DATA REPOSITORY:

Analytical methods

(U-Th)/He age determinations were conducted on single apatite grains, typically with 2-3 single grain analyses per sample. Apatite grains were selected for analysis under isopropyl alcohol using a stereographic microscope. Selected grains were clear, euhedral, and free of inclusions and fractures (e.g. Farley, 2002; Ehlers and Farley, 2003; Fitzgerald et al., 2006). Selected grains were photographed and measured along three principle axes to determine the F_T correction for each grain (Farely et al., 1996). Individual apatite grains were packed in 1 mm Nb stents and heated at 1150˚C for 15 minutes in a resistance furnace. The released radiogenic ^4He was spiked with a known volume of ^3He, purified with getters, and analyzed with a Balzers quadrupole mass spectrometer at Lehigh University. Calibration shots of known volume and $^4He/^3He$ concentration were run prior to and following a series of analyses to assess the sensitivity of the mass spectrometer, which is checked by the ^3He spike added to each unknown. Internal shards of Durango fluorapatite standard were run in conjunction with unknowns and prepared and analyzed using the same techniques. Following degassing, the grain stents were extracted from the furnace and analyzed for U, Th, and Sm concentrations at the University of Arizona. Apatite grains were dissolved directly from the stent using dilute (~20%) warm nitric acid, and spiked with ^{233}U, ^{229}Th, and ^{147}Sm and analyzed by an Element2 HR-ICP-MS. Effective uranium (eU) concentrations (Shuster et al., 2006) are calculated using the volume from the geometric approximation of the grain from the F_T correction to calculate a mass of the grain and the measured mass of the ^{238}U and ^{232}Th from the same grain.

The F_T correction is calculated using the measured axes and either a cylindrical (including flattened cylinder), ellipsoidal (including sphere), or tetragonal prism geometry dependent upon which best approximates the shape of the grain. The tetragonal prism geometry can accommodate the sharp tips of some grain morphologies (e.g. zircon grains) that have been shown to improve the accuracy of the FT corrections (Hourigan et al., 2005). Instead of using the surface-to-volume ratio of an equivalent sphere to calculate the F_T correction for a non-spherical grain (Meesters and Dunai, 2002), we used a Monte-Carlo method that causes decays of all alpha producing isotopes at random x, y, and z coordinates within the input geometric approximation of the grain. The new point created by the decay (the alpha particle's stopping point) is then determined to be in or out of the grain. This is then repeated for 10^7 decays and the ratio of alphas that are "in" to the total number of alphas created is the F_T correction for that grain geometry.

TABLE DR1. AHe ANALYTICAL FT CORRECTION AND MEASUREMENTS

Sample name	Ft correction	^{4}He (mol)	U (ng)	Th (ng)	Sm (ng)	Grain length (µm)	Grain width 1 (µm)	Grain width 2 (µm)
GR-20	0.838	9.84693E-15	0.128	0.024	2.605	256.4	149.6	141.7
	0.882	3.35345E-14	0.337	0.054	7.487	364.7	198.9	197.1
GR-19	0.691	5.55415E-15	0.077	0.006	1.101	187	72.2	65.5
	0.821	2.92405E-15	0.027	0.067	0.317	299.9	149.3	121.2
	0.790	1.97881E-14	0.137	0.422	1.879	246.6	115.1	115.1
GR-1	0.787	1.35093E-14	0.105	0.287	1.253	265.3	121.2	101.9
	0.767	5.73883E-15	0.036	0.092	1.432	180.2	109.2	101.3
GR-28	0.731	2.39219E-15	0.028	0.043	0.646	164.3	88.7	86.9
	0.667	4.43164E-14	0.062	0.511	1.109	175.3	73.7	70.7
	0.665	1.59861E-14	0.068	0.039	1.287	140.5	80.8	57.2
GR-2	0.776	8.44411E-15	0.054	0.023	0.842	197.7	108.3	99.4
	0.660	2.45895E-14	0.100	0.034	1.298	205.3	61.5	61.2
	0.622	9.80365E-15	0.044	0.018	0.500	138.3	57.5	56.9
GR-26	0.760	1.23E-14	0.130	0.088	2.118	240.2	104	82.3
	0.796	7.47349E-15	0.074	0.047	2.112	234.7	108.9	114.4
	0.811	7.41665E-15	0.073	0.027	2.183	188.2	131.9	126.1
GR-22	0.807	7.7466E-15	0.081	0.055	2.383	211.4	123.6	122.7
GR-8	0.798	7.01088E-15	0.074	0.018	1.259	250.6	102.2	120.3
	0.826	2.06344E-14	0.097	0.078	1.786	226.1	142	138.6
	0.787	7.40768E-15	0.066	0.027	1.922	314.3	95.5	103.1
	0.839	9.84693E-15	0.128	0.024	2.605	256.4	149.6	141.7