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Magmatic-Hydrothermal evolution of zircon in ~2.5 Ga Bundelkhand Granitoids, India

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Zircons from the ~2.52 ± 7 Ga [1] peraluminous to metaluminous A_2-type Bundelkhand granitoids have a magmatic-to-hydrothermal crystallization history. They provide insights into the role of evolving magmatic fluids in silicic magmatic systems. Two types of zircon are recognized based on texture and geochemistry: Type-1 (cores) and Type-2 (rims). Type-1 zircon cores have low concentrations of light rare earth elements (LREEs; 51–215 ppm), low abundances of non-formula elements (Ca, Fe, Al, Hf, Th, Y), and display positive Ce and negative Eu anomalies. Radiation-damaged zones are present in some Type-1 zircons, which were altered by fluids and enriched in non-formula elements. Type-2 rims overgrowing magmatic Type-1 cores show higher concentrations of LREEs (130–729 ppm) and non-formula elements (CaO ≤4.13 wt. %, FeO ≤1.91 wt. %, Al_2O_3 ≤4.09 wt. %, Y_2O_3 ≤3.29 wt. %, Th 236–969 ppm, U 495–721 ppm). Type-2 zircons lack Ce anomalies, exhibit minimum radiation damage, and reflect fluid-induced dissolution-precipitation processes. The absence of zircons with Th/U ≤ 0.5 further supports a fluid-mediated origin of Type-2 zircons. Ti-in-zircon thermometry yields crystallization temperatures of 747°–872°C for Type-1 and fluid-precipitation temperatures of 769°–885°C for Type-2, consistent with zircon saturation conditions (~830°–860°C: [2]) in the Bundelkhand granitoids. Interestingly, recent studies have reported comparable fluid-enriched zircons from Mars, where zircon enriched in non-formula elements Al-Fe-Y crystallized from exsolved aqueous fluids from crystallizing magma [3]. This study emphasizes that syn-magmatic zircon dissolution-precipitation from silicate-rich fluids in large silicic systems can serve as an analog for aqueous processes on planetary bodies. It also highlights the importance of considering zircon trace-element geochemistry during U-Pb analyses to improve age screening and the interpretation of magmatic, hydrothermal, and metamorphic histories.

References: [1] Mondal MEA et al. (2002), *Precambrian Research* 117, 85-100. [2] Sensarma S *et al.* (2021), *Precambrian Research* 352, 105951. [3] Gillespie J et al. (2024), *Science Advances* 10(47), eadq3694.