Vermont and New Hampshire Paragonite

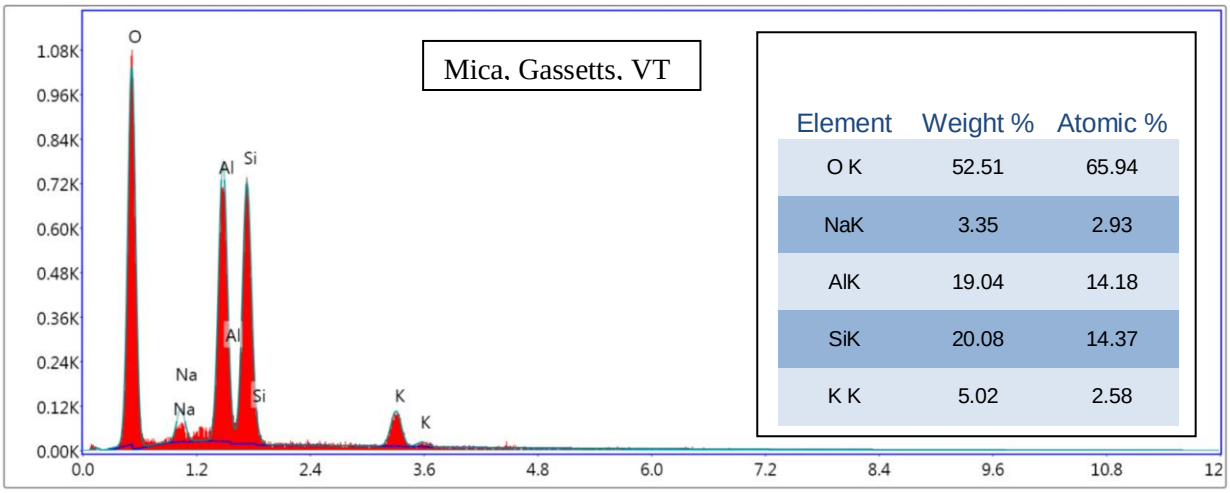
Tom Mortimer

Introduction: This article was initially planned for the October, 1019 MMNE newsletter. I sent review copies to Peter Cristofono and Fred Davis. In reply, Peter and Fred forwarded a dozen technical articles on the paragonite-muscovite series. Several articles specifically report on the Gassetts, VT, occurrence. Most are very technical, but the articles enlightened me to the complexity of this mineral "pseudo-series." As a result of much new information, I have acquired additional EDS data and divided this article into two parts, expanding on my initial investigation.

Part 1: Data and conclusions from my initial analysis (my original article).

As part of my mica mineral group investigation last spring, I became aware of the sodium mica, paragonite. Webmineral.com includes a paragonite specimen photo from Route 103 in Gassetts, a village of Chester, Vermont. Mindat.org also has photos of Gassetts paragonite and references Grant's 1968 book *Mineral Collecting in Vermont*. I visited this locality in 1993 to collect garnet and staurolite, both reported from there. These species, found embedded in a silvery mica, are not particularly remarkable. I assumed the mica was simply muscovite (see photo, Fig. 1).

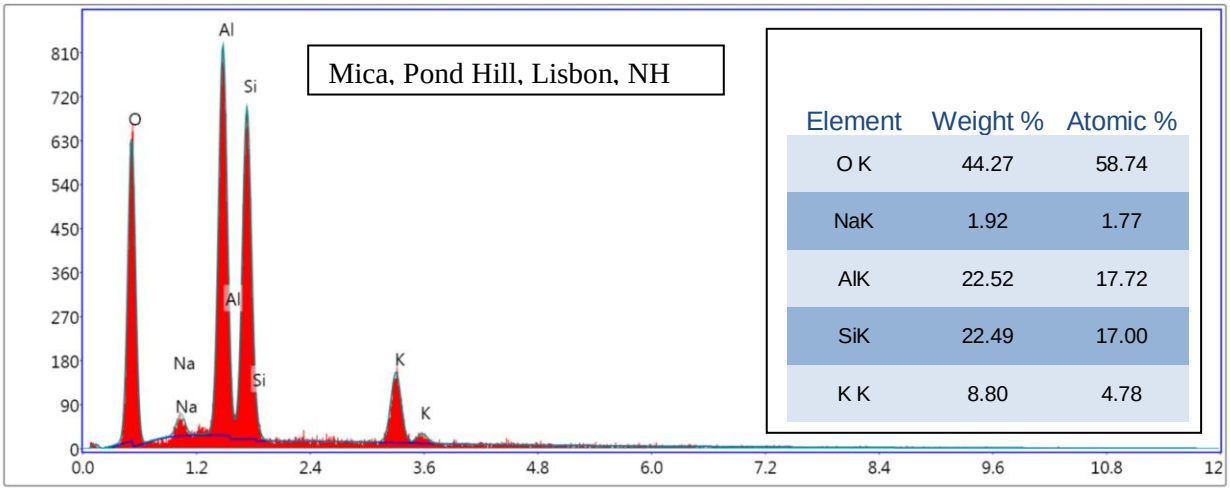
As paragonite is a moderately rare mineral (at least based on the number of photos on Mindat), I added a sample to my June, 2019 EDS analysis set. The result below, indicated a sodium-bearing mica.



Element	Weight %	Atomic %
O K	52.51	65.94
NaK	3.35	2.93
AlK	19.04	14.18
SiK	20.08	14.37
K K	5.02	2.58

Lsec: 100.0 0 Cnts 0.000 keV Det: Octane Plus Det

A review of paragonite photos on Mindat.org shows this mica frequently associated with kyanite. A cabinet-size kyanite specimen in my collection (Fig. 2) from Pond Hill, Lisbon, NH (the staurolite locale) has a moderate mica content. So I also included a sample of this mica in my June, 2019 analysis set. This mica also has a high sodium content. Both analyses were grains on carbon tape, side-by-side.



Element	Weight %	Atomic %
O K	44.27	58.74
NaK	1.92	1.77
AlK	22.52	17.72
SiK	22.49	17.00
K K	8.80	4.78

Lsec: 100.0 0 Cnts 0.000 keV Det: Octane Plus Det

Mindat.org has a page dedicated to the "muscovite-paragonite series": https://www.mindat.org/min-38729.html
The series spans the chemistry range: muscovite = $KAl_2(AlSi_3O_{10})(OH)_2$ to paragonite = $NaAl_2(AlSi_3O_{10})(OH)_2$
The APFU chemistries from my two analyses (normalized for 3 Si):
Gassetts, VT mica: $(K_{0.39},Na_{0.75})Al_{3.08}Si_3O_{24.17}$
Pond Hill, NH mica: $(K_{0.61},Na_{0.38})Al_{3.26}Si_3O_{18.2}$

I judge these analyses as quite good for the muscovite-paragonite series. The sum of the K + Na is close to 1 in both, and the (K + Na):Al:Si ratios are close to the expected 1:3:3. The analyses show that my Gassetts mica is sodium dominant, indicating paragonite, and the Pond Hill mica is potassium dominant, indicating a sodium-rich muscovite.

One can wonder how the Mindat reference (Grant, 1968) came to the identification of the Gassetts paragonite[1]; perhaps from a yellow sodium flame test[2] or an earlier report on the locality. Phillip Morrill and Robert Chaffee published two editions of *Vermont Mines and Mineral Localities*. The first booklet edition was printed in two parts: part 1 in 1957 and part 2 in 1960. A later printing in 1964 combined parts 1 and 2 into a single booklet. Paragonite is listed from four "unlocated mineral areas" in these booklets, none of which is Gassetts or Chester. The *Encyclopedia of Minerals* (1990) gives two localities for paragonite, one being Glebe Mtn. in Windham, VT.

The Yale Peabody Museum has a 10-cm Gassetts, VT "Paragonite with Almandine" specimen, catalog # YPM MIN. 026715, (Fred Davis, personal communication).

Figure 1: Paragonite, with garnets. 7-cm specimen. Gassetts village, Chester, VT

Figure 2: Kyanite in quartz with Na-rich muscovite, top left. Pond Hill (Pearl Lake locality), Lisbon, NH. 13-cm specimen. Collected by Bob Whitmore. Gifted to Tom Mortimer Feb., 2009.

Figure 3: Almandine Gassetts, VT. 13-mm crystal

Figure 4: Staurolite, Gassetts, VT. 2-mm crystal

[1] Literature research by Fred Davis provided the reference from Grant, 1968: "There are several outcrops just north of the village of Gassetts where Route 103 crosses the Williams River. The large outcrop south of the river contains garnet, staurolite, kyanite (gem quality has been reported), muscovite, paragonite (cannot be distinguished from muscovite in hand specimen), quartz, and chlorite."

[2] I tried a sodium flame test on the Gassetts mica, and the slight yellow coloration was no different from a compared pegmatite muscovite.

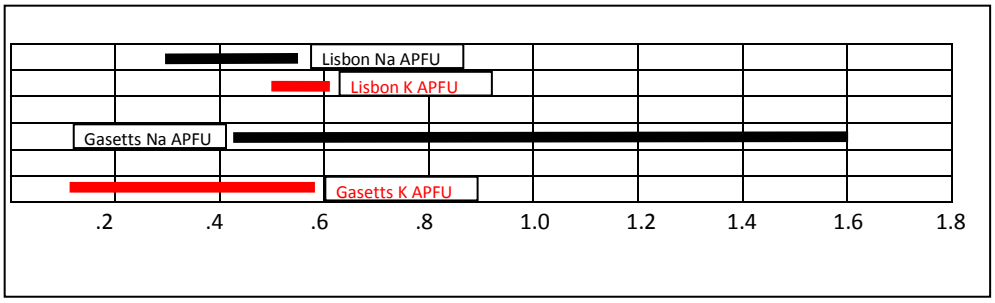
Part 2: Data and conclusions from additional analysis and study.
Most serious mineral collectors are obsessed with having correct labels on their specimens. This passion for accuracy frequently necessitates revisiting the identification of collection specimens when new information comes to light. However, new research and study does not always end with a conclusive result. This was my experience for my recent attempts to "nail down" NH glauconite and diadochite. So with this disclosure, read on….

As part of the October, 2019 EDS session, the two mica samples from the June 2019 session were reanalyzed (at different spots), and three additional samples of the Gassetts mica were tested. Multiple probes of each sample were done. This data is tabulated below. Samples were mounted on carbon tape, as mica samples do not hold up well in polished grain mounts. EDS beam voltage was 15 KeV for all collections. Shading has been added to the Pond Hill mica samples as a visual aid. APFU is **A**toms **P**er **F**ormula **U**nit.

Source Locality	Analysis Reference	APFU Na	APFU K	APFU Mg	APFU Al	APFU Si[2]	Na/(Na+K) %[7]	K/(K+Na) %[8]	% Na_2O	% K_2O
Lisbon, NH[4]	BC347[1]	0.38	0.61	0	3.26	3.0	38.4	61.2	2.39	5.77
Lisbon, NH[4,5]	BC350	0.30	0.56	0.07	2.45	3.0	34.9	65.1	1.86	5.34
Lisbon, NH[4,6]	BC350A	0.56	0.61	0.04	2.85	3.0	47.9	52.1	3.48	5.75
Lisbon, NH[4]	BC350B	0.47	0.50	0.11	2.53	3.0	48.5	51.5	2.75	4.43
Gassetts, VT[3]	BC348[1]	0.75	0.39	0	3.08	3.0	65.8	34.2	3.95	3.11
Gassetts, VT[3]	BC351	0.43	0.49	0.29	3.03	3.0	46.7	53.4	2.56	4.48
Gassetts, VT[3]	BC351A	0.44	0.58	0.22	3.09	3.0	43.1	56.9	2.73	5.42
Gassetts, VT[3]	BC352	1.60	0.08	0	3.79	3.0	95.2	4.8	7.81	0.63
Gassetts, VT[3]	BC352B	1.42	0.11	0	3.74	3.0	93.4	7.2	7.85	0.90
Gassetts, VT[3]	BC353B	0.42	0.26	0.19	3.58	3.0	61.8	38.2	1.75	0.48
							Na >38% **For paragonite**	**K<15%** **For paragonite**		

Notes:
1 My first EDS analysis, June, 2019.
2 All APFU's normalized for 3 atoms of Si.
3 Rt. 103 – beneath underpass, Gassetts village, Chester, VT. [43° 19' 55.65" N, 72° 36' 54.34 " W]
4 Pond Hill, Lisbon, NH. [44° 11' 59.71" N, 71° 52' 19.71" W]
5 Same sample as BC347, reanalyzed October, 2019
6 Same sample as BC348, reanalyzed October, 2019
7 Na(Na+K) must be greater than 38% to be paragonite (up to 38% Na is allowed in muscovite).
8 K(K+Na) must not be greater than 15% to be paragonite**.**

My first observation from the tabulated data is that there is a substantial variation in the sodium-potassium content reported in these results, even with analyses that were collected within a millimeter on the same grain. The bar plot below visually shows the range variations within my EDS data.



Literature research

A 1934 analysis[3] of two Gassetts paragonite samples gave two quite different results for sodium and potassium content. (Note some my EDS Na_2O and K_20 values fall within this range)

	Sample 1	Sample 2
Na_2O	4.65	3.24
K_2O	2.49	6.01
SiO_2	44.25	47.16

Researching further, a 1941 *American Mineralogist* article[4] noted:

"The alkalies in mica from a schist (the Gassetts schist of Richardson) in Vermont, were determined by Dr. R. C. Wells of the Geological Survey who found 5.4 per cent Na_2O and 3.1 per cent K_2O...

"Plotting selected analyses of muscovite and paragonite on the basis of their weight percentage composition of the two end members (M)$H_2KAl_3Si_3O_{12}$ with 11.82 percent K_2O and (P)$H_2NaAl_3Si_3O_{12}$ with 8.11 percent Na_2O, there is an almost continuous series from 95M, 5P to about 60M, 40P and from 30M, 70P to nearly 100P. The large gap from 60M, 40P, to 30M, 70P apparently has no representative.

"It seems to be impossible to differentiate between muscovite and paragonite on the basis of their optical properties, those of paragonite lying within the variable range of the indices of refraction of the muscovites."

A Harvard University microprobe analyses[5] of Gassetts paragonite samples gave ranges of:

Na_20 6.28 – 6.59

K_2O 1.10 – 1.39

A 1971 *American Mineralogist* article by Laduron[6] describes a staining method to distinguish muscovite from paragonite. The method requires the use of extremely dangerous hydrofluoric acid, which I am not about to try. Laduron applied his test to a sample of Gassetts, VT paragonite, and provided the photo below. A revelation from this photo is that the paragonite and muscovite are inter-layered on a microscopic scale (the field of view is only 3 mm).

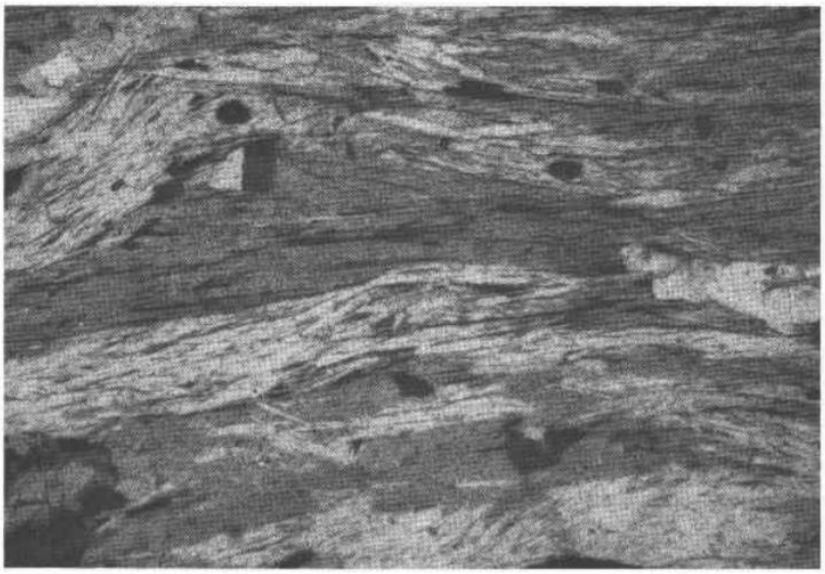


FIG. 1—Stained thin section of a garnet-muscovite-paragonite-schist from Gassetts, Vermont, photographed under blue light (Balzer interference filter: 493 mμ). Muscovite, stained yellow, appears gray; paragonite remains unstained and appears white. Field of photograph 3×2.1 mm.

[3] Cunnren, L.W. (1934). Notes on staurolite and associated minerals from schist at Gassetts, Vermont. *Am. Min.* 335-339.

[4] Schaller, W.T. and R.E. Stevens (1941). The validity of paragonite as a mineral species. *Am.Min.*541-545.

[5] Thompson et al. (1977). *Am. Jour. Sci.* 227 (November 1977): 1124-1151.

[6] Laduron, D.M. (1971). A staining method for distinguishing paragonite from muscovite in thin section. *Am. Min.* 56:1117-1119.

Figure 5: Kyanite (pale blue) in paragonite with red garnets. Field of view is 1.5 cm. Route 103, Gassetts, VT

Figure 6: 1.2 x 1.0 cm pale green apatite in paragonite. Route 103, Gassetts, VT

I provided samples of the Gassetts, VT mica to MMNE member George Adleman for Raman analysis with his RMX unit. Two Raman spectrum plots from George's data are shown in figures 7 and 8. These are areas where RUFF reference paragonite, muscovite, and the Gassetts mica have spectral peaks.

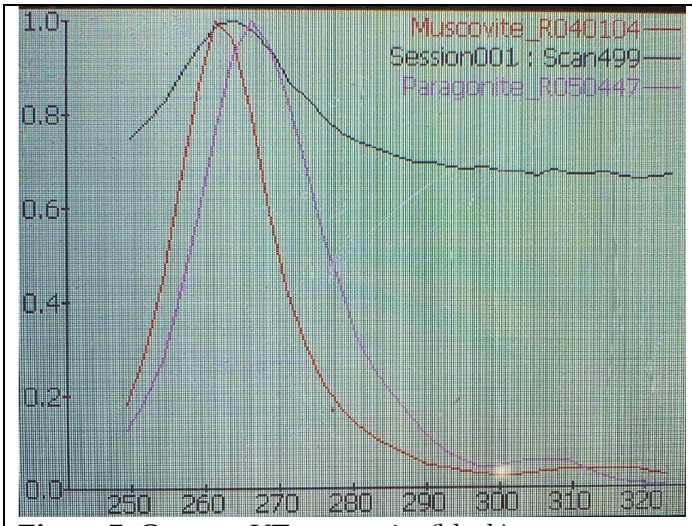


Figure 7: Gassetts, VT paragonite (black)
Raman spectrum, zoom 240-320
RUFF muscovite reference (orange)
RUFF paragonite reference (purple)

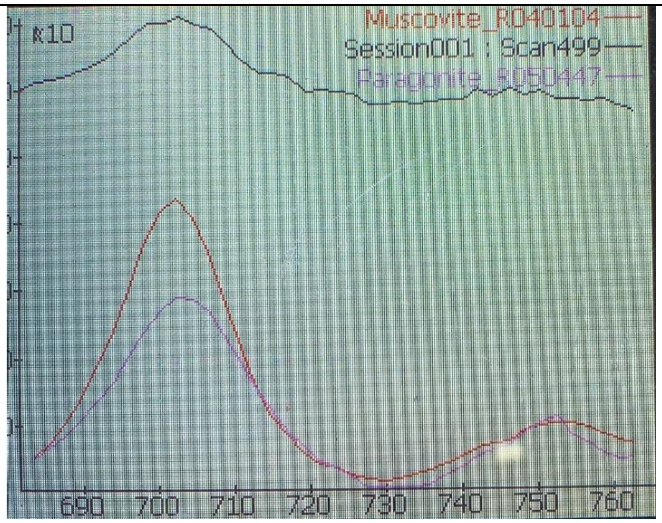
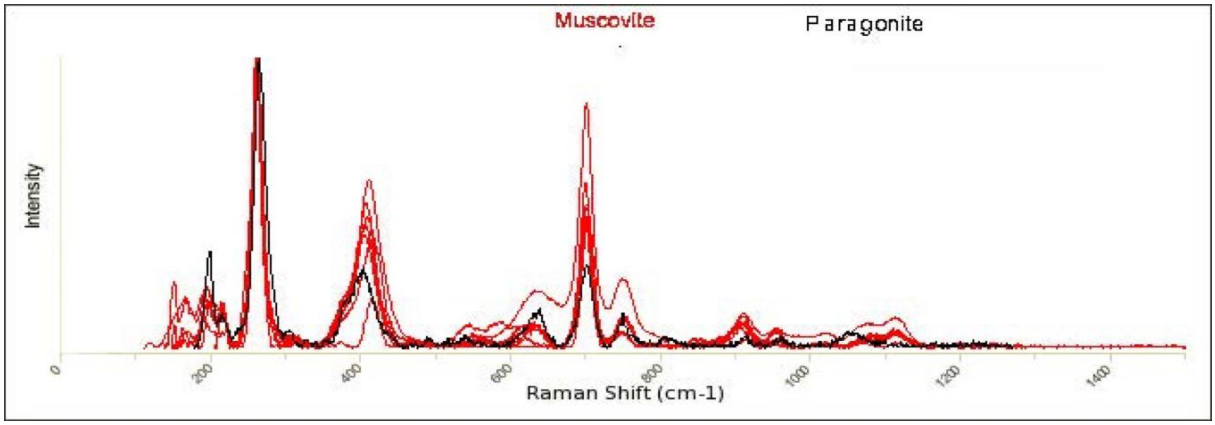


Figure 8: Gassetts, VT paragonite (black)
Raman spectrum, zoom 680-760
RUFF muscovite reference (orange)
RUFF paragonite reference (purple)

RUFF is a huge database of reference Raman spectra used for comparison with unknowns. George noted that the RUFF references for muscovite and paragonite are *very* similar. An overlay of the RUFF muscovite and paragonite plots are shown below.



One interpretation of the Figure 7 and Figure 8 plots is that the Raman unit is picking up both paragonite and muscovite in the sample. This intimate coexistence is stated in a 1964 *American Mineralogist* article by Zen & Albee:
"Because coexisting paragonite and muscovite commonly occur in intimate physical mixtures, it is very difficult to get single-phase separates of these two minerals in amounts adequate for chemical analyses."

From the brief Wikipedia article on paragonite: "Micas of intermediate composition [between paragonite and muscovite] are most commonly a microscopic (or even sub-microscopic) intergrowth of two distinct micas, one rich in K, and the other in Na."

Conclusions:

So, from my analysis results, how should I label my Gassetts and Pond Hill mica specimens? In the past I have applied the "Fifty Percent Rule" to solid solution binary species choices. For example, in the series childrenite $(Fe^{2+},Mn^{2+})Al(PO_4)(OH)_2 \cdot H_2O$ and eosphorite $(Mn^{2+},Fe^{2+})Al(PO_4)(OH)_2 \cdot H_2O$, if an EDS analysis gave Fe > Mn, I had childrenite, if the result showed Mn > Fe, then I labeled the specimen eosphorite. My EDS results for this paragonite study showed quite varied amounts of Na and K, even within the same small sample. It would seem the only legitimate option is to label them paragonite-muscovite. Only my EDS analysis of sample BC352 gave a definitive composition for paragonite.

Finally, as a New Hampshire mineral species collector, does paragonite occur in NH? I would say yes, but as an intimately inter-layered mineral with muscovite and, therefore, not visually identifiable.