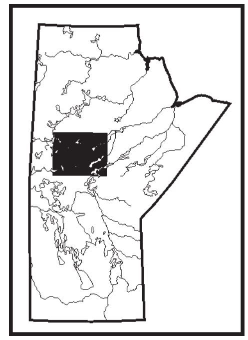
GS-11 Pikwitonei–Snow Lake, Manitoba transect (parts of NTS 63J, 63O and 63P), Trans-Hudson Orogen–Superior Margin Metallotect Project: initial geological, isotopic and SHRIMP U-Pb results

by J.A. Percival[1], J.B. Whalen[1] and N. Rayner[1]



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Summary

The Trans-Hudson Orogen–Superior Margin Metallotect Project, extending from Manitoba to Quebec, aims to provide new insight into the tectonic significance and metallogenic potential of this major feature of the Canadian Shield. In contrast to the eastern parts of the margin, which remained extensional until ca. 1800 Ma, the Pikwitonei–Snow Lake segment shows evidence for arc magmatism on Superior crust by ca. 1845 Ma, and possibly as early as 1890 Ma. Implications for plate interaction and ca. 1880 Ma rift magmatism are being explored through further geological, geochronological and geochemical studies.

Introduction

This preliminary report describes both preliminary results and work in progress from the Trans-Hudson Orogen–Superior Margin Metallotect Project, being carried out under the Northern Resources Development Program of Natural Resources Canada. More specifically, the Pikwitonei–Snow Lake transect is a collaborative project with the Manitoba Geological Survey, and aims to shed light on the age, setting and origin of nickel deposits of the Thompson Nickel Belt by refining the tectonic framework of interaction between the Trans-Hudson internides and Superior margin.

Traditional views on the setting of mafic-ultramafic bodies hosting the Thompson nickel deposits regard a continental-margin rift environment as key. Their age and tectonic history, however, remain enigmatic. Evidence of early deformation of ultramafic intrusions and hostrocks prior to emplacement of the ca. 1880 Ma Molson dike swarm (Bleeker, 1990; Bleeker and Macek, 1996; cf. Hulbert et al., 2004) indicates complexity not accounted for in a simple rift model. Furthermore, the authors' recent results have identified felsic intrusions as old as ca. 1890 Ma in the Superior Boundary Zone whose setting and significance are poorly understood (cf. Zwanzig et al., 2003).

At a broad scale, it is important to understand the nature and timing of interaction among the various tectonic components identified regionally: the Archean Superior, Sask (Lucas et al., 1996) and Assean (Böhm et al., 2000, 2003) domains, and juvenile Paleoproterozoic Trans-Hudson internides (cf. White et al., 2002).

Geological setting

Major tectonic elements of the Thompson area include the Archean Superior Province in the southeast, Sask craton in the west and Assean Lake Block in the north. The complexly deformed Ospwagan Group and contained nickel-bearing intrusions of the Thompson Nickel Belt (TNB) are autochthonous with respect to Superior Province basement (Bleeker, 1990). The boundary zone between units of Superior Province affinity and migmatite of the Kisseynew Domain (KD) of the Trans-Hudson Orogen to the west consists dominantly of plutonic rocks of Paleoproterozoic age (Zwanzig et al., 2003), and will be referred to as the TNB-KD boundary zone (Figure GS-11-1).

Superior Province basement has a complex Archean history dominated by 3.0–2.65 Ga plutonic and high-grade metamorphic rocks (Hubregtse, 1980; Weber, 1990). These units were cut by 2.07 Ga Cauchon and 1.83 Ga Molson dikes (Halls and Heaman, 1997) prior to ca. 1.80 Ga thermotectonic reworking. Paleoproterozoic structural, metamorphic and plutonic effects increase in intensity from east to west across the western edge of the Superior Province. Structural effects include development of shear zones, foliation and folds at metamorphic grades ranging from greenschist to amphibolite facies. Before this study, plutonic rocks of Paleoproterozoic age were known to range from ca.1845 to 1780 Ma (Machado, 1990; Zwanzig et al., 2003).

The Ospwagan Group lies unconformably on Superior Province basement and was deformed with it. Distinctive stratigraphic units (Bleeker and Macek, 1996) have been recognized along at least 200 km of strike length through compilation of drillcore (Thompson Nickel Belt Working Group, 2001). Although strongly deformed and attenuated,

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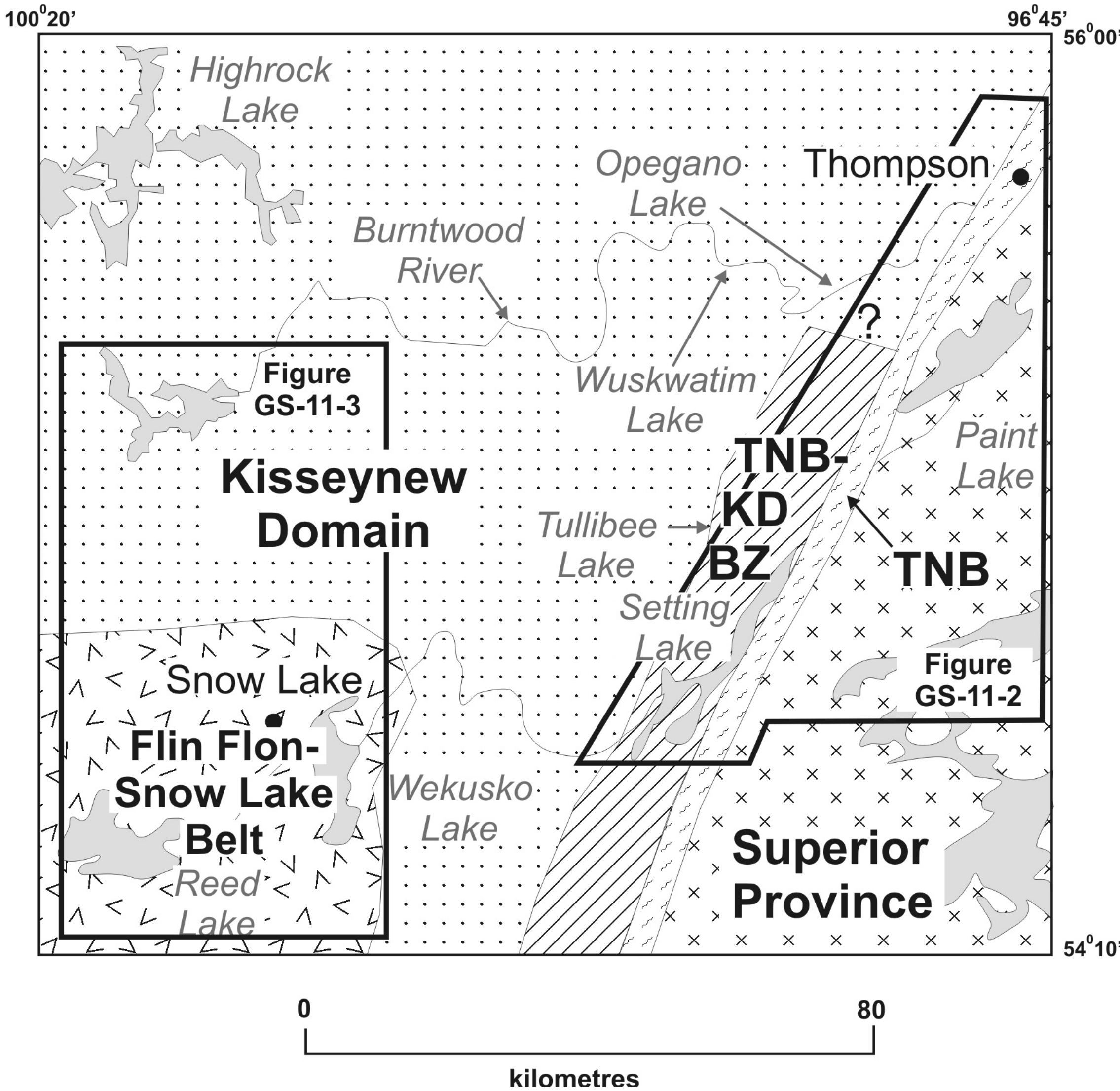

Figure GS-11-1: *Distribution of major tectonic features in the Pikwitonei–Snow Lake transect area. Eastern and western dashed boxes correspond to detailed maps in Figures GS-11-2 and GS-11-3, respectively. Abbreviations: TNB, Thompson Nickel Belt; TNB-KD BZ, Thompson Nickel Belt–Kisseynew Domain boundary zone.*

the sedimentary-volcanic sequence is coherent and youngs stratigraphically to the west (Zwanzig, 1998). Detrital zircon studies indicate provenance from the Superior Province to the east, although a single grain dated at ca. 1974 Ma provides a maximum depositional age for the Setting Formation in the upper Ospwagan Group (Hamilton and Bleeker, 2002). The youngest unit, amphibolite of the Bah Lake assemblage, appears to extend into the Superior Boundary Zone as enclaves within plutonic units.

As defined by Zwanzig et al. (2003), the TNB-KD boundary zone (Fig. GS-11-2) contains remnants of at least three distinctive supracrustal packages and several generations of plutonic rock. As noted above, amphibolite correlated with the Bah Lake assemblage occurs as enclaves. Larger units of sandstone and conglomerate make up the Grass River Group (Zwanzig, 1997), and belts of migmatitic greywacke of the Burntwood Group can be traced from the Kisseynew Domain eastward into the Superior boundary zone. With the exception of the Burntwood Group (ca. 1850–1840 Ma; Machado et al. 1999), the age of the supracrustal packages are poorly constrained. Plutonic units are mainly granodiorite and granite, with some diorite, monzodiorite, syenite and leucogranite. They have U-Pb ages in the range 1891–1830 Ma (Zwanzig et al., 2003 and data reported below) and Nd-Sm model ages between 3.3 and 1.8 Ga (Zwanzig et al., 2003 and data reported below).The Reindeer zone forms the juvenile, internide part of the Trans-Hudson Orogen (Lewry, 1981; Lucas et al., 1996). It includes the Flin Flon–Snow Lake (Figure GS-11-3; Syme et al., 1999) and La Ronge–Lynn Lake

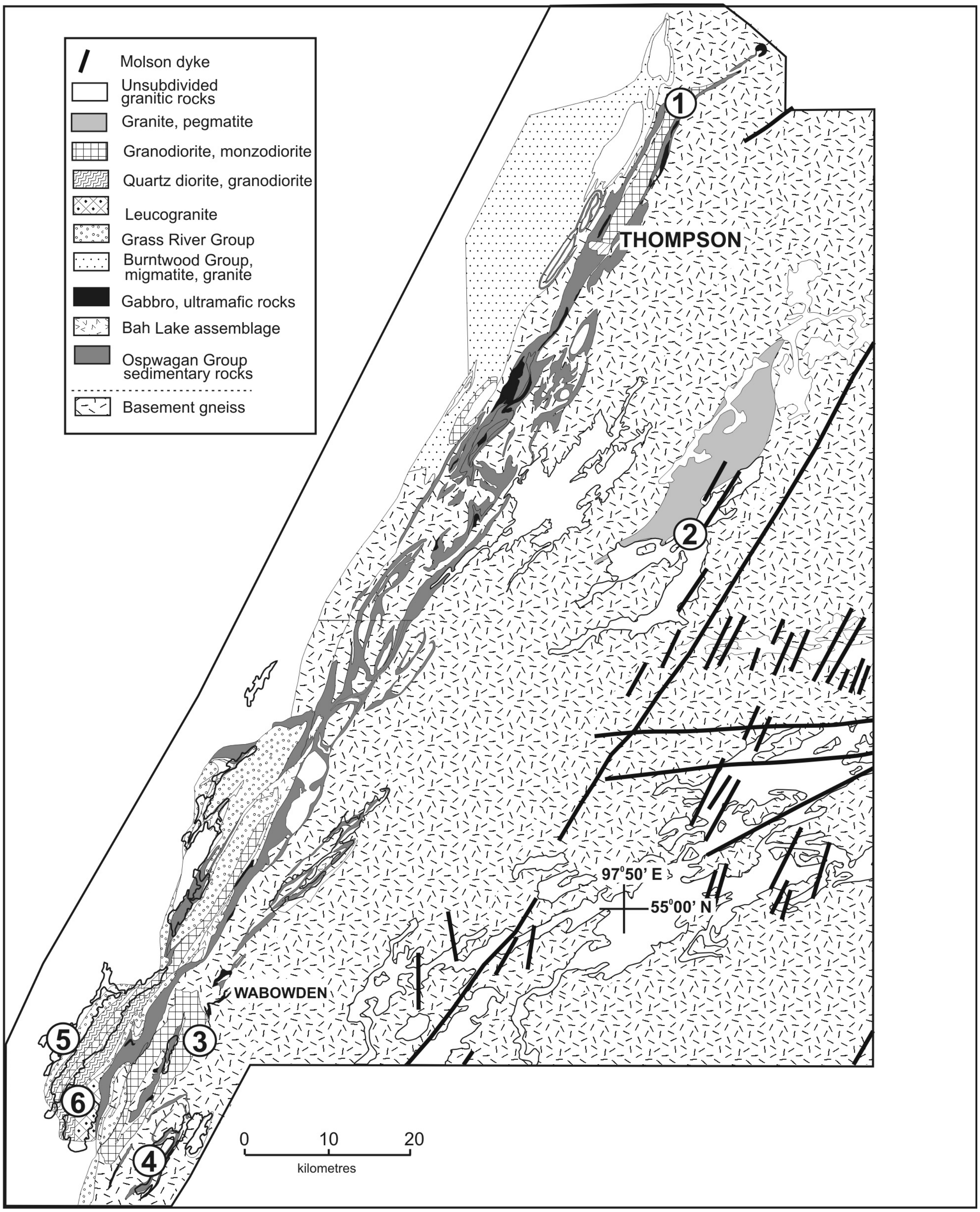

Figure GS-11-2: *Simplified geology of the Thompson Nickel Belt–Kisseynew Domain (TNB-KD) boundary zone (*after *Zwanzig et al., 2003). Study locations: 1, Mystery Lake pluton; 2, Wintering Lake pluton; 3, Bucko pluton; 4, Clarke Lake pluton; 5, Favel Island pluton; 6, Kiski Creek pluton.*

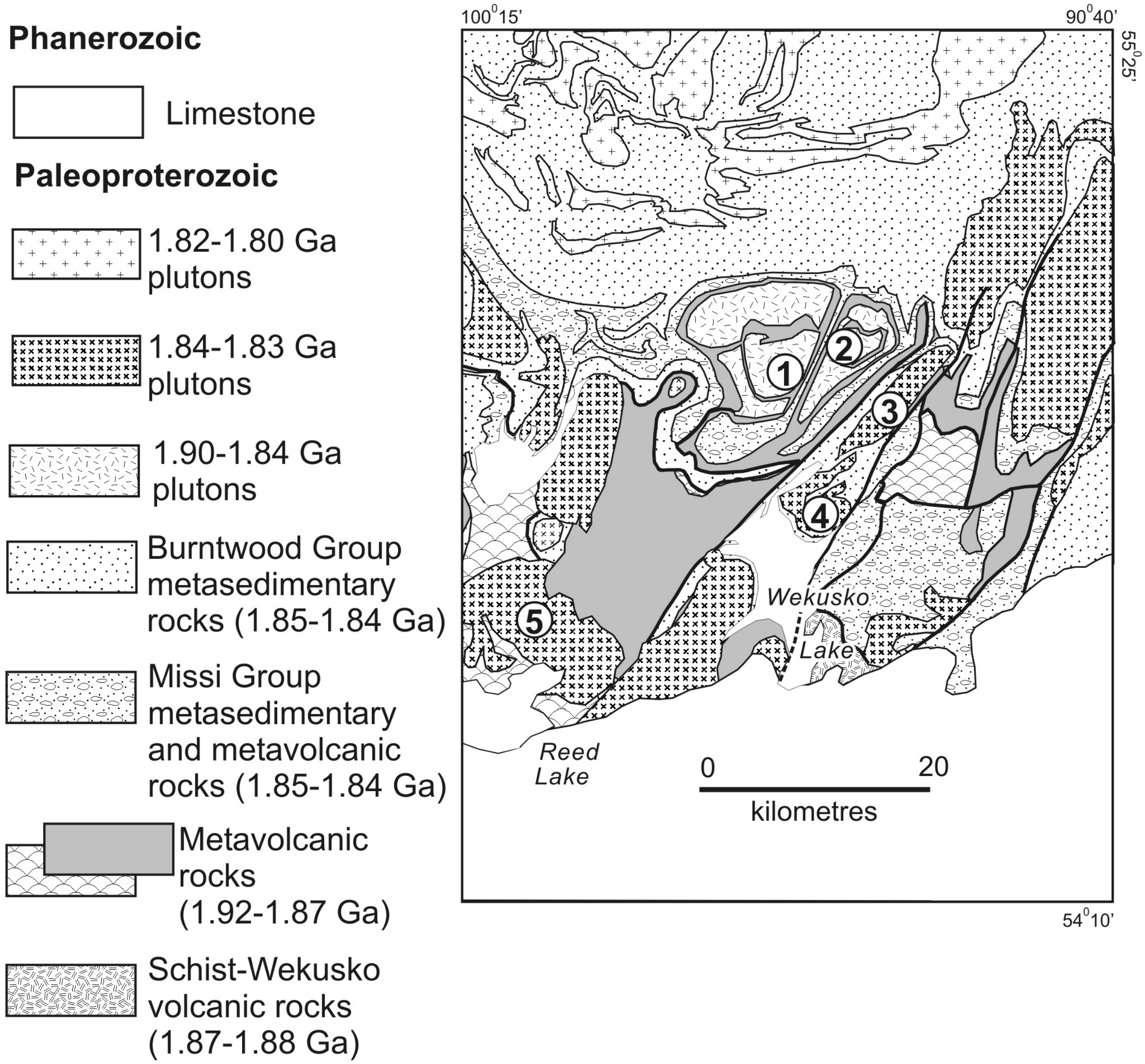

Figure GS-11-3: *Simplified geology of the Snow Lake area (*modified after *Bailes and Galley, 1999). Study locations: 1, Herblet Lake pluton; 2, Pulver dome; 3, Crowduck pluton; 4, Rex Lake pluton; 5, Reed Lake pluton.*

volcanic belts, the intervening Kisseynew Domain (Zwanzig, 1999) and plutonic rocks (Whalen et al., 1999). Ranging in age from ca. 1.92 to 1.83 Ga, both supracrustal and plutonic rocks of the Flin Flon–Snow Lake belt generally have juvenile isotopic signatures and appear to have developed within an intraoceanic arc setting (Stern et al., 1995; Syme et al., 1999; Whalen et al., 1999). They appear to be in thrust contact with Archean rocks of the Sask craton (White et al., 1994). Their relationship to the Superior Boundary Zone and Superior craton are more cryptic (cf. Green et al., 1985; Lewry et al., 1994; White et al., 2002), although the latest (ca. 1.8 Ga) motion was sinistral transcurrent (Bleeker, 1990).

Methods

Owing to complex zircon systematics, the sensitive high-resolution ion microprobe (SHRIMP) technique was used in conjunction with scanning electron microscope images to distinguish inheritance, igneous-crystallization and metamorphic-overgrowth zircon phases. Four plutons were dated, two from the autochthonous Superior Province and two from the TNB-KD boundary zone. In addition, Nd isotopic analyses were obtained from these bodies, as well as several additional intrusions.

SHRIMP U-Pb geochronology

All crushing and analytical work was performed at the Geological Survey of Canada Geochronology Laboratory in Ottawa. Zircons were extracted from the rock samples using standard crushing, heavy-liquid and magnetic-separation techniques. Sensitive high-resolution ion microprobe (SHRIMP) U-Pb analytical procedures followed those described by Stern (1997), with standards and U-Pb calibration methods following Stern and Amelin (2003). The internal features of the zircons (such as zoning, structures, alteration, etc.) were characterized with back-scattered electrons (BSE) using a Cambridge Instruments scanning electron microscope. Analyses were conducted using an $^{16}O^-$ primary beam. The sputtered area used for analysis was approximately 35 µm in diameter, with a beam current of approximately 8 nA. The count rates of ten isotopes of Zr^+, U^+, Th^+ and Pb^+ in zircon were sequentially measured over five scans with a single electron multiplier and a pulse-counting system with deadtime of 32 ns. Offline data processing was accomplished using customized in-house software. The 1σ external errors of $^{206}Pb/^{238}U$ ratios reported in Table GS-11-1 incorporate a ±1.0 % error in calibrating the standard zircon (*see* Stern and Amelin, 2003). Isoplot v. 2.49 software (Ludwig, 2001) was used to generate concordia plots and calculate weighted means. The errors presented in the text and the ellipses plotted in the figures are reported at the 2σ uncertainty level. The errors in Table GS-11-1 are reported at the 1σ uncertainty level.

Nd isotopic analysis

Samarium-neodymium isotopic ratios were measured using the Nu Plasma™ multicollector inductively coupled plasma–mass spectrometer (ICP-MS) at the Geological Survey of Canada in Ottawa. The $^{143}Nd/^{144}Nd$ isotopic ratios are reported relative to the value of 0.51186 in the La Jolla Nd standard. Nine spiked and unspiked analyses of BCR-1 yielded a weighted average value for $^{143}Nd/^{144}Nd$ of 0.512636 ±0.000009. The $\varepsilon^{143}Nd$ has been calculated for the igneous age, relative to the accepted Chondritic Uniform Reservoir (CHUR) with $^{143}Nd/^{144}Nd$ of 0.512636 and $^{147}Sm/^{144}Nd$ of 0.1966. Neodymium model ages (T_{CR}) were calculated according to the model of Goldstein et al. (1984).

Results

Paleoproterozoic plutons of northeastern Superior Province

Mystery Lake pluton

The Mystery Lake pluton (Figure GS-11-2, location 1) cuts both Superior Province gneiss and supracrustal rocks of the Ospwagan Group. It consists of at least two phases: 1) a foliated, pink, medium-grained biotite granodiorite with K-feldspar augen up to 2 cm and local boudinaged mafic dikes; and 2) a weakly foliated, white, medium-grained muscovite-biotite granodiorite. Contact relationships were not observed between the two phases, although the second appears younger based on its less strained state. Samples of each phase were collected for geochronology and geochemistry, and results are available for the second phase. Dated sample WX03-T022 yielded a ε_{Nd} value (calculated at 1844 Ma) of -6.1 and a T_{CR} of 3.23 Ga.

Muscovite-biotite granodiorite sample WX03-T22 (GSC lab #7799) yielded a small number of zircon fragments, most exhibiting well-developed sector or oscillatory zoning. No overgrowths were observed. Analysis by SHRIMP of five of these zircon fragments gives a range of ages from 2669 to 2818 Ma (Table GS-11-1, Figure GS-11-4). These are interpreted as inherited zircon, as there is no indication of igneous grain morphologies in the zircon population. Three single-grain monazite fractions were submitted for thermal ionization mass spectrometry (TIMS) analysis in order to constrain the igneous age. The three fractions are collinear and variably discordant with an upper intercept of age of 1844 ±2 Ma (Figure GS-11-4), interpreted as a minimum age for crystallization.

Wintering Lake pluton

The Wintering Lake pluton (Figure GS-11-2, location 2; sample 97-0302, GSC lab #7802) is an elongate body of massive, homogeneous, biotite leucogranite located 25 km east of the Thompson Nickel Belt. It appears compositionally uniform along its 33 km length but ranges texturally to K-feldspar porphyritic, pegmatitic and aplitic. A sample processed for SHRIMP U-Pb geochronology yielded two dominant zircon morphologies. The majority of the zircons were large, clear, colourless fragments with no zoning or broad sector zoning. These zircons were typically low in U (75–350 ppm). There is also a population of pale brown, strongly oscillatory zoned zircon that is higher in U (180–1360 ppm). This zircon occurs as rims over the clear colourless zircon and as discrete crystals. Analysis by SHRIMP of the clear, colourless zircon yielded a range of inherited ages from 2380 to 3230 Ma. The weighted mean $^{207}Pb/^{206}Pb$ age of twelve analyses of the oscillatory zoned zircon is 1820 ±10 Ma (Table GS-11-1, Figure GS-11-5). The well-developed oscillatory

Table GS-11-1: Sensitive high-resolution ion microprobe (SHRIMP) U-Pb data for zircons extracted from samples collected in the Pikwitonei–Snow Lake area. See Stern (1997) for further details.

Spot ID	U (ppm)	Th (ppm)	Th/U	Pb* (ppm)	^{204}Pb (ppb)	$^{204}Pb/^{206}Pb$		f(206)^{204} (1)	$^{208*}Pb/^{206*}Pb$		$^{207*}Pb/^{235}U$		$^{206*}Pb/^{238}U$		Correlation Coefficient	$^{207*}Pb/^{206*}Pb$		Apparent ages (Ma) $^{206}Pb/^{238}U$		Apparent ages (Ma) $^{207}Pb/^{206}Pb$		Discordance (2) (%)
						Value	±		Value	±	Value	±	Value	±		Value	±	Value	±	Value	±	
Mystery Lake pluton (WX03-T22):																						
7799-16.1	142	78	0.57	88	8	1.20E-04	4.89E-05	0.00208	0.1597	0.0026	13.722	0.295	0.5306	0.0059	0.6171	0.18756	0.0032	2744	25	2721	28	-0.8
7799-17.1	36	43	1.23	25	10	6.31E-04	2.58E-04	0.01094	0.3191	0.0109	14.401	0.478	0.5249	0.0104	0.6905	0.19897	0.00481	2720	44	2818	40	3.5
7799-8.1	58	100	1.78	43	7	2.62E-04	4.39E-04	0.00454	0.5088	0.0174	13.241	0.552	0.4991	0.0075	0.4717	0.1924	0.00713	2610	32	2763	62	5.5
7799-25.1	58	76	1.35	38	9	3.66E-04	8.59E-05	0.00634	0.3660	0.0053	12.289	0.265	0.4904	0.0085	0.8667	0.18174	0.00197	2572	37	2669	18	3.6
7799-9.1	123	179	1.50	86	8	1.53E-04	6.61E-05	0.00265	0.4221	0.0059	12.884	0.200	0.5039	0.0061	0.8431	0.18543	0.00156	2631	26	2702	14	2.6
Wintering Lake pluton (97-0302):																						
7802-59.3	249	119	0.49	82	13	2.04E-04	4.68E-05	0.00354	0.1411	0.0027	4.590	0.119	0.3052	0.0048	0.6956	0.10907	0.00204	1717	24	1784	35	3.7
7802-66.2	1010	95	0.10	323	17	6.03E-05	1.91E-05	0.00104	0.0246	0.0016	4.935	0.087	0.3275	0.0048	0.8946	0.10927	0.00087	1826	24	1787	15	-2.2
7802-97.2	1056	105	0.10	328	19	6.68E-05	1.69E-05	0.00116	0.0306	0.0028	4.797	0.129	0.3165	0.0067	0.8557	0.10995	0.00154	1772	33	1799	26	1.5
7802-47.1	458	412	0.93	176	13	1.03E-04	3.40E-05	0.00179	0.2698	0.0023	4.892	0.071	0.3225	0.0038	0.8684	0.11002	0.0008	1802	19	1800	13	-0.1
7802-91.1	691	438	0.65	259	71	3.56E-04	2.84E-05	0.00617	0.1869	0.0016	5.110	0.078	0.3348	0.0036	0.7782	0.11067	0.00107	1862	17	1811	18	-2.8
7802-85.2	802	82	0.11	250	14	6.16E-05	1.87E-05	0.00107	0.0249	0.0018	4.893	0.081	0.3186	0.0041	0.841	0.11138	0.001	1783	20	1822	16	2.1
7802-25.2	582	66	0.12	182	39	2.43E-04	8.02E-05	0.00422	0.0308	0.0038	4.901	0.100	0.3191	0.0044	0.7538	0.11142	0.0015	1785	21	1823	25	2.1
7802-93.1	1360	112	0.09	445	11	2.89E-05	7.25E-06	0.0005	0.0252	0.0007	5.152	0.058	0.3352	0.0035	0.9527	0.11148	0.00039	1864	17	1824	6	-2.2
7802-74.1	1074	97	0.09	361	72	2.26E-04	3.02E-05	0.00392	0.0254	0.0020	5.291	0.110	0.3441	0.0062	0.9158	0.11152	0.00093	1906	30	1824	15	-4.5
7802-104.1	464	231	0.52	165	10	7.49E-05	1.70E-05	0.0013	0.1506	0.0013	5.041	0.071	0.3266	0.0036	0.8529	0.11195	0.00083	1822	18	1831	13	0.5
7802-10.1	416	70	0.17	137	11	9.77E-05	2.19E-05	0.00169	0.0503	0.0011	5.094	0.079	0.3288	0.0041	0.8714	0.11235	0.00086	1833	20	1838	14	0.3
7802-59.2	246	99	0.42	80	9	1.35E-04	6.50E-05	0.00235	0.1243	0.0029	4.738	0.110	0.3042	0.0055	0.8509	0.11296	0.00139	1712	27	1848	22	7.3
7802-102.1	182	73	0.42	63	12	2.35E-04	5.79E-05	0.00407	0.1277	0.0040	5.050	0.157	0.3240	0.0065	0.7318	0.11305	0.00241	1809	32	1849	39	2.2
7802-97.1	76	83	1.13	40	4	1.66E-04	1.46E-04	0.00287	0.3400	0.0185	8.721	0.319	0.4138	0.0056	0.4827	0.15286	0.00493	2232	26	2378	56	6.1
7802-85.1	342	208	0.63	190	31	2.23E-04	3.09E-05	0.00386	0.1705	0.0058	11.552	0.212	0.4798	0.0064	0.7986	0.17462	0.00194	2526	28	2602	19	2.9
7802-25.1	69	170	2.53	56	17	5.74E-04	1.06E-04	0.00994	0.6824	0.0132	12.430	0.295	0.5001	0.0079	0.75	0.18025	0.00285	2614	34	2655	26	1.5
7802-12.1	193	169	0.91	123	9	1.01E-04	3.43E-05	0.00175	0.2482	0.0029	12.949	0.173	0.5202	0.0059	0.9084	0.18053	0.00102	2700	25	2658	9	-1.6
7802-74.2	845	73	0.09	457	30	8.06E-05	1.74E-05	0.0014	0.0246	0.0023	13.028	0.199	0.5211	0.0073	0.9569	0.18133	0.00081	2704	31	2665	7	-1.5
7802-24.1	139	129	0.96	86	10	1.77E-04	4.35E-05	0.00307	0.2657	0.0033	12.457	0.192	0.4948	0.0067	0.9226	0.1826	0.00109	2591	29	2677	10	3.2
7802-66.1	187	127	0.71	118	10	1.23E-04	3.14E-05	0.00213	0.2230	0.0101	13.757	0.626	0.5211	0.0064	0.3857	0.19149	0.0081	2704	27	2755	71	1.9
7802-54.1	340	190	0.58	278	12	6.02E-05	1.18E-05	0.00104	0.1559	0.0091	23.785	1.668	0.6720	0.0196	0.5222	0.25669	0.01548	3314	76	3227	99	-2.7
Favel Island granodiorite gneiss (WX03-T14):																						
7800-2.1	414	285	0.71	160	4	2.94E-05	1.51E-05	0.00051	0.2054	0.0014	5.409	0.072	0.3393	0.0037	0.8767	0.11561	0.00074	1883	18	1889	12	0.3
7800-6.1	879	1616	1.90	427	5	1.87E-05	1.04E-05	0.00032	0.5574	0.0020	5.374	0.065	0.3365	0.0037	0.9467	0.11581	0.00046	1870	18	1892	7	1.2

Table GS-11-1: Sensitive high-resolution ion microprobe (SHRIMP) U-Pb data for zircons extracted from samples collected in the Pikwitonei–Snow Lake area. See Stern (1997) for further details. *(continued)*

Spot ID	U (ppm)	Th (ppm)	Th/U	Pb* (ppm)	^{204}Pb (ppb)	^{204}Pb/^{206}Pb		f(206)^{204} (1)	^{208*}Pb/^{206*}Pb		^{207*}Pb/^{235}U		^{206*}Pb/^{238}U		Correlation Coefficient	^{207*}Pb/^{206*}Pb		Apparent ages (Ma) ^{206}Pb/^{238}U		Apparent ages (Ma) ^{207}Pb/^{206}Pb		Discordance (2) (%)
						Value	±		Value	±	Value	±	Value	±		Value	±	Value	±	Value	±	
Favel Island granodiorite gneiss (WX03-T14):																						
7800-14.1	321	227	0.73	123	0	3.40E-06	3.69E-05	0.00006	0.2136	0.0023	5.369	0.083	0.3331	0.0038	0.8035	0.1169	0.00109	1853	18	1909	17	2.9
7800-33.1	801	1813	2.34	431	3	1.37E-05	1.42E-05	0.00024	0.6761	0.0041	5.530	0.078	0.3480	0.0045	0.9487	0.11526	0.00052	1925	21	1884	8	-2.2
7800-45.1	393	421	1.11	161	6	5.15E-05	2.39E-05	0.00089	0.3227	0.0024	5.312	0.079	0.3307	0.0038	0.8362	0.11652	0.00095	1842	18	1904	15	3.3
7800-47.1	248	392	1.63	110	5	6.58E-05	2.95E-05	0.00114	0.4750	0.0055	5.219	0.077	0.3222	0.0039	0.8739	0.11748	0.00085	1800	19	1918	13	6.1
7800-22.1	243	109	0.46	142	9	7.90E-05	3.56E-05	0.00137	0.1249	0.0018	13.207	0.188	0.5168	0.0060	0.878	0.18534	0.00127	2686	26	2701	11	0.6
7800-25.1	198	179	0.94	79	5	8.33E-05	3.19E-05	0.00144	0.2699	0.0027	5.332	0.080	0.3330	0.0039	0.8554	0.11615	0.00091	1853	19	1898	14	2.4
7800-40.1	163	160	1.02	65	6	1.37E-04	4.18E-05	0.00237	0.2898	0.0029	5.271	0.089	0.3304	0.0041	0.8188	0.11573	0.00112	1840	20	1891	18	2.7
7800-57.1	473	631	1.38	209	8	5.52E-05	1.44E-05	0.00096	0.4034	0.0019	5.379	0.066	0.3376	0.0036	0.9141	0.11558	0.00058	1875	17	1889	9	0.7
7800-59B.1	230	351	1.58	108	7	1.02E-04	3.66E-05	0.00177	0.4541	0.0066	5.532	0.089	0.3479	0.0040	0.793	0.11531	0.00114	1925	19	1885	18	-2.1
7800-61.1	980	1697	1.79	482	6	1.90E-05	7.04E-06	0.00033	0.5147	0.0015	5.585	0.064	0.3501	0.0037	0.9582	0.11568	0.00038	1935	18	1890	6	-2.4
7800-78.1	163	190	1.21	69	1	2.93E-05	7.94E-05	0.00051	0.3481	0.0041	5.465	0.110	0.3355	0.0041	0.6908	0.11814	0.00173	1865	20	1928	27	3.3
7800-66.1	572	689	1.24	249	12	7.22E-05	1.41E-05	0.00125	0.3566	0.0028	5.461	0.070	0.3427	0.0038	0.9187	0.11559	0.00059	1900	18	1889	9	-0.6
7800-21.1	1164	2266	2.01	593	6	1.61E-05	5.80E-06	0.00028	0.5801	0.0033	5.515	0.069	0.3488	0.0039	0.927	0.11467	0.00054	1929	18	1875	9	-2.9
Kiksi Creek granodiorite (WX03-T11):																						
7801-12.1	833	415	0.51	309	22	8.86E-05	1.50E-05	0.00153	0.1512	0.0010	5.383	0.064	0.3413	0.0037	0.9409	0.11439	0.00047	1893	18	1870	7	-1.2
7801-3.1	1117	423	0.39	391	4	1.38E-05	6.77E-06	0.00024	0.1120	0.0010	5.253	0.063	0.3319	0.0036	0.9428	0.11478	0.00046	1848	17	1876	7	1.5
7801-18.1	873	6	0.01	273	4	1.52E-05	7.52E-06	0.00026	0.0017	0.0003	5.023	0.063	0.3271	0.0037	0.9444	0.11139	0.00047	1824	18	1822	8	-0.1
7801-38.1	1029	360	0.36	367	8	2.50E-05	9.51E-06	0.00043	0.1031	0.0007	5.389	0.075	0.3405	0.0038	0.8629	0.11479	0.00082	1889	18	1877	13	-0.7
7801-53.1	912	1203	1.36	399	3	9.75E-06	1.05E-05	0.00017	0.3916	0.0023	5.376	0.094	0.3371	0.0039	0.7446	0.11568	0.00135	1873	19	1890	21	0.9
7801-54.1	1553	1078	0.72	607	17	3.75E-05	1.07E-05	0.00065	0.2107	0.0015	5.449	0.068	0.3422	0.0039	0.947	0.11548	0.00047	1897	19	1887	7	-0.5
7801-56.1	821	425	0.53	295	7	3.12E-05	1.06E-05	0.00054	0.1567	0.0013	5.199	0.062	0.3280	0.0035	0.9356	0.11496	0.00049	1829	17	1879	8	2.7
7801-59.1	1270	35	0.03	414	7	1.91E-05	6.35E-06	0.00033	0.0085	0.0003	5.381	0.069	0.3377	0.0038	0.9191	0.11556	0.00059	1876	18	1889	9	0.7
7801-64.1	563	170	0.31	173	9	6.30E-05	1.73E-05	0.00109	0.1008	0.0018	4.491	0.065	0.2944	0.0037	0.924	0.11063	0.00062	1664	19	1810	10	8.1
7801-70.1	1029	764	0.77	406	3	9.39E-06	9.67E-06	0.00016	0.2234	0.0011	5.433	0.073	0.3428	0.0042	0.9581	0.11497	0.00045	1900	20	1879	7	-1.1
7801-74.1	290	141	0.50	105	8	9.21E-05	2.36E-05	0.0016	0.1404	0.0016	5.321	0.088	0.3347	0.0046	0.8897	0.11532	0.00088	1861	22	1885	14	1.3
7801-120.1	2122	430	0.21	730	6	1.03E-05	5.19E-06	0.00018	0.0603	0.0005	5.374	0.059	0.3403	0.0035	0.9679	0.11453	0.00032	1888	17	1872	5	-0.8
7801-129.1	98	179	1.88	44	5	2.06E-04	6.85E-05	0.00356	0.5424	0.0059	4.989	0.092	0.3135	0.0038	0.7472	0.11542	0.00142	1758	19	1886	22	6.8

Uncertainties calculated by numerical propagation of all known sources of error and reported at 1σ (absolute)

* radiogenic Pb

[1] f(206)^{204} refers to mole fraction of total ^{206}Pb that is due to common Pb, calculated using the ^{204}Pb-method; common Pb composition used is the surface blank

[2] Discordance relative to origin = 100 (1 – (^{206}Pb/^{238}U age)/(^{207}Pb/^{206}Pb age))

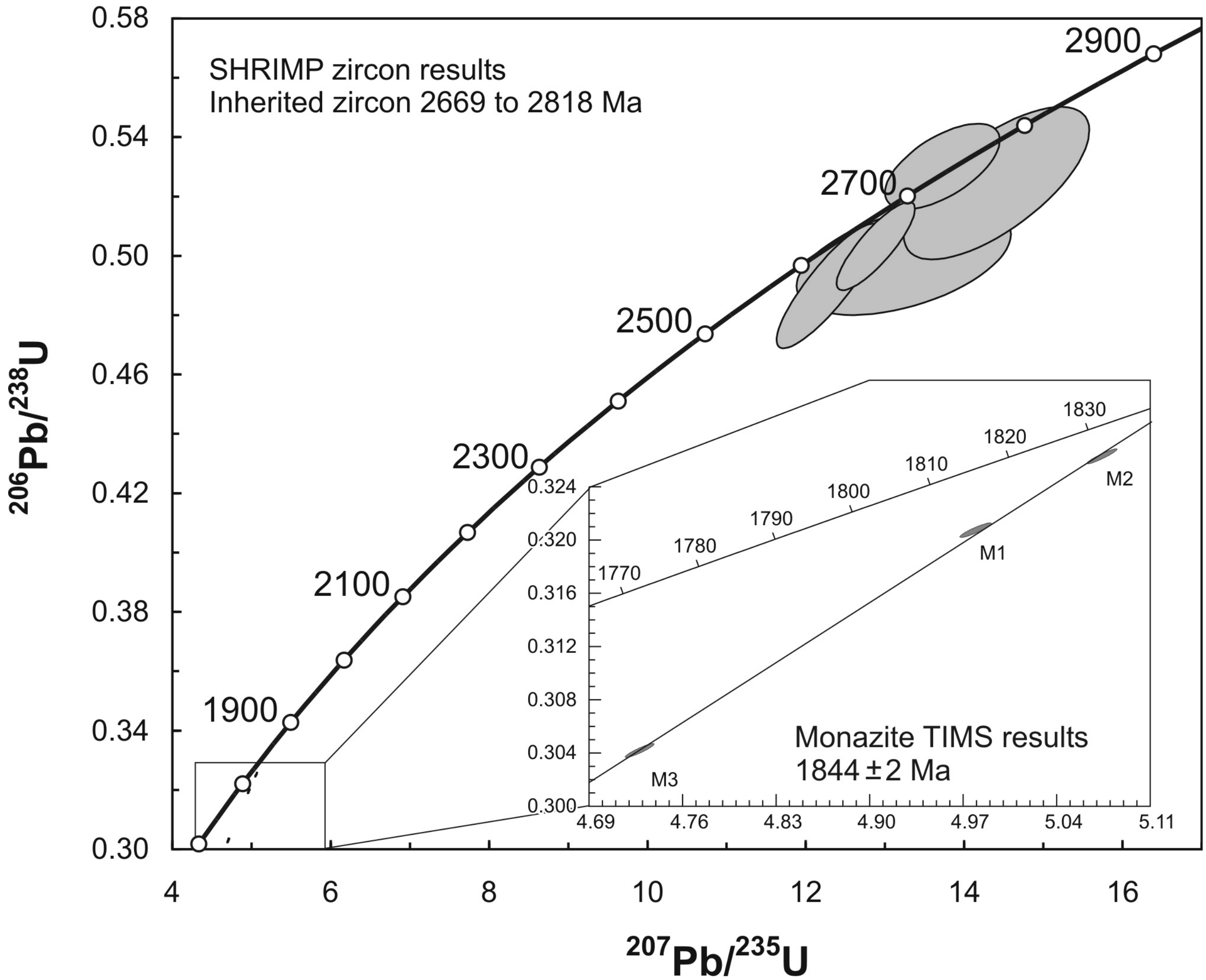

Figure GS-11-4: Uranium-lead concordia plot of sensitive high-resolution ion microprobe (SHRIMP) age data on zircon and thermal ionization mass spectrometry (TIMS) age data on monazite from the Mystery Lake pluton.

zoning suggests that the high-U zircon grew from a melt; therefore, this age is interpreted as the time of crystallization. The dated sample yielded an ε_{Nd} value (calculated at 1820 Ma) of –6.4 and a T_{CR} of 2.49 Ga.

Bucko pluton

The Bucko pluton (Figure GS-11-2, location 3) is an elongate body of homogeneous, massive to foliated, hornblende-biotite monzodiorite located along the eastern edge of the TNB-KD boundary zone. It is compositionally uniform along its 25 km strike length, and varies texturally from coarse to fine grained. Prominent accessory phases include zircon, titanite and allanite. An unpublished U-Pb zircon age of 1845 Ma (N. Machado, pers. comm. through H. Zwanzig, 1999) likely indicates the time of igneous crystallization.

The Bucko pluton is characterized by elevated contents of large-ion lithophile elements (LILE) and high La/Yb ratio and Mg#, as well as high Ni and Cr contents. These distinctive features resemble those of Archean sanukitoid suites (Stern et al., 1989). A sample collected from a quarry just east of Setting Lake yielded a ε_{Nd} value (calculated at 1845 Ma) of –1.4 and a T_{CR} of 2.49 Ga.

Clarke Lake pluton

The Clarke Lake pluton (Figure GS-11-2, location 4) intrudes Thompson Nickel Belt rocks on the west and Superior Province basement on the east. The body is at least 8 km wide and 15 km long, but its southern extent is unknown.

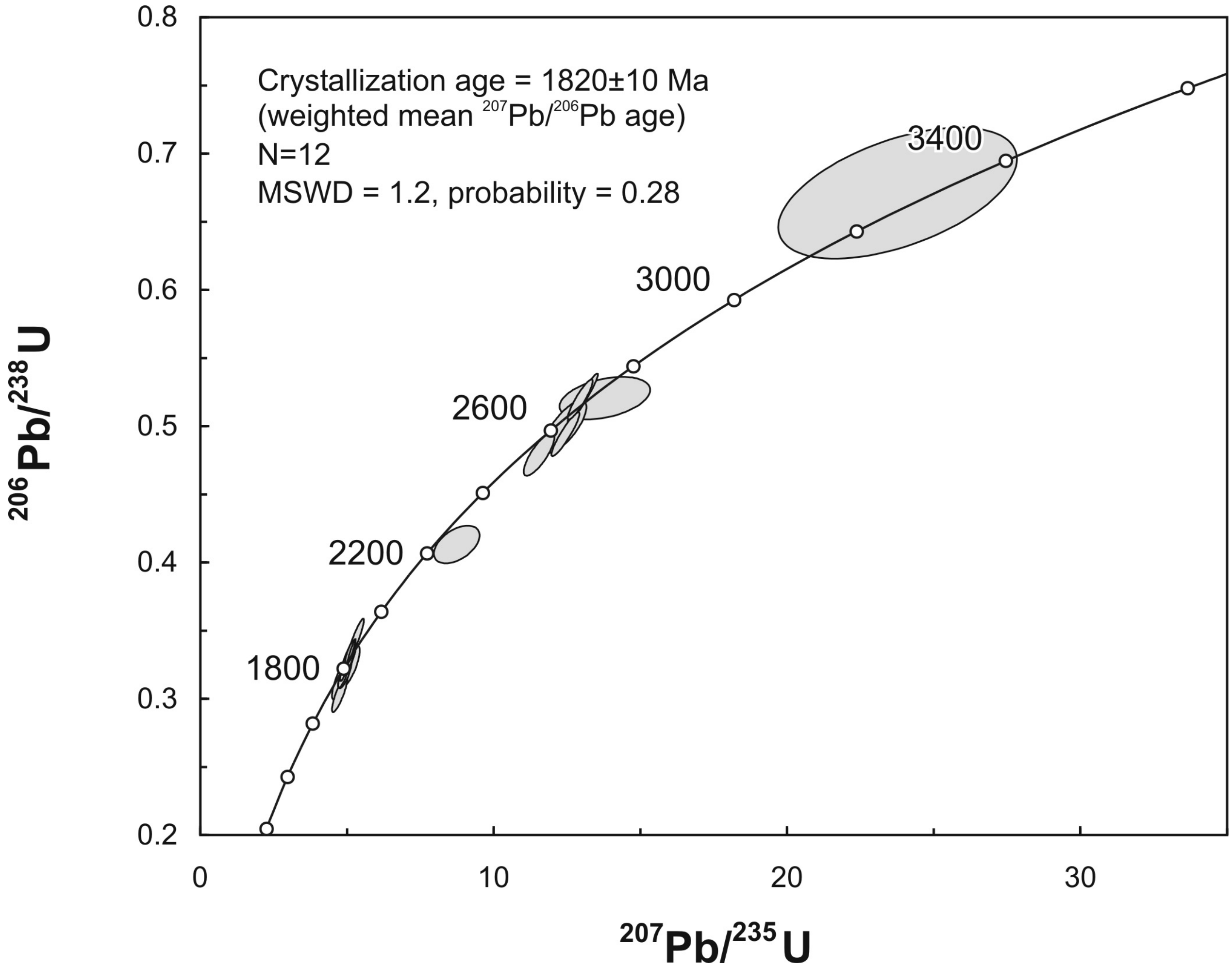

Figure GS-11-5: *Uranium-lead concordia plot of sensitive high-resolution ion microprobe (SHRIMP) age data on zircon from the Wintering Lake pluton. Abbreviations: N, number of analyses; MSWD, mean standard weighted deviate.*

Previously mapped as Archean granite, this medium- to coarse-grained, homogeneous, foliated biotite granodiorite carries a single foliation, unlike adjacent polydeformed Archean gneiss, and lacks deformed mafic dikes. Its field characteristics resemble those of Paleoproterozoic intrusions in the TNB-KD boundary zone. Large units of similar description have been observed in drill core beneath Paleozoic cover to the south (Thompson Nickel Belt Geology Working Group, 2001). A sample was collected in 2004 for SHRIMP U-Pb geochronology.

Thompson Nickel Belt–Kisseynew Domain (TNB-KD) boundary zone

Three distinctive packages of supracrustal rocks occur within the TNB-KD boundary zone. The Burntwood Group of migmatitic metagreywacke occupies large parts of the Kisseynew Domain. These rocks were likely deposited after 1850 Ma and metamorphosed to high grade by ca. 1800 Ma (Machado et al., 1999; Zwanzig, 1999). Amphibolite that is likely correlative with the Bah Lake assemblage of the Ospwagan Group (Zwanzig, 1998) also occurs within the TNB-KD boundary zone, although there is little to distinguish these rocks from sparse amphibolite units within the Kisseynew Domain. The Grass River Group is restricted to the TNB-KD boundary zone. It consists of arkose and minor conglomerate, and exhibits ambiguous field relationships. Early work indicated that these sedimentary rocks are cut by plutonic rocks (Zwanzig, 1997), whereas recent interpretations regard them as unconformable on some plutons (Zwanzig et al., 2003). A sample of Grass River arkose was collected for detrital zircon analysis.

Plutonic rocks within the TNB-KD boundary zone occur as elongate sheets with steeply dipping contacts and subvertical foliation (Figure GS-11-2; Zwanzig, 1998). Most are in the granodiorite and granite compositional range, although some gabbro, diorite and syenite are also present.

Favel Island pluton

The Favel Island pluton (Figure GS-11-2, location 5) is an elongate body of foliated, homogeneous, hornblende-biotite quartz diorite exposed on Setting and Pakwa lakes. It is variably injected by concordant, pink, aplitic granite veins. The body has been variously interpreted as intrusive into (Zwanzig, 1998), or unconformably overlain by (Zwanzig et al., 2003), metasedimentary rocks of the Grass River Group. A U-Pb zircon age of 1878 ±34 Ma was obtained by TIMS techniques on the northern part of the pluton (Zwanzig et al., 2003) and the unit has Nd model ages of 2.9–3.0 Ga. A body of similar composition and texture occurs to the southeast on Kiski Lake, although it ranges to diorite and gabbro and contains preserved ortho- and clinopyroxene.

Zircons extracted from sample WX03-T14 (GSC lab #7800) from Pakwa Lake yielded a range of zircon morphologies from stubby prisms (aspect ratio 2:1) to elongate needles (aspect ratio up to 6:1). All morphologies have slightly resorbed/rounded edges and well-developed oscillatory zoning visible in BSE images. The entire suite of morphologies was targeted with the SHRIMP, but no variation in age was observed (Table GS-11-1; Figure GS-11-6). The weighted mean $^{207}Pb/^{206}Pb$ age (n=14) for the Favel Island pluton, which is interpreted as the time of crystallization, is 1891 ±5 Ma. Only one inherited zircon was found, an unzoned, rounded core with a concordant $^{207}Pb/^{206}Pb$ age of ca. 2.7 Ga.

The dated sample WX03-T014 yielded a ε_{Nd} value (calculated at 1891 Ma) of –14.0 and a T_{CR} of 3.31 Ga. Three additional samples from the Favel Island pluton yielded ε_{Nd} values (calculated at 1891 Ma) of –5.6, –6.5, and –15.1 and T_{CR} ages of 2.71, 3.07 and 3.24 Ga.

Kiski Creek granite

The Kiski Creek granite (Figure GS-11-2, location 6) is an oval pluton consisting of foliated, homogeneous,

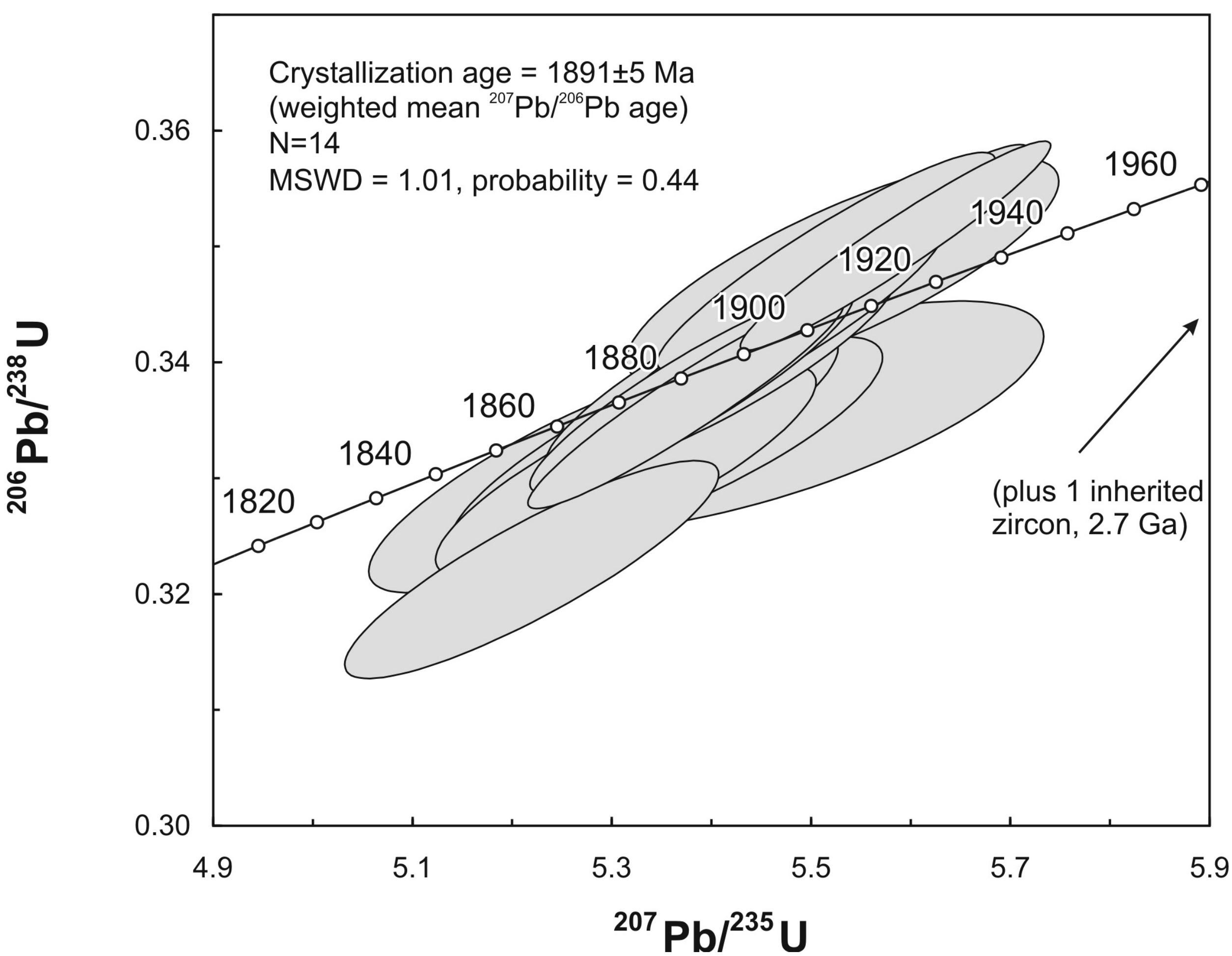

Figure GS-11-6: *Uranium-lead concordia plot of sensitive high-resolution ion microprobe (SHRIMP) age data on zircon from the Favel Island plutonic suite. Abbreviations: N, number of analyses; MSWD, mean standard weighted deviate.*

coarse-grained granodiorite exposed in a dome surrounded by older metasedimentary and plutonic rocks. Feldspars and mafic minerals are altered to chlorite, epidote and sericite. Previous U-Pb TIMS analyses of zircons suggested an age of ca. 1864 Ma, with some inheritance, and a Nd model age of 2.74 Ga (Zwanzig et al., 2003).

The zircons recovered from sample WX03-T11 (GSC lab# 7801) from southeastern Setting Lake are pale brown, prismatic and contain numerous inclusions and fractures. Oscillatory zoning is visible in both transmitted light and in the back-scattered electron images, a feature that is accentuated by strong alteration of the zircon. Every attempt was made to avoid these altered regions during the SHRIMP analyses. The weighted mean $^{207}Pb/^{206}Pb$ age of 10 analyses of oscillatory zoned zircon is 1878 ±5 Ma (Table GS-11-1; Figure GS-11-7). This is interpreted as the time of crystallization. Two highly discordant analyses were excluded from the calculation of the weighted mean. One younger, concordant (1822 Ma) date was determined from a patch of high U that appeared to overprint low-U, zoned zircon. This result is tentatively interpreted as a metamorphic overgrowth. No zircon inheritance was observed in this sample. Dated sample WX03-T011 yielded a ε_{Nd} value (calculated at 1878 Ma) of –5.4 and a T_{CR} of 2.52 Ga.

Eastern Trans-Hudson Orogen

Kisseynew Domain

Several occurrences of mafic rocks in the Kisseynew Domain were investigated for comparison with external mafic units. At Tullibee Lake, located 10 km west of the TNB-KD boundary zone, mafic units are generally concordant to foliation and migmatitic layering in Burntwood metagreywacke. Some homogeneous units preserve coarse ophitic textures and are inferred metagabbro, whereas others are fine- to medium grained, have centimetre-scale heterogeneity and local sulphide-bearing zones, and are consequently interpreted as metavolcanic rocks. Metamorphic grade is high in this area,

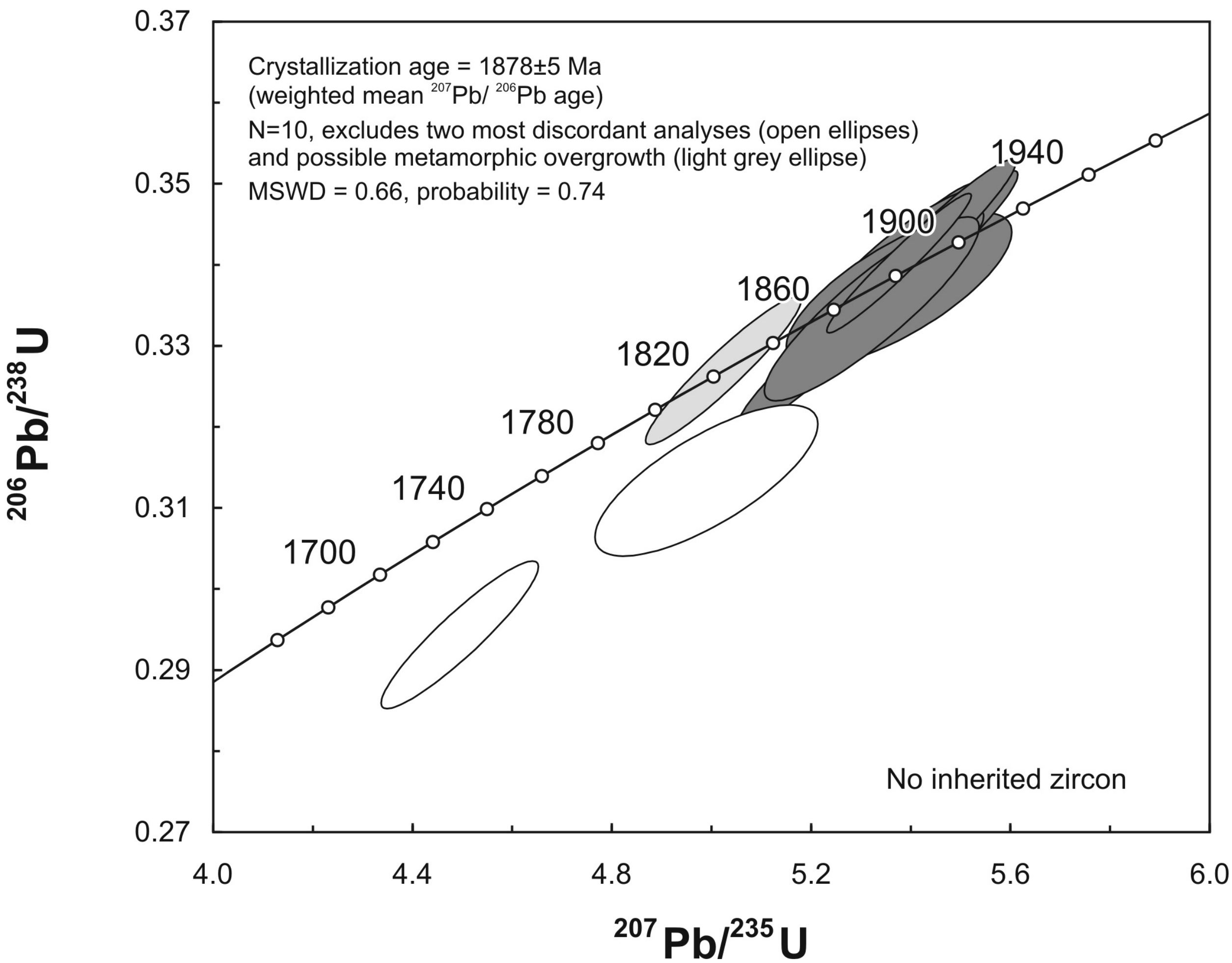

Figure GS-11-7: Uranium-lead concordia plot of sensitive high-resolution ion microprobe (SHRIMP) age data from the Kiski Creek granodiorite. Abbreviations: N, number of analyses; MSWD, mean standard weighted deviate.

judging by the occurrence of well-preserved ortho- and clinopyroxene in mafic units and also in more strongly foliated (older?) granodioritic plutonic rocks.

Mafic rocks in the vicinity of Wuskwatim Lake form part of a coherent belt of supracrustal rocks that extends northwestward for at least 10 km along the Burntwood River. The metabasalt units, up to 5 m thick, are interlayered with thinly layered, fine-grained felsic metavolcanic rocks, chert and metagreywacke. A felsic volcanic unit was sampled for geochronology. Metamorphic grade is high in this part of the Kisseynew Domain, based on widespread occurrences of ortho- and clinopyroxene, zones of diatexite within Burntwood migmatite, and the presence of charnockitic granite.

At Opegano Lake, a poorly exposed belt of supracrustal rocks is clearly distinguished from Burntwood migmatite. The main rock type is a centimetre-scale layered, medium-grained, quartz- and biotite-rich schist with some orthopyroxene and boudinaged concordant mafic layers thought to be dikes. Two generations of mafic rocks are present in one exposure: 1) early, concordant mafic granulite (hornblende-plagioclase-clinopyroxene-orthopyroxene assemblages); and 2) mafic dikes, also in the granulite facies, that cut folded migmatitic layering and are themselves deformed. In one location, a spectacular igneous breccia appears to be hosted within a relatively late intrusion. A coarse-grained, massive matrix of biotite, quartz, plagioclase, garnet and sulphide carries angular and rounded blocks, up to 1 m in diameter, of pyroxenite, lherzolite and gabbro. The xenoliths appear to represent a dismembered mafic-ultramafic complex of unknown origin. The spatial association of the quartz-rich supracrustal package with deformed dikes and the mafic-ultramafic complex invites comparisons with the Thompson Nickel Belt. This area is approximately 15 km west of the Thompson Nickel Belt and 50 km southwest of the Mel zone (Zwanzig and Böhm, 2002), suggesting the possibility that additional inliers of the Thompson Nickel Belt exist in the Kisseynew Domain.

Flin Flin–Snow Lake Belt

Various plutonic bodies were visited in the Snow Lake area (Figure GS-11-3), to investigate possible correlations and petrogenetic linkages with units in the TNB-KD boundary zone. This was necessary because an earlier geochemical plus Nd isotopic study of Flin Flon Belt granitoid rocks (Whalen et al., 1999) only included samples from three Snow Lake area plutons (cf. Stern et al., 1999). Juvenile ε_{Nd} values obtained from the Richard Lake (calculated at 1889 Ma), Sneath Lake (calculated at 1886 Ma) and Wekusko Lake (calculated at 1834 Ma) plutons (+3.3, +4.1 and +3.6, respectively; Stern et al., 1999) contrast with exclusively negative ε_{Nd} values reported by Zwanzig et al. (2003) for TNB-KD boundary zone granitoid rocks of similar age.

Ages of 1890 +8/–6 Ma (Gordon et al., 1990), 1901 ±4 Ma and 1884 ±6 Ma (David et al., 1996) have been reported for the approximately 20 km wide Herblet Lake dome (Figure GS-11-3, location 1). Both it and the nearby 10 by 6 km Pulver dome (Figure GS-11-3, location 2) consist of homogeneous biotite-hornblende±garnet granodiorite surrounded by steeply dipping supracrustal units. Their homogeneous and simply foliated character are unusual for intrusions emplaced early in the history of Snow Lake arc magmatism. Such plutons are generally cut by numerous younger intrusive phases, particularly multiple generations of mafic dikes. A sample from the Herblet Lake dome was collected for SHRIMP U-Pb geochronology and both domes were sampled for geochemistry and Nd isotopes.

The Crowduck Bay pluton (Figure GS-11-3, location 3) consists of foliated hornblende-biotite±garnet granodiorite that closely resembles the Herblet Lake plutonic rocks. It was sampled for compositional comparison and Nd isotopic analysis, as was the proximal Rex Lake complex (Figure GS-11-3, location 4). The authors' observations indicate that the Rex Lake complex contains mainly gabbro to diorite and quartz diorite, interpreted as cumulate rocks.

Based on a sampling transect along a former railway bed, the Reed Lake complex (Figure GS-11-3, location 5) comprises at least two discrete portions. The east-central zone, a tonalitic gneiss phase, consists of fine- to medium-grained, thinly layered, biotite tonalite gneiss. Open to close folds of layering are cut by metre-scale mafic dikes, themselves foliated and boudinaged. These petrological and structural characteristics resemble those of Superior Province basement east of the Thompson Nickel Belt, so a sample of gneiss was collected for SHRIMP U-Pb geochronology. The western marginal phase of the Reed Lake complex is a homogeneous, medium- to coarse-grained, biotite-hornblende-orthopyroxene-clinopyroxene diorite to quartz diorite. Together, the pyroxene-bearing intrusive units and gneiss complex suggest that deep crustal units are exposed within the Reed Lake complex, possibly providing a rare view of basement to the Snow Lake arc (cf. Leclair et al., 1993).

The Ham Lake, Barron Lake, Tramping Lake and Broad Bay plutons were also sampled for geochemistry and Nd isotopes. For less readily accessible plutons in this area, such as the northern Ham Lake, Nelson Bay and Saw Lake intrusions, archived Manitoba Geological Survey samples collected by A. Bailes will be analyzed. Results will be reported in next year's *Report of Activities*.

Economic considerations

The Thompson Nickel Belt is one of the most richly mineralized segments of the Trans-Hudson Orogen–Superior margin metallotect. Factors that may have favoured concentration of metals in this zone include an enriched mantle source and processes of magma genesis and evolution. Correlation between the age of mafic-ultramafic magmatism and changes in tectonic regime would help shed light on mantle enrichment and petrogenetic processes. This information will, in turn, help to focus the search for additional mineralized bodies elsewhere along the Superior margin.

Preliminary observations from Opegano Lake suggest possible equivalents of the Thompson Nickel Belt 15 km west of Thompson. Based on the structural model proposed for the Mel zone (Zwanzig and Böhm, 2002), additional inliers of the Ospwagan Group could be present within areas assumed to be made up of Burntwood migmatite. Further mapping in this zone would provide insight into the structural topology of the Superior-Ospwagan-Burntwood interface, with implications for exploration for buried ore deposits.

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Geological Survey of Canada contribution 2004149.

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