

Ferrolaueite, a new mineral from Monmouth County, New Jersey, USA

¹Curt G. Segeler

286 East 16 St, Brooklyn, NY 11226, USA

²Paul B. Moore

Department of the Geophysical Sciences, The University of Chicago, Chicago, Illinois, USA

³M. Darby Dyar

Department of Geological Sciences, University of Oregon, Eugene, Oregon 97403, USA

⁴Frank Leans

1030 Fox Chase Road, Philadelphia, Pennsylvania 19111, USA

¹Deceased January 22, 1989

²currently Spring, Texas, USA

³Department of Astronomy, Mount Holyoke College, 50 College Street, South Hadley MA 01075, USA

⁴Deceased December 11, 2005

James A. Ferraiolo

2206 Harwood Lane, Bowie, Maryland 20716 USA

email: jferr@erols.com

ABSTRACT

Ferrolaueite, $\text{Fe}^{2+}(\text{H}_2\text{O})_4\text{Fe}^{3+}_2(\text{H}_2\text{O})_2(\text{OH})_2(\text{PO}_4)_2 \cdot 2\text{H}_2\text{O}$, is a new mineral structurally related to laueite. It occurs as a minor constituent with ferrostrunzite, beraunite, cacoxenite and glauconite in marl banks along My Creek near New Egypt, Monmouth County, New Jersey.

Crystals are up to 200 μm in length, are light brown to orange-brown, have a hardness of 3, good cleavage on {100} and {010}, and its density is 2.515 g/cm^3 . The optical characters are: $\alpha = 1.610(1)$, $\beta = 1.665(1)$, $\gamma = 1.692(1)$ and $2V = 68^\circ$; pleochroism: X = brown, Y = yellow and Z = light brown. The unit cell parameters are: $a = 5.34(8)$, $b = 10.63(8)$, $c = 7.21(8)$ Å, $\alpha = 107.35^\circ$, $\beta = 111.26^\circ$ and $\gamma = 71.27^\circ$. The five strongest X-ray lines [d in Å, (hkl)] are: 6.56, (10)(001), 3.28 (10)(002), 9.87(9)(010), 4.96 (8)(020), 3.97 (6)(-110). Crystal forms are $b\{010\}$, $M\{1-10\}$, $c\{001\}$, $a\{100\}$ and $m\{110\}$.

The mineral name and data were approved by the IMA Commission on New Minerals and Mineral Names (CNMNMN) [now the Commission on New Minerals, Nomenclature and Classification (CNMNC)] prior to publication (IMA 87-046a). Ferrolaueite is the Fe^{2+} analogue of laueite, $\text{Mn}^{2+}(\text{H}_2\text{O})_4\text{Fe}^{3+}_2(\text{H}_2\text{O})_2(\text{OH})_2(\text{PO}_4)_2 \cdot 2\text{H}_2\text{O}$.

PRELUDE

The following paper is a time capsule from 1990. And as such it requires a short history.

Ferrolaueite was approved by the IMA Commission on New Minerals and Mineral Names (CNMNMN) in 1987. The IMA proposal number, IMA 87-046a, indicates it was not approved on the first submission, but required additional data concerning the Fe^{2+} - Fe^{3+} ratio and direct determination of H_2O before it could be approved. (C. Segeler, letter to M. Darby Dyar, 24 May 1988). The final approval occurred in late 1988. Segeler passed away on the 22nd January 1989 after he had largely completed the paper, which was then completed by Paul (Paulus) B. Moore in September 1990.

A preprint of the paper was sent to Frank Leans with a letter dated 1 October 1990, indicating the paper was "sent to *Rocks and Minerals* about one month ago". According to an email from Marie Huizing (4 April 2007), the paper was

submitted to *Rocks and Minerals* on 22 September 1990, and the reviewer recommended "not to publish it", because it was "too technical" for the magazine.

Around the same time (1990-1991), Frank Leans attended various mineral/micromount symposia trying to sell specimens of ferrolaueite. He also distributed copies of the preprint and covering letter from Paul Moore, in order to verify the validity of the species.

The first publication of the name appears to be in the July-August 1992 issue of *Lapis* (Weiß, 1992). 'Ferrolaueit' is given, with composition, crystal system and some physical properties, and the Strunz number VII/D.10-4b (NM). The name is not in bold indicating it was not considered an approved mineral name.

As an indication of how 'lost' ferrolaueite and its publication had become, in 2000 I requested a reprint of a new paper from Dr Paulus Moore (in the old days before e-prints of

articles existed), and in the email request (which I no longer possess), I asked about the status of ferrolaueite. His reply "Ferrolaueite is now 10 years old. You encouraged me to write it up. Thanks. Paulus B Moore, Oct, '00". I recall responding that the paper already existed and needed to be prepared for publication. No other response was received.

In 2007, John Ebner, Jr, of Wall, New Jersey, asked me to assist in finally getting the ferrolaueite paper published. After five additional years of waiting, finally we are here.

We have kept the data herein as it was presented in the original preprint, modified to fit the style of this journal, and with some additional tables, new photos and references.

James A. Ferraiolo, Bowie, MD, USA

INTRODUCTION

Each investigator played a specific role in this study. Therefore, initials of the investigator's name (such as C.G.S. for Curt G. Segeler) will be used when needed.

Publication of the occurrence of ferrostrunzite in the Cretaceous sediments at Mullica Hill, New Jersey (Figure 1) by Peacor *et al.* (1983) suggested that the three hypothetical phases related to ferrostrunzite, e.g., 'ferrolaueite', 'ferrostewartite', and 'ferropseudolaueite' might exist and occur elsewhere in similar New Jersey sedimentary deposits where there was an absence of Mn. In contrast, related Mn²⁺ bearing minerals are principally known from granitic pegmatites. The hypothetical phases would have predominant Fe²⁺ in lieu of Mn²⁺ found in the established species laueite, stewartite and pseudolaueite. Since the Fe²⁺ ion oxidizes much more easily than Mn²⁺, we would even expect 'ferri-' analogues. Indeed, Peacor *et al.* (1987) described the new mineral ferristrunzite from Blaton, Belgium.

F. L. had already noted a number of occurrences of 'strunzite' in marl in Monmouth and Burlington Counties, in usually fine specimens near Marlton, Burlington County, and as abundant material at Mullica Hill, Gloucester County, all in New Jersey, USA. Tests by C.G.S. showed that Mn was absent, and that ferrous iron was abundant, so the specimens were deemed to be ferrostrunzite.

Searching along the banks of My Creek not far from New Egypt, Monmouth County, F.L. found ferrostrunzite intergrown with crystals of habit and colour resembling laueite, a mineral that had not previously been reported from New Jersey. Optical and qualitative tests by C.G.S. suggested that the mineral was the ferrous iron analogue of laueite. The refractive indices and density were somewhat higher than those obtained from laueites found at the Palermo Quarry, North Groton, New Hampshire. Electron microprobe, Mössbauer resonance and vapor pressure analyses; and single crystal and powder X-ray investigation have now confirmed that the mineral is indeed the ferrous iron analogue of laueite, or **ferrolaueite**, named according to its novel chemical composition and its isomorphism

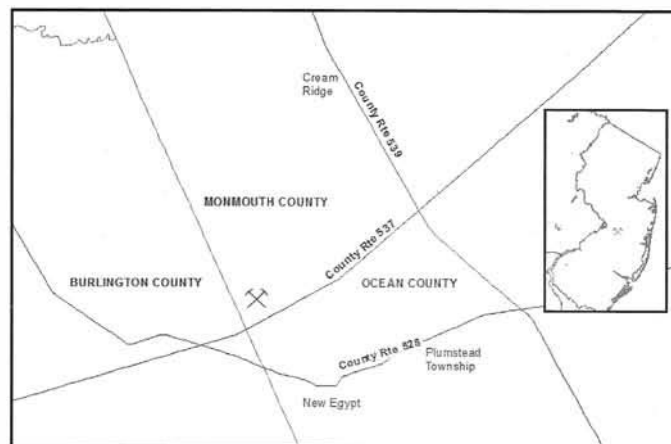


Figure 1: Locality map.

to the laueite structure type. As yet, beyond strunzite and laueite, the ferrous iron analogues of the other related phases have not been found.

The ferrolaueite garnered for investigation appeared as euhedral crystals and formed the basis of the entire study. The new mineral is uncommon and appears to occur in restricted environments. The limited amount available forced us to use several rather specialized techniques. The mineral data and name were approved by the IMA Commission on New Minerals and New Mineral Names (IMA 87-046a).

OCCURRENCE

(F.L.) Ferrolaueite was found at two locations embedded in marl along creek banks in the area whose coordinates are 74°32.6' W and 40°5.5' N (Fig. 1). The first location is 600 metres (2000 ft) north of the bridge that crosses My Creek along the Monmouth-Burlington County border road near New Egypt (My Creek is the name given by F.L. to an otherwise unnamed minor creek because he was once told by a nearby resident "You're in my creek.") (Mindat.org, 2011). At that point a small brook crosses the road through a culvert. The ferrolaueite was found in the marl banks along the brook some 6–15 metres (20 to 50 feet) east of the road. It is intergrown with ferrostrunzite, and appears to be the later mineral to crystallise. Vivianite, beraunite and cacoxenite were found with the ferrolaueite, but their paragenetic sequence was uncertain. Specimens have been found, however, with vivianite (an Fe²⁺ mineral) replacing the beraunite (an Fe²⁺-Fe³⁺ mineral). This suggests that redox reactions became more reducing with time.

The second locality is about 900 metres (3000 feet) along My Creek east of the road bridge and on the south bank, just past a small side stream entering from the north. The ferrolaueite was not found throughout the marl but only made a sporadic appearance in narrow bands, even down below the water level. At this locality the crystals are free-standing and are not intergrown with ferrostrunzite (Figure 4). Here, the marl is black to greenish in colour. Glauconite-1M, KFe³⁺₂[AlSi₃O₁₀](OH)₂, occurs throughout as bluish-green balls up to 1 mm in diameter. It was identified by



Figure 2: Ferrolaueite crystals in marl. FOV about 1.5 mm. Largest group about 300 μm wide. Photo: Peter Cristofono. Specimen: Collection of George and Doug Rambo.

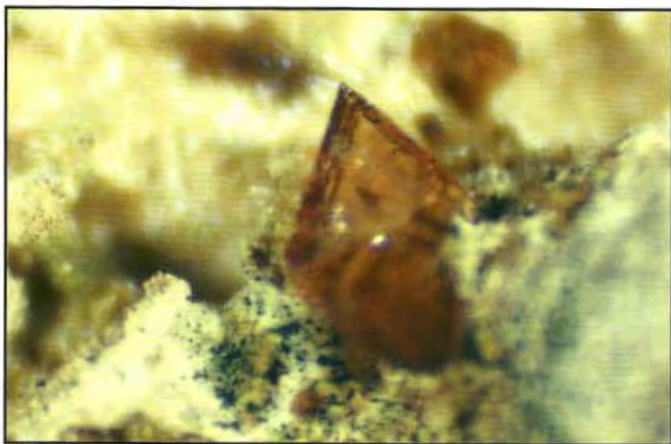


Figure 3: Ferrolaueite with bluish-green glauconite balls. FOV about 2.0 mm, crystal approx. 500 μm . Photo & specimen: Frank Leans.

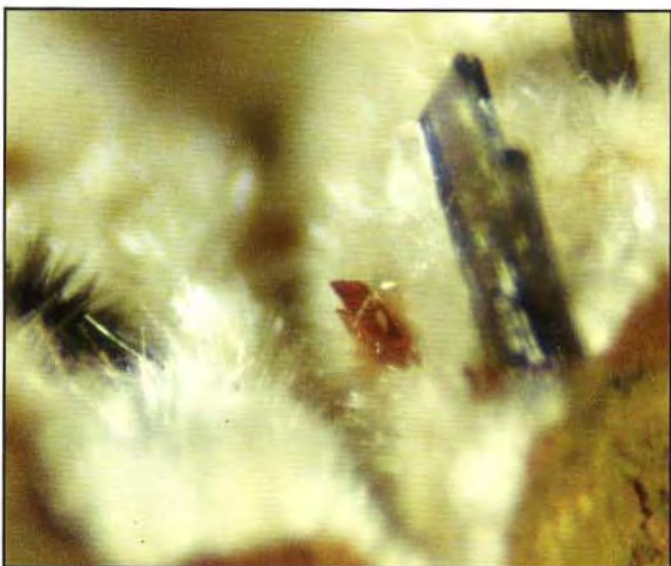


Figure 4: Ferrolaueite with bluevivianite on ferrostrunzite. FOV about 1.4 mm. Ferrolaueite, approx. 250 μm . Photo & specimen: Frank Leans.



Figure 5: Ferrolaueite in marl. FOV about 0.75 mm. Crystal about 250 μm wide. Photo: Peter Cristofono. Specimen: Collection of George and Doug Rambo.

X-ray powder diffraction and compared well with JCPDS 9-439 (Bayliss, 1966) and was not investigated further.

Both sites are on posted private property, and permission from the owners is essential for collecting purposes. Access to the sites is possible only by wading in the creeks.

APPEARANCE AND PROPERTIES

Physical Properties. Ferrolaueite occurs as sporadic crystals and crystal bunches in marl. The crystals range from 50 μm to 200 μm in maximum dimension. Rosettes of several crystals, with individual blades striated on {100} and parallel to {001} are typical (Figure 2). The crystals are light brown to orange-brown, translucent to transparent, have a vitreous lustre and a pale-yellow streak. Crystals easily dehydrate, especially under a microscope lamp, and become ivory-coloured. It is suspected that only water which is hydrogen-bonded and not ligated to a metal are lost.

Ferrolaueite crystals (Figures 2 and 5) resemble the type laueite and paravauxite (Palache *et al.*, 1951). The forms and frequency from observations on a dozen crystals are: $b\{010\}(10)$, $M\{1-10\}(6)$, $c\{001\}(5)$, $a\{100\}(5)$ and $m\{110\}(1)$. A SEM photo of ferrolaueite crystals surrounded by and having attached ferrostrunzite appears in Figure 7. It demonstrates the likelihood of ferrostrunzite contaminant in ferrolaueite studies.

Ferrolaueite is not stimulated by short- or long-wave UV radiation. The Mohs hardness of crystals is 3, tenacity is brittle, there is good cleavage parallel to {100} and {010} and fair parallel to {001}. Fracture is uneven and no parting is observed. The specific gravity, determined by suspension in heavy liquids, ranges from 2.514 to 2.519, mean 2.515(2) g/cm^3 . The density determined from the mean formula and unit cell parameters (*vide infra*) is 2.506(2) g/cm^3 .

Table 1. Ferrolaueite ^{57}Fe Mössbauer results

Peaks	δ	σ	Δ	σ	% area
1-8	1.26	0.006	3.13	0.009	21 $\pm$ 2 %
2-7	1.32	0.137	1.72	0.025	3 $\pm$ 2 %
3-6	0.40	0.005	1.29	0.005	30 $\pm$ 2%
4-5	0.41	0.005	0.66	0.002	46 $\pm$ 2%

Note: Four doublets are listed, δ = isomer shift, σ =standard deviation, Δ = quadrupole splitting. See Dyar (1984) for explanation. Peak 4-5 is broad.

Optical Properties (C.G.S.). The mineral is biaxial (-), $\alpha = 1.610(3)$, $\beta = 1.665(3)$, $\gamma = 1.692(3)$, $2V_{(\text{obs})} = 68(2)^\circ$ and $2V_{(\text{calc})} = 68(3)^\circ$, measured in white light with a blue filter. Errors in parenthesis are combined estimates of deviations in the oils, and of several independent readings of immersed crystals. The dispersion is $r > v$ moderate and orientation: $Z:c = 50^\circ$. The pleochroism is $X = \text{brown}$, $Y = \text{yellow}$ and $Z = \text{light brown}$. The absorption was not determined.

CHEMICAL COMPOSITION

(*M.D.D.*). Chemical analysis was the most difficult part of the ferrolaueite study because little bulk material was available. The laueite structure is complex, so knowledge of the structure type is of tantamount importance. The laueite structure was interpreted by Moore (1965), back at the time when very few phosphate minerals had their structures known. With $R = 0.12$, the structure results admitted refinement of 13 atoms in the asymmetric unit. Bond distances were good to $\pm 0.03 \text{ \AA}$, and gave clear evidence for assigning atomic species. Three distinct transition metal cation sites were available: $M(1) = \text{Mn}^{2+}$, $M(2) = \text{Fe}^{3+}$ and $M(3) = \text{Fe}^{3+}$.

Table 2: Analytical data (wt %) for ferrolaueite

	1	2	3
FeO	6.9 (0.5)	7.1	13.4
Fe ₂ O ₃	30.8 (2.2)	31.5	29.8
P ₂ O ₅	26.2 (2.3)	26.9	26.5
H ₂ O	34.5	34.5	30.3
Total	98.4 %	100.0%	100.0%

Note: 1. The $\text{Fe}^{2+} - \text{Fe}$ ratio from Mössbauer resonance and electron probe is 0.21(2). H_2O by cryopump and vapor pressure measurement. The results are weight per cent oxides. Low total due to cracks? This result gives $\text{H}_{2.06}\text{Fe}_{0.52}^{2+}\text{Fe}_{2.09}^{3+}\text{P}_{2.00}\text{O}_{18.96}$ for $P = 2$ and $D_{\text{calc}} = 2.506 \text{ g cm}^{-3}$. The CAMECA probe range was Fe 24.7 - 28.5% and P=10.6 - 12.8%. The mean is Fe 26.9, P 11.4%. These were the only elements detected above 0.2 wt. % which were greater than fluorine. Estimated errors in parenthesis.

2. FeO , Fe_2O_3 and $\text{P}_2\text{O}_5 \times 1.0263$ to give total 100.0% assuming cracks.

3. For ideal $\text{Fe}^{2+}(\text{H}_2\text{O})_4\text{Fe}^{3+}_2(\text{H}_2\text{O})_2(\text{OH})_2(\text{PO}_4)_2 \cdot 2\text{H}_2\text{O}$.



Figure 6: Ferrolaueite crystals in parallel growth. The crystals are about 280 μm wide. The acicular crystals on and around the ferrolaueite are ferrostrunzite. FOV approx. 680 μm .

The cell contents are:



The formula is expressed to portray as best as possible the ligands which are associated with the appropriate cations. All three unique larger cations are octahedrally coordinated by ligands. The $M(1)$ corresponds to Mn^{2+} of the $[\text{Mn}^{2+}(\text{H}_2\text{O})_4(\text{O})_2(\text{O}_p)_4]$ octahedron, $M(2)$ to the $[\text{Fe}^{3+}(\text{OH})_2(\text{O})_2(\text{O}_p)_4]$ octahedron, and $M(3)$ to the $[\text{Fe}^{3+}(\text{H}_2\text{O})_2(\text{OH})_2(\text{O}_p)_4]$ octahedron. The $M(1)$ octahedron does not link to another octahedron, but $M(2)$ and $M(3)$ link to form corner-sharing octahedral chains through bridging $(\text{OH})^-$ ligands. Thus, there exist two charged octahedral cations, Mn^{2+} and Fe^{3+} , and three distinct octahedra, each with a unique ligand environment.

Mössbauer resonance was the method of choice to allocate atom species and charges in ferrolaueite. In our study, Table 1 outlines the observed results on ferrolaueite. Four ^{57}Fe Mössbauer doublets (peaks) must be explained among

the three Fe-bearing unique octahedral sites. We interpreted Table 1 as follows: $M(1)\text{-Fe}^{2+}$ 21(2)% + Fe^{3+} 13(2)%; $M(2)\text{-Fe}^{3+}$ 30(2)%; $M(3)\text{-Fe}^{3+}$ 33(2)%. The $\text{Fe}^{2+}:\text{Fe}$ total ratio is 0.21(2) and fixes the Fe valences for ferrolaueite.



Figure 7: Ferrolaueite blades in parallel growth. The acicular crystals on and around the ferrolaueite are ferrostrunzite. The crystal group is about 350 μm high.

Table 3: X-ray powder diffraction data for ferrolaueite. The five strongest lines are marked in bold face.

I/I_0	d_{obs}	d_{calc}	h	k	l
9	9.87	9.85	0	1	0
10	6.56	6.56	0	0	1*
3	6.08	6.08	0	-1	1*
8b	4.90	4.93	0	2	0*
1	4.23	4.24	-1	-2	1*
6	3.97	3.99	-1	1	0*
5	3.92	3.94	1	2	0*
2	3.66	3.68	-1	1	1*
3	3.42	3.42	-1	-1	2*
10	3.28	3.29	0	0	2*
2	3.19	3.19	-1	0	2
5	3.10	3.11	-1	2	0
5	2.86	2.87	-1	2	1*
3b	2.73	2.72	0	3	1*
4	2.61	2.61	-1	-4	1*
1	2.53	2.53	-2	0	1*
4b	2.47	2.46	0	4	0
5	2.40	2.40	1	0	2
3b	2.32	2.32	-1	2	2
4	2.19	2.19	1	-2	2
3	2.13	2.13	1	2	2
3	2.09	2.09	2	1	1
1	2.03	2.03	-2	-3	3
3	2.01	2.01	-1	4	0
2b	1.998	1.994	-2	2	0
1	1.903	1.904	1	3	2
1	1.872	1.872	0	-5	2
3	1.843	1.840	-2	2	2
4	1.805				
1	1.760				
1	1.744				
1	1.714				
4	1.679				
4	1.670				
4	1.652				
5	1.641				
3	1.611				
4	1.594				

Note: Miller indices were assigned based on single crystal $F(hkl)$ observed intensities. Those indices at variance with JCPDS 14-246 are starred. JCPDS indices stopped at $d = 2.50 \text{ \AA}$. Our X-ray data were corrected for absorption. The film was corrected for minor shrinkage.

A CAMECA electron microprobe, using synthetic $\text{Ca}_2\text{P}_2\text{O}_7$ and manganoan hortonolite ($\text{FeO } 44.15\%$) standards and wavelength dispersive detector (15 kV, 20 nA, 20 μm beam spot) on 10 points from three grains, provided the contents of elements with atomic number greater than fluorine.

Water content was determined by cryopump and vapor-pressure measurement using the procedure announced by Harris (1981) on 340(10) μg crystals. The losses were 0.6% at 80°C, 23.4 % at 200°C, 10.5% at 500°C, total 34.5%. The errors at each pass are uncertain. Chemical analyses for ferrolaueite appear in Table 2.

The Mössbauer peak sum is low. This is believed to be due to 3(2)% Fe^{2+} contaminant (peaks 2-7) from some associated ferrostrunzite.

CRYSTALLOGRAPHY

X-ray Crystallography (P.B.M.). Establishing the crystallographic characters for ferrolaueite was not a simple problem. Preliminary Buerger precession photographs (MoK_α radiation) confirmed the earlier derived reciprocal lattice of the structure type. Gandolfi mount powder photographs (FeK_α radiation) were then obtained from crushed pure single crystals. It was hoped that least-squares refinement of the d -spacings would yield cell parameters of reasonable precision.

Unfortunately, most of the Miller indices in the International Centre for Diffraction Data (JCPDS) file (Bayliss, 1986), a standard reference for diffraction data, appear to be incorrect. The file for laueite, JCPDS 14-246, could not be reconciled with our data. Triclinic crystals are difficult to index, because no extinction criteria exist and many d -spacings with different Miller indices may overlap. Fortunately, the complete $F(hkl)_{\text{obs}} - F(hkl)_{\text{calc}}$ data were preserved from the single crystal structure study of Moore (1965). It was simply a matter of matching d -spacing with intensities from the visually estimated powder data for related ferrolaueite. Table 3 gives the powder data for ferrolaueite.

With the d -spacings and new Miller indices at hand, the initial unit cell for the precession photographs was refined, including six variable parameters ($a, b, c, \alpha, \beta, \gamma$) and the first 28 observed powder data, which were corrected for absorption. Combining the pertinent diagnostic characters: $a = 5.34(1)$, $b = 10.63(1)$, $c = 7.21(1) \text{ \AA}$, $\alpha = 107.35(8)^\circ$, $\beta = 111.26(8)^\circ$ and $\gamma = 71.27(8)^\circ$, $V = 353.2(7) \text{ \AA}^3$ and $Z = 1$. The unit cell formula is: $[(\text{Fe}^{2+}_{1-x}\text{Fe}^{3+}_x)(\text{H}_2\text{O}_{4-x}\text{OH}_x)\text{Fe}^{3+}_2(\text{H}_2\text{O})_2(\text{OH})_3(\text{PO}_4)_2 \cdot 2\text{H}_2\text{O}]$

Since the Fe valences were fixed to $\text{Fe}^{2+}:\text{Fe}^{3+}(\text{total}) = 0.21(2)$ by Mössbauer resonance, $x = 0.4$, or $(\text{Fe}^{2+}_{0.6}\text{Fe}^{3+}_{0.4})(\text{H}_2\text{O}_{3.6}\text{OH}_{0.4})\text{Fe}^{3+}_2(\text{H}_2\text{O})_2(\text{OH})_3(\text{PO}_4)_2 \cdot 2\text{H}_2\text{O}$. This formula indicates a ferrianferrolaueite. Its calculated density is $D_{\text{calc}} = 2.505(2) \text{ g cm}^{-3}$; that for the hypothetical ferrous end-member, $\text{Fe}^{2+}(\text{H}_2\text{O})_4\text{Fe}^{3+}_2(\text{H}_2\text{O})_2(\text{OH})_2(\text{PO}_4)_2 \cdot 2\text{H}_2\text{O}$ is $D_{\text{calc}} = 2.517 \text{ g cm}^{-3}$. These values compare favorably with $D_{\text{obs}} = 2.515$. The hypothetical 'ferrilaueite' ($\text{Fe}^{3+} > \text{Fe}^{2+}$ in $M(1)$) almost certainly exists: a simple test for $\text{Fe}^{3+}/\text{Fe}^{2+}$ or $\text{Fe}^{2+}/\text{Fe}^{3+}(\text{total})$ ratio in other My Creek occurrences would be helpful.

The good cleavage $\parallel \{010\}$ expresses the sheet-like character of the structure. This plane includes the $[\text{Fe}^{3+}_2(\text{H}_2\text{O})_2(\text{OH})_2(\text{PO}_4)_2]^{2-}$ corner-linked system of octahedra and tetrahedra (Moore, 1975).

RELATIONSHIP WITH OTHER SPECIES

Ferrolaueite belongs to the laueite group, Nickel-Strunz (Nickel and Ferraiolo, 2011) classification 8.DC.30, and

Table 4: Laueite group minerals (Strunz group 8.DC.30)

NS10	Dana	Name	Composition	System Space	Ref
8.DC.30	42.11.10.1	Laueite	$\text{Mn}^{2+}\text{Fe}^{3+}_2(\text{PO}_4)_2(\text{OH})_2 \cdot 8\text{H}_2\text{O}$	Tric. P-1	(1)
8.DC.30	42.11.10.7	Ferrolaueite	$\text{Fe}^{2+}\text{Fe}^{3+}_2(\text{PO}_4)_2(\text{OH})_2 \cdot 8\text{H}_2\text{O}$	Tric. P-1	(2)
8.DC.30	42.11.10.5	Gordonite	$\text{MgAl}_2(\text{PO}_4)_2(\text{OH})_2 \cdot 8\text{H}_2\text{O}$	Tric. P1	(3)
8.DC.30	42.11.11.2	Kastningite	$\text{Mn}^{2+}\text{Al}_2(\text{PO}_4)_2(\text{OH})_2 \cdot 8\text{H}_2\text{O}$	Tric. P-1	(4)
8.DC.30	42.11.10.8	Maghrebite	$\text{MgAl}_2(\text{AsO}_4)_2(\text{OH})_2 \cdot 8\text{H}_2\text{O}$	Tric. P-1	(5)
8.DC.30	42.11.10.6	Mangangordonite	$\text{Mn}^{2+}\text{Al}_2(\text{PO}_4)_2(\text{OH})_2 \cdot 8\text{H}_2\text{O}$	Tric. P-1	(6)
8.DC.30	42.11.10.3	Paravauxite	$\text{Fe}^{2+}\text{Al}_2(\text{PO}_4)_2(\text{OH})_2 \cdot 8\text{H}_2\text{O}$	Tric. P-1	(7)
8.DC.30	42.11.12	Pseudolaueite	$\text{Mn}^{2+}\text{Fe}^{3+}_2(\text{PO}_4)_2(\text{OH})_2 \cdot 8\text{H}_2\text{O}$	Tric. P-1	(8)
8.DC.30	42.11.10.4	Sigloite	$\text{Fe}^{2+}\text{Al}_2(\text{PO}_4)_2(\text{OH})_2 \cdot 7\text{H}_2\text{O}$	Tric. P-1	(9)
8.DC.30	42.11.11.1	Stewartite	$\text{Mn}^{2+}\text{Fe}^{3+}_2(\text{PO}_4)_2(\text{OH})_2 \cdot 8\text{H}_2\text{O}$	Tric. P-1	(10)
8.DC.30	42.11.10.2	Ushkovite	$\text{MgFe}^{3+}_2(\text{PO}_4)_2(\text{OH})_2 \cdot 8\text{H}_2\text{O}$	Tric. P-1, P1	(11)

(1) Strunz (1954); (2) This work; (3) Anthony *et al.* (2000); (4) Schlüter, *et al.* (1999); (5) Meisser *et al.* (2006); (6) Leavens, *et al.* (1991); (7) Anthony *et al.* (2000); (8) Strunz (1956); (9) Hurlbut and Honea (1962); (10) Anthony *et al.* (2000); (11) Chesnokov *et al.* (1983). Strunz codes from Nickel, E. H. and J. A. Ferraiolo (2011); Dana codes from Ferraiolo (2011)

Table 5: Comparison of ferrolaueite, laueite, stewartite, ushkovite $\text{M}(1)^{2+}\text{M}(2)^{3+}(\text{PO}_4)_2(\text{OH})_2 \cdot 8\text{H}_2\text{O}$
Data from Anthony *et al.* (2000) (HB)

Name	laueite	ferrolaueite	gordonite	ushkovite
$\text{M}(1)^{2+} - \text{M}(2)^{3+}$	Mn - Fe	Fe - Fe	Mg - Al	Mg - Fe
<i>a</i> (Å)	5.28	5.34 (1)	5.246 (2)	5.196 (9)
<i>b</i> (Å)	10.66	10.63 (1)	10.532 (5)	10.70 (2)
<i>c</i> (Å)	7.14	7.21 (1)	6.975 (3)	7.14 (2)
α	107.92°	107.35 (8)°	107.51 (3)°	108.6 (1)
β	110.98°	111.26 (8)°	111.03 (3)°	106.95 (5)
γ	71.11°	71.27 (8)°	72.21 (3)°	72.70 (5)
<i>V</i> (Å ³)	346.5	353.2 (7)	334.48	351.13
5 strongest lines in powder pattern				
	9.90 (10)	6.56 (10)	9.78 (10)	9.86 (100)
	3.28 (9)	3.28 (10)	3.17 (8)	6.57 (80)
	4.95 (8)	9.87 (9)	2.87 (7)	3.20 (80)
	6.57 (7)	4.90 (8)	2.56 (6)	3.28 (60)
	2.88 (6)	3.97 (6)	6.32 (5)	4.95 (50)
D (meas.); (calc.)	2.44-2.49; 2.56	2.515(2); 2.506	2.23; 2.22	2.38; 2.40
Mohs hardness	3	3	3.5	3.5
α	1.588 - 1.603	1.610	1.534	1.584 (2)
β	1.654 - 1.659	1.665	1.543	1.637 (2)
γ	1.680 - 1.682	1.692	1.558	1.670 (2)
Opt. character	Biaxial (-)	Biaxial (-)	Biaxial (+)	Biaxial (-)
2V (meas.)	63-66°	68°	73°	50°
2V (calc.)	62-66°	68°		
Colour	orange, honey brown, amber, yellow	light brown orange brown	smoky white buff to colourless	pale yellow yellow-orange to yellow, light-brown
Dispersion	<i>r</i> < <i>v</i> , strong	<i>r</i> > <i>v</i> , moderate	<i>r</i> > <i>v</i> , weak	<i>r</i> > <i>v</i> , strong
Orientation		Z:c = 50° Z:a = 60°	$X \approx \{010\}$	$Y \wedge c = 26^\circ$ X & Y nearly in {010}
X (colour)		brown		
Y (colour)		yellow		
Z (colour)		light brown		
Cleavage	perfect {010}	good {100} } good {010} fair {001}	perfect {010} fair {100} poor {001}	perfect {010}
Reference	HB	This work	HB	HB

Dana (Ferraiolo 2011), Class 42, Hydrated phosphates, etc. containing hydroxyl or halogen, 42.11.10.1–42.11.12 (Table 4). Table 5 lists comparative data for several of the related members.

TYPE SPECIMEN

As of this publication, we have been unable to locate the original type specimen of ferrolaueite. Page 4 of the preprint indicates the holotype was to be placed in the University of Chicago collection and co-types sent to the National Museum of Natural History (NMNH) (Smithsonian Institution). Dr Ian M. Steele (*pers. comm.*, 2007) confirmed there is no type specimen in the University of Chicago's mineral collection. Both Pete Dunn and Paul Powhat (*pers. comm.*, 2007) verified that no ferrolaueite specimens were deposited in the NMNH type collection. Dr George Harlow (*pers. comm.* 2011) also confirmed that no ferrolaueite of any sort was deposited at the American Museum of Natural History, New York.

Frank Leans's letter (6 May 1998) to Dr Bob Ramik of the ROM states that he would be sending material from the My Creek locality and that "I have the gold plated original specimen used for the SEM and analysis, should you want it". Dr Ramik has verified that the ROM does not have that specimen, but they do have a micromount and loose material they received from Frank Leans and John Hallahan. The micromount specimen (ROM accession number M56407) has been declared a **neotype** (Dunn and Mandarino, 1987), and approved by the Commission on New Minerals, Nomenclature and Classification (CNMNC) of the International Mineralogical Association.

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ROM by Frank Leans, digital scans of the SEMs taken for the original paper, which were thought long lost, a scan of Frank Leans's 6 May 1998 letter, and the ferrolaueite micromount specimen presented to the ROM by Frank Leans and John Hallahan in 1998.

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