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Reconstructing the oceanic crustal carbon cycle since the Triassic

Dietmar Müller and Adriana Dutkiewicz

EarthByte Group, School of Geosciences, University of Sydney, Australia (dietmar.muller@sydney.edu.au)

Supercontinent cycles are thought to drive long-term fluctuations in atmospheric CO_2 concentrations on long timescales of 100s of millions of years, regulating secular changes in the Earth's surface temperature. However, a recent synthesis of CO_2 data for the last 420 Myrs also reveals short-term fluctuations, particularly 26-32 Myr cycles. Equivalent cycles in the geological record, including extinctions, have been interpreted to be driven by an extraterrestrial mechanism, possibly cosmic showers related to a $\sim$30 Myr half period of the Solar System's oscillation about the plane of the Milky Way Galaxy. Here we explore whether time dependent changes in the capacity of the vast oceanic carbon reservoir may instead be responsible for atmospheric CO_2 and climate variations at these time scales. Carbon accumulates mainly in the upper 300 m of the ocean crust due to the long-term alteration of the crust by low-temperature basement fluids, precipitating calcite cements in veins and voids. About 80% of the calcite forms within 20 Myr of crustal accretion, with the remainder continuing to precipitate in crust aged 20–50 Myr. Precipitation of calcite is further controlled by ocean bottom water temperature, which determines reaction kinetics, explaining why the CO_2 content of Cretaceous crust is significantly elevated relative to Late Cenozoic crust. Using all published records of crustal CO_2 from ocean drilling sites, we calculate the volume of crustal carbon sequestered from 230 Ma to the present. We derive a robust, weighted log-linear relationship between crustal CO_2 content, crustal age, and bottom water temperature. This relationship captures the rapid increase of crustal CO_2 in ocean crust in the initial 20 million years after its formation. When bottom water is relatively cold, as it is at present, this initial phase of hydrothermal alteration increases crustal CO_2 to about 2 wt%. During hothouse climates, when bottom water temperature was 10–20°C higher than today, this process resulted in a larger increase in crustal CO_2 in young ocean floor to around 3 wt%. In order to produce paleo-oceanic crustal CO_2 grids, we utilise a global bottom water temperature evolution curve based on published paleo-ocean bottom water temperature estimates. We track the age and paleo-ocean bottom water temperature for any given parcel of ocean crust to compute its CO_2 content through time. Next we use pyGPlates to compute the intersections of subduction zones with paleo-crustal CO_2 grids, allowing us to compute subducted carbon volumes through time. We complete our oceanic carbon budget by considering degassing of CO_2 along mid-ocean ridges and the uptake of CO_2 by serpentinisation of mantle peridotite along the trench-parallel outer rise caused by bending and faulting of subducting oceanic plates. Our results show that seafloor spreading rates as well as the combined storage, subduction and emission of oceanic crustal and mantle CO_2 fluctuate with a period of 26 My. A connection with seafloor spreading rates and equivalent cycles in subduction zone rollback suggests that these periodicities are driven by the dynamics of subduction zone migration, not extraterrestrial causes.