Cyclostratigraphic calibration of the Middle Devonian time scale (Eifelian Stage, Appalachian Basin, western NY, USA)

Netherlands Organisation for Scientific Research

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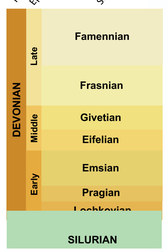
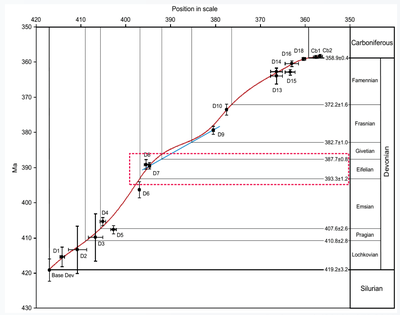
INTRODUCTION

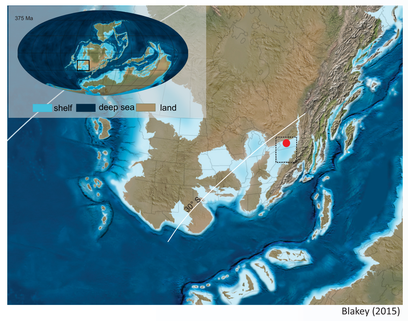
The Devonian Time Scale Problem



	Recent cyclostratigraphic calibration
13.3 ± 0.8 Myr	13.5 ± 0.5 Myr (Pas et al. 2018)
10.5 ± 2.5 Myr	4.1 ± 2.1 Myr (De Vleeschouwer et al. 2012)
5 My. ± not calculated	4.35 ± 0.45 Myr (De Vleeschouwer et al. 2015)
5.6 ± 1.9 Myr 14.3 ± 2.9 Myr	***THIS PROJECT***
3.2 ± 3.8 Myr 8.4 ± 4.3 Myr	1.7 ± 0.7 Myr (Da Silva et al. 2016) 7.7 ± 2.8 Myr (Da Silva et al. 2016)
Stage duration ± uncertainty	Stage duration ± uncertainty



Becker et al. (2012), GTS-2012



Blakey (2015)

The GTS 2012 duration estimate for the Eifelian Stage (**5.6 ± 1.9 Myr**) is based on a cubic spline-fit method tied to only two high-resolution zircon dates with relatively high uncertainties. This **poorly constrained time-scale** does not fully resolve the sequence of events recorded across this interval. So, the question is **how can we increase the precision, accuracy and resolution of the Eifelian time scale** order to better assess the timing, magnitude and the cause and effect of Middle Devonian environmental changes.

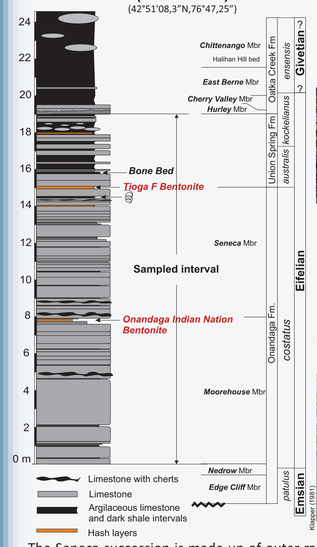
Over these last decade, a growing amount of research has been directed towards building an astronomical Devonian time scale. This has led to major improvements in estimates of the duration for most of the Devonian stages, and as a consequence in constraining the timing and causes of Devonian environmental changes.

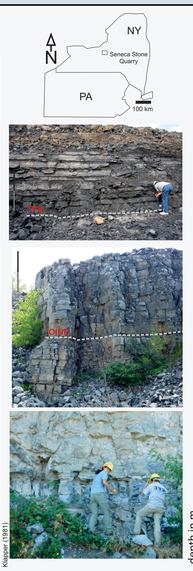
The Middle Devonian Epoch was characterized by a greenhouse climate, a relatively high sea-level and favorable environmental conditions. The Middle Devonian Eifelian Stage records the onset of a dramatic drop in CO_2 concentration and two major bioevents, respectively the **Choteč** event at its base and the **Kačák** event just prior to the Eifelian – Givetian boundary. Both events are characterized by significant physical and biotic turn-overs in the marine realm, including sea-level rise, faunal extinctions, appearance of new life forms and maximum evolutionary radiation.

FIELD AND DATA

Seneca Stone quarry (western NY)

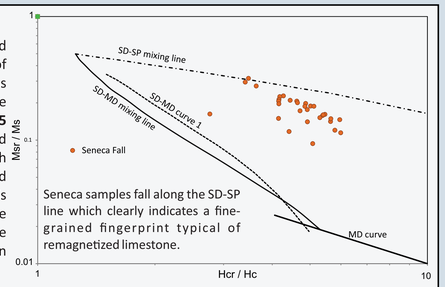
(42°51'08,3"N,76°47,25")





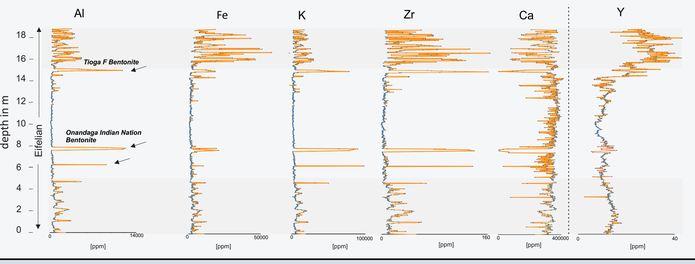
The Seneca succession is made up of outer-ramp and deep-shelf deposits that accumulated in the Appalachian Basin. It extends from the early to late Eifelian (Po. *costatus costatus* – T. *kockelianus kockelianus*) and is composed of carbonate, marl, organic-rich shale and two bentonites (Tioga F and Onandanga Indian Nation).

To capture the astronomically-forced sedimentary cycles and to develop a model of the climatic and oceanographic variations that affected the Appalachian Basin, we collected **700 samples at an average of 2.5 cm-interval** in the **Seneca section**. Trace and major elements were measured on each sample with ICP-OES. The cyclicity recorded in this high-resolution geochemical dataset is used to construct a cyclostratigraphy for the Eifelian Stage, which will be anchored to the radiometrically dated bentonites occurring in the section.



Prior to start measuring the elemental concentration on our samples we first tested the potential of magnetic susceptibility as a proxy for paleoclimatic variations in the Seneca section through hysteresis measurements. **Hysteresis** analysis (hysteresis loops and Day diagram) indicate an **important remagnetization** component.

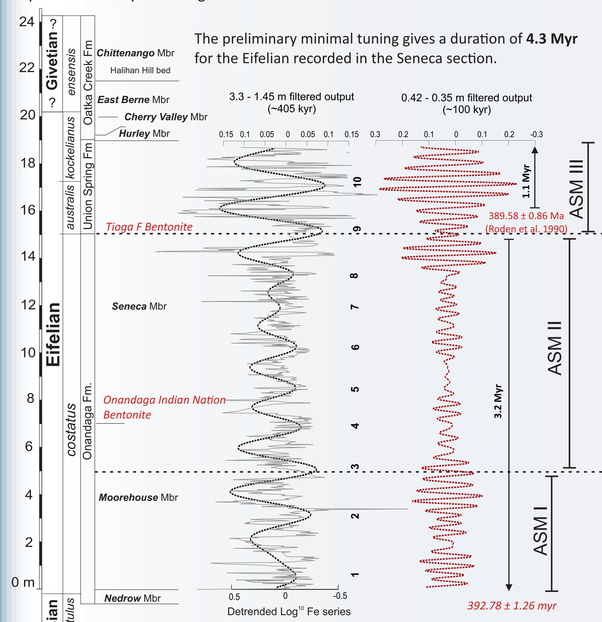
Proxies used for the cyclostratigraphic analysis



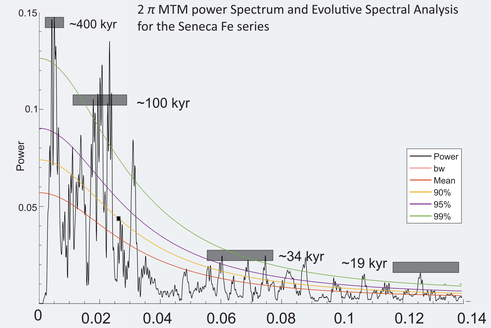
CYCLOSTRATIGRAPHY

Method 1 (minimal tuning)

The 2 π MTM power spectrum shows prominent sedimentary cycles at multiple wave-lengths which can also be seen in the evolutive FFT spectrogram. Based on the GTS-2012, the field data and the available biostratigraphy, we estimate a sedimentation rate that varies between 0.5 and 0.6 cm/kyr for the Seneca section. We interpreted the main wave-lengths as the imprint of long- and short-eccentricity, obliquity and precession cycles. Evolutive FFT in the depth domain shows that main wave-lenghts are not very stable which is likely related to change in sedimentation rate. Changes in lithology through the section support this interpretation. The 400-kyr and 100-kyr filter outputs were used to visualize cycles and to carry out tuning.

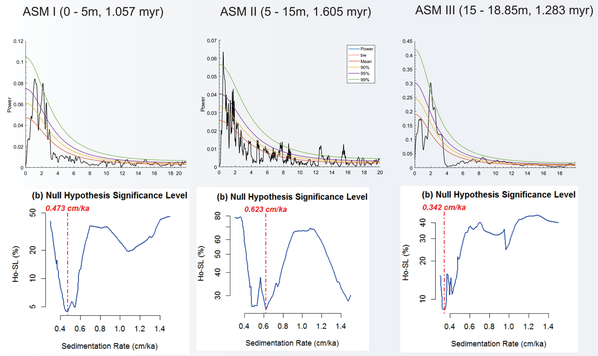


The preliminary minimal tuning gives a duration of **4.3 Myr** for the Eifelian recorded in the Seneca section.



By combining the high-precision numerical date of the Tioga F Bentonite with our new duration (including error bars) we obtained a new estimate of the numerical age of the Emsian - Eifelian boundary **([389.58 ± 0.86 Ma] + [3.2] = [392.78 ± 0.86 Ma]).**

Method 2 (ASM)



To support and strengthen our preliminary duration estimate from the minimal tunning we also applied the **ASM** (Average Spectral Misfit, Meyers & Sageman 2007) method on the detrended Fe record. The ASM method was carried out on three intervals (ASMI-III) marked by different sedimentation rates. Average sedimentation rates obtained for each interval allowed us to calculate an estimate duration of **3.945 Myr** for the Seneca section.

CONCLUSIONS

Implications on the Time Scale

Time-series analysis of our chemostratigraphic profiles reveals prominent cycles attributed to orbital forcing (400-kyr, 100-kyr, 34-kyr, 19 kyr).

Minimal tuning of the 400-kyr cycles leads to a high temporal resolution and a much more precise estimate duration of 4.3 Myr for the early-late Eifelian.

We provide a new estimate of the numerical age of the Emsian - Eifelian boundary (392.78 ± 1.26 Ma).

The best estimate for the duration using ASM method arrives at 3.9 Myr for the early-late Eifelian interval.

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De Vleeschouwer, D., Whalen, M.T., Day, J.E. and Claeys, P. (2012) Cyclostratigraphic calibration of the Frasnian (Late Devonian) time scale (Western Alberta, Canada). *Bulletin of the Geological Society of America*, **124**, 928-942. **Meyers, S.R. and Sageman, B.B.** (2007) Quantification of deep-time orbital forcing by average spectral misfit. *American Journal of Science*, **307**, 773-792. **Pas, D., Hinnov, L., Day, J.E., Kodama, K., Sinnesael, M. and Liu, W.** (2018) Cyclostratigraphic calibration of the Famennian stage (Late Devonian, Illinois Basin, USA). *Earth and Planetary Science Letters*, **488**, 102-114. **Roden, M.K., Parrish, R.R. and Miller, D.S.** (1990) The Absolute Age of the Eifelian Tioga Ash Bed, Pennsylvania. *The Journal of Geology*, **98**, 282-285.