Synchronizing rock clocks in the late Cambrian

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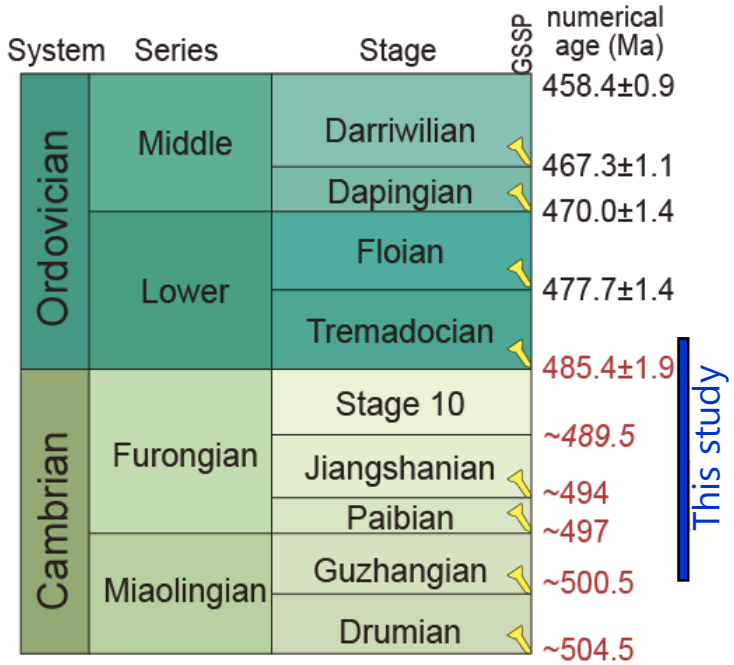
Research issue

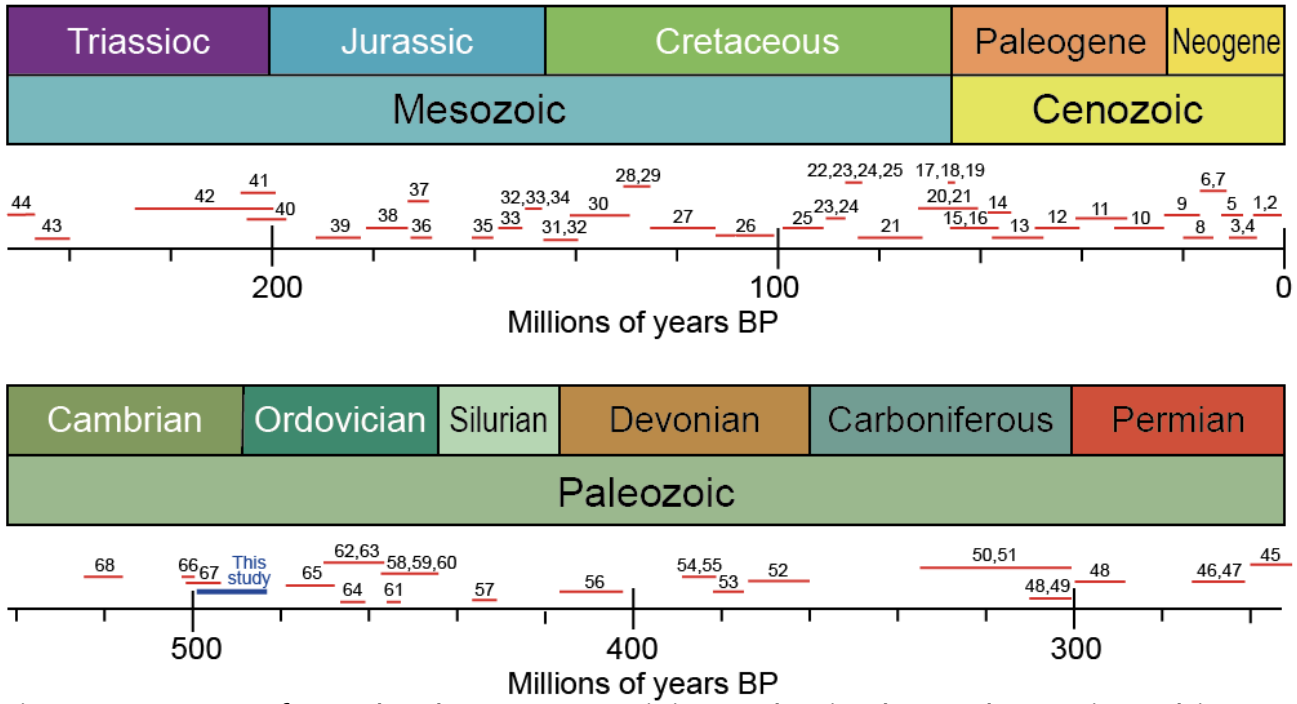
Cambrian: the most poorly dated period of the entire Phanerozoic

1-Rare dated bentonite beds in the Cambrian stratigraphic record.
2-Estimate stage boundary ages by assuming equal time (1Myr) to successive biozones.
3-Pronounced faunal provincialism in the Cambrian limits global biostratigraphic correlation.



Chronostratigraphic chart, V2022/02

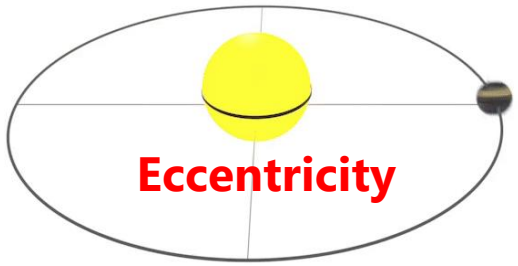
Cyclostratigraphy?

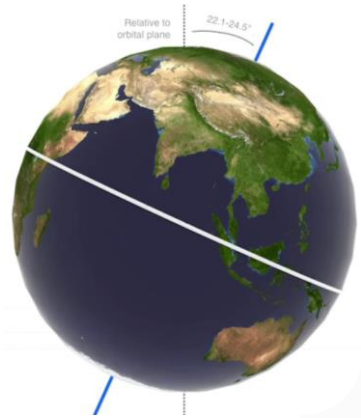


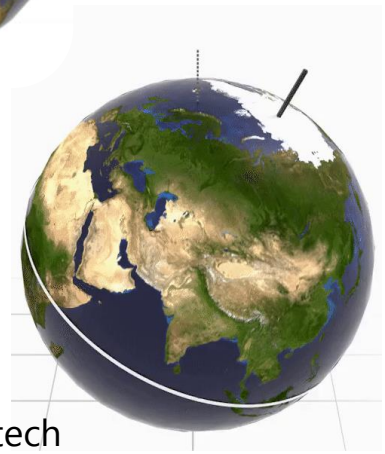
Major sequences of 405-kyr long-eccentricity cycles in the cyclostratigraphic record

Hinnov (2018), Zhong (2019), Zhang et al., (2022)

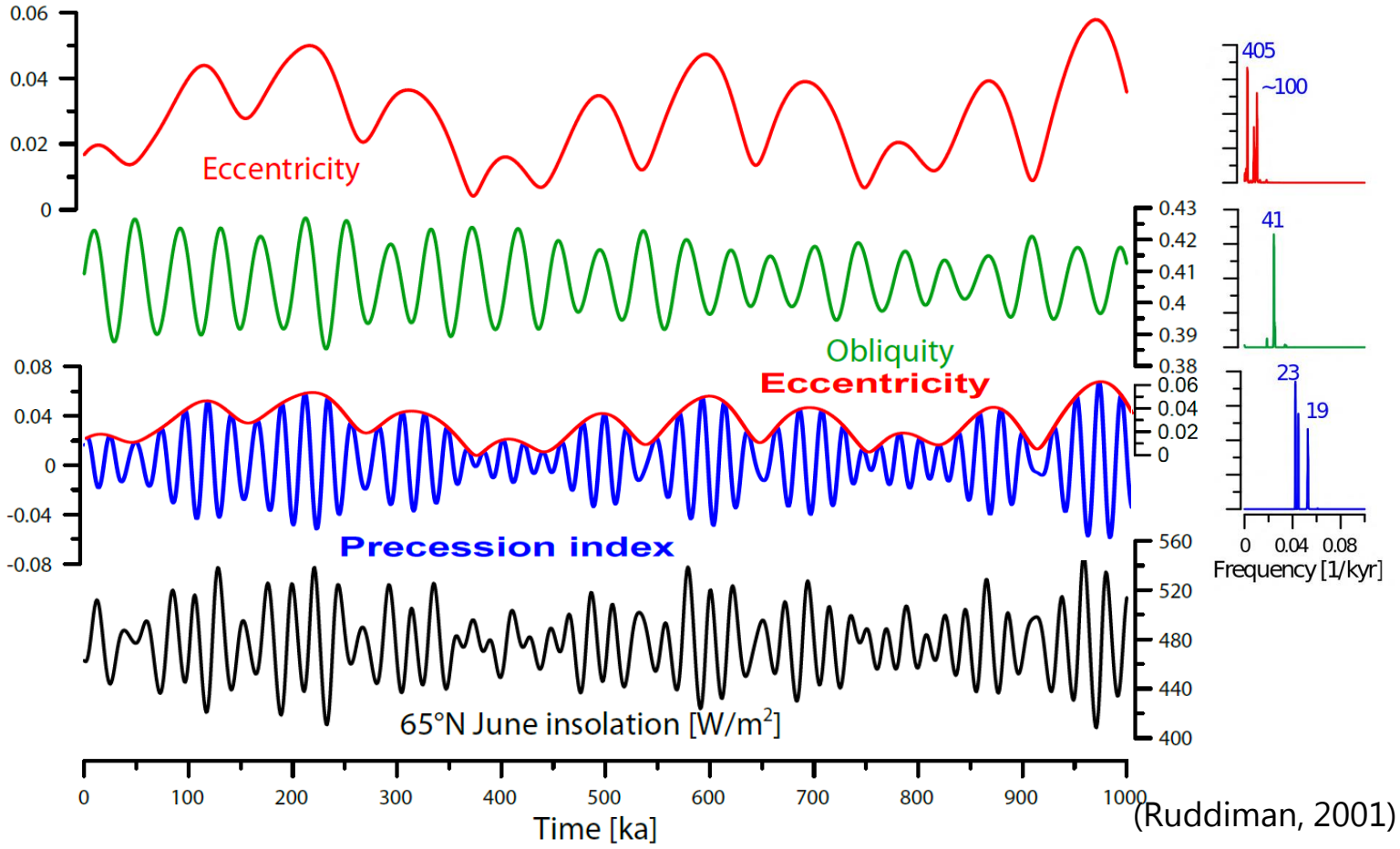
Orbital parameters







Credit: NASA/JPL-Caltech



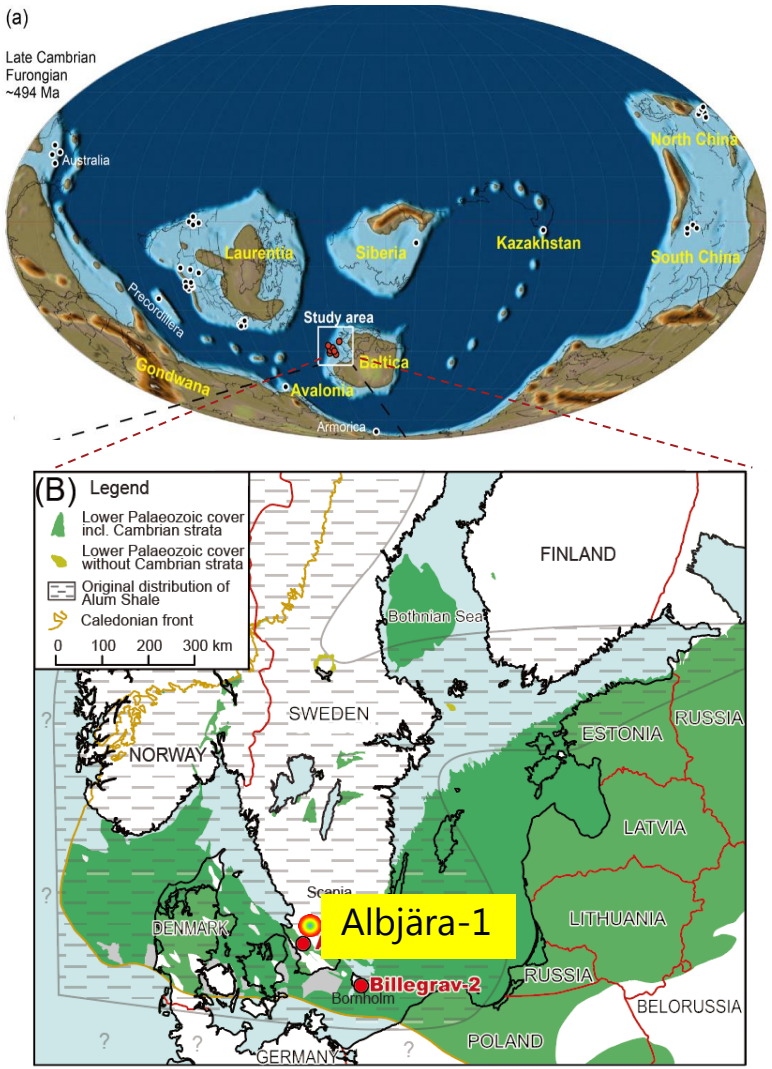
(Ruddiman, 2001)

Insolation changes translate into climate changes, which in turn influence the sedimentology and ecological life.

405-kyr long eccentricity cycle: stable over most of Earth's history and can be a reliable astronomical metronome.

Late Cambrian Alum Shale in Scandinavia

Widely distributed Alum Shale

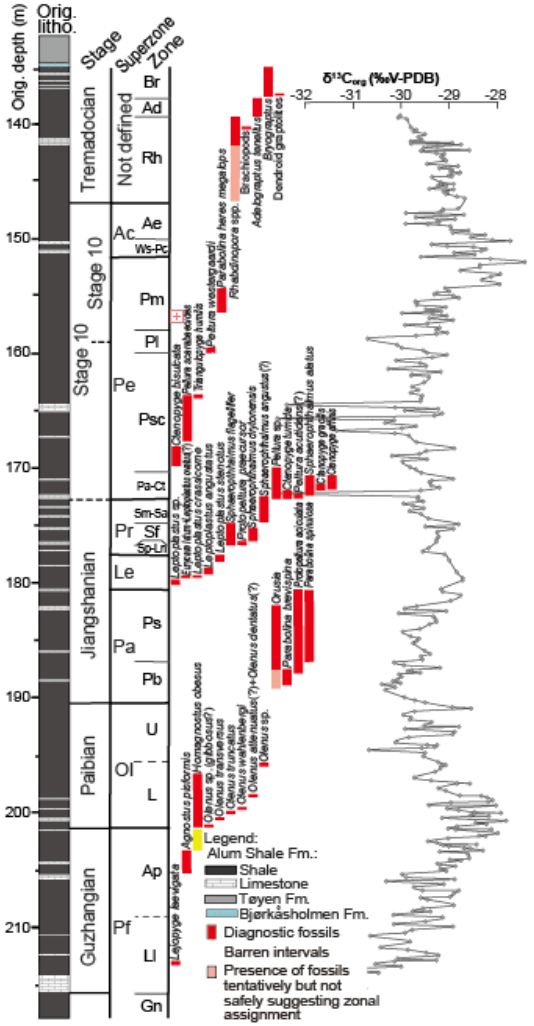


The distribution of the Alum Shale and the location of Albjära-1 well

Monotonous lithology

Core photo (by Schovosbo)

low-diverse but highly abundant benthic trilobite fauna

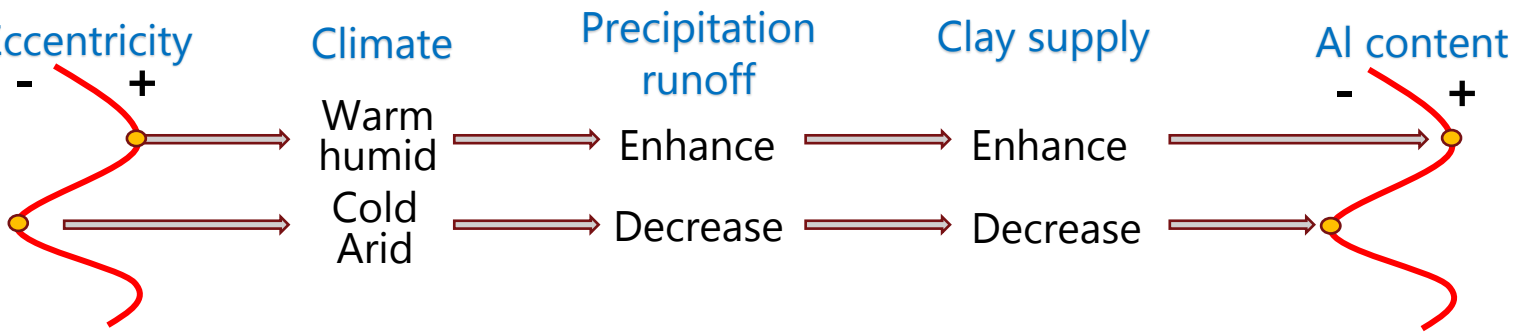


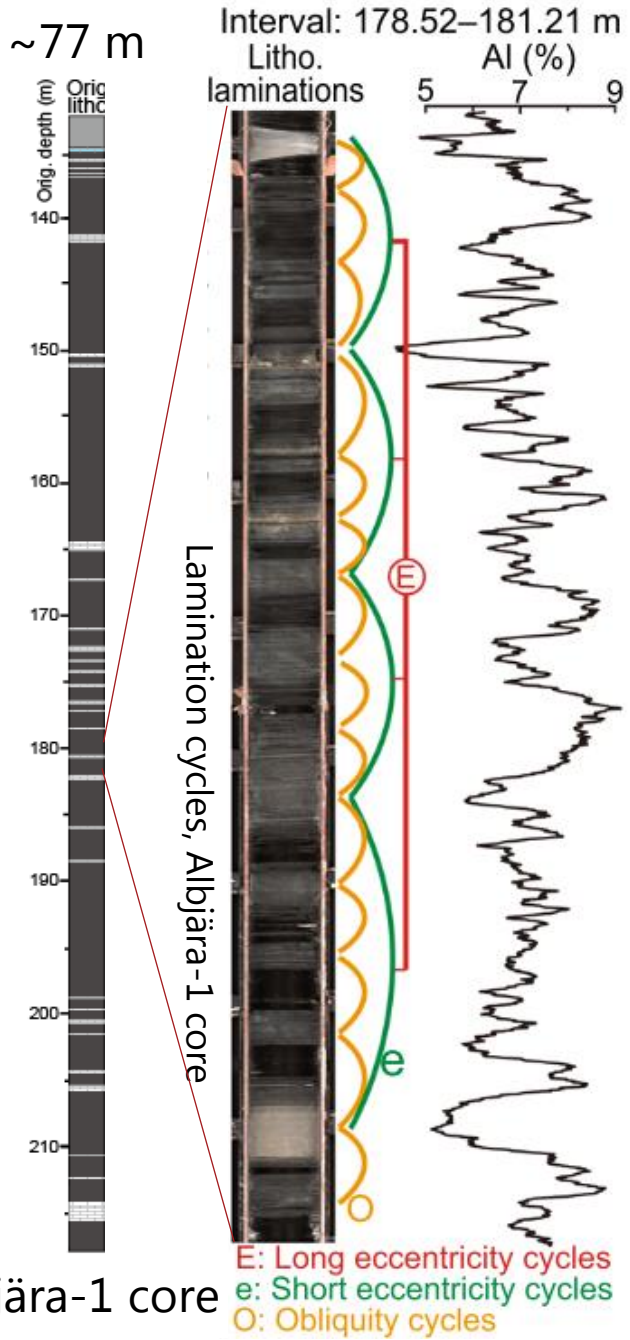
Lithology, Biozonation and $\delta^{13}C_{org}$ of the Albjära-1 core

Paleoclimate proxy-Al

- Highly affected by continental weathering processes
- Less sensitive to diagenetic alteration

XRF-core scanner
(resolution 1mm)





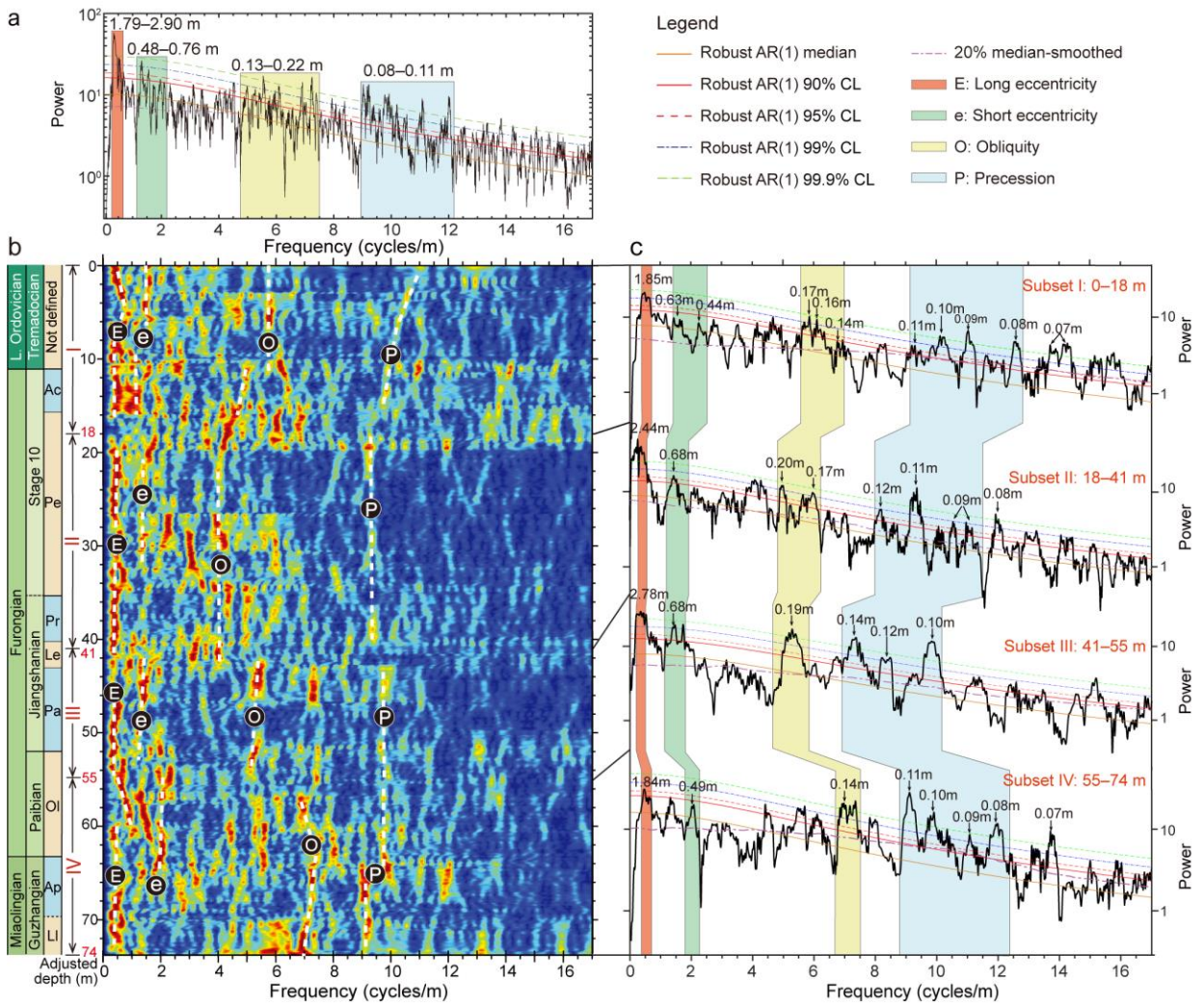
Albjära-1 core

Cyclostratigraphic analysis

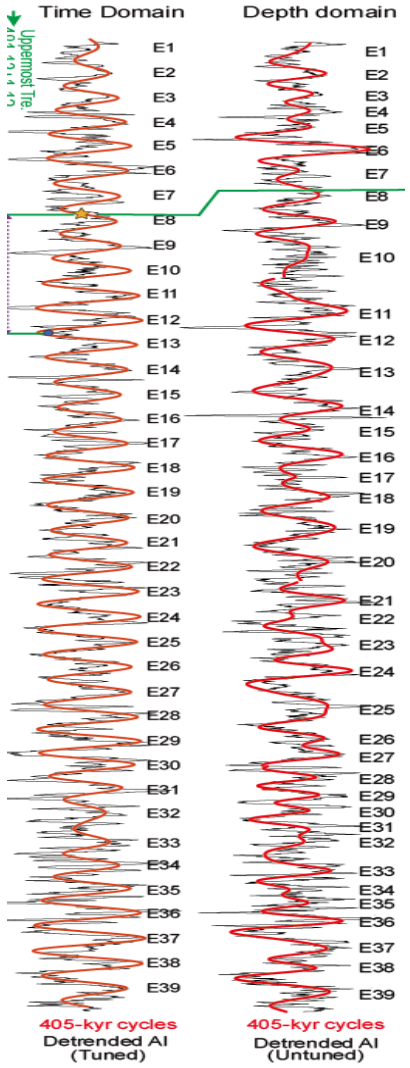
MTM spectrum of uncalibrated Al series shows dominant wavelengths

- E: 1.79–2.90 m
- e: 0.48–0.76 m
- O: 0.13–0.22 m
- P: 0.08–0.11m

Ratios fit well with those of the theoretical late Cambrian orbital parameters (Waltham, 2015)



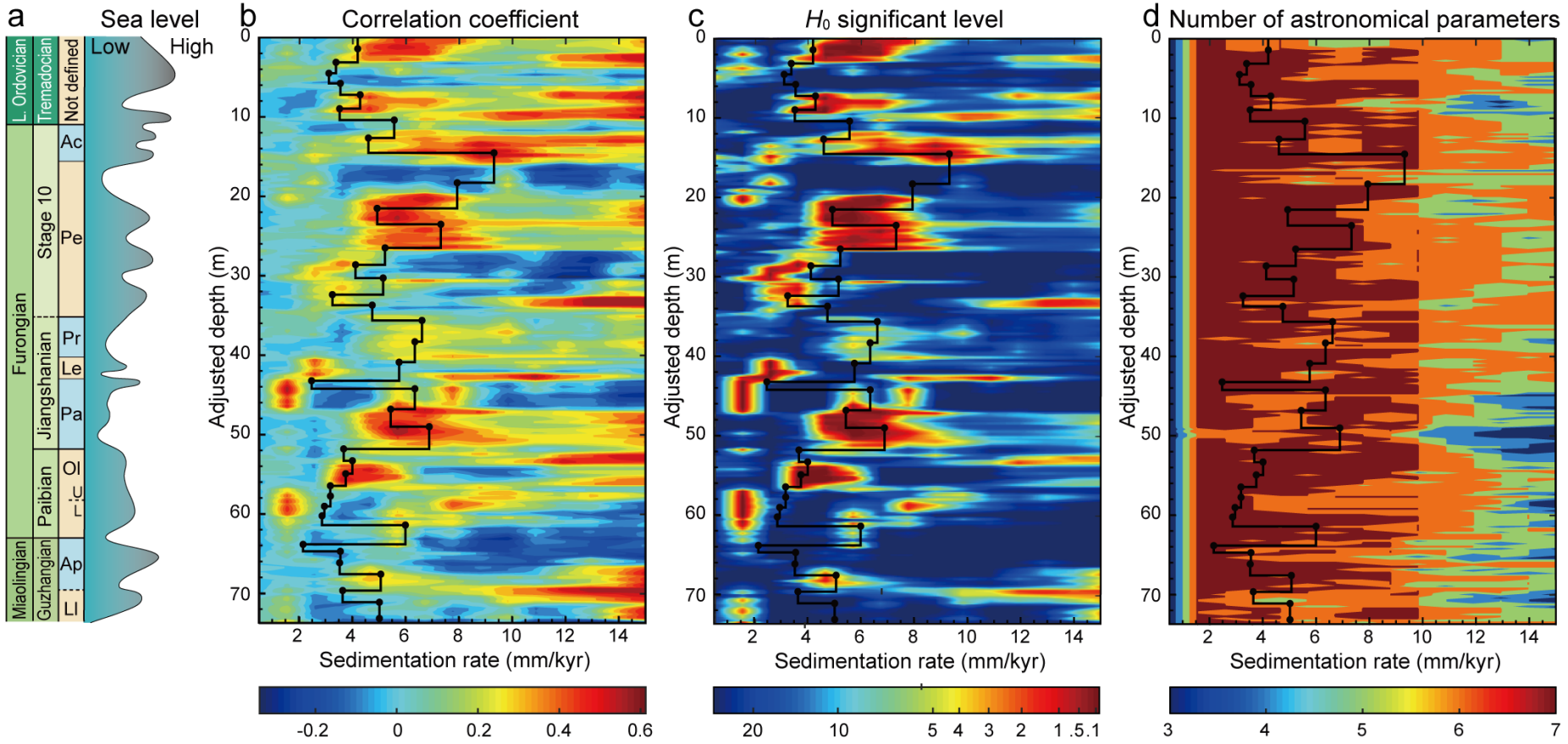
Thirty-nine 405 kyr cycles:
16-Myr-long floating time scale



Age model verification

1-Sedimentation rate (SR) verification

- SR anti-correlates with sea level changes: expanded in lowstand intervals and condensed in highstand intervals (Nielsen et al., 2020)
- SR matches well with the SR map derived from eCOCO



Age model verification

2-Other lithogenic elements:

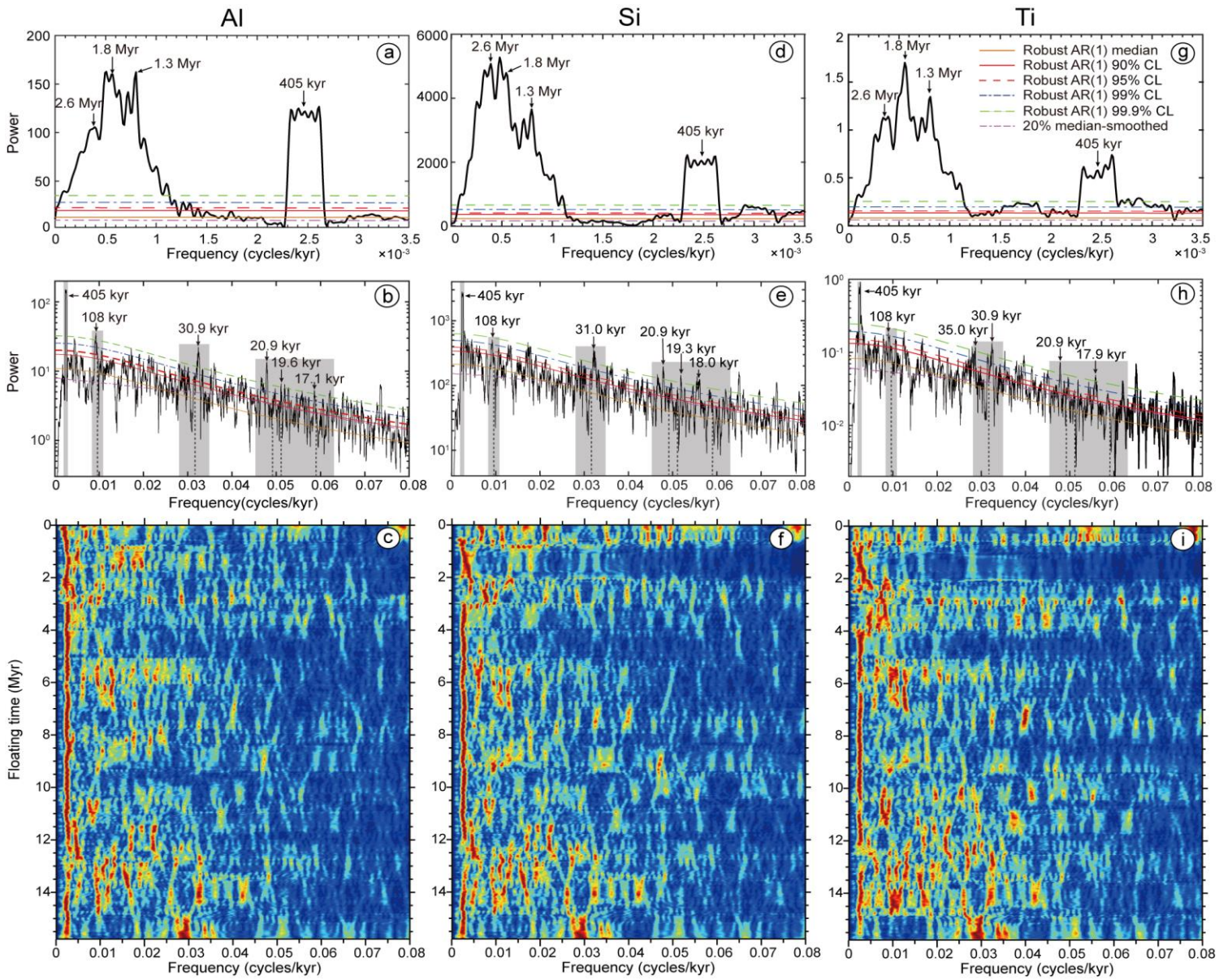
- The 405-kyr time framework established based on Al series applies well on lithogenic elements Si and Ti

E: 405 kyr

e: ~108 kyr

O: ~30.9 kyr

P: ~17.1–20.9 kyr

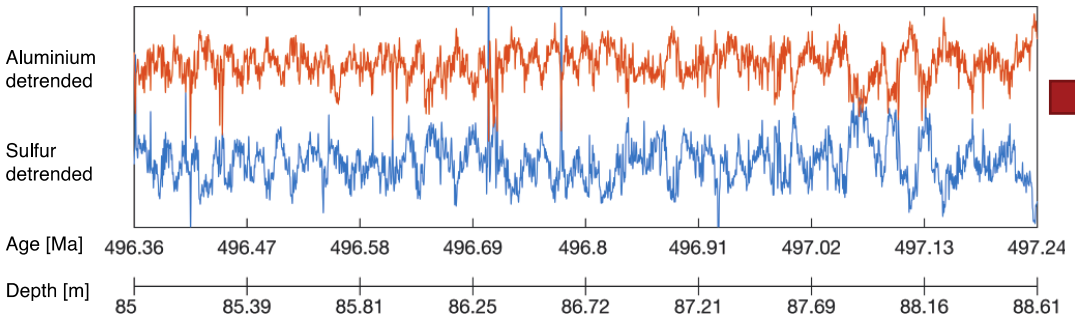


Age model verification

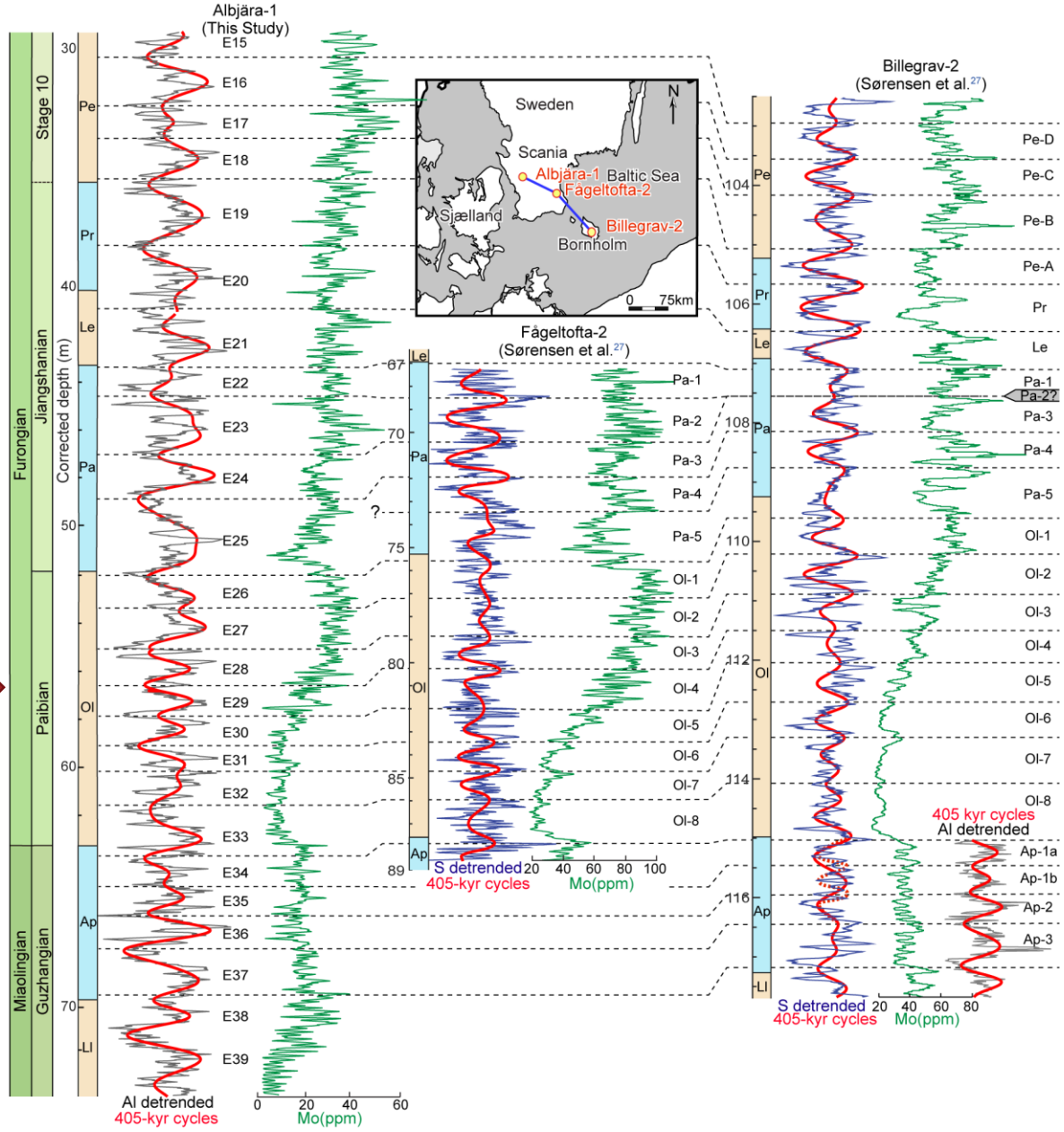
3-Comparison with previous cyclic interpretation

- Nearly perfect 405-kyr cycle correlations between three Alum Shale cores

Anti-correlation between Al and S signals



(Sørensen et al., 2020)

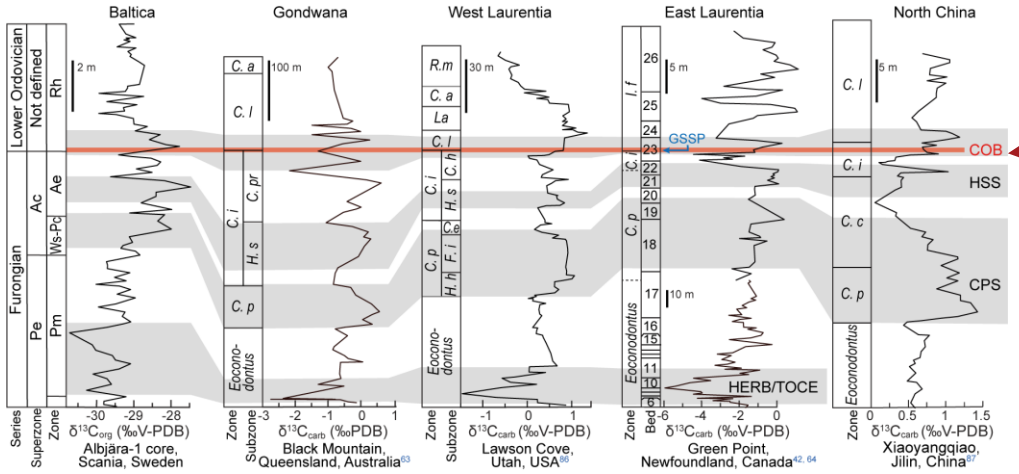


Stratigraphic correlation with other two Alum Shale cores

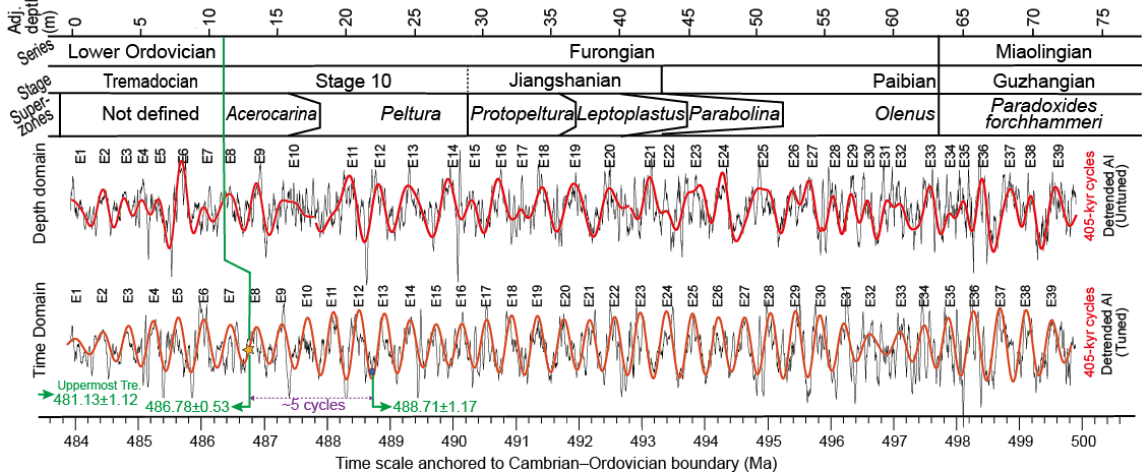
Age model verification

4-intercalibration with other approaches

Global $\delta^{13}C_{org}$ correlation: identify COB (anchor point)



U-Pb datings: intercalibrated with 405-kyr cycles

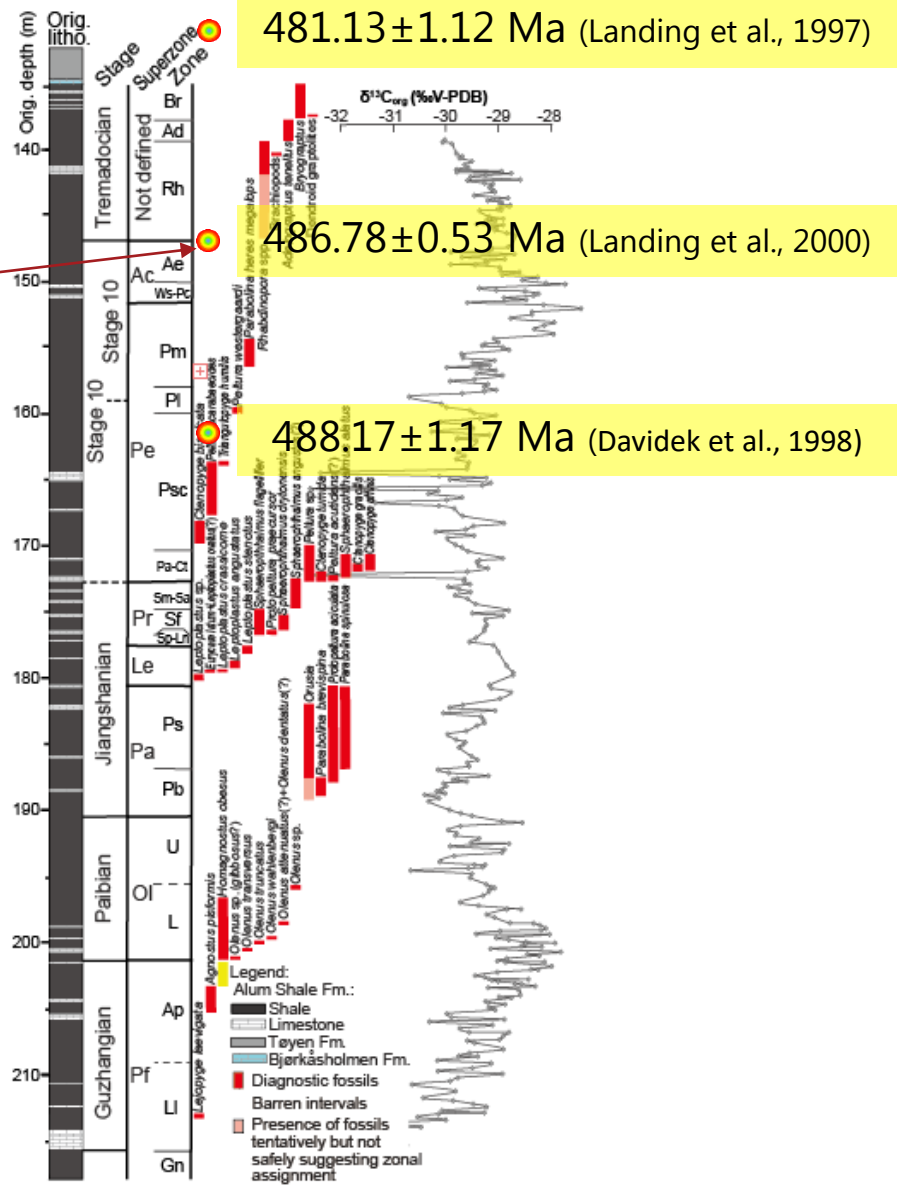


Biostratigraphy

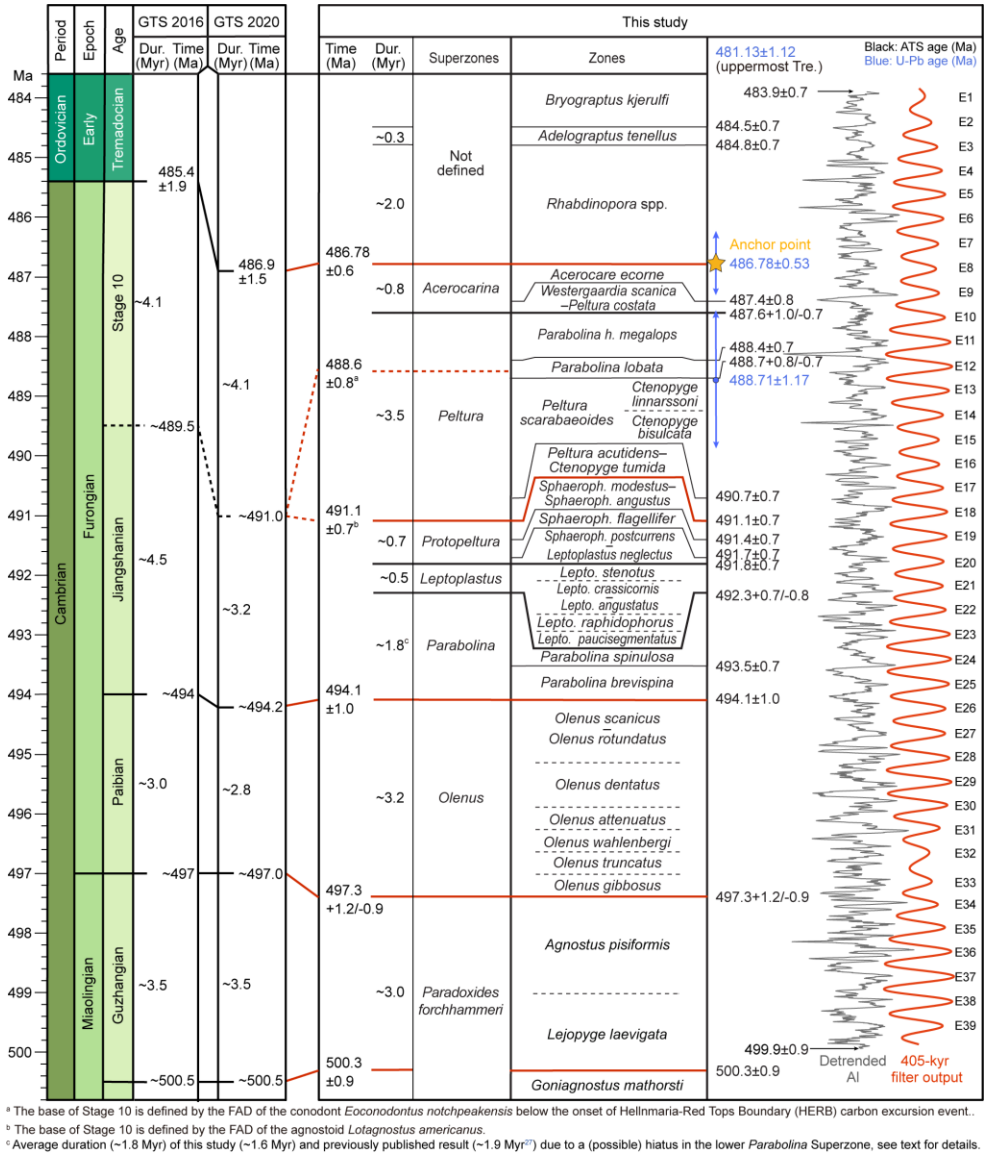
481.13±1.12 Ma (Landing et al., 1997)

486.78±0.53 Ma (Landing et al., 2000)

488.17±1.17 Ma (Davidek et al., 1998)

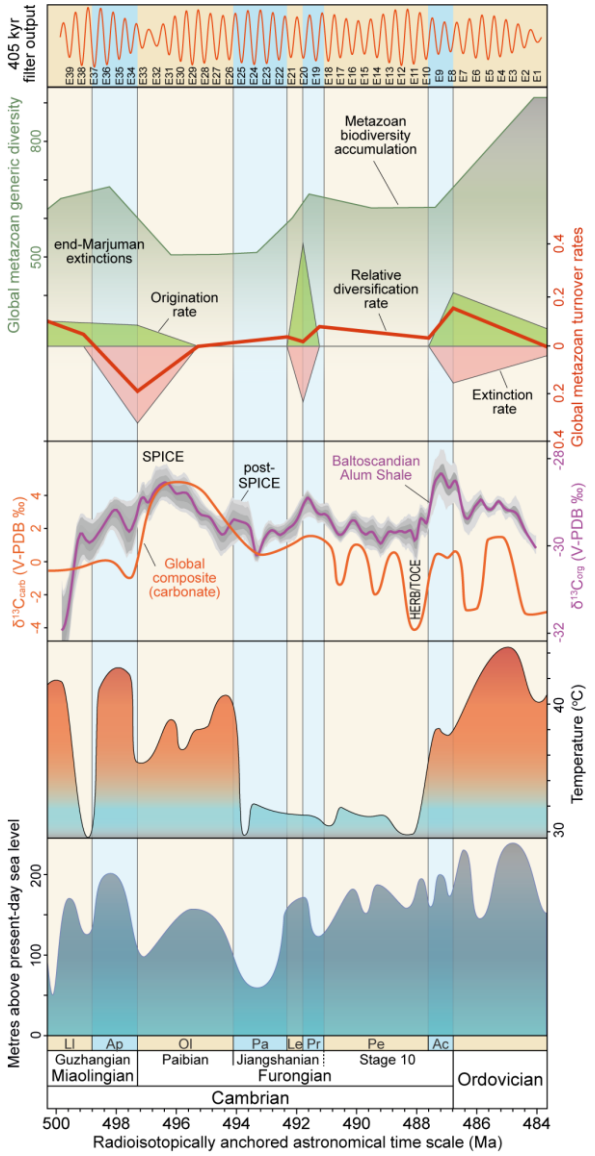


Radiometrically anchored astronomical time scale



[a] The base of Stage 10 is defined by the FAD of the conodont *Eoconodontus notchpeakensis* below the onset of Hellnmaria-Red Tops Boundary (HERB) carbon excursion event..
[b] The base of Stage 10 is defined by the FAD of the agnostoid *Lotagnostus americanus*.
[c] Average duration (~1.8 Myr) of this study (~1.6 Myr) and previously published result (~1.9 Myr[27]) due to a (possible) hiatus in the lower *Parabolina* Superzone, see text for details.

Temporal constraints on major biotic and abiotic events



- End-Marjuman extinction
- Global carbon isotope excursions (SPICE, post-SPICE, TOCE/HERB)
- Elevated extinction rates coincide with extreme heat and high sea level

Conclusion

- Milankovitch climate cycles are exquisitely recorded in the late Cambrian Alum Shale, Scandinavia.
- The radioisotopically anchored astronomical time scale provides age controls for the bases of the provisional Stage 10 (491.1±0.7 Ma), Jiangshanian (494.1±1.0 Ma), Paibian (497.3+1.2/-0.9 Ma) and Guzhangian (500.3±0.9 Ma), as well as the Scandinavian trilobite biozones.
- The calibrated 405-kyr framework provides temporal constraints on the palaeoenvironmental and biological changes during the late Cambrian, their temporal synchronicity likely implies potential causal mechanisms.

Thanks for your attention!

For more details:
Zhao, Z., Thibault, N., Dahl, T. W., Schovsbo, N. H., Sørensen, A. L., Rasmussen, M. Ø., & Nielsen, A. T. (2022). Synchronizing rock clocks in the late Cambrian. *Nature Communications*, 13(1), 1990.
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EGU abstract