22 Craig an Chanaich to Frenich Burn

[NN 811 546]–[NN 818 545]

J.E. Treagus

Published in: The Dalradian rocks of the central Grampian Highlands of Scotland. PGA 124 (1–2) 2013
https://doi.org/10.1016/j.pgeola.2012.07.009. Also on NORA

22.1 Introduction

The Craig an Chanaich to Frenich Burn GCR site incorporates the principal exposures of a body of stratiform baryte that is unique in the British Isles and in Europe. As well as the unusually pure, bedded baryte, the body also contains rare barium silicate minerals and stratiform sulphides. It has a maximum thickness of 80 m and extends for 7 km to the east of the GCR site along the Meall Tairneachan–Farragon Hill ridge between Strath Tummel and Strath Tay. The baryte occurs within the Ben Eagach Schist Formation of the Easdale Subgroup; it is involved in all three of the regional phases of deformation and the regional metamorphism.

The mineralization was first discovered by the Geological Survey in 1975 during stream-sediment sampling and was described by Coats *et al.* (1978, 1981). It was the subject of a PhD. thesis by Moles (1985a) and was summarized by Hall (1993) and by Pattrick and Treagus (1996). The consensus of this research was that the body is a sedimentary deposit, resulting from the exhalation of metal-laden fluids onto the floor of a deep-sea basin. Other barium enrichments in the Ben Eagach Schist are now known near Braemar at Loch Kander [NO 192 803] and Allt an Loch [NO 196 796] (Gallagher *et al*., 1989) and near Loch Lyon [NN 414 383] (Coats *et al*., 1984). The body has been the subject of extensive underground and surface mining (Foss Mine) from 1984 to the time of writing (1999); the GCR site is largely comprised of the artificial exposures created by this mining activity.

22.2 Description

Natural exposures of the mineral body are generally poor, the most significant occurring on Creag an Chanaich [NN 8122 5457], in the Frenich Burn East [NN 8196 5492] and on Creag an Loch [NN 8267 5504]. However, in the area of the GCR site, around Foss Mine, the body has been exposed extensively in opencast workings, along the access road on Creag an Chanaich and around the adits to the underground workings, especially on the north-eastern face of Creag an Chanaich (Figure 3.51).

The total thickness of the mineral body reaches 80 m, and the maximum thickness of baryte is 15 m. It is hosted by the graphitic muscovite schist of the Ben Eagach Schist Formation and is close to, or at the contact with, the calcareous schist of the overlying Ben Lawers Schist. There are two main mineral horizons, the Upper and Lower horizons. The high-grade Upper Mineral Horizon is characterized by bedded pyritiferous baryte, generally bounded above and below by quartz-celsian (barium feldspar) rock, barium-enriched muscovite schist and sulphide-bearing graphitic schist. Layers of massive sulphide (pyrite, chalcopyrite, sphalerite and galena) are rare but significant components. The thicknesses and relative importance of the mineral lithologies vary considerably along strike and down dip, but the bedded baryte and the quartz-celsian rock are major components and this is one of the largest occurrences of celsian in the world. The description here is confined to the exposures on or near to the mine track at Creag an Chanaich and those in the opencast pits to the east (Figure 3.53).

The most westerly exposure of the body is seen on the western slope of Creag an Chanaich, where massive baryte of the Upper Mineral Horizon, dipping steeply to the south, is overlain by quartz-celsian rock at [NN 8109 5461]. On the ridge of Creag an Chanaich, between [NN 8114 5459] and [NN 8122 5457], the 3.5 m-thick baryte body, containing pyritic layers, is overlain by 1 m of siliceous schist and then by quartz-celsian rock. In this area, 8 m of graphitic schist separate the Upper Mineral Horizon from the Ben Lawers Schist. On the steep, east slope of Creag an Chanaich, the surface trace of the mineral body is controlled by two WSW-plunging regional fold sets; F2 folds, which were originally upright, are here locally recumbent, having been affected by a major F3 fold-pair (Figure 3.52) that is well seen in the outcrop sub-parallel to the hairpin bends of the mine track, especially between [NN 8128 5457] and [NN 8131 5453] (Figure 3.51). One metre of baryte is here enclosed in an envelope of quartz-celsian rock, 2 m thick below and over 3 m thick above, which is affected by a F2 fold-pair (Figure 3.51). At [NN 8135 5453] the baryte and quartz-celsian rock form the core of an F2 antiform. The more-penetrative S2 cleavage, as well as a superimposed well-developed upright S3 crenulation cleavage, is well seen in the schists adjacent to these folds. Within the outcrop of the Ben Eagach Schist in this area is a 3 m-thick, broadly concordant sheet of calcareous hornblende schist (a basic meta-igneous rock), which crosses the track in several places on the hairpin bends.

The mineral body is also well exposed in the western wall of the track, in a disused adit [NN 8135 5455]. Here the baryte layer is 4 m thick, massive, white or grey depending on the concentration of pyrite layers and occupies the synformal core of an F2 fold. A 10 cm-thick layer of massive pyrite is present at the stratigraphical base of the baryte, in the north wall of the adit. To the east a further (lower) adit has been driven into the baryte, which is here 3.5 m thick in an envelope of quartz-celsian rock in an F3 antiformal structure. Farther down the track, the Ben Eagach Schist–Ben Lawers Schist contact is exposed [NN 8137 5450]. A structural synthesis of these exposures in the mine track is shown in (Figure 3.52).

The Lower Mineral Horizon is also present on Creag an Chanaich, although it thins progressively eastwards (Figure 3.51). A small outcrop is present on the top of the ridge at [NN 8122 5464] and comprises quartz-celsian rock with a sheet of heavily weathered calcareous hornblende schist (basic meta-igneous rock) at the base; the associated scree contains massive baryte. A trench by the track at [NN 8124 5463] has exposed 2–3 m of pyritic quartz-celsian rock with 1 m of basic meta-igneous rock at the basal contact; the lithologies are repeated in an F3 fold core and the Ben Eagach Schist is exposed in the southerly end of the trench, in which a flat-lying crenulation cleavage (local S4) can be seen as well as D3 and D2 folds and cleavages. In the most-easterly exposure of the Lower Mineral Horizon, at [NN 8133 5457], 30 cm of pyritic quartz-celsian rock and sulphide-rich schist are found; here too the lower contact of the horizon is marked by a 50 cm-thick sheet of basic meta-igneous rock.

The surface trace of the Upper Mineral Horizon is offset by a pair of NNE-trending, left-lateral faults that separate the underground workings from the opencast pits; the area between the faults is occupied by mine buildings and plant (Figure 3.51). The most easterly fault-plane is exposed in the western end of the opencast workings and contains an altered microdiorite dyke [NN 8144 5446]. To the east of the fault, the mineral horizons have been mined in several pits, which are exploiting the thickest, near-surface occurrences of the baryte (Figure 3.51) and (Figure 3.52). In the south-western part of the opencast workings, exploitation has focussed on baryte rock in the core of a southwards plunging F2 synform. On the southern limb of this synform the Ben Lawers Schist, the muscovitic, graphitic, Ben Eagach Schist and quartz-celsian rock are well exposed in the pit wall; the Ben Eagach Schist is also exposed in the core of the synform at [NN 8147 5448] (Figure 3.53). An F3 antiformal structure causes the baryte and quartz-celsian rock to crop out again to the north at [NN 8152 5450]. To the east, the outcrop of the Upper Mineral Horizon is complicated by small NE-trending faults and F2/F3 folding and thins rapidly towards the Frenich Burn Fault.

22.3 Interpretation

The mineral body in the area of the GCR site is considered to be a SedEx-type (sedimentary exhalative) deposit (Coats *et al*., 1980; Willan and Coleman, 1983; Russell *et al.*, 1984; Moles, 1985a; Hall, 1993). It is thought to have resulted from the exhalation of metal-laden mineralizing fluids onto the floor of a marine basin at the time of Easdale Subgroup sedimentation. The baryte formed by the mixing of barium, carried in reduced hydrothermal fluids, with sulphate in the relatively oxidized seawater. Barium also reacted with the aluminosilicate-rich seafloor muds to produce barian clays and cymrite ($BaAl_2Si_2O_8.H_2O$), the precursors to the barian micas and barian feldspar (celsian), the transition taking place during metamorphism, with estimates of a pressure of 6.5 kbar and a temperature of 530°C (Moles, 1985b). The hydrothermal fluid was also the source of the metals for the sulphides and iron oxides but, in contrast to many SedEx deposits, these rarely formed thick accumulations. Exhalative silica precipitated as cherts in the aluminosilicate muds and recrystallized during metamorphism.

The mineral horizons are interpreted as successive exhalative hydrothermal pulses emanating onto the seafloor, the variation in the horizons being a function of both intensity of hydrothermal activity and the distance from exhalative centres. Although two of the horizons are laterally very extensive, occurring along the 2 km strike length in the GCR site area and extending for a further 7 km eastwards, the recognition of exhalative centres within these horizons has not proved possible. To explain the sharp contacts to the massive baryte layers, Russell *et al.* (1984) suggested that the sulphate for the baryte was derived from evaporitic shallow coastal areas which periodically produced flows of dense sulphate-rich brine into the sulphate-poor basin deeps at the time of hydrothermal activity, thus providing an episodic and finite sulphate supply.

The fundamental cause of the mineral influx is considered to be the crustal instability during Argyll Group times that resulted in the break-up of the Dalradian basin into several second-order basins (Coats *et al*., 1984; Russell *et al*., 1984; Pattrick and Treagus, 1996, figure 7b). The basic meta-igneous rocks of oceanic affinity in the Farragon Volcanic Formation overlying the Ben Lawers Schist are a product of the continuation of this process as the basins extended and deepened. The thick basic meta-igneous sheets in the mine area that post-date the mineralization are interpreted as sills and are also associated with this process. The crustal extension and thinning that led to the break-up of the basin resulted in a high geothermal gradient and large-scale convection of seawater into the underlying lithologies (to a depth of at least 10 km) where it was heated by interaction with the buried older Dalradian lithologies. This fluid leached metals from the rocks (especially barium from the feldspathic Grampian Group), before rising to the seafloor to form the SedEx deposit. These same conditions prevailed over all of the Dalradian basins at this time and resulted in similar mineralization being developed in the Easdale Subgroup elsewhere.

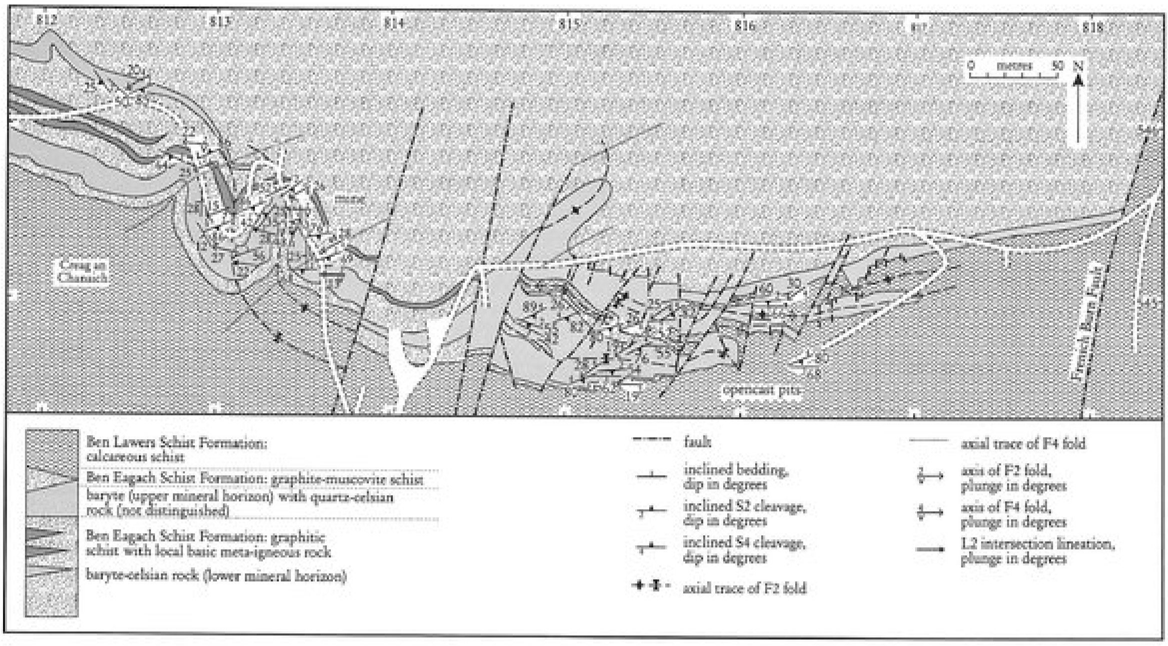
In terms of the regional structure, the deposit lies on the steep, south-dipping limb of the major upward-facing F1 Creag an h-Iolaire Anticline (Treagus, 2000, figure 14); there is no significant mineral body on the north limb of this fold. F1 minor folds have not been recorded, but the structural relationships between the well-developed minor folds and cleavages of D2 and D3 age (as well as of the local D4) in the area of the GCR site are exceptionally clear. They also clearly reveal the geometry and superimposition of major folds of both D2 and D3 ages (Figure 3.52).

22.4 Conclusions

The Creag an Chanaich to Frenich Burn GCR site is of international importance in providing excellent exposure of a metamorphosed synsedimentary mineral body, which is unique in British and European geology and has few equals worldwide. The barium sulphate mineral baryte ($BaSO_4$), which forms a large proportion of the body in an unusually pure concentration, has been an important source of drilling mud for oil exploration in the North Sea. In addition it contains concentrations of sulphide minerals, as well as two unusual barium silicate minerals, celsian (barium feldspar) and cymrite (a hydrous aluminosilicate). The latter two minerals have been used to calculate the temperature and pressure (and hence the depth of burial) to which the Dalradian rocks were subjected during the creation of the mountain-belt; and this is one of the largest known ocurrences of celsian in the world.

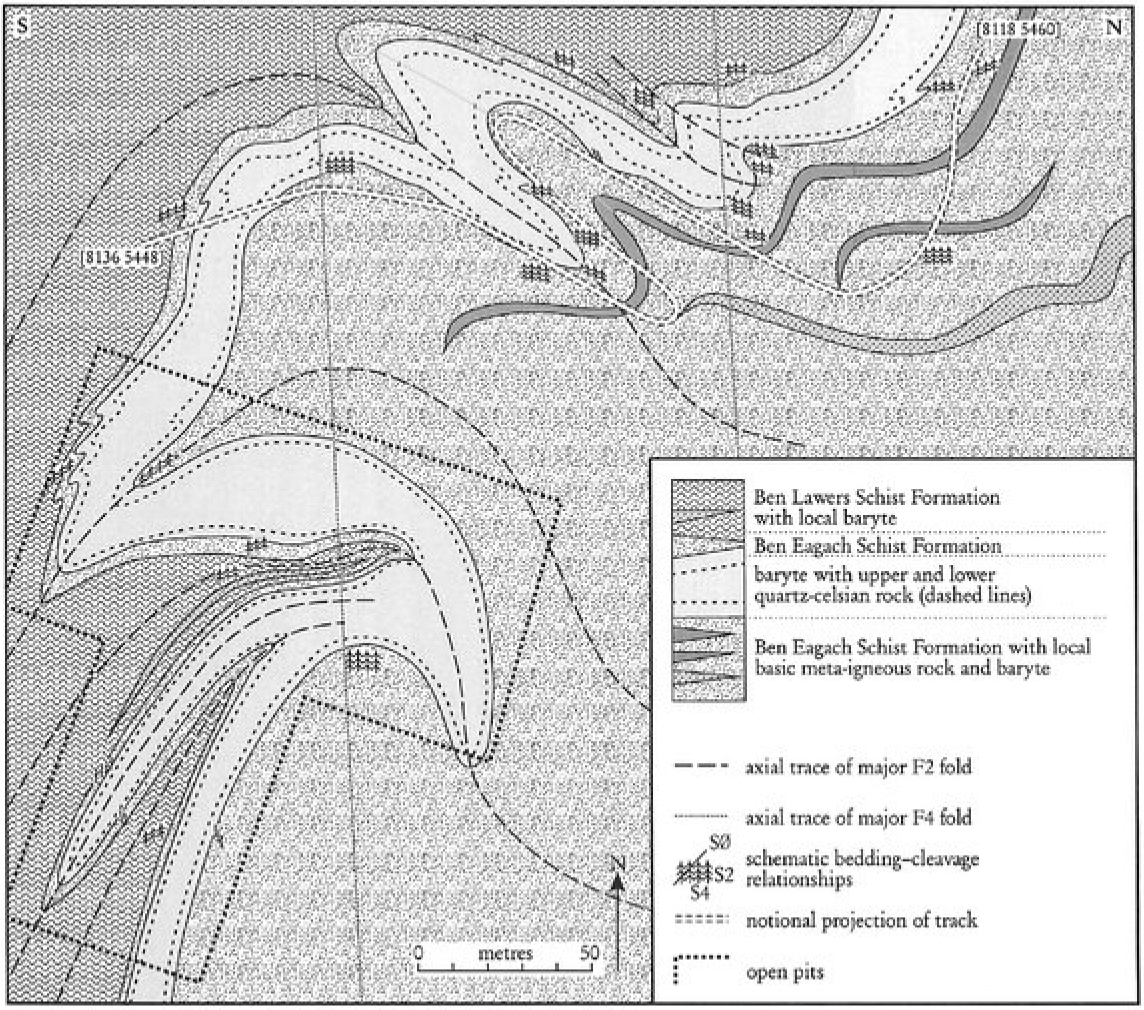
The unique feature of this body is that it is of sedimentary origin, believed to have been precipitated directly from brines in a small marine basin, fed by metal-rich hot fluids percolating through the underlying sedimentary pile. The site also provides unusually clear minor structures (folds and cleavages) of two generations, which affect the mineral body and which have been used in the understanding of the geometry of some major folds that make up the Grampian fold-belt.

References



(Figure 3.51) Map of Creag an Chanaich and the area of opencast pits. Mapping west of easting 8145 is based on Moles (1985a) and Treagus (2000); to the east it is based on unpublished mapping by J.M. Maclachlan and N.J. Butcher. Compilation and structural observations by J.E Treagus.

(Figure 3.53) The opencast workings at Creag an Chanaich, in which Ben Eagach Schist (dark area, centre) is exposed in the core of an F2 synform within the stratiform baryte. Cliff exposure is 10 m high. (Photo: J.E. Treagus.)



(Figure 3.52) Schematic down-plunge profile view of major and minor F2 and F3 folds in the area of the Craig an Chanaich mine and opencast pits. A plunge of 25° to 255° is assumed; fault movement restored. After Pattrick and Treagus (1996, figure 6).