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Jurassic to present seawater chemistry and climate: Links with the history of seafloor spreading and subduction

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Major ion chemistry of global oceans has alternated between aragonite and calcite seas at least five times during the Phanerozoic Eon. These oscillations reflect changes in the Mg/Ca ratio of seawater, which in turn controls the composition of marine carbonates. Although tectonic processes are frequently evoked, the exact cause of these changes remains tenuous. Here we show that variations in hydrothermal flux calculated as a function of the changing age-area distribution of ocean floor after supercontinent break-up and dispersal correlate with Mg/Ca contents of marine carbonates over the last 200 million years. The onset of a major period of calcite precipitation is linked to the break-up of Pangaea, leading to a doubling in the length of the global mid-ocean ridge system and a 50% increase in hydrothermal fluid flux. Increased hydrothermal flux enhances alteration of fresh basalt, resulting in lowered Mg/Ca ratio of the seawater and ultimately hypercalcification. Formation of massive chalk deposits in the Late Cretaceous coincided with the maximum area of young (0 to 65 million year-old) ocean floor that drives hydrothermal flux and with rapid rates of seafloor spreading. The transition towards present-day Mg-rich aragonite seas correlates with a reduction in spreading rates, and a decrease in the area of young ocean floor due to progressive subduction of ridge flanks along the Pacific rim. Our oceanic palaeo-age maps also allow us to link crustal palaeo-age with macroporosity and crustal CO2 content based on DSDP and ODP data. Global mean oceanic crustal macroporosity fluctuates between 3.8 and 5% since 200 Ma, with a Cretaceous porosity maximum corresponding to a mean crustal age minimum of $\sim$ 40 million years. Contemporaneous fluctuations in mean upper crustal CO2 content yield a Cretaceous crustal CO2 low between 2.0 and 2.1 weight % and Jurassic/Cainozoic highs with a maximum of 2.55 weight % computed for the present. In the Cretaceous and Cainozoic, the long-term evolution of mean oceanic crustal CO2 content is inversely correlated with global surface temperature. During the Cretaceous the ocean crust was relatively deprived of its ability to absorb CO2 due to its relatively young mean age, contributing to elevated atmospheric CO2 and surface temperatures, up to 5.5 ºC higher than at present. Both in the Jurassic and Cainozoic an elevated capacity of the ocean crust to bind CO2 corresponds to reduced surface temperatures relative to the Cretaceous. The Earth's transition towards icehouse climates since the Cretaceous may in part be due to an increased uptake of CO2 by the ageing crust in maturing ocean basins. This observation supports the notion that altered seafloor basalt represents a significant sink for carbon.