

## Waylandite: new data, from an occurrence in Cornwall, with a note on 'agnesite'

IN the course of a continuing review of rare minerals that have been reported from the British Isles, we have examined Cornish specimens that purported to be the bismuth silicate, eulytine (Collins, 1881). Two localities are involved: the Restormel (also Royal) iron mine, near Lostwithiel, noted for its remarkable goethite crystals; and Wheal Coates, St Agnes, best known for its pseudomorphs of cassiterite after orthoclase.

Collins' specimens, one from each locality (nos. 1588 and 1589, respectively), are in the mineral collection of the Royal Institution of Cornwall, Truro; and another Restormel specimen (BM 32875, Talling no. 614) is in that of the British Museum (Natural History). Specimens from both localities are rather unprepossessing, showing some 'bismuth ochre'. Only on the Restormel material are there a few small, shining crystals, which have proved to be waylandite, a member of the crandallite group; but we have found no eulytine (Macpherson, 1983, p. 249). The dealer Richard Talling, who supplied the BM specimen in 1861, invoiced the crystals as being 'bismuth blende' (= eulytine) and thus seems to be responsible for the original identification, presumably on the basis of appearance and association.

A second Talling specimen was acquired as bismutite with the Russell collection (BM 1964R, 7185), and the exact fit of its broken surface shows that it is the 'other half' of BM 32875. It bears the printed number 765, with solid lines above and below, in contrast with the handwritten no. 614; and it is instructive to note that Talling used written numbers for the best specimens he sold, with a different sequence of printed ones for those that he considered less good.

The Wheal Coates specimen (RIC no. 1589) has neither waylandite nor eulytine on it, and the earthy mineral gives a clear X-ray powder pattern of bismutite, the basic carbonate of bismuth. Similar material was first examined by the Revd W. Gregor, in about 1809, who supplied the specimen described as an earthy steatite-like mineral and figured in Sowerby's *British Mineralogy* (Vol. IV, 1811). The status of this material as a carbonate was doubted by Beudant (1832), and later by Greg and Lettsom (1858), but was accepted by Brooke and Miller (1852) who named it agnesite for the locality. It would seem that Gregor (misnamed 'Macgregor'

by Greg and Lettsom, and in the 5th and 6th editions of Dana's *System*, 1868 and 1892), for whom the mineral was called gregorite by Adam (1869), has finally been vindicated. We have not, unfortunately, been able to examine the Gregor specimen discredited by Greg and Lettsom; once in the Allan-Gregor collection, it was exchanged to Columbia College (now University), New York, in 1891.

The crandallite group contains about twenty minerals (Fleischer *et al.*, 1984); they are rhombohedral phosphates and arsenates with the general formula  $AB_3(XO_4)_2(OH)_6$ . Waylandite is a bismuth aluminium phosphate and is a very rare mineral; it was first described by von Knorring and Mrose (1963) as a white compact fine-grained powder replacing bismutotantalite in the lithium pegmatite at Wampewo Hill, Busiro County, Uganda. Its formula given by these authors is  $(Bi,Ca)Al_3(PO_4, SiO_4)_2(OH)_6$ . As far as we know, the only other occurrence of waylandite is from Ngusa, Kivu, Zaïre; an analysis of material from this locality has been included in this investigation.

The significance of the Cornish occurrence of waylandite is that the Restormel crystals, although less than 0.5 mm in size, are sufficiently large to permit, for the first time, determination of the mineral's optical properties and character. X-ray examination of both specimens showed, again, that the massive brown matrix was bismutite while the colourless or brownish crystals scattered over both specimens and several bluish crystalline bands were all waylandite. Microscopic examination of grains from the polished mount used in the electron probe microanalysis of BM 32875 showed the mineral to be uniaxial positive, as are most other members of the crandallite group (Fleischer *et al.*, 1984). The fragments examined were colourless with minute brown inclusions (probably bismutite); the refractive indices were  $\omega$  1.748 and  $\epsilon$  1.774. Most grains showed twinning, cyclic in some cases. Similar observations were obtained on waylandite grains from the Truro Museum specimen. Our findings are at variance with the one optical observation von Knorring and Mrose (1963) were able to make on the Ugandan waylandite; they reported it to be uniaxial negative. It is possible that the nature of their material makes this observation questionable.

Electron probe analyses have been obtained (Table I) on fragments of waylandite from BM 32875 and Truro 1588, using both wavelength-dispersive (Cornish specimens) and energy-dispersive (Zaire specimen) techniques (on a Cambridge Microscan 9 and Geoscan with Link energy-dispersive system respectively). Standards used in the Microscan 9 were wollastonite (Ca and Si), jadeite (Al), apatite (P), barium fluoride (Ba), and pure iron, copper and bismuth. The energy-dispersive analyses were standardized on previously calibrated pure cobalt metal. In both cases an acceleration potential of 20 kV was used. After ZAF corrections, the water content was estimated by the difference to 100% for each determination. The Zaire waylandite (BM 1982, 439) was powdery and unsuitable for the relatively slow analysis time in a wavelength-dispersive instrument.

TABLE I. Waylandite analyses

	1	2	3	4	5	6
Al <sub>2</sub> O <sub>3</sub>	26.52	28.1	27.33	25.29	29.27	26.23
SiO <sub>2</sub>	0.15	0.11	0.18	0.06	4.68	-
P <sub>2</sub> O <sub>5</sub>	23.96	22.04	20.96	21.81	22.15	24.39
CaO	0.75	1.17	0.63	1.40	2.93	-
FeO	0.81	0.18	0.15	0.65	-	-
MnO	-	-	-	0.02	-	-
CuO	0.81	0.81	1.06	-	-	-
BaO	1.01	0.94	0.77	-	-	-
Bi <sub>2</sub> O <sub>3</sub>	54.84	32.27	34.89	37.32	28.28	40.04
H <sub>2</sub> O	11.15*	14.32*	14.03*	13.45*	12.89*	9.29

\*Calculated by difference

\*H<sub>2</sub>O\* = 12.34%, H<sub>2</sub>O<sup>-</sup> = 0.55%.

1. BM 32875. Restormel Mine, Cornwall. Brownish crystal.
2. Truro Museum 1588. Restormel Mine, Cornwall. Brownish crystal.
3. Truro Museum 1588. Restormel Mine, Cornwall. Bluish crystal.
4. BM 1982,439. Ngusa, Kivu, Zaire.
5. Busiro County, Uganda (von Knorring and Mrose, 1963). Total 100.20%.
6. Ideal composition for BiAl<sub>3</sub>(PO<sub>4</sub>)<sub>2</sub>(OH)<sub>6</sub>.

The agreement between the two methods of analysis is good, and the figures obtained are a good fit to the idealized formula BiAl<sub>3</sub>(PO<sub>4</sub>)<sub>2</sub>(OH)<sub>6</sub>. They are broadly similar to those published by von Knorring and Mrose (1963) for the type waylandite from Uganda but the Cornish specimens contain much less SiO<sub>2</sub>, somewhat less CaO, and significant additional quantities of Ba, Cu and Fe. There is no obvious chemical distinction between the brownish and bluish crystals of waylandite.

Indexed X-ray powder diffraction data for bluish

TABLE II. X-ray powder data for waylandite from Restormel, Cornwall

hk.l	d <sub>calc.</sub>	d <sub>obs.</sub>	I <sub>obs.</sub>	hk.l	d <sub>calc.</sub>	d <sub>obs.</sub>	I <sub>obs.</sub>
-	-	6.100	<3	-	-	1.329	<3
10.1	5.665	5.648	86	20.11	1.322	-	-
00.3	5.392	5.360	18	21.10	1.320	1.319	5
-	-	5.100	<3	41.0	1.320	-	-
10.2	4.843	4.833	15	32.4	1.312	-	-
11.0	3.492	3.482	45	31.8	1.291	-	-
10.4	3.362	3.345	15	41.3	1.282	1.282	8
-	-	3.217	<3b	32.5	1.275	-	-
20.1	2.972	-	-	40.7	1.265	1.267	<3
11.3	2.931	2.918	100	11.12	1.257	-	-
10.5	2.853	2.836	17	22.9	1.252	1.256	7
20.2	2.832	-	-	21.11	1.237	1.236	<3
-	-	2.756	<3	10.13	1.219	1.219	5
00.6	2.696	2.691	20	40.8	1.211	-	-
-	-	2.630	<3	50.1	1.206	-	-
-	-	2.502	<3	50.2	1.196	1.195	<3
20.4	2.422	2.417	14	32.7	1.190	1.189	9
21.1	2.263	2.258	11	41.6	1.185	-	-
21.2	2.209	2.201	33	-	-	1.175	<3
10.7	2.200	-	-	31.10	1.164	-	-
11.6	2.134	2.129	14	33.0	1.164	1.164	8
30.0	2.016	2.016	<3	50.4	1.159	-	-
21.4	1.990	1.988	9	20.13	1.151	-	-
10.8	1.918	1.918	5	32.9	1.144	-	-
30.3	1.888	1.888	33	42.1	1.140	-	-
21.5	1.867	1.863	8	33.3	1.138	1.138	<3
20.7	1.836	-	-	10.14	1.135	-	-
-	-	1.826	<3b	50.5	1.133	-	-
00.9	1.797	-	-	42.2	1.132	-	-
-	-	1.772	<3	30.12	1.121	1.120	5
22.0	1.746	1.744	21	31.11	1.106	-	-
20.8	1.681	1.681	5	40.10	1.105	1.105	5
31.1	1.668	-	-	42.4	1.100	-	-
22.3	1.661	1.662	<3	21.13	1.093	1.093	9
31.2	1.642	1.644	<3	51.1	1.084	-	-
21.7	1.629	1.625	4	20.14	1.079	-	-
30.6	1.614	1.615	<3	00.15	1.078	1.080	6
11.9	1.598	1.596	11	42.5	1.076	-	-
-	-	1.576	<3	51.2	1.077	-	-
10.10	1.563	1.562	<3	50.7	1.072	-	-
31.4	1.549	-	-	33.6	1.069	-	-
21.8	1.514	-	-	22.12	1.067	1.068	<3
40.1	1.505	1.505	<3	41.9	1.064	1.064	6
31.5	1.489	1.487	11	40.11	1.054	1.053	<3
40.2	1.486	-	-	32.10	1.053	-	-
22.6	1.465	1.464	9	51.4	1.049	-	-
10.11	1.429	-	-	50.8	1.038	-	-
20.10	1.426	1.427	9	21.14	1.031	-	-
40.4	1.416	1.415	<3	11.15	1.030	1.031	5
32.1	1.382	1.383	<3	51.5	1.030	-	-
40.5	1.370	-	-	42.7	1.024	-	-
32.2	1.367	-	-	32.11	1.009	1.008	<3
31.7	1.357	1.356	5	60.0	1.008	-	-
00.12	1.348	-	-	31.13	0.999	0.9996	6
30.9	1.342	1.341	7	-	-	-	-

Fe-K $\alpha$  radiation.  $a = 6.9834 \pm 3 \text{ \AA}$ ,  $c = 16.175 \pm 1 \text{ \AA}$ 

waylandite from Truro specimen 1588 are given in Table II. The data have been refined from high-angle extrapolation graphs and indexed on a rhombohedral cell with  $a = 6.9834 \pm 3$  and  $c = 16.175 \pm 1 \text{ \AA}$  with only a very few additional (impurity) lines. The radiation used was Fe-K $\alpha$ . These dimensions give a unit cell volume of  $683.14 \text{ \AA}^3$ , very close to the value derived from von Knorring, and Mrose's data,  $682.93 \text{ \AA}^3$ . The unit cell contains three formula units, yielding a calculated density for the Cornish waylandite of  $4.08 \text{ g cm}^{-3}$ .

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## Cathodoluminescence of phenakite

A VARIETY of minerals are known to luminesce under electron excitation, i.e. the property of cathodoluminescence. They include calcite, dolomite, apatite, isokite, sellaite, fluorite, strontianite, zircon, wollastonite, scheelite, baddeleyite, monticellite, vesuvianite, scapolite, sodalite and feldspars (Mariano, 1978). The cathodoluminescence of minerals is used as a diagnostic tool to observe textures, to distinguish between different carbonates, different oxidation ratios of trace elements in feldspars, to recognize minerals present in small and infrequent grains and others not readily identifiable by their optical properties (Smith and Stenstrom, 1965; Mariano, 1978; Nickel, 1978; Kopp, 1981; Pierson, 1981). This contribution describes the occurrence of luminescing phenakite in samples from Late Proterozoic phlogopitized, tourmalinized metapelites which comprise the thermal aureole of Palaeozoic alkaline to peralkaline granites at Umberatana, South Australia (Lottermoser, 1986).

Cathodoluminescence studies were conducted on glass-mounted, polished thin sections in a Nuclide Corporation Luminoscope, model R ELM-2A. Observations were performed under vacuum ( $10^{-4}$  bars) at 10 kV with a current of 0.4 mA.

Specimens comprising mineral assemblages of

fluorophlogopite, tourmaline, albite, quartz, corundum, apatite, columbite usually contained several phenakite grains which gave a sky blue cathodoluminescence. A few phenakite grains lacked any signs of any luminescence. This may be interpreted as follows: Luminescing phenakite contains trace element impurities or structural defects which behave as luminescence activators, while non-luminescing phenakite is quenched by the presence of unknown ions. Absence or presence of luminescence may indicate different phenakite generations containing different impurity ions, structural defects or quenching ions.

In contrast to phenakite, beryl present within the alkaline to peralkaline granites did not luminesce under the same electron bombardment conditions. As phenakite possesses many similar optical properties under the microscope to quartz and beryl, cathodoluminescence studies can detect and distinguish minute phenakite grains from faint red, faint dull blue and white luminescing quartz as described by Long and Agrell (1965), Nickel (1978), and Kopp (1981) and from non-luminescing beryl.

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