

Supplementary Material 1

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) south of the Beagle Channel. Its geological record documents the complex tectonic history of Tierra del Fuego, which includes the opening and closure of the Rocas Verdes basin, Cordillera arc collision and subsequent subduction processes. The geology of the island is mostly composed of the Cretaceous Yahgán Formation, a marine metasedimentary sequence, which is intruded by diverse plutons that are mostly exposed on the northwestern tip of the island. We herein present a new dataset that shows the presence of three Cretaceous-earliest Paleocene magmatic suites of active margin magmatism emplaced during the early stage of the Fuegian Andes, which are referred to as (1. Major oxide concentrations (SiO₂, Al₂O₃, TiO₂, Fe₂O₃, CaO, MgO, MnO, Na₂O, K₂O, and P₂O₅) 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.

⁴⁰Ar/³⁹Ar 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 CO₂ 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 ³⁶Ar, ³⁷Ar, ³⁸Ar, ³⁹Ar, and ⁴⁰Ar isotopes were measured simultaneously using a multi-collector system consisting of an electron multiplier (³⁶Ar) 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 (⁴⁰Ar, ³⁹Ar, ³⁸Ar, ³⁷Ar, and ³⁶Ar). A plateau age was defined by three or more consecutive heating steps that together account for at least 50% of the total ³⁹Ar 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):

$\lambda(^{40}\text{K}_e) = 0.581 \times 10^{-10} \text{ yr}^{-1}$, $\lambda(^{40}\text{K}_\beta) = 4.962 \times 10^{-10} \text{ yr}^{-1}$, isotopic abundance ⁴⁰K = 0.01167 atom%, atmospheric ratio ⁴⁰Ar/³⁶Ar = 295.5. The ⁴⁰Ar/³⁹Ar 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) to test correlation between Proterozoic inliers, and to characterise source regions. These include successions considered to be the oldest presently exposed in Tasmania. Typical features of the age distributions of the Proterozoic rocks are prominent data concentrations at 1800-1650 Ma and 1450-1400 Ma, and a minor spread of Archaean ages. Statistical testing of the similarity of the age profiles shows that widespread quartzarenaceous samples from the Detention Subgroup, Needles Quartzite and from the Tyennan region are strongly similar, consistent with broad correlation. Relatively large differences are seen between the Detention Subgroup and the conformable, stratigraphically higher Jacob Quartzite, which contains an additional spread of 1300-1000 Ma zircons suggestive of a Grenvillian source. Age profiles of the quartzarenites and quartzwacke turbidites (Oonah Formation and correlatives) were 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) Czech Republic 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/cm², 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 ²⁰⁶Pb, ²⁰⁷Pb, ²³²Th, and ²³⁸U were measured via peak switching, using an electron multiplier detector. The U isotope was determined based on the natural abundance (²³⁵U/²³⁸U) 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, ²⁰⁶Pb/²³⁸U ages were corrected for common lead (Williams, 1998) at some stage, there did not arise a question of timing. The answer is often to be found through direct observation; the principles of superposition and crosscutting relationships apply in determining the order of events on all scales from the microscopic to the macroscopic, from crystallization history to continental assembly. By augmenting those principles with the means to establish sequence and correlation provided by palaeontology, the geologist has the capability, through observation and logical reasoning alone, to determine the relative ages of a great range of geological processes. However, while these techniques make it possible to place geological events in time order, they do not provide an absolute measure of time itself. The measurement of absolute time in geology- geochronology- requires a quantifiable physical process that takes place continuously at a known rate from the time of the event to be dated to the present day. Some cyclic processes, such as the passage of the seasons, leave their imprint in parts of the geological record and can provide detailed, accurate measurements of elapsed time intervals, but they do not permit the measurement of absolute time (age using the decay constants used from Steiger and Jäger (1977): $\lambda(^{238}\text{U}) = 1.55125 \times 10^{-10} \text{ yr}^{-1}$, $\lambda(^{235}\text{U}) = 9.8485 \times 10^{-10} \text{ yr}^{-1}$, atomic ratio $^{238}\text{U}/^{235}\text{U} = 137.88$. 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/cm³. 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 ²⁰²Hg, ²⁰⁴Pb+Hg, ²⁰⁶Pb, ²⁰⁷Pb, ²⁰⁸Pb, ²³²Th, ²³⁵U, and ²³⁸U. 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) Czech Republic, FC-1 (Paces and Miller, 1993) spatial, and compositional similarities with the nearby Logan sills in Ontario. Four Duluth Complex anorthositic and troctolitic series samples from widely separated areas have unresolvable ages between 1099.3±0.3 and 1098.6±0.5 Ma, indicating a very short duration for peak intrusive activity (0.5-1 my and Fish Canyon Tuff sanidine (Schmitz and Bowring, 2001) a voluminous ash flow from the San Juan Mountains of Colorado and widely used ⁴⁰Ar/³⁹Ar geochronological standard, has been used to evaluate the influence of various sources of analytical and geological uncertainty on the calculated age of this tuff by the isotope dilution U-Pb zircon method. Twenty-three single zircon grains and seven small multi-grain fractions of the FCT yield an inverse-variance weighted mean ²⁰⁶Pb/²³⁸U date of 28.402 ± 0.023 Ma (2σ; MSWD 0.93 were used as secondary reference materials. Common Pb corrections were applied using the ²⁰⁷Pb method (Williams, 1998) at some stage, there did not arise a question of timing. The answer is often to be found through direct observation; the principles of superposition and crosscutting relationships apply in determining the order of events on all scales from the microscopic to the macroscopic, from crystallization history to continental assembly. By augmenting those principles with the means to establish sequence and correlation provided by palaeontology, the geologist has the capability, through observation and logical reasoning alone, to determine the relative ages of a great range of geological processes. However, while these techniques make it possible to place geological events in time order, they do not provide an absolute measure of time itself. The measurement of absolute time in geology- geochronology- requires a quantifiable physical process that takes place continuously at a known rate from the time of the event to be dated to the present day. Some cyclic processes, such as the passage of the seasons, leave their imprint in parts of the geological record and can provide detailed, accurate measurements of elapsed time intervals, but they do not permit the measurement of absolute time (age). U-Pb diagrams and ages were calculated using Isoplot (Ludwig, 2012a). Interpreted ages are reported as ²⁰⁶Pb/²³⁸U ages for grains younger than 1200 Ma and as ²⁰⁶Pb/²⁰⁷Pb ages for grains older than 1200 Ma. The U-Pb age data are provided in Supplementary Table 2.

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