Onset of Oceanic Anoxic Event 2 in the Lower Saxony Basin – Insights from high-resolution stable isotope stratigraphy and geochemical modelling

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INTRODUCTION

Mesozoic Oceanic Anoxic Events (OAEs) are characterized by increased deposition of marine-derived organic matter in sediments underlying oxygen-depleted oceanic bottom-waters. However, they are not only evidenced by the occurrence of marine organic-rich strata in geological records, but also by prominent changes in the $\delta^{13}C$ signature of marine-derived carbonates and organic matter, which indicates a pronounced disturbance of the marine biogeochemical cycle.

OAE 2 spanning the Cenomanian-Turonian boundary (94.1 Ma) represents a major perturbation of the global carbon cycle. The eruption of the Caribbean Large Igneous Province is considered to be the main cause for rapidly increasing CO_2 concentrations and resulting global warming accompanied by widespread oceanic anoxia. In the Lower Saxony Basin of northern Germany, deposits of the OAE 2 are preserved in several industry drill cores close to the village of Wunstorf.

The aim of this study is:
- to provide a comprehensive and highly resolving geochemical data set to investigate the onset of the OAE 2 in the Lower Saxony basin
- to examine potential trigger mechanisms for the pronounced carbon isotope excursion (CIE) and associated anoxia with geochemical modelling

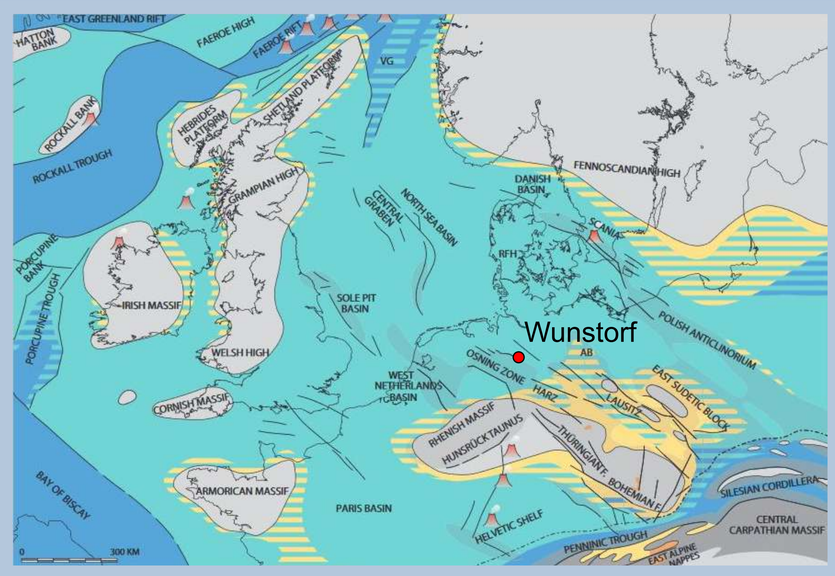

Fig. 1 - Paleogeography of Central Europe in the Cenomanian to Danian with the location of Wunstorf. AB-Altmark-Brandenburg Basin, RFH-Ringkobing-Fyn High, VG-Viking Graben (modified after Ziegler, 1990).

LITHOLOGY

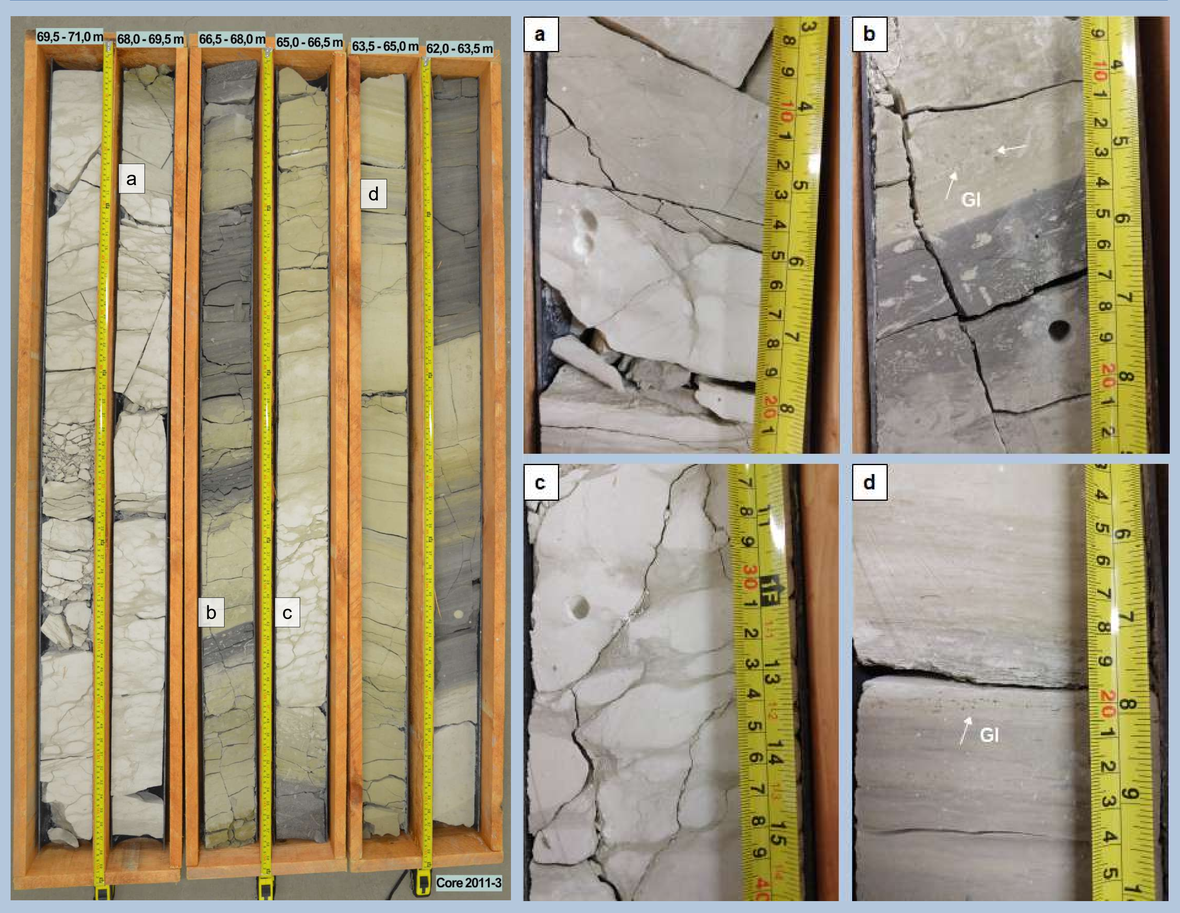

Fig. 2 - Examined drill cores 2011-3, composed of limestones, marly limestones, marls and black shales.
Fig. 3 - Lithological characteristics of the drill core 2011-3. **a**-Facies change. Transition in the form of omission between Brochterbeck and Hessetal Formation. Light limestone with nodular structure to slightly darker marly limestone, **b**-Chondrites 2-Event. Dark grey black shales with mm-cm sized trace fossils. Above the layer glauconite is occasionally found, **c**-*Plenus* bed. Light, white limestone with a nodular to lenticular structure;interspersed with a slightly darker marl, **d**-Thin glauconite layer in beige laminated marl to marly limestone.

STABLE ISOTOPE STRATIGRAPHY

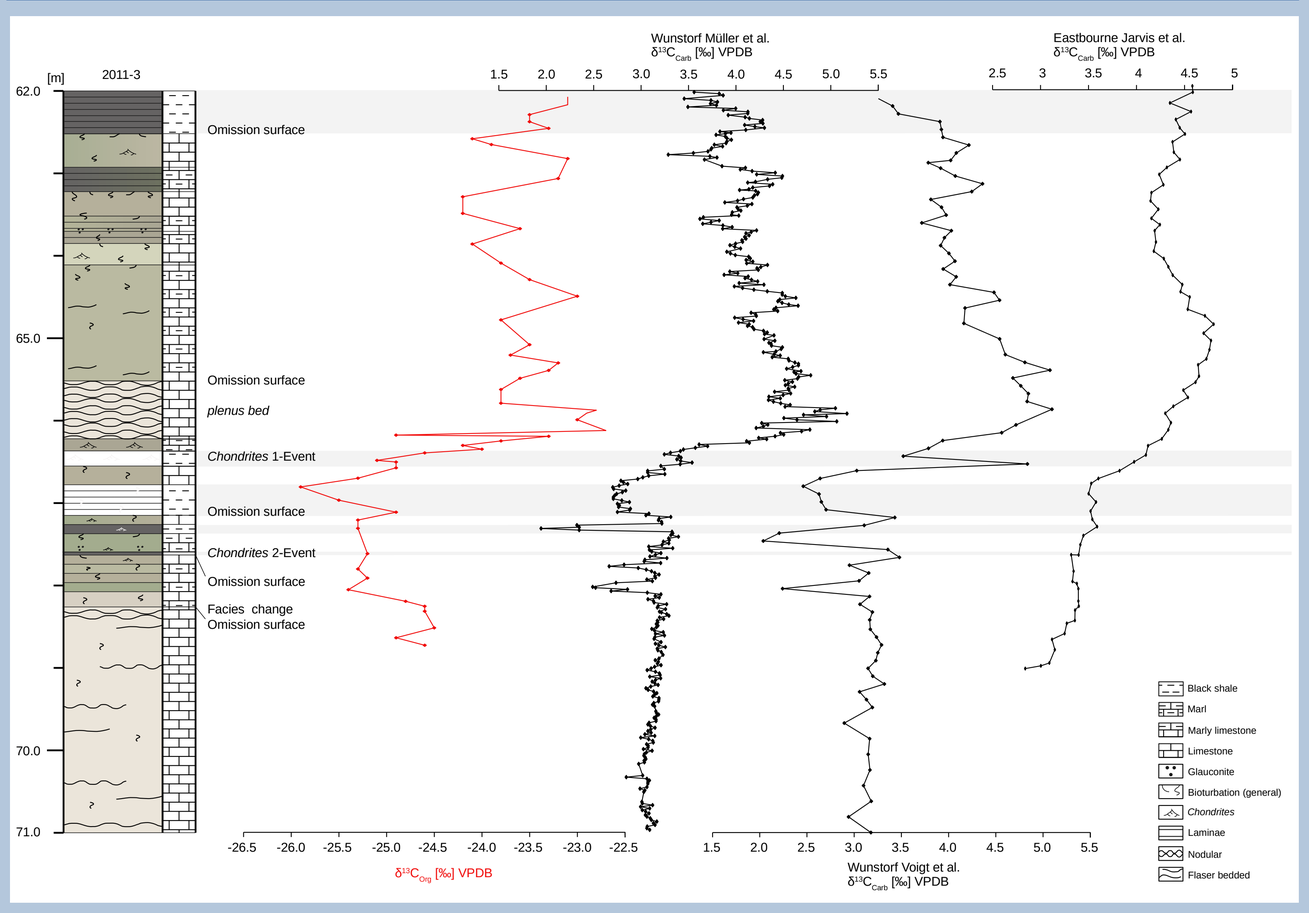

Fig. 4 - Geochemical results across the onset of OAE 2. Stable carbon isotope stratigraphy ($\delta^{13}C_{Carb}$ black, $\delta^{13}C_{Org}$ red) plotted against the lithostratigraphy of drill core 2011-3. Correlation of carbon isotope stratigraphies between the North German basinal successions at Wunstorf (this study and Voigt et al. (2008)) and English Chalk (Jarvis et al. (2006)).The high-resolution $\delta^{13}C$ curve exhibits overall stable values before the onset of the *Plenus* event. This background level is interrupted by three short-lived and small but significant negative carbon isotope excursions (CIEs). Immediately before the main rise in the *Plenus* bed, a longer-lasting negative CIE is observed, preceding the large positive CIE of the OAE 2. Thereafter, the $\delta^{13}C$ values decrease.

GEOCHEMICAL MODELLING

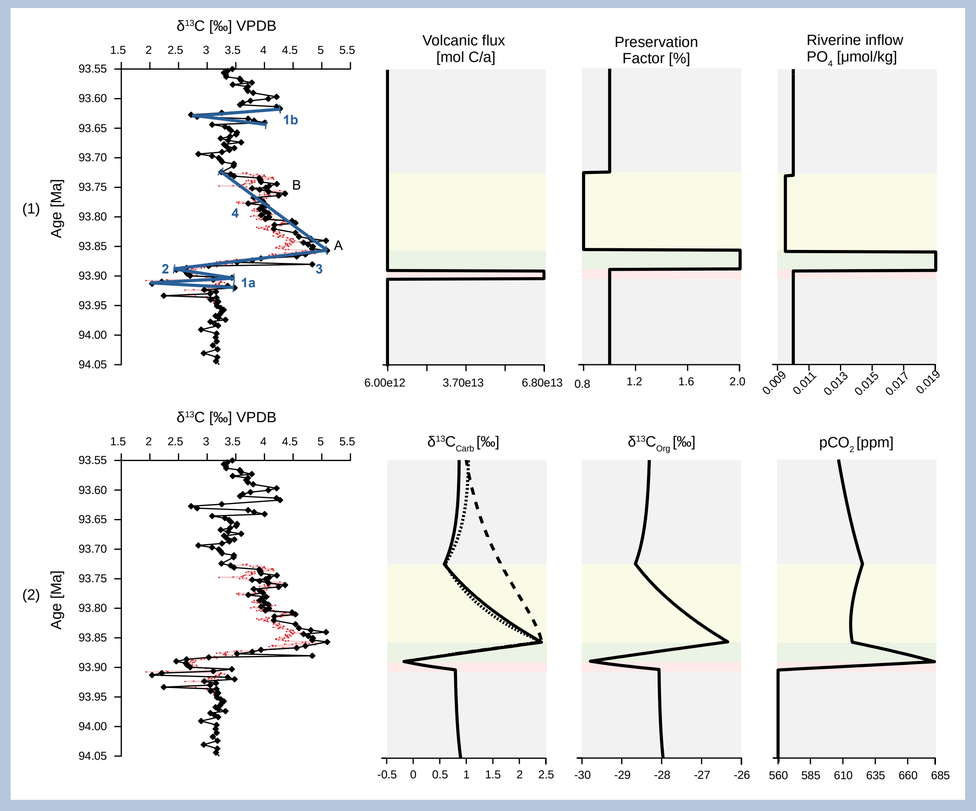

Fig. 5 - Stable isotope stratigraphy by Voigt et al. (2008) *(black)* with selected modelling trends and the results from this study *(red)* plotted against the different parameters from the model based on Kump & Arthur (1999). *Grey* background: steady state, *red*: volcanic exhalation of excursion 2, *green:* increased primary productivity and carbon conservation of excursion 3, *light green:* minimal decreased primary productivity and carbon conservation of excursion 4, $\delta^{13}C_{Carb}$ *thick dashed lines:* natural decrease after the perturbations, $\delta^{13}C_{Carb}$ *fine dashed lines:* attempt to reproduce the decreasing values with a repeated volcanic exhalation.

RESULTS

- Small-scale negative excursion 1a and 1b: The high-amplitude negative shifts in the $\delta^{13}C$ isotope trend could not be reproduced in the model
- Negative excursion 2: The decrease of 1.0 ‰ within 14 ka before the main rise of the OAE 2 CIE can be explained by a massive volcanic pulse releasing $0.95*10^{18}$ mol CO_2
- Positive excursion 3: The characteristic positive CIE of 2.6 ‰ to maximum A can be reproduced by an increase of the riverine phosphate input from 0.01 µmol/kg PO_4 to 0.019 µmol/kg and an increase in the preservation factor from 1 % to 2 % for ~ 33 ka
- Negative excursion 4: The comparatively gentle decrease of 1.8 ‰ to maximum B within ~ 133 ka can be simulated with a decreased preservation factor of 0.8 % and a reduced phosphate input of 0.0095 µmol/kg
- The simulated drawdown of CO_2 in the atmosphere-ocean system can be correlated with the globally recognized Plenus cold event (PCE)

CONCLUSION

- An isolated and massive volcanic pulse during the negative shift before the OAE 2 CIE
- High volcanic CO_2 exhalation results in increasing atmospheric pCO_2 and rising temperatures
- Enhanced hydrological cycle increases continental weathering rates to the ocean and thus nutrient supply
- Elevated nutrient supply causes expansion of the oxygen minimum zone into deep water layers and anoxic conditions develop
- Anoxia results in decreased remineralization efficiency, which leads to better preservation of the organic material
- Lower temperatures, higher oxygen contents in surface waters and the inflow of boreal cold oxygen-rich waters may have led to the re-oxygenation of deep waters during the PCE

REFERENCES

Baker, S. J. et al.(2019). CO_2-induced climate forcing on the fire record during the initiation of Cretaceous oceanic anoxic event 2. *GSA Bulletin*, *132*(1–2), 321–333.

Jarvis, I. et al. (2011). Black shale deposition, atmospheric CO_2 drawdown, and cooling during the Cenomanian-Turonian Oceanic Anoxic Event. *Paleoceanography*, *26*(3).

Jenkyns, H. C. (2010). Geochemistry of oceanic anoxic events. *Geochemistry, Geophysics, Geosystems*, *11*(3). Turgeon & Creaser, 2008)

Kump, L. R. & Arthur, M. A. (1999). Interpreting carbon-isotope excursions: carbonates and organic matter. *Chemical Geology*, *161*(1–3), 181–198.

Turgeon, S. C. & Creaser, R. A. (2008). Cretaceous oceanic anoxic event 2 triggered by a massive magmatic episode. *Nature*, *454*(7202), 323–326.

Voigt, S. et al. (2008). The Cenomanian Turonian of the Wunstorf section (North Germany): global stratigraphic reference section and new orbital time scale for Oceanic Anoxic Event 2. *Newsletters on Stratigraphy*, *43*(1), 65–89.