Pegmatites of New York State: The Batchellerville pegmatite

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INTRODUCTION

Despite their interesting petrographic features, geological associations, and mineral assemblages, there are only a few modern scientific studies on the pegmatite bodies of New York State (Tan 1966; Putman and Sullivan 1979). The pegmatites are found in two geological units: the Grenville-age (1300 - 1000 Ma) metamorphic rocks of the Adirondack Mountains (Figure 1) and the Taconic-age (~ 450 Ma) metamorphic rocks of southern New York. There are approximately 25 significant pegmatite bodies known in New York, and they can be placed into six different geologic / geographic groups:

A. The Bedford pegmatite district consisting of the amazonite- and the peristerite-bearing pegmatites at Valhalla in Westchester County, and the small pegmatite bodies in the Taconic-age metamorphic rocks of the Manhattan Prong (New York City) that are xenotime, or beryl- and chrysoberyl-bearing;
B. The Cranberry Creek (Mayfield), Batchellerville, Greenfield, Day (Overlook), and Corinth belt of pegmatites in the southern Adirondack Highlands;
C. The Crown Point, Rose Rock, Spar Bed Hill, Chestertown, and Fort Ann pegmatites in the central-eastern Adirondack Highlands;
D. The Scott Farm - Benson Mines pegmatite belt in the northwestern Adirondack Highlands;
E. The Lyons Falls and Stiles Farm pegmatites in the western Adirondacks; and
F. The McLear and other small pegmatite bodies in the Adirondack Lowlands.

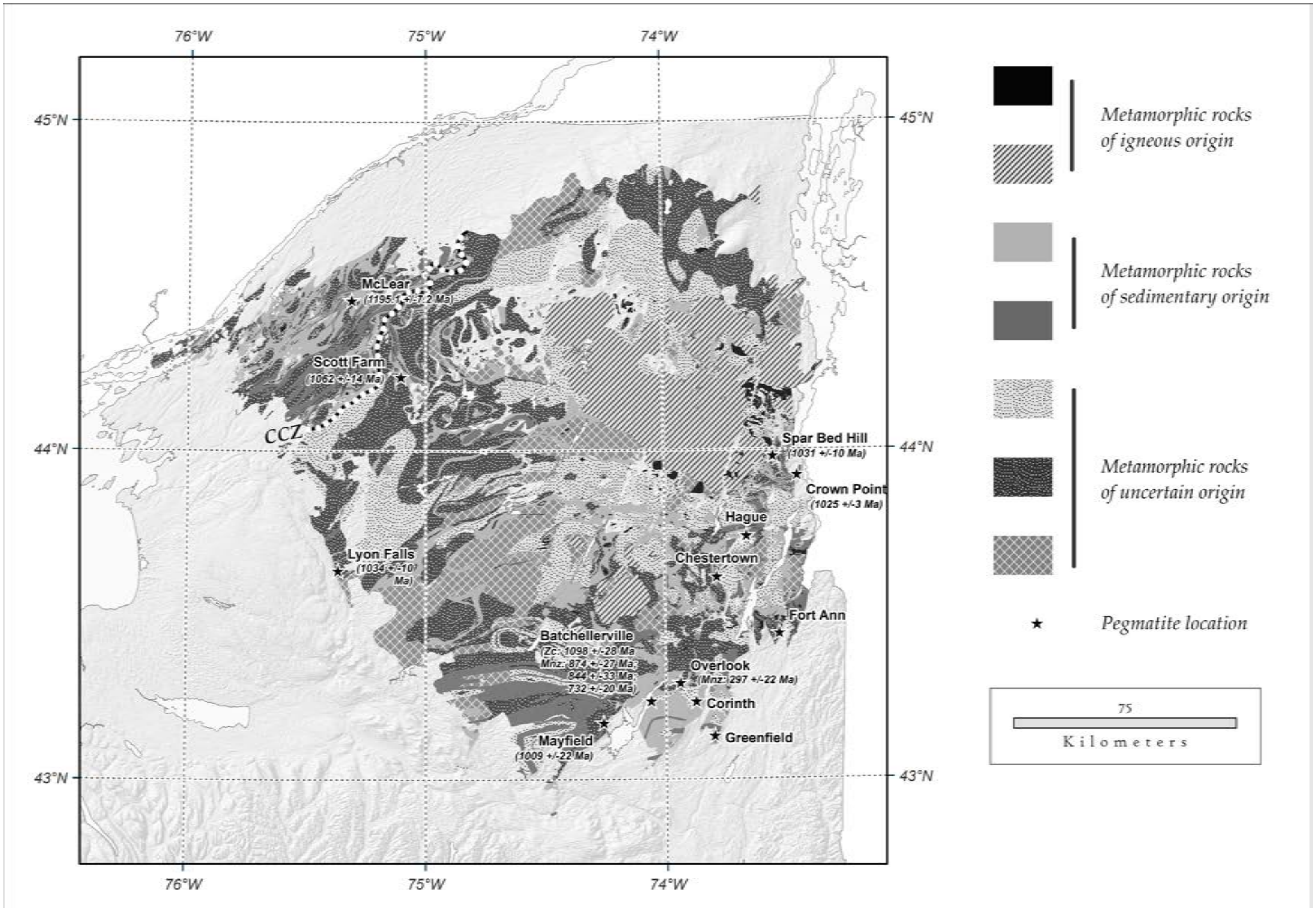

Figure 1. Locations and ages of major pegmatite bodies in the Adirondacks. (Zc – zircon age, Mnz – monazite age (Lupulescu et al. 2011). Map courtesy of Janet Manchester).

HISTORY

General

Interest in the pegmatites of New York started with the rush to find and mine high-quality feldspar in the second half of the nineteenth century. The second stage for pegmatite exploration began in 1950 when the USGS initiated a nationwide search for uranium resources. The first attempt to mine pegmatites in New York State began around 1878 at the Bedford pegmatite. Mining at Bedford lasted until 1949, and in 1962 and 1963 the dumps and most of the mine structures were leveled to build houses (Tan 1966).

The pegmatites in the east central Adirondacks were first mined for enamel, crushed stone, grit for chicken feed, and on a smaller scale, for quartz used in glass manufacturing. Mining began in the late nineteenth century and lasted until around 1926 (Tan 1966).

In the northwestern Adirondacks, the McLear pegmatite was discovered in 1907. Here, feldspar was found in high-quality masses 6 in to 3 feet in length with no iron staining, but with rare grains of pyrite as inclusions. The quarry was worked by the White Hill Mineral Company until 1937, and after that, by the Green Hill Mining Company. The feldspar that was mined was shipped to Trenton, New Jersey, and used in the ceramics industry. The mine was closed around 1938 (Tan 1966).

Batchellerville

The Batchellerville pegmatite is located in the south-central Adirondacks, in the northwestern corner of the Broadalbin 7.5” quadrangle, Saratoga County. The pegmatite was discovered on the Adelbert Gordon Farm, and in 1906 the Clapska Mining Company from Trenton, New Jersey began mining the feldspar. The pegmatite was worked continuously until 1921 and sporadically until about 1934 (Tan 1966). The main product was high-quality microcline for the ceramics industry (Tan 1966). A secondary product, very coarse muscovite, was typically sought after as a dielectric material. However, microgranular iron oxide inclusions and staining made most of it unsuitable for electrical applications (Tan 1966).

The nearby Cranberry Creek (Mayfield) pegmatite on the Richard Tyrell Farm was exploited at about the same time as the Batchellerville pegmatite by the Clapska Mining

Company, which later transferred it to the United States Feldspar Corporation (Tan 1966). The mining stopped here shortly before 1916. The Overlook (Day) body was worked until 1920. The Corinth prospect was mined first in 1899 by American Feldspar Company (Bastin 1910) and then transferred to the local Corinth Feldspar Company (Tan 1966).

Tan (1966) identified and named eight distinct pegmatite bodies that were mined at the Batchellerville property (Figure 2).

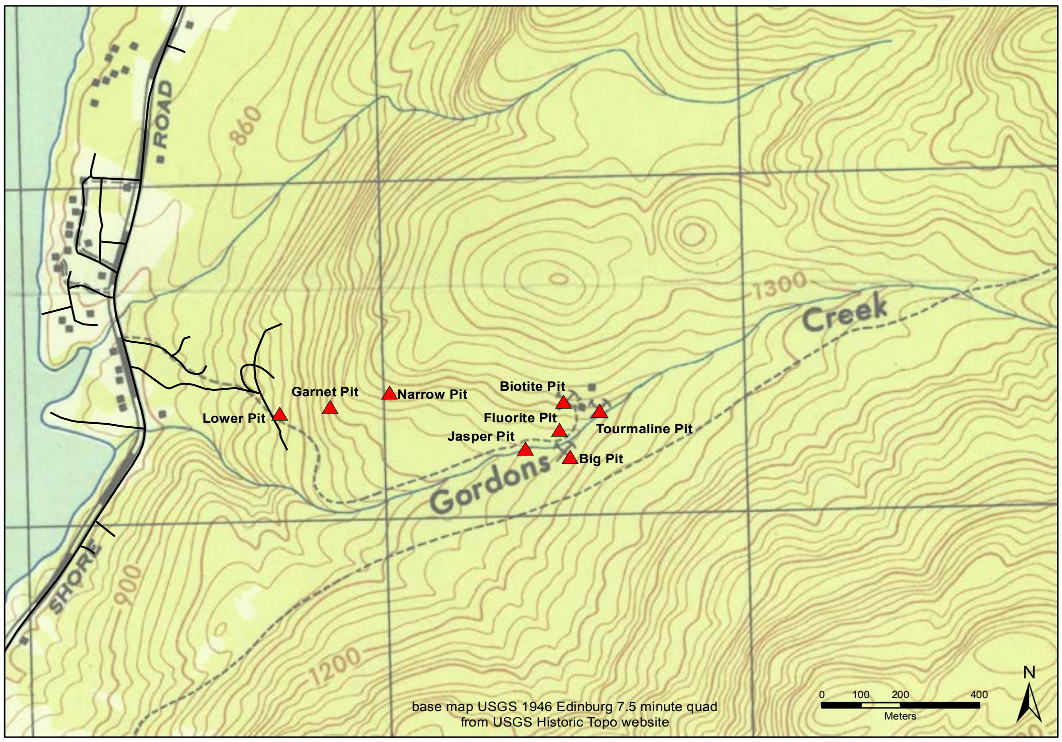

Figure 2: Map of the Batchellerville Pegmatite showing locations of eight distinct mine / exploration pits (modified after Tan (1966)).

The two largest excavations were at the Lower Pit and at the Big Pit, although both are still less than 150' in any dimension (Tan 1966). The pits appear to have worked a series of small tabular bodies with roughly E-W trends. The larger bodies exhibited mineralogical zonation, with quartz-rich cores and with Al-rich phases (muscovite, biotite, sillimanite, garnet, etc.) concentrated in the outer zones or along the contact with the surrounding biotite gneiss (Tan 1966).

GEOCHRONOLOGY

General

There are no modern or precise age data on the pegmatites emplaced in the Taconian-age rocks from the Manhattan Prong in southern New York (Bedford, Valhalla, and New York City). Most of the pegmatites from the Adirondacks were generated and emplaced during the late Elzeverian, Shawinigan, Ottawan, and Rigolet orogenies of the Grenville Orogenic Cycle (Figure 1)(Lupulescu et al. 2011). The oldest pegmatite ages reported are from the McLear pegmatite in the Adirondack Lowlands (1195 ± 7.2 Ma); the youngest pegmatite ages are on the Mayfield pegmatite in the southern Adirondack Highlands (1009 ± 22 Ma) (Lupulescu et al. 2011).

Batchellerville

Zircon Geochronology

One zircon crystal from the Batchellerville pegmatite was analyzed by LA-MC-ICPMS for an U-Th-Pb age. The crystal contained between 1562 and 5204 ppm uranium and a very high U/Th ratio (up to 189) and was almost completely metamict. Based on the concordant analysis within the analytical error of the upper concordia intercept, the crystallization age of this zircon was interpreted to be 1090 ± 28 Ma (Lupulescu et al. 2011).

Monazite geochronology

Monazite-(Ce) was found in the Batchellerville pegmatite as crystals up to 8 cm in length. One monazite crystal was analyzed by electron probe for chemical ages. The sample contains 18.1 Ce, 17.01 Th, 7.89 La, 7.12 Nd, and 1.69 Y (all in wt. % element). The crystal is fractured and contains tiny thorite crystals. Back-scattered electron images revealed a nearly homogeneous crystal with some patchy, lower atomic number areas. Twenty-four analyses on the crystal far from the fractures or inclusions yielded an average age of 874 ± 27 Ma; analyses closer to the fractures and from the darker, low-intensity backscatter areas yielded an average of 751 ± 71 Ma and 844 ± 33 Ma respectively (Lupulescu et al. 2011).

There are two ways to interpret the differences in the zircon and monazite ages (Lupulescu et al. 2011): 1) the zircon age is the intrusion age of the pegmatite and the monazite formed later, possibly as a result of the infiltration of crustal fluids during uplift, or,

2) the zircon age represents inheritance and the chemical age obtained on the monazite is the real age of the pegmatite. In the first scenario, the intrusion of the Batchellerville pegmatite would be associated with the early manifestation of the Ottawan phase of the Grenville orogeny; in the second, the pegmatite would have been entirely post-Grenville, an interpretation supported by the lack of any significant deformational features within the pegmatite itself (Lupulescu et al. 2011).

MINERALOGY

General

The pegmatites of New York have simple to complex, and variable, mineral assemblages (Table 1). The pegmatites from Valhalla and New York City, as well as those from the Adirondack Lowlands, do not show mineralogical zoning. Such zoning is a common feature of the Bedford pegmatites and those in the southern and eastern Adirondack Highlands. Post-emplacement metamorphic deformation features are commonly observed in the pegmatites from the Adirondack Lowlands and less commonly in the pegmatites from the Highlands. The pegmatites from southern New York lack even weak metamorphic features.

By world standards, the list of mineral species found in New York pegmatites is modest (Table 1) although museum quality specimens of columbite (the largest being a 5 lb crystal from the Baylis Quarry), beryl, chrysoberyl, amazonite, sillimanite, molybdenite, and schorl have been collected. At some locations, secondary minerals formed at the expense of primary igneous minerals; not all of these secondary minerals, including some of the uranium-bearing minerals, have yet been identified or well characterized.

Batchellerville

The Batchellerville pegmatite has a relatively complex mineral assemblage that varies widely from pit to pit (Table 2). Common pegmatite minerals such as quartz, feldspar and mica persist throughout the pegmatite; however, its unusually Al-rich assemblage and presence of rare-earth-bearing minerals sets the Batchellerville pegmatite apart from others in New York State.

Table 1. Minerals identified in selected New York pegmatites.

	Adirondacks										Southern NY	
MINERALS	**Bat**	**G**	**M**	**O**	**CP**	**HF**	**L**	**McL**	**SBH**	**SF**	**Bed**	**NY**
Albite	x		x		x			x	x	x		x
Almandine	x	x	x								x	x
Allanite-Ce					x				x			
Amphibole*					x							
Autunite											x	
Annite-Phlogopite*	x		x	x	x		x	x	x		x	x
Fluorapatite			x				x			x		
Beryl	x		x								x	x
Chabazite-Ca										x		
Chernikovite			x									
Columbite*		x									x	x
Chrysoberyl	x	x										
Danburite								x				
Diopside							x	x		x		
Dumortierite	x											x
Euxenite-Y	x			x								
Fergusonite-Y												
Ferro-actinolite										x		
Fluorite	x									x		
Fluoro-edenite								x				
Fluoriantremolite								x				
Heulandite-Ca										x		
Magnetite	x		x									
Microcline	x		x	x	x		x	x	x	x	x	x
Monazite-Ce	x			x								
Muscovite	x		x	x	x							x
Polycrase-Y				x								
Pyrrhotite									x			
Quartz	x	x	x	x	x	x	x	x	x	x	x	
Schorl	x	x	x	x		x			x		x	
Sillimanite	x	x										
Stilbite-Ca										x		
Stellerite										x		
Titanite							x	x				
Torbernite											x	
Uraninite	x							x	x			
Vanmeersscheite											x	
Xenotime-Y			x									x
Zircon	x				x	x	x				x	

Bat – Batchellerville; CP – Crown Point; G – Greenfield; HF – Hall's Falls; L – Lewis; M – Mayfield; McL – McLear; Bed - Bedford; O – Overlook; SBH – Spar Bed Hill; SF – Scott Farm; NY- NY City pegmatites.
(*)= Species not identified. Bold = Museum quality specimens.

Characteristic of all pegmatites, mineral sizes at Batchellerville vary from a few millimeters to tens of centimeters in length. Minerals occur in coarse- to fine-grained aggregates of anhedral to subhedral crystals.

Quartz, feldspar and mica are the most abundant mineral phases in the Batchellerville pegmatite. Quartz and feldspar commonly occur as the characteristic "graphic granite" texture most often associated with pegmatites (Figure 3). Quartz occurs in a variety of colors including clear, "milky" white, rose, and smoky varieties. Some rose quartz exhibits an internal play of color, and the smoky quartz ranges from light gray to black in color (Seadler 2011). Perthitic microcline and albite occur at the Batchellerville pegmatite in pink, white, and green-gray varieties (Seadler 2011). Though located in all of the pits, quartz, feldspar and mica appear most abundantly in the Lower Pit of the Batchellerville pegmatite. A dark brown annite-phlogopite is the most common mica associated with the pegmatite, followed by muscovite. Each of these micas occurs in massive aggregates and small- to moderate-sized books (up to 30 cm in diameter).

Figure 3. "Graphic Granite", intergrown smoky quartz and feldspar from the Lower Pit (Seadler 2011).

Aluminum-rich minerals, typically uncommon in the pegmatites of New York State, are abundant in the Batchellerville pegmatite. Beryl, chrysoberyl, sillimanite, dumortierite, almandine, and Al-rich tourmaline (var. schorl) are all found in hand sample, although not in all pits. In fact, Batchellerville is one of the best localities for chrysoberyl in New York State (Lupulescu 2007).

The chrysoberyl at the Batchellerville pegmatite is found only in the Garnet Pit, and occurs as pale green to yellow crystals in aggregate with quartz and feldspar (Seadler 2011). Green to blue gemmy beryl can be found in the Lower Pit, and large beryl samples (up to 25 cm wide and 50 cm long) have been recovered from the Big Pit (Figure 4). Sillimanite is common in the Garnet pit as radiating to bladed, gray/blue to yellow/black crystals up to 3 cm (Seadler 2011). Small (up to 3 mm in length), blue-gray to purple dumortierite crystals, though uncommon, can be found in the Lower and Garnet pits of the Batchellerville pegmatite. They typically occur in the finer-grained graphic intergrowths of quartz and feldspar (Seadler 2011).

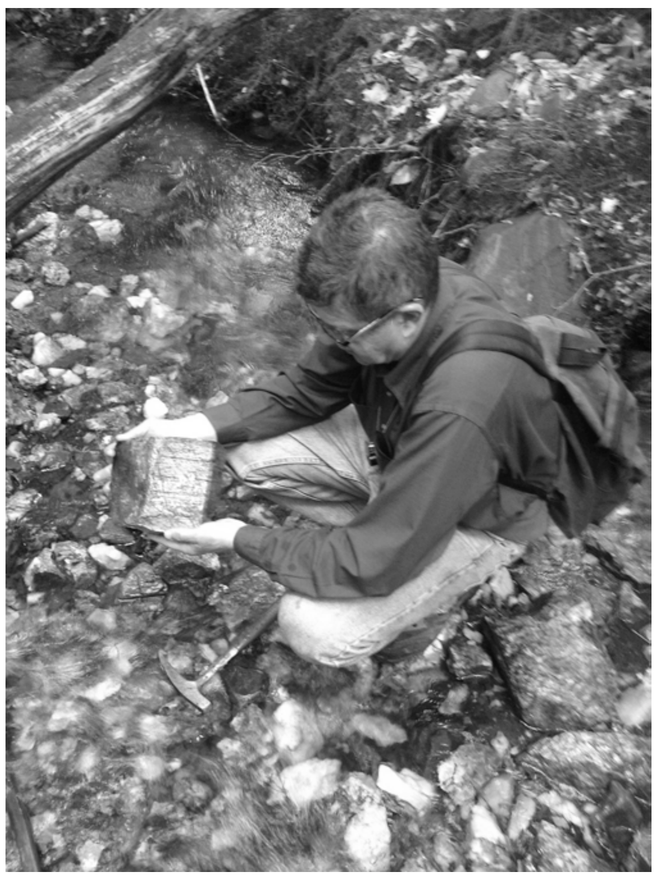

Figure 4. Large beryl crystal (14 cm across) collected by authors in June 2012.

Except for beryl, these Al-rich mineral phases are most common in the Garnet Pit of the Batchellerville pegmatite. Beryl and, to a lesser extent, dumortierite and schorl, can all be found in the Lower Pit; and, beryl and schorl can be found in the Big and Fluorite Pits.

Poorly formed, red-brown almandine crystals (up to 1 cm) are also found in the Garnet Pit (Tan 1966).

Many other minerals have been identified at the Batchellerville pegmatite (Tables 1 and 2). Most, however, are only visible in thin section or with the SEM/EDS. These minerals include allanite-(Ce), chlorite, columbite-(Fe), euxenite-(Y), fluorapatite, fluorite, magnetite, monazite-(Ce), phenakite, pyrite, rutile, uraninite, and zircon. Some Th-U-Y-bearing minerals mentioned by Seadler (2011) have yet to be identified.

Table 2. Minerals identified in three major pits of the Batchellerville pegmatite. Compiled from Tan (1966), Lupulescu (2007), Seadler (2011).

MINERALS	Lower Pit	Big Pit / Fluorite Pit	Garnet Pit
Albite (Ab_{70-95})	C	C	C
Allanite-(Ce)	U		
Almandine			C
Annite-Phlogopite	C	C	A
Beryl	U	C	
Chlorite	U	U	U
Chrysoberyl			C
Columbite-(Fe)			U
Dumortierite	U		U
Euxenite-(Y)		U	
Fluorapatite	U		
Fluorite		U	
Hematite		A	U
Magnetite			U
Microcline	C	A	A
Monazite-Ce	U		
Muscovite	A	C	U
Phenakite			?
Pyrite		U	
Quartz	A	A	A
Rutile*	C	U	C
Schorl	U	U	C
Sillimanite			C
Uraninite	U		U
Zircon			U

(A=Abundant, C=Common, U=Uncommon, *= as exsolved needles in biotite and muscovite)

CLASSIFICATION & ORIGIN

There have been multiple attempts to create a suitable pegmatite classification scheme. Landes (1933) classified pegmatites based on the silica content of their derivative magmas and cites Harker (1909), Lacroix (1922), and Fersman's (1931) prior classifications while trying to explain his own. More recent attempts include the classification systems developed by Černý (1991), Wise (1999), Zagorsky, Makagon & Shmakin (1999), Pezzotta (2001), Ercit (2004), Černý and Ercit (2005) and Simmons (2007). All of these classification systems confirm one thing: classifying pegmatites is extremely difficult. The complex origins of pegmatites, their ambiguous definition, and the disagreement amongst professionals even about the classification of their assumed parent melts – granites – all contribute to the confusion (London 2008).

Historically, pegmatite classification relied on simple mineralogical and field criteria; however, as technology and overall understanding of geologic processes have advanced, current classification schemes have gone beyond these criteria, focusing on the chemical composition and tectonic settings of pegmatites.

Following the classification system of Černý (1991) there are two broad categories of pegmatites: simple and complex. The vast majority of pegmatites are simple, composed primarily of quartz, feldspar, and mica. Complex pegmatites, however, attract the most attention due to their exotic mineral assemblages and enrichment in unusual elements (e.g. Li, Be, B, U, etc.). Within this framework, the most widely used pegmatite classification scheme was set forth by Černý (1991). His classification subdivided pegmatites based on emplacement depth, metamorphic grade of the host rocks, and minor element content of the pegmatite itself (Table 3). From deep to shallow, Černý's categories or "classes" are: 1) abyssal (4-9kb), 2) muscovite (5-8kb), 3) rare-element (2-4kb) and 4) miarolitic (1-2kb).

Černý (1991) further subdivides the rare-element and miarolitic classes of pegmatites into two families on the basis of minor element chemistry: the NYF and LCT families. Initially, these acronyms simply represented the geochemical signatures relating to the relative concentrations of <u>n</u>iobium-<u>y</u>ttrium-<u>f</u>luorine and <u>l</u>ithium-<u>c</u>esium-<u>t</u>antalum found within a specific pegmatite deposit.

Table 3. Pegmatite classification scheme based on depth of emplacement (Černý 1991).

THE FOUR CLASSES OF GRANITIC PEGMATITE CERNY, 1991						
CLASS	**Family**	**Typical Minor Elements**	**Metamorphic Environment**	**Relation to Granite**	**Structural Features**	**Examples**
Abyssal	–	U, Th, Zr, Nb, Ti, Y, REE, Mo Poor (to moderate) mineralization	(Upper amphibolite to) low- to high-P granulite facies ~4-9kb ~700-800C	None (segregations of anatectic leucosome)	Conformable to mobilized cross-cutting veins	Rae and Hearne Princes, Sask. (Tremblay, 1978); Aldan and Anabar Shields, Siberia (Bushev and Koplus, 1980); Eastern Baltic Shield (Kalita, 1965)
Muscovite	–	Li, Be, Y, REE, Ti, U, Th, Nb>Ta Poor (to moderate) mineralization, micas and ceramic minerals	High-P, Barrovian amphibolite facies (kyanite-sillimanite) ~5-8kb ~650-580C	None (anatectic bodies) to marginal and exterior	Quasi-conformable to cross-cutting	White Sea region, USSR (Gorlov, 1975); Appalachian Province (Jahns *et al*., 1952); Rajahstan, India (Shmakin, 1976)
Rare-Element	**LCT**	Li, Rb, Cs, Be, Ga, Nb< > Ta, Sn, Hf, B, P, F Poor to abundant mineralization, gemstock industrial minerals	Low-P, Abukuma amphibolite to upper greenschist facies (andalusite-sillimanite) ~2-4kb ~650-500C	(Interior to marginal to) exterior	Quasi-conformable to cross-cutting	Yellowknife field, NWT (Meintzer, 1987); Black Hills, South Dakota (Shearer *et al*, 1987); Cat Lake-Winnipeg River Field, Manitoba (Cerny *et al*., 1981)
	NYF	Y, REE, Ti, U, Th, Zr, Nb>Ta, F Poor to abundant mineralization, ceramic minerals	Variable	Interior to marginal	Interior pods, conformable to cross-cutting exterior bodies	Llano Co., Texas (Landes, 1932); South Platte district, Colorado (Simmons *et al*., 1987); Western Keivy, Kola, USSR (Beus, 1960)
Miarolitic	**NYF**	Be, Y, REE, Ti, U, Th, Zr, Nb>Ta, F Poor mineralization gemstock	Shallow to sub-volcanic ~1-2 kb	Interior to marginal	Interior pods and cross-cutting dikes	Pikes Peak, Co (Foord, 1982); Sawtooth batholith, Idaho (Boggs, 1986); Korosten pluton, Ukraine (Lazarenko *et al*., 1973)

However, these criteria do not always apply, as some LCT pegmatites can be extremely rich in niobium, and some NYF pegmatites can have Li-bearing minerals. Therefore, whether or not a pegmatite can actually be classified as an NYF- or an LCT-type pegmatite also depends on the detailed mineralogy of the specific body. Furthermore, highly evolved NYF-type pegmatites can sometimes resemble LCT pegmatites, and under-evolved LCT pegmatites can sometimes resemble NYF pegmatites.

Chemically and mineralogically, New York pegmatites span the range of nearly all of Černý's (1991) pegmatite classes, with the exception of the shallow "Miarolitic" and "REE – LCT" classes, of which there are no clear examples.

Many of the pegmatites from the southern Adirondack Highlands (e.g. Batchellerville, Mayfield, and Greenfield) and from New York City contain Al-rich silicates with or without Be and B such as sillimanite, beryl, chrysoberyl, dumortierite, and tourmaline as well as monazite-(Ce) and uraninite. In addition, they do not show any spatial or temporal relationship with any granitic intrusions (Lupulescu et al. 2011). On the basis of their mineral assemblages, in particular the presence of allanite-(Ce), polycrase-(Y), columbite, titanite, zircon, fluorite, microcline, and albite, many of the Adirondack pegmatites (e.g. the Scott's Farm, Crown Point, Roe Spar Bed, Day (Overlook) Bedford and some of the New York City pegmatites are most closely related to Černý's (1991) REE class NYF-type.

The Batchellerville and Mayfield pegmatites are clusters of small pegmatitic bodies hosted by gneisses. Based upon their geological setting, lack of associated granitic bodies, and their mineralogies, they seem to belong to Černý's (1991) Muscovite and/or Abyssal class of pegmatite. They appear to have formed from in situ partial melts of the local country rock rather than as late-stage magmatic derivatives of larger granitic intrusions. The lack of any significant deformation features within the Batchellerville pegmatite itself indicates that crustal anatexis and the intrusion of these bodies occurred in an extensional setting after the Ottawan orogeny collapse.

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ROAD LOG

The field trip will depart from Hamilton College at 7:30 AM and return around 5 PM. The Road Log starts at the intersection of NY State Thruway Exit 27 (Amsterdam) ramp and NY-30N.

Miles from Last Point	Cumulative Mileage	Description
0.0	0.0	Intersection NY-30 N and Thruway Exit 27 ramp. Head NORTH on NY-30 N.
1.0	1.0	Bear left. Stay on NY-30 N.
7.9	8.9	At traffic circle, continue straight on NY-30 N.
0.4	9.3	Go straight; take Co Rd 155 (Do NOT take NY-30 N)
1.1	10.4	In Broadalbin. Continue onto Co Rd 110/117 (N Main St)
0.9	11.3	Bear right, continue on Co Rd 110
1.1	12.4	Bear left, continue on Co Rd 110
6.5	18.9	Continue straight onto Co Rd 7 (S Shore Rd)
4.7	23.6	Slight right to stay on Co Rd 7 (S Shore Rd)
2.4	32.8	Get permission to park.

STOP #1: Access Road to Batchellerville Pegmatite Pits

**NOTE: The Batchellerville pegmatite is on private property; trespassing is not allowed! Permission is required before entering the property for any reason. We are extremely fortunate that the landowner has allowed us to access the site for this field trip. Please do not jeopardize the possibility of future trips for scientific research by trespassing and/or any large-scale mineral collecting activities.

Stop 1a). The "Lower Pit" (Lat: 43.23917, Long: -74.06146)
Stop 1b). The "Big Pit" (Lat: 43.23816, Long: -74.05219)
Stop 1c). The "Garnet Pit" (Lat: 43.23953, Long: -74.05979)