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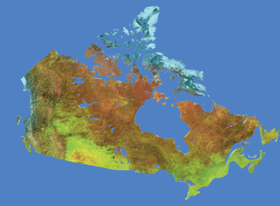

Uranium-lead geochronology of detrital zircon grains from bedded greywacke, Sangster Township, Abitibi greenstone belt, Ontario

O. van Breemen and J.A. Ayer

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Abstract: Uranium-lead zircon ages from a sample of metamorphosed bedded greywacke in Sangster Township yield a maximum U-Pb TIMS age of 2697 ± 2 Ma with the data further suggesting that these sedimentary rocks are younger than 2687 Ma. These age constraints are consistent with the rocks being correlative with the Porcupine assemblage of the southern Abitibi greenstone belt. This correlation is further supported by a U-Pb SHRIMP detrital age distribution showing a major peak at 2701 Ma and small peaks around 2794 Ma and 2835 Ma.

Résumé : Les âges U-Pb sur zircon d'un échantillon de grauwacke stratifié métamorphisé du canton de Sangster définissent un âge maximal de 2697 ± 2 Ma (âge U-Pb déterminé par spectrométrie de masse à thermoionisation). De plus, les données laissent supposer que ces roches sédimentaires sont âgées de tout au plus 2687 Ma. Ces limites d'âge soutiennent la corrélation de ces roches avec celles de l'assemblage de Porcupine, dans le sud de la ceinture de roches vertes de l'Abitibi. Cette corrélation est également appuyée par les âges U-Pb de zircons détritiques déterminés à la microsonde SHRIMP, dont la répartition est caractérisée par l'existence d'un pic principal à 2701 Ma et de pics secondaires à environ 2794 Ma et 2835 Ma.

INTRODUCTION

Mapping by the Ontario Geological Survey in the Detour-Burntbush area, north of Cochrane (Fig. 1), outlined an extensive area of clastic rocks consisting mostly of bedded greywacke units that are metamorphosed to amphibolite facies (Ayer et al., 2007). These ‘metasandstones’ are similar to greywacke units of the Porcupine assemblage of the southern Abitibi greenstone belt (Ayer et al., 2002), which is younger than 2690 ± 2 Ma, but older than the Timiskaming assemblage. The age of these metasedimentary rocks determines the stratigraphic position of a large paragneiss terrane north of Cochrane, contributing to stratigraphic knowledge of the Abitibi region and interpretation of the northern part of the Discover Abitibi regional seismic sections northeast of Timmins. In this paper the authors present precise single-grain U-Pb ID-TIMS (Isotope Dilution – Thermal Ionization Mass Spectroscopy) analyses in order to place a maximum age constraint on deposition of the metasedimentary rocks. Also presented is a statistically representative population of U-Pb SHRIMP (Sensitive High-Resolution Ion Micro Probe) ages in order to characterize sedimentary provenance.

PROCEDURES

A sample of bedded greywacke was collected from a large outcrop on the west side of the highway to Detour Lake in Sangster Township (NAD 83; UTM Zone 17; 537292E, 5465595N). The outcrop is an enclave of metasedimentary rocks enclosed within an extensive granodiorite pluton. The sampled unit consists of bedded greywacke and siltstone units metamorphosed to ampbibolite facies. Zircon grains were separated by standard procedures of disc mill crushing, Wilfley table concentration, heavy-liquid separation, and magnetic purification. Zircon grains consist of subhedral prisms (L:B = 3:1 to 1:1) that feature moderate to weak igneous zoning, some rounding of grains, but no truncation of internal zoning. Cracks and inclusions are abundant.

For ID-TIMS analysis, single, clear zircon grains were selected and strongly abraded (Krogh, 1982). Analytical methods and error treatment are presented in Parrish et al. (1987) and Roddick (1987), respectively. Uranium-lead isotopic data are presented in Table 1 together with $^{207}Pb/^{206}Pb$ ages and uncertainties at the 2σ level.

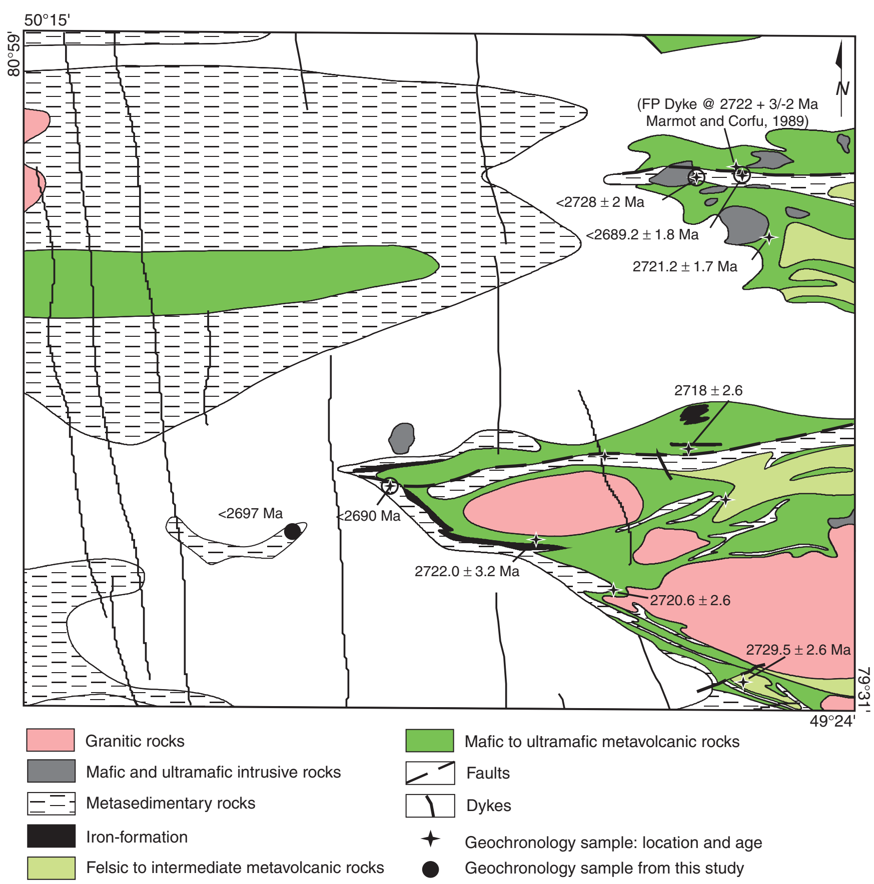

Figure 1. Geological map with ages after Ayer et al. (2009) shows location of bedded greywacke sampled for this study. Nine other published ages are shown on the map including maximum ages (Ayer et al., 2009) for three other greywacke samples (open circles with crosses) and five ages from felsic extrusive rocks that constrain the volcanic stratigraphy. In addition, a minimum age for volcanic host rocks is indicated by the age of a feldspar porphyry (FP) dyke (Marmont and Corfu, 1989).

Table 1. Uranium-lead TIMS analyses on single zircon grains.

Fraction[1]	Weight[2] (µg)	U (ppm)	Pb[3] (ppm)	$^{206}Pb/^{204}Pb$[4]	Pb[5] (pg)	$^{208}Pb/^{206}Pb$[6]	$^{207}Pb/^{235}U$[6]	$^{206}Pb/^{238}U$[6]	$^{207}Pb/^{206}Pb$[6]	$^{207}Pb/^{206}Pb$[7]	Disc[8]
Sample 06JAA-066; z9096 (49.342°N; 80.487°E)											
A, N1	3	91	59	1277	7	0.25	13.211 ± 0.14	0.5182 ± 0.10	0.18489 ± 0.07	2697 ± 2	0.3
B, N1	2	91	56	2287	3	0.21	12.904 ± 0.13	0.5094 ± 0.11	0.18374 ± 0.05	2687 ± 2	1.5
C, N1	3	42	25	1407	3	0.13	13.553 ± 0.15	0.5241 ± 0.14	0.18755 ± 0.07	2721 ± 2	0.2
D, N1	5	77	44	576	12	0.14	12.877 ± 0.23	0.5059 ± 0.24	0.18460 ± 0.12	2695 ± 4	2.5
E, N1	5	52	33	3480	2	0.24	13.016 ± 0.12	0.5125 ± 0.10	0.18419 ± 0.05	2691 ± 2	1.1
F, N1	5	99	55	3820	4	0.09	13.006 ± 0.12	0.5072 ± 0.09	0.18598 ± 0.05	2707 ± 2	2.8
G, M1	10	79	49	7346	3	0.24	12.636 ± 0.11	0.5012 ± 0.09	0.18286 ± 0.04	2679 ± 1	2.7
H, M1	11	96	58	9855	3	0.14	14.220 ± 0.11	0.5256 ± 0.09	0.19620 ± 0.04	2795 ± 1	3.2
I, M1	44	38	23	7440	7	0.23	12.912 ± 0.11	0.5095 ± 0.09	0.18380 ± 0.04	2687 ± 1	1.5
J, M1	7	52	29	3548	3	0.08	13.253 ± 0.12	0.5138 ± 0.10	0.18709 ± 0.05	2717 ± 2	2.0

[1] M = magnetic, N = nonmagnetic at a side slope given in degrees on a Frantz isodynamic magnetic separator operating at 1.8 amps;
[2] Error on weight = ±15 per cent;
[3] Radiogenic Pb;
[4] Measured ratio corrected for spike and Pb fractionation of 0.11 ± 37 per cent per AMU;
[5] Total common Pb on analysis corrected for fractionation and spike;
[6] Corrected for blank Pb and U, common Pb, errors quoted are 1σ in per cent;
[7] Age errors quoted are 2σ in Ma;
[8] Discordance in per cent along a discordia to origin.

For SHRIMP microbeam analysis, zircon grains were mounted and polished on a 2.5 cm epoxy disk along with fragments of the BR266 SHRIMP zircon standard ($^{206}Pb/^{238}U$ age of 559 Ma). The mount was imaged using a Cambridge Instruments scanning electron microscope in backscattered electron modefor the purpose of guiding the placement of ion probe analyses. A spot size of 17 µm x 23 µm was used. Analytical methods are given in Stern (1997) and Stern and Amelin (2003). Table 2 presents U-Pb analytical data with $^{206}Pb/^{238}U$ and $^{207}Pb/^{206}Pb$ ages and uncertainties at the 1σ level. Age uncertainties in the text are given at the 2σ level.

ID-TIMS RESULTS

Uranium-lead isotopic ratios are plotted in Figure 2a. Of eight grains analyzed, only two yielded concordant analyses, corresponding to $^{207}Pb/^{206}Pb$ ages of 2697 ± 2 Ma and 2721 ± 2 Ma. The remaining six analyses, 1.1% to 3.2% discordant, have $^{207}Pb/^{206}Pb$ ages ranging from 2679 ± 1 Ma to 2795 ± 1 Ma. The $^{207}Pb/^{206}Pb$ ages for seven analyses are in the interval 2679 ± 1 Ma to 2721 ± 2 Ma.

The maximum age of deposition is 2697 ± 2 Ma, which does not provide a sufficiently tight maximum age constraint to characterize Porcupine assemblage sediments; however, two analyses correspond to $^{207}Pb/^{206}Pb$ ages of 2687 ± 1 Ma and 2687 ± 2 Ma. These analyses are both moderately discordant (1.5%) and suggest that the time of deposition does not significantly exceed 2687 Ma. In the absence of younger grains, the data would indicate the greywacke deposits are the same age as the Porcupine assemblage (van Breemen and Bleeker, 2008).

SHRIMP RESULTS

A concordia plot of isotopic ratios (Fig. 2b) shows that the analyses are mostly concordant and are strongly clustered. Figure 2c shows a histogram and probability density plot of 66 $^{207}Pb/^{206}Pb$ ages excluding data that are more than 5% discordant. The majority of ages form a Neoarchean peak of ca. 2701 Ma. A small peak, corresponding to four ages, centres on 2794 Ma. Another small peak representing two ages is late Mesoarchean at 2835 Ma.

DISCUSSION

The detrital zircon age distribution presented above is similar to those analyzed in sandstone and conglomerate samples within more extensive clastic sedimentary rocks intercalated with older volcanic units within the Burntbush belt to the east (*see* Ayer et al., 2009). While the clastic sediments selected from the Abitibi greenstone belt north of Cochrane are younger than 2697 ± 2 Ma, the data suggest they are likely younger than 2687 Ma. The maximum depositional age is consistent with these sediments being equivalent to the Porcupine assemblage farther south. The detrital age distribution with a major peak at ca. 2701 Ma is

Table 2. Uranium-lead SHRIMP spot analyses.

Analysis*	U (ppm)	Th (ppm)	Th/U	Pb (ppm)	^{204}Pb (ppb)	^{204}Pb/^{206}Pb	±1σ	f^{206}	^{208}Pb/^{206}Pb	±1σ	^{207}Pb/^{235}U	±1σ	^{206}Pb/^{238}U	±1σ	^{207}Pb/^{206}Pb	±1σ	^{206}Pb/^{238}U	±1σ	^{207}Pb/^{206}Pb	±1σ	Disc. (%)
9096-56.1	91	57	0.6	53	6	0.00015	0.00005	0.0025	0.187	0.007	12.405	0.276	0.4982	0.0077	0.1806	0.0026	2606	33	2658	24	2
9096-44.1	43	23	0.6	25	10	0.00054	0.00014	0.0094	0.141	0.007	12.748	0.309	0.5087	0.0085	0.1818	0.0029	2651	36	2669	26	0.7
9096-29.1	328	209	0.7	188	4	0.00003	0.00002	0.0005	0.185	0.002	12.235	0.187	0.4881	0.0065	0.1818	0.0011	2562	28	2669	10	4
9096-7.1	123	42	0.4	69	4	0.00007	0.00004	0.0011	0.095	0.002	12.890	0.205	0.5090	0.0072	0.1837	0.0011	2652	31	2686	10	1.3
9096-38.1	169	101	0.6	101	2	0.00003	0.00002	0.0006	0.169	0.002	12.966	0.238	0.5116	0.0079	0.1838	0.0015	2663	34	2688	14	0.9
9096-48.1	143	120	0.9	90	2	0.00002	0.00006	0.0004	0.240	0.004	13.005	0.212	0.5131	0.0071	0.1838	0.0013	2670	30	2688	12	0.7
9096-72.1	86	68	0.8	54	1	0.00004	0.00005	0.0007	0.228	0.006	13.129	0.225	0.5167	0.0075	0.1843	0.0014	2685	32	2692	12	0.2
9096-18.1	394	219	0.6	235	8	0.00005	0.00002	0.0008	0.159	0.001	13.108	0.206	0.5158	0.0073	0.1843	0.0009	2681	31	2692	8	0.4
9096-133.1	143	75	0.5	83	6	0.00009	0.00004	0.0016	0.147	0.004	12.860	0.253	0.5056	0.0091	0.1845	0.0011	2638	39	2694	10	2.1
9096-26.1	193	129	0.7	118	5	0.00006	0.00003	0.0010	0.194	0.002	13.110	0.208	0.5152	0.0075	0.1846	0.0009	2679	32	2694	8	0.6
9096-51.1	370	213	0.6	225	11	0.00007	0.00002	0.0012	0.165	0.001	13.304	0.208	0.5223	0.0072	0.1847	0.0011	2709	30	2696	10	-0.5
9096-33.1	152	181	1.2	104	1	0.00001	0.00003	0.0001	0.346	0.003	13.232	0.226	0.5194	0.0074	0.1848	0.0015	2697	31	2696	13	0
9096-146.1	133	115	0.9	84	1	0.00002	0.00002	0.0004	0.247	0.002	13.069	0.204	0.5130	0.0072	0.1848	0.0010	2669	31	2696	9	1
9096-84.1	159	82	0.5	94	6	0.00008	0.00005	0.0014	0.142	0.003	13.210	0.218	0.5183	0.0075	0.1848	0.0012	2692	32	2697	10	0.2
9096-61.1	239	157	0.7	144	7	0.00006	0.00003	0.0011	0.184	0.002	13.062	0.218	0.5123	0.0078	0.1849	0.0010	2666	33	2698	9	1.2
9096-89.1	82	66	0.8	52	3	0.00007	0.00004	0.0012	0.235	0.003	13.186	0.226	0.5170	0.0077	0.1850	0.0013	2687	33	2698	12	0.4
9096-80.1	215	161	0.8	132	4	0.00004	0.00002	0.0007	0.214	0.004	13.036	0.221	0.5109	0.0075	0.1851	0.0012	2660	32	2699	11	1.4
9096-27.1	171	87	0.5	102	7	0.00010	0.00003	0.0017	0.147	0.002	13.298	0.247	0.5211	0.0086	0.1851	0.0012	2704	37	2699	11	-0.2
9096-14.1	126	90	0.7	79	0	0.00001	0.00002	0.0002	0.205	0.002	13.364	0.233	0.5236	0.0078	0.1851	0.0014	2715	33	2699	12	-0.6
9096-35.1	47	30	0.7	28	6	0.00027	0.00023	0.0047	0.189	0.009	12.971	0.365	0.5083	0.0081	0.1851	0.0039	2649	35	2699	35	1.9
9096-131.1	26	15	0.6	16	2	0.00018	0.00013	0.0031	0.157	0.006	13.251	0.374	0.5187	0.0094	0.1853	0.0036	2694	40	2701	33	0.2
9096-58.1	200	125	0.6	122	3	0.00004	0.00002	0.0007	0.187	0.002	13.134	0.215	0.5140	0.0074	0.1853	0.0012	2673	31	2701	10	1
9096-77.1	181	86	0.5	107	4	0.00005	0.00002	0.0009	0.135	0.003	13.287	0.211	0.5195	0.0071	0.1855	0.0012	2697	30	2703	11	0.2
9096-151.1	248	151	0.6	149	4	0.00003	0.00002	0.0006	0.176	0.002	13.123	0.218	0.5130	0.0076	0.1856	0.0011	2669	33	2703	9	1.3
9096-2.1	187	211	1.2	128	1	0.00001	0.00001	0.0002	0.326	0.003	13.462	0.241	0.5262	0.0081	0.1856	0.0014	2725	34	2703	12	-0.8
9096-37.1	215	152	0.7	132	3	0.00003	0.00002	0.0005	0.204	0.002	13.111	0.197	0.5122	0.0070	0.1857	0.0009	2666	30	2704	8	1.4
9096-90.1	499	428	0.9	317	2	0.00001	0.00001	0.0001	0.247	0.002	13.204	0.203	0.5157	0.0073	0.1857	0.0009	2681	31	2704	8	0.9
9096-110.1	90	43	0.5	53	4	0.00009	0.00004	0.0016	0.136	0.003	13.288	0.278	0.5190	0.0083	0.1857	0.0022	2695	35	2704	19	0.4
9096-19.1	192	125	0.7	118	1	0.00002	0.00002	0.0003	0.186	0.002	13.327	0.223	0.5202	0.0077	0.1858	0.0012	2700	33	2705	10	0.2
9096-22.1	127	124	1.0	82	6	0.00010	0.00003	0.0017	0.281	0.003	13.200	0.207	0.5151	0.0072	0.1859	0.0010	2678	31	2706	9	1
9096-76.1	89	77	0.9	57	3	0.00006	0.00010	0.0011	0.253	0.005	13.232	0.283	0.5163	0.0086	0.1859	0.0022	2684	37	2706	19	0.8
9096-60.1	77	68	0.9	48	0	0.00001	0.00001	0.0002	0.255	0.004	13.027	0.246	0.5082	0.0081	0.1859	0.0016	2649	35	2706	14	2.1
9096-52.1	134	106	0.8	85	2	0.00003	0.00003	0.0006	0.236	0.003	13.265	0.229	0.5173	0.0075	0.1860	0.0014	2688	32	2707	13	0.7
9096-8.1	142	146	1.1	94	0	0.00000	0.00002	0.0001	0.301	0.008	13.254	0.801	0.5164	0.0284	0.1862	0.0035	2684	122	2709	32	0.9
9096-10.1	231	155	0.7	140	5	0.00005	0.00002	0.0009	0.190	0.003	13.092	0.216	0.5099	0.0070	0.1862	0.0014	2656	30	2709	12	2
9096-66.1	275	137	0.5	165	6	0.00004	0.00002	0.0008	0.146	0.002	13.437	0.223	0.5231	0.0076	0.1863	0.0012	2712	32	2710	11	-0.1
9096-36.1	305	239	0.8	156	6	0.00005	0.00002	0.0009	0.220	0.003	10.886	0.294	0.4238	0.0105	0.1863	0.0016	2278	48	2710	14	16
9096-24.1	189	128	0.7	117	1	0.00002	0.00003	0.0003	0.193	0.003	13.420	0.225	0.5216	0.0080	0.1866	0.0010	2706	34	2712	8	0.2
9096-64.1	71	32	0.5	42	3	0.00011	0.00008	0.0018	0.135	0.004	13.406	0.311	0.5210	0.0095	0.1866	0.0023	2703	40	2713	20	0.3
9096-13.1	133	60	0.5	78	1	0.00002	0.00002	0.0004	0.133	0.002	13.321	0.213	0.5172	0.0075	0.1868	0.0010	2687	32	2714	9	1
9096-53.1	53	50	1.0	35	2	0.00009	0.00015	0.0015	0.273	0.007	13.333	0.354	0.5176	0.0083	0.1868	0.0036	2689	35	2714	32	0.9
9096-136.1	88	83	1.0	57	4	0.00011	0.00008	0.0019	0.278	0.004	13.181	0.239	0.5115	0.0073	0.1869	0.0018	2663	31	2715	16	1.9
9096-99.1	117	88	0.8	71	3	0.00006	0.00007	0.0011	0.214	0.003	12.906	0.242	0.5005	0.0079	0.1870	0.0016	2616	34	2716	14	3.7
9096-116.1	105	47	0.5	62	2	0.00005	0.00008	0.0009	0.127	0.005	13.435	0.257	0.5197	0.0080	0.1875	0.0018	2698	34	2720	16	0.8
9096-41.1	78	73	1.0	52	3	0.00008	0.00003	0.0014	0.274	0.004	13.542	0.258	0.5227	0.0082	0.1879	0.0017	2711	35	2724	15	0.5
9096-15.1	104	46	0.5	59	4	0.00008	0.00005	0.0014	0.122	0.005	13.062	0.233	0.5038	0.0074	0.1881	0.0016	2630	32	2725	14	3.5
9096-11.1	487	210	0.4	287	4	0.00002	0.00001	0.0003	0.123	0.002	13.607	0.204	0.5231	0.0071	0.1887	0.0010	2712	30	2731	8	0.7
9096-112.1	145	65	0.5	85	3	0.00004	0.00003	0.0007	0.133	0.003	13.471	0.250	0.5167	0.0080	0.1891	0.0016	2685	34	2734	14	1.8
9096-42.1	53	32	0.6	33	3	0.00014	0.00006	0.0024	0.178	0.004	13.813	0.355	0.5298	0.0091	0.1891	0.0032	2741	38	2734	28	-0.2
9096-28.1	126	83	0.7	78	3	0.00005	0.00003	0.0008	0.191	0.003	13.497	0.287	0.5176	0.0087	0.1891	0.0021	2689	37	2735	18	1.7
9096-102.1	148	42	0.3	85	2	0.00003	0.00005	0.0006	0.081	0.002	13.739	0.225	0.5267	0.0073	0.1892	0.0014	2728	31	2735	12	0.3
9096-114.1	48	32	0.7	30	6	0.00027	0.00011	0.0047	0.188	0.005	13.757	0.335	0.5273	0.0103	0.1892	0.0023	2730	44	2735	20	0.2
9096-62.1	168	139	0.9	111	1	0.00001	0.00002	0.0002	0.240	0.004	13.960	0.231	0.5340	0.0074	0.1896	0.0014	2758	31	2739	12	-0.7
9096-16.1	77	29	0.4	44	3	0.00009	0.00009	0.0015	0.109	0.004	13.227	0.284	0.5055	0.0080	0.1898	0.0024	2637	35	2740	21	3.7
9096-86.1	110	54	0.5	66	3	0.00006	0.00006	0.0010	0.140	0.003	13.790	0.256	0.5249	0.0077	0.1906	0.0019	2720	33	2747	16	1
9096-17.1	198	159	0.8	127	26	0.00030	0.00005	0.0051	0.240	0.003	13.754	0.222	0.5221	0.0073	0.1911	0.0012	2708	31	2752	11	1.6
9096-49.1	91	47	0.5	55	0	0.00001	0.00004	0.0001	0.151	0.002	13.850	0.254	0.5218	0.0086	0.1925	0.0012	2707	37	2764	10	2.1
9096-25.1	143	51	0.4	84	10	0.00015	0.00004	0.0027	0.099	0.002	14.164	0.259	0.5302	0.0081	0.1938	0.0016	2742	34	2774	14	1.2
9096-21.1	71	29	0.4	42	1	0.00004	0.00010	0.0008	0.117	0.004	14.213	0.324	0.5280	0.0089	0.1952	0.0026	2733	38	2787	22	1.9
9096-39.1	124	37	0.3	70	2	0.00004	0.00003	0.0007	0.081	0.002	13.888	0.352	0.5150	0.0106	0.1956	0.0024	2678	45	2790	20	4
9096-97.1	59	29	0.5	37	6	0.00021	0.00009	0.0036	0.135	0.004	14.643	0.276	0.5426	0.0082	0.1957	0.0019	2794	34	2791	16	-0.1
9096-115.1	207	161	0.8	135	4	0.00004	0.00004	0.0008	0.226	0.004	14.445	0.224	0.5347	0.0074	0.1959	0.0010	2761	31	2792	9	1.1
9096-71.1	267	116	0.4	166	9	0.00007	0.00003	0.0013	0.124	0.002	14.914	0.472	0.5463	0.0115	0.1980	0.0042	2810	48	2810	35	0
9096-1.1	205	164	0.8	134	3	0.00003	0.00005	0.0005	0.224	0.003	14.587	0.286	0.5332	0.0083	0.1984	0.0020	2755	35	2813	17	2.1
9096-104.1	104	80	0.8	69	0	0.00001	0.00004	0.0002	0.223	0.003	14.966	0.276	0.5437	0.0078	0.1997	0.0020	2799	33	2823	16	0.9
9096-113.1	353	166	0.5	227	1	0.00001	0.00001	0.0001	0.138	0.002	15.461	0.216	0.5575	0.0074	0.2011	0.0006	2856	31	2835	5	-0.7

*Analysis# = Sample#-grain#.analysis spot#

f^{206} refers to mole fraction of total ^{206}Pb that is due to common Pb; data are common-Pb corrected according to procedures outlined in Stern (1997).

Disc. = 100 x (1 - ^{206}Pb/^{238}U age)/(^{207}Pb/^{206}Pb age)

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consistent with the dominant source being synvolcanic plutons, coeval with the volcanic pile of the Abitibi greenstone belt to the south; i.e. the Tisdale, Kinojevis, and Blake River assemblages (Ayer et al., 2002, 2005). Small age peaks at the end of the Mesoarchean and beginning of the Neoarchean are also characteristic of Porcupine assemblage detrital zircon age distributions found farther south (van Breemen and Bleeker, 2008).

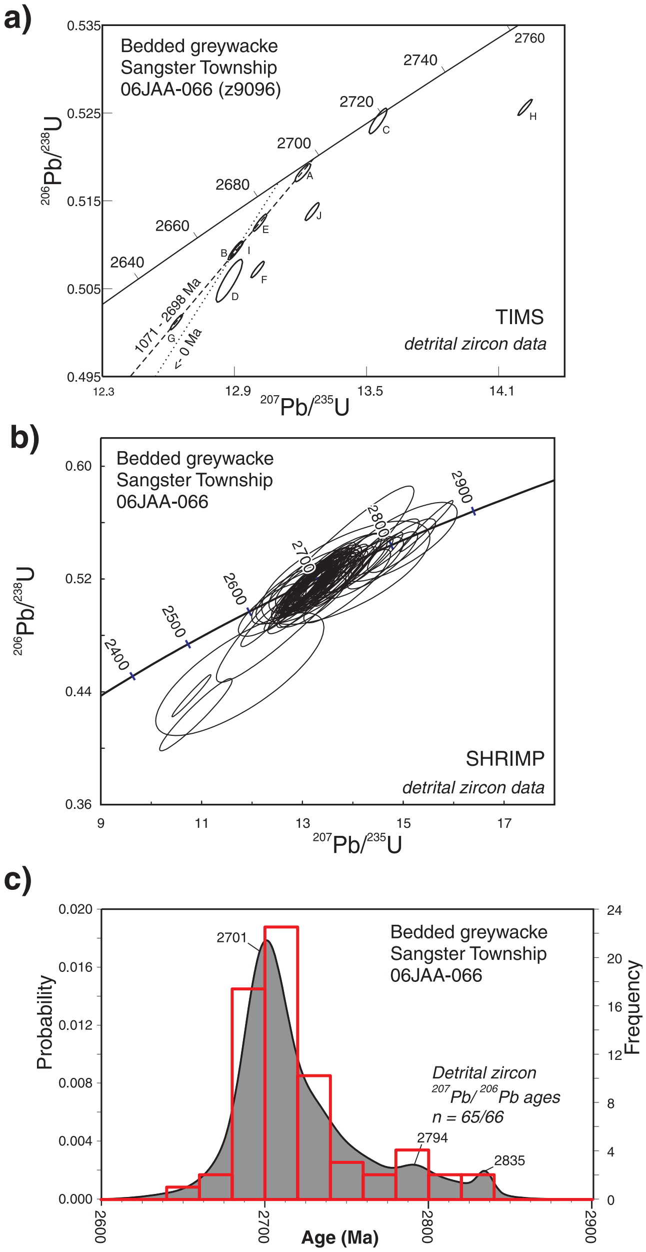

Figure 2. a) Isotope ratio plot of ID-TIMS U-Pb data, **b)** isotope ratio plot of SHRIMP U-Pb data, and **c)** probability distribution plot and histogram for SHRIMP $^{207}Pb/^{206}Pb$ ages.

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