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Supplemental Material

Supplementary Information: Geochronology Methods

Table S1. $^{40}Ar/^{39}Ar$ isotopic data for white mica, Kalymnos and Telendos islands, Dodecanese, Greece

Table S2. $^{40}Ar/^{39}Ar$ isotopic data for white mica, Kalymnos and Telendos islands, Dodecanese, Greece

Supplementary Information

Paleogeographic position of the central Dodecanese, southeastern Greece: the push-pull of Pelagonia

B. Grasemann[1], D.A. Schneider[2], K. Soukis[3], V. Roche[4], B. Hubmann[5]

1) Department of Geology, University of Vienna, Austria

2) Department of Earth and Environmental Sciences, University of Ottawa, Canada

3) Faculty of Geology and Geoenvironment, National and Kapodistrian University of Athens, Greece

4) UPMC Institut des Sciences de la Terre Paris, Sorbonne Université, France

5) Institute for Earth Sciences, University of Graz, Austria

Introduction

Herein are the analytical methods used, and data tables of, the geochronological analyses of the rocks from Kalymnos and Telendos islands, Dodecanese, Greece. See Figure 9 of the manuscript for sample locations.

Tables

Table S1. $^{40}Ar/^{39}Ar$ isotopic data from multiple single-grain total fusion for white mica, Kalymnos and Telendos islands, Dodecanese, Greece

Table S2. $^{40}Ar/^{39}Ar$ isotopic data from step heated experiments for white mica, Kalymnos and Telendos islands, Dodecanese, Greece

Text S1. Analytical Methods

Sample preparation

Conventional procedures were used to extract and select the most appropriate minerals from rock samples in preparation for (U-Th)/He and $^{40}Ar/^{39}Ar$ dating. Each sample was cleaned with a wire brush and water to remove any surface contamination. The sample was allowed to air dry and was then crushed to a size fraction of ≤1 cm with the use of a standard jaw crusher. The material was then passed through a series of sieves to obtain grain size fractions >250 µm, 63-250 µm and <63 µm. The 63-250 µm fraction was then rinsed through a decantation process to remove any remaining fine powder adhering to the grains and dried for 24 h at a temperature of 30°C using a heat lamp. Heavy mineral separation was then conducted using methylene iodide (SG: 3.0 g/cm^3) in order to obtain a more concentrated fraction of zircon. The heavy mineral separates were then individually passed through a Frantz magnetic mineral separator as needed to further isolate zircon. White mica was obtained from the >250 µm size fraction using a mortar and pestle to further crush the sample while preserving the integrity of the mica. Samples were sieved to obtain a 150 µm-250 µm size fraction. In the case of white mica and zircon grains were then picked using tweezers under a binocular microscope.

^{40}Ar/^{39}Ar geochronology: multiple single-grain total fusion analysis

Once samples were picked and characterized, ^{40}Ar/^{39}Ar analytical work was performed at the University of Manitoba (Winnipeg, Canada) using a multi-collector Thermo Fisher Scientific ARGUS VI mass spectrometer, linked to a stainless steel Thermo Fisher Scientific extraction/purification line and Photon Machines (55 W) Fusions 10.6 CO^2 laser. Argon isotopes (from mass 40 to 37) were measured using Faraday detectors with low noise 1 x 1013 Ω resistors and mass 36 was measured using a compact discrete dynode detector. The sensitivity for argon measurements is ~6.312 x 1017 moles/fA as determined from measured aliquots of Fish Canyon Sanidine (Dazé et al., 2003; Kuiper et al., 2008).

Standards and unknowns were placed in 2 mm deep wells in 18 mm diameter aluminium disks, with standards placed strategically so that the lateral neutron flux gradients across the disk could be evaluated. Planar regressions were fit to the standard data, and the ^{40}Ar/^{39}Ar neutron fluence parameter, J, interpolated for the unknowns. Uncertainties in J are estimated at 0.1-0.2% (1s), based on Monte Carlo error analysis of the planar regressions (Best et al., 1995). All specimens were irradiated in the cadmium-lined, in-core CLICIT facility of the Oregon State University TRIGA reactor. The duration of irradiation was 12 h and using the Fish Canyon sanidine (Kuiper et al., 2008) and GA1550 biotite (Spell and McDougall, 2003) standards.

Irradiated samples were placed in a Cu sample tray, with a KBr cover slip, in a stainless steel high vacuum extraction line and baked with an infrared lamp for 24 h. Single crystals were either fused or step-heated using the laser, and reactive gases were removed, after ~3 min, by three GP-50 SAES getters (two at room temperature and one at 450°C) prior to being admitted to an ARGUS VI mass spectrometer by expansion. Five argon isotopes were measured simultaneously over a period of 6 min. Measured isotope abundances were corrected for extraction-line blanks, which were determined before every sample analysis. Line blanks averaged ~5 fA for mass 40 and ~0.022 fA for mass 36.

Mass discrimination was monitored by online analysis of air pipettes, which gave during two separate sessions mean of D: 1.0063 ± 0.0001 and D: 1.0089 ± 0.0005 per amu, based on 67 aliquots interspersed with the unknowns. A value of 295.5 was used for the atmospheric $^{40}Ar/^{36}Ar$ ratio (Steiger and Jäger, 1977) for the purposes of routine measurement of mass spectrometer discrimination using air aliquots, and correction for atmospheric argon in the $^{40}Ar/^{39}Ar$ age calculation. Corrections are made for neutron-induced ^{40}Ar from potassium, ^{39}Ar and ^{36}Ar from calcium, and ^{36}Ar from chlorine (Roddick, 1983; Renne et al., 1998; Renne and Norman, 2001). Results are reported in **Table S1**.

$^{40}Ar/^{39}Ar$ geochronology: incrementally heating analysis

Individual mineral separates were loaded into 2-3 mm-deep aluminum foil packets, which were subsequently stacked vertically into 35-mm long foil tubes and placed into the tubular holes of an aluminum cylinder. Several flux monitor grains of Fish Canyon tuff sanidine (Renne et al., 1998; Steiger and Jäger, 1977) were loaded into each sample packet. The vessel was irradiated for 160 MWH in medium flux position 8A at the research nuclear reactor of McMaster University (Hamilton, Canada). Neutron fluence was ~1.08×10^{13} neutrons/cm^2 operating at a 2.5 MW power level. Correction factors for typical interference species produced by thermal neutrons during irradiation are 0.058 ($^{40}Ar/^{39}Ar_K$), 0.000743 ($^{39}Ar/^{37}Ar_{Ca}$) and 0.000258 ($^{36}Ar/^{37}Ar_{Ca}$).

Analytical conditions follow the protocol of Kellett and Joyce (2014). Single grain aliquots and monitors were loaded into separate 1.5 mm diameter pits in a copper planchet and placed under vacuum. Individual grains were progressively heated and analyzed using a Photon Machines Ltd. Fusion 10.6 55W CO_2 laser coupled to the all-metal extraction line and a Nu Instruments Noblesse multicollector mass spectrometer operated at the Geological Survey of Canada (Ottawa, Canada). Laser heating was homogenized over a beam radius of 2 mm for a total of 40 s, after which the released gas was exposed to SAES NP-10 (~400˚C) and HY-STOR 201 (25°C) getters in the extraction line for three minutes. Following gettering, sample gas was expanded into the mass spectrometer. The Nu Noblesse is a single-focussing, Nier-source, magnetic sector multicollector noble gas spectrometer equipped with two quadrupole lens arrays. Argon ions were measured with a fixed array of three ETP discrete dynode ion-counting multipliers (IC0, IC1, IC2). Data collection occurred in two multicollection cycles: cycle 1 = $^{40}Ar_{IC0}$, $^{38}Ar_{IC1}$ and cycle 2 = $^{39}Ar_{IC0}$, $^{37}Ar_{IC1}$, $^{36}Ar_{IC2}$. Blanks were run every five analyses, in an identical manner to unknowns. Air shots were analyzed every 10 analyses to monitor efficiency and mass fractionation. Relative collector efficiency and mass bias corrections were made for IC1 and IC2 collectors relative to IC0 using $^{40}Ar_{IC0}/^{36}Ar_{IC1}$ and $^{40}Ar_{IC0}/^{36}Ar_{IC2}$ measurements of air. Mass bias in IC0 was not corrected as it would be equally applied to the $^{40}Ar/^{39}Ar$ ratio in unknowns and J-factors determined from monitors in the age calculation, thereby cancelling out (e.g. Brumm et al., 2010). Error in J-factor values are conservatively estimated at ±0.6% (2s). Sensitivity of the Nu Noblesse at the time of analyses was 7.1-7.5 Amps/mol. Data collection, reduction, error propagation, age calculation and plotting were performed using the software MassSpec (version 7.93; Deino, 2001).

Analytical results are presented in **Table S2**; **Figure 10** presents the data as spectra where the width of each bar (thermal increment) represents the proportion of evolved gas, and the height represents the uncertainty associated with the apparent age. The integrated (or total gas: Tg) age is an average age for the sample calculated by summing the isotopic measurements of all steps with an uncertainty calculated by quadratically combining errors of isotopic measurements of all steps. Plateau ages are conventionally defined as the portion of an age spectrum composed of contiguous increments representing >70% of gas released which result in concordant ages (Mahon, 1996). A preferred age (Tp), on the other hand, is calculated as the weighted mean of a selection of mostly contiguous increments which represent >50% of ^{39}Ar gas released and result in concordant ages. The calculated age uncertainties are relatively small because analytical precision in the age of each heating step is high.

(U-Th)/He geochronology

The analytical portion of the (U-Th)/He experiments was conducted at the TRaIL (Thermochronology Research and Instrumentation Laboratory) facility at the University of Colorado (Boulder, USA). Individual mineral grains are handpicked using a Leica M165 binocular microscope equipped with a calibrated digital camera and capable of both reflected and transmitted, polarized light. The grains are screened for quality, including crystal shape and the presence of inclusions. The dimensions of the crystals are measured and converted to equivalent spherical radius (ESR) as this value is more readily incorporated into the equations that govern the diffusion of He throughout the grain; from this point forward in the paper references to grain size are measurements of ESR. After characterization, grains are placed into small Nb tubes that are then crimped on both ends. This Nb packet is then loaded into an ASI Alphachron He extraction and measurement line. The packet is placed in the UHV extraction line (~$3x10^{-8}$ torr) and heated with a diode laser to ~800-1100°C for 5 to 10 m to extract the radiogenic ^{4}He. The degassed ^{4}He is then spiked with approximately 13 ncc of pure ^{3}He, cleaned via interaction with two SAES getters, and analyzed on a Balzers PrismaPlus QME 220 quadrupole mass spectrometer. Degassed grains are then removed from the line, and taken to a Class 10 clean lab for dissolution. Zircon are dissolved using Parr large-capacity dissolution vessels in a multi-step acid-vapor dissolution process. Grains (including the Nb tube) are placed in Ludwigstyle Savillex vials, spiked with a ^{235}U-^{230}Th tracer, and mixed with 200 µl of Optima grade HF. The vials are then capped, stacked in a 125 mL Teflon liner, placed in a Parr dissolution vessel, and baked at 220°C for 72 h. After cooling, the vials are uncapped and dried down on a 90°C hot plate until dry. The vials then undergo a second round of acid-vapor dissolution, this time with 200 µl of Optima grade HCl in each vial that is baked at 200°C for 24 h. Vials are then dried down a second time on a hot plate. Once dry, 200 µl of a 7:1 HNO_3:HF mixture is added to each vial, the vial is capped, and cooked on the hot plate at 90°C for 4 h. Once the minerals are dissolved, regardless of the dissolution process, they are diluted with 1 to 3 mL of doubly-deionized water, and taken to the ICP-MS lab for analysis. Mineral standards of Durango apatite (31.5 Ma) and Fish Canyon Tuff zircon (28.2 Ma) are routinely analyzed (degassed and dissolved) in conjunction with the samples with each run to ensure data integrity. Sample solutions, along with standards and blanks, are analyzed for U, Th, and Sm content using a Thermo Element 2 magnetic sector mass spectrometer. Once the U, Th, and Sm contents have been measured, He dates and all associated data are calculated on a custom spreadsheet made by TRaIL staff. Results are reported in **Table 1** of the manuscript.

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