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Heyite, $Pb_5Fe_2(VO_4)_2O_4$, a new mineral from Nevada

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SUMMARY. Heyite occurs in silicified limestone with other oxidation-zone minerals derived from galena, chalcopyrite, and pyrite. The occurrence is near Ely, Nevada. Most common are pyromorphite, cerussite, and chrysocolla. Heyite occurs on and replaces corroded tungstenian wulfenite. Crystals are small (up to 0·4 mm), simple in habit, and monoclinic. Only {001}, {100}, {110}, and $\{\bar{1}01\}$ have been observed. Twinning on {110} is relatively common. The colour is yellow-orange with a yellow streak, H = 4. Electron probe analyses (average of three) gave PbO 75·4 %, ZnO 0·81 %, FeO 8·41 %, V_2O_5 12·65 %. This leads to $Pb_5(Fe,Zn)_2(VO_4)_2O_4$, with $Z = 1$.

The space group is $P2_1/m$. Cell constants, refined from powder data, are a 8·910 Å, b 6·017, c 7·734 (all ±0·004 Å); β 111° 53′±4′. The strongest powder lines (Cr-$K\alpha$) are: 3·248, $11\bar{2}$, (100); 2·970, $30\bar{1}$, $21\bar{2}$, (69); 2·767, 211 (61); 4·873, 110, (46); 3·674, 111, (35); 2·306 (33); 3·010, 020, (29); 3·412, $20\bar{2}$, $11\bar{2}$, (25); 8·281, 100, (25); and 2·113 (20). G_{calc} 6·284, G_{meas} 6·3±0·2. Optically biaxial with $2V_\gamma$ 82°_{calc}, 89°_{meas}; α_D 2·185, β_D 2·219, γ_D 2·266; all values ±0·01 and determined in S–Se melts. Dispersion is weak with $\rho > \nu$. The orientation is $\beta = b$, α: [001] 36° (in obtuse β). Nonpleochroic.

Three small specimens were found, and represent a total of less than 100 mg of the mineral. One has been deposited with the British Museum (Natural History). The name is for Dr. Max Hey, eminent British chemist and mineralogist.

The cell is strikingly similar to that of brackebuschite but electron probe examination of a newly analysed (by atomic absorption) specimen of the latter from the type locality in Argentina shows a marked chemical difference. Heyite strongly resembles descloizite in appearance.

Occurrence. Heyite was first found on the Betty Jo claim in 1964. The claim, which then belonged to me, is located about eight miles south-east of Ely in White Pine County, Nevada. The mineral was discovered during small scale mining operations. Mineralization on the claim occurs in silicified breccia along the axis of a gentle, plunging fold in Palaeozoic limestone. Sulphides (mostly pyrite, chalcopyrite, and galena) were sparingly disseminated in the quartz, and only traces of galena have survived later oxidation. The most abundant ore mineral in the prospect is pyromorphite, and associated species are heyite, cerussite, wulfenite, mimetite, shattuckite, and chrysocolla. Heyite was found in one small pod of silicified limestone with pale, fresh coloured tungstenian wulfenite. The wulfenite crystals occur in fractures in the quartz and are deeply corroded and replaced by small heyite crystals. Later drusy quartz locally encrusts the heyite.

Physical properties. Heyite crystals are small, never exceeding 0·4 mm in length. The total quantity found would undoubtedly be less than 100 mg. The colour is marigold orange (28–B on the Royal Horticultural Society colour chart) and the streak is amber yellow (18–A). Crystals are transparent and brittle with no cleavage and an irregular fracture. Hardness on the Mohs scale is 4. The specific gravity is 6·3±0·2, measured three times on 7·4 mg in toluene at 24·0 °C with the Berman balance. The appearance and association of heyite could readily lead to confusion with descloizite. Oxide zone assemblages including wulfenite, vanadinite, and descloizite are quite common and could be fruitful future sources of heyite.

Chemical analyses were accomplished on the electron probe after qualitative analyses by the same method showed only lead, iron, and vanadium. Tungsten, molybdenum, and manganese were particularly sought but not found (i.e. less than 0·05 %). No water was found upon stepwise heating to ignition, nor could it be observed in the closed tube. The results of these analyses are presented in table I. The ideal formula derived from this analysis is $Pb_5Fe_2(VO_4)_2O_4$ or perhaps $Pb_5(Fe,Zn)_2(VO_4)_2O_4$. The extent to which Zn could replace Fe is not known, of course, but it could be considerable.

TABLE I. *Chemical analyses of heyite*

	1	2	3	4	5	4a		
PbO	74·5	75·6	76·1	77·52	77·41	Pb^{2+}	5·01	
ZnO	0·89	0·81	0·72	0·83	—	Zn^{2+}	0·17	1·88
FeO	8·41	8·63	8·20	8·65	9·97	Fe^{2+}	1·71	
V_2O_5	12·3	13·4	12·3	13·00	12·62	VO_4^{3-}	2·06	
Sum	96·1	98·4$_4$	97·3$_2$	[100·00]	100·0	O^{2-}	3·80	

1 and 2. Electron-probe analyses by R. F. Symes, British Museum (Natural History).

3. Electron-probe analysis by A. M. Clark, British Museum (Natural History).

4. Average of analyses 1 to 3, calculated to 100 %.

4a. Empirical unit-cell contents, from the average analysis of col. 4.

5. $Pb_5Fe_2^{2+}(VO_4)O_{24}$.

In cold 1 : 1 HNO_3 heyite is unaffected but it slowly and completely dissolves when warmed. In 1 : 1 HCl it reacts quickly to form $PbCl_2$. It quickly dissolves in hot 40 % KOH but is unaffected when cold.

Morphology. Crystals of heyite tend to be imperfect and larger ones show composite structure like the 'bow ties' of prehnite, with *b* axes diverging by a few degrees. Smaller crystals did provide goniometric data but cell constants obtained from X-ray data were used for indexing the goniometric reflections, since many were slightly blurred or streaky.

Crystals are elongate on the *b* axis and tabular on {100}. The only forms found are *a* {100}, *c* {001}, *d* $\{\bar{1}01\}$, and *m* {110}. Twinning on {110} is fairly common in the specimens, and the twin drawn in fig. 1 is typical. No repetitive twinning was observed, most twins consisting of two individuals joined as a Y, but a few triplets resembling a K were found.

X-ray analysis. One of the smallest crystals was used for Weissenberg and rotation photographs. Diffraction spots were slightly blurred but readily indexable, and the space group $P2_1/m$ was found. Cell constants were refined from powder data using a programme written by F. B. Millett: a 8·910 Å, b 6·017, c 7·734, all ±0·004 Å, β 111° 53′±4′. The indexed powder pattern is given in table II. The cell volume is 380·88 Å^3, and if $Z = 1$ the calculated density is 6·284 g/cc.

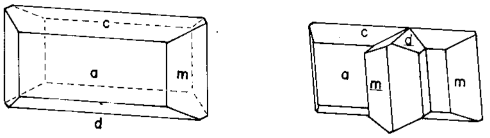

FIG. 1. Heyite; simple crystal and twin on *m*(110).

TABLE II. *X-ray powder data for heyite;* Cr/V *Kα radiation,* 114 *mm camera*

I	d_{meas}	d_{calc}	*hkl*	I	d_{meas}	d_{calc}	*hkl*	I	d_{meas}
25	8·281 Å	8·270 Å	100	12	3·166 Å	3·117 Å	201	9	2·277 Å
46	4·873	4·868	110	29	3·010	3·011	020	9	2·255
16	4·628	4·635	101	69	2·970	2·970	$30\bar{1}$	6	2·172
5	4·350	4·351	$20\bar{1}$			2·968	$21\bar{2}$	20	2·113
9	4·134	4·135	200	4	2·916	2·920	102	15	2·082
12	3·861	3·859	$10\bar{2}$	17	2·825	2·829	120	6	2·046
35	3·674	3·673	111	61	2·767	2·768	211	10	2·022
9	3·592	3·590	002	18	2·625	2·628	112	5	1·984
9	3·524	3·527	$21\bar{1}$	9	2·484			7	1·952
25	3·412	3·411	$20\bar{2}$	10	2·392			10	1·930
		3·409	210	7	2·358			22	1·872
100	3·248	3·249	$11\bar{2}$	33	2·306			plus 21 additional weak lines to 1·250 Å	

Optics. In thin section heyite strongly resembles descloizite, although heyite has somewhat lower birefringence. The colour is orange-yellow and pleochroism is imperceptible. The indices were measured for the sodium D line in S–Se melts: α 2·185, β 2·219, γ 2·266, all ±0·01. The melts were uncovered and checked by the Brewster method after immersion. The calculated $2V_\gamma$ is 82°, measured is 89°. The optic orientation is $\beta = b$, α: [001] 36° in obtuse β. Extinction in thin section is of course parallel in prismatic sections. Dispersion of the optic axes is weak with $r > v$.

Discussion. Although heyite strongly resembles descloizite upon casual examination, the differences melt away when the two species are closely compared. More striking is the resemblance of heyite and brackebuschite. At one point in this study I thought the two species might be isomorphous. An essentially Mn-free brackebuschite has been described incompletely by Herman *et al.* (1961) but their data are unconvincing. This interesting problem is discussed more fully in the following paper.

There are a number of mineral names from the past that are now relegated to synonymy with descloizite. Descriptions of these were examined to see if heyite might have been poorly described in the past and mistakenly considered descloizite by later workers; such an error is not unlikely. But dechenite (Bergemann, 1850), eusynchite (Fischer and Nessler, 1854), aræoxene (von Kobell, 1850), wicklowite (d'Achiardi, 1883), etc., are all notably deficient in PbO when compared with heyite. It may be argued that analyses in some cases are suspect, but if earlier reports are taken as literally accurate, heyite has not been observed previously.

Heyite is named to honour Max M. Hey, eminent British chemist and mineralogist. A type specimen has been deposited at the British Museum (Natural History). The mineral and name have been approved by the committee on new minerals and mineral names, I.M.A.

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