Volcanogenic quartz-magnetite-hematite veins, Snowdon, North Wales

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Abstract

In the Ordovician Snowdon Volcanic Group caldera quartz–magnetite–hematite–pyrite assemblages occur in a breccia vein in rhyolitic tuff and vein swarms in basalt. The veins developed pre-cleavage. Elevated levels of tin and tungsten in the veins, and of fluorine in the wall rocks, suggest a magmatic contribution to the mineralising fluids. The chemistry of the veins differs from that of the base-metal sulphide veins found elsewhere in the caldera.

KEYWORDS: quartz, magnetite, hematite, Snowdon, Wales, volcanic rocks.

Introduction

QUARTZ–magnetite–hematite–pyrite veins and breccias occur within the Ordovician (Caradoc) Snowdon Volcanic Group caldera in Cwm Tregalan, just south of Snowdon, in two areas about 400 m apart separated by glacial moraine (Fig. 1). The veins are emplaced along synvolcanic faults and the host rocks lie above magnetite-bearing sandstones. This paper describes the setting, mineralogy and geochemistry of the magnetite veins.

Geological setting

The Snowdon Volcanic Group caldera forms a roughly circular, asymmetric, downsag structure about 14 km in diameter. It was formed during the emplacement of up to 600 m of acid ash-flow tuff, the Lower Rhyolitic Tuff Formation (LRTF) (Howells *et al.*, 1986). The LRTF, and the overlying Bedded Pyroclastic Formation (BPF), host base metal sulphide mineralisation at, or near the contact, in synvolcanic faults (Reedman *et al.*, 1985).

The veins in Cwm Tregalan [SH 61320 53520], are emplaced within pillowed basalts at the base of the LRTF and overlie marine siltstones and sandstones of Caradoc age. The sedimentary rocks are enriched in magnetite, which occurs both as disseminated grains and within placer bands up to 3 mm thick. The placer bands, which can be traced [SH 61325 53350] over 20 m, contain some chromite and ilmenite grains. The vein in Shadow Gully [SH 60640 53450] is a breccia vein, trending 300–330° within the basal LRTF welded tuffs, with clasts of welded tuff up to 10 cm across, supported by quartz and magnetite.

Mineralisation

Cwm Tregalan. The pre-cleavage quartz–hematite–magnetite veins crop out over a strike length of 60 m and typically are narrow (<1 m), steeply dipping, and trend between 320–350° and 040–060°. The most common are NW-trending and deformed. These occur singly and as dense swarms (Fig. 2). The veins are commonly banded, with magnetite and hematite usually occupying the central bands. The main vein, up to 70 cm wide, is fault bounded on the footwall and consists of swirling bands of hematite and magnetite with blocks of basalt wall rock impregnated with magnetite. A thick (up to 15 cm) band of contorted, 'cabbage-textured' quartz and hematite occurs on the hanging-wall side of the vein only. This is formed of alternating layers of quartz and hematite which have been deformed into tight folds. Net-vein quartz and hematite occurs on both sides.

The most abundant vein mineral is hematite, developed in thin euhedral acicular crystals.

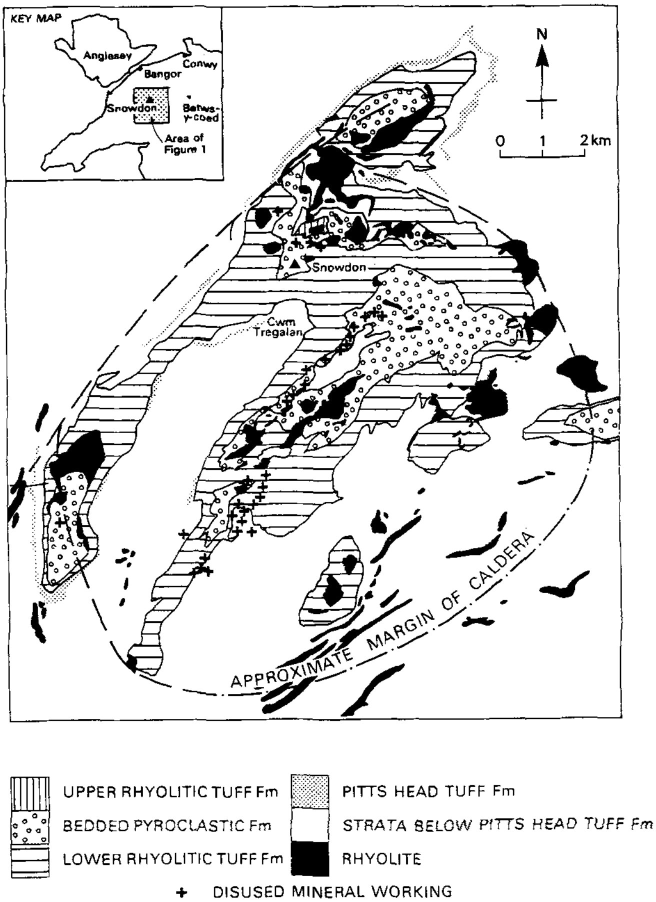

FIG. 1. Snowdon Volcanic Group caldera showing the location of Cwm Tregalan.

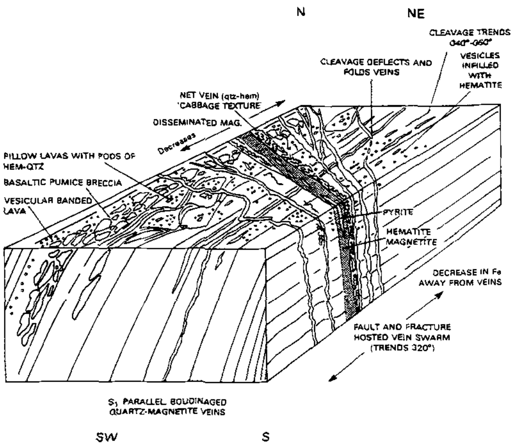

FIG. 2. Block diagram of the Cwm Tregalan mineralisation.

These can reach up to 1 cm in length in large vesicles with clumps of tiny bladed crystals around the margins and larger bladed crystals growing radially into the centre. Some of the larger blades are pseudomorphed by later magnetite. At high magnification, interlocking lobate contacts indicate that early magnetite growth overlapped that of late hematite. Magnetite usually forms as small euhedral crystals in banded quartz veins and as disseminated grains, with specular hematite, in the basalt host rock.

Disseminated mineralisation only occurs very close to the dense vein swarms [SH 61296 53530], where the basalt is black and sparkly due to specular hematite grains. Vesicles from 2 mm to 2 cm are commonly infilled with acicular hematite crystals and magnetite. The larger vesicles form resistant, pod-like structures of quartz and hematite standing up from the rock surface.

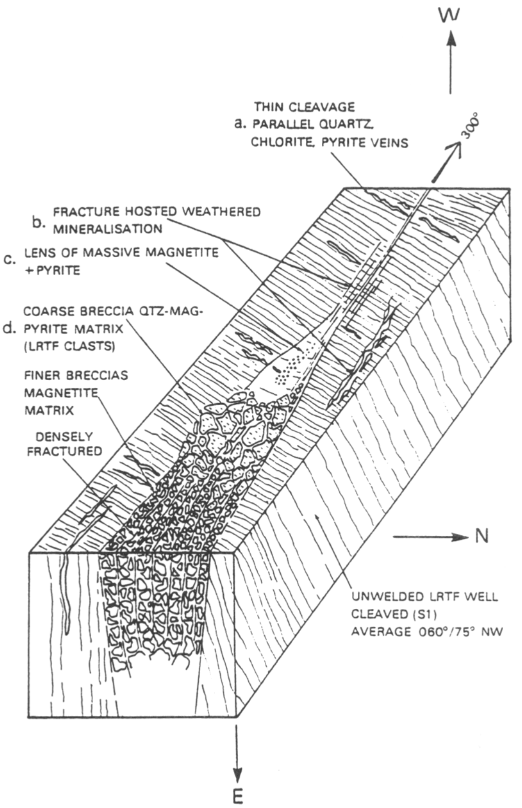

FIG. 3. Block diagram of the Shadow Gully mineralisation.

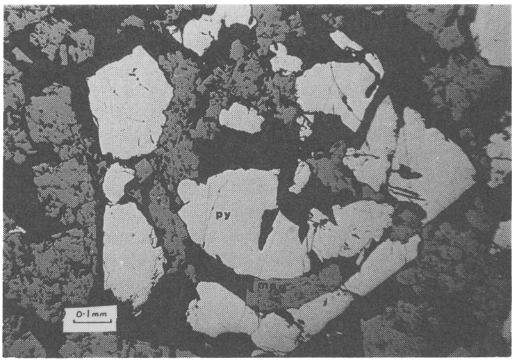

FIG. 4. Atoll texture in pyrite (py) replaced by magnetite (mag). Shadow Gully.

Isolated pillows in a basaltic tuff horizon [SH 61302 53497] contain vesicles of hematite. With increasing distance from the veins the vesicles become progressively more quartz-rich and correspondingly depleted in hematite which suggests that the mineralised vesicles formed coevally with the veins.

Shadow Gully. The breccia vein crops out over about 100 m in the centre of the valley and varies between 2 and 10 m in width. Four different styles of mineralisation (Fig. 3) have been recognised (Appleby, 1988).

(*a*) Thin quartz veins and lenses parallel with cleavage in the upper part of the gully which contain small (<1 mm) euhedral grains of pyrite with chlorite. The veins are commonly cut by quartz veins normal to the cleavage.

(*b*) A coarse network of fracture-hosted quartz veins with magnetite and pyrite. The veins occur within and to the sides of the main fault. They anastomose within the iron-stained tuff and some thinner veins only contain granular octohedral magnetite (2 mm) and no quartz. The veins are deformed and the cleavage offsets and folds them.

(*c*) Well-defined veins of magnetite and quartz within the main fault and smaller, parallel fractures. These veins coalesce to form a 2 m wide, 5 m long lens of massive magnetite–pyrite (75% magnetite, 25% pyrite). The magnetite is fine-grained (<1 mm) and granular in euhedral crystals up to 2 mm, commonly with interpenetration twinning. Pyrite forms euhedral to rounded, large (up to 1 cm) crystals with a zoned structure defined by small, lath-shaped inclusions of magnetite and hematite. The zonation reflects either fluctuating changes of fluid temperature and composition at the time of deposition or subsequent preferential replacement within the zoned pyrite. Later replacement of pyrite by magnetite and hematite occurs with fractured parts of the pyrite crystal replaced by the lath-shaped inclusions. Continued replacement can form an atoll texture (Fig. 4). Later deformation of pyrite results in its *in-situ* fragmentation with the voids infilled by chlorite. Hematite replaces pyrite and magnetite. It occurs as rims on euhedral magnetite crystals and as anastomosing veinlets though pyrite and magnetite grains (Fig. 5). Small amounts of chalcopyrite are associated with the massive magnetite-pyrite mineralisation. It occurs between pyrite grains and where pyrite is fractured. It is commonly rimmed by covellite.

(*d*) Breccias of angular rhyolitic tuff clasts, up to >1 m, in a matrix of magnetite, pyrite and quartz. The magnetite matrix to the breccias consists of a mass of tiny euhedral crystals which grow between and into the margins of the breccia clasts. The contact between the wall-rock and breccia is nearly vertical and irregular; pull-apart structures with little relative rotation of the clasts is common. Thin, deformed quartz veins anastomose through the breccia implying it is pre-cleavage. Small grains of cassiterite and a tungsten mineral (?wolframite) were found as inclusions in magnetite during electron microprobe analysis (Seenan, 1988).

The relative proportions of minerals differ between the two areas. At Cwm Tregalan hematite is more abundant than magnetite and very little pyrite occurs. Shadow Gully has abundant magnetite and pyrite compared to hematite; chalcopyrite and covellite also occur here.

Paragenesis

The mineral paragenesis for the two areas is generalised in Fig. 6. Quartz deposition extends through the whole mineralising episode. The two areas have a generally similar paragenesis except that at Cwm Tregalan hematite occurs earlier than magnetite, with only minor pyrite whereas at Shadow Gully pyrite is more abundant and is the first iron mineral to form, followed by magnetite and chalcopyrite, with hematite at a later stage. These variations reflect differences in the fluid chemistry and indicate that the Shadow Gully fluids were less oxidised than those at Cwm Tregalan.

Mineral chemistry

The analyses of the magnetite and pyrite in Cwm Tregalan (Reedman *et al.*, 1985) show that pyrite has a high Co:Ni ratio of 6:1 which is characteristic of volcanogenic pyrite (Bralia *et al.*, 1979). Magnetite has a low TiO_2 (0.4%) and V_2O_3 (0.4%) content. In contrast, the placer magnetites of the underlying sandstones are zoned with a titanium-rich core and titanium-poor rim (Seenan, 1988). Chromite and ilmenite grains also occur (Seenan, 1988). These minerals are not found in the vein mineralisation and are almost certainly derived from an earlier stage of basic volcanism.

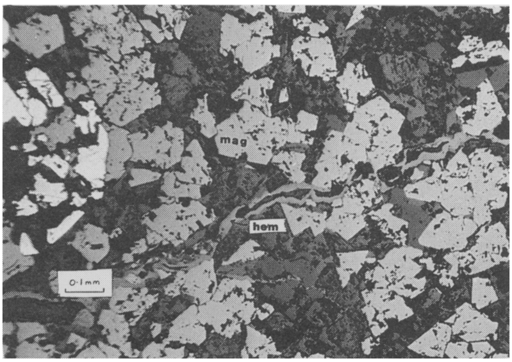

FIG. 5. Subhedral magnetite (mag) grains cut by later hematite (hem) veins. Shadow Gully.

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CWM TREGALAN

Quartz        --------------------------
Haematite       --------------
Magnetite               -------------
Pyrite          ----------
Cassiterite
   and              -----
Wolframite

SHADOW GULLY

Quartz        -------------------------
Pyrite          -----------
Magnetite               ----------
Haematite                       ------------
Chalcopyrite               -------
Cassiterite
   and            -----
Wolframite
Covellite                                    ----
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FIG. 6. Paragenesis of the vein mineralisation.

XRF scans of milled samples of the quartz–magnetite veins (Table 1) show high (up to 1000 ppm) levels of tin and tungsten. Even higher levels, up to 2400 ppm, are reported by Seenan (1988). The veins contain low levels of arsenic, barium and nickel (in common with the quartz–sulphide veins elsewhere in the caldera). They also contain very low levels of copper, lead and zinc in contrast to the base-metal veins. The underlying magnetite-bearing sandstones contained no detectable tin and low levels of tung-

Table 1. XRF analyses of quartz-hematite-magnetite vein samples from Cwm Tregalan and Shadow Gully

No. of samples = 5

ppm	Mean	S.D.	Maximum	Minimum
As	18	38	86	0
Ba	214	320	785	41
Co	52	37	112	15
Cu	22	8	35	15
Ni	44	40	97	0
Pb	42	51	126	9
S	-	-	25642	0
Sn	249	82	339	140
V	229	168	452	51
W	491	201	760	273
Zn	94	60	157	23

Table 2. XRF analyses of magnetite-bearing sandstones from Cwm Tregalan

No. of samples = 3

	Mean	S.D.	Max	Min
%				
SiO_2	50.48	4.14	54.49	46.21
Al_2O_3	11.69	0.14	11.80	11.53
TiO_2	1.11	0.31	1.47	0.92
Fe_2O_3	27.28	4.97	32.60	22.75
MgO	3.87	0.36	4.28	3.60
CaO	0.55	0.15	0.72	0.45
Na_2O	1.52	1.07	2.61	0.47
K_2O	0.94	0.46	1.31	0.43
MnO	0.88	0.17	1.04	0.70
P_2O_5	0.36	0.06	0.42	0.29
ppm				
As	5	7	13	1
Ba	343	169	526	193
Ce	73	12	88	66
Co	41	2	43	39
Cr	322	103	414	211
Cu	15	3	18	12
Ga	18	4	23	15
La	19	10	31	13
Ni	119	43	168	91
Nb	9	2	12	8
Pb	13	2	15	10
Rb	37	14	49	21
S	79	18	100	68
Sn	0	-	0	0
Sr	30	27	61	9
Th	7	4	12	5
U	2	-	3	0
V	157	10	165	146
W	10	6	17	5
Y	35	2	37	33
Zn	93	21	112	70
Zr	130	9	139	121

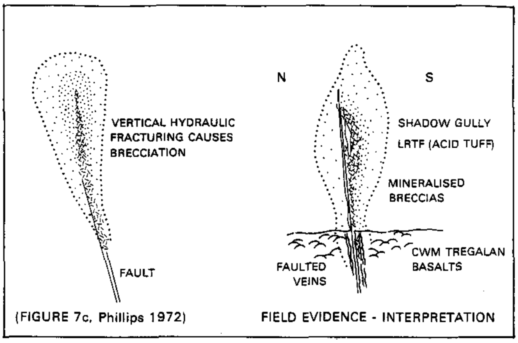

FIG. 7. Cartoon of the vein formation.

sten, base metals and sulphur (Table 2). They are iron-rich, with a mean content of 27% Fe_2O_3 and relatively low MnO content of 0.88% which is no higher than the basic tuffs of the BPF. Chromium is slightly elevated due to the presence of chromite. Other elements commonly found in placers, such as thorium and zirconium, occur at low levels.

Structure

The Shadow Gully mineralisation is strongly controlled by faulting. However, the 'pull-apart' character of the breccia clasts suggests that the vein breccia is due to hydraulic fracturing (Phillips, 1972, 1986), rather than to fault movement. When the rock fails, angular breccias occur as the fault rapidly propagates upwards to form vertical breccia zones close to the surface with well developed footwalls and hanging walls as seen in Shadow Gully.

The Cwm Tregalan veins are confined to the basalt; mineralisation does not extend into the subjacent sandstone. This suggests that the basalt exerted a chemical or physical control on mineral deposition. The overlying LRTF has been removed by erosion.

Magnetite in adjacent areas

Fluorite–pyrite–magnetite mineralisation occurs on the tip of a small, flooded working [SH 5486 5569] near Llyn Cwellyn on the south-east side of Mynydd Mawr, about 10 km north-west of Cwm Tregalan. The magnetite forms a very distinctive swirling pattern of small elongate grains in a chlorite matrix. The magnetite and pyrite have not been analysed. The high rare earth element content of the fluorite is similar to that of the adjacent Mynydd Mawr Ordovician microgranite (T. K. Ball, pers. comm.) and indicates a magmatic source (Colman, in press).

Conclusions

The quartz–magnetite mineralisation forms a group of veins of distinct mineralogy and structure within the overall setting of the Snowdon caldera mineralisation. The mineralisation is pre-cleavage and occurred as part of the evolution of the LRTF caldera, probably as a result of late-stage, hydrothermal activity as suggested by Reedman *et al.* (1985). A magmatic component of the mineralising fluids is suggested by the high levels of tin and tungsten in the veins and by the presence of elevated levels of fluorine in the adjacent basalt (Colman, in press).

The different styles of mineralisation at Cwm Tregalan (vein swarms and disseminations) and Shadow Gully (breccias) may be due to the lowering of the confining pressure as the hydrothermal fluids moved upwards (Fig. 7) allowing the fluids to move further away from the main fracture and brecciate the host rock. The timing of the mineralisation with respect to the quartz-sulphide veins seen elsewhere in the caldera (Reedman *et al.*, 1985) cannot be established without isotopic and other information. The subjacent placer magnetite mineralisation appers to be fortuitous in its proximity to the hydrothermal magnetite deposits; there is no genetic link because of the very different mineral chemistry. The origin of the placer magnetites is still unknown.

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