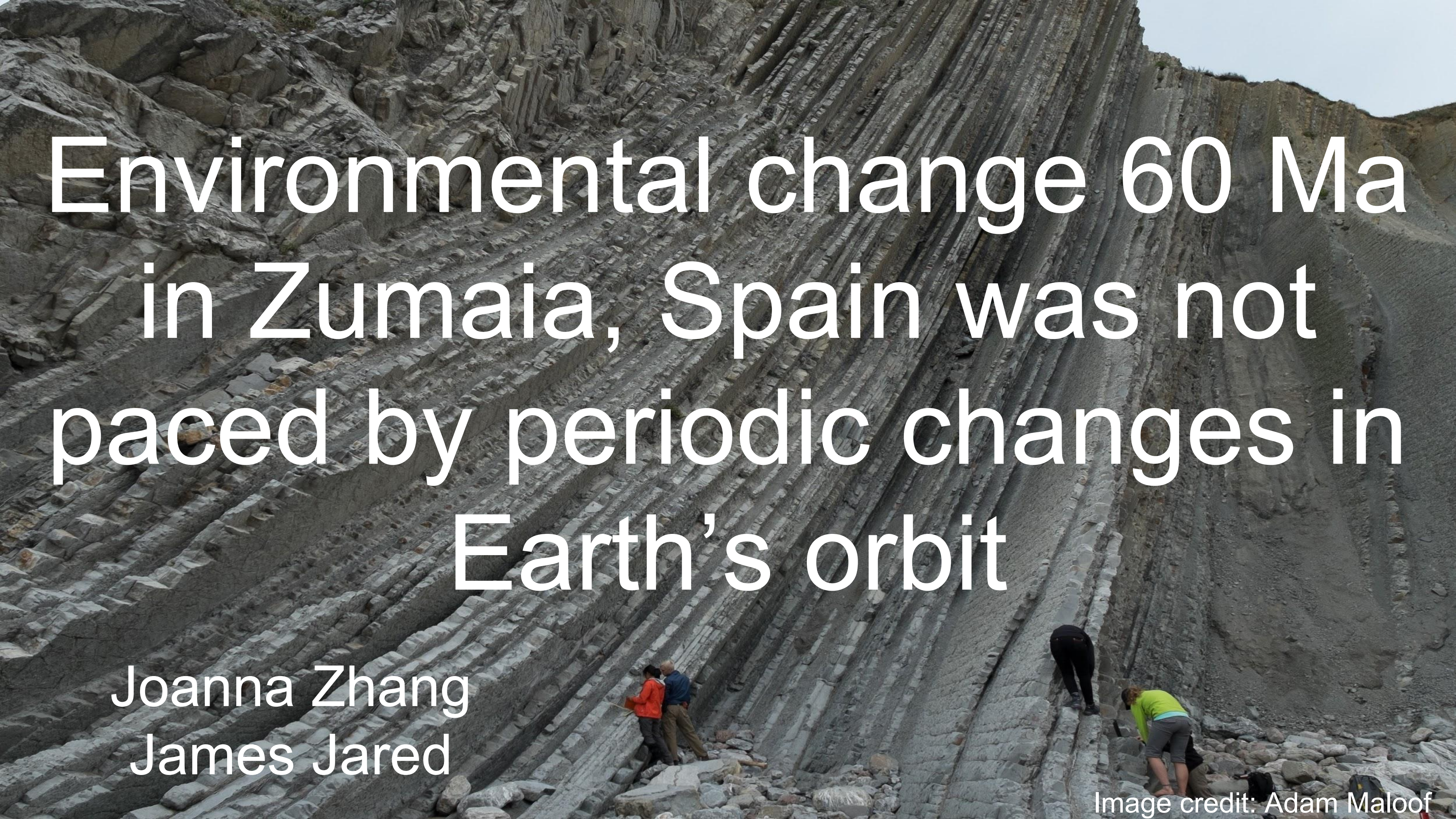
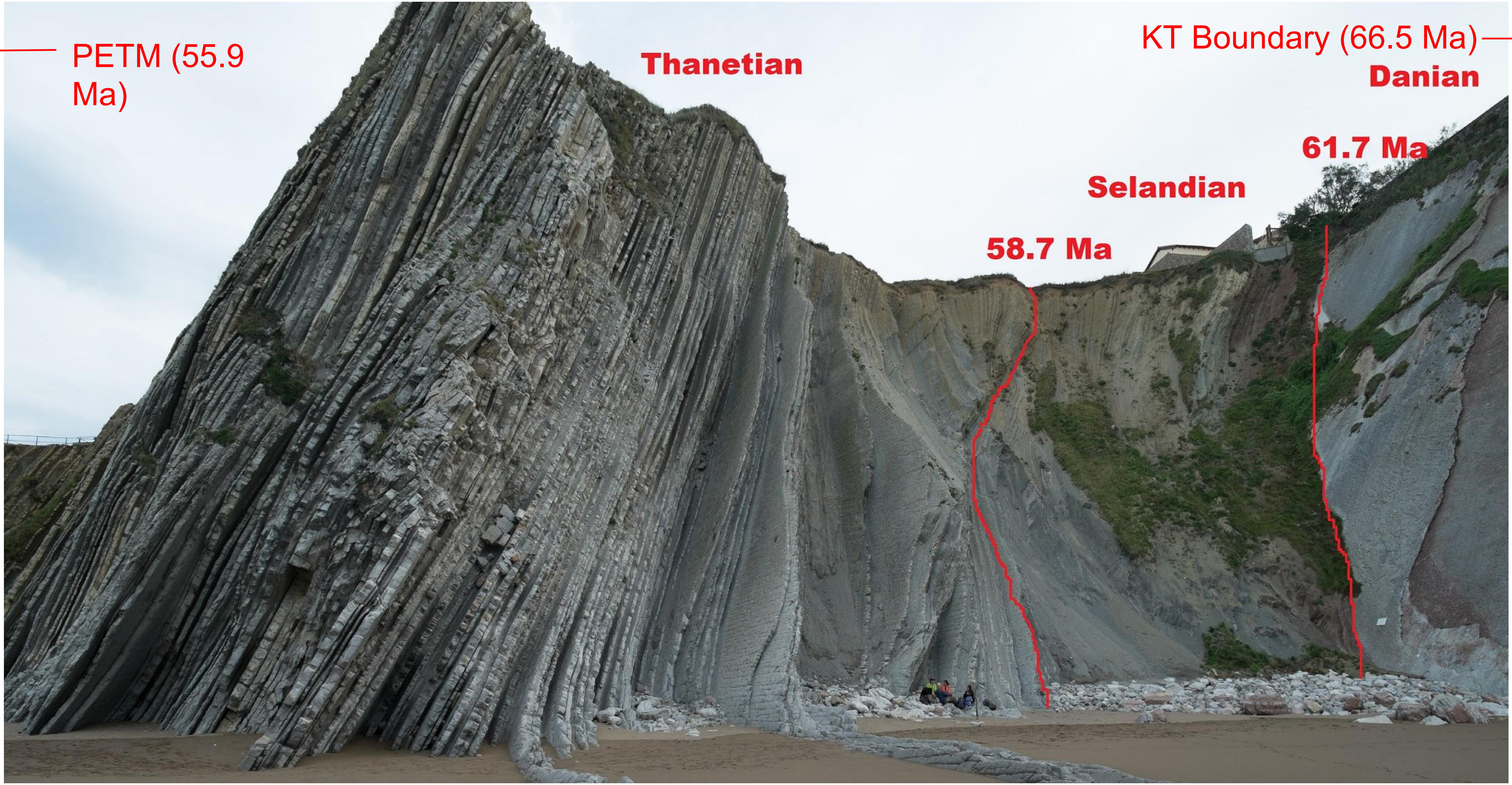


Environmental change 60 Ma in Zumaia, Spain was not paced by periodic changes in Earth’s orbit

Joanna Zhang
James Jared

Image credit: Adam Maloof


Bay of Biscay
Zumaia
Oviedo
Bilbao
FRANCE
Galicia
Cordillera Cantabrica
Pamplona
Pyrennees
Ebro
Valladolid
Duero
Zaragoza
Aragon
Catalonia
Barcelona
Tarragona
Salamanca
Cordillera Central
MADRID
PORTUGAL
Toledo
Tajo
SPAIN
Valencia
Ibiza
Islands


PETM (55.9 Ma)
Thanetian
KT Boundary (66.5 Ma)
Danian
61.7 Ma
Selandian
58.7 Ma


PETM (55.9 Ma)
Thanetian
KT Boundary (66.5 Ma)
Danian
61.7 Ma
Selandian
58.7 Ma
ZUMAIA SECTION
Global Boundary Stratotype Section and Point
43.3005° N Latitude / 3.3594° W Longitude
Selandiar Estaien oinerako Estratotipo Globala
Estratotipo Global para la base del Piso Selandiense
Global Stratotype for the base of the Selandian Stage
Estimated age: 61.1 ± 0.2 Ma
ICS

Paleocene Eocene Thermal Maximum (PETM)

- extreme global warming event about 55.9 Myr ago

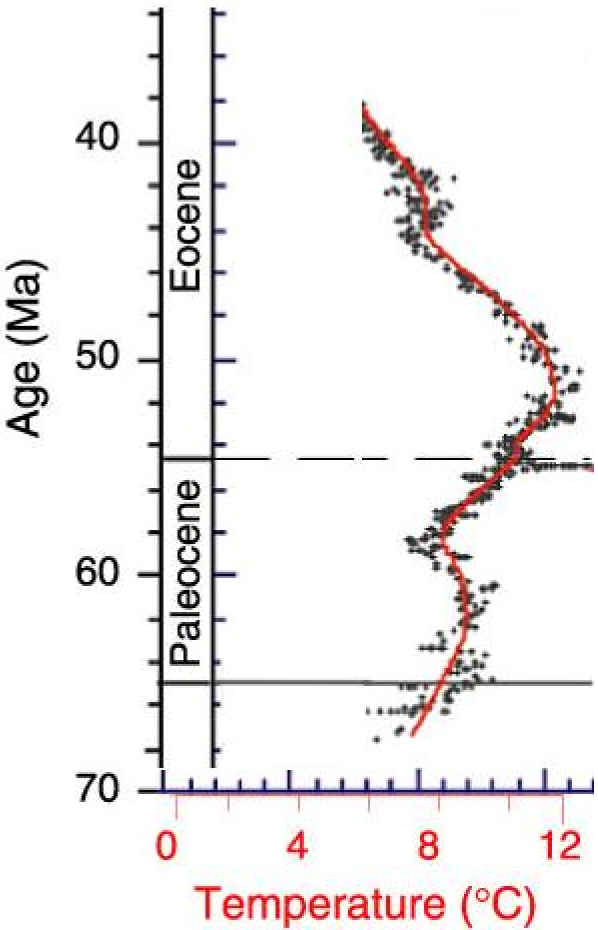


Image credit: Zachos et al. (2001)

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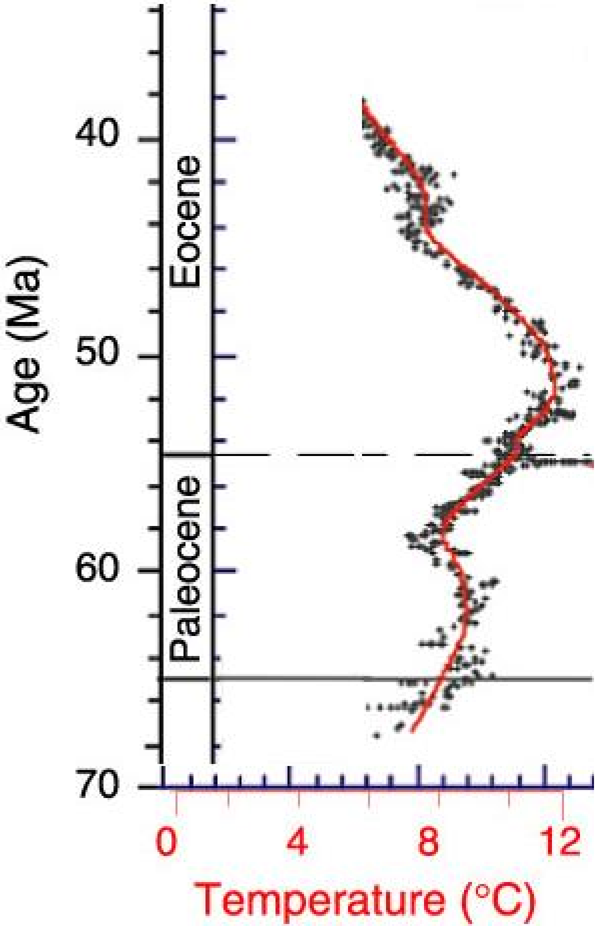

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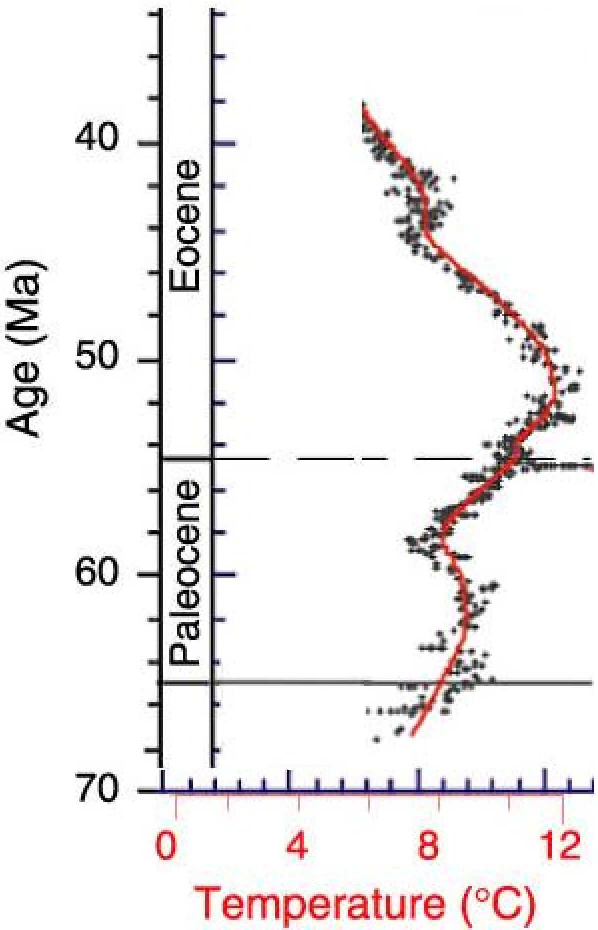

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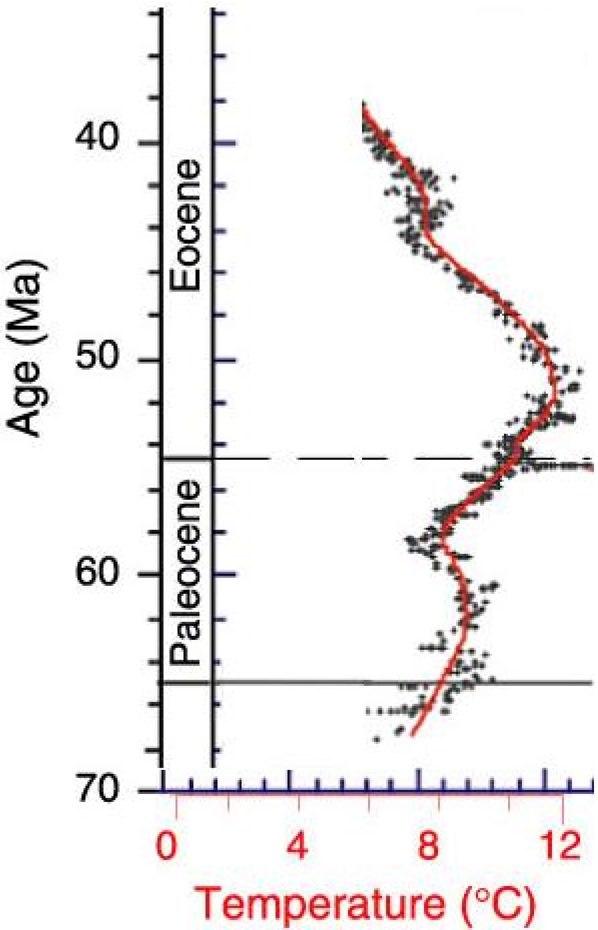

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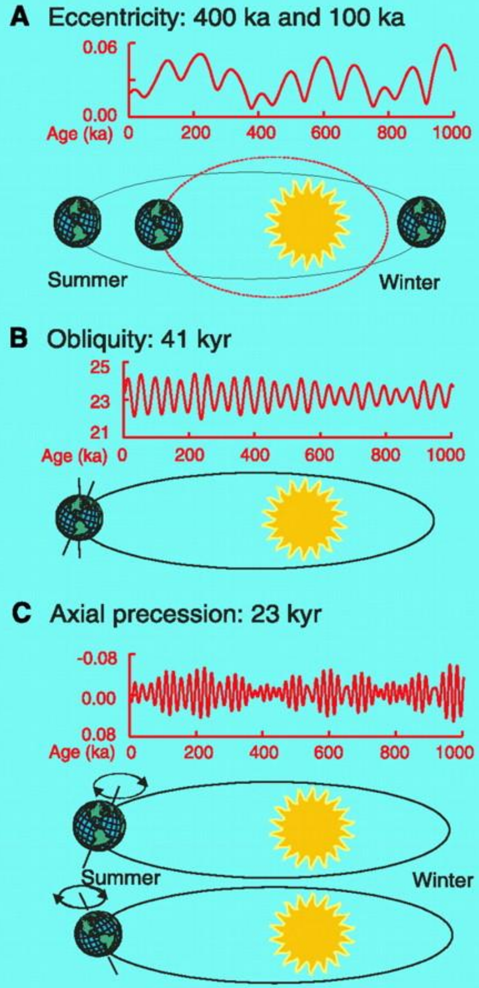
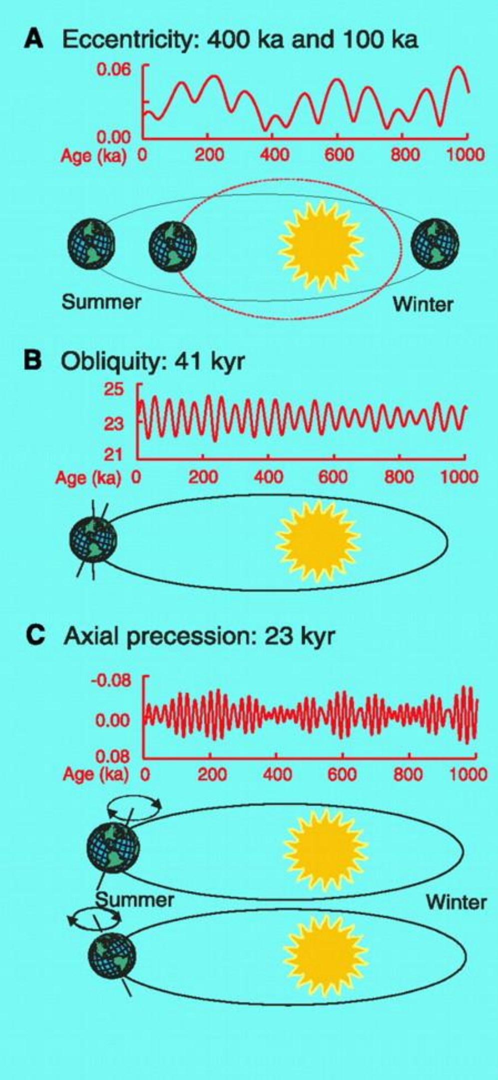
- closest rate of carbon emissions to present day (Cui et al. 2011)
- mass extinction of benthic foraminifera, largest mammalian turnover of Cenozoic (McInerny and Wing 2011)
- don't know exactly how long ancient warming or extinction took → study geologic record of this time period to find out for anthropocene

Image credit: Zachos et al. (2001)

Orbital Components



- Eccentricity - the shape of Earth's orbit around the sun
  - varies from elliptical to near circular
  - every ~400 kyr and 100 kyr



Orbital Components

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  - varies between 22.1° and 24.5°
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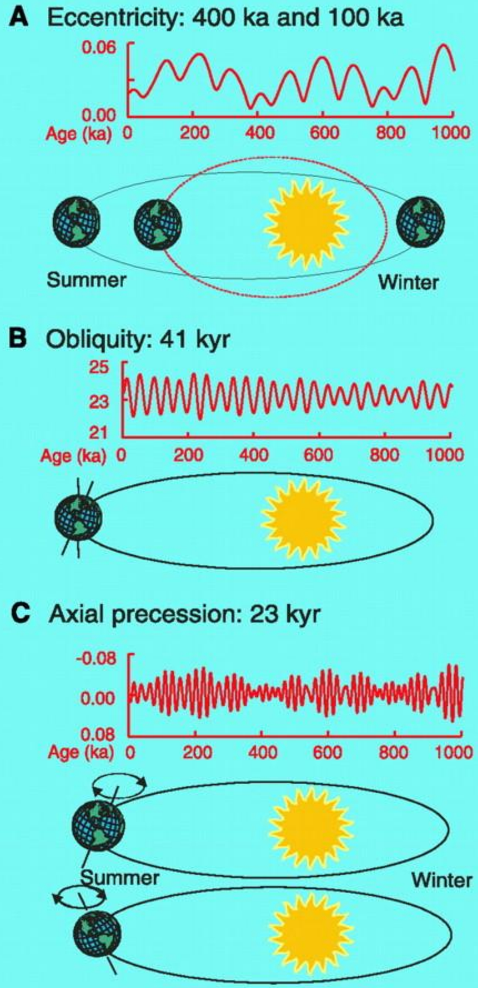

Orbital Components

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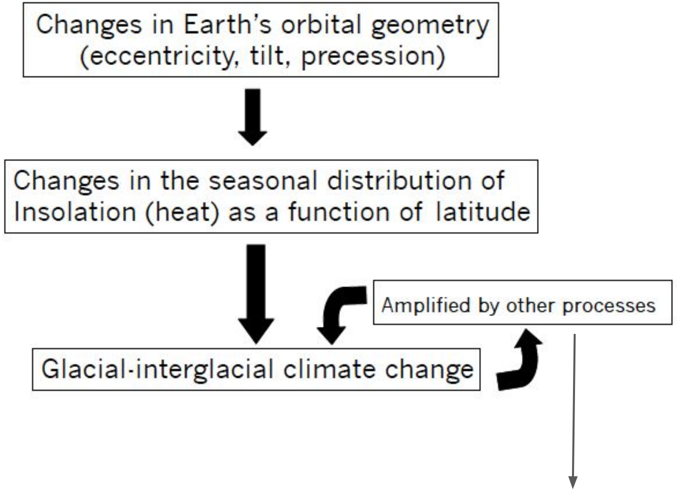
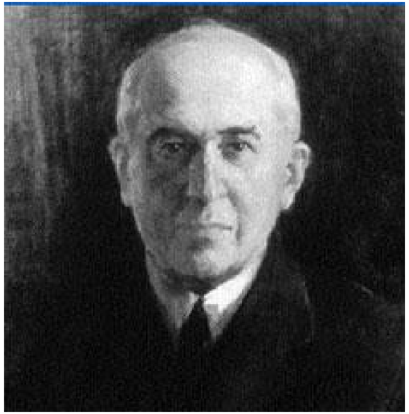
- Obliquity - the tilt of Earth’s axis
  - varies between 22.1° and 24.5°
  - every 41 kyr
- Precession - the wobble of the axis of rotation
  - when modulated by eccentricity, determines where on the orbit the seasons occur
  - increases seasonal contrast in one hemisphere, decreases in other
  - every 19 kyr and 23 kyr

Orbital forcing of Earth’s climate



ice albedo feedback: cooling leads to increased ice, increases reflectivity (albedo), reduces solar energy absorbed, increases cooling and vice versa



Milutin Milankovitch (Serbian mathematician, 1879-1958)

- studied Earth’s orbit while imprisoned during WWI

Image credit:
Adam Maloof

Image credit:
Adam Maloof

- limestone-marl couplets show cyclic variation of bioproductivity dependent on orbital forcing (Batenburg et al. 2012)

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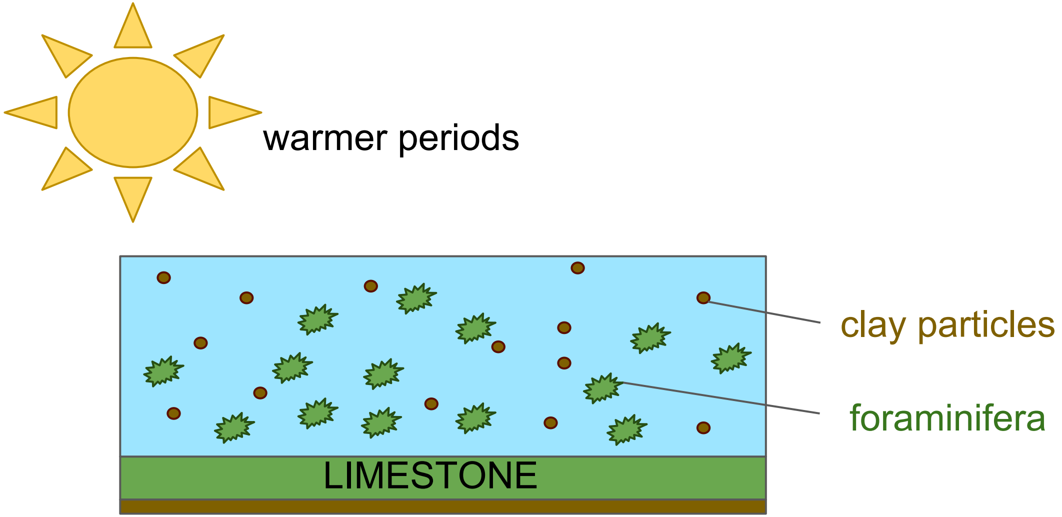
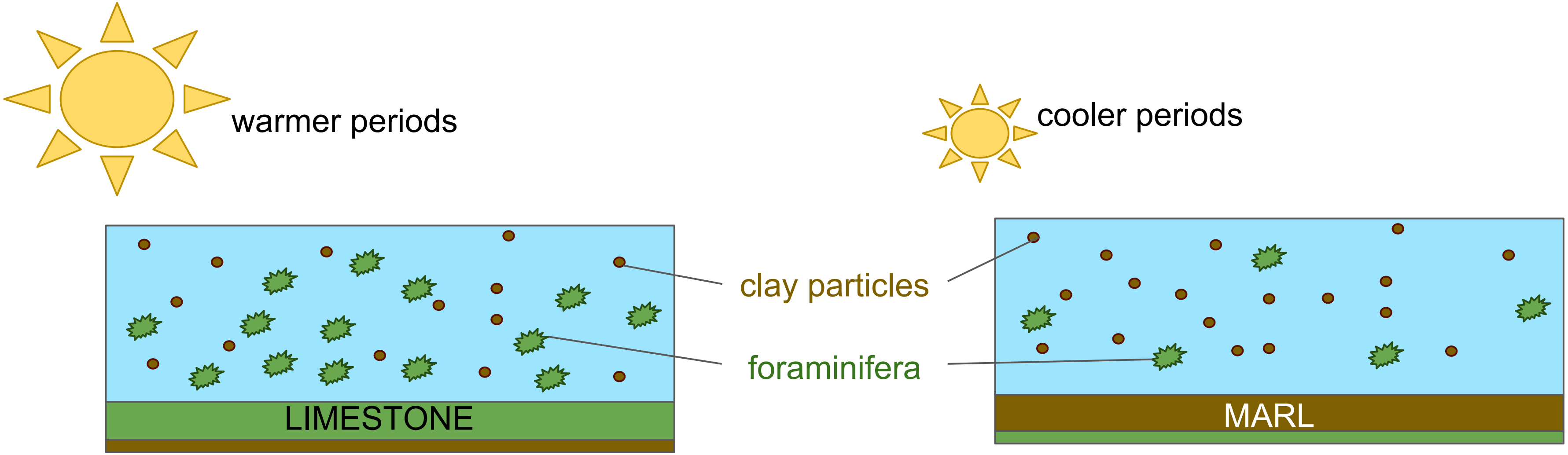


- limestone-marl couplets show cyclic variation of bioproductivity dependent on orbital forcing (Batenburg et al. 2012)
  - warm periods - increased organic production (plankton)
    - thicker limestone beds
  - cool periods - decreased organic production
    - thin limestone beds
    - accounts for adjacent marl layers - “crowded couplets”



LIMESTONE

MARL

Image credit:
Adam Maloof

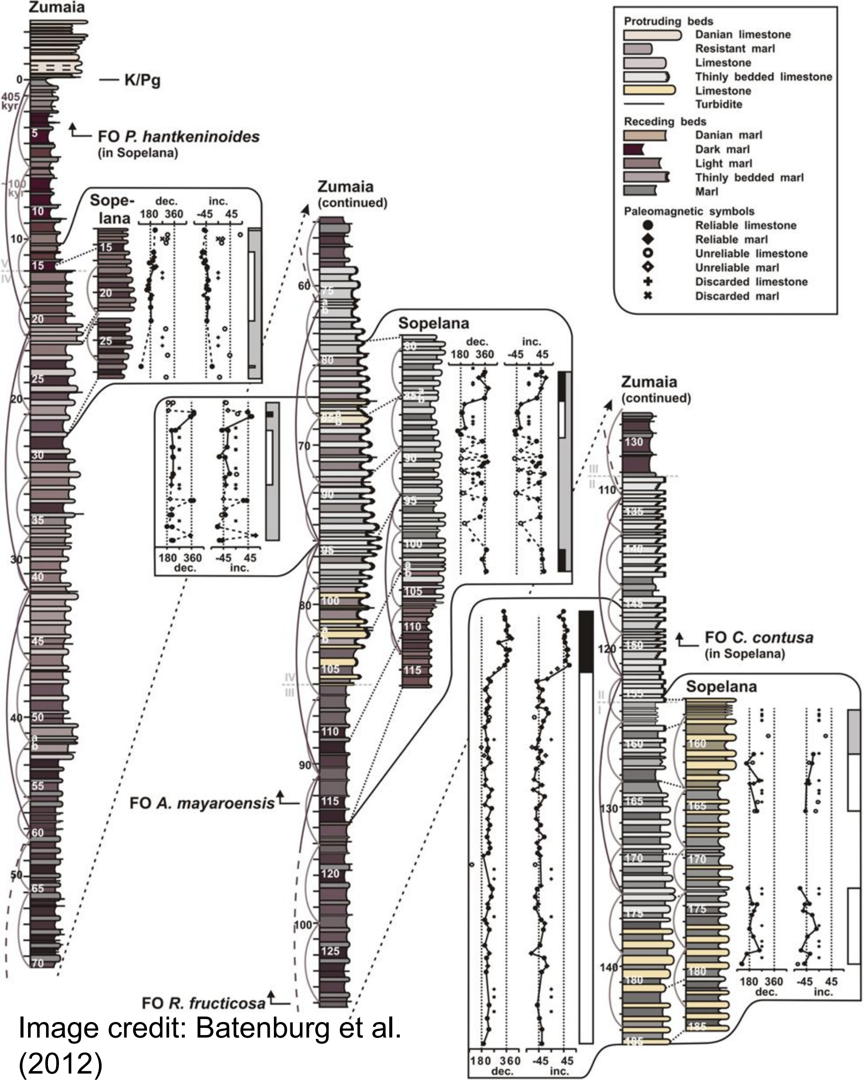


Image credit: Batenburg et al. (2012)

Batenburg et al. 2012

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Batenburg et al. 2012

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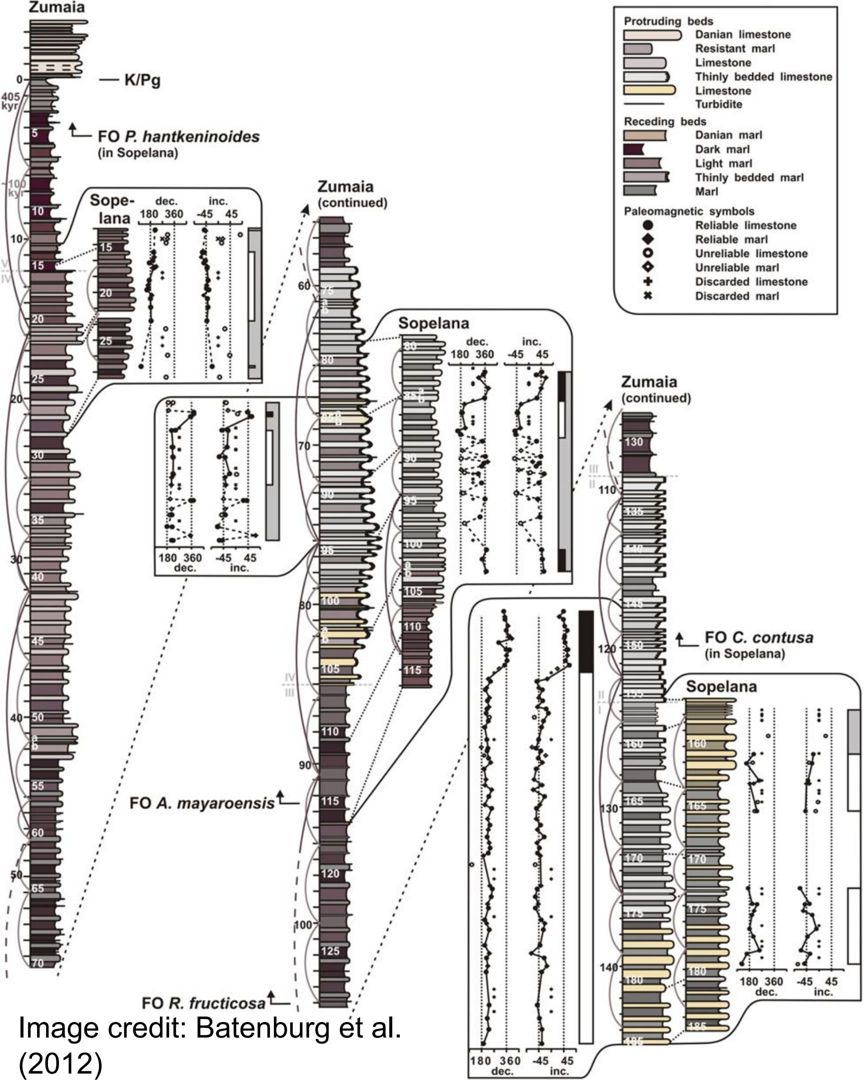

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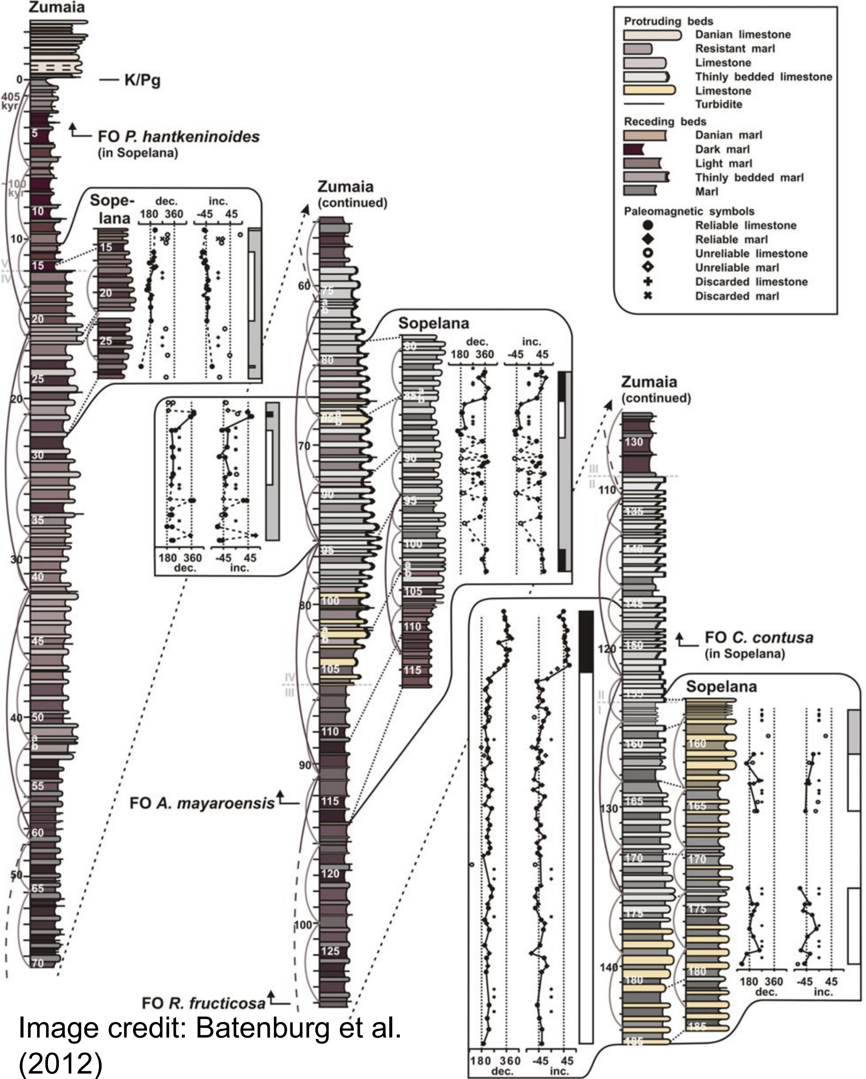

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Batenburg et al. 2012

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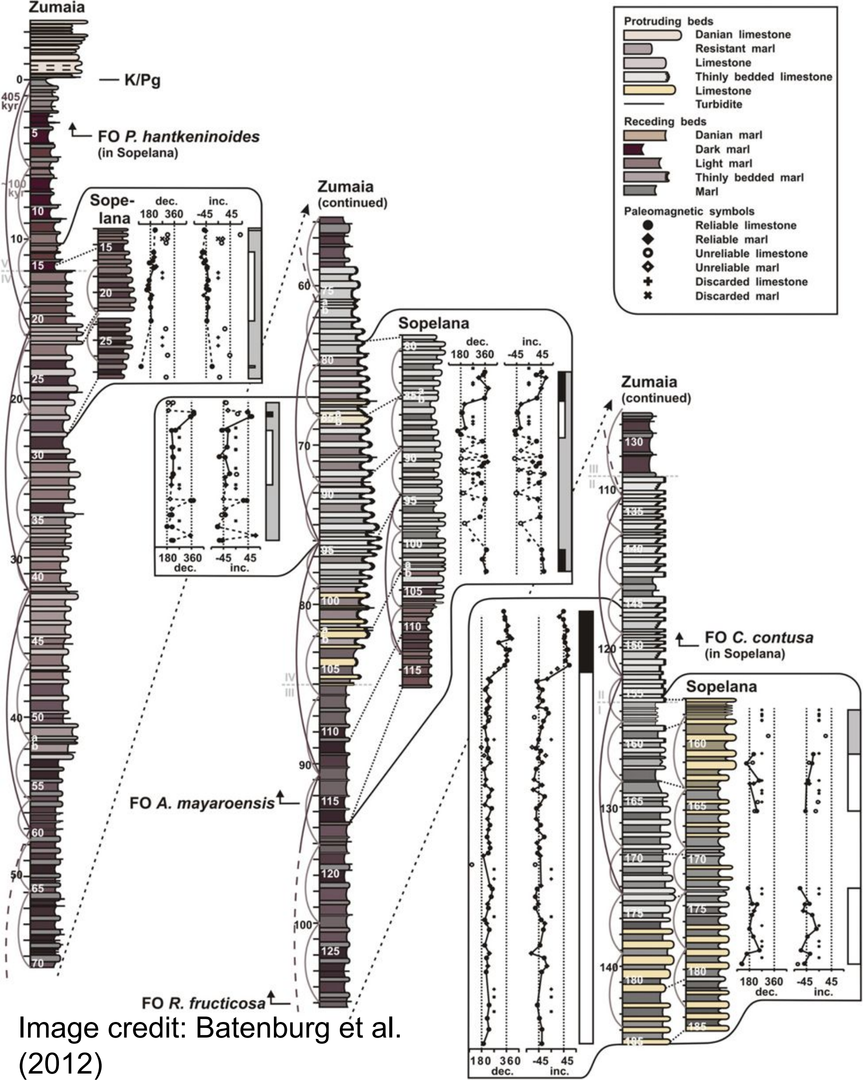

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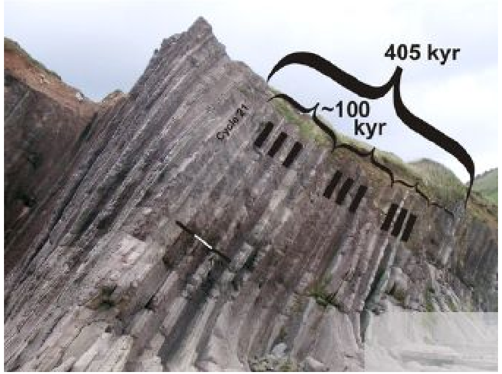

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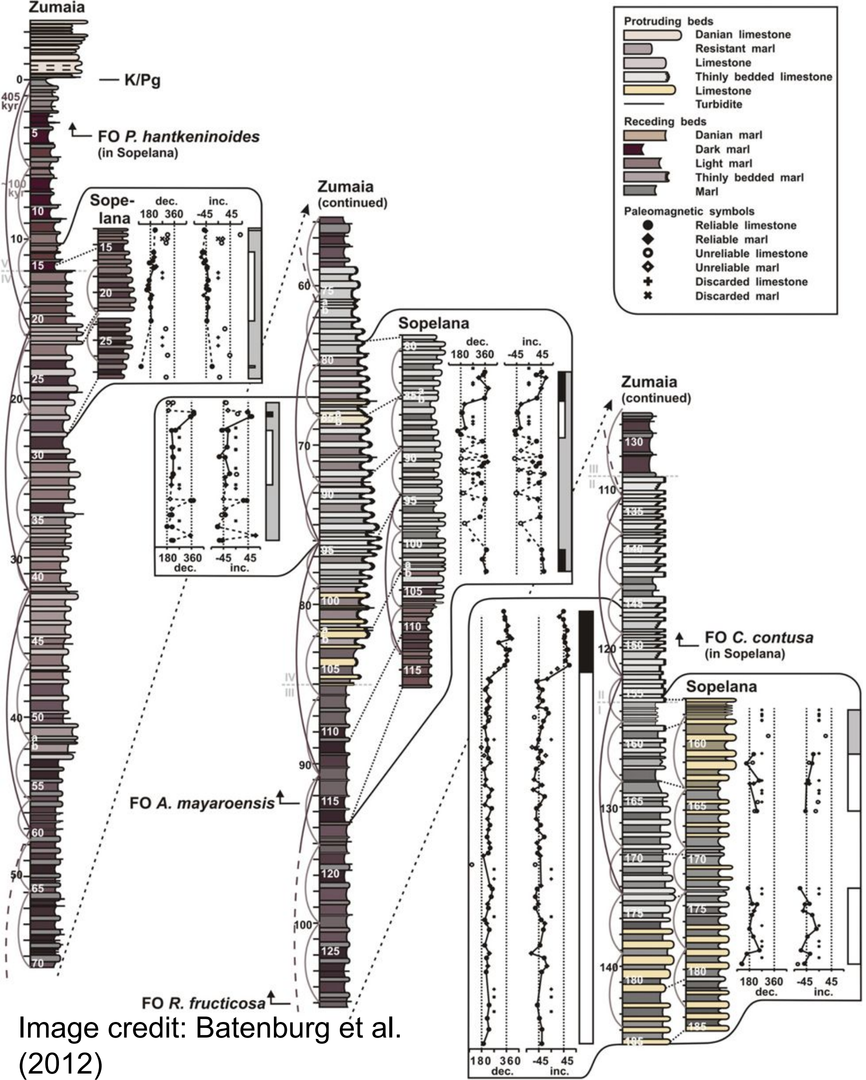

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- each couplet represents precessional cycle (~20kyr)
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- four bundles represent long eccentricity cycle (~405kyr)
- used to decrease age uncertainties, provide dates for planktonic events

New Methodology

New Methodology

1. Did not assume coupling

LIMESTONE

MARL

Image credit:
Adam Maloof

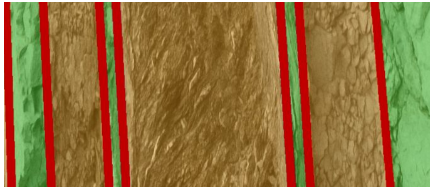
Image credit:
Adam Maloof

Image credit:
Adam Maloof

New Methodology

1. Did not assume coupling

vs



2. Removed turbidites

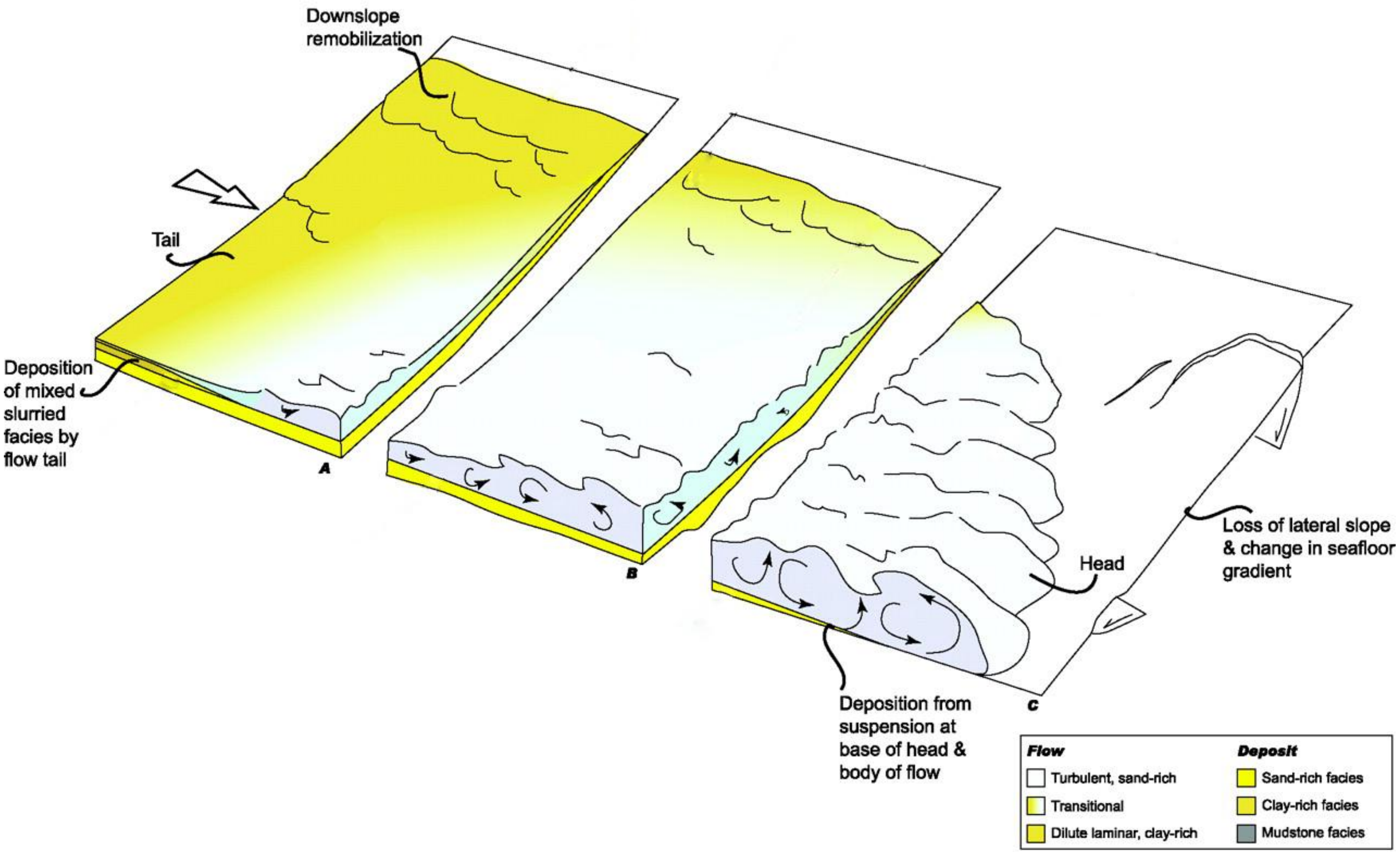
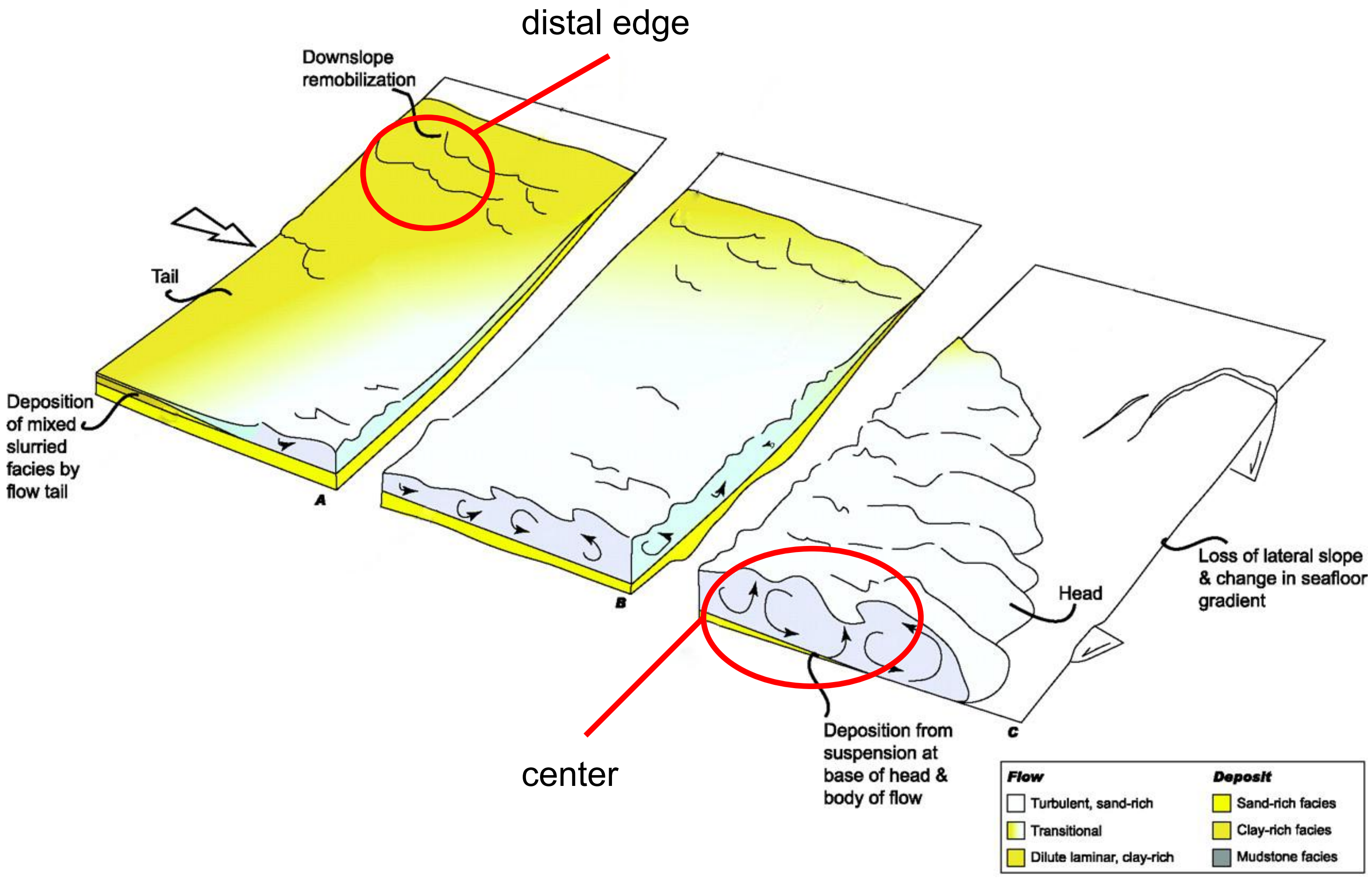


Image credit: GeoScienceWorld



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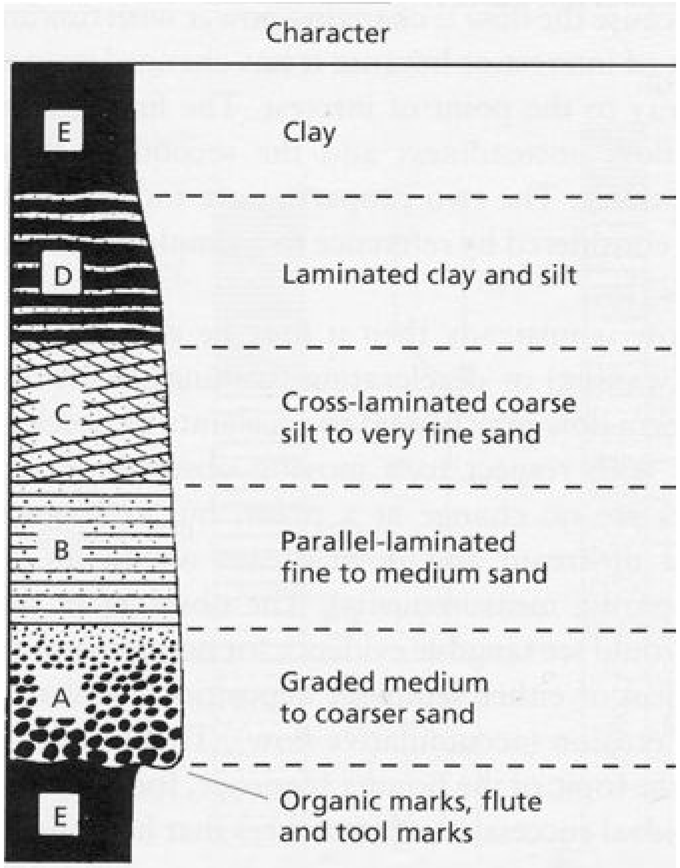

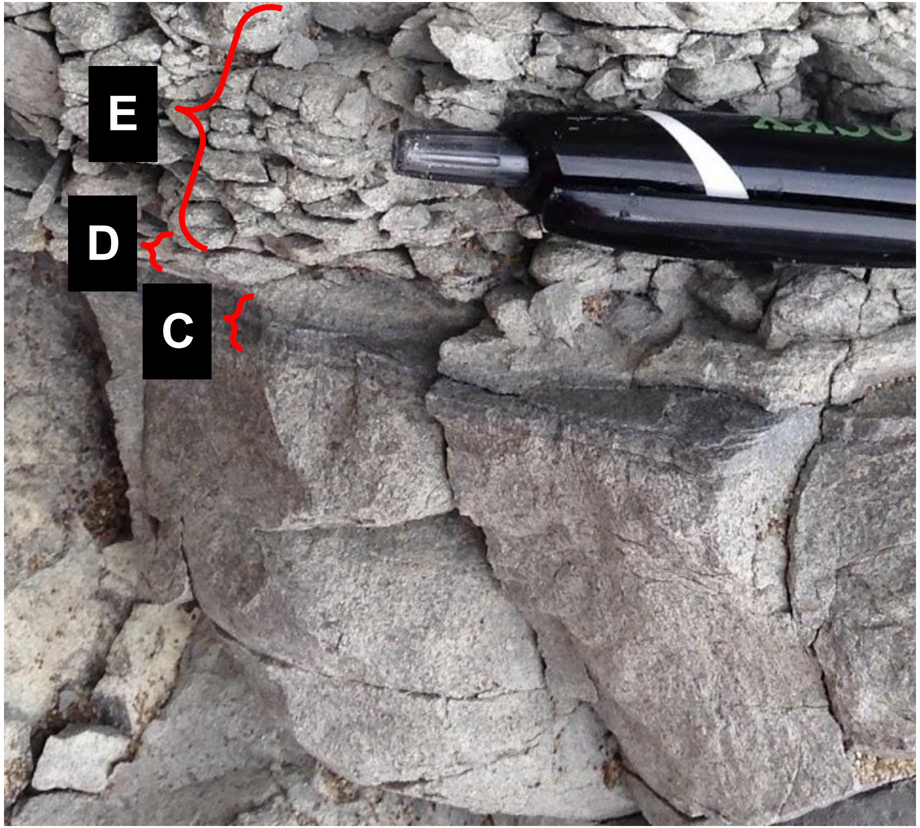

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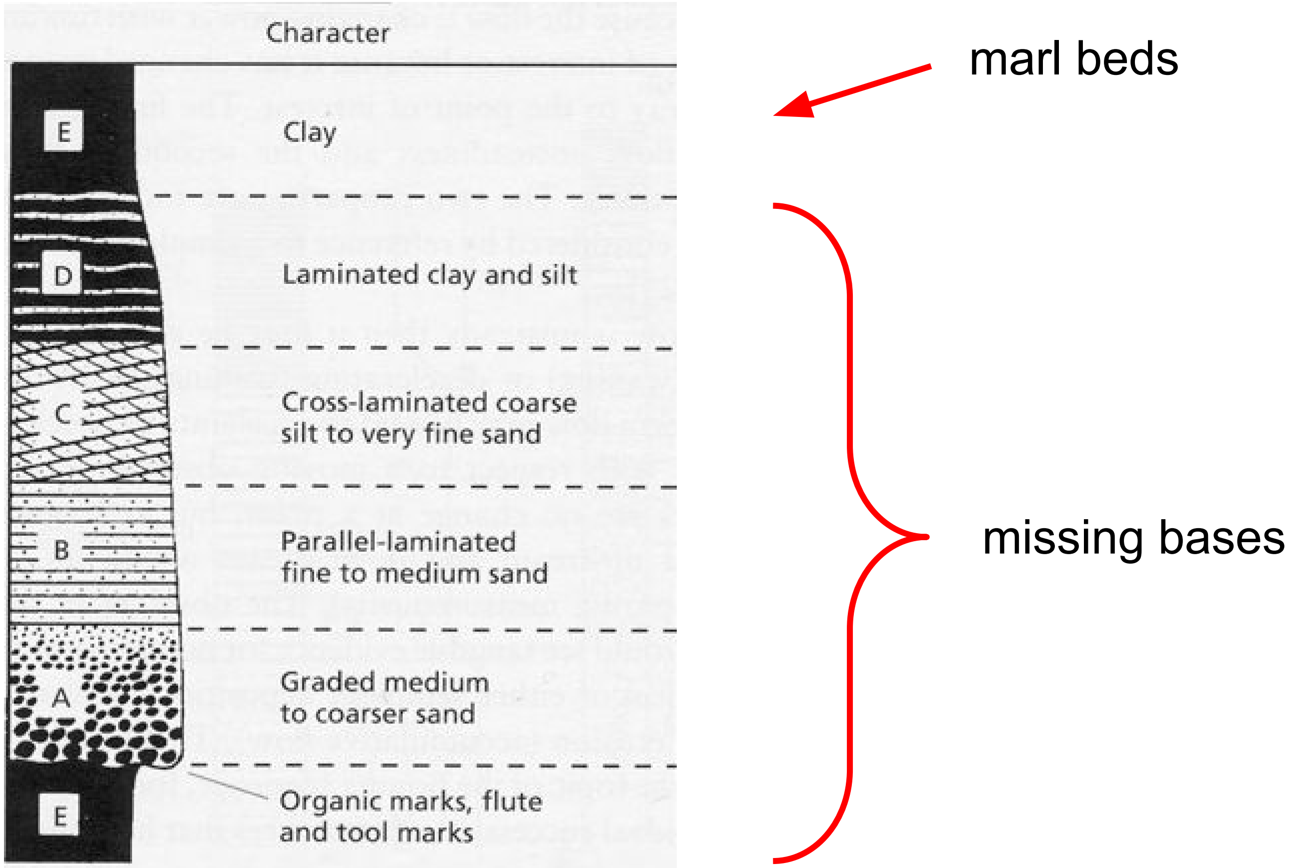

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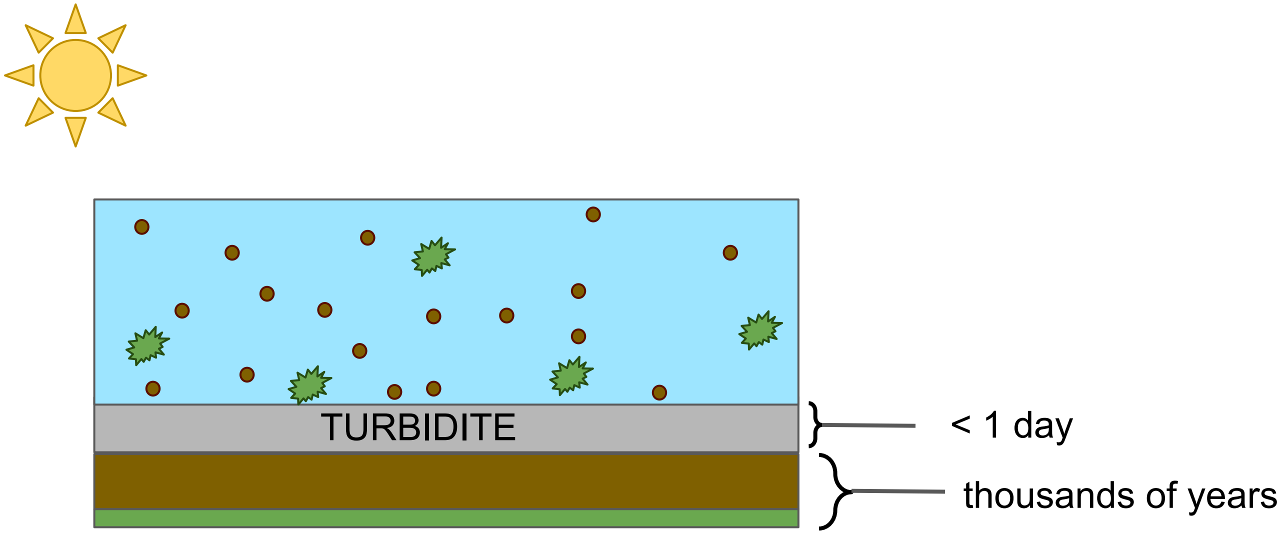
TURBIDITE
< 1 day
thousands of years

New Methodology

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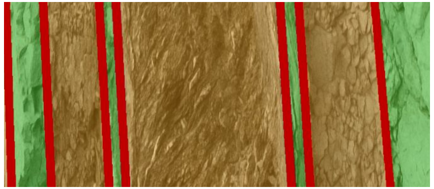
vs



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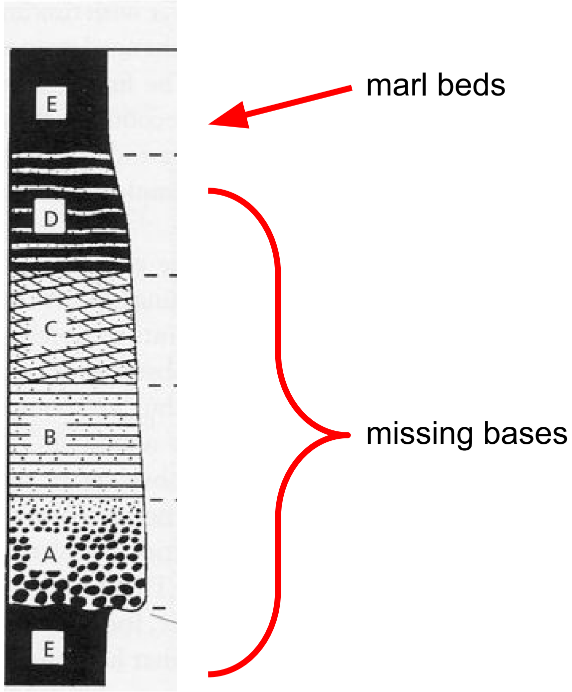
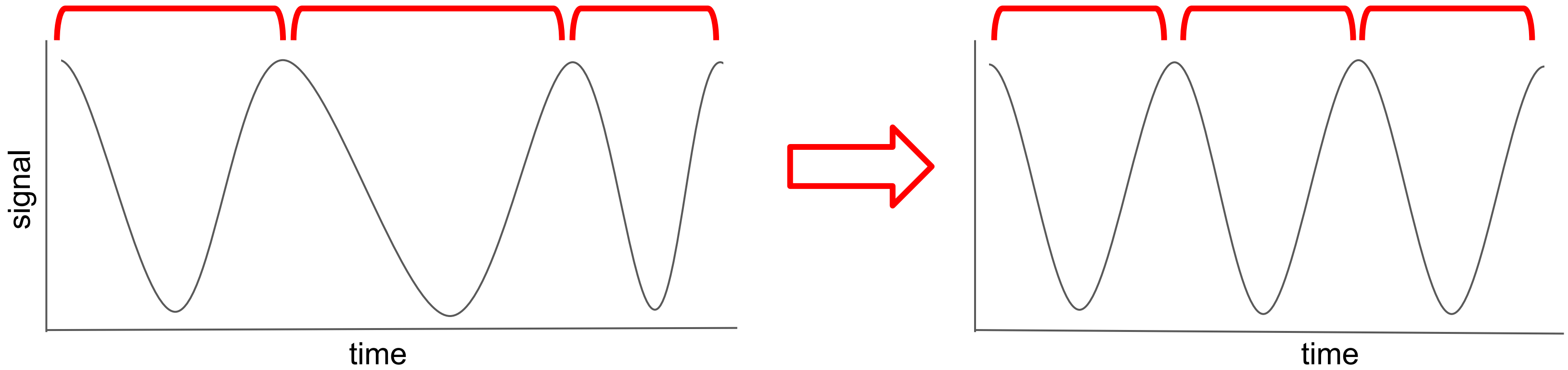


3. Did not tune data

Tuning



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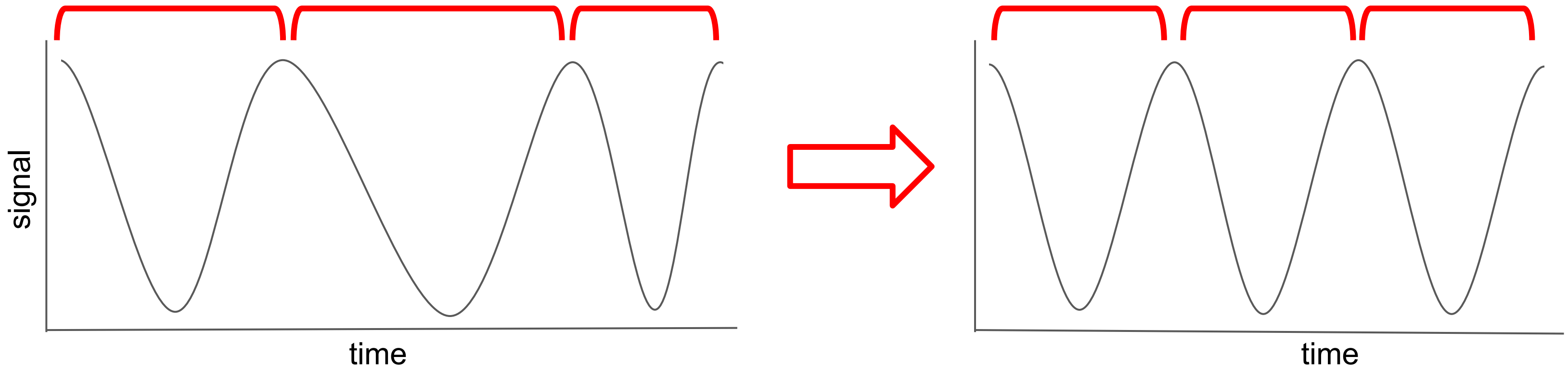

1. better not to tune if signal-to-noise ratio is less than ~1 (Proistosescu et al. 2012)

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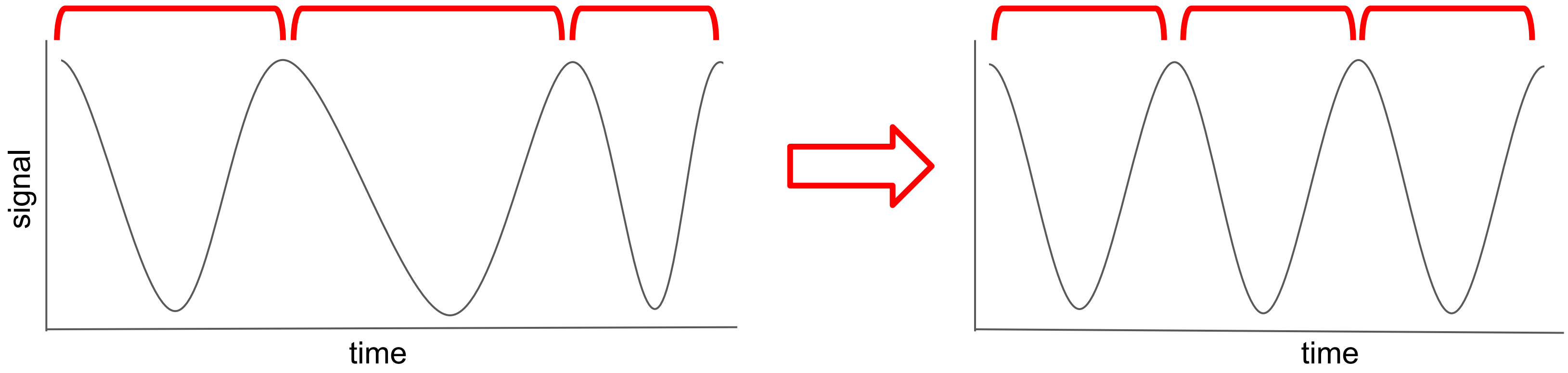

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    - artificially increased signal

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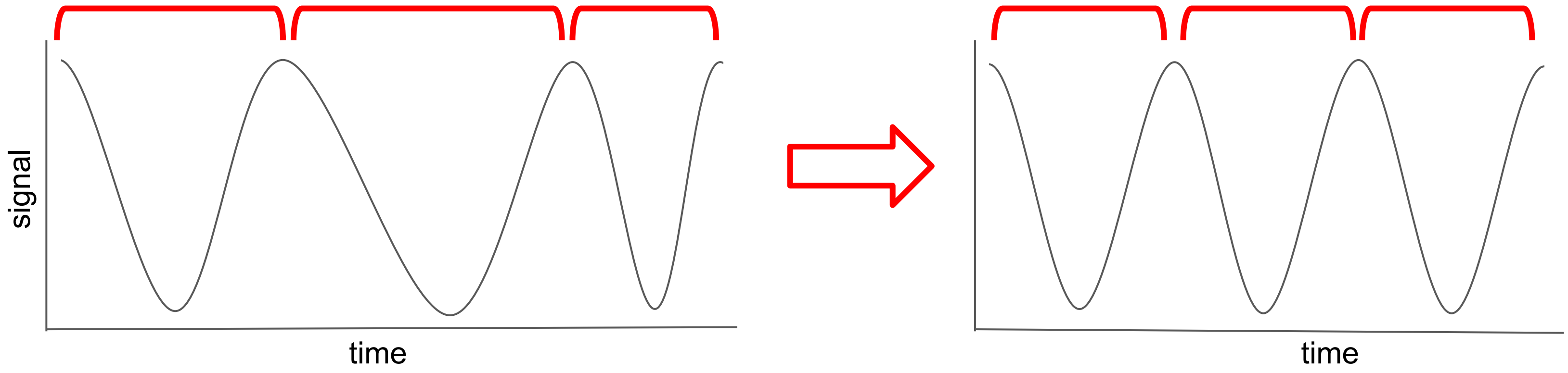

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2. tuning was employed in previous work because data were defined as Milankovitch cycles to begin with
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3. our data were too noisy for reliable tuning → did not tune

New Methodology

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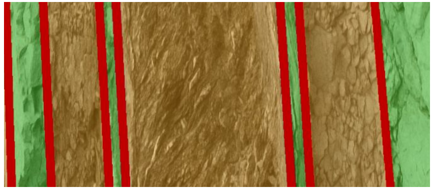
vs



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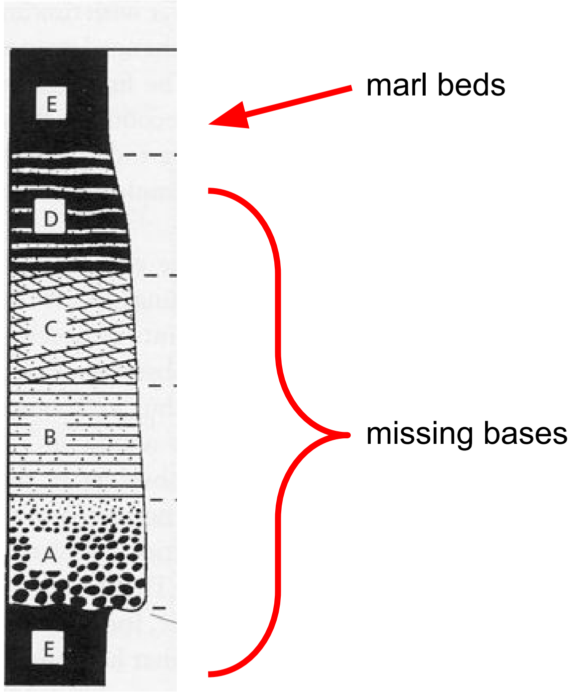
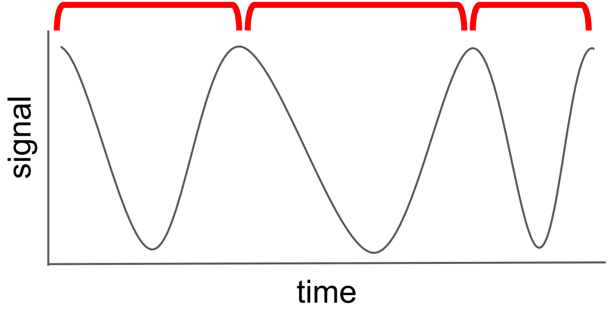
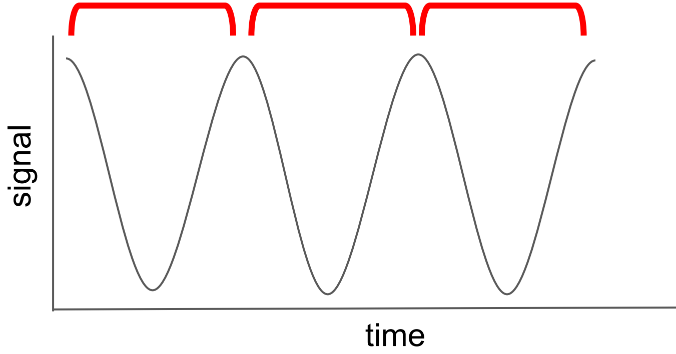


3. Assessed applicability of tuning





1. Check percent marl per meter for Milankovitch cycles using fast Fourier transform

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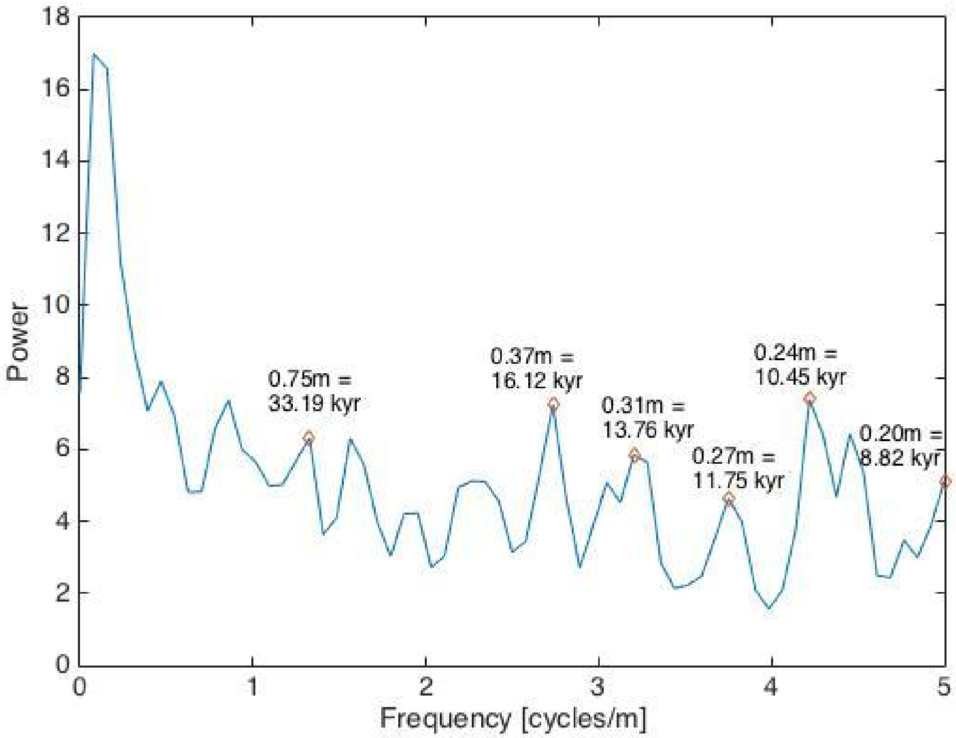

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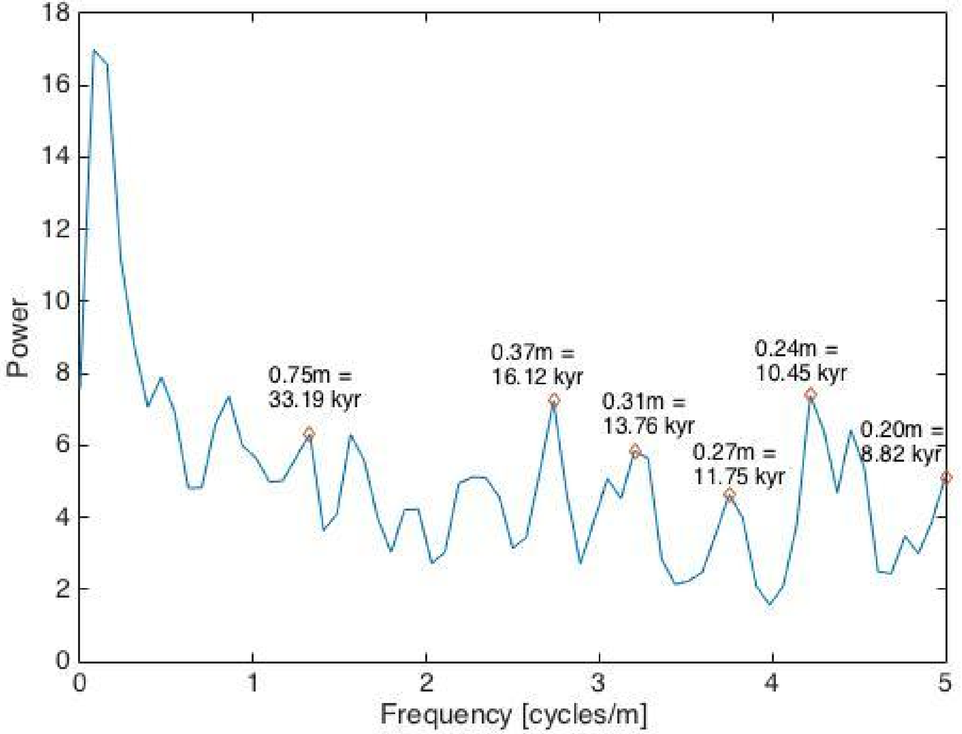

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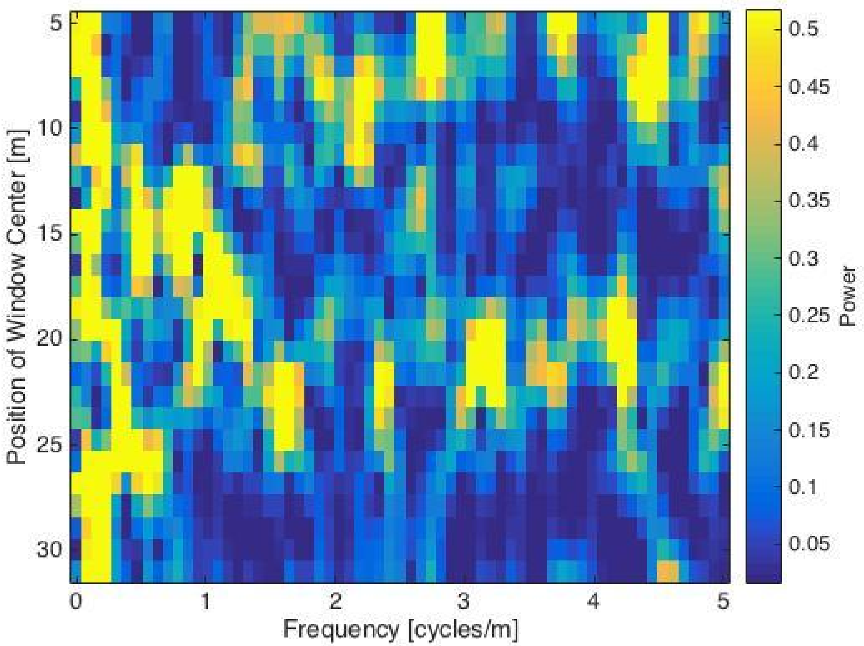

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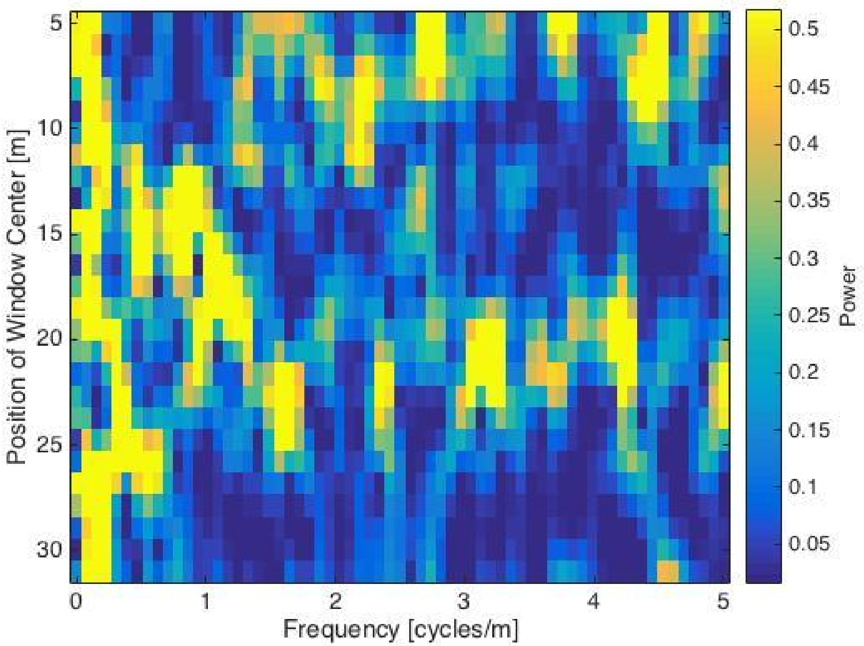

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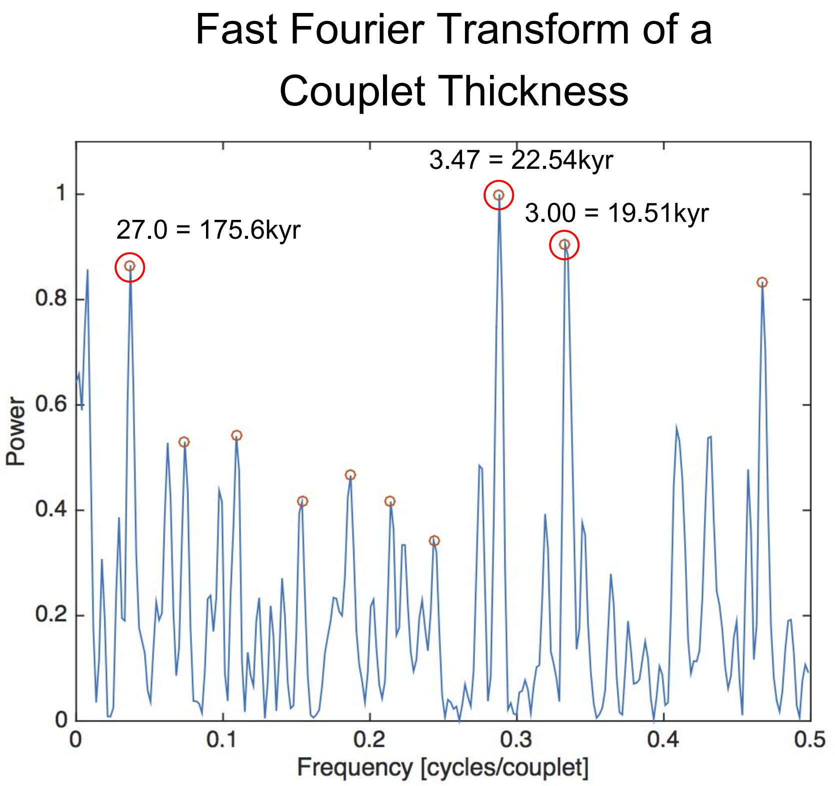

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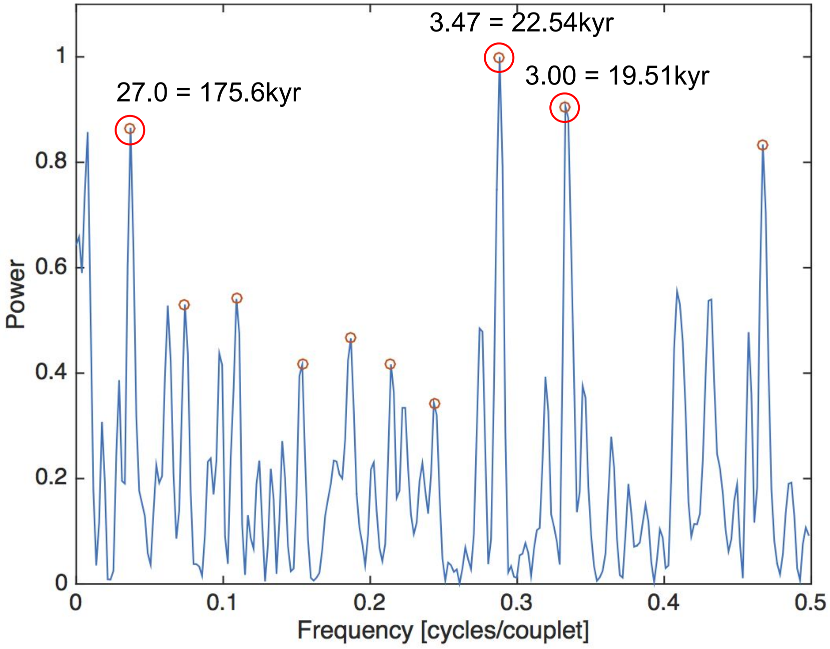
Fast Fourier Transform of a Couplet Thickness



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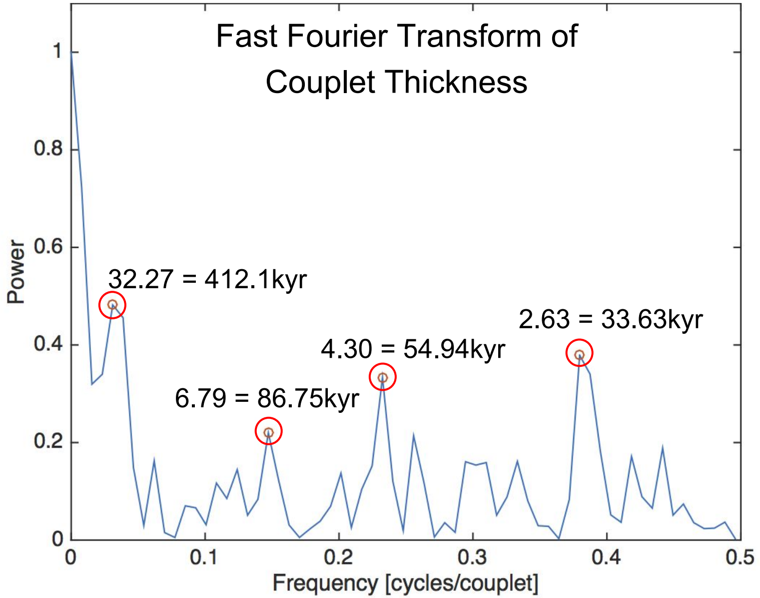

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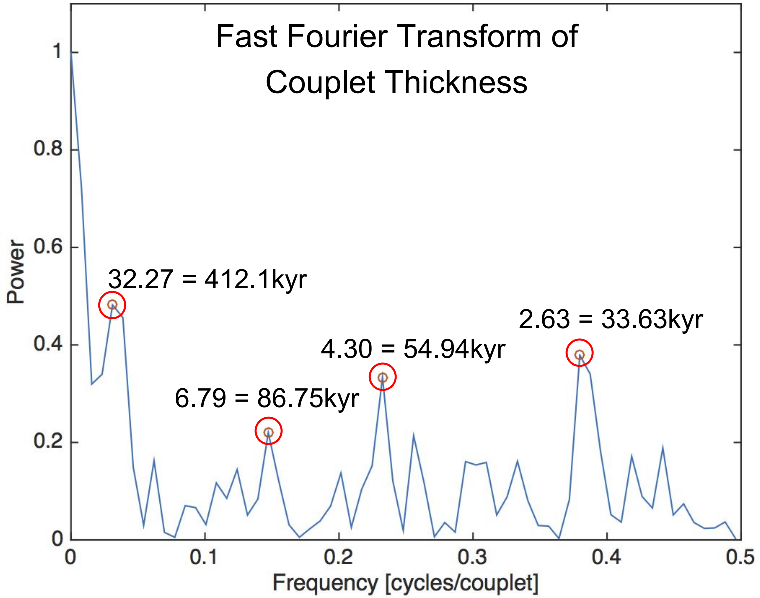

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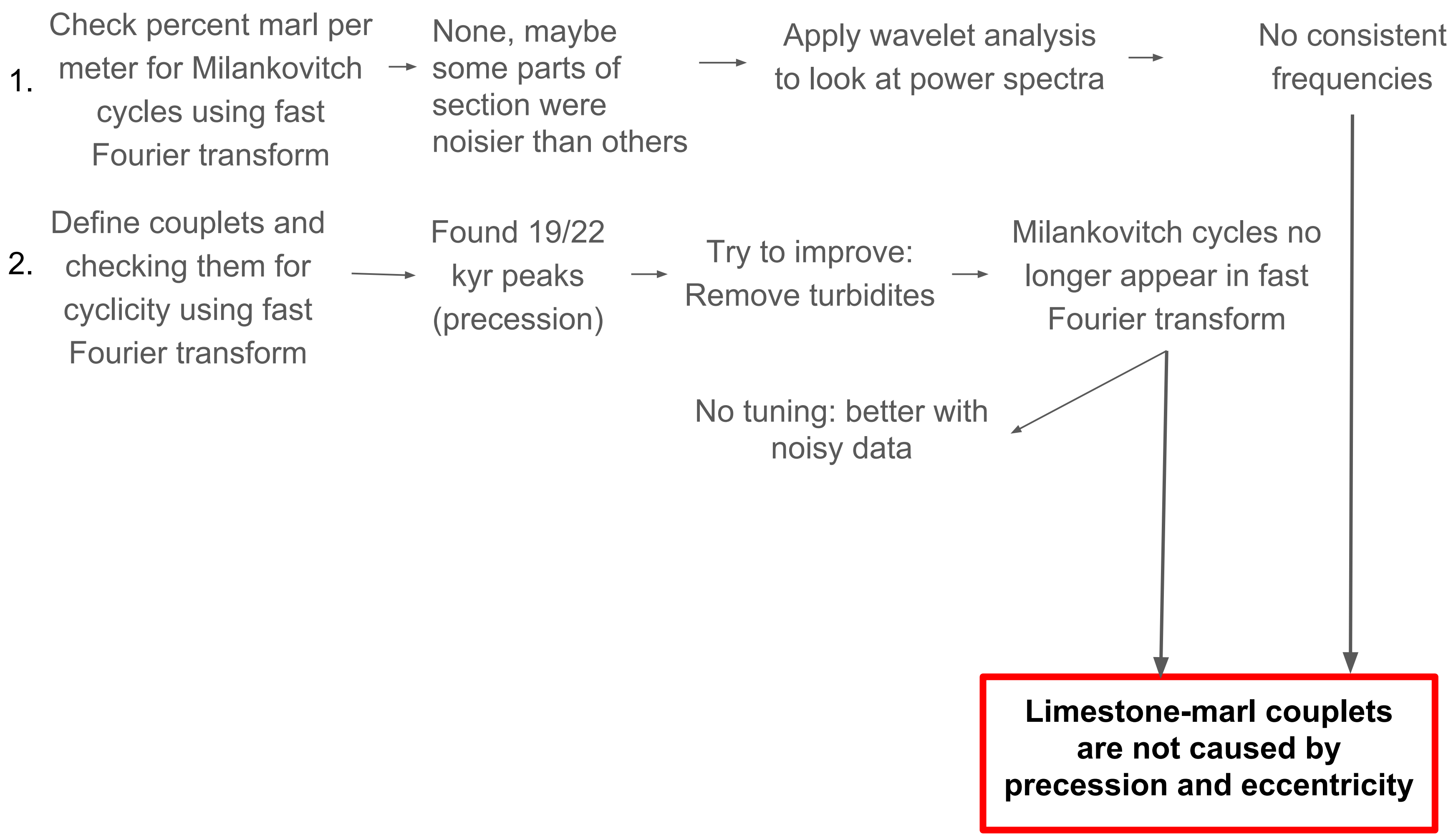
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Limestone-marl couplets are not caused by precession and eccentricity

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Turbidites are periodic

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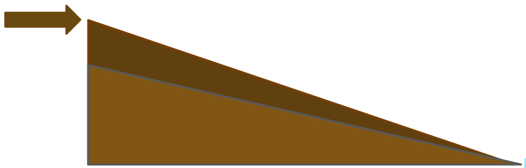

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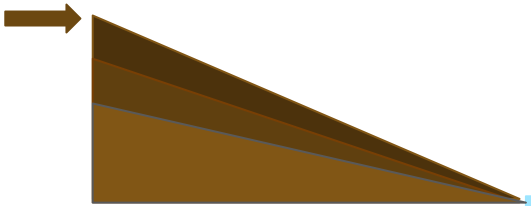

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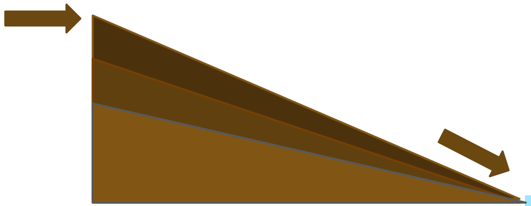

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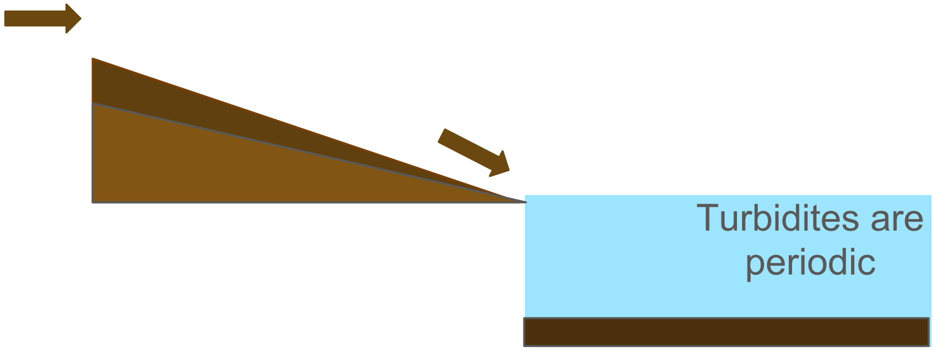

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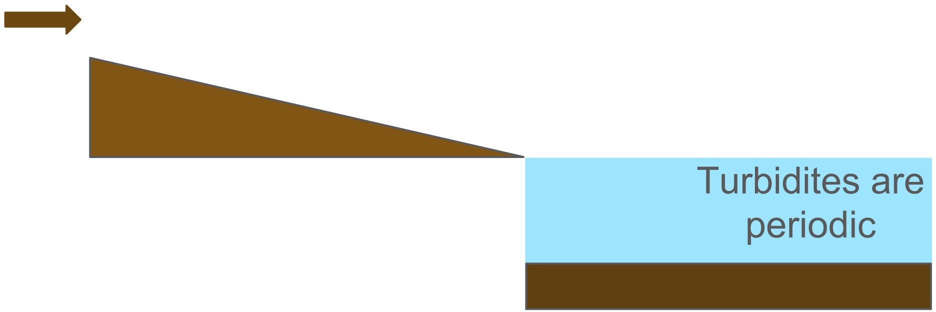

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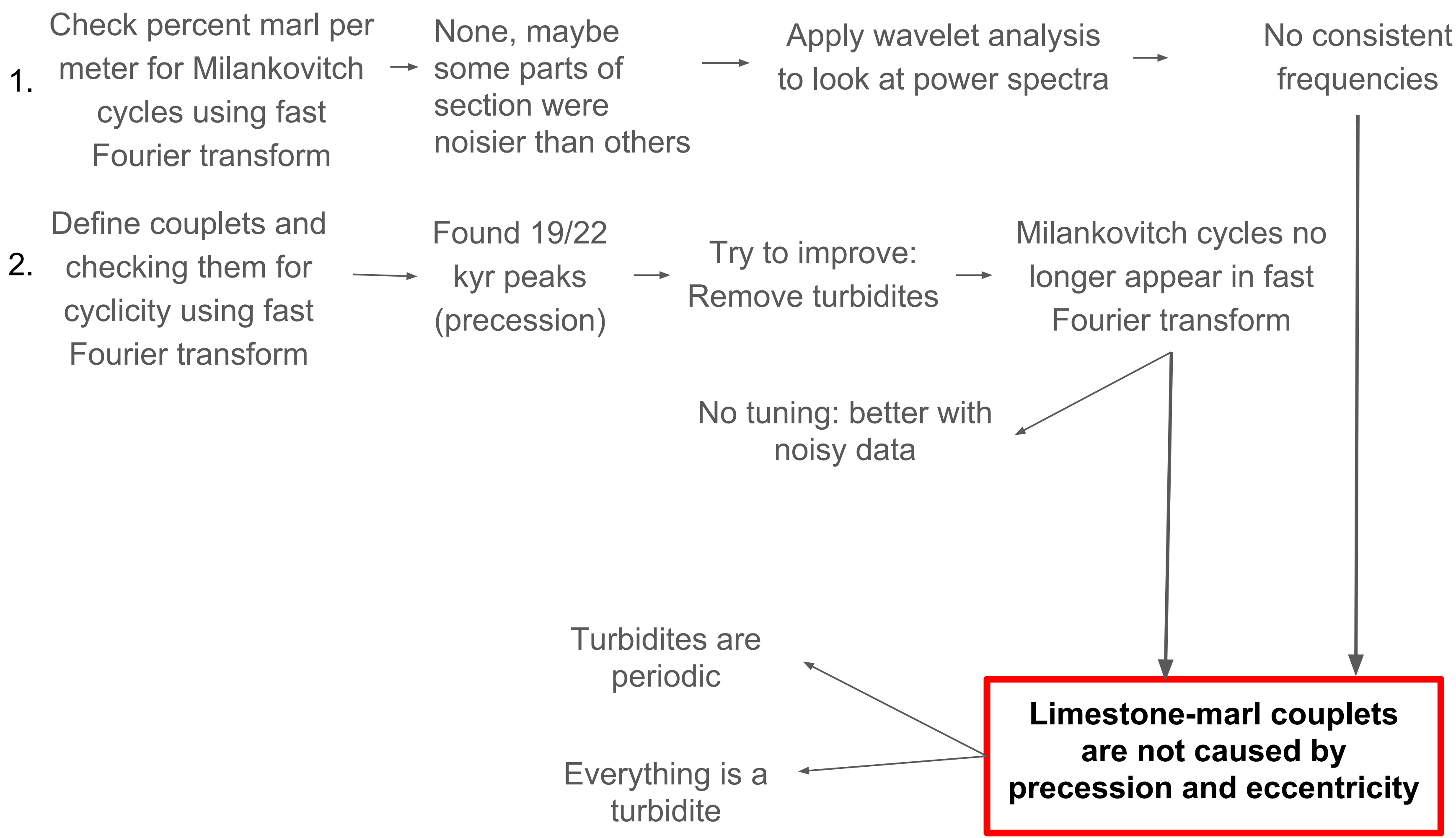
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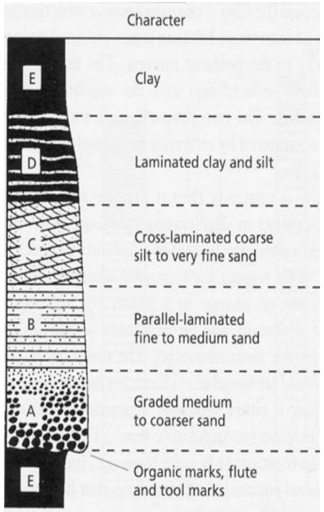

marl beds

missing bases

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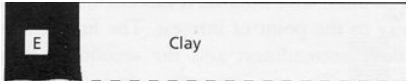

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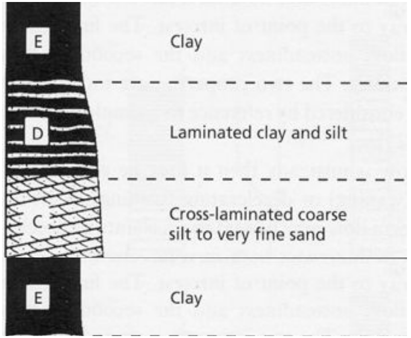

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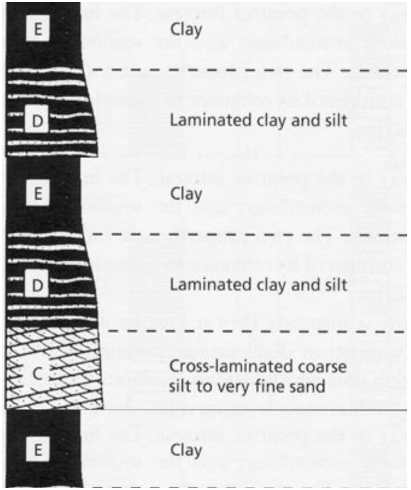

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Questions?

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