Foundations of Complex Life

Photo © Winston Macdonald, 2014

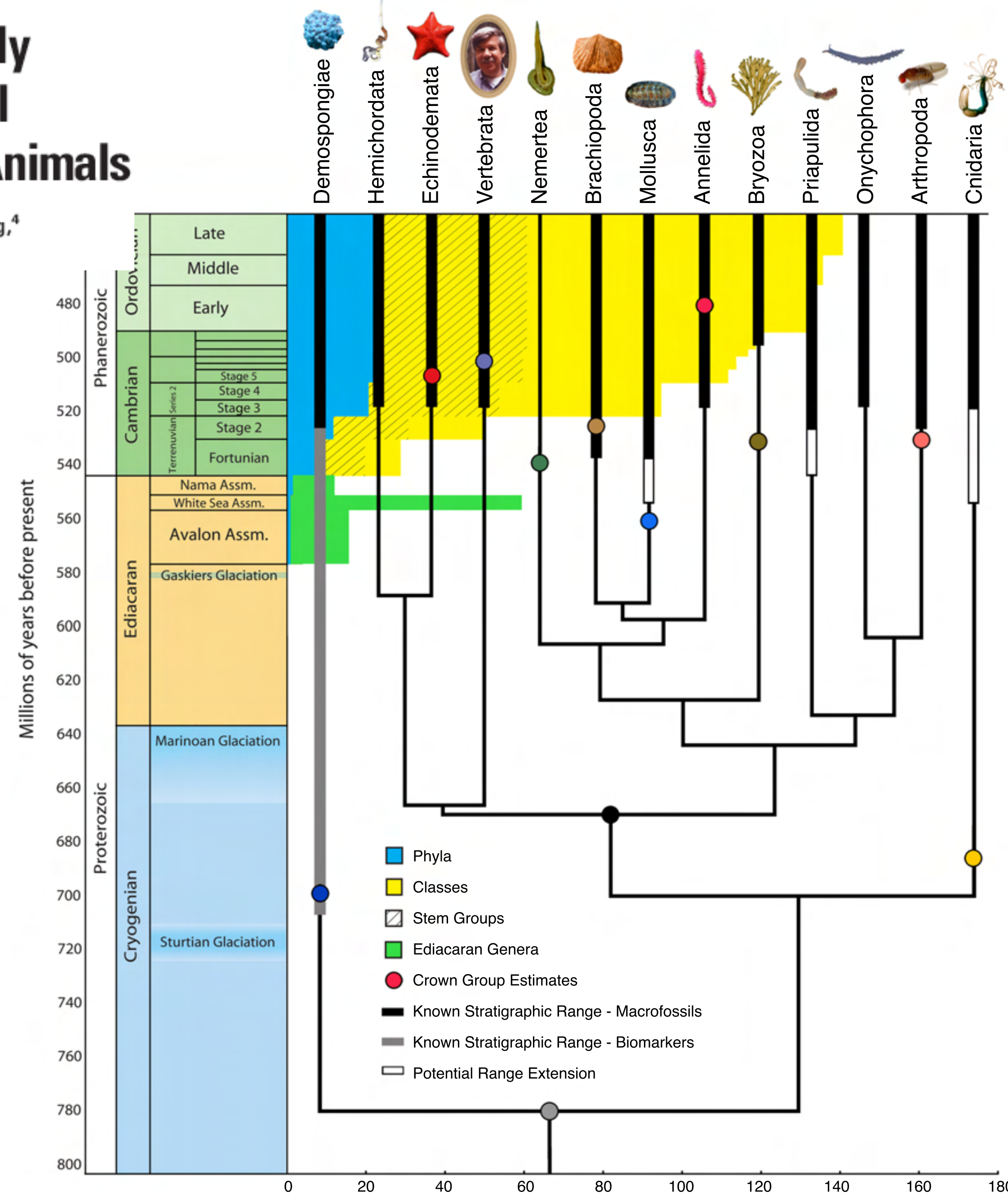
The co-investigators are: Roger Summons (PI)
Eric Alm, Kristin Bergmann, Tanja Bosak, Derek Briggs, Phoebe Cohen, Douglas Erwin, Greg Fournier, Katherine Freeman, John Grotzinger, Colleen Hansel, John Higgins, David Jacobs, David Johnston, Andrew Knoll, Marc LaFlamme, Francis Macdonald, David McGee, Ralph Milliken, Carol Oliver, Shuhei Ono, Ann Pearson, Kevin Peterson, Sara Pruss, Dan Rothman, Dimitar Sasselov, Erik Sperling, Ken Stedman, Dawn Sumner, Malcolm Walter, Martin Van Kranendonk, Scott Wankel, Benjamin Weiss, and Paula Welander.

Benjamin Kotrc, EPO lead: Virtual Field Trips, MIT Museum activities etc

The Cambrian Conundrum: Early Divergence and Later Ecological Success in the Early History of Animals

Douglas H. Erwin,[1,2*] Marc Laflamme,[1] Sarah M. Tweedt,[1,3] Erik A. Sperling,[4] Davide Pisani,[5] Kevin J. Peterson[6*]

Multiple kinds of molecular clocks, and empirical evidence, suggest complex life had its inception in the Cryogenian



Tree constructed from 7 housekeeping genes from 118 taxa

Erwin et al., SCIENCE 2011

Five Research Themes of FCL Team

The earliest history of animals:

Use methods from molecular biology, experimental taphonomy, and paleontology to explore the early divergence of animals

Peterson, Erwin, Jacobs, Knoll, Briggs, Gold, Fournier, Alm, Sperling

Field-based paleontology, sedimentology, and geochemistry:

Track the origin of complex protists and animals

Document the stratigraphy, isotopic records, microfossil assemblages of well-preserved rock successions from 1200 to 540 Ma

Macdonald, Johnston, Pearson, Cohen, Pruss, Bosak, Ono

Five Research Themes

Carbon cycle dynamics:

Investigate how changes in the preservation of organic carbon may have driven the Neoproterozoic oxygenation of the oceans coincident with the appearance of complex life

Rothman, Bosak, Summons

Taphonomy and Curiosity:

As Curiosity explores Gale Crater, a site chosen in large part because of taphonomical reasoning, integrate research on Mars and Earth to understand martian environments and geochemistry

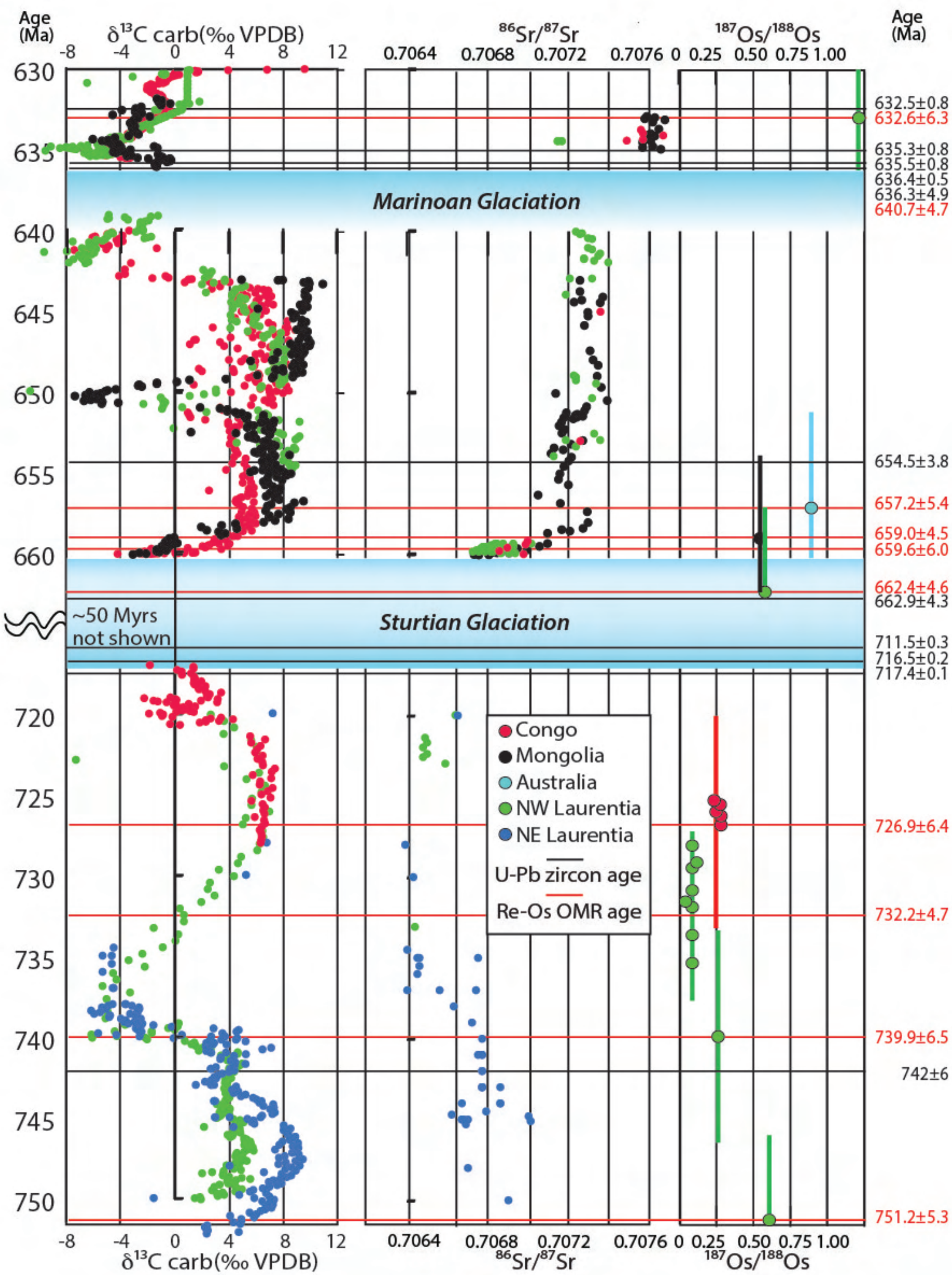
Grotzinger, Sumner, Milliken

Synthesis:

Generate an expanded view of major transitions on Earth, environmental and biological; develop a synthesis of the history of habitability on Mars.

EPO: Virtual Field Trips, MIT Museum activities, Science club for girls, teacher workshops

Kotrc, Cohen



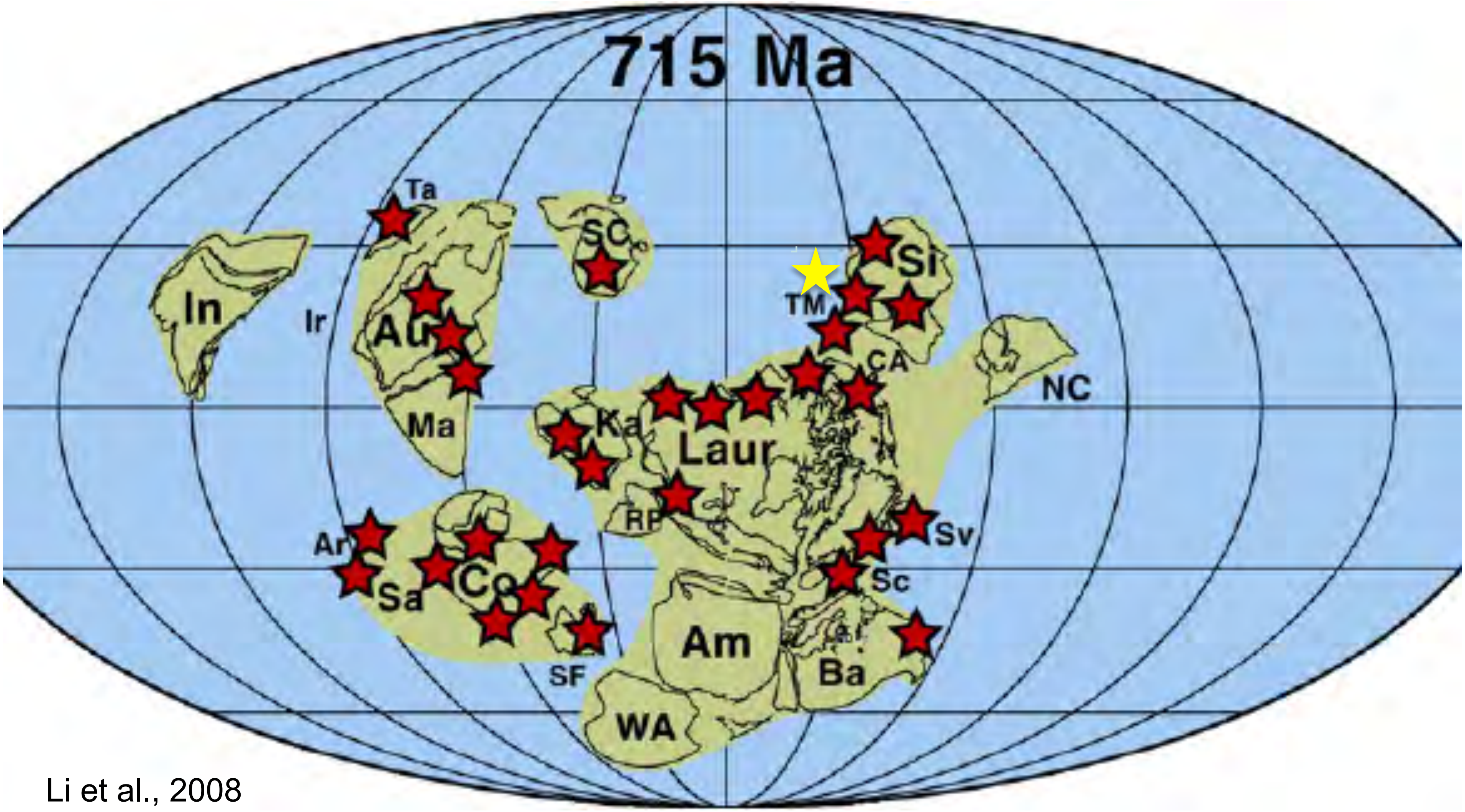
'Extreme' C isotope variability – what drives this?

Positive carbon isotope values => increase OC burial, consistent with increased basalt weathering and P fertilization

Rise in oxygen? Yes, but not mole wise because basalts also deliver reduced Fe…

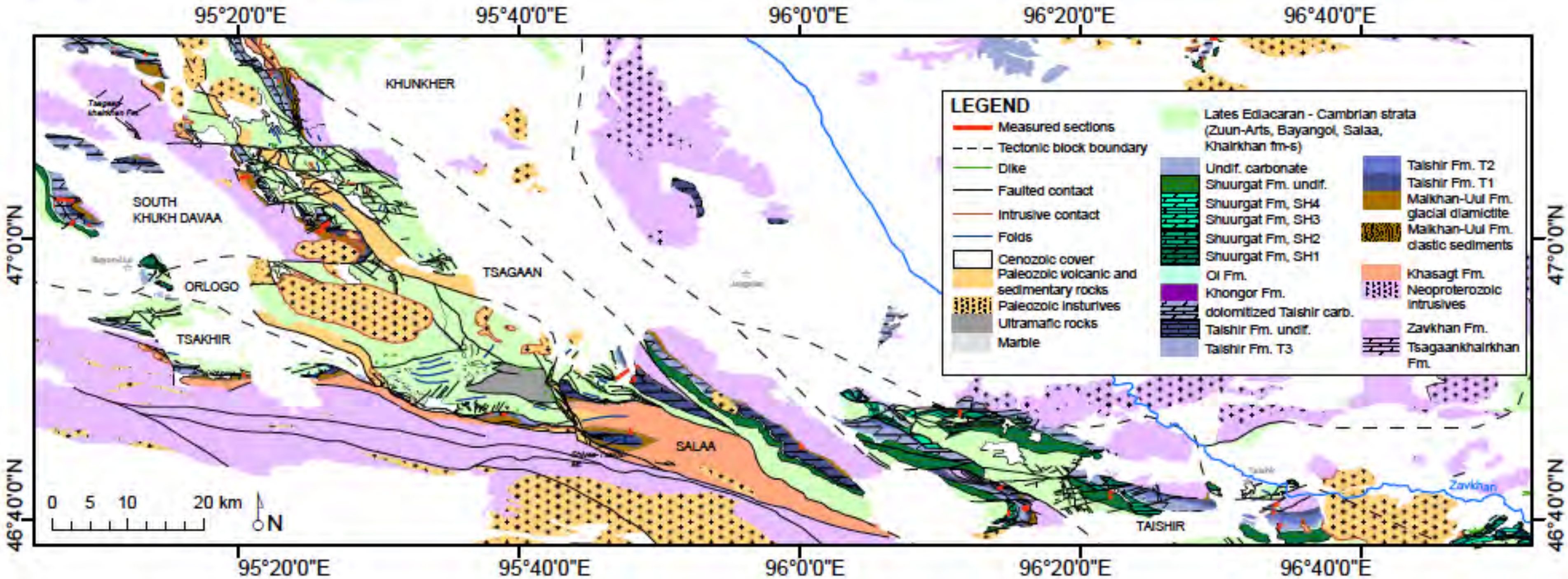
Are negative anomalies due to mantle carbon (e.g. Sobelev, et al., 2011) or crashes in the carbon cycle (e.g. Tziperman, et al., 2011)—an organic carbon capacitor?

Cryogenian Paleogeography

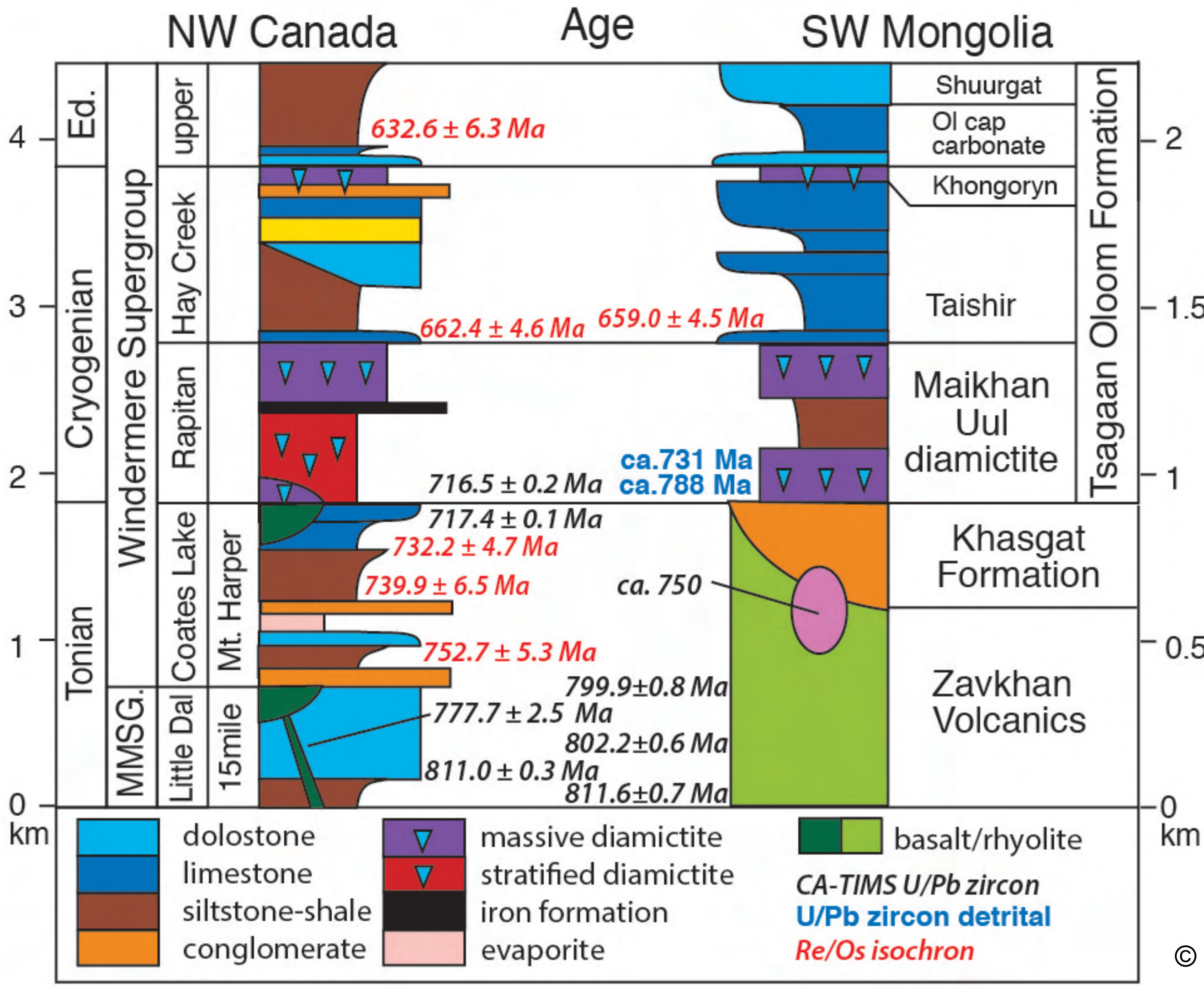


Red stars mark Sturtian glacial deposits
Yellow star marks approximate position of Mongolia at ca. 715 Ma
(rifted continental arc with Siberian basement….)

Geology of the Zavkhan Region, Southwestern Mongolia

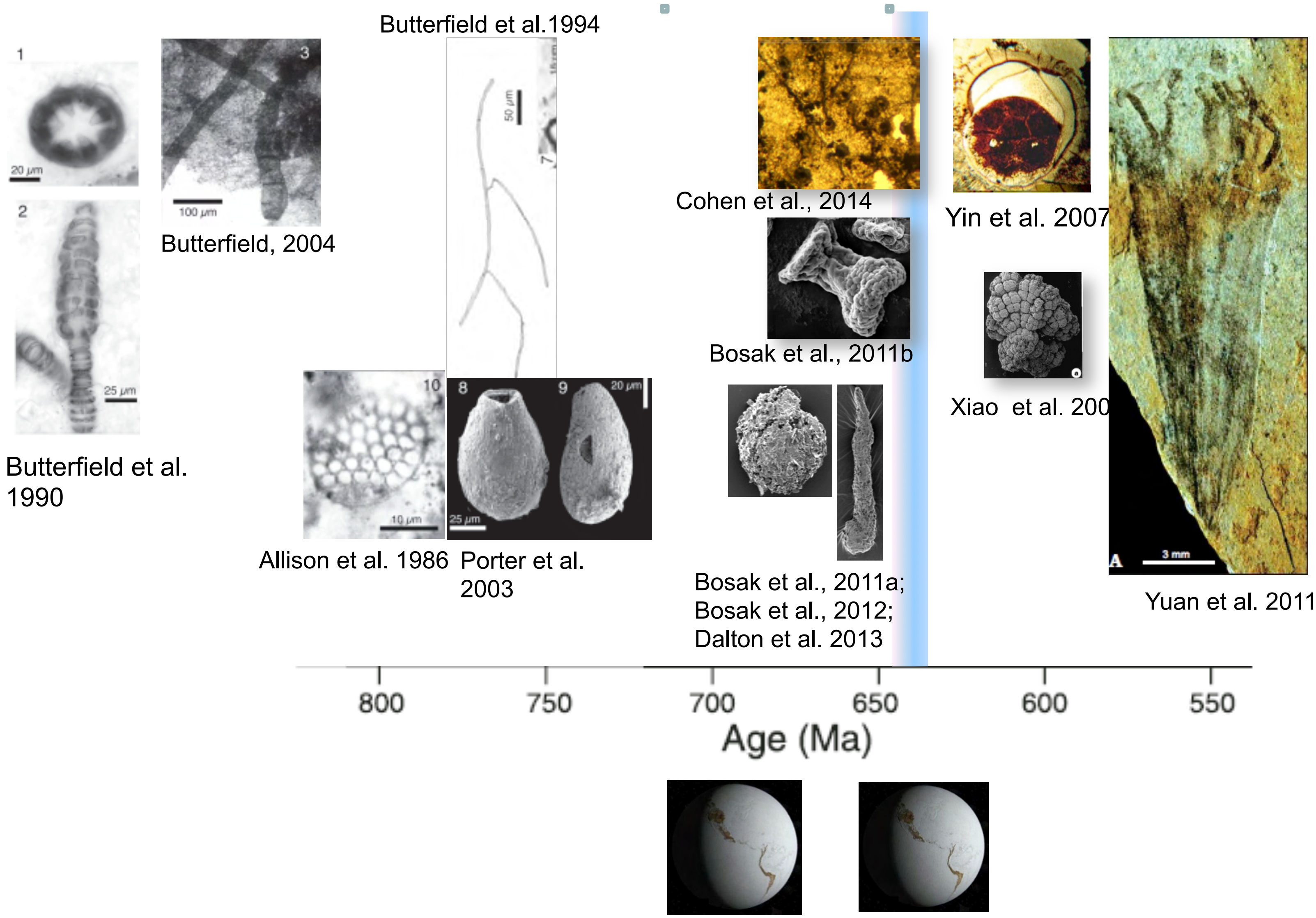


Why NW Canada and Mongolia?



-Low grade carbonate and organic-rich strata interbedded with volcanic rocks: Sr, Re, Os, Corg, Ccarb, S, and U/Pb in zircons—we can use proxy data to test hypotheses about the evolution of the carbon cycle and atmospheric oxygen

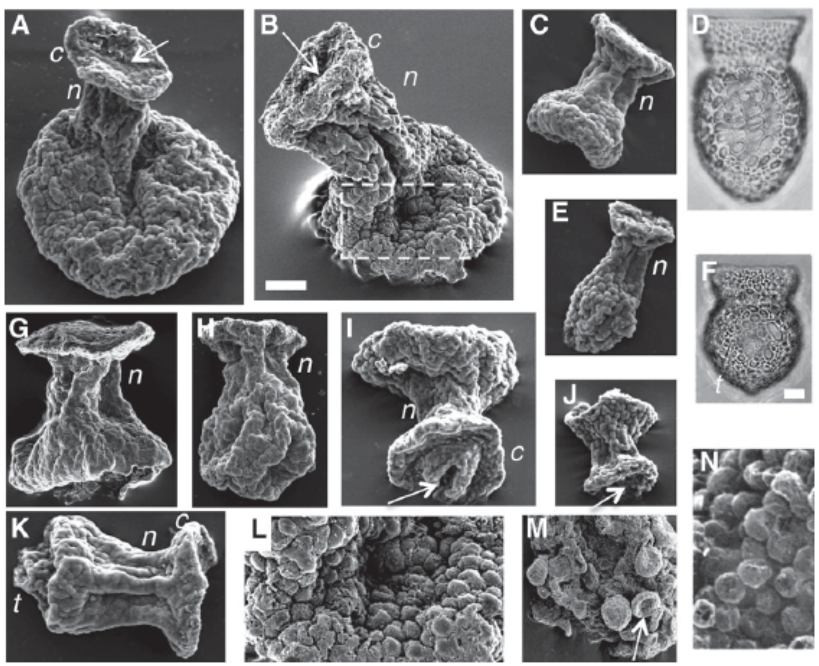
DISCOVERED MORPHOLOGICALLY MODERN EUKARYOTES IN CARBONATE ROCKS

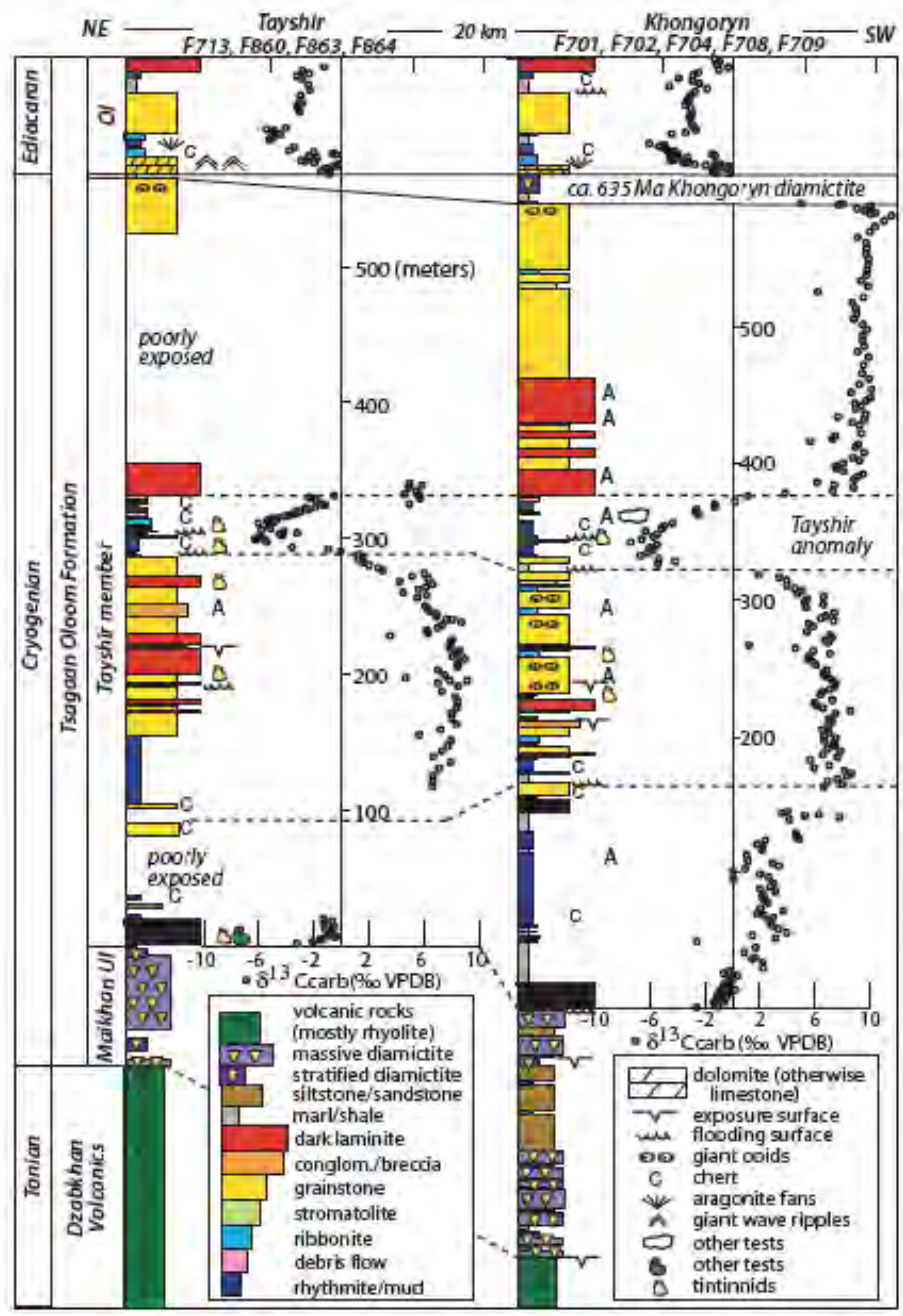


Putative Cryogenian ciliates from Mongolia

T. Bosak, F. Macdonald, D. Lahr & E. Matys

Geology 2011;39;1123-1126





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Agglutinated tests in post-Sturtian cap carbonates of Namibia and Mongolia

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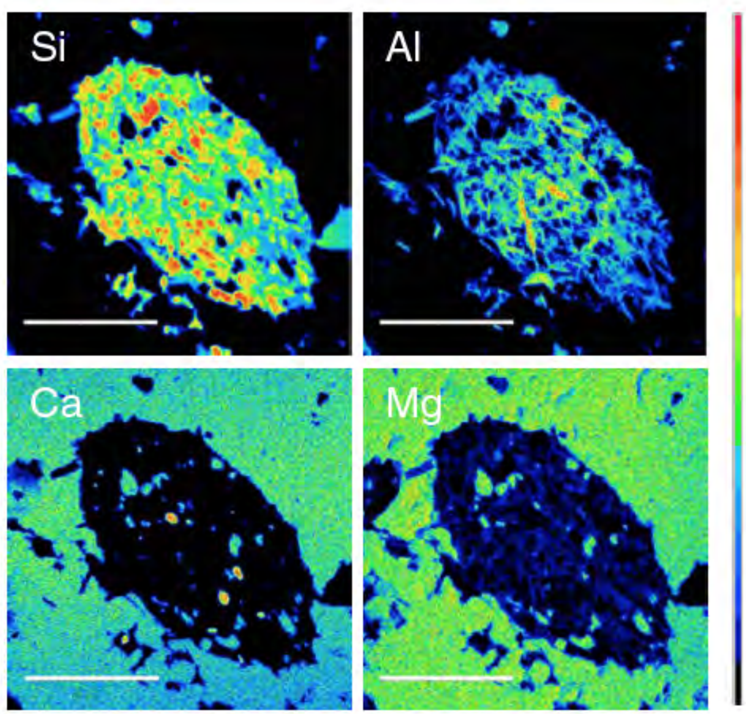
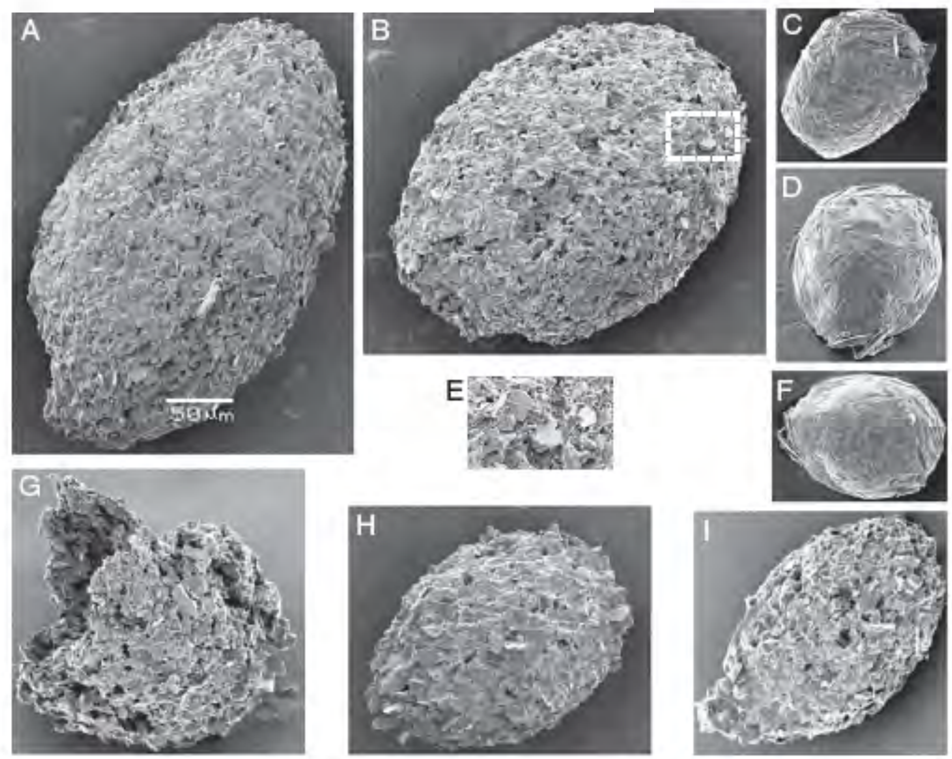
[b] Graduate Program in Organismic and Evolutionary Biology, University of Massachusetts, Amherst, MA 01003, United States
[c] Department of Geosciences, Smith College, Northampton, MA 01063, United States
[d] Department of Earth and Planetary Sciences, Harvard University, Cambridge, MA 02138, United States



1) 29–40



Possible early foraminiferans in post-Sturtian (716–635 Ma) cap carbonates

Tanja Bosak[1], Daniel J.G. Lahr[2], Sara B. Pruss[3], Francis A. Macdonald[4], Andrew J. Gooday[5], Lilly Dalton[3], and Emily D. Matys[1]

[1]Department of Earth, Atmospheric and Planetary Sciences, Massachusetts 02139, USA
[2]Department of Zoology, University of São Paulo, 05508-090 São Paulo, Braz
[3]Department of Geosciences, Smith College, Northampton, Massachusetts C
[4]Department of Earth and Planetary Sciences, Harvard University, Cambridg
[5]National Oceanography Centre, Southampton, UK

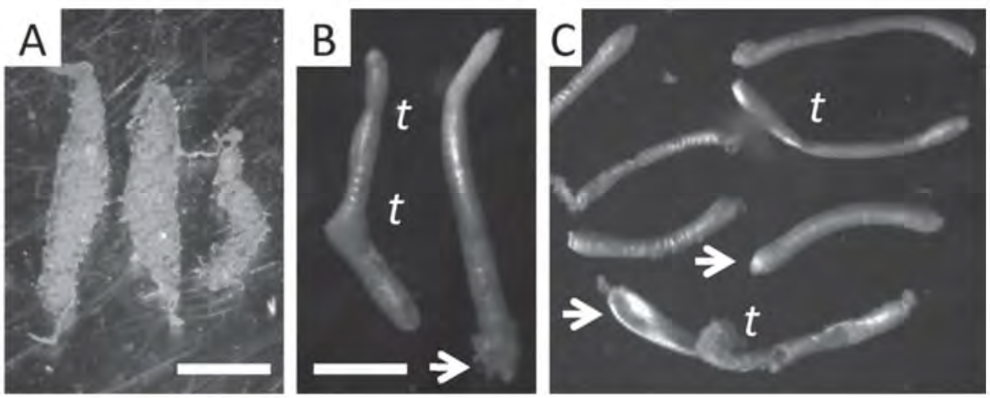


Figure 3. Photographs of modern agglutinated tubular monothalamous foraminiferans. A: Modern *Pelosina* sp.; scale bar is 200 μm. B, C: Modern silver-brown saccaminids with constricted tests (*t*) and bulbous ends (arrows). Some tests in C are collapsed due to flexible walls, as well as covered by mineral grains. Scale bar in B is 100 μm. Tests in C are as much as 2 mm long.

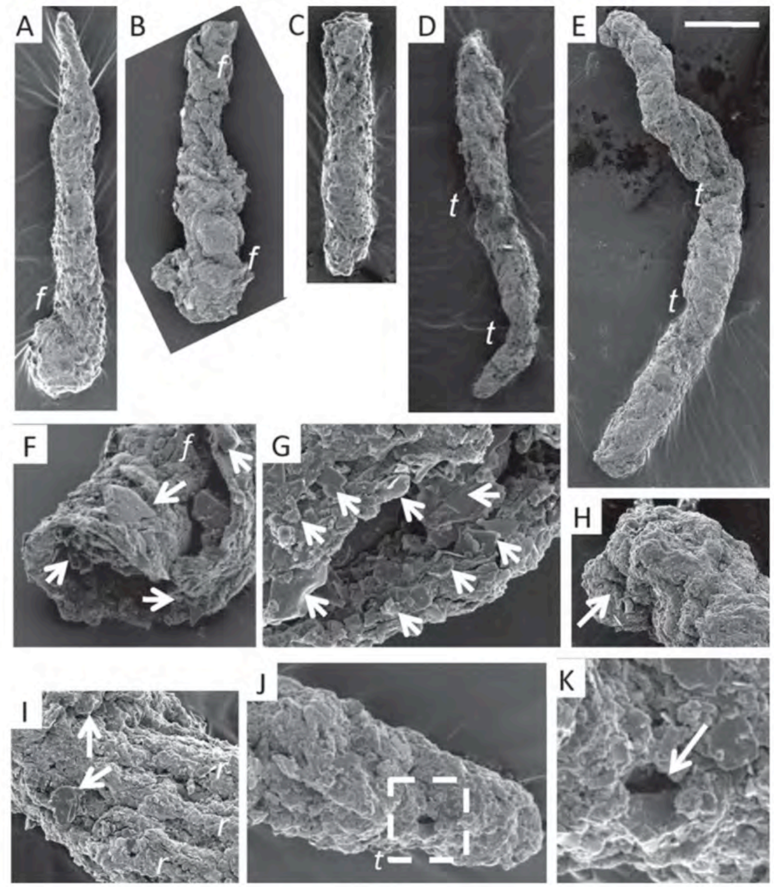
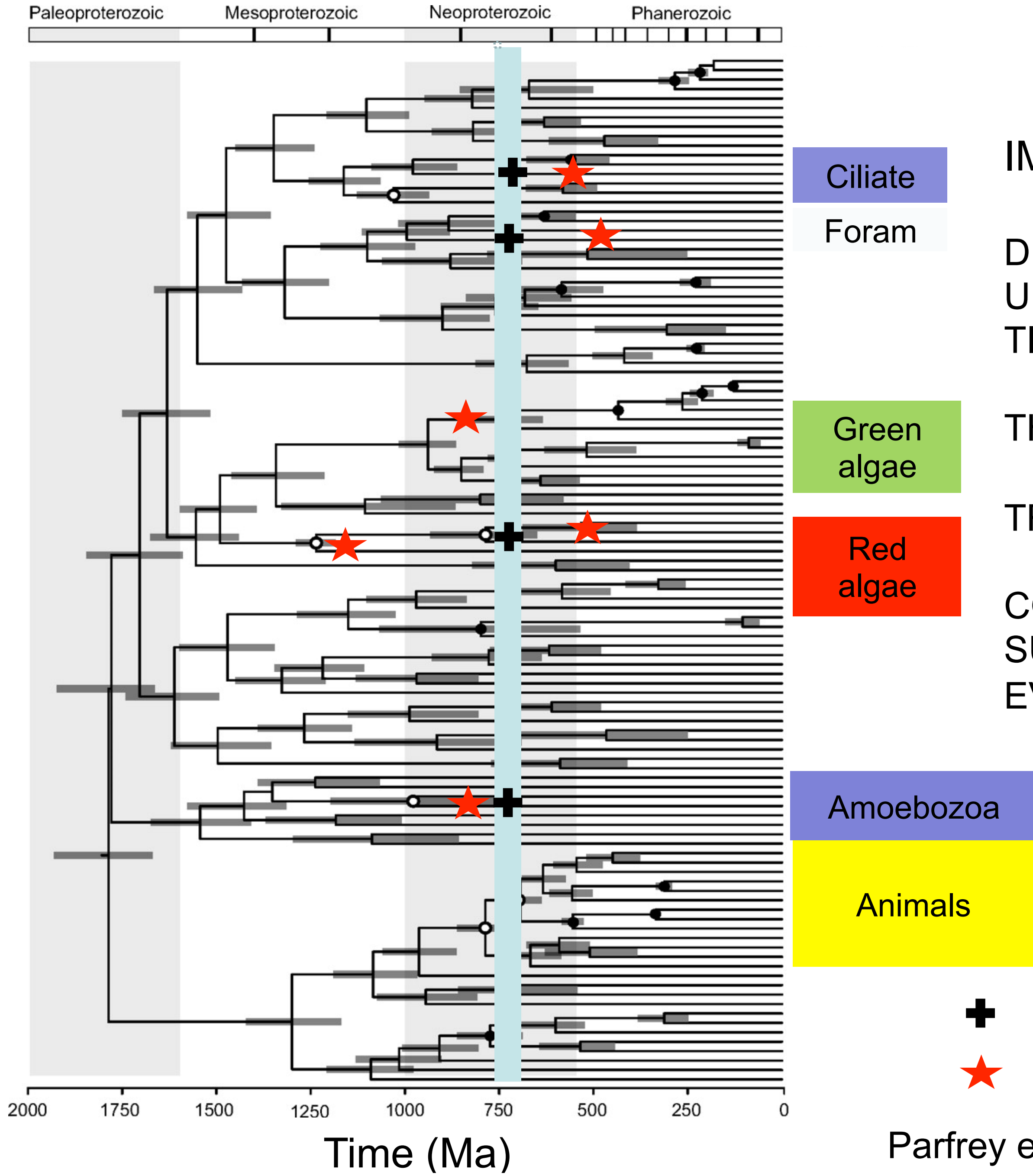


Figure 2. Representative morphologies of tubular tests from Rasthof Formation (Namibia). All images are scanning electron micrographs. A–E: Tubular tests with transverse constrictions (*t*) and folds (*f*). F:

FOSSILIZED REPRESENTATIVES OF ROBUST TAXA



IMPLICATIONS

DIVERSE PROTISTS IN UNEXPECTED TAPHONOMIC & TIME WINDOWS

THEY APPEAR TO BE MODERN

TRADITIONAL WINDOWS BIASED?

COMPLEX COMMUNITIES SURVIVED SNOWBALL EARTH EVENTS

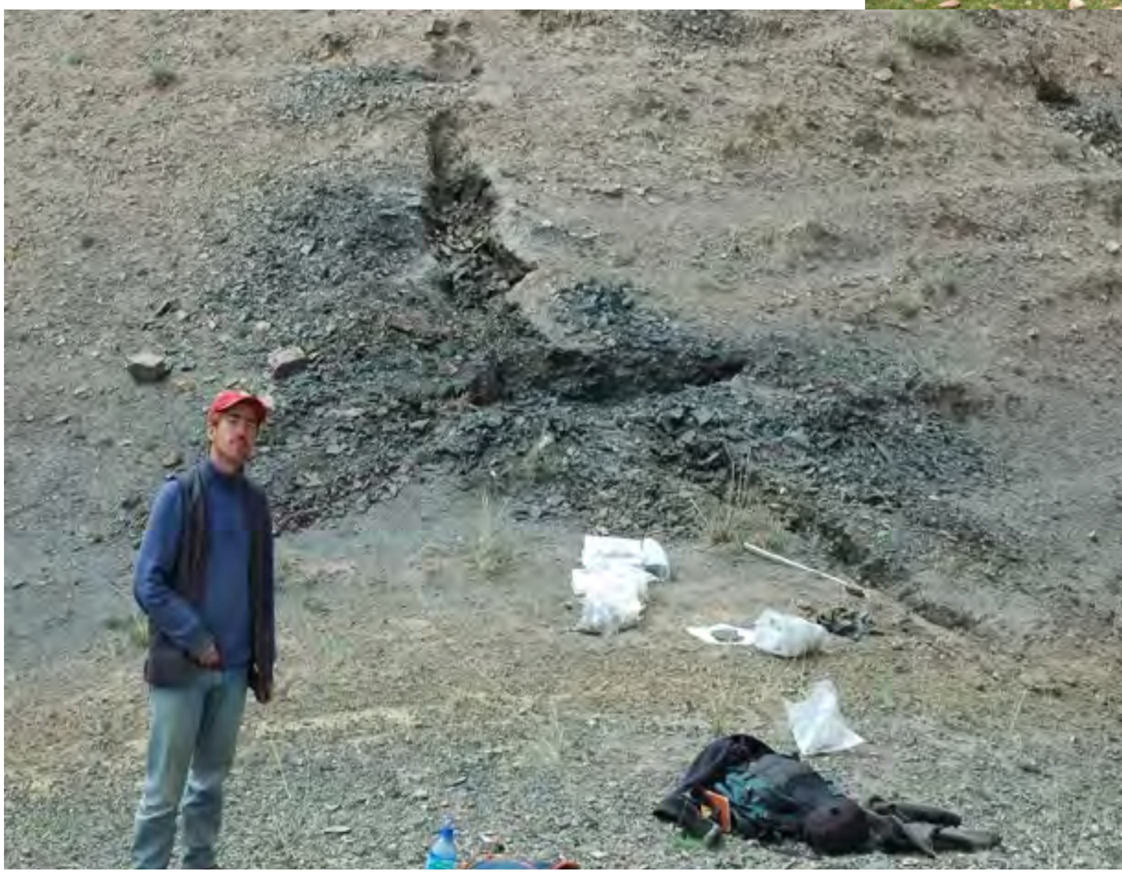
✚ BOSAK ET AL DISCOVERIES

★ KNOWN FIRST APPEARANCE

Parfrey et al. 2011; Erwin et al., 2011

Fieldwork in Mongolia 2014

Ross Anderson etc



Distributions & Taphonomy of Eukaryotic Microfossils

Fieldwork in Svalbard 2014

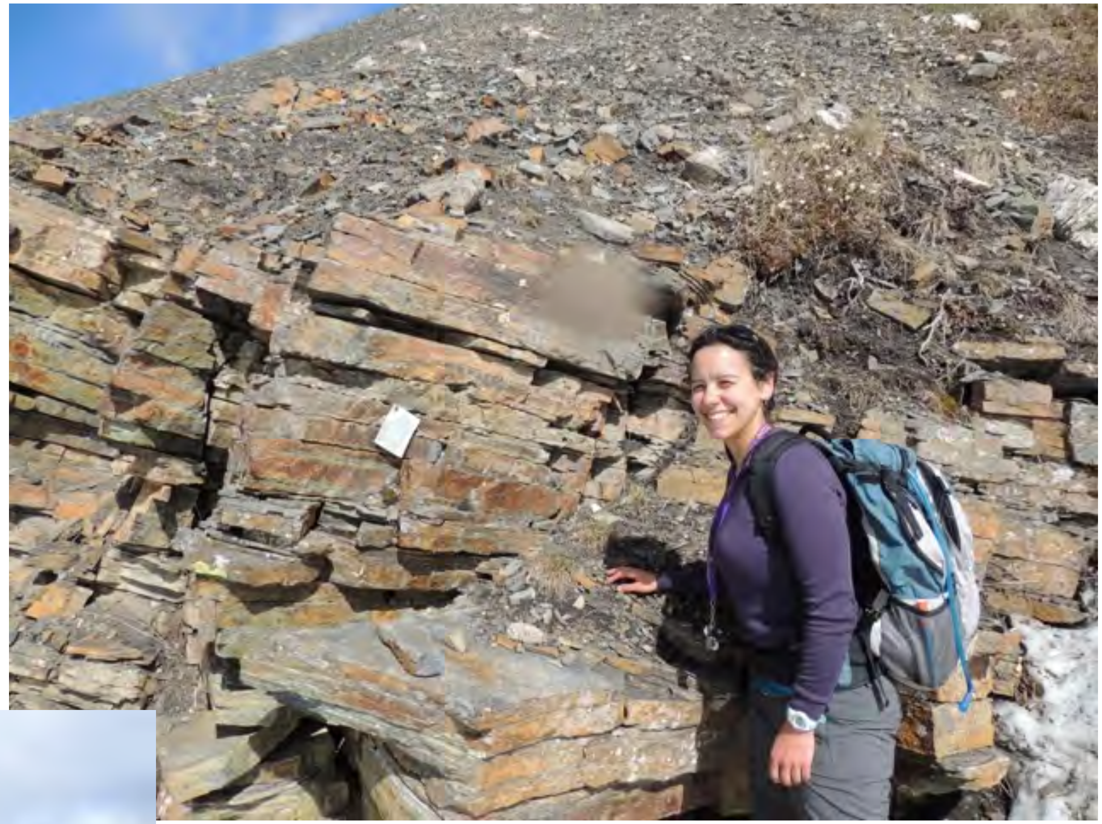
Kristin Bergmann, Andrew Knoll

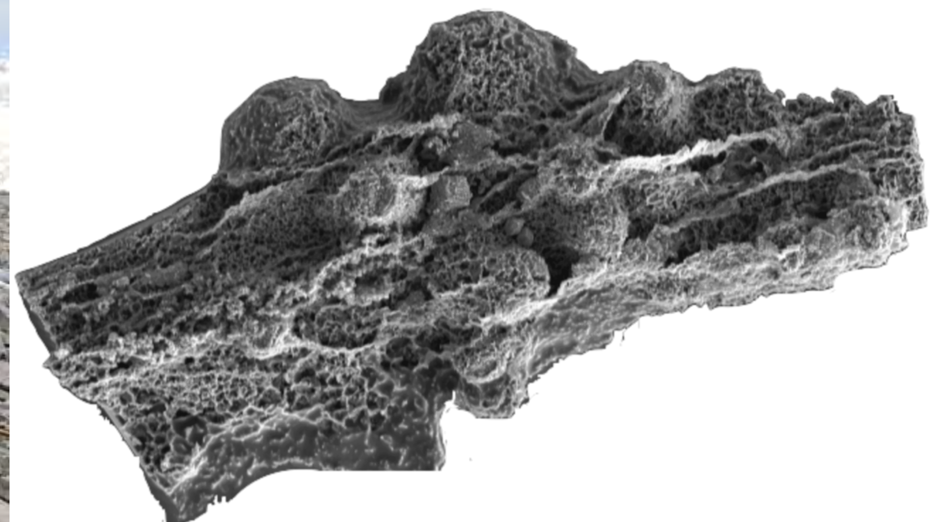
Clumped isotope thermometry, micropaleontology and organic geochemistry of the Bitter Springs anomaly

Yukon Fieldwork 2014

Phoebe Cohen
and Justin Strauss

Distributions and origins of scale microfossils, vase-shaped microfossils & macroscopic organic sheets





Cohen et al., 2014

The Oldest Communities

Fractal Organization Supports Osmotrophy

Foundations of Complex Life Astrobiology Team

How do rangeomorphs compete with bacteria?

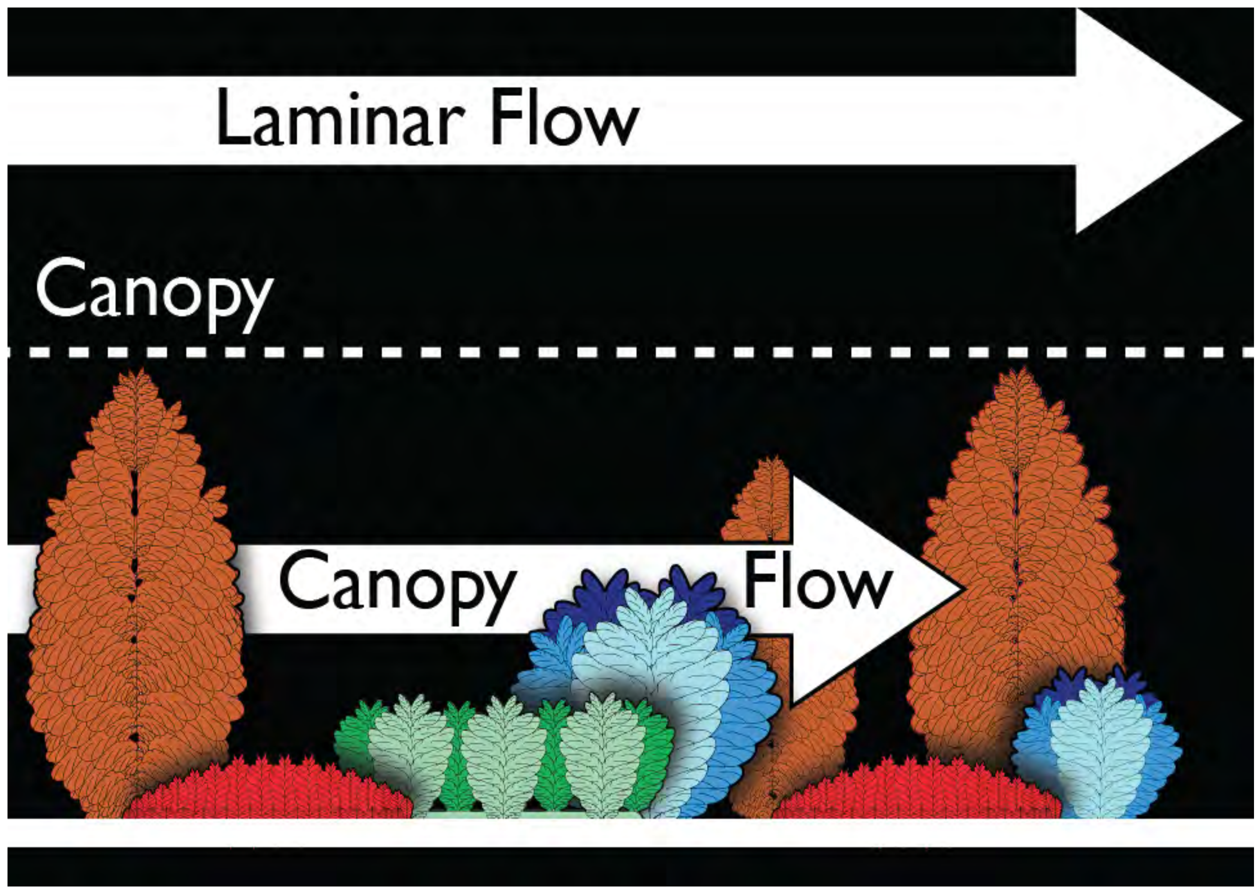
Current Biology 24, 305–309, February 3, 2014 http://dx.doi.org/10.1016/j.cub.2013.12.017

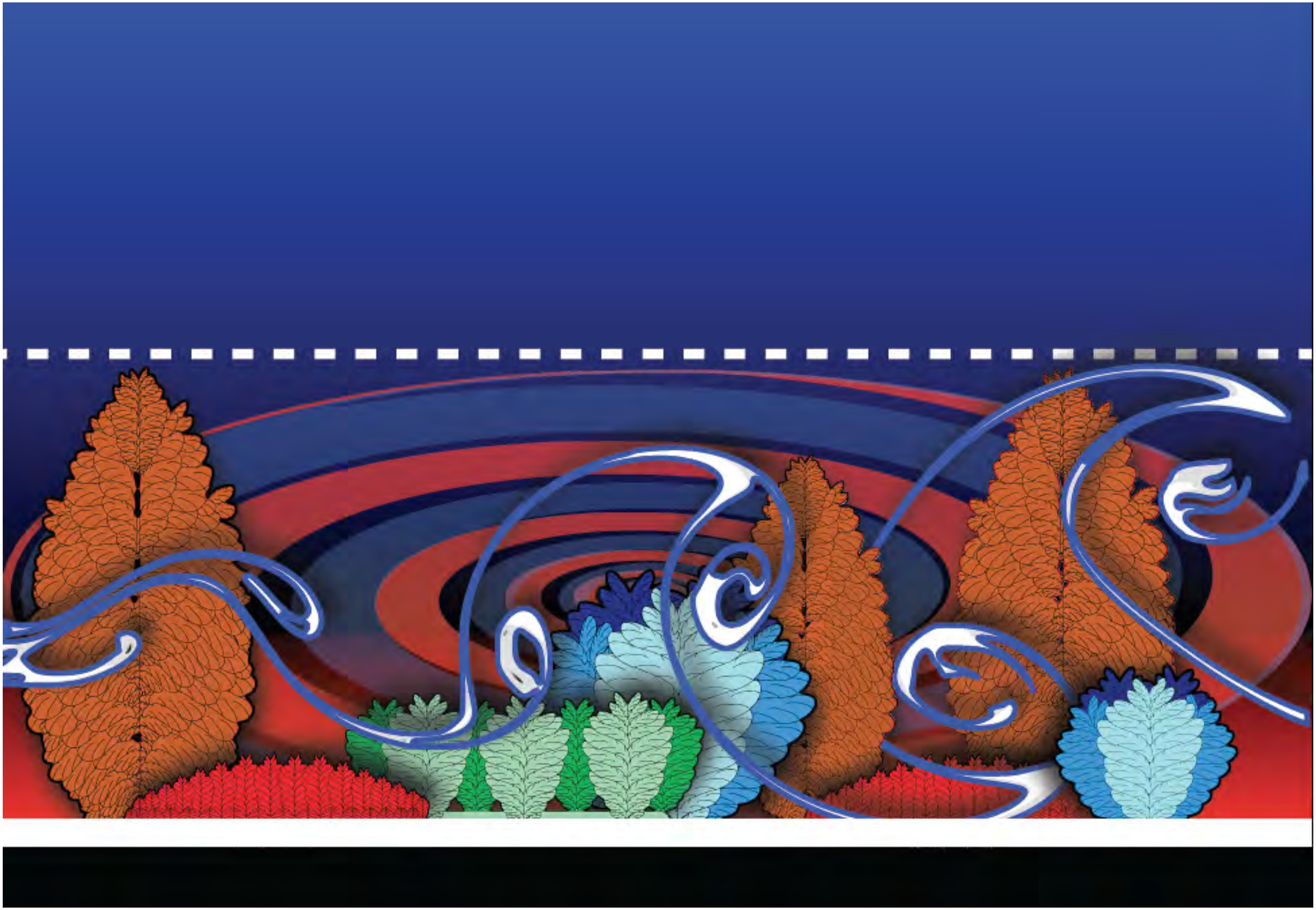
Report

Canopy Flow Analysis Reveals the Advantage of Size in the Oldest Communities of Multicellular Eukaryotes

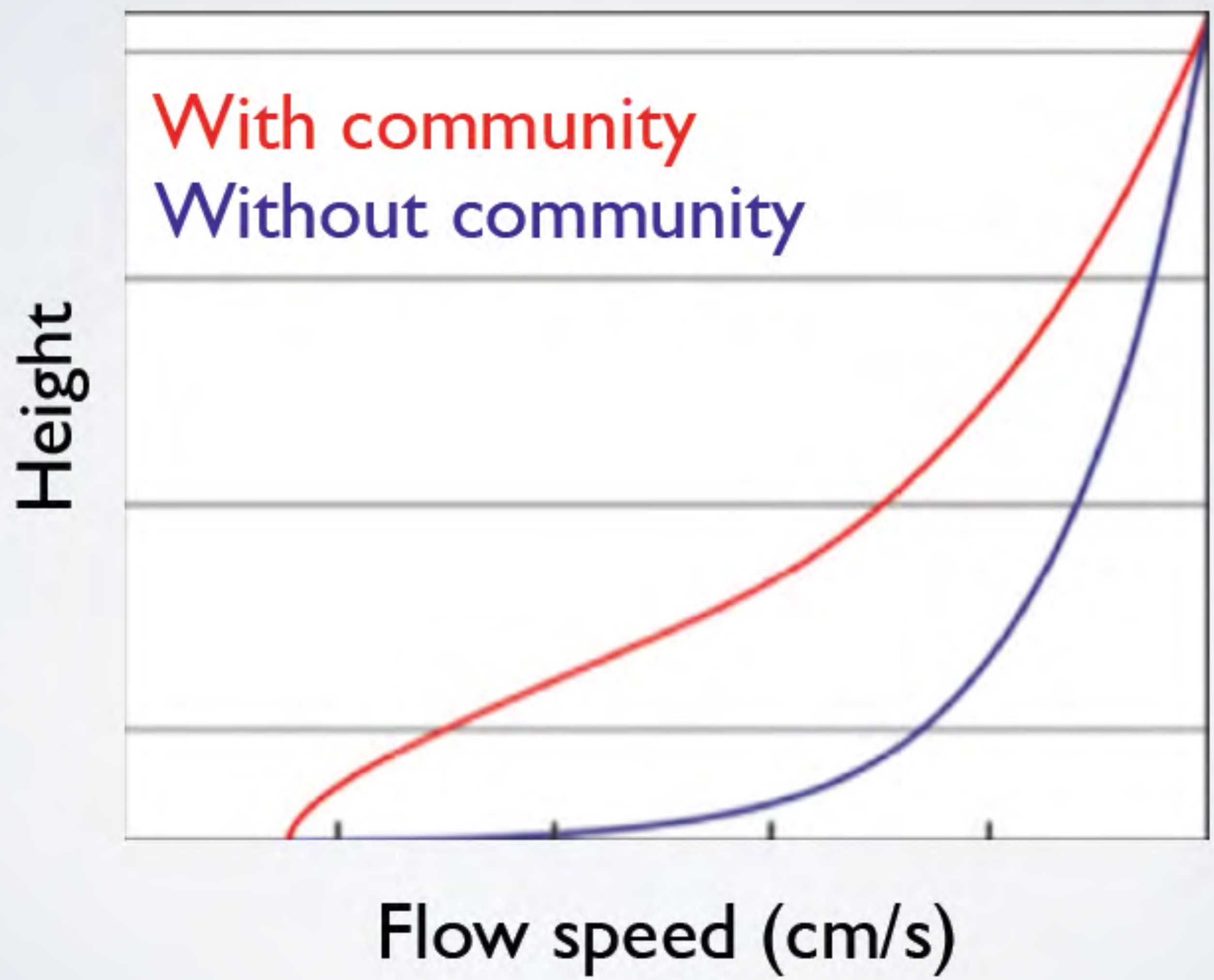
Marco Ghisalberti,[1] David A. Gold,[2] Marc Laflamme,[3] Matthew E. Clapham,[4] Guy M. Narbonne,[5] Roger E. Summons,[6] David T. Johnston,[7] and David K. Jacobs[2,8,*]

Results and Discussion

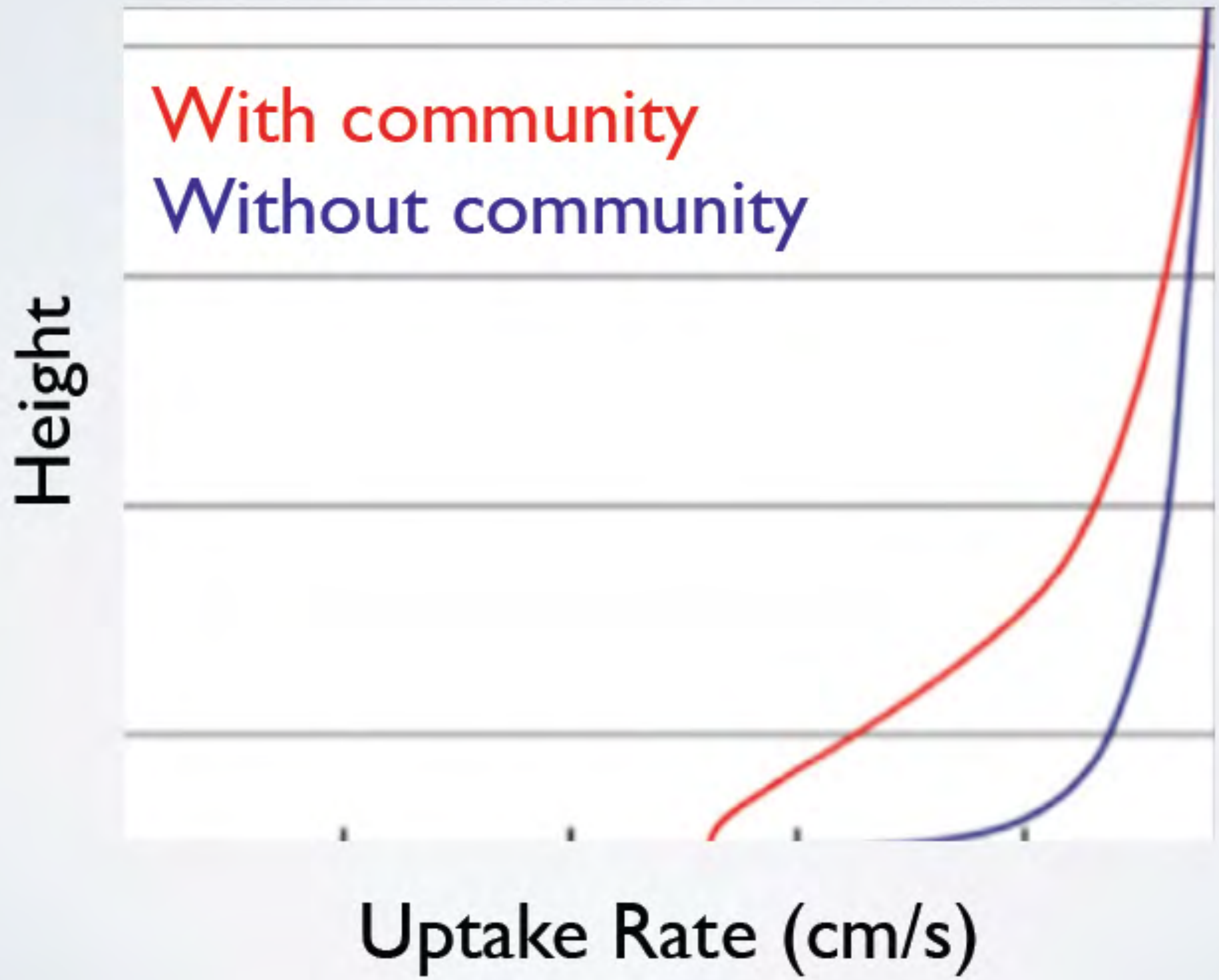




Velocity of water flow increases with height



Uptake potential also increases with height



Integration

Field Geology

Paleontology

Geochemical Data

Genomics and Bioinformatics

Laboratory Experiments

Theory and Modeling