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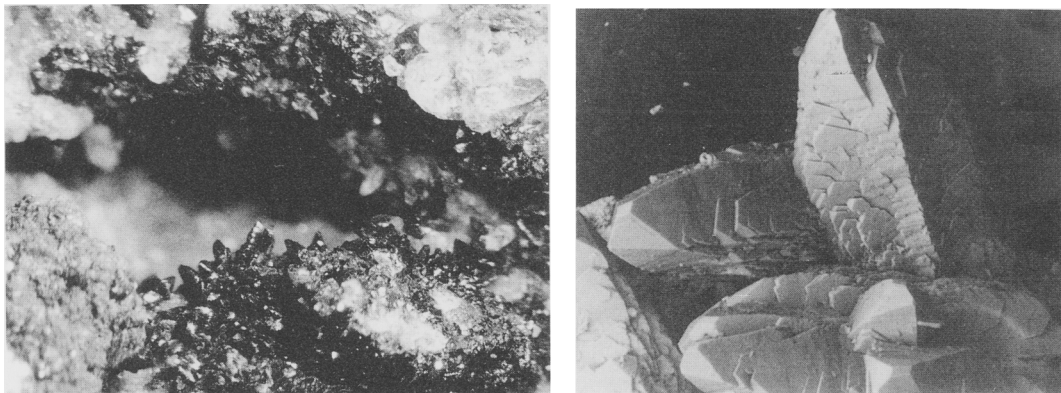
Hentschelite and perloffite from the Spring Creek Copper Mine, South Australia

HENTSCHELITE, $\text{CuFe}_2^{3+}(\text{PO}_4)_2(\text{OH})_2$, a new member of the lazulite group, was recently described from Reichenbach, Federal Republic of Germany (Sieber *et al.*, 1987). At the same time as the proposal to establish hentschelite as a new species was before the IMA Commission on New Minerals and Mineral Names, a barbosolite-like mineral was discovered on specimens from the Spring Creek Copper Mine, near Wilmington, South Australia. These specimens had been forwarded for identification to one of the authors (W. D. B.) by a local collector, Mr John Toma. The mineral was recognised as a new species, but subsequently confirmed as being hentschelite following advice from the Commission Chairman, Dr Joe Mandarino, and discussions with Professor Ekkehart Tillmanns, one of the authors describing the new species.

This paper presents data on the South Australian occurrence of hentschelite and records the first discovery of perloffite, $\text{Ba}(\text{Mn,Fe}^{2+})_2\text{Fe}_2^{3+}(\text{PO}_4)_3(\text{OH})_3$, in Australia, also from the Spring Creek Mine.

Occurrence and appearance. Both hentschelite and perloffite occur as well-formed crystals in cavities lined with colourless quartz crystals in a brecciated quartz–limonite host rock. The two minerals have not been observed together. Associated species in the cavities include cuprite crystals, spongy aggregates and crystalline masses of native copper, together with less abundant malachite and baryte. On perloffite specimens, the quartz may also enclose patches of dark brown glassy material forming partially etched tubules and spherules.

The hentschelite forms lustrous, deep greenish



FIGS. 1 and 2. FIG. 1 (*left*). Hentschelite crystals up to 0.4 mm long. FIG. 2 (*right*). Group of hentschelite from the Spring Creek Mine showing twinning and multiple interpenetration. Scanning electron photomicrograph; largest crystal 0.4 mm long.

black crystals up to 0.5 mm long, usually in clusters and drusy patches (Fig. 1). The crystals may be short and dominated by pyramidal forms or more elongate with 'prism' faces slightly concave. What appear to be single crystals are usually made up of many sub-parallel interpenetrating individuals (Fig. 2). Rotation and Weissenberg studies show that the hentschelite crystals are elongated along the $[102]$ direction. Although the characteristic twinning along $[102]$ shown by the German hentschelite crystals is not observed (Fig. 3), the elongation of the Spring Creek crystals and the symmetry of their terminal faces are suggestive of twinning. Optical examination confirmed the presence of a twin plane parallel to the elongation direction.

A typical Spring Creek hentschelite crystal is compared to one from the type locality in Fig. 3. Forms common to both include $\{011\}$ and $\{\bar{1}11\}$. However, on the Spring Creek crystals, an additional form which is probably $\{203\}$ or $\{201\}$ gives small faces at the intersections of the main terminal forms. In thin section, hentschelite from Spring Creek shows marked pleochroism from bluish green to yellowish brown, very similar to that shown by crystals from the type locality.

Perloffite occurs as opaque, deep clove brown and transparent reddish brown, spear-shaped crystals up to 1 mm long (Fig. 4). Crystals may also occur as subparallel intergrowths, while a massive, concretionary form has also been observed (Fig. 5). Twinning has not been observed in perloffite and most crystals appear to consist of the simple forms $\{101\}$ and $\{021\}$.

X-ray crystallography. A total of 23 X-ray powder diffraction reflections was used to refine the con-

stants of the monoclinic unit cell of hentschelite, a 6.981, b 7.764, c 7.284 Å, β 117.68°, which are in close agreement with hentschelite from the type locality. Weissenberg and rotation studies on single crystals were attempted but the difficulty of obtaining untwinned or non-penetrating individuals precluded further structural refinement. X-ray powder diffraction data for perloffite are in close agreement with the data for the type material.

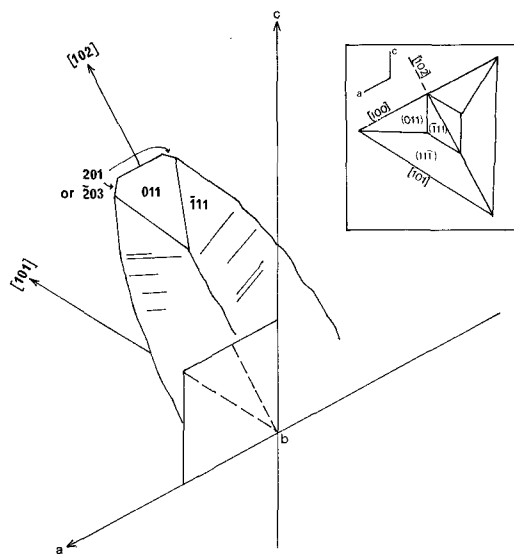


FIG. 3. Typical Spring Creek hentschelite crystal showing relationship of characteristic forms to those of twinned hentschelite from Reichenbach (inset).



FIGS. 4 and 5. FIG. 4 (left). Scanning electron photomicrograph showing typical perloffite crystals from the Spring Creek Mine. Crystals are about 0.5 mm long. FIG. 5 (right). Massive, concretionary perloffite about 5 mm thick from Spring Creek Mine.

Chemistry. Both minerals were analysed on a JEOL electron microprobe at 15 kV and approximate specimen current of 0.02 μ a. Standards used were pure metals (Cu, Zn, Mn), benitoite (Ba), fluorapatite (P), arsenopyrite (As), corundum (Al), periclase (Mg) and hematite (Fe). The compositions and resulting formulae are shown in Table 1.

TABLE 1. Electron microprobe analyses of hentschelite and perloffite from the Spring Creek Mine.

wt%	1	2	3	3a	4	5	6	7
CuO	17.87	15.24	16.60	16.60	19.89	24.08	23.47	24.43
BaO						17.20	20.13	14.74
MnO						1.34	0.20	1.53
CaO						0.46	0.13	0.20
MgO								
FeO				2.59				
Fe ₂ O ₃	39.05	42.31	41.10	38.25	36.37	21.62	21.21	25.75
Al ₂ O ₃	0.15	0.23	0.25	0.25	1.52	0.04	0.28	1.19
As ₂ O ₃	0.87	0.67	0.77	0.77	2.11	0.25	0.34	0.46
P ₂ O ₅	35.56	35.24	36.09	36.09	33.24	30.69	31.17	30.75
H ₂ O			4.0	4.0	4.4			
Total	93.50	93.69	98.81	98.11	97.53	95.68	96.93	99.05
Formula based on 10 oxygen					Formula based on (P+As)=3			
Cu			0.84	0.84	1.03	1.08	1.04	1.09
Ba						1.67	1.93	1.43
Mn						0.17	0.02	0.19
Ca						0.08	0.02	0.03
Mg								0.38*
Fe ²⁺				0.15				
Fe ³⁺			2.06	1.93	1.88	1.87	1.81	1.84
Al			0.02	0.02	0.12	0.01	0.04	0.16
As			0.03	0.03	0.07	0.01	0.02	0.03
P			2.04	2.05	1.93	2.99	2.98	2.97
OH			1.78	1.79	2.02			

Hentschelite from Spring Creek Mine

1,2: analyses show range in Cu:Fe

3: average of 13 analyses

3a: composition in 3 with 7% Fe³⁺ redistributed to Fe²⁺

Hentschelite from Reichenbach

4: analysis from Sieber et al (1987)

Perloffite from Spring Creek Mine

5,6: crystals; analyses show range in Ca:Mn

7: massive form (* Excess iron as Fe²⁺)

Analyst: W. Birch (1, 2, 3, 5, 6, 7)

For the hentschelite, the composition was determined on 13 points, with oxygen plus hydrogen calculated by difference and hydroxyl apportioned by charge balancing. This gives rise to an initial empirical formula close to $\text{Cu}_2\text{Fe}_3^+(\text{PO}_4)_3(\text{OH})_4 \cdot \text{H}_2\text{O}$. Wavelength-dispersive scanning of the hentschelite revealed no further elements with atomic number greater than 8, other than Cu, Fe, Al, As and P, present in consistently detectable amounts.

Differential thermal analysis of 2.78 mg of sample showed no evidence for low-temperature water loss (Fig. 6) and a water content close to 4 wt. %.

Recalculation of the formula on the basis of 10 oxygen atoms and by assuming all Fe is present in the trivalent state gives $\text{Cu}_{0.84}(\text{Fe,Al})_{2.08}(\text{PO}_4, \text{AsO}_4)_{2.05}(\text{OH})_{1.8}$. By comparison, the formula calculated on the same basis for the type hentschelite (Table 1) is $\text{Cu}_{1.03}(\text{Fe,Al})_{1.99}(\text{PO}_4, \text{AsO}_4)_{1.99}(\text{OH})_{2.0}$.

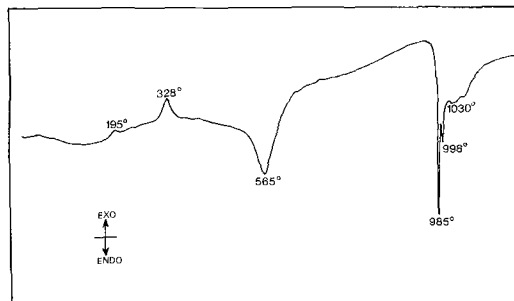


FIG. 6. Differential thermal analysis curve for hentschelite from Spring Creek Mine.

Hentschelite is isostructural with lazulite and the lazulite-group minerals which include scorzalite and barbosalite (Sieber *et al.*, 1984). It may be regarded as the Cu-Fe³⁺ analogue of lazulite (scorzalite). As such, Cu occupies the 2(a) site and Fe³⁺ a 4(e) site (of space group No. 14, P2₁n/n) instead of, respectively, (Fe²⁺, Mg) and Al in lazulite (scorzalite). Alternatively, hentschelite may be regarded as the Cu analogue of barbosalite, in which case Cu occupies the 2(a) site instead of Fe²⁺.

The deficiency in Cu in the formula presented above for Spring Creek hentschelite (relative to the lazulite-type formula) is best explained not by invoking vacancies in the 2(a) sites but by redistribution of some of the total Fe to the divalent state. The formula for Spring Creek hentschelite which best fits the ideal structural formula for the lazulite-group minerals, $M^{2+}M_2^{3+}(PO_4)_2(OH)_2$, is one for which approximately 7% of the total Fe is present as Fe²⁺. The formula, based on 10 oxygen atoms, is $(Cu_{0.84}, Fe_{0.15}^{2+})_{0.99}(Fe_{1.93}^{3+}, Al_{0.02})_{\Sigma 1.95}(PO_4)_{2.05}(AsO_4)_{0.03}(OH)_{1.79}$ (Table 1, 3a). The preferred simplified formula for the South Australian hentschelite is therefore $(Cu, Fe^{2+})Fe_2^{3+}(PO_4)_2(OH)_2$, representing a ferroan hentschelite. This suggests a degree of solid solution from the end-member hentschelite composition towards the end-member barbosalite composition.

Five analyses were obtained on perloffite, three on crystals and two on the massive material. All analyses are richer in Ba than the type material from the Big Chief Mine, South Dakota, USA (Kampf, 1977), to the extent that it was necessary to group all Ca with Mn and Mg for formula calcula-

tion. In both the crystals and the massive variety, variation in Mn, Ca and Fe was noted, with an apparent substitution relationship between Mn and Ca. In the massive form, some of the total iron was assigned to Fe to fill the divalent cation (i.e. 'Mn') site.

The amorphous dark brown glassy material occurring on the perloffite specimens was found to be silica-rich (94 wt. % SiO₂), with small amounts of manganese (4 wt. % MnO) and barium (2 wt. % BaO) and trace amounts of sodium and phosphorus. This composition suggests that the dissolution of this glassy material may have provided the necessary elements for crystallisation of the perloffite.

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New mineral records from Funafuti, Tuvalu: gypsum, brucite, ettringite

AMATUKU is one of the northern islets of Funafuti atoll (lat: 179° E., long: 8° 30' S.) lying north and west of the main inhabited islets of Fongafale-

Tengako. On the eastward-facing ocean coast, ruins of an old wall occur at the top of the intertidal zone, built on an eroding low rampart of dead