Biogeochemical effects of volcanic degassing on the oxygen-state of the oceans during the Cenomanian/Turonian Anoxic Event 2

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Introduction

Cretaceous anoxic events may have been triggered by massive volcanic CO_2 degassing as large igneous provinces (LIPs) were emplaced. Here, we present a comprehensive modeling study to decipher the marine biogeochemical consequences of enhanced volcanic CO_2 emissions. A biogeochemical box model is used for transient model runs with time-dependent volcanic CO_2 forcing. The model considers continental weathering processes, marine export production, degradation processes in the water column, the rain of particles to the seafloor, benthic fluxes of dissolved species across the seabed, and burial of particulates in marine sediments. To estimate horizontal and vertical fluxes between boxes, a coupled ocean-atmosphere general circulation model (AOGCM) is run to derive the circulation patterns of the global ocean under Late Cretaceous boundary conditions.

Climate modeling

GENESIS 3.0 earth system model coupled to MOM2

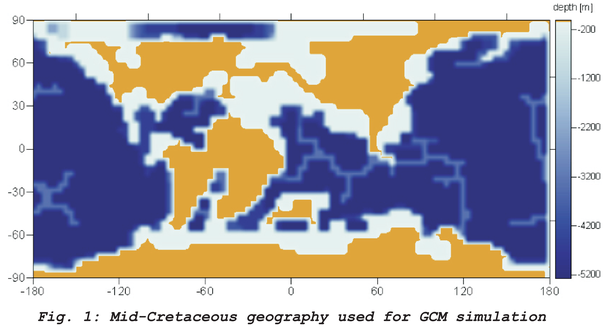


Fig. 1: Mid-Cretaceous geography used for GCM simulation

AOGCM - circulation at 2240 ppmv CO_2

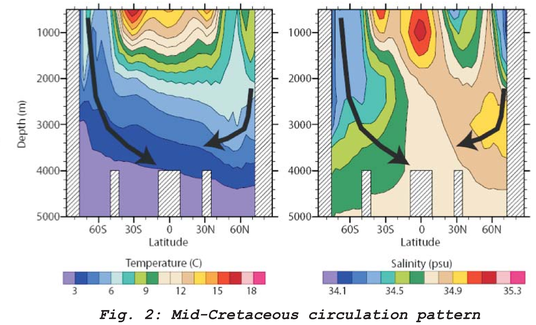


Fig. 2: Mid-Cretaceous circulation pattern

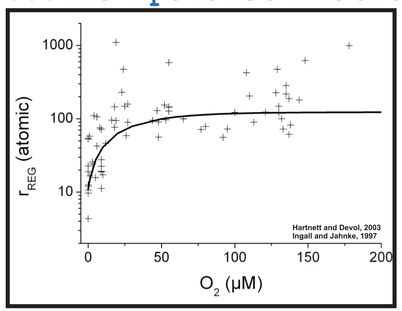
- Deep water formation in S-Pacific off Antarctica and N-Pacific
- northern source is mixture of cool-fresh N-Pacific waters and warm high saline intermediate waters of W-Tethys
- The AOGCM predicts a strong thermohaline circulation and intense ventilation in the Late Cretaceous under high pCO_2.

Cretaceous Ocean is NOT stagnant

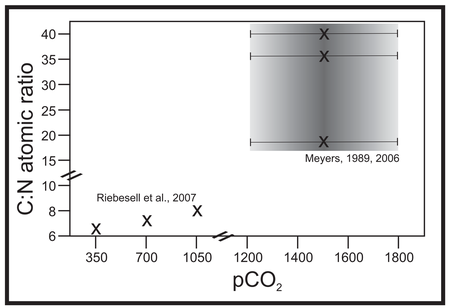
Provides vertical and horizontal fluxes for BPM circulation

Biogeochemical modeling withthe BPM (Benthic Pelagic Module)

... new parametrizations

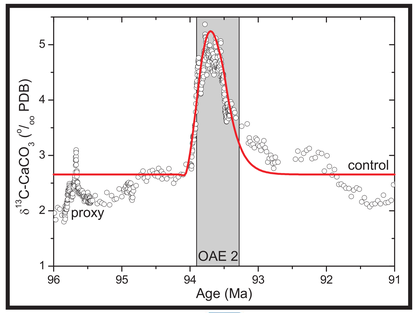


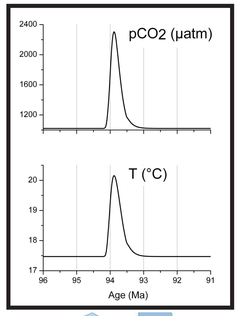
O_2 dependant ratio of POM degradaion and benthic PO_4 release (r_{REG}=RPOC/BenPO$_4$)

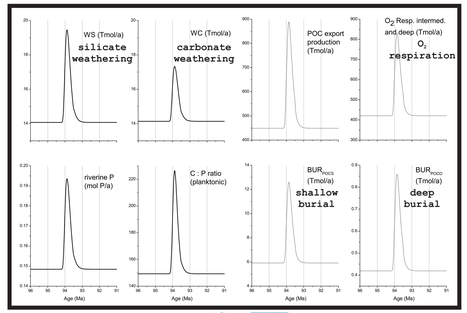


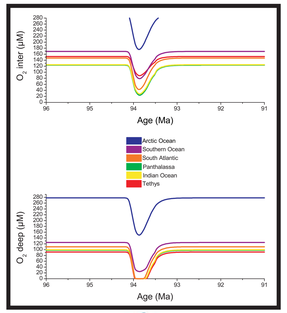
- increased C:P ratio under elevated pCO_2
- pCO_2 dependant rise in C:N but no change in N:P
- *Redfield* ratio is pCO_2 dependant

... model results









Spread of anoxia is supported by an increase in riverine P fluxes under high pCO_2 and a decrease in P burial efficiency in marine sediments under low oxygen bottom waters

yields → drives → results in

Conclusions

- With an appropriate choice of parameter values the model produces ocean anoxia at low to mid latitudes and changes in marine $\delta^{13}C$ that are consistent with geological data.
- An additional mechanism might contribute to anoxia, an increase in the C:P ratio of marine plankton is induced by high pCO_2.
- The AOGCM model results imply an intensively ventilated Cretaceous ocean that turns anoxic only if the C:P ratio of organic particles exported into the deep ocean is allowed to increase under high pCO_2.
- Being aware of the uncertainties such as diagenesis, this modeling study implies that potential changes in Redfield ratios might be a strong feedback mechanism to attain ocean anoxia.
- Formation of C-enriched marine organic matter may also explain the frequent occurrence of global anoxia during other geological periods characterized by high pCO_2.

Flögel, S., Wallmann, K., Poulsen, C. J., Zhou, J., Oschlies, A., Voigt, S., and Kuhnt, W. (2011): Simulating the biogeochemical effects of volcanic CO_2 degassing on the oxygen-state of the deep ocean during the Cenomanian/Turonian Anoxic Event (OAE2). Earth and Planetary Science Letters 305, 371-384, doi:10.1016/j.epsl.2011.03.018.