

RECONSTRUCTING PAST CO₂ CONCENTRATIONS USING MOLECULAR FOSSILS

Jort Ossebaar, Geert Jan Brummer & Stefan Schouten*

We have assessed the possibility to reconstruct past oceanic CO₂ concentrations using organic molecules derived from algae as a molecular barometer. In particular, the stable carbon isotopic composition of long chain lipids (alkenones) was used. Our results show that the pattern of reconstructed CO₂ concentrations from alkenones resemble that found in air-bubbles trapped in deep ice-cores of the same age. However, the impact of differences in growth-rates of the algae on carbon isotope composition and, thus, nutrient levels at the time of active growth, are needed before this biogeochemical technique can be successfully applied.

The element carbon occurs in two stable forms or isotopes. The great majority consists of the light isotope (¹²C) and only about 1% of the heavy isotope (¹³C). For the reconstruction of past oceanic CO₂ concentrations, we applied the concept of the “paleobarometer” and used the ¹³C-contents of alkenones (Fig. 1.). Reconstruction of the CO₂ levels in the environment relies on the fact that the ratio of the stable carbon isotopes ¹²C and ¹³C in phytoplankton varies with the ambient concentration of CO₂. Carbon fixation by photosynthesis takes place in the photic zone of seas and oceans, of which the surface constantly exchanges CO₂ with the atmosphere. Therefore, changes in the atmospheric concentration of CO₂ influence the ¹³C/¹²C ratio ($\delta^{13}\text{C}$) of the phytoplankton. A small part of the organic material will be archived in the sediment at the seabottom and thus conserves information on the CO₂ level in the upper mixed layer of the oceans.

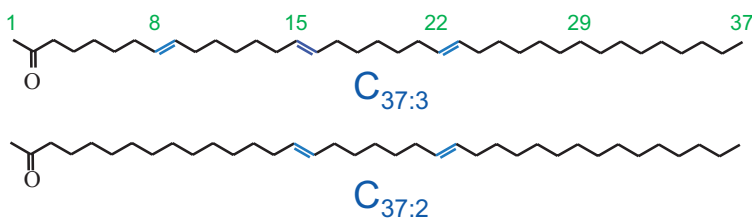


Fig. 1. Structure of the alkenones investigated.

At high CO₂ concentrations in air and surface water, the difference between the ¹³C-contents of alkenones and the ¹³C-contents of CO₂ will be large, but at low CO₂ concentrations, the difference will be smaller.

Application in the Arabian Sea.

For reconstruction of past CO₂ levels, we analysed the stable carbon isotope composition of C₃₇ alkenones in samples from discrete time intervals in sediment core NIOP 464 recovered from the central Indian Ocean.

Stable carbon isotope compositions varied between -21.7 ‰ and -24.0 ‰. The CO₂ concentrations calculated from these data showed large differences for the successive

time intervals given in fig. 2.

Clearly, all CO₂-concentrations we reconstructed in this manner are well above those directly measured in air bubbles from the Vostok ice core. This suggests that the Indian Ocean was over-saturated at times and thus remained a source for atmospheric CO₂ just like it is today. Interestingly, the pattern of changes in our biogeochemically reconstructed CO₂ concentrations parallels that of atmospheric CO₂ from the ice-core (Fig. 2.). However, before these reconstructions can be confidently used, the algal growth rates need to be assessed. When inorganic nutrients are amply available, the ¹³C/¹²C ratio of algae tends to become smaller than when nutri-

ents are scarce and limit algal growth. Thus, when these constraints on growth rates will become available, for example by the analysis of the ratio of cadmium and calcium in the shells of foraminifera occurring in the same sediment layers, better insights can be obtained on the reliability of this proxy for paleo-CO₂ reconstructions.

This research was part of the EU-project "C6", Carbon Cycle, Carbonate Chemistry and Climate Change.

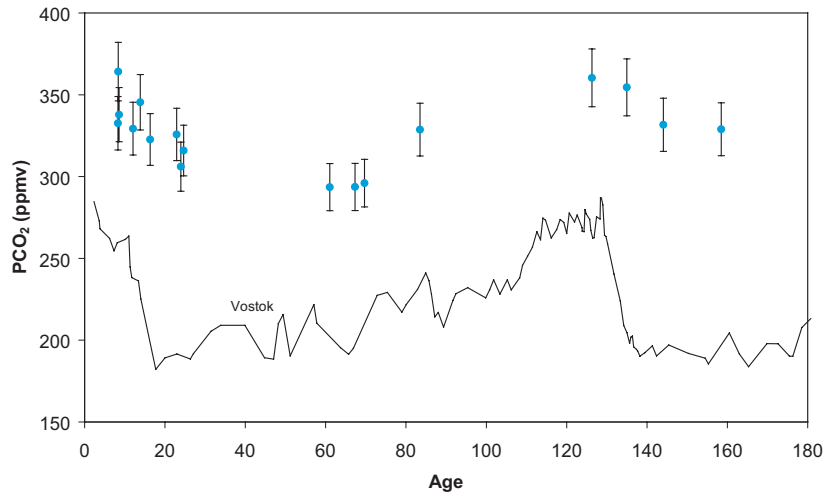


Fig. 2. Calculated CO₂ levels based on the alkenone isotope composition is given as vertical bars. The continuous profile represents the CO₂ levels from air bubbles in the Vostok ice-core.