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Supporting Information for

Timing of magnetite growth associated with peridotite-hosted carbonate veins in the SE Samail ophiolite, Wadi Fins, Oman

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Introduction

Here we report X-Ray CT working conditions (Table S1) and a detailed description of (U-Th)/He error propagation.

Table S2 is attached as an excel sheet. It reports the data and errors for each measurement affecting (U-Th)/He and documents error propagation.

Figure S1 shows the relationship between propagated error and measured (blank corrected) He concentration.

Figure S2 shows the relationship between propagated error and measured (blank corrected) U, Th and Sm ratio.

Figure S3 shows the relationship between propagated error and aliquot mass.

Table S1. X-Ray computed tomography scanning conditions

Sample	Objective	Power	Voltage	Filter	Voxel
15OM21	4x	150kV	10W	1.6mm CaF2	4.27 microns
15OM25B	4x	150kV	10W	1.6mm CaF2	3.87 microns
15OM24bg	4x	150kV	10W	1.6mm CaF2	4.22 microns
15OM24g2	4x	150kV	10W	1.6mm CaF2	3.28 microns

Details on the measurements and error propagation for Wadi Fins magnetite (U-Th)/He data

^{4}He measurements:

Measurements:

Helium 4 was measured in two ways. First, samples 15OM21ab and 15OM25ab were degassed on a Thermo Helix split-flight-tube single collector (SFT). Grains were packed into platinum tubes and heated to a pyrometer controlled temperature of 950-1000C using a diode laser. The platinum capsules were heated for 10 minute increments. Ten minute cold blanks (no laser heating) were performed before and after every unknown in order to monitor background and stability of ^{4}He in the instrument. The number of cold blanks measured per analytical run varied from 20 to 78 over 5 or 6 day. Helium 4 standards were also run throughout the analysis to monitor the instruments sensitivity and stability. The number of standards measured per analytical run varied from 12 to 42 over 5 or 6 days.

Samples 15OM24bg and 15OM24g2 were measured on a Blazers Prisma quadrupole mass spectrometer (QMS). Grains were prepared and heated in the same way as above. The main difference in these analyses is that gas released from the samples were spiked with ^{3}He prior to entering the QMS and the ^{4}He/^{3}He ratio was measured and calibrated against a known ^{4}He/^{3}He standard shot of gas.

Due to low ^{4}He gas abundances in these magnetite, each unknown analysis was blank corrected against the cold blank run before the unknown. If an aliquot had multiple re-extracts, then each analysis was blank corrected and all were summed for a final value. Final blank corrected ^{4}He abundances in ncc were used for age calculation.

Error propagation:

In order to account for the full analytical uncertainty on each measurement, the following must be considered:

1) The analytical uncertainty on the ^{4}He sample measurement
2) The standard deviation of the cold blanks over the analytical run (background stability).
3) The standard deviation of the He standards over the analytical run (machine precision)

These uncertainties were all propagated into a combined analytical uncertainty and applied to the blank corrected final 4He ncc abundances of the unknowns. Final propagated ^{4}He measurement errors ranged from 4-10% of the blank corrected values, which more-or-less correlates with the amount of gas in the aliquot (Figure S1).

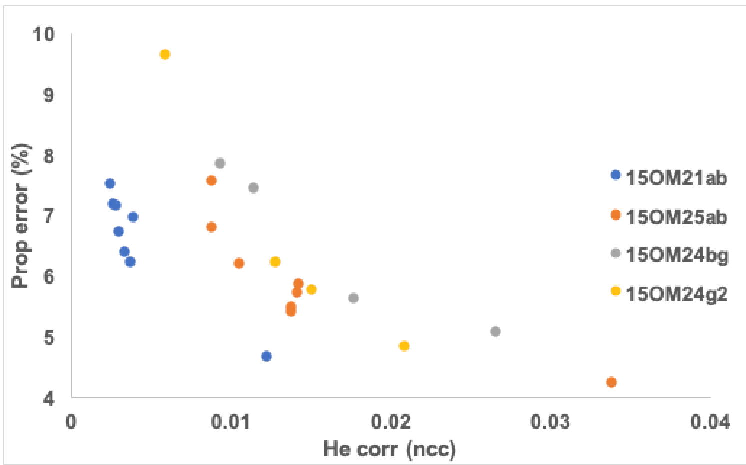

Figure S1: The percentage of the propagated uncertainty on the measured 4He value versus the abundance of gas in each aliquot. In general, lower gas aliquots yielded higher uncertainties, as would be expected. Some of the scatter may be explained by different analytical runs, which had slightly different instrument behaviors.

U, Th, Sm measurements:

Measurements:

U, Th and Sm were measured by isotope dilution on a Thermo Element2 HR ICP-MS. After degassing, magnetite grains were removed from the platinum tubing and dissolved in a hot-plate dissolution procedure outlined in the Methods section. Prior to acid digestion, a ^{235}U-^{230}Th-^{149}Sm spike was added to each aliquot. At the same time, standard solutions and spike blanks were made. Each digestion also included two procedural blanks.

Isotopic ratios for $^{238}U/^{235}U$,$^{232}Th/^{230}Th$, and $^{147}Sm/^{149}Sm$ were measured for each sample, blank and standard. Unknowns were blank corrected by the average blank value, and these blank corrected ratios were calibrated against the standard solution and used for age calculation.

Error propagation:

Similar to the He measurements, the U, Th and Sm ratio uncertainty must take into account:

1) Analytical uncertainty on the unknown measurement
2) The standard deviation of the blanks
3) The uncertainty on the standard solution measurement

These uncertainties were all propagated into a combined uncertainty to account for analytical precision, instrument drift, and standard/blank precision. Propagated uncertainties were applied to blank-corrected ratios. Uranium propagated errors ranged from 1-23% of the blank corrected sample values. Most Th and Sm unknown measurements were within error of background, and as a result have uncertainties >100%. These have been labeled as “b.d.l.” in Table 1. As with the He measurements, all U, Th and Sm uncertainties are correlated with the amount of U, Th and Sm in the aliquots, consistent with expectations (Figure S2).

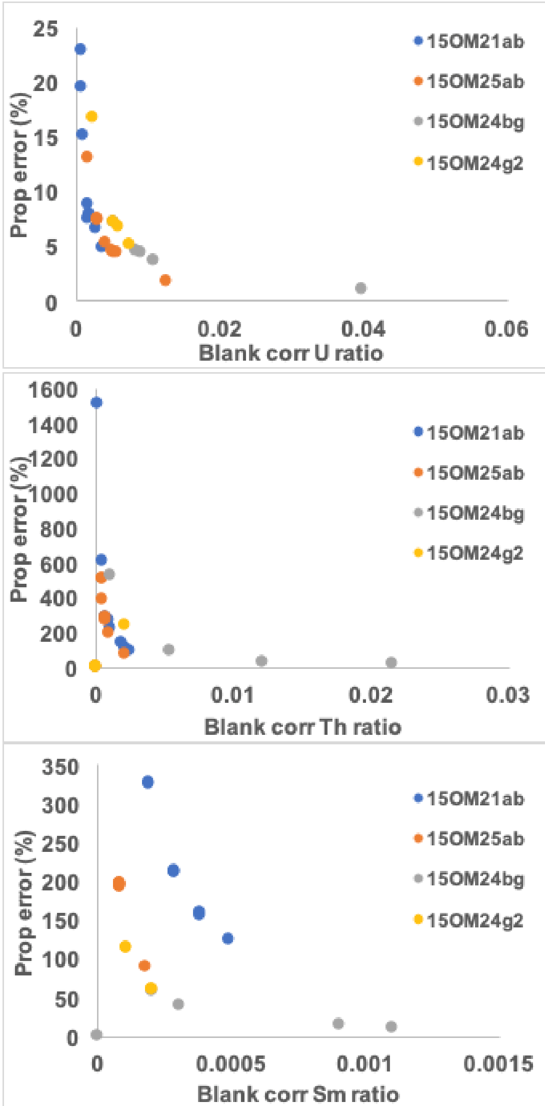

Figure S2: Top to bottom – Propagated analytical uncertainty (in percent) versus the blank corrected measurements for U (top), Th (middle), and Sm (bottom). Overall, lower measured values have higher uncertainties, consistent with expectations. Only values with propagated errors <100% are reported and used for age calculation.

<u>Age and concentration errors:</u>

The final (U-Th)/He age is calculated by converting the He, U, Th and Sm measurements into atoms and then iteratively solving the age equation. Error propagation through the age equation is not a straightforward endeavor, and many (U-Th)/He systems apply a standard error of 6-8% to each age. As there is not yet a magnetite standard, the standard error cannot be used. In order to capture the full age uncertainty, the (U-Th)/He ages were calculated with the minimum and maximum values for He, U, Th, and Sm based on the propagated uncertainties from the previous section. This produces (U-Th)/He ages with percent errors from 3-69%, which we believe is the most conservative estimate we can make for these uncertainties. The final age uncertainties correlate with the original aliquot size (Figure S3).

Concentrations and uncertainties reported in Table 1 in the manuscript are calculated based on the measurements and propagated errors outlined above normalized to the mass of the aliquot. Each aliquot was weighed on a microbalance that has a ±1 µg uncertainty. This resulted in a <1% addition to the uncertainty for the majority of aliquots.

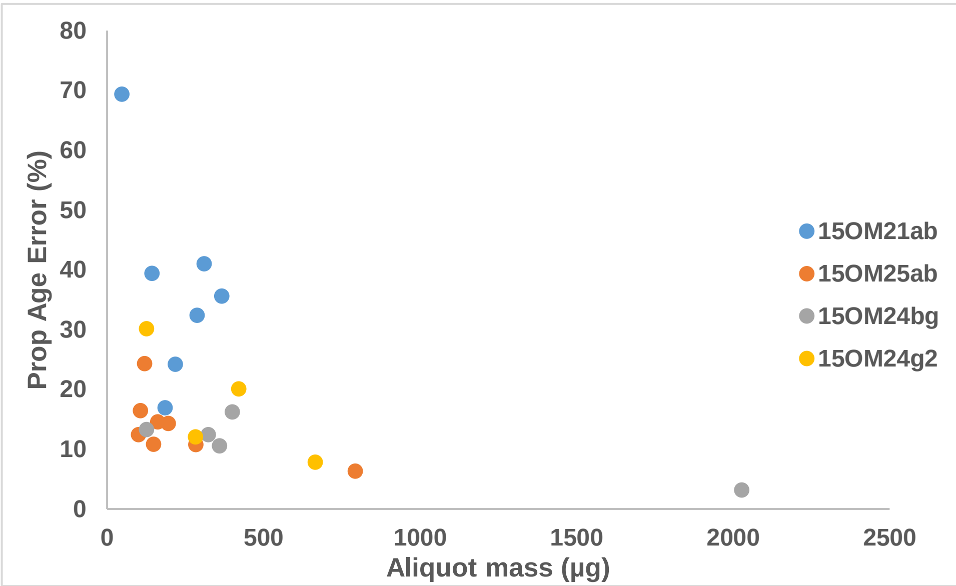

Figure S3: Propagated (U-Th)/He age aliquot errors (in percent) versus the size of the aliquot measured. In general, the larger aliquots have lower age uncertainty, which reflects lower overall analytical uncertainties due to higher counting statistics.