# U-Pb Zircon, Titanite, and Monazite Ages from the Wollaston Domain: A Summary[1]

*Irvine R. Annesley[2], Catherine Madore[2], and Tom E. Krogh[3]*

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Recent geological investigations by Annesley (1990), Annesley and Madore (1988, 1989a, 1989b, 1990a, 1990b, 1991a, 1991b), and Madore and Annesley (1992) have refined the geological characteristics of the Wollaston Group and the underlying Archean basement, so as to better understand the genesis of Athabasca Basin unconformity-type uranium deposits. More specifically, the objective of the investigations has been to examine the role of Wollaston Group stratigraphy and sub-Athabasca basement structure in uranium metallogenesis. These investigations included mapping of selected areas of the Wollaston Domain, logging of sub-Athabasca drill cores from the eastern Athabasca Basin, and establishing type sections for the Wollaston Group. Supporting petrological and geochemical studies recognized and focused on two major geological problems: 1) identification of the protolith(s) of very fine- to medium-grained quartzofeldspathic gneisses and 2) determination of the age of these gneisses. Annesley and Madore (1990b, 1991a) have reinterpreted some of the quartzofeldspathic gneisses, previously mapped as meta-arkoses, as highly strained and metamorphosed granitoid rocks of Archean and Lower Proterozoic age. This reinterpretation has implications for stratigraphic correlation and geophysical interpretation in the exposed and sub-Athabasca Wollaston Domain.

As an aid to resolving the above mentioned problems, several samples were collected and submitted in 1990 and 1991 to the Royal Ontario Museum (ROM) for U-Pb zircon, titanite, and monazite age determinations. The objective of this and future age dating work is to: 1) constrain the timing of thermotectonic events in the Wollaston Domain, 2) establish the age patterns of continental crust in the Wollaston Domain, 3) bracket the depositional age of the Wollaston Group, and 4) further resolve the controversy surrounding the ages of certain quartzofeldspathic gneisses (see conclusions of Annesley and Madore, 1990b).

Sample locations are shown in Figure 1 and results are summarized in Table 1. Annesley *et al.* (1991) reported briefly on the 1990 results. Only a summary of the U-Pb age results is presented herein, since a detailed description of the isotopic age determinations and their interpretation will be given in a forthcoming paper by the authors. The U-Pb analytical procedures of this study are similar to those described elsewhere (Davis, 1982; Krogh, 1973, 1982a, 1982b; Machado *et al.*, 1989, 1990). The decay constants recommended by the International Union of Geological Sciences (Steiger and Jäger, 1977) are used in this study. Analytical errors associated with the results of this study are quoted within a 95 percent confidence interval.

## 1. Geological Setting

The area investigated includes the Wollaston Domain and the eastern part of the Mudjatik Domain (Figure 1),

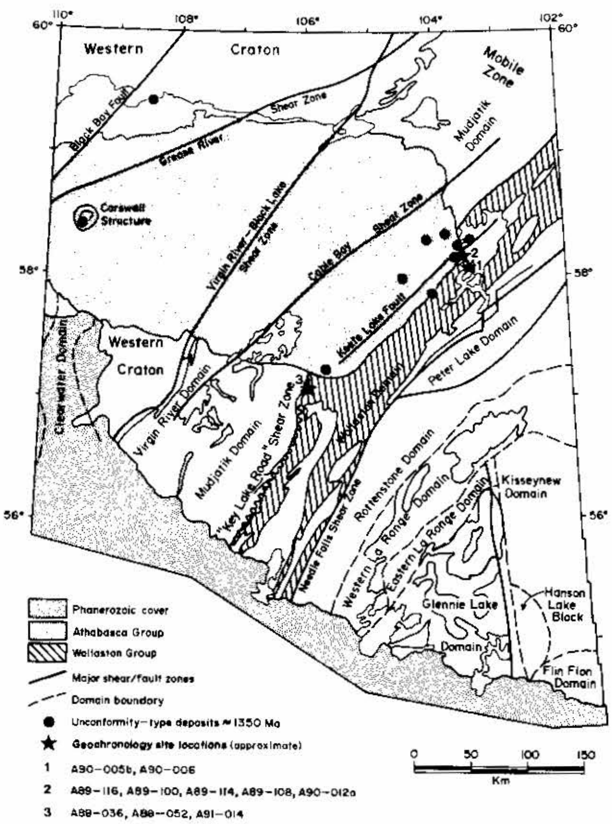


*Figure 1 - Location map of the Wollaston Domain with geochronology sampling localities.*

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(2) Saskatchewan Research Council, 15 Innovation Blvd., Saskatoon, Saskatchewan, S7N 2X8.
(3) Jack Satterly Geochronology Laboratory, Royal Ontario Museum, 100 Queen's Park, Toronto, Ontario, M5J 2C6.

*Table 1 - Summary of U-Pb geochronological results.*

| Sample No. | Rock Type | Location (NTS) | Longitude | Latitude | UTM E | UTM N | n | mineral | U-Pb age (Ma) |
|---|---|---|---|---|---|---|---|---|---|
| A90-005b | Tonalitic Gneiss | 64L/4 | 103°31'44" | 58°04'41" | 586815 | 6438100 | 3 | zircon | 2689 +19/-18 |
| | | | | | | | 3 | zircon | 2566 +23/-21 |
| | | | | | | | 1 | titanite | 1778 ±2 |
| A90-006 | Quartz Dioritic Gneiss | 64L/4 | 103°30'45" | 58°08'19" | 587565 | 6444850 | 5 | zircon | 2602 +29/-26 |
| | | | | | | | 1 | titanite | 1779 ±2 |
| A89-116 | Granodioritic Gneiss | 64L/4 | 103°45'25" | 58°08'48" | 573125 | 6445480 | 5 | zircon | 2620 +10/-9 |
| | | | | | | | 1 | titanite | 1789 ±2 |
| A89-100 | Porphyritic Granite | 64L/4 | 103°44'00" | 58°10'36" | 574540 | 6448860 | 4 | zircon | 1815 ±2 |
| | | | | | | | 1 | titanite | 1788 ±2 |
| A89-114a,c | Meta-quartzite | 64L/4 | 103°45'40" | 58°08'38" | 572990 | 6445200 | 7 | zircon | 2686-2863* |
| | | | | | | | 1 | monazite | 1816 ±2 |
| A91-014 | Pelitic Gneiss | 74B/16 | 106°07'58" | 56°56'23" | 431075 | 6311050 | 5 | zircon | 2546-2792* |
| | | | | | | | 1 | monazite | 1814 ±2 |
| A89-108 | Pelitic Gneiss | 64L/4 | 103°45'20" | 58°08'43" | 573200 | 6445425 | 1 | monazite | 1812 ±2 |
| A90-012a | Meta-gabbro | 64L/4 | 103°35'07" | 58°12'19" | 583150 | 6452195 | 4 | zircon | 1820 ±5 |
| A88-052 | Mylonitic Tonalitic Gneiss | 74G/1 | 106°03'12" | 57°00'27" | 436026 | 6318502 | 5 | zircon | 2733 +9/-8 |
| A88-036 | Calc-silicate Vein | 74B/16 | 106°07'45" | 56°49'48" | 431090 | 6298818 | 2 | titanite | 1793 ±4 |

Note:
n = number of analysed mineral fractions;
* denotes a range of U-Pb ages for detrital zircons in samples A89-114a, c and A91-014

two of the major subdivisions of the Cree Lake Zone of the Trans-Hudson Orogen (Lewry *et al.*, 1985). This area comprises the ensialic margin of an Archean craton, the Hearne Province (Hoffman, 1988 and 1989). It was previously mapped on a reconnaissance scale by many workers (see 1:250 000 scale Compilation Bedrock Geology Map Series and references therein, Saskatchewan Energy and Mines). Results of recent work in this region were reported by Annesley and Madore (1988, 1989a, 1989b), Quirt (1989), Annesley (1990), Annesley *et al.* (1991), and Madore and Annesley (1992), among others. The geological details of the area are not reported herein, as they have been summarized elsewhere by Sibbald (1983), Annesley (1989), Annesley and Madore (1991a), and Bickford *et al.* (1990).

## 2. Previous U-Pb Zircon and Monazite Geochronology

Detailed isotopic work from Archean and Early Proterozoic rocks of the Wollaston Domain is sparse and widely scattered. Early work, mostly Rb-Sr and K-Ar studies, identified two major thermotectonic events in the Wollaston Domain, an Archean one (2.5 to 2.6 Ga) and a Proterozoic one (1.7 to 1.9 Ga). All of the Rb-Sr ages of Archean age are from a relatively uniform magmatic suite of syenogranites and monzogranites. Until 1987, the only U-Pb age from this granitic suite was a U-Pb zircon age of 2494 ±38 Ma from the Johnston River Granite (Ray and Wanless, 1980). Also until recently, no conclusive evidence existed for even older components of Archean basement in the Wollaston Domain of Saskatchewan. However, this possibility was suggested by Rb-Sr ages of 2636 ±163 Ma and 2745 ±124 Ma from orthogneisses within the Wollaston Domain basement of Manitoba (Weber *et al.*, 1975). More recently, a U-Pb zircon age of 2652 ±20 Ma from a sheared granite near Key Lake indicates an older component (Krogh and Clark, 1987). As shown in Table 2, the U-Pb data obtained from the Wollaston Domain during the last few years provide a spectrum of ages from 1742 to 2652 Ma. The U-Pb ages from 2188 to 2390 Ma are regarded as bulk whole-rock ages (i.e. derived from mixed type zircon separates). However, the 2188 ±46 Ma age possibly suggests another Proterozoic event at ca. 2.1 to 2.2 Ga. This event may be contemporaneous with the ca. 2.1 Ga felsic magmatism documented along the boundary zone of the Wollaston and Peter Lake Domains (see Annesley *et al.*, 1992; Annesley *et al.*, this volume). Because there are only a small number of U-Pb age dates, both the Archean and Early Proterozoic thermotectonic histories in the Wollaston Domain are poorly constrained, and further studies, like the one reported herein, are necessary.

## 3. Hidden Bay Area (southwest Wollaston Lake)

Twenty samples were collected in 1990 and 1991 from this area, and eight of these were selected for U-Pb

*Table 2 - Summary of previous U-Pb zircon and monazite ages from the Wollaston Domain.*

| Lithology | Location (NTS) | U-Pb age (Ma) | Reference |
|---|---|---|---|
| Johnston River Granite | 74H/1 | 2494 ±38 Ma (z) | Ray and Wanless, 1980 |
| Granite | 74H/4, 6 | 2600 ±18 Ma (z) | Krogh and Clark, 1987 |
| Granite | 74H/4 | 2652 ±20 Ma (z) | Krogh and Clark, 1987 |
| Granite | 74H/4 | 1742 ±15 Ma (m) | Krogh and Clark, 1987 |
| Granitic Gneiss | 64E/14 | 2188 ±46 Ma (z) | Bickford *et al.*, 1987 |
| Tonalitic Gneiss | 64E/14 | 2321 ±95 Ma (z) | Bickford *et al.*, 1988 |
| Granitic Gneiss | 64E/14 | 2390 ±160 Ma (z) | Bickford *et al.*, 1988 |
| Horton Island Granite | 64E/13 | 1840 ±29 Ma (z) | Bickford *et al.*, 1988 |

Note: letter designation in brackets refers to analysed mineral: z = zircon, m = monazite

studies. The samples investigated include quartzofeldspathic gneisses (A90-005b, A90-006, A89-116), a porphyritic granite (A89100), a meta-gabbro (A90-012a), a pelitic gneiss (A89108), and two meta-quartzites (A89-114a, A89-114c). These samples were studied to constrain the timing of magmatism, sedimentation, metamorphism, and deformation in the area, and to address the problem of protolith identification.

A migmatitic tonalitic gneiss (A90-005b; unit 8a (meta-arkose) of Wallis, 1971), occurring near the northwestern margin of the Trout Narrows granite, yielded two types of zircons: 1) colourless, rounded, and resorbed; and 2) brown, euhedral crystals. A discordia through analyses of the first type has an upper intercept of 2689 +19/-18 Ma and a lower intercept of 1783 ±26 Ma. Analyses of the second type define a discordia with an upper intercept of 2566 +23/-21 Ma and a lower intercept of 1792 ±27 Ma. The upper intercepts of the zircon data are interpreted as a 2689 Ma igneous protolith that underwent metamorphism at ca. 2566 Ma to form new zircons and overgrowths. The two discordia lines project to the essentially concordant titanite age of 1778 ±2 Ma. The titanite age is interpreted as a late Hudsonian event. The degree of lead loss in the zircons suggest that this event was relatively intense.

A quartz dioritic gneiss from Ashley Peninsula (A90-006, unit 6 (biotite-hornblende psammite) of Wallis, 1971) has four of five zircon fractions that are collinear with a 1779 Ma titanite age. A fifth fraction plots below the line, which suggests recent Pb loss has occurred. The four collinear fractions yielded an upper intercept of 2602 +29/-26 Ma and a lower intercept of 1793 ±26 Ma with a 47 percent probability of fit. The upper intercept is interpreted as the age of crystallization of the quartz dioritic gneiss.

A granodioritic gneiss (A89-116; unit 4d (biotite psammite) of Wallis, 1971) outcropping southeast of Rabbit Lake has four of five zircon analyses that are collinear. The four collinear analyses define a discordia that yielded an upper intercept of 2620 ±9 Ma and a lower intercept of 1798 ±14 Ma. Coexisting titanite in the rock is 0.3 percent discordant and yielded an age of 1789 Ma. The morphology of the zircons identifies them as magmatic in origin. This is consistent with petrographic and geochemical evidence for an igneous origin of the rock. Therefore, the 2620 Ma age is interpreted as the emplacement age of the granodioritic gneiss.

Four single and multigrain fractions of zircons were analysed from a porphyritic granite (A89-100), occurring south of Rabbit Lake. All fractions are concordant, and have nearly identical (within error) $^{207}Pb/^{206}Pb$ ages between 1812 and 1818 Ma. A mean $^{207}Pb/^{206}Pb$ age of 1815 ±2 Ma is considered the best estimate for the intrusion and crystallization age of the porphyritic granite. An analysis of titanite in the rock yielded a $^{207}Pb/^{206}Pb$ age of 1788 Ma and is 0.7 percent discordant. The 1788 ±2 Ma age is tentatively interpreted as a cooling age, but it may represent a later thermotectonic event. The porphyritic granite, like the meta-gabbro, is weakly deformed (except at intrusion margins) and intrusive into the Wollaston Group.

Four analyses of selected, sharp-faceted, euhedral zircons from the meta-gabbro (unit 4a (garnet amphibolite rock) of Wallis, 1971) yielded $^{207}Pb/^{206}Pb$ ages of 1820, 1816, 1813, and 1810 Ma, and are 0.5, 1.0, 0.25, and 1.4 percent discordant, respectively. The data are closely spaced and nearly concordant, and define an age of 1820 ±5 Ma. The extremely small zircon yield and the morphology of the zircons in the meta-gabbro implies a magmatic origin. The 1820 Ma age is interpreted as the precise time of emplacement for the meta-gabbro, and provides a minimum age for sedimentation of the Wollaston Group.

Seven single zircons from two metaquartzite samples of the Wollaston Group gave essentially concordant U-Pb data, and yielded projected $^{207}Pb/^{206}Pb$ ages of 2749 ±22 Ma, 2686 ±22 Ma, 2731 ±22 Ma, 2700 ±22 Ma, 2705 ±22 Ma, 2863 ±20 Ma, and 2728 ±34 Ma. This data suggests that Archean basement (>2700 Ma) was the main source of detritus for the metaquartzites. Coexisting monazite in one of the metaquartzites is concordant at 1816 Ma, and is interpreted as metamorphic in origin. The zircon ages were calculated as projected primary ages from 1816 Ma because the monazite age is concordant, and it is assumed that the zircons lost minor Pb at that time.

A sample of garnetiferous pelitic gneiss (A89-108) was collected <1 km from the metaquartzite samples. The quality and yield of detrital zircons were poor in this sample, hence no zircon ages were obtained. However, a multigrain monazite analysis from this sample yielded a $^{207}Pb/^{206}Pb$ age of 1812 Ma and is 0.5 percent discordant. This age is identical to that found in the metaquartzites, and provides a minimum age for the time of peak metamorphism in this area. These ages are nearly identical to the emplacement ages of the porphyritic granite and the meta-gabbro.

## 4. Karpinka Lake Area

Three samples, a pelitic gneiss (A91-014), a protomylonitic tonalitic gneiss (A88-052, previously interpreted as semipelitic gneiss by Gilboy, 1985), and a titanite-bearing calc-silicate vein (A88-036), were collected and studied to constrain the timing of felsic magmatism, sedimentation, and thermotectonism in the Karpinka Lake area.

Analyses of 4 single grains and one 20-grain fraction of selected, high-quality detrital zircons from the pelitic gneiss yielded $^{207}Pb/^{206}Pb$ ages of Archean age and variable discordance. A multigrain fraction of monazite in the pelitic gneiss gave a 0.8 percent discordant age of 1814 ±2 Ma. The 1814 Ma age is interpreted as a metamorphic age, and is identical (within analytical error) to the monazite ages from the Hidden Bay area. The U-Pb data of the zircons have been projected from 1814 Ma to correct for diffusive lead loss during metamorphism. The projected primary ages are 2703 ±12 Ma, 2722 ±13 Ma, 2578 ±20 Ma, 2546 ±14 Ma, and 2792 ±21 Ma. The projection from 1814 Ma, the time of primary Pb loss, is considered realistic because it is consistent with the degree of discordance observed in zircons from the protomylonitic tonalitic gneiss.

Five analyses (3 single and 2 multigrain fractions) of selected, resorbed, colourless to pale yellow zircons from the protomylonitic tonalitic gneiss yielded $^{207}Pb/^{206}Pb$ ages of 2723, 2673, 2670, 2648, and 2570 Ma, and are 0.26, 3.1, 3.1, 3.5, and 6.1 percent discordant, respectively. A discordia with an upper intercept of 2733 +9/-8 Ma, a lower intercept of 1755 +56/-52 Ma, and 21 percent probability of fit is defined by these five analyses. The upper intercept is interpreted as a crystallization age. It is deemed reliable because the data from the best fraction (a high-quality single grain) yielded a minimum age of 2723 ±2 Ma. The 2733 Ma age is the oldest reported age of felsic magmatism in the Wollaston Domain.

One sample of titanite-bearing calc-silicate veins that crosscut the fabric of mylonitic albite gneisses was collected to establish the timing of retrograde metamorphism and metasomatism in the area. Replicate analyses of titanite fragments yielded analytically identical $^{207}Pb/^{206}Pb$ ages of 1795 and 1790 Ma, and are -1.6 and 1.2 percent discordant. An age of 1793 ±4 Ma is determined by this data, and is considered reliable even though the analyses plot slightly above the concordia curve. The 1793 Ma age provides a minimum estimate for retrograde calc-silicate alteration in the area, and also gives a minimum age of albitization since the calc-silicate vein crosscuts the mylonitic fabric of the albite gneisses.

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