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Jerrygibbsite, a new polymorph of $Mn_9(SiO_4)_4(OH)_2$ from Franklin, New Jersey, with new data on leucophoenicite

PETE J. DUNN

Department of Mineral Sciences
Smithsonian Institution, Washington, D.C. 20560

DONALD R. PEACOR

Department of Geological Sciences
University of Michigan, Ann Arbor, Michigan 48109

WILLIAM B. SIMMONS

Department of Earth Sciences
University of New Orleans, New Orleans, Louisiana 70148

AND ERIC J. ESSENE

Department of Geological Sciences
University of Michigan, Ann Arbor, Michigan 48109

Abstract

Jerrygibbsite, ideally $Mn_9(SiO_4)_4(OH)_2$, is polymorphous with the Mn-humite sonolite, and a probable member of the leucophoenicite group. It occurs as intergrown grains with a typical metamorphic texture at Franklin, New Jersey, intimately associated with leucophoenicite. It is orthorhombic with space group *Pbnm* or $Pbn2_1$ and unit cell parameters $a = 4.85(1)$, $b = 10.70(1)$, and $c = 28.17(3)$Å. The strongest lines in the powder diffraction pattern are d (I): 2.557 (100), 1.806(100), 2.869(78), 2.752(49), 2.702(46), 2.362 (39). Optical parameters include: biaxial negative, $2V = 72°$, $\alpha = 1.772(4)$, $\beta = 1.783(4)$, $\gamma = 1.789(4)$; $Z = \mathbf{a}$, $X = \mathbf{b}$, amd $Y = \mathbf{c}$. The color is violet-pink; the Mohs' hardness is approximately 5.5; the observed density is 4.00(2) and the calculated density is 4.045 g/cm^3. The name is in honor of Professor Gerald V. Gibbs of Virginia Polytechnic Institute and State University. Chemical analytical data for leucophoenicite indicate that minor amounts of Ca and/or Zn may serve to stablilize leucophoenicite-group minerals relative to humite-group minerals at Franklin, New Jersey.

Introduction

During a systematic survey of the chemical composition of specimens of leucophoenicite by electron microprobe analysis, several samples were found to be another, but closely related phase. These samples gave X-ray powder diffraction patterns which, although generally similar to those of leucophoenicite and members of the humite group, were unique and did not match any known species. The powder X-ray diffraction data, combined with the chemical analyses, implied that this material was a new manganese member of either the humite or leucophoenicite groups. The distinctions between these two series or families of structures has been described by White and Hyde (1983) and is summarized in Table 1. Our subsequent investigation has confirmed that this phase is a new mineral.

We take great pleasure in naming this mineral jerrygibbsite in honor of Dr. Gerald V. Gibbs, Professor at Virginia Polytechnic Institute and State University, in recognition of his outstanding contributions to the science of mineralogy and the society of mineralogists. The new mineral and the name were approved, prior to publication, by the Commission on New Minerals and Mineral Names, IMA. Type material is preserved at the Smithsonian Institution under catalogue numbers C3209 and R18772 (holotypes) and 149037 (cotype).

Description and physical properties

Jerrygibbsite occurs as a massive mineral in interlocking anhedral crystals, up to 0.5 × 2.0 mm, which display a typical metamorphic texture; there are no euhedral crystals. The hardness (Mohs) is approximately 5.5. The

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Table 1. Crystallographic data and formulae for the leucophoenicite and humite groups

Species	Ideal formula	Space group	a	b	c	α	Reference
LEUCOPHOENICITE GROUP							
Jerrygibbsite	$Mn_9(SiO_4)_4(OH)_2$	$Pbnm/Pbn2_1$	4.85	10.70	28.17	90°	Present study
Leucophoenicite	$Mn_7(SiO_4)_3(OH)_2$	$P2_1/b$	4.828	10.85	11.380	103.73°	Present study
HUMITE GROUP							
Norbergite	$Mg_3(SiO_4)(OH)_2$	Pbnm	4.7104	10.2718	8.7476	90°	Gibbs and Ribbe (1969)
Synthetic phase	$Mn_3(SiO_4)(OH)_2$	Pbnm	4.869	10.796	9.179	90°	Francis and Ribbe (1978)
Chondrodite	$Mg_5(SiO_4)_2(OH)_2$	$P2_1/b$	4.7284	10.2539	7.8404	109.06°	Gibbs et al., (1970)
Alleghanyite	$Mn_5(SiO_4)_2(OH)_2$	$P2_1/b$	4.8503	10.7198	8.2747	108.64°	Rentzeperis (1970)
Humite	$Mg_7(SiO_4)_3(OH)_2$	Pbnm	4.7408	10.2580	20.8526	90°	Ribbe and Gibbs (1971)
Manganhumite	$Mn_7(SiO_4)_3(OH)_2$	Pbnm	4.815	10.580	21.448	90°	Francis and Ribbe (1978)
Clinohumite	$Mg_9(SiO_4)_4(OH)_2$	$P2_1/b$	4.7441	10.2501	13.6635	100.79°	Robinson et al. (1973)
Sonolite	$Mn_9(SiO_4)_4(OH)_2$	$P2_1/b$	4.872	10.669	14.287	100.3°	Kato (1978) in Ribbe (1980)

streak is light pink. The luster is vitreous on both cleavage and fracture surfaces. There is one imperfect cleavage, parallel to {001}. The density, determined using heavy liquid techniques, is 4.00(2) g/cm^3, which compares favorably with the calculated value of 4.045 g/cm^3.

Jerrygibbsite is medium violet-pink in color and light pink in thin-section. It does not fluoresce when exposed to ultraviolet radiation and there is no cathodoluminescence under the beam of the electron microprobe. Grains typically exhibit lamellar structure, parallel to {001} which is defined by lamellae differing in opacity; that is, more transparent lamellae alternate with relatively translucent lamellae. Aside from this difference, the lamellae are optically identical. The cause of the difference is not definitely known, but is ascribed tentatively to differences in fluid inclusion densities. Optically, jerrygibbsite is biaxial negative with $2V = 72°$. The indices of refraction are $\alpha = 1.772(4)$, $\beta = 1.783(4)$ and $\gamma = 1.789(4)$. Jerrygibbsite is not pleochroic; dispersion is moderate to strong, $r > v$. The orientation of the indicatrix is $Z = \mathbf{a}$, $X = \mathbf{b}$, and $Y = \mathbf{c}$.

Chemical composition

Jerrygibbsite was chemically analyzed with an ARL-SEMQ electron microprobe utilizing an operating voltage of 15 kV and a sample current of 0.025 μA, measured on brass. Water was determined using the Penfield method. The resultant analyses, together with standards used, are presented in Table 2. The two jerrygibbsite samples have very similar compositions, but differ slightly in Zn-content. The ratio of M^{2+} ions to silicon is 8.85:4.00 (sample R18772) and 8.78:4.00 (sample C3209), Z = 4, both in reasonable agreement with the 9:4 ratio of sonolite, which is consistent with the relation that jerrygibbsite is a polymorph of $Mn_9(SiO_4)_4(OH)_2$. Although the M^{2+}:Si ratio is less than the ideal 9:4, we attribute this to analytical error and not to admixed leucophoenicite inasmuch as leucophoenicite impurities would increase the ratio to >9:4, and not decrease it.

Table 2. Chemical analyses of jerrygibbsite and leucophoenicite

	JERRYGIBBSITE				LEUCOPHOENICITE
	Weight percent	Atoms per unit cell	Weight percent	Atoms per unit cell	Weight percent
	#R18772		#C3209		#149543
SiO_2	27.1	16.00	26.6	15.71	26.2
FeO	0.3	0.15	0.3	0.15	0.3
MgO	1.4	1.23	1.1	0.97	2.6
CaO	0.4	0.25	1.0	0.63	5.2
MnO	64.1	32.05	62.1	31.05	57.6
ZnO	3.9	1.70	5.3	2.31	5.6
H_2O	2.13*	8.38	2.25*	8.86	2.5**
F	0.0		n.d.		n.d.
Total	99.3		98.6		100.0

* - Water determined by the Penfield method.
**- Water calculated by difference.
Accuracy of data: ±3% of the amount present for major elements.
Standards: hornblende (Si,Fe,Mg,Ca); manganite(Mn); synthetic ZnO(Zn); and fluorapatite(F) for samples R18772 and 149543.
: synthetic tephroite (Si,Mn); hornblende (Fe,Mg,Ca); and synthetic ZnO (Zn).

X-ray crystallography

Cleavage fragments from specimens R18772 and C3209 have been studied using Weissenberg and precession single-crystal techniques, and the results are identical for all crystals. The photographs show that jerrygibbsite is orthorhombic with space group *Pbnm* or $Pbn2_1$, with refined unit cell parameters $a = 4.85(1)$, $b = 10.70(1)$, and $c = 28.17(3)$Å. This setting of the unit cell translations is used so as to emphasize the relation to the related members of the humite group, all of which have $a = 4.9$ and $b = 10.5$Å translations in common; this setting was recommended by Jones (1969). The space group identification is somewhat tentative as extinction rules are not as well defined as usual due to the presence of classes of systematically weak reflections. For example, very few *h0l* reflections are observable. We feel that the space group as determined is very probably correct, although there is a possibility that intensities as determined in the course of a structure determination may show that the apparent glide-planes are not required in the detailed structure.

Individual lamellae from the zones defined by translucency differences noted above were separately studied using single-crystal X-ray diffraction and chemical analytical techniques. The results for all lamellae studied were identical, showing that the lamellae are not a function of differences in the structure. Because the lamellae have {001} as the interface and because it is this plane which is the common interface between intergrowths of two or more members of the humite or leucophoenicite groups (White and Hyde, 1982), it was especially important to establish this relation. White and Hyde (1982) have shown, using high-resolution TEM lattice-fringe-imaging techniques, that members of the humite family may exhibit fine-scale, mixed layering parallel to {001}. We therefore examined the X-ray photographs especially carefully in order to determine the presence of any streaking parallel to (001). None was observed, indicating that if there is random mixed layering of more than one species, it is below levels of detection by such X-ray techniques.

Powder X-ray diffraction data are given in Table 3. These were obtained using a powder X-ray diffractometer, Cu$K\alpha$ X-radiation monochromated with a flat graphite crystal. The powder was mounted on a glass slide and Si was used as an internal standard. The lattice parameters *b* and *c* are relatively large, resulting in a large number of symmetrically non-equivalent *d*-values; thus few reflections could be unambiguously indexed. The limited number of unambiguously indexable reflections occurred despite the elimination of the classes of systematically weak reflections. We have therefore given indices for only a limited number of reflections and only 6 could be used in least-squares refinement of the lattice parameters.

Our original attempts to obtain high-quality powder diffraction patterns were unsuccessful. We subsequently determined that this was due to contamination by other phases. The principal contaminating phase is leucophoenicite although other Mn-humites such as alleghanyite also are found with jerrygibbsite. Indeed, we have been unable to obtain a jerrygibbsite powder pattern which is entirely free of leucophoenicite contamination. The patterns for jerrygibbsite, leucophoenicite, and the Mn-humites have many features in common. Because multiphase patterns appear to be the rule and not the exception, and because it is difficult to interpret these patterns even after considerable experience with them, we have gone to some lengths to try to obtain standard, single-phase patterns of each phase. These patterns were shown to be single-phase in two ways: (1) *d*-values lead to satisfactory indexing of unit cell parameters, and (2) reflections known to be characteristic of other phases are found to be very weak (in which case appropriate reflections were subtracted from the pattern) or absent in the pattern chosen to be representative of a given single phase. We have separately described patterns for alleghanyite, sonolite, and manganhumite (Winter et al., 1983) and report the leucophoenicite and jerrygibbsite patterns here (Table 3). It should be possible to characterize any mixture of leucophoenicite-humite family phases with these patterns as a guide.

No jerrygibbsite pattern is entirely free of peaks of leucophoenicite. We therefore first separately characterized the diffractometer pattern of leucophoenicite using several samples from Franklin, New Jersey, including type material, and then substracted the peaks of leucophoenicite from the jerrygibbsite pattern. The reflections displayed in the Debye-Scherrer and Gandolfi patterns of powdered, polycrystalline samples of the same leucophoenicite and jerrygibbsite samples are invariably weak and diffuse. We have no explanation of this phenomenon, inasmuch as the diffractometer patterns of these same samples are of high quality. We note this because in such Debye-Scherrer and Gandolfi powder patterns the weaker peaks of contaminating leucophoenicite are generally not detectable.

Occurrence

Jerrygibbsite occurs in specimens from the Franklin Mine, in Franklin, Sussex County, New Jersey. Three specimens have been characterized. Two are the holotypes and the third, a cotype (#149037) was generously donated to the Smithsonian Institution by its owner, Mr. Charles Key, when he was informed of its significance. No data have been preserved as to the geological occurrence(s) within the Franklin orebody, as is the case with most specimens collected in past years. A label with specimen #C3209 suggests it was collected in 1907. Inasmuch as the three known specimens were all labelled leucophoenicite, and because jerrygibbsite also resembles the Mn-humites from Franklin, it is quite possible

Table 3. X-ray powder diffraction data for jerrygibbsite and leucophoenicite. The *d*-values are listed so as to facilitate direct comparison of the patterns.

Jerrygibbsite[1]				Leucophoenicite[2]			
d(obs)	d(calc)	hkl	I/I_0	d(obs)	d(calc)	hkl	I/I_0
5.25	5.26	021	9	5.26	5.27	$0\bar{2}1$	13
					5.27	002	
4.40	4.41	110	11	4.40	4.39	110	19
					4.37	$0\bar{2}2$	
					4.37	021	
4.25	4.26	024	9				
				3.95	3.95	111	18
3.74	3.74	114	24	3.62	3.64	102	41
					3.62	$1\bar{1}2$	
3.56	3.56	121	5	3.56	3.56	$1\bar{2}1$	10
	3.53	026			3.56	120	
3.48	3.52	008	29				
	3.48	115					
				3.28	3.28	112	30
3.21	3.22	116	14	3.24	3.24	$1\bar{2}2$	6
	3.22	027			3.24	121	
				2.971	2.971	$1\bar{1}3$	16
2.869	2.873	130	78	2.890	2.889	$1\bar{3}1$	100
	2.859	131					
2.813	2.817	00,10	9	2.840	2.842	130	5
	2.815	132					
2.752	2.753	118	49	2.751	2.751	$1\bar{3}2$	32
	2.748	133			2.764	004	
2.702	2.702	029	46	2.722	2.728	$0\bar{2}4$	54
					2.714	$0\bar{4}1$	
2.661	2.664	041	34	2.695	2.694	131	94
	2.661	134					
2.631	2.629	042	3	2.628	2.635	$0\bar{4}2$	32
					2.636	040	
					2.633	131	
2.557	2.560	135	100				
	2.554	119					
				2.493	2.493	$1\bar{3}3$	20
				2.450	2.450	$1\bar{1}4$	52
2.416			16	2.426			25
2.377			11	2.371			29
2.362			39				
2.342			28				
2.225			4	2.202			12
2.118			5	1.973			9
1.806			100	1.811			96
1.730			18	1.752			28
1.712			10	1.709			20
1.692			11				
1.661			9	1.642			7
				1.619			8
				1.598			14
				1.576			27
1.567			26	1.566			28
1.550			34				
1.458			18	1.473			19

Data obtained using powder diffractometer (1°/min. scan rate) with graphite monochromator, using an internal standard.

[1] $\underline{a}$ = 4.85, $\underline{b}$ = 10.70, $\underline{c}$ = 28.17Å.

[2] $\underline{a}$ = 4.828, $\underline{b}$ = 10.85, $\underline{c}$ = 11.380Å, α = 103.73°.

that other samples may repose misidentified in public or private systematic collections, particularly those of Franklin minerals.

Jerrygibbsite occurs in contact with franklinite, willemite, zincite, and sonolite in a very colorful and uncommon assemblage. The mineral resembles some leucophoenicite, but is decidedly more brown and violet-colored than most leucophoenicite. As with leucophoenicite and members of the Mn-humites, jerrygibbsite is not easily recognized without X-ray or chemical data. In one of the type specimens (R18772), jerrygibbsite is associated with, but not seen to be in contact with, leucophoenicite. On specimen #149037, jerrygibbsite occurs in contact with dark brownish-pink sonolite; both were analyzed and have essentially identical compositions within analytical error, which further supports their polymorphic relationship. The analyses are low by 2–3 weight percent and are not given here, but they nonetheless confirm equality of composition for these phases. The sonolite and jerrygibbsite composition, with (OH) calculated and F undetermined, yields the formula calculated on the basis of Si = 4: $(Mn_{8.24}Zn_{0.45}Mg_{0.22}Ca_{0.11}Fe_{0.03})_{\Sigma 9.05}(SiO_4)_4(OH)_{2.10}$. The compositions of both the sonolite and jerrygibbsite are identical to two decimal places. Both species were also characterized by X-ray powder diffraction techniques.

A notable characteristic of the jerrygibbsite assemblages, compared with those of most leucophoenicite, is the virtual absence of calcium-bearing minerals, which are almost invariably found associated with leucophoenicite. This is, however, only a rule-of-thumb; leucophoenicite has been found, albeit rarely, without associated calcium-bearing phases. These latter observations are of a general nature, based on the examination of a large number of specimens.

Discussion

The chemical, X-ray diffraction, and other data for jerrygibbsite clearly shows that it belongs to the humite or leucophoenicite group of minerals, but the precise nature of the relation is ambiguous. There appear to be two possible structural relations for jerrygibbsite, and its classification depends on which of these two structure types it possesses.

First, because orthorhombic jerrygibbsite and monoclinic sonolite are both polymorphs of $Mn_9(SiO_4)_4(OH)_2$ and because the relationship between their unit cell dimensions is that of a classic unit-cell twinning relation: *a* (jerrygibbsite) ≃ *a* (sonolite); *b* (jerrygibbsite) ≃ *b* (sonolite); and *c* (jerrygibbsite) ≃ 2 *d* (100) (sonolite), it initially appeared to us as if jerrygibbsite is simply the unit-cell twinned equivalent of sonolite, where the term "unit-cell twinning" is used in the sense of Ito's definition (1950). Single-crystal diffraction photographs of both twinned and untwinned crystals of sonolite were directly compared with those of jerrygibbsite in order to investigate such a relation. These comparisons verified the unique diffraction characteristics of jerrygibbsite relative to sonolite and were at least consistent with a unit-cell twinning relation and not twinning by pseudo-merohedry as observed in sonolite. Such evidence is merely nonexclusive of unit-cell twinning, however, and does not exclude other possibilities. It is interesting that where unit-cell twinning is found in other mineral systems, disorder exemplified by streaking of X-ray reflections is common. None has been observed in this case, implying that such a relation may not exist.

A second possible structural relation for jerrygibbsite has been pointed out by White (personal communication, 1982) and is based on the nature of structural relations within the leucophoenicite group *vis-a-vis* those of the humite group as defined, for example, by White and Hyde

(1983). Their view of the structures focuses on the closest-packing of the cations, rather than of the anions, as is conventional (Moore, 1970). Sequences of Mn cations are designated $(1,2^x)$ for leucophoenicite-group phases, and $(2^x,3)$ for the humite-group phases. This is related to the twinned cubic closest packed array of Ni atoms (. . . . 2,2 . . .) in Ni_2In and of Cr atoms (. . . . 1,1 . . .) in CrB, with leucophoenicite having the twinned c.c.p. sequence for Mn of (. . . . 1,2,2,2,1,2,2,2 . . .) or $(1,2^3)$. White (pers. comm., 1982) points out that jerrygibbsite could well be a member of the leucophoenicite-group with sequence $(1,2^4)^2$. White and Hyde (1983) have carried out a TEM study of leucophoenicite and they report that other members of the leucophoenicite series, such as $(1,2^4)$, and $(1,2^5)$ do occur within the prevalent $(1,2^3)$ units which define leucophoenicite. Whether jerrygibbsite is a member of the leucophoenicite or humite groups cannot be proven without a crystal structure analysis or high-resolution TEM study. In this regard, Dr. T. Kato (pers. comm.) has undertaken a structure analysis and we are carrying out a TEM analysis of jerrygibbsite, for which only preliminary results are described below.

There is strong circumstantial evidence that jerrygibbsite is a member of the leucophoenicite group because of the close association of these minerals. Indeed, we noted above that we have not been able to isolate enough jerrygibbsite for a powder diffractometer pattern without including some leucophoenicite. In order to understand this association, an ion-thinned, single-crystal of jerrygibbsite was studied using conventional TEM techniques, with (001) (the interface common to members of the leucophoenicite and humite groups) parallel to the electron beam. Parallel lamellar features, approximately 1000Å in width, were found to be randomly distributed throughout the jerrygibbsite which was otherwise homogeneous. We tentatively assume that these features correspond to interleaved leucophoenicite. The close spatial relation between leucophoenicite and jerrygibbsite strongly implies that they are closely related structurally and that the structure tentatively suggested by White is the correct one for jerrygibbsite. These very tentative results also imply that physical and chemical properties as reported for jerrygibbsite may include a small (<5%) contribution from included leucophoenicite.

The limited occurrence of leucophoenicite and jerrygibbsite relative to the well-known Mn-humites alleghanyite, sonolite, and manganhumite, is somewhat puzzling. Winter *et al.* (1983) have shown that these humites plus the Mn-analogue of olivine, tephroite, all occur at the Bald Knob manganese deposit in Sparta, North Carolina. These phases are shown to exist in equilibrium assemblages as a function of the ratios of SiO_2 and H_2O activities, under amphibolite *P–T* conditions. These minerals are also not uncommon throughout the world, where bulk-rock compositions are appropriate.

Leucophoenicite and jerrygibbsite are relatively rare polymorphs of $Mn_7(SiO_4)_3(OH)_2$ and $Mn_9(SiO_4)_4(OH)_2$, respectively. They occur at Franklin, New Jersey, where sonolite, alleghanyite, and tephroite also occur, in parageneses similar to those of the Mn-humites. Neither jerrygibbsite nor leucophoenicite is known to occur in the very similar deposit at Sterling Hill, New Jersey, suggesting very localized conditions might be needed for the formation of these phases.

In the next section we discuss some compositional factors which may be related to the formation of leucophoenicite. We show that it is characterized, in part, by the presence of Ca and/or Zn, implying that these elements stabilize leucophoenicite relative to manganhumite, and that the two phases may not be, *sensu strictu*, polymorphs. Assuming that jerrygibbsite has a leucophoenicite-group type structure, we tentatively postulate that the stable polymorph of pure $Mn_9(SiO_4)_4(OH)_2$ is sonolite under the *P–T* conditions of formation at Franklin. Because jerrygibbsite always has been found intimately intergrown with leucophoenicite, we postulate that the initial formation of leucophoenicite may serve as the nucleus which requires further growth of a coherent leucophoenicite-group phase, which under the proper bulk composition conditions is jerrygibbsite. Alternatively, some Zn may serve to stabilize the jerrygibbsite structure relative to sonolite, in which case these minerals may not be polymorphs, *sensu strictu*. If the former is correct, sonolite should prove to be the common form of $Mn_9(SiO_4)_4(OH)_2$ and it should generally be the phase observed in synthesis experiments, but jerrygibbsite should continue to be found only rarely and always in intimate association with leucophoenicite.

Leucophoenicite

In order to obtain additional samples of jerrygibbsite, we searched in several private collections. One sample, labelled leucophoenicite, was found in the mineral collection of Mrs. Alice Kraissl, and evidenced a markedly lamellar texture. Inasmuch as this texture is similar to that of jerrygibbsite, but unlike that of other leucophoenicite samples, the specimen was subjected to a detailed investigation. That work indicated that this lamellar mineral is indeed leucophoenicite, albeit one of uncommon habit; most leucophoenicite is glassy with no evident textural features. The identification of this leucophoenicite (NMNH 149543) was verified using single-crystal methods and powder diffractometer techniques as previously described. The powder diffraction data are given in Table 2. The refined unit cell parameters are $a = 4.828(5)$, $b = 10.85(1)$, $c = 11.380(9)$Å, $\alpha = 103.73(5)°$. The powder diffraction data are free of peaks from other phases, including those of jerrygibbsite. This texturally atypical leucophoenicite sample was found to give diffractometer data identical to that obtained from type leucophoenicite. We obtained a microprobe analysis of this sample, using the operating conditions and standards used for jerrygibbsite (R18772); the analysis is presented in Table 2. This yields the chemical formula, calculated on the basis of 14 (O+OH) with water by difference: $(Mn_{5.59}Ca_{0.64}Zn_{0.47}Mg_{0.44}Fe_{0.03})_{\Sigma 7.17}Si_{2.97}O_{12.11}(OH)_{1.89}$, in excellent agreement with the ideal composition of leucophoenicite, $Mn_7(SiO_4)_3(OH)_2$.

As mentioned previously, all the Mn-humites are found in diverse localities except for leucophoenicite and jerrygibbsite. Jerrygibbsite is so far restricted to the Franklin deposit, as was leucophoenicite until recently, when it was reported from Pajsberg, Sweden, by White and Hyde (1983). The Pajsberg occurrence is one of very small quantity and these two species are known in bulk samples only from Franklin. This localized restriction is not easily explained in terms of assemblages or *P–T* conditions. Accordingly, we have examined a large number of leucophoenicite samples in an attempt to make some observations of a general and specific nature which might help to explain the occurrence at Franklin of these species. Unlike many of the 34 species unique to Franklin and Sterling Hill, leucophoenicite does not occur in a very restricted assemblage. An attempt to sort over 70 specimens into assemblages based on associated minerals, textures, ore-relations, and available chemical components failed to limit these samples to a restricted number of parageneses. The opposite, in fact, was evident; leucophoenicite occurs with a broad and diverse array of species both rare and common, and occurs both within ore and in vein assemblages.

Microprobe analyses of 30 samples of leucophoenicite, representing a wide variety of parageneses were carried out. Data from these analyses indicates:

a. Of 30 samples analyzed, 28 have CaO values between 3.8 and 6.9 weight percent, and only two have Mn in excess of 6 atoms of the 7 possible octahedral cations. The Ca content of the 28 calcic samples varies from 0.47 to 0.85 Ca atoms per 7 octahedrally coordinated cations.

b. The two samples with very low Ca content and Mn contents of 6.0 and 6.3 atoms per 7 octahedral cations were studied using single-crystal and powder diffraction methods and found to be leucophoenicite, but multiply twinned.

c. All the analyzed leucophoenicites contain zinc which varies from 0.23 to 0.47 Zn atoms per 7 octahedrally coordinated cations. There is no apparent systematic variation between Ca and Zn, Mg or $\Sigma(Zn+Mg)$. The Zn content is highest in those samples associated with zincite, although these samples comprise a minority among known leucophoenicite assemblages. In the majority of leucophoenicite assemblages, zincite is usually absent and willemite is the dominant Zn-bearing phase.

d. Almost all the leucophoenicite assemblages studied have bulk-rock compositions high in calcium. The associated minerals vary, but calcite and/or andradite are the dominant Ca-bearing species. Although a few samples were found which were not associated with Ca minerals, these were very small samples, perhaps not at all indicative of the complete *in situ* assemblage.

e. No known leucophoenicite approaches end-member composition; all have some Zn and/or Ca replacing Mn.

The above observations suggest that special compositional factors, at least in part, may be responsible for the formation of leucophoenicite and, perhaps, jerrygibbsite. This suggestion is prompted by the lack of evidence for other special conditions; the presence of Ca or Zn in all samples; the absence of any pure end-member; and the very localized occurrence at Franklin of these minerals in bulk quantities.

The conditions necessary for the formation of jerrygibbsite and leucophoenicite remain enigmatic. Although the solution to this dilemma may be a complex one, involving many factors, it seems likely to us that the above mentioned compositional factors may play some role in stabilizing these species.

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