DATA REPOSITORY ITEM DR-1, U-PB SHRIMP-RG ANALYTICAL DATA:

U-Pb SHRIMP-RG Analytical Procedures

U-Pb analyses were performed at the Stanford - U.S.G.S. Micro Analytical Center (SUMAC). Zircon grains were prepared at Stanford University using standard mineral separation techniques, including, Frantz magnetic and heavy liquid separations. Separated zircons were handpicked under a binocular microscope to ensure purity and freedom from cracks, inclusions, or obvious alteration. The selected grains were mounted in epoxy with the laboratory standard R33 (419 Ma) and polished with diamond compound to expose the mid-points of the crystals. Polished grain mounts were imaged in reflected light with an optical microscope, gold-coated, and imaged in cathodoluminescence (CL) mode with a JEOL 5600 scanning electron microscope (SEM).

The SHRIMP-RG ion microprobe at SUMAC was operated with an O_2^- primary ion beam varying from 4 to 6 nA, which produced a spot with a diameter of ~20–30 μm and a depth of 1–2 μm on the target zircons. Eleven peaks were measured sequentially for 10 min with an ETP electron multiplier (Zr_2O, ^{204}Pb, ^{206}Pb, ^{207}Pb, ^{208}Pb, ^{238}U, ThO, UO, ErO, YbO, and HfO). Data was reduced following the methods described by Ireland and Williams (2003), using the SQUID and IsoPlot programs of Ludwig (2001, 2003).

References

Ireland, T.R. and Williams, I.S., 2003, Considerations in zircon geochronology by SIMS: Reviews in Mineralogy and Geochemistry, v. 53, p. 215-241.

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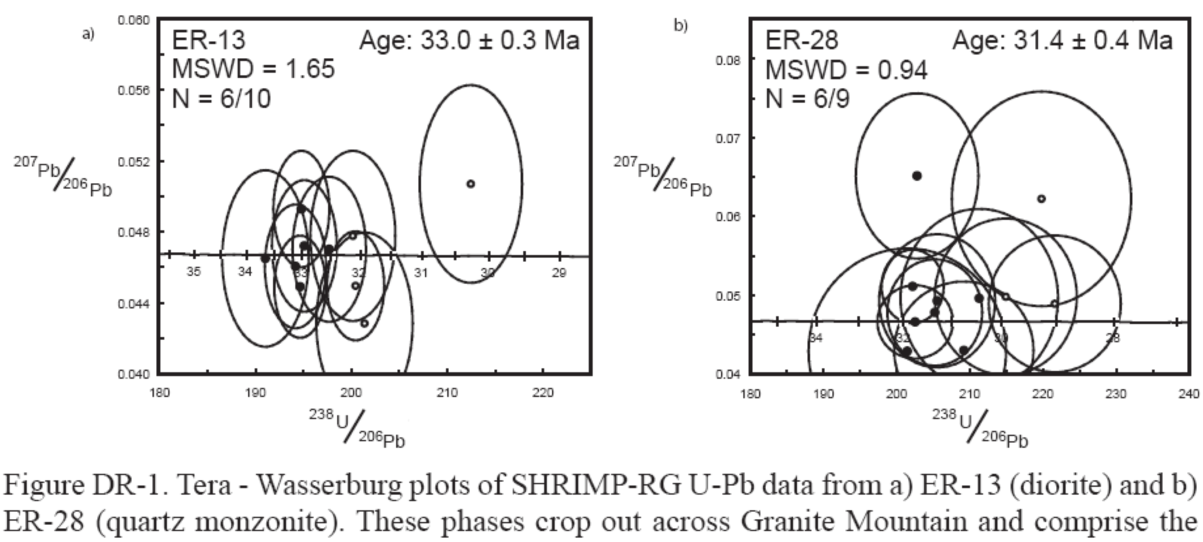

Figure DR-1. Tera - Wasserburg plots of SHRIMP-RG U-Pb data from a) ER-13 (diorite) and b) ER-28 (quartz monzonite). These phases crop out across Granite Mountain and comprise the rocks sampled for thermochronology. Filled circles represent data used to determine age (2σ). Open circles are data not included in the age calculation because they do not fall within 2σ of the calculated mean age.

Table DR-1: U-Pb isotopic data for ER-28 (quartz monzonite) and ER-13 (diorite) at Granite Mountain, East Range.

Spot Name	core/ rim	comm 206 * (%)	U (ppm)	Th (ppm)	232Th/ 238U	207corr 206Pb/238U Age (Ma)	1σ err (Ma)	Total 238/206	err (%)	Total 207/206	err (%)	207r/235	err (%)	206r/238	err (%)	err corr
ER28-1.1	rim	-0.46	299	152	0.52	**30.9**	**0.6**	209.19	1.9	0.0430	8.3	0.02	21.9	0.0047	2.0	0.092
ER28-2.1	rim	0.33	381	235	0.64	**31.2**	**0.5**	205.55	1.6	0.0493	7.0	0.02	24.8	0.0048	1.8	0.074
ER28-3.1	rim	0.40	328	180	0.57	**29.8**	**0.6**	214.93	1.8	0.0498	8.2	0.02	50.3	0.0045	2.5	0.049
ER28-4.1	rim	1.98	220	114	0.53	**28.7**	**0.7**	219.80	2.3	0.0622	8.9	0.02	63.9	0.0044	3.1	0.048
ER28-5.1	rim	0.29	419	262	0.65	**28.9**	**0.5**	221.62	1.7	0.0489	7.3	0.02	49.8	0.0044	2.2	0.044
ER28-5.2	core	-0.01	1007	747	0.77	**31.8**	**0.3**	202.53	1.0	0.0466	4.1	0.03	6.9	0.0049	1.1	0.156
ER28-6.1	rim	0.38	246	126	0.53	**30.3**	**0.7**	211.29	2.1	0.0496	9.3	0.03	9.6	0.0047	2.1	0.217
ER28-7.1	rim	0.56	1213	952	0.81	**31.6**	**0.3**	202.19	0.9	0.0511	3.7	0.03	3.8	0.0049	0.9	0.225
ER28-7.2	core	-0.48	125	103	0.85	**32.1**	**0.9**	201.46	2.7	0.0429	12.4	0.03	6.9	0.0047	4.6	0.156
ER28-7.3	rim	2.34	309	170	0.57	**31.0**	**0.5**	202.80	1.7	0.0651	6.6	0.03	29.3	0.0048	2.2	0.074
ER28-8.1	rim	0.15	542	282	0.54	**31.3**	**0.4**	205.21	1.3	0.0478	5.8	0.03	5.9	0.0049	1.3	0.218
ER13-1.1	rim	0.14	1103	965	0.90	**32.1**	**0.3**	200.16	0.9	0.0478	4.1	0.03	7.6	0.0050	1.0	0.125
ER13-2.1	rim	0.07	1693	1488	0.91	**32.9**	**0.2**	195.11	0.7	0.0472	3.2	0.03	6.7	0.0051	0.8	0.114
ER13-3.1	rim	-0.49	817	709	0.90	**32.1**	**0.3**	201.38	1.0	0.0428	4.9	0.03	5.0	0.0050	1.0	0.204
ER13-4.1	rim	0.04	1263	1204	0.99	**32.5**	**0.3**	197.70	0.8	0.0470	3.6	0.03	5.4	0.0050	0.8	0.151
ER13-5.1	rim	-0.22	2471	1663	0.70	**32.1**	**0.2**	200.45	0.6	0.0449	2.8	0.03	3.4	0.0050	0.6	0.180
ER13-6.1	core	-0.08	1826	976	0.55	**33.1**	**0.2**	194.19	0.7	0.0460	3.1	0.03	3.2	0.0051	0.7	0.213
ER13-7.1	rim	-0.23	2683	2800	1.08	**33.1**	**0.2**	194.66	0.6	0.0449	2.6	0.03	2.7	0.0051	0.6	0.211
ER13-8.1	rim	0.33	2297	816	0.37	**32.9**	**0.2**	194.79	0.6	0.0493	2.7	0.03	3.5	0.0051	0.6	0.176
ER13-9.1	rim	-0.03	912	766	0.87	**33.7**	**0.3**	191.05	1.0	0.0465	4.4	0.03	6.5	0.0052	1.0	0.152
ER13-10.1	rim	0.51	800	677	0.87	**30.1**	**0.3**	212.46	1.0	0.0507	4.5	0.03	9.4	0.0047	1.1	0.118

DATA REPOSITORY ITEM DR-2, Fission Track Analytical Data

Fission Track Analytical Procedures

All samples were prepared and analyzed at Stanford University. Apatite concentrates were prepared using standard mineral separation techniques, including crushing, grinding, Frantz magnetic separation, and heavy liquids. All samples were rinsed ultrasonically with acetone and deionized water to remove surface contaminants. Apatite grains were mounted in epoxy on glass slides and ground and polished by hand. Polished grain-mounts were etched for 20 s in 5N nitric acid at room temperature and affixed to muscovite external detectors. Samples and external detectors were stacked single-file in plastic reactor cans and irradiated in well thermalized positions of the Oregon State University TRIGA reactor. CN5 dosimetry glasses with muscovite external detectors were used as neutron flux monitors (3 per can). After irradiation, external detectors were etched in 48% HF.

Tracks were counted by J. Colgan with a Zeiss Axioskop microscope with a 100x air objective, 1.25x tube factor, 10x eyepieces, and transmitted light with supplementary reflected light as needed. External detector prints were located with Kinetek automated scanning stage (Dumitru, 1993). Only grains with c axes subparallel to the slide plane were dated. Ages calculated using zeta calibration factor of 367.6 (e,g, Hurford and Green, 1983). Ages reported are the fission-track central age of Galbraith and Laslett (1993). Confined track lengths were measured only in apatite grains with c axes subparallel to slide plane; only horizontal tracks were measured (within ± 5–10°), following protocols of Laslett et al. (1982). Lengths were measured with computer digitizing tablet and drawing tube, calibrated against a stage micrometer (Dumitru, 1993). Confined track lengths were measured along with angles of tracks to the grains' c-axes and the Dpar track entrance diameter, following the protocols of Ketcham et al., 1999. Confined tracks hosted by surface tracks and by cleavage surfaces were both measured. Age calculations were done with an Excel® program by J. Colgan. Length models were generated using the HeFTy® program by Ketcham (2005). Model runs assume that AFT ages are drawn from a single kinetic population and that chemical zoning is absent.

References

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Galbraith, R.F., and Laslett, G.M., 1993, Statistical models for mixed fission-track ages: Nuclear Tracks and Radiation Measurements, v. 21, p.459-470.

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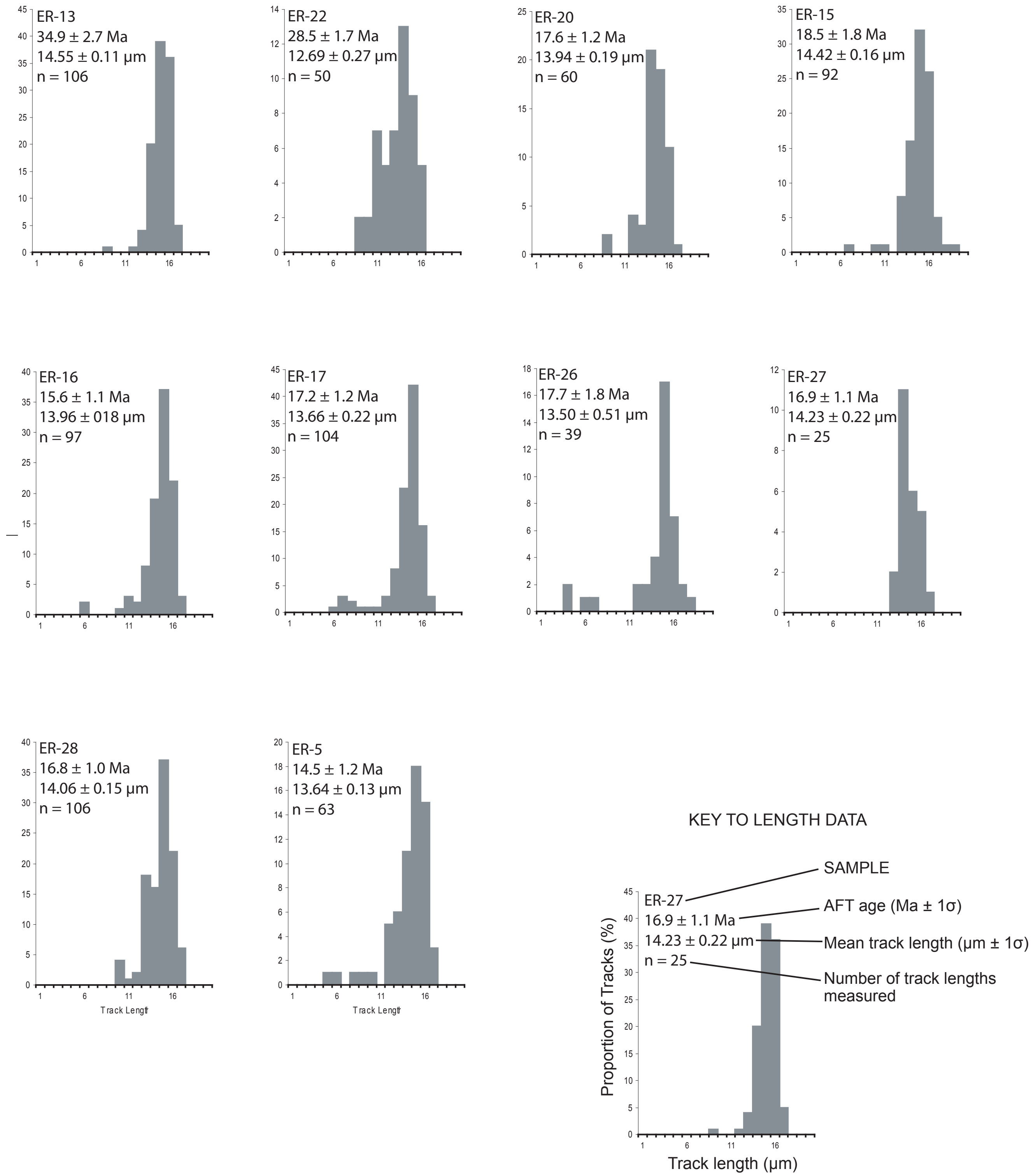
Figure DR-2. Fission track length data



DATA REPOSITORY ITEM DR-3, Apatite (U-Th)/He Analytical Data

Apatite (U-Th)/He Analytical Procedures

Apatite crystals were separated at Stanford University from crushed samples using standard heavy liquid separation techniques. Apatite (U-Th)/He analyses were performed at Stanford University by Ar laser heating for He extraction and at UC Santa Cruz by sector ICP-MS for U and Th determinations following methods of Metcalf (2006).

Euhedral and inclusion-free grains were selected by hand and carefully inspected under high power (112.5X) stereo-zoom with cross-polarization for screening inclusions. Single grains (2 per sample) were photographed and measured in two different orientations before they were individually inserted into 1 mm Pt foil tubes, which were then loaded into individual wells within a copper pan and placed in a laser cell connected to the He extraction line by high-vacuum flexhose. The laser cell was pumped down to 10^{-8} torr and individual samples were heated with an Argon laser for 3 minutes at 1–5 W. Temperatures of heated foil packets were not measured but are estimated at about 1000 ºC based on experiments relating luminosity and stepwise degassing of apatite. ^{4}He blanks (~ 0.05 fmol ^{4}He) were determined without sample heating using the same procedures.

Helium gas liberated from samples was processed by: 1) spiking with ~4pmol of ^{3}He, 2) cryogenic concentration at 10K on a charcoal trap and purification by release at 38K, and 3) measurement of ^{4}He/^{3}He ratios on a Pfieffer Vacuum™ Prisma quadrapole mass spectrometer. All ratios were referenced to multiple same-day measured ratios and known volumes of ^{4}He standards processed in the same way. After degassing, samples were retrieved from the laser cell, spiked with 40 ppb calibrated ^{229}Th and ^{233}U solution, and dissolved *in-situ* from Pt tubes in ~70 % HNO_3 in teflon vials and heated to 85°C for 2 hours. Each batch of samples was prepared with a series of acid blanks and spiked blanks to check the purity and calibration of the reagents and spikes. Spiked solutions were analyzed as ~ 0.5 mL of ~5-20 ppm U-Th solutions by isotope dilution on a Finnigan MAT Element ICP-MS at UC Santa Cruz.

Age calculations were done with an Excel® program by J. Metcalf that applies an alpha-ejection correction to derive final (U-Th)/He ages that account for diffusion-domain-dependent loss of the daughter nuclide (after Farley et al., 1996 and Farley, 2002). Replicate analyses of Durango apatite during the period of these analyses yielded an age of 31.37 ± 2.35 (1σ, n = 4). On the basis of these and other laboratory standards, we estimate 7% uncertainty on expected ages. (U-Th)/He age models were generated using the HeFTy® program after Ketcham (2005). The Ketcham and others (1999) AFT annealing calibration and Farley (2000) (U-Th)/He diffusion calibration are used.

References

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Ketcham, R.A., 2005, Forward and inverse modeling of low-temperature thermochronometry data: Reviews in Mineralogy and Geochemistry, v. 58, n. 1, p. 275-314.

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Table DR-2. Apatite (U-Th)/He analytical data

Sample	Age ± 1σ (Ma)	Weighted Age ± 1σ (Ma)	[U] (ppm)	[Th] (ppm)	U/Th	[^{4}He] (nmol/g)	F_t**
ER5	10.6 ± 1.3	**10.2 ± 0.4**	44.06	63.82	0.69	2.35	0.63
	9.2 ± 0.5		27.14	79.94	0.34	1.76	0.69
	13.1 ± 1.4		22.14	65.40	0.34	1.87	0.64
	11.2 ± 0.8		26.81	72.76	0.37	1.91	0.65
ER4	11.5 ± 0.7	**10.9 ± 0.4**	18.29	56.46	0.32	1.72	0.80
	10.6 ± 0.6		16.81	51.28	0.33	1.41	0.77
ER3	12.7 ± 0.6	**11.9 ± 0.3**	27.70	78.21	0.35	2.28	0.65
	11.9 ± 0.6		20.68	62.32	0.33	1.77	0.70
	11.7 ± 0.8		20.56	56.04	0.37	1.57	0.67
	11.3 ± 0.6		20.70	69.45	0.30	1.78	0.71
ER28	12.3 ± 0.7	**11.8 ± 0.5**	37.51	96.78	0.39	2.73	0.62
	10.5 ± 1.2		16.35	38.61	0.42	1.04	0.65
	11.7 ± 1.1		26.14	72.37	0.36	1.84	0.61
ER27	13.5 ± 0.7	**13.1 ± 0.4**	18.03	58.04	0.31	1.86	0.73
	13.1 ± 0.6		21.84	64.65	0.34	2.15	0.75
	12.8 ± 0.7		22.19	70.07	0.32	2.06	0.70
ER26	12.7 ± 0.7	**12.4 ± 0.5**	19.40	59.15	0.33	1.77	0.70
	12.1 ± 1.0		19.39	55.13	0.35	1.60	0.68
	11.8 ± 0.8		23.61	68.76	0.34	1.87	0.67
	13.6 ± 1.4		18.77	58.86	0.32	1.77	0.66
ER18	14.5 ± 1.3	**14.6 ± 0.7**	29.23	90.45	0.32	2.66	0.61
	14.6 ± 1.2		24.68	80.88	0.31	2.72	0.71
	14.6 ± 1.1		25.50	83.55	0.31	2.52	0.64
ER17	15.7 ± 0.7	**15.6 ± 0.5**	34.45	111.13	0.31	3.69	0.65
	15.3 ± 0.7		26.46	86.33	0.31	2.78	0.65
	17.8 ± 1.9		24.82	75.23	0.33	2.75	0.61
ER16	15.5 ± 0.9	**14.6 ± 0.4**	22.79	71.19	0.32	2.49	0.68
	15.1 ± 0.6		21.93	76.27	0.29	2.59	0.72
	14.6 ± 0.8		25.65	90.26	0.28	2.90	0.71
	13.0 ± 0.8		15.56	45.74	0.34	1.44	0.71
ER15	16.9 ± 1.9	**15.9 ± 1.1**	34.32	52.59	0.65	2.92	0.62
	15.4 ± 1.3		36.04	37.56	0.96	2.77	0.67
ER20	13.8 ± 1.3	**14.7 ± 0.7**	25.78	120.56	0.21	3.24	0.72
	16.4 ± 1.3		36.18	194.79	0.19	5.58	0.69
	14.1 ± 1.2		26.30	117.82	0.22	3.30	0.73
ER21	15.4 ± 0.7	**14.5 ± 0.5**	30.96	83.18	0.37	3.22	0.69
	13.3 ± 1.3		20.44	55.95	0.37	1.77	0.66
	15.7 ± 1.3		23.77	87.94	0.27	2.65	0.63
	13.2 ± 0.9		14.46	44.02	0.33	1.39	0.71

Table DR-2 (continued). Apatite (U-Th)/He analytical data

Sample	Age ± 1σ (Ma)	Weighted Age ± 1σ (Ma)	[U] (ppm)	[Th] (ppm)	U/Th	[^{4}He] (nmol/g)	F_t**
ER22	17.0 ± 1.3		54.09	269.63	0.20	8.04	0.68
	15.4 ± 0.8		29.26	139.97	0.21	4.01	0.70
	14.3 ± 1.0		28.75	134.39	0.21	3.34	0.65
ER23	15.2 ± 1.2	**14.9 ± 0.6**	43.10	185.80	0.23	5.05	0.64
	15.2 ± 1.2		34.87	158.94	0.22	4.31	0.66
	14.4 ± 0.9		47.43	200.35	0.24	5.28	0.65
ER24	14.0 ± 0.9	**15.3 ± 0.5**	58.86	170.96	0.34	6.58	0.79
	16.6 ± 0.9		93.00	292.25	0.32	10.57	0.66
	15.2 ± 0.9		81.90	240.07	0.34	8.78	0.70
ER25	16.8 ± 1.4	**16.5 ± 0.5**	17.04	34.17	0.50	1.80	0.71
	16.1 ± 0.8		29.09	62.06	0.47	3.06	0.73
	15.2 ± 0.9		28.71	49.65	0.58	2.57	0.70
	18.4 ± 1.7		16.88	35.23	0.48	1.92	0.69
	19.9 ± 1.5		33.47	58.90	0.57	3.55	0.63
ER13	16.3 ± 1.7	**15.7 ± 0.8**	43.37	91.54	0.47	3.50	0.55
	15.3 ± 1.0		23.59	48.56	0.49	2.21	0.69
	16.3 ± 1.5		34.39	58.33	0.59	2.90	0.62

* Pre-extensional paleodepth is measured as distance beneath the basal Tertiary tuffaceous sedimentary rocks in the East Range that dip 30° east and rest unconformably on Paleozoic and Mesozoic footwall rocks.

**** F_t alpha-ejection correction calculation after Farley 2002**