**Supplementary Material for:**

# Late Triassic to Early Jurassic carbon isotope chemostratigraphy and organo-facies evolution in a distal to proximal transect of the North German Basin

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**Content:**



## Methods – cyclostratigraphic analysis

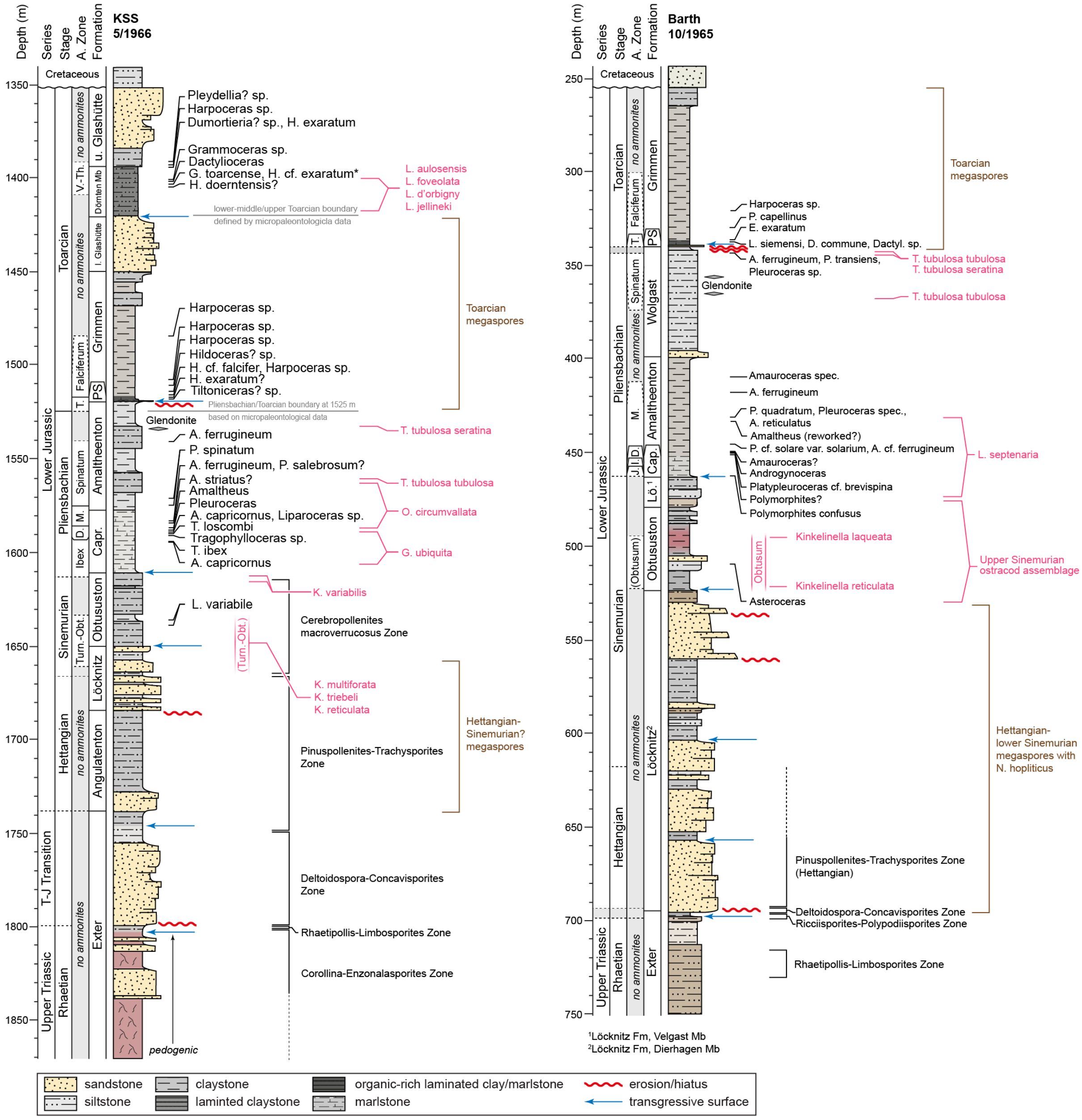


**Fig. S1:** Biostratigraphic framework for cores KSS 5/1966 and Barth 10/1965 (Zimmermann et al. 2015, 2018; Barth et al. 2018a, 2018b and references therein) (abbreviations of ammonite zones: Turn.: Turneri, Obt.: Obtusum, D.: Davoei, I: Ibex; J: Jamesoni; M.: Margaritatus, T.: Tenuicostatum, V.: Variabilis, Th.: Thouarense; abbreviations for formations: Cap.: Capricornumergel, PS: Posidonienschiefer; l./u. Glashüttte: lower/upper Glashütte).

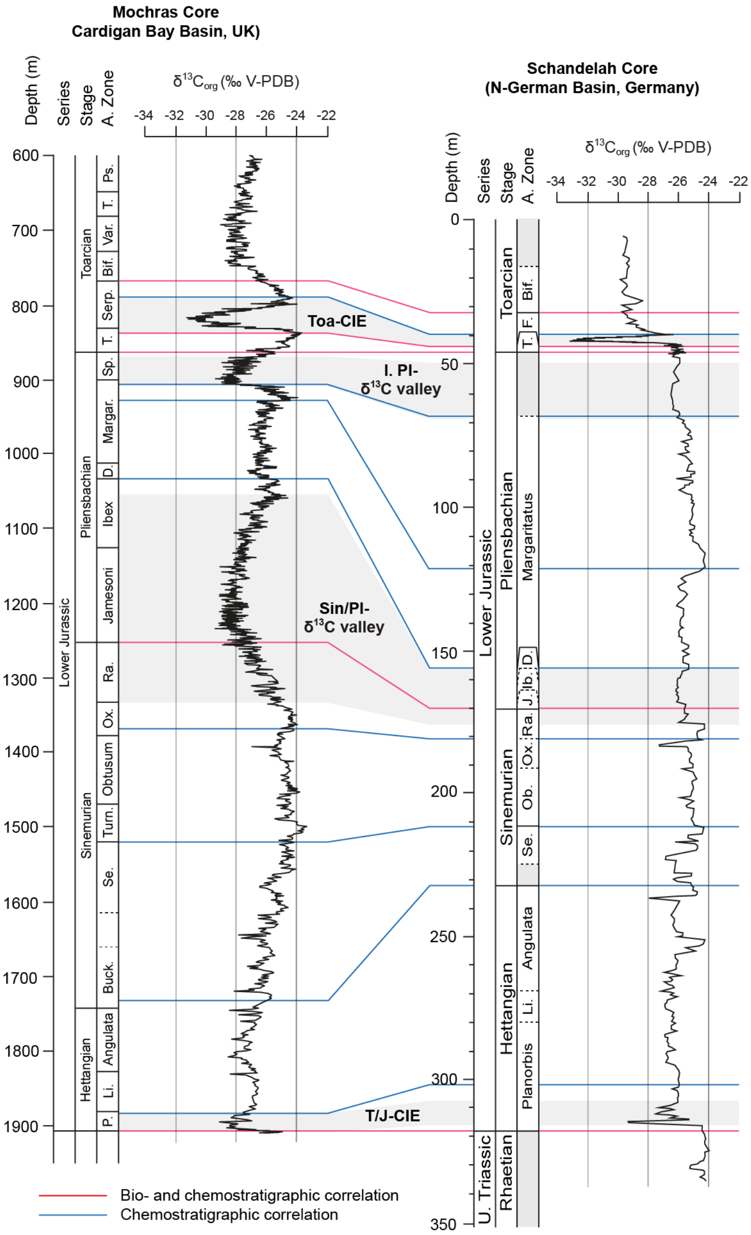


**Fig. S2:** Biostratigraphic and chemostratigraphic correlation of the Mochras Core (Xu et al. 2018; Storm et al. 2020) with Core Schandelah (van de Schootbrugge et al. 2018) (Buck.: Bif.: Bifrons; Bucklandi; D.: Davoei; Li.: Liasicus; Margar.: Margaritatus; Ox.: Oxynotum; P.: Planorbis; Ps.: Pseudoradiosa; Ra.: Raricostatum; Sp.: Serp.: Serpentinum; Sp.: Spinatum; T.: Tenuicostatum; Turn.: Turneri; Var.: Variabilis). Both cores reveal comparable trends in sedimentary $\delta^{13}C_{org}$ values. Differences are seen in the magnitude of isotopic changes, as well as in the magnitude of $\delta^{13}C_{org}$ absolute values. In particular, the $\delta^{13}C$ valley across the Sinemurian/Pliensbachian boundary (Sin/Pl $\delta^{13}C$ valley) and in the late Pliensbachian (l. Pl $\delta^{13}C$ valley) show lower values in the Mochras Core (T/J-CIE: Triassic/Jurassic carbon isotope excursion; Toa-CIE: Toarcian carbon isotope excursion). This indicates that trend in $\delta^{13}C_{org}$ values reflect trans-regional (global) carbon cycle dynamics. Absolute values in the $\delta^{13}C_{org}$ values, however, reflect local processes.

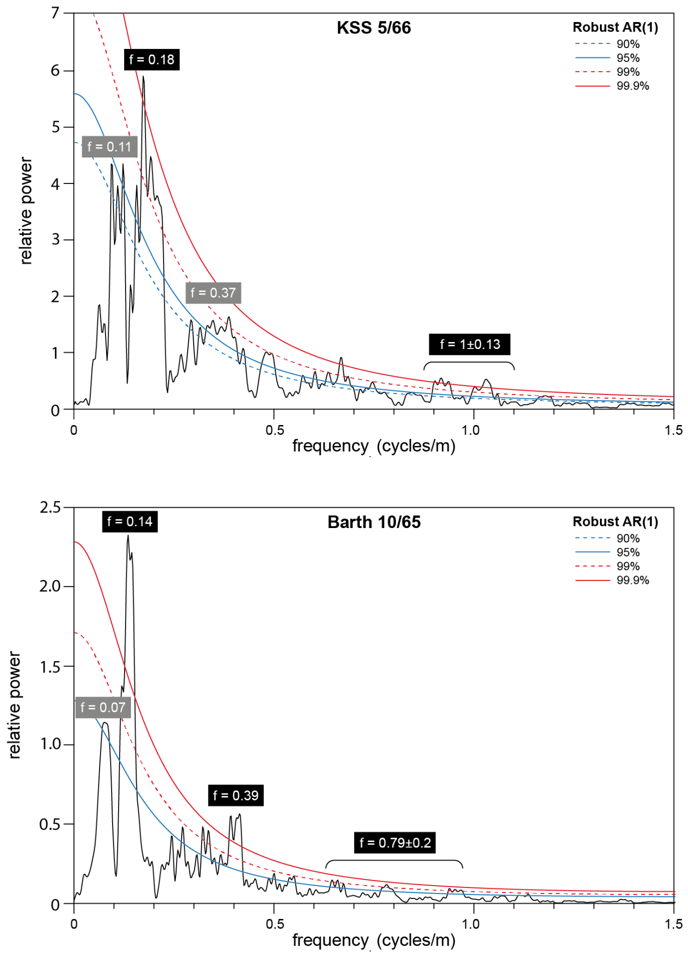


**Fig. S3:** MTM power spectra for gamma ray data of Toarcian strata in Core KSS 5/66 (top) and Barth 10/65 (bottom)

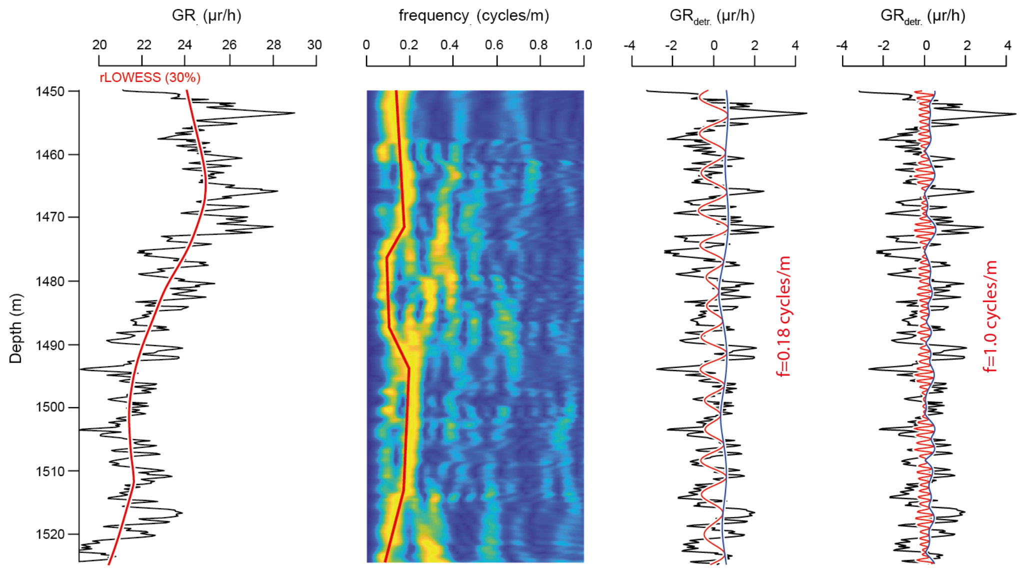


**Fig. S4:** Gamma ray data, evolutionary power spectra and filter outputs for Core KSS 5/66.

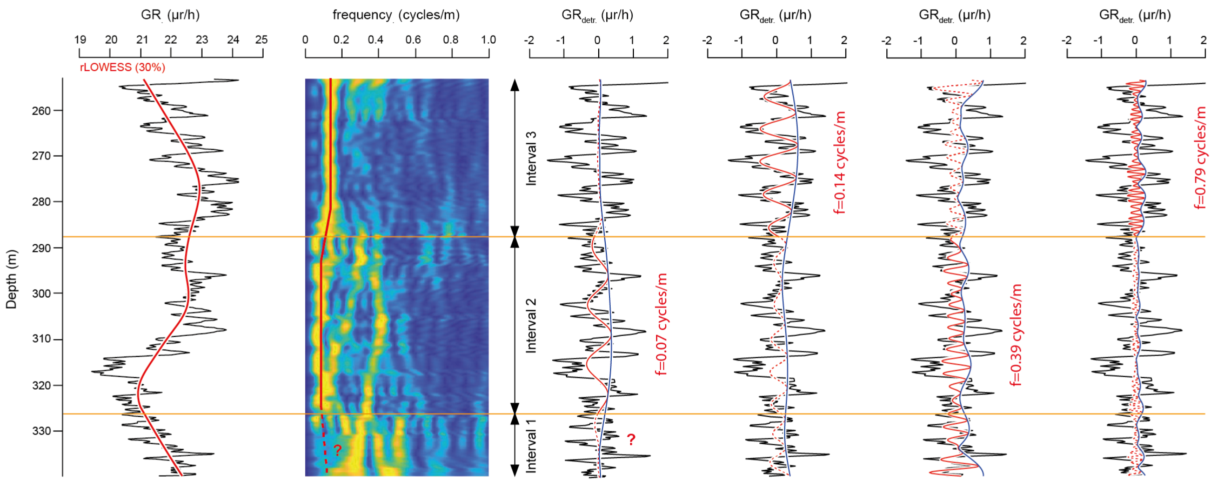


**Fig. S5:** Gamma ray data, evolutionary power spectra and filter outputs for Core Barth 10/65.

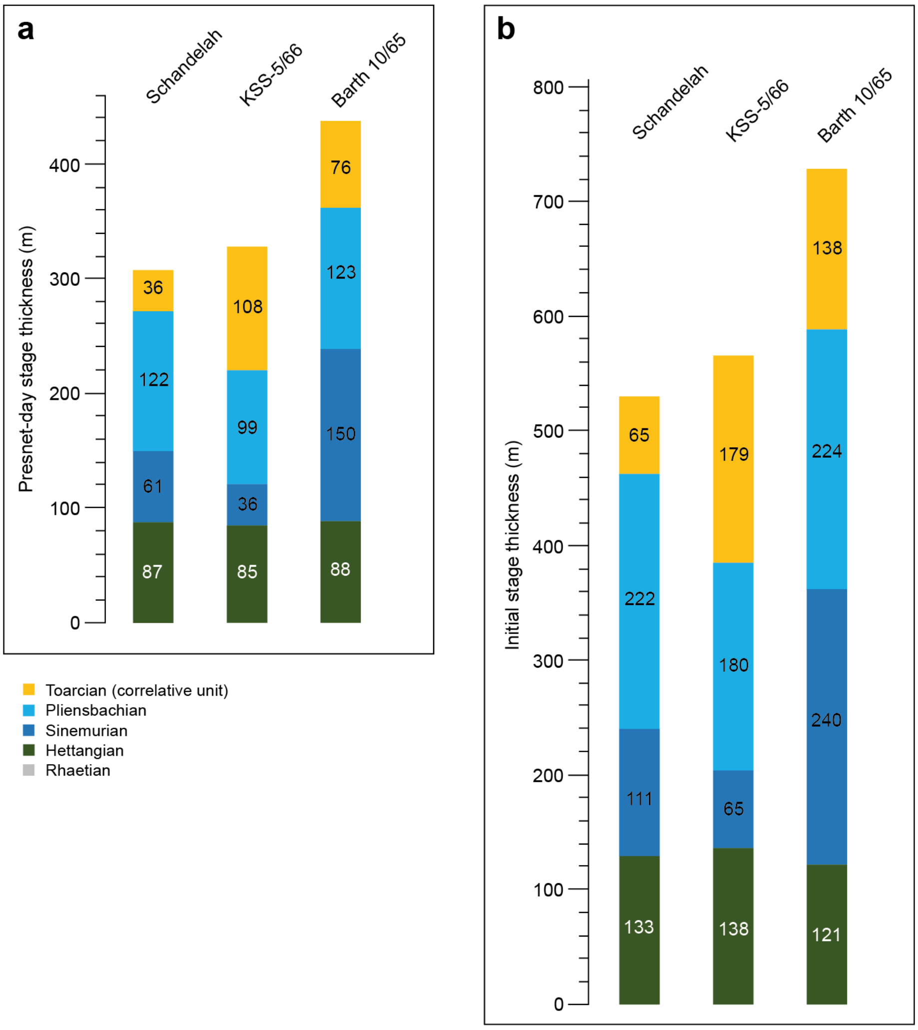


**Fig. S6:** Comparison of the present-day sediment thickness (**a**) and the initial stage thickness before compaction (**b**) along the distal-proximal transect. Sediment compaction and thickness reduction is the product of lithology and burial depth. Based on the low to moderate $T_{max}$ values we estimated the burial depth to 1000-1500 m. We used compactions factors for sandstones and mudstones of 0.55 and 0.8, respectively (Lee, 2018). However, substantially higher compaction rates of 0.1 (or lower) have been assumed for the bituminous Posidonienschiefer of southern Germany (Bandel and Knitter 1986).

**Methods – cyclostratigraphic analysis**

Cyclostratigraphic investigations for the Toarcian Grimmen Formation were performed on gamma ray data. Prior to cyclostratigraphic analysis, data were detrended using the weighted-average rLOESS method. Cyclostratigraphic analyses of the carbonate and TOC data were performed using the ACYCLE 2.3 tool for Matlab (Li et al. 2019). For spectral analyses we used the 2π multitaper method (MTM) (Thomsen 1982), together with robust red-noise models (Mann and Lees 1996). Statistically significant spectral peaks were filtered from the data series using Taner-Hilbert filtering. Evolutionary spectral analysis was performed using Fast Fourier transform (LAH) as implemented in the ACYCLE 2.3 tool for Matlab (Li et al. 2019). We used a sliding window size of 200 and step size of 2. Evolutionary spectral analysis allows assessing the evolution of spectral components along the investigated section.

We here do not aim to establish an astronomical timescale for the Posidonienschiefer and Grimmen Formations, as sedimentation will have been affected by hiatuses, condensation and varying sediment accumulation rates. We here use cyclostratigraphic analysis as additional correlation tool for the biostratigraphically-poor constrained Grimmen Formation.

**References:**

Bandel K, Knitter H (1986). On the origin and diagenesis of the bituminous Posidonia Shale (Toarcian) of southern Germany. Mitt. Geol.-Paläont. Inst. Univ. Hamburg 60: 151–177.

Barth G, Franz M, Heunisch C, Ernst W, Zimmermann J, Wolfgramm M (2018a) Marine and terrestrial sedimentation across the T–J transition in the North German Basin. Palaeogeography, Palaeoclimatology, Palaeoecology 489: 74–94.

Barth G, Pienkowski G, Zimmermann J, Franz M, Kuhlmann G (2018b) Palaeogeographical evolution of the Lower Jurassic: high-resolution biostratigraphy and sequence stratigraphy in the Central European Basin. Geological Society, London, Special Publications 469: 341–36.

Lee, EY (2018) Numerical analysis of sedimentary compaction: Implications for porosity and layer thickness variation. Journal of the geological society of Korea 54: 631-640.

Li M, Hinnov L, Kump LR (2019) Acycle: Time-series analysis software for paleoclimate research and education. Comput. Geosci. 127: 12–22.

Mann ME, Lees JM (1996) Robust estimation of background noise and signal detection in climatic time series. Clim. Change 33: 409–445.

Storm MS, Hesselbo SP, Jenkyns HC, Ruhl M, Ullmann CV, Xu W et al. (2020) Orbital pacing and secular evolution of the Early Jurassic carbon cycle. Proc. Natl. Acad. Sci. 117: 3974–3982.

Thomsen DJ (1982) Spectrum estimation and harmonic analysis. IEE Proc. 70: 1055–1096.

van de Schootbrugge B, Richoz S, Pross J, Luppold FW, Hunze S, Wonik T, Blau T, Meister C, van der Weijst CMH, Suan G, Fraguas A, Fiebig J, Herrle JO, Guex J, Little CTS, Wignall PB, Püttmann W, Oschmann W (2018) The Schandelah Scientific Drilling Project: a 25-million year record of Early Jurassic palaeo-environmental change from northern Germany. Newsl. Stratigr. 52: 249–296.

Xu W, Ruhl M, Jenkyns HC, Leng MJ, Huggett JM, Minisini D, Ullmann C, Riding J, Weijers J, Storm M, Percival L, Tosca N, Tegelaar E, Percival LM (2018) Evolution of the Toarcian (early Jurassic) carbon-cycle and global climatic controls on local sedimentary processes (Cardigan Bay Basin, UK). Earth Planet. Sci. Lett. 484: 396–411.

Zimmermann J, Franz M, Heunisch C, Luppold FW, Mönnig E, Wolfgramm M (2015) Sequence stratigraphic framework of the Lower and Middle Jurassic in the North German Basin: epicontinental sequences controlled by Boreal cycles. Palaeogeography, Palaeoclimatology, Palaeoecology 440: 395–416.