

GEOCHEMISTRY OF TOURMALINE FROM SOME ADIRONDACKS LOCATIONS: INDICATOR OF THE HOST ENVIRONMENT

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“With its plethora of chemical constituents, its wide range of stability from conditions near the Earth’s surface to the pressures and temperatures of the upper mantle, and its extremely low rates of volume diffusion, tourmaline can acquire a chemical signature from the rock in which it develops and can retain that signature through geologic time.” (Dutrow and Henry 2011)

INTRODUCTION

Tourmaline is a complex borosilicate and it can record the chemistry of its host environment and the chemical changes in the composition of the generating fluids or associated minerals.

Tourmaline-supergroup minerals are found as a primary accessory phase in granites and pegmatites, breccia, and hydrothermal quartz veins (London and Manning 1995), metamorphic rocks ranging from zeolite to granulite facies (Henry and Dutrow 1992; Ertl et al. 2010), volcanogenic massive sulfide deposits (Slack et al. 1996), and authigenic overgrowths in sedimentary rocks (Henry et al. 1994; Lupulescu et al. 2010). Variation in the chemical composition of tourmaline species allows them to form in a wide range of environments. This feature makes them an excellent indicator of the environmental conditions of their host and is further enhanced by their very low rate of diffusion at high temperature and resistance to weathering (Hinsberg et al. 2011).

Due to its hardness and lack of cleavage, the tourmaline in sedimentary rocks can be used as a provenance indicator (Henry and Guidotti 1985; Henry and Dutrow 1992; Morton et al. 2005; Marschall et al. 2008) and the varied colors contribute to make it a desired gemstone (Pezzota and Laurs 2011). It also has pyroelectric, piezoelectric, and optical (polarizing light) properties. The ability to polarize light adds credibility to the legend of the “*Viking Sunstone*”, but it was used in the modern times to make polarizers for petrographic microscopes.

The goal of this trip is to visit and discuss the significance of the chemical, major and trace elements, of tourmaline from different locations and environments within the Adirondack Lowlands, such as tourmalinites, talc-tremolite schists, quartz veins, simple pegmatites, Balmat SEDEX-type deposits, and authigenic tourmaline. In addition, some new geochronological information is present to help put the tourmaline occurrences in geologic context. The quantity and variability of tourmaline occurrences in the Adirondack Lowlands is still poorly understood and this trip hopes to bring attention to their diversity.

THEORETICAL BACKGROUND

Tourmaline generalized structural formula is: $XY_3Z_6(T_8O_{18})(BO_3)_3V_3W$ where:

$X = Na^+, Ca^{2+}, K^+$;

$Y = Fe^{2+}, Mg^{2+}, Mn^{2+}, Al^{3+}, Li^+, Fe^{3+}, Cr^{3+}$;

$Z = Al^{3+}, Fe^{3+}, Mg^{2+}, Cr^{3+}$;

$T = Si^{4+}, Al^{3+}$;

$V = OH^-, O^{2-}$;

$W = OH^-, F^-, O^{2-}$

Table 1. Simplified classification of tourmaline species recognized by International Mineralogical Association (Henry et al. 2011 – modified)

Alkali group
Dravite - $\text{NaMg}_3\text{Al}_6\text{Si}_6\text{O}_{18}(\text{BO}_3)_3(\text{OH})_3(\text{OH})$
Schorl - $\text{NaFe}^{2+}_3\text{Al}_6(\text{Si}_6\text{O}_{18})(\text{BO}_3)_3(\text{OH})_3(\text{OH})$
Chromium-dravite - $\text{NaMg}_3\text{Cr}_6(\text{Si}_6\text{O}_{18})(\text{BO}_3)_3(\text{OH})_3(\text{OH})$
Vanadium-dravite - $\text{NaMg}_3\text{V}_6(\text{Si}_6\text{O}_{18})(\text{BO}_3)_3(\text{OH})_3(\text{OH})$
Fluor-dravite - $\text{NaMg}_3\text{Al}_6(\text{Si}_6\text{O}_{18})(\text{BO}_3)_3(\text{OH})_3\text{F}$
Fluor-schorl - $\text{NaFe}^{2+}_3\text{Al}_6(\text{Si}_6\text{O}_{18})(\text{BO}_3)_3(\text{OH})_3\text{F}$
Tsilaisite - $\text{NaMn}_3\text{Al}_6(\text{Si}_6\text{O}_{18})(\text{BO}_3)_3(\text{OH})_3\text{OH}$
Elbaite - $\text{Na}(\text{Li},\text{Al})_3\text{Al}_6(\text{Si}_6\text{O}_{18})(\text{BO}_3)_3(\text{OH})_3(\text{OH})$
Fluor-elbaite - $\text{Na}(\text{Li}_{1.5}\text{Al}_{1.5})\text{Al}_6(\text{Si}_6\text{O}_{18})(\text{BO}_3)_3(\text{OH})_3\text{F}$
Povondraite - $\text{NaFe}^{3+}_3(\text{Fe}^{3+}_4\text{Mg}_2)_6(\text{Si}_6\text{O}_{18})(\text{BO}_3)_3(\text{OH})_3\text{O}$
Chromo-alumino-povondraite - $\text{NaCr}_3(\text{Al}_4\text{Mg}_2)_6(\text{Si}_6\text{O}_{18})(\text{BO}_3)_3(\text{OH})_3\text{O}$
Oxy-schorl - $\text{Na}(\text{Fe}^{2+}_2\text{Al})\text{Al}_6(\text{Si}_6\text{O}_{18})(\text{BO}_3)_3(\text{OH})_3\text{O}$
Oxy-vanadium-dravite - $\text{NaV}_3(\text{V}_4\text{Mg}_2)(\text{Si}_6\text{O}_{18})(\text{BO}_3)_3(\text{OH})_3\text{O}$
Vanadio-oxy-chromium-dravite - $\text{NaV}_3(\text{Cr}_4\text{Mg}_2)(\text{Si}_6\text{O}_{18})(\text{BO}_3)_3(\text{OH})_3\text{O}$
Oxy-chromium-dravite - $\text{NaCr}_3(\text{Cr}_4\text{Mg}_2)(\text{Si}_6\text{O}_{18})(\text{BO}_3)_3(\text{OH})_3\text{O}$
Oxy-dravite - $\text{Na}(\text{Al}_2\text{Mg})(\text{Al}_5\text{Mg})(\text{Si}_6\text{O}_{18})(\text{BO}_3)_3(\text{OH})_3\text{O}$
Vanadio-oxy-dravite - $\text{NaV}_3(\text{Al}_4\text{Mg}_2)(\text{Si}_6\text{O}_{18})(\text{BO}_3)_3(\text{OH})_3\text{O}$
Darrellhenryite - $\text{Na}(\text{LiAl}_2)\text{Al}_6(\text{Si}_6\text{O}_{18})(\text{BO}_3)_3(\text{OH})_3\text{O}$
Fluor-buergerite - $\text{NaFe}^{3+}_3\text{Al}_6(\text{Si}_6\text{O}_{18})(\text{BO}_3)_3\text{O}_3\text{F}$
Olenite - $\text{NaAl}_3\text{Al}_6(\text{Si}_6\text{O}_{18})(\text{BO}_3)_3\text{O}_3(\text{OH})$
Calcic-group
Fluor-uvite - $\text{CaMg}_3(\text{Al}_5\text{Mg})(\text{Si}_6\text{O}_{18})(\text{BO}_3)_3(\text{OH})_3\text{F}$
Feruvite - $\text{CaFe}^{2+}_3(\text{MgAl}_5)_6(\text{Si}_6\text{O}_{18})(\text{BO}_3)_3(\text{OH})_3(\text{OH})$
Uvite - $\text{Ca}(\text{Mg},\text{Fe}^{2+})_3\text{Al}_5\text{Mg}(\text{Si}_6\text{O}_{18})(\text{BO}_3)_3(\text{OH})_3(\text{OH})$
Fluor-liddicoatite - $\text{Ca}(\text{Li}_2\text{Al})_3\text{Al}_6(\text{Si}_6\text{O}_{18})(\text{BO}_3)_3(\text{OH})_3\text{F}$
Vacant-group
Foitite - $?(\text{Fe}^{2+}_2\text{Al})\text{Al}_6(\text{Si}_6\text{O}_{18})(\text{BO}_3)_3(\text{OH})_3(\text{OH})$
Magnesio-foitite - $?(\text{Mg}_2(\text{Al})\text{Al}_6(\text{Si}_6\text{O}_{18})(\text{BO}_3)_3(\text{OH})_3(\text{OH})$
Rossmannite - $?(\text{LiAl}_2)\text{Al}_6(\text{Si}_6\text{O}_{18})(\text{BO}_3)_3(\text{OH})_3(\text{OH})$

TOURMALINES OF NEW YORK

The tourmaline-supergroup minerals are commonly found in the rocks of the Grenville Province in New York State. Although, most specimens are not of gem quality, the tourmaline minerals from New York are scientifically interesting. They are well documented and represented in the literature by: (a) occurrence; (b) composition; (c) mode of formation; (d) crystal structure; and (e) the potential for discovery of new species (Dunn et al. 1977; Ayuso and Brown 1984; Cotkin 1989; Grice and Ercit 1993; Dyar et al. 1998; Dalton 2003; Lupulescu, Bailey, and Pyle 2005; Lupulescu and Pyle 2006; Lupulescu 2007; 2008; Chamberlain, Lupulescu, and Rowe 2008; Lupulescu and Rakovan 2008; Lupulescu et al. 2010; Lupulescu and Rowe 2011).

Herein the trace element composition of the tourmaline-group minerals from New York State is examined in relationship to their local geological environment.

GENERAL FEATURES, HOST ENVIRONMENT, AND CLASSIFICATION OF THE NEW YORK TOURMALINE SPECIES

General features. The main features of the tourmaline species found in New York are:

- (a) In polarizing light some crystals display weak zoning, however, the difference in the chemical composition between zones is not significant. An interesting exception occurs at Bigelow, St. Lawrence County, where diagenetic uvite is overgrown by dravite (Lupulescu et al. 2010);
- (b) Alteration is not common, attesting to the recalcitrant nature of tourmaline. Only one specimen was found extensively altered to a glassy, yellow-green, sheet silicate along fractures and crystal faces;
- (c) The chemical composition of New York tourmalines shows extensive substitutions of Na^+ and K^+ for Ca^{2+} in the X-site; and
- (d) There is significant replacement of $(\text{OH})^-$ and O^{2-} by F in the W-site. Fluorine-dominant species are predominant in marbles.

We studied the variation in major components in two of the zoned (in plane-polarized light) tourmaline crystals, one from Edwards and the other from the Rt. 58 pegmatite. Sodium, Ca, Mn, and F do not display significant variation while Al, Ti, Mg, and Fe show variation along the “c” axis of the crystals. This variation may cause the zonation observed optically in thin-section.

Host environment. The geological distribution of the tourmaline species shows their preference for a specific host. This indicates both the source of their chemical components and their mineral-forming reactions.

- (a) Schorl and some dravite specimens generally occur in pegmatites and uvite, fluor-uvite, dravite, and fluor-dravite are found in marbles;
- (b) Mn-rich uvite and Mn-rich dravite are specifically associated with talc-tremolite schists in the upper marble unit in the Adirondack Lowlands;
- (c) The unusual occurrence of Al-rich, chromium-dravite in pods in talc-tremolite schists (Lupulescu and Rowe 2011) in the upper marble is related to the local geologic setting.

There is a remarkable occurrence of rossmanite in Newcomb, Essex County. This locality is significant because: (a) it is the first occurrence of rossmanite in New York; (b) rossmanite is extremely rare in the USA; (c) it occurs in marble rather than in its more typical setting within granitic pegmatites; and (d) this is a new occurrence of tourmaline with boron in tetrahedral coordination (Lupulescu and Rakovan 2008).

Classification. The chemical composition of tourmaline species was determined using JEOL 733 Superprobe or CAMECA SX 100 at the Department of Earth and Environmental Sciences, Rensselaer Polytechnic Institute, Troy, N.Y.. The operating conditions were 15 kV accelerating voltage, 15 nA beam current, and 5- μm beam diameter. Standards used were: kyanite (Si, Al), synthetic forsterite (Mg), synthetic fayalite (Fe), synthetic diopside (Ca), jadeite (Na), rutile (Ti), synthetic tephroite (Mn), orthoclase (K), chromite (Cr), synthetic V_2O_3 , and topaz (F).

The dominant compositional groups of New York tourmalines, based on electron microprobe data and cation assignment to crystallographic sites (Henry et al. 2011), are: (a) alkali group - schorl, dravite, fluor-dravite, and Al-rich-chromium-dravite; (b) vacant group – rossmanite, and (c) calcic group (uvite, fluor-uvite, and feruvite) tourmalines.

In this article we present the revised classification of the tourmalines of New York utilizing modern nomenclature (Table 2 at end of manuscript). All the specimens mentioned in the table are from the New York State Museum mineral collection and were investigated by optics and SEM-EDS and quantitatively analyzed by electron microprobe as part of our ongoing research of New York’s mineralogy. The tourmaline species are named according to the latest nomenclature (Henry et al. 2011). This data allows the establishment of ‘standard’ specimens from a specific site in order to help others label their tourmaline species more accurately.

Trace elements. Trace element analysis was carried out on polished thin-sections of tourmaline crystals using laser ablation – inductively coupled plasma- mass spectrometry (LA-ICP-MS). Laser ablation was carried out with a detachable Photon Machines, Inc. Analyte.193 ultra-short pulse, excimer laser ablation workstation. A Bruker 820-MS inductively coupled plasma mass spectrometer was used for major elements.

We analyzed tourmaline crystals from: (a) talc-tremolite schists (Arnold Pit, St. Lawrence County); (b) quartz-tourmaline vein cutting a metamorphosed ultramafic body (Warrensburg, Warren County); (c) paleokarst filling sandstone in marble (Bigelow, St. Lawrence County); (d) graphitic schists (Columbia graphite mine, Essex County); (e) quartz-tourmaline veins in calc-silicate schists (Bower Powers farm, St. Lawrence County); (f) pod of tourmaline in marble (Balmat, St. Lawrence County); (g) tourmalinite (Rock Island and Richville, St. Lawrence County); (h) danburite-diopside rock (Russell, St. Lawrence County); (i) pegmatoid separation with quartz, feldspar, and halite (Balmat, St. Lawrence County); (j) simple pegmatite vein in gneiss (Rt. 58, St. Lawrence County); and (k) rossmanite with dravite and scapolite in marble (Newcomb, Essex County). The concentrations of the trace elements in the tourmalines noted above are listed in Table 3.

Table 3. Trace elements in tourmaline specimens analyzed in this study.

Element (ppm)	AP	W	BG	CG	BP	B	RI	RUS	RICH	BP	RT58	N
Li	37.72	15.17	47.02	26.15	11.50	41.33	11.48	20.06	8.10	158.07	12.23	2825.5
Sc	2.76	7.88	3.40	0.54	61.28	34.33	87.62	2.17	78.66	0.52	31.48	nd
Ni	27.35	130.82	2.86	1.78	4.47	3.08	37.28	2.29	18.56	0.87	52.3	0.45
Cu	4.28	0.28	0	0.62	0.89	3.36	0.67	2.21	18.56	0.87	0	nd
Zn	7.57	89.16	33.6	82	60.72	55.06	11.82	148.74	10.30	726.4	38.75	nd
Rb	0.01	0.04	0.04	0.02	0.01	0	0	0	0.03	3.69	0.03	nd
Sr	509.63	203.4	533.6	196.68	1018.4	700.8	160.96	856.6	125.8	1213	51.2	51.78
Y	0.39	0.52	0.01	0.10	0.02	0.06	0.21	0.04	0.31	0.04	0.26	0.01
Zr	2.60	1.69	0.23	0.28	0.49	1.86	136.02	0.60	2.84	1.33	0.53	0.014
Nb	0.80	1.49	0.03	0.67	0.33	0.09	0.30	1.82	0.03	12.16	0.39	nd
Ag	0.03	0.03	0.02	0.02	0	0	0.01	0.01	0.01	0.02	0	nd
Ba	57.50	2.93	2.93	0.67	6.01	12.09	1.24	3.13	1.77	3.28	0.50	0.04
La	7.95	21.27	0.06	5.14	22.88	1.48	20.99	8.96	6.78	4.01	6.98	0.02
Ce	6.97	35.42	0.06	6.40	24.08	2.56	18.39	9.73	11.23	5.19	14.16	0.01
Pr	0.59	3.17	0.01	0.43	1.42	0.24	0.92	0.55	0.95	0.30	1.33	nd
Nd	1.27	9.26	0.09	0.91	3.07	0.88	1.76	0.94	2.91	0.56	3.71	nd
Sm	0.10	1.01	0.02	0.05	0.14	0.09	0.09	0.02	0.32	0.04	0.52	nd
Eu	0.03	0.58	0.03	0.31	0.26	1.24	0.19	0.12	0.50	0	0.40	nd
Gd	0.09	0.53	0.10	0.02	0.12	0.08	0.07	0.02	0.13	0.02	0.32	nd
Tb	0.01	0.04	0.01	0.01	0	0	0	0	0.01	0	0.03	nd
Dy	0.06	0.17	0.02	0.03	0	0.02	0.01	0.01	0.08	0.05	0.11	nd
Ho	0.02	0.03	0.01	0.01	0.01	0	0.01	0	0.01	0	0.02	nd
Er	0.04	0.05	0	0.01	0	0	0.03	0	0.05	0	0.04	nd
Tm	0.01	0.01	0.01	0.01	0	0	0.01	0	0.01	0	0	nd
Yb	0.06	0.12	0.04	0.06	0.02	0.01	0.12	0	0.12	0	0.03	0.06
Lu	0.01	0.05	0.01	0.02	0.01	0	0.02	0	0.03	0.01	0	nd
Hf	0.22	0.29	0.04	0.09	0.07	0.11	3.31	0.11	0.12	0.09	0.08	nd
Ta	0.25	0.54	0	0.21	0.06	0.01	0	0.12	0	0.14	0.10	nd
W	0.03	0.05	0.04	0.07	0.01	0.03	0.07	0.01	0	0.30	0.09	nd
Pb	15.93	19.36	0.42	7.30	0.73	2.03	0.22	1.04	0.41	53.98	2.45	0.07
Th	0	0	0	0.2	0	0.21	0.32	0.25	0.06	0.06	0	nd
U	0	0	0.02	0.03	0	0.03	0.25	0.02	0.05	0.06	0.12	0.01

Abbreviations: AP Arnold Pit; W Warrensburg; BG Bigelow; CG Columbia graphite mine; B Balmat; RI Rock Island; RUS Russell; RICH Richville; BP Balmat pegmatite; Rt 58 Route 58; N Newcomb; nd not-determined

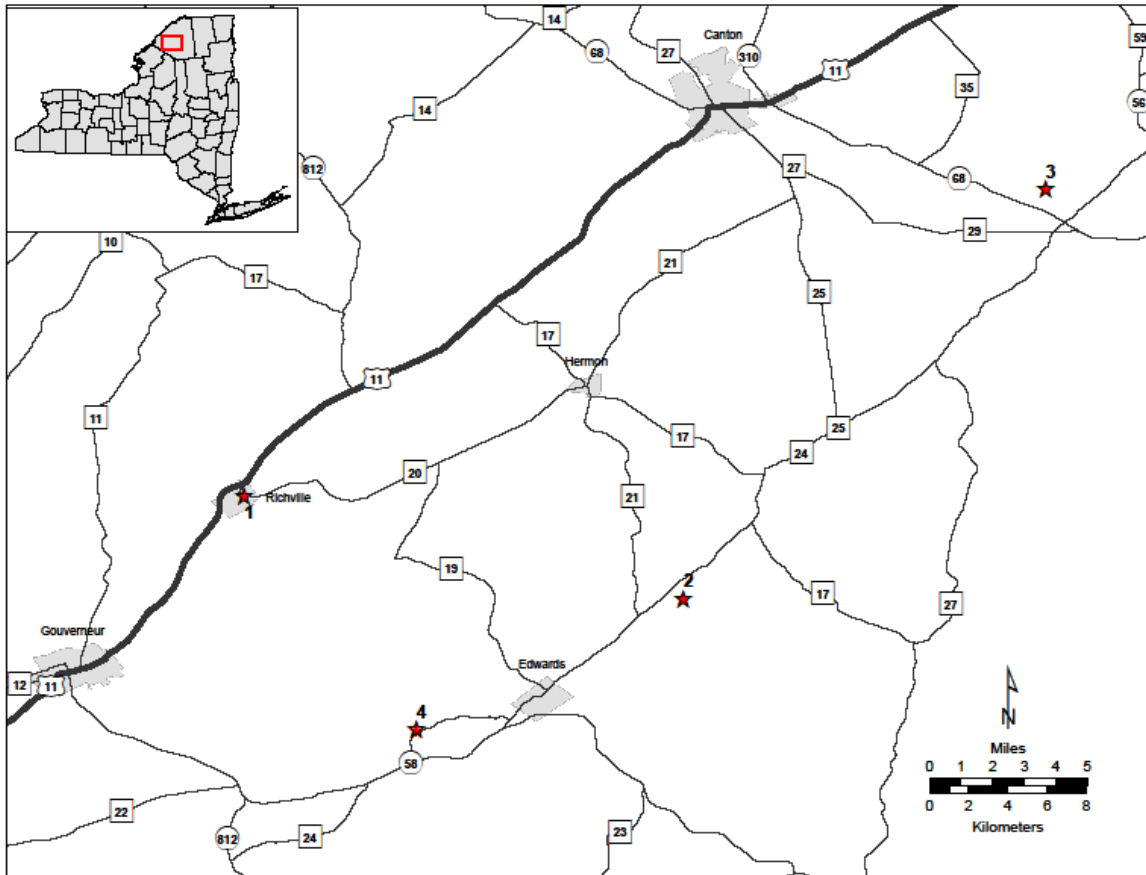


Figure 1. Map showing the tourmaline locations to be visited during this trip. Stop 1- Richville; 2. Stop 2 – Danburite location at Russell; 3. Stop 3 – Bower Powers Farm; 4. Stop 4 – Talcville.

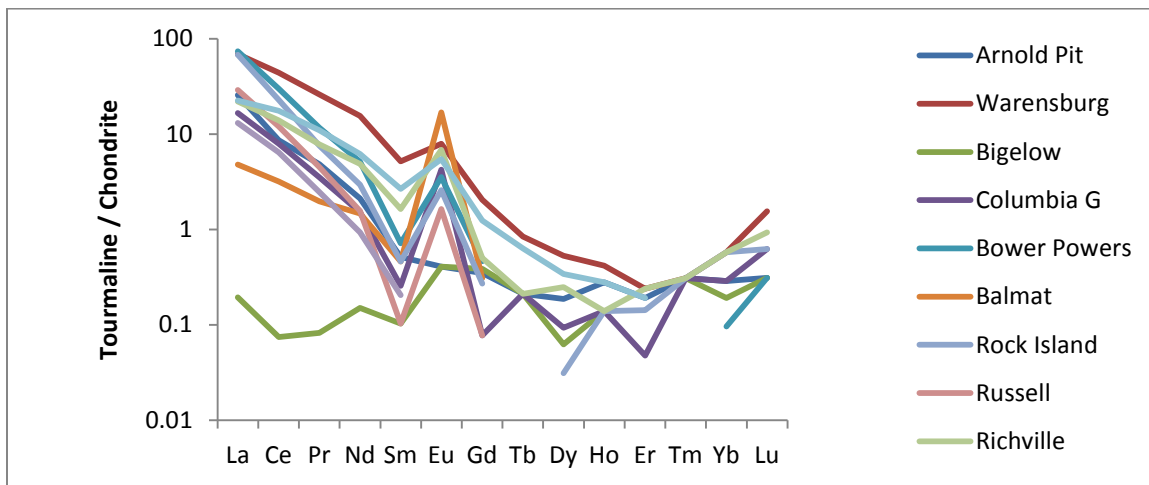


Figure 2. Rare earth elements in tourmaline normalized to chondritic values.

During this trip we will visit several interesting tourmaline occurrences in St. Lawrence County (Figure 1). Tourmaline species that formed in different environments show a wide range of trace element concentrations. The Bigelow tourmaline, formed as authigenic mineral in the paleo karst filling sandstones, is strongly depleted in trace elements. The Newcomb tourmaline contains the highest amount of lithium (2825.5 ppm) followed by the dravite associated with quartz, feldspar, and halite from Balmat (158.07). Strontium varies from 51.2 ppm (Rt. 58) to 1213 ppm (BP). Zirconium displays enrichment (136.02 ppm) in the Rock Island tourmaline. The REEs are at very low concentrations in all the tourmaline species analyzed; often below chondritic values for the mid-heavy REEs. Almost all of the tourmaline species display a high Eu* (Figure 2).

Divalent europium stability is predicted in aqueous solutions at high temperature and is consistent with large positive europium anomalies in some hydrothermal and metamorphic barite (Sverjensky 1984). The peak temperature of metamorphism in the Lowlands is estimated at 650° to 700°C (Edwards and Essene 1988) and is consistent the presence of the Europium anomalies observed in Figure 2. Ratios of La_N/Yb_N , La_N/Sm_N , and Gd_N/Yb_N are a reflection of the enrichment of light REEs in the analyzed tourmalines.

FIELD TRIP STOP LOCATIONS

Stop 1.

TOURMALINE BEARING GNEISSES AT RICHVILLE (RT. 11)

N 44° 25' 21"N, W 75° 23' 19"

Outcrop on north side of busy State Highway 11, exercise extreme caution

Exposed in this outcrop is a layered sequence of quartzfeldspathic gneisses containing up to 50%, or more, black tourmaline as small equant grains (Figure 3). These tourmaline-rich rocks and tourmalinites can be traced for 50 kilometers or more north of Route 11 in the Lowlands. They occur as a northeast-trending belt of northwest-dipping tourmaline-bearing metasedimentary rocks in the lower marble and were originally studied by Brown and Ayuso (1984). Spectacular breccias comprised of angular blocks of these rocks help define the trace of a large Paleozoic wrench fault north of Gouverneur (Selleck, 2005).

Well defined layering within the outcrop is suggestive of a detrital origin for the rocks. Despite deformation and upper Amphibolite facies metamorphism layers are defined by changes in grain-size, layer thickness, color and staining, and modal mineralogy, including variations in quartz, k-spar, tourmaline, and pyrite. Note the iron staining related to sulfide-rich areas in the outcrop. A metasedimentary origin is also indicated by detrital zircon studies which are summarized below.

The meter-scale layer quartzose layer dipping slightly across the face of the outcrop to the west was sampled for U-Pb zircon analysis (Figure 4). The rock is a feldspathic quartzite with abundant detrital? tourmaline grains. Approximately one kilogram of rock was collected and a small number of zircons, ranging in size from 25-150 microns were separated by standard techniques at the Arizona Laserchron Center at the University of Arizona in Tucson. The zircons separated were imaged by scanning electron microscope including both back scattered electron (BSE) and cathodoluminescence (CL) modes (Figure 5).

While zoning and other internal features were common, metamorphic rims are restricted to 1-2 micron euhedral overgrowths on a small population of the zircon present prohibiting their analysis. The shape of grains ranges considerably from nearly perfect rounded grains in two dimensional cross-sections to a wide variety of euhedral and subhedral to subrounded shapes. The grains have substantially difference BSE and CL signatures suggestive of a wide variation in trace element chemistry and multiple sources.

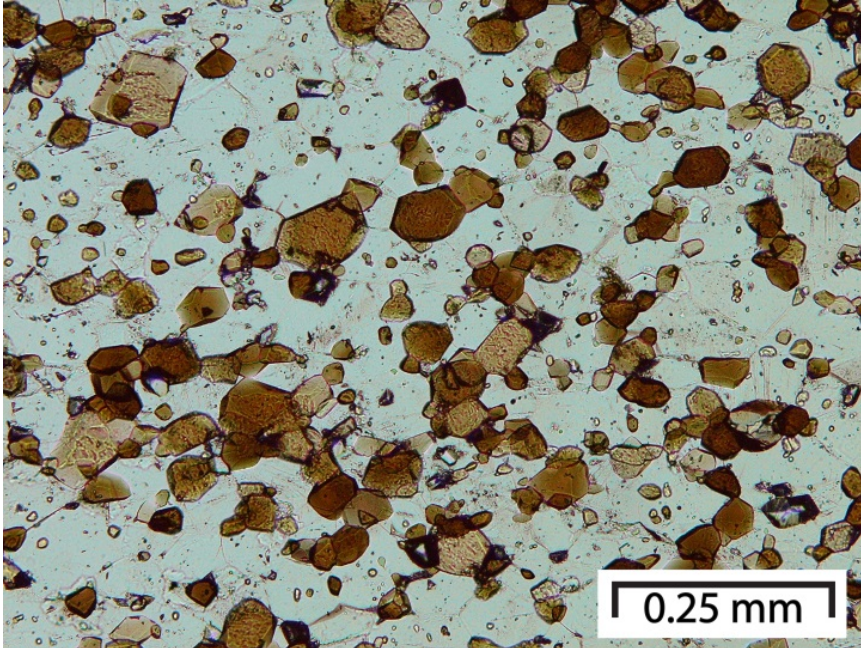


Figure 3. Polygonal to hexagonal, nearly equant grains of tourmaline in the tourmalinite layers from Richville.

Zircons from the quartzite layer have a complex age distribution (Figure 6). Most grains appear to have been derived from Proterozoic terranes to the west, yielding ages corresponding to the Mid-continent Granite-rhyolite province and Mazatzal, Yavapai, and Penokean orogens, rather than a more limited source to the north in the Grenville Province. Particularly telling are the lack of ca. 2.65-2.75 Ga zircons from the adjacent Southern Superior Province and the relative abundance of 1.80-2.00 Ga zircons compatible with Penokean or Trans-Hudson sourcing. A possible southern source is ruled out by the presence of Early Proterozoic and Archean components and the scarcity of 1.30-1.40 Ga detrital zircons indicative of the Southern Adirondack tonalitic rocks.

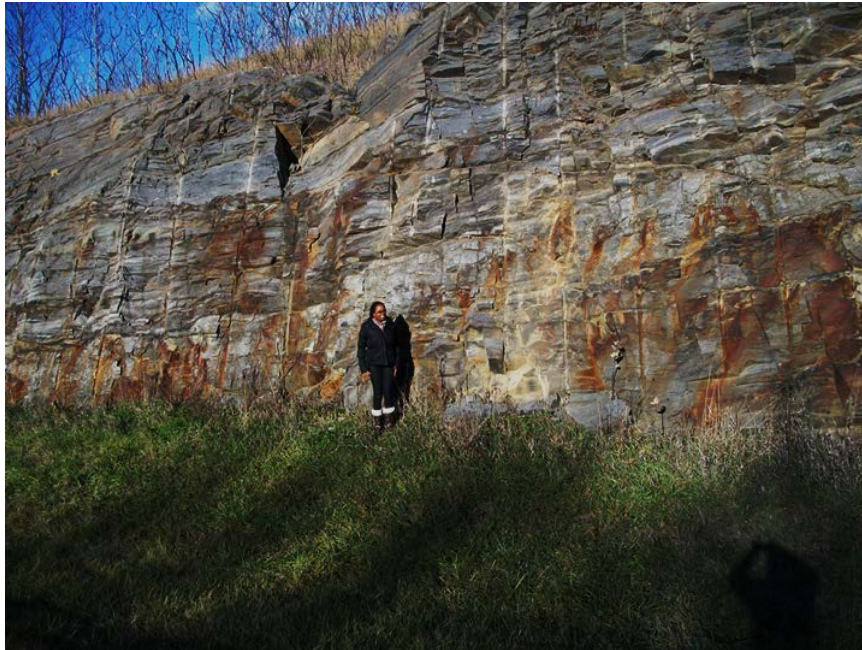


Figure 4. The layer sampled for detrital zircon analysis at Richville is just above Roselyne Laboso.

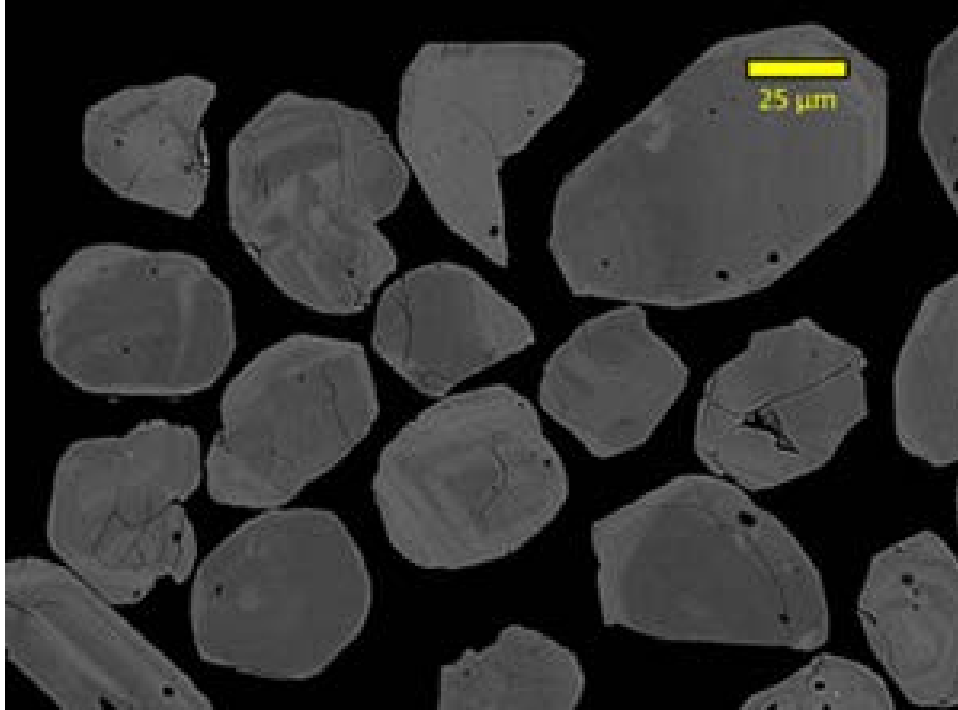


Figure 5. Back scattered electron image of detrital zircons from the Richville feldspathic quartzite.

The youngest zircons in the rock yield an age of 1257.6 ± 16 Ma. This age yields maximum age of deposition for the Lower Marble between ca. 1241-1273 Ma and establishes its deposition prior to the Elzevirian Orogeny. This result is consistent with the Lu-Hf dating of apatite in the Lower Marble (1274 ± 9 Ma; Barfod et al., 2005) and the presence of large isoclinal folds in the Lower Marble crosscut by the Antwerp-Rossie granitoids (1203 ± 13.6 Ma; Chiarenzelli et al., 2010).

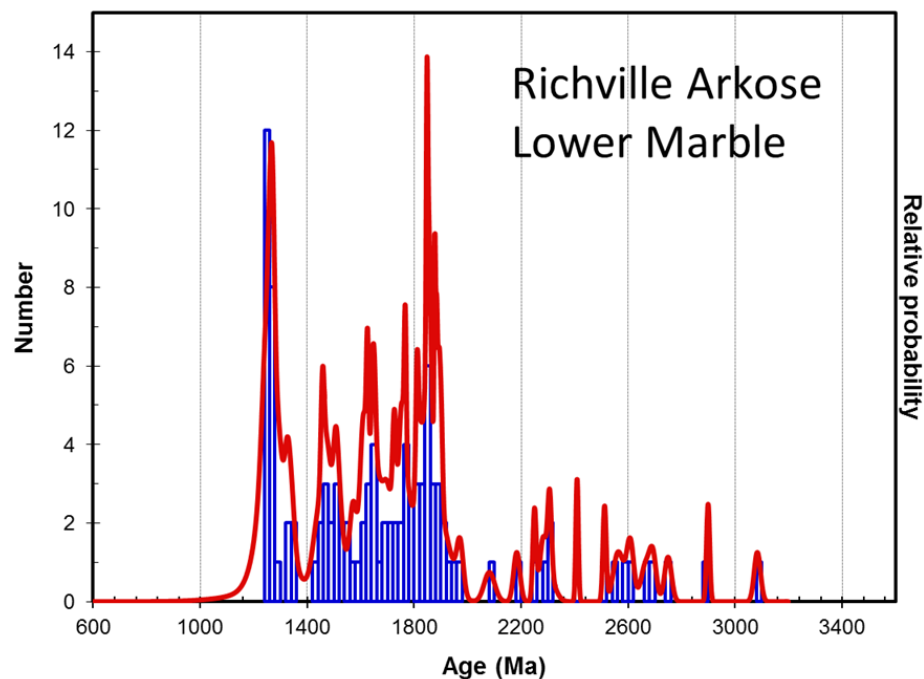


Figure 6. Detrital zircon ($n = 100$) age spectrum of the Richville feldspathic quartzite.

While the ultimate origin of these tourmaline-bearing gneisses is still equivocal; here they are undisputedly a reflection of a sedimentary environment yielding copious amounts of tourmaline. This environment punctuated the carbonate dominated shelf sedimentation of the Lower Marble. Here we interpret the rocks as arkosic to mud-rich playa deposits deposited within isolated fault blocks and rift basins during the opening of the Trans-Adirondack Back-arc Basin (Chiarenzelli et al. 2011).

Stop 2.

DANBURITE LOCATION AT RUSSELL (THE OLD VAN BUSKIRK FARM).

N 44° 22' 09", W 75° 11' 13"

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At Russell, danburite is found as compact masses, alternating layers of danburite and diopside and vugs with terminated prismatic crystals in a diopside-rich rock. It is associated with diopside, very rare datolite, dravite, phlogopite, quartz, pyrite, calcite (rare), fluorapatite, marialite, microcline, rare chalcopyrite and bornite, titanite, and tremolite.

Danburite formed as a prograde mineral in the assemblage danburite – diopside – microcline – quartz – scapolite. Dravite developed as a late mineral, probably at the expense of danburite. The metamorphic peak for the area seems to be T 650°C to 700°C and P 6 to 7 kbars (Edwards and Essene 1988). Grew (2002) considered that the layered danburite-diopside assemblage probably represents the highest-temperature danburite association ever reported. Danburite veins, cutting the host rock, formed after the metamorphic peak at lower temperature.

Stop 3.

BOWER POWERS FARM, PIERREPONT, NEW YORK

N 44°33'28"; W 75°01'14"

Private property, please ask permission from the landowners to visit and collect. \$5/person collection fee.

The quartz-tourmaline veins from the Bower Powers Farm location occur cross-cutting metasedimentary rocks of Grenville-age. The main minerals found in different trenches and pits in this area are uvite-dravite, quartz, calcite, tremolite, diopside, fluorapatite, phlogopite. A very detailed mineral composition of the veins can be found in Chamberlain and Robinson (2013).

Fluid inclusion microthermometry on quartz from the quartz-tourmaline vein yielded a temperature of 438° – 500°C and P 3.1 to 3.5 kbars (Kelson et al. 2013). A sample of coarse-grained tourmaline-quartz-calcite pegmatite yielded a substantial number of zoned euhedral zircon crystals (Figure 7) that gave an U-Pb zircon age of 1158.3±3 Ma (Figure 8). This age is interpreted as the timing of intrusion of pegmatitic veins cross-cutting the country rock as can be observed in the trenches along the stream. Given the lack of fabric in the pegmatites, this result suggests intrusion after, or during, the waning stages of the Shawinigan Orogeny.

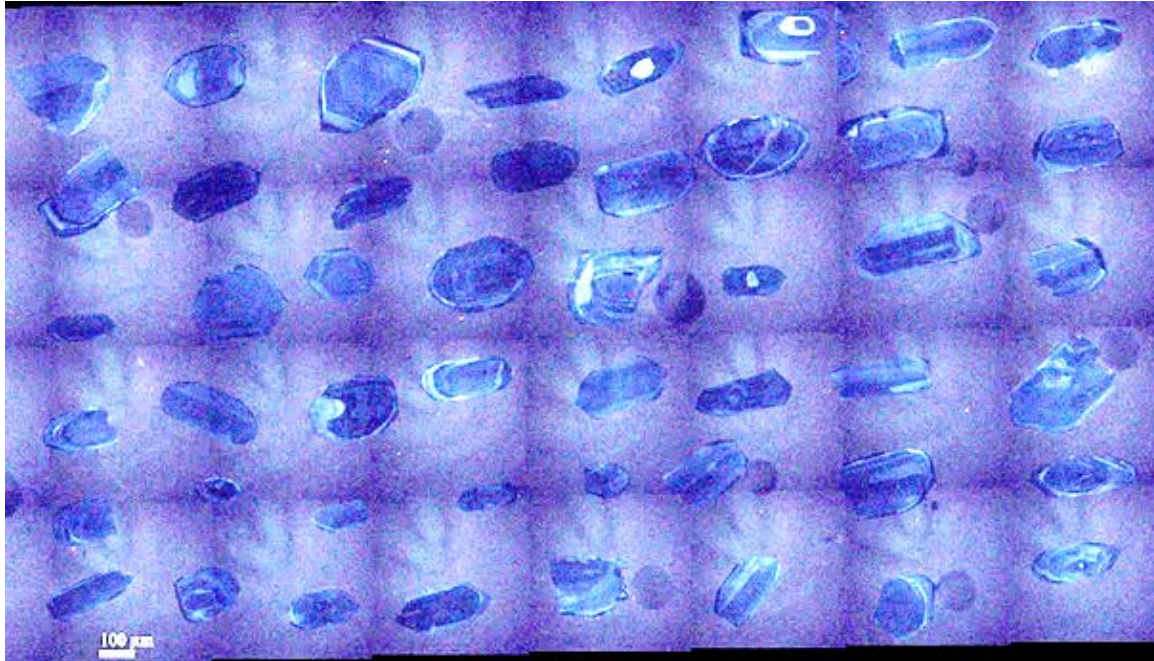


Figure 7. Cathodoluminescence photograph of zircons from Powers Farm tourmaline-bearing pegmatite.

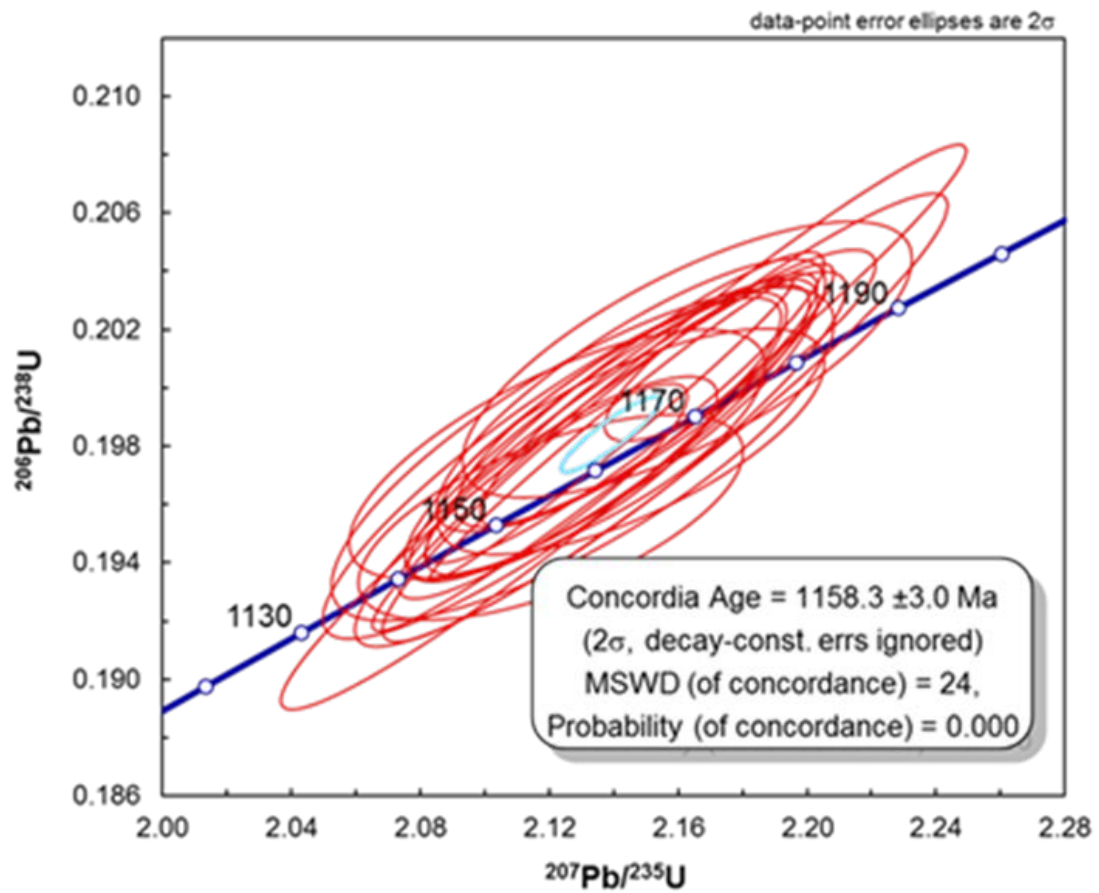


Figure 8. Concordia diagram of zircons separated from the tourmaline-bearing pegmatite at Bower Powers Farm.

Tourmaline crystals (some up to tens of cm in diameter) are black and shortened on the “c” axis. A few comments on the composition of some species and how this relates to the species name could be easily exemplified by the tourmaline from the Bower Powers Farm in Pierrepoint. This is a well-known location and the name of the species varied in time from one author to another – uvite (Dunn et al. 1977) or dravite (Grice and Ercit 1993; Dyar et al. 1998; Lupulescu 2008). Some of our recent analyses (unpublished data) indicates dravite is present. The crystals from this location are large and zoned. Our analyses show very little difference between Na^+ and Ca^{2+} in terms of their atoms per formula units at the X-site; some analyses have more Ca^{2+} , others with more Na^+ . It is very difficult to assign the name uvite or dravite to the tourmaline from this location and would require multiple analyses on different parts of the large crystals from thorough the mineralized area. We feel that for the moment the best choice is not to use the species name, but to utilize the solid solution name uvite-dravite.

Stop 4.

WINTERGREEN MINE WASTE ROCK PILE, TALCVILLE
N 44°18'32.5"; W 75°18'34.2"

Our goal at this locality is to take a look at some mineral associations that are similar with those occurring in the Arnold Pit in Balmat. The Arnold Pit is no longer available for study and we will focus our observations and discussions on the rocks found on the dump of the Wintergreen mine. This location is part of the Balmat-Edwards talc belt, a metasedimentary sequence of rocks containing mainly talc and tremolite, mangancummingtonite, and serpentine. Locally, in the talc-tremolite sequences, some Mn-bearing minerals occur. The Mn-bearing-dravite or -uvite are common and in places they form centimeter wide layers containing more than 50 % tourmaline.

From the tailings dump along the Oswegatchie River one can collect pink to purple tremolite (hexagonite), brown, acicular crystals of mangancummingtonite, talc, and Mn-bearing tourmaline. Talc often shows a dark green to bluish color which gave the mine its name. Tourmaline from this location is dravite and contains up to 3 % MnO. An uvite crystal collected from the Arnold Pit (Ayuso and Brown 1984) contained 5% MnO.

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Table 2. The tourmaline species of New York held in the State Museum.

TOURMALINE FROM NEW YORK		
NYSM #	Location	Species
2048	Crown Point (Essex Co.)	Schorl
426.61	Crown Point (Essex Co.)	Schorl
20560	Russell (St. Lawrence Co.)	Feruvite
1987	Edenville (Orange Co.)	Dravite
426.57	Roe Spar Bed (Essex Co.)	Schorl
2957-8	Macomb (St. Lawrence Co.)	Fluor-uvite
15295(A)	Pierces Corners (St. Lawrence Co.)	Schorl
15295(B)	Pierces Corners (St. Lawrence Co.)	Fluor-uvite
15658	Broadway (New York Co.)	Uvite
15927	Chestertown (Warren Co.)	Schorl
13855	Chestertown (Warren Co.)	Dravite
51.4.6.0-45	Brant Lake (Warren Co.)	Fluor-uvite
15768	Brown Site? (St. Lawrence Co.)	Fluor-uvite
19245	Dale Bush Farm (St. Lawrence Co.)	Fluor-uvite
18935	Bigelow (St. Lawrence Co.)	Fluor-uvite
17900	Rustley Road (St. Lawrence Co.)	Fluor-uvite
19007	Jefferson Co.?	Dravite
13794	St. Joe Lead Mine (St. Lawrence Co.)	Fluor-uvite
14143	Beaver Creek (St. Lawrence Co.)	Fluor-uvite
12925	Wight Mine (St. Lawrence Co.)	Dravite (Mn)*
10373	Parishville (St. Lawrence Co.)	Fluor-uvite
19739	Selleck Road (St. Lawrence Co.)	Fluor-uvite
10357	Brant Lake (Warren Co.)	Fluor-uvite
2003	Edenville (Orange Co.)	Fluor-uvite
20838	Seven Springs (St. Lawrence Co.)	Dravite
12702	Newcomb (Essex Co.)	Fluor-uvite
20244	Port Henry (Essex Co.)	Uvite
12583	Newcomb (Essex Co.)	Fluor-uvite
22534	Long Lake (Hamilton Co.)	Fluor-uvite
22547	Talcville st. Lawrence Co.)	Uvite
426.21	Newcomb (St. Lawrence Co.)	Rossmannite
	Cream of Valley (St. Lawrence Co.)	Fluor-dravite
15248	Wight Mine (St. Lawrence Co.)	Uvite (Mn)*
	Columbia Graphite Mine (Essex Co.)	Dravite
	Balmat (with halite)-St. Lawrence Co.	Dravite
	Rock Island (St. Lawrence Co.)	Schorl
	Talcville (St. Lawrence Co.)	Dravite (Mn)*
	Sugar Hill (Essex Co.)	Uvite
	Warrensburg (B minerals outcrop)-Warren Co.	Dravite
21435 (brown core)	Fowler (St. Lawrence Co.)	Fluor-uvite
21435 (green rim)	Fowler (St. Lawrence Co.)	Fluor-uvite
20902	Alexandria Bay (Jefferson Co.)	Uvite
21489 (yellow)	Balmat (St. Lawrence Co.)	Dravite
21489 (green)	Balmat (St. Lawrence Co.)	F-uvite
20149	Newcomb (Essex Co.)	Feruvite
21008	Dana Hill (St. Lawrence Co.)	Dravite
15909	Emery Quarry (Westchester Co.)	Dravite
2980-1	Macomb (St. Lawrence Co.)	Fluor-uvite
21300	Macomb (St. Lawrence Co.)	Fluor-uvite

12337	Tilly Foster (Putnam Co.)	Dravite
51.4.6.0-35	Rossie (St. Lawrence Co.)	Fluor-uvite
12333	Tilly Foster (Putnam Co.)	Dravite
51.4.6.0-46	Hague (Warren Co.)	Dravite
18091	Atlas Quarry (Saratoga Co.)	Fluor-uvite
1991	Cedar Lake (St. Lawrence Co.)	Uvite
17781	Trout Lake (St. Lawrence Co.)	Schorl
12701	Newcomb (Essex Co.)	Fluor-dravite, dravite (yellow), elbaite (green and dark green)
	Balmat, # 1 American Mine (St. Lawrence Co.)	Al-rich chromium dravite
51.4.6.0-47	Overlook Quarry (Saratoga Co.)	Schorl
23575	Benson Mines (St. Lawrence Co.)	Schorl
22933	Peekskill (Westchester Co.)	Dravite
13581	Balmat (St. Lawrence Co.)	Dravite
51.4.6.0-27	DeKalb (St. Lawrence Co.)	Fluor-uvite
1654	Wight Mine (St. Lawrence Co.)	Dravite (Mn) (listed under tremolite -hexagonite). Newland specimen.*
426.39	DeKalb (St. Lawrence Co.)	Fluor-uvite
2064	New York Co?	Dravite
1863	Monroe (Orange Co.)	Fluor-uvite
20592	Oxbow (Jefferson Co.)	Fluor-uvite
10242	North Creek (Warren Co.)	Uvite
19390	Arnold Pit (St. Lawrence Co.)	Schorl
10353	Horicon?	Fluor-uvite
18336	Pottersville (Warren Co.)	Uvite
21064	Bower Powers Farm (St. Lawrence Co.)	Dravite
2000	Edenville (Orange Co.)	Fluor-uvite
1989	Bedford (Westchester Co.)	Schorl
16919	Manhattan (New York co.)	Dravite
21430	Glenn Mills Road (St. Lawrence Co.)	Dravite
2064	New York (no precise location)	Dravite
18592	Ellis farm (St. Lawrence Co.)	Dravite