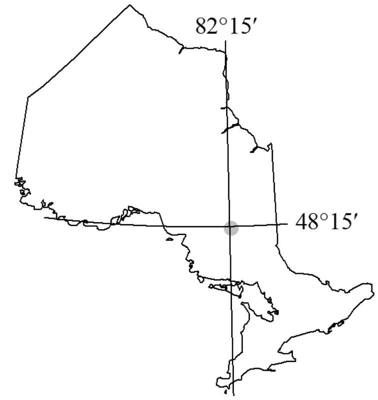
Targeted Geoscience Initiative 4

40. Constraining the Age of Synorogenic Conglomerate and Sandstone in Penhorwood Township, Northern Swayze Greenstone Belt



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INTRODUCTION

New outcrops (trenches) of coarse clastic sedimentary rocks in Penhorwood Township, northern Swayze greenstone belt, approximately 66 km west-southwest of Timmins, were previously described (Bleeker, Atkinson and Stalker 2014; *see* Figure 40.1 for general locality). These rocks, which include polymict conglomerate and pebbly sandstone, with some granitoid clasts, were deposited in a rapidly evolving environment that must have included transient fluvial to fluvio-deltaic high-energy conditions. They were tentatively interpreted as being of synorogenic origin, that is, deposited in an active tectonic environment following the onset of regional deformation. As such, they might represent the western continuation of the “Timiskaming assemblage” of the Porcupine mining camp. To test this interpretation, an initial detrital zircon U/Pb age study was undertaken to help constrain the time of deposition of this clastic sedimentary package. Herein are reported the U/Pb age results on 13 single zircon grains that were selected for isotopic analysis. The youngest concordant zircon analysis constrains the deposition of the conglomerate and pebbly sandstone to younger than 2687.6±1.6 Ma (uncertainties quoted at 2σ level throughout). A slightly reversely discordant zircon analysis has an age of 2682.8±4.7 Ma. These results are consistent with a synorogenic age of this clastic package, but do not unequivocally prove such an origin. Notably, among the zircons analyzed, there were no ages of synorogenic syenite plutons with ages of *circa* 2680 to 2670 Ma, which are commonly associated with Timiskaming clastic rocks farther east.

BACKGROUND AND SAMPLE DESCRIPTION

The outcrops and trenches in Penhorwood Township expose a variety of rock types, including dark slaty siltstone, conglomerates, pebbly sandstones and deformed intrusive mafic dikes (Photo 40.1; *see also* Bleeker, Atkinson and Stalker 2014). All these rocks are deformed, with steeply dipping bedding planes, and were metamorphosed at low metamorphic grade. The best conglomerate outcrops show a polymict clast population of mafic and felsic volcanic rocks, various porphyries, a few rounded granitoid clasts and some clasts of vein quartz. Abundant clasts of plagioclase porphyry may be derived from a nearby porphyry intrusion exposed in outcrop. This would signify the presence of an unconformity in the area. The observed association of rock types provides a good match to parts of the Timiskaming assemblage, particularly the upper part of this assemblage (Figure 40.2). The deformed mafic dikes may represent synorogenic mafic magmatism of a more alkaline nature, as seen elsewhere associated with the Timiskaming assemblage. However, syenitic intrusions, or clasts thereof, have not been observed.

Summary of Field Work and Other Activities 2015,
Ontario Geological Survey, Open File Report 6313, p.40-1 to 40-10.

All observed bedding planes are steeply dipping and generally trend approximately east-west; however, there is some notable variation in trend (from ~250 to ~285°). A steep cleavage is also present and changes vergence (angle relative to bedding trace) from one outcrop or trench to the next, indicating the package of sedimentary rocks is fairly tightly folded on a local scale. More work is required to resolve the local structure and to fit the outcrops into the regional map pattern (e.g., Milne 1972a, 1972b, 1972c).

A sample of representative (pebbly) sandstone (BNB-14-096), interlayered with pebbly conglomerates, was taken from one of the more extensively exposed trenches, across a sample width of approximately 1 m (*see* Photo 40.1A). Co-ordinates of the exact sample location (±4 m), obtained by GPS, are included in Table 40.1. The same outcrop shows a deformed and metamorphosed mafic dike intruding into the sandstones and conglomerates (*see* Photo 40.1B).

URANIUM–LEAD GEOCHRONOLOGY OF DETRITAL ZIRCONS

After thorough cleaning of the sandstone sample, approximately 15 kg was crushed. About half of the crushed material was then milled. A concentrate of the mineral zircon was recovered by reprocessing the heavy mineral splits on a Wilfley table until a significantly reduced sample size of approximately 5 to 10 g remained. This was followed by standard mineral separation procedures using magnetic separation

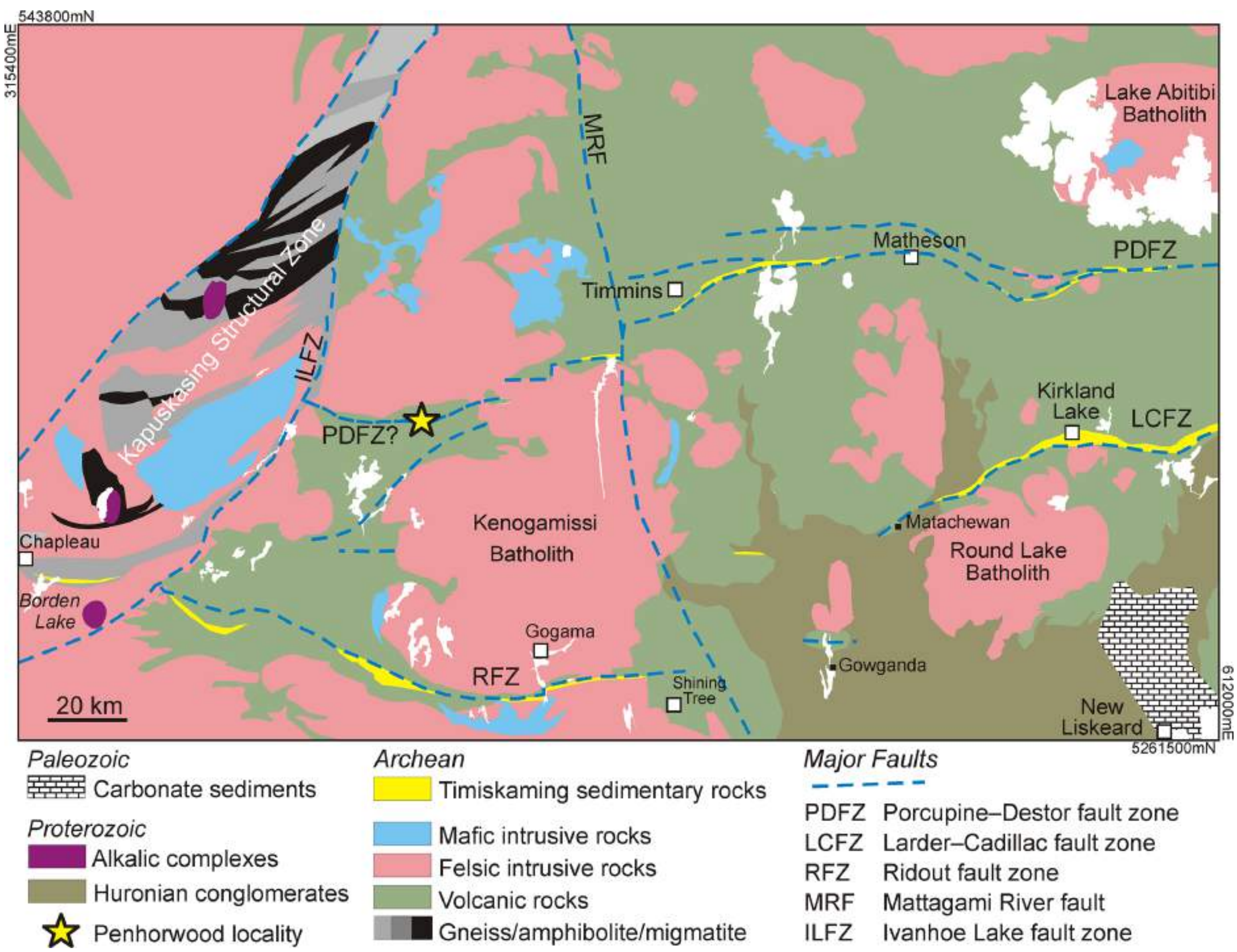

Figure 40.1. Simplified geology of the western Abitibi greenstone belt and the Kapuskasing Structural Zone, highlighting the presence of known Timiskaming assemblage rocks. The yellow star identifies the location of the "new" occurrence of Timiskaming rocks in the northern part of the Swayze greenstone belt being discussed in this report.

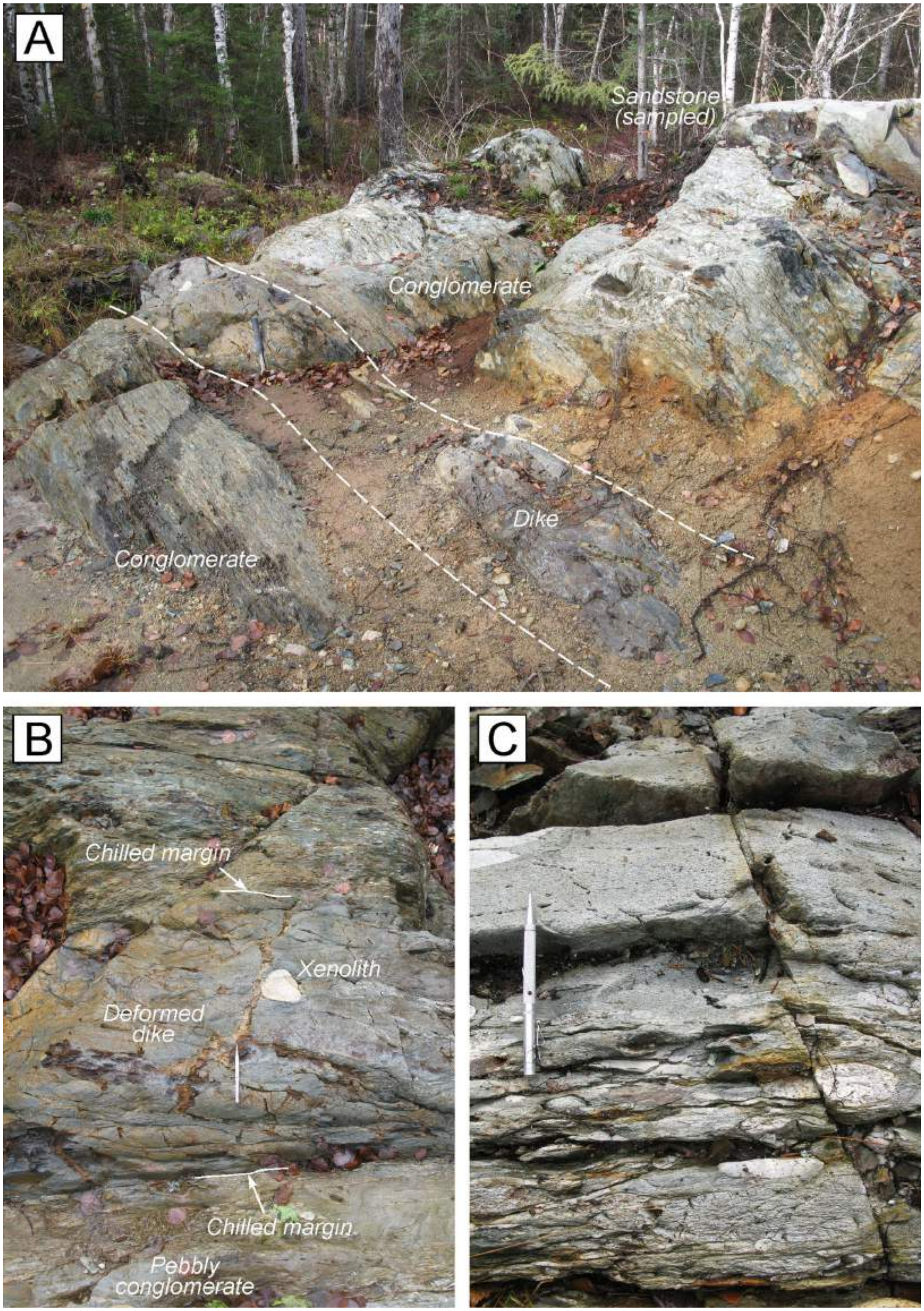

Photo 40.1. Outcrop pictures of the main trench in Penhorwood Township. **A**) Steeply dipping, deformed, pebbly conglomerates and sandstones. The sequence is intruded by a deformed synorogenic mafic dike. Hammer for scale. The sandstone section that was sampled shows up on the upper right side of the image. **B**) Close-up of the approximately 1 m wide, deformed mafic dike that intrudes pebbly conglomerates. The dike shows chilled margins, and carries xenoliths of felsic porphyry. It is cut by deformed quartz veins and affected by carbonate alteration. **C**) The section of sandstone and pebbly sandstone that was sampled for the detrital zircon study. Pen for scale.

and methylene iodide methods to produce a zircon concentrate. Crushing, mineral separation and isotopic analysis were carried out at the Jack Satterly Geochronology Laboratory of the University of Toronto. All U/Pb results were obtained on carefully selected single zircon grains pre-treated by "chemical abrasion" (Mattison 2005). Analyses were by isotope dilution thermal ionization mass spectrometry (ID-TIMS) methods. Analytical protocols are more fully described in the Appendix.

An abundance of zircon grains was recovered from the sample. These show a range in colour (colourless to dark pink) and morphological characteristics, and degree of detrital rounding. Most grains show modest surface abrasion, with slight rounding at crystal face intersections; a few grains are extensively rounded and pitted, indicating extensive detrital transport. Some grains are euhedral and show little or no evidence of transport. These zircons were either sourced locally, or they may have escaped erosional effects by being encased within clasts or other minerals. However, as the sample was dominated by sand size material, the latter explanation is less applicable.

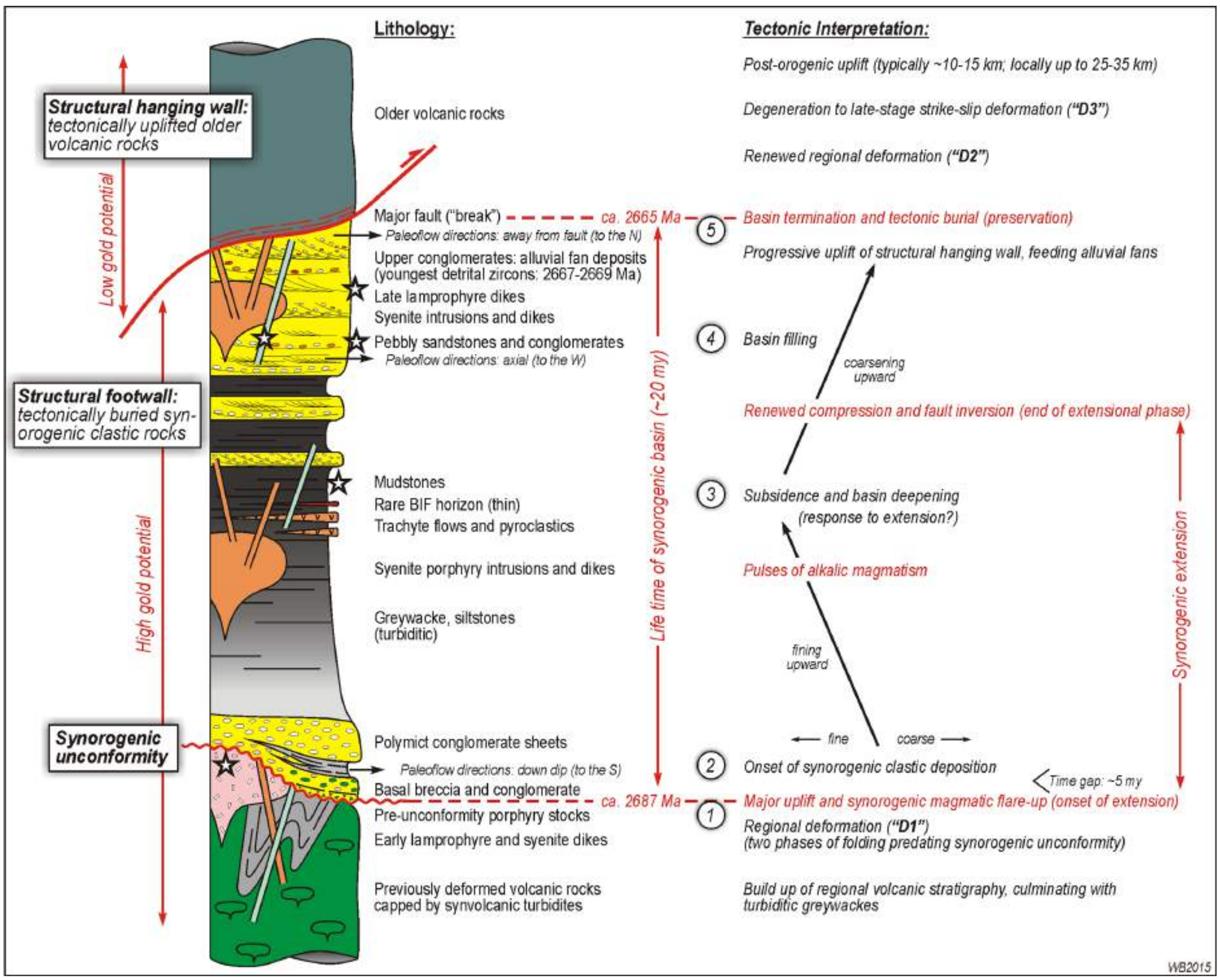

Figure 40.2. Composite model stratigraphy and structural setting of typical occurrences of synorogenic clastic (± volcanic-plutonic) rocks in the Abitibi greenstone belt (*after* Bleeker 2015). Stratigraphic column and main lithologies are shown on the left, and tectonic interpretation is given on the right. The overall evolution or "life time" of the synorogenic basin remnants can be divided into 5 phases, with a total duration of approximately 20 million years (my) (*see* Bleeker 2015, for additional detail). The tectonic switch to synorogenic processes occurred at 2687 Ma. Bold white stars indicate the association of rock types exposed in the Penhorwood Township trenches. Abbreviation: BIF, banded iron formation.

In detrital zircon studies of clastic sedimentary rocks, the youngest, concordant, single zircon age constrains the maximum age of deposition of the sedimentary unit. To maximize the probability of dating a potentially youngest zircon grain, and thus placing a tighter constraint on the (maximum) age of deposition, euhedral crystals with a variety of morphologies were selected for this study.

Uranium–Lead Analytical Results

A total of 13 single zircon crystals were analyzed. Representative grains are shown in Photo 40.2 and analytical results are provided in Table 40.1. They are displayed on a Concordia diagram in Figure 40.3. A number of the analyses are reversely discordant, which may be as a result of incomplete dissolution, which does not affect the $^{207}Pb/^{206}Pb$ ages. Below, results are thus discussed and quoted as model $^{207}Pb/^{206}Pb$ ages. They appear to define 4 approximate age groupings: *circa* 2688 Ma (4 zircons), *circa* 2700 Ma (1 zircon), *circa* 2709 Ma (6 zircons) and *circa* 2723 Ma (2 zircons).

Elongate, lath-like grains are from the age group of *circa* 2709 Ma. Equant or short prismatic grains with sharp crystal face intersections define the youngest age group at *circa* 2688 Ma. The youngest, concordant zircon grain has a $^{207}Pb/^{206}Pb$ age of 2687.6±1.6 Ma (*see* Table 40.1, grain #10), which defines the maximum age of deposition for these sandstones and conglomerates. A single result may be somewhat younger, with a $^{207}Pb/^{206}Pb$ age of 2682.8±4.7 Ma (*see* Table 40.1, grain #13), but is less precise and slightly reversely discordant. Thus, this result should be treated with some caution. To complete the data presentation, Figure 40.4 plots the results as a relative probability diagram versus age.

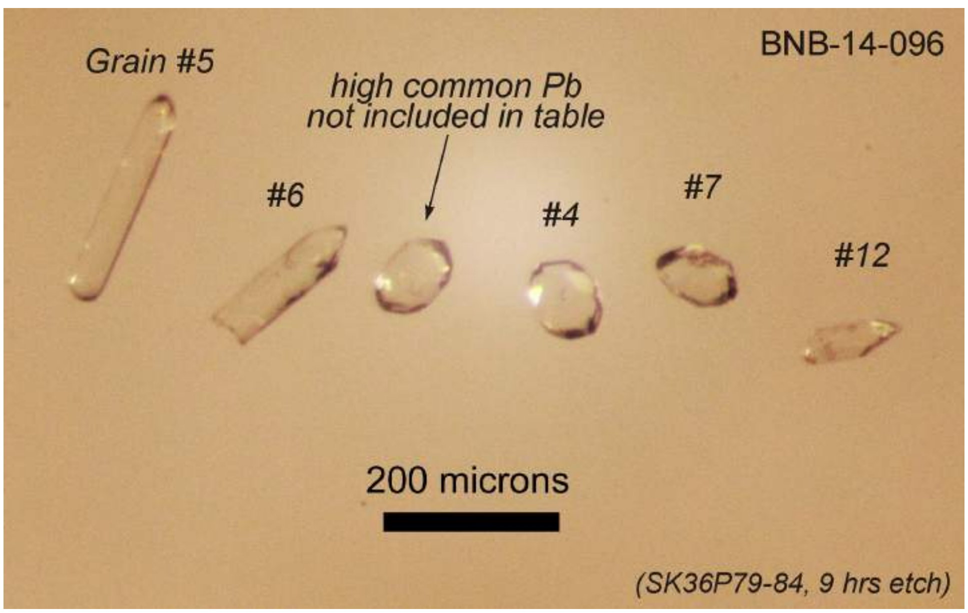

Photo 40.2. Image of representative detrital zircon grains from sample BNB-14-096, shown after “chemical abrasion” pre-treatment. Grain identifiers correspond with those in Table 40.1.

Table 40.1. Uranium–lead isotopic data for chemically abraded single zircon crystals from a synorogenic clastic unit, Penhorwood Township, sample BNB-14-096. The youngest concordant to nearly concordant zircon grains (#10 and #13) are indicated in bold.

No.	Th/U	PbC (pg)	$^{206}Pb/^{204}Pb$ measured	$^{207}Pb/^{235}U$	2σ	$^{206}Pb/^{238}U$	2σ	Error Corr.	$^{207}Pb/^{206}Pb$	2σ	$^{206}Pb/^{238}U$ Age (Ma)	2σ	$^{207}Pb/^{235}U$ Age (Ma)	2σ	$^{207}Pb/^{206}Pb$ Age (Ma)	2σ	% Disc
BNB-14-096 (UTM co-ordinates, Zone 17U, 415102E 5337335N, WGS84)																	
1	0.49	0.3	2714	13.389	0.066	0.5170	0.0024	0.951	0.18784	0.00029	2686	10	2707	5	2723.3	2.5	1.7
2	0.24	0.9	995	13.381	0.099	0.5175	0.0033	0.924	0.18752	0.00053	2689	14	2707	7	2720.5	4.7	1.4
3	0.26	0.2	508	13.968	0.467	0.5429	0.0176	0.974	0.18661	0.00141	2796	73	2748	31	2712.5	12.5	-3.8
4	0.44	0.2	6781	13.519	0.058	0.5261	0.0021	0.963	0.18639	0.00022	2725	9	2717	4	2710.6	1.9	-0.6
5	0.50	0.2	2273	13.662	0.154	0.5323	0.0058	0.973	0.18617	0.00048	2751	25	2727	11	2708.6	4.3	-1.9
6	0.74	0.2	2642	14.044	0.119	0.5472	0.0046	0.949	0.18615	0.00050	2813	19	2753	8	2708.5	4.4	-4.8
7	1.67	1.0	1392	13.559	0.063	0.5288	0.0019	0.864	0.18594	0.00044	2737	8	2719	4	2706.6	3.9	-1.4
8	0.72	0.3	4419	13.078	0.046	0.5105	0.0016	0.952	0.18580	0.00020	2659	7	2685	3	2705.4	1.8	2.1
9	0.68	0.2	5012	13.342	0.061	0.5224	0.0024	0.927	0.18524	0.00032	2709	10	2704	4	2700.3	2.9	-0.4
10	**0.40**	**0.2**	**9572**	**13.114**	**0.040**	**0.5174**	**0.0014**	**0.945**	**0.18381**	**0.00018**	**2688**	**6**	**2688**	**3**	**2687.6**	**1.6**	**0.0**
11	0.65	1.1	2045	13.302	0.045	0.5241	0.0020	0.759	0.18407	0.00047	2717	9	2701	3	2689.9	4.2	-1.2
12	2.49	0.3	2498	13.671	0.076	0.5395	0.0028	0.963	0.18378	0.00028	2781	12	2727	5	2687.3	2.5	-4.3
13	**0.45**	**0.3**	**2442**	**13.303**	**0.088**	**0.5264**	**0.0029**	**0.903**	**0.18329**	**0.00053**	**2726**	**12**	**2701**	**6**	**2682.8**	**4.7**	**-2.0**

Notes:

All zircon grains have been thermally annealed and etched in HF (Mattinson 2005).

Th/U calculated from radiogenic $^{208}Pb/^{206}Pb$ ratio and $^{207}Pb/^{206}Pb$ age assuming concordance.

PbC is total amount of common Pb in picograms (pg); assigned the isotopic composition of laboratory blank.

$^{206}Pb/^{204}Pb$ corrected for fractionation and common Pb in the spike.

Pb/U ratios corrected for fractionation, common Pb in the spike, and blank.

Error Corr. is correlation coefficients of X-Y errors on the Concordia plot.

Correction for ^{230}Th disequilibrium in $^{206}Pb/^{238}U$ and $^{207}Pb/^{206}Pb$ assuming Th/U of 4.2 in the magma.

Disc. is percent discordance for the given $^{207}Pb/^{206}Pb$ age; negative values indicate reverse discordance.

DISCUSSION AND CONCLUSIONS

A robust result stemming from these new data is that the Penhorwood conglomerates and pebbly sandstones have a maximum depositional age of *circa* 2688 Ma (*see* Table 40.1, grain #10). One less precise and slightly reversely discordant grain (#13) hints at a younger maximum age. These maximum ages of deposition are both suggestive and permissive of a synorogenic origin. Ages obtained farther east indicate that the transition to synorogenic magmatism occurred as early as 2687±3 Ma (Barrie 1990), that is, immediately following, if not during, final deposition of the Porcupine Group turbidites. The large Adams pluton, south of Timmins, already postdated the first significant folding event and has an age of *circa* 2686 Ma (Frarey and Krogh 1986).

The maximum age of deposition obtained here is thus at the time of transition to synorogenic processes, and the polymict character of the conglomerates supports uplift and erosion of some granitoid plutons in the source area. The sediment package was then intruded by synorogenic mafic dikes and subsequently deformed. The data from this study do not indicate a contribution to the Penhorwood sandstones and conglomerates of typical Timiskaming-age syenitic plutons. Thus, perhaps the Penhorwood clastic rocks are best interpreted as "early synorogenic". However, the observed rock association is certainly compatible with the main part of the Timiskaming assemblage (*see* Figure 40.2). Perhaps younger synorogenic zircons were absent in the source of this particular sandstone package, or such grains were not picked during the grain selection for this exploratory study. In any case, these results and field observations support the presence of synorogenic mafic magmatism in the area, younger than 2688 Ma.

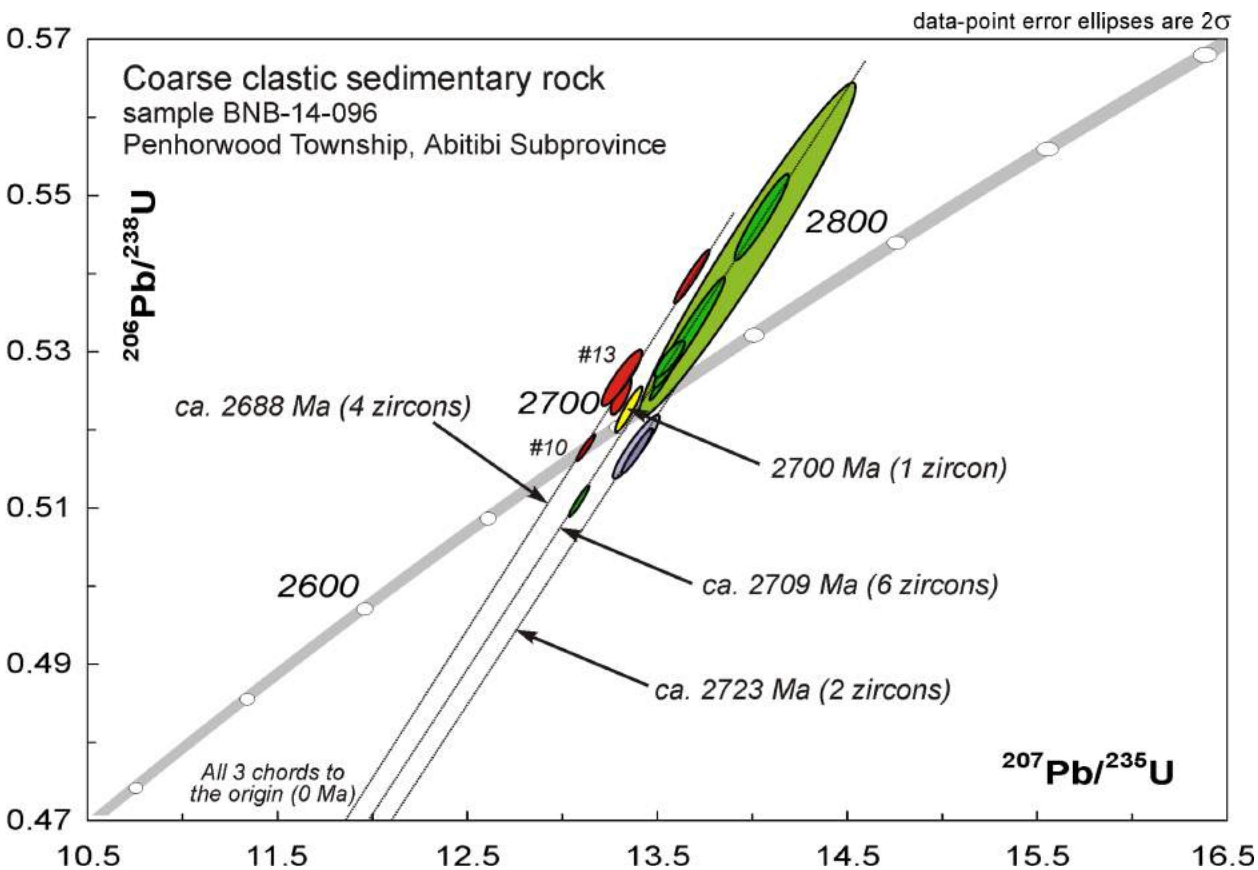

Figure 40.3. Results of 13 single grain zircon analyses displayed on standard U/Pb Concordia diagram. Colours identify the 4 groups of results. Youngest grains (#10 and #13) are identified.

It is also noted that the constraint obtained from the youngest concordant detrital zircon (i.e., younger than 2688 Ma) is similar, if not identical, to the detrital zircon age constraint on the Ridout assemblage farther south (van Breemen, Heather and Ayer 2006), a more extensively preserved clastic sequence dominated by polymict conglomerates and sandstones, and for which a synorogenic origin is not in doubt. In this study, the youngest detrital zircon grain, with a $^{207}Pb/^{206}Pb$ age of 2682.8±4.7 Ma, although less precise and slightly reversely discordant, could be derived from synorogenic plutons that intruded the northern Swayze greenstone belt. An example is the nearby Kukatush pluton, for which van Breemen, Heather and Ayer (2006) report an age of 2684±2 Ma. This would also provide a proximal source for some of the granitoid clasts observed (*see* Bleeker, Atkinson and Stalker 2014).

Apart from the youngest zircon ages obtained, the other detrital ages represent well-known source assemblages in the Swayze greenstone belt or, more generally, the south-central Abitibi greenstone belt. Specifically, the 2 oldest grains agree well with the climax of felsic volcanism toward the end of the regional Deloro assemblage and its correlative units (Corfu 1993; Ayer et al. 2002; Thurston et al. 2008). Zircon ages of *circa* 2710 to 2705 Ma generally match those of the Tisdale assemblage. In more detail, the relatively precise detrital ages at *circa* 2705 to 2707 Ma could be derived from felsic volcanism and associated porphyries of the Heenan Formation (van Breemen, Heather and Ayer 2006).

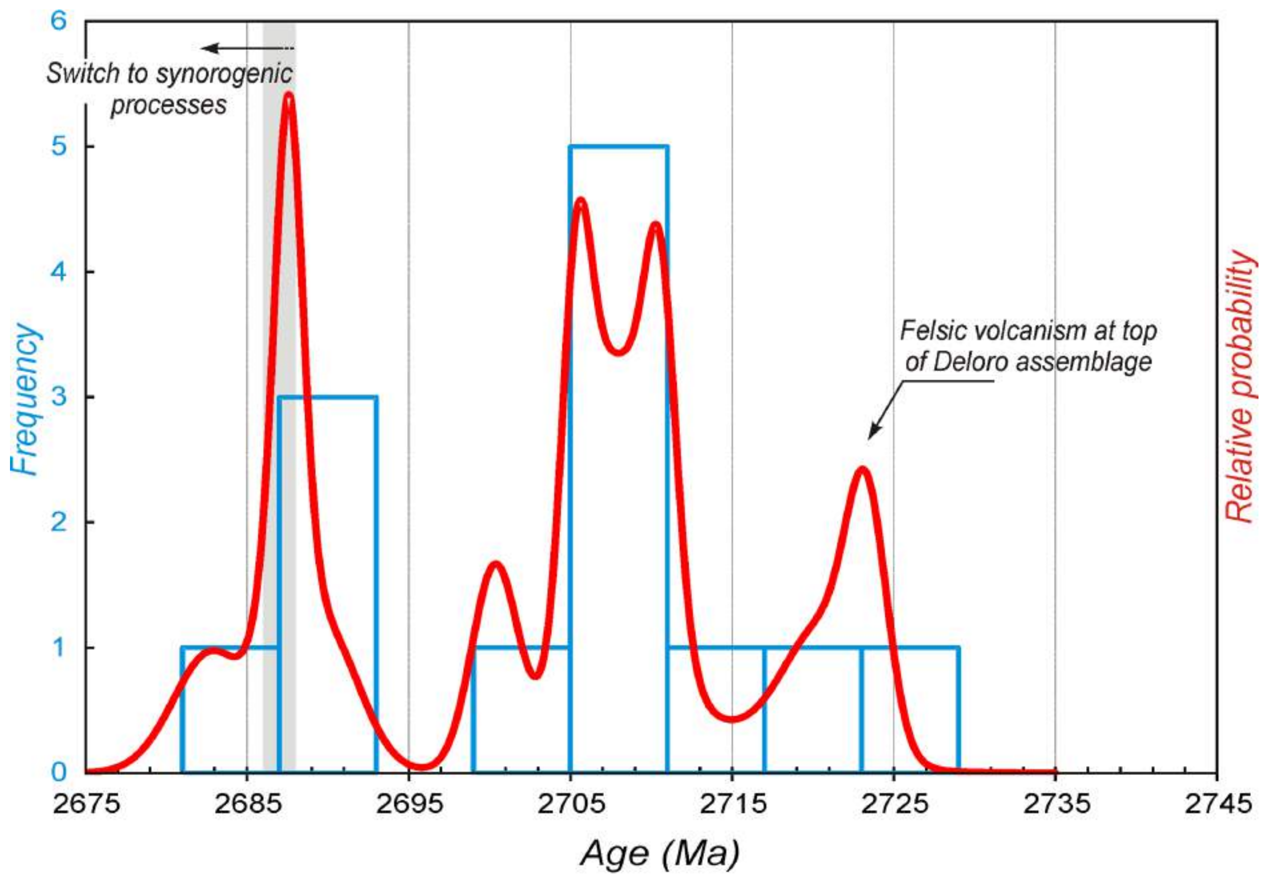

Figure 40.4. Age histogram (blue) and relative probability curve (red) for the 13 single zircon results. Grey bar indicates timing of the switch to synorogenic processes (*circa* 2687 Ma). The maximum depositional age of the pebbly sandstone is 2688 Ma (based on the youngest peak (including grain #10), and possibly somewhat younger (grain #13). In the limited sampling (n=13) conducted to date, zircon grains with ages of *circa* 2680 to 2670 Ma were not identified, either because the sandstone was deposited prior to this time, or because it was sourced from a local area with no zircon-bearing felsic rocks of that age, or such grains were not picked during the grain selection for this study.

In conclusion, the weight of the evidence suggests that the Penhorwood Township polymict conglomerates and pebbly sandstones are of synorogenic origin and represent an occurrence of Timiskaming assemblage rocks well to the west of Timmins. The maximum depositional age is 2688 Ma, and possibly somewhat younger. After deposition in an active tectonic environment, the sequence was intruded by synorogenic mafic dikes, before being deformed and tightly folded into its present position. The new age constraint is identical to that for the Ridout sequence farther south.

ACKNOWLEDGMENTS

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APPENDIX: ANALYTICAL PROTOCOL

The rock sample was crushed and milled using standard methods, involving a jaw crusher and Bico disk mill, respectively. Initial sample weight of the composite sandstone sample was ~15 kg. After crushing to ~1 cm pieces, half the sample was milled to a powder. A heavy mineral concentrate was recovered by reprocessing the heavy mineral splits on the Wilfley table until a significantly reduced sample size of ~5 to 10 g remained. This was followed by standard mineral separation procedures using magnetic separation and methylene iodide methods to produce a zircon concentrate.

Uranium–lead analysis was by isotope dilution thermal ionization mass spectrometry methods (ID-TIMS). Prior to analysis, zircon crystals were selected under a binocular microscope, and then thermally annealed and chemically etched (chemical abrasion), which has the advantage of penetrative removal of alteration zones where Pb loss has occurred and generally improving concordance (Mattinson 2005). These zones correlate with high U domains that have suffered radiation damage prior to alteration. The pre-treatment involved placing zircon grains in a muffle furnace at ~1000°C for ~24 to 60 hours to repair radiation damage and anneal the crystal lattice, followed by a modified single-step partial dissolution procedure in ~0.10 mL of ~50% HF (occasionally diluted if zircon grains appeared to be severely metamict) and 0.020 mL 7N HNO_3 in Teflon™ dissolution vessels at 195°C for 7 to 9 hours. Zircon grains were rinsed with 8N HNO_3 at room temperature prior to dissolution. A ^{205}Pb–^{235}U spike was added to the Teflon™ dissolution capsules during sample loading. Zircon was dissolved using ~0.10 mL of concentrated HF acid and ~0.02 mL of 7N HNO_3 at 195°C for 3 to 5 days, then dried to a precipitate and redissolved in ~0.15 mL of 3N HCl overnight (Krogh 1973). U and Pb were isolated from the zircon using 50 µL anion exchange columns using HCl, deposited onto outgassed rhenium filaments with silica gel (Gerstenberger and Haase 1997), and analyzed with a VG354 mass spectrometer using a Daly detector in pulse-counting mode. Corrections to the ^{206}Pb–^{238}U ages for initial ^{230}Th disequilibrium in the zircon have been made assuming a Th/U ratio in the magma of 4.2. All common Pb was assigned to procedural Pb blank for zircon. Dead time of the measuring system for Pb and U was 16 and 14 ns, respectively. The mass discrimination correction for the Daly detector is constant at 0.05% per atomic mass unit. Amplifier gains and Daly characteristics were monitored using the SRM 982 Pb standard. Thermal mass discrimination corrections are 0.10% per atomic mass unit. Decay constants are those of Jaffey et al. (1971).

All age errors quoted in the text and table, and error ellipses in the Concordia diagrams are given at the 95% confidence interval. Plotting and age calculations were done using Isoplot 3.00 (Ludwig 2003).