# SHORT COMMUNICATIONS

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# Rare minerals, including several new to Britain, in supergene alteration of U–Cu–As–Bi–Co mineralisation near Dalbeattie, south Scotland

As a result of a radiometric survey carried out by the Atomic Energy Division of the Institute of Geological Sciences, Miller and Taylor (1966) reported on uranium mineralisation on the coastline south of Dalbeattie, Dumfries and Galloway, Scotland. Some sixty mineralised structures were located and mapped, thirteen of them containing visible uraninite. The uraniferous veins occupy NW trending tear faults, structurally similar to those forming the larger, well-known lead–zinc–copper deposits further west, e.g. near Newton Stewart, and related to the Leadhills–Wanlockhead mineralisation. The formation of the uraninite has been dated by the uranium–lead isotope ratio method as $185 \pm 20$ m.y. (Darnley *et al*, in Miller and Taylor 1966). The vein fractures are mostly in a Silurian hornfels on the footwall side of a major NE–SW fault which downthrows Carboniferous sediments on its SE side. A few of the veins are thought to extend into these Carboniferous beds (Miller and Taylor, 1966).

The primary ore minerals reported by Miller and Taylor (1966) were uraninite, hematite, chalcopyrite, pyrite, native bismuth and minor niccolite, löllingite and sphalerite in a gangue of quartz and dolomite with minor calcite, baryte, and black vitreous 'hydrocarbon'. An interesting suite of supergene alteration products was reported, involving bornite, covellite, zeunerite, boltwoodite, uranophane, erythrite, annabergite, atacamite, connellite, bismoclite, and mixite. This mineralisation is reminiscent of those of the classical sites of Schneeberg in Saxony, Wittichen in the Black Forest, and the Talmessi mine in central Iran.

The present authors and colleagues have investigated the area on a number of occasions from 1967, and from a small number of sites have identified a number of species additional to those listed by Miller and Taylor (1966). These include several species not previously recorded from the British Isles.

Three localities were found to be of particular interest, adjacent to each other, around NX 915 562, near Needle's Eye in the parish of Colvend and Southwick. These are numbered from E to W. *Locality 1* is the native bismuth vein outcrop trench at the topmost edge of the cliff, mentioned by Miller and Taylor (1966). *Locality 2* is a stockwork of cupriferous veinlets in a rock wall just east of our main excavations at Locality 3; this site was not mentioned by Miller and Taylor (1966). *Locality 3* consists of two highly uraniferous fissure veins striking N 10° W, which converge to unite at the top of the cliff. The outcrop of these veins is marked by the trenching carried out during the original survey, and most of our material was obtained from excavations in the trench of the western branch, about half way up the cliff.

## Mineralogy

*Locality 1.* At this locality the vein-filling of granular crystalline native bismuth is bordered by an alteration rim of greenish yellow material surrounding relics of bismuth grains and extending into the neighbouring hornfels. This alteration rim contains bright green mammillary growths and radiating needles of mixite, $BiCu_6(AsO_4)_3(OH)_6.3H_2O$, as reported by Miller and Taylor (1966), and also small brown spherules to 0.2 mm of bismutite, $Bi_2CO_3O_2$, and very rarely, bright yellow transparent long-prismatic crystals of walpurgite, $(BiO)_4(UO_2)(AsO_4)_2.2H_2O$, with oblique terminations, a characteristic habit reminiscent of the type material from the Walpurgis vein at the Weisser Hirsch mine at Schneeberg, Saxony (Weisbach, 1871, 1877). Walpurgite is of particular interest in view of its rarity, being known from few localities in the world, this being the first recorded find from the British Isles. Its identification was confirmed by X-ray powder diffraction by the late Dr R. J. Davis at the British

Museum (Natural History) in 1968. Pale green translucent radiating spherules to 0.25 mm on and around the altered bismuth were identified by the authors and Dr T. M. Seward, and confirmed by Dr R. J. Davis as eulytine, $Bi_4(SiO_4)_3$. Eulytine is also of rare occurrence and new to Britain. The 'eulytine' reported from Cornwall (Collins, 1881) has been re-investigated recently (Clark *et al.*, 1986) and the specimens involved, from Restormel mine, Lostwithiel, and from Wheal Coates, St. Agnes, both in Cornwall, have been shown to be free from eulytine, and to contain waylandite from the former locality and bismutite from the latter.

*Locality 2.* This cupriferous stockwork consists of an interlacing network of veinlets occupying near-rectangular joints exposed on a nearly vertical cliff face a little to the WSW of the bismuth vein. Chalcopyrite and bornite are present, but are mostly oxidised here to blue to green coatings containing small gypsum crystals, langite laths to 0.5 mm, twinned pseudohexagonally, small crystals of brochantite, connellite forming thin but densely packed coatings of deep blue radiating spherules to 0.05 mm in diameter, and small green blades of botallackite. Particularly at its eastern end, well-crystallised rosettes to 1 mm across are found of pink radiating blades of erythrite, with small amounts of associated pale blue spherular aggregates to 0.1 mm of lavendulan, $NaCaCu_5(AsO_4)_4Cl.5H_2O$. Lavendulan was also found, as material of better quality, at Locality 3, and is another very rare species. This lavendulan was collected and identified by infrared spectroscopy by us in 1968 (not 1978 as recorded in Macpherson and Livingstone, 1982), and confirmed by X-ray powder diffraction by Dr R. J. Davis in 1971. This was the first authenticated find of lavendulan from the British Isles. The only other recorded British find is that of sparse powdery material on one specimen from a concretion near Littleham Cove, near Budleigh Salterton, Devon, identified by X-ray powder diffraction as 'freirinite (=Lavendulan of Goldsmith)' (Harrison *et al.*, 1975). Goldsmith's (1877) 'lavendulan' was renamed 'freirinite' by Foshag (1924), and then found by Guillemin (1956) to be identical with the lavendulan of Breithaupt (1837).

*Locality 3.* From the walls of the outcrop exploration trenches of these veins, especially the western branch, orange to yellow to pale greenish microcrystalline supergene uranium minerals can be obtained. These include much uranophane in yellow delicate needles in dark pulvurent material rich in uraninite, with spots of pitchy bitumen. Among this material, orange shiny spherical aggregates less than 0.1 mm across proved to be vandendriesscheite, $PbU_7O_{22}.12H_2O$. This is the first recorded find of vandendriesscheite in the British Isles, and it was identified by X-ray powder diffraction in 1968 by Dr R. J. Davis. Associated with this vandendriesscheite are brownish to orange-yellow short prismatic pseudohexagonal crystals of schoepite to 0.1 mm. Schoepite, $UO_3.2H_2O$, is also new to Britain and was first identified by Dr T. M. Seward by X-ray powder diffraction. An energy-dispersive scanning electron microscope scan of this material by Mr Ian Brough of the Metallurgy Department, University of Manchester and U.M.I.S.T. showed the presence of only major uranium among elements of $Z>8$, the lack of Ca, Ba and Pb in particular confirming the absence of minerals easily confused with schoepite even by X-ray powder diffraction. This has been confirmed by electron microprobe analysis at the Royal Scottish Museum (Macpherson and Livingstone, 1982).

An interesting suite of minerals was found in shaly to slaty country rock from the west wall of the western branch of this vein system, adjacent to the richest vandendriesscheite-schoepite locality. Spots of relict primary tennantite, uraninite and native bismuth remain here, but their secondary oxidation products form well-crystallised encrustations on joint and cavity surfaces. These include beautiful spherical aggregates of bright pale blue lavendulan to 0.25 mm across, with green platy zeunerite and metazeunerite to 0.2 mm, yellow platy metaautunite, pale creamy-yellow tabular kahlerite with metakahlerite, malachite, green globular cornubite, glassy dark green globular mixite and bright green sheaves of tyrolite to 1 mm long. Wulfenite also occurs with these minerals, in grey-brown crystals to 0.5 mm, varying in habit from rectangular plates to tablets to long prismatic crystals elongated on [001], and giving molybdenum blue on evaporation with concentrated hydrochloric acid. The kahlerite $Fe(UO_2)_2(AsO_4)_2.10\text{–}12H_2O$ and metakahlerite, the octahydrate, identified by Dr T. M. Seward by X-ray powder diffraction, are also new to the British Isles. The other species listed were identified by X-ray powder diffraction or by infrared spectroscopy.

## Conclusion

A number of rare mineral species, found associated with veins on the coastline near Dalbeattie, South Scotland, have been produced by interaction of the products of oxidative supergene alteration of primary uranium, copper, bismuth, lead, cobalt, arsenic, and iron minerals. Among these species, the identifications of walpurgite, eulytine, lavendulan, schoepite, vandendriesscheite, kahlerite and metakahlerite are confirmed for the first time from the British Isles.

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# Occurrences of grandidierite, serendibite and tourmaline near Ihosy, southern Madagascar

TOURMALINE is a nearly ubiquitous accessory mineral in metapelites at low and medium grades of metamorphism, whereas the high-temperature borosilicates kornerupine, grandidierite, and serendibite are very rare and occur at the high-grade conditions of the granulite and pyroxene-hornfels facies (de Roever and Kieft, 1976; Grew, 1988; Lonker, 1988, etc.). Grandidierite and serendibite have been found near Ihosy, in southern Madagascar, the former in a seven-phase anatectic gneiss, the latter in a calcsilicate gneiss.

### Grandidierite in anatectic gneiss

In the Precambrian Ihosy formation, banded cordierite–garnet gneisses, leptynites, two-pyroxene metabasic granulites, calcsilicate gneisses and marbles indicate conditions of the hornblende intermediate-pressure granulite facies. A widespread anatectic event produced migmatitic gneisses with seven phases: quartz, K-feldspar, plagioclase, garnet, cordierite, sillimanite, and biotite (with green spinel included in cordierite and garnet) and aluminous residues rich in biotite (biotite–cordierite–garnet or sillimanite, ± quartz) and sometimes containing sapphirine and kornerupine (Mégerlin, 1968; von Knorring *et al.*, 1969; Nicollet, 1985, 1988, 1990). Monazite and zircon from a granodiorite dyke produced by the anatectic event yielded a U–Pb age of $561 \pm 12$ Ma (Andriamarofahatra *et al.*, in preparation).

Dark green tourmaline and blue grandidierite (included in cordierite) occur as very rare crystals in the anatectic gneisses. However, these two