# *True Polar Wander, and its impact on Life?*


## Joe Kirschvink

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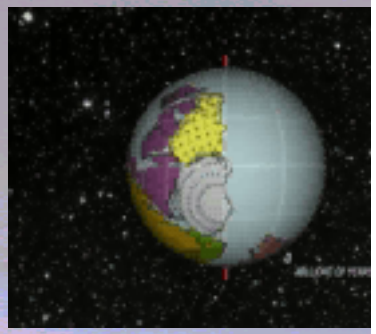
Snowball Earth

And help from:

Tim Raub, Ross Mitchell, Adam Maloof, David Evans,

Chris Thissen, Nic Swanson-Hysell, & Victor Tsai



True Polar Wander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NASA - Exobiology

NSF - EAR


Earth-Life Science Institute, Kickoff Symposium
March 27-29, 2013

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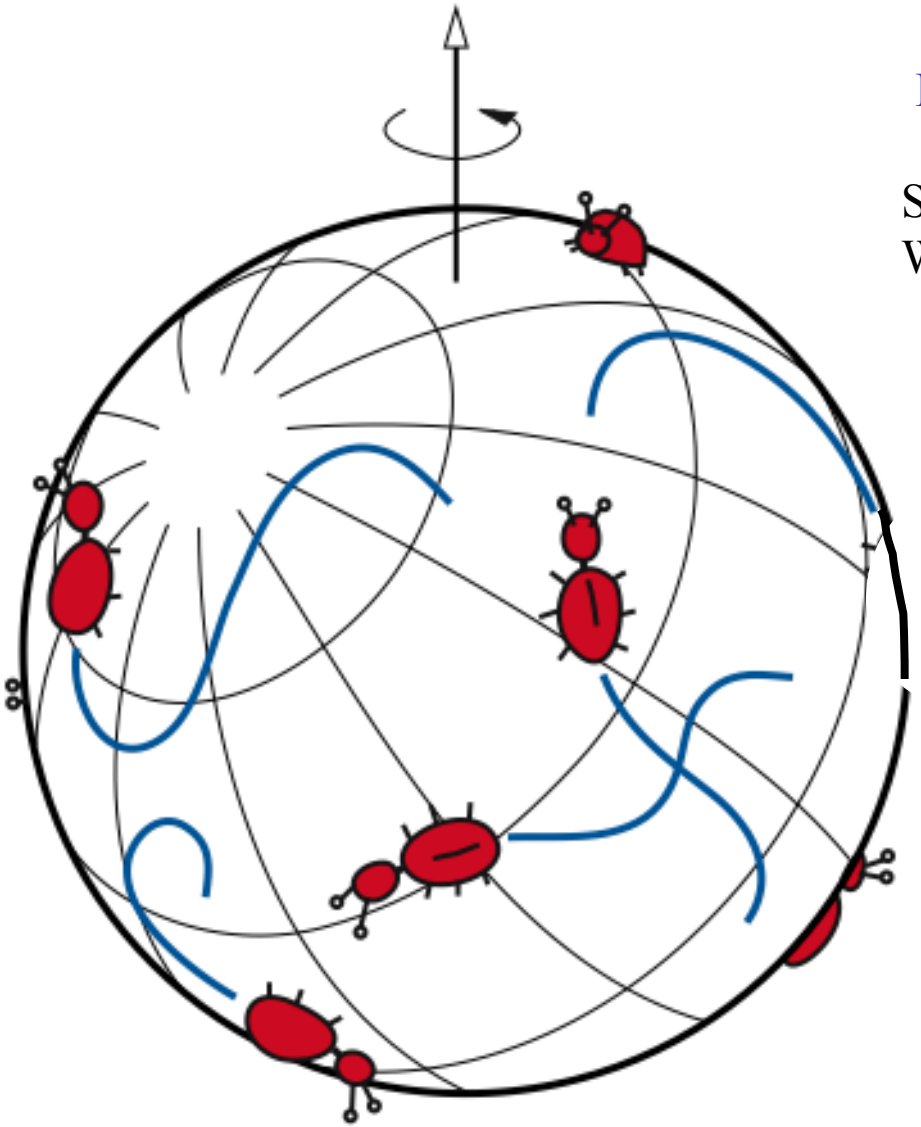
   b. The Bitter Springs Events (c.a., 800 Ma)

III. Plume-Driven? Evidence from the Late Cretaceous … (the REAL cause for Dinosaur's death!)

# TRUE POLAR WANDER

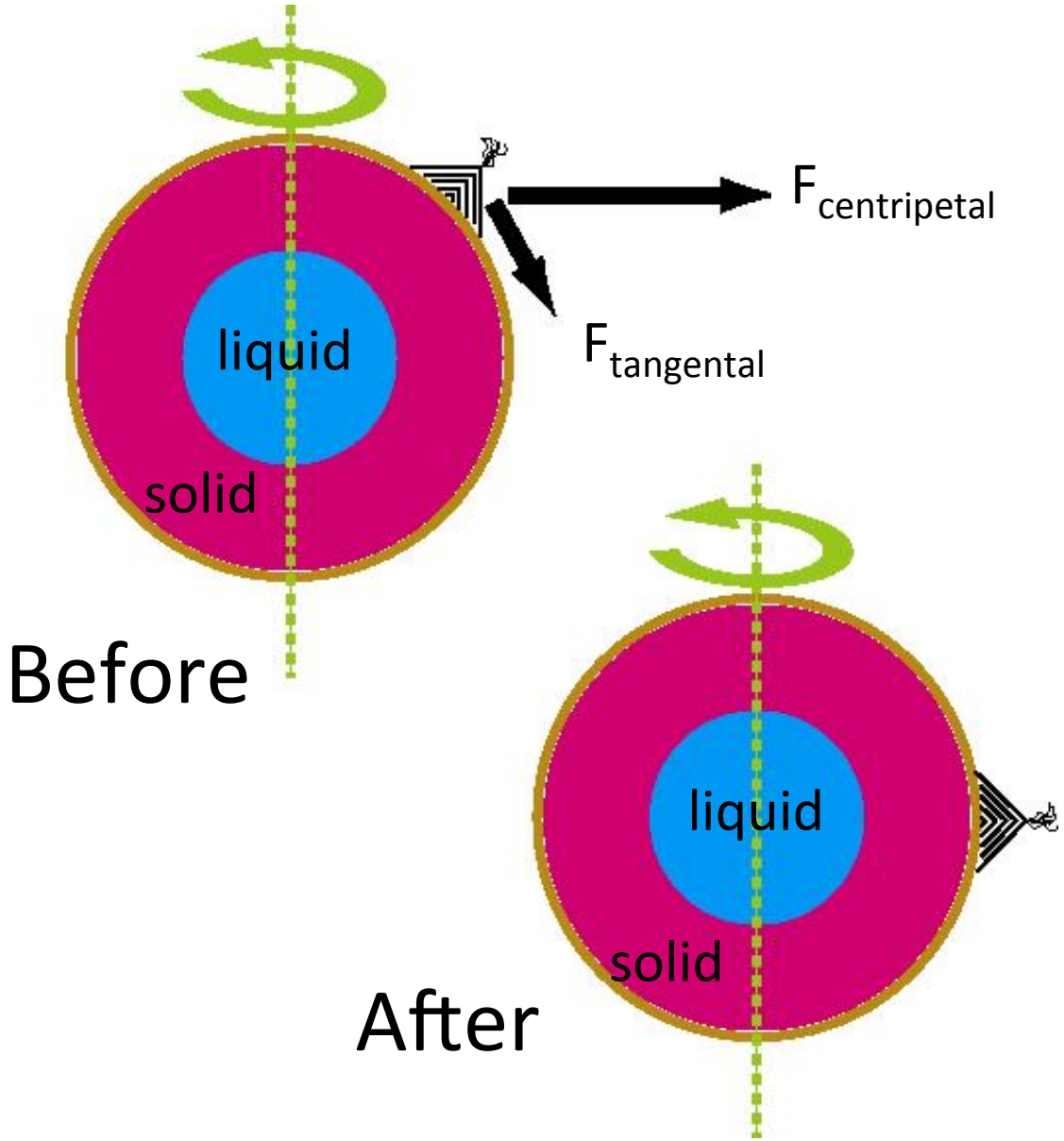


Peter Goldreich & Alar Toomre

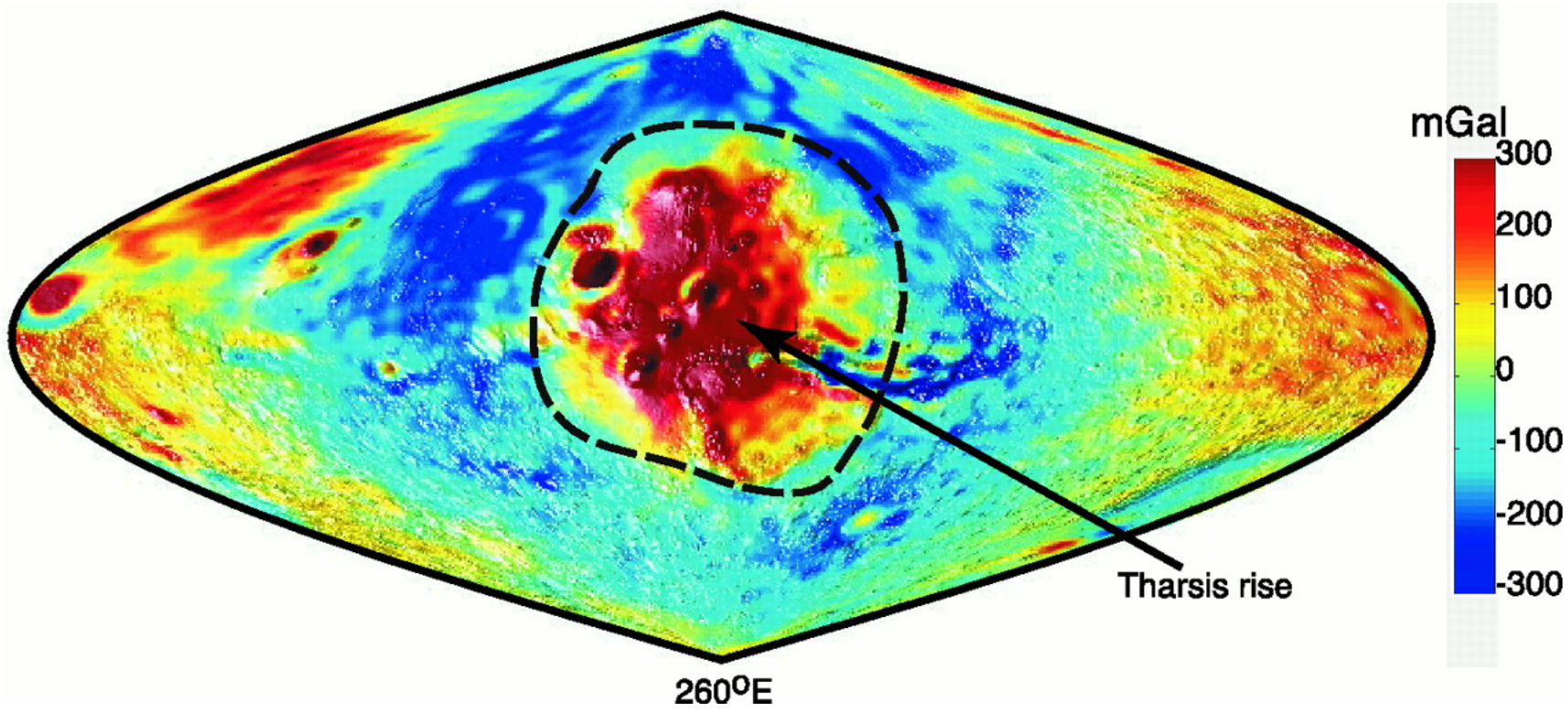
Some remarks on Polar Wandering. JGR 74, 1969.

*Gold (1955), Goldreich and Toomre (1969)*

# A Positive Mass Anomaly will be Pulled to the Equator

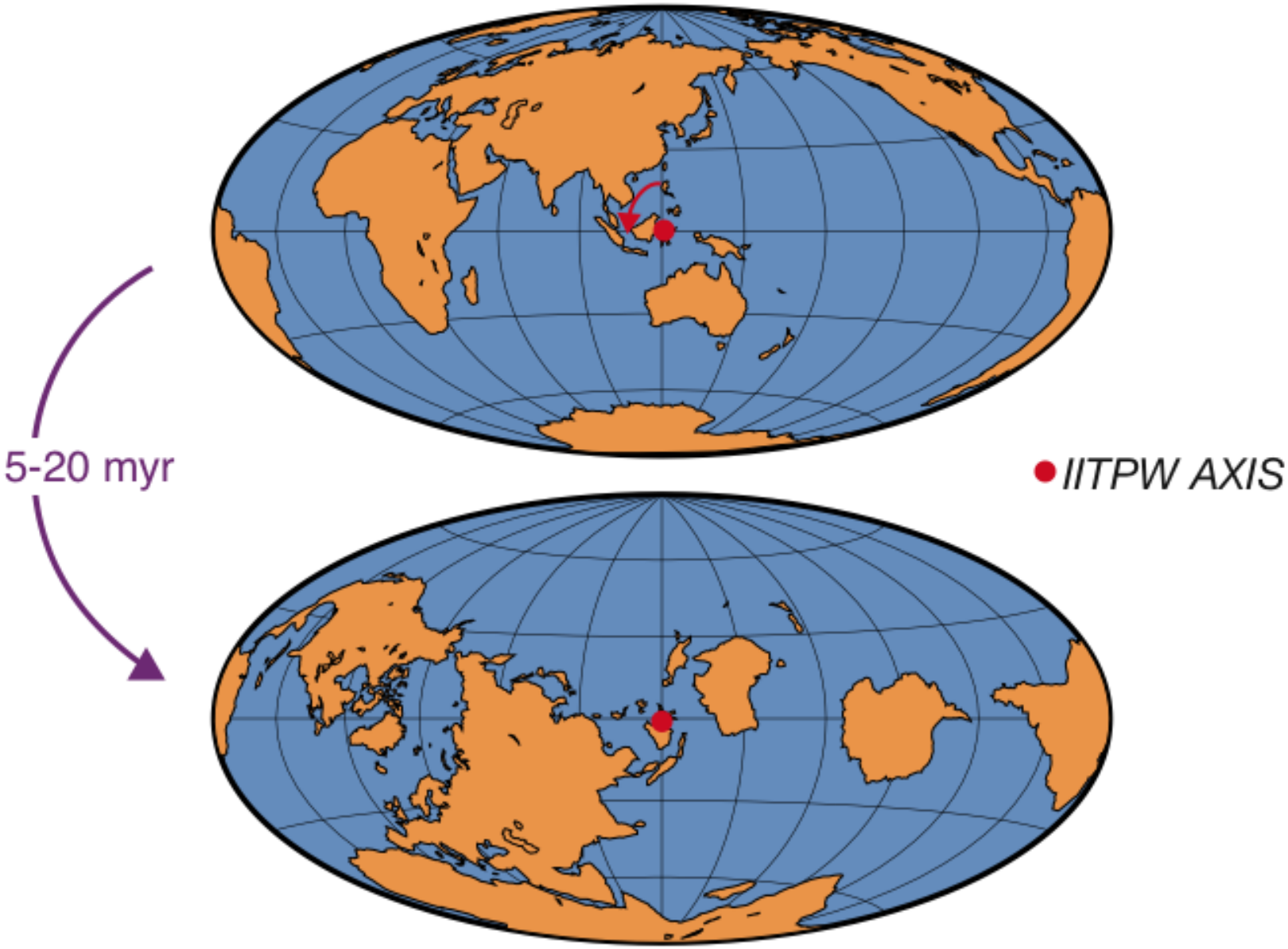


# The Tharsis Volcanic Province on Mars Produces the Largest Known Gravity Anomaly in the Solar System




From: Phillips, Zuber, Solomon, et al. Science 291: (5513) 2587-2591 MAR 30 2001

# AN INERTIAL INTERCHANGE EVENT TODAY




Courtesy Adam Maloof

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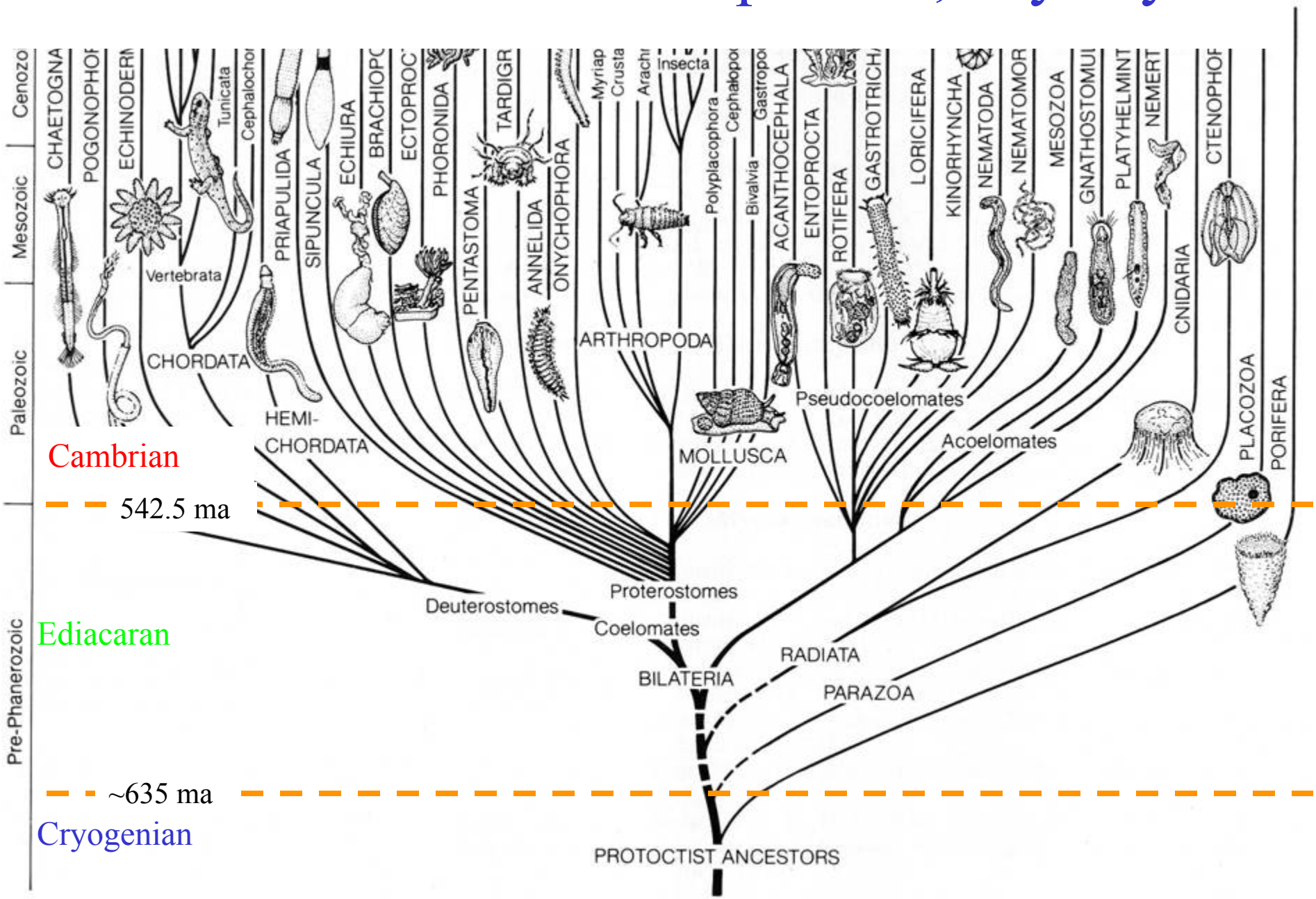
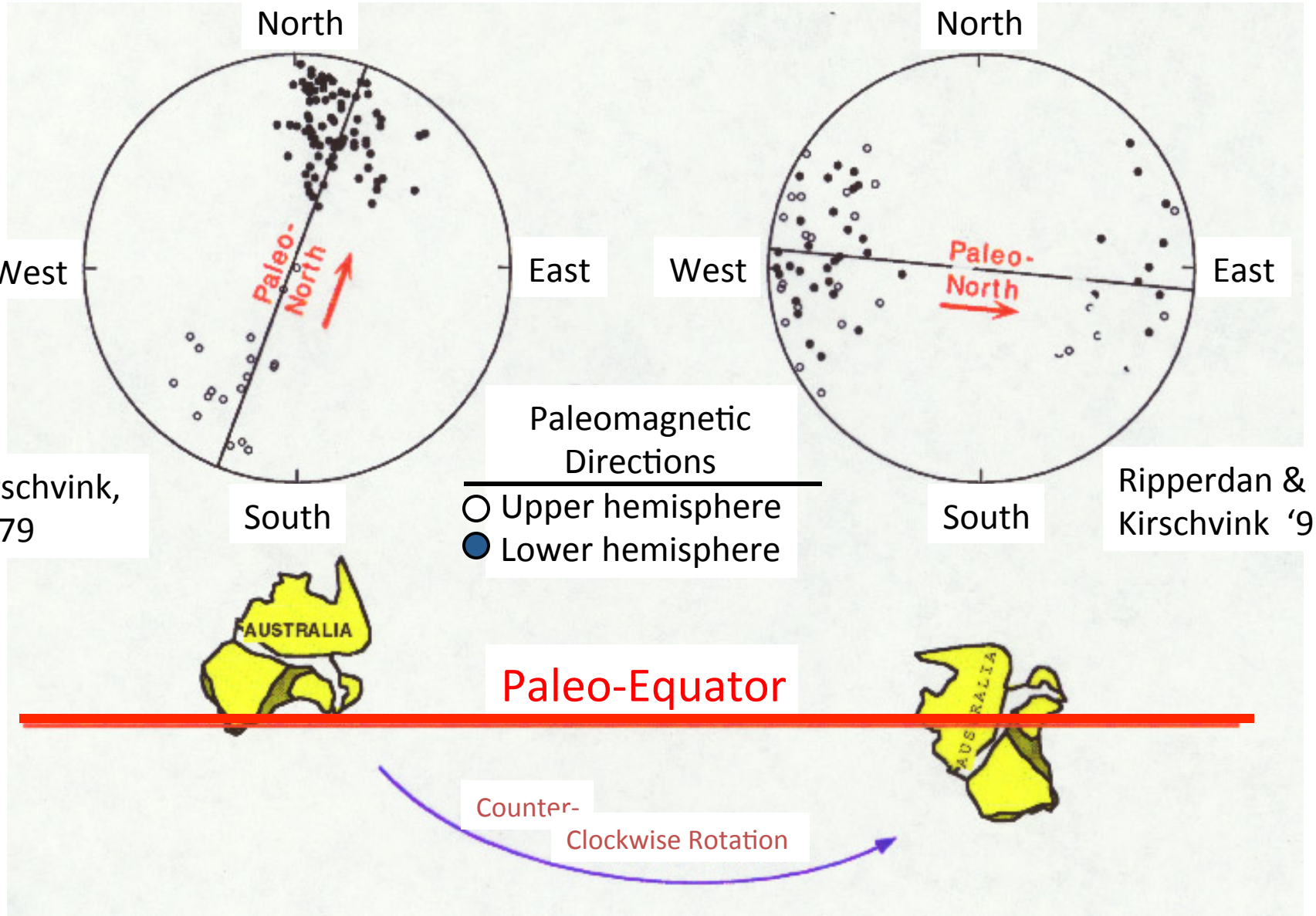
# What is the Cambrian Explosion, anyway?

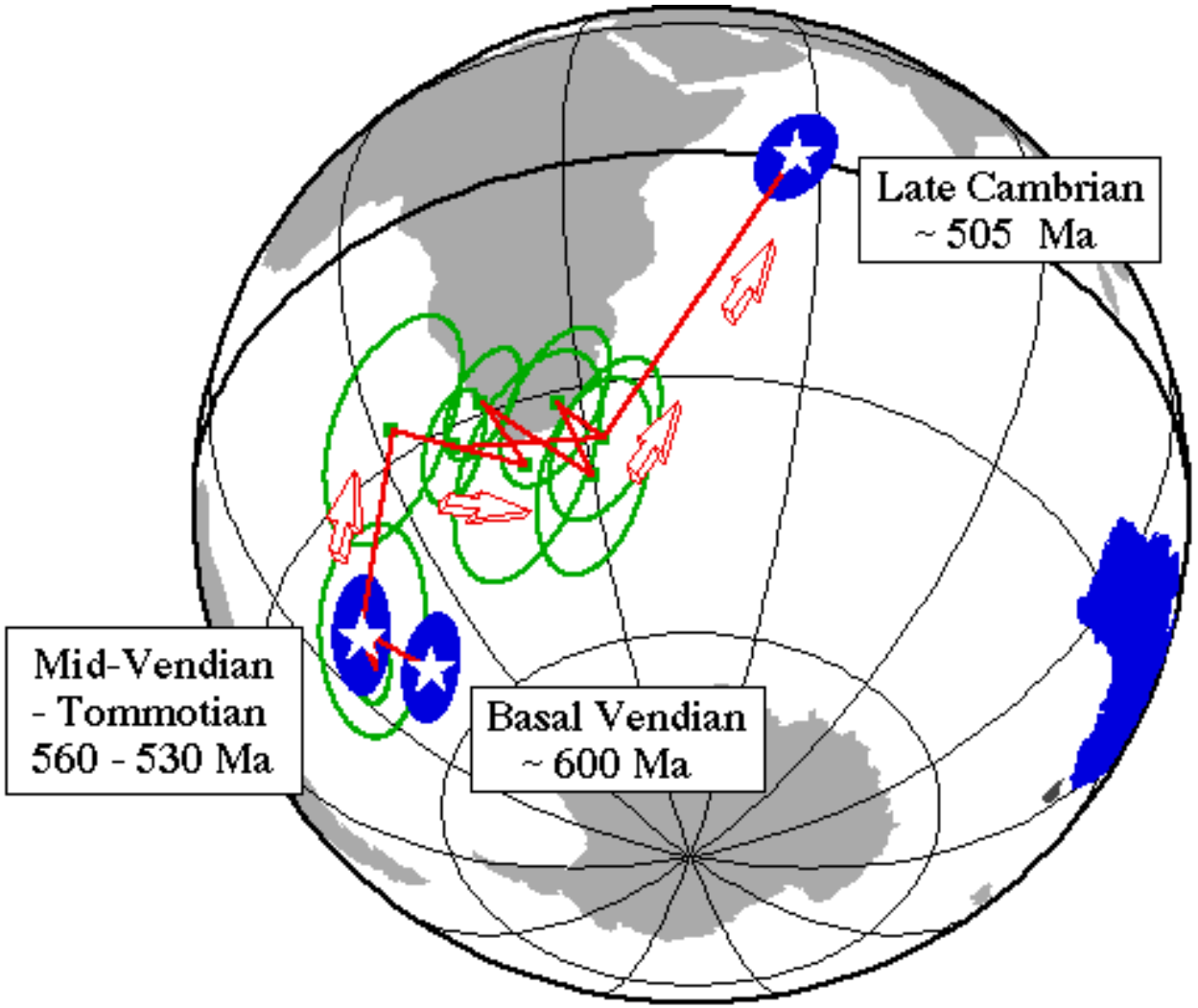


# Cambrian Rotation of Australia

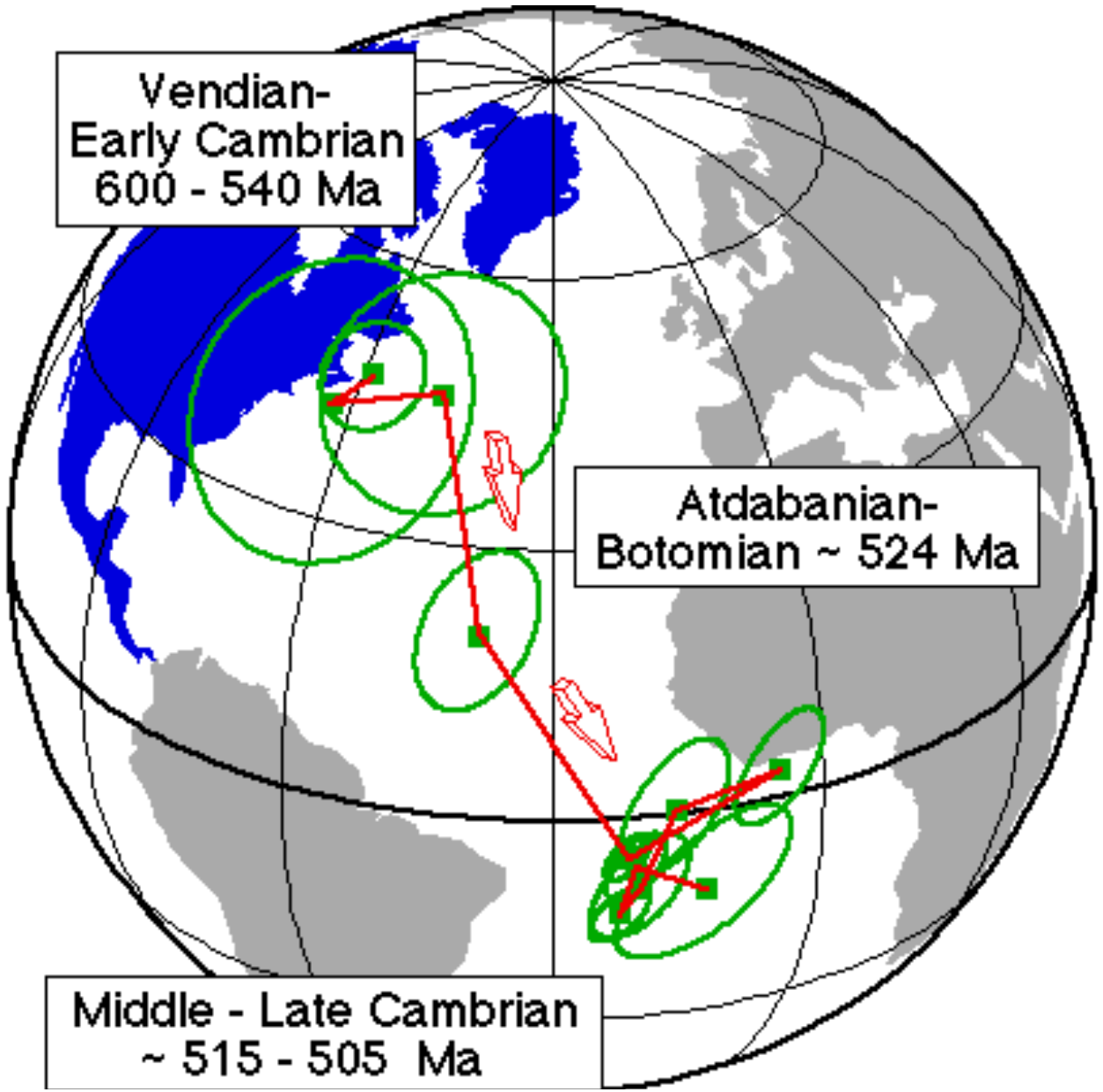
– pC/C Boundary  C/O Bdry



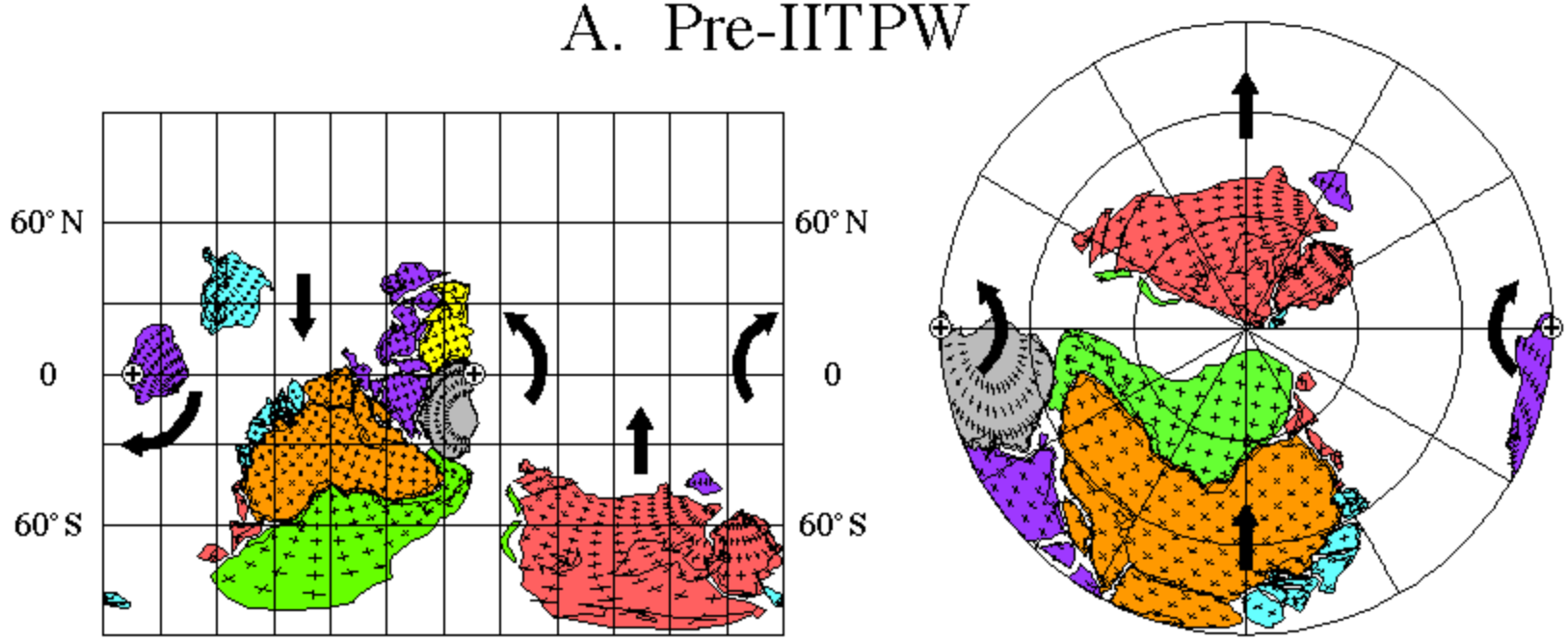
# Australian APW Path



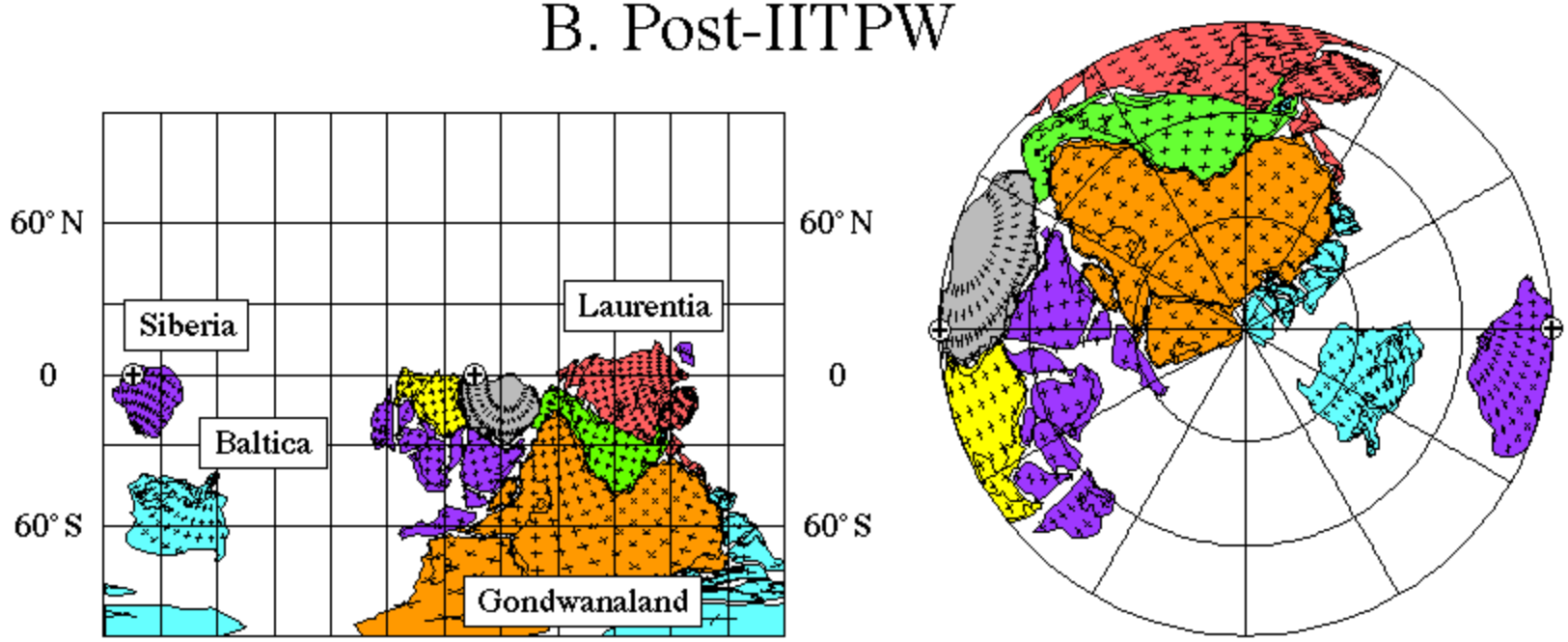
# North America APW Path



# A. Pre-IITPW




# B. Post-IITPW



# *Early Cambrian True Polar Wander Animation*

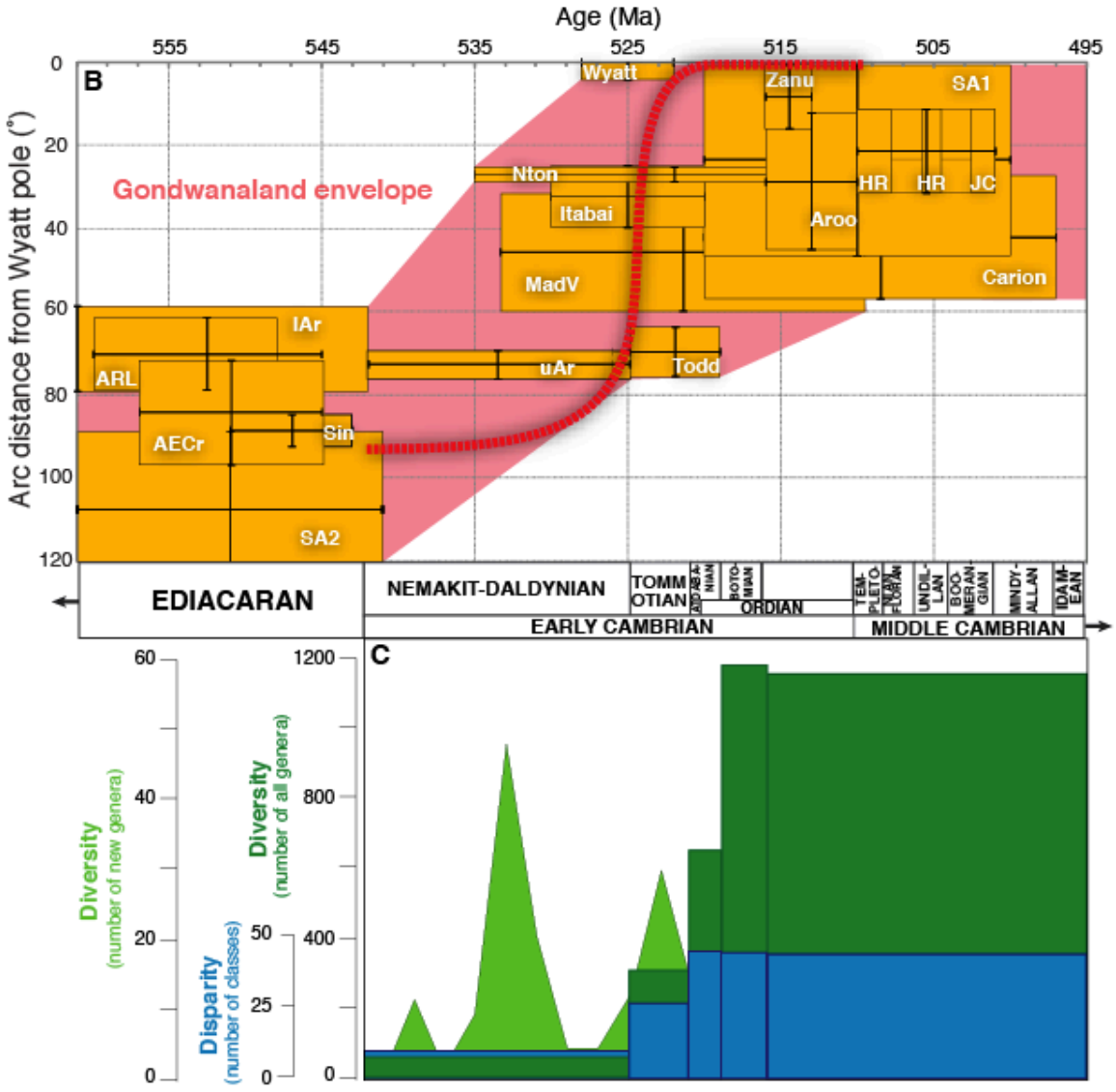
**Joseph L. Kirschvink**
Division of Geological & Planetary Sciences
California Institute of Technology

**Robert L. Ripperdan**
Department of Geology
University of Puerto Rico, Mayaguez

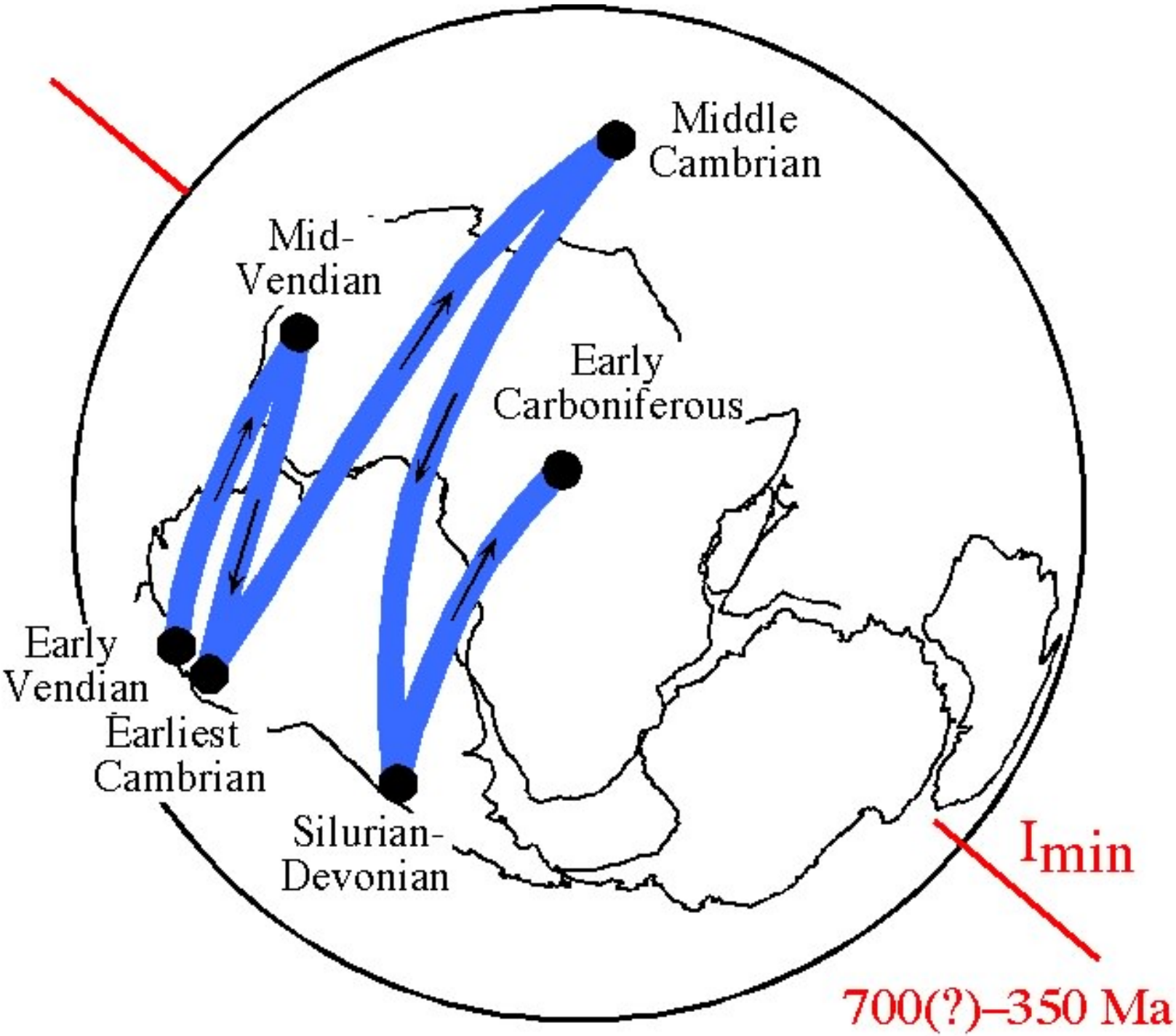
**David A. Evans**
Division of Geological & Planetary Sciences
California Institute of Technology

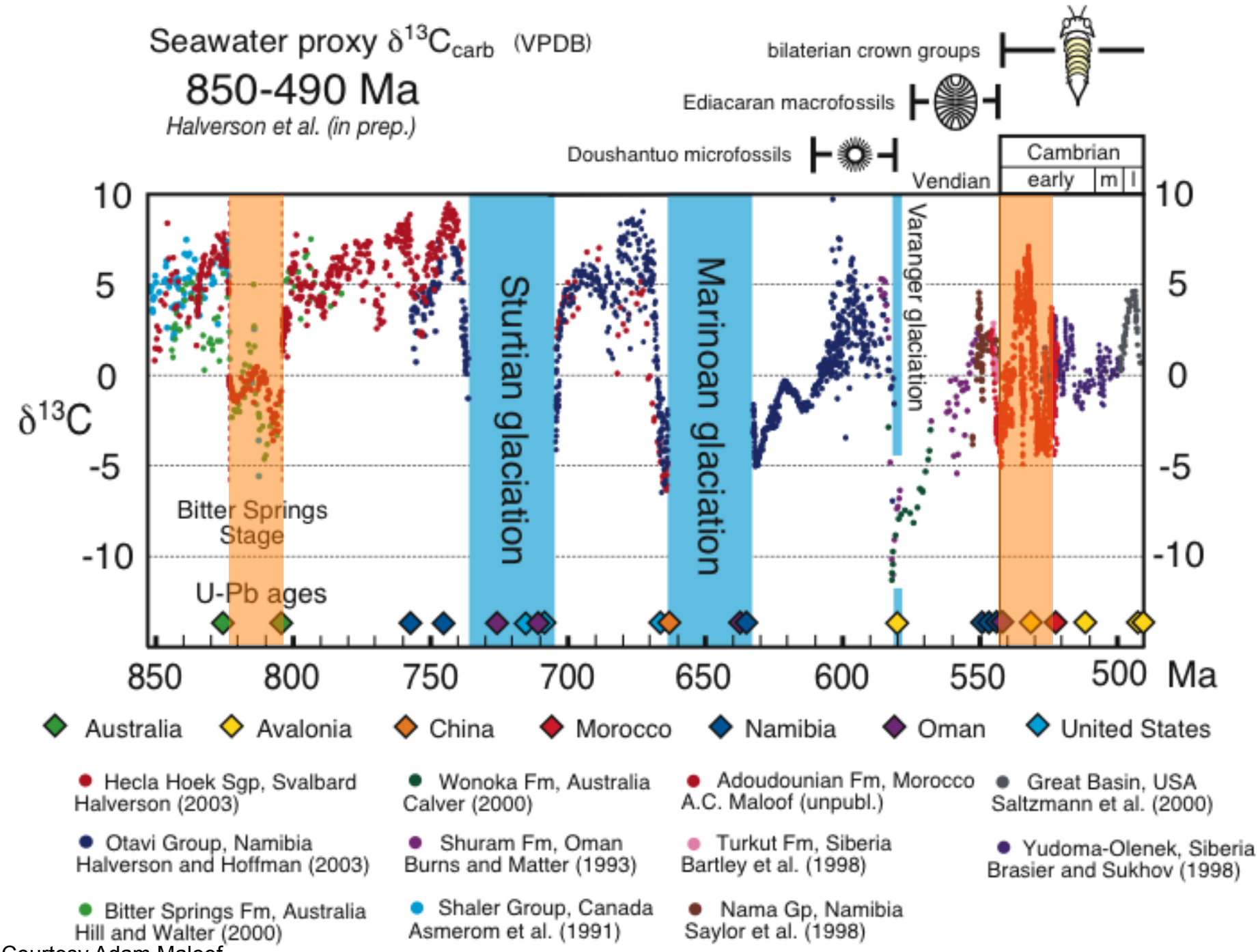
# Rapid Early Cambrian rotation of Gondwana

**Ross N. Mitchell, David A.D. Evans, and Taylor M. Kilian**
Department of Geology and Geophysics, Yale University, 210 Whitney Avenue, New Haven, Connecticut 06511, USA




*Geology, August 2010; v. 38; no. 8; p. 755–758; doi: 10.1130/G30910.1*


Middle
Cambrian
Mid-
Vendian
Early
Carboniferous
Early
Vendian
Earliest
Cambrian
Silurian-
Devonian
Imin
700(?)–350 Ma




Courtesy Adam Maloof

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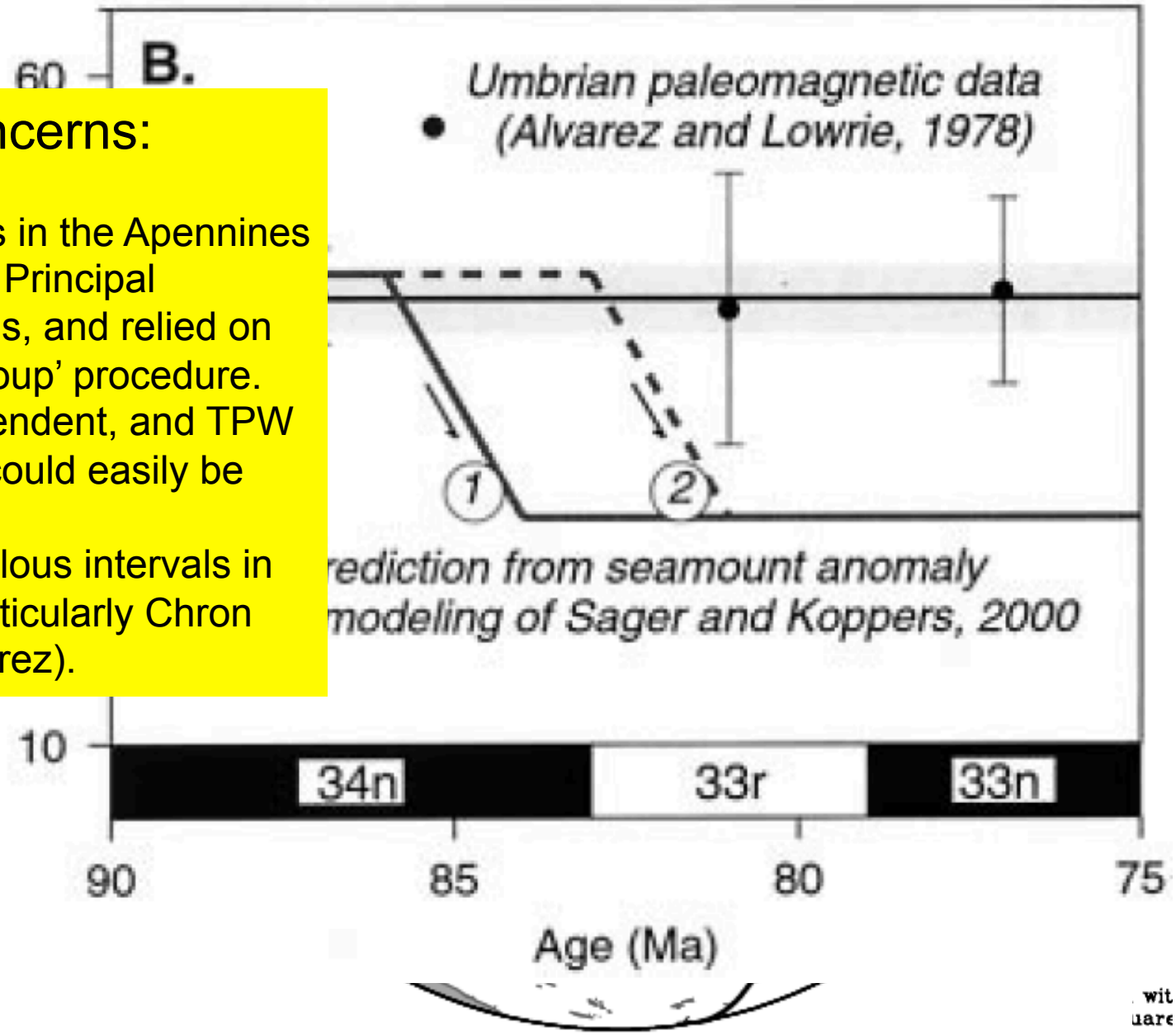
## Our concerns:

- Most of the studies in the Apennines pre-date the use of Principal Component Analysis, and relied on the 'best demag group' procedure. Data are not independent, and TPW events of this sort could easily be obscured.
- There ARE anomalous intervals in the Italian data, particularly Chron 33R (Lowrie & Alvarez).




Late Cretaceous TPW debate: Sager & Koppers vs. Cottrell & Tarduno, 2000

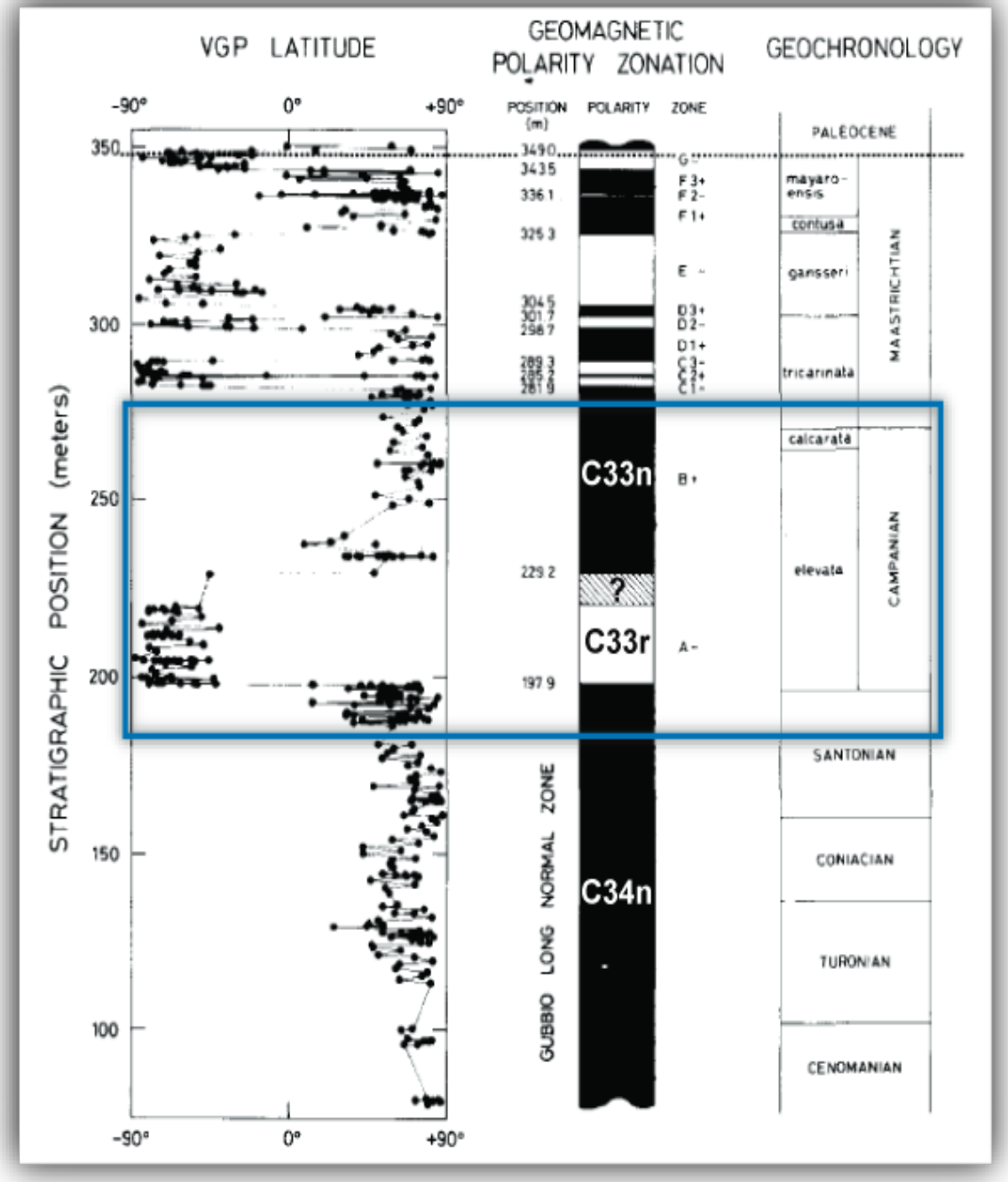
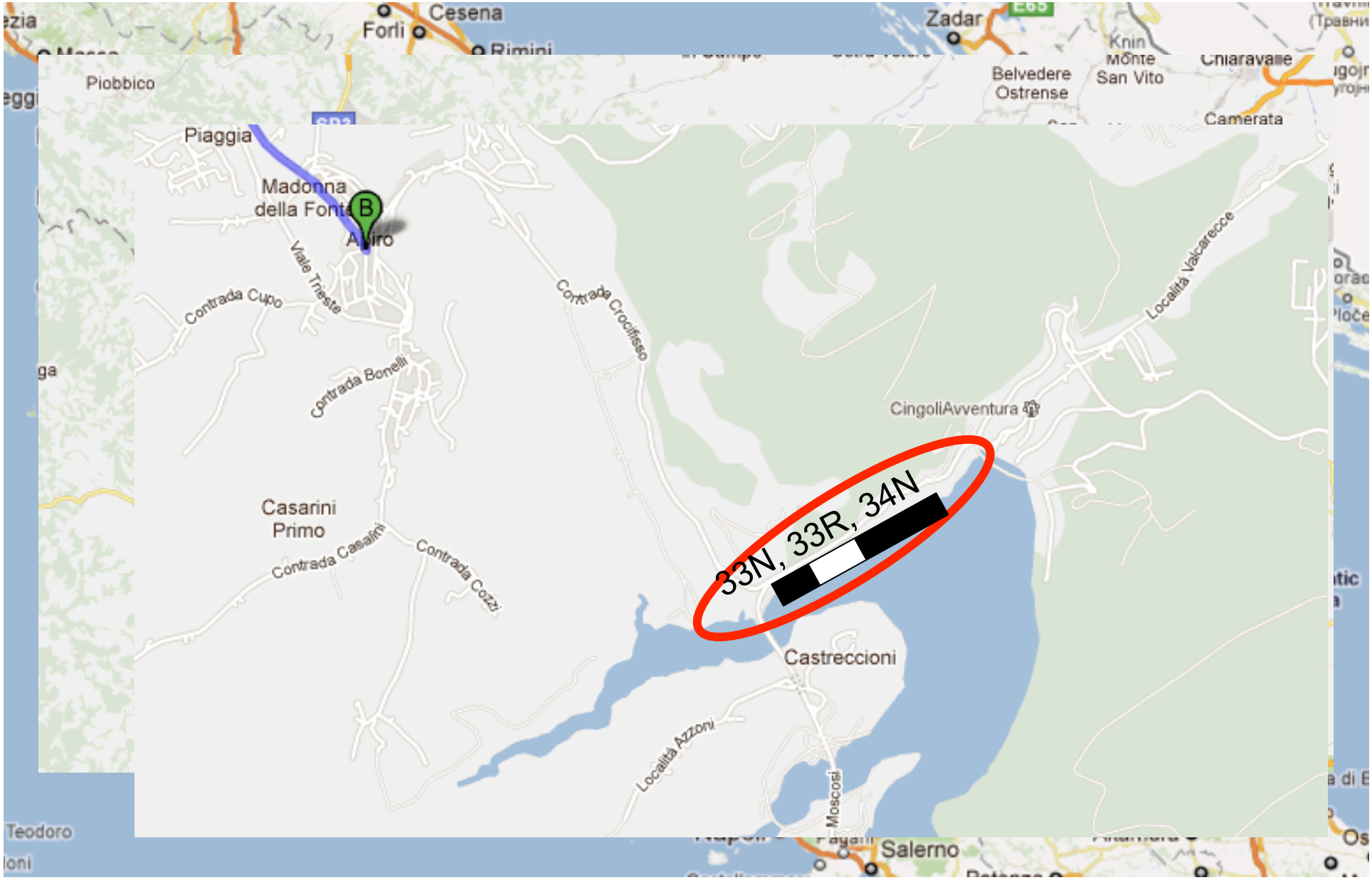
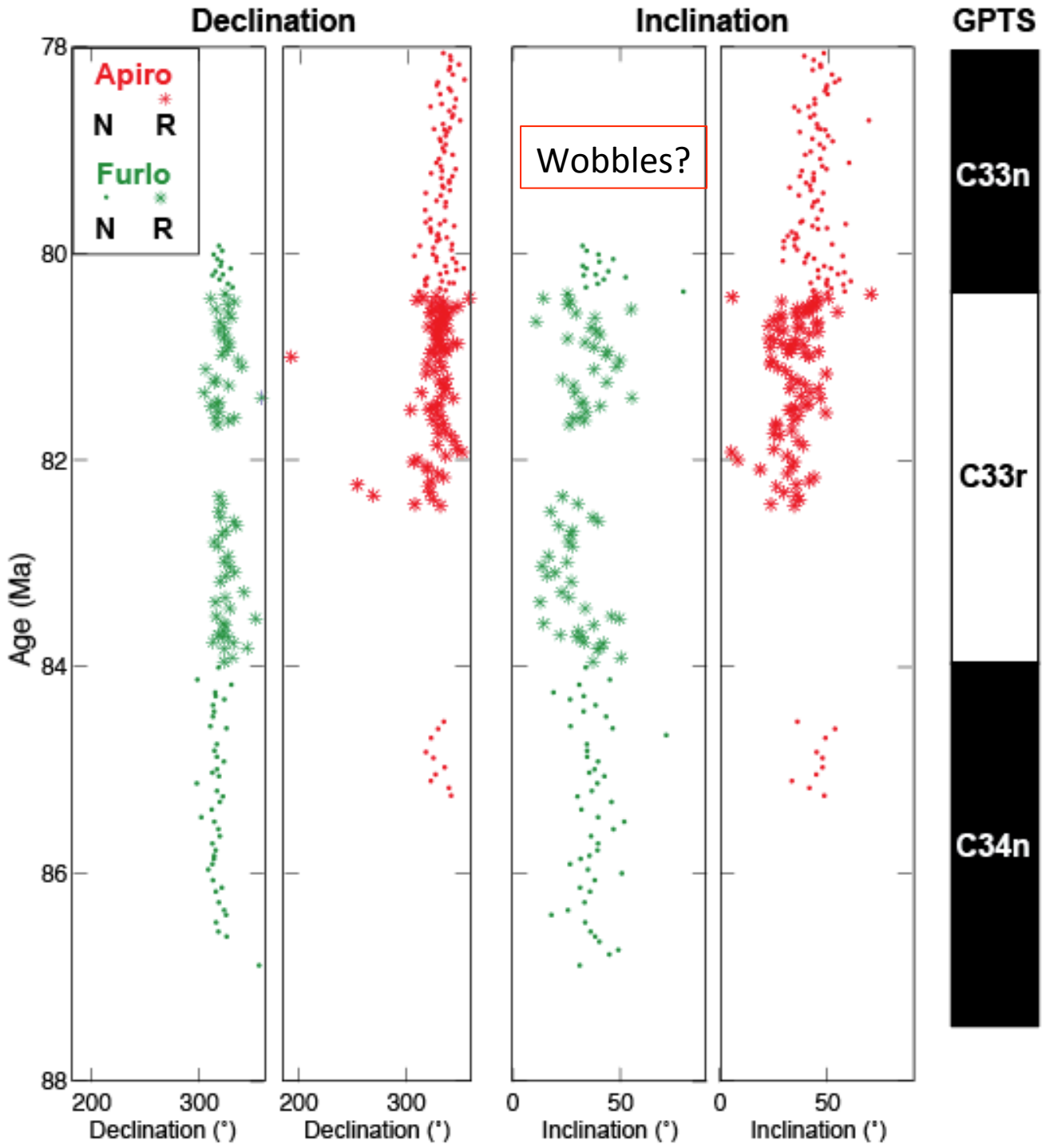


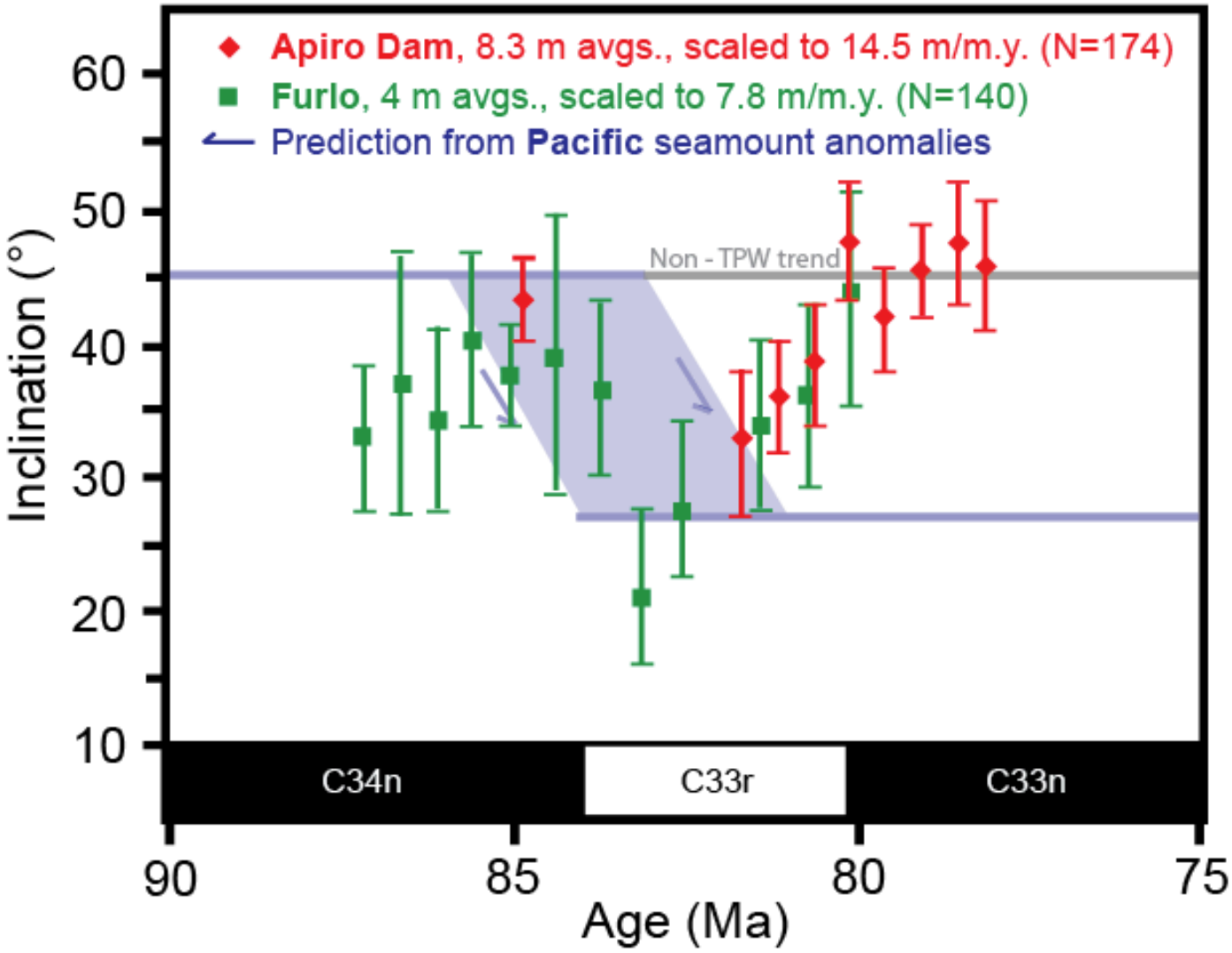

**Fig. 1** Classic magnetostratigraphy of the Scaglia Rossa at the Gubbio section by Lowrie and Alvarez (1977) which matched contemporary seafloor polarity patterns so well. Blue box indicates focus of our re-study; note the transitional (?) polarity zone in between C33r and C33n. This critical interval at the Gubbio section, however, is plagued by both faults and slumps, the latter of which can give rise to spurious, seemingly transitional paleomagnetic directions (Alvarez and Lowrie, 1984), not to mention the shortcomings of outmoded paleomagnetic laboratory methods and analytical techniques discussed in the text. See Fig. 3 to witness the decreased scatter of the new Italy data that prompt this proposal--the increased precision being requisite for identifying relatively small-magnitude (10°) TPw cycles.



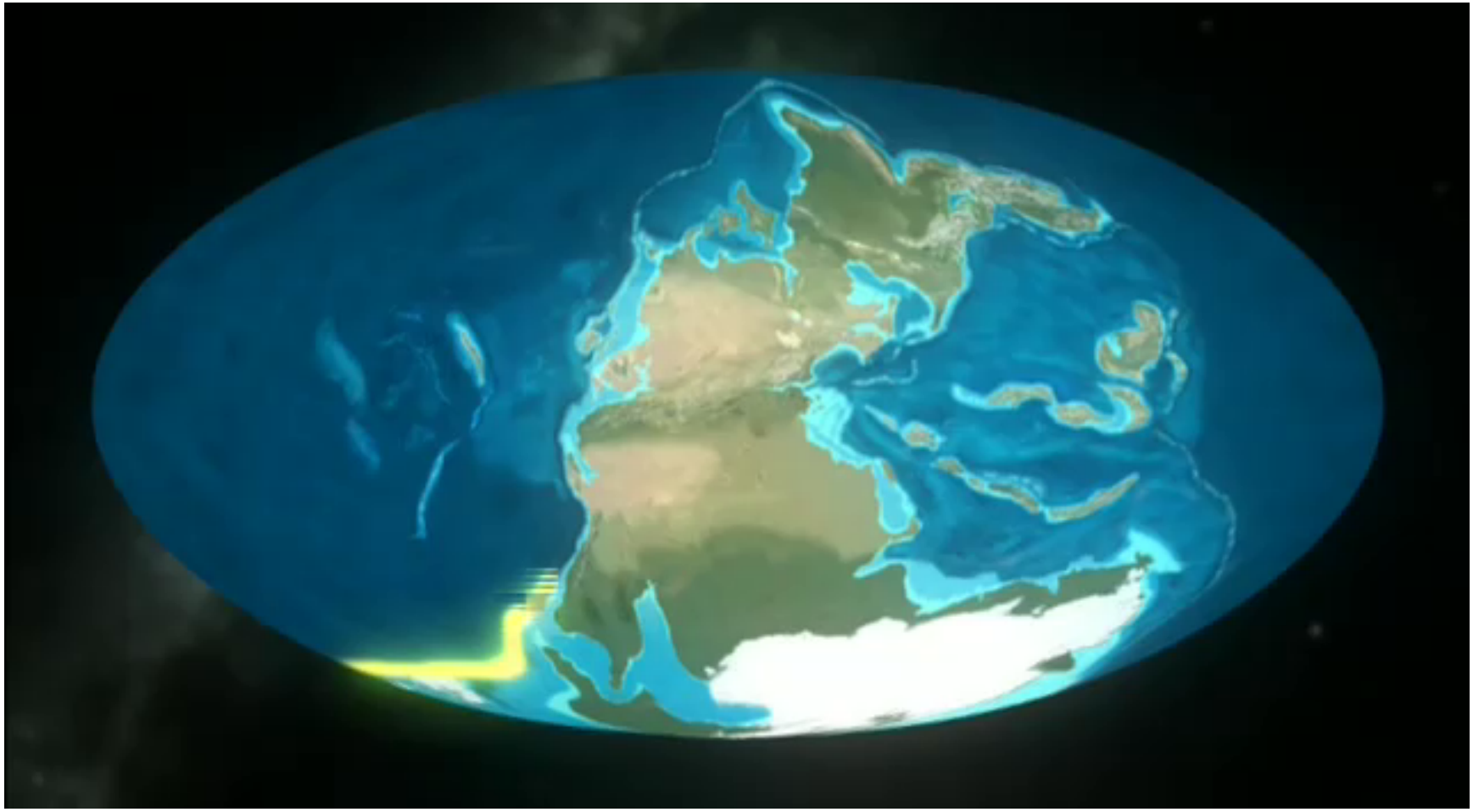

Gubbio to Apiro, Italy ….


33N
33R
265
264
C10APD
May 11, '10
263
262
261
260
259
258
257
256
255
254
253
252


Declination
Inclination
GPTS
Apiro
N R
Furlo
N R
Wobbles?
C33n
C33r
C34n
Age (Ma)
78
80
82
84
86
88
200
300
Declination (°)
0
50
Inclination (°)


Apiro Dam, 8.3 m avgs., scaled to 14.5 m/m.y. (N=174)
Furlo, 4 m avgs., scaled to 7.8 m/m.y. (N=140)
Prediction from Pacific seamount anomalies
Non - TPW trend
Inclination (°)
60
50
40
30
20
10
C34n
C33r
C33n
90
85
80
75
Age (Ma)

# Super-Plume Eruption (for P/T boundary_



From NHK, “Miracle Planet II”

# Indian Superplume and TPW

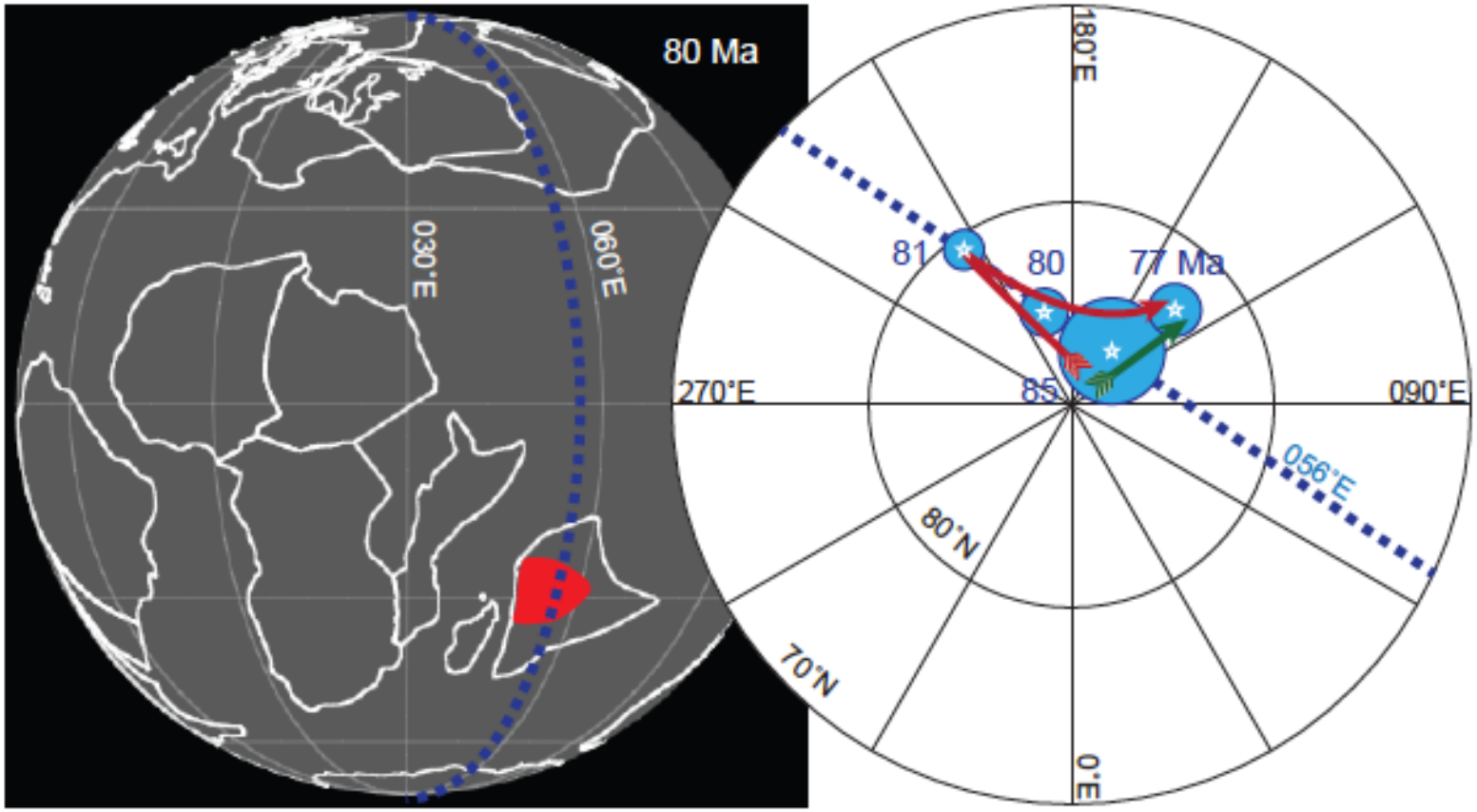
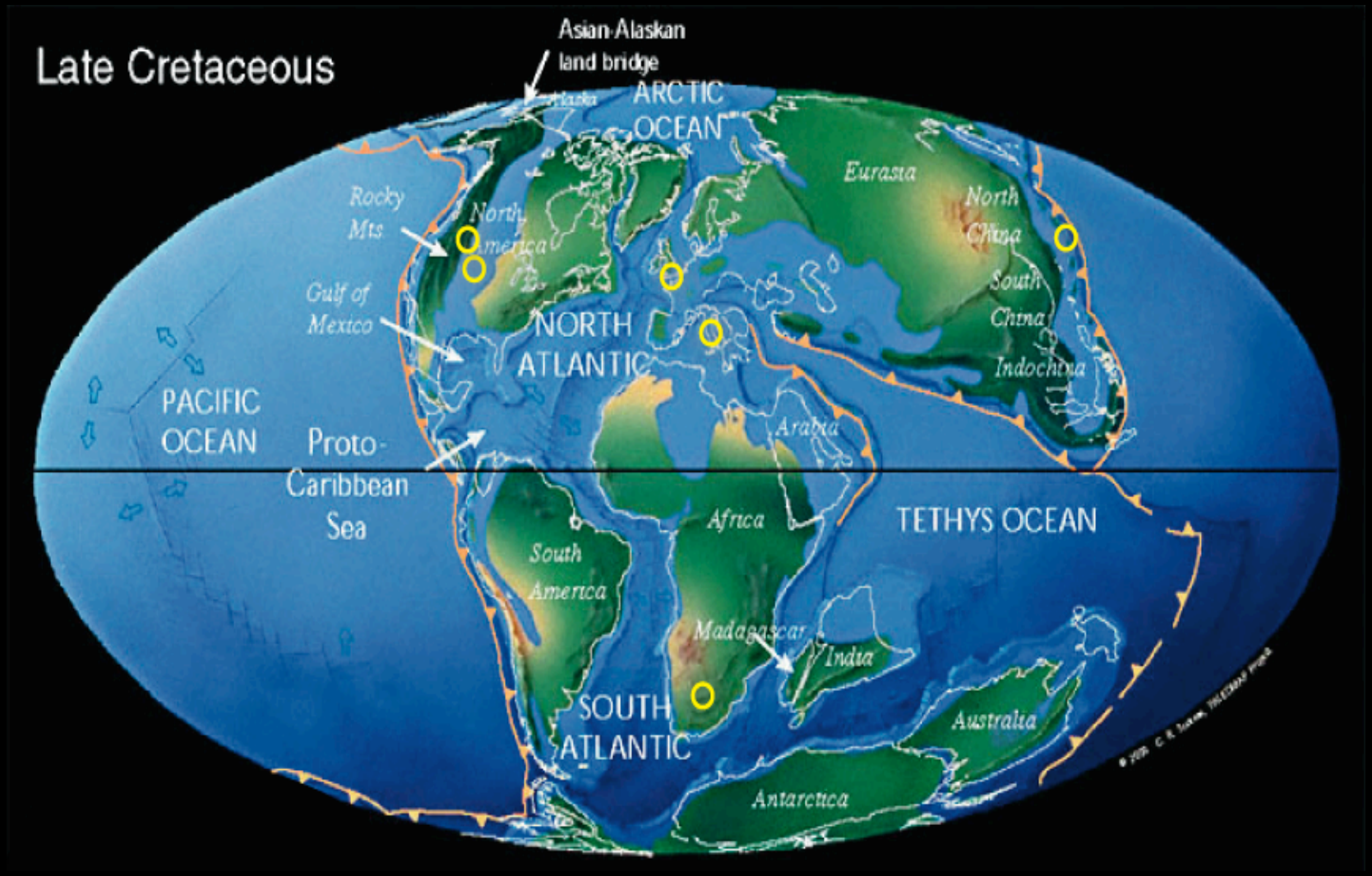


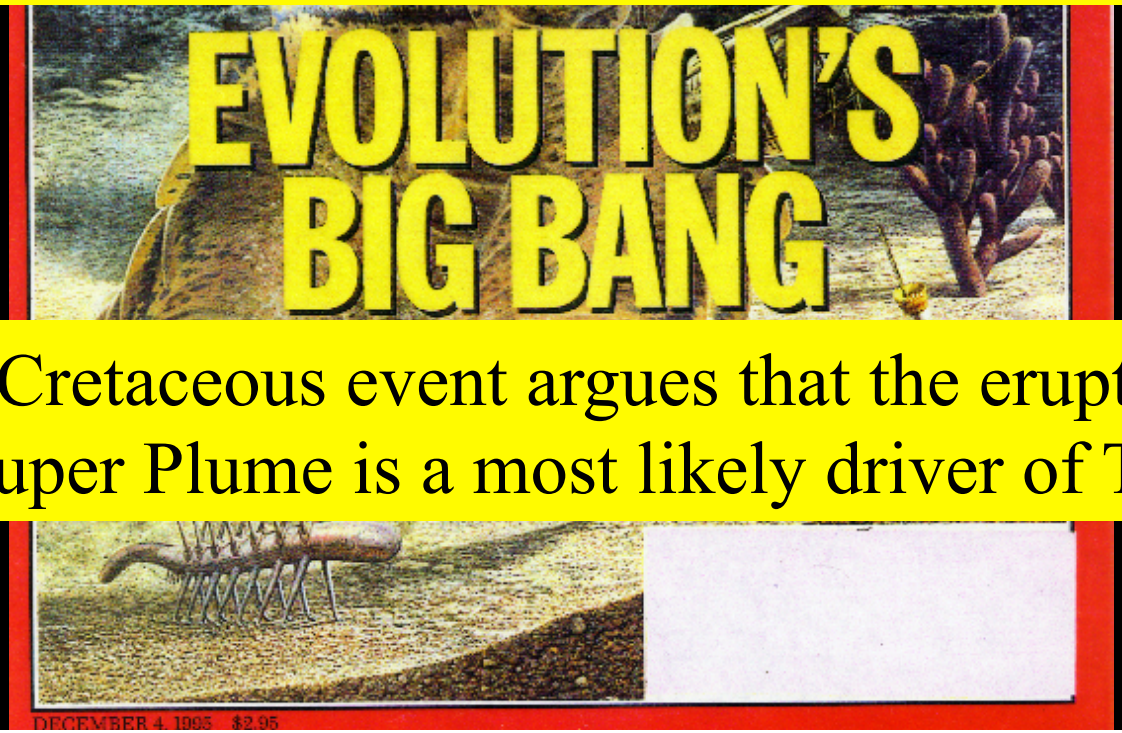

**Fig. 1** (Left) Paleogeographic reconstruction at 80 Ma with locations of (future, 65 Ma) Deccan traps and great circle from Italy data. (Right) Zoomed-in plot of pole positions from Scaglia Rossa limestones (*5*). Red arrow indicates APW path, which is dominated by a ~10° oscillation. Green arrow indicates longer-term variation interpreted as tectonic motion. Dashed line is best-fit great circle to poles (excluding 77 Ma) and is superimposed on left.

# Proposed localities of C33r interval for three-year project

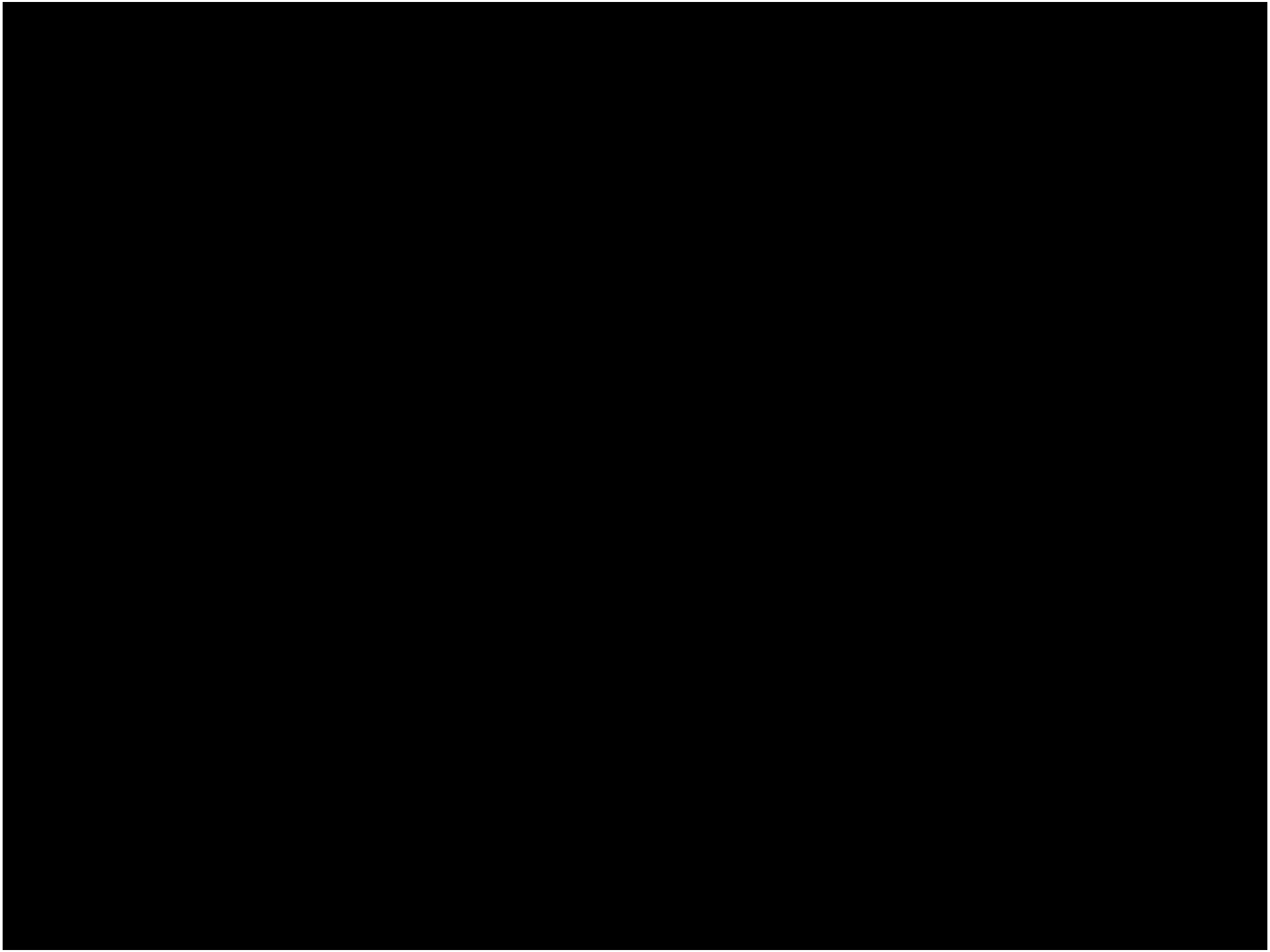


# Conclusions:

The hypothesis of a large (60˚ or more) TPW event coincident with the Cambrian Explosion has stood up the test of time remarkably well, given major changes in the Cambrian Time Scale.




The Cretaceous event argues that the eruption of a Super Plume is a most likely driver of TPW.

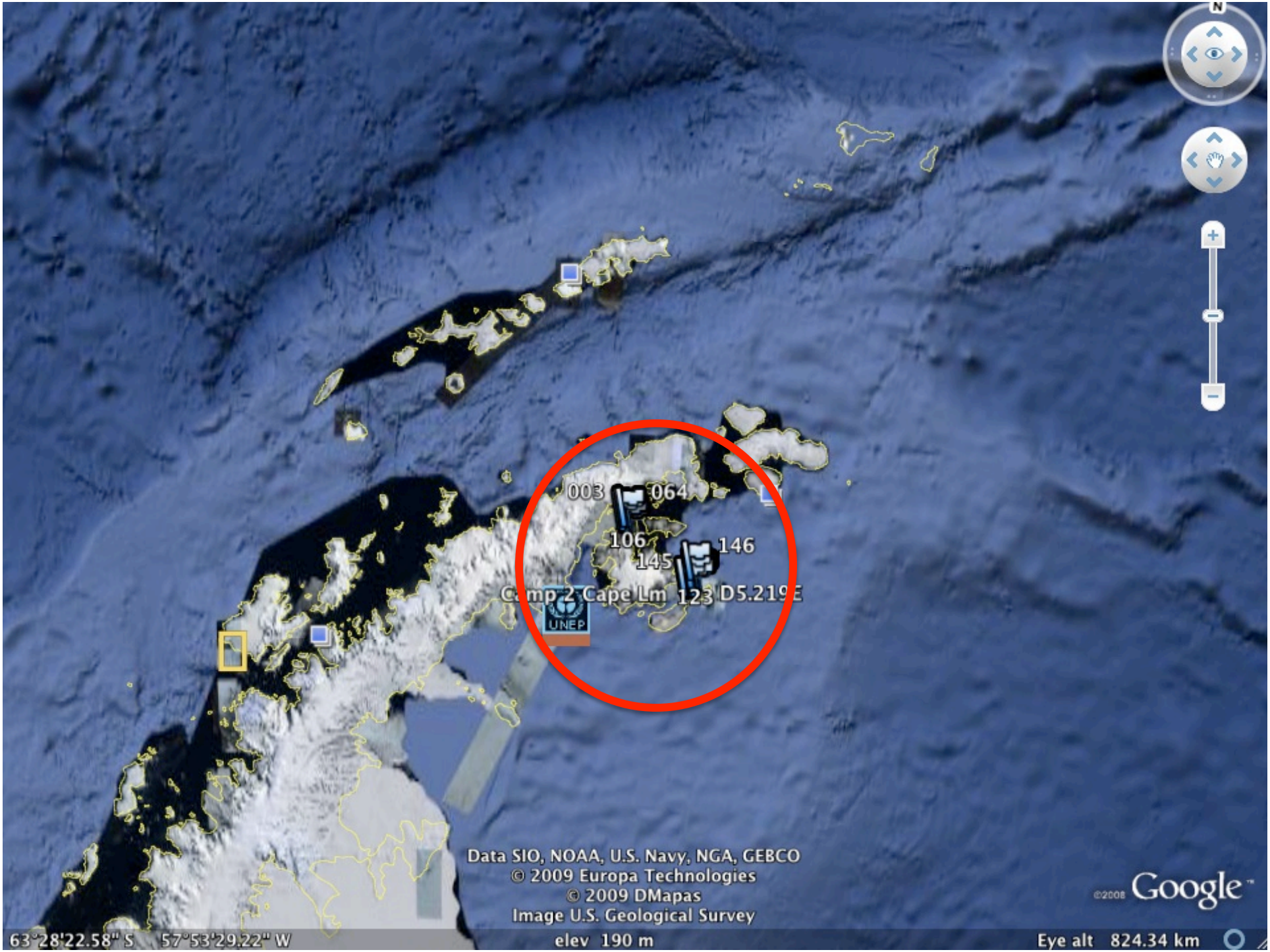


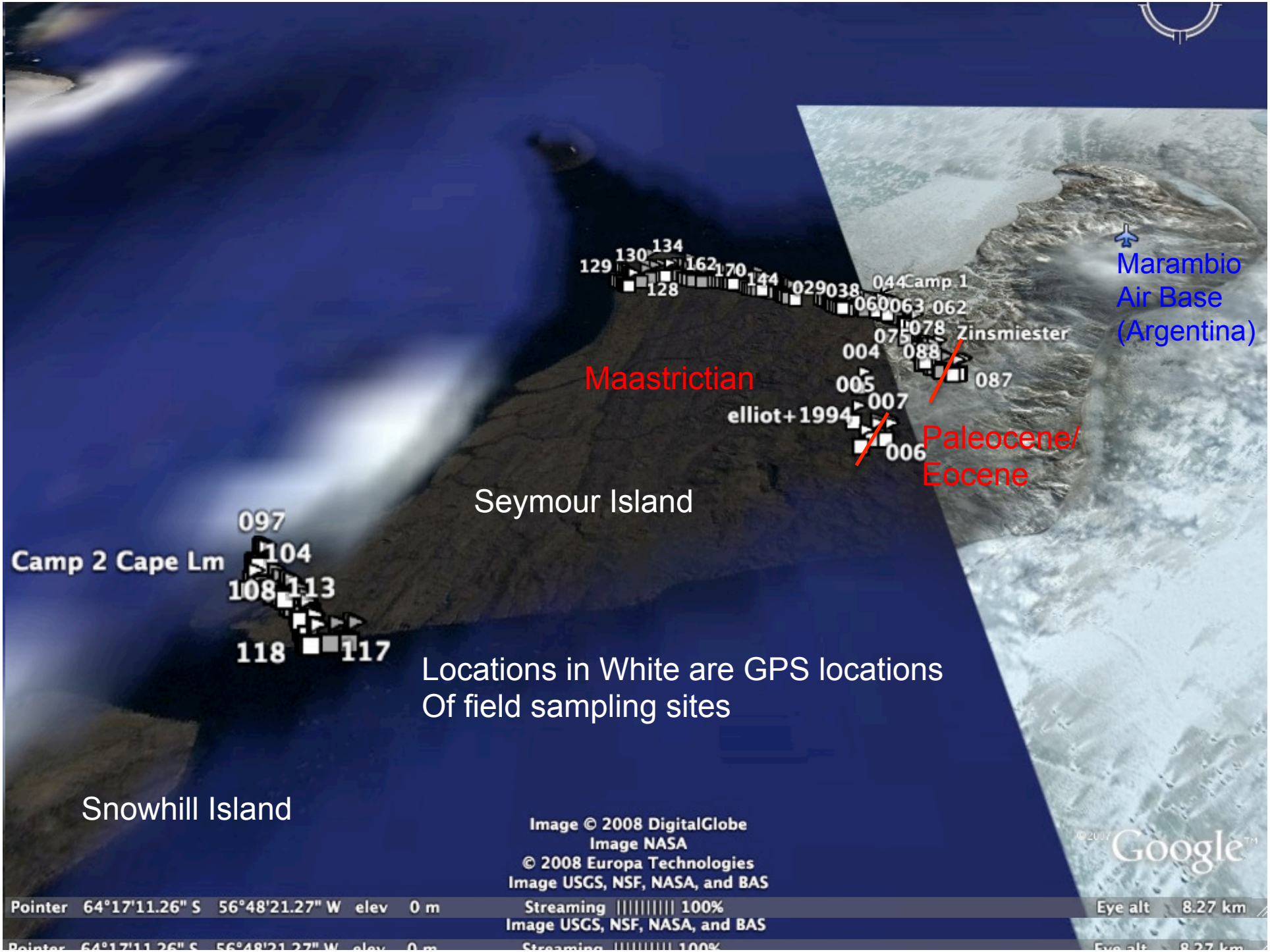
# Association of Deccan Flood Volcanism, Climate, and Extinction at High Southern Latitudes

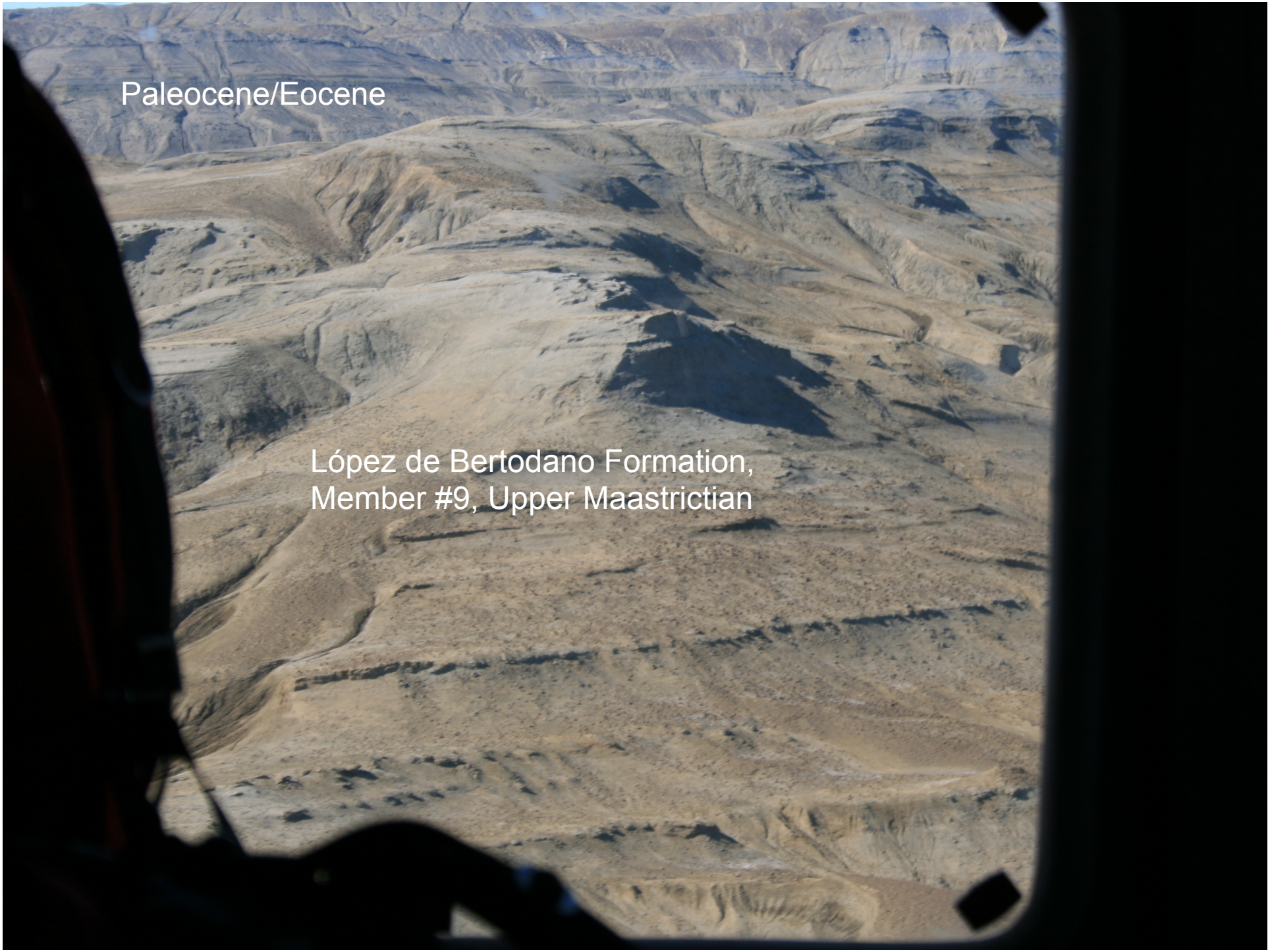
Tom Tobin, Peter Ward, Joe Kirschvink, Eric Steig,
Eduardo Olivero, Isaac Hilburn, Ross Mitchell, Tim Raub,

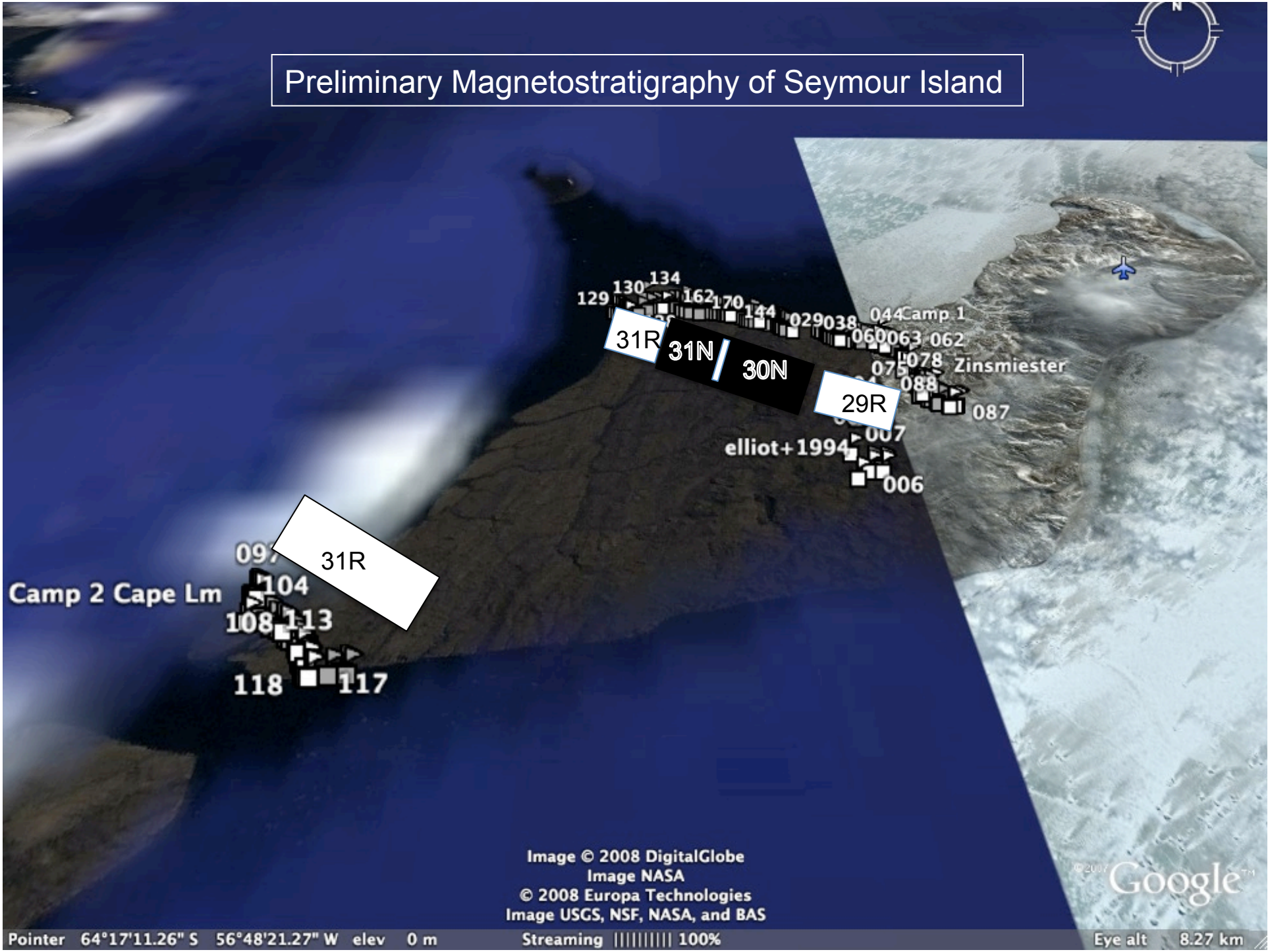
Affiliations:
California Institute of Technology
University of Washington
Yale University
Centro Austral de Investigaciones Cientificas

We acknowledge support from:

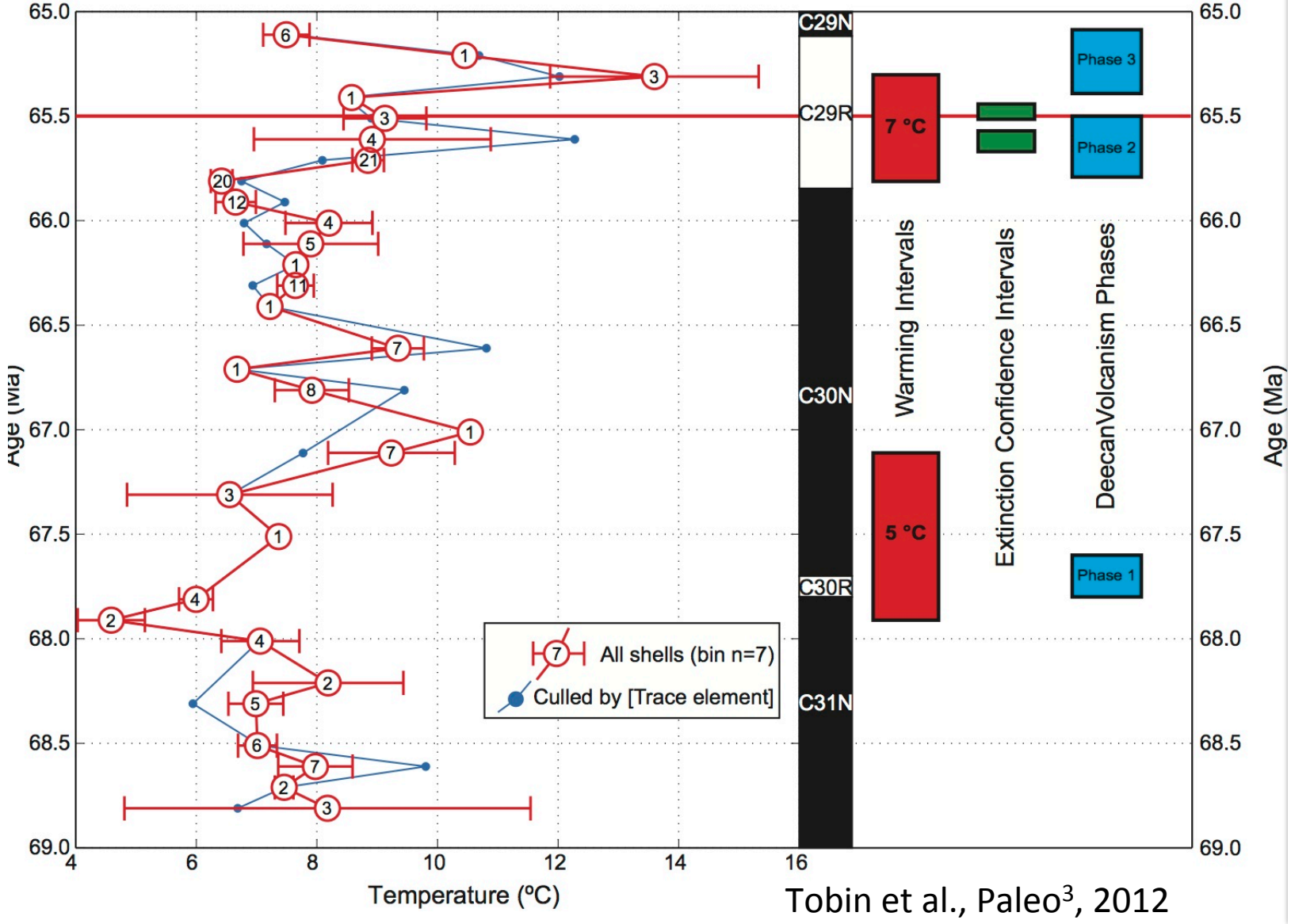

003
064
106
146
145
123
UNEP
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2009 Europa Technologies
© 2009 DMapas
Image U.S. Geological Survey
©2008 Google
63°28'22.58" S 57°53'29.22" W
elev 190 m
Eye alt 824.34 km


129
130
134
128
162
170
144
029
038
044
Camp 1
060
063
062
078
075
Zinsmiester
004
088
087
005
007
elliot+1994
006
Maastrictian
Paleocene/
Eocene
Marambio
Air Base
(Argentina)
Seymour Island
097
Camp 2 Cape Lm
104
108
113
118
117
Locations in White are GPS locations
Of field sampling sites
Snowhill Island
Image © 2008 DigitalGlobe
Image NASA
© 2008 Europa Technologies
Image USGS, NSF, NASA, and BAS
Pointer 64°17'11.26" S 56°48'21.27" W elev 0 m
Streaming 100%
Image USGS, NSF, NASA, and BAS
Eye alt 8.27 km
Google


Paleocene/Eocene
López de Bertodano Formation,
Member #9, Upper Maastrictian

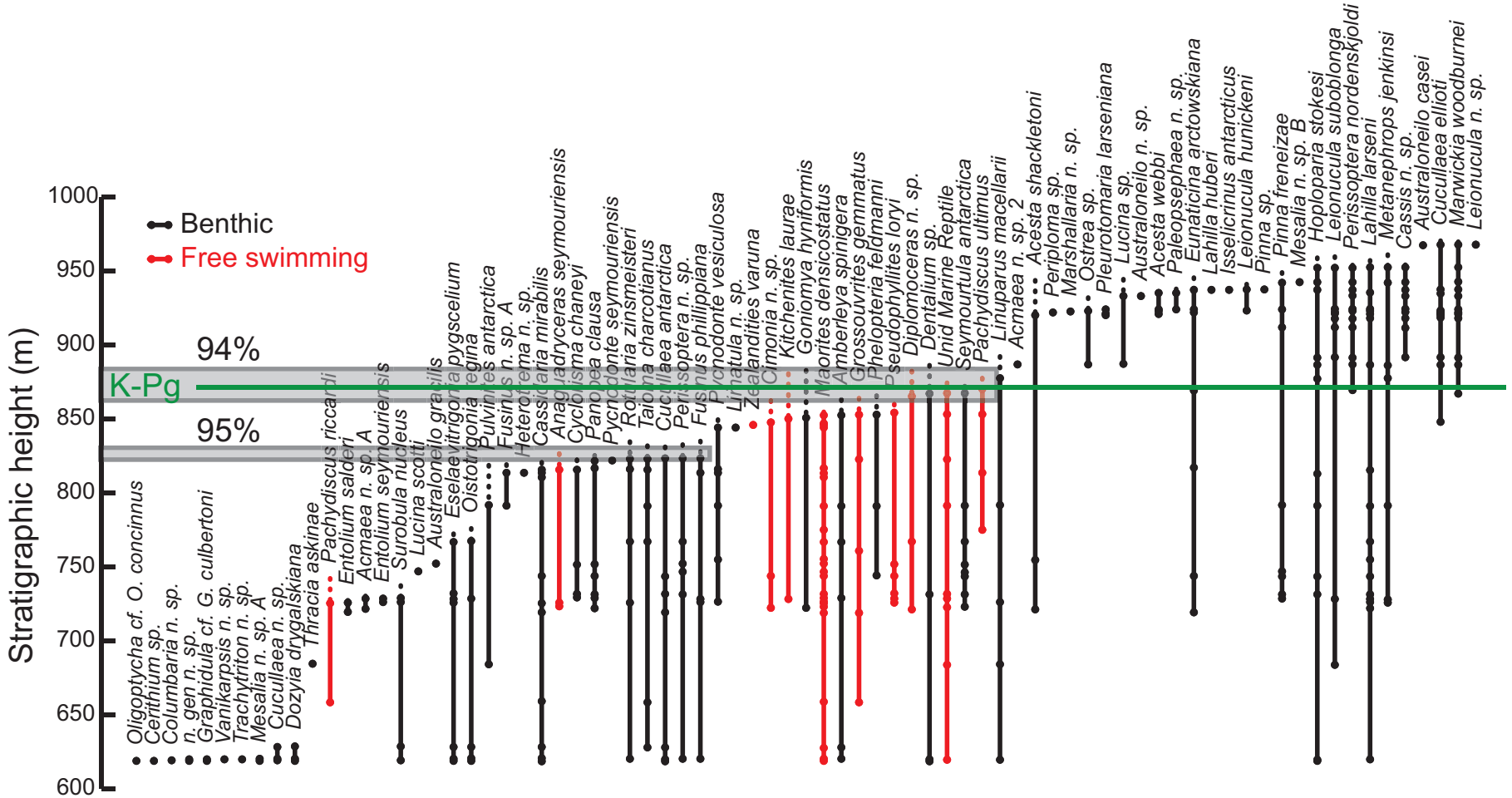

Preliminary Magnetostratigraphy of Seymour Island
129
130
134
162
170
144
029
038
044
Camp 1
060
063
062
078
Zinsmiester
075
088
087
007
elliot+1994
006
31R
31N
30N
29R
31R
097
104
Camp 2 Cape Lm
108
113
118
117
Image © 2008 DigitalGlobe
Image NASA
© 2008 Europa Technologies
Image USGS, NSF, NASA, and BAS
Google
Pointer 64°17'11.26" S 56°48'21.27" W elev 0 m
Streaming 100%
Eye alt 8.27 km

# Warming Pulses
## (inferred from $\delta^{18}O$ from aragonite)




Tobin et al., Paleo[3], 2012

# Two statistically robust extinctions can be resolved, due to high deposition rate.




Tobin et al., Paleo[3], 2012