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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  $(\text{Cu}_{0.7}\text{Zn}_{0.3})_2\text{AsO}_4\text{OH}$ , 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  $(\text{Cu}_{0.84}\text{Zn}_{0.13}\text{Fe}_{0.03})_{1.2}(\text{As}_{0.77}\text{Sb}_{0.23})_{3.6}\text{S}_{13.1}$ ; 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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