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Geochronology of Basin-Scale LIP Sill Emplacement in the Karoo Basin during the Toarcian

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Large Igneous Provinces (LIPs) are commonly correlated with global climate change, and environmental, as well as biological, crises. These are short-lived igneous events, typically much less than 5 Ma, can erupt more than 1 Mkm^3 of volcanic rocks, while potentially emplacing over 500,000 km^3 of upper crustal intrusions. Detailing the duration and pace of these high flux magmatic events has, however, been complicated by a lack of high-precision geochronology. This is crucial to understand, as they represent some of the most rapid upper crustal magmatic accretion mechanisms in Earth's history. We focus on the Karoo LIP in southern Africa as a natural laboratory for testing models how such intrusive complexes emplace. The LIP is comprised of a suite of basaltic lava flows, sills, dike swarms, and was emplaced during the early Toarcian. Approximately 340,000 km^3 of sills are interlaid within Karoo Basin sedimentary rocks. Differential uplift, erosion and availability of drill core material allows for sampling of the entire intrusive succession in the basin.

We report new high-precision U-Pb zircon and baddeleyite ages and Hf isotope compositions for sills emplaced from base to top of the Karoo Basin. Using these data, we are able to address several fundamental questions of LIP emplacement: (1) we corroborate the anticipated short (10^4-10^5 kyr) duration of intrusive magmatism, and (2) the high intrusive magma flux of the Karoo LIP; (3) is there is a relationship between age and emplacement depth of sills within the basin; and (4) is it justified to correlate the intrusion of the LIP with global climate change at this level of precision? These data indicate that the 340,000 km^3 of intrusive magmas were emplaced in approximately 500 ka, solidifying new mafic upper crust through a downward stacking assembly, and that the entirety of intrusive magmatism was emplaced within the uncertainty of the Toarcian oceanic anoxic event. In addition, these data also indicate that dolerite sills throughout the basin assimilated sedimentary wall rock during crystallization, which helped facilitate zircon crystallization within pegamatic pods interfingered within the sills.