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Thermochronological Insights from Modelling U–Pb Diffusion, Decay, and Ingrowth in Zircon

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Geochronology provides critical insights into Earth's geological history by determining the ages of geological events recorded by radiogenic isotopes. Zircon is one of the most reliable and widely used geochronometers due to its ability to preserve uranium–lead (U–Pb) isotopic information over geological timescales and conditions. However, post-crystallization processes, including the diffusion of lead isotopes at elevated temperatures, can alter the zircon's record and complicate precise age determinations and the interpretation of geological events. In this study, we utilise U–Pb in zircon geochronology to determine the thermochronological evolution by combining diffusion, radioactive decay, and ingrowth using the numerical modelling software *Underworld3*. By comparing analytical U–Pb measurements with our numerical simulations, we provide additional insights into the role of diffusion on discordant U–Pb ages across a zircon crystal and how discordance can be used to estimate an upper limit on peak temperatures. We apply our model to the Trivandrum block in Southern India, a region known for its high-temperature metamorphic history. By simulating various temperature–time paths constrained by multiple geochronometers, we compare the numerical U–Pb results to analytical measurements to identify the thermal history most consistent with the measured isotopic values. Our models indicate that temperatures in the Trivandrum block potentially reached as high as 1000°C during Gondwana assembly to replicate the analytical measurements. The numerical approach can be adapted to explore the effects of diffusion on other isotopic systems within any mineral, further extending its utility to unraveling the thermal history of regions.