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Refining the temporal relation between Large Igneous Provinces and carbon cycle perturbations: not every LIP triggers environmental crises, not every crisis is due to a LIP!

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The connection between volcanic activity of large igneous provinces and the respective feedback from environment and biosphere contributing to the carbon cycle has been investigated at the present temporal resolution of high-precision U/Pb dating. Uncertainties of 0.05 % on the $^{206}Pb/^{238}U$ age from zircon dating allow a resolution of 30-50 ka pulses of magmatic activity; simultaneously, the duration of carbon isotope excursions (CIE) can be determined, the geological boundaries dated, or global sedimentary gaps can be quantified at the same level of precision. This contribution demonstrates with two case studies that we can refine the contemporaneity and start to reliably infer causality of consecutive events at the 10^4 year level.

Until the Anisian the aftermath of the Permo-Triassic Boundary Mass extinction (PTBME; ~251.94 Ma, Baresel et al., 2017) is characterized by profound fluctuations of the global carbon cycle with amplitudes of up to 8 ‰ in $d^{13}C_{carb}$ values. These represent large variations in the global climate and biological crises, in particular during the end-Smithian extinction event (~249.1 Ma). A precise chronology from the southern Nanpanjiang basin (China) allows for a quantification of these fluctuations of Earth climate. Following the volcanic pulse causing the PTBME, several discontinuous episodes of volcanism of the Siberian Large Igneous Province (S-LIP) were generally assumed to have caused the subsequent Early Triassic carbon cycle fluctuations. This is, however, in disagreement with the geochronological database of precise zircon U/Pb dates that put an end to the volcanic activity at 250.6 Ma (Burgess & Bowring, 2015; Augland et al., 2019). Therefore, recurrent S-LIP volcanism is an unlikely explanation for the Early Triassic unstable carbon cycle.

The initial intrusive pulse of the Karoo Large Igneous Province (K-LIP) formed the sill/dyke complex of the Karoo basin, South Africa. New, precise U/Pb geochronology confirms its very short duration at around 183.2-182.8 Ma (Burgess et al., 2015; Corfu et al., 2016), as well as its synchronicity with the lower Toarcian oceanic anoxic event (T-OAE), and a carbon cycle disturbance of presumable global importance. Repeated excursions in $d^{13}C_{org}$ of up to 3 ‰ in the late Pliensbachian (~185.5 Ma) as well as at the Pliensbachian-Toarcian boundary (~183.5 Ma) are therefore at least partly

older than any known magmatic activity of the K-LIP (Lena et al., 2019). We therefore, again, must invoke non-volcanic drivers in order to explain the instability of the carbon cycle.

These two case histories demonstrate that in order to invoke causality and global importance to carbon cycle instability, as well as for the testing of its correlation with volcanic episodes, we need to rely on geochronology of both sedimentary and volcanic records at the 10^4 years level of precision.

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