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Impact of trace metal concentrations on coccolithophore growth and morphology: species-specific responses in past and present ocean

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The Cretaceous witnessed intervals of profound perturbation named "Oceanic Anoxic Events (OAEs)" characterized by volcanic injection of large amounts of CO_2, ocean anoxia, eutrophication, and introduction of biologically relevant metals. Some of these extreme events were characterized by size reduction and/or morphological changes of a number of nannofossil species. To detect the cause/s of such changes in the fossil record is challenging. Evidence of a correspondence between intervals of high trace metals concentrations and nannofossil dwarfism may be suggestive for a negative effect of these elements on nannoplankton biocalcification process.

In order to verify the hypothesis that anomalously high quantities of essential and/or toxic metals were the cause of coccolith dwarfism, we explored the toxicities of a mixture of trace metals on four living coccolithophores species, namely *Emiliania huxleyi, Gephyrocapsa oceanica, Pleurochrysis carterae* and *Coccolithus pelagicus*. The trace metals tested were chosen based upon concentration peaks identified in the geological record and upon known trace metal interaction with living coccolithophores algae.

Our results demonstrate a species-specific response to trace metal enrichment in living coccolithophores: *E. huxleyi*, *G. oceanica* and *C. pelagicus* showed a decrease in their growth rate with progressively and exponentially increased trace metal concentrations, while *P. carterae* is unresponsive to trace metal content. Furthermore, *E. huxleyi*, *G. oceanica* and *C. pelagicus* evidenced a decrease in the cell diameter. Smaller coccoliths were detected in *E. huxleyi* and *C. pelagicus,* while coccolith of *G. oceanica* showed a decrease in size only at the highest trace metal concentrations tested. *P. carterae* size was unresponsive for changing trace metal concentration.

Our results on living coccolithophore algae, demonstrate that elevated trace metal concentrations not only affect growth but also coccolith size and/or weight and that there are large differences between different species. These species-specific differences must be considered before morphological features of coccoliths are used to reconstruct paleo-chemical conditions.

Following the laboratory experiment results, elevated trace metal conditions in the past oceans could have caused at least part of the observed morphological changes detected during some Mesozoic OAEs.