SHORT COMMUNICATIONS

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Armenite from the Middle Dalradian of Scotland

THE rare barium–calcium aluminosilicate armenite [$BaCa_2Al_3(Al_3Si_9O_{30}).2H_2O$] forms porphyroblasts in sulphidic calc-silicate-rich quartz-rock of the Argyll Group (Middle Dalradian) at Coire Loch Kander (NGR:NO 192 807], 11 km SSE of Braemar in the Grampian Highlands [BGS rock samples GLR1851, 1852, 1891 and 1892]. The occurrence was found during a reconnaissance for stratabound mineralisation (Coats *et al.*, 1988; Gallagher *et al.*, 1989) following earlier discoveries of such mineralisation in the Ben Eagach Schist of the Argyll Group north of Aberfeldy (Coats *et al.*, 1980) and south of Loch Lyon (Coats *et al.*, 1984), respectively 45 km and 90 km to the SW along strike.

Geology

Bands of armenite-bearing quartz rock occur in the upper part of the Glas Maol graphitic schist. Following Upton (1986), Gallagher *et al.* (1989) regard this formation as part of the along-strike extension of the Ben Eagach schist of the Central Highlands, and thus to belong to the Late Precambrian to Lower Cambrian Argyll Group or Middle Dalradian (Harris and Pitcher, 1975). They divide the Ben Eagach schist into an upper 'graphitic schist' member (the Glas Maol Graphitic Schist) and a lower 'laminated' member (the Cairn of Claise Laminated Transition of Upton, 1986). At Coire Loch Kander, the former is represented by an attenuated sequence of calc-silicate-rich schist, pyrite-rich black schist and the banded calc-silicate rich sulphidic quartz-rock which contains armenite. The latter member is thicker and represented by a sequence of interbedded quartzite and graphitic schist. In addition, bedded baryte–quartz rock attributed to the upper member extends over at least 0.8 km of strike 2 km SSE of Coire Loch Kander, and an isolated 30 cm thick baryte–galena vein lies concordant with the foliation in quartz–mica schist of the lower member within the coire about 300 m west of the armenite locality (Gallacher *et al.*, 1989).

The armenite-bearing quartz-rock unit is at least 15 m thick, locally strikes 060°, and dips SE between a thick concordant amphibolite unit and the NW margin of a diorite intrusion of probable late-Silurian age. The beds are inverted, highly deformed on NE–SW trending folds, and were metamorphosed to amphibolite facies during the Cambro–Ordovician Grampian orogeny. They have also undergone contact metamorphism and metasomatism in proximity to the intrusion.

Mineralogy

The armenite-bearing rock can be described as a calc-silicate-rich, cherty sulphidic quartzite (*sensu lato*) in which cm scale bands and lenticles of pale pyritic quartz-rock are interleaved with mafic laminae in which sphalerite and galena occur. The pale component has a uniformly fine-grained, granoblastic texture characterised by planar or arcuate grain boundaries, which suggests metamorphism of a massive, fine-grained, chert-like rock rather than a clastic sediment. Minute grains of pyrite and mafic silicates (including salitic pyroxene and tremolite–actinolite) occur throughout, and arrays of rounded pyrite granules (5–50 μm diameter) follow quartz grain boundaries. The quartz is also locally rich in fluid inclusions.

The mafic component is more varied, containing salitic pyroxene, tremolite–actinolite, pyrite, pyrrhotite, sphalerite and galena. Porphyroblasts of hyalophane and armenite are found principally in this component whose minor constituents also include clinozoisite, titanite, chalcopyrite and rare granules of baryte. Hylophane crystals are locally mantled and partially replaced by armenite.

A similar assemblage of mafic silicate minerals forms bands in the calc-silicate schist, augmented by quartzose and feldspathic laminae and the

TABLE 1. Representative armenite analyses from Coire Loch Kander.

	1	2	Mean	sd	Median
Weight percentages					
SiO_2	47.19	48.08	47.53	0.55	47.37
Al_2O_3	26.36	25.98	26.01	0.73	26.05
FeO^t	n.d.	n.d.	0.44	0.77	0.0
CaO	9.82	9.59	9.59	0.36	9.68
BaO	14.11	12.67	13.22	0.60	13.30
Na_2O	0.4	0.40	0.22	0.25	0.0
K_2O	n.d.	0.39	0.12	0.17	0.0
Total	97.88	97.11	96.93		96.40
Formulae calculated for 30 oxygen atoms					
Si	8.992	9.130	9.054	0.071	9.033
Al	5.922	5.816	5.864	0.105	5.876
Fe^{2+}			0.072	0.128	0.0
Ca	2.005	1.951	2.016	0.065	1.959
BA	1.054	0.943	0.991	0.041	0.999
Na	0.148	0.147	0.082	0.094	0.0
K		0.094	0.029	0.041	0.0
Total	18.121	18.081	18.108		17.867

1 & 2: armenite porphyroblasts from BGS specimens GLR1851 and 1852 respectively. The statistics refer to all armenite analyses in the present study (n = 17). Analyses by Cambridge Instruments Microscan V microprobe with LINK energy dispersive system at BGS, Keyworth: operating potential −15 KV; beam current approximately 5 nanoamps. Spectrum data were corrected using the LINK ZAF4 FLB + program. n.d.—not detected: FeO^t—total iron treated as FeO.

presence of hedenbergite and scapolite, but armenite has not been observed. Bands of this assemblage are inter-digitated on a mm- to cm-scale with bands of quartz–muscovite schist in this rock.

Contact metamorphism is expressed by replacement of garnet in the 'laminated' member by fine-grained biotite, and by patchy feldspar replacement of muscovitic bands in the calc-silicate schist. In the case of the vein, bladed baryte crystals are partially annealed, but remain distinct from the granoblastic baryte recrystallised during regional metamorphism. The calc-silicate schist and armenite-bearing quartz-rock themselves probably represent contact metamorphism of dolomitic schist with only limited chemical modification, as discussed below. Metasomatic features include discordant mm-scale tremolite–actinolite–pyrrhotite lenses in muscovitic bands of the calc-silicate schist and epidotisation of amphibolite close to the diorite.

The armenite porphyroblasts are up to 2 mm wide. In thin section some display a crudely prismatic form extended parallel to their single prominent cleavage, but most appear anhedral. They are poikiloblastic, enclosing and marginally intergrown with minute amphibole prisms, irregular patches of pyrrhotite and grains of sphalerite. Where unaltered, the armenite is colourless and exhibits low first-order birefringence. It is distinguished from accompanying hyalophane by its straight extinction, and poikiloblastic habit. Its relief is slightly higher than quartz and slightly lower than hyalophane. It displays interpenetrant twinning which resembles that observed in basal sections of biaxial armenite by Neumann (1941) and Pouliot *et al.* (1984). Infrequent armenite grains *ca.* 0.3 mm wide in the pale quartz-rich component have squat, crudely prismatic forms. Many armenite crystals display partial to complete replacement by fine-grained chlorite, and some contain films of iron-stained chlorite on crystal boundaries and internal partings.

The armenite was identified by X-ray diffraction and electron microprobe analysis (EPMA). Material was extracted from polished section and mounted in a Gandolfi camera. D-spacings and intensities from the best film match data for armenite from the Broken Hill and Remigny occurrences described below. EPMA results, given in Table 1, are consistent, approaching the 'ideal' composition of the mineral and compositions recorded from other localities. Strontium was not recorded, although the detection limit for the analytical system used is of the order of 0.1%, higher than the recorded concentrations at Armen Mine and Broken Hill.

Discussion

Armenite was first described from Armen silver mine, Kongsberg, Norway, where it forms colourless to pale green pseudo-hexagonal prisms in a calcite vein (Neumann, 1939, 1941). The vein is one of a set hosting Ag–Ni–Co–As mineralisation, baryte, hyalophane, harmotome, albite and adularia, and associated with retrograde fahlbands of micaceous, chloritic sulphidic schist (Neumann, 1944). At Remigny, Quebec, armenite occurs in veins cutting metasomatised diorite (Pouliot *et al.*, 1984), and a similar occurrence is reported from the Tokovian granite massif, USSR (Semenenko *et al.*, 1987). At Su Zufurin mine, Sardinia, armenite forms bands and veins at the contact of skarns and hornfels (Balasonne *et al.*, 1989). In the Broken Hill area of Southern Australia, armenite is a minor constituent of aplitic gneiss rich in bytownite and celsian, and is also the major constituent of a calc-silicate rock with minor celsian (Mason, 1987).

At Coire Loch Kander, bedded baryte, sulphide-rich graphitic schist and base-metal enriched quartz-rock point to a synsedimentary exhalative origin. The calc-silicate schist and armenite-bearing quartz-rock are interpreted as having been deposited as dolomitic mudstone and chert, although relatively high Ti and Zr concentrations in the schist suggest a tuffaceous component (Gallagher *et al.*, 1989). The chert is seen as having formed originally as a hydrothermal seafloor quartz–carbonate deposit containing Zn, Pb, Cu, and Fe sulphides, minor baryte, gypsum and an alumino-silicate component (clay minerals, Ba-zeolites or a direct precursor of cymrite). Barium feldspar and an hydrated equivalent occur respectively in un-metamorphosed Carboniferous sub-seafloor mineralisation at Moyvoughly, Ireland (Kucha, 1988) and in mudstone associated with stratabound mineralisation in northern Greenland (Jacobsen, 1990). Authigenic to early diagenetic precipitation of Ba-aluminosilicates was proposed at Aberfeldy by Fortey and Beddoe-Stephens (1982) and Russell *et al.* (1984).

The armenite and calc-silicate-bearing quartz rock at Coire Loch Kander is comparable in many respects with sulphidic, dolomitic quartz–celsian rock of the Aberfeldy deposits (Coats *et al.*, 1980), but differs in being rich in calc-silicates and lacking carbonates. Ca could have become incorporated into armenite by reaction with precursor Ba-aluminosilicates or combination with Ba released by baryte dissolution during decarbonation. Mason (1987) concluded that growth of armenite rather than Ba-feldspar would be promoted by elevated P_{H_2O} conditions. At Coire Loch Kander, armenite is intergrown with amphibole and replaces hyalophane, suggesting that an increase in P_{H_2O} may have been involved in its formation.

It is proposed that armenite growth took place during alteration of a dolomitic exhalative chert. Proximity to the late-Silurian diorite intrusion suggests moreover that this occurred as a result of its emplacement. However, introduction of Ca, Mg, Ba, S and base metals at this stage is unlikely in view of the bedded nature of the mineralisation and the permeation of sulphides throughout the metamorphic fabric of the rocks. The armenite-bearing rock is thus a calc-silicate hornfels rather than a true skarn.

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Radiate, bladed quartz from Zimbabwe

BOULDERS of quartz displaying textures which are thought to be previously undescribed for pure quartz rocks occur in the Lower Zambezi valley of northern Zimbabwe (15°48′S 30°12′E). They have thus far only been found as float in small high-gradient streams near their headwaters and are therefore presumed to be close to outcrop. The locality lies between the Zambian and Zimbabwean bounding faults of a basin thought to be a pull-apart complex (Orpen *et al.*, 1989). Although the quartz rock is yet to be found *in situ*, it is thought to occur within extensional tension gashes of high angle normal and strike-slip faults. These faults occur within the Chewore Complex basement inliers and within part of the poorly exposed tectonic contact between the Chewore Complex and a new formation of the Karoo Supergroup, the Kondo Pools Formation (Tromp, in preparation), of Permian age. The former is predominantly biotite–hornblende gneiss while the Kondo Pools Formation is here mainly a massive pebbly greywacke facies of a submarine fan.

The buff coloured boulders, which are up to