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Coeval Formation of Zircon Megacrysts and Host Magmas in the Eifel Volcanic Field (Germany) Based on High Spatial Resolution Petrochronology

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Zircon megacrysts (approx. 0.5-6 mm in diameter) from the Quaternary West and East Eifel volcanic fields, Germany, occur as euhedral crystals in porous K-spar rich plutonic ejecta clasts, and as partially resorbed xenocrysts in tephrite lava. Their relation to the host volcanic rocks has remained contentious because the dominantly basanitic to phonolitic magma compositions in the Eifel are typically zircon undersaturated. We carried out a detailed microanalytical study of zircon megacrysts from seven locations (Emmelberg and Rockeskyll in the West Eifel; Bellerberg, Laacher See, Mendig, Rieden, and Wehr in the East Eifel). Crystals were embedded in epoxy, sectioned to expose interiors through grinding with abrasives, diamond-polished, and mapped by optical microscopy, backscattered electron, and cathodoluminescence imaging. Subsequently, isotope-specific analysis using secondary ionization mass spectrometry (SIMS) and laser ablation inductively coupled mass spectrometry (LA-ICP-MS) was carried out placing $\sim$100 correlated spots on $\sim$20 selected crystals. Concordant U-Th disequilibrium and U-Pb ages determined by SIMS are between ca. 430 ka (Rieden) and 170 ka (Mendig) and indicate that the megacryst zircons crystallized almost always briefly before eruption. A significant gap between zircon megacryst crystallization (ca. 230 ka) and eruption (ca. 45 ka) ages was only detected for the Emmelberg location. SIMS trace element abundances (e.g., rare earth elements) vary by orders-of-magnitude and correlate with domain boundaries visible in cathodoluminescence; trace element patterns match those reported for zircon from syenitic origins. Isotopic compositions are homogeneous within individual crystals, but show some heterogeneity between different crystals from the same locality. Average isotopic values (δ18O SMOW = +5.3$\pm$0.6 ‰ by SIMS; present-day εHf = +1.7$\pm$2.5 ‰ by LA-ICP-MS; 1 standard deviation), however, are consistent with source magmas being dominantly mantle-derived. The porous structure and relatively small grain size of the host enclaves suggests that they originated from subvolcanic intrusions. Moreover, the preservation of zircon in hot, zircon undersaturated magmas requires brief residence times. Zircon megacrysts thus appear to have crystallized in highly differentiated magmas or nearly solidified intrusions from which crystals or rock aggregates were incorporated into more primitive magmas en route to surface. This implies that chemical signatures of apparently primitive magmas in basaltic volcanic fields can be modified by interaction with evolved melts that differentiated prior to eruption, mostly within an interval less than the ca. 10-25 ka uncertainty range of the radiometric ages.