ULTRAMAFIC/MAFIC ROCKS OF THE PYRITES COMPLEX

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INTRODUCTION

General overviews of the geology of the Adirondack Lowlands incorporating new results can be found in Chiarenzelli et al. (2010a; 2010b; 2011a; 2012), Lupulescu et al. (2010), Peck et al. (2013), and Wong et al. (2011), among others. The purpose of this trip is to provide additional insight into the tectonics of the Adirondack Lowlands by highlighting mafic and the ultramafic rocks exposed in the region. The trip will leave from Alexandria Bay and end at Pyrites, where ultramafic rocks of the Pyrites Complex occur (Figure 1).

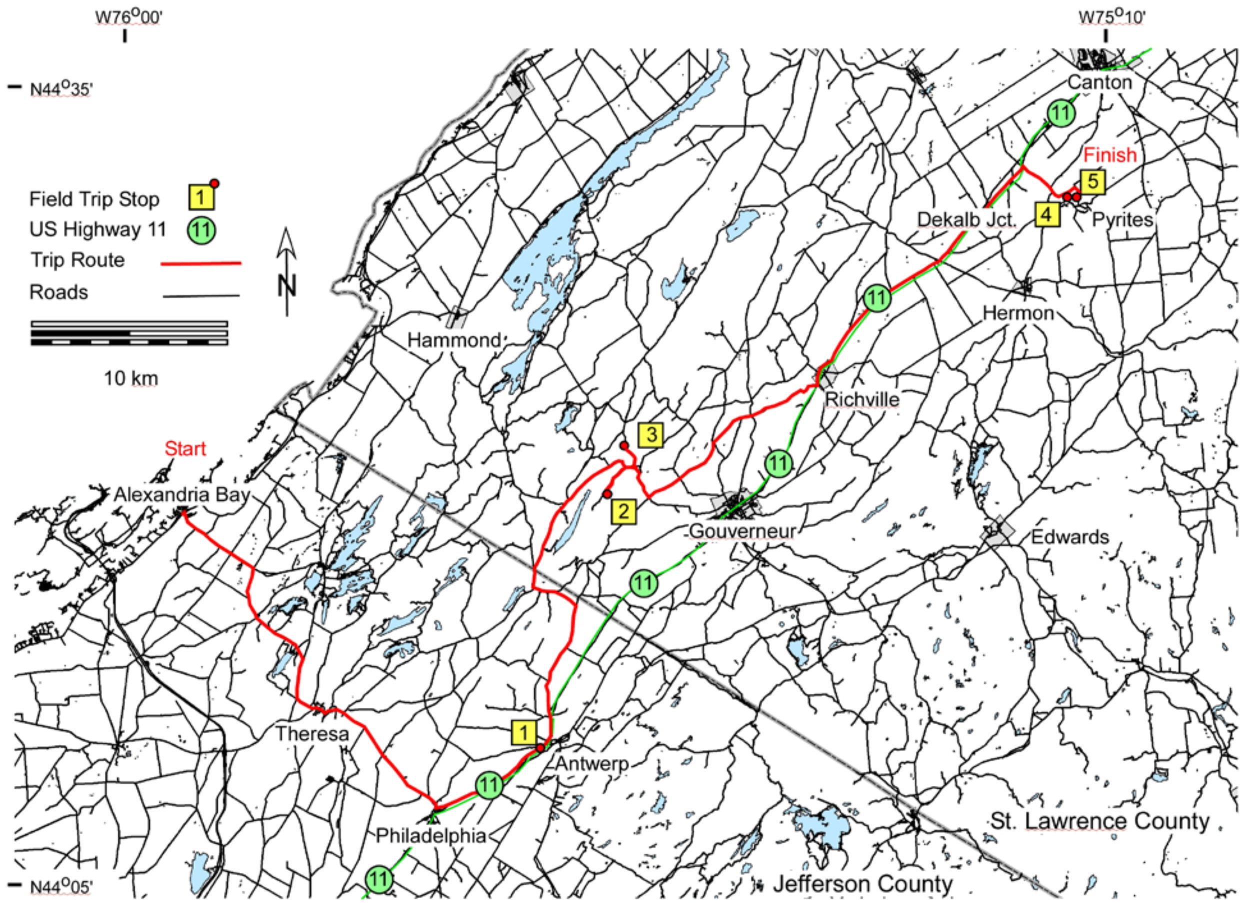

Figure 1. Route of trip B-2 showing location of roadways, field trip stop locations, larger lakes, villages, and other features.

The Adirondack Lowlands are a small part of the greater Grenville Province (Figure 2), a Mesoproterozoic orogenic belt of global proportions. The tectonic assembly and collisional orogenesis recorded here, and elsewhere, resulted in the formation of Rodinia, one of the Earth's Supercontinents. In fact, breakup of Rodinia set the stage for the deposition of the widespread blanket of Potsdam sandstone along the rifted margin of Laurentia, to our east in the Champlain Valley, and exposed nearby on the fringes of the Ottawa Embayment.

The Adirondack Lowlands are delineated from the Adirondack Highlands by a long-lived shear zone that displays evidence for both a ductile and brittle history (Figure 3). This structure, named the Carthage-Colton Shear Zone, marks a number of distinct geologic changes such as the proportion of metasedimentary to metaigneous lithologies, differences in metamorphic grade, variation in the timing of metamorphism, the orientation of structural grain, and a change in topographic relief and elevation. The Lowlands is composed mostly of metasedimentary rocks, predominantly marble, and was metamorphosed to Upper Amphibolite facies during the Shawinigan Orogeny (ca. 1150-1200 Ma), leading to widespread melting in some pelitic gneisses and the growth of metamorphic zircon at 1160-1180 Ma (Heumann et al., 2006). Its position higher in the crust has led to a lack of widespread (any?) effects of the Ottawan Orogeny (ca.1020-1090 Ma), in contrast to the Highlands where metamorphic zircon of this age and resetting of zircon is widespread (Chiarenzelli and McLelland, 1993; Chiarenzelli et al., 2011b).

The oldest known rocks in the Lowlands consist of metasedimentary rocks of Grenville Supergroup, first noted in the literature by Sir William Logan in 1863 to describe the sequence of metasedimentary rocks that occur across large areas of southern Ontario and adjacent parts of Quebec. In the Lowlands these rocks provide evidence of shallow water, marine deposition and include, among other lithologies, voluminous marbles, calc-silicate gneisses, tourmaline-rich quarztofeldspathic gneisses, the sedex sulfide exhalatives of the Balmat zinc mines, and metaevaporites. A tripartite stratigraphy and/or structural stratigraphy has been recognized and consists of the lower marble, Popple Hill Gneiss, and the upper marble, which has been further subdivided into 16 lithologic units (deLorraine, 2001; deLorraine and Sangster, 1997). In contrast to the proposed setting of the carbonate rocks, a deep water turbidite origin has been proposed for the Popple Hill pelitic and psammitic gneisses and equivalents (Chiarenzelli et al., 2012). However, all of these rocks may be allochthonous, as older basement rocks have yet to be identified. The maximum depositional age for the Grenville Supergroup in the Lowlands has recently been constrained between <1258 and <1284 Ma (Chiarenzelli et al., in review).

Recent investigation has revealed that ultramafic-mafic igneous rocks occur within northeast-trending linear belts (Figure 4) in the Lowlands and may be older or equivalent in age to the Grenville Supergroup. Named the Pyrites Complex for exposures along the Grasse River near Pyrites, New York, these rocks have required rethinking of the depositional environment of not only the Grenville Supergroup equivalents in the Adirondack Region but the origin of the Zn-Pb sedimentary exhalatives of the Balmat-West Pierrepont Belt. A model incorporating the discovery of ultramafic rocks suggests that the rocks of the Grenville Supergroup were deposited after 1300 Ma in a back-arc basin which closed at about 1240 Ma during the Elzevirian Orogeny (Chiarenzelli et al., 2011a; 2012). This back-arc basin has been named the Trans-Adirondack Back-arc Basin and is thought to be temporally equivalent to a similar basin in the Central Metasedimentary Belt of Ontario and Quebec (Dickin and McNutt, 2007). This implies that a broad region of the southeast margin of Laurentia underwent rifting and extension at this time.

During this trip we will see what is thought to be the remnants of a highly disrupted ophiolite complex and deep water sedimentary rocks including hydrothermal altered ultramafic rocks (Stops 4 and 5), amphibolite (Stop 1), and possible turbidites (Stop 4). We will observe a lamprophyre dike cutting the ultramafic rocks at Stop 5. In addition, two stops will be made to investigate candidates for inclusion in the the Pyrites Complex including a large block of serpentine (Stop 2) and a hornblendite unit (Stop 3), both which require further investigation. Isotopic and geochemical studies indicate widespread enrichment in incompatible elements suggests that the Pyrites ultramafic complex and associated rocks formed in a suprasubduction zone setting. Although the surface exposure of the ultramafic rocks is small, the largest gravity anomaly in the Lowlands extends from Pyrites to the southwest for over 10 km parallel to the trend of the Carthage-Colton Shear Zone, indicating substantial amounts of high density rocks at depth.

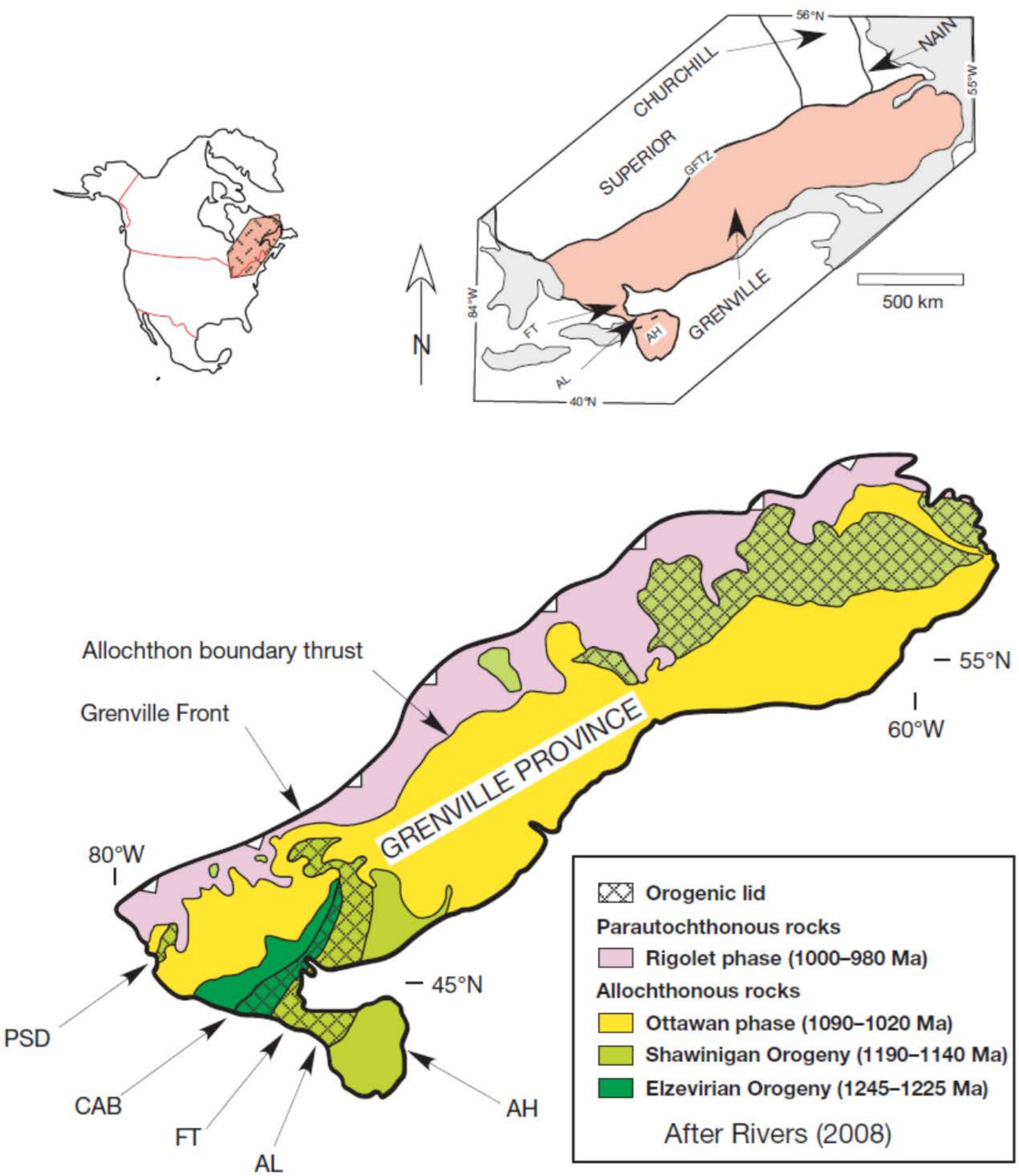

Figure 2. Figure showing the location of the Grenville Province within North America (upper left). Expanded polygon (upper right) shows the same region blown up to show surrounding provinces of the Canadian Shield. Abbreviations include: AH (Adirondack Highlands), AL (Adirondack Lowlands), FT (Frontenac Terrane), and GFTZ (Grenville Front Tectonic Zone). Lower figure shows the timing of recognized deformational events that make up the Grenville Orogenic Cycle (after Rivers, 2008). Additional abbreviations include: CAB (Central Arc Belt) and PSD (Parry Sound Domain). From Chiarenzelli et al. (2011a).

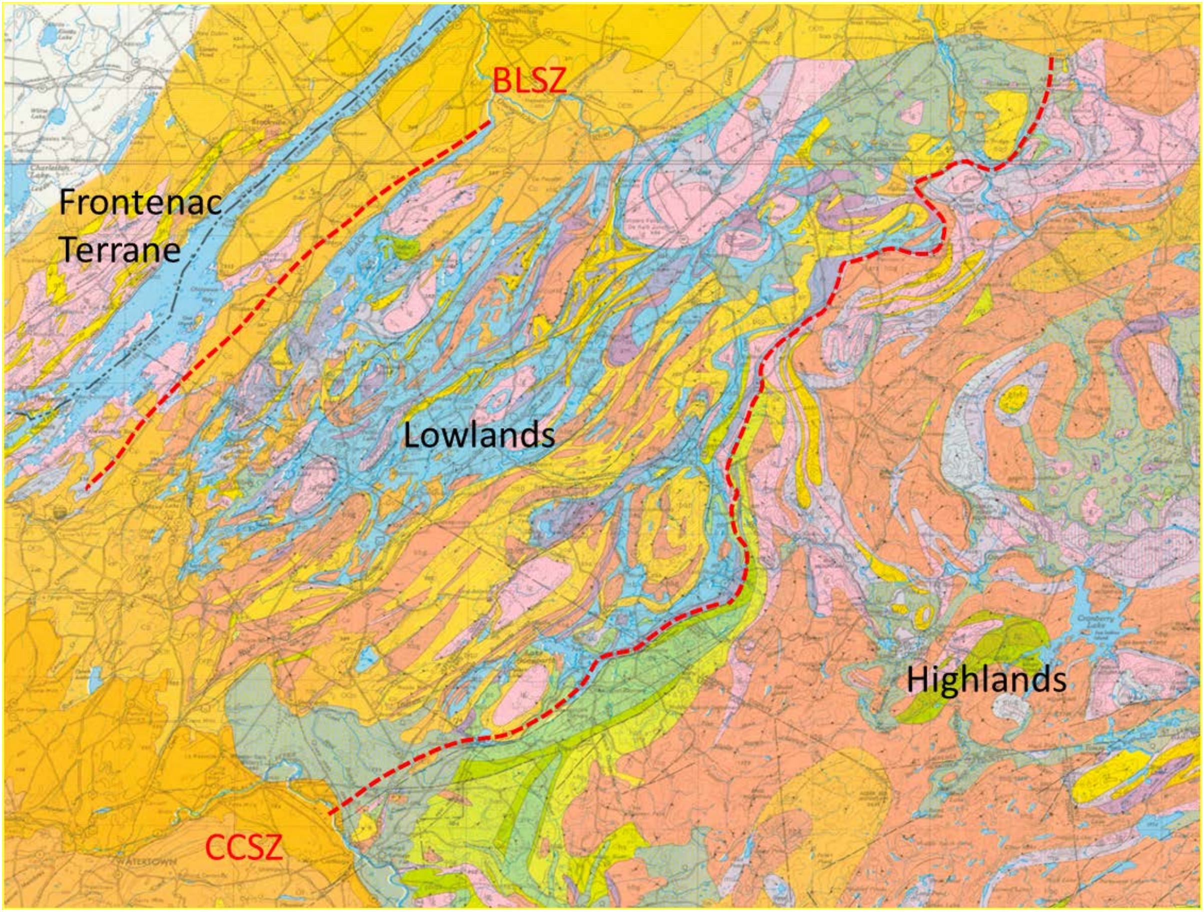

Figure 3. Geology of the Adirondack Lowlands and surrounding terranes from Isachsen and Fisher (1970). The Black Lake (BLSZ) and Carthage-Colton (CCSZ) shear zones define the boundaries of the Adirondack Lowlands. Flat-lying Paleozoic rocks (orange) overlie Grenville basement rocks much of the St. Lawrence River Valley and Tug Hill plateau to the southwest. Note the predominance of marble (blue) in the Lowlands and general lack thereof in bounding Frontenac Terrane and Adirondack Highlands.

Stop 1 Amphibolite and Pyritic Gneisses near Antwerp
<1 km southwest of Antwerp, along Rt. 11; Latitude 44°11’41.7”, Longitude 75°37’28.8”

We have driven south from Alexandria Bay to the southern belt of pyritic gneisses, amphibolites, metagabbros, and ultramafic rocks exposed in the Lowlands. Here near Antwerp, New York we will see some of the amphibolites, associated pyrite-rich metasedimentary rocks, and igneous rocks which intrude them (Figure 4). This belt can be traced nearly 50 kilometers to Pyrites and beyond. The large outcrop in the foreground shows a sequence of rocks dipping shallowly to the northwest. The darker rocks are amphibolites with MORB-like geochemistry. Those with rusty staining are of metasedimentary origin and contain detrital zircons, in addition to pyrite. Unfortunately these zircons are metamict and discordant. However, similar rocks at Pyrites have yielded intriguing results that will be discussed later at Stop 4. Both of these rocks are cut by a variety of intrusive pegmatites which are correlative in age to the Antwerp-Rossie Suite (ca. 1200 Ma).

The intrusive age of the Antwerp-Rossie Suite provides a minimum age for rocks of the Grenville Supergroup and ultramafic mafic rocks of the Pyrites Complex. Further east along Route 11 large banded outcrops of marble, and isoclinal folds within it, are cut by rocks of the Antwerp-Rossie Suite (Figure 5) dated at ca. 1200 Ma. The Antwerp-Rossie Suite is calc-alkaline and the product of northward subduction which preceded the Shawinigan Orogeny.

Figure 4. Field photograph showing dark amphibolitic rocks along Route 11 in Antwerp, NY cut by light-colored pegmatite veins related to the Antwerp-Rossie plutonic suite (ca. 1200 Ma). Note the strongly layered rusty gneisses on either side of the geologist.

Figure 5. Outcrop of Grenville Supergroup lower marble along Route 11 showing a large recumbent isoclinal fold (just above the geologist's hand) cut by rocks of the Antwerp-Rossie Suite (ca. 1200 Ma).

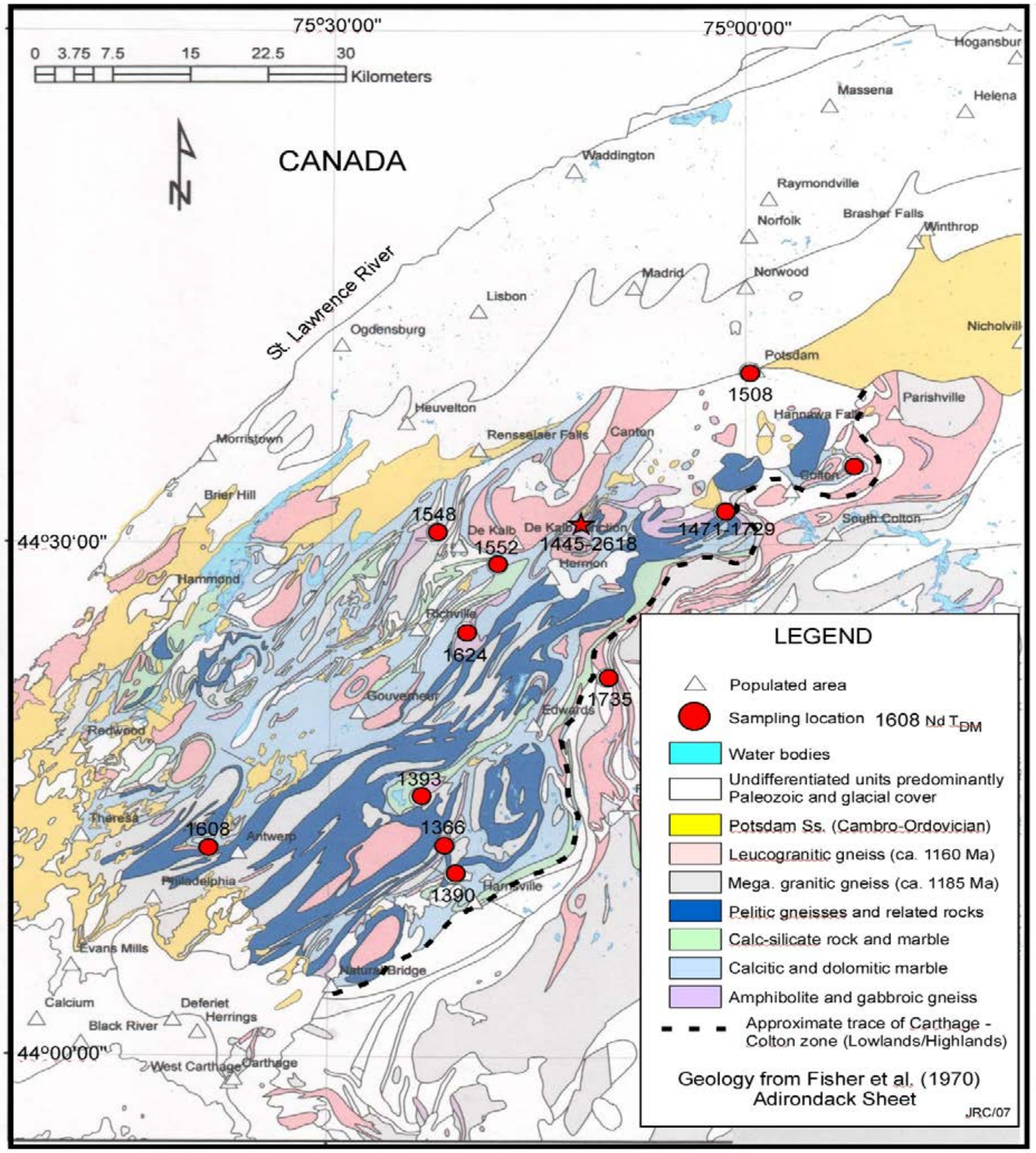

Figure 6. Generalized geologic map of the Adirondack Lowlands showing the locations of mafic and ultramafic rocks (in purple) analyzed for Nd isotopic systematics and corresponding Nd T_{DM} (red circles). The sample collected along Rt. 11 at Antwerp, which we will visit, yielded an unrealistically old model age of 1608 Ma). The red star denotes the cluster of samples collected at Pyrites where model ages varied between 1445-2618.

Orogeny (ca. 1150-1200 Ma). The deformation preserved in the marble must pre-date this subduction event and subsequent Shawinigan orogenesis (Figure 5). This implies that the Grenville Supergroup and Pyrites Complex where deformed during the Elzevirian Orogeny (ca. 1220-1245 Ma), consistent with the minimum age for the Grenville Supergroup in the region constrained by detrital zircons (Chiarenzelli et al., in review).

The amphibolite outcropping here has been characterized by geochemistry and Nd-systematics. The amphibolites and metagabbros of this belt yield unrealistically old NdT_{DM} ages of 1508-1624 Ma, as do ultramafic rocks at Pyrites, which in some cases are even older (Figure 6). This suggests disturbance of the Sm-Nd isotopic system and the influence of a metasomatically altered mantle wedge in their origin. Elevated oxygen isotopic ratios have been found zircon in plutonic rocks extending across the Lowlands into the Frontenac Terrane by Peck et al. (2004). Peck et al. (2004) interpreted these elevated ratios as indicative of the influence of subducted hydrothermally altered oceanic crust and/or sedimentary material beneath the leading edge of Laurentia. As a group, rocks of the Pyrites Complex plot between the Nd isotopic arrays of Quebecia ca. 1570 Ma (Dickin and Higgins, 1992) and Ontario Juvenile Crust ca. 1277 Ma (Dickin and McNutt, 2007) indicating an age in excess of 1277 Ma (Figure 7) but younger than 1570 Ma.

An age greater than 1277 Ma for the Pyrites Complex is compatible with several lines of evidence. Barfod et al (2005) obtained a 1274±9 Ma Lu-Hf date on apatite from the lower marble and interpreted it as the time of diagenetic apatite growth in the marble. Sager-Kinsman and Parrish (1993) obtained a maximum depositional age of <1306±16 Ma from the youngest detrital zircon in a quartzite unit of the Grenville Supergroup on Wellesley Island. And as will be discussed below, Chiarenzelli et al. (in review) found a maximum age of 1284+/-7 on detrital zircons from turbiditic rocks overlying ultramafic rocks at Pyrites. A model for the generation of oceanic crust within a series of back-arc basins along the leading edge of Laurentia has been proposed by Chiarenzelli et al. (2011a). The opening of the Trans-Adirondack Back-arc Basin is believed to have been synchronous with the opening of a similar basin in the Central Metasedimentary Belt of Ontario and Quebec (Dickin and McNutt, 2007).

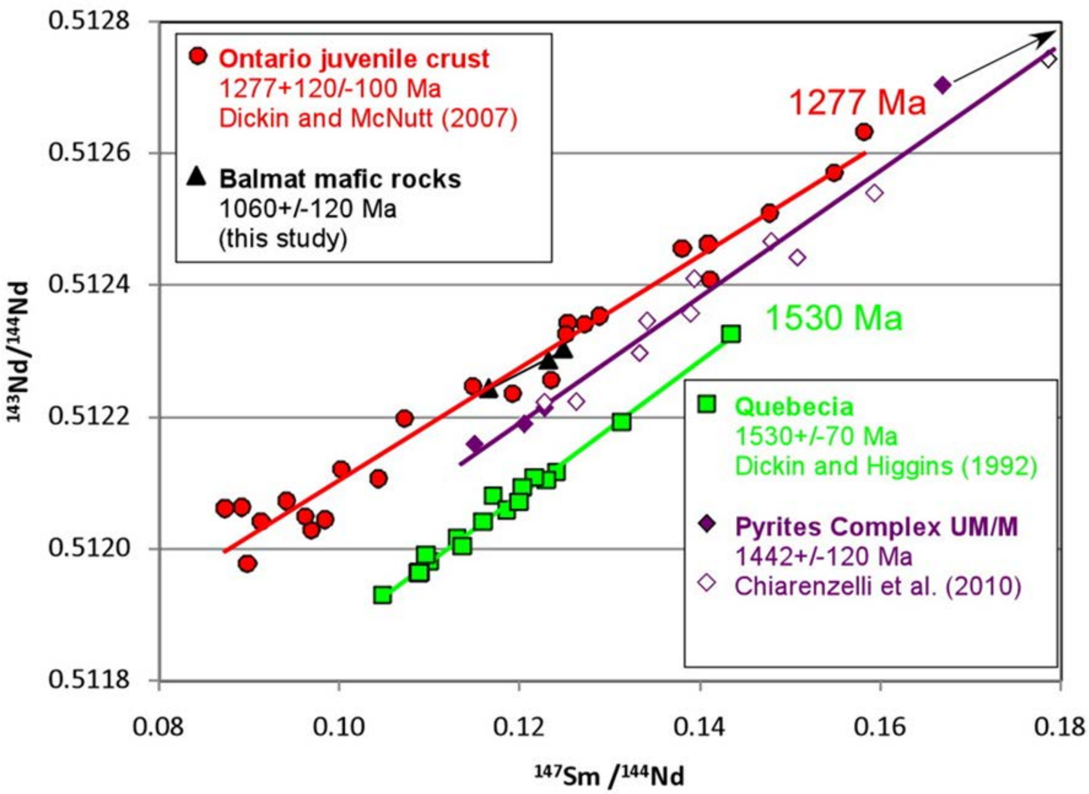

Figure 7. Neodymium evolution diagram showing the trend from mafic and ultramafic rocks of the Pyrites Complex and other Grenville rock suites from Dickin and McNutt (2007) and Dickin and Higgins (1992) used for comparative purposes.

Stop 2 Yellow Lake Serpentinite
~8.5 km west of Gouverneur, off of Campbell Rd between Yellow Lake and the Oswegatchie River; Latitude 44°20'14.3", Longitude 75°34'47.8"

This stop is on private land and permission was obtained for this field trip to visit the area. Please respect the landowner's wishes and do not revisit this location without permission. Respecting land owners rights insures that future geologists will have access to key scientific sites. If in doubt, ask first.

While serpentine is a common mineral throughout much of the Lowlands, massive serpentinite, like that exposed here, is unusual. While this exposure may be a large serpentinized block of metasedimentary rock, the location of this body puts it within a linear trend of mafic and ultramafic rocks approximately 10 kilometers north and west of the Pyrites belt which we will visit again in the near future. These and other linear belts may represent separate thrust sheets, or perhaps, opposing limbs of a major nappe-like structure. In any event, the uniqueness of this exposure makes it an excellent place to visit regardless of its origin.

The Yellow Lake serpentinite is an unusually large body (~100 m) of massive serpentine hosted within marble of the Adirondack Lowlands metasedimentary sequence. The only detailed geologic map of the area shows a thin band of lower marble surrounded by the "Hermon granite-amphibolite" unit (Buddington, 1934). On the Adirondack Sheet this unit is denoted as amg and consists of highly disrupted and intruded amphibolite and metagabbro engulfed within the Hermon granitic gneiss. While localized areas of disseminated serpentine within the marble were noted in the report and are particularly common in the upper marble which is found to the south, this large mass of serpentine was apparently not recognized or described. Intriguingly about 10 kilometers to the southwest near Theresa a small stream is named Soapstone Creek, suggesting more massive serpentinite or talc is yet to be rediscovered.

It appears that the Yellow Lake serpentinite first came to the attention of geologists in the mid-1980s when it was discovered by George Robinson and Michel Picard while on a St. Lawrence County mineral collecting excursion (G. Robinson, pers. comm.). Since that time, local mineral collectors have explored the outcrop and found nice sky blue apatite crystals and a few nicely formed pseudomorphs of serpentine after forsterite (S. Chamberlain, pers. comm.).

The outcrop is extensively fractured and incoherent, and because of this property, has been used locally as a source of rock aggregate and fill. Most of the exposure is composed of a dull yellow-green massive serpentine with abundant radiating dendrites of an unknown black oxide /hydroxide mineral coating fracture surfaces and disseminated throughout the massive serpentine (Figure 8). Small (2-20 cm wide) irregular veins of coarsely crystalline calcite cut through the unit, and it is within these veins that the blue apatite crystals (up to 3 cm long) are found. Pseudomorphs after forsterite occur along the sides of the veins (S. Chamberlain, pers. comm.). Pyrite, talc, and an unidentified Ca-Mg-silicate (possibly harkerite?) have also been found within these veins (Chamberlain and Bailey, unpub. data). Table 1 gives the composition of select mineral phases in the serpentinite, including Mn-rich dendritic growths and serpentine.

The occurrence of a relatively large body of ultramafic rock within the metasedimentary sequence of the Adirondack Lowlands is enigmatic; possible explanations for its origin include a localized accumulation of komatiitic ash, or an unusual clay-rich evaporite horizon within the carbonate sequence. Alternatively it may prove to be another block of highly altered ultramafic metaigneous rock such as that exposed at Pyrites. Additional field, mineralogical, and geochemical studies at this location and along this belt are needed to better understand this unusual ultramafic body and place it in its proper geologic context.

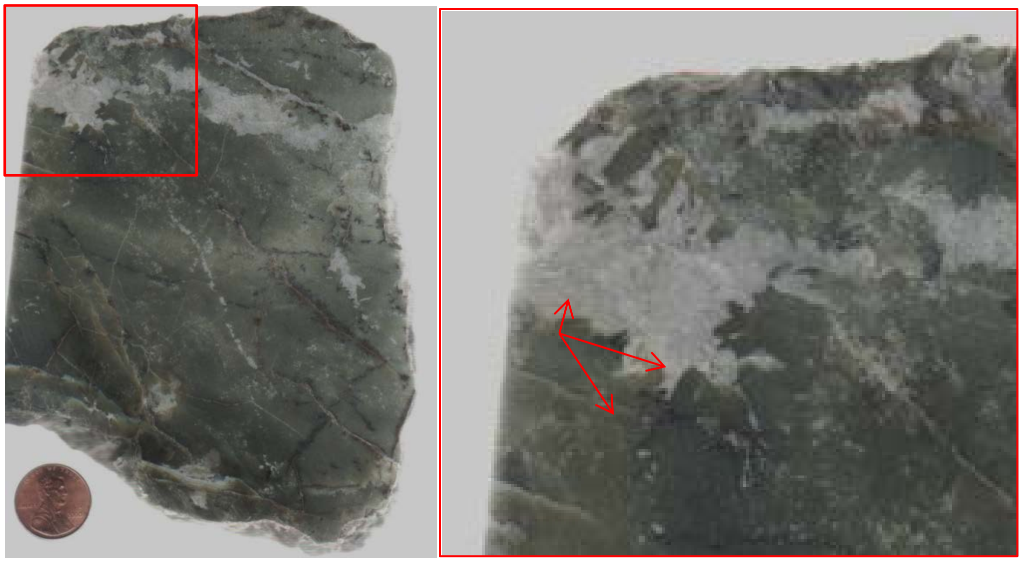

Figure 8. Cut slab of Yellow Lake serpentinite body showing dull green color, calcite pockets and veins, and massive nature. Note the irregular network of carbonate veins and black dendritic growths. The area in the red square has been enlarged in the right hand photograph to show the region where pseudomorphs after euhedral crystals, perhaps olivine, can be seen in the calcite pocket in the upper left of the left-hand figure.

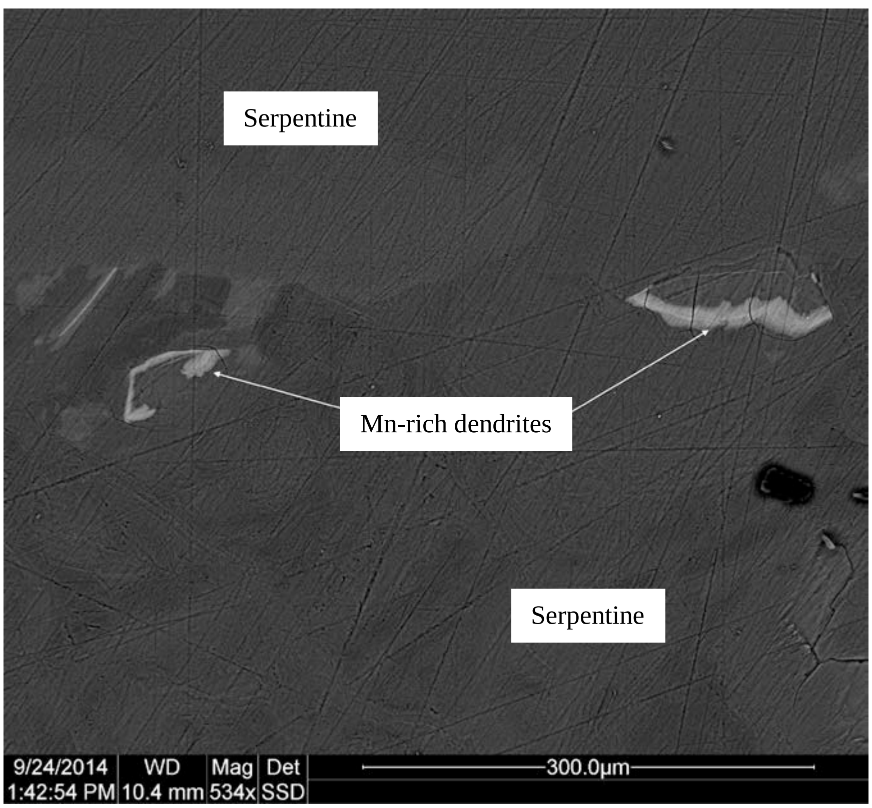

Figure 9. Scanning electron microscope back scatter image of the Yellow Lake serpentinite showing Mn-rich dendritic growths in a groundmass of serpentine.

Stop 3 Hornblendite near Elmdale
~1 mile north of Elmdale, right side of Rt. 58; Latitude 44°22'20", Longitude 75°33'14"

This outcrop consists largely of hornblendite whose age and origin is unknown. The rock falls along the general trend of serpentinite (last stop), and within a 40 kilometer linear, but highly disrupted, belt of amphibolite, pyritic gneisses, and metagabbro extending to the northeast from Yellow Lake to near Kendrew Corners, north of Dekalb. It is composed 1-2 centimeter blocky, equant black crystals of hornblende surrounded by k-feldspar, titanite, and apatite (Table 1 and Figures 10 and 11). The rock shows relatively little evidence of wholesale deformation but is cut by pegmatite, which is also undeformed.

Table 1. Composition (wt.%) of select mineral phases from Stops 2 and 3 (Analysis by David Bailey).

Sample	Serpentinite	Serpentinite	Hornblendite	Hornblendite	Hornblendite
Mineral	Serpentine	Mn-dendrites / serpentine	Epidote	Hornblende	K-Fsp
SiO2	51.93	39.17	38.32	42.73	64.95
TiO2				1.16	
Al2O3	0.08	0.52	20.12	13.57	19.84
FeO	1.64		12.46	17.50	
MnO		25.44			
MgO	46.35	30.27	0.80	10.10	
CaO		3.44	15.04	10.35	
BaO		1.15			1.56
Na2O				2.26	2.06
K2O				2.32	11.58
P2O5					
La2O3			4.21		
Ce2O3			8.15		
Sm2O3			0.91		
Total	100	100	100	100	100

Figure 10. Cut slab of the Elmdale hornblendite displaying large, equant hornblende crystals.

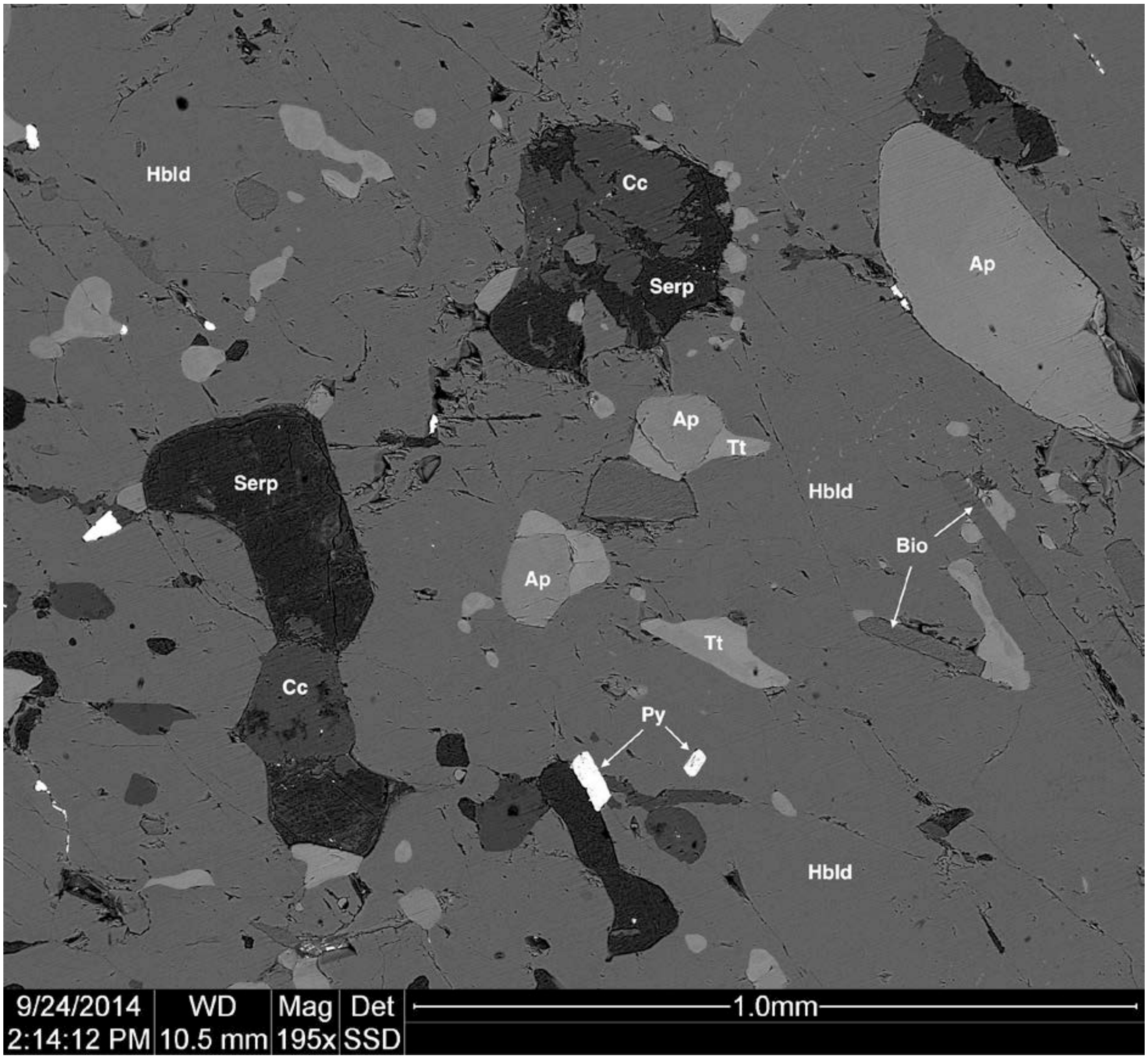

Figure 11. Scanning electron microscope back scatter image of the Elmdale hornblendite. Abbreviations: Ap-apatite; Bio-biotite; CC-calcite; Hbld-hornblende; K-spar-potassium feldspar; Py-pyrite; Serp-serpentine; Tt-titanite.

Hornblende-rich ultramafic rocks are relatively rare and can have a variety of origins. Detailed petrographic, geochemical, and geochronological study will hopefully provide further constraints on the origin of this rock. However, it may represent the one of the magmatic products of subduction in the Lowlands. Previous work has identified a strong subduction signature in many of the plutonic rocks exposed in the Lowlands (Figure 12; Chiarenzelli et al., 2010b). In particular, the lamprophyre dike we will see later in the day is indicative of this enriched mantle signature prevalent in mafic and ultramafic rocks of the Pyrites Complex as well.

Shawinigan plutonic suites in the Lowlands crosscut the fabric and isoclinal folds (Figure 5) in metasedimentary rocks of the Grenville Supergroup (Chiarenzelli et al., 2010a; Peck et al., 2013). The geochemistry and Nd signature of these plutonic suites (Antwerp-Rossie Suite, Hermon Granitic Gneiss, and Hyde School Gneiss), intruded between 1170-1200 Ma, mark the evolution of arc magmatism to granitic