

From alkenones to Cretaceous marine Isochrysidales to coccoliths

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Living coccolithophore communities are dominated by a small group of marine species of the genera *Emiliania* and *Gephyrocapsa*. They have an unambiguous marine record back to the early Eocene when *Reticulofenestra* evolved. All three genera belong to the Family Noelaerhabdaceae in the Order Isochrysidales. The current consensus among the nanoplankton community is that there were no calcifying marine Isochrysidales in the Mesozoic (Henderiks et al., 2022), despite taxonomic evidence (Black, 1975; Covington & Wise, 1987), molecular evidence (Medlin et al., 2008; Liu et al., 2010), and alkenone data (Brassell, 2014; Hasegawa & Goto, 2024) suggestive of Cretaceous occurrences. Of these three sources of information, the biomarker is structurally unique and stable over geological time, and it holds the best potential for an unambiguous demonstration of the presence of alkenones in Cretaceous sediments identical to those known from Holocene coretop sediments, as well as cultures of *Emiliania huxleyi* and *Gephyrocapsa oceanica*. Thus, it can be used as a fingerprint for identifying the occurrence of Isochrysidales in marine sediments even if the calcite skeleton is not produced or not preserved. The molecular profile of alkenones can also be lineage-specific and provide clues of Isochrysidales evolution.

Our recent investigation (Si et al., 2024) of hemipelagic sediments from the Hauterivian through Santonian (130–80 Ma) that are broadly distributed in the Atlantic Basin has yielded abundant and diverse alkenones among which are those specific to marine Isochrysidales. From this we have concluded that mostly unsuspected coccolith-bearing species in this order synthesized alkenones already by ~132 Ma. This has important implications. From an evolutionary perspective, this implies that the Cenozoic Family Noelaerhabdaceae is directly rooted in a genetic stock of Mesozoic Isochrysidales ancestors. We have undertaken a search for these ancestral coccoliths, based on the structural and optical characters found in Noelaerhabdaceae, aware that these early morphotypes may depart markedly from the crown taxa,

and focused our attention on the genera *Repagulum* and *Pickelhaube*. From a paleoclimatic perspective, the association of alkenone C37:2 and inferred Isochrysidales species has led us to an estimated $p\text{CO}_2$ in the range of 548–4090 ppm (median of 908 ppm) during the warm Cretaceous.

References:

- Black, M. 1975. British Lower Cretaceous coccoliths. I. Gault Clay, part 2. *Palaeontographical Society Monographs*, **127**: 49–112. <https://doi.org/10.1080/25761900.2022.12131729>
- Brassell, S.C. 2014. Climatic influences on the Paleogene evolution of alkenones. *Paleoceanography*, **29**: 255–272. <https://doi.org/10.1002/2013PA002576>
- Covington, J. & Wise Jr, S. 1987. Calcareous nannofossil biostratigraphy of a Lower Cretaceous deep sea fan complex: DSDP Leg 93, Site 603, lower continental rise off Cape Hatteras, USA. *Initial Reports of the Deep Sea Drilling Project*, **93**: 617–660. <https://doi.org/10.2973/dsdp.proc.93.116.1987>
- Hasegawa, T. & Goto, A.S. 2024. Paleoceanographic importance of tri- and di-unsaturated alkenones through the early phase of Cretaceous Oceanic Anoxic Event 2 from southern high latitudes of the proto-Indian Ocean. *Organic Geochemistry*, **188**: 104722. <https://doi.org/10.1016/j.orggeochem.2023.104722>
- Henderiks, J., Sturm, D., Šupraha, L. & Langer, G. 2022. Evolutionary rates in the Haptophyta: Exploring molecular and phenotypic diversity. *Journal of Marine Science and Engineering*, **10**: 798. <https://doi.org/10.3390/jmse10060798>
- Liu, H., Aris-Brosou, S., Probert, I. & de Vargas, C. 2010. A time line of the environmental genetics of the haptophytes. *Molecular Biology and Evolution*, **27**: 161–176. <https://doi.org/10.1093/molbev/msp222>
- Medlin, L.K., Sáez, A.G. & Young, J.R. 2008. A molecular clock for coccolithophores and implications for selectivity of phytoplankton extinctions across the K/T boundary. *Marine Micropaleontology*, **67**: 69–86. <https://doi.org/10.1016/j.marmicro.2007.08.007>
- Si, W., Novak, J.B., Richter, N., Polissar, P., Ma, R., Santos, E., Nirenberg, J., Herbert, T.D. & Aubry, M.P. 2024. Alkenone-derived estimates of Cretaceous $p\text{CO}_2$. *Geology*, **52**(7): 555–559. <https://doi.org/10.1130/G51939.1>