Cyclo and chemostratigraphic characteristics of the Middle Silurian in Gotland, Sweden

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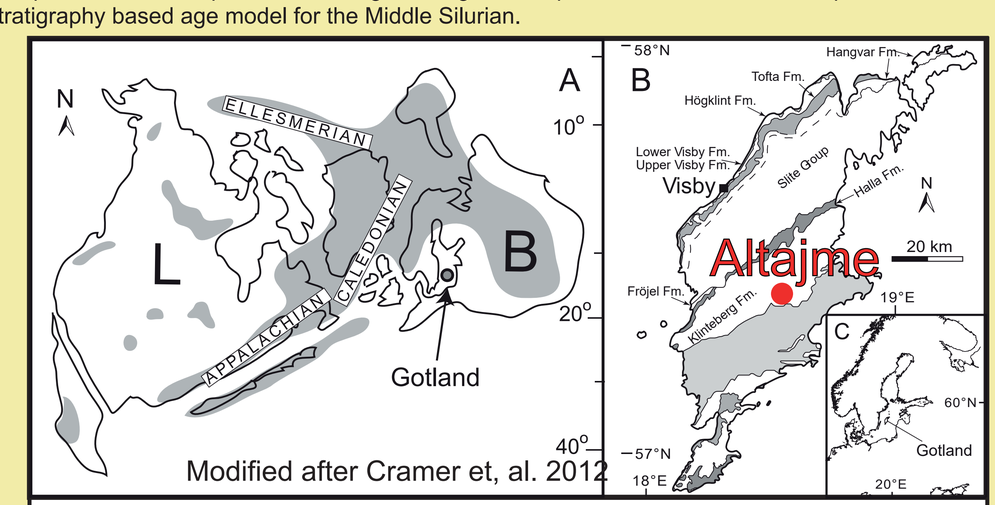
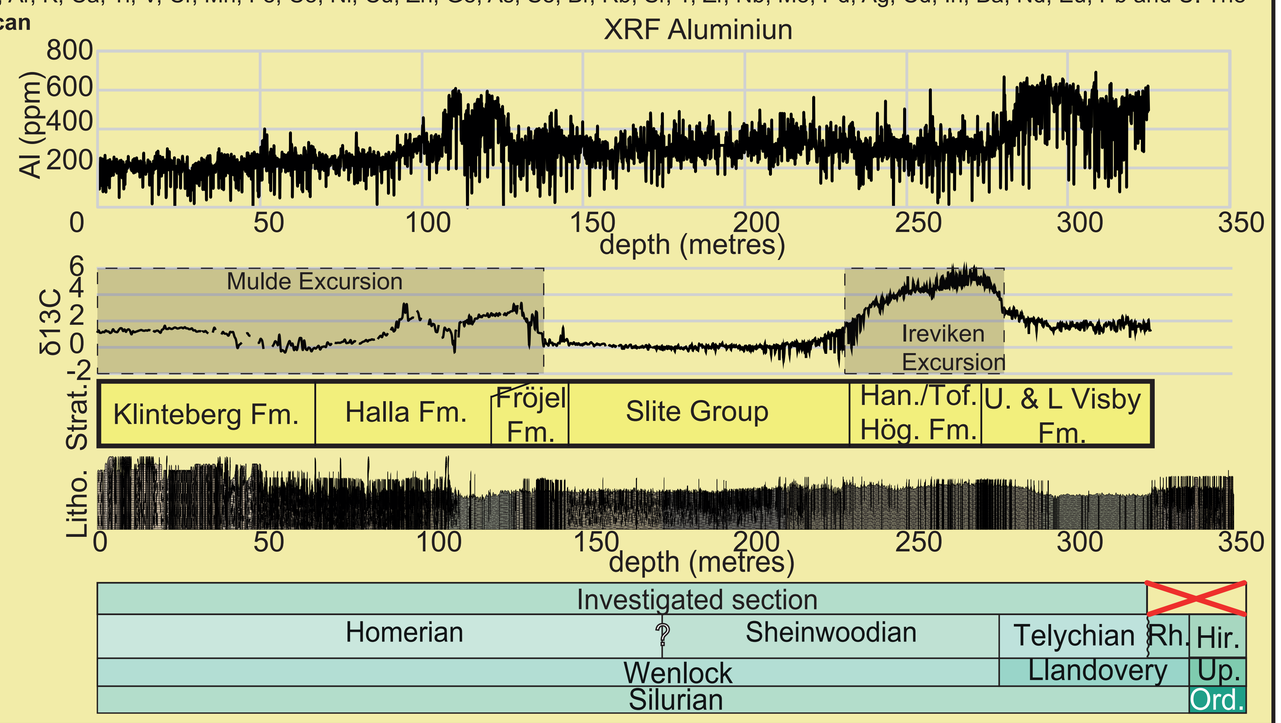
Introduction

The cumulative work of geoscientists over the past decades has shown that the Silurian Period which was once thought as warm and climatically stable time interval is in fact punctuated by numerous paleoenvironmental perturbations or events. These Silurian events follow a similar pattern where a minor extinction event precedes a substantial carbon isotope excursion (Jeppsen 2000 &1997). Many theories have been brought forward to explain these events ranging from glaciations, to changes in precipitations patterns, ocean currents, volcanism induced ocean anoxia and SEDEX deposit formation. Constraints on the duration and timing of these extinction events and subsequent positive carbon isotope excursions are weak, which hampers a full understanding of the processes at play. **The Altajme well drilled in South Central Gotland in Sweden in 2015 spans the latest Ordovician to Homerian succession of Gotland.** The data from theAltajme core provides us with a unique opportunity to look at two of these climatic perturbations during the Silurian. **The Altajme core spans both the Sheinwoodian Ireviken event and the Homerian Mulde event.** The Altajme core dataset includes a litholog, high-resolution δ13C data, correlated bentonites with U-Pb dates and a highresolution XRF core scan: important data required for and integrated stratigraphic study. **A new high resolution (0.5-1cm resolution) XRF-dataset was gathered in December 2019** constituting of the elements: Al, Si, P, S, Cl, Ar, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ge, As, Se, Br, Rb, Sr, Y, Zr, Nb, Mo, Pd, Ag, Cd, In, Ba, Nd, Eu, Pb and U. The U-Pb-dated bentonites give us age constraints. **The δ13C data in combination with the high resolution XRF scan gives us insights into the changes in the ocean before during and after the events, while the XRF data is also used to give cyclostratigraphic age constraints** for the events and for the whole core. This stratigraphic study will provide us with a palaeoclimatological insights to explain these two events and provide us with a cyclostratigraphy based age model for the Middle Silurian.



A. Silurian paleogeography
B. Geological map of Gotland, with the Altajme well location as red dot
C. Map of Northern Europe with Gotland

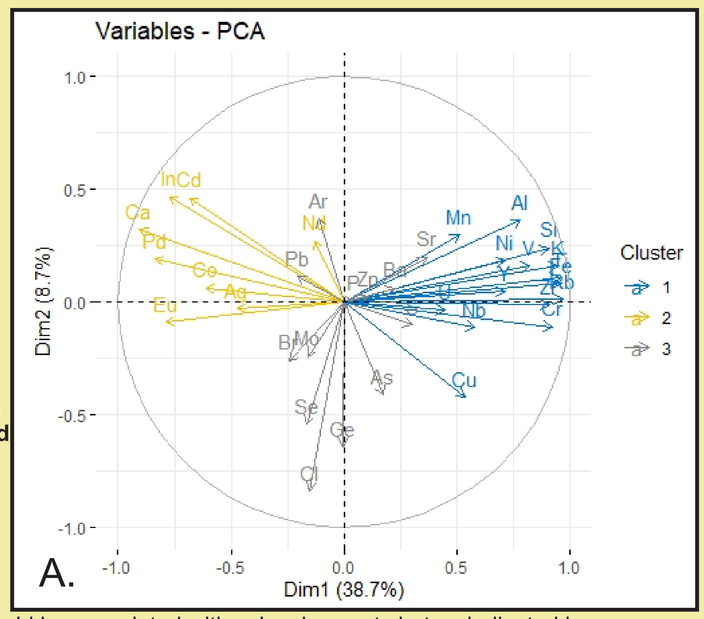


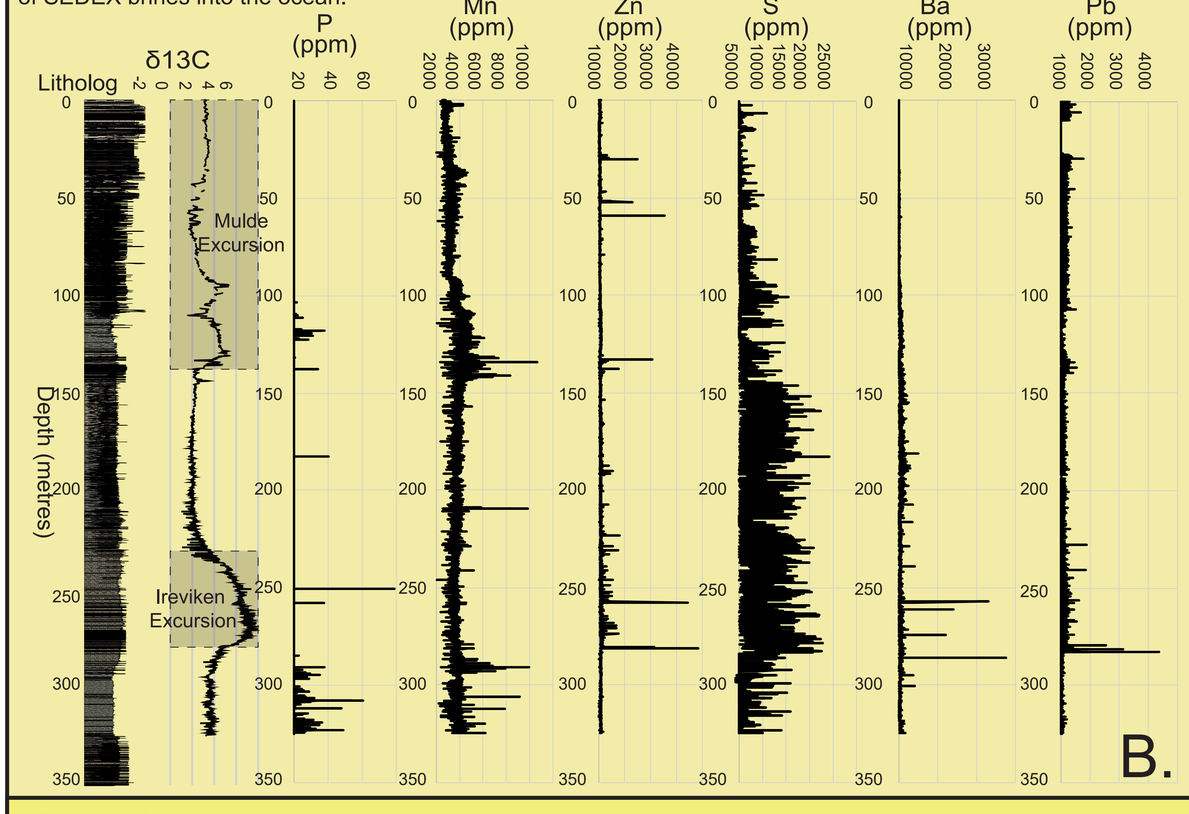
Chemostratigraphy

To provide insights into the paleoclimatological role of different elements a Principle Component Analysis was conducted using the FactoMineR (Le et al., 2008) function from R. The results (**A**) show that Dim 1 and 2 cover almost 50% of the variance and that 3 clusters can be defined:
Cluster 1: detrital elements
Cluster 2: carbonate associated elements
Cluster 3: Chalcophile/low oxygen elements

Aluminium a detrital element is selected for the tuning. Gotland was located In mid to lower latitudes during the Silurian. Higher summer insolation should lead to higher precipitation and thus higher aluminium values thus a maxima in the **405-kyr filtered aluminium record should correspond to a 405-kyr eccentrcity maxima**.

The XRF chemostratigraphic record also shows enrichments in P, Mn, Zn, S, Ba and Pb at and and during the onset of the carbon isotope excursions (**B**). Elemental enrichments before carbon isotope excursions could be associated with volcanic events but as indicated in Emsbo. (2017) the elemental enrichment of **P, Mn, Zn, S, Ba and Pb** could also be indicative of the formation of **Sedimentary exhalative deposits (SEDEX).** The pre-excursion extinction and excursion could be due to a release of SEDEX brines into the ocean.

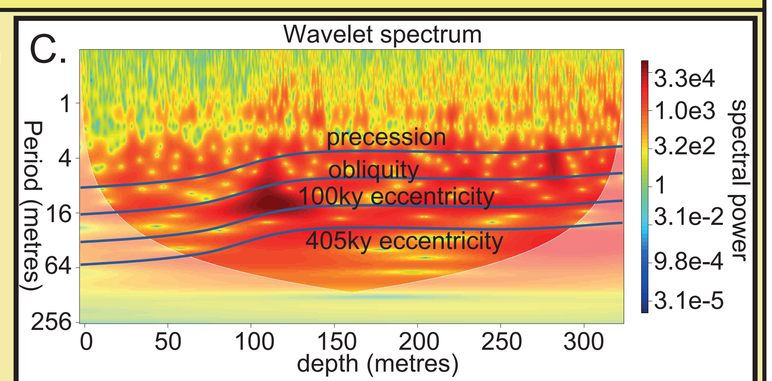




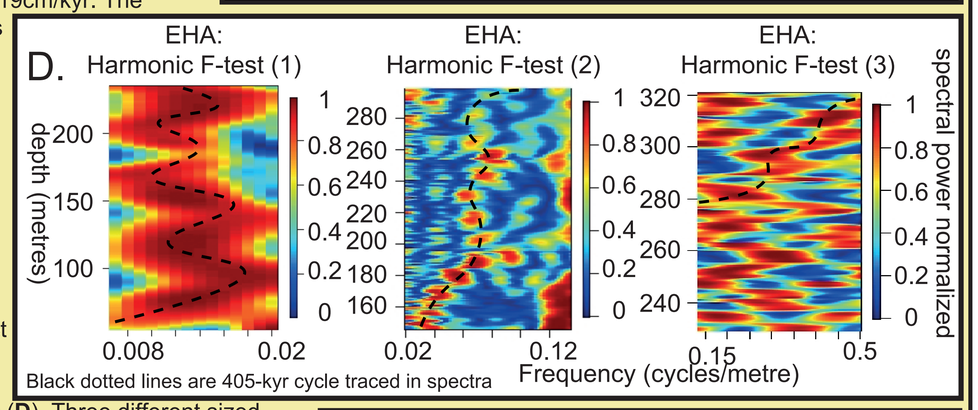
Cyclostratigraphy

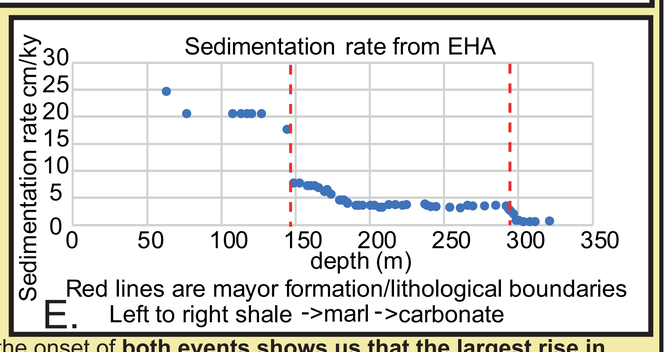
To asses the presence of orbital cycles the XRF Aluminium record was analyzed using the R Astrochron and Biwavelet packages (Meyers 2014 and Gouhier T.C. et al.,).

As indicated by Barnes. et al. (2019) **the core contains 3 U/Pb dated bentonites:** Ireviken 281.5m 431.83Ma +/- 0.23, Grotlingbo: 134m 428.45 Ma +/- 0.35 and Djupvik: 62.9m 428.06Ma +/- 0.35. The 281.5-134m interval has an average sedimenation rate of ~4cm/kyr and the 134-62.9m interval has an average sedimentation rate of ~19cm/kyr. The bentonite data supports our identification of precession, obliquity, long and short eccentricity in the wavelet spectra (**C**).

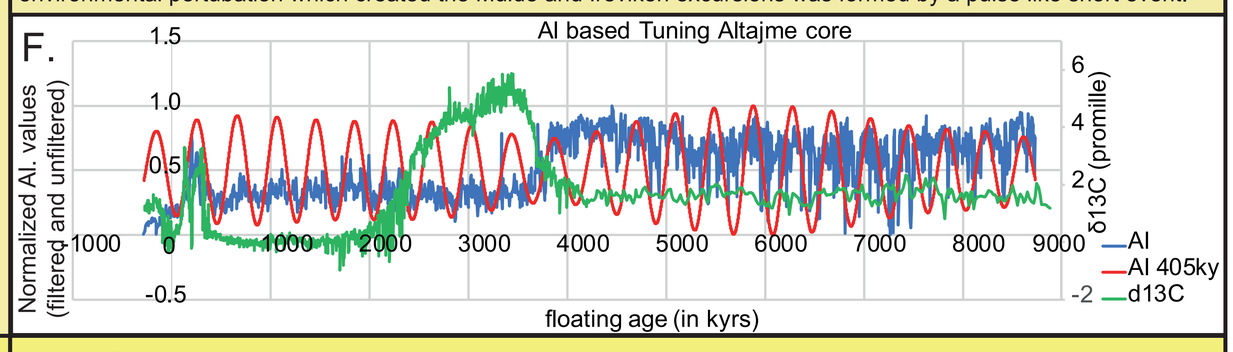


The stable 405kyr eccentrcity cycle can be used to create a floating time scale for the paleozoic (Laskar et al., 2004). The 405kyr cycle was traced in the EHA windowed spectra (**D**). Three different sized windows with overlap in the depth domain were used to account for the large changes in sedimenation rate in the Altajme core and provide a complete trace of the 405-kyr cycle in the depht domain. The traced EHA results are combined and converted to a EHA based composite sedimentation rate (**E**). The sedimentation rate is used to convert from the depth to the time domain (**F**).





The duration of the **Ireviken event is 5*405-kyr eccentricity cycles giving a duration of 2.025Myr** for the whole event. The steep rise in δ13C values at the onset of **both events shows us that the largest rise in δ13C occured in a only very short interval.** The short timespan indicates that the processes which lead to the environmental pertubation which created the Mulde and Ireviken excursions was formed by a pulse like short event.



Conclusions

A new cyclostratigraphy based age model for the Telychian to Homerian of Gotland is presented. The duration of the Ireviken event is 2.025Myrs eg. 5*405-kyr eccentricity cycle. The steep rises in δ13C values indicate that the largest rise in δ13C occured in a event like paced timespan.
The enrichments of P, Mn, Zn, S, Ba and Pb before and during the excursions indicate that the δ13C excursions might be the result of a sudden release of SEDEX brines into the ocean.

Acknowledgments

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References

Barnes. L., Trayler R. B., Cramer B. D., Calner M., Bancroft A. M., Oborny S.C., (2019) A Bayesian Age-Depth Model for the Silurian Altajme Core, Gotland, Sweden. 10.1130/abs/2019AM-337871.

Cramer, & Condon, Daniel & Söderlund, Ulf & Marshall, & Worton, & Thomas, Alan & Calner, Mikael & Ray, David & Perrier, Vincent & Boomer, & Patchett, & Jeppsson,. (2012). U-Pb (zircon) age constraints on the timing and duration of Wenlock (Silurian) paleocommunity collapse and recovery during the ‘Big Crisis’. Geological Society of America Bulletin. 124. 1841-1857. 10.1130/B30642.1.

Emsbo P., (2017). Sedex brine expulsions to Paleozoic basins may have changed global marine 87Sr/86Sr values, triggered anoxia, and initiated mass extinctions, 86. 474-486. https://doi.org/10.1016/j.oregeorev.2017.02.031 \.

Gouhier T. C., Grinsted. A., Viliam S., https://CRAN.R-project.org/package=biwavelet

Jeppsson, L (1997). "The anatomy of the Mid-Early Silurian Ireviken Event and a scenario for P-S events". In Brett, C.E.; Baird, G.C. (eds.). Paleontological Events: Stratigraphic, Ecological, and Evolutionary Implications. New York: Columbia University Press. pp. 451–492.

Jeppsson, Lennart & Calner, Mikael. (2002). The Silurian Mulde Event and a scenario for secundo–secundo events. Earth and Environmental Science Transactions of the Royal Society of Edinburgh. 93. 135 - 154. 10.1017/S0263593300000377.

Laskar J., Robutel P., Joutel F., Gastineau M., Correia A. C. M., and Levrard B. A&A, 428 1 (2004) A long-term numerical solution for the insolation quantities of the Earth, 261-285 DOI: https://doi.org/10.1051/0004-6361:20041335

Le, S., Josse, J. & Husson, F. (2008). FactoMineR: An R Package for Multivariate Analysis. Journal of Statistical Software. 25(1). pp. 1-18. http://www.jstatsoft.org/v25/i01/

Meyers, S.R. (2014). Astrochron: An R Package for Astrochronology. https://cran.r-project.org/package=astrochron