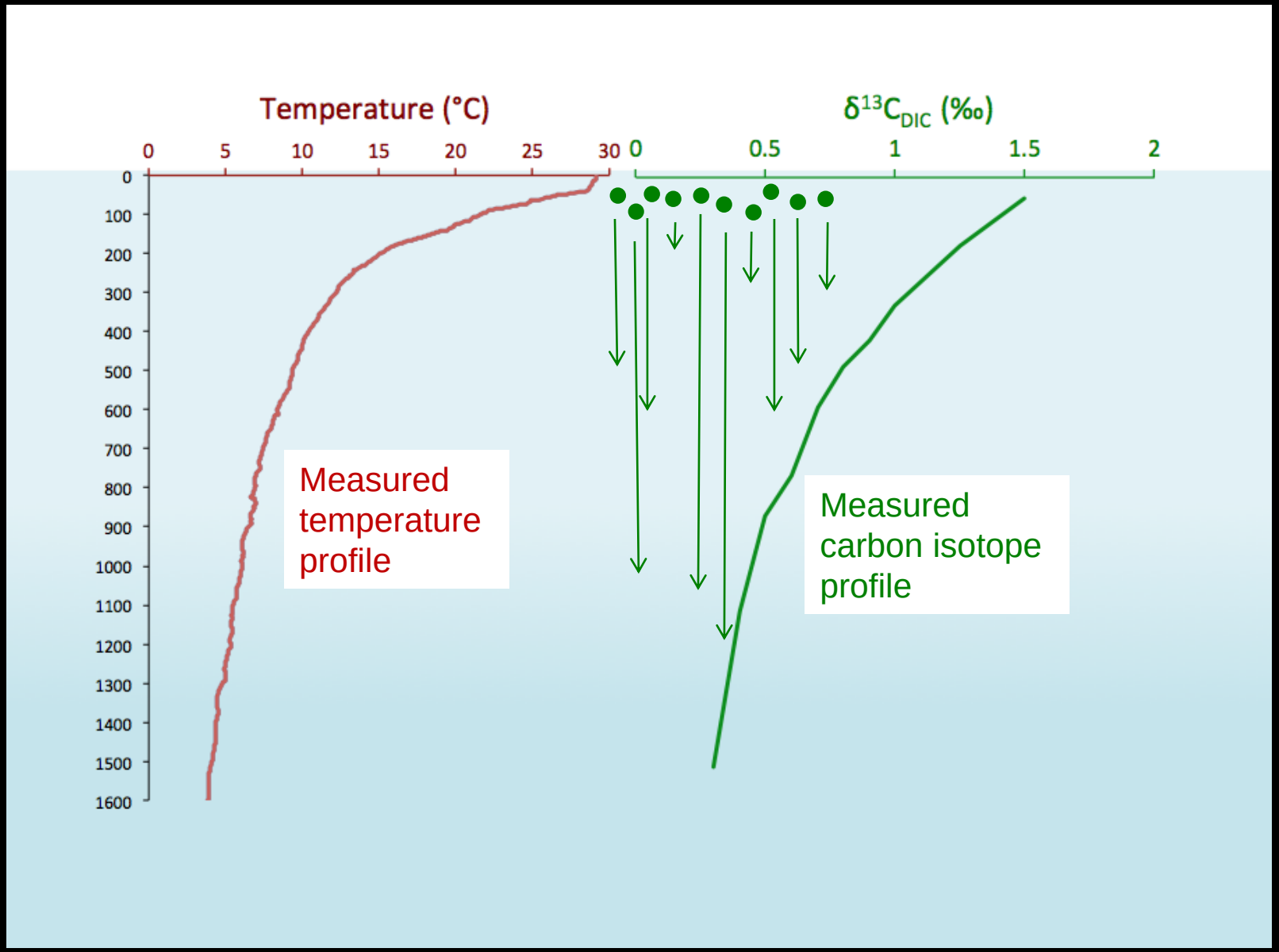
Missing organic carbon in Eocene marine sediments: Is metabolism the biological feedback that maintains end-member climates?

Annette Olivarez Lyle[1] and Mitchell W. Lyle[1]

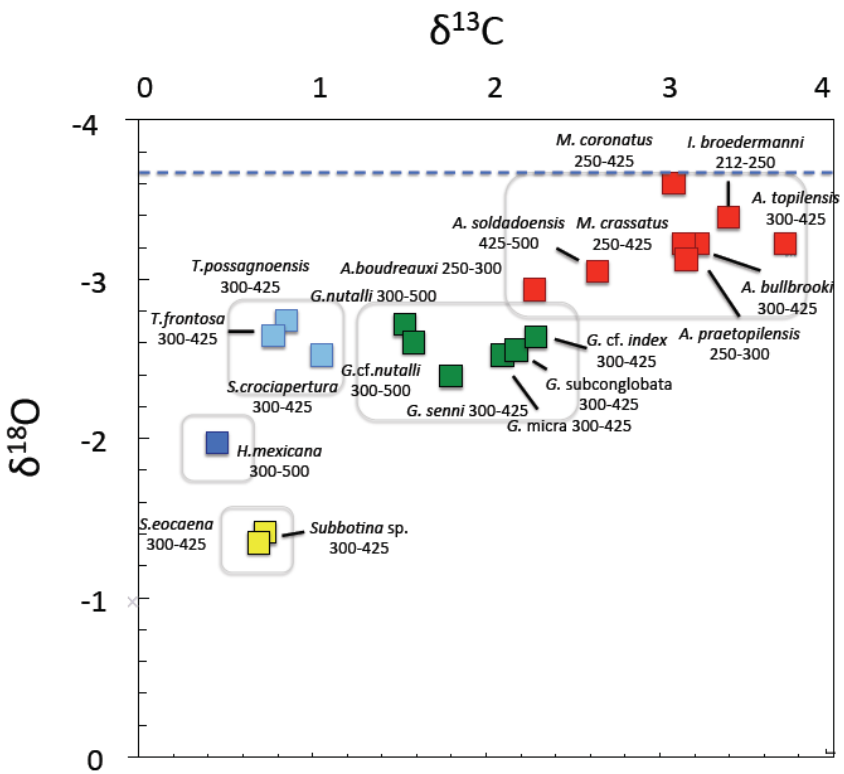


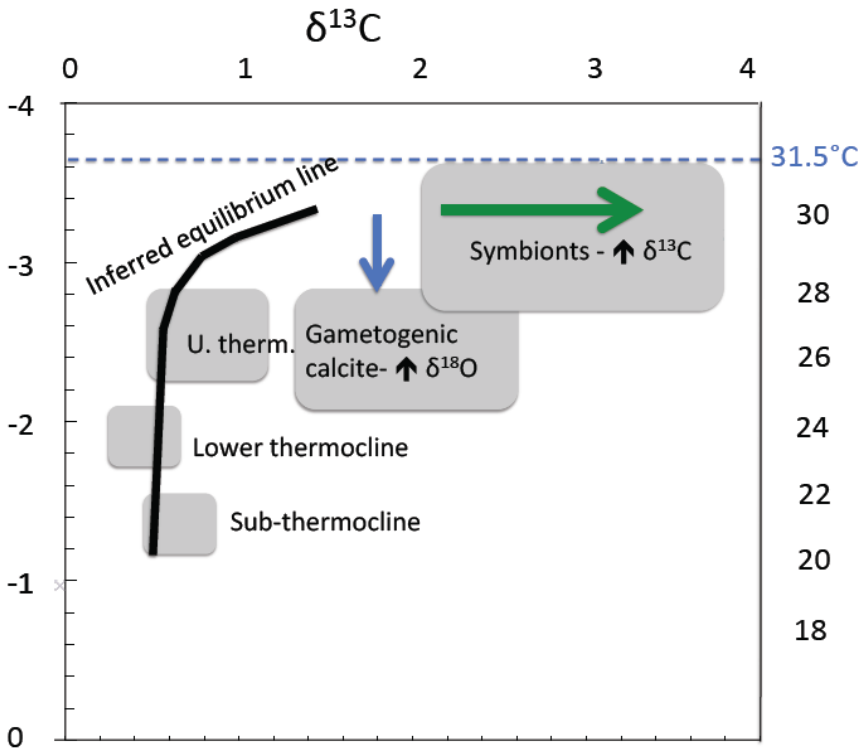


Carbon isotopes and the “biological pump”

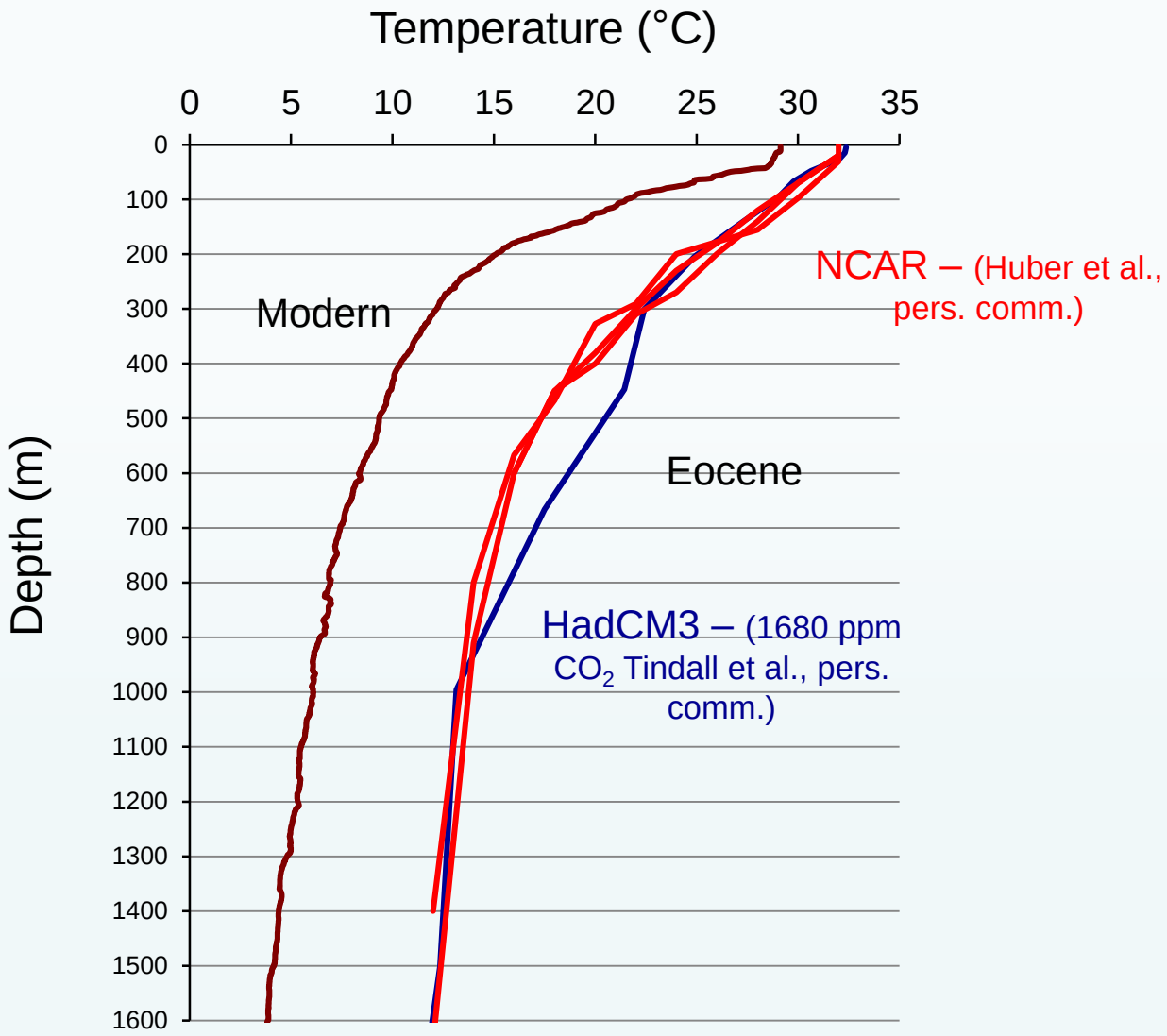


Reconstructing warm climate carbon isotope profiles





Modern (measured) and Eocene (modelled) water column temperature profiles for offshore Tanzania



PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A

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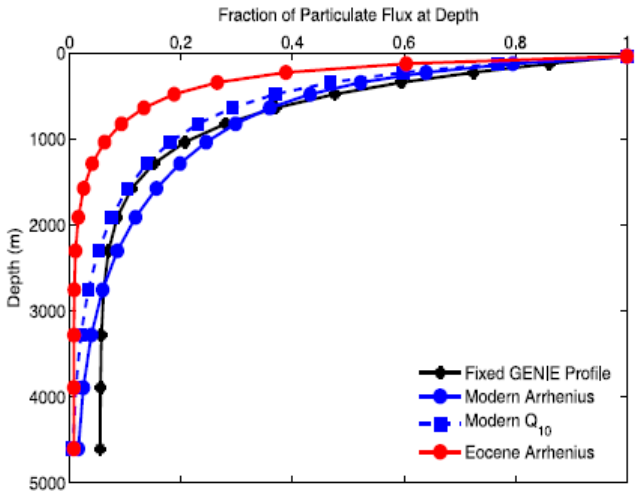
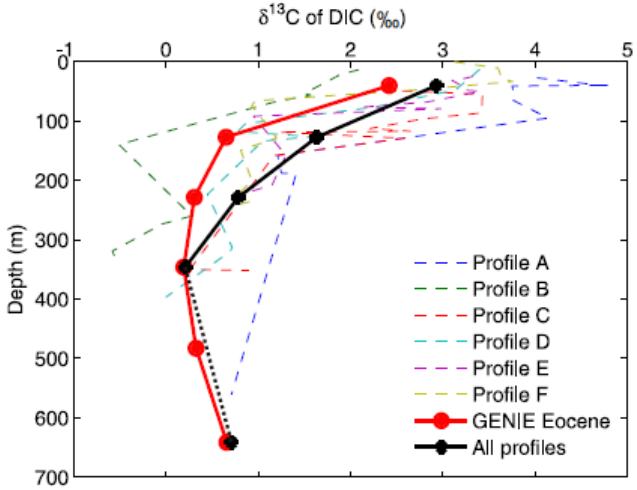
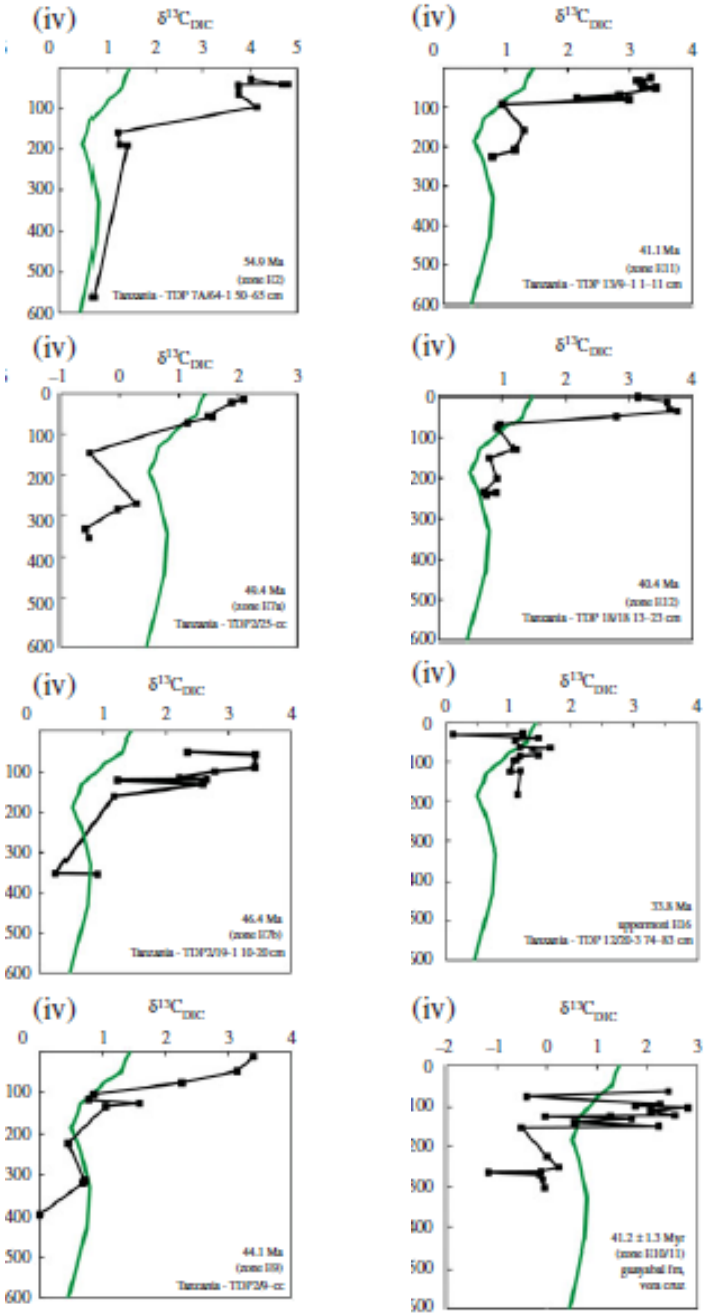
Warm ocean processes and carbon cycling in the Eocene

Eleanor H. John[1], Paul N. Pearson[1], Helen K. Coxall[2], Heather Birch[1], Bridget S. Wade[3] and Gavin L. Foster[4]

[1]School of Earth and Ocean Sciences, Cardiff University,





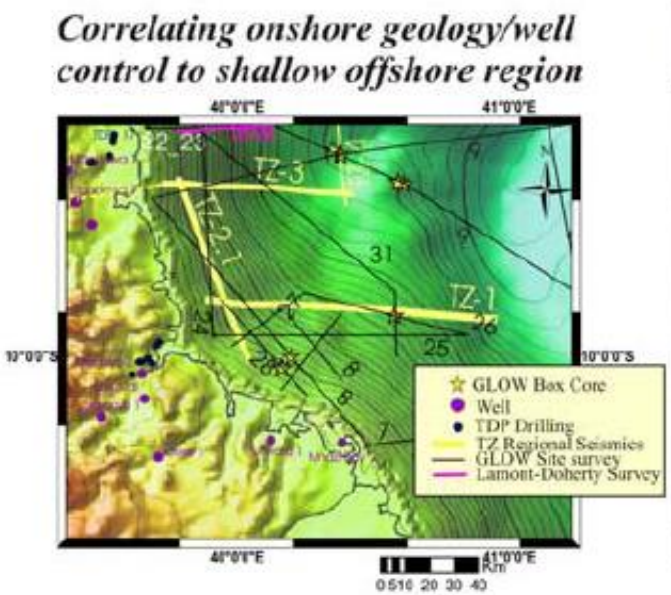


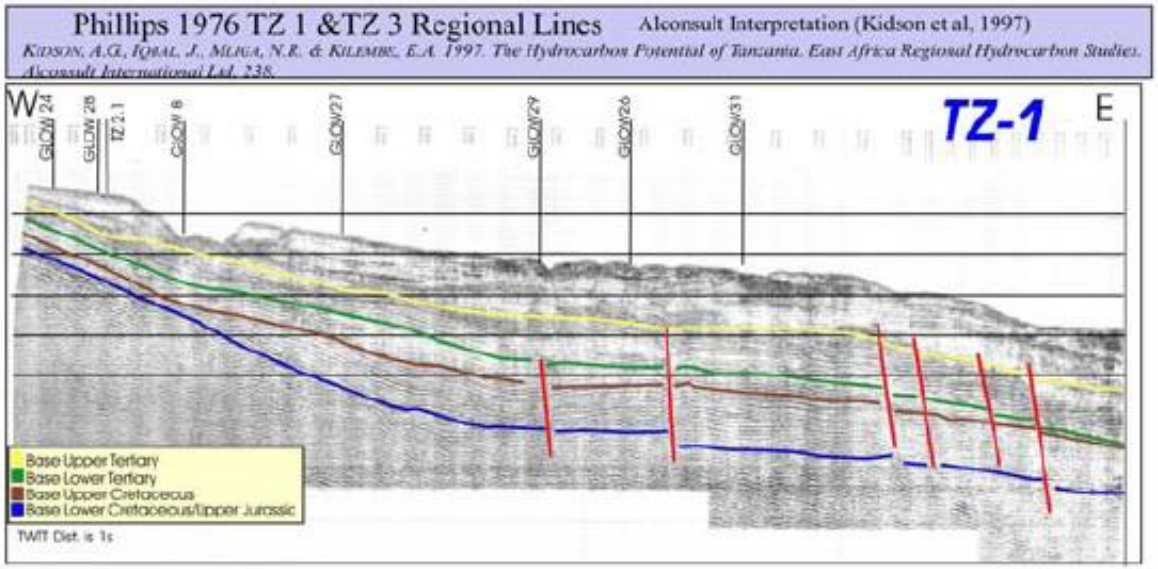
Limitations...

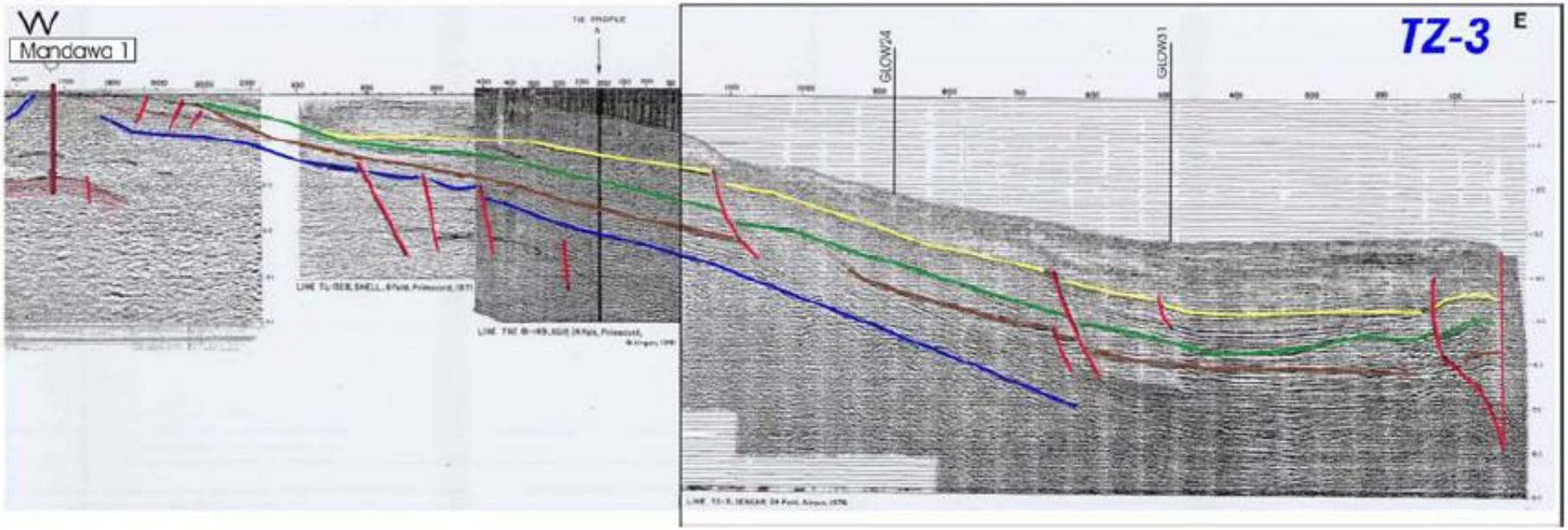
- Many missing gaps (50%)
- Maximum penetration 150 m
- No wireline logs (no orbital cycles)
- No magnetostratigraphy
- Variable recovery

ENORMOUS REMAINING POTENTIAL

Kilwa Group dips gently offshore, under clay-rich Neogene







ICDP Panels

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IODP

INTERNATIONAL OCEAN DISCOVERY PROGRAM

INTERNATIONAL OCEAN DISCOVERY PROGRAM

Exploring the Earth underneath the Sea

ICDP Workshop proposal (Academia + Industry):

Tanzania Onshore Paleogene Integrated Coring (TOPIC)

Recover Paleocene – Oligocene in a single 1 km site

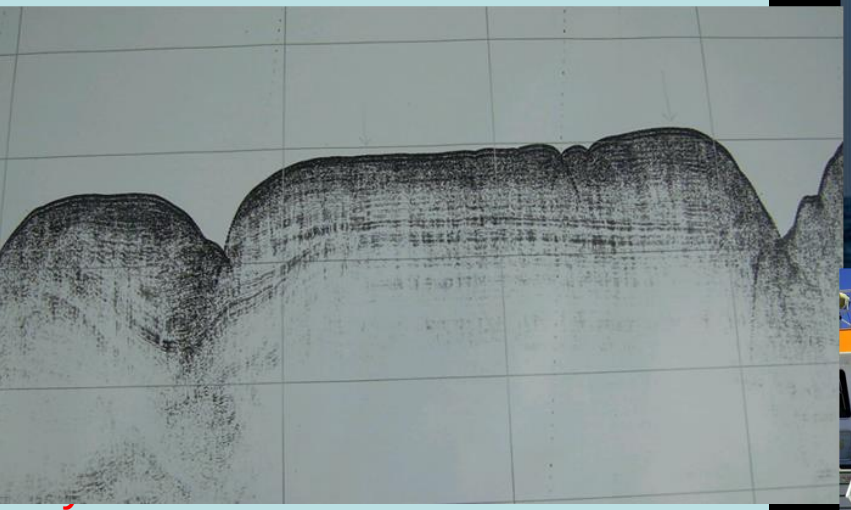
Wide diameter cores, logging, magnetostratigraphy

Phase I: Workshop funded ($60K)

Towards IODP

2009: Seismic survey cruise RV *Pelagia*

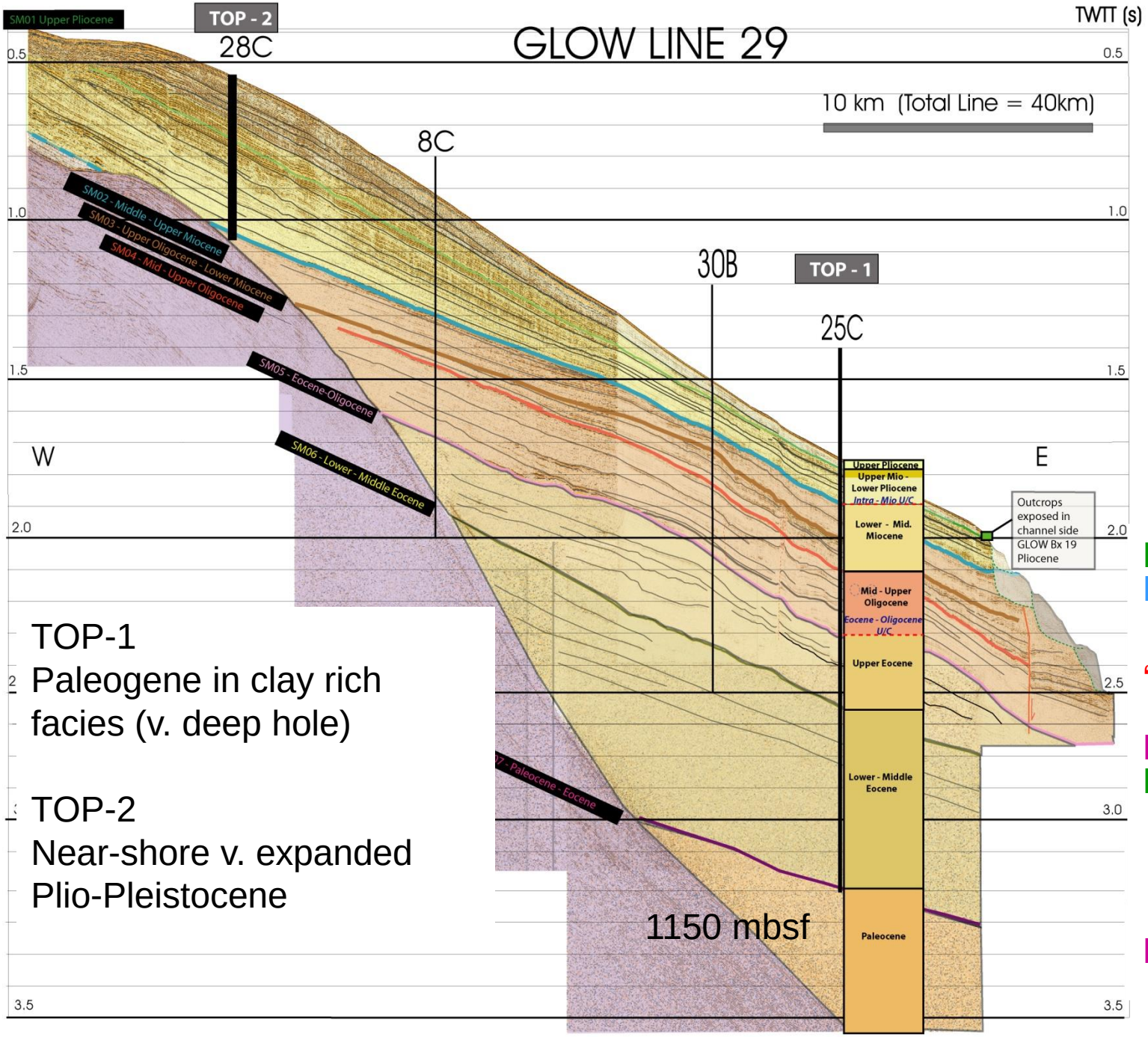
Locate potential IODP drill sites



Box and piston coring,
Dating outcropping reflectors
on sea floor
Plankton sampling

IODP Proposal 778

Tanzania Offshore Paleoclimate (TOP)



TOP-1
Paleogene in clay rich facies (v. deep hole)

TOP-2
Near-shore v. expanded Plio-Pleistocene

Pliocene
Mid Miocene

'Mid' Oligocene

E/O boundary
Mid Eocene

P/E boundary

Objectives

- Temperature: multiple proxies ($\delta^{18}O$, Mg/Ca, TEX86, UK37).
- pCO_2: inorganic and organic proxies
- Evolution: terrestrial and marine biotic evolution and the biotic response to climate perturbations
- Terrestrial Africa: connect marine records with terrestrial vegetation, continental air temperatures, and hydrology to hominin evolution.
- Chronology: carbonate microfossils, dinoflagellates and paleomagnetics, cycles.

… ranked ‘excellent’ by IODP Proposal Evaluation Panel

Formal IODP – ICDP linkage...

- Deep targets difficult and time consuming from ship
- Combined and complementary objectives
- Linked planning
- Coordinated scientific teams and meetings
- Combined synthesis and publication