Supplementary Material

Geochemistry

Whole-rock geochemical analyses of samples MM100320-1Dd (granite) and MM100320-4A (andesite) were carried out at the Sernageomin laboratory following the methodology described by Velásquez *et al.* (2023). Major oxide concentrations (SiO_2, Al_2O_3, TiO_2, Fe_2O_3, CaO, MgO, MnO, Na_2O, K_2O, and P_2O_5) and trace element concentrations (Cu, V, Cr, Co, Ni, Zn, Rb, Sr, Y, Zr, Nb, Ba, Pb, and Sc) were determined by Wavelength-Dispersive X-Ray Fluorescence (WD-XRF) spectrometry. Rare Earth Element (REE) concentrations (La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu), together with high field strength elements (HFSE: Cs, Hf, Ta, Th, and U), were determined by Triple Quadrupole Inductively Coupled Plasma Mass Spectrometry (ICP-MS/MS), a technique employing three quadrupoles in series (Q1, Q2/reaction cell, and Q3) to suppress spectral interferences and maximise analytical sensitivity. Geochemical results are provided in Supplementary Table 1.

$^{40}Ar/^{39}Ar$ geochronology

Thin sections were first examined to evaluate the degree of alteration and muscovite grain size. Mineral separation was conducted using a Frantz isodynamic separator, and muscovite grains were subsequently hand-picked under a binocular microscope. The selected grains were loaded into high-purity aluminium discs alongside sanidine grains from the Fish Canyon Tuff (Kuiper *et al.*, 2008) which acted as neutron flux monitors during reactor irradiation. The discs were sealed with aluminium planchettes of equivalent specification and dispatched to the 5 MW Herald pool nuclear reactor RECH-1, operated by the Chilean Nuclear Energy Commission. Before age determination, the reactor neutron flux parameter (J) was established using Fish Canyon Sanidine of known age. Samples were analysed by the step-heating method, whereby gas release was induced by progressively increasing the CO_2 laser power from 5 to 30 W over a 6×6 mm sample pit. The released noble gases were purified through a cold trap maintained at −133 °C in conjunction with chemical getters, before being introduced into a MAP 215-50 mass spectrometer. The ^{36}Ar, ^{37}Ar, ^{38}Ar, ^{39}Ar, and ^{40}Ar isotopes were measured simultaneously using a multi-collector system consisting of an electron multiplier (^{36}Ar) and Faraday cups (remaining isotopes). Baseline measurements were acquired at the start and end of each heating step and subtracted from the corresponding peak intensities. The apparent age for each heating step was calculated with corrections applied for atmospheric argon contamination and for argon isotopes produced from K, Ca, and Cl irradiation (^{40}Ar, ^{39}Ar, ^{38}Ar, ^{37}Ar, and ^{36}Ar). A plateau age was defined by three or more consecutive heating steps that together account for at least 50% of the total ^{39}Ar released, with individual step errors overlapping at the 2σ confidence level (Fleck *et al.*, 1977). All calculations employed the decay constants and isotopic abundances reported by Steiger and Jäger (1977): $\lambda(^{40}K_{\varepsilon}) = 0.581\times10^{-10}$ yr^{-1}, $\lambda(^{40}K_{\beta}) = 4.962\times10^{-10}$ yr^{-1}, isotopic abundance ^{40}K = 0.01167 atom%, atmospheric ratio $^{40}Ar/^{36}Ar = 295.5$. The $^{40}Ar/^{39}Ar$ age data is provided in Supplementary Material 2.

U-Pb geochronology at Sernageomin, Chile

Rock samples were crushed and pulverised using a Retsch pulveriser to a grain size below 500 µm. Subsequently, heavy mineral concentration was carried out using a Gemini shaking table, followed by zircon separation with UV lamps and heavy liquids. Zircon grains were then hand-picked under a binocular microscope and mounted on a 2.5 cm diameter epoxy resin disc. The number of mounted zircons per sample varied between 30 and 120 crystals, depending on whether igneous or detrital zircon populations were being sought. A Temora-2 standard crystal (Black *et al.*, 2004) was mounted in the same epoxy disc as the samples. Prior to laser ablation, cathodoluminescence (CL) images were acquired to characterise the internal structure of the zircon grains, while backscattered electron (BSE) images were collected to identify fractures and inclusions within each crystal. Both imaging techniques utilized a Zeiss EVO MA10 scanning electron microscope equipped with a Gatan ChromaCL 2 UV detector and a Zeiss 5-diode annular BSE detector. The briquettes were loaded into an Analyte G2 193nm excimer (ArF-ATL2) laser ablation system. A briquette containing the primary standard GJ-1 (Jackson *et al.*, 2004) and secondary standards Mud Tank (Black and Gulson, 1978) and Plešovice (Sláma *et al.*, 2008) was placed in a central position. The ablation spot diameter was 30 μm, with a firing frequency of 10 Hz and energy density of 2 J/cm^2, resulting in a crater depth of 15-20 μm. The ablated material was transported into a Thermo Fisher Element XR single-collector sector field ICP-MS. Isotopic masses of ^{206}Pb, ^{207}Pb, ^{232}Th, and ^{238}U were measured via peak switching, using an electron multiplier detector. The U isotope was determined based on the natural abundance ($^{235}U/^{238}U$) ratio of 137.88. Data reduction was performed using the Iolite software (Petrus and Kamber, 2012). Isotopic fractionation during ablation and transport, as well as instrumental drift, were corrected using the GJ-1 primary reference zircon. Potential second-order variations in isotope ratios due to sample position within the ablation chamber were monitored using the Temora-2 standard, distributed across each sample disc. Secondary standards (Plešovice and Mud Tank) were treated as unknowns for quality control purposes. The standards allowed for the monitoring of U and Pb ratios across a wide range of concentrations. For Phanerozoic samples, $^{206}Pb/^{238}U$ ages were corrected for common lead (Williams, 1998) using the decay constants used from Steiger and Jäger (1977): $\lambda(^{238}U) = 1.55125\times10^{-10}$ yr^{-1}, $\lambda(^{235}U) = 9.8485\times10^{-10}$ yr^{-1}, atomic ratio $^{238}U/^{235}U = 137.88$. The U-Pb age data are provided in Supplementary Table 2.

U-Pb geochronology at ZirChron LLC laboratory (Arizona, USA)

Zircon concentrates from all samples were separated at ZirChron LLC, Tucson, Arizona. Each sample was individually unpacked and pressure-washed to remove debris and foreign material. Sample fragments were placed in the chamber of an Electro Pulse Disaggregator (EPD, Marx generator) and subjected to electrical pulses at a repetition rate of 1-2 Hz and a discharge voltage of ~220 kV for 15 minutes. The resulting 25-500 μm grain fraction was subsequently processed using conventional mineral separation techniques, including a Wilfley water table, a Frantz paramagnetic separator, and heavy liquid separation with methylene iodide (MEI) at 3.32 g/cm^3. Zircon grains from the non-magnetic fraction were mounted together with reference standards in 1-inch epoxy pucks and polished following standard laboratory procedures. Following CL imaging, U-Pb geochronological analyses were conducted by LA-ICP-MS using an Analyte G2 193 nm excimer laser coupled to an Element 2 high-resolution ICP-MS. Analyses followed the methodology of Chang *et al.* (2006), with laser parameters comprising a 35 µm spot size, a repetition rate of 10 Hz, and a fluence of ~4 J/cm². Each analysis consisted of a 30-second background measurement with the laser off, followed by approximately 30 seconds of ablation during which 250 sweeps were acquired across masses ^{202}Hg, ^{204}Pb+Hg, ^{206}Pb, ^{207}Pb, ^{208}Pb, ^{232}Th, ^{235}U, and ^{238}U. Sample aerosol was transported to the plasma via He and Ar carrier gases. Unknowns were analysed in blocks of ten, bracketed by reference standards. Data reduction was performed offline using the Iolite software (Paton *et al.*, 2010). Time-independent elemental fractionation was corrected by normalising U/Pb and Pb/Pb ratios of unknowns to those of the zircon primary standard (Chang *et al.*, 2006). U and Th concentrations were determined by reference to the 91500 zircon standard. Plešovice (Sláma *et al.*, 2008), FC-1 (Paces and Miller, 1993) and Fish Canyon Tuff sanidine (Schmitz and Bowring, 2001) were used as secondary reference materials. Common Pb corrections were applied using the ^{207}Pb method (Williams, 1998). U-Pb diagrams and ages were calculated using Isoplot (Ludwig, 2012a). Interpreted ages are reported as ^{206}Pb/^{238}U ages for grains younger than 1200 Ma and as ^{206}Pb/^{207}Pb ages for grains older than 1200 Ma. The U-Pb age data are provided in Supplementary Table 2.

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