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Rozenite and other sulphate minerals from the Cumbrian coalfield

ROZENITE ($FeSO_4 . 4H_2O$) occurs with copiapite ($Fe^{2+}Fe_4^{3+}(SO_4)_6(OH)_2 . 20H_2O$), pickeringite ($MgAl_2(SO_4)_4 . 22H_2O$) epsomite ($MgSO_4 . 7H_2O$), jarosite ($KFe_3^{3+}(SO_4)_2(OH)_6$) and gypsum ($CaSO_4 . 2H_2O$) encrusting pyrite-rich coal seams in the Oughterside Opencast Coal Site, near Aspatria, Cumbria [NY 110 398].

Although rozenite was first proposed as a new species by Kubisz (1960) its validity was challenged by Fleischer (1961). Further work by Jambor and Traill (1963) established the validity of the name (Mandarino, 1964). Since then the mineral has been reported from several localities, most commonly accompanying other soluble sulphate minerals in oxidized pyrite or marcasite-rich coal seams (e.g. Tien, 1967; Grunner and Hood, 1971; Zodrow and McCandlish, 1978; Coskren, 1981) or in sulphide-rich vein outcrops or tailings dumps (e.g. Wiggins and Horne, 1967; Nambu *et al.*, 1974; Good, 1980; Sabelli and Brizzi, 1984). To date rozenite has been reported from only three British localities: Slateford, Edinburgh; West Mains Coal Mine, West Calder, Midlothian; and Howcommon Limestone Mine, Kilmarnock, Dumbartonshire (Macpherson and Livingstone, 1981). Jambor and Traill (*op. cit.*) have suggested however that the siderotil reported by Midgley (1962) from Thames river gravels may in fact be rozenite.

British records of copiapite are few. It has been described as an associate of melanterite at Ushaw Moor Colliery, Co. Durham (Smythe, 1933), and as an encrustation on decomposing pyrite at Wanlockhead, Dumfriesshire, and Slateford, Edinburgh (Macpherson and Livingstone, *op. cit.*). The British Museum (Natural History) collection includes a specimen from Mount Wellington Mine, Bissoe, Cornwall. Ferricopiapite was described by Smith (1973) from Groverake Mine, Weardale, Co. Durham.

References to British occurrences of pickeringite are also few. Macpherson and Livingstone (*op. cit.*) record Dunkeld, Perthshire. Specimens from Bishop Auckland, Co. Durham, and Gwynfynydd Mine, Trawsfynydd, Merionethshire, are in the British Museum (Natural History) collection.

Rozenite, together with copiapite, pickeringite, epsomite, jarosite and gypsum have recently been found at the Oughterside Opencast Coal Site near Aspatria, Cumbria. The minerals occur here as encrustations and efflorescences on joint surfaces and on the walls of old workings in coal seams near the outcrop.

In the Ten Quarters Seam rozenite (Ph 7367*) occurs as thin white saccharoidal crusts, < 0.2 mm thick and up to 50 mm across, coating pyrite-rich coal. Portions of this seam are locally encrusted with vivid yellow efflorescences of copiapite (Ph 7369) up to 1 mm thick, commonly accompanied by rather globular crusts of epsomite (Ph 7368) up to 3 mm thick and 40 mm across. Areas of bright yellow, crudely globular crusts up to 40 mm across composed of a mixture of epsomite, gypsum and copiapite (Ph 7366) are abundant. Thin white finely crystalline efflorescent crusts of gypsum (Ph 7365) are very common. Earthy pale yellowish brown jarosite (Ph 7357) commonly coats the walls of old underground workings in the coal.

In the Slaty Seam, copiapite (Ph 7354) has been identified as bright yellow rather nodular crusts up to 2 mm thick and 10 mm across. It is accompanied locally by stellate clusters of white acicular crystals of pickeringite (Ph 7364) up to 1.5 mm across.

The supergene minerals recorded here have all developed by oxidation of pyrite-rich coals within 10 m of the present ground surface. Oxidation within the Ten Quarters Seam has no doubt been aided by the extensive old pillar and stall workings within it. In a number of reported occurrences rozenite is accompanied by melanterite ($FeSO_4 . 7H_2O$) and szomolnokite ($FeSO_4 . H_2O$). It has been suggested by Tien (1967) that rozenite has formed by partial dehydration of previously formed melanterite. Neither melanterite nor szomolnokite have been observed at Oughterside and the development here of rozenite as the only ferrous sulphate is probably a function of the relative humidity in the immediate area of crystallization as suggested by Grunner and Hood (1971).

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* BGS X-ray number.

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Cuproadamite and tennantite from Higher Longrigg mine, Hartley Birkett, Cumbria

THE workings of High or Higher Longrigg mine form a series of largely overgrown shallow opencast trials, centred at [NY 798 096] on several small veins in the Great Scar limestone south of Cote Garth at Hartley Birkett, near Kirkby Stephen, Cumbria (Dakyns *et al.*, 1891; Dunham and Wilson, 1985). The gangue consists mostly of opaque pinkish baryte of the 'cawk' variety, sometimes forming large hemispherical aggregates 20 cm or more across. Lesser amounts of fluorite and calcite accompany this baryte. The primary ore minerals are galena and chalcopyrite, but the oxidised copper minerals azurite and malachite are more conspicuous, the former sometimes being relatively well crystallised, usually in blades rarely over 0.5 mm long.

A few of the specimens collected from this site by the author and colleagues (R. Lamb and D. Hacker) in 1966 and 1985, and a specimen collected in 1985 by Brian Young and presented to the author, showed, in addition to the minerals mentioned above, translucent pale green crystals to about 0.1 mm, in crusts growing on azurite (itself sometimes on malachite) in cavities in baryte, and commonly associated with a grey massive sulphide of the tennantite–tetrahedrite group.

The infrared spectrum of the pale green mineral indicates that it is an almost phosphate-free cuproadamite with a composition approximating to $(Cu_{0.7}Zn_{0.3})_2AsO_4OH$, according to the criteria of Braithwaite (1983). This find is of interest in that arsenate minerals are very rare in the Pennine ore deposits, and that no proper description of British adamite, or mention of cuproadamite, has been published. The occurrence of adamite from 'several localities in Cumberland and Cornwall' was mentioned by Kingsbury (1958) and Spencer (1958). None of Kingsbury's Cumberland localities are in the Northern Pennines; they are all in the Lake District (A. W. G. Kingsbury, pers. comm., 1960), and are supported by specimens in the British Museum (Natural History). Hartley (1984), who worked with Kingsbury, lists adamite from the middle level dump of Sandbed mine, from Potts Gill and from the top level on the Netherrow Brow vein, near Dumpy Stone, all in the Caldbeck Fells. The British Museum (Natural History) holds a specimen of beautiful pale blue adamite from Wanthwaite mine, St John's Castlerigg, near Threlkeld.

A sample of the grey sulphide mineral was analysed by Ian Brough of the Metallurgy Department, UMIST and the University of Manchester, using a Philips SEM 505 scanning electron microscope fitted with an EDAX 9100/60 energy dispersive X-ray spectrometer, and using a standardless analysis procedure. The average of four analyses with good reproducibility gave a composition: Cu 35.2; Zn 5.3; Fe 1.3; As 9.8; Sb 2.9; S 45.6 atom %, corresponding to a formula $(Cu_{0.84}Zn_{0.13}Fe_{0.03})_{12}(As_{0.77}Sb_{0.23})_{3.6}S_{13.1}$; the mineral is, therefore, a zincian tennantite. Reports of tennantite–tetrahedrite in the N. Pennines are sparse; Goodchild (1881–2) mentions tetrahedrite from 'east of Harcla, Kirkby Stephen', probably meaning east of Hartley Birkett, which would fit Higher Longrigg mine, and also from Clouds mine in Ravenstonedale. Clough mentions the latter occurrence in Dakyns *et al.* (1891). Small (1982) analysed tennantite from Clouds mine, and tetrahedrite from Cumpston Hill, Mallerstang.

The zincian tennantite seems the likely source of the copper, zinc, and arsenic required for the formation of the cuproadamite by oxidation processes.

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