MESOPROTEROZOIC MAGMATISM OF THE ADIRONDACK LOWLANDS: THE RESULT OF CLOSURE OF THE TRANS-ADIRONDACK BACKARC BASIN

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INTRODUCTION AND REGIONAL BACKGROUND

The Mesoproterozoic Grenville orogenic belt is one of the world's largest preserved Precambrian convergent margins, with a North American extent from Labrador to Texas. It records several tectonic, magmatic, and accretionary pulses typically referred to as the Grenville orogenic cycle (Ca. 1.30 – 1.0 Ga; Rivers, 2008). This sequence of punctuated crustal growth is thought to have culminated during a ca. 1.08 Ga terminal collision, which resulted in the final assembly of the supercontinent Rodinia (McLelland et al., 2001). The Adirondack Mountains in New York are a domical uplift forming the southern extension of the Canadian Shield into New York, and expose rocks that formed and evolved during this orogenic cycle. The Adirondack Highlands and Adirondack Lowlands are separated by the Carthage-Colton shear zone (Fig. 1; Selleck et al., 2005). The Adirondacks record sedimentation, plutonism, high-grade metamorphism and deformation during the Elzevirian and Shawinigan orogenies of the Grenville orogenic cycle, and are variably affected by terminal, Ottawan, deformation (Fig. 1b; McLelland et al., 1992; Chiarenzelli et al., 2011c;).

The Adirondack Lowlands are dominated by supracrustal, amphibolite-facies metasedimentary rocks arrayed in NE-SW striking belts (Wong et al., 2011; Baird and Shrady, 2012). The Lowlands contain relatively subordinate, variably deformed igneous intrusives (Carl and deLorraine, 1997; Wasteneys et al., 1999; Peck et al., 2013). In contrast, the Adirondack Highlands are dominated by granulite facies metaigneous rocks, with minor supracrustal rocks (McLelland et al., 2004). Published data suggest that unlike the Highlands, the Adirondack Lowlands did not experience penetrative Ottawan deformation, and that the rocks of the Lowlands were likely at a higher crustal position during the Ottawan (McLelland et al., 1992; Selleck et al., 2005; Heumann et al., 2006). Thus, the Adirondack Lowlands are an ideal location to study earlier phases of Grenvillian orogenesis because of a lack of pervasive overprinting, such as is seen in the Highlands.

This field trip focuses on the major igneous rock suites that were emplaced into the metasedimentary units of the Adirondack Lowlands. Recent work on these rocks is presented in several contributions (Chiarenzelli et al., 2010b; Wong et al., 2011; Peck et al., 2013), which grew from a Keck Geology Consortium Project led by Colgate University during the summer of 2008. This project produced a new igneous whole rock geochemical dataset from many of the major intrusive suites exposed in the Lowlands. Accompanying these data, Sm-Nd isotopic analyses were acquired along with SHRIMP-RG U-Th-Pb analyses of zircon and titanite (Chiarenzelli et al., 2010b; Wong et al., 2011; Peck et al., 2013). This trip will visit localities where igneous bodies are in contact with surrounding metasediments, providing an opportunity to address the deformation history of the metasedimentary rocks. However, the central goal is to document how magmatism evolved during Shawinigan orogenesis, and the relationships between igneous rock geochemistry and regional tectonic history of the Grenville Province.

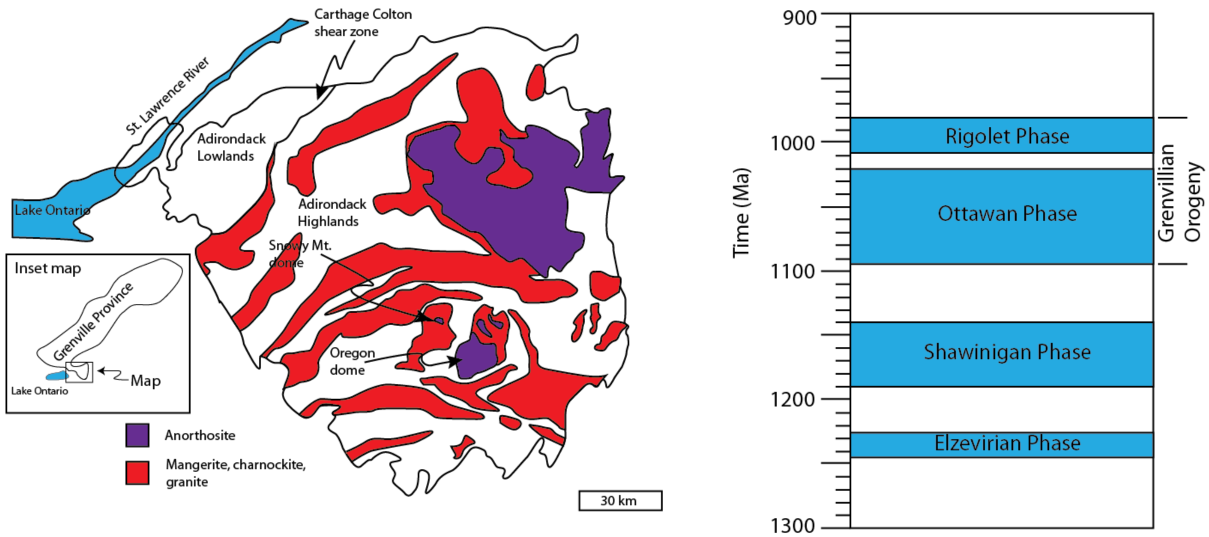


Figure 1. Left: A simplified map of the Adirondacks divided into the northwestern lowlands and southeastern highlands. The map displays the distribution of the ca. 1155-1165 Ma AMCG suite (modified from McLelland et al., 2004). Right: A schematic diagram displaying the traditional orogenic phases of the Grenville Province (after Rivers, 2008).

The Adirondack Lowlands of northern New York are primarily composed of amphibolite facies metasedimentary rocks that can be grouped into three lithotectonic units. These may represent an originally coherent stratigraphic sequence, consisting of, from bottom to top: 1) lower marble, 2) the Popple Hill Gneiss, and 3) upper marble (Carl et al., 1990). Subsequent to the deposition of this sequence, several intrusive suites were emplaced into the metasedimentary rocks (Carl et al., 1990; Wasteneys et al., 1999). Four distinct and variably deformed intrusive suites are recognized within the Adirondack Lowlands, from oldest to youngest: 1) the 1203 Ma Antwerp-Rossie Suite (Wasteneys et al., 1999; Chiarenzelli et al., 2010b), 2) the 1182 Ma Hermon granite gneiss (Heumann et al., 2006), 3) the 1172 Ma Hyde School Gneiss and Rockport Granite (McLelland et al., 1992), and 4) relatively undeformed ca. 1150 Ma syenite to monzonites (Peck et al., 2013).

Recent geochemistry, geochronology, and structural work in area of the Black Lake shear zone (BLsz) was undertaken to determine its regional significance, and to test the hypothesis that it is a fundamental boundary between the Adirondack Lowlands and the Frontenac terrane to the northwest (Chiarenzelli et al., 2010b; Wong et al., 2011; Peck et al., 2013). The Black Lake shear zone is a belt of intensely deformed rocks oriented parallel to the NE-SW structural grain variably developed throughout the Adirondack Lowlands. In addition to differences in Shawinigan metamorphic ages and grade across the boundary, it delineates a major discontinuity in igneous activity between the terranes, with Lowlands igneous suites older than ca. 1180 Ma only occurring to the south and 1170 Ma magmatism stitching the boundary (Wong et al., 2011; Peck et al., 2013).

A recently discovered ophiolite and newly recognized oceanic crust (Pyrites ultramafic complex; Chiarenzelli et al., 2011b; Pyrites Field Trip B-2) in the Adirondack Lowlands has led to further evidence for major differences across the BLsz. These observations suggest that metasediments in the Lowlands were deposited proximal to oceanic crust, but no fragments of ophiolite or oceanic crust have been identified in the Frontenac terrane north of the BLsz. Furthermore, the geochemical character of the ophiolite suggests a suprasubduction origin (Chiarenzelli et al., 2010a), and it has been interpreted as having developed in a back arc basin (Chiarenzelli et al., 2010b, 2011b).

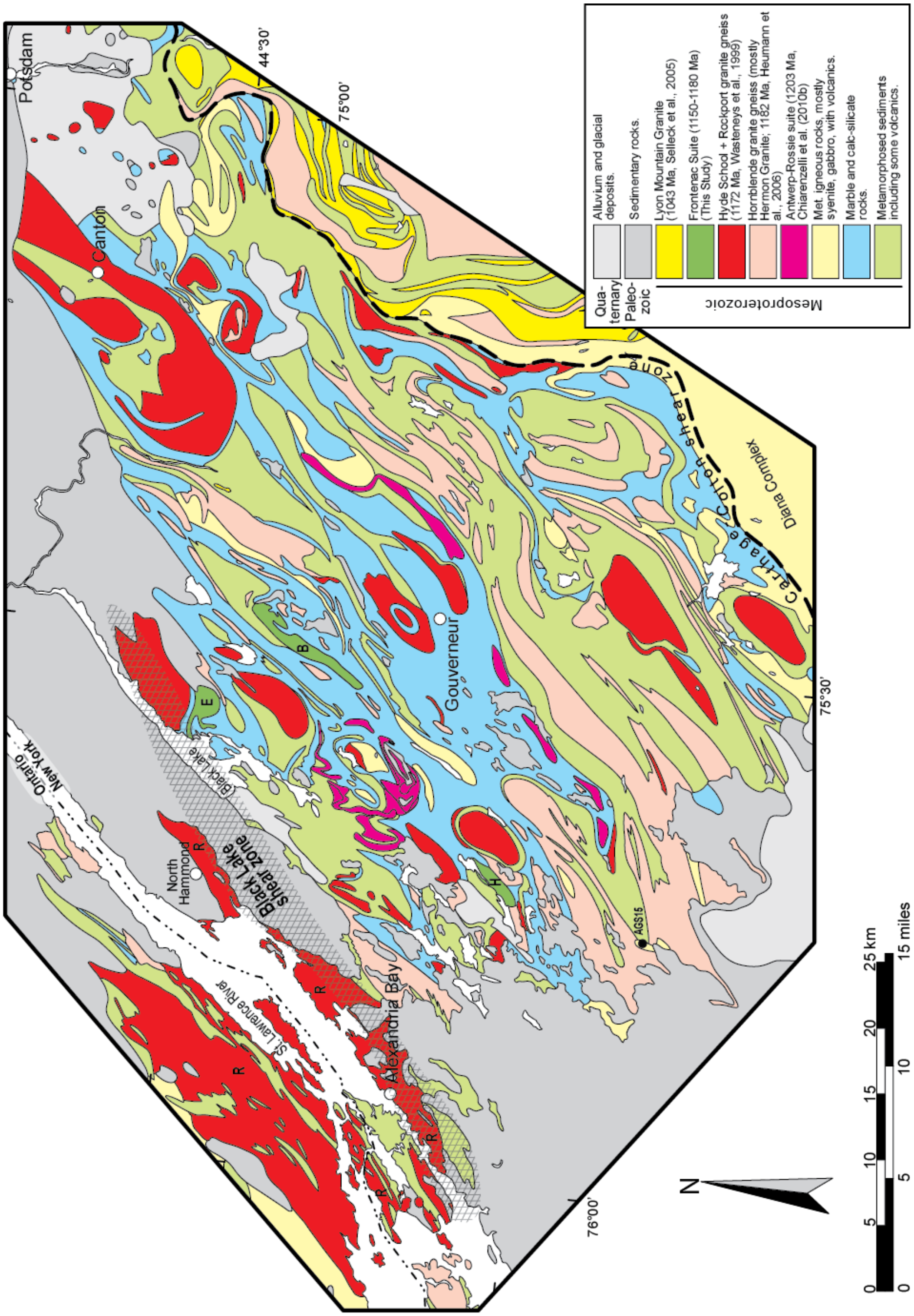


Figure 2. Geology of the Adirondack Lowlands complied from Fisher et al. (1970), Carl et al. (1990), Wasteneys et al., (1999), Selleck et al. (2005), and Wong et al. (2011). E – Edwardsville pluton, R – Rockport Granite, H – Honey Hill pluton, B – Beaver Creek pluton (from Peck et al., 2013).

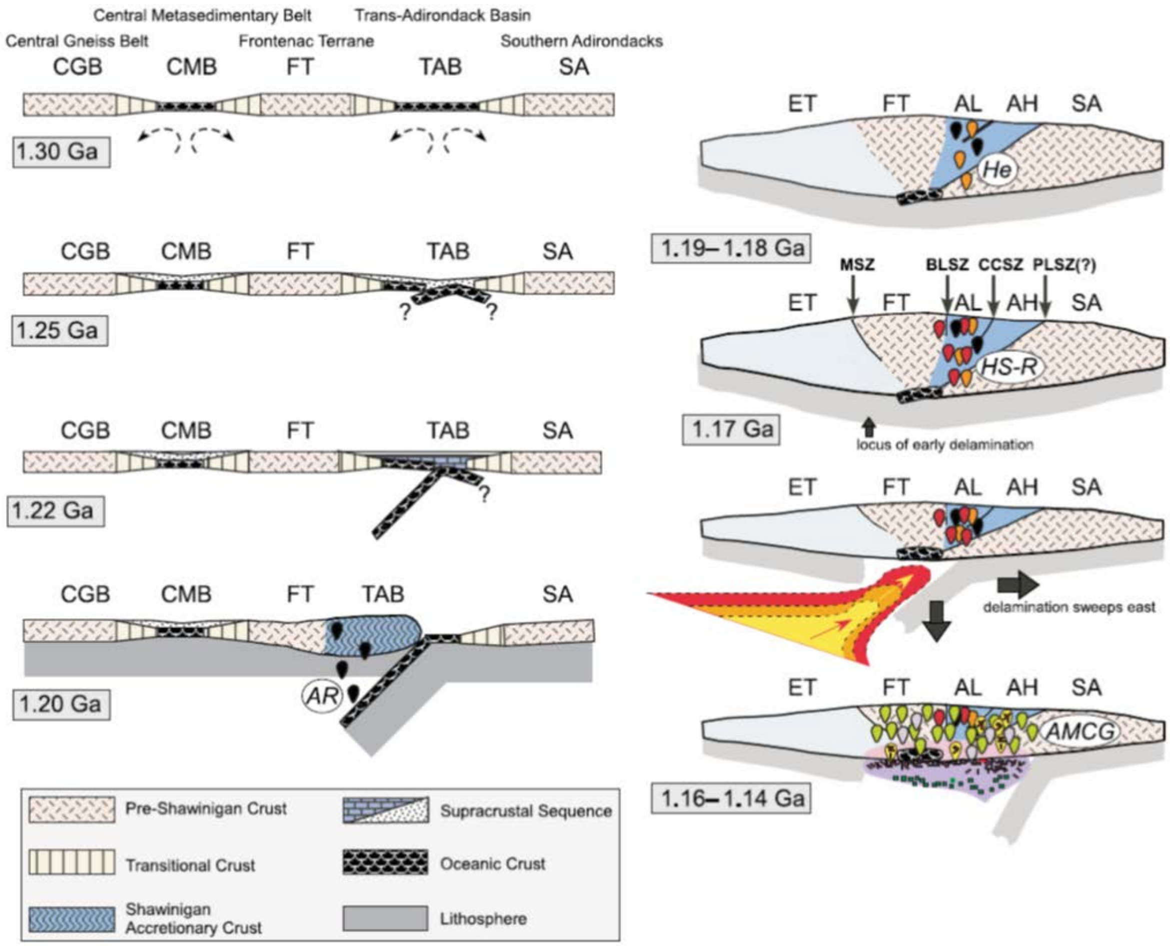


Figure 3. Tectonic model for the evolution of the Trans-Adirondack back arc basin and subsequent closure during Shawinigan orogenesis after Chiarenzelli et al. (2010b), Regan et al. (2011), and Peck et al. (2013). Subduction and other details of the ca. 1.19–1.14 Ga Shawinigan orogeny are not specified in the Central Metasedimentary Belt (CMB.) CGB—Central Gneiss Belt, ET—Elzevir terrane, FT—Frontenac terrane, TAB—Trans-Adirondack basin, SA—Southern Adirondacks, AH—Adirondack Highlands, AL—Adirondack Lowlands, MSZ—Maberly shear zone, BLSZ—Black Lake shear zone, CCSZ—Carthage-Colton shear zone, PLSZ—Piseco Lake shear zone, AR—Antwerp-Rossie suite (black plutons), He—Hermon granite gneiss (orange plutons), HS-R—Hyde School gneiss and Rockport granite (red plutons), AMCG—anorthosite-mangerite-charnockite-granite (and gabbro) plutons, including the Frontenac suite (anorthosites are yellow, granitoids are green, and gabbros are purple). Dark purple is underplating mafic magma, and dark pink is melted lower crust. In panels after 1.20 Ga (right), light blue is undifferentiated crust in the Elzevir terrane and dark blue shows the amalgamated Trans-Adirondack basin (Adirondack Lowlands and Adirondack Highlands). For these panels, the nature of the pre-Ottawan lower crust is necessarily schematic.

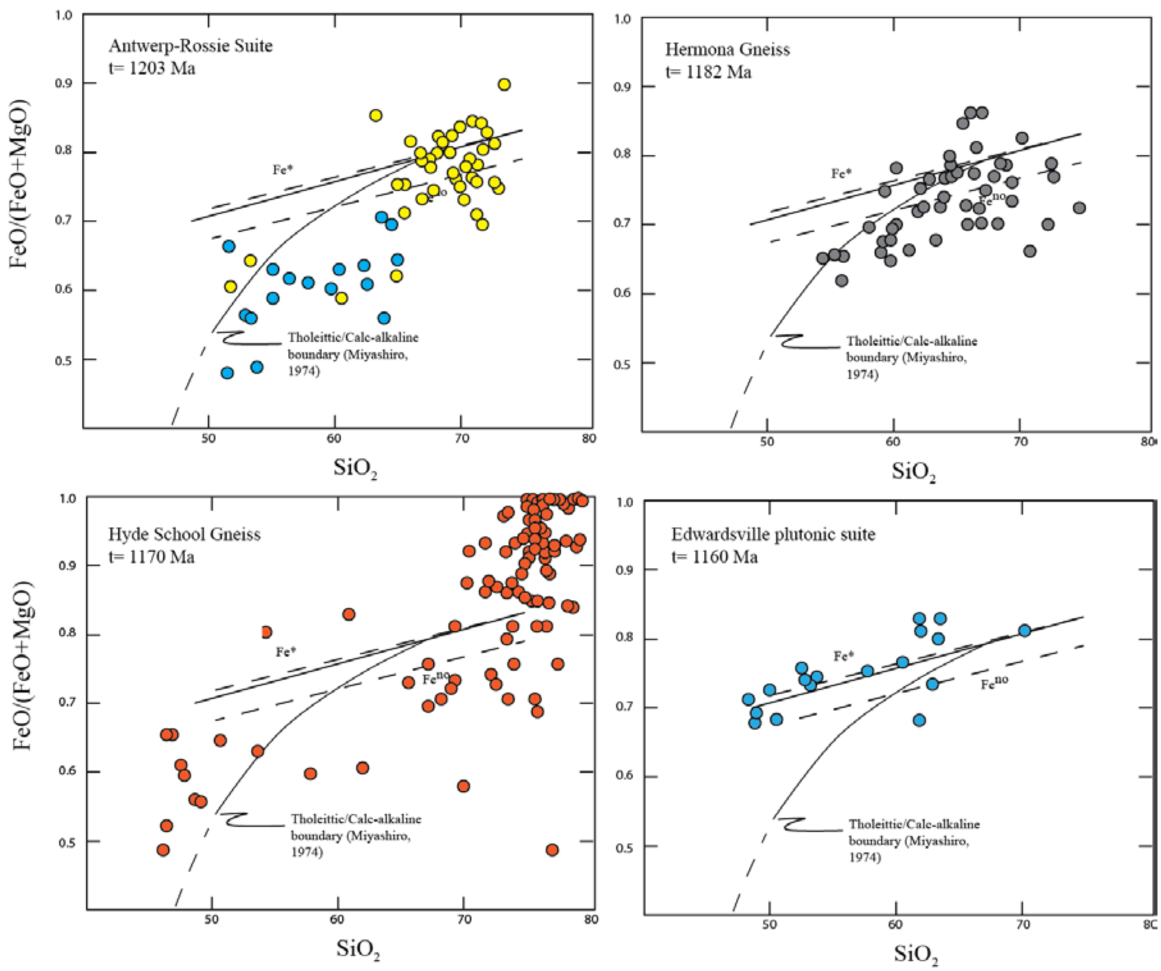
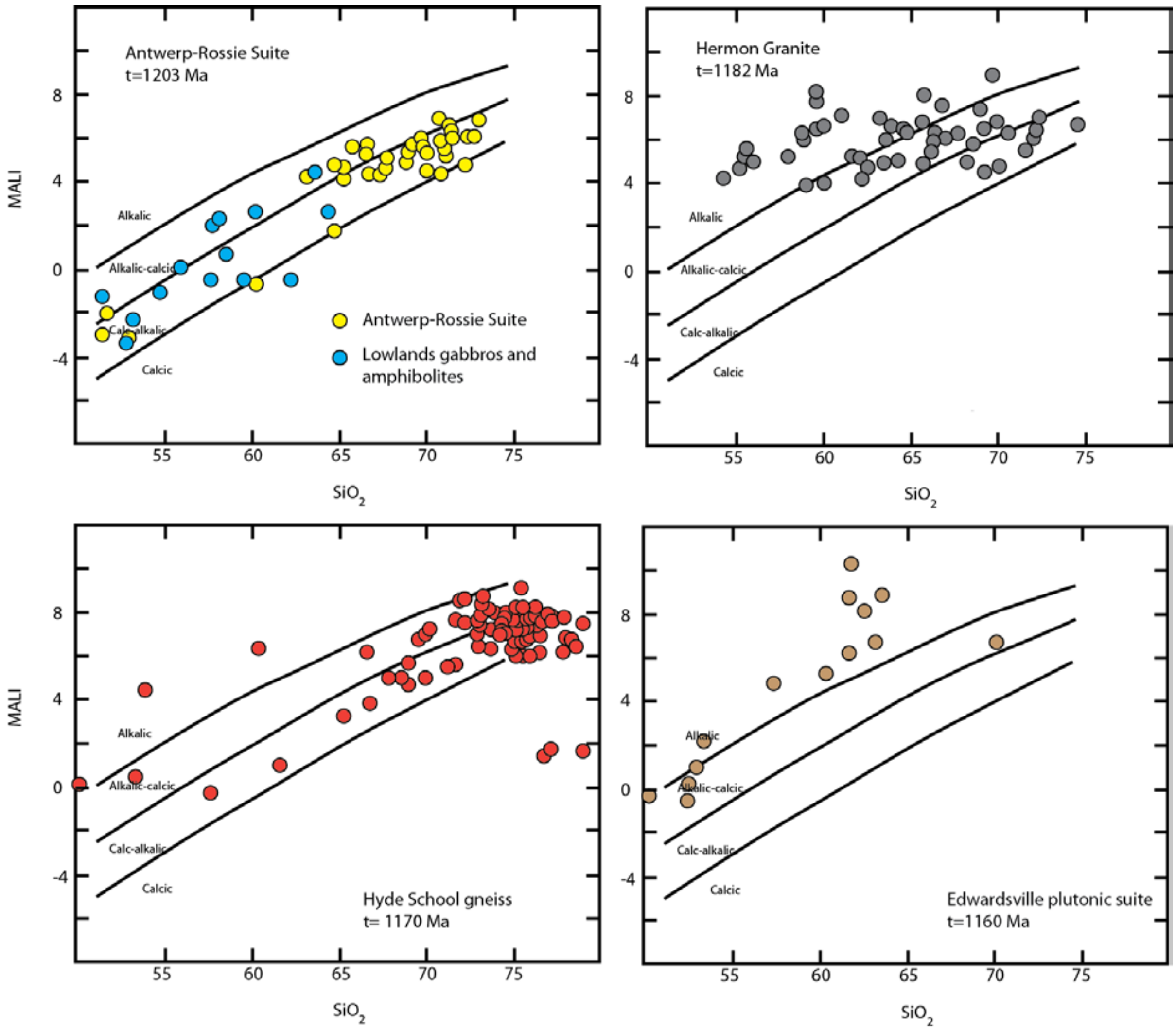


Figure 4. Fe index vs. SiO_2 after Frost and Frost (2008) of major igneous suites within the Adirondack Lowlands. Fe-index (FeO/(MgO+FeO) differentiates rocks categorized as ferroan or magnesian. Magnesian rocks are generally interpreted as being sourced from a hydrous protolith (oxidizing) and ferroan rocks are interpreted as being sourced from an anhydrous protolith (reducing magma). The oldest igneous events within the Adirondack Lowlands have a magnesian trend (Antwerp-Rossie suite and the Hermon Granite) whereas subsequent intrusions appear to be more ferroan (Hyde School Gneiss and Edwardsville plutonic suite). These are believed to be original magmatic characteristics imparted by their respective source(s).



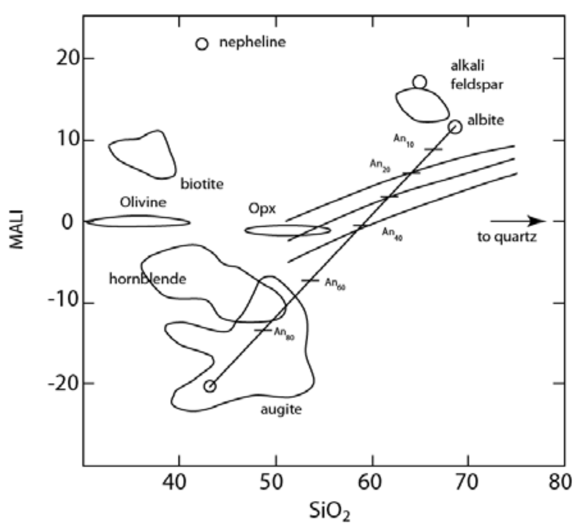


Figure 5. Modified alkali-lime index plot (MALI; Na_2O+K_2O-CaO) of all major igneous events in the Adirondack Lowlands. Left: redrawn figure from Frost and Frost (2008) displaying the location of many rock-forming minerals on the MALI projection. The Antwerp-Rossie Suite shows a strong calc-alkaline trend which weakens through time to the more alkalic Edwardsville pluton (Peck et al. 2013).

The Black Lake shear zone represents a major lithotectonic boundary within the Mesoproterozoic basement of New York and Ontario marking the NE extent of ca. 1180 – 1200 Ma subduction and the >1250 Ma ophiolite in the Lowlands (Chiarenzelli et al., 2010b; 2011a; Wong et al., 2011; Peck et al., 2013). This shear zone has recently been interpreted to represent magmatism and the approximate location of the rifted margin of Laurentia prior to Shawinigan orogenesis (Fig. 3; Chiarenzelli et al., 2010b). This interpretation suggests that stratigraphic correlations across the shear zone are possible, and would predict shallower facies assemblages (ie quartzites, psammites) consisting of clastic material to the northwest, grading into carbonate (limestone) and pelitic (mud) assemblages to the southeast. The gross stratigraphy preserved within the Adirondack Lowlands is interpreted to record a period of protracted opening and subsequent basin closure and restriction consistent with a back arc model (Carl et al., 1990; Chiarenzelli et al., 2010b; 2011b)

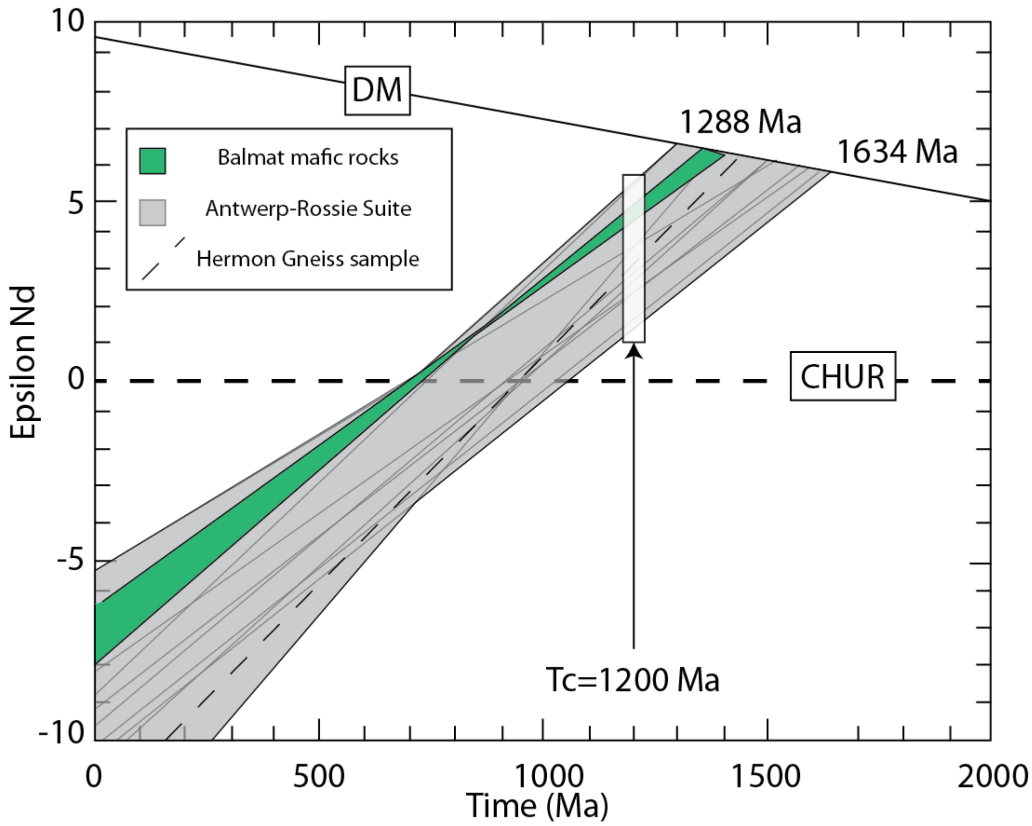
A maximum age on rifting is not well constrained, despite well understood stratigraphic and spatial relationships. Detrital zircon analyses from quartzites in the Frontenac terrane yield a maximum deposition age of 1306 Ma (Sager-Kinsman and Parrish, 1993). Detrital zircon geochronology three samples from the metasedimentary sequence indicates deposit prior to ca. 1250 Ma (Chiarenzelli et al., 2013), and likely represents silicilastic deposition during basin evolution from opening to closure. Deposition of carbonate and evaporitic rocks of the upper Marble likely occurred in isolated remnants of the collapsing basin restricted from the open ocean immediately prior to Elzevirian orogeneisis. Cessation of extension likely occurred during the onset of the Elzevirian orogeny within the Central Metasedimentary Belt to the NW (ca. 1220-1240 Ma) and stepped to the southeast into the Adirondack Lowlands (Chiarenzelli et al., 2011b).

MAJOR IGNEOUS EVENTS

The Antwerp-Rossie Suite (data from Chiarenzelli et al., 2010b; Peck et al., 2011; and Carl and deLorraine, 1997; Carl, 2000)

The ca. 1200 Ma Antwerp-Rossie suite (ARS) is the oldest recognized plutonic suite within the Adirondack Lowlands (Wasteneys et al., 1999; Chiarenzelli et al., 2010b). Rocks of the ARS outcrop only southeast of the Black Lake shear zone (Fig. 2), and are exposed near the villages of Antwerp and Rossie, NY. This suite intrudes lower marble unit, is equigranular, and lacks a well-defined and/or regionally extensive tectonic fabric despite experiencing amphibolite facies metamorphism. The ARS includes rocks ranging from diorite to granite in composition. These rocks are plagioclase, quartz, K-spar, and hornblende-bearing, with rare clinopyroxene in more mafic members of the suite. Apatite, monazite, and zircon are common accessory phases. Compositions span relatively broad spectrum of SiO_2, ranging from 46.8 to 78.8 wt% SiO_2, with a noticeable gap between 52.5-62.5 wt% SiO_2. However, some analyzed mafic bodies (Carl, 2000) have been thought to be correlative to the Antwerp-Rossie suite and span some of that compositional gap (Peck et al., 2013). Data form linear trends on Harker-type variation diagrams, and plot in the magnesian field on Fe index vs. SiO_2 diagrams (Fig. 4; Frost and Frost, 2008). On modified alkali-lime index plots (Fig. 5; after Frost and Frost, 2008), the ARS displays a linear trend, defining a shallow slope of increasing SiO_2 with increasing MALI, plotting largely in the calc-alkalic field (Fig. 5). The ARS exhibits relatively high-K chemical trends, mildly calc-alkaline compositions, and plot in the volcanic arc granite field on tectonic discrimination diagrams (Pearce et al., 1984). When normalized to primitive mantle (Fig. 7; Sun and Mcdonough, 1981), the suite shows strong enrichment in LILE and Pb, and depletion in HFSE. Furthermore, the ARS contains REE that display LREE enrichment and HREE depletions, typical of a garnet-bearing source.

Sm-Nd isotopic systematics have been used extensively to fingerprint magmatic processes, and have been quite successful at differentiating juvenile vs. evolved sources (Fraure and Mensing, 2005). Twelve ARS samples were analyzed for Sm-Nd isotopes, with sampling focused on spatial and compositional representation (Fig. 6; Chiarenzelli et al., 2010b). The ARS contains $\varepsilon_{Nd(t)}$ (t=1200 Ma) values, ranging from 1.5 – 5.4, plotting between contemporaneous depleted mantle and CHUR. These values show no discernable correlation with SiO_2, suggesting minimal, if any, continental contamination. Furthermore, the majority of samples have T_{DM} (depleted mantle model age) values <1400 Ma, consistent with a juvenile source region. However, there is a geographic pattern with the lowest $\varepsilon_{Nd(t)}$ values corresponding to samples located along the eastern margin of the BLsz. These three samples also yield the three oldest T_{DM} ages (>1600 Ma). This excursion is interpreted to represent an increase in continental influence, and may be the expression of more evolved crust along the BLsz as suggested by the tectonic model above where the BLsz marks the southeastern rifted margin of Laurentia prior to Shawinigan orogenisis.



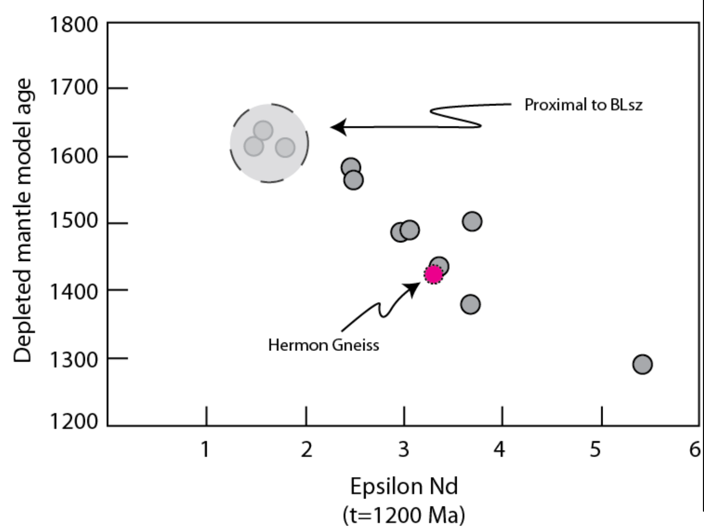


Figure 6. Sm-Nd results of the A-R suite, and a Hermon Granite sample (dotted). Above: the evolutionary envelope of the A-R suite. Note that the Hermon Granite falls entirely within the envelope defined by the A-R Suite. Left: Epsilon Nd vs. depleted mantle model ages. Note the three oldest model ages and the lowest epsilon Nd values correspond to samples adjacent to the BLsz (Chiarenzelli et al., 2010b)

Hermon Granite (data from Peck et al., 2014; Carl and DeLorraine, 1997)

The Hermon granite is a megacrystic, K-feldspar hornblende granite that occurs southeast of the Black Lake shear zone (Fig.2). Despite its geographic overlap with the ARS, the Hermon granite is slightly younger, yielding a U-Pb zircon age of 1182 +/- 7 Ma (Heumann et al., 2006). It is often observed intruding the Popple Hill Gneiss, unlike the ARS, which is commonly in contact with marble. The Hermon Granite Gneiss suite has a broad compositional range, from 54.5 to 74.6 wt % SiO_2, and plots from calc-alkalic to alkalic on MALI diagrams (Fig. 5), with no systematic variation despite a broad range in SiO_2 contents. Like the ARS, the Hermon lithologies are predominately magnesian with regard to their Fe-index (Fig. 4; Frost and Frost, 2008).

On tectonic discrimination diagrams, the Hermon granite plots as a volcanic arc granite, but forms a broad field which straddles the within-plate granite field (Pearce et al., 1984). When normalized to primitive mantle (after Sun and McDonough, 1989), the Hermon granite shares similar geochemical attributes as the preceding ARS, but lacks the distinctive Pb anomaly. The Hermon granite has similar Sm-Nd isotopic systematics (Chiarenzelli et al., 2010b).

1172 Ma Hyde School Gneiss (data from Fischer, 1995; Carl and deLorraine, 1997; Carl, 2000; Peck et al., 2013)

The Hyde School Gneiss (HSG) forms domical bodies initially interpreted as rootless intrusions, or phacoliths (Buddington, 1929). These bodies range from alkali granite to tonalite in composition and have been interpreted as intrusive igneous rocks (McLelland et al., 1992) or ash flow tuffs (Carl and deLorraine, 1997). On the map scale, the Hyde School gneiss forms large (>10 km) domes with apparently concordant lenses of amphibolite, and have a composite igneous/metamorphic fabric that parallels the margin of individual bodies (Carl et al., 1990). The HSG contains variable enrichments with respect to its LILE and minor depletions in its HFSE when normalized to primitive mantle (Sun and McDonough, 1989), with the majority of samples sharing many of the trace element characteristics of the ARS. They plot from alkali-calcic to calc-alkalic with nearly constant MALI with increasing SiO_2 (Peck et al., 2013). Both multi-grain TIMS and single grain SHRIMP U-Pb analyses of zircon yield igneous age of ca. 1170 Ma (McLelland et al., 1992; Wasteneys et al., 1999). The zircon ages of the Hyde School Gneiss require that it was emplaced as a series of plutons within the Adirondack Lowlands. Deformation and associated gneissic layering developed during or subsequent to emplacement, consistent with monazite and garnet ages from leucosomes in the Popple Hill Gneiss (Heumann et al., 2006).

The Hyde School Gneiss intrusive ages overlap with zircon ages of the Rockport Granite, which outcrops immediately northwest of the BLsz.

1160-1150 Ma Edwardsville Pluton (and other members of the Frontenac Suite) Post Shawinigan Ferroanmagmatism (data from Peck et al., 2013)

The youngest igneous suite within the Adirondack Lowlands, and, importantly, the adjacent Frontenac Terrane, is a series of ferroan rocks referred to as the Frontenac Suite, represented in the area of this trip by the Edwardsville Pluton (the Pope Mills mass of Buddington, 1929). Ranging from syenitic to subordinate gabbro, the Edwardsville pluton is texturally and compositionally heterogeneous. Recent single grain SHRIMP analyses (Peck et al., 2013) have corroborated older multi-grain TIMS work (1164 Ma; McLelland et al., 1993), which yield an age of 1149 +/- 22 and 1161+/- 16 Ma from a monzonitic member of the Edwardsville plutonic suite and a granite from the Honey Hill syenite, respectively (Peck et al., 2013). These ages correspond to anorthosite-mangerite-charnockite-granite (AMCG) magmatism within the Adirondack Highlands (McLelland et al., 2004; Hamilton et al., 2004) and the similarly ferroan Frontenac Suite in the Frontenac terrane to the northwest (1180-1160 Ma).

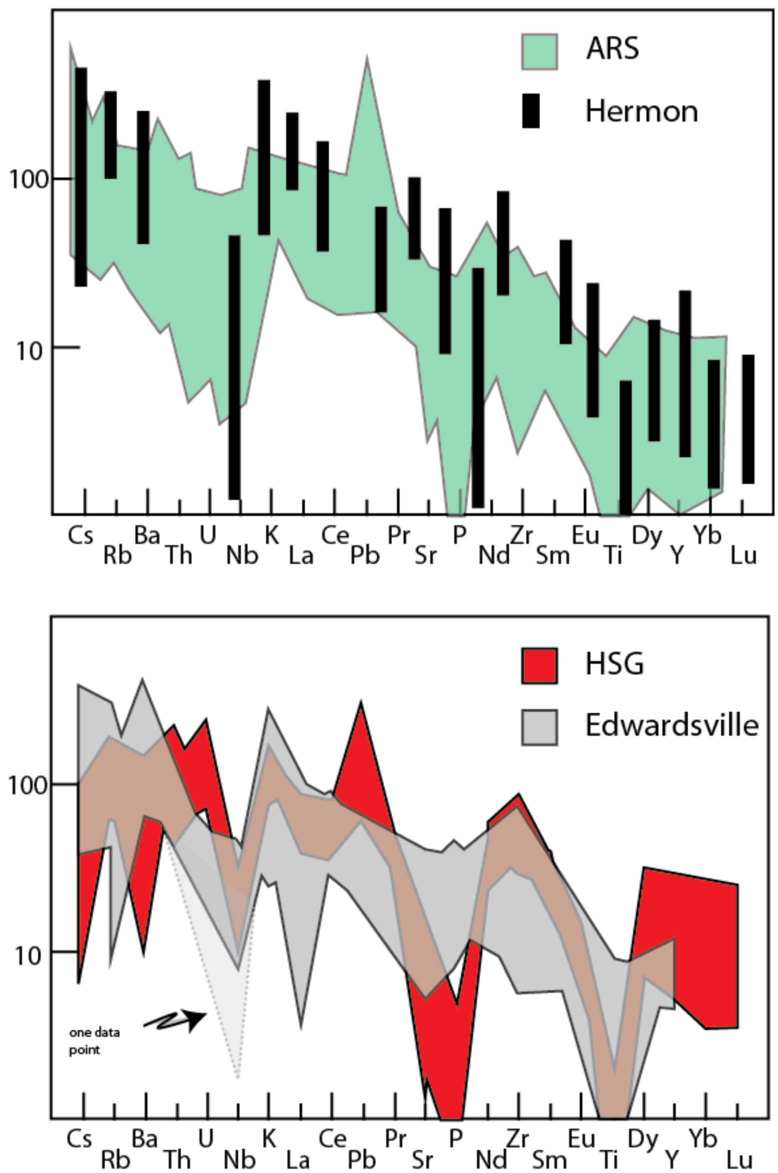


Figure 7. Incompatible element plots normalized to primitive mantle (Sun and McDonough, 1989) of the four major igneous suites. Note the strong enrichment in LILE and depletion in HSFE, characteristic of a metasomatized source (Chiarenzelli et al., 2010).

Unlike the older igneous suites in the Lowlands, this late intrusive suite plots as strongly ferroan and alkali-rich on geochemical diagrams. These data suggest that the influence of a metasomatized lithospheric mantle/lower crust was completely gone by this time and that anhydrous, lower crustal sources were likely dominant. This is consistent with post-orogenic delamination of the lithospheric mantle as presented in several other contributions (McLelland et al., 2004; Regan et al., 2011; Peck et al., 2013). This was likely due to upwelling of asthenospheric mantle, and melting of the lower crust (McLelland et al., 2010a,b; Regan et al., 2011; Peck et al, 2013), processes that extended across the Adirondack Lowlands and adjacent Frontenac Terrane as Shawiningan plutonism was ending. These relationships establish that the Lowlands and Frontenac terranes were a coherent tectonic unit by ca 1160 Ma, representing complete closure of the earlier, pre-Shawinigan sedimentary basin. The high-strain features observed within the BLsz are a manifestation of this collisional boundary.

CONCLUSIONS

The Adirondack Lowlands record several geochemically distinct, plutonic suites which were emplaced into an older metasedimentary sequence. The earliest pulse of magmatism, the Antwerp-Rossie, has a wide range in SiO_2 content and has a strong arc signature with mild calc-alkaline character. Despite its pre-Shawinigan age (ca. 1203 Ma), it appears to cross-cut tectonic fabrics within the surrounding metasedimentary units (stop 1), suggesting that an earlier (accretionary phase?) of deformation preceded the Shawinigan orogeny. Sm-Nd isotopic analyses suggest a juvenile source for the ARS, but with a strong continental influence immediately adjacent to the BLsz, where ε_{Nd} values decrease drastically and yield T_{DM} ages >1600 Ma. Following this phase of magmatism, the 1182 Ma (Heumann et al., 2006), megacrystic Hermon gneiss was emplaced, which shares many of the same geochemical attributes as the ARS. Circa 1172 Ma magmatism (McLelland et al., 1992; Wasteneys et al., 1998) is represented by the domical Hyde School Gneiss bodies southeast of the BLsz, and the voluminous Rockport granite to the northwest. Although sharing some of the incompatible element trends present within earlier magmatic suites, the HSG and Rockport granite are more ferroan and aluminous. The last magmatic event, the Frontenac suite (ca. 1180-1150 Ma; McLelland et al., 1991; Peck et al., 2014), represented by the Edwardsville pluton in New York, has recently been interpreted as the southern extension of ferroan magmatism in the Frontenac terrane (Peck et al., 2013). Furthermore, this event is interpreted to represent the mid-crustal expression of AMCG plutonism present in the Adirondack Highlands (Peck et al., 2013). Therefore, these suites contain a record of the evolving tectonic environment during the final closure of the Trans-Adirondack back arc basin from subduction to post collisional delamination.

STOPS AND TRIP LOG

Meeting Location: Price Chopper parking lot (east of I-81; last exit before bridge if headed north)

Address: 43615 New York 12, Alexandria Bay, NY 13607

Secondary meeting location: outcrop at 8:45 am

Meeting time: 8 AM; Depart Price Chopper by 8:15 AM
Drive I-81 S, take exit 49….. 9.7 Miles
Turn Left onto NY-411 E….. 3.1 Miles
Continue on NY 26 S….. 1.7 Miles
Turn Left onto Commercial St…… 0.2 miles
Continue onto NY 26-S/Mill Street….. 6.1 miles
Turn left onto US-11 N….. 6.4 miles
27.2 Miles, 30 minutes
Pull over on southeast side of road (Right side – large shoulder). Cross carefully! Heavy traffic.
Arrive: 8:45 AM

Stop 1: Route 11 east of Antwerp, NY

Coordinates: N 44°14,184' W 075°35.950'

This outcrop is one of many exposures of the Antwerp-Rossie suite, and surrounding marble, exposed along this section of US-11. Interestingly, the granitoid appears to cross -cut an isoclinal, recumbant fold in the marble, and contains quartzite xenoliths. However, Shawinigan deformation is generally accepted to postdate 1200 Ma. An important question to consider at this outcrop is the origin of this layering. Is the folding related to deformation around the more competent granitoid, or does the granitoid cross cut an earlier phase of deformation?

Depart 9:30 AM
Head North on US-11….. 11.3 Miles
Turn right on NY-812/58/William Street….. 2.9 Miles
14.2 Miles, 17 minutes
Pull over on east shoulder of road, outcrop immediately adjacent to road.
Arrive: 9:47 AM

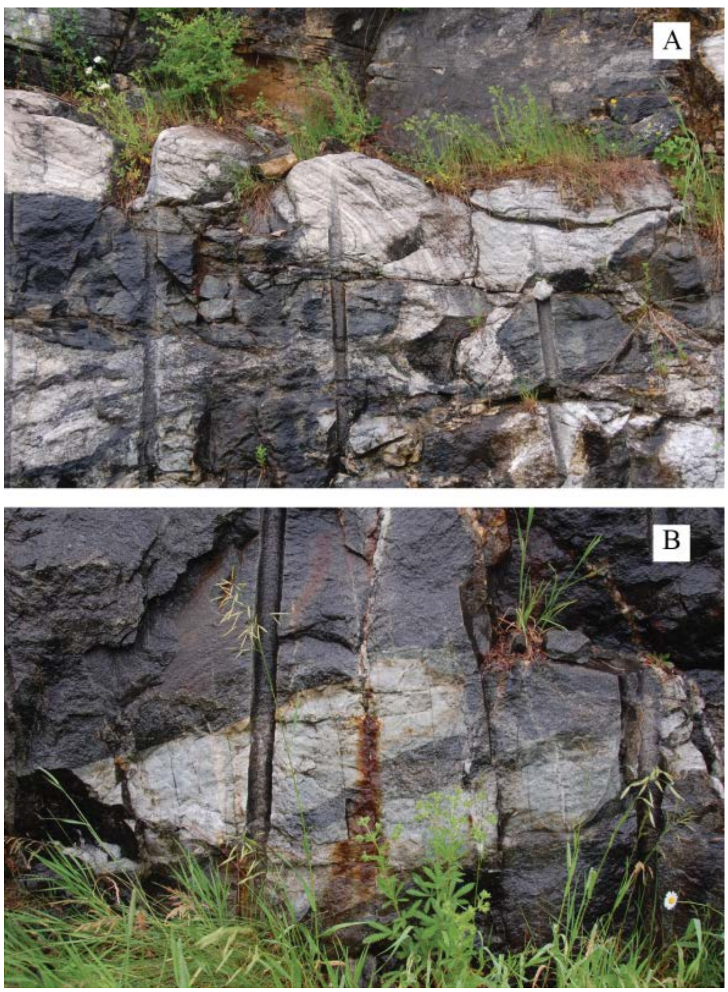


Figure 8. Photographs from Stop 1. A) intrusive contact between the Antwerp-Rossie suite and the lower marble; note isoclinal fold.. B) quartzite xenoliths in granodiorite of the Antwerp-Rossie suite.

Stop 2: The Steers Head locality

Coordinates: N 44°18,723’ W 075°27.289’

The steers head locality is one of the many classic field trip localities in the Adirondack Lowlands. The marble contains graphite-rich layers and dismembered calc-silicate gneisses with well-developed reaction rims along their margins. The reaction rims contain tremolite, diopside, phlogopite, quartz, and calcite, among others. Do you see any other minerals in the reaction rims? Also, try to find the folded tourmaline vein on the north end of the outcrop within the marble.

It is important to note that the ARS has a wide range of SiO_2 contents. The rocks seen at Stop 1 and 2 are representative of the more felsic members of the ARS. Samples from this belt have relatively juvenile Sm-Nd systematics with no systematic relationship between ε_{Nd} with SiO_2, suggesting a minimal, if any, signal of crustal contamination.

This outcrop was host to an important stable isotope study by Cartwright and Valley (1991). Stable isotope ratios were measured in both metaigneous and metasedimentary country rocks across the intrusive contact to assess the importance of metamorphic fluid flow; essentially looking for a hydrologic ‘breakthrough curve’ caused by the difference in $\delta^{18}O$ between these lithologies. No breakthrough curve is present, and the gradient in $\delta^{18}O$ between lithologies contains an inflection point at the contact, with a several meter equilibration gradient from high $\delta^{18}O$ values in the marble, to lower $\delta^{18}O$ values in the granite. The preservation of these steep isotopic gradients and lack of offset of the inflection point suggest that minimal fluid flow occurred during regional metamorphism (Cartwright and Valley, 1991).

Figure 9. The classic “steers head” locality. Notice the large marble block entrained in the surrounding granodioritic Antwerp-Rossie Suite rocks.

Depart 10:30 AM
Head Northeast on NY812/58 towards Main Street….. 2.9 Miles
Turn right onto NY-812/US-11/East Main Street….. 11.4 Miles
Turn left onto NY-812 N….. 2.6 Miles
Turn left onto County Road 17/86….. 0.6 Miles
17.9 Miles, 24 minutes
Please pull over onto right (east) shoulder.
Arrive: 10:54 AM

Stop 3: County Road 17 north of De Kalb Junction

Coordinates: N 44°30.369' W 075°21.405'
The megacrystic Hermon Granite gneiss is a distinctive rock unit throughout the Adirondacks, with coarse K-spar augen. Here, the Hermon gneiss was emplaced into marble. With an age of 1182 Ma (Heumann et al., 2006), all deformation within the Hermon Granite gneiss is likely associated with Shawinigan tectonism. As noted above, this suite of rock shares many similarities to the ARS, but lacks a major Pb anomaly when normalized to primitive mantle and typically plots on field boundaries on tectonic discrimination diagrams (Pearce et al., 1984). Note the strong fabric development at this outcrop. Do the different minerals show varying amounts of deformation or recrystallization? What is the strike and dip of the gneissic layering?

Depart: 10:40 AM
Continue on County Road 17/86/7….. 2.7 Miles
Park at intersection with Child's Road
3.2 Miles, 5 minutes
Arrive: 10:45 AM

Figure 10. A concordant layer of Hermon granite in pelitic gneiss, containing xenoliths of the host rock along its margin.

Stop 4: South of Beaver Creek, County Route 7. Park on Childs Road. BE CAREFUL!!! SMALL SHOULDER!

Coordinates: N 44°31.517' W 075°24.001'

This outcop contains meter to submeter concordant layers of the Hermon granite gneiss (HGG) within a fine grained sulfidic, pelitic gneiss. Both contain a well-developed, upright foliation, and a moderately plunging stretching lineation. Near the margin of the Hermon granite gneiss, there are sub-meter scale pelitic xenoliths aligned with the tectonic fabric (Figure 10). What is the strike and dip of the major fabric in the metapelite? The granitic gneiss? The foliation is fairly representative of the major structural fabrics throughout the Adirondack Lowlands and is well developed within the Hermon granite gneiss, suggesting that the NE-SW structural grain, predominate throughout the Adirondack Lowlands occurred after the emplacement of the Hermon granite gneiss.

Similarly to the ARS, the Sm-Nd systematics for the HGG form a fairly steep evolutionary curve. They plot between CHUR and contemporaneous depleted mantle at time of crystallization suggesting a juvenile source. The sample analyzed plots entirely within the evolutionary envelope for the ARS.

Depart: 11:45 AM
Head North on County Road 17/86/De Kalb DePeyster Road….. 1.3 Miles
Turn Right onto County Rd 11/45….. 1.8 Miles
Turn Right on County Road 10….. 1.1 Miles
Take first left onto Plimpton Road….. 1.4 Miles
Continue onto Lake and Kokomo Road….. 0.1 Miles
Turn left onto NY-184 W….. 7.9 Miles
Sharp left onto County Road 7/95….. 1.5 Miles
Total: 15.2 Miles, 28 Minutes
Park on right shoulder (east side of road), and cross road carefully.
Arrive 12:13 PM Bring Lunch

Stop 5: County Road 76, north of Cooper Rd, south of Turner Rd. BEWARE ANTS

Coordinates: N 44°27.568' W 075°33.354'

This outcrop is representative of the Hyde School Gneiss (HSG). The HSG has been interpreted alternatively as having an intrusive, or an extrusive (ash flow) protolith. However, substantial work has confirmed its plutonic origin (McLelland et al., 1992; Wasteneys et al., 1999).This outcrop displays rhythmic layering characteristic of the HSG, with amphibolite lenses to continuous layers that are relatively thin here. On a larger scale, the HSG forms km-scale domical lenses within surrounding metasedimentary packages, and contains a composite igneous/metamorphic fabric that parallels its margin. Medium grained in this locality, the HSG ranges from coarse leucogranite to tonalite, to finer grained aplitic layers. Geochemically, it shares many of the same characteristics as the older magmatic suites. It contains minor enrichments with respect to its LILEs and minor depletions in its HFSE when normalized to primitive mantle (Sun and McDonough, 1989), and plots from alkali-calcic to calc-alkalic with constant MALI with increasing SiO_2. Furthermore, unlike the ARS and Hermon Gneiss, the HSG samples plot as largely ferroan with regard to their Fe-index, with a subset plotting in the magnesian field (Peck et al., 2013; Frost and Frost, 2008).

Depart: 1:00 PM

Head north on County Road 7/95….. 1.8 Miles
Continue onto NY-184W….. 0.6 Miles
Contine straight onto NY-58 N….. 0.3 Miles
Total: 2.5 Miles, 7 minutes
Park on right shoulder just north of Pope Mills town center
Arrive: 1:07 PM

Stop 6: Route 58 north of junction with Acres Road outside Pope Mills, NY.

Coordinates: N 44°29.282' W 075°34.880'

The youngest igneous suite within the Adirondack Lowlands is a series of ferroan rocks collectively referred to as the Edwardsville pluton (Buddington, 1929). Ranging from syenitic to subordinate gabbro, this suite of rocks is both texturally and compositionally heterogeneous. Recent single grain SHRIMP analysis (Peck et al., 2013) has corroborated older multi-grain TIMS work (1164 Ma; McLelland et al., 1993), which yield an age of 1149 +/- 22 and 1161+/- 16 Ma from a monzonitic member of the Edwardsville pluton and a granite from the Honey Hill syenite, respectively (Peck et al., 2013). These ages correspond to anorthosite-mangerite-charnockite-granite (AMCG) magmatism within the Adirondack Highlands (McLelland et al., 2004; Hamilton et al., 2004), and the similarly ferroan magmatic event in the Frontenac terrane to the northwest (1180-1160 Ma).

Although texturally similar to the Hermon Gneiss, can you see a mineralogical difference? Is there a strong tectonic fabric? Lastly, is this outcrop homogeneous, or are there texturally distinct rocks types, and, if so, what is the relationship between them?

Depart: 1:50 PM
Head north on NY-58 toward Brown Road….. 2.6 Miles
Turn left on County Route 6….. 6.8 Miles
Continue onto Lake street….. 0.5 Miles
Turn left onto NY-37 W/South Main street….. 0.9 Miles
Take 3rd left onto County Road 3/31….. 1.7 Miles
Turn right onto Split Rock Road….. 2.3 Miles
Total: 14.8 Miles, 23 minutes
Park on right shoulder. Please park as far right as possible. This is a narrow road.
Arrive: 2:13 PM

Stop 7: Rossie Diorite, Split Rock Road. Very close to private property, please be courteous!

Coordinates: N 44°23.598' W 075°41.807'

The Rossie diorite represents a more mafic component of the ARS suite. It is important to note that we are very close to the Black Lake shear zone, an important structural and lithologic discontinuity separating the Adirondack Lowlands from the Frontenac Terrane (Wong et al., 2011). Although slightly more mafic than its southern counterparts, the Rossie diorite displays similar geochemical signatures. However, despite these similarities, the belt of dioritic rocks exposed along the eastern margin of the Black Lake shear zone contain the lowest $\varepsilon_{Nd(T)}$ values, and yield the oldest T_{DM} ages, approximately as much as 400 My older than ARS samples analyzed further south. These data suggest a major source of contamination by, or interaction with, older more evolved continental lithosphere (n=3 samples along the northwestern extent of the ARS).

Depart: 2:50 PM
Head South on Split Rock Road….. 1.2 Miles
Take 1st right onto South Hammond Road….. 3.1 Miles
Turn left onto NY-37 W….. 0.1 Miles
Take 1st right onto Webster Road….. 1.6 Miles
Continue onto Calaboga Road….. 1.7 Miles
Turn left onto NY-12 S….. 3.0 Miles
Total: 10.7 Miles, 22 minutes
Park on right (north) shoulder. Large shoulder, but abundant and very fast traffic on road. Please do not cross Rt. 12
Arrive 3:12 PM

Stop 8: Rockport Granite; US 12.
Coordinates: N 44°24.182' W 075°47.984

These exposures are on the NW side of the Black Lake shear zone (Wong et al., 2011). We are now in the Frontenac Terrane. This outcrop exposes the voluminous Rockport granite (ca. 1170 Ma; Wasteneys et al., 1998), which extends across the Thousand Islands region and into Ontario, Canada. Here, the Rockport Granite is in contact with strongly deformed calc-silicate (metasedimentary) gneisses. There is a faint, near-vertical gneissic layering within the Rockport Granite that is shared by the adjacent calc-silicate gneisses. This suite of granitic rocks is time equivalent to the domical Hyde School gneisses in the Adirondack Lowlands. However, the Rockport Granite has a much different intrusive style, and is hosted most commonly by quartzite and quartzite-calc-silicate country rock. The Rockport granite is generally slightly to moderately deformed, and doesn't occur as strongly deformed domical bodies like its Hyde School gneiss counterpart. Furthermore, no exposures of ARS or Hermon Granite gneiss have been identified on this side of the Black Lake shear zone.

Discussion: 4:15 PM
Depart 5:00 PM

Figure 11. Intrusive contact between ca. 1170 Ma Rockport granite and calc-silicate gneisses NW of the BLsz.

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