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Lithospheric and Atmospheric Changes Associated with Rapid, Pulsed Assembly of Mafic Upper Crust: Assembly of the Karoo LIP Intrusive Complex

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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. As a result, LIPs represent some of the most rapid periods of lithospheric growth, generating enormous volumes of mafic upper crust. Detailing the duration and pace of these high flux magmatic events has, however, is hampered by a lack of high-precision geochronology. We focus on the Karoo LIP in southern Africa as a natural laboratory for testing models on the formation of mafic upper crust through large-volume mafic LIP intrusions. The Karoo 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, Hf isotope compositions and apatite volatile compositions from 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) what is the total of intrusive LIP magmatism within the Karoo Basin; (2) is there variable magma flux during assembly of the intrusive complex; (3) is there is a relationship between age and structural position of sills within the basin; (4) is it justified to correlate the intrusion of the LIP with global climate change at this level of precision; (5) does the composition and extent of thermogenic degassing vary throughout the basin?

Our new data indicate that the 340,000 km^3 of intrusive magmas were emplaced in approximately 500 kyr, solidifying new mafic upper crust through a downward stacking assembly, and that the entirety of intrusive magmas were emplaced within the uncertainty of the early Toarcian oceanic anoxic event. This pulsed assembly is in agreement with atmospheric models that require pulsed degassing of the basin to cause the observed early Toarcian isotope excursions. In addition, these data also indicate that dolerite sills throughout the basin assimilated sedimentary wall rock during crystallization, which helped facilitate zircon crystallization within pegmatitic pods interfingered within the sills. Finally, volatile compositions preserved in apatite indicate that thermogenic

wallrock-sill interactions significantly affected the final volatile compositions of the sills, and trace the release of LIP-driven gases from the basin.