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Thermal erosion of cratonic lithosphere as a potential trigger for mass-extinction

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The temporal coincidence between large igneous provinces (LIPs) and mass extinctions has led many to pose a causal relationship between the two. However, there is still no consensus on a mechanistic model that explains how magmatism leads to the turnover of terrestrial and marine plants, invertebrates and vertebrates. Here, we present a synthesis of stratigraphic constraints on the Triassic-Jurassic (T-J) and Pliensbachian-Toarcian (Pl-To) boundaries combined with geochronological data in order to establish the sequence of events that initiate two of the major mass extinctions recorded in Earth's history. This synthesis demonstrates that these biotic crises are both associated with rapid change from an initial cool period to greenhouse conditions. The initial regressive events recorded at T-J and Pl-To boundaries seem difficult to reconcile either with large initial CO_2 degassing associated with plume activity or by volatile-release (CO_2, CH4, Cl2) from deep sedimentary reservoirs during contact metamorphism associated to dykes and sills intrusion because massive CO_2 degassing is expected to produce super greenhouse conditions. We evaluate, here, an alternative suggesting that the initial cooling could be due to gas release during the initial thermal erosion of the cratonic lithosphere due to emplacement of the CAMP and Karoo-Ferrar volcanic provinces.

Petrological constraints on primary magmas indicate that the mantle is hotter and melts more extensively to produce LIP lavas than for current oceanic islands basalts. However, available data suggest that the Karoo and CAMP areas were underlain by thick lithosphere (>200 km) prior to continental break up. The presence of thick lithosphere excludes significant melting of the asthenospheric mantle without initial stage of thermal erosion of the cratonic lithosphere. This initial step of thermal erosion / thermal heating of the cratonic lithosphere is critical to understand the volatile budget associated with LIPs while studies of the composition of the Kaapvaal craton have shown that sulfide minerals are enclosed in the basal part of the cratonic lithosphere. The formation of these sulfide minerals are linked to multiple refertilization/metasomatic events, which affected the base of the subcontinental lithospheric mantle from the Archean to the Proterozoic. We suggest that the transitions from an initial cool period to greenhouse conditions recorded by T-J and Pl-To sedimentary sections result of changing gas species emitted during the progressive thermal erosion of cratonic lithosphere by plume activity or thermal internal heating of the lithosphere. Our petrological model for LIP magmatism argues that initial gas emission was dominated by sulfur liberated from sulfide-bearing cratonic lithosphere causing global cooling and eustatic regression, which was followed by warming/transgression associated with the progressive increase of CO_2 in the atmosphere associated to LIPs emission and metamorphic reactions in sedimentary basins.

We suggest that the nature of the underlying lithosphere during large LIP eruption potentially exerts an important control on the consequences at the Earth's surface. This model offers an explanation for why LIPs erupted through oceanic lithosphere are not associated with climatic and biotic crises comparable to LIPs emitted through cratonic lithosphere.