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Geophysical modeling of the impact of Central Atlantic Magmatic Province emplacement on sea-level changes at the Triassic-Jurassic boundary

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Mass extinctions have been linked to the emplacement of Large Igneous Provinces (LIPs). While increasing precision in the dating of LIPs indicates that extinctions are often synchronous with LIP eruptions, the complete causal chain of events - including impacts on climate, ocean chemistry, and sea level - remains incompletely understood. Here we utilize a numerical modeling approach to examine one possible link in this chain: the capacity of LIP emplacement to drive sea-level changes. We focus on the Late Triassic and Early Jurassic, an interval encompassing the end-Triassic mass extinction and the emplacement of the Central Atlantic Magmatic Province (CAMP). Excursions in sea level are also well documented at this time and in many places indicate a rapid fall followed by a sea-level rise coincident with the extinction.

To explore the impact of CAMP on sea-level changes we use a geophysical model of solid-Earth deformation together with a reconstructed paleotopography during the end-Triassic. We perturb the model in two steps, corresponding to two phases of LIP emplacement: (1) Uplift associated with the ascending plume that leads to the CAMP eruption; and (2) loading and flexure of the lithosphere associated with the emplaced magma. We model the former process with a mantle convection code to assess the tempo-spatial behavior of dynamic uplift for varying plume sizes. The latter process is modeled as a viscoelastic loading problem that allows us to isolate contributions from the initial elastic and subsequent viscous response. Both mechanisms are combined in a gravitationally self-consistent sea-level theory that accounts for loading effects associated with displaced water, as well as shoreline migration and perturbations in Earth rotation. We compare model outputs to geological data from a set of sites in which the direction, magnitude, and age of sea level changes have been estimated for the end-Triassic period.

Our calculations place bounds on the magnitude and timing of possible sea-level changes associated with the two processes described above. In particular, our results indicate that while LIP emplacement is capable of driving large sea-level changes in the vicinity of the magmatic province, the magnitude of these changes drops off rapidly as a function of the distance. Thus, large sea level excursions as well as regression-transgression couplets reported for the Triassic-Jurassic transition can only be explained by these mechanisms for sites in the near field of the provinces. Large sea-level changes observed in the far-field would require additional mechanisms, perhaps linked to climate forcing or other feedbacks.