180256: metagranodiorite, Hubert Soak

Location and sampling

SCOTT (SG52-6), BATES (4646)
MGA Zone 52, 488577E 7143422N

Sampled on 24 September 2003

The sample was taken from an outcrop about 1 km southeast of Hubert Soak.

Tectonic unit/relations

The unit sampled is a moderately to strongly foliated seriate to porphyritic metamorphosed granodiorite that contains rare rounded K-feldspar phenocrysts up to 4 cm in length, and pyroxene-rich clots up to 2 cm long that are strongly flattened parallel to the foliation. The granodiorite is part of the Miturtu Monzogranite, within the Mesoproterozoic Pitjantjatjara Supersuite of the Musgrave Complex (Howard et al., in prep.), and was sampled in order to constrain the age of Miturtu plutonism.

Petrographic description

The visually estimated primary mineralogy of this sample includes 15% quartz, 40% K-feldspar, 20% plagioclase, 10% clinopyroxene, 7–8% orthopyroxene, 5% garnet, 2–3% opaque oxide minerals, and accessory minerals (apatite, biotite, and zircon). The quartz and feldspars are anhedral and, apart from rare plagioclase to 8 mm long, are mostly less than 4 mm in size. K-feldspar is microperthite, with very narrow exsolution lamellae of plagioclase. The mafic minerals lie in subparallel lenses up to 7 mm long, and comprise granular clinopyroxene, less abundant granular to prismatic orthopyroxene, granular opaque oxide minerals, and apatite. Partial rims of fine-grained garnet enclose most of these mafic aggregates, especially adjacent to opaque oxide minerals and orthopyroxene. There are also rare flakes of biotite containing symplectites of quartz. Zircon, and possible monazite, forms grains 0.1 – 0.5 mm in diameter within the mafic aggregates. Some orthopyroxene grains are veined and rimmed by small amounts of brown clay minerals, but most of the minerals reflect granulite facies metamorphism, with garnet rims possibly formed during isobaric cooling from peak metamorphic conditions.

Zircon morphology

Zircons isolated from this sample range from subhedral to well-rounded, and are clear and colourless. They are up to 250 μm long (although some are fragments of larger crystals), with aspect ratios up to 4:1. Many are pervasively cracked. Most crystals consist of central cores (in some cases showing evidence of alteration or resorption) in which concentric growth zoning is prominent, surrounded by relatively featureless rims. A cathodoluminescence image of representative zircons is shown in Figure 1.

Analytical details

This sample was analysed on 21 November 2004 (using SHRIMP-B) and 9 December 2004 (using SHRIMP-A). Analyses 1.1 to 24.2 were obtained during the first session, together with 13 analyses of the CZ3 standard that indicated a $^{238}U/^{206}Pb^*$ calibration uncertainty of 1.80% (1σ). Analyses 26.1 to 55.2 were obtained during the second session, together with 15 analyses of the CZ3 standard. Following the deletion of one standard analysis as an outlier, the remaining 14 analyses indicated a $^{238}U/^{206}Pb^*$ calibration uncertainty of 1.71% (1σ).

Common-Pb corrections were initially applied using Broken Hill common-Pb isotopic compositions for all analyses, and these data are presented in Table 1. However, owing to the existence of a strong negative correlation between $f204$ and $^{207}Pb^*/^{206}Pb^*$ dates (corrected for common Pb) in each of the analytical sessions (Fig. 2), explicit correction for common Pb was avoided for the purpose of weighted mean date calculations (see below).

Results

Sixty-seven analyses were obtained from 55 zircons, with 12 grains (3, 5, 6, 18, 22, 24, 25, 35, 43, 47, 50, and 55) each analysed twice. Results are listed in Table 1, and shown in Figure 3.

Interpretation

With the exception of analysis 6.1, all analyses yield $^{207}Pb/^{206}Pb$ dates (uncorrected for common Pb) of approximately 1180 Ma. However, owing to the existence of a strong negative correlation between common-Pb corrected $^{207}Pb^*/^{206}Pb^*$ dates and $f204$ (Fig. 2), the weighted mean date of the zircons is not based on $^{207}Pb^*/^{206}Pb^*$ ratios corrected for common Pb by reference to measured $^{204}Pb/^{206}Pb$. Instead the weighted mean date is determined from the intersection of a regression line (Fig. 3), anchored at contemporaneous crustal common Pb ($^{207}Pb/^{206}Pb$ = 0.924 at 1180 Ma; Stacey and Kramers, 1975), with the concordia curve. The analyses can be divided into three groups based on their uncorrected $^{238}U/^{206}Pb$ and $^{207}Pb/^{206}Pb$ ratios and their discordance values.

Group 1 comprises 63 broadly concordant analyses of 52 zircons that have $^{238}U/^{206}Pb$ and $^{207}Pb/^{206}Pb$ ratios within error of a regression line (anchored at $^{238}U/^{206}Pb$ = 0, $^{207}Pb/^{206}Pb$ = 0.924) that intersects the concordia curve at 1176 ± 6 Ma (MSWD = 1.02).

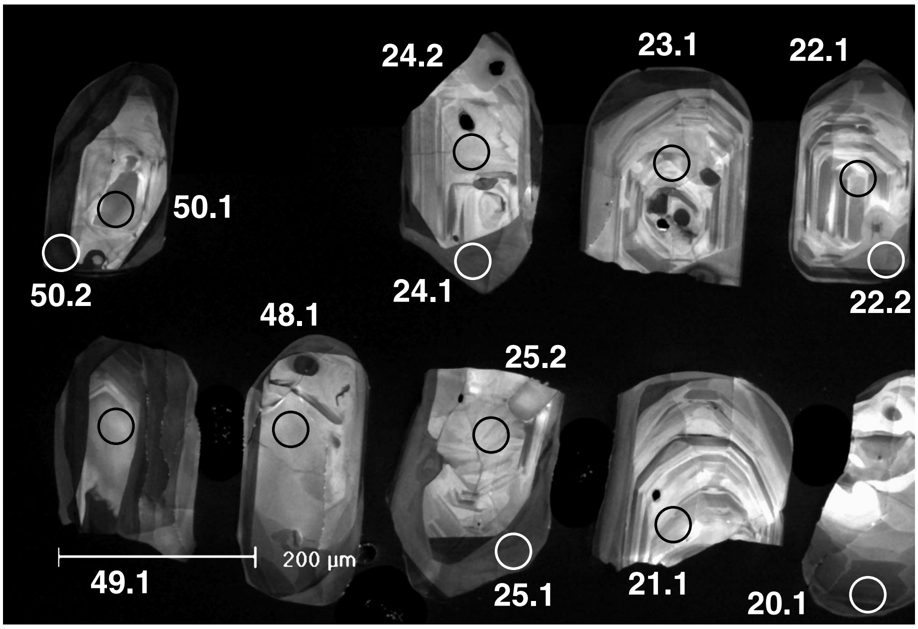

Figure 1. Cathodoluminescence image of representative zircons from sample 180256: metagranodiorite, Hubert Soak. Numbered circles represent approximate positions of analysis sites

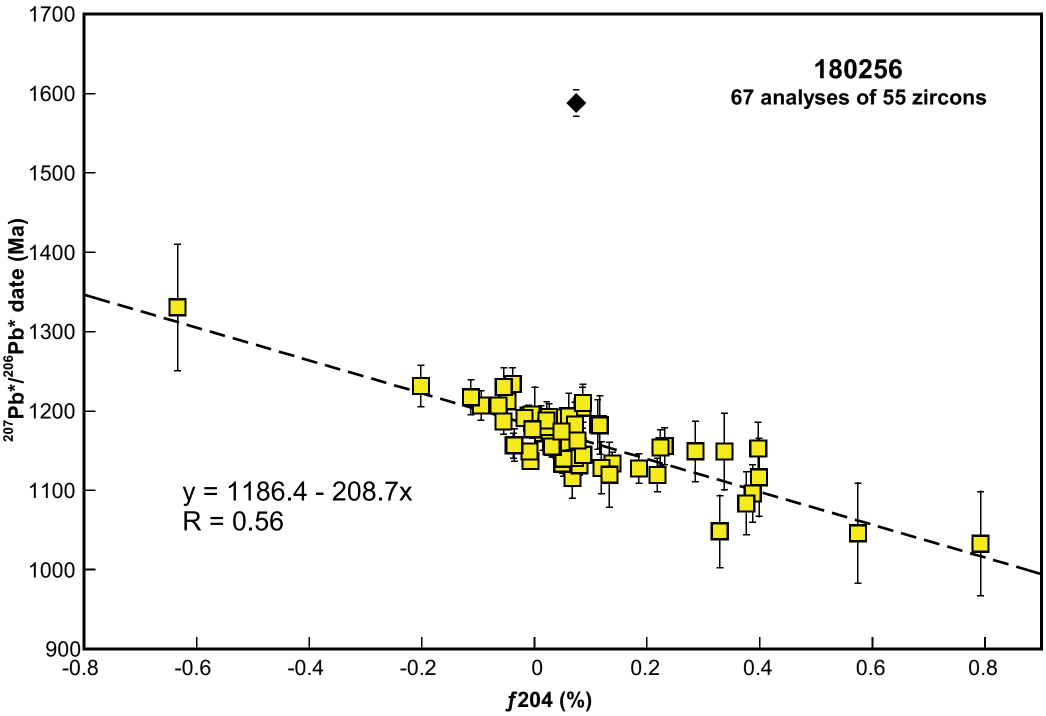

Figure 2. Correlation between ƒ204 and $^{207}Pb^*/^{206}Pb^*$ date (corrected for common Pb) for sample 180256: metagranodiorite, Hubert Soak. Dashed line depicts a regression through all data (excluding analysis 6.1, shown by filled diamond). The equation of the regression line is included, and R is Pearson's correlation coefficient

Table 1. Ion microprobe analytical results for zircons from sample 180256: metagranodiorite, Hubert Soak

Grain .spot	U (ppm)	Th (ppm)	Th/U	f204 (%)	$^{238}U/^{206}Pb$ ±1σ	$^{207}Pb/^{206}Pb$ ±1σ	$^{238}U/^{206}Pb^*$ ±1σ	$^{207}Pb^*/^{206}Pb^*$ ±1σ	$^{238}U/^{206}Pb^*$ age (Ma) ±1σ	$^{207}Pb^*/^{206}Pb^*$ age (Ma) ±1σ	Disc (%)
1.1	171	150	0.91	0.015	5.073 ± 0.097	0.07913 ± 0.00075	5.074 ± 0.097	0.07900 ± 0.00087	1160 ± 20	1172 ± 22	1.1
2.1	117	75	0.66	0.397	5.109 ± 0.099	0.08172 ± 0.00096	5.129 ± 0.100	0.07821 ± 0.00133	1148 ± 20	1152 ± 34	0.3
3.1	78	75	0.99	0.399	5.095 ± 0.103	0.08034 ± 0.00108	5.116 ± 0.103	0.07681 ± 0.00190	1151 ± 21	1116 ± 49	–3.1
3.2	450	213	0.49	0.050	5.052 ± 0.093	0.08022 ± 0.00045	5.054 ± 0.093	0.07978 ± 0.00051	1164 ± 20	1191 ± 13	2.3
4.1	220	124	0.58	0.087	4.948 ± 0.095	0.07869 ± 0.00060	4.952 ± 0.095	0.07793 ± 0.00078	1186 ± 21	1145 ± 20	–3.6
5.1	47	49	1.08	0.001	5.196 ± 0.110	0.07978 ± 0.00132	5.196 ± 0.110	0.07977 ± 0.00157	1135 ± 22	1191 ± 39	4.8
5.2	206	134	0.67	0.186	5.011 ± 0.094	0.07889 ± 0.00063	5.020 ± 0.094	0.07724 ± 0.00071	1171 ± 20	1128 ± 18	–3.9
6.1	238	195	0.85	0.074	3.607 ± 0.067	0.09873 ± 0.00079	3.609 ± 0.067	0.09809 ± 0.00089	1577 ± 26	1588 ± 17	0.7
6.2	165	124	0.77	0.012	4.918 ± 0.093	0.07964 ± 0.00068	4.918 ± 0.093	0.07953 ± 0.00084	1193 ± 21	1185 ± 21	–0.7
7.1	149	187	1.30	0.231	4.951 ± 0.094	0.08038 ± 0.00077	4.963 ± 0.094	0.07834 ± 0.00091	1183 ± 21	1155 ± 23	–2.4
8.1	257	143	0.58	0.050	4.956 ± 0.092	0.07862 ± 0.00056	4.958 ± 0.092	0.07818 ± 0.00061	1184 ± 20	1151 ± 15	–2.9
9.1	80	82	1.05	0.286	5.072 ± 0.101	0.08060 ± 0.00105	5.086 ± 0.101	0.07808 ± 0.00150	1157 ± 21	1149 ± 38	–0.7
10.1	123	82	0.69	0.223	5.130 ± 0.098	0.08025 ± 0.00080	5.141 ± 0.099	0.07828 ± 0.00087	1146 ± 20	1154 ± 22	0.7
11.1	115	125	1.12	0.086	4.950 ± 0.096	0.08103 ± 0.00088	4.955 ± 0.096	0.08028 ± 0.00106	1185 ± 21	1204 ± 26	1.6
12.1	69	51	0.77	0.113	5.010 ± 0.102	0.08043 ± 0.00114	5.016 ± 0.102	0.07943 ± 0.00125	1172 ± 22	1183 ± 31	0.9
13.1	162	119	0.76	0.067	5.155 ± 0.098	0.07736 ± 0.00075	5.158 ± 0.098	0.07676 ± 0.00097	1142 ± 20	1115 ± 25	–2.4
14.1	174	185	1.10	0.068	5.071 ± 0.101	0.07889 ± 0.00064	5.074 ± 0.101	0.07829 ± 0.00076	1160 ± 21	1154 ± 19	–0.5
15.1	137	171	1.29	–0.095	4.834 ± 0.092	0.07957 ± 0.00076	4.829 ± 0.092	0.08041 ± 0.00077	1213 ± 21	1207 ± 19	–0.5
16.1	59	47	0.82	0.792	5.495 ± 0.118	0.08070 ± 0.00144	5.539 ± 0.120	0.07367 ± 0.00239	1070 ± 21	1032 ± 66	–3.6
17.1	279	158	0.59	0.049	5.167 ± 0.096	0.07845 ± 0.00055	5.170 ± 0.096	0.07802 ± 0.00059	1140 ± 19	1147 ± 15	0.6
18.1	119	75	0.65	–0.039	4.875 ± 0.094	0.08118 ± 0.00084	4.873 ± 0.094	0.08151 ± 0.00086	1203 ± 21	1234 ± 21	2.5
19.1	93	70	0.79	0.388	4.967 ± 0.098	0.07946 ± 0.00094	4.986 ± 0.098	0.07603 ± 0.00138	1178 ± 21	1096 ± 36	–7.5
20.1	431	249	0.60	0.047	4.805 ± 0.088	0.07898 ± 0.00059	4.808 ± 0.088	0.07857 ± 0.00063	1218 ± 20	1161 ± 16	–4.9
21.1	75	64	0.87	0.376	4.910 ± 0.098	0.07890 ± 0.00103	4.928 ± 0.099	0.07556 ± 0.00150	1191 ± 22	1084 ± 40	–9.9
22.1	111	128	1.19	0.068	5.015 ± 0.097	0.07953 ± 0.00087	5.019 ± 0.097	0.07892 ± 0.00099	1171 ± 21	1170 ± 25	–0.1
23.1	74	65	0.91	0.574	5.029 ± 0.101	0.07926 ± 0.00124	5.058 ± 0.102	0.07416 ± 0.00233	1163 ± 22	1046 ± 63	–11.2
24.1	214	94	0.45	–0.055	4.941 ± 0.092	0.07911 ± 0.00061	4.939 ± 0.092	0.07959 ± 0.00066	1189 ± 20	1187 ± 16	–0.1
25.1	308	134	0.45	0.138	4.983 ± 0.092	0.07871 ± 0.00052	4.990 ± 0.092	0.07749 ± 0.00054	1177 ± 20	1134 ± 14	–3.9
24.2	78	65	0.86	0.116	4.979 ± 0.099	0.08043 ± 0.00108	4.985 ± 0.100	0.07940 ± 0.00148	1178 ± 22	1182 ± 37	0.3
26.1	393	198	0.52	0.014	4.815 ± 0.084	0.07939 ± 0.00042	4.816 ± 0.084	0.07927 ± 0.00044	1216 ± 19	1179 ± 11	–3.2
27.1	452	213	0.49	0.054	4.776 ± 0.085	0.07887 ± 0.00039	4.779 ± 0.085	0.07840 ± 0.00042	1225 ± 20	1157 ± 11	–5.9
28.1	403	204	0.52	0.080	4.988 ± 0.087	0.07812 ± 0.00040	4.992 ± 0.087	0.07741 ± 0.00050	1177 ± 19	1132 ± 13	–4.0
29.1	449	203	0.47	–0.006	4.968 ± 0.086	0.07756 ± 0.00038	4.968 ± 0.086	0.07762 ± 0.00038	1182 ± 19	1137 ± 10	–4.0
30.1	233	131	0.58	0.218	4.988 ± 0.093	0.07886 ± 0.00053	4.999 ± 0.094	0.07693 ± 0.00081	1176 ± 20	1119 ± 21	–5.0
31.1	269	140	0.54	0.072	5.080 ± 0.090	0.07839 ± 0.00051	5.084 ± 0.090	0.07776 ± 0.00063	1158 ± 19	1141 ± 16	–1.5
32.1	423	158	0.39	–0.037	5.087 ± 0.091	0.07802 ± 0.00059	5.085 ± 0.091	0.07835 ± 0.00062	1157 ± 19	1156 ± 16	–0.1
33.1	379	157	0.43	0.050	4.733 ± 0.083	0.07791 ± 0.00043	4.735 ± 0.083	0.07747 ± 0.00045	1235 ± 20	1133 ± 12	–9.0
34.1	78	72	0.95	–0.048	4.831 ± 0.091	0.08021 ± 0.00093	4.828 ± 0.091	0.08063 ± 0.00097	1213 ± 21	1213 ± 24	–0.1
35.1	384	197	0.53	–0.010	4.938 ± 0.086	0.07980 ± 0.00049	4.938 ± 0.086	0.07990 ± 0.00049	1189 ± 19	1194 ± 12	0.5
35.2	79	65	0.85	0.061	5.161 ± 0.097	0.08037 ± 0.00093	5.164 ± 0.097	0.07984 ± 0.00120	1141 ± 20	1193 ± 30	4.3
36.1	284	166	0.60	0.051	4.916 ± 0.086	0.07817 ± 0.00082	4.918 ± 0.086	0.07772 ± 0.00086	1193 ± 19	1140 ± 22	–4.7
37.1	473	231	0.51	–0.005	4.916 ± 0.085	0.07946 ± 0.00036	4.916 ± 0.085	0.07950 ± 0.00037	1194 ± 19	1185 ± 9	–0.8
38.1	427	209	0.51	0.026	4.988 ± 0.087	0.07926 ± 0.00038	4.989 ± 0.087	0.07903 ± 0.00043	1178 ± 19	1173 ± 11	–0.4
39.1	94	93	1.02	–0.054	4.851 ± 0.089	0.08087 ± 0.00096	4.848 ± 0.089	0.08135 ± 0.00102	1209 ± 20	1230 ± 25	1.7

Table 1 (continued)

Grain .spot	U (ppm)	Th (ppm)	Th/U	f204 (%)	$^{238}U/^{206}Pb$ ±1σ	$^{207}Pb/^{206}Pb$ ±1σ	$^{238}U/^{206}Pb^*$ ±1σ	$^{207}Pb^*/^{206}Pb^*$ ±1σ	$^{238}U/^{206}Pb^*$ age (Ma) ±1σ	$^{207}Pb^*/^{206}Pb^*$ age (Ma) ±1σ	Disc (%)
40.1	249	121	0.50	0.086	5.014 ± 0.090	0.07866 ± 0.00049	5.018 ± 0.090	0.07790 ± 0.00055	1171 ± 19	1144 ± 14	–2.4
41.1	453	208	0.47	–0.006	4.931 ± 0.087	0.07989 ± 0.00041	4.931 ± 0.087	0.07994 ± 0.00041	1190 ± 19	1195 ± 10	0.4
42.1	307	120	0.40	0.033	5.088 ± 0.089	0.07859 ± 0.00047	5.090 ± 0.089	0.07831 ± 0.00053	1156 ± 19	1155 ± 13	–0.1
43.1	432	212	0.51	–0.017	4.943 ± 0.087	0.07960 ± 0.00040	4.943 ± 0.087	0.07975 ± 0.00040	1188 ± 19	1191 ± 10	0.3
43.2	133	79	0.62	–0.113	5.172 ± 0.094	0.07983 ± 0.00074	5.167 ± 0.094	0.08082 ± 0.00090	1141 ± 19	1217 ± 22	6.3
44.1	92	91	1.02	0.119	5.046 ± 0.094	0.07831 ± 0.00086	5.052 ± 0.094	0.07726 ± 0.00128	1164 ± 20	1128 ± 33	–3.2
45.1	121	148	1.26	0.072	5.105 ± 0.093	0.08005 ± 0.00077	5.109 ± 0.093	0.07942 ± 0.00113	1152 ± 19	1183 ± 28	2.6
18.2	448	236	0.54	0.026	4.850 ± 0.085	0.08002 ± 0.00066	4.851 ± 0.085	0.07979 ± 0.00069	1208 ± 19	1192 ± 17	–1.4
46.1	349	175	0.52	0.031	4.979 ± 0.087	0.07860 ± 0.00043	4.981 ± 0.087	0.07832 ± 0.00050	1180 ± 19	1155 ± 13	–2.1
47.1	73	54	0.77	0.133	5.142 ± 0.098	0.07811 ± 0.00099	5.148 ± 0.098	0.07694 ± 0.00157	1144 ± 20	1120 ± 41	–2.2
47.2	397	195	0.51	0.021	4.997 ± 0.089	0.07948 ± 0.00042	4.998 ± 0.089	0.07930 ± 0.00044	1176 ± 19	1180 ± 11	0.3
22.2	253	150	0.61	0.077	5.164 ± 0.091	0.07928 ± 0.00054	5.168 ± 0.091	0.07860 ± 0.00069	1140 ± 18	1162 ± 17	1.9
25.2	90	67	0.77	0.022	5.072 ± 0.094	0.07981 ± 0.00090	5.073 ± 0.095	0.07962 ± 0.00096	1160 ± 20	1188 ± 24	2.3
48.1	114	75	0.68	–0.063	4.941 ± 0.091	0.07982 ± 0.00080	4.938 ± 0.091	0.08038 ± 0.00084	1189 ± 20	1206 ± 21	1.5
49.1	114	107	0.97	–0.202	4.963 ± 0.091	0.07964 ± 0.00081	4.953 ± 0.091	0.08141 ± 0.00107	1186 ± 20	1231 ± 26	3.7
50.1	456	207	0.47	–0.009	5.048 ± 0.088	0.07799 ± 0.00040	5.047 ± 0.088	0.07807 ± 0.00041	1165 ± 19	1149 ± 10	–1.4
50.2	128	155	1.26	–0.036	4.983 ± 0.091	0.07808 ± 0.00078	4.981 ± 0.091	0.07840 ± 0.00080	1179 ± 20	1157 ± 20	–1.9
51.1	134	91	0.70	0.086	5.043 ± 0.092	0.08127 ± 0.00094	5.047 ± 0.092	0.08051 ± 0.00098	1165 ± 19	1210 ± 24	3.7
52.1	320	140	0.45	0.048	4.984 ± 0.088	0.07951 ± 0.00049	4.987 ± 0.088	0.07909 ± 0.00055	1178 ± 19	1174 ± 14	–0.3
53.1	69	52	0.77	0.337	5.034 ± 0.097	0.08105 ± 0.00113	5.051 ± 0.098	0.07807 ± 0.00190	1164 ± 21	1149 ± 48	–1.4
54.1	82	64	0.81	0.329	4.993 ± 0.095	0.07716 ± 0.00098	5.009 ± 0.095	0.07424 ± 0.00167	1173 ± 20	1048 ± 45	–12.0
55.1	13	28	2.22	–0.634	4.946 ± 0.134	0.08010 ± 0.00249	4.915 ± 0.134	0.08565 ± 0.00352	1194 ± 30	1330 ± 80	10.3
55.2	418	251	0.62	–0.004	4.947 ± 0.088	0.07916 ± 0.00047	4.946 ± 0.088	0.07920 ± 0.00047	1187 ± 19	1177 ± 12	–0.8

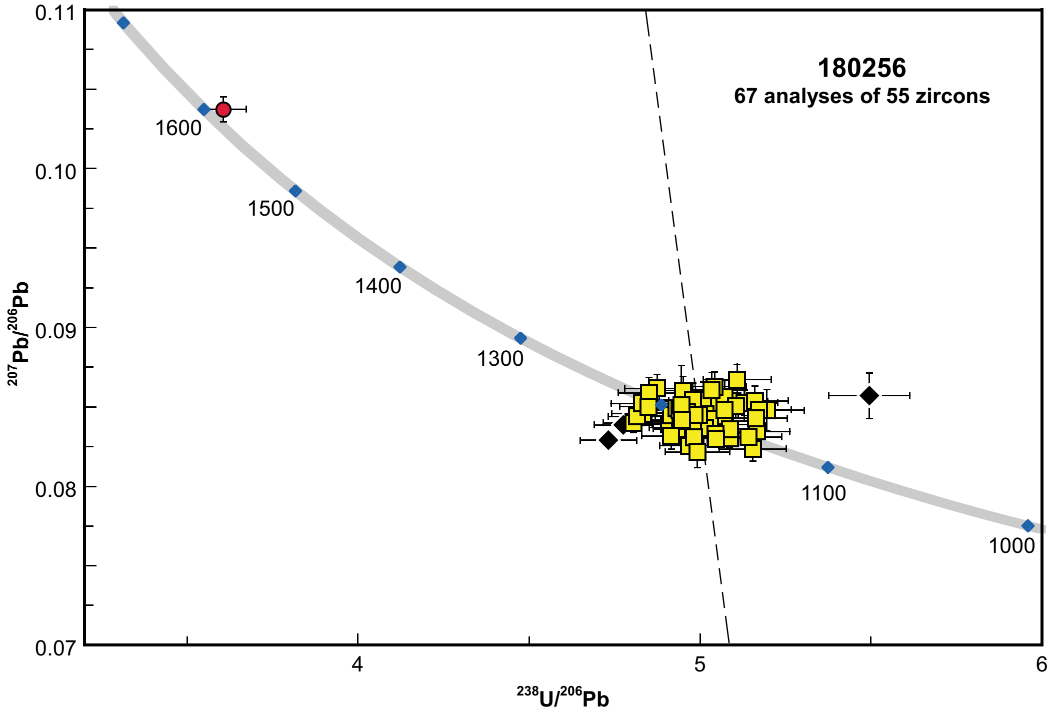

Figure 3. U–Pb analytical data, not corrected for common Pb, for sample 180256: metagranodiorite, Hubert Soak. Squares denote Group 1 (igneous crystallization and metamorphism); filled diamonds denote Group 2 (xenocrystic material or radiogenic Pb loss); filled circle denotes analysis 6.1 (xenocrystic core). Dashed line depicts a regression line defined by the data in Group 1, and anchored at contemporaneous crustal common Pb ($^{207}Pb/^{206}Pb$ = 0.924 at 1180 Ma; Stacey and Kramers, 1975)

Group 2 comprises three analyses of three zircons (16.1, 27.1, and 33.1) that lie beyond uncertainty of the 1176 ± 6 Ma regression line. Analyses 27.1 and 33.1 are reversely discordant and lie on the old side of the regression line, whereas analysis 16.1 is normally discordant and lies on the younger side of the regression line.

The remaining analysis (6.1) is concordant and has a $^{207}Pb^*/^{206}Pb^*$ date of 1588 ± 17 Ma (1σ).

The vast majority of analyses sited within the core and rim zircon identified in the cathodoluminescence images (Fig. 1) yielded uncorrected $^{238}U/^{206}Pb$ and $^{207}Pb/^{206}Pb$ ratios within uncertainty of the 1176 ± 6 Ma regression line. This implies that igneous crystallization of the precursor granodiorite and subsequent granulite facies metamorphism were not significantly separated in time. Consequently the date of 1176 ± 6 Ma indicated by the uncorrected $^{238}U/^{206}Pb$ and $^{207}Pb/^{206}Pb$ ratios of the 63 analyses in Group 1 is interpreted as the best estimate of the age of igneous crystallization of the precursor granodiorite, and a maximum age for granulite facies metamorphism. Analysis 6.1 is from a zircon core with anomalously low cathodoluminescence response and well-developed oscillatory zoning, and is interpreted as a xenocrystic core.

Analyses 27.1 and 33.1 yielded uncorrected $^{238}U/^{206}Pb$ and $^{207}Pb/^{206}Pb$ ratios slightly older than the Group 1 regression line, and possibly incorporated minor amounts of older (xenocrystic) zircon. Analysis 16.1 yielded uncorrected $^{238}U/^{206}Pb$ and $^{207}Pb/^{206}Pb$ ratios younger than the Group 1 regression line, and is interpreted to be of a zircon that has undergone minor post-metamorphic loss of radiogenic Pb.

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Data released: 30 June 2006