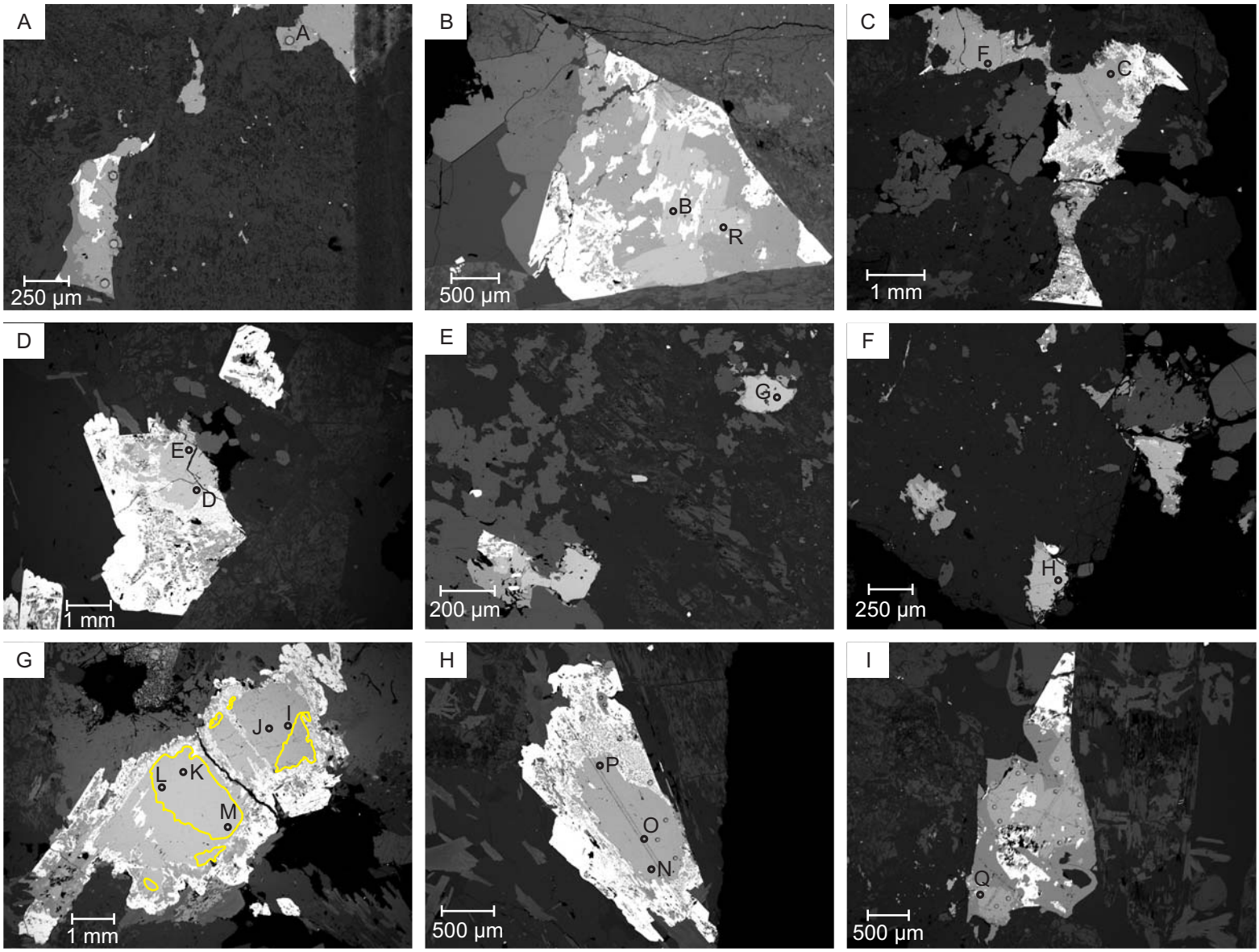
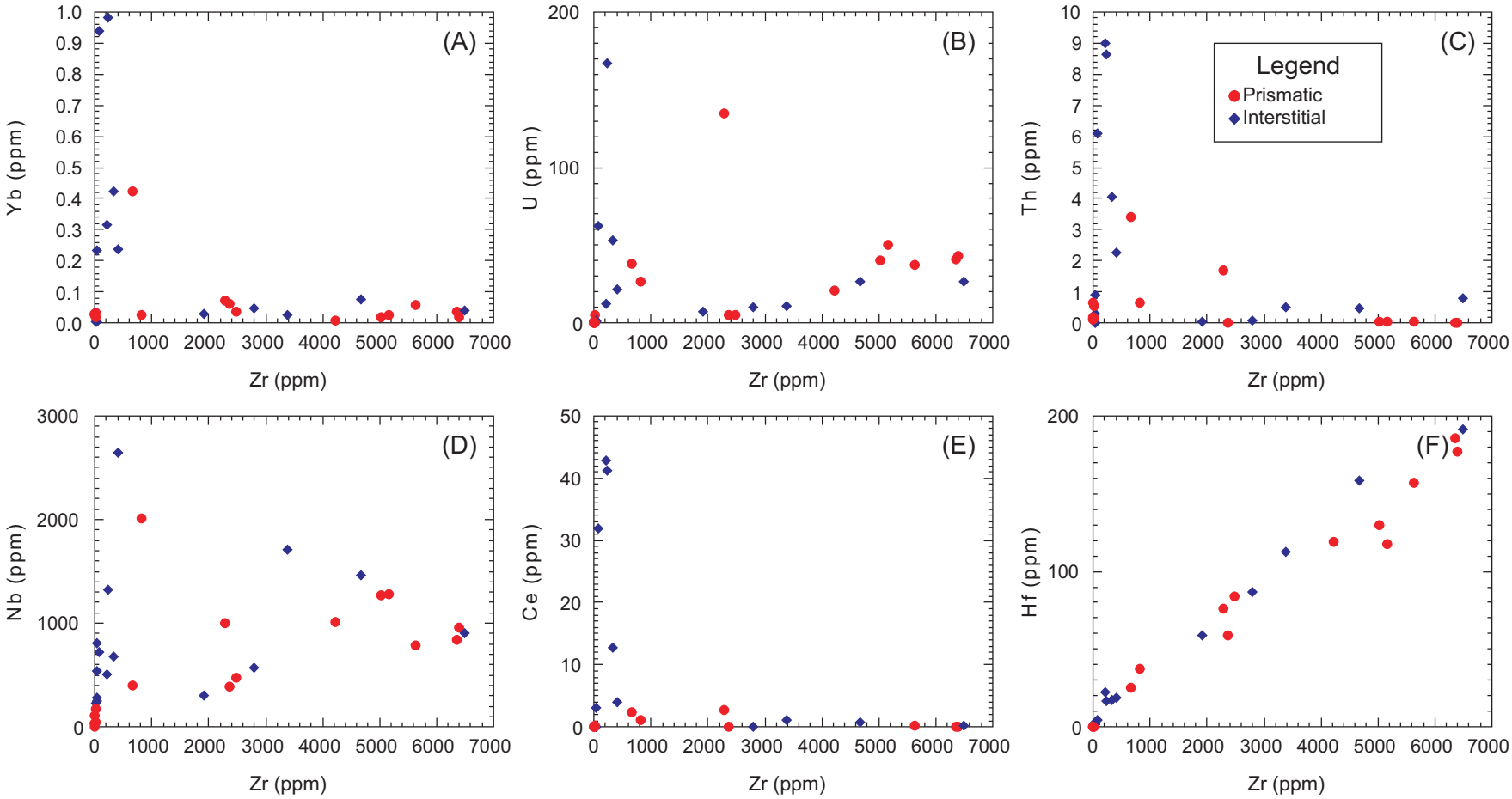
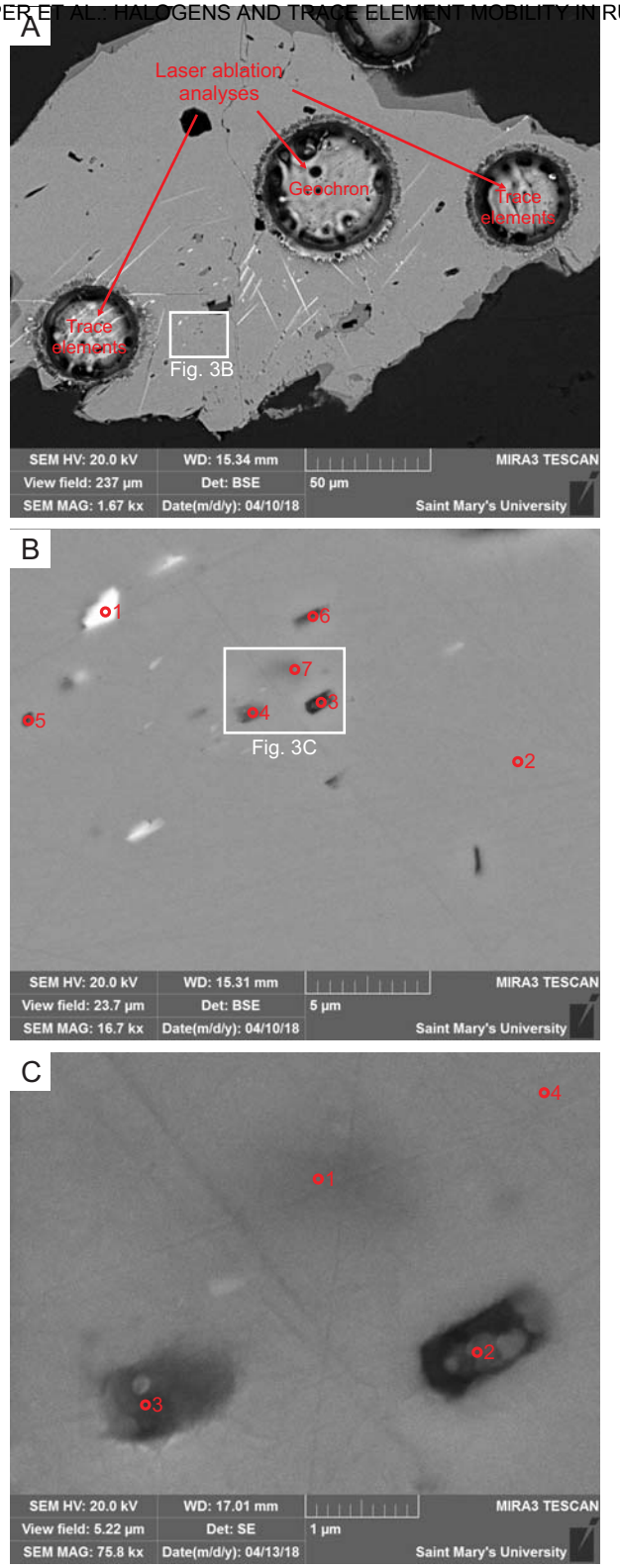


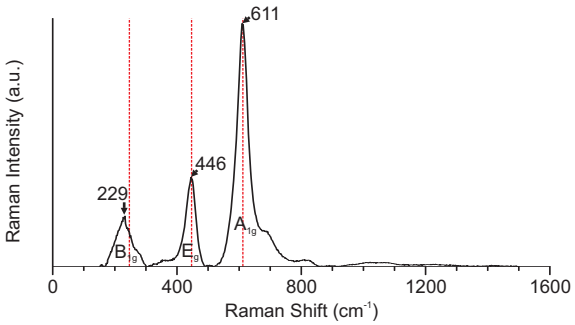
Supplementary Figure S1
BSE images of all rutile grains analyzed for geochronology. The letters indicate the analyses in Table 2 and Figure 8. Yellow outline indicates high Zr domain in panel (G) (cf. Fig. 6).

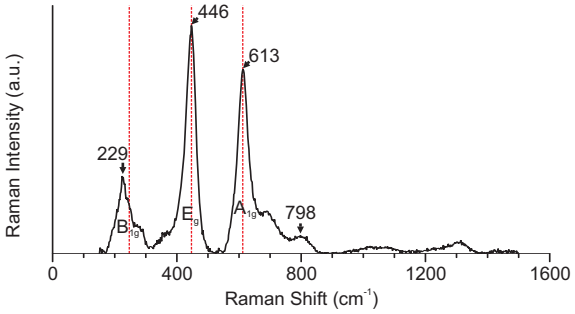


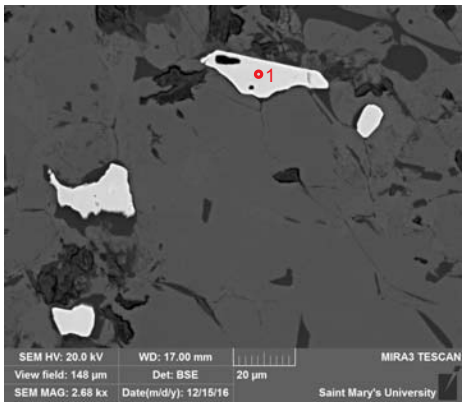
Supplementary Figure S2
Variation of trace elements with Zr in rutile, determined by LA-ICP-MS (Table 2).



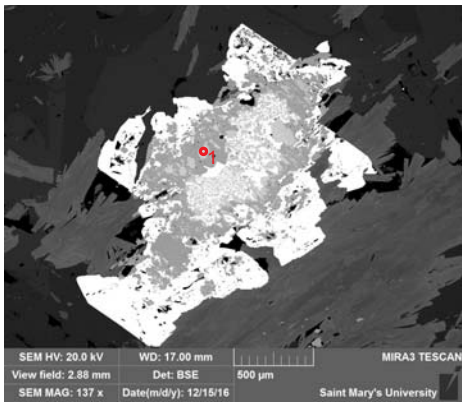
Supplementary Figure S3
Back-scattered electron images (A&B) and secondary electron images (C) from sample 9956d showing mineral inclusions in rutile.
A: Laser analyzed rutile grain with inclusions.
B: Zoom of A.
C: Zoom of B.
High backscatter inclusion has 46% TiO_2 and 44% FeO (Supp. Table 2, analysis S3B 1) and is probably ilmenite, but possibly magnetite (with analysed TiO_2 from the rutile). Low backscatter spots, with low EDS totals, in panel C may be voids.



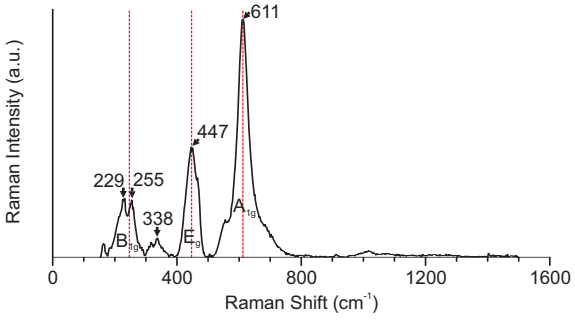


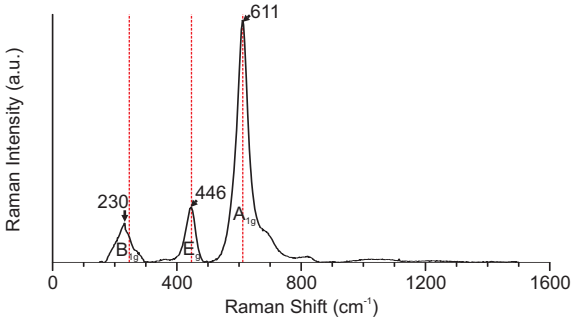


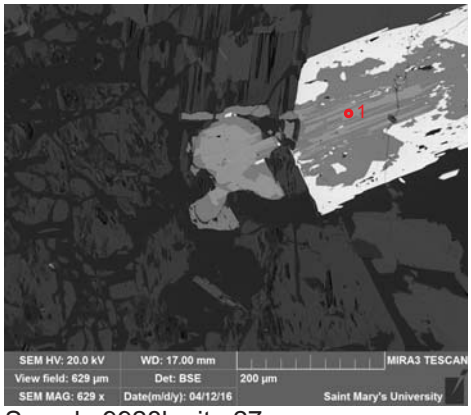
Sample 9956a site 11.



Sample 9956a site 38.



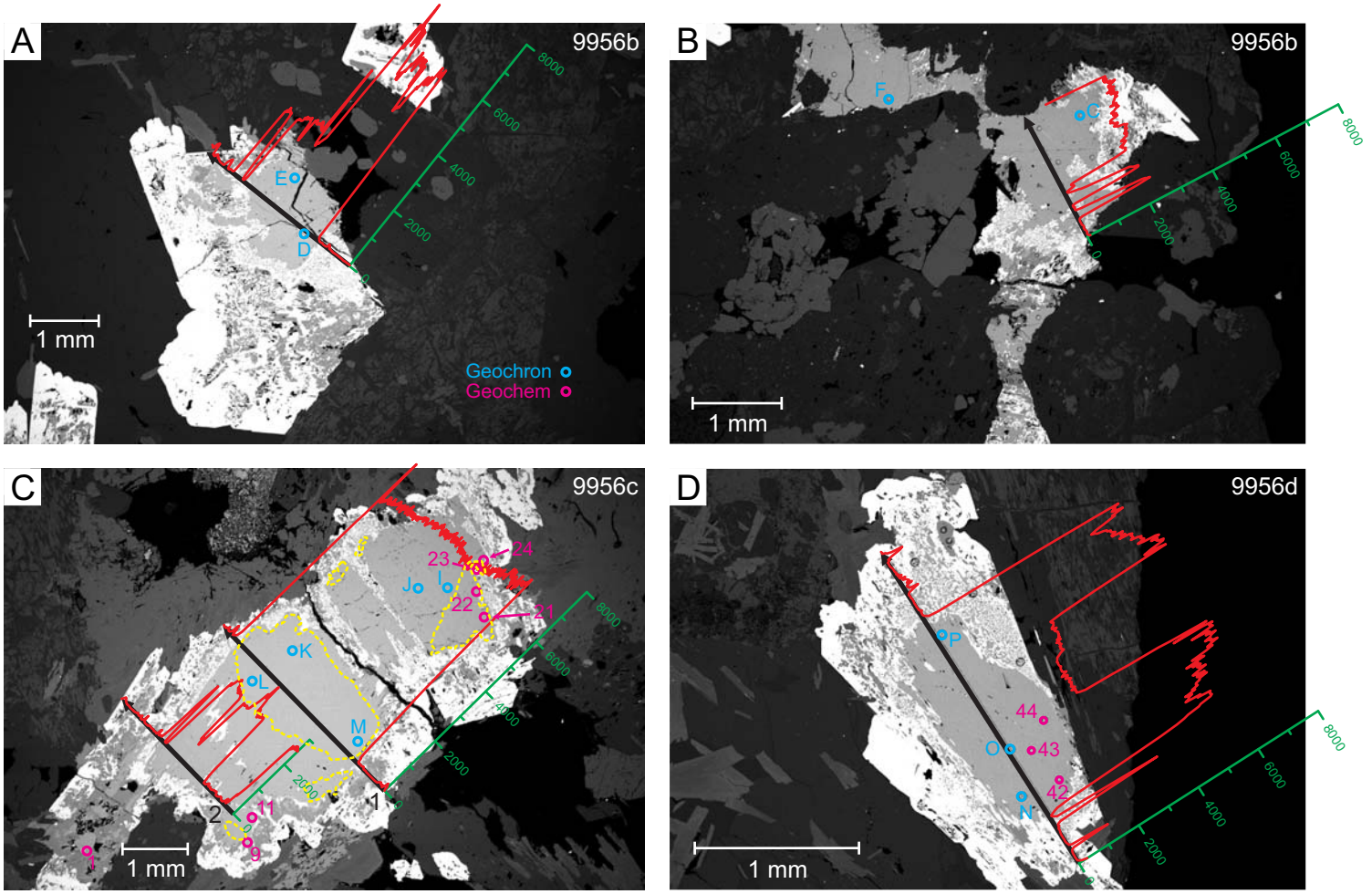




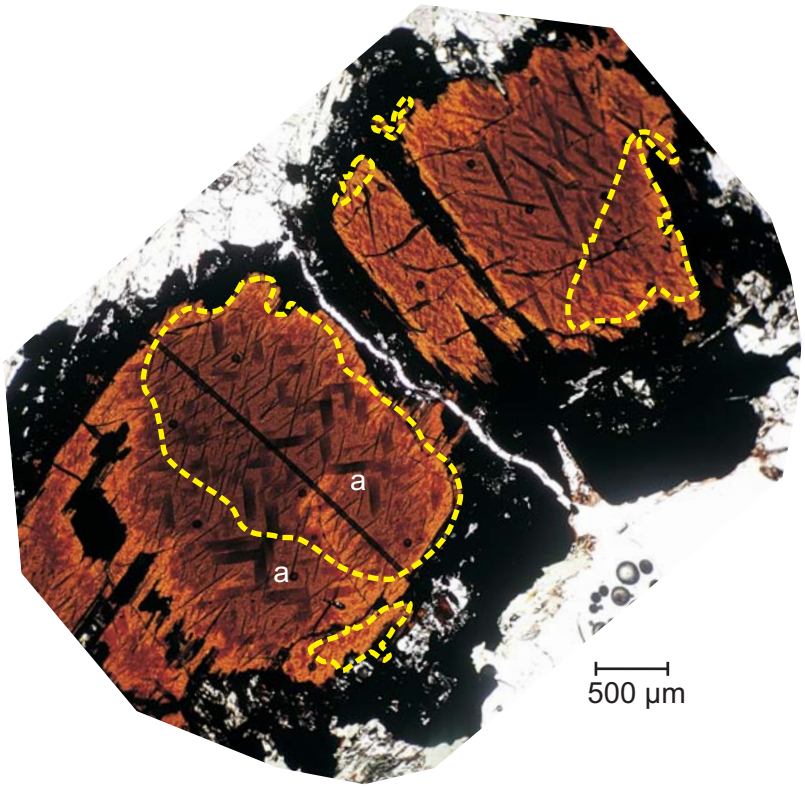
Sample 9928b site 27.

Sample 9956a site 4.

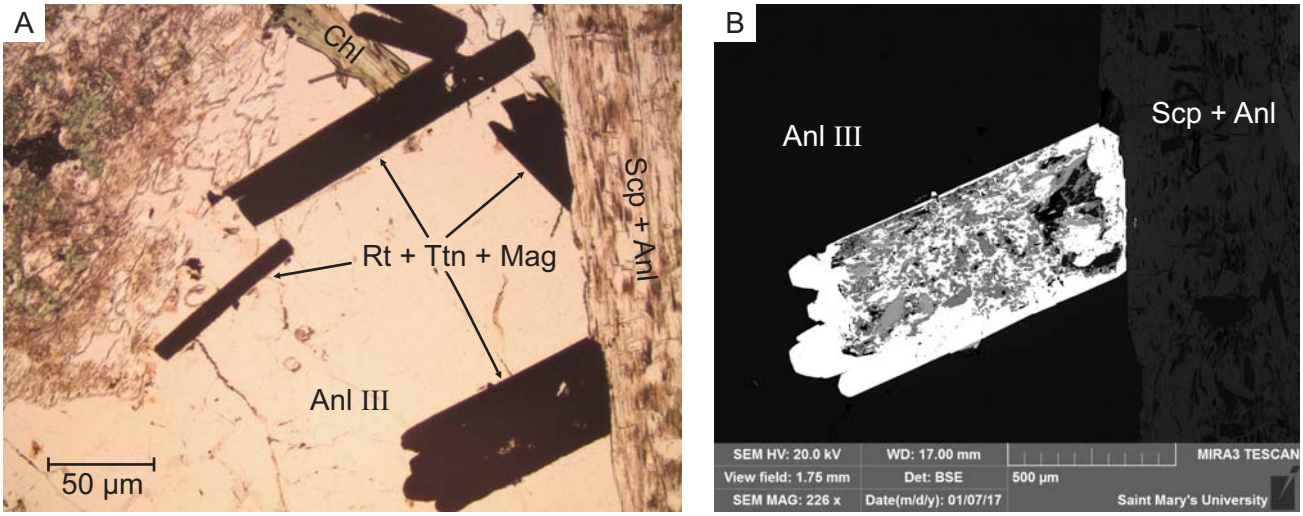
Supplementary Figure S4
Raman spectra from representative rutile grains confirming the presence of rutile.



Supplementary Figure S5
Raster data of Zr content by LA-ICPMS (red graph, green scale in ppm) in four rutile grains from samples 9956b, 9956c, and 9956d. Also shows location of U-Pb geochronology spots (cyan) and trace element geochemical spots (magenta). The high-Zr domains are outlined in yellow in panel (C).



Supplementary Figure S6
Microphotograph of part of the large rutile grain in Fig. 6. The dark brown domains show a set of almost perpendicular striations (positions a). High-Zr domains are outlined in yellow.



Supplementary Figure S7
(A) Microphotograph (ppl) of complex rutile-titanite-magnetite grains that have grown in a vug bounded by large scapolite (pseudomorphing K-feldspar) crystals, and is thus late magmatic or post-solidus. Vug later filled by analcime III. (B). BSE image with spot analyses of one grain from panel (A) showing rutile overgrown by Fe-oxide/hydroxide and replaced by titanite and Fe-oxide/hydroxide. Sample 9956d.

SUPPLEMENTAL TABLE S1: Analytical details of dated spots in rutile

Sample	Spot	Grain no.	Habit	Approx. concentrations (ppm)			Counts				Final isotope ratios							Age (Ma)			Data for inverse isochron				
				U	Th	U/Th	^{204}Pb cps	2σ int	^{206}Pb/^{204}Pb cps	%Pb*	^{207}Pb/^{235}U	2σ	^{206}Pb/^{238}U	2σ	err. corr.	^{207}Pb/^{206}Pb	2σ	^{206}Pb/^{238}U	2σ	% conc-cordency	^{238}U/^{206}Pb	2σ	^{207}Pb/^{206}Pb	2σ	err. corr.
28a - 18	A	A	I	15.29	0.107	143	0	13	1741	99.68	0.422	0.041	0.056	0.002	0.05	0.0551	0.0055	350	14	100.9	17.92	0.71	0.055	0.006	0.26
56b - 2	C	C	I	27.79	<0.002	-	-17	16	3187	99.16	0.456	0.038	0.056	0.002	0.10	0.0595	0.0053	350	13	93.6	17.92	0.67	0.060	0.005	0.36
56b - 10	D	D	P	24.81	0.032	775	2	20	1384	99.53	0.415	0.045	0.054	0.002	0.12	0.0576	0.0072	337	13	97.7	18.66	0.77	0.058	0.007	0.45
28a - 18	E	D	P	25.13	0.004	6444	-11	17	3066	99.98	0.413	0.034	0.056	0.002	0.12	0.0541	0.0049	354	11	103.1	17.73	0.60	0.054	0.005	0.33
56b - 20	F	C	I	5.522	<0.002	-	2	16	319	99.30	0.456	0.080	0.056	0.003	0.05	0.0600	0.0100	348	20	100.9	17.99	1.10	0.060	0.010	0.20
56c - 3	G	E	I	19.74	1.730	11	3	14	765	99.61	0.438	0.038	0.057	0.002	0.13	0.0562	0.0054	359	12	99.8	17.45	0.61	0.056	0.005	0.42
56c - 9	H	F	I	27.14	3.990	7	-10	16	3250	99.50	0.427	0.034	0.055	0.002	0.10	0.0565	0.0046	347	12	96.9	18.08	0.65	0.057	0.005	0.26
56c - 13	I	G	P	7.58	<0.002	-	20	12	43	98.90	0.440	0.072	0.054	0.003	0.00	0.0620	0.0110	336	17	98.8	18.62	0.97	0.062	0.011	0.18
56c - 17	J	G	P	5.438	<0.002	-	-4	14	630	98.20	0.445	0.081	0.054	0.003	0.13	0.0670	0.0130	340	19	99.1	18.42	1.05	0.067	0.013	0.31
56c - 20	K	G	P	31.06	<0.002	-	-1	14	3381	99.99	0.385	0.028	0.053	0.002	0.09	0.0528	0.0039	335	11	103.2	18.73	0.63	0.053	0.004	0.26
56c - 21	L	G	P	42.12	0.254	166	11	13	431	99.86	0.392	0.023	0.054	0.002	0.08	0.0532	0.0034	338	11	101.9	18.55	0.62	0.053	0.003	0.19
56c - 24	M	G	P	38.51	<0.002	-	7	15	602	99.45	0.415	0.032	0.053	0.002	0.09	0.0571	0.0045	334	10	96.3	18.80	0.60	0.057	0.005	0.23
56d - 1	N	H	P	45.31	<0.002	-	5	15	1035	99.63	0.402	0.022	0.054	0.002	0.04	0.0548	0.0032	339	10	99.6	18.55	0.55	0.055	0.003	0.06
56d - 2	O	H	P	67.17	0.002	39512	6	16	1275	99.69	0.401	0.022	0.053	0.002	0.02	0.0553	0.0029	331	9	97.5	18.95	0.54	0.055	0.003	0.04
56d - 4	P	H	P	52.16	<0.002	-	-9	13	5850	100.15	0.387	0.023	0.055	0.002	0.03	0.0515	0.0032	344	10	104.5	18.25	0.53	0.052	0.003	0.26
56c - 22				5.44	<0.002	-	-5	19	584	99.50	0.380	0.100	0.052	0.004	0.16	0.0570	0.0150	326	26	112.0	19.23	1.59	0.057	0.015	0.24
28a - 11				1.407	0.030	48	9	13	18	94.60	0.380	0.180	0.054	0.006	0.06	0.0870	0.0450	335	38	223.3	18.55	2.13	0.087	0.045	0.61
28a - 35				3.69	4.350	1	-2	13	438	99.60	0.400	0.120	0.053	0.005	0.35	0.0550	0.0180	329	32	117.1	19.05	1.89	0.055	0.018	-0.60
56c - 9				43.2	0.619	70	1	14	4590	99.54	0.397	0.026	0.052	0.002	0.17	0.0553	0.0036	328	10	97.8	19.17	0.59	0.055	0.004	0.19
28a - 38				9.97	0.980	10	11	14	104	99.04	0.453	0.052	0.054	0.002	0.12	0.0599	0.0066	339	15	93.6	18.52	0.82	0.060	0.007	0.25
28a - 21				63.1	63.000	1	8	14	945	99.04	0.444	0.024	0.055	0.002	0.14	0.0597	0.0032	343	10	92.6	18.32	0.57	0.060	0.003	0.29
56b - 3				5.475	<0.002	-	-6	15	630	97.80	0.488	0.080	0.056	0.003	0.07	0.0700	0.0130	350	20	93.8	17.89	1.06	0.070	0.013	0.47
56b - 12				6.26	<0.002	-	-2	14	756	97.90	0.528	0.081	0.058	0.003	0.04	0.0700	0.0110	361	18	91.4	17.33	0.90	0.070	0.011	0.23
56b - 5				5.348	0.002	2674	-10	18	625	97.90	0.540	0.100	0.057	0.003	0.06	0.0700	0.0130	356	21	88.3	17.61	1.05	0.070	0.013	0.23
56b - 19				27.54	1.510	18	17	13	205	98.67	0.516	0.037	0.058	0.002	0.11	0.0636	0.0044	365	13	88.0	17.15	0.62	0.064	0.004	0.34
56b - 9				5.797	0.319	18	22	14	31	97.70	0.508	0.082	0.054	0.003	0.05	0.0720	0.0120	337	17	84.7	18.59	1.00	0.072	0.012	0.16
56b - 8				44.12	0.146	302	4	27	1273	97.90	0.522	0.064	0.055	0.003	0.13	0.0696	0.0086	345	15	82.5	18.18	0.83	0.070	0.009	0.19
56b - 17				47.95	0.002	26639	8	15	821	97.87	0.535	0.030	0.056	0.002	0.03	0.0702	0.0040	348	10	80.3	18.02	0.55	0.070	0.004	0.29
56c - 18				5.386	<0.002	-	-16	16	595	98.80	0.448	0.081	0.054	0.003	0.13	0.0630	0.0120	340	20	100.0	18.45	1.12	0.063	0.012	0.15
56c - 25				7.93	<0.002	-	-1	16	931	98.70	0.464	0.075	0.056	0.003	0.18	0.0600	0.0110	351	20	98.3	17.86	1.05	0.060	0.011	0.32
56c - 26				7.32	<0.002	-	15	14	62	98.80	0.469	0.077	0.058	0.003	0.16	0.0640	0.0110	364	20	97.8	17.18	0.97	0.064	0.011	0.41
56c - 23				7.93	<0.002	-	15	14	58	99.10	0.451	0.060	0.055	0.003	0.27	0.0602	0.0079	343	17	96.3	18.28	0.94	0.060	0.008	-0.01
56c - 31				6.88	0.395	17	12	15	64	98.50	0.464	0.076	0.054	0.003	0.12	0.0630	0.0110	336	18	94.9	18.69	1.01	0.063	0.011	0.35
56c - 14				10.04	<0.002	-	10	14	114	98.80	0.448	0.059	0.053	0.003	0.07	0.0622	0.0083	335	16	94.4	18.73	0.91	0.062	0.008	0.21
56c - 16				5.615	<0.002	-	-9	13	658	97.30	0.521	0.087	0.056	0.003	0.02	0.0740	0.0140	349	19	90.2	17.92	1.03	0.074	0.014	-0.03
56c - 12				53.45	<0.002	-	-2	19	6170	98.43	0.486	0.038	0.054	0.002	0.10	0.0656	0.0054	341	11	85.4	18.42	0.64	0.066	0.005	0.35
56c - 15				8.48	0.038	221	-7	13	918	97.40	0.490	0.062	0.052	0.003	0.09	0.0730	0.0100	325	16	83.8	19.31	0.97	0.073	0.010	0.34
28a - 13				13.66	1.017	13	8	14	194	98.69	0.475	0.055	0.056	0.002	0.01	0.0628	0.0073	350	14	92.1	17.89	0.74	0.063	0.007	0.19
28b - 8				8.86	0.157	56	8	15	123	98.90	0.439	0.064	0.055	0.003	0.68	0.0608	0.0095	346	17	99.4	18.12	0.92	0.061	0.010	-0.22
28b - 10				106.1	4.580	23	12	12	969	99.56	0.410	0.018	0.053	0.002	0.05	0.0558	0.0024	336	9	96.7	18.71	0.52	0.056	0.002	0.32

Notes: Sample: number is preceded by 99. Spots are labelled in Fig. 8. Grain no. is shown in Supplementary Figure S1. Habit: I = interstitial, P = prismatic. %Pb* = percentage radiometric Pb calculated by the methods of Andersen (2002). cps= integrated counts per second.

Andersen, T. (2002) Correction of common lead in U–Pb analyses that do not report ^{204}Pb. Chemical Geology, 192, 59–79.

Supplemental Table 2: Normalized wt.% oxide for the EDS analyses of inclusions in rutile in Supplementary Figure S3.

Sample	Image	Position	SiO_2	TiO_2	Al_2O_3	FeO	MgO	CaO	Na_2O	K_2O	Cl	Cr_2O_3	ZnO	Total	Actual Total
9956d	S3B	1		45.63	0.53	43.76					0.56	8.86	0.68	100	108.04
9956d	S3B	2		98.84								0.61	0.55	100	109.12
9956d	S3B	3	0.61	97.05		0.71					0.46	0.67	0.5	100	107.37
9956d	S3B	4	0.44	89.68		3.53		0.71	0.79	0.48	3.84	0.53		100	106.58
9956d	S3B	5		98.8								0.81	0.39	100	108.49
9956d	S3B	6		98.68								0.66	0.66	100	108.31
9956d	S3B	7		90.52		4.17		0.66			3.52	0.6	0.53	100	105.4
9956d	S3C	1		84.23		4.75		0.64	2.02	0.24	7.61	0.51		100	45.47
9956d	S3C	2	0.93	96.49		0.65			0.87		0.43	0.63		100	46.21
9956d	S3C	3	0.53	90.95		3.08		0.9		0.35	3.15	0.62	0.42	100	45.38
9956d	S3C	4		98.96								0.69	0.35	100	46.05
EDS analyses of inclusions in rutile are shown in Supplementary Figure S3															