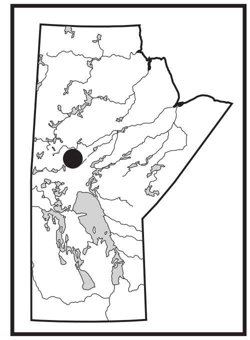
GS-3 Detrital zircon provenance of the Saw Lake protoquartzite, east end of the exposed Flin Flon Domain, Manitoba (NTS 63J13NE)

by A.H. Bailes[1] and C.O. Böhm



Bailes, A.H and Böhm, C.O. 2008: Detrital zircon provenance of the Saw Lake protoquartzite, east end of the exposed Flin Flon Domain, Manitoba, (NTS 63J13NE); *in* Report of Activities 2008, Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, p. 29–37.

Summary

The Saw Lake protoquartzite occurs in the eastern part of the Flin Flon Domain, where thrust-style tectonics and partly Archean structural inliers have been identified in adjacent areas. The U-Pb detrital zircon data for the Saw Lake protoquartzite indicate a Neoarchean provenance, with the best estimate of its depositional age being ≤2.50 Ga, making it unrelated to the younger sedimentary rocks of the Burntwood and Missi groups of the Flin Flon and Kisseynew domains. The dominant ca. 2.7 Ga zircon provenance for this sample is very similar to that determined for the Ospwagan Group of the Thompson Nickel Belt (TNB). If the Saw Lake protoquartzite is indeed a correlative with the passive-margin sequence (Ospwagan Group) of the TNB, then the structural panel that contains it will have potential as a Ni exploration target. Combined with the traditionally known, premier Au and base-metal potential of the arc- and successor-arc magmatic rocks, this new interpretation of the Saw Lake protoquartzite significantly expands the mineral potential of the easternmost Flin Flon Domain and adjacent Kisseynew Domain.

Introduction

Recent work by the Manitoba Geological Survey (MGS) and the Geological Survey of Canada (GSC) in the northeastern Kisseynew Domain of the Trans-Hudson Orogen has identified structural windows of Archean orthogneiss where the rocks had previously been mapped only as Burntwood Group metaturbidite. These Archean structural inliers, typically in fold culminations, locally contain a supracrustal sequence that is quartz rich at the base and resembles the Ospwagan Group, and thus has potential to host Thompson-type Ni mineralization (Percival et al., 2006; Rayner et al., 2006; Zwanzig et al., 2006).

East of Niblock Lake in the Kisseynew Domain, protoquartzite and siliceous paragneiss with uncertain stratigraphic and tectonic setting occur adjacent to the east end of the Flin Flon Domain (Figure GS-3-1). Although these rocks were considered by Bailes (1985) to be Paleoproterozoic members of the Kisseynew Domain and to be, perhaps, the youngest member of the Missi Group, they have never been satisfactorily correlated with any of the typical Paleoproterozoic units of the Kisseynew Domain or the Missi Group. With the recent discovery in the northeastern Kisseynew Domain of structural inliers containing Archean orthogneiss, siliceous supracrustal rocks and an intrusive suite with Archean Nd model ages (Whalen et al., GS-6, this volume), definitive geochronology for the Saw Lake protoquartzite and spatially associated units became a priority. Resolving the age and tectonic setting of these units is critical for evaluating their potential economic significance.

In the summer of 2007, the protoquartzite between Niblock and Saw lakes (hereafter referred as the Saw Lake protoquartzite) and a spatially associated granitic body (the Saw Lake pluton) were sampled for U-Pb geochronology. The objectives were to determine the provenance of the Saw Lake protoquartzite and the age and isotopic affinity of the Saw Lake pluton; establish their stratigraphic setting and tectonic significance; and test the possibility that the Saw Lake protoquartzite and associated pluton could be part of a structural inlier with an Archean affinity.

Only the geochronological data for the Saw Lake protoquartzite was available at the time of writing, with the results for the Saw Lake pluton pending. This report presents the U-Pb detrital zircon data for the protoquartzite and discusses the potential implications and economic considerations that derive from these data.

Geological setting

The Kisseynew and Flin Flon domains, which belong within the juvenile (internal) zone of the Trans-Hudson Orogen (Figure GS-3-1), are part of a collision zone formed during the 2.0–1.8 Ga amalgamation of several Archean microcontinents into a supercontinent, Laurentia (Hoffman, 1988). This collage was assembled during the 1.88–1.87 Ga intraoceanic accretion and subsequent 1.84–1.78 Ga terminal collision of the bounding Archean cratons (Lucas et al., 1996).

The east ends of the Flin Flon and Kisseynew domains (Figure GS-3-1) are dominated by 1.84–1.81 Ga fold-thrust–style to mid-crustal nappe tectonics (Connors, 1996; Krause and Williams, 1999; Zwanzig, 1999) and characterized by a series of northeast-dipping allochthons of volcanic and sedimentary rocks. The volcanic domains are typically bounded by thrust faults that are separated by intervening slices of younger, ca. 1.84 Ga

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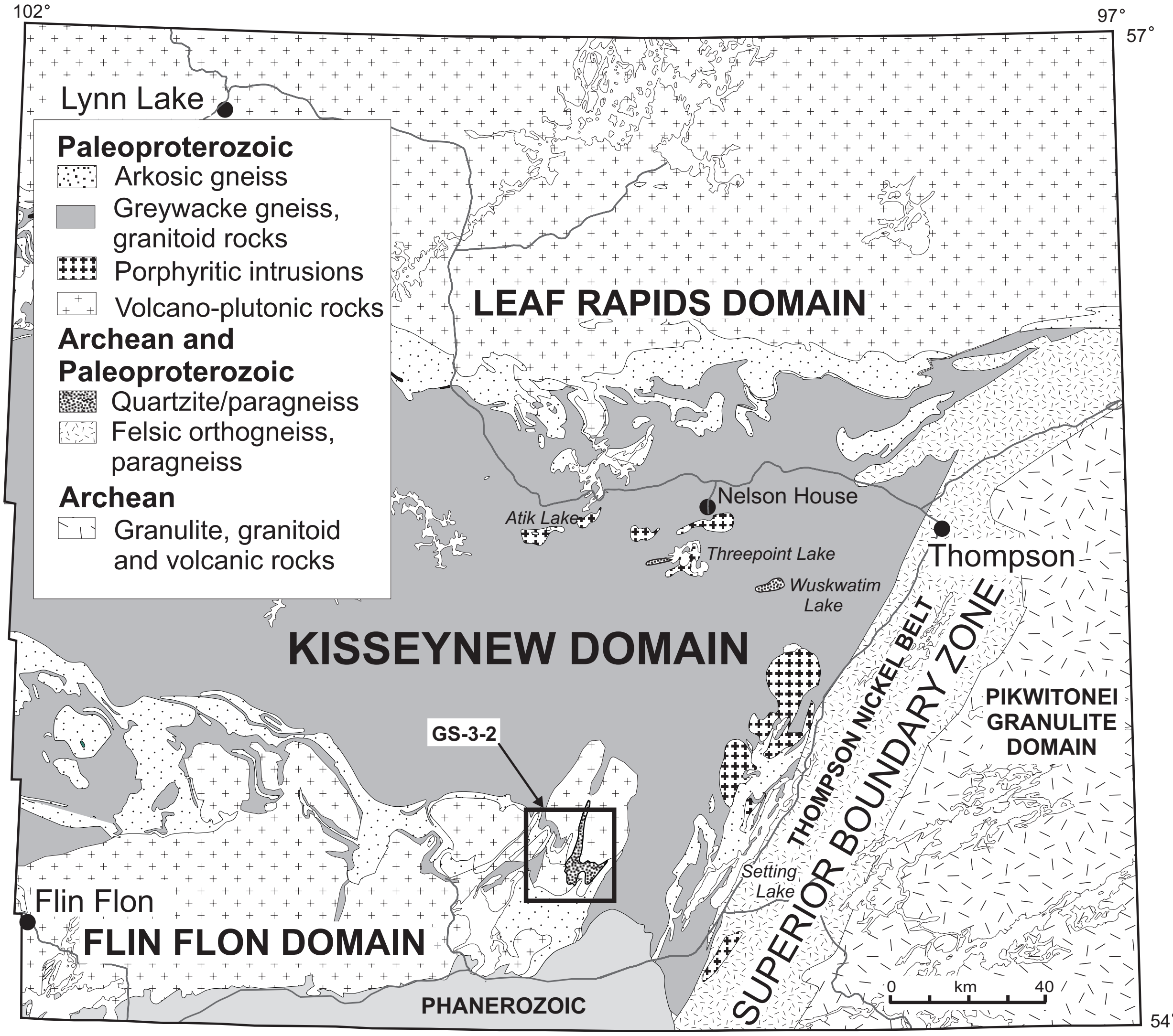

***Figure GS-3-1:** Geology of the northeastern Kisseynew Domain and adjacent Thompson Nickel Belt (modified after Murphy and Zwanzig, 2007), showing the location of the Saw Lake area at the east end of the exposed Flin Flon Belt.*

sedimentary rocks belonging to the Burntwood Group (Connors, 1996; David et al., 1996; Zwanzig, 1999; Bailes and Galley, 2007). The deformed fold-thrust package is intruded (stitched) by 1.84–1.83 Ga late 'successor arc' granitic plutons, further deformed by northeast-plunging folds and recrystallized to lower to upper almandine-amphibolite–facies mineral assemblages during a 1.82–1.81 Ga regional metamorphic episode (Froese and Moore, 1980; Bailes, 1985; David et al., 1996).

The Saw Lake area, which forms part of the east end of the exposed Flin Flon Domain, is located between Niblock Lake to the west and Setting Lake to the east. It is characterized by intense overprint by tectonic and magmatic events related to terminal collision with the adjacent Archean Superior craton (Bailes, 1985). This includes strong development of northeast-trending folds, increase of regional metamorphic grade from greenschist-facies mineral assemblages in areas to the west to middle to upper almandine–amphibolite and, rarely, granulite facies towards the Superior craton margin, and increase in abundance of magnetite-bearing and potassium-feldspar–porphyritic granitic rocks from west to east. The latter granitic rocks have been reported by Zwanzig et al. (2003), Percival et al. (2006) and Whalen et al. (GS-6, this volume) to display negative ε_{Nd} values, indicative of contamination by interaction with Archean crust, a sign that Archean Superior 'basement' likely extends beneath the Kisseynew Domain west of the Thompson Nickel Belt (TNB). Whalen et al. (GS-6, this volume) have also provided a strong argument for underlying Archean mantle.

The original geological mapping of the Saw Lake area by Bailes (1985) preceded the modern tectonic synthesis of the eastern Flin Flon and Kisseynew domains (Lucas et al., 1996) and, as a result, the supracrustal rocks were interpreted to be part of a coherent stratigraphic sequence. However, the provenance of the Saw Lake protoquartzite, revealed by the detrital zircon geochronological data in this report, indicates that a coherent, unfaulted stratigraphy does not exist at Saw Lake and that major revision to the stratigraphic and tectonic framework of the area is required.

Saw Lake protoquartzite

The Saw Lake protoquartzite has a 25 km along-strike length, a ≤1.5 km width and, based on current mapping, an occurrence restricted to the Saw Lake area. The unit dips to the east and north, and is exposed in a series of northeast-trending and moderately northeast-plunging open folds. It occurs between Missi Group massive metabasalt to the west and south, and the Saw Lake granodiorite-tonalite pluton to the east and north (Figure GS-3-2). The stratigraphic facing of the protoquartzite is

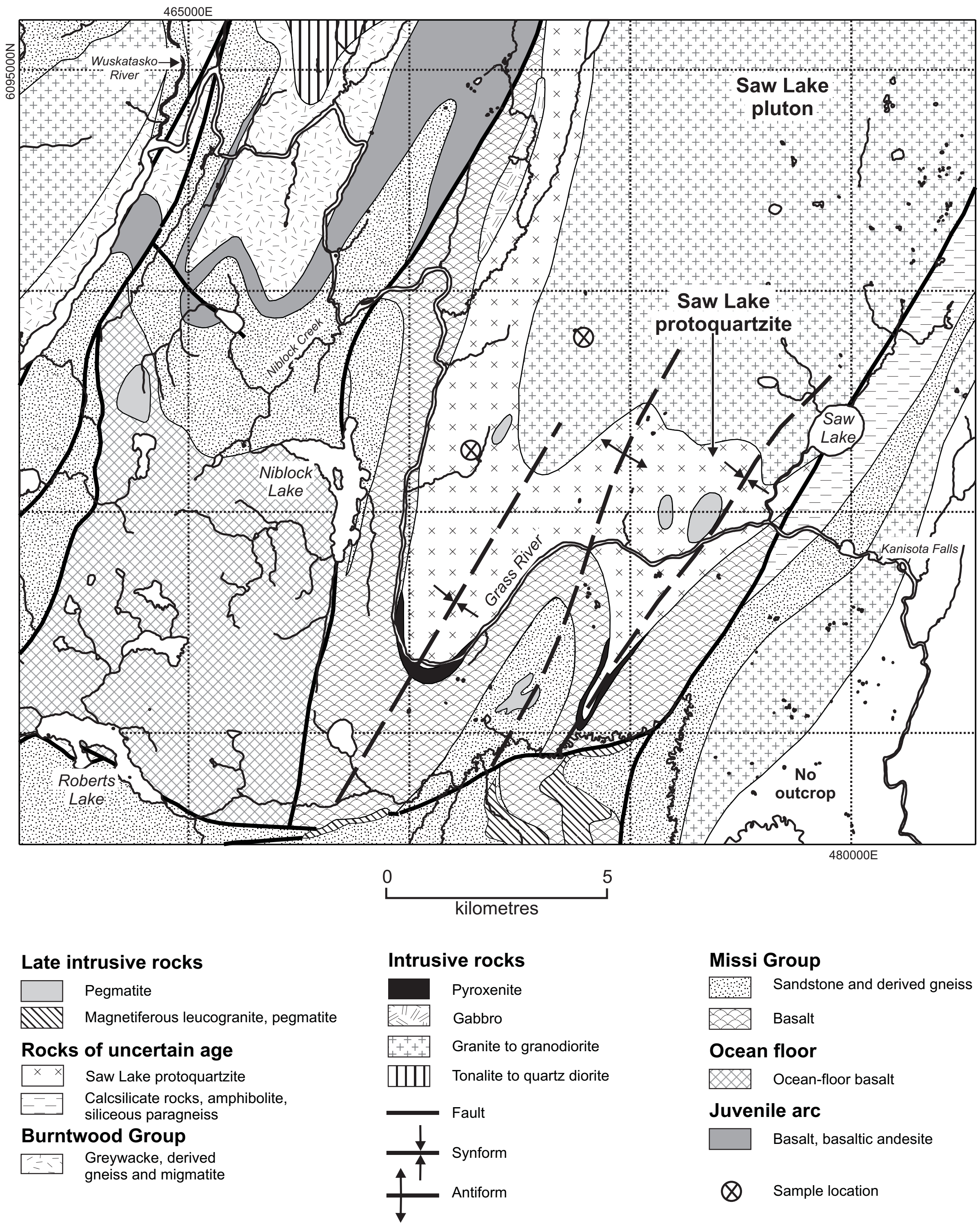

***Figure GS-3-2:** Generalized geology of the east end of the Flin Flon Domain, showing the distribution of major rock units and the location of geochronology sample sites (*modified from *Bailes, 1985).*

unknown. The structurally lower contact with the Missi Group basalt appears to be concordant, although the exact nature of this contact is unclear due to lack of exposure and the presence of intrusive bodies of pyroxenite and gabbro (Figure GS-3-2). The upper contact of the Saw Lake protoquartzite with the Saw Lake pluton appears to be structurally conformable and unfaulted, and is assumed to be intrusive. No dikes from the pluton, however, were observed in the adjacent protoquartzite.

The lower 500 m of the protoquartzite, adjacent to the Missi Group basalt, is poorly exposed and consists of siliceous paragneiss that weathers light grey to pale rusty brown. This is followed by 500 m of white to light grey protoquartzite with minor interbeds of siliceous paragneiss and local narrow (<5 m) layers of amphibolite. A 300 m wide, poorly exposed interval is followed by 100 m of rusty-weathering, sillimanite- and biotite-rich quartzofeldspathic gneiss and a 100 m wide layer of fine-grained mafic orthoamphibolite that is in direct contact with the Saw lake pluton. Late post-foliation bodies of granitic pegmatite locally intrude the Saw Lake protoquartzite.

The protoquartzite and siliceous paragneiss are typically massive featureless rocks, but locally display rare bedding and biotite-rich laminations. The protoquartzite has silica contents that exceed 85% (Bailes, 1985). The siliceous paragneiss rarely contains more than a few percent biotite, from which it can be inferred that the sandy sediment contained very little mud or clay. Bailes (1985) suggested that the high quartz content of these sedimentary rocks may indicate extensive reworking of detritus, perhaps in a beach or shallow-water environment, prior to deposition.

Sampling and geochronology

In order to constrain the timing of sedimentation and magmatism in the Saw Lake area, samples of the Saw Lake protoquartzite and the Saw Lake pluton were collected for U-Pb zircon geochronological analysis (Figure GS-3-2). The Saw Lake protoquartzite sample was taken from the middle of the unit, approximately 2.5 km east of the north end of Niblock Lake. At this location, the unit is characterized by interbedded white protoquartzite and slightly more biotitic, rusty brown–weathering siliceous paragneiss. Most of the outcrop is riddled by up to 10% anastomosing quartz veinlets and intruded by pods of pink granitic pegmatite. The sample (471539E, 6086486N, UTM zone 14, NAD 83) was taken from a 2 m wide layer of white-weathering protoquartzite containing negligible quartz veinlets and no adjacent bodies of pegmatite.

The sample consisted of ~15 kg of least-altered, homogeneous and representative rock, which was collected by hammer from bedrock and manually trimmed in the field to remove all weathered surfaces, veins, altered fractures or other heterogeneities. The resulting clean rock chips were bagged, sealed in a plastic rock-pail and shipped to the University of Alberta Radiogenic Isotope Facility in Edmonton, Alberta for mineral separation, processing and U-Pb dating.

The detrital zircons separated from the Saw Lake protoquartzite sample underwent U-Pb dating by laser-ablation, multicollector, inductively coupled plasma–mass spectrometry (LA-MC-ICP-MS), which generally followed the procedures outlined by Simonetti et al. (2005). The resulting zircons were hand picked, mounted in epoxy and polished to half-section thickness for analysis. All analyses were performed on a Nu Plasma MC-ICP-MS coupled to a frequency quintupled Nd:YAG laser-ablation system. Ion-counting detectors were used to measure ^{207}Pb, ^{206}Pb and ^{204}Pb, whereas U was measured on Faraday collectors. The procedures for determining the Faraday ion-counter factor and the Faraday multiplier calibration, and correcting the measured Pb isotope ratios for instrumental mass bias, were described by Simonetti et al. (2005). Common Pb corrections utilized the projected age of the zircon and the corresponding initial Pb isotopic compositions from the two-stage evolution model of Stacey and Kramers (1975). The resulting U-Pb zircon isotopic data are listed in Table GS-3-1 and plotted in Figure GS-3-3. The ^{207}Pb/^{206}Pb zircon age results are displayed in a diagram combining a binned frequency histogram and probability-density distribution curve (Figure GS-3-3a), which was generated using the 'Age-Display' application of Sircombe (2004). For the purposes of interpretation, the results were filtered to include only the most concordant (≥95%) and precise (2σ analytical errors ≤20 Ma) ^{207}Pb/^{206} ages. The concordia diagram in Figure GS-3-3b was generated using the 'Isoplot version 3.0' application of Ludwig (2003), and the error ellipses on this diagram are shown at 2σ. Figure GS-3-3c shows a representative suite of zircons hand-picked from the Saw Lake protoquartzite sample prior to mounting and polishing.

The Saw Lake protoquartzite sample contains zircons of variable size, morphology, degree of roundness and colour (Figure GS-3-3c), which is typical for a detrital zircon suite in a siliciclastic sedimentary rock. Most grains are short prismatic to stubby and subhedral to well rounded. The sample also contains a few smaller, euhedral, prismatic and tabular crystals. The zircons are mostly colourless; some are tan to light brown. The ^{207}Pb/^{206}Pb ages of 82 zircon analyses range from 2983 to 2512 Ma (Table GS-3-1; Figure GS-3-3a). There does not appear to be any systematic variation between morphology and ^{207}Pb/^{206}Pb age. The ^{207}Pb/^{206}Pb ages define distinct clusters, the main one with a 2691 Ma age maximum (Figure GS-3-3a).

Implications and economic considerations

The U-Pb detrital zircon ages for a sample from the Saw Lake protoquartzite range in age from ca. 2.98 to

Table GS-3-1: U-Pb laser-ablation multicollector inductively coupled plasma–mass spectrometer (LA-MC-ICP-MS) analytical data for detrital zircons from the Saw Lake protoquartzite, east end of the Flin Flon Belt.

Grain no.	^{206}Pb (cps)	Isotopic ratios						ρ	Apparent age (Ma)						Disc. (%)
		$^{206}Pb/^{238}U$	± (2σ)	$^{207}Pb/^{235}U$	± (2σ)	$^{207}Pb/^{206}Pb$	± (2σ)		$^{206}Pb/^{238}U$	± (2σ)	$^{207}Pb/^{235}U$	± (2σ)	$^{207}Pb/^{206}Pb$	± (2σ)	
1	71444	0.51066	0.02114	11.99105	0.36004	0.17047	0.00287	0.938	2659.5	89.6	2603.7	27.8	2562.3	28.2	-4.6
2	116487	0.50853	0.02143	12.59502	0.37816	0.17953	0.00268	0.970	2650.3	90.9	2649.8	27.9	2648.5	24.8	-0.1
3	277283	0.52724	0.02247	13.49140	0.40506	0.18458	0.00207	0.705	2729.8	94.1	2714.7	28.0	2694.5	18.5	-1.6
4	234322	0.51935	0.02139	13.06719	0.39229	0.18149	0.00217	0.993	2696.4	90.1	2684.5	27.9	2666.5	19.8	-1.4
5	175383	0.51118	0.02001	12.49454	0.37506	0.17720	0.00220	0.970	2661.7	84.8	2642.3	27.8	2626.9	20.6	-1.6
6	301818	0.52336	0.02055	13.25755	0.39795	0.18373	0.00204	0.984	2713.4	86.4	2698.2	28.0	2686.8	18.4	-1.2
7	307815	0.54125	0.02268	14.06941	0.42238	0.18845	0.00203	0.716	2788.7	94.2	2754.4	28.1	2728.6	17.7	-2.7
8	70821	0.52634	0.02137	12.71653	0.38179	0.17539	0.00404	0.828	2726.0	89.6	2658.9	27.9	2609.7	38.4	-5.5
9	1037533	0.55716	0.02366	14.71447	0.44175	0.19151	0.00198	0.707	2854.9	97.2	2797.0	28.2	2755.1	17.0	-4.5
10	145423	0.51183	0.02196	12.31494	0.36979	0.17349	0.00251	0.983	2664.4	93.0	2628.7	27.8	2591.6	24.2	-3.4
11	98362	0.50757	0.02095	11.86331	0.35620	0.16950	0.00300	0.924	2646.2	88.9	2593.7	27.7	2552.7	29.7	-4.5
12	152692	0.50171	0.02266	11.85661	0.35611	0.17137	0.00247	0.665	2621.1	96.5	2593.1	27.7	2571.1	24.1	-2.4
13	322302	0.51949	0.02127	12.84132	0.38551	0.17917	0.00203	0.996	2697.0	89.6	2668.1	27.9	2645.2	18.8	-2.4
14	132457	0.51543	0.01959	12.60512	0.37835	0.17800	0.00257	0.937	2679.8	82.8	2650.6	27.9	2634.4	24.0	-2.1
15	176312	0.50496	0.02048	12.11625	0.36375	0.17391	0.00199	0.992	2635.1	87.1	2613.4	27.8	2595.6	19.1	-1.9
16	134517	0.50172	0.02129	11.61994	0.34893	0.16791	0.00274	0.956	2621.2	90.8	2574.3	27.7	2536.9	27.3	-4.0
17	125105	0.48468	0.01876	11.06199	0.33208	0.16542	0.00226	0.952	2547.6	81.0	2528.4	27.6	2511.8	23.0	-1.7
18	175392	0.49333	0.01955	11.63098	0.34917	0.17093	0.00225	0.966	2585.1	83.8	2575.2	27.7	2566.8	22.0	-0.9
19	257370	0.51003	0.02051	12.55303	0.37684	0.17838	0.00195	0.993	2656.7	87.0	2646.7	27.8	2637.9	18.2	-0.9
20	443536	0.55500	0.02301	15.64171	0.46952	0.20426	0.00217	0.724	2845.9	94.7	2855.2	28.3	2860.6	17.3	0.6
21	312108	0.51950	0.02321	12.85278	0.38597	0.17941	0.00206	0.672	2697.0	97.7	2668.9	27.9	2647.4	19.1	-2.3
22	138029	0.51471	0.01866	12.11991	0.36376	0.17070	0.00339	0.837	2676.7	78.9	2613.7	27.8	2564.5	33.2	-5.4
23	102118	0.50959	0.02042	11.75274	0.35286	0.16726	0.00356	0.854	2654.9	86.6	2584.9	27.7	2530.4	35.7	-6.0
24	69035	0.48841	0.02067	9.76678	0.29339	0.14501	0.00404	0.754	2563.8	88.9	2413.0	27.3	2287.9	47.9	-14.6
25	368907	0.51362	0.01919	12.93078	0.38809	0.18236	0.00193	0.974	2672.1	81.2	2674.6	27.9	2674.4	17.5	0.1
26	534059	0.52884	0.02086	15.76966	0.47329	0.21584	0.00228	0.991	2736.6	87.3	2862.9	28.3	2949.9	17.0	8.9
27	90386	0.51091	0.02017	13.07053	0.39234	0.18434	0.00242	0.965	2660.5	85.5	2684.8	27.9	2692.3	21.7	1.4
28	122163	0.49902	0.02000	12.46137	0.37408	0.18096	0.00237	0.971	2609.6	85.4	2639.8	27.8	2661.7	21.7	2.4
29	96041	0.57566	0.02193	17.43354	0.52318	0.22032	0.00250	0.973	2931.0	89.1	2959.0	28.4	2983.0	18.2	2.2
30	316450	0.51518	0.02354	13.62997	0.40929	0.19029	0.00247	0.657	2678.7	99.4	2724.3	28.0	2744.7	21.4	2.9
31	485995	0.521	0.021	13.317	0.400	0.185	0.002	0.743	2703.9	88.6	2702.4	28.0	2699.2	17.0	-0.2
32	157649	0.503	0.020	12.674	0.380	0.184	0.002	0.985	2626.4	86.2	2655.7	27.9	2685.0	19.5	2.7
33	38994	0.498	0.020	12.079	0.363	0.175	0.004	0.803	2603.3	85.4	2610.5	27.8	2606.1	40.0	0.1
34	74259	0.510	0.020	12.578	0.378	0.179	0.003	0.933	2655.9	83.5	2648.6	27.8	2641.3	25.2	-0.7
35	281561	0.511	0.021	12.980	0.390	0.184	0.002	0.996	2661.8	88.0	2678.2	27.9	2688.7	18.3	1.2
36	273903	0.529	0.022	13.776	0.414	0.189	0.002	0.999	2736.3	91.5	2734.4	28.0	2732.4	18.9	-0.2
37	130084	0.509	0.021	12.861	0.386	0.183	0.002	0.988	2651.5	89.9	2669.5	27.9	2678.0	21.3	1.2
38	107378	0.501	0.022	12.449	0.374	0.179	0.003	0.983	2617.4	91.9	2638.9	27.8	2646.3	24.1	1.3
39	388215	0.518	0.019	13.174	0.395	0.184	0.002	0.975	2688.6	82.2	2692.2	27.9	2691.4	17.7	0.1
40	190440	0.507	0.020	12.772	0.383	0.182	0.002	0.981	2645.0	84.4	2663.0	27.9	2672.1	18.7	1.2
41	201963	0.507	0.019	12.668	0.380	0.181	0.002	0.961	2642.1	79.5	2655.2	27.9	2660.8	19.2	0.9
42	78724	0.497	0.019	11.798	0.354	0.171	0.003	0.853	2599.6	80.1	2588.5	27.7	2567.9	33.0	-1.5
43	122783	0.481	0.018	11.816	0.355	0.177	0.003	0.853	2529.5	77.7	2589.9	27.7	2625.8	32.6	4.4
44	207534	0.501	0.021	12.562	0.377	0.181	0.002	0.987	2619.9	87.6	2647.4	27.9	2665.4	20.3	2.1
45	335633	0.564	0.023	16.453	0.494	0.211	0.002	0.996	2885.1	92.6	2903.5	28.3	2912.1	17.2	1.2
46	364974	0.511	0.020	12.639	0.379	0.179	0.002	0.982	2662.7	83.1	2653.1	27.9	2641.2	17.5	-1.0
47	91687	0.488	0.019	11.257	0.338	0.167	0.003	0.905	2560.2	79.8	2544.6	27.6	2529.0	28.1	-1.5
48	183011	0.533	0.018	14.203	0.426	0.193	0.002	0.943	2755.0	76.2	2763.3	28.1	2770.3	19.0	0.7

Table GS-3-1: U-Pb laser-ablation multicollector inductively coupled plasma–mass spectrometer (LA-MC-ICP-MS) analytical data for detrital zircons from the Saw Lake protoquartzite, east end of the Flin Flon Belt. *(continued)*

Grain no.	^{206}Pb (cps)	Isotopic ratios						ρ	Apparent age (Ma)						Disc. (%)
		$^{206}Pb/^{238}U$	± (2σ)	$^{207}Pb/^{235}U$	± (2σ)	$^{207}Pb/^{206}Pb$	± (2σ)		$^{206}Pb/^{238}U$	± (2σ)	$^{207}Pb/^{235}U$	± (2σ)	$^{207}Pb/^{206}Pb$	± (2σ)	
49	284384	0.493	0.016	12.742	0.382	0.187	0.002	0.946	2583.0	68.4	2660.8	27.9	2717.0	17.3	6.0
50	76913	0.499	0.017	12.607	0.378	0.182	0.002	0.955	2607.7	74.4	2650.7	27.8	2672.1	18.0	2.9
51	51479	0.506	0.019	12.977	0.389	0.186	0.002	0.948	2638.5	81.5	2678.0	27.9	2703.8	22.1	2.9
52	83094	0.489	0.018	12.515	0.376	0.185	0.002	0.960	2565.3	77.2	2643.9	27.8	2701.2	18.9	6.1
53	322947	0.513	0.020	13.586	0.408	0.192	0.002	0.981	2669.1	83.2	2721.3	28.0	2760.5	17.5	4.0
54	172474	0.513	0.019	13.438	0.403	0.190	0.002	0.968	2669.0	81.4	2710.9	28.0	2738.7	18.7	3.1
55	487990	0.529	0.020	13.734	0.412	0.188	0.002	0.982	2738.3	84.5	2731.5	28.0	2722.5	17.1	-0.7
56	645989	0.536	0.022	13.564	0.407	0.183	0.002	1.000	2768.6	90.1	2719.7	28.0	2678.9	17.0	-4.1
57	135572	0.502	0.019	12.810	0.384	0.185	0.002	0.978	2622.3	81.1	2665.8	27.9	2695.1	17.4	3.3
58	57579	0.491	0.018	12.152	0.365	0.180	0.003	0.908	2576.2	77.4	2616.2	27.8	2648.8	26.1	3.3
59	97994	0.501	0.019	12.705	0.381	0.184	0.002	0.952	2616.2	80.5	2658.1	27.9	2689.0	21.4	3.3
60	138775	0.507	0.019	12.927	0.388	0.185	0.002	0.969	2642.2	80.8	2674.3	27.9	2694.0	18.6	2.3
61	414903	0.505	0.018	12.701	0.381	0.183	0.002	0.968	2634.7	77.8	2657.8	27.9	2679.2	17.1	2.0
62	46356	0.494	0.018	12.438	0.373	0.182	0.002	0.956	2589.0	76.3	2638.0	27.8	2673.7	18.9	3.8
63	213357	0.504	0.020	12.849	0.386	0.185	0.002	0.990	2629.7	84.3	2668.6	27.9	2696.6	17.3	3.0
64	159395	0.495	0.018	12.731	0.382	0.186	0.002	0.967	2592.8	79.2	2660.0	27.9	2709.9	18.6	5.2
65	371848	0.498	0.018	12.682	0.381	0.185	0.002	0.965	2604.3	76.0	2656.3	27.9	2694.4	17.1	4.1
66	87641	0.495	0.018	12.888	0.387	0.189	0.003	0.935	2591.1	77.6	2671.5	27.9	2732.0	22.5	6.3
67	264490	0.488	0.018	12.545	0.376	0.186	0.002	0.962	2563.2	75.6	2646.1	27.8	2708.0	17.8	6.5
68	207252	0.502	0.019	12.900	0.387	0.186	0.002	0.977	2622.6	80.2	2672.4	27.9	2709.2	17.1	3.9
69	169702	0.497	0.018	12.511	0.375	0.182	0.002	0.963	2602.6	76.2	2643.6	27.8	2673.1	17.6	3.2
70	236468	0.550	0.020	15.142	0.454	0.199	0.002	0.960	2826.5	81.2	2824.2	28.2	2821.8	17.7	-0.2
71	150865	0.521	0.022	13.424	0.403	0.187	0.002	0.708	2702.7	92.9	2709.9	28.0	2713.2	18.8	0.5
72	82276	0.506	0.020	12.886	0.387	0.184	0.002	0.983	2639.1	83.2	2671.3	27.9	2693.2	17.6	2.5
73	382499	0.528	0.021	14.851	0.446	0.205	0.002	0.991	2733.7	87.1	2805.7	28.2	2864.7	16.8	5.6
74	213660	0.507	0.021	13.093	0.393	0.186	0.002	0.712	2642.9	90.7	2686.4	27.9	2710.5	17.2	3.0
75	37796	0.541	0.022	16.027	0.481	0.215	0.004	0.885	2786.2	92.7	2878.4	28.3	2946.6	32.7	6.7
76	242171	0.506	0.024	12.834	0.385	0.184	0.002	0.635	2637.6	101.6	2667.6	27.9	2691.5	18.4	2.4
77	242610	0.496	0.021	12.445	0.374	0.183	0.002	0.707	2597.7	90.2	2638.6	27.8	2678.9	18.6	3.7
78	181288	0.480	0.019	11.962	0.359	0.181	0.002	0.985	2526.6	82.9	2601.5	27.7	2659.0	19.2	6.0
79	169787	0.549	0.020	16.342	0.490	0.216	0.002	0.966	2821.2	84.6	2897.0	28.3	2949.0	18.3	5.3
80	130552	0.508	0.019	13.013	0.391	0.186	0.002	0.964	2648.2	81.9	2680.6	27.9	2703.5	19.8	2.5
81	137063	0.622	0.025	22.805	0.684	0.266	0.003	0.988	3117.9	98.3	3218.7	28.8	3280.5	17.9	6.2
82	773196	0.526	0.022	13.467	0.404	0.185	0.002	0.727	2725.6	91.2	2713.0	28.0	2702.4	16.8	-1.1
83	204261	0.500	0.021	12.415	0.373	0.181	0.002	0.701	2615.9	91.4	2636.4	27.8	2660.5	18.6	2.0
84	107952	0.514	0.024	12.576	0.378	0.177	0.003	0.646	2674.8	101.0	2648.4	27.9	2626.9	23.4	-2.2

Uncertainties are reported at 2σ (absolute) and are calculated by numerical propagation of all known sources of error.

2.51 Ga, with a dominant ca. 2.69 Ga Neoarchean provenance (Figure GS-3-3a). The ca. 2.69 Ga zircon age maximum is flanked by minor peaks around 2645 and 2755 Ma, but no input of zircon detritus from a Paleoproterozoic source such as the Flin Flon Domain appears to be present.

The twelve youngest analyzed zircons in the Saw Lake protoquartzite sample have $^{207}Pb/^{206}Pb$ (minimum) ages between ca. 2.60 and 2.51 Ga, with an apparent maximum at ca. 2566 Ma (Figure GS-3-3a). Assuming these youngest zircons are detrital, their age provides a maximum age of sedimentation. The $^{207}Pb/^{206}Pb$ age of the youngest analyzed zircon is 2512 ±12 Ma (1σ error), so the current best estimate for the age of deposition of the Saw Lake protoquartzite is ≤2.50 Ga. Consequently, the Saw Lake protoquartzite is unrelated to the sedimentary rocks of the Burntwood and Missi groups of the Kisseynew Domain, which contain mainly Paleoproterozoic detrital zircons (David et al., 1996; Machado et al., 1999).

The dominant Neoarchean detrital zircon ages in the Saw Lake protoquartzite coincide with the main tectonometamorphic pulses in the adjacent margin terranes of the

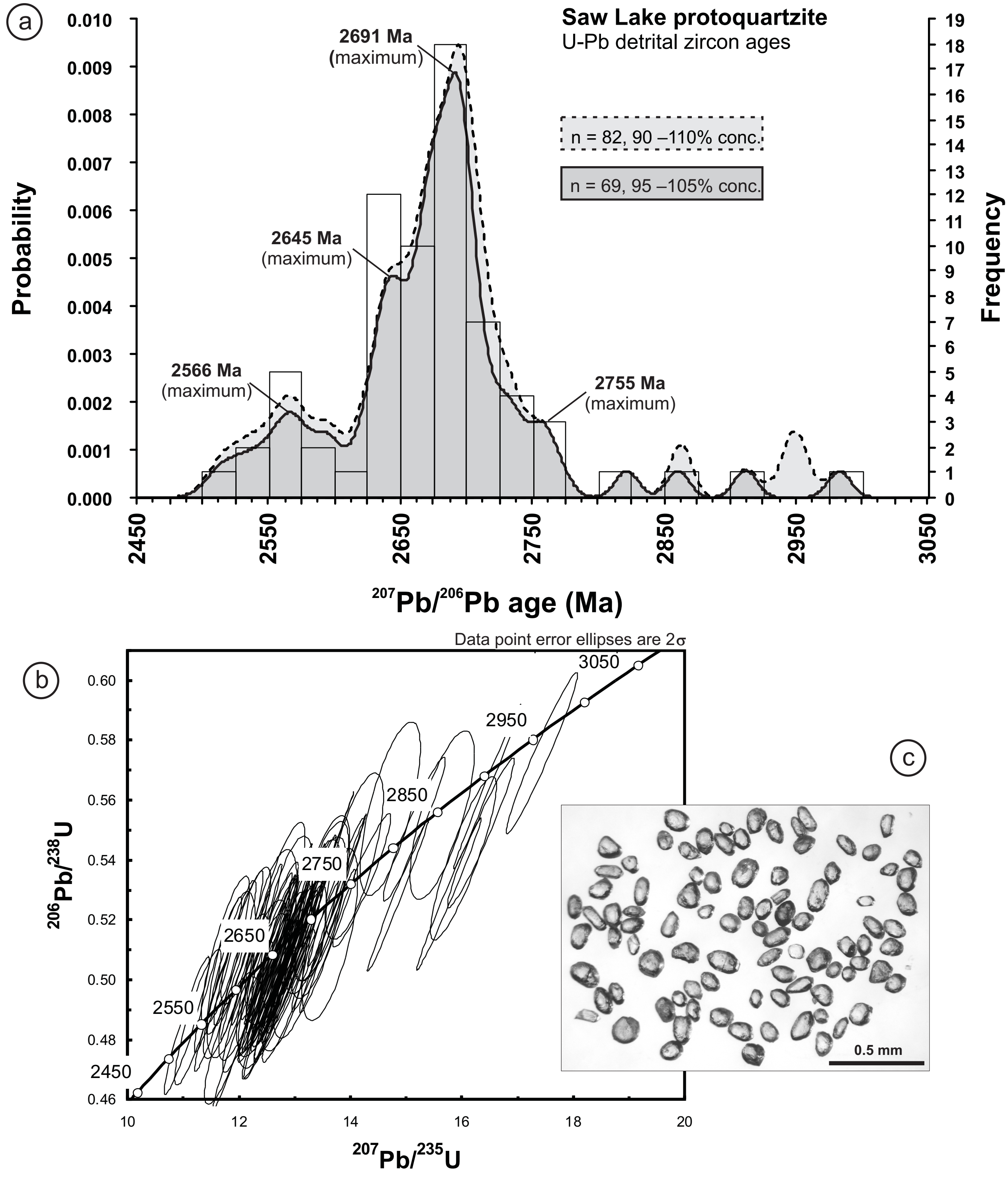

Figure GS-3-3: ***a)*** *Combined frequency histogram and probability-density distribution (PDD) curves of $^{207}Pb/^{206}Pb$ ages (Ma) for detrital zircons from the Saw Lake protoquartzite; light-shaded, dashed curve indicates PDD for the unfiltered data set (n = 82), whereas the dark-shaded curve indicates PDD for the filtered data sets (n = 69, analyses ≥95% concordant, with 2σ errors ≤20 Ma).* ***b)*** *U-Pb concordia diagram for detrital zircons from the Saw Lake protoquartzite.* ***c)*** *Heterogeneous detrital zircon suite from the Saw Lake protoquartzite.*

Superior craton to the east, making these terranes the most likely sediment sources. In the Pikwitonei Granulite Domain and Thompson Nickel Belt basement, some tonalite-trondhjemite-granodiorite (TTG) gneiss units are 3.0 Ga or older, but most have emplacement ages between ca. 2.78 and 2.71 Ga and underwent an early, prograde phase of metamorphism with associated magmatism around 2.71–2.68 Ga, followed by peak, granulite-grade metamorphism around 2.66–2.64 Ga (Heaman et al., 1986; Mezger et al., 1990; Böhm et al., 1999). The post–2.64 Ga tectonometamorphic record, however, is scarce.

The dominant ca. 2.7 Ga zircon provenance is also the same as that determined from the Ospwagan Group of the Thompson Nickel Belt (TNB; Hamilton and Bleeker, 2002; Rayner et al., 2006). Although this does not mean that the Saw Lake protoquartzite is part of the Ospwagan Group, it does indicate that this is a possibility. An occurrence of Ospwagan Group rocks at Saw Lake is conceivable, as other studies have suggested the possible existence of Ospwagan Group rocks in structural inliers and fold culminations as much as 60 km west of the Superior margin (Zwanzig et al., 2006; Percival et al., 2006). All significant Ni deposits in the main part of the TNB are hosted by the Paleoproterozoic Ospwagan Group, so the presence of inliers of similar rocks within areas dominated by the presumably barren Burntwood Group metasedimentary rocks and granitoid rocks of the Kisseynew Domain is significant because the area for nickel exploration in Manitoba is then extended well beyond the confines of the traditional areas in the TNB.

The Neoarchean detrital zircon provenance of the Saw Lake protoquartzite also indicates that a structural discontinuity must exist between it and the Missi Group basalt to the west and south. The fault is most likely a thrust, as it is semiconformable, dips moderately to the northeast and placed older (Saw Lake protoquartzite) over younger strata (ca. 1.84–1.83 Ga Missi Group basalt). The fault is most likely the same age (ca. 1.84–1.82 Ga) as the numerous southwest-verging thrust faults in the eastern Flin Flon Domain (Connors, 1996; Krause and Williams, 1999; Bailes and Galley, 2007). Similar to the other thrust faults, the one at the base of the Saw Lake protoquartzite is deformed by northeast-trending open folds.

The presence of a thrust fault at the structural base of the Saw Lake protoquartzite indicates that the pattern of southwest-verging thrust faults recognized throughout the Kisseynew Domain along its contact with the Flin Flon Domain continues into the Saw Lake area. The thrust faults result in allochthonous strata of disparate stratigraphic and tectonic affinity being juxtaposed. Because of this, each allochthon has different metallogenic associations and differing exploration possibilities. If the Saw Lake protoquartzite is indeed correlative with the passive-margin sequence (Ospwagan Group) of the TNB, then the structural panel that contains it will have potential as a Ni exploration target. Combined with the traditionally known, premier Au and base-metal potential of the arc- and successor-arc magmatic rocks, the new interpretation of the Saw Lake protoquartzite significantly expands the mineral potential of the easternmost Flin Flon Domain and the adjacent Kisseynew Domain.

Acknowledgments

The authors thank Hudson Bay Exploration and Development Co. Ltd. for providing the helicopter support needed to acquire geochronology samples of the Saw Lake protoquartzite and the Saw Lake pluton. The manuscript benefited from the helpful review and comments of H. Zwanzig.

References

Bailes, A.H. 1985: Geology of the Saw Lake area; Manitoba Energy and Mines, Geological Report GR83-2, 47 p. and 1 map at 1:50 000 scale.

Bailes, A.H. and Galley, A.G. 2007: Geology of the Chisel–Anderson lakes area, Snow Lake, Manitoba (NTS areas 63K16SW and west half of 63J13SE); Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, Geoscientific Map MAP2007-1, scale 1:20 000, with accompanying notes.

Böhm, C.O., Heaman, L.M. and Corkery, M.T. 1999: Archean crustal evolution of the northwestern Superior craton margin: U-Pb zircon results from the Split Lake Block; Canadian Journal of Earth Sciences, v. 36, p. 1973–1987.

Connors, K.A. 1996: Unravelling the boundary between turbidites of the Kisseynew Belt and volcano-plutonic rocks of the Flin Flon Belt, Trans-Hudson Orogen, Canada; Canadian Journal of Earth Sciences, v. 33, p. 811–829.

David, J., Bailes, A.H. and Machado, N. 1996: Evolution of the Snow Lake portion of the Palaeoproterozoic Flin Flon and Kisseynew belts, Trans-Hudson Orogen, Manitoba, Canada; Precambrian Research, v. 80, no. 1–2, p. 107–124.

Froese, E. and Moore, J.M. 1980: Metamorphism in the Snow Lake area, Manitoba; Geological Survey of Canada, Paper 78-27, 16 p. and 1 map at 1:50 000 scale.

Hamilton, M.A. and Bleeker, W. 2002: SHRIMP U-Pb geochronology of the Ospwagan Group: provenance and depositional age constraints of a Paleoproterozoic rift sequence, SE externides of the Trans-Hudson Orogen (abstract); Geological Association of Canada–Mineralogical Association of Canada, Joint Annual Meeting, Program with Abstracts, v. 27, p. 44–45.

Heaman, L.M., Machado, N., Krogh, T.E. and Weber, W. 1986: Preliminary U-Pb zircon results from the Pikwitonei granulite domain, Manitoba; Geological Association of Canada–Mineralogical Association of Canada, Joint Annual Meeting, Program and Abstracts, v. 11, p. 79.

Hoffman, P.F. 1988: United Plates of America, the birth of a craton: Early Proterozoic assembly and growth of Laurentia; Annual Review of Earth and Planetary Sciences, v. 16, p. 543–603.

Krause, J. and Williams, P.F. 1999. Structural development of the Snow Lake allochthon and its role in the evolution of the southeastern Trans-Hudson Orogen in Manitoba, central Canada; Canadian Journal of Earth Sciences, v. 36, p. 1881–1899.

Lucas, S.B., Stern, R.A., Syme, E.C., Reilly, B.A. and Thomas, D.J. 1996. Intra-oceanic tectonics and the development of continental crust: 1.92–1.84 Ga evolution of the Flin Flon Belt, Canada; Geological Society of America Bulletin, v. 108, p. 602–629.

Ludwig, K.R. 2003: Isoplot 3.00: a geochronological toolkit for Microsoft Excel; Berkeley Geochronology Center, Berkeley, California, Special Publication 4, 71 p.

Machado, N., Zwanzig, H.V. and Parent, M. 1999: U-Pb ages of plutonism, sedimentation, and metamorphism of the Paleoproterozoic Kisseynew metasedimentary belt, Trans-Hudson Orogen (Manitoba, Canada); Canadian Journal of Earth Sciences, v. 36, p. 1829–1842.

Mezger, K., Bohlen, S.R. and Hanson, G.N. 1990: Metamorphic history of the Archean Pikwitonei Granulite Domain and the Cross Lake Subprovince, Superior Province, Manitoba, Canada; Journal of Petrology, v. 31, p. 483–517.

Murphy, L.A. and Zwanzig, H.V. 2007: Preliminary stratigraphy and structure of the Notigi Lake area, Manitoba (parts of NTS 63O14, 64B3); *in* Report of Activities 2007, Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, p. 51–62.

Percival, J.A. Zwanzig, H.V. and Rayner, N. 2006: New tectonostratigraphic framework for the northeastern Kisseynew Domain, Manitoba (parts of NTS 63O); *in* Report of Activities 2006, Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, p. 74–84.

Rayner, N., Zwanzig, H.V. and Percival, J.A. 2006: Detrital zircon provenance of the Pipe Formation, Ospwagan Group, Thompson Nickel Belt, Manitoba, NTS 63O8; *in* Report of Activities 2006, Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, p. 116–124.

Simonetti, A., Heaman, L.M., Hartlaub, R.P., Creaser, R.A., MacHattie, T.G. and Böhm, C. 2005: U-Pb zircon dating by laser ablation-MC-ICP-MS using a new multiple ion counting Faraday collector array; Journal of Analytical Atomic Spectrometry, v. 20, p. 677–686.

Sircombe, K.N. 2004: AgeDisplay: an EXCEL workbook to evaluate and display univariate geochronological data using binned frequency histograms and probability density distributions; Computers and Geosciences, v. 30, p. 21–31.

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

Zwanzig, H.V. 1999: Structure and stratigraphy of the south flank of the Kisseynew Domain in the Trans-Hudson Orogen, Manitoba: implications for 1.845–1.77 Ga collision tectonics; *in* NATMAP Shield Margin Project, Volume 2; Canadian Journal of Earth Sciences, v. 36, p. 1859–1880.

Zwanzig, H.V., Böhm, C.O. Protrel, A. and Machado, N. 2003: Field relations, U-Pb zircon ages and Nd model ages of granitoid intrusions along the Thompson Nickel Belt–Kisseynew Domain boundary, Setting Lake area, Manitoba (NTS 63J15 and 63O2); *in* Report of Activities 2003, Manitoba Industry, Economic Development and Mines, Manitoba Geological Survey, p. 118–129.

Zwanzig, H.V. Murphy, L. Percival, J.A. Whalen, J.B. and Rayner, N. 2006: Thompson Nickel Belt–type units in the northeastern Kisseynew Domain, Manitoba (parts of NTS 63O); *in* Report of Activities 2006, Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, p. 85–103.