177910: metamorphosed quartz sandstone, Peters Dam

Location and sampling

WIDGIEMOOLTHA (SH 51-14), YARDILLA (3434)
MGA Zone 51, 484173E 6464384N

Sampled on 29 April 2004

The sample was taken from a low rubbly outcrop located on the northwestern edge of the Fraser Range, about 5.2 km northwest of Peters Dam.

Tectonic unit/relations

The unit sampled is a pale grey, strongly foliated quartz sandstone that has undergone high-grade metamorphism. It is interlayered with amphibolite and pyroxene granulite of the mafic meta-igneous Fraser Complex, and is interpreted to be part of a larger metasedimentary package along the northwestern margin of the Biranup Complex, within the Albany–Fraser Orogen (Jones, 2005). The foliation in the metasedimentary rocks is parallel to that developed within the Fraser Complex.

Petrographic description

The visually estimated primary mineralogy of this sample is dominated by quartz (85–90%), with lesser amounts of garnet (7–8%), K-feldspar (3–4%), graphite (1–2%), and accessory muscovite, rutile, monazite, and zircon. Most quartz occurs as large, strained grains (up to 10 mm) elongated parallel to the foliation, but recrystallized new grains are also present, and most of their c-axes are at a low angle to the foliation. Garnet up to 3 mm in size is weakly elongated parallel to the foliation, and mostly occurs in a layer about 6 mm wide that is characterized by the presence of flakes of schistose graphite up to 1 mm long, some of which are partly enclosed in garnet grains. Minor orthoclase forms anhedral grains up to 2 mm in diameter. Accessory minerals include muscovite as small flakes in association with garnet, acicular rutile crystals up to 0.7 mm in length, and rare monazite and zircon up to 0.3 mm in diameter. Limonite-filled microfractures occur within garnet and limonite has also replaced rare anhedral grains.

The protolith of this rock was probably a quartz-dominated, sparsely carbonaceous sandstone, and the stable co-existence of garnet and rutile suggests that high-temperature metamorphism and deformation took place under relative high-pressure conditions. Minor retrogression is indicated by the occurrence of muscovite with garnet, and surface weathering and alteration is consistent with the partial to complete replacement of garnet by limonite.

Zircon morphology

The zircons isolated from this sample are subhedral to well-rounded or subspherical, and are mainly clear and colourless. They are up to 350 μm long, with aspect ratios up to 4:1. Most zircons display concentric growth zoning, which, in many cases, is truncated by a younger zircon rim. Cathodoluminescence images of representative zircons are shown in Figure 1.

Analytical details

This sample was analysed on 30–31 March 2005, using SHRIMP-B. Thirteen analyses of the CZ3 standard indicated an external spot-to-spot (reproducibility) uncertainty of 1.24% (1σ), and a $^{238}U/^{206}Pb^*$ calibration uncertainty of 0.40% (1σ). Common-Pb corrections were applied to all analyses using contemporaneous common-Pb isotopic compositions determined by the method of Stacey and Kramers (1975).

Results

Fifty eight analyses were obtained from 35 zircons, with 23 grains (spot numbers 1–22, and 24) each analysed twice. Results are listed in Table 1, and shown in concordia diagrams (Figs 2 and 3) and a probability density diagram (Fig. 4).

Interpretation

The analyses range from concordant to strongly discordant (Fig. 2). Six analyses are characterized by moderate to strong discordance (>10%). The dates obtained from these six analyses (Group D; Table 1) are imprecise or unreliable, and are not considered geologically significant. The remaining 52 analyses can be divided into three groups, based on their $^{207}Pb^*/^{206}Pb^*$ ratios, their Th/U ratios, and their positions within the grains.

Group 1 comprises 21 analyses of 21 zircon rims (Table 1) with low Th/U ratios (<0.30), which yield a weighted mean $^{207}Pb^*/^{206}Pb^*$ date of 1304 ± 7 Ma (MSWD = 1.87).

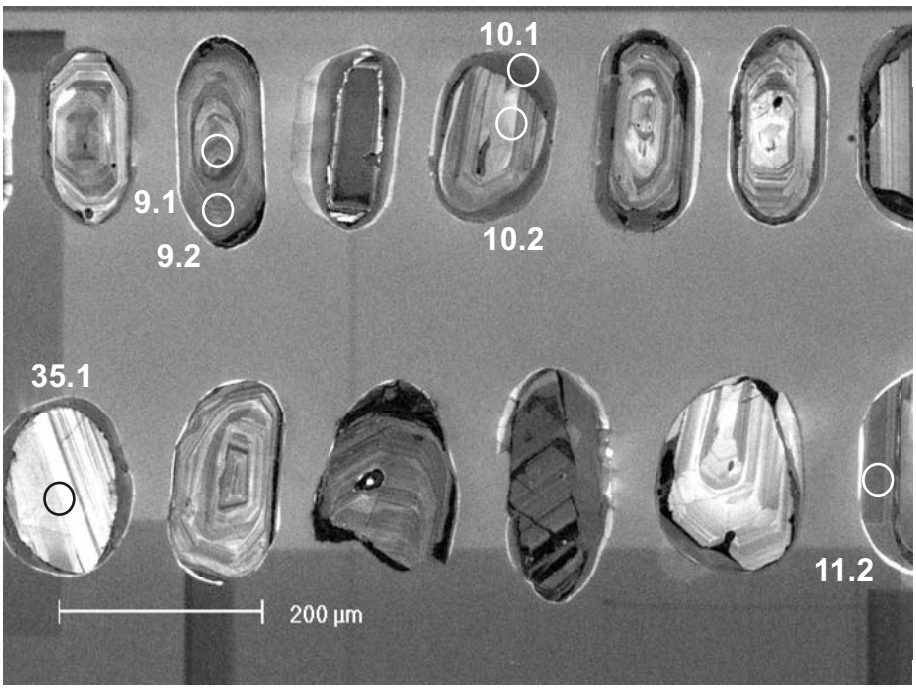

Figure 1. Cathodoluminescence image of representative zircons from sample 177910: metamorphosed quartz sandstone, Peters Dam. Numbered circles indicate approximate positions of analysis sites

Group 2 comprises four analyses of four zircon cores (Table 1) with moderate Th/U ratios (0.24–0.92), which yield a weighted mean $^{207}Pb^*/^{206}Pb^*$ date of 1466 ± 17 Ma (MSWD = 0.73).

Group 3 comprises 27 analyses of 26 zircon cores (Table 1) with highly variable Th/U ratios (0.10 – 1.35), which yield $^{207}Pb^*/^{206}Pb^*$ dates of 2651–1550 Ma.

The date of 1304 ± 7 Ma for the 21 analyses in Group 1 is interpreted as the age of zircon rim growth during high-grade metamorphism, which took place during Stage I of the Albany–Fraser Orogeny (1345–1260 Ma; Clark et al., 2000).

It is possible that all analyses of zircon cores represent unmodified detrital zircons, in which case the $^{207}Pb^*/^{206}Pb^*$ date of 1436 ± 30 Ma (1σ) for analysis 7.1 (within Group 2) represents a maximum age for deposition of the quartz sandstone protolith of this metasedimentary rock. However, analysis 7.1 is slightly discordant, and this zircon may have undergone minor ancient loss of radiogenic Pb. Consequently, the weighted mean $^{207}Pb^*/^{206}Pb^*$ date of 1466 ± 17 Ma for the four analyses in Group 2 represents a more robust estimate of the maximum depositional age.

The remaining analyses (Group 3) yield $^{207}Pb^*/^{206}Pb^*$ dates that define significant age components (based on three or more data-points) at c. 1466, c. 1582, c. 1640, and c. 1680 Ma, and a minor component at c. 2651 Ma (Fig. 3). These are interpreted as the ages of zircon-bearing rocks in the detrital source region(s) of the quartz sandstone protolith of this metasedimentary rock.

References

CLARK, D. J., HENSEN, B. J., and KINNY, P. D., 2000, Geochronological constraints for a two-stage history of the Albany–Fraser Orogen, Western Australia: Precambrian Research, v. 102, p. 155–183.

JONES, S. A., 2005, Geology of the Yardilla 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 34p.

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Recommended reference for this publication

WINGATE, M. T. D., and BODORKOS, S., 2007, 177910: metamorphosed quartz sandstone, Peters Dam; Geochronology dataset 660, *in* Compilation of geochronology data: Western Australia Geological Survey.

Data obtained: 31 March 2005
Data released: 31 May 2007

Table 1. Ion microprobe analytical results for zircons from sample 177910: metamorphosed quartz sandstone, Peters Dam

Grp no.	Spot no.	Grain .spot	^{238}U (ppm)	^{232}Th (ppm)	$^{232}Th/^{238}U$	f204 (%)	$^{238}U/^{206}Pb$ ±1σ	$^{207}Pb/^{206}Pb$ ±1σ	$^{238}U/^{206}Pb^*$ ±1σ	$^{207}Pb^*/^{206}Pb^*$ ±1σ	$^{238}U/^{206}Pb^*$ date (Ma) ±1σ	$^{207}Pb^*/^{206}Pb^*$ date (Ma) ±1σ	Disc (%)
1	4	2.2	308	19	0.06	0.044	4.451 ± 0.057	0.08587 ± 0.00042	4.453 ± 0.057	0.08550 ± 0.00048	1306 ± 15	1327 ± 11	1.6
1	6	3.2	75	13	0.17	0.000	4.557 ± 0.065	0.08538 ± 0.00086	4.557 ± 0.065	0.08539 ± 0.00086	1279 ± 17	1324 ± 19	3.4
1	28	14.2	181	15	0.08	0.011	4.767 ± 0.062	0.08547 ± 0.00051	4.768 ± 0.062	0.08538 ± 0.00053	1227 ± 15	1324 ± 12	7.3
1	14	7.2	367	17	0.05	–0.015	4.582 ± 0.059	0.08513 ± 0.00040	4.581 ± 0.059	0.08526 ± 0.00041	1273 ± 15	1322 ± 9	3.7
1	16	8.2	391	7	0.02	–0.017	4.538 ± 0.062	0.08499 ± 0.00038	4.537 ± 0.062	0.08514 ± 0.00038	1284 ± 16	1319 ± 9	2.6
1	38	19.2	78	23	0.30	0.047	4.527 ± 0.063	0.08541 ± 0.00080	4.529 ± 0.063	0.08501 ± 0.00106	1286 ± 16	1316 ± 24	2.3
1	46	24.2	140	17	0.13	0.138	4.608 ± 0.063	0.08605 ± 0.00072	4.615 ± 0.063	0.08487 ± 0.00094	1264 ± 16	1313 ± 22	3.7
1	10	5.2	274	15	0.06	0.044	4.608 ± 0.060	0.08516 ± 0.00046	4.610 ± 0.060	0.08479 ± 0.00051	1266 ± 15	1311 ± 12	3.5
1	12	6.2	406	12	0.03	0.022	4.816 ± 0.062	0.08491 ± 0.00039	4.817 ± 0.062	0.08473 ± 0.00042	1216 ± 14	1309 ± 10	7.1
1	22	11.2	376	34	0.09	0.016	4.487 ± 0.057	0.08481 ± 0.00038	4.488 ± 0.058	0.08467 ± 0.00039	1297 ± 15	1308 ± 9	0.9
1	39	20.1	77	18	0.25	–0.095	4.475 ± 0.063	0.08372 ± 0.00079	4.471 ± 0.063	0.08452 ± 0.00079	1301 ± 16	1305 ± 18	0.3
1	24	12.2	374	12	0.03	–0.017	4.516 ± 0.059	0.08424 ± 0.00037	4.515 ± 0.059	0.08438 ± 0.00037	1290 ± 15	1301 ± 9	0.9
1	20	10.2	553	6	0.01	0.005	4.485 ± 0.057	0.08440 ± 0.00031	4.485 ± 0.057	0.08436 ± 0.00031	1297 ± 15	1301 ± 7	0.3
1	32	16.2	83	15	0.18	–0.054	4.440 ± 0.066	0.08386 ± 0.00072	4.438 ± 0.066	0.08432 ± 0.00075	1310 ± 18	1300 ± 17	–0.8
1	8	4.2	463	6	0.01	0.036	4.779 ± 0.063	0.08435 ± 0.00035	4.780 ± 0.063	0.08405 ± 0.00037	1225 ± 15	1294 ± 9	5.3
1	40	20.2	238	30	0.13	0.020	4.422 ± 0.057	0.08420 ± 0.00045	4.423 ± 0.057	0.08404 ± 0.00047	1314 ± 15	1293 ± 11	–1.6
1	26	13.2	276	33	0.13	0.010	4.473 ± 0.058	0.08394 ± 0.00042	4.473 ± 0.058	0.08386 ± 0.00044	1301 ± 15	1289 ± 10	–0.9
1	36	18.2	286	23	0.08	0.037	4.486 ± 0.060	0.08382 ± 0.00041	4.487 ± 0.060	0.08351 ± 0.00044	1297 ± 16	1281 ± 10	–1.2
1	42	21.2	85	16	0.19	0.106	4.527 ± 0.069	0.08405 ± 0.00077	4.532 ± 0.069	0.08316 ± 0.00082	1285 ± 18	1273 ± 19	–1.0
1	30	15.2	95	14	0.15	0.068	4.387 ± 0.060	0.08317 ± 0.00069	4.390 ± 0.060	0.08259 ± 0.00085	1323 ± 16	1260 ± 20	–5.0
1	34	17.2	82	20	0.25	0.287	4.880 ± 0.067	0.08481 ± 0.00075	4.894 ± 0.067	0.08238 ± 0.00102	1199 ± 15	1255 ± 24	4.5
2	13	7.1	64	57	0.92	0.058	4.436 ± 0.065	0.09098 ± 0.00112	4.438 ± 0.065	0.09048 ± 0.00143	1310 ± 17	1436 ± 30	8.8
2	56	33.1	250	78	0.32	0.009	3.846 ± 0.076	0.09198 ± 0.00047	3.847 ± 0.076	0.09190 ± 0.00047	1490 ± 26	1465 ± 10	–1.7
2	33	17.1	221	52	0.24	0.043	4.221 ± 0.063	0.09359 ± 0.00142	4.222 ± 0.063	0.09322 ± 0.00145	1370 ± 18	1492 ± 29	8.2
2	47	25.1	24	17	0.73	0.263	4.130 ± 0.133	0.09564 ± 0.00184	4.141 ± 0.133	0.09339 ± 0.00244	1394 ± 40	1496 ± 49	6.8
3	48	26.1	121	144	1.22	0.005	3.675 ± 0.062	0.09617 ± 0.00176	3.675 ± 0.062	0.09613 ± 0.00178	1551 ± 23	1550 ± 35	–0.1
3	23	12.1	110	47	0.44	0.049	3.619 ± 0.054	0.09756 ± 0.00337	3.621 ± 0.054	0.09714 ± 0.00339	1572 ± 21	1570 ± 65	–0.1
3	51	29.1	359	423	1.22	0.000	3.785 ± 0.049	0.09770 ± 0.00041	3.785 ± 0.049	0.09770 ± 0.00041	1511 ± 17	1581 ± 8	4.4
3	18	9.2	269	54	0.21	–0.009	3.669 ± 0.068	0.09819 ± 0.00208	3.669 ± 0.068	0.09827 ± 0.00208	1554 ± 25	1591 ± 40	2.4
3	21	11.1	205	70	0.35	–0.028	3.223 ± 0.177	0.09854 ± 0.00276	3.222 ± 0.177	0.09878 ± 0.00276	1742 ± 84	1601 ± 52	–8.8
3	41	21.1	153	70	0.47	–0.018	3.548 ± 0.068	0.09877 ± 0.00168	3.547 ± 0.068	0.09892 ± 0.00169	1601 ± 27	1604 ± 32	0.2
3	58	35.1	44	58	1.35	0.277	3.404 ± 0.068	0.10223 ± 0.00138	3.414 ± 0.068	0.09983 ± 0.00158	1656 ± 29	1621 ± 30	–2.2
3	50	28.1	193	18	0.10	–0.009	3.601 ± 0.049	0.10030 ± 0.00124	3.601 ± 0.049	0.10038 ± 0.00124	1580 ± 19	1631 ± 23	3.1
3	52	29.1	193	18	0.10	–0.009	3.601 ± 0.049	0.10030 ± 0.00124	3.601 ± 0.049	0.10038 ± 0.00124	1580 ± 19	1631 ± 23	3.1
3	54	31.1	123	104	0.87	0.009	3.523 ± 0.090	0.10049 ± 0.00198	3.524 ± 0.090	0.10041 ± 0.00200	1611 ± 36	1632 ± 37	1.3
3	27	14.1	180	44	0.25	–0.049	3.823 ± 0.111	0.10108 ± 0.00298	3.821 ± 0.111	0.10150 ± 0.00299	1499 ± 39	1652 ± 55	9.3
3	1	1.1	271	205	0.78	–0.015	3.548 ± 0.065	0.10154 ± 0.00118	3.547 ± 0.065	0.10167 ± 0.00118	1601 ± 26	1655 ± 22	3.3
3	5	3.1	408	246	0.62	–0.005	3.508 ± 0.045	0.10300 ± 0.00110	3.508 ± 0.045	0.10305 ± 0.00110	1617 ± 18	1680 ± 20	3.7
3	43	22.1	251	175	0.72	–0.009	3.317 ± 0.043	0.10303 ± 0.00043	3.317 ± 0.043	0.10311 ± 0.00043	1699 ± 19	1681 ± 8	–1.1
3	57	34.1	64	20	0.32	–0.180	3.297 ± 0.048	0.10182 ± 0.00226	3.291 ± 0.048	0.10338 ± 0.00234	1710 ± 22	1686 ± 42	–1.5
3	35	18.1	80	74	0.95	–0.087	3.075 ± 0.094	0.10270 ± 0.00105	3.073 ± 0.094	0.10346 ± 0.00111	1816 ± 49	1687 ± 20	–7.7

Table 1. (continued)

Grp no.	*Spot no.*	*Grain .spot*	^{238}U *(ppm)*	^{232}Th *(ppm)*	$^{232}Th/^{238}U$	*f204 (%)*	$^{238}U/^{206}Pb$ *±1σ*	$^{207}Pb/^{206}Pb$ *±1σ*	$^{238}U/^{206}Pb^*$ *±1σ*	$^{207}Pb^*/^{206}Pb^*$ *±1σ*	$^{238}U/^{206}Pb^*$ *date (Ma) ±1σ*	$^{207}Pb^*/^{206}Pb^*$ *date (Ma) ±1σ*	*Disc (%)*
3	45	24.1	62	65	1.09	0.074	3.329 ± 0.140	0.10476 ± 0.00208	3.332 ± 0.140	0.10412 ± 0.00216	1692 ± 63	1699 ± 38	0.4
3	7	4.1	182	138	0.78	0.035	3.455 ± 0.070	0.10448 ± 0.00165	3.456 ± 0.070	0.10418 ± 0.00166	1638 ± 29	1700 ± 29	3.6
3	19	10.1	108	50	0.48	0.043	3.346 ± 0.083	0.10601 ± 0.00403	3.347 ± 0.084	0.10564 ± 0.00404	1685 ± 37	1725 ± 70	2.3
3	3	2.1	68	72	1.10	0.127	3.213 ± 0.058	0.10793 ± 0.00126	3.217 ± 0.058	0.10682 ± 0.00136	1745 ± 27	1746 ± 23	0.1
3	55	32.1	79	83	1.09	0.002	3.336 ± 0.062	0.10698 ± 0.00434	3.336 ± 0.062	0.10697 ± 0.00434	1690 ± 28	1748 ± 74	3.3
3	49	27.1	152	72	0.49	0.058	3.202 ± 0.102	0.10812 ± 0.00487	3.204 ± 0.102	0.10762 ± 0.00487	1751 ± 49	1759 ± 83	0.5
3	17	9.1	210	275	1.35	–0.002	3.217 ± 0.042	0.10843 ± 0.00185	3.216 ± 0.042	0.10845 ± 0.00185	1745 ± 20	1773 ± 31	1.6
3	53	30.1	138	127	0.95	0.082	3.322 ± 0.094	0.11053 ± 0.00163	3.325 ± 0.094	0.10982 ± 0.00168	1695 ± 42	1796 ± 28	5.6
3	29	15.1	181	145	0.83	–0.008	3.450 ± 0.131	0.11092 ± 0.00300	3.450 ± 0.131	0.11099 ± 0.00300	1641 ± 55	1816 ± 49	9.6
3	15	8.1	177	113	0.66	–0.006	3.310 ± 0.055	0.11171 ± 0.00234	3.310 ± 0.055	0.11176 ± 0.00234	1702 ± 25	1828 ± 38	6.9
3	9	5.1	496	319	0.67	0.007	1.890 ± 0.049	0.17989 ± 0.00224	1.890 ± 0.049	0.17983 ± 0.00224	2737 ± 58	2651 ± 21	–3.2
D	37	19.1	580	69	0.12	0.162	4.991 ± 0.065	0.08643 ± 0.00032	4.999 ± 0.065	0.08505 ± 0.00039	1175 ± 14	1317 ± 9	10.7
D	11	6.1	388	294	0.78	–0.022	3.804 ± 0.057	0.10327 ± 0.00186	3.804 ± 0.057	0.10346 ± 0.00186	1505 ± 20	1687 ± 33	10.8
D	44	23.1	220	63	0.29	0.011	3.509 ± 0.095	0.12722 ± 0.00448	3.510 ± 0.095	0.12712 ± 0.00449	1616 ± 39	2058 ± 62	21.5
D	31	16.1	433	166	0.39	0.037	4.857 ± 0.068	0.09710 ± 0.00092	4.858 ± 0.068	0.09678 ± 0.00094	1207 ± 15	1563 ± 18	22.8
D	25	13.1	491	59	0.12	0.481	5.651 ± 0.078	0.09777 ± 0.00081	5.678 ± 0.078	0.09363 ± 0.00095	1046 ± 13	1501 ± 19	30.3
D	2	1.2	3350	39	0.01	0.022	10.723 ± 0.134	0.06848 ± 0.00020	10.726 ± 0.134	0.06830 ± 0.00021	575 ± 7	878 ± 6	34.5

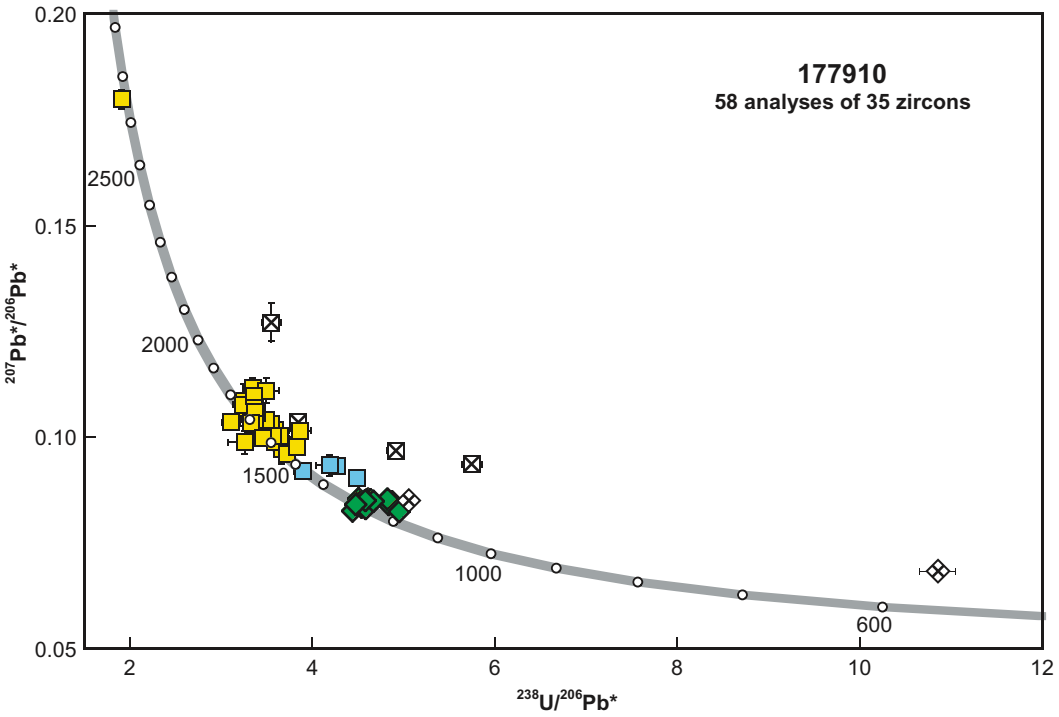

Figure 2. **U–Pb analytical data for sample 177910: metamorphosed quartz sandstone, Peters Dam. Green diamonds indicate Group 1 (metamorphic zircon rims); blue squares indicate Group 2 (youngest detrital zircon cores); yellow squares indicate Group 3 (older detrital zircon cores); crossed symbols (diamonds and squares) indicate ungrouped rim and core analyses, respectively (discordance >10%)**

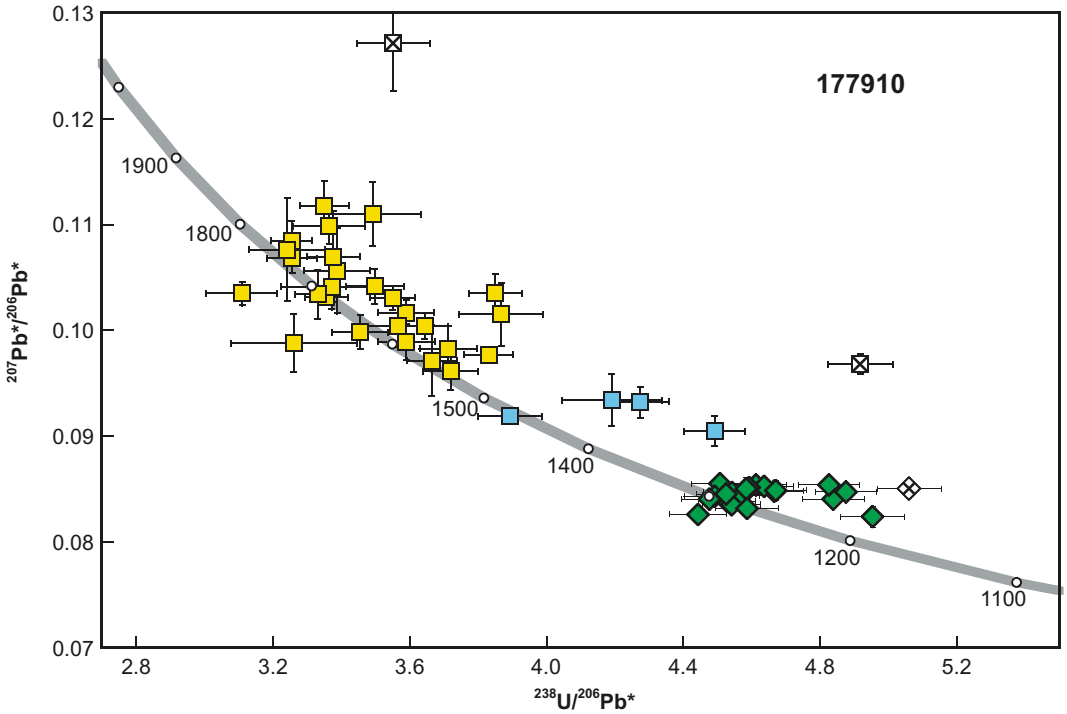

Figure 3. **Expanded view of U–Pb analytical data for sample 177910: metamorphosed quartz sandstone, Peters Dam. Symbols as in Figure 2**

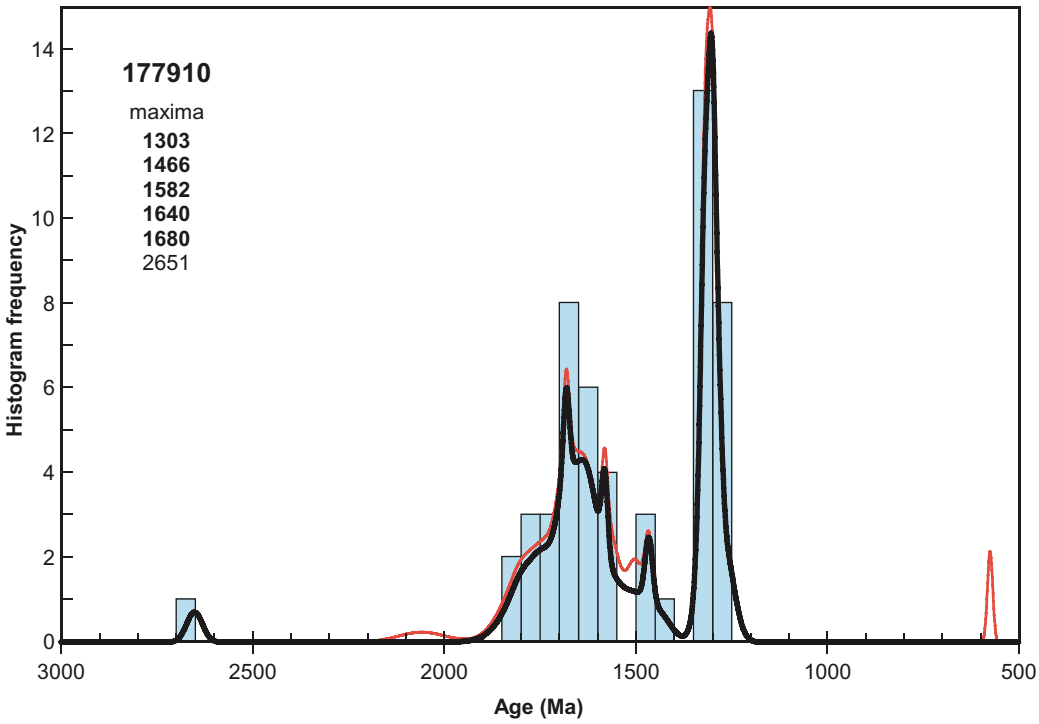

Figure 4. **Probability density plot and histogram for sample 177910: metamorphosed quartz sandstone, Peters Dam. Heavy curve, maxima values, and frequency histogram (bin width 50 Ma) include only data with discordance <10% (52 analyses of 34 zircons). Lighter curve includes all data (58 analyses of 35 zircons)**