225756: volcaniclastic rock, Wittenoom Gorge

(Dales Gorge Member, Brockman Iron Formation, Hamersley Group, Hamersley Basin, Capricorn Orogen)

Location and sampling

Mount Bruce (SF 50-11), Wittenoom (2553)
MGA Zone 50, 636102E 7529919N

Sampled on 11 September 2017

This sample was collected from a subvertical exposure on the east side of Joffre Creek in Wittenoom Gorge, about 23 km east-southeast of Mount King, 8.5 km north-northeast of Joffre Falls, and 2.0 km southwest of Club Pool.

Geological context

The unit sampled is a volcaniclastic bed within the 2494–2454 Ma Brockman Iron Formation of the Hamersley Group (Martin, 2020a). The Brockman Iron Formation is about 0.5 km thick, consists of banded iron-formation, chert, mudstone, and siltstone, with minor dolerite sills, and conformably overlies the Mount McRae Shale and is conformably overlain by the Weeli Wolli Formation (Martin, 2020a). Numerous tuffaceous horizons within the Brockman Iron Formation have been dated, and indicate depositional ages between 2495 and 2454 Ma (Trendall et al., 1998; Pickard, 2002; Trendall et al., 2004). Tuffaceous horizons within the Dales Gorge Member are marker beds that are commonly referred to as shale bands (Trendall and Blockley, 1968) and abbreviated as DS1-16. The sampled volcaniclastic layer is about 10 cm thick (Fig. 1) and occurs within DS9 in the middle of the 2494–2464 Ma Dales Gorge Member, which is 120–180 m thick and the lowermost of four members within the Brockman Iron Formation (Martin, 2020b). An underlying volcaniclastic bed within DS9 at this locality yielded a maximum depositional age of 2477 ± 4 Ma (GSWA 225757, Wingate et al., 2021a). Tuffaceous volcanic rocks near the base of the Dales Gorge Member (DS1 and DS2), about 0.9 km to the northeast, yielded igneous crystallization ages of 2485 ± 9 Ma (GSWA 225758, Wingate et al., 2021b) and 2480 ± 7 Ma (GSWA 225760, Wingate et al., 2021c).

Petrographic description

The sample is an altered volcaniclastic rock, consisting of about 80–85% clay minerals, 15–20% chlorite, and trace rutile, quartz, and opaque minerals. The main clay minerals are pale yellow to orange, fibrous crystals up to 0.1 mm long, which are either not aligned or form bundles of radiating fibres. The clay exhibits moderate birefringence and may be a smectite group mineral. Pale green chlorite forms oval and elongate features up to 0.15 mm long, and smaller, less well-defined grains intergrown with clay minerals. The chlorite does not resemble typical detrital mica and is considered more likely to be authigenic, possibly infilling pores during diagenesis. Opaque grains are mostly <0.05 mm in size, have cubic or elongate forms, and are mostly magnetite and hematite, and minor high-relief rutile. Rare detrital quartz grains are angular and up to 0.1 mm in size. There is no indication of sedimentary layering, although there is a poorly developed fissility defined by discontinuous wavy dark iron oxide folia. No evidence for a volcanic origin was observed in thin section, although this may have been obliterated by the abundant clay. The sample is not deformed or metamorphosed.

Zircon morphology

Zircons isolated from this sample are colourless to dark brown, anhedral to euhedral, and variably rounded. The crystals are up to 200 μm long, and equant to elongate, with aspect ratios up to 4:1. In cathodoluminescence (CL) images, most zircons exhibit concentric zoning, some are dominated by high-U metamict zones, and many contain inclusions of other minerals. A CL image of representative zircons is shown in Figure 2.

Analytical details

This sample was analysed over three sessions: on 17–18, 18–19, and 25–26 January 2019, using SHRIMP-B. Analyses 1.1 to 29.1 (spot numbers 1–29) were obtained during the first session, together with 13 analyses of the M257 standard, of which 12 analyses indicated an external spot-to-spot (reproducibility) uncertainty of 0.50% (1σ) and a $^{238}U/^{206}Pb^*$ calibration uncertainty of 0.17% (1σ). Analyses 30.1 to 49.1 (spot numbers 30–49) were obtained during the second session, together with 11 analyses of the M257 standard, which indicated an external spot-to-spot (reproducibility) uncertainty of 0.50% (1σ) and a $^{238}U/^{206}Pb^*$ calibration uncertainty of 0.19% (1σ). Analyses 50.1 to 55.1 (spot numbers 50–55) were obtained during the third session, together with 11 analyses of the M257 standard, of which 10 analyses indicated an external spot-to-spot (reproducibility) uncertainty of 0.71% (1σ) and a $^{238}U/^{206}Pb^*$ calibration uncertainty of 0.31% (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 isotopic compositions determined according to the model of Stacey and Kramers (1975).

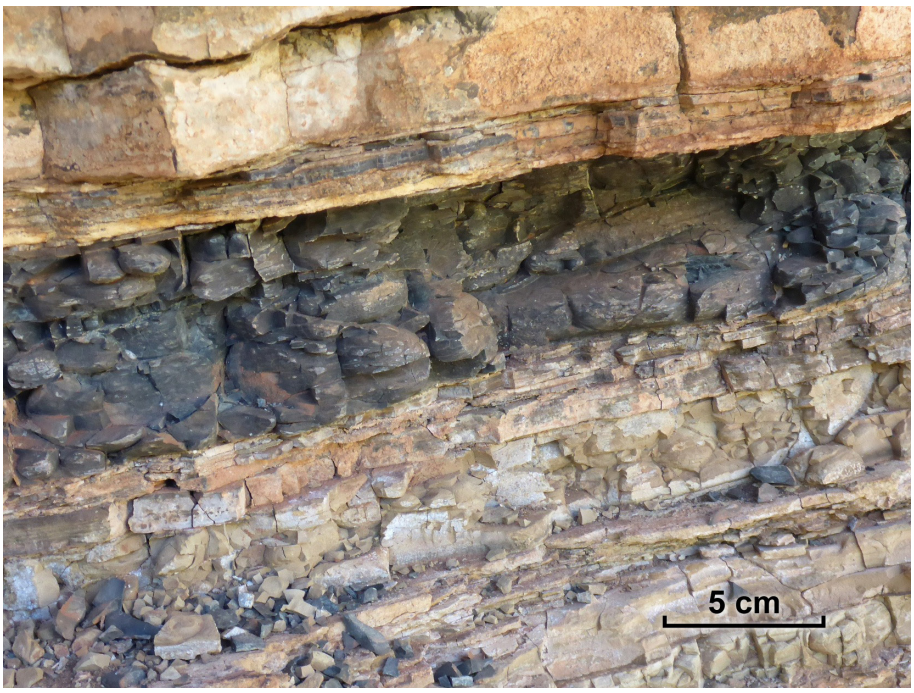

Figure 1. Outcrop image for sample 225756: volcaniclastic rock, Wittenoom Gorge. The geochronology sample was obtained from the dark layer

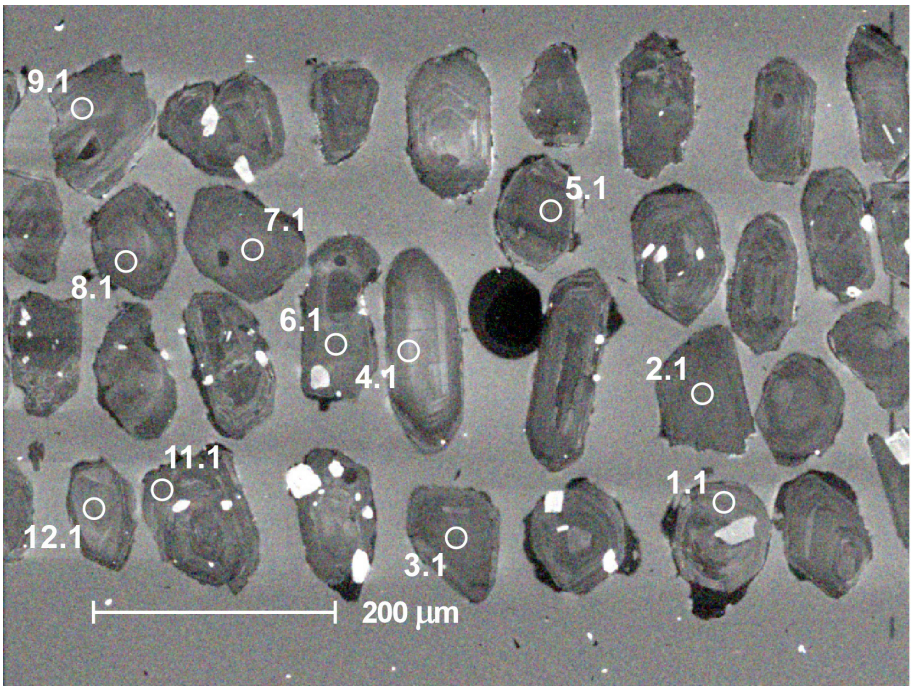

Figure 2. Cathodoluminescence image of representative zircons from sample 225756: volcaniclastic rock, Wittenoom Gorge. Numbered circles indicate the approximate locations of analysis sites

Table 1. Ion microprobe analytical results for zircons from sample 225756: volcaniclastic rock, Wittenoom Gorge

Group ID	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. (%)
Y	4	4.1	86	102	1.18	0.224	2.135	0.020	0.16183	0.00089	2.139	0.020	0.15984	0.00102	2472	20	2454	11	-0.8
S	29	29.1	187	78	0.42	0.060	2.167	0.017	0.16154	0.00061	2.168	0.017	0.16100	0.00063	2445	16	2466	7	0.9
S	53	53.1	137	86	0.63	0.067	2.162	0.023	0.16170	0.00076	2.163	0.023	0.16110	0.00079	2449	22	2467	8	0.7
S	54	54.1	210	154	0.73	0.040	2.173	0.021	0.16146	0.00059	2.174	0.021	0.16110	0.00061	2440	20	2467	6	1.1
S	31	31.1	209	91	0.44	0.052	2.177	0.037	0.16163	0.00060	2.178	0.037	0.16117	0.00062	2435	35	2468	6	1.3
S	12	12.1	142	90	0.64	0.015	2.178	0.029	0.16133	0.00068	2.179	0.029	0.16119	0.00069	2435	27	2468	7	1.3
S	13	13.1	154	55	0.35	0.000	2.126	0.033	0.16134	0.00068	2.126	0.033	0.16134	0.00068	2485	32	2470	7	-0.6
S	36	36.1	229	104	0.46	0.146	2.247	0.029	0.16278	0.00096	2.250	0.029	0.16148	0.00099	2371	25	2471	10	4.1
S	3	3.1	245	181	0.74	0.042	2.179	0.022	0.16190	0.00054	2.180	0.022	0.16153	0.00055	2434	20	2472	6	1.5
S	6	6.1	227	100	0.44	0.020	2.139	0.016	0.16182	0.00055	2.140	0.016	0.16165	0.00056	2472	15	2473	6	0.0
S	46	46.1	256	133	0.52	0.019	2.163	0.017	0.16184	0.00054	2.164	0.017	0.16167	0.00055	2449	16	2473	6	1.0
S	51	51.1	185	86	0.46	0.066	2.137	0.021	0.16226	0.00063	2.139	0.021	0.16168	0.00066	2473	21	2473	7	0.0
S	52	52.1	185	143	0.77	0.124	2.250	0.022	0.16282	0.00065	2.253	0.022	0.16172	0.00071	2368	20	2474	7	4.3
S	43	43.1	380	196	0.51	0.007	2.153	0.023	0.16180	0.00045	2.153	0.023	0.16174	0.00045	2459	22	2474	5	0.6
S	30	30.1	244	160	0.65	0.025	2.117	0.016	0.16197	0.00055	2.118	0.016	0.16175	0.00056	2493	15	2474	6	-0.8
S	17	17.1	186	252	1.35	0.026	2.202	0.032	0.16200	0.00064	2.203	0.032	0.16177	0.00065	2413	29	2474	7	2.5
S	45	45.1	244	111	0.45	0.016	2.152	0.016	0.16194	0.00057	2.152	0.016	0.16180	0.00057	2460	15	2475	6	0.6
S	32	32.1	145	58	0.40	0.067	2.193	0.028	0.16241	0.00072	2.194	0.028	0.16180	0.00075	2421	26	2475	8	2.2
S	25	25.1	253	184	0.73	0.233	2.207	0.023	0.16391	0.00054	2.212	0.023	0.16184	0.00065	2405	21	2475	7	2.8
S	20	20.1	472	561	1.19	0.100	2.239	0.018	0.16276	0.00038	2.241	0.018	0.16187	0.00041	2379	16	2475	4	3.9
S	27	27.1	266	123	0.46	0.023	2.145	0.015	0.16214	0.00053	2.146	0.015	0.16193	0.00054	2466	15	2476	6	0.4
S	24	24.1	305	185	0.61	0.101	2.214	0.024	0.16285	0.00051	2.217	0.024	0.16195	0.00054	2400	22	2476	6	3.1
S	5	5.1	304	353	1.16	0.000	2.130	0.015	0.16197	0.00051	2.130	0.015	0.16197	0.00051	2481	15	2476	5	-0.2
S	21	21.1	150	146	0.98	0.071	2.167	0.017	0.16263	0.00066	2.169	0.018	0.16200	0.00069	2444	17	2477	7	1.3
S	23	23.1	207	232	1.12	0.000	2.193	0.017	0.16205	0.00061	2.193	0.017	0.16205	0.00061	2422	15	2477	6	2.2
S	38	38.1	232	125	0.54	0.006	2.134	0.030	0.16211	0.00059	2.135	0.030	0.16206	0.00059	2477	29	2477	6	0.0
S	14	14.1	200	106	0.53	0.006	2.252	0.034	0.16211	0.00059	2.252	0.034	0.16206	0.00060	2369	30	2477	6	4.4
S	49	49.1	226	140	0.62	0.150	2.201	0.017	0.16342	0.00061	2.204	0.017	0.16208	0.00067	2412	15	2478	7	2.7

Table 1. continued

Group ID	Spot no.	Grain. spot	^{238}U (ppm)	^{232}Th (ppm)	$\frac{^{232}Th}{^{238}U}$	ƒ204 (%)	$^{238}U/^{206}Pb$ ± 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. (%)
S	37	37.1	264	159	0.60	-0.004	2.158	0.016	0.16210	0.00053	2.158	0.016	0.16214	0.00053	2455	15	2478	5	0.9
S	8	8.1	201	114	0.57	0.011	2.148	0.016	0.16226	0.00057	2.148	0.016	0.16216	0.00057	2464	16	2478	6	0.6
S	26	26.1	205	136	0.66	0.034	2.148	0.030	0.16250	0.00059	2.148	0.030	0.16219	0.00060	2464	29	2479	6	0.6
S	41	41.1	199	153	0.77	-0.030	2.160	0.017	0.16195	0.00061	2.159	0.017	0.16222	0.00062	2453	16	2479	6	1.0
S	2	2.1	229	111	0.49	0.073	2.205	0.016	0.16291	0.00056	2.207	0.016	0.16227	0.00059	2409	15	2479	6	2.8
S	50	50.1	244	137	0.56	0.056	2.173	0.027	0.16282	0.00059	2.174	0.027	0.16232	0.00061	2439	26	2480	6	1.6
S	19	19.1	247	192	0.78	0.041	2.157	0.028	0.16270	0.00053	2.158	0.028	0.16233	0.00055	2455	27	2480	6	1.0
S	16	16.1	195	84	0.43	0.019	2.176	0.017	0.16252	0.00063	2.177	0.017	0.16235	0.00063	2437	16	2480	7	1.7
S	10	10.1	125	106	0.85	0.036	2.140	0.018	0.16272	0.00075	2.140	0.018	0.16240	0.00076	2471	18	2481	8	0.4
S	47	47.1	179	206	1.15	-0.014	2.193	0.017	0.16234	0.00065	2.193	0.017	0.16246	0.00065	2422	16	2481	7	2.4
S	1	1.1	188	123	0.66	0.048	2.137	0.032	0.16300	0.00061	2.138	0.032	0.16257	0.00063	2474	31	2483	7	0.4
S	55	55.1	238	142	0.60	0.000	2.212	0.021	0.16267	0.00056	2.212	0.021	0.16267	0.00056	2404	19	2484	6	3.2
S	40	40.1	204	128	0.63	-0.013	2.172	0.017	0.16266	0.00063	2.172	0.017	0.16278	0.00064	2442	16	2485	7	1.7
S	22	22.1	116	102	0.88	0.124	2.200	0.019	0.16397	0.00080	2.203	0.019	0.16286	0.00086	2413	18	2486	9	2.9
S	44	44.1	229	137	0.60	-0.022	2.149	0.027	0.16269	0.00059	2.148	0.027	0.16288	0.00059	2464	26	2486	6	0.9
S	9	9.1	138	153	1.11	0.106	2.126	0.025	0.16399	0.00069	2.128	0.025	0.16305	0.00074	2483	24	2488	8	0.2
S	7	7.1	139	96	0.70	-0.059	2.132	0.018	0.16278	0.00072	2.131	0.018	0.16331	0.00074	2481	17	2490	8	0.4
S	48	48.1	228	122	0.53	0.066	2.147	0.030	0.16390	0.00058	2.149	0.030	0.16331	0.00061	2463	28	2490	6	1.1
S	33	33.1	180	235	1.31	0.101	2.164	0.026	0.16471	0.00073	2.166	0.027	0.16382	0.00153	2447	25	2495	16	1.9
S	39	39.1	265	130	0.49	0.021	2.187	0.029	0.16410	0.00063	2.188	0.029	0.16392	0.00064	2427	27	2497	7	2.8
S	15	15.1	109	75	0.69	-0.010	2.096	0.019	0.16664	0.00081	2.096	0.019	0.16673	0.00081	2515	19	2525	8	0.4
S	34	34.1	204	100	0.49	0.030	1.935	0.021	0.18146	0.00061	1.935	0.021	0.18119	0.00062	2685	24	2664	6	-0.8
D	28	28.1	112	38	0.34	0.000	2.207	0.019	0.14232	0.02191	2.207	0.019	0.14232	0.02191	2409	18	2256	266	-6.8
D	18	18.1	167	1618	9.68	0.167	2.371	0.035	0.16294	0.00072	2.375	0.035	0.16145	0.00080	2265	28	2471	8	8.3
D	42	42.1	158	233	1.48	0.081	2.294	0.032	0.16225	0.00071	2.295	0.032	0.16152	0.00075	2331	27	2472	8	5.7
D	35	35.1	188	182	0.97	0.073	2.281	0.018	0.16262	0.00062	2.283	0.018	0.16197	0.00064	2342	15	2476	7	5.4
D	11	11.1	292	326	1.12	0.078	2.289	0.022	0.16272	0.00049	2.291	0.022	0.16203	0.00051	2335	19	2477	5	5.7

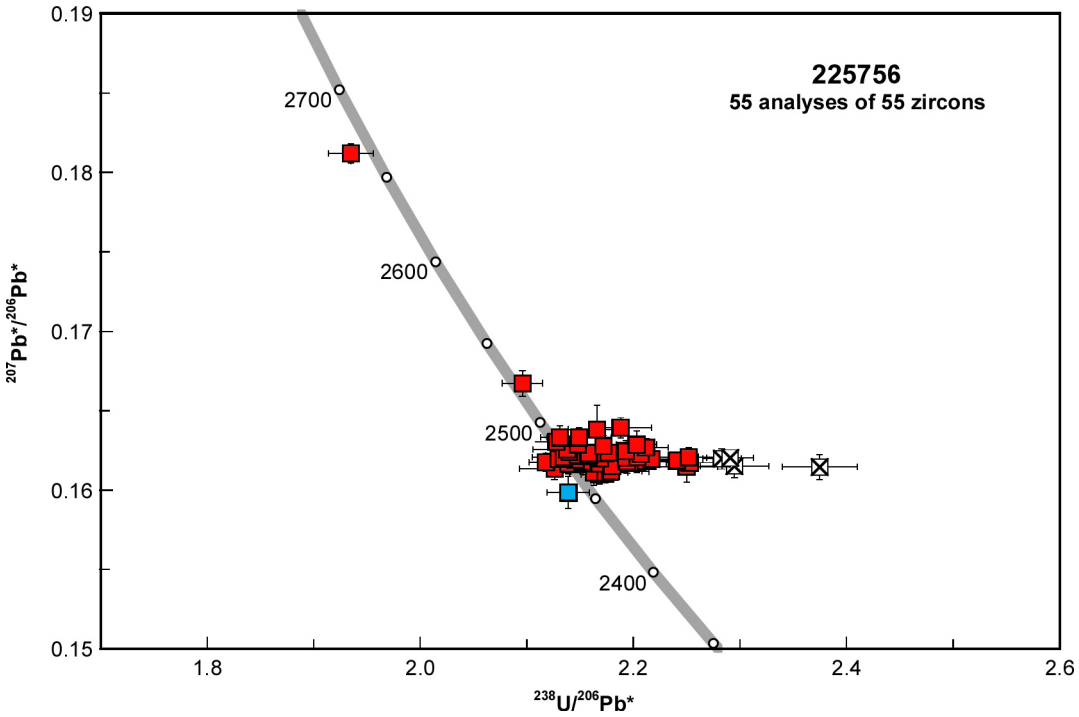

Figure 3. U–Pb analytical data for zircons from sample 225756: volcaniclastic rock, Wittenoom Gorge. Blue square indicates Group Y (youngest detrital zircon); red squares indicate Group S (older detrital zircons); crossed squares indicate Group D (discordance >5%)

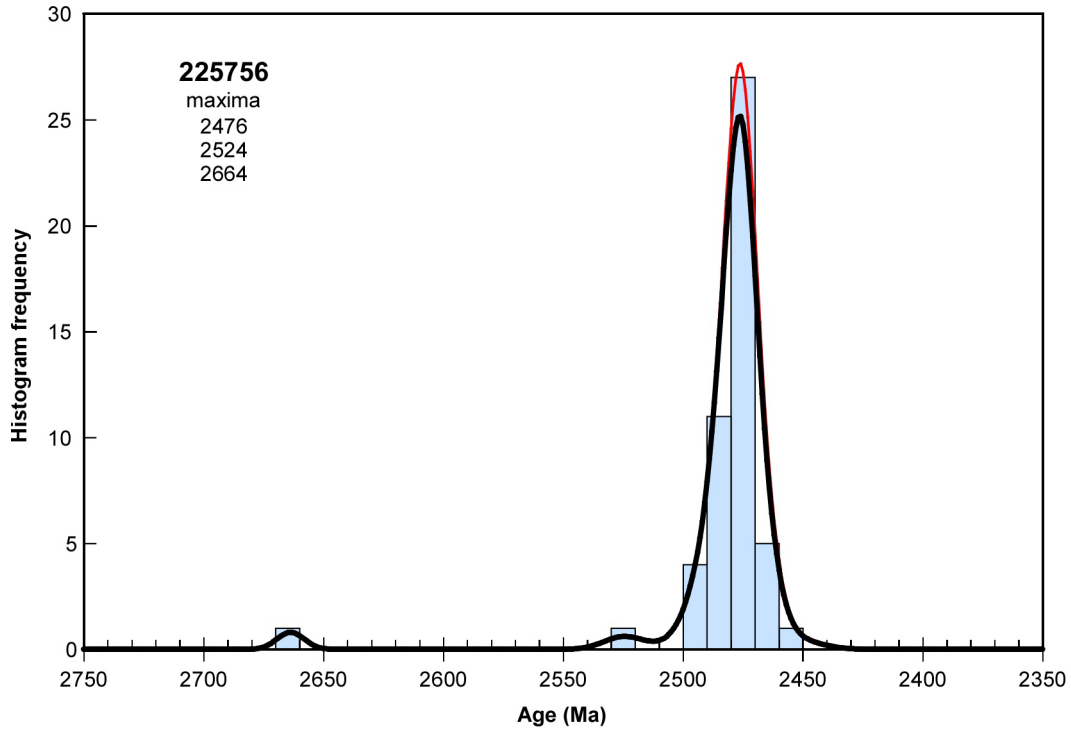

Figure 4. Probability density diagram and histogram for sample 225756: volcaniclastic rock, Wittenoom Gorge. Thick curve, maxima values, and blue histogram (bin width 10 Ma) include only data with discordance <5% (50 analyses of 50 zircons). Thin curve includes all data (55 analyses of 55 zircons)

Results

Fifty-five analyses were obtained from 55 zircons. Results are listed in Table 1, and shown in a concordia diagram (Fig. 3) and a probability density plot (Fig. 4).

Interpretation

The analyses are concordant to moderately discordant (Fig. 3). Five analyses are >5% discordant. The dates obtained from these five analyses (Group D; Table 1) are unreliable, and are considered not to be geologically significant. The remaining 50 analyses can be divided into two groups, based on their $^{207}Pb^*/^{206}Pb^*$ ratios.

Group Y comprises one analysis (Table 1), which yields a $^{207}Pb^*/^{206}Pb^*$ date of 2454 ± 11 Ma (1σ).

Group S comprises 49 analyses (Table 1), which yield $^{207}Pb^*/^{206}Pb^*$ dates of 2664–2466 Ma.

It is possible that all of the analyses in Groups Y and S are of unmodified detrital zircons, in which case the date of 2454 ± 11 (1σ) for the single analysis in Group Y represents a maximum depositional age. A more conservative estimate of the maximum depositional age can be based on the weighted mean $^{207}Pb^*/^{206}Pb^*$ date of 2477 ± 2 Ma (MSWD = 0.83) for the youngest 47 analyses in Groups Y and S.

The data for combined Groups Y and S indicate a significant age component at c. 2476 Ma, based on contributions from approximately 45 analyses (Fig. 4). This is interpreted as the age of the dominant zircon-crystallizing rock in the detrital source region, or as the age of the dominant detrital component within sediments that have been reworked into this rock.

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