Perhamite at the Palermo Mine, N. Groton, NH

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I have had a specimen of Palermo crandallite in my New Hampshire minerals species display since its inception eight years ago - (on display at the McAuliffe-Shepard Discovery Center, Concord, NH). This specimen was given to me by Janet and Steve Cares, founding members of the Micromounters of New England and inductees into the Micromounters Hall of Fame. A photo of this specimen, Figure 1, shows 0.3 mm crandallite balls on a quartz crystal.

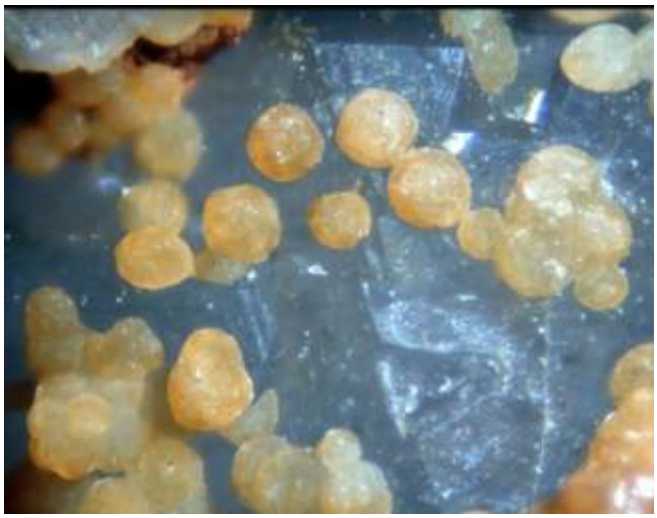


Figure 1: 0.3 mm "crandallite" balls on a quartz crystal. Palermo Mine, N. Groton, NH

Since I lacked a confirmation of this moderately rare Palermo species, in the early winter of 2015 I extracted a tiny ball from another similar Cares collected specimen (given to me by Gene Bearss, #u1884) for an EDS analysis. A polished grain, semi-quantitative, standardless, EDS analysis indicated a chemistry of $Ca_3Al_{8.9}Si_{2.9}P_{5.3}O_{41}$. Crandallite chemistry is $CaAl_3(PO_4)(PO_3OH)(OH)_6$, or grouping elements and eliminating hydrogen (which EDS cannot detect): $CaAl_3P_2O_{14}$. The presence of silicon in my EDS analysis was troublesome, but I "wrote it off" as a bit of quartz contamination.

At the January 2017 MMNE meeting, an egg carton appeared on the give-away table that contained many dime to nickel sized specimens similar to that shown in Figure 1. This carton (Figure 2) was from the bulk micromount material from the collection of Gene Bearss.

Figure2: Egg box from Feb 18, 2017 MMNE meeting containing many "crandallite" on quartz crystals specimens.

I, along with several other members, obtained a few samples from this carton. I now possessed ample material for additional testing. Photos from one of these specimens are shown in Figures 3 and 4.

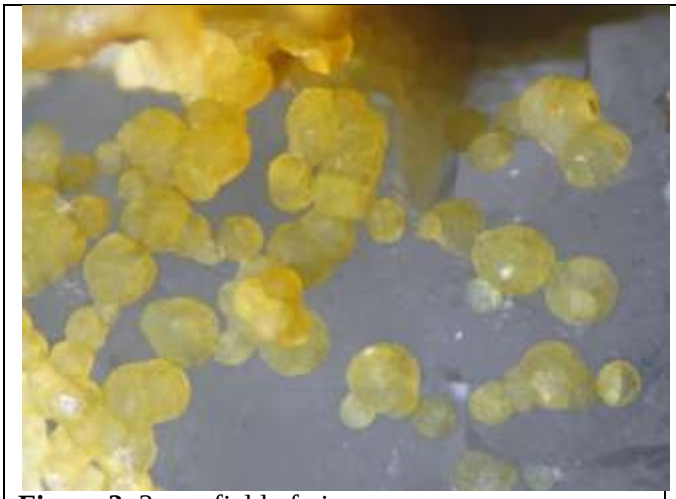


Figure 3: 3 mm field of view

Figure 4: 1.7 cm specimen

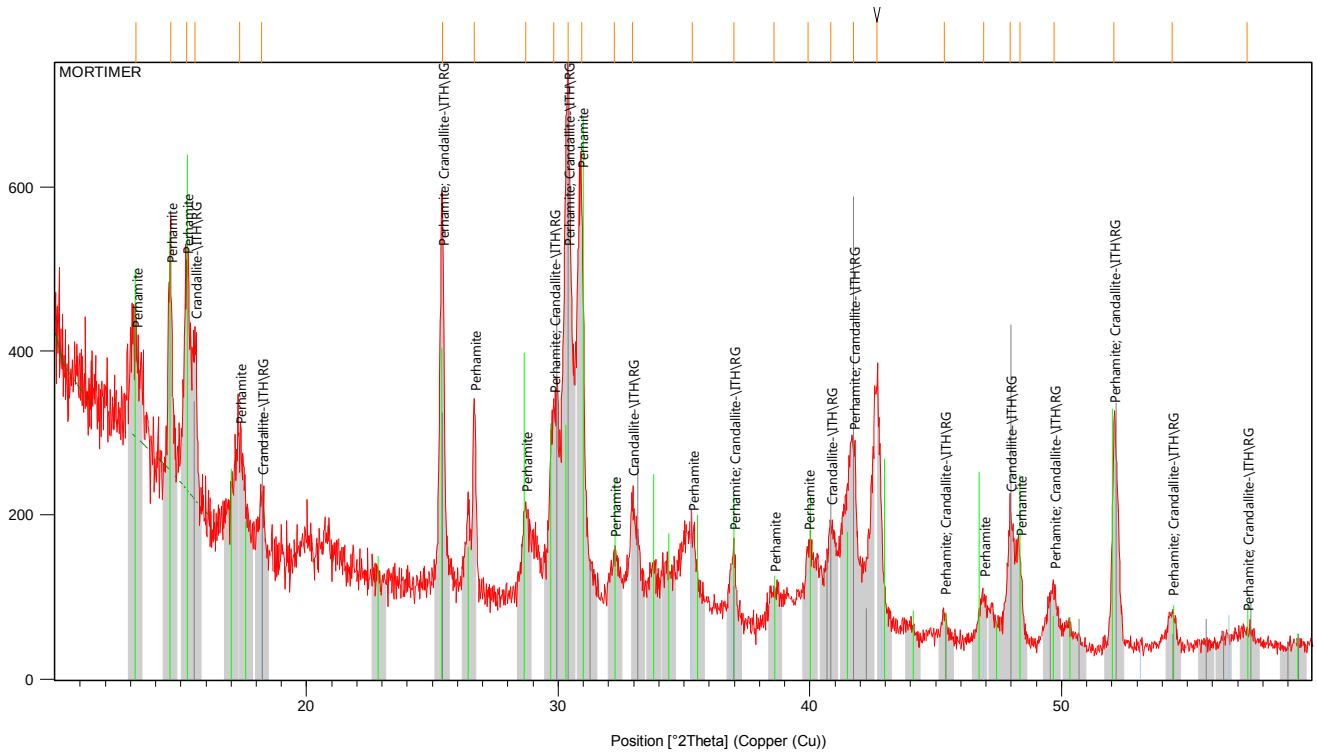
The results of three probings of a polished grain (BC121) from one of these specimens (plus the earlier BC63 analysis) are tabulated below.
The atoms per unit formula were calculated from the EDS Atomic %'s
** Hydrogen atomic % of 2.76 % was added to EDS result, (discussion follows).
The APFU's have been normalized for three (Ca + Sr).

	Atoms per formula unit from EDS atomic %'s							
Analysis run	**Ca***	**P**	**Sr**	**Al**	**Si**	**O**	**H****	**Implied formula**
BC121	2.85	4.7	0.15	8.4	2.4	32.5	30.9	$(Ca_{2.85}Sr_{0.15})Al_{8.4}Si_{2.4}P_{4.7}O_{32.5}H_{30.9}$
BC121a	2.86	4.5	0.14	8.3	2.0	37.4	32.5	$(Ca_{2.86}Sr_{0.14})Al_{8.3}Si_{2.0}P_{4.5}O_{37.4}H_{32.5}$
BC121c	2.78	4.4	0.22	10.2	3.4	70.5	50.1	$(Ca_{2.78}Sr_{0.22})Al_{10.2}Si_{3.4}P_{4.4}O_{70.5}H_{50.1}$
BC63	3.0	5.3	-	8.9	2.9	41.5	36.0	$Ca_3Al_{8.9}Si_{2.9}P_{5.3}O_{41.5}H_{36.0}$

All four analyses consistently showed a presence of two to three silicon atoms per formula unit (APFU). There is only ONE mineral that contains only Ca, Al, P, Si, O: Perhamite ! Although perhamite is reported from several Maine localities, it has not been reported from the Palermo Mine, nor from any other NH locality. Perhamite chemistry is: $Ca_3Al_{7.7}Si_3P_4O_{23.5}(OH)_{14.1}\cdot 8H_2O$ or with like elements grouped: $Ca_3Al_{7.7}Si_3P_4O_{45.6}H_{30.}$ Of note, in the *Handbook of Mineralogy*, an Emmons Mine (Maine) perhamite WDS analysis showed Strontium (Sr) substituting for some Ca, resulting the first cation being indicated as (Ca,Sr). Strontium (Sr) showed in all three BC121 grain analyses. Although the formula implied from the BC EDS analyses are not close to "dead-on" for perhamite, it is as close as we typically see for the BC instrument's results for many minerals. For the oxygen content, in particular, we see moderate deviation from ideal values. Perhamite contains 2.7 atomic % hydrogen. My atomic % to APFU conversion program allows for user adjustment for non-EDS detected light elements, such as hydrogen.

Since a claim of perhamite occurrence at the Palermo Mine is somewhat extraordinary, I felt further evidence was required. A sample from the egg-carton was sent to John Attard, San Diego, CA for XRD analysis. The XRD plot is shown in figure 5. Although there is very good

peak correlation with perhamite, several peaks are common to both perhamite and crandallite, and a few are specific to crandallite only.



Pos. [°2Th.]	Height [cts]	FWHM Left [°2Th.]	d-spacing [Å]	Rel. Int. [%]
13.211530	109.918300	0.629760	6.70164	17.12
14.605850	230.493900	0.137760	6.06487	35.90
15.232010	265.008900	0.196800	5.81693	41.28
15.577150	198.942900	0.118080	5.68882	30.99
17.339600	114.033000	0.393600	5.11436	17.76
18.219660	71.240280	0.236160	4.86926	11.10
25.388960	479.770800	0.177120	3.50821	74.73
26.662860	219.655000	0.118080	3.34342	34.21
28.702540	99.266630	0.236160	3.11030	15.46
29.818720	217.865300	0.236160	2.99637	33.94
30.384000	641.993700	0.157440	2.94190	100.00
30.922250	498.350600	0.236160	2.89190	77.63
32.238780	50.486710	0.314880	2.77675	7.86
32.946480	121.106800	0.118080	2.71871	18.86
35.337250	85.018930	0.472320	2.54006	13.24
36.988770	77.734180	0.236160	2.43036	12.11
39.917980	79.018510	0.236160	2.25851	12.31
40.839080	111.694200	0.236160	2.20967	17.40
41.746390	206.402100	0.236160	2.16372	32.15
42.658360	291.127800	0.314880	2.11956	45.35
46.904050	53.479590	0.275520	1.93712	8.33
47.949380	158.039100	0.157440	1.89730	24.62
48.336650	106.985600	0.157440	1.88300	16.66
49.694440	68.211380	0.314880	1.83469	10.62
52.093060	276.989000	0.137760	1.75572	43.15

Figure 5: Perhamite XRD data.

Subsequently I forwarded my EDS and XRD data to Al Falster, mineral analyst at the Maine Mineral Museum. I wanted to know if perhamite and crandallite could occur intergrown. After consulting with mineralogist Skip Simmons, Al's reply stated that they could occur "either intergrown or present in the same vug" and that based on my data that "one can be reasonably but not fully confident on the presence of perhamite. like 90% or so." Well, not 100%, but a 90% vote for perhamite at Palermo is likely about as good as I will get.

I have two Maine perhamite specimens in my collection, both from the Emmons Quarry in Greenwood, ME. Figure 6 is a photo of a single perhamite cluster on my specimen # u773.

Figure 6: 0.7 mm perhamite cluster on albite. Emmons Quarry, Greenwood, ME

Figure 7: 1.2 mm perhamite cluster on quartz. Palermo Mine, N. Groton, NH

The Emmons Quarry perhamites have a distinct hexagonal characteristic, Figure 6. This hexagonal structure is not present in the Palermo Mine perhamite, Figure 7.

I have some closing thoughts on this Palermo Mine perhamite identification. How did the Cares make the crandallite determination? Crandallite had been known since 1917, but perhamite was first described in 1977. The Cares "crandallites" (of Figures 1, 2, and 3) were collected in 1976 according to the micro-box label added by Gene Bearss. Janet Cares was a very accomplished chemist, and was responsible for identifying many Palermo minerals for her collection. Janet may have determined via wet chemistry techniques that these were a calcium-aluminum-phosphate and that the morphology and Palermo environment strongly indicated the species to be crandallite, particularly since perhamite was quite possibly not yet defined at the time of her analysis.

A second thought is: what level of analysis is sufficient to identify (and label) with confidence a particular specimen? What threshold needs to be crossed for acceptance?

Third, the labeling on my specimen #u1884 shows the importance of preserving the history of the specimen. The original collector (Cares) and date (1976) make the crandallite identification understandable.

And finally, this is an example of an investigation made possible by the EDS analysis program financed and sponsored by the Micromounters of New England. Continued club support for this activity will bring forth reports of new discoveries. Several are already in process.