

Supplement to:

Evolution of deep-water circulation in the North-East Atlantic during the latest Miocene warming

- 5 Boris-Theofanis Karatsolis, Matthias Sinnesael, Tom Dunkley Jones, Anna Joy Drury, Leah LeVay, Anne Briaais, Ross Parnell-Turner, Emma Hanson, Paul N. Pearson, Margaret Morris, Haley Svadlenak, Sidney R. Hemming, Claire E. Jasper, Anita Di Chiara, Sara Satolli, Sarah Friedman, Deepa Dwyer, Philippe Claeys

10

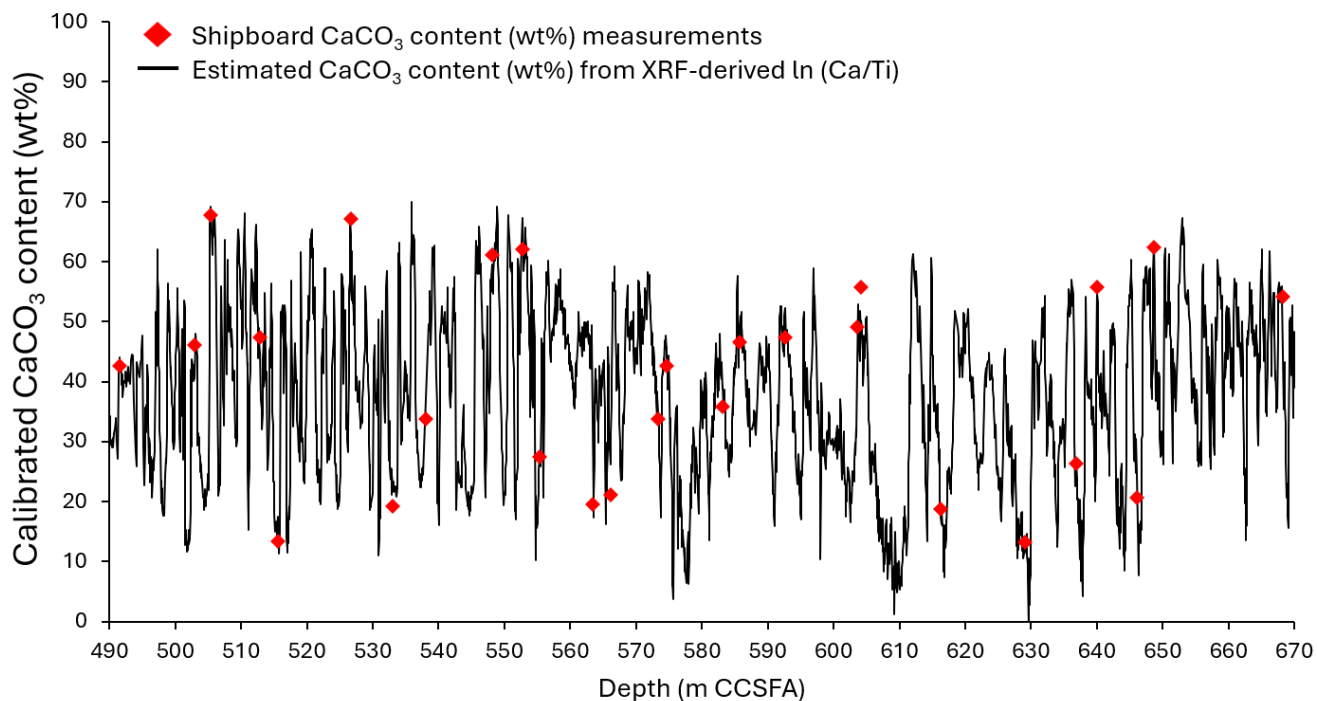
Contents of this file

Supplementary Figures S1-S2

Summary

- 15 This supplement includes two figures that support the findings presented in the main text. The supplementary figures provide additional details on the CaCO₃ content record calibration and the deep ocean circulation proxy records beyond the study interval (younger interval). All data tables associated with this study are deposited in ZENODO and will become available upon publication at: [10.5281/zenodo.20849518](https://doi.org/10.5281/zenodo.20849518)

20



25 **Figure S1: CaCO₃ calibration at Site U1564.** The red diamonds represent the shipboard CaCO₃ (wt%) measurements and the black line represents the resulting CaCO₃ (wt%) record after calibration (see main text). The calibration points spanned between ~491 and ~673 m CCSF. The latter depth represents the end of the spliced record for this site. An overall good match can be observed between the shipboard points and the fluctuations in XRF-derived carbonate content across the record.

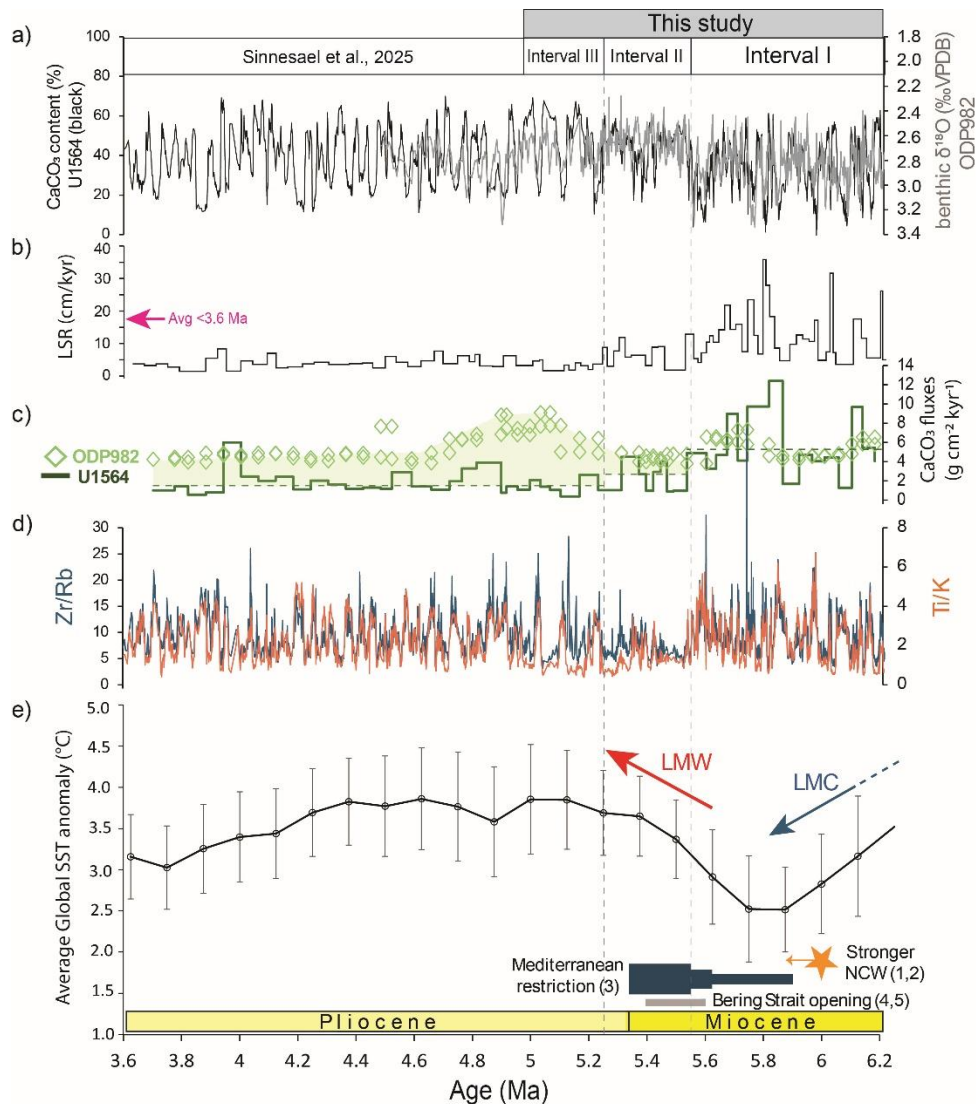


Figure S1: Bottom current activity, paleoclimatic conditions and tectonic reconfigurations across the latest Miocene and early Pliocene (extended to 3.6 Ma).

35 a) Astronomically tuned and calibrated CaCO₃ content (wt%) record (black line) at Site U1564 (this study), plotted together with the δ¹⁸O record from Drury et al., 2018 (grey line).
 40 b) Sedimentation rates at U1564 derived from age-depth points of the astronomically tuned age model. c) CaCO₃ fluxes (g cm⁻² kyr⁻¹) at Site U1564 (dark green line) and at ODP Site 982 (light green diamonds; Diester-Haass et al., 2005). For the latter, ages are updated to the Drury et al., (2018) age model. Horizontal dashed lines indicate the average CaCO₃ fluxes at U1564 during Intervals I-III. The shaded area highlights the offset between CaCO₃ fluxes at the two sites. d) XRF derived Zr/Rb (orange) and Ti/K (blue) time series at Site U1564, presented in the astronomically tuned age model. e) Compiled globally averaged Sea Surface Temperature (SST) anomaly relative to today (Data Table 6; initial data from Herbert et al., 2016). Pink arrow: Average sedimentation rate (cm/kyr) after 3.6 Ma (Sinnesael et al., 2025). Orange star with arrow: The beginning of stronger NCW as suggested by Wright and Miller 1996 (1) and Poore et al., 2006 (2); Blue bars: Restriction of the Mediterranean as summarized in Roveri et al., 2025 (3); Gray bar: Bering Strait opening as proposed by Hall et al., 2023 (4) and Gladenkov et al., 2002 (5).

Figure S2 represents an extended version of Figure 7, which is presented in the main text (interval 6.2-5.00 Ma). It demonstrates the evolution of the proxy data used to reconstruct deep-ocean activity in this study, for the time interval between 5.00-3.60 Ma. The extended records indicate that the prevailing deep-ocean conditions established by 5 Ma persisted until at least 3.6 Ma, after which a major reorganization of deep-ocean circulation occurred in the North Atlantic area west of the Reykjanes Ridge (Sinnesael et al., 2025).

References

- 55 Diester-Haass, L., Billups, K., and Emeis, K. C.: In search of the late Miocene–early Pliocene “biogenic bloom” in the Atlantic Ocean (Ocean Drilling Program Sites 982, 925, and 1088), *Paleoceanography*, 20, PA4001, <https://doi.org/10.1029/2005PA001139>, 2005.
- Drury, A. J., Westerhold, T., Hodell, D., and Röhl, U.: Reinforcing the North Atlantic backbone: revision and extension of the composite splice at ODP Site 982, *Clim. Past*, 14, 321–338, <https://doi.org/10.5194/cp-14-321-2018>, 2018.
- 60 Gladenkov, A. Y., Oleinik, A. E., Marincovich Jr., L., and Barinov, K. B.: A refined age for the earliest opening of Bering Strait, *Palaeogeogr. Palaeoclimatol. Palaeoecol.*, 183 (3–4), 321–328, [https://doi.org/10.1016/S0031-0182\(02\)00249-3](https://doi.org/10.1016/S0031-0182(02)00249-3), 2002.
- Hall, J. R., Allison, M. S., Papadopoulos, M. T., Barfod, D. N., and Jones, S. M.: Timing and consequences of Bering Strait opening: New insights from $^{40}\text{Ar}/^{39}\text{Ar}$ dating of the Barmur Group (Tjörnes Beds), northern Iceland, *Paleoceanogr. Paleoclimatol.*, 38, e2022PA004539, <https://doi.org/10.1029/2022PA004539>, 2023.
- 65 Herbert, T. D., Lawrence, K. T., Tzanova, A., Peterson, L. C., Caballero-Gill, R., and Kelly, C. S.: Late Miocene global cooling and the rise of modern ecosystems, *Nature Geosci.*, 9, 843–847, <https://doi.org/10.1038/ngeo2813>, 2016.
- Poore, H. R., Samworth, R., White, N. J., Jones, S. M., and McCave, I. N.: Neogene overflow of Northern Component Water at the Greenland–Scotland Ridge, *Geochem. Geophys. Geosyst.*, 7, Q06010, <https://doi.org/10.1029/2005GC001085>, 2006.
- Roveri, M., Lugli, S., and Manzi, V.: The desiccation and catastrophic refilling of the Mediterranean: 50 years of facts, hypotheses, and myths around the Messinian Salinity Crisis, *Annu. Rev. Mar. Sci.*, 17, 485–509, <https://doi.org/10.1146/annurev-marine-021723-110155>, 2025.
- 75 Sinnesael, M., Karatsolis, B.-T., Pearson, P. N., Briais, A., Hemming, S. R., LeVay, L. J., Dunkley Jones, T., Cui, Y., Di Chiara, A., Dodd, J. P., Dwyer, D., Eason, D. E., Friedman, S. A., Hanson, E., Hochmuth, K., Ibrahim, H. E., Jasper, C. E., Lee-Takeda, S., LeBlanc, D. E., Lindsay, M. R., McNamara, D. D., Modestou, S. E., Morris, M. A., Murton, B. J., OConnell, S., Pasquet, G., Qian, S.-P., Rosenthal, Y., Satolli, S., Suzuki, T., Thulasi, T., Wade, B. S., White, N. J., Wu, T., Yang, A. Y., and Parnell-Turner, R. E.: Onset of strong Iceland-Scotland overflow water 3.6 million years ago, *Nat Commun.*, 16, 4323. <https://doi.org/10.1038/s41467-025-59265-5>, 2025.
- Wright, J. D., and K. G. Miller: Control of North Atlantic Deep Water Circulation by the Greenland-Scotland Ridge, *Paleoceanography*, 11 (2), 157–170, <https://doi.org/10.1029/95PA03696>, 1996.