Chapter 3 The Northern Pennines

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Introduction

This GCR Block includes the Pennine orefields of the Alston and Askrigg blocks (Figure 3.1). Whereas these fields exhibit numerous structural and mineralogical features in common there are also significant differences which serve to distinguish one from another. In this introduction the main characteristics of the Northern Pennine Orefield are outlined, with attention being drawn, where appropriate, to these differences.

Scientific interest in the area's geology and mineral deposits dates from the earliest days of geological research and has resulted in a huge volume of literature. Excellent summaries, together with extensive references to earlier works, include those by Johnson (1970), Rayner and Hemmingway (1974), Johnson (1995), and the British Geological Survey (1992, 1996b). Detailed descriptions of the mineral deposits are contained in the classic accounts of Dunham (1948, 1990), and Dunham and Wilson (1985). Other literature references are given in site descriptions.

The Alston and Askrigg blocks are structural units which comprise comparatively thin sequences of Carboniferous sedimentary rocks overlying Lower Palaeozoic rocks which were intruded by the Devonian Weardale and Wensleydale granites. Substantial parts of the Lower Carboniferous succession in these areas consist of marine limestones, especially in the southern, Askrigg Block. Cyclic 'Yoredale-type' sequences, composed of regularly repeated units of limestone, mudstone, sandstone and locally thin coals, pass upwards into cyclic sequences in which limestones become subordinate, culminating in the almost wholly non-marine mudstone–sandstone–coal-dominated sequences of the Coal Measures. The block areas are bounded by major fault belts, many of which controlled Carboniferous sedimentation, allowing substantially greater thicknesses of sediment to accumulate in the intervening 'troughs' than on the 'blocks'. To the north of the Alston Block, and separated from it by the Stublick–Ninety Fathom Fault System, lies the Northumberland–Solway Trough. The Stainmore Trough, bounded on the north by the Lunedale Fault System, separates the Alston and Askrigg blocks. The Craven Fault System bounds the Askrigg Block on the south, separating it from the Craven Basin. In the Alston Block the extensive tholeiitic quartz-dolerite intrusions of the Whin Sill suite were emplaced during late Carboniferous to early Permian times. In the block areas the overall easterly dip of the Carboniferous strata is interrupted by some, mainly gentle, flexuring and by a number of major faults. Both the Alston and Askrigg blocks are cut by conjugate sets of normal faults with maximum throws typically of only a few metres. It is these faults which host the main mineral veins.

Wall-rock lithology exerts a profound influence on the potential of each fault as a mineralized vein. Hard, competent wall-rocks, such as limestone and sandstone, and in the Alston Block the dolerite of the Whin Sill, and in the Askrigg Block chert, provided clean open fissures favourable for vein mineralization. Weak, incompetent rocks such as mudstones typically allowed fault fissures to close, effectively preventing their filling by mineralizing fluids. The influence of wall-rock lithology is especially marked in Yoredale-type sequences where laterally extensive ore-shoots against or between hard beds alternate with barren intervals against weak beds. The resulting 'ribbon ore-shoots' are a characteristic feature of these orefields.

Whereas the majority of Northern Pennine ore deposits occur as fissure veins, such as at the Killhope Head GCR site, in the Alston Block and the Gunnerside Gill (potential) GCR site in the Askrigg GCR Block, the area is noted for the widespread occurrence of metasomatic replacement orebodies, mainly of limestone wall-rock, by introduced minerals. Adjacent to many veins, especially in the Alston Block, limestone has undergone extensive metasomatism with the original lithology replaced wholly or partly by ankerite, dolomite, siderite, quartz, fluorite, galena, sphalerite and smaller amounts of other minerals (see Smallcleugh Mine GCR site report, this chapter). This replacement is commonly restricted to certain beds within the limestones, and may extend for many metres laterally from the parent vein, such as at the Tynebottom Mine GCR site. From their characteristic horizontal form these deposits are known as 'flats' in the Alston Block or occasionally as Tots' in the Askrigg Block. Orebodies of this sort have provided several of the area's richest and most productive deposits of galena and sphalerite and a few important deposits of barite, as at the Scordale Mines GCR site. Within the Alston Block, large 'flat' deposits of iron ores, both fresh carbonate ores, seen at the Killhope Head GCR site, and oxidized iimonitic' ores, as at the West Rigg Opencut and Killhope Head GCR sites, have been worked in places.

The Pennine orefields may be considered as part of the worldwide Mississippi Valley-type, although Dunham (1983) suggested grouping them with the deposits of the Illinois–Kentucky fields of the USA within a fluoritic subgroup.

Throughout the Pennines the main sulphide ore minerals are galena and sphalerite. Most of the galena in the Alston Block is argentiferous, typically with silver contents ranging from 111–251 ppm, although with exceptional values of up to 2511 ppm at a very few locations (Dunham, 1990). Silver was a valuable byproduct of lead smelting in this part of the ore-field. Historical claims of silver production in the 11th and 12th centuries could not have been sustained from ores with the silver contents normally encountered during 18th and 19th century smelting, leading Dunham *et al.* (2001) to speculate on the possibility that ores with a much higher silver content, perhaps resulting from a supergene enrichment in silver, may then have been available. Silver was also recovered from a number of mines in the Askrigg Block from galena with silver contents of between 50 ppm and 166 ppm. However, the galena throughout much of this area typically exhibits silver contents of less than 100 ppm, although with very rare occurrences of values as high as 2052 ppm. Sphalerite is abundant in parts of the Alston Block. It is generally less common in the Askrigg Block, although the local abundance here of substantial amounts of supergene hemimorphite and smithsonite suggests it may formerly have been more abundant. A unique deposit of supergene smithsonite, known locally as 'calamine', was worked at the Pikedaw Calamine and Copper Mines (potential) GCR site. Copper minerals are widespread in trace amounts throughout the Pennine deposits. Small economic concentrations were found locally, for example in the Alston area, and on the western, eastern and southern extremities of the Askrigg Block, for example at the Cumpston Hill North and South Veins GCR site, near Kirkby Stephen, at the Black Scar GCR site, near Richmond, and immediately north of the Craven Fault System at the Greenhow Quarry GCR site, respectively.

The iron carbonate minerals siderite and ankerite are widespread within the Alston Block deposits where they have been of considerable economic importance. They are generally rare or absent from most of the Askrigg Block. Dunham (1948, 1990) has suggested that the abundance of iron in the Alston Pennine deposits, compared to its general scarcity in the Askrigg area, may indicate derivation of the iron from the Whin Sill in the former area. Gangue minerals throughout the Northern Pennine Orefield include barite, locally with abundant witherite, and fluorite. Calcite is common, particularly in the Askrigg Block, while quartz is abundant in the Alston Block.

Both orefields, but especially that of the Alston Block, are characterized by a strong zonal distribution of the constituent minerals, particularly the gangue minerals. Central, fluorite-rich zones, as seen at the Killhope Head and Pike Law Mines GCR sites in the Alston Block, are surrounded by outer zones in which barium and calcium carbonate minerals are dominant, as at the Blagill Mine, Foster's Hush and SettLingstones Mine GCR sites. The genetic significance of this pattern was first recognized by Dunham (1934), who drew comparisons with the zonation of minerals around the granites of South-west England. By analogy with that area, a concealed Hercynian granite beneath the Northern Pennines was postulated to account for the mineralization. Geophysical evidence in both the Alston and Askrigg blocks lent strong support to this hypothesis (Bost and Masson-Smith, 1957; Bott, 1967). Drilling at Rookhope in the Alston Block and at Raydale in the Askrigg Block proved the presence of pre-Carboniferous granite at each site. Clearly the mineralization could not be the direct result of the intrusion of these granites.

The discovery of pre-Carboniferous granites beneath the Northern Pennine Orefield provided a fresh impetus for research on the origin of these deposits, and much has since been published on the topic. Notable contributions include those of Sawkins (1966a, 1976), Mitchell and Krouse (1971), Solomon *et al.* (1971), Russell and Smith (1979), Brown *et al.* (1987), Dunham and Wilson (1985), Plant and Jones (1989), Dunham (1990), Halliday *et al.* (1990), Ixer and Vaughan (1993), Crowley *et al.* (1997), Cann and Banks (2001), and Bouch *et al.* (2006). Most recent work suggests that the ore-forming fluids were 'oilfield'-type brines derived by the dewatering of adjoining penecontemporaneous Carboniferous basins. The abundance of fluorite within the Pennine deposits may indicate a contribution of fluorine to the mineralizing fluids from the granites, although a source within the sedimentary basins is also possible. By virtue of being 'high-heat-production' granites the Pennine granites also offer an explanation for the relatively high mineralization temperatures and for the complex ore mineralogy, including elements characteristic of granite associations. An interaction between the basinal brines and the granites is thus envisaged, including the role of the granites, especially in the Alston Block, in creating convective circulation of fluids and the formation of well-developed mineral zonation. The mineralization must have been introduced soon after the emplacement of the late Carboniferous to early Permian Whin Sill. The Lady's Rake Mine GCR site (Young *et al.,* 1985b) represents a sulphide-bearing skarn deposit and provides an important insight into the genesis of the Northern Pennine sulphide-bearing veins and their relationship to the Whin Sill.

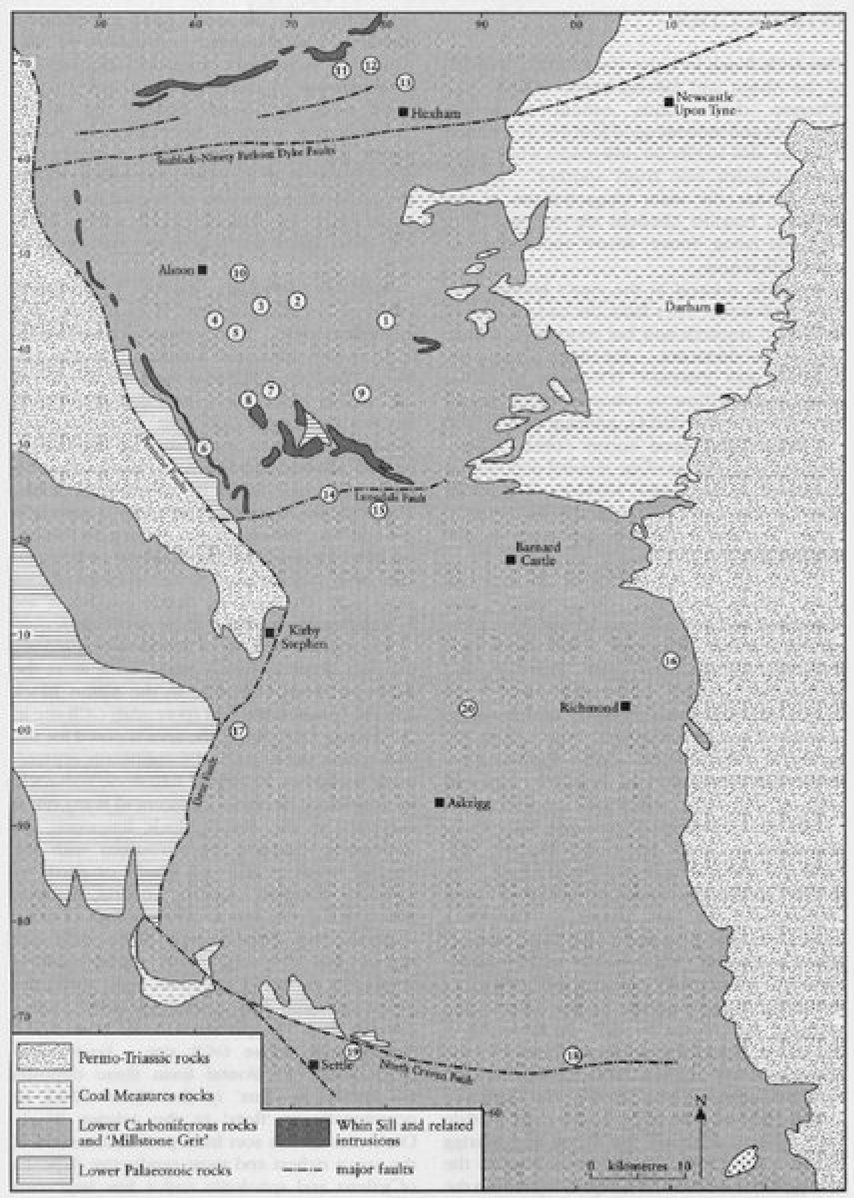
Mining in the Pennine orefields may be traced back over several centuries. Originally worked for iron, lead and locally minor associated silver, the working of zinc became important last century, for example at the Smallcleugh Mine and Stonecroft Mine GCR sites. In the late 19th and early 20th centuries, witherite (at the Settlingstones Mine and the Fallowfield Mine GCR sites), barite (at the Closehouse Mine GCR site), and fluorite became the main mineral products, although apart from some commercial mining for high-grade fluorite specimens at Rogerley Mine in Weardale, all mining of vein minerals has now ended.

The Northern Pennines have long been famous as a source of beautiful specimens of a number of minerals which are to be seen in major mineralogical collections throughout the world. Pre-eminent amongst these are spectacular examples of purple, green and yellow fluorite, and beautiful examples of barite and witherite (e.g. Greg and Lettsom, 1858; Hacker, 2003; Symes and Young, 2008). The Northern Pennine Orefield is unique for the abundance of barium carbonate minerals and provides the type locations for witherite together with the much rarer double calcium, barium carbonate minerals alstonite (from the Fallowfield Mine GCR site) and barytocalcite (from the Blagill Mine GCR site) (Young, 1985c).

The Northern Pennine deposits have also yielded some fine examples of supergene species (Young *et al.,* 1989, 1992a, 2005; Dunham, 1990; Bridges and Young, 1998), and include the type locality for the supergene zinc carbonate sulphate hydrate mineral brianyoungite (Livingstone and Champness, 1993). The Willyhole Mine GCR site is renowned for the extensive development of supergene greenockite after primary sphalerite.

Reports of a number of very rare supergene species from a group of veins on Grassington Moor, in the southern part of the Askrigg Block, are based on specimens collected by the late A.W.G. Kingsbury. Species recorded from here include cinnabar, metacinnabarite and native mercury (Kingsbury, 1968), parahopeite and spencerite (Embrey, 1977), and plumbojarosite and argentojarosite (Dunham and Wilson, 1985). Ryback *et al.* (2001) have shown that Kingsbury falsified the localities of numerous rare mineral species in his collection. It seems that from about 1951 he began to pass off classic foreign material from old collections as having been collected by him from British localities. Ryback *et al.* (2001) demonstrated that his specimens of mercury minerals, alleged to have been collected on Grassington Moor, are quite atypical of Pennine material and probably originated from the Berehove–Dubrinihi area in Hungary. Although Kingsbury's specimens of other rare species from Grassington have not been examined in detail, serious doubt must be attached to his claims, as, despite the best efforts of numerous subsequent collectors, none of his supposed finds have been repeated.

References



(Figure 3.1) Geological sketch map with locations of GCR sites. 1– West Rigg Opencut; 2 – Killhope Head; 3 – Smallcleugh Mine; 4 – Tynebottom Mine; 5 – Sir John's Mine; 6– Scordale Mines; 7 – Lady's Rake Mine; 8 – Willyhole Mine; 9 – Pike Law Mines; 10 – Blagill Mine; 11 – Settlingstones Mine; 12 – Stonecroft Mine; 13 – Fallowfield Mine; 14 – Closehouse Mine; 15 – Foster's Hush; 16 – Black Scar; 17 – Cumpston Hill North and South Veins; 18 – Greenhow (Duck Street) Quarry; 19 – Pikedaw Calamine and Copper Mines; 20 – Gunnerside Gill.