183596: laminated paragneiss, Mount Fanny

(Wirku Metamorphics, Musgrave Province)

Location and sampling

SCOTT (SG 52-6), BATES (4646)
MGA Zone 52, 460840 E 7146470N

Sampled on 4 August 2005

This sample was collected on the northern slope of a small hill approximately 4 km southeast of the summit of Mount Fanny and 6 km southeast of Warlpapuka homestead.

Tectonic unit/relations

The unit sampled is a fine-grained, finely laminated, quartz-rich, garnet-bearing paragneiss from the central western part of BATES (Howard et al., 2009a). The unit belongs to the 1360–1317 Ma Wirku Metamorphics of the Musgrave Province. Musgrave Province supersedes the term Musgrave Complex (Howard et al., 2009b).

Petrographic description

This sample is a strongly laminated, granulite facies, orthoclase–quartz–plagioclase–garnet–biotite gneiss (probable metasandstone) with opaque oxide minerals and rare zircon. The visually assessed mineralogy includes 44% orthoclase perthite, 32% quartz, 18% plagioclase, 4% garnet, 1% opaque oxide minerals, and accessory biotite. Accessory zircon is mostly rounded, with rare monazite up to 0.2 mm in size. Quartz is partly interstitial and up to 3 mm in size. Elliptical grains of orthoclase are up to 2.5 mm long, whereas plagioclase grains are typically less than 2.5 mm across. Grains and lenses of garnet are common and range from 0.2 mm to more than 1 mm in diameter. Garnet is commonly poikiloblastic, with inclusions of opaque oxide minerals. Biotite defines a foliation in which lenses of garnet, elongate opaque oxide minerals, and elongate K-feldspar grains are oriented parallel to each other.

Zircon morphology

Zircons separated from this sample are predominantly rounded and (sub)spherical to elongate. Most grains are colourless, although several are pale brown, and are up to 100 µm long with aspect ratios up to 4:1. Cathodoluminescence (CL) images reveal cores with variable CL emission, but well-developed concentric oscillatory zoning and other igneous textures that are overgrown by several generations of rims (some displaying homogeneous features whereas others show concentric zoning). A CL image of representative zircons is shown in Figure 1.

Analytical details

This sample was analysed during two sessions on 3–5 April 2006, using SHRIMP-B, and on 15 August 2006, using SHRIMP-A. Analyses 1.1 to 54.1 (spot numbers 1–66) were obtained during the first session, together with 25 analyses of the CZ3 standard. Following rejection of one analysis as an outlier, the remaining 24 analyses indicated an external spot-to-spot (reproducibility) uncertainty of 1.05% (1σ), and a $^{238}U/^{206}Pb^*$ calibration uncertainty of 0.24% (1σ). Analyses 55.1 to 78.1 (spot numbers 67–91) were obtained during the second session, together with eight analyses of the CZ3 standard which indicated an external spot-to-spot (reproducibility) uncertainty of 1.69% (1σ), and a $^{238}U/^{206}Pb^*$ calibration uncertainty of 0.62% (1σ). Calibration uncertainties are included in the errors of $^{238}U/^{206}Pb^*$ ratios and dates listed in Table 1. Common-Pb corrections were applied to all analyses using contemporaneous common-Pb isotopic compositions determined according to the model of Stacey and Kramers (1975).

Results

Ninety-one analyses were obtained from 78 zircons, with 13 grains each analysed twice. Results are listed in Table 1, and shown in a concordia diagram (Fig. 2) and a probability density diagram (Fig. 3).

Interpretation

The analyses are concordant to slightly normally or reversely discordant (Fig. 2). Seventeen analyses (Group D; Table 1) are > 5% discordant whereas a further six analyses are interpreted as core-rim mixtures. The dates obtained from the 23 analyses in Group D are imprecise or unreliable, and are not considered geologically significant. The remaining 68 analyses can be divided into four groups based on their positions within the crystals, U and Th contents, and $^{207}Pb^*/^{206}Pb^*$ ratios (Fig. 2).

Group Y comprises two analyses of two zircon cores (Table 1), which yield a weighted mean $^{207}Pb^*/^{206}Pb^*$ date of 1272 ± 15 Ma (MSWD = 0.0054).

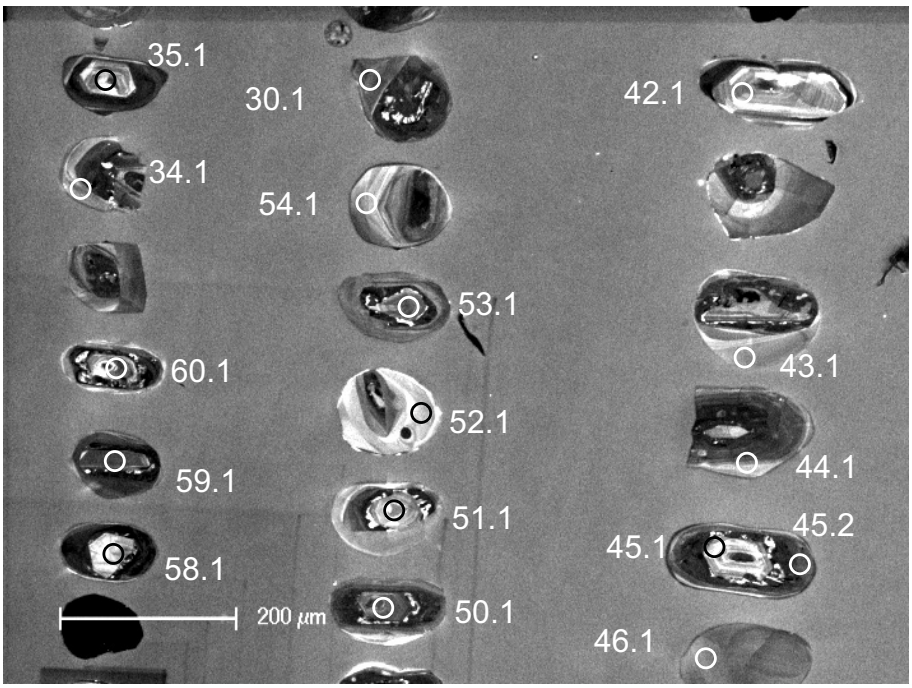

Figure 1. Cathodoluminescence image of representative zircons from sample 183596: laminated paragneiss, Mount Fanny. Numbered circles indicate the approximate positions of analysis sites.

Group S comprises 30 analyses of 30 zircons (Table 1), which yield $^{207}Pb^*/^{206}Pb^*$ dates of 1644–1313 Ma. These analyses were located in zircon cores, which show various textures, including oscillatory zoning.

Group M comprises 27 analyses of 27 zircons (Table 1), which yield a weighted mean $^{207}Pb^*/^{206}Pb^*$ date of 1161 ± 7 Ma (MSWD = 2.0). These analyses were located in zircon rims with low CL response and homogeneous textures, and indicate moderate to low Th/U ratios (1.39–0.03).

Group P comprises nine analyses (Table 1), which yield $^{207}Pb^*/^{206}Pb^*$ dates of 1247–1118 Ma. These zircons exhibit evidence of recrystallization, including fading of primary igneous textures and the development of homogeneous, inward penetrating zones. They are texturally different to Group M. These analyses indicate Th/U ratios intermediate between Group M and Group S.

It is possible that all the analyses in Groups Y and S represent unmodified detrital zircons, in which case the date of 1272 ± 15 Ma for the two analyses in Group Y represents the maximum age for the deposition of the sedimentary protolith to this metamorphic rock.

The 32 analyses in combined Groups Y and S indicate dates that define significant age components at c. 1642, 1576, 1523, 1467, 1400, and 1355 Ma (Fig. 3). These are interpreted as the ages of zircon-crystallizing rocks in the detrital source region(s) of the protolith, or the ages of detrital components within sediments which have been reworked into this rock.

The date of 1161 ± 7 Ma for the 27 analyses of zircon rims in Group M is interpreted as the age of a high-grade metamorphic event affecting this rock.

Group P is interpreted to represent radiogenic-Pb loss from zircon cores dominantly during the high-grade metamorphic event dated by Group M zircon rims.

References

Howard, HM, Smithies, RH, Evins, P, Pirajno, F and Skwarnecki, MS 2009a, Bates, WA Sheet 4646, Geological Survey of Western Australia, 1:100 000 Geological Series.

Howard, HM, Smithies, RH, Kirkland, CL, Evins, PM and Wingate, MTD 2009b, The age and geochemistry of the Alcurra Suite and implications for orthomagmatic mineralization during the Giles Event: Geological Survey of Western Australia, Record 2009/16.

Stacey, JS and Kramers, JD 1975, Approximation of terrestrial lead isotope evolution by a two-stage model: Earth and Planetary Science Letters, v. 26, p. 207–221.

Recommended reference for this publication

Kirkland, CL, Wingate, MTD, Bodorkos, S and Howard, HM 2009, 183596: laminated paragneiss, Mount Fanny; Geochronology Record 758: Geological Survey of Western Australia, 5p.

Data obtained: 15 August 2006
Data released: 30 September 2009

Table 1. Ion microprobe analytical results for zircons from sample 183596: laminated paragneiss, Mount Fanny

Group ID	Spot no.	Grain. spot	^{238}U (ppm)	^{232}Th (ppm)	$^{232}Th/^{238}U$	f204 (%)	$^{238}U/^{206}Pb$ ± 1 σ		$^{207}Pb/^{206}Pb$ ± 1 σ		$^{238}U/^{206}Pb^*$ ± 1 σ		$^{207}Pb^*/^{206}Pb^*$ ± 1 σ		$^{238}U/^{206}Pb^*$ date (Ma)	± 1 σ	$^{207}Pb^*/^{206}Pb^*$ date (Ma)	± 1 σ	Disc. (%)
Y	13	10.1	511	163	0.33	0.212	4.421	0.077	0.08488	0.00037	4.431	0.078	0.08307	0.00055	1312	25	1271	13	-3.2
Y	16	12.1	682	446	0.67	0.024	4.528	0.076	0.08333	0.00036	4.529	0.077	0.08312	0.00039	1286	24	1272	9	-1.1
S	54	45.1	234	127	0.56	0.231	4.330	0.082	0.08684	0.00183	4.340	0.083	0.08487	0.00192	1337	28	1313	44	-1.8
S	73	60.1	247	310	1.29	0.244	4.321	0.097	0.08870	0.00062	4.332	0.101	0.08662	0.00079	1339	34	1352	17	1.0
S	84	71.1	294	252	0.88	0.388	4.345	0.077	0.09007	0.00045	4.361	0.082	0.08676	0.00068	1331	28	1355	15	1.8
S	88	75.1	353	261	0.76	0.190	4.366	0.075	0.08857	0.00075	4.375	0.080	0.08695	0.00083	1327	27	1359	18	2.4
S	74	61.1	283	229	0.83	0.049	4.140	0.084	0.08839	0.00283	4.142	0.088	0.08798	0.00283	1394	33	1382	62	-0.9
S	61	49.1	472	848	1.86	0.005	4.234	0.046	0.08882	0.00039	4.234	0.048	0.08878	0.00039	1367	17	1399	8	2.3
S	60	48.2	132	80	0.62	1.303	4.139	0.056	0.10165	0.00081	4.193	0.058	0.09050	0.00167	1379	21	1436	35	4.0
S	25	21.1	332	260	0.81	0.035	4.189	0.047	0.09098	0.00046	4.190	0.048	0.09068	0.00049	1380	18	1440	10	4.2
S	89	76.1	207	136	0.68	0.051	4.189	0.109	0.09125	0.00080	4.192	0.112	0.09082	0.00088	1379	41	1443	18	4.4
S	65	53.1	402	320	0.82	0.029	4.045	0.045	0.09144	0.00069	4.046	0.046	0.09120	0.00071	1424	18	1451	15	1.9
S	79	66.1	602	702	1.21	0.067	3.970	0.068	0.09194	0.00136	3.973	0.072	0.09136	0.00137	1447	29	1454	29	0.5
S	70	57.1	674	267	0.41	0.017	4.042	0.107	0.09181	0.00082	4.042	0.110	0.09167	0.00083	1425	43	1461	17	2.4
S	82	69.1	480	521	1.12	0.140	4.010	0.069	0.09307	0.00067	4.015	0.073	0.09187	0.00074	1434	29	1465	15	2.1
S	51	42.1	485	163	0.35	0.002	3.785	0.058	0.09207	0.00033	3.785	0.058	0.09206	0.00035	1511	26	1469	7	-2.9
S	72	59.1	376	516	1.42	0.733	3.774	0.066	0.09924	0.00048	3.802	0.070	0.09295	0.00076	1505	31	1487	15	-1.2
S	58	47.2	437	372	0.88	0.401	4.026	0.044	0.09666	0.00041	4.042	0.046	0.09322	0.00064	1425	18	1492	13	4.5
S	46	37.1	223	84	0.39	0.169	3.939	0.064	0.09474	0.00178	3.945	0.065	0.09329	0.00184	1456	27	1494	37	2.5
S	62	50.1	516	421	0.84	0.031	3.859	0.043	0.09491	0.00033	3.860	0.044	0.09464	0.00040	1485	19	1521	8	2.4
S	6	4.1	371	312	0.87	0.186	3.841	0.043	0.09688	0.00044	3.848	0.044	0.09529	0.00059	1489	19	1534	12	2.9
S	20	16.1	355	263	0.77	0.048	3.857	0.086	0.09656	0.00043	3.858	0.086	0.09615	0.00049	1486	37	1551	10	4.2
S	69	56.2	307	206	0.69	0.020	3.748	0.140	0.09732	0.00148	3.749	0.142	0.09714	0.00149	1524	65	1570	29	2.9
S	31	25.1	320	350	1.13	0.102	3.736	0.042	0.09809	0.00055	3.740	0.043	0.09721	0.00064	1527	20	1571	12	2.8
S	44	35.1	280	258	0.95	0.475	3.799	0.043	0.10151	0.00059	3.818	0.045	0.09741	0.00086	1500	20	1575	17	4.8
S	4	3.1	253	241	0.98	0.065	3.741	0.043	0.09809	0.00048	3.744	0.044	0.09753	0.00058	1526	20	1577	11	3.2
S	63	51.1	257	241	0.97	0.038	3.603	0.051	0.09787	0.00078	3.604	0.052	0.09754	0.00105	1579	26	1578	20	-0.1
S	33	26.1	197	126	0.66	0.028	3.603	0.043	0.09781	0.00065	3.604	0.044	0.09757	0.00068	1578	22	1578	13	0.0
S	81	68.1	62	44	0.73	-0.153	3.512	0.115	0.09677	0.00456	3.507	0.117	0.09809	0.00456	1617	61	1588	87	-1.8
S	78	65.1	131	88	0.70	0.107	3.380	0.061	0.09961	0.00182	3.383	0.064	0.09868	0.00187	1669	36	1599	35	-4.4
S	85	72.1	198	123	0.64	-0.051	3.607	0.107	0.09896	0.00203	3.605	0.110	0.09940	0.00204	1578	54	1613	38	2.2
S	90	77.1	238	178	0.78	-0.019	3.502	0.082	0.10091	0.00059	3.502	0.085	0.10107	0.00060	1619	45	1644	11	1.5
P	35	27.1	208	305	1.51	0.147	5.090	0.059	0.07813	0.00059	5.098	0.060	0.07689	0.00064	1155	15	1118	17	-3.2
P	76	63.1	302	265	0.90	0.018	5.078	0.087	0.07851	0.00046	5.079	0.093	0.07836	0.00055	1159	23	1156	14	-0.2
P	32	25.2	699	26	0.04	0.093	5.024	0.054	0.08050	0.00030	5.029	0.056	0.07972	0.00034	1169	14	1190	9	1.8
P	12	9.1	432	168	0.40	0.060	4.953	0.055	0.08062	0.00117	4.956	0.057	0.08012	0.00118	1185	15	1200	29	1.3
P	27	22.1	265	13	0.05	0.240	5.015	0.060	0.08226	0.00057	5.027	0.061	0.08023	0.00087	1170	16	1203	21	2.8
P	11	8.1	492	429	0.90	0.030	4.959	0.060	0.08094	0.00037	4.960	0.061	0.08069	0.00042	1184	16	1214	10	2.5
P	56	46.1	350	416	1.23	-0.006	5.042	0.056	0.08079	0.00044	5.042	0.058	0.08084	0.00051	1166	15	1217	12	4.2
P	37	29.1	1447	188	0.13	0.026	4.909	0.079	0.08208	0.00027	4.910	0.080	0.08186	0.00029	1195	21	1242	7	3.8
P	49	40.1	868	179	0.21	0.153	4.595	0.049	0.08337	0.00050	4.602	0.051	0.08206	0.00055	1267	15	1247	13	-1.6
M	1	1.1	286	95	0.34	0.135	5.142	0.059	0.07859	0.00053	5.149	0.060	0.07745	0.00065	1144	15	1133	17	-1.0
M	7	5.1	509	73	0.15	0.065	5.117	0.056	0.07802	0.00038	5.121	0.058	0.07747	0.00039	1150	14	1133	10	-1.5
M	18	14.1	376	231	0.64	0.081	5.149	0.057	0.07827	0.00044	5.153	0.059	0.07759	0.00052	1143	14	1136	13	-0.6
M	3	2.2	665	29	0.04	0.072	5.123	0.056	0.07825	0.00034	5.127	0.057	0.07764	0.00039	1149	14	1138	10	-1.0
M	52	43.1	242	219	0.94	0.155	5.081	0.058	0.07904	0.00054	5.089	0.060	0.07774	0.00081	1157	15	1140	21	-1.4
M	64	52.1	164	192	1.21	0.058	5.003	0.076	0.07839	0.00063	5.006	0.078	0.07791	0.00209	1174	20	1144	53	-2.6
M	59	48.1	415	136	0.34	0.006	5.371	0.233	0.07801	0.00038	5.371	0.234	0.07796	0.00038	1101	52	1146	10	3.9
M	57	47.1	515	229	0.46	0.058	5.077	0.063	0.07850	0.00036	5.080	0.065	0.07801	0.00038	1158	16	1147	10	-1.0
M	24	20.1	312	404	1.34	0.076	5.117	0.058	0.07877	0.00049	5.120	0.059	0.07813	0.00054	1150	15	1150	14	0.0

Table 1. (continued)

Group ID	Spot no.	Grain. spot	^{238}U (ppm)	^{232}Th (ppm)	$^{232}Th/^{238}U$	f204 (%)	$^{238}U/^{206}Pb$ ± 1 c		$^{207}Pb/^{206}Pb$ ± 1 c		$^{238}U/^{206}Pb^*$ ± 1 c		$^{207}Pb^*/^{206}Pb^*$ ± 1 c		$^{238}U/^{206}Pb^*$ date (Ma)	± 1 c	$^{207}Pb^*/^{206}Pb^*$ date (Ma)	± 1 c	Disc. (%)
M	50	41.1	603	382	0.65	0.062	5.001	0.054	0.07870	0.00042	5.004	0.056	0.07817	0.00042	1174	14	1151	11	-2.0
M	10	7.1	238	321	1.39	0.119	5.086	0.058	0.07931	0.00056	5.092	0.060	0.07831	0.00112	1156	15	1155	28	-0.1
M	19	15.1	211	256	1.25	0.332	5.159	0.060	0.08123	0.00059	5.177	0.061	0.07842	0.00096	1139	15	1158	24	1.6
M	29	23.1	490	318	0.67	0.048	5.113	0.056	0.07897	0.00038	5.116	0.058	0.07857	0.00045	1151	14	1161	11	0.9
M	9	6.2	843	33	0.04	0.029	5.113	0.057	0.07887	0.00043	5.114	0.059	0.07862	0.00047	1151	14	1163	12	1.0
M	45	36.1	394	124	0.32	0.102	5.056	0.056	0.07952	0.00041	5.061	0.057	0.07866	0.00051	1162	14	1164	13	0.1
M	43	34.1	317	176	0.57	-0.025	5.090	0.057	0.07854	0.00045	5.089	0.058	0.07875	0.00052	1156	14	1166	13	0.8
M	42	33.2	398	9	0.02	0.061	4.991	0.055	0.07945	0.00040	4.994	0.056	0.07893	0.00041	1177	15	1170	10	-0.5
M	15	11.2	1093	48	0.05	0.012	4.833	0.052	0.07917	0.00045	4.833	0.054	0.07907	0.00046	1212	15	1174	11	-3.3
M	30	24.1	378	316	0.86	0.033	4.966	0.060	0.07943	0.00111	4.967	0.061	0.07915	0.00115	1182	16	1176	29	-0.6
M	68	56.1	565	46	0.08	0.002	5.062	0.087	0.07932	0.00033	5.062	0.092	0.07930	0.00049	1162	23	1180	12	1.5
M	38	30.1	475	276	0.60	0.038	5.068	0.064	0.07963	0.00064	5.070	0.065	0.07931	0.00069	1161	16	1180	17	1.6
M	67	55.1	244	153	0.65	0.043	4.903	0.090	0.07978	0.00049	4.905	0.095	0.07941	0.00053	1196	25	1182	13	-1.2
M	66	54.1	219	294	1.39	-0.057	5.045	0.064	0.07900	0.00055	5.042	0.065	0.07948	0.00065	1166	16	1184	16	1.5
M	47	38.1	235	178	0.78	-0.019	4.927	0.057	0.07939	0.00051	4.926	0.059	0.07955	0.00056	1191	16	1186	14	-0.5
M	40	32.1	335	180	0.55	0.007	5.095	0.057	0.07967	0.00045	5.095	0.058	0.07961	0.00074	1155	14	1187	18	2.7
M	17	13.1	494	183	0.38	-0.025	5.190	0.061	0.07949	0.00041	5.188	0.062	0.07970	0.00052	1136	15	1190	13	4.5
M	26	21.2	627	23	0.04	0.051	4.979	0.059	0.08035	0.00063	4.982	0.060	0.07992	0.00064	1179	16	1195	16	1.3
D	28	22.2	139	222	1.65	0.292	5.064	0.061	0.07734	0.00071	5.079	0.063	0.07489	0.00106	1159	16	1066	28	-8.7
D	48	39.1	354	128	0.37	0.216	4.977	0.061	0.07816	0.00045	4.987	0.063	0.07634	0.00079	1178	16	1104	21	-6.7
D	41	33.1	202	124	0.63	0.100	3.341	0.055	0.09927	0.00104	3.345	0.056	0.09841	0.00106	1686	32	1594	20	-5.8
D	91	78.1	88	95	1.11	0.023	3.291	0.059	0.09988	0.00075	3.292	0.062	0.09968	0.00076	1710	37	1618	14	-5.7
D	55	45.2	915	15	0.02	0.028	4.730	0.069	0.07914	0.00121	4.731	0.070	0.07891	0.00122	1236	20	1170	31	-5.7
D	87	74.1	528	258	0.50	0.055	3.644	0.068	0.09330	0.00108	3.646	0.072	0.09283	0.00123	1562	35	1484	25	-5.2
D	5	3.2	1053	30	0.03	0.053	4.877	0.053	0.07935	0.00025	4.880	0.054	0.07890	0.00028	1202	15	1170	7	-2.7
D	34	26.2	1254	16	0.01	0.032	4.855	0.069	0.08030	0.00037	4.857	0.070	0.08003	0.00038	1207	19	1198	9	-0.8
D	75	62.1	443	74	0.17	0.002	5.226	0.091	0.07751	0.00037	5.226	0.097	0.07749	0.00048	1129	23	1134	12	0.5
D	53	44.1	459	124	0.28	0.200	5.222	0.057	0.07942	0.00038	5.233	0.059	0.07773	0.00057	1127	14	1140	15	1.1
D	80	67.1	389	15	0.04	0.047	5.201	0.091	0.07887	0.00041	5.203	0.097	0.07847	0.00044	1133	23	1159	11	2.2
D	21	17.1	691	21	0.03	0.020	4.958	0.058	0.08189	0.00033	4.959	0.059	0.08172	0.00036	1184	15	1239	9	4.4
D	23	19.1	753	42	0.06	0.152	4.673	0.051	0.08652	0.00082	4.680	0.053	0.08522	0.00086	1248	15	1321	20	5.5
D	71	58.1	153	60	0.41	0.952	4.050	0.102	0.10173	0.00243	4.088	0.106	0.09354	0.00268	1411	41	1499	54	5.9
D	39	31.1	170	209	1.27	-0.084	5.084	0.060	0.08072	0.00062	5.079	0.061	0.08144	0.00075	1159	15	1232	18	6.0
D	83	70.1	537	407	0.78	0.054	4.644	0.080	0.08648	0.00041	4.646	0.085	0.08602	0.00043	1257	25	1339	10	6.1
D	36	28.1	335	253	0.78	0.115	3.811	0.043	0.10019	0.00051	3.815	0.044	0.09920	0.00061	1501	20	1609	11	6.7
D	14	11.1	351	233	0.69	0.020	4.309	0.049	0.09102	0.00073	4.310	0.050	0.09085	0.00073	1345	17	1444	15	6.8
D	8	6.1	263	320	1.26	-0.032	4.261	0.048	0.09207	0.00127	4.259	0.050	0.09234	0.00128	1360	18	1474	26	7.8
D	77	64.1	360	287	0.82	0.073	4.050	0.113	0.09670	0.00051	4.053	0.116	0.09607	0.00071	1422	45	1549	14	8.2
D	2	2.1	453	250	0.57	0.087	4.195	0.056	0.09460	0.00121	4.199	0.057	0.09385	0.00123	1377	21	1505	25	8.5
D	86	73.1	228	165	0.75	0.489	4.065	0.070	0.10204	0.00184	4.085	0.075	0.09783	0.00201	1411	29	1583	38	10.8
D	22	18.1	184	75	0.42	0.355	4.216	0.052	0.10214	0.00083	4.231	0.053	0.09908	0.00108	1368	19	1607	20	14.9

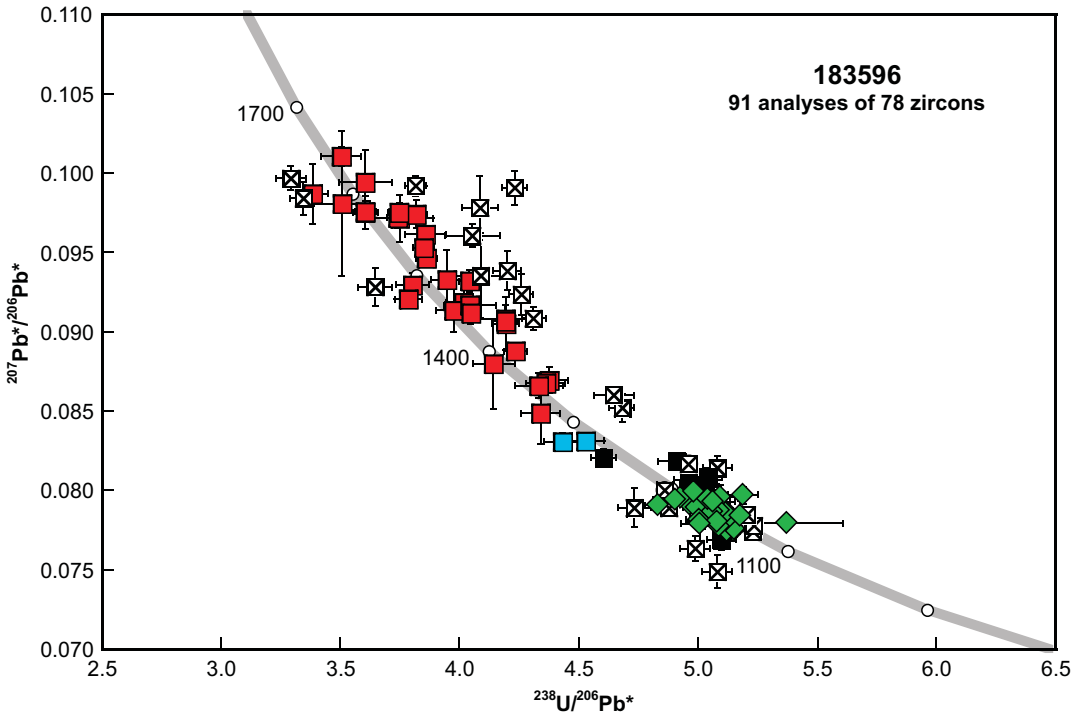

Figure 2. **U–Pb analytical data for sample 183596: laminated paragneiss, Mount Fanny. Blue squares indicate Group Y (youngest detrital zircons); red squares indicate Group S (older detrital zircons); green diamonds indicate Group M (metamorphic zircon rims); black squares indicate Group P (detrital zircons affected by radiogenic-Pb loss); crossed squares indicate Group D (discordance >5% or core-rim mixture).**

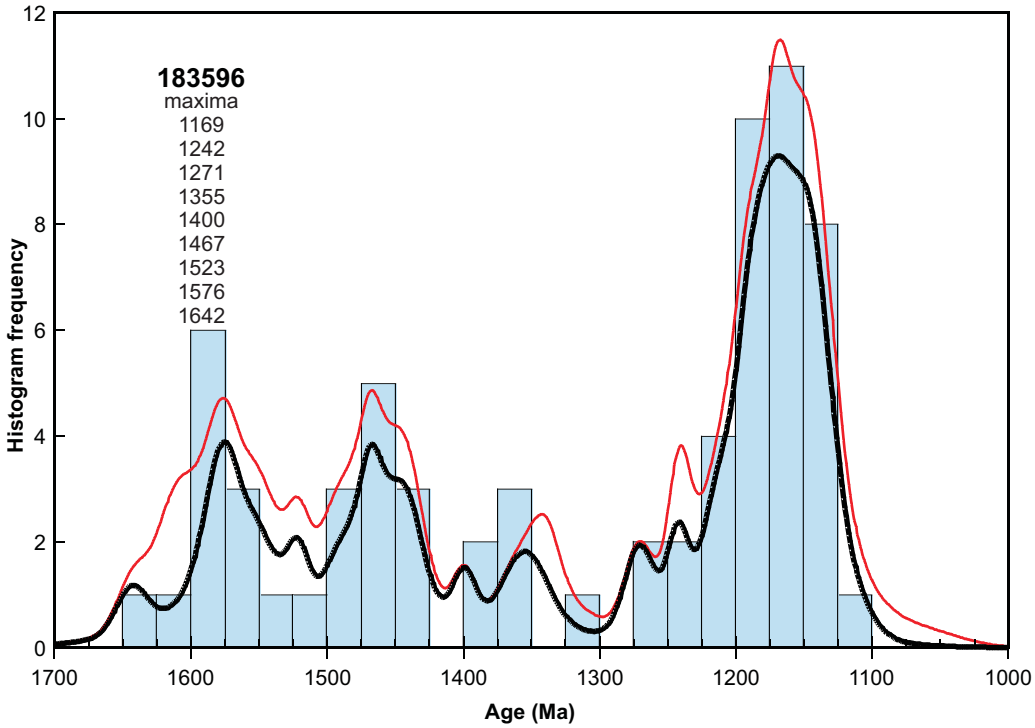

Figure 3. **Probability density diagram and histogram for sample 183596: laminated paragneiss, Mount Fanny. Heavy curve, maxima values, and frequency histogram (bin width 25 Ma) include only data with discordance <5% and that are not core-rim mixtures (68 analyses of 64 zircons). Lighter curve includes all data (91 analyses of 78 zircons).**