

## SHORT COMMUNICATIONS

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### The mineralogy and metamorphism of some gahnite-bearing silicate inclusions in massive sulphides from Fornas, north-west Spain

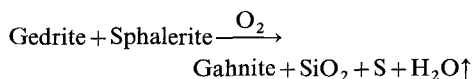
THE metamorphosed copper deposit at Fornas lies 4 km south-east of Santiago de Compostela in north-west Spain (fig. 1). The orebody, which was mined out by 1980, consisted of a lens of pyrrhotite, pyrite, and chalcopyrite with lesser amounts of sphalerite, magnetite, and ilmenite. The massive sulphides contain numerous deformed and disrupted silicate inclusions having 'rolled ball' or *durchbewegung* texture (Vokes, 1969). This texture was produced by deformation of the inclusions within the massive ore. The deformation also effected some mechanical mixing of the sulphide and silicate fractions.

Badham and Williams (1981) and Williams (1982) considered the mineralization to be syngenetic and to have suffered the same history of deformation and metamorphism as its host rocks which are polymetamorphic amphibolite-facies

metabasites. These rocks underwent two periods of amphibolite-facies metamorphism (Williams, *op. cit.*).  $M_1$  crystallized garnet in the metabasites and kyanite in nearby metapelites. It is therefore considered that  $M_1$  was associated with moderate confining pressures.  $M_2$  caused migmatization and hornblende recrystallization in the metabasites but did not crystallize garnet.  $M_1$  assemblages are preserved or were only partially recrystallized during  $M_2$ . Brittle and semibrittle structures of late- $M_2$  age are associated with greenschist-facies retrogression. These data suggest that in comparison to  $M_1$ ,  $M_2$  was a short-lived event which occurred under reduced confining pressures possibly associated with uplift.

The earliest metamorphic assemblages of the silicate inclusions are assumed to have crystallized during  $M_1$ . They contain gedrite, hornblende, phlogopite, plagioclase, zincian staurolite, quartz, and rutile (cf. Table I) usually in this order of decreasing abundance. After these assemblages had crystallized they were deformed and physically mixed with sulphide minerals. The rolled balls are much disrupted, particularly at their margins where trails of silicate grains and grain fragments lie in a sulphide matrix. Within the inclusions there are parallel trails of mechanically introduced sulphides. Gahnite occurs in the inclusions as a reaction product of gedrite with mechanically introduced sphalerite (fig. 2). It forms skeletal overgrowths which corrode, disrupt and engulf grains of both gedrite and sphalerite. Thin rims of cryptocrystalline silica surround sphalerite grains which have undergone this reaction. Blebs of quartz are commonly included in gahnite.

These textures suggest a partial reaction equation of the form:



This equation cannot be balanced even if the minor Na, Ca, Mn, and Ti contents of gedrite are ignored. This is because gedrite has a much greater Mg:Al ratio than gahnite and these elements are

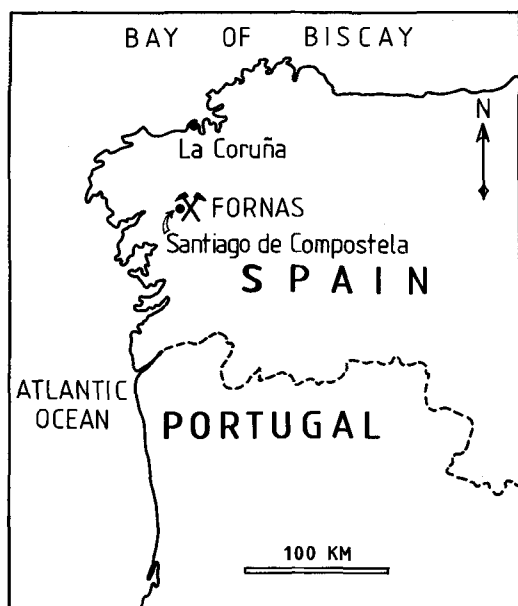


FIG. 1. Map showing the location of the Fornas copper mine.

TABLE I. *Representative analyses of selected minerals from the Fornas silicate inclusions*

	Gedrite	Hornblende	Phlogopite	Staurolite	Gahnite
SiO <sub>2</sub>	45.19	45.05	38.69	27.65	0.00
TiO <sub>2</sub>	0.25	0.63	1.28	0.57	0.00
Al <sub>2</sub> O <sub>3</sub>	14.26	14.71	16.52	51.79	57.98
FeO	15.71	10.46	9.97	8.63	7.97
MnO	0.46	0.41	0.00	0.00	0.00
MgO	18.20	14.17	17.63	3.47	1.85
CaO	0.66	9.66	0.00	—	—
Na <sub>2</sub> O	2.98	2.42	0.69	—	—
K <sub>2</sub> O	0.00	0.23	8.54	—	—
ZnO	0.00	0.00	0.00	6.37	33.53
Total	97.71	97.74	93.52	98.48	101.33

— Not analysed.

not contained in the other phases (Table I). The reaction must therefore have involved other (unseen) phases or recrystallization of remaining gedrite with changed composition. The interpretation favoured here, in the absence of textural evidence is that the reaction consumed staurolite which is in some cases found to be preferentially concentrated in association with gahnite.

The gahnite-forming reaction must have occurred after M<sub>1</sub>. It probably involved both desulphurization and dehydration. Post-M<sub>2</sub> retrogression involved hydration and it is therefore likely that gahnite crystallized during M<sub>2</sub>. The loss of volatile components during M<sub>2</sub> may reflect high-temperature metamorphism in association with decreased partial pressures having occurred in

sympathy with decreased total confining pressures and large-scale uplift. It is possible that similar processes have occurred in sulphide-bearing polymetamorphic high-grade terrains elsewhere. For example, such may be the case for desulphurization by reaction with silicates which has been inferred in the high grade rocks enclosing the Broken Hill orebodies, Australia (Plimer, 1977).

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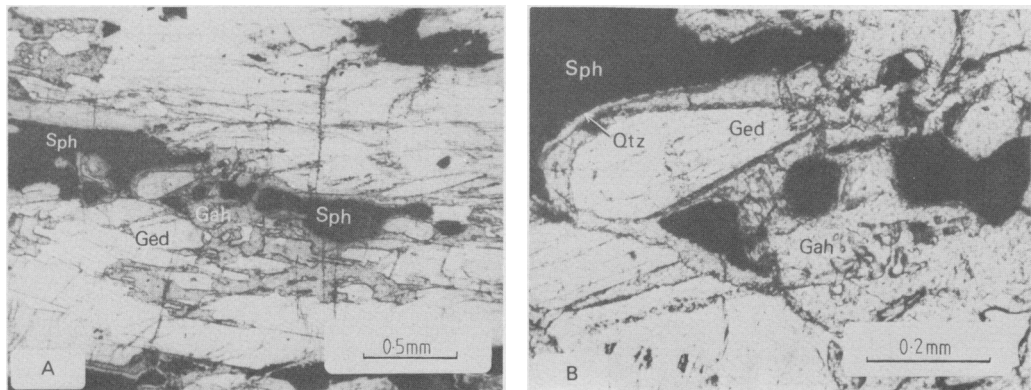


FIG. 2(a). Photomicrograph (p.p.l.) showing the reaction of sphalerite (sph) and gedrite (ged) to form gahnite (gah). (b) High-magnification view showing silica (qtz) rim to sphalerite which has undergone the gahnite-forming reaction. Blebs of quartz are visible in the gahnite.

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## Cumengéite from Cornwall

THE rare mineral cumengéite (formulated as  $Pb_{19}Cu_{24}Cl_{42}(OH)_{44}$  by Winchell and Rouse, 1974) has been found associated with other secondary minerals in the oxidized section of a vein carrying Pb-Cu-Sb mineralization. This is the first reported British occurrence of cumengéite (Dean, 1982) and this note presents additional chemical information on the find.

The deposit is located in the parish of Budock at Newport Beach (National Grid Ref. SW799303), approximately 2 km southwest of Falmouth, Cornwall. Middle Devonian shales, siltstones, and sandstones forming part of the Mylor Beds are exposed in the cliffs at Newport Beach, and have undergone low-grade regional metamorphism. The resulting phyllites show extensive small-scale folding with well-developed false cleavage oblique to the bedding. The bedding dips at about 50° to the southeast, whilst the cleavage dips approximately 60° in the same direction but is locally highly variable and associated with minor faulting (Edmonds *et al.*, 1975; Hill and MacAlister, 1906). Minor late-stage siliceous hydrothermal fluids bearing metallic elements, probably associated with the Upper Carboniferous emplacement of the Carnmenellis granite (Edmonds *et al.*, *op. cit.*), were intruded into these beds.

Little mining activity has been reported within the parish of Budock. Wheal Penrose, 1 km west of Newport Beach, near to Maenporth, is said to have produced Pb-Zn-Cu ores, but there are no records of yields (Dines, 1956). A lode was worked at the Swanpool mine, 1 km southwest of Falmouth, for Pb and Ag, and Wheal Pennance consisted of three trial shafts on an extension to this lode (Stephens, 1886). Shallow trial adits at sea level can still be seen along the coast at

Newport Beach; one of these explored a series of small quartz lenses, in one of which the cumengéite was found.

Primary minerals in this lens include galena, bournonite, and tetrahedrite, with minor chalcopyrite, pyrite, and pyrrhotine. Galena and tetrahedrite are well crystallized, the latter reaching 2 mm in size. Bournonite rarely exhibits crystal faces and occurs mainly in a massive habit. Quartz was the only observed gangue mineral.

The secondary minerals which have been found along with Fe(III) oxyhydroxides are cerussite, bindheimite, cumengéite, malachite, and atacamite. Cerussite is abundant and frequently forms twinned crystals up to 8 mm in size. Some of the cerussite is blue, but the origin of this colouration is not yet understood. This mineral often lines quartz vughs, in one of which was also found a single crystal of anglesite. Bindheimite,  $Pb_2Sb_2O_6(O,OH)$ , is the most abundant secondary species and forms thick, sulphur-yellow to yellow-orange, poorly crystalline crusts and masses with a resinous lustre, which often contain a core of bournonite in various stages of alteration. Cumengéite occurs as pale blue microcrystalline crusts coating bournonite, cerussite, quartz and the rock matrix, but is most frequently associated with bindheimite. Malachite and atacamite are intimately associated with bindheimite when it is present with cumengéite, and the four minerals often coalesce into an apparently amorphous mass.

The comparatively rare chloro-carbonate phosphogénite,  $Pb_2CO_3Cl_2$ , was also found in the oxidized assemblage. Single crystals up to 3 mm in size were frequently found lining quartz vughs and perched on quartz crystal groups.

The presence of bindheimite, cumengéite, and