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Enhanced volcanic CO_2 degassing at oceanic hotspots and mid-ocean ridges in response to falling sea level

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Evidence from paleo-climate proxy data as well as results from geodynamical and biogeochemical modelling point to complex interactions between sea level variations, pressure-release melting of oceanic mantle, associated volcanic degassing, and atmospheric CO_2 concentrations. Ice core data shows that the orbital component in global temperature records gradually declined between ~85,000-70,000 yr BP, while atmospheric CO_2—instead of continuing its long-term correlation with Antarctic temperatures—remained relatively stable for several thousand years. Based on 2-D and 3-D geodynamical models we show that the massive (60-100 m) sea level drop during this period of Earth history led to a significant increase in magma and possibly CO_2 fluxes along mid-ocean ridges (MOR) and especially oceanic hotspot volcanoes.

We assess the MOR magma and CO_2 fluxes using 2-D thermo-mechanical models that solve for wet melting of the mantle and the partitioning of highly incompatible carbon dioxide into the melt. These models have been run at various MOR opening rates, and we integrate these results with the global distribution of spreading rates to compute baseline fluxes as well as enhanced fluxes during the sea level fall. Furthermore we conducted more than 120 3-D simulations of rising and melting mantle plumes to construct a four-dimensional parameter space that covers a wide range of plume buoyancy fluxes, plume excess temperatures, lithosphere thicknesses and plate speeds. Using published data on 43 oceanic hotspots and locating them in the parameter space we derive a global hotspot-melting model that predicts magma and CO_2 fluxes before and during the sea level drop.

We find that, during a 80 m sea level drop over 10 kyr, global degassing at MOR and oceanic hotspots increases by 26 % and 36 %, respectively. Biogeochemical carbon cycle modelling further shows that the combined predicted increase in volcanic emissions along the global mid-ocean ridge system and at oceanic hotspots is likely to have raised atmospheric CO_2 concentrations by up to 17 ppm_v—sufficient to explain the different trends of temperature and atmospheric CO_2 over this period.