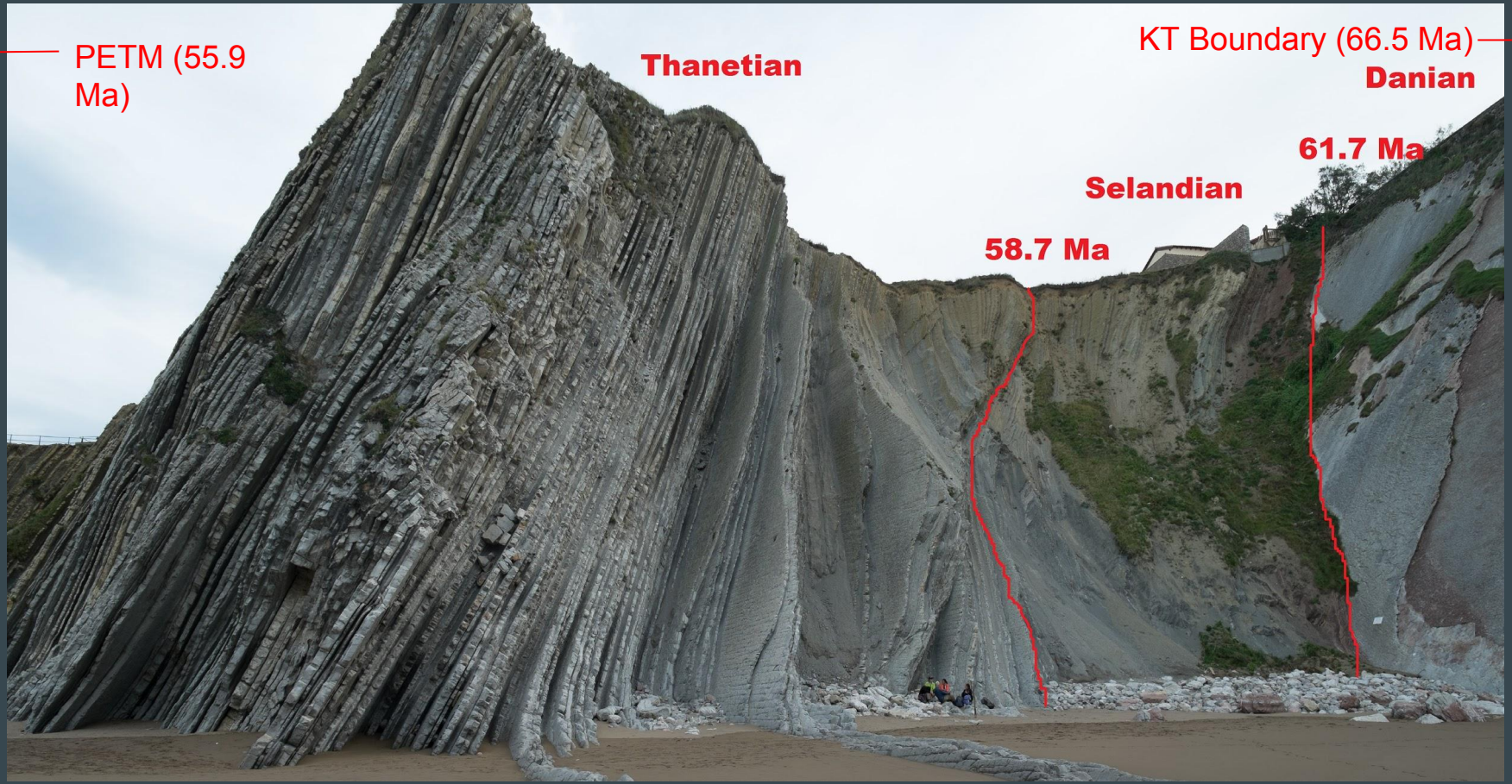
Climate cycles on an ice-free planet:

...

magnetic susceptibility as a metric
for Late Paleocene environmental fluctuations in Zumaia, Spain

ARTEMIS EYSTER & AMBER Y. LIN


Bay of Biscay
Zumaia
FRANCE
Oviedo
Bilbao
Galicia
Cordillera Cantabrica
Pamplona
Pyrenees
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

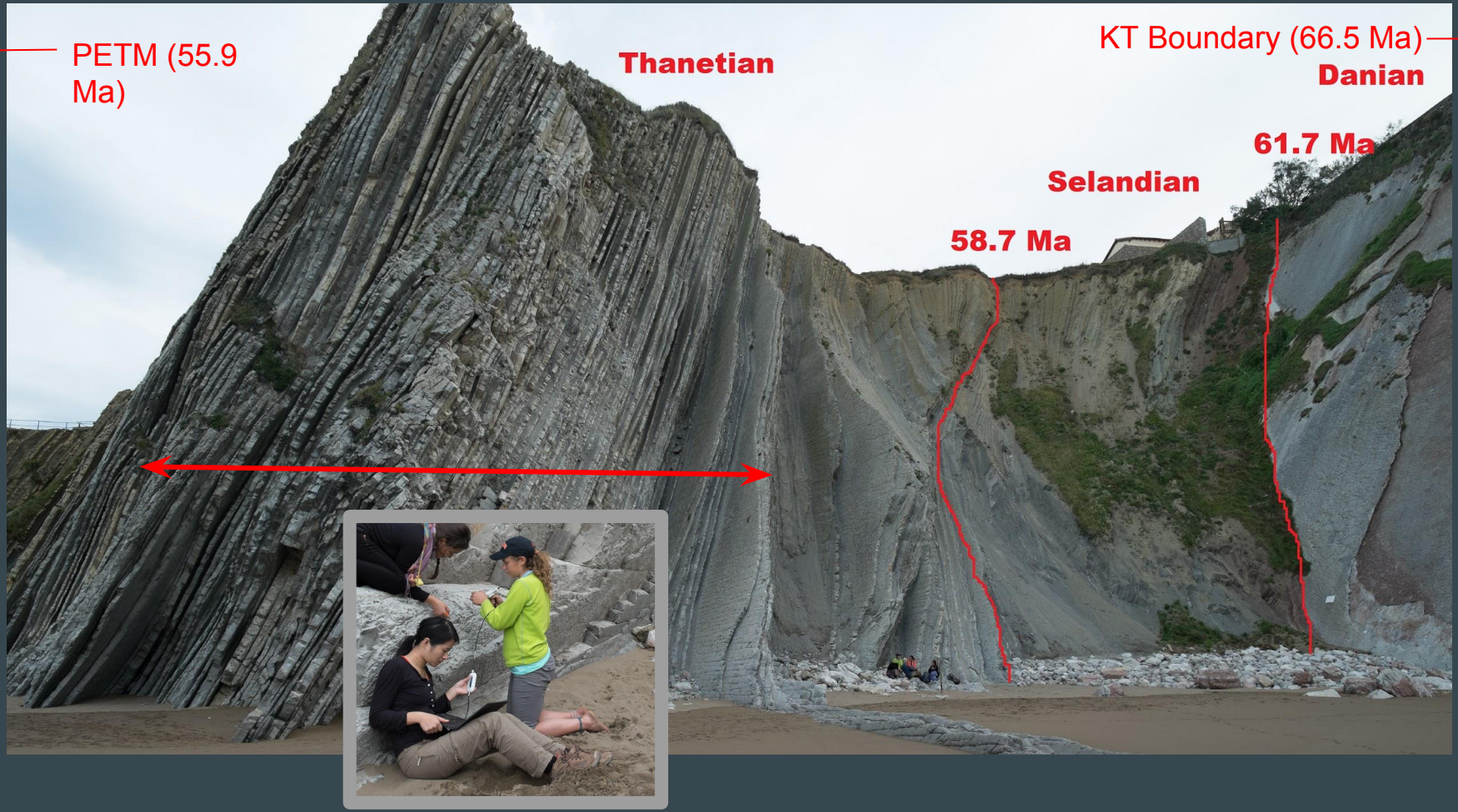
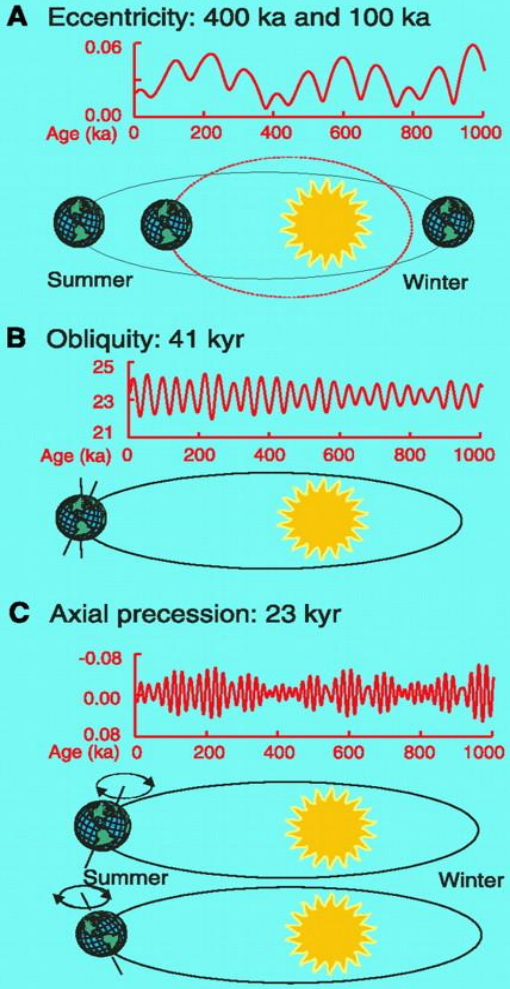
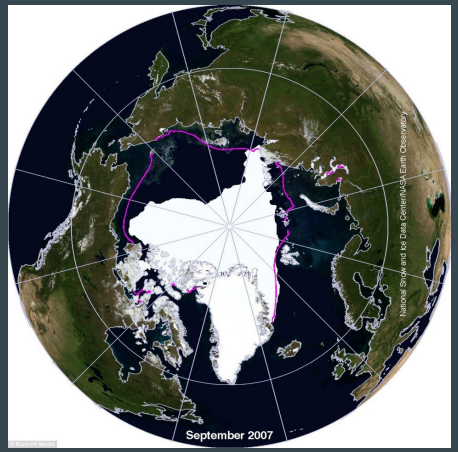


Image Credit: Adam Maloof

Milankovitch Cycles



TODAY: Obliquity



PALEOCENE: Eccentricity modulated precession

Image credit: NASA Earth Observatory

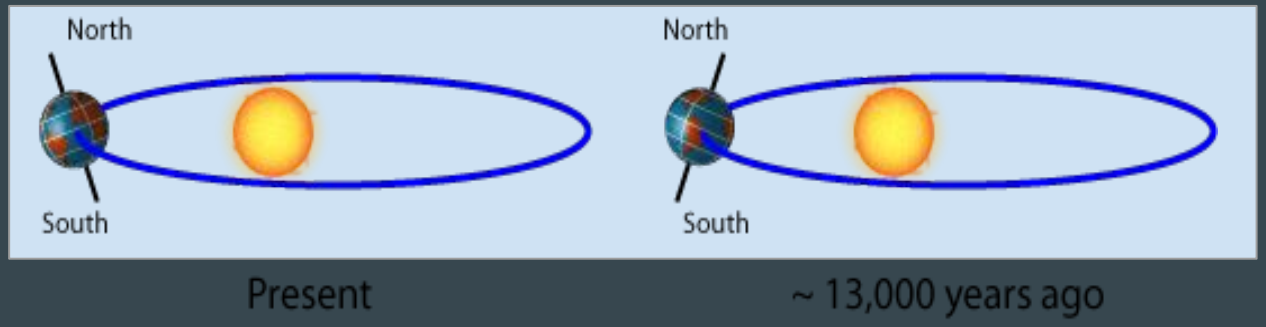


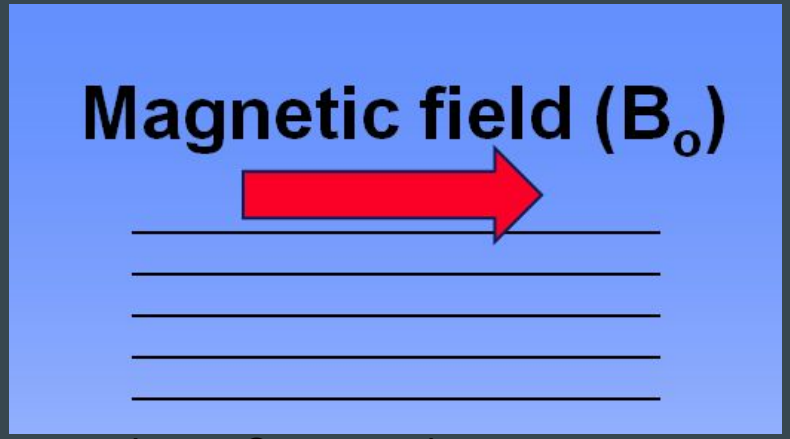
Image source:http://www.skepticalscience.com

Sedimentation Cycles

Image credit: Adam Maloof

Image source: wnpr.org

Image source: dawn.com



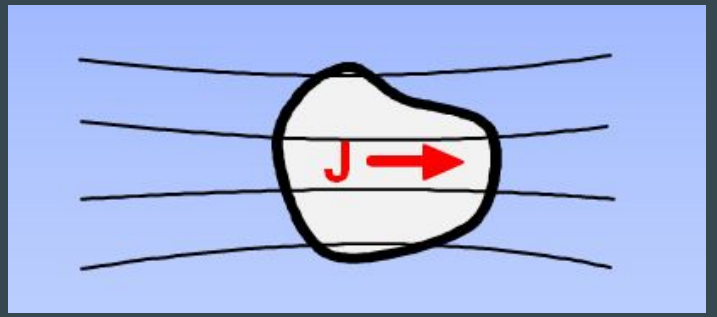


Image Source: mri-q.com

Bartington Instruments MS2k Surface Scanning Sensor

Image Source: bartington.com

CONTROL SAMPLE

Image credit:
Adam Maloof

Past findings of Milankovitch cycles in Zumaia

- Batenburg et al. 2014
- Ellwood et. al 2008

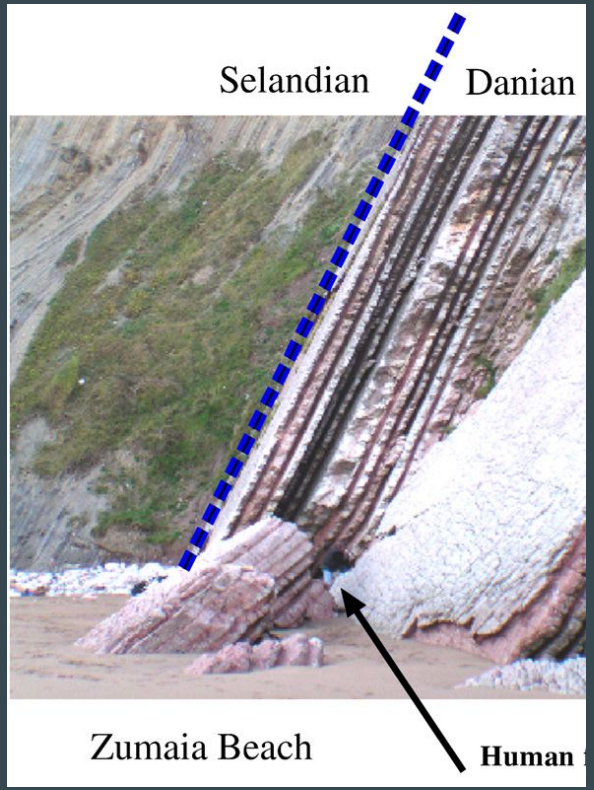
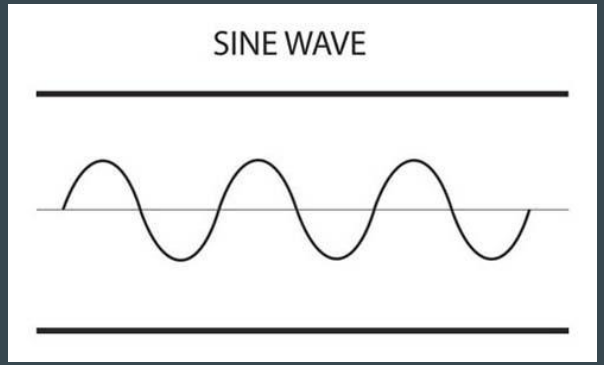


Image source: Ellwood et. al

Milankovitch cycles

(precession and eccentricity)

“LARGE”

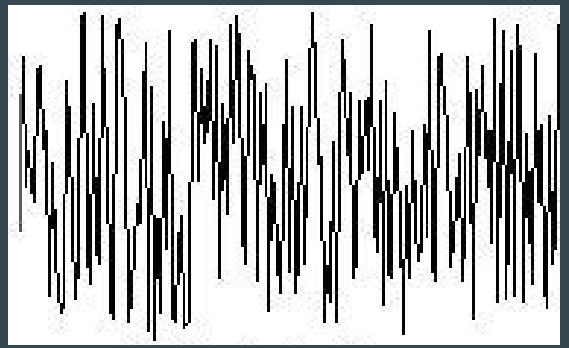


Sediment transport

stochastic processes

(storms, avulsion, turbidites)

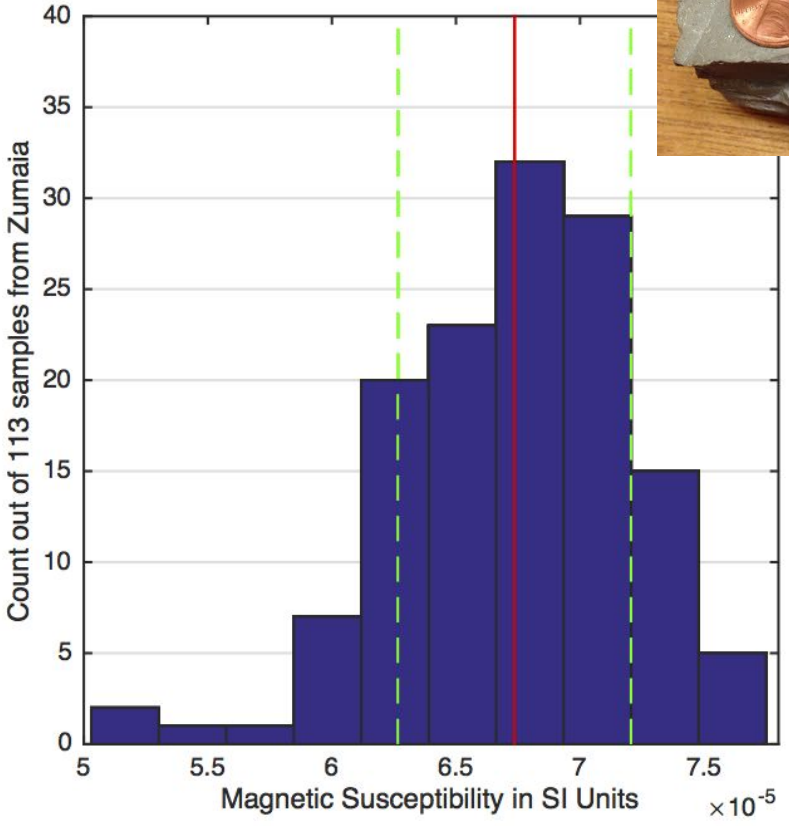
“small”

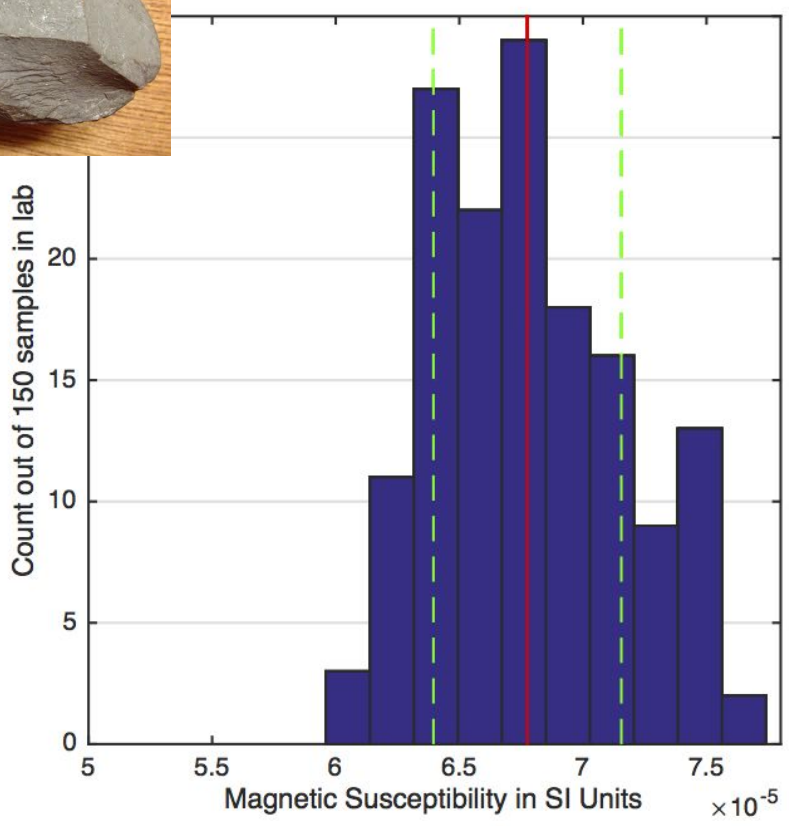


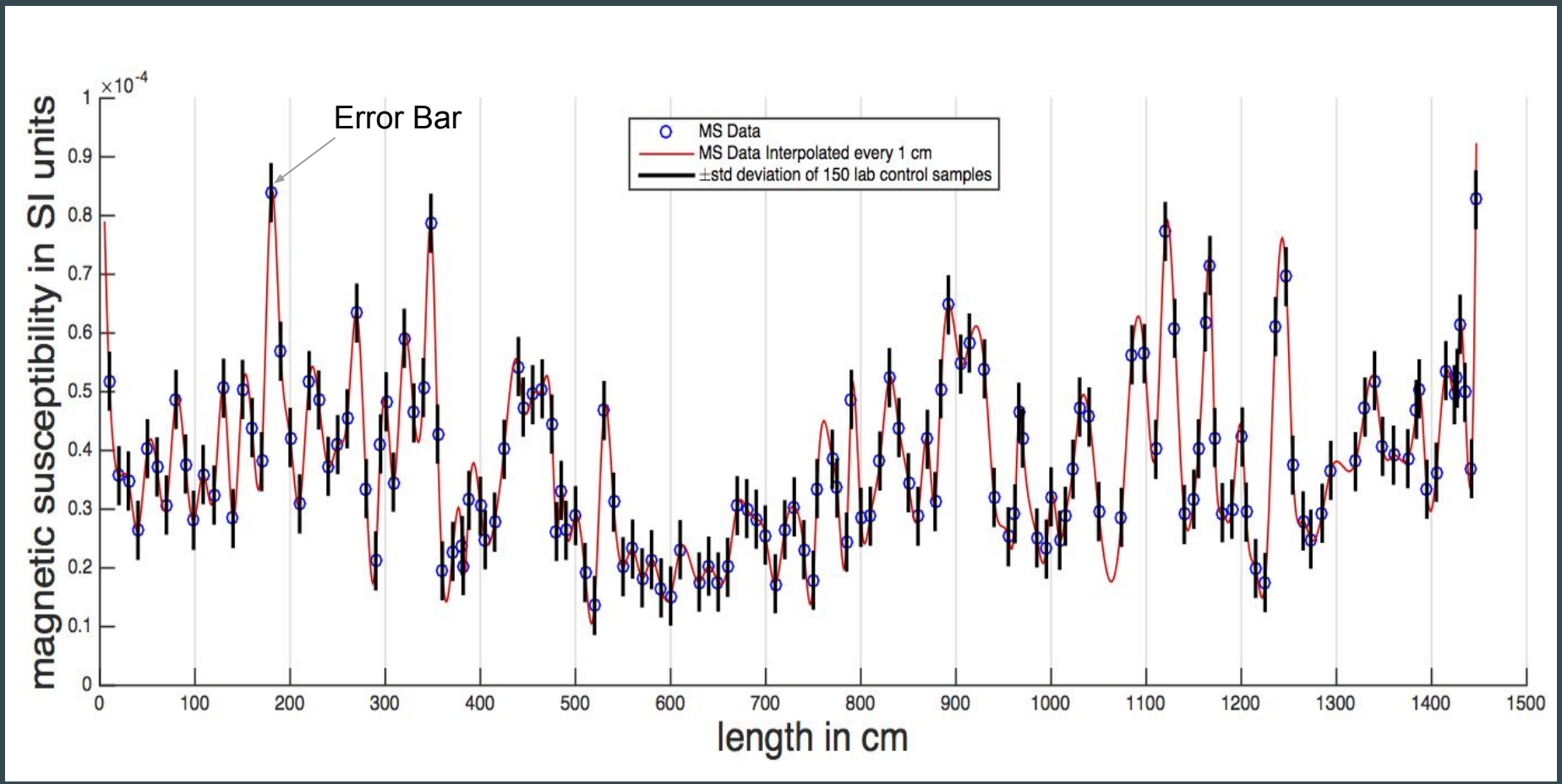
magnetic susceptibility

Zumaia

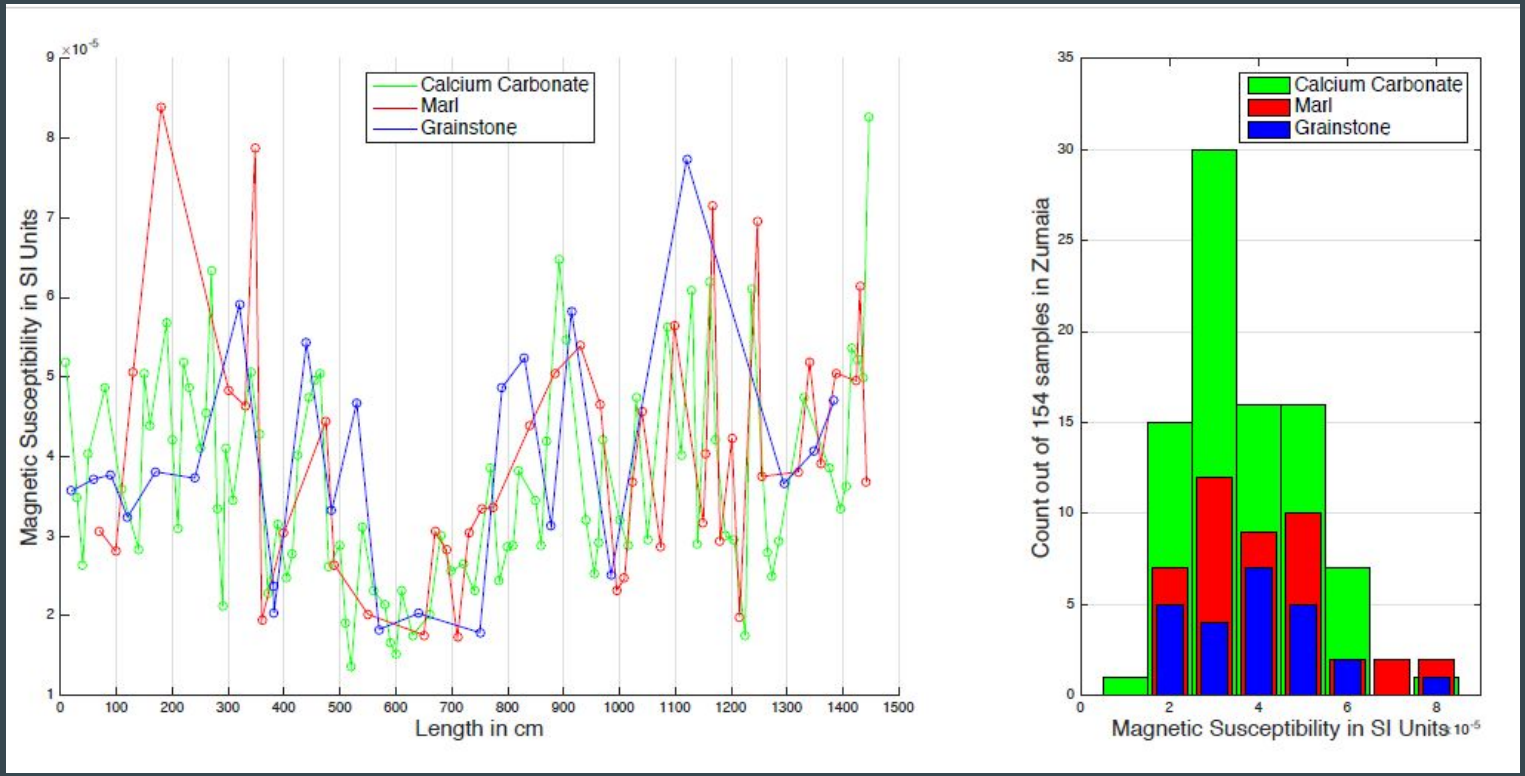
Guyot

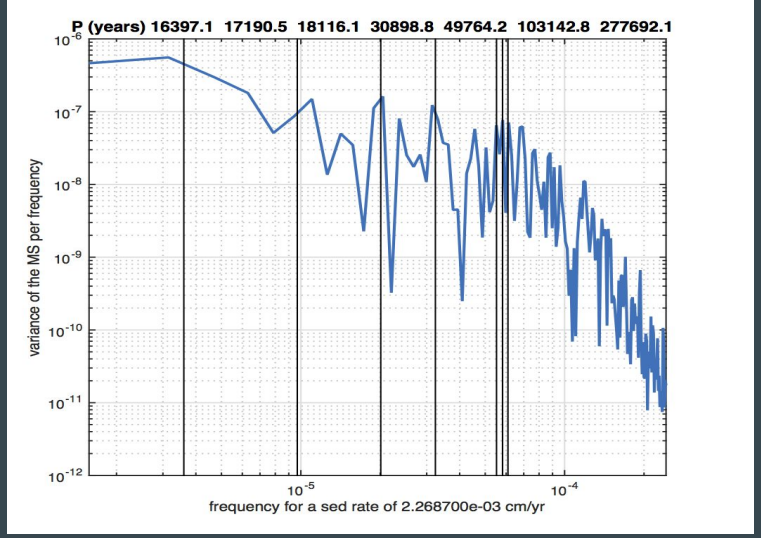


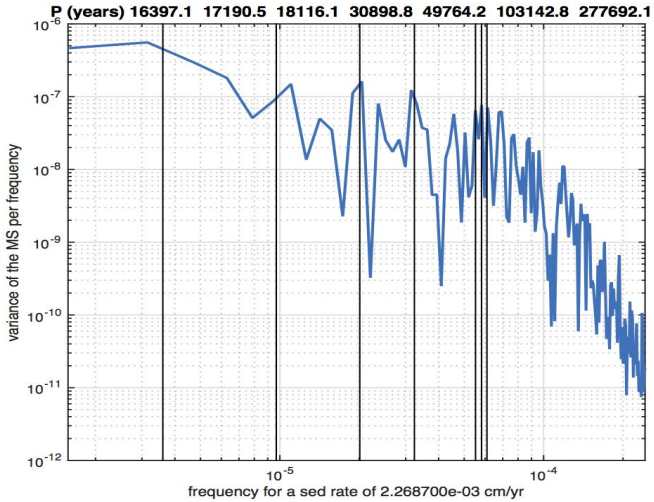



Error Bar
MS Data
MS Data Interpolated every 1 cm
±std deviation of 150 lab control samples
magnetic susceptibility in SI units
×10^-4
length in cm
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500

MS independent of facies




P (years) 16397.1 17190.5 18116.1 30898.8 49764.2 103142.8 277692.1
variance of the MS per frequency
frequency for a sed rate of 2.268700e-03 cm/yr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variance of the MS per frequency
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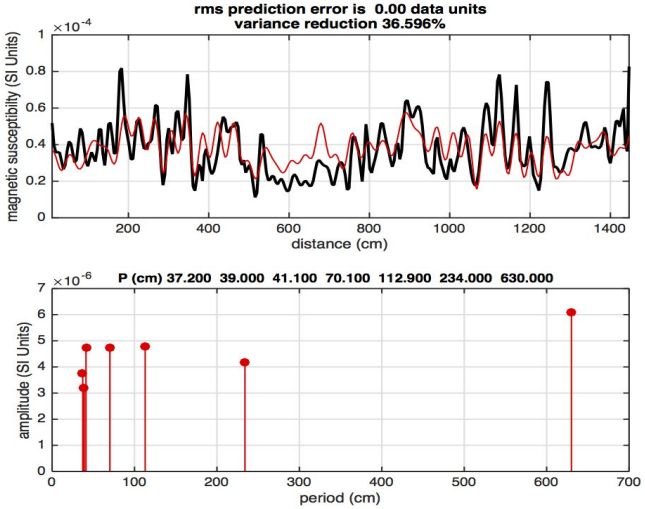
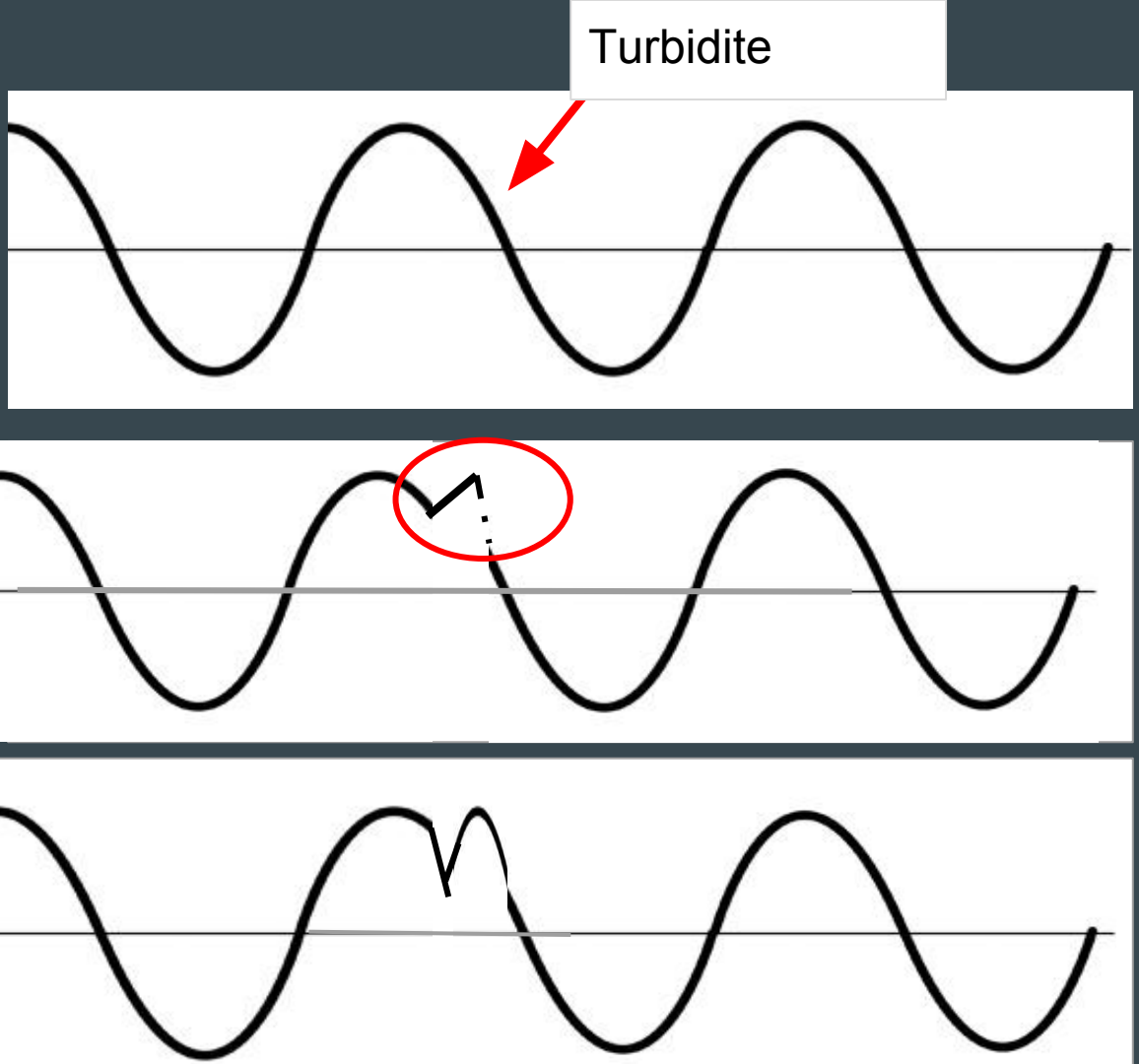
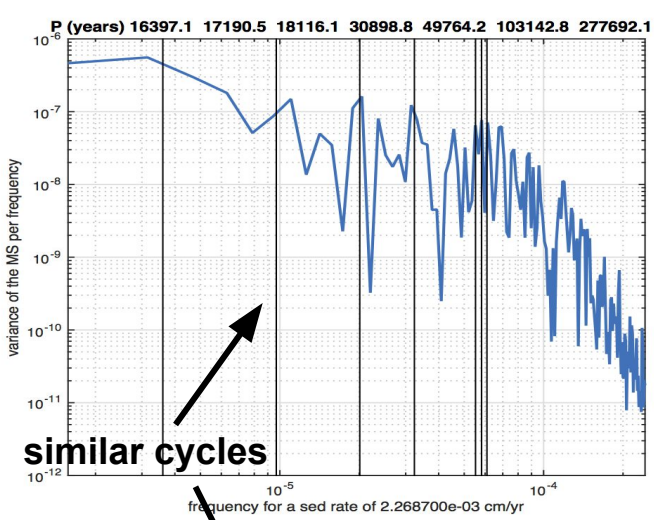

rms prediction error is 0.00 data units
variance reduction 36.596%
magnetic susceptibility (SI Units)
distance (cm)
P (cm) 37.200 39.000 41.100 70.100 112.900 234.000 630.000
amplitude (SI Units)
period (cm)

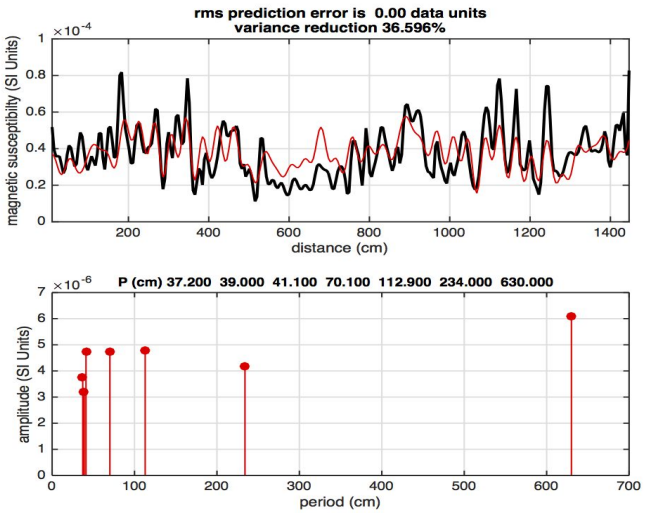
Remove Turbidites



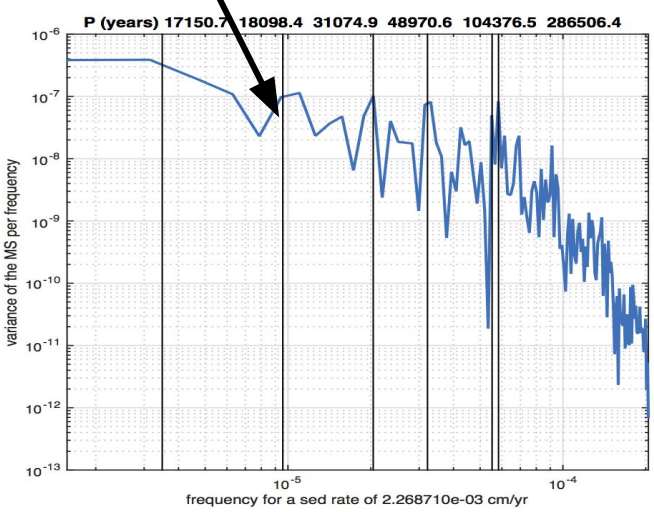
turbidites included

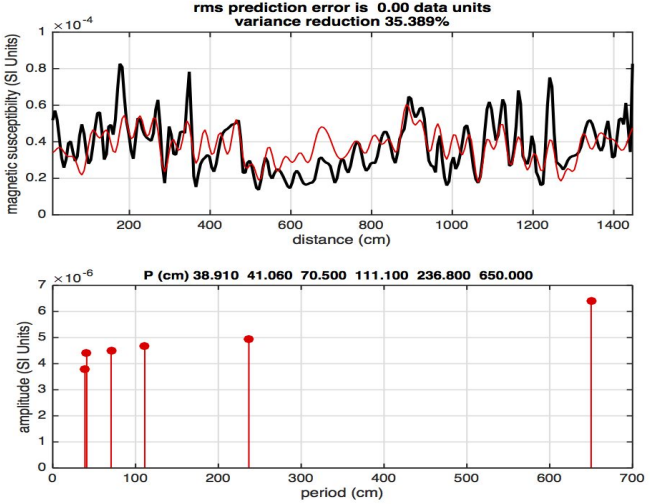


similar cycles



turbidites removed





MS all				MS with turbidities and ribbons removed			
Period (cm)	Period (beds)	Period (kyr)	Variance reduction	Period (cm)	Period (beds)	Period (kyr)	Variance reduction
37.2	5.7	16.3	3.3				
39.0	5.9	17.1	3.8	38.9	7.6	17.1	4.0
41.1	6.3	18.1	5.1	41.1	8.0	18.1	4.9
70.1	10.7	30.8	5.2	70.5	13.7	31.1	4.7
112.9	17.3	49.7	5.4	111.1	21.6	48.9	6.2
234	35.9	103.1	5.1	236.8	46.0	104.37	7.1
630	96.9	277.6	9.5	650	126.5	286.5	10.4
				1090		480.5	16.68

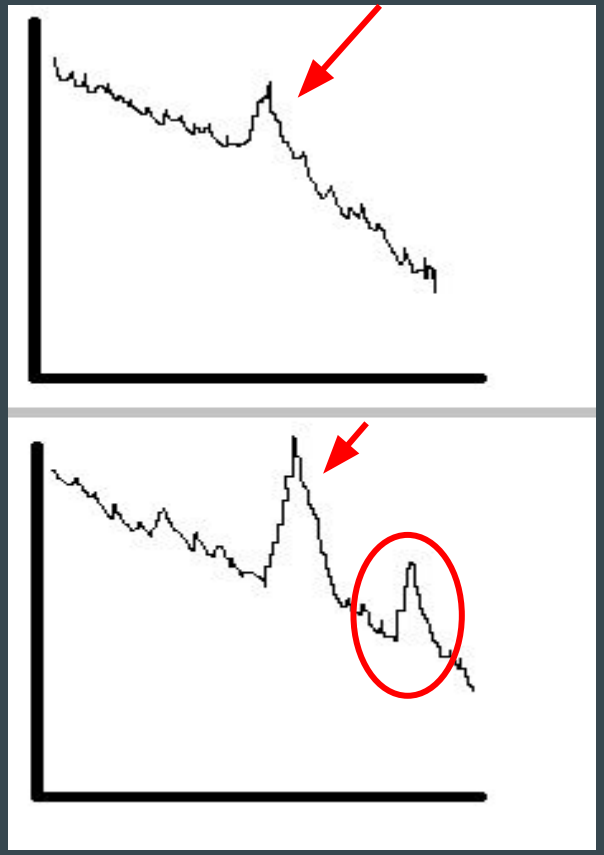
Larger variance reduction

Smaller variance reduction

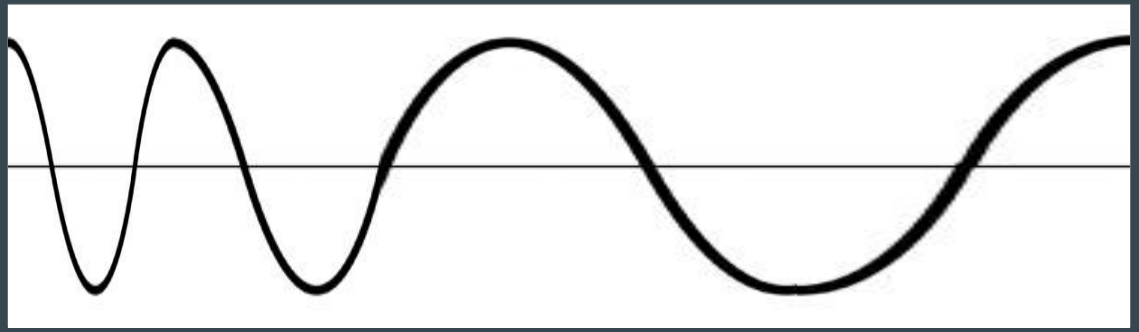
New cycles

MS all				MS with turbidities and ribbons removed			
Period (cm)	Period (beds)	Period (kyr)	Variance reduction	Period (cm)	Period (beds)	Period (kyr)	Variance reduction
37.2	5.7	16.3	3.3				
39.0	5.9	17.1	3.8	38.9	7.6	17.1	4.0
41.1	6.3	18.1	5.1	41.1	8.0	18.1	4.9
70.1	10.7	30.8	5.2	70.5	13.7	31.1	4.7
112.9	17.3	49.7	5.4	111.1	21.6	48.9	6.2
234	35.9	103.1	5.1	236.8	46.0	104.37	7.1
630	96.9	277.6	9.5	650	126.5	286.5	10.4
				1090		480.5	16.68

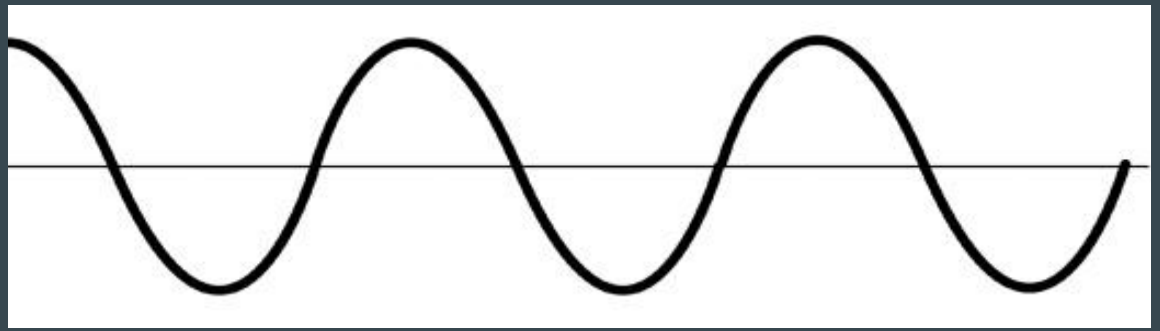
What is tuning?



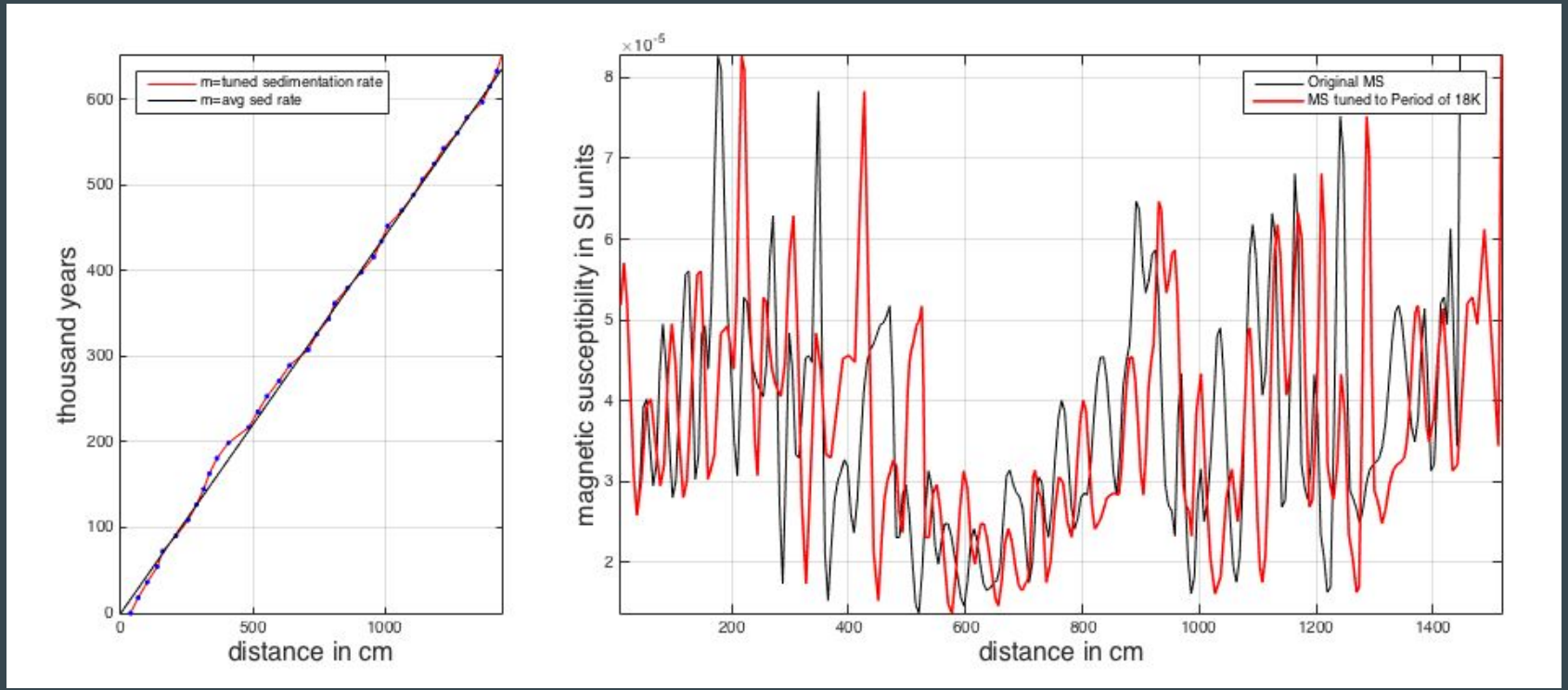
Increasing sedimentation rate



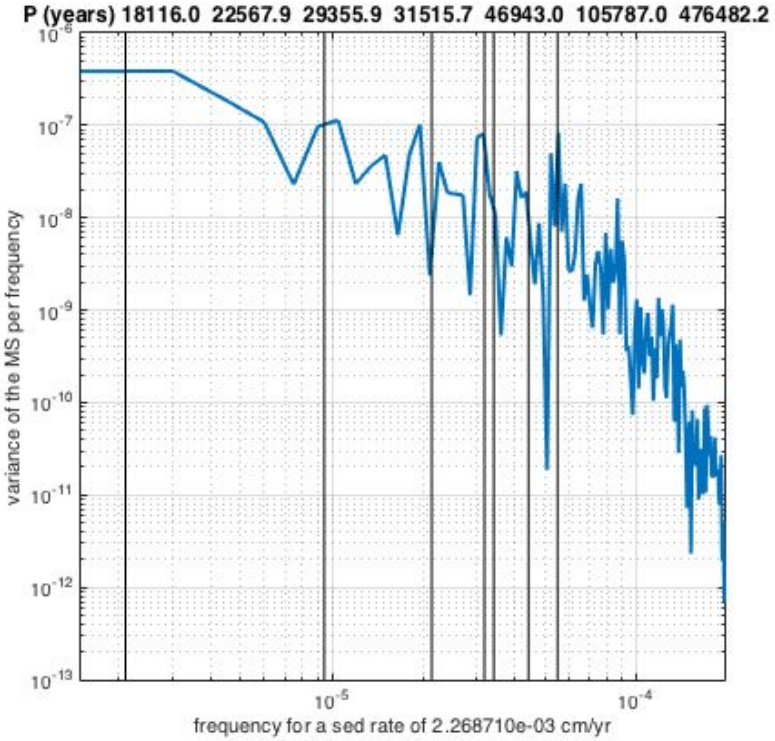
Tuned

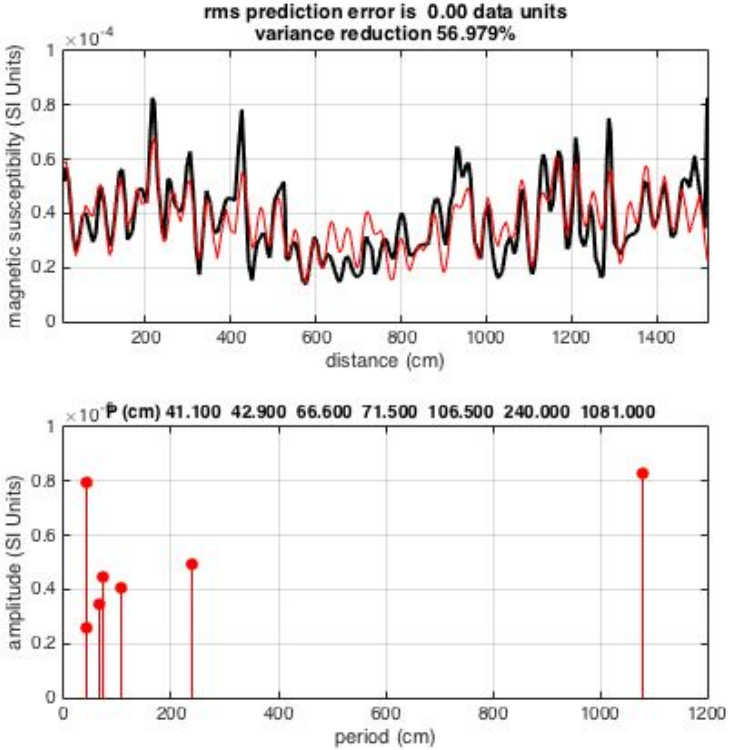


Tune to 18K (~21K)



Tune to 18K (~21K)





MS all				MS with turbidities and ribbons removed				Tuned to 41.1 cm (18.1 kyr)			
Period (cm)	Period (beds)	Period (kyr)	Variance reduction	Period (cm)	Period (beds)	Period (kyr)	Variance reduction	Period (cm)	Period (beds)	Period (kyr)	Variance reduction
37.2	5.7	16.3	3.3								
39.0	5.9	17.1	3.8	38.9	7.6	17.1	4.0	41.1	**6.3**	**18.1**	19.8
41.1	6.3	18.1	5.1	41.1	8.0	18.1	4.9	42.9	**6.6**	**22.6**	4.15
70.1	10.7	30.8	5.2	70.5	13.7	31.1	4.7	71.5	**11.0**	**31.5**	7.4
112.9	17.3	49.7	5.4	111.1	21.6	48.9	6.2	106.5	**16.4**	**47.0**	5.75
234	35.9	103.1	5.1	236.8	46.0	104.37	7.1	240	**36.9**	**105.8**	4.3
630	96.9	277.6	9.5	650	126.5	286.5	10.4				
				1090		480.5	16.68	1081	**166.3**	**476.5**	16.3

Larger variance reduction

Smaller variance reduction

New cycles

Periods calculated in kiloyears using an average sedimentation rate of 2.687 cm/kyr

MS all				MS with turbidities and ribbons removed				Tuned to 41.1 cm (18.1 kyr)			
Period (cm)	Period (beds)	Period (kyr)	Variance reduction	Period (cm)	Period (beds)	Period (kyr)	Variance reduction	Period (cm)	Period (beds)	Period (kyr)	Variance reduction
37.2	5.7	16.3	3.3								
39.0	5.9	17.1	3.8	38.9	7.6	17.1	4.0	41.1	**6.3**	**18.1**	19.8
41.1	6.3	18.1	5.1	41.1	8.0	18.1	4.9	42.9	**6.6**	**22.6**	4.15
70.1	10.7	30.8	5.2	70.5	13.7	31.1	4.7	71.5	**11.0**	**31.5**	7.4
112.9	17.3	49.7	5.4	111.1	21.6	48.9	6.2	106.5	**16.4**	**47.0**	5.75
234	35.9	103.1	5.1	236.8	46.0	104.37	7.1	240	**36.9**	**105.8**	4.3
630	96.9	277.6	9.5	650	126.5	286.5	10.4				
				1090		480.5	16.68	1081	**166.3**	**476.5**	16.3

Key Points

1. Failed 2 tests of Milankovitch theory
    a. Milankovitch cycles could be present... but many others present as well
    b. Tuning to a supposed Milankovitch cycle does not increase variance reduction
2. What is the explanation?
    a. Noise swamps signal
    b. Milankovitch cycles do not exist in this time
3. **NOT** what most other studies have shown

Key Points

1. Failed 2 tests of Milankovitch theory

Key Points

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    a. Milankovitch cycles could be present... but many others present as well

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2. What is the explanation?

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    a. Milankovitch cycles could be present... but many others present as well
    b. Tuning to a supposed Milankovitch cycle does not increase variance reduction
2. What is the explanation?
    a. Noise swamps signal

Key Points

1. Failed 2 tests of Milankovitch theory
    a. Milankovitch cycles could be present... but many others present as well
    b. Tuning to a supposed Milankovitch cycle does not increase variance reduction
2. What is the explanation?
    a. Noise swamps signal
    b. Milankovitch cycles do not affect sedimentation

Key Points

1. Failed 2 tests of Milankovitch theory
    a. Milankovitch cycles could be some of the many significant cycles
    b. Tuning to a supposed Milankovitch cycle does not increase variance reduction
2. What is the explanation?
    a. Noise swamps signal
    b. Milankovitch cycles do not affect sedimentation
3. **NOT** what other studies have shown

Perhaps in a greenhouse world…
climate is not as affected by Milankovitch cycles

Thank you.

Image credit: Amanda WIlkins

APPENDIX

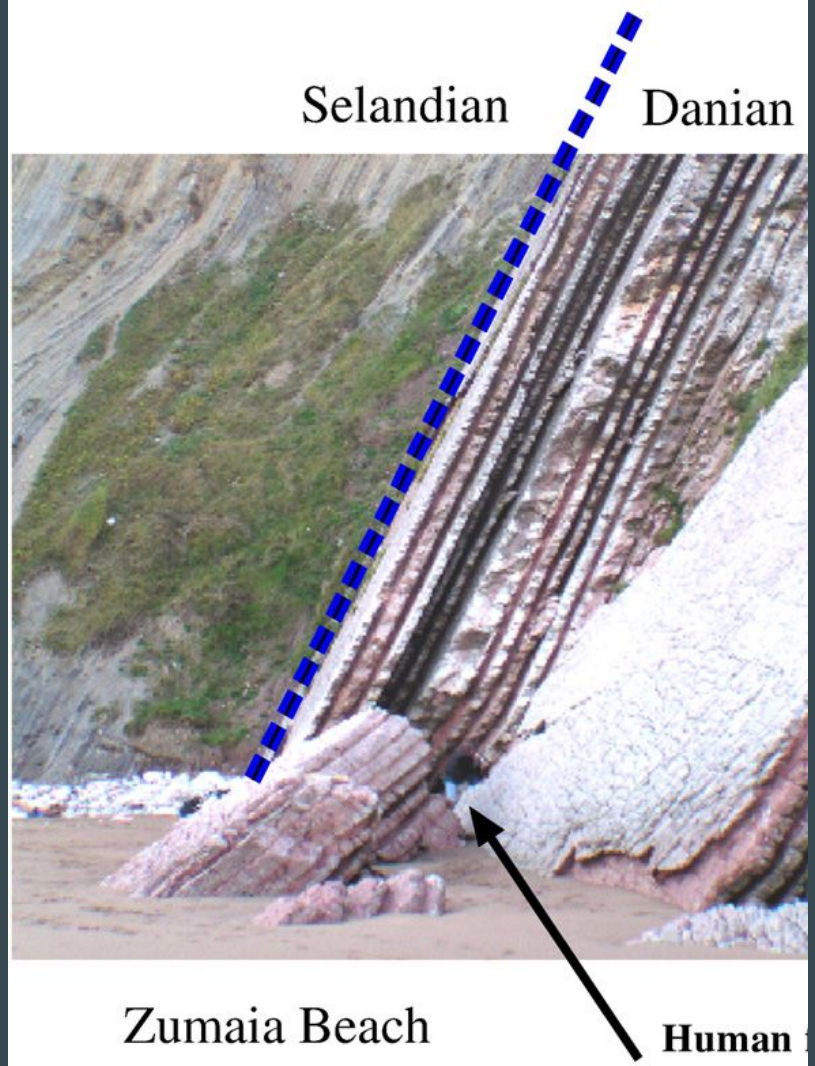


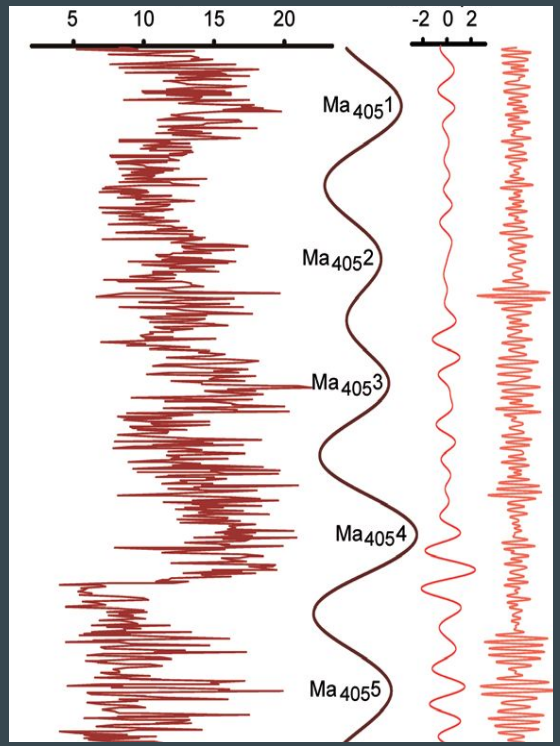
Image provided by Ellwood et. al

Ellwood et. al 2008

- Location: 8.91 centered around boundary
- Methods:
  - Tested every 5 cm
  - Tested with susceptibility bridge
  - Create varying sedimentation rate
- Results:
  - Obliquity more in danian than saladian
  - Eccentricity more in salandian than danian
  - Precession in upper danian
  -

Batenburg et al. 2014

Magnetic susceptibility



- Location:140 meters before K-PG Boundary
- Methods:
  - Eight samples per couplet
  - Average 8cm between each sample
  - All samples measured twice and alternated with blanks
  - band-pass filter centered at 405 kyr
- Results: Main periodicities of 415, 409, 23.6, 22.3, 17.9 kyr
- Conclusion: Eccentricity modulated precession 405 kyr

Image provided by Batenburg et. al

Diamagnetic, Para/Ferromagnetic and Field Direction