Appendix 1 Metalliferous mineralization

By M J Gallagher

Most of the mineral locations in south-west Scotland are veins, many of which were trialled or mined for lead, copper and zinc in the 18th and 19th centuries, with limited work continuing in places until about 1920 (Wilson, 1921). Production of haryte from Barlocco probably continued until 1954.

Subsequently, uranium veins and both disseminated and vein occurrences of minerals of arsenic, molybdenum, lead, copper and zinc were discovered using modern techniques, but none has proved economic. Minor quantities of gold have also been discovered recently at several localities.

The known mineral veins of south-west Scotland are concentrated at the southern and western margins of the granitic complexes of Cairnsmore of Fleet in the west, and Criffell in the east. The composition of the veins changes in a general way from dominantly lead-zinc in the west to copper, barium and uranium in the east. The veins are highly variable in trend (Table 5), cutting sedimentary rocks of Ordovician to Lower Carboniferous age and intrusions of diorite, granodiorite and granite dated isotopically at late Silurian to early Devonian (Stephens and Halliday, 1984; Stephens et al., 1985). The lead-zinc vein at Blackcraig may postdate a dyke of Permo-Carboniferous type (Gallagher, 1964) and pitchblende from one of the Dalbeattie veins has yielded a Mesozoic age (Miller and Taylor, 1966).

Eight types of mineralisation (A–H) are described in this account, with reference to 29 of the more significant mineral locations in the region (located on (Figure 67)). Much further information can be found in the geochemical atlas *Regional geochemistry of southern Scotland and part of northern England* (British Geological Survey, 1993c) which contains coloured distribution maps for many elements.

A. Associated with ultrabasic rocks

The oldest mineralisation known in southwest Scotland is of chrome-spinel, as concentrations in the early Ordovician Ballantrae ophiolite complex. Accessory quantities of chrome spine' occur widely in serpentinised harzburgite and dunite, the main rock types of the complex, and at Poundland Burn nodular chrome spine' is visible in outcrop (location 7, (Table 5) and (Figure 67)). At Pinbain (6), true chromite forms 30–90 per cent of a small unit 4–5 m wide, most probably a chromitite pod (Stone et al., 1986).

B. Associated with Ordovician or Silurian sedimentary rocks

Two mineral occurrences very unusual to Scotland fall into this group. Ordovician siliceous mudstone and siltstone contain finely disseminated pyrite and sphalerite some 2 km SW of the Loch Doon granitic pluton in the vicinity of Penkiln Burn (9); thin quartz veinlets containing galena, sphalerite and pyrite cut across the strata (Stone and Leake, 1984; Stone et al., 1984). A third style of mineralisation in the same area contains lead and arsenic, in the form of plumbogummite–beudantite assemblages, both in the altered margins of dykes and in a gossan occupying a N–S fault zone.

Stratabound arsenopyrite and pyrite were intersected by drilling in Silurian greywackes on the north side of Glenshanna Burn close to the old Glendinning antimony mine (3) (Gallagher et al., 1983). The arsenopyrite is enriched in antimony and the pyrite in arsenic, thus providing a suitable source of metals for the later vein mined for stibnite (see Type F).

C. Associated with diorite and granodiorite

Base and precious metal mineralisation is located in or near the margins of several diorite–granodiorite intrusion in south-west Scotland. Three varieties can be recognised.

1. The Talnotry deposit (11) is the only instance of a magmatic copper-nickel ore-body in the Southern Uplands. The host rock is a late Caledonian diorite sill in which a basal lens of sulphide, 4 X 20 m in size, contains pyrrhotite, pentlandite, chalcopyrite, nickeline and gersdorffite, plus numerous minor constituents including gold (Stanley et al., 1987).
2. A second variety is that of volcanic porphyry Cu-Mo-Au-Ag mineralisation, exemplified by disseminations and veinlets of mineral in diorite complexes. The Fore Burn complex (2) is a Lower Devonian igneous assemblage lying immediately north of the Southern Upland Fault. Arsenopyrite, pyrite, chalcopyrite, gold, silver and tetrahedritetennantite occur in quartz-carbonate veins and in small intrusion breccias which are intensely tourmalinised. Gold is also present locally in quartz-arsenopyrite-chalcopyrite veins. Grades varying up to about 50 gm per tonne are reported by Charley et al. (1989). Porphyry-style copper mineralisation is weakly developed in a late Caledonian complex of intersecting porphyrite dykes, gran odiorite intrusions and breccia pipes at Black Stockarton Moor (22) on the western margin of the Criffell granodiorite pluton (Leake and Cooper, 1983). Breccia veins are enriched in As, Sb and gold (maximum 0.06 ppm Au in samples) in association with molybdenite (350 ppm Mo) and with chalcopyrite and bornite (4400 ppm Cu). In one borehole, an average of 0.05 per cent Cu was maintained over 34 m (Leake and Brown, 1979).
3. Arsenic-antimony-gold mineralisation is a third variey, represented by mineral locations at Glenhead Burn, Hare Hill and Moorbrock Hill. These, together with the Fore Burn occurrences, are interpreted as mesothermal gold systems spatially related with regional strike-slip shears as well as with late-tectonic Caledonian intrusives (Boast et al., 1990). Quartz veins containing gold (8.8 ppm Au maximum), arsenopyrite (up to 3.5 per cent As) and pyrite cut Ordovician turbidites at Glenhead Burn (8) at the southern margin of the Loch Doon granitic pluton. The hornsfelsed wallrocks are strongly sericitised and contain fine-grained, disseminated arsenopyrite. The mineralisation may be related, in part at least, to a swarm of dioritic dykes which are older than the pluton. At Hare Hill (1) (Excursion 6), gold is associated with a zoned As-Sb-Cu-Pb-Zn assemblage in fractured and sericitised granodiorite (Boast et al., 1990) adjacent to late-stage antimony veins (see Type F). At the margin of the Carsphairn intrusion at Moorbrock Hill (29), gold values of 1–3 ppm occur mainly in quartz-pyrite-arsenopyrite veins in a NE-trending zone of intense brecciation and hydrothermal alteration. Native gold forms isolated grains, 5–10 p m in size, adjacent to chalcopyrite-pyrite intergrowths and inclusions of graphitic Moffat Shale Group wall rock (Naden and Caulfield, 1989).

D Haematite veins

Fracture-bound haematite deposits are located at the margins of the Criffell granodiorite pluton (Phillips, 1956) and a weakly radioactive deposit occurs within the granodiorite (see Type H). The Auchenleck vein (25) was the most important economically, consisting of botryoidal haematite, quartz and baryte. The NE margin of the Loch Doon granitic pluton is transected by a haematite breccia vein, 0.5 m to at least 3 m in width, which has been prospected and/or mined over some 3 km of strike length. The occurrence lies about 7 km west of Carsphairn (5) and has yielded around 400 tonnes of haematite (Excursion 7).

(Table 5) Significant metalliferous mineral locations in south-west Scotland

Location no.	Deposit name	Exposure types[1]	Commodity[2]	Mineralisation type[3]	Trend of vein	NGR	1:50 000 Geological Sheet	Key reference
1	Hare Hill	T	Sb Au	C, F	010	[NS 658 104]	15W	Dewey et al., 1920
2	Fore Burn	I	As Cu Au	C	—	[NX 420 996]	8E	Allen et al., 1982
3	Glendinning	M	Sb As Zn Pb Cu	B, F	045	[NY 313 966]	10E	Gallagher et al., 1983
4	Woodhead	M	Pb Zn Cu	E	110	[NX 531 936]	8E	Wilson, 1921
5	Carsphairn (near)	M	Fe	D	000	[NX 504 929]	8E	Macgregor et al., 1920

6	Pinbain	O	Cr	A	—	[NX 138 917]	7 Stone and Smellie, 1988
7	Poundland Burn	O	Cr	A	—	[NX 170 882]	7 Stone and Smellie, 1988
8	Glenhead Burn	I	As Pb Zn Au	C, F	000	[NX 449 780]	8E Leake et al., 1981
9	Penkiln Burn	I	Pb Zn As Cu	B	000	[NX 446 767]	8E Stone et al., 1984
10	Talnotry (near)	T	As	F	045	[NX 480 702]	4E Dewey et al., 1920
11	Talnotry	T	Ni Cu	C	—	[NX 477 704]	4E Wilson, 1921
12	Wood of Cree	M	Pb Zn Cu	E	155	[NX 386 695]	4E Wilson, 1921
13	Beeswing	I	U Cu	H	135	[NX 885 681]	5E Gallagher et al., 1971
14	Blackcraig	M	Pb Zn Cu Ba	E	110	[NX 435 650]	4E Wilson, 1921
15	Cairnsmore	M	Pb Zn Ba	E	105	[NX 463 636]	4E Wilson, 1921
16	Drumruck	T	Cu	F	110	[NX 583 637]	4E Wilson, 1921
17	Dromore	T	Cu Zn	F	155	[NX 537 622]	4E Wilson, 1921
18	Pibble	M	Cu Pb Zn Ba	E	110	[NX 525 607]	4E Foster-Smith, 1967
19	Kings Laggan	T	Cu Pb Zn	F	105	[NX 562 578]	4E Wilson, 1921
20	Ironhash Hill	I	Fe U	D	080	[NX 858 563]	5E Gallagher et al., 1971
21	Needle's Eye	I	U Cu Bi Fe HC	H	135-170	[NX 915 562]	5E Miller and Taylor, 1966
22	Black Stockarton Moor	I	Cu Mo	C	—	[NX 725 555]	5W Brown et al., 1979
23	Powbrade Burn	I	U	H	045; 135	[NX 902 554]	5E Miller and Taylor, 1966
24	Colvend	M	Cu	F	045	[NX 869 538]	5E Wilson, 1921
25	Auchenleck	M	Fe	D	108	[NX 773 525]	5W Macgregor et al., 1920
26	Auchencairn	M	Ba Cu	G	070	[NX 821 485]	5E Wilson et al., 1922
27	Barlocco	M	Ba Cu	G	098	[NX 788 475]	5E Wilson et al., 1922
28	Tonderghie	O	Cu Ba	F	080	[NX 438 350]	2 Wilson, 1921
29	Moorbrock Hill	I	As Au Cu Zn	C	045	[NX 620 980]	9W Naden and Caulfield, 1989

1 Exposure type: M — old mine; T — old trial; 0 — outcrop; 1— detected by modem investigation

2 Commodity (mined where bold): As — Arsenopyrite; Au — gold; Ba — baryte; Bi — native bismuth and secondary Bi — Cu minerals; Cr —chromite; Cu — chalcopyrite; Fe— haematite; HC —hydrocarbon; Ni — niccolite, nickeliferous pyrrhotite; Mo — molybdenite; Pb — galena; Sb — stibnite; bournonite; U — uraninire, secondary uranium minerals; Zn — sphalerite

3 Mineralisation type: A— ass.riaced with ultrabasic rocks; B — associated with Ordovician or Silurian sedimentary rocks; C — associated with diorite and granodiorite; D — haematite vein; E — lead-zinc vein; F — copper, antimony and/or arsenic veins; G — baryte vein; H — uranium vein.

E Lead-zinc veins

Numerous metalliferous veins were exploited in the past around Newton Stewart and lead mining near Carsphairn was important for a time (Excursion 7). In a little known review of the mines and trial workings in south-west Scotland (Foster-Smith, 1967), minimum productions of lead, zinc and copper in ore concentrates are given as 25.6, 1.3 and 0.24 thousand tonnes respectively.

Of this production, more than half the lead, almost all of the zinc and a proportion of the copper were recovered from the Blackcraig mines (14), some 5 km from the SW margin of the Cairnsmore of Fleet granodiorite pluton. Little can now be seen of this deposit, the most important in southwest Scotland, and the extensive dumps are mainly landscaped. Wilson (1921) recorded the presence of galena, sphalerite and chalcopyrite, set in a gangue of calcite, dolomite, baryte and some quartz. Mineralisation extended for 0.8 km along a fault zone trending ESE and up to 18 m wide in Silurian greywackes. The fault zone was evidently intruded by a Permo-Carboniferous dolerite dyke prior to mineralisation (Gallagher, 1964). The Cairnsmore lead-zinc vein (15) probably represents an extension of the vein at Blackcraig, as may also the copper-lead vein at Pibble (see Type F). The Wood of Cree mine (12) was sited on a wide line of fracture trending SSE and containing numerous stringers of sphalerite and galena, mingled with chalcopyrite and pyrite.

The Woodhead mines (4) near Carsphairn (Excursion 7) produced 6700 tonnes of lead ore from veins cutting Ordovician greywackes. Sphalerite and chalcopyrite are associated with the galena in a gangue of calcite, dolomite and quartz. The location is midway between the Loch Doon and Carsphairn granitic bodies which are probably continuous at depth, providing a favourable structural and geochemical environment for mineralisation.

F Copper, antimony and arsenic veins

Foster-Smith (1967) refers to Pibble Mine (18) as the dominant 19th century copper producer in south-west Scotland, although no production figures are given by Wilson (1921). The vein, about 1 m thick, cuts Silurian greywackes interbedded with black shales some 3 km south of the southern contact of the Cairnsmore of Fleet granitic pluton. It contains lenses of galena, sphalerite and chalcopyrite and, unusually for the veins of south-west Scotland, a variety of secondary minerals. These include linarite, pyromorphite, hemimorphite and malachite, all recorded from the upper levels of the mine. A variety of ruined mine buildings and spoil dumps remain at the site. Also to the south of the Cairnsmore of Fleet pluton, chalcopyrite-bearing veins have been trialled at Drumruck (16), Dromore (17) and Kings's Laggan (19).

Copper veins at Colvend (24) and Tonderghie (28) postdate Caledonian felsite intrusions in Silurian rocks. Chalcopyrite, in a calcite-quartz gangue, is accompanied by malachite and azurite at Colvend whereas at Tonderghie the gangue is baryte-quartz and the associate minerals are pyrite and malachite.

The Louisa mine at Glendinning (3) produced nealy 200 tonnes of antimony from narrow quartz-carbonate veins cutting Silurian greywackes. The remains of mine buildings, shafts, adits and crushing floors are still clearly visible. Stibnite and other antimony minerals (semsyite, bournonite and tetrahedrite) are accompanied by pyrite, arsenopyrite, galena, sphalerite and chalcopyrite. There is no evidence of Caledonian intrusive igneous activity in the area and the vein contents probably derive from the stratabound mineralisation nearby (see Type B) (Gallagher et al., 1983). Similarly, at Hare Hill (1), enrichments of metal in the granodiorite (see Type C) are probably the source of metals in later

stibnite-galena veins, one of which has been trialled for antimony.

Modern investigations have demonstrated that arsenopyrite and geochemical *enrichments* of arsenic are much more widespread in the rocks of South-west Scotland than had previously been reported (Stone et al., 1995). Nevertheless only near Talnotry (10), at the west edge of the Cairnsmore of Fleet granodiorite, is there any record of recovery. A few tonnes of arsenopyrite were raised from a small shaft on a quartz vein about 1 m thick.

G Baryte veins

A group of baryte veins south of Auchencairn underwent exploitation in the late 19th century and until just after World War 2 (cf. MacGregor et al., 1944). Some 2800 tons of baryte were produced from Barlocco Mine (27), mainly from the more northerly of two approximately east—west subvertical veins. The principal vein is 0.5–2.1 m thick and occupies a fault breccia traceable for at least 300 m in altered Silurian shale. The high-quality white baryte remaining on the dumps is accompanied by calcite and traces of chalcopyrite, malachite and bornite. At Auchencairn mine (26) '700 tons of baryte are said to have been taken out of one pocket' in the latter part of the 19th century, and a little more in 1916 (Wilson, 1921). The Auchencairn vein, which is 0.5 m thick at surface and reputedly widens at depth, cuts Lower Carboniferous conglomeratic sandstone and is accompanied by multiple thin stringers of baryte and a 0.5 m thick quartz vein seen in the foreshore exposures.

H Uranium veins

Pitchblende is present in thin veins cutting hornfelsed Silurian turbidites at the southern margin of the Criffell pluton and cutting Lower Carboniferous strata at Needle's Eye (21), on the south side of the ENE-trending North Solway Fault. Over 30 anomalously radioactive veins are concentrated in a 400 m coastline section between Marbruie Cove and Powbrade Burn (23) which is one of the principal localities. Pitchblende is accompanied by black vitreous hydrocarbon, specular haematite, chalcopyrite, pyrite and native bismuth. Quartz and dolomite are the main gangue minerals with smaller amounts of calcite and baryte. Pitchblende from a vein at Steps gave a U-Pb isotopic age of 185 ± 20 Ma (reported in Miller and Taylor, 1966), that is Upper Triassic or Lower Jurassic and therefore the youngest vein mineralisation in Britain.

A uraniferous structure of similar NW trend also occurs at the northern edge of the Criffell pluton, at Beeswing (13), where joints in the greywackes adjacent to thin, impersistent quartz-haematite veins are coated with uraninite and chalcopyrite. Within the granodiorite mass itself, a haematite-impregnated shatter zone at Ironhash Hill (20) is anomalously radioactive.

The presence of anomalous radioactivity in association with copper veins of Type F at King's Laggan (19) and Pibble (18) was observed by Miller and Taylor (1966).

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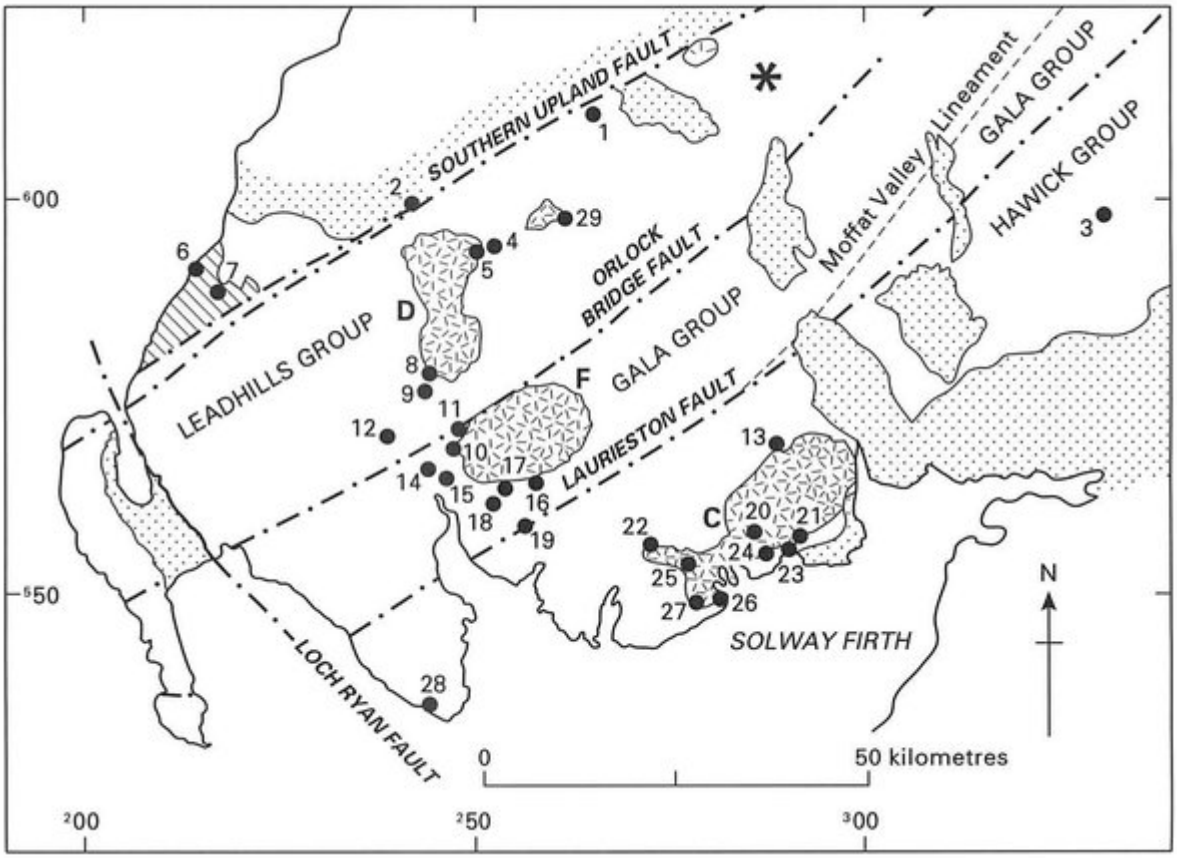

(Figure 67) Location of significant metalliferous mineralisation in south-west Scotland. Full details are listed in (Table 5).