Data repository items

Methods

Allanite and monazite for geochronology were analyzed in thin sections. Back-scattered electron (BSE) images were carried out before dating at the Electron Microscope Unit, Australian National University with a Cambridge S360 scanning electron microscope using a voltage of 20 kV, current of ~2 nA and a working distance of 17-20 mm.

U-Th-Pb analyses of monazite were performed using a sensitive, high-resolution ion microprobe (SHRIMP II) at the Research School of Earth Sciences (RSES). Age calculation for all minerals was done using the software Isoplot/Ex (Ludwig, 2003).

For monazite, instrumental conditions and data acquisition were generally as described by Williams (1998). The data were collected in sets of six scans throughout the masses. The measured ^{206}Pb/^{238}U ratio was corrected using reference monazite S44069 (425 Ma, Aleinikoff et al., 2007). Data were corrected for common Pb on the basis of the measured ^{207}Pb/^{206}Pb ratios as described in Williams (1998). This approach avoids the problem of having to eliminate the isobaric interference on ^{204}Pb. Tera-Wasserburg intercept ages were forced to the composition of the surface-derived Pb in the ANU laboratory (Broken Hill Pb: ^{207}Pb/^{206}Pb = 0.9618). This choice was driven by the fact that analyses were done in thin section, where polishing is inevitably limited, and thus common Pb is mainly surface-derived. Notably, free intercepts or intercepts forced to model common Pb compositions produced ages identical within error. Error on the calibration standard was added in quadratic to the error on the intercept. For both samples, the Th-Pb system returns age within error of the U-Pb demonstrating that in this metamorphic monazite there was no significant excess ^{206}Pb from ^{230}Th decay, as instead documented for magmatic young monazite in differentiated leucogranites (e.g. Schärer, 1984). The absence of ^{206}Pb excess is explained by the similar Th/U ratio in allanite and monazite (Δ^{206}Pb <<1% at 18-19Ma for Th/U fractionation factor (f)~0.5, in Schärer 1984)

For allanite, instrumental conditions and data acquisition were as described by Gregory et al. (2007), with isotope data collected from sets of six scans through the masses. The measured ^{208}Pb/^{232}Th ratio was corrected using the allanite standard CAP (276 Ma, Barth et al., 1994). All analyses were corrected for common Pb based on measured ^{207}Pb/^{206}Pb and ^{208}Pb/^{206}Pb (Gregory et al., 2007). Common Pb measured in allanite is essentially inherent and therefore an estimate of initial Pb composition at the time of crystallisation from an evolving model Pb composition was assumed (Stacey and Kramers, 1975). This assumption was justified by applying free regressions to the uncorrected data: Th-Pb isochrons of MF161 and APi0413 data yielded initial ^{208}Pb/^{206}Pb intercepts of 2.1±0.3 (2σ), and Tera-Wasserburg initial ^{207}Pb/^{206}Pb intercepts of 0.824±0.012 (2σ). Such initial Pb values are within error of the model Pb compositions at ~30 Ma. Furthermore, the use of a significantly different common Pb composition (e.g. >400 Ma) would not change the age at the 2-sigma level. On the other hand, only a few percents of inherited radiogenic Pb from the precursor monazite would force the regression to a much lower value of initial Pb.

As clinozoisite has more U than Th (Th/U <1), the U-Pb system was targeted. The measured $^{206}Pb/^{238}U$ ratio measured was corrected using CAP allanite (274 Ma, Barth et al., 1994). A free Tera-Wasserburg regression of uncorrected data gave an initial Pb intercept of 0.826±0.004 (2σ). A ^{207}Pb-based correction was applied to individual analyses.

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Table DR1. SHRIMP U-Th-Pb analyses of allanite in APi0413 and MF161

Label	^{208}Pbc %	Th/U	^{208}Pb/^{232}Th	±1 sigma	**^{208}Pb/^{232}Th Age**	**±1 sigma**
Sample APi0413						
A2-4a1	82	20	0.00166	0.00011	33.60	2.14
A2-4a2	82	28	0.00160	0.00015	32.24	2.93
A2-4a3	74	33	0.00152	0.00011	30.79	2.17
A2-4a4	82	22	0.00159	0.00011	32.04	2.22
A2-7ba1	86	13	0.00151	0.00013	30.55	2.71
A2-2a1	72	39	0.00153	0.00010	30.90	2.03
A2-2a2	71	43	0.00153	0.00008	30.87	1.65
A2-2a3	76	36	0.00151	0.00011	30.53	2.26
A2-5.1	83	24	0.00160	0.00013	32.28	2.69
A2-5.2	88	15	0.00153	0.00012	30.97	2.39
A2-5.3	83	20	0.00146	0.00015	29.44	3.12
A2-6B.1	86	12	0.00160	0.00012	32.36	2.49
A2-6D	87	12	0.00161	0.00013	32.59	2.58
Sample MF161						
A3-2a	81	10	0.00143	0.00010	28.83	1.95
A3-1a.1	87	6	0.00157	0.00012	31.64	2.40
A3-3a	80	17	0.00147	0.00009	29.60	1.83
A3-3b	84	12	0.00139	0.00011	28.02	2.16
A3-3c	80	15	0.00147	0.00014	29.76	2.78
A3-3d	83	13	0.00147	0.00010	29.73	2.11
A3-3e	86	10	0.00149	0.00011	30.08	2.25
A3-4a	81	17	0.00147	0.00010	29.66	2.01
A3-5a	84	13	0.00134	0.00012	27.04	2.35
A3-5b	83	13	0.00137	0.00011	27.69	2.28
A3-6a	82	7	0.00144	0.00009	29.04	1.74
A3-7a	94	5	0.00150	0.00009	30.31	1.77
A3-7b	87	9	0.00148	0.00017	29.94	3.38
A3-7c	86	10	0.00145	0.00012	29.25	2.39
A3-9a	79	11	0.00140	0.00008	28.22	1.54
A3-11	78	10	0.00142	0.00009	28.69	1.91
A3-5c	87	11	0.00147	0.00010	29.65	2.10

Table DR2. SHRIMP U-Th-Pb analyses of clinozoisite in APi0413

Label	^{206}Pbc %	Th/U	Total ^{238}U/^{206}Pb	% error	Total ^{207}Pb/^{206}Pb	% error	^{206}Pb/^{238}U	±1 sigma	**^{206}Pb/^{238}U Age**	**±1 sigma**
A2-3a.1	83	0.5	49.8	1.7	0.716	0.003	0.00282	0.00010	18.1	0.7
A2-3a2	75	0.3	82.6	2.8	0.651	0.003	0.00271	0.00007	17.5	0.5
A2-3a3	67	0.2	108.2	3.6	0.589	0.002	0.00281	0.00006	18.1	0.4
A2-3a4	78	0.3	65.7	2.2	0.674	0.002	0.00295	0.00008	19.0	0.5
A2-3a5	91	0.6	22.3	0.7	0.783	0.003	0.00236	0.00016	15.2	1.0
A2-2a5	80	0.2	58.6	2.0	0.695	0.003	0.00285	0.00008	18.4	0.5
A2-6C.1	80	0.3	61.8	2.1	0.690	0.001	0.00281	0.00007	18.1	0.4

Table DR3. SHRIMP U-Th-Pb analyses of monazite in APi0413

Label	^{206}Pbc %	U (ppm)	Th (ppm)	Th/U	Total ^{238}U/^{206}Pb	% error	Total ^{207}Pb/^{206}Pb	% error	^{206}Pb/^{238}U	±1 sigma	**^{206}Pb/^{238}U Age**	**±1 sigma**	**^{208}Pb/^{232}Th Age**	**±1 sigma**
M1-3c5*	4.5	3596	24723	6.9	368.6	0.98	0.0877	1.21	0.002590	0.0000256	16.68	0.16	16.49	0.29
M1-45b2*	3.0	2970	19854	6.7	361.9	0.94	0.0736	1.11	0.002681	0.0000254	17.26	0.16	16.86	0.24
M1-3c2*	4.3	3480	35908	10.3	353.6	0.94	0.0854	1.02	0.002708	0.0000256	17.43	0.16	17.05	0.20
M1-1a1	7.1	11759	199802	17.0	336.4	1.08	0.1118	1.97	0.002760	0.0000310	17.77	0.20	17.13	0.27
M1-3c4	8.7	3020	26931	8.9	329.6	0.98	0.1256	7.51	0.002772	0.0000416	17.84	0.27	16.88	0.31
M1-45b1	2.7	5182	47013	9.1	354.1	0.92	0.0715	1.05	0.002746	0.0000254	17.68	0.16	17.30	0.21
M1-5b1	3.4	2540	18115	7.1	350.7	0.96	0.0778	1.22	0.002754	0.0000268	17.73	0.17	17.30	0.23
M1-3c1	2.6	3451	26184	7.6	351.7	0.93	0.0702	1.05	0.002769	0.0000260	17.83	0.17	17.54	0.24
M1-1b1	4.5	2767	23584	8.5	342.5	0.98	0.0875	1.25	0.002789	0.0000276	17.95	0.18	17.83	0.25
M1-2b1	2.5	3743	21522	5.7	350.5	0.95	0.0688	1.15	0.002783	0.0000266	17.92	0.17	17.63	0.22
M1-3c3	4.1	3519	36084	10.3	341.4	0.93	0.0839	1.01	0.002809	0.0000265	18.08	0.17	17.90	0.22
M1-5a1	1.0	4991	8721	1.7	353.6	0.92	0.0552	1.21	0.002801	0.0000258	18.03	0.17	17.68	0.26
M1-2a1	2.6	3576	28144	7.9	345.4	0.96	0.0701	1.07	0.002820	0.0000271	18.15	0.17	17.93	0.23
M1-2a2	3.7	4208	20833	5.0	338.0	0.92	0.0799	2.48	0.002850	0.0000271	18.35	0.17	18.22	0.23

* Data excluded from the average age calculation.

Table DR4. SHRIMP U-Th-Pb analyses of monazite in MF315

Label	^{206}Pbc %	U (ppm)	Th (ppm)	Th/U	Total ^{238}U/^{206}Pb	% error	Total ^{207}Pb/^{206}Pb	% error	^{206}Pb/^{238}U	±1 sigma	**^{206}Pb/^{238}U Age**	**±1 sigma**	**^{208}Pb/^{232}Th Age**	**±1 sigma**
M3-4a4	5.2	2020	21997	10.9	329.7	1.41	0.0939	1.74	0.002875	0.0000410	18.51	0.26	19.90	0.35
M3-4a5	13.7	1796	29961	16.7	291.9	1.23	0.1716	1.94	0.002957	0.0000392	19.04	0.25	19.90	0.36
M3-4a1	3.1	2238	16947	7.6	332.9	1.14	0.0744	1.79	0.002912	0.0000336	18.74	0.22	19.41	0.45
M3-4a3	6.1	1239	18795	15.2	320.1	1.25	0.1022	2.15	0.002934	0.0000377	18.89	0.24	19.74	0.35
M3-4a2	4.5	1514	18016	11.9	322.1	1.21	0.0872	2.06	0.002966	0.0000365	19.09	0.23	18.53	0.35
M3-2b	4.2	2876	38774	13.5	317.9	1.25	0.0849	1.54	0.003014	0.0000380	19.40	0.24	20.14	0.30
M3-4b1	8.5	1481	28987	19.6	297.2	1.90	0.1242	7.26	0.003079	0.0000674	19.81	0.43	20.35	0.45
M3-3b1	5.1	588	9245	15.7	308.7	1.43	0.0935	3.04	0.003073	0.0000452	19.78	0.29	20.01	0.44
M3-2a	6.2	1746	29777	17.1	319.0	1.16	0.1030	1.66	0.002937	0.0000369	18.93	0.24	20.77	0.37
M3-1a	3.3	1464	13040	8.9	324.7	1.20	0.0771	1.96	0.002972	0.0000383	19.16	0.25	21.60	0.37
M3-3c2*	6.4	1375	33881	24.6	291.1	1.61	0.1051	2.11	0.003215	0.0000527	20.69	0.34	20.97	0.40
M3-3c1*	4.1	2125	32891	15.5	295.3	1.18	0.0841	1.75	0.003247	0.0000388	20.90	0.25	21.19	0.31

* Data excluded from the average age calculation.

Table DR5. Fission track data in MRP214 and MRP215

Sample No and Locality†	Mineral and No. Crystals	Spontaneous ρ_s (N_s)§	Induced ρ_i (N_i)§	$P\chi^2$ #	Dosimeter ρ_d* (N_d)	**Central FT Age in Ma (-1σ/+1σ)††**	Mean Track Length§§	1σ S.d. of distribution (No. Tracks)
MR P 214								
Solario, Adula nappe	apatite (20)	0.005 (46)	0.156 (1406)	64%	11.84 (2886)	6.7 (-0.9/+1.1)	13.61	1.35 (51)
(8.95120/46.52579/1150)	zircon (20)	0.112 (737)	0.400 (2626)	<1%	4.864 (3944)	9.1 (-0.4/+0.5)	10.36	1.38 (10)
MR P 215								
Lai da Santa Maria	apatite (20)	0.003 (46)	0.090 (1234)	97%	11.77 (2869)	7.5 (-1.1/+1.2)	14.56	1.21 (32)
(8.79791/46.58837/1915)	zircon (20)	0.170 (692)	0.565 (2298)	<1%	4.853 (3924)	9.7 (-0.5/+0.5)	10.41	1.22 (50)

Notes:

†Coordinates indicate longitude (°)/latitude (°)/altitude (m).

§Track densities are ($x10^7$ tr cm^{-2}), *=($x10^5$ tr cm^{-2})numbers of tracks counted (N) shown in brackets; analyses by external detector method using 0.5 for the 4π/2π geometry correction factor

#P(χ^2 is probability for obtaining χ^2value for v degrees of freedom, where v = no. crystals - 1

††ages calculated using dosimeter glass CN-5 for apatite with ζ_{CN5} =344 ± 5 and CN-2 for zircon with ζ_{CN5} =133 ± 3

§§track length data are given in 10^{-6}m

Fission track dating note:

Despite that apatite composition was not analyzed, texture of the fission track argues for a F-rich composition. Dpar values (etch pits of fission tracks on internal grain surfaces) of the counted apatite have mean lengths of 1.5 to 3 microns, characteristic of the apatites with low Cl contents.