

# Use of a Hand-Held Gamma-ray Spectrometer as a Mapping Tool: Examples from the Canadian Shield of Ontario

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## Introduction

Assay-mode measurements of K, U and Th content of rocks, obtained from a hand-held Exploranium™ GR-135G MiniSpec gamma-ray spectrometer are an effective field mapping tool.

Initially used primarily to document radioactive mineral occurrences located in the Grenville and Southern provinces of the Canadian Shield in Ontario (see Location Figure Ontario), since 2007, the spectrometer has been used to distinguish between different granitic suites of Proterozoic and Archean age and to map differences in clay content in low-grade metasedimentary rocks (see Tables 1, 2, 3, 4, 5, 6).

It has also been effective in distinguishing between mafic extrusive and intrusive rocks of Archean and Paleoproterozoic age, including mafic dikes, even at low abundance levels (see Table 5, 6).

The spectrometer results have been verified by subsequent whole-rock geochemical analyses (e.g., see Table 2), as well as by detailed tests of reproducibility and accuracy at several test sites. The spectrometer has the advantage of providing real-time data during mapping, as well as providing data from a greater number of stations than would be possible solely on geochemical sampling.

This poster highlights how the scintillometer can be used as an effective mapping tool.

**Table 1**  
Summary of magnetic susceptibility and scintillometer measurements from granitic rocks in Cavendish Township in the Grenville Province (see Location Figure 1).

Site	Intrusive Unit and Age	Rock Type	UTM Location (NAD83, Zone 17)	Average Specific Gravity	Average Scintillometer Data			Average Magnetic Susceptibility ( $\times 10^{-3}$ SI)
					K (wt %)	U (ppm)	Th (ppm)	
1	Catchacoma (high Th) Suite, 1067±4 Ma	syenogranite	710700E 4954000N	2.64	4.0	3.5	28.3	10.6 (max 15.5)
2	Quartz Monzodiorite Suite emplacement age unknown	quartz monzodiorite gneiss	710670E 4954400N	2.73	2.7	1.2	0.6	14.8 (max 39.8)
3	Methuen Suite, Junction pluton 1221±2 Ma	gneissic monzogranite	707425E 4969475N	2.66	2.9	4.1	9.1	3.6 (max 10.0)
4	Methuen Suite, Galloway pluton ~1220–1240 Ma	gneissic granodiorite to monzogranite	708000E 4964600N	2.68	2.8	4.2	6.1	0.1 (max 0.22)
5a	Elzevir Suite, ~1270–1290 Ma	granodiorite gneiss	704640E 4953250N	n/a	4.5	7.3	7.9	81.4
5b	age unknown	saprolite	704640E 4953250N	n/a	3.6	5.5	8.0	49.8

**Table 2**  
Comparison of geochemical and scintillometer data for granitic rocks in Cavendish Township (from Banman 2009, Easton 2009).

Site	Rock Type	Average Geochemistry Values			Average Scintillometer Data		
		K (wt %)	U (ppm)	Th (ppm)	K (wt %)	U (ppm)	Th (ppm)
1	Syenogranite	4.7	4.4	42.5	4.0	3.5	28.3
2	Quartz monzodiorite gneiss	3.2	1.7	3.2	2.7	1.2	0.6
3	Gneissic monzogranite	3.2	3.9	14.7	2.9	4.1	9.1
4	Gneissic granodiorite to monzogranite	2.3	4.1	7.9	2.8	4.2	6.1
5a	Granodiorite gneiss	4.1	4.5	9.7	4.5	7.3	7.9
5b	Saprolite	3.6	4.1	11.6	3.6	5.5	8.0

**Table 3**  
Representative scintillometer assay mode readings for granitoid rocks in Poulin, Sagard, Thorp and Tweedle townships, Superior Province, northwest of Elliot Lake (see Location Figure 2).

Rock unit	K wt. %	U ppm	Th ppm	Total cpm	K cpm	U cpm	Th cpm
<b>Non-radiogenic granites</b>							
Megacrystic granodiorite, Thorp Township	3.1	1.3	14.6	653	114	23	14
Megacrystic granodiorite, Sagard Township	3.5	1.4	13.5	656	125	22	14
Megacrystic monzogranite, Highway 810	4.8	3.2	40.4	1170	200	65	38
Equigranular monzogranite, Thorp Township	3.9	3.3	21.1	838	152	38	21
Equigranular monzogranite, Sagard Township	4.1	3.6	11.1	761	148	26	12
<b>Radiogenic granites</b>							
Equigranular monzogranite, Thorp Township	4.4	18.2	39.8	1362	221	87	37
Equigranular monzogranite with pegmatitic patches, Thorp Township	2.9	32.7	20.3	1581	252	132	20
Equigranular monzogranite, north-central Poulin Township	3.4	23.8	23.7	1448	232	108	23
Equigranular monzogranite, Tweedle Township	5.5	8.4	37.5	1339	240	77	36
Equigranular monzogranite, Highway 144	4.5	15.3	36.6	1525	243	99	35

**Abbreviations:** cpm = counts per minute, cps = counts per second, n/a = not applicable, wt % = weight percent.  
**Notes:** Multiply K by 1.2046 for K<sub>2</sub>O, Th by 1.1379 for ThO<sub>2</sub>, U by 1.1793 for U<sub>3</sub>O<sub>8</sub>.

## Granitoid Rocks

### Cavendish area: Distinguishing felsic intrusive rocks

A detailed study focussed on 5 outcrop areas from 5 separate intrusions exposed in Cavendish Township, within the Central Metasedimentary Belt of the Grenville Province (Banman and Easton 2008)(see Location Figure 1). The sites were chosen because of accessibility and an abundance of fresh outcrop for both geochemical sampling and the collection of measurements.

At each station, 4 to 7 sets of magnetic susceptibility measurements (each set contains 10 readings) and 4 to 7 scintillometer readings were taken within a 1 to 2 m<sup>2</sup> area. A sample was collected, from under one of the scintillometer measurement locations at each station, for thin section, whole-rock geochemistry, and specific gravity determination in order to link the geophysical data directly with the petrography of the sample. A total of 74 sets of magnetic susceptibility readings, 74 assay-mode scintillometer measurements, and 17 rock samples were collected. Raw data is available in Easton (2010). Results are summarized in Tables 1 and 2.

All 5 sites exhibit differences in magnetic susceptibility, and potassium, thorium and uranium contents as determined by the scintillometer and by geochemistry. The Galloway and Junction plutons differ notably in magnetic susceptibility and thorium content (see Table 1), even though they are of similar age and geochemical affinity. Thorium is higher in the Junction pluton, in part reflecting the overall monzogranitic composition of that more homogeneous intrusion.

Statistical analysis by Banman (2009) found that there was no significant difference between the geochemical and the scintillometer measurements for potassium or uranium. This is not surprising, as the scintillometer collects data from a volume of rock, roughly similar in volume to a large hand sample. There was a significant difference for thorium, however, with the scintillometer measurements being consistently lower than the geochemical results by 30 to 40% (see Table 2). This was the case even for samples with higher thorium abundances (>20 ppm). The most likely explanation for the difference is that there is a calibration problem with the software program that is used within the instrument to calculate thorium content. Regardless, the relative abundance of thorium in outcrop was measured consistently by the scintillometer, and it is possible to recognize differences in thorium content between all 5 sample sites (see Tables 1, 2) even though the scintillometer-determined thorium content was not wholly accurate.

### Elliot Lake area: Corroborating lake sediment anomalies

Dyer (2010a, 2010b) found a uranium lake sediment geochemical anomaly in the Elliot Lake area in southern Thorp and Tweedle townships (see Location Figure 2). Ground investigation of the lake sediment anomaly found that it lies at the southwestern edge of a large airborne gamma-ray uranium and thorium anomaly centered at UTM 37100E, 5182000N.

Three main types of granitoid rocks are present in the area of the anomaly: non-radiogenic equigranular monzogranite and potassium feldspar megacrystic granodiorite (1 to 4 ppm U, Table 3), and radiogenic equigranular monzogranite (8 to 18 ppm U, locally higher, Table 3). The radiogenic monzogranite intruded the megacrystic monzogranite, and locally contains pegmatitic patches which are also radiogenic (see Table 3).

Similar age and compositional relationships have been observed in the granitoid terrain north of Sudbury (J. Ayer, Ontario Geological Survey, personal communication, 2010), where non-radiogenic potassium feldspar megacrystic granodiorite is intruded by a radiogenic equigranular monzogranite which forms a prominent regional airborne gamma-ray uranium anomaly. The difference in uranium content between the radiogenic and non-radiogenic granitic rocks in both areas is moderate (typically only 2 to 4 times higher in the radiogenic granites, see Table 3), but is uniform over a broad area and is sufficient to account for the lake sediment anomaly in Thorp and Tweedle Township.



**Photo 1**  
Cavendish area. Scintillometer in operation on a granite pegmatite vein cutting tonalite gneiss.



**Photo 2**  
Cavendish area. Typical monzogranite gneiss of the Catchacoma intrusive suite, Site 1 of Tables 1 and 2.



**Photo 3**  
Cavendish area. Typical quartz monzodiorite gneiss, Site 2 of Tables 1 and 2.



**Photo 4**  
Cavendish area. Typical monzogranite gneiss of the Junction pluton, Methuen intrusive suite, Site 3 of Tables 1 and 2.



**Photo 5**  
Cavendish area. Typical granodioritic gneiss of the Galloway pluton, Methuen intrusive suite, Site 4 of Tables 1 and 2.



**Photo 6**  
Cavendish area. Saprolite developed in granodiorite gneiss of the Elzevir intrusive suite, Site 5 of Tables 1 and 2.

# Discrimination of Huronian and Archean metavolcanic rocks

Criteria for discriminating Archean (Photo 7) versus Huronian Supergroup metavolcanic rocks (Photo 8, 14) are summarized in Table 4. Most of these criteria can be used on surface exposures, but those applicable to diamond drill core are limited. The scintillometer was an effective discrimination tool on surface outcrops (Tables 4, 5, 6), but cannot be used effectively on diamond drill core.

Mafic rocks are harder to discriminate than more intermediate composition rocks, but, as shown in Table 5 (compare dikes 1 and 3 versus dikes 2, 4 and 5), there is a range in K (0.1-1.3 wt. %) and Th (1.0-2.5 ppm) content within the mafic dikes of the Matachewan dike swarm. There is no correlation between K and Th and host rock composition (i.e., low K and Th contents are not associated only with dikes intruded into mafic host rocks), so if the variation in K and Th is in part due to interaction between the magma and the country rocks, it is occurring prior to dike emplacement.



**Photo 7**  
Elliot Lake area. Archean pillowed flow.



**Photo 8**  
Elliot Lake area. Paleoproterozoic Thessalon Formation pillowed flow.



**Photo 9**  
Elliot Lake area. Contact between leuconorite of the Paleoproterozoic Stone Ridge Intrusion (left) and a cross-cutting Matachewan dike (right).



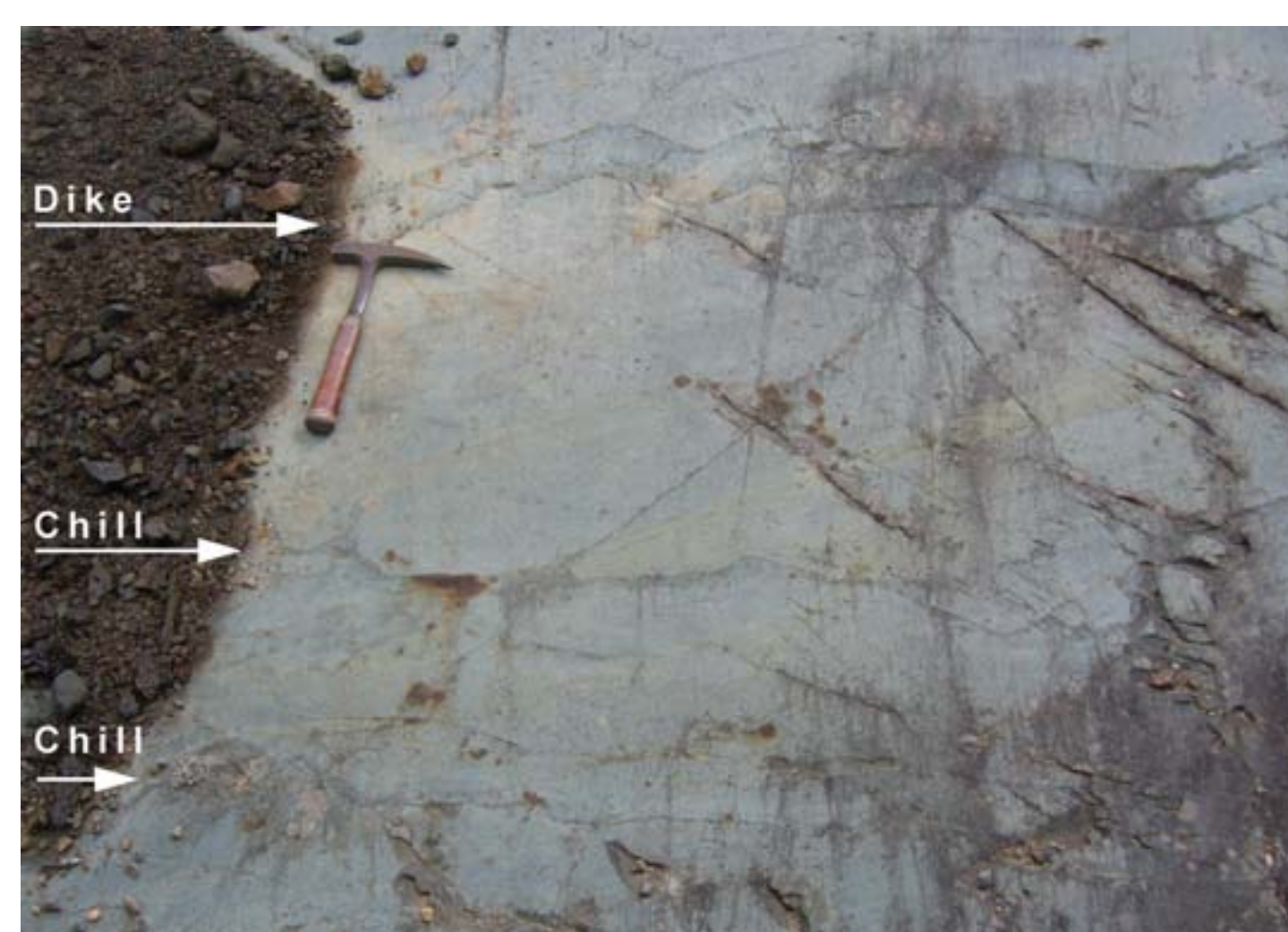
**Photo 10**  
Elliot Lake area. Typical Matachewan dike with large plagioclase glomerocrysts present throughout the dyke.



**Photo 11**  
Elliot Lake area. Typical Matachewan dike with large plagioclase glomerocrysts present near the dike margin.



**Photo 12**  
Elliot Lake area. Typical Matachewan dike with sparsely distributed lath-shaped plagioclase primocrysts



**Photo 13**  
Elliot Lake area. Composite Matachewan dike, single textural type. Note discrete dike by hammer head. Arrows point to chill contacts within the body of the dike, resulting from multiple injections of magma. At least 2 internal contacts are present in this 4 m wide dike, excluding the discrete dike by the hammer head.



**Photo 14**  
Elliot Lake area. Vesicular basaltic andesite flow of the Thessalon Formation, Huronian Supergroup.



**Photo 15**  
Elliot Lake area. Steep-walled, near vertical, vesicular basaltic andesite dike cutting through Archean granodiorite on Highway 108.



**Photo 16**  
Elliot Lake area. Close-up of vesicles in basaltic andesite dike shown in Photo 15. Geochemically this rock is indistinguishable from the flow rock shown in Photo 14.

**Table 4**  
Field and drill core criteria for discrimination of Archean versus Huronian Supergroup metavolcanic rocks.

Criteria	Archean	Paleoproterozoic	Applicable to drill core
<b>Texture</b>			
Pillows	Common, small to moderate, thin selvages (<0.5 cm)	Locally present, moderate to large, wider selvages (>0.5 cm)	NO
Pillow basalt, hyaloclastite	Common	Uncommon	YES
Vesicles	Uncommon	Large, quartz-filled, round to irregular, up to 5% of rock	YES
<b>Structure</b>			
Foliation	Common, moderate to strong	Uncommon, typically weak	YES, but not always easily
Veining	Common, thin quartz veins and white, fine-grained veins	Veining is generally uncommon	YES
<b>Magnetic Susceptibility</b>	Metabasalt, typically <1.0x10 <sup>-3</sup> SI units	Metabasalts, typically <5.0x10 <sup>-3</sup> SI units Basaltic meta-andesite, typically >5.0x10 <sup>-3</sup> SI units	YES
<b>Scintillometer</b>	<b>Metabasalt, typically 0% K, 0 ppm U, 0 ppm Th</b>	<b>Basalts and basaltic meta-andesite, typically &gt;0.5 % K, &gt;4 ppm Th</b>	NO

**Table 5**  
Summary of features observed in an outcrop containing multiple Matachewan dikes that intruded Archean granodiorite, metagabbro and metabasalt. Outcrop is located on Highway 108 in Proctor Township (outcrop centre UTM 379680E 512920 N). K, U and Th determined by scintillometer assay-mode measurement. Scintillometer parameters are listed in Table 8.2.

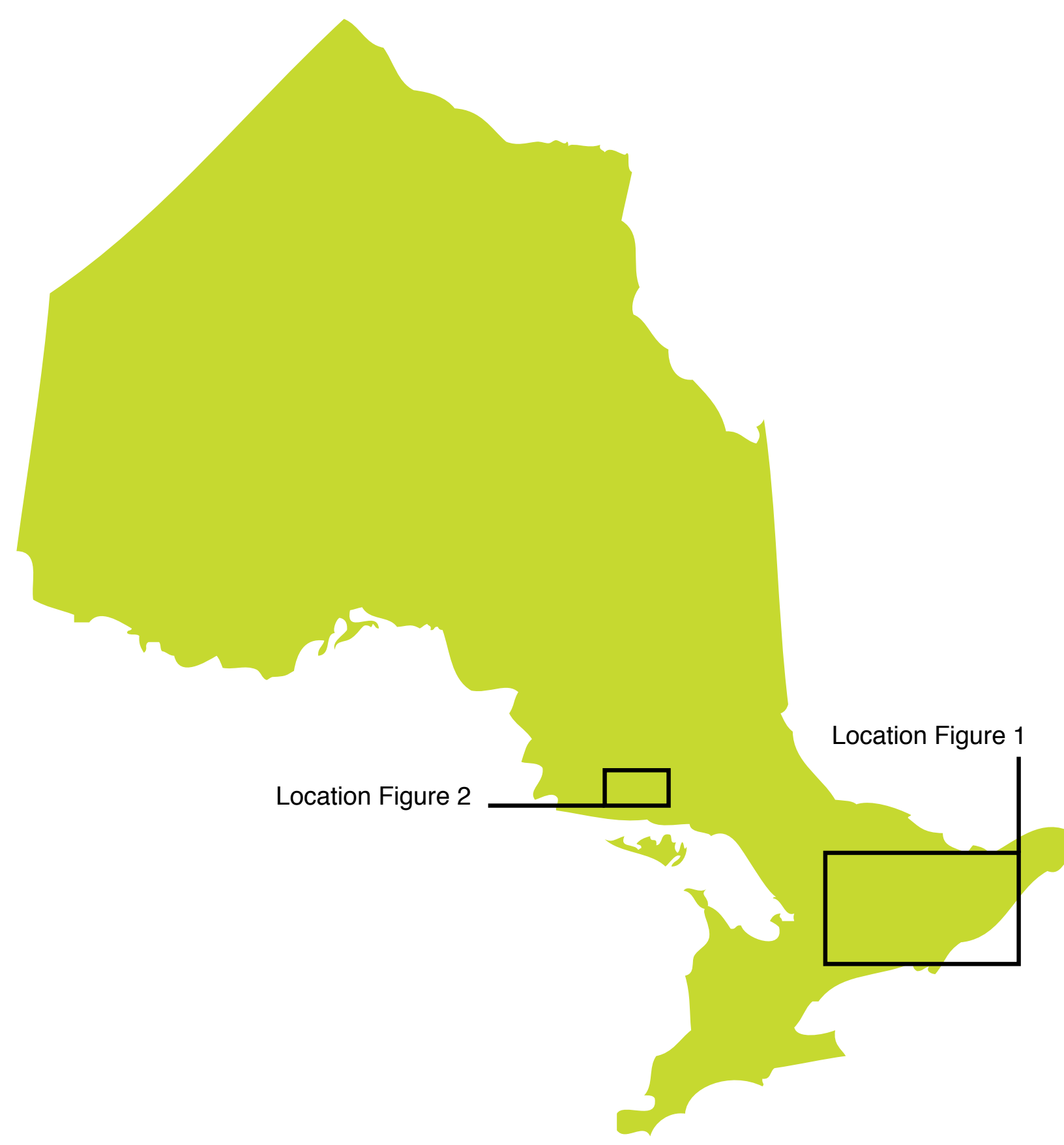
Feature	Dike 1	Dike 3	Dike 2	Dike 4	Dike 5
Texture	Medium-grained	Medium-grained	Medium-grained	Fine- to medium-grained	Medium-grained
Weathered surface colour	Medium green	Medium green	Medium green	Medium green to green-grey	Light green
Plagioclase	Non-phyric	Non-phyric	Non-phyric	10% large laths and glomerocrysts	abundant large laths and glomerocrysts
Width	7 m	6 m	8 m	9 m	2 m
Nature of contact	With mafic country rock	Dike 2-3 contact	Dike 1-2 contact	Dike 3-4 contact	With mafic country rock
Trend of contact	315°/75°	280°/65°	305°/75°	295°/70°	315°/75°
Magnetic susceptibility	0.89	0.78	0.78	0.91	0.79
K (wt. %) lab	1.1	1.0	0.5	0.6	0.5
K (wt. %) Scint	<b>1.1</b>	<b>1.0</b>	0.3	0.5	0.4
U (ppm)	0	0	0	0	0
Th (ppm)	<b>4.0</b>	<b>3.4</b>	1.7	2.4	1.4
Total Count (cpm)	<b>235</b>	<b>229</b>	168	174	167

**Table 5**  
Summary of features observed in an outcrop containing multiple Matachewan dikes that intruded Archean granodiorite, metagabbro and metabasalt. Outcrop is located on Highway 108 in Proctor Township (outcrop centre UTM 379680E 512920 N). K, U and Th determined by scintillometer assay-mode measurement. Scintillometer parameters are listed in Table 8.2.

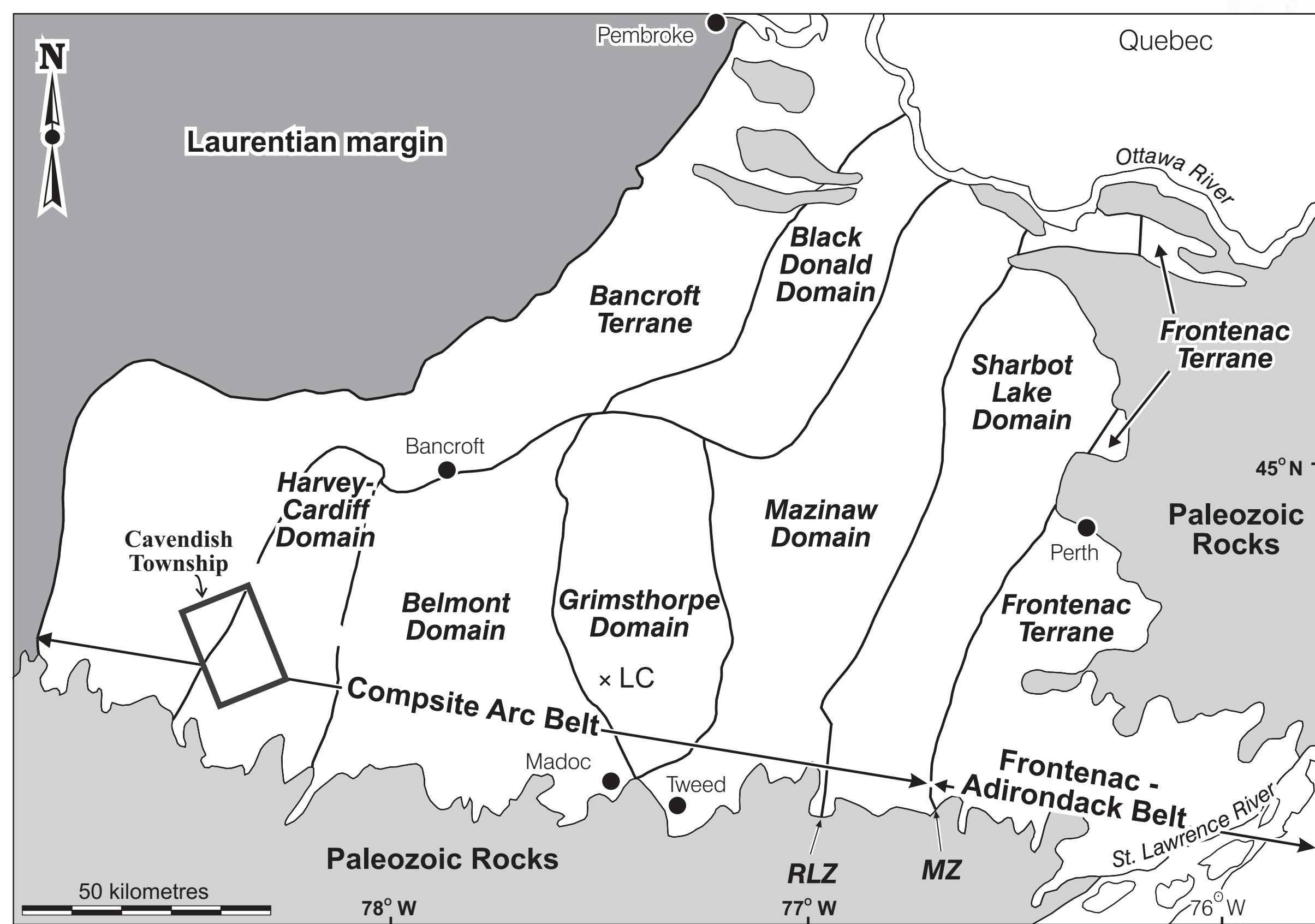
Rock unit	n	K wt. %	U ppm	Th ppm	Total cpm	K cpm	U cpm	Th cpm
<b>Archean rocks</b>								
tholeiitic mafic metavolcanic rocks	10	0.0	0.0	0.0	100	0	0	0
calc-alkalic mafic metavolcanic rocks	19	0.6	0.0	1.6	186	19	1	2
intermediate metavolcanic rocks	25	0.9	0.0	1.4	217	28	2	2
metagabbro, type 1,	20	0.0	0.0	0.0	95	0	0	0
metagabbro, type 2	10	0.2	0.0	1.7	132	6	0	2
<b>East Bull Lake intrusive suite</b>								
Stone Ridge metanorite	47	0.2	0.0	0.9	132	6	0	1
Tennyson sill metagabbro, Highway 553	14	0.2	0.0	1.4	146	7	0	1
Tennyson sill metagabbro, Tennyson Township	8	0.2	0.0	1.6	135	6	0	1
Plagioclase-phyric dikes, unknown affinity	9	0.1	0.0	1.0	111	2	0	2
Dikes, unknown affinity	6	0.0	0.0	1.1	103	0	0	1
<b>Matachewan dike swarm</b>								
Matachewan dikes, plagioclase-phyric (all)	88	0.7	0.4	1.7	206	23	2	2
Matachewan dikes, higher K	18	1.3	1.5	2.5	311	46	7	3
Matachewan dikes, moderate K	28	0.9	0.2	2.1	224	28	2	2
Matachewan dikes, typical K	30	0.5	0.1	1.2	168	15	1	1
Matachewan dikes, low K	12	0.1	0.0	1.0	108	1	0	1
<b>Other</b>								
Nipissing metagabbro	16	0.8	0.0	2.3	210	23	2	3
<b>Thessalon Formation</b>								
mafic metavolcanic rocks	32	0.8	0.9	4.5	293	33	7	5
Gerow Township dike (feeder to Thessalon mafic flows?)	4	1.4	0.4	4.5	314	48	7	5
Lewis Township dike (feeder to Thessalon mafic flows?)	4	1.1	1.6	7.6	361	48	13	7
intermediate metavolcanic rocks	22	3.2	2.0	6.1	466	87	17	8
vesicular dikes (feeders to Thessalon intermediate metavolcanic rocks)	10	2.8	2.7	7.0	547	103	16	8

**Abbreviation:** cpm = counts per minute, ppm = parts per million, wt. % = weight percent.  
**Notes:** multiply K by 1.2046 for K<sub>2</sub>O, multiply U by 1.1793 for U<sub>3</sub>O<sub>8</sub>.

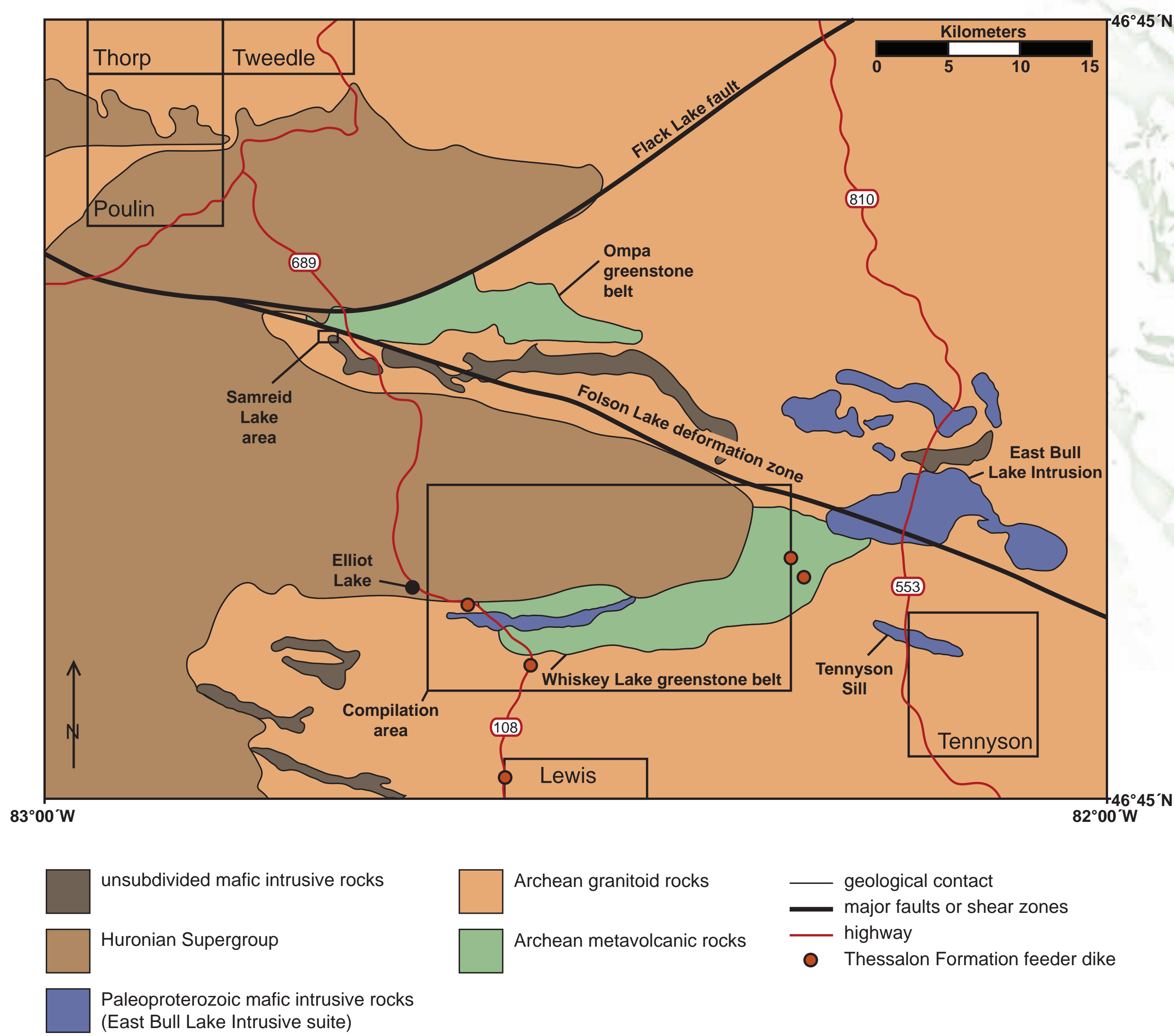
# PRECAMBRIAN GEOSCIENCE SECTION



**Location Figure Ontario**  
Location of study areas within the Province of Ontario, Canada.



**Location Figure 1**  
Location of study area and simplified geology within the Grenville geological province, Ontario.



**Location Figure 2**  
Location of study areas and simplified geology in the Elliot Lake area, Southern and Superior geological provinces, Ontario.

## References

- Banman, S. 2009. Characterization of plutonic suites in Cavendish Township by in-situ geophysical measurements and geochemistry; unpublished BSc thesis, Carleton University, Ottawa, 51p.
- Banman, S. and Easton, R.M. 2008. Characterization of plutonic suites in Cavendish Township, Grenville Province, by in-situ geophysical measurements and geochemistry, in Summary of Field Work and Other Activities, 2008, Ontario Geological Survey, Open File Report 6226, p.15-1 to 15-4.
- Dyer, R.D. 2010a. Elliot Lake-Sault Ste. Marie area lake sediment geochemical survey, northeastern Ontario; Ontario Geological Survey, Open File Report 251, 195p.
- Dyer, R.D. 2010b. Lake sediment and water geochemical data from the Elliot Lake-Sault Ste. Marie area, northeastern Ontario; Ontario Geological Survey, Miscellaneous Release—Data 267.
- Easton, R.M. 2009. Characterization of rock units in the Grenville and Southern Provinces by in-situ geophysical measurements and geochemistry; in Summary of Field Work and Other Activities, 2009, Ontario Geological Survey, Open File Report 6240, p.9-1 to 9-4.
- Easton, R.M. 2010. Geological, geochemical and geophysical data from Cavendish Township, Grenville Province; Ontario Geological Survey, Miscellaneous Release—Data 240, 1 CD-ROM.

