12 Auchindoun Castle

[NJ 345 368]–[NJ 362 375]

D. Stephenson

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12.1 Introduction

The ruins of Auchindoun Castle stand on a knoll of metalimestone above the River Fiddich, 3.5 km south-east of Dufftown. Exposures below the castle, in the river banks, are of dark graphitic pelite of the Mortlach Graphitic Schist Formation, and it is the regional metamorphic minerals in the pelite that are the main feature of interest at this GCR site. Square cross-sections of chiastolite (a variety of andalusite), clearly seen in hand specimen, are seen in thin section to have been replaced by kyanite, indicating a significant increase in regional pressure. The metalimestone is the Dufftown Limestone Member at the base of the Mortlach Formation, which in this area marks the base of the Ballachulish Subgroup.

The primary survey of the area was published as one-inch Sheet 85 (Rothes) in 1898, together with a brief memoir (Hinxman and Grant Wilson, 1902). The area was not revisited until it was remapped by the British Geological Survey for 1:50 000 Sheet 85E (Glenfiddich, 1996), which was when the interesting relationships between the regional metamorphic minerals were discovered. This led to a detailed investigation of the pressure–temperature conditions of metamorphism by Beddoe-Stephens (1990) that formed part of a wider study of metamorphic conditions on either side of the Portsoy–Duchray Hill Lineament. The rocks at Auchindoun lie on the west side of the lineament, where peak pressures were up to 4 kbar higher than they were immediately to the east of the lineament, due to near-isothermal compression beneath westerly directed thrusting along the line of the Portsoy-Duchray Hill Lineament/Shear-zone. Samples from this locality were also used in a regional geochemical study of Dalradian metacarbonate rocks, which proved to be of significant value in stratigraphical correlation (Thomas, 1989), and calcsilicate beds within the pelites provided material for a study of amphibole geochemistry that revealed implications for the original depositional environment (Stephenson, 1993).

12.2 Description

The area around Auchindoun lies on the south-eastern limb of the Ardonald Anticline, a NW-verging, tight, regional-scale fold of possible D3 age. The right-way-up succession extends from the Pitlurg Calcareous Flag Formation of the Lochaber Subgroup, here poorly exposed, through the Mortlach Graphitic Schist Formation, to the Corriehabbie Quartzite Formation of the Ballachulish Subgroup, which forms a continuous ridge to the south-east of Glen Fiddich (Figure 6.23). Bedding dips to the south-east at between 30° and 65° and the dominant cleavage in the pelites (?S2) commonly dips at a lower angle, indicating local inversions possibly due to intermediate-scale folds.

The Dufftown Limestone Member in this area is of variable thickness, up to about 3 m, but at Auchindoun Castle the outcrop is thickened by a series of tight, SSW-plunging folds. The member is composed typically of banded, grey, crystalline metalimestone, but in places thin beds of metalimestone and pinkish brown-weathering calcsilicate rock are interbedded with phyllitic pelites. At the castle, thin pelitic partings in the metalimestone have a strong spaced cleavage (?S2) as is seen in the overlying pelites. South-west of the castle the metalimestone outcrop is terminated by a fault.

The main part of the Mortlach Graphitic Schist Formation, above the Dufftown Limestone Member, is well exposed in the banks of the River Fiddich and in tributaries on the south-east side of Glen Fiddich, in particular the Allt a' Choileachain, the Red Burn and the Small Burn, where the outcrop width is greatly increased by tight folding. In this area, it is composed predominantly of dark-grey, fine-grained, finely banded pelite. Banding takes the form of thin, 1–5 mm-wide bands of pale semipelite or psammite, which enable the orientation of the original bedding to be seen in most exposures. The pelites are usually hard and blocky, but are phyllitic to schistose in places, with a strong S2 spaced/crenulation cleavage. Where the dominant cleavage is near coincident with the bedding, the rock becomes very hard and slaty. Such slates have been quarried at several places on the hill slopes to the east (e.g. at [NJ 358 370] and [NJ 375 386]). In most exposures the pelites contain prominent, square-sectioned chiastolite and many are garnetiferous. Most are graphitic and some are quite pyritiferous. Bands and pods of tremolitic amphibole, with or without subsidiary carbonate-rich laminae, within the pelites have been interpreted as para-amphibolites and indicate a continuation of the calcareous facies above the basal metalimestone member (Stephenson, 1993).

Throughout the exposures of pelitic rocks, there is good evidence in thin section of replacement of chiastolite by kyanite in what appears to be a direct pseudomorph relationship. Squarish to rectangular porphyroblasts of chiastolite with preserved inclusion ‘crosses’ of graphite have been replaced by radial fan-like sheaves of kyanite (Figure 6.24), which commonly show varying degrees of later replacement by muscovite. A fine-grained crenulated micaceous fabric can be seen to post-date the chiastolite and slight strain effects in the kyanite suggest that this fabric might also post-date kyanite growth. Other regional metamorphic minerals present are garnet and biotite.

12.3 Interpretation

It has long been recognized that metamorphism in the Buchan region, to the east of the Portsoy–Duchray Hill Lineament, is distinct from that elsewhere in the Grampian Terrane, being characterized by relatively low-pressure/high-temperature mineral assemblages (see 1.3 in *Introduction*). The western limit of this low-pressure metamorphism is broadly coincident with the shear-zones that define the Portsoy–Duchray Hill Lineament and also mark the western margin of the structurally and stratigraphically distinct ‘Buchan Block’ (Baker, 1985; Fettes *et al*., 1986; Harte and Dempster, 1987). To the west of the lineament, lower structural levels and older Dalradian rocks are exposed and the metamorphic mineral assemblages are characteristic of a higher pressure.

The low- and high-pressure assemblages are characterized essentially by andalusite and kyanite respectively, and D.J. Fettes (on the BGS 1:250 000 Sheet 57N 04W, Moray–Buchan, 1977) and Chinner and Heseltine (1979) each plotted andalusite–kyanite isograds, parallel and close to the Portsoy–Duchray Hill Lineament. However, there is a well-defined zone, up to 10 km wide on the western side of the lineament, where original andalusite has inverted to kyanite indicating a pressure increase after the initial metamorphism (Chinner and Heseltine, 1979; Baker, 1985). On the Banffshire coast, this zone is narrow but is beautifully illustrated in the well-known chiastolite-bearing pelites at the swimming pool west of Portsoy (see the *Cullen to Troup Head* GCR site report). There, the chiastolite is clearly seen in thin section to be pseudomorphed by kyanite and muscovite, but the relationships are complicated by the presence of sillimanite, which pre-dates the kyanite, and by later overgrowths of kyanite and muscovite that post-date the main fabric. Inland, and especially in the area around Auchindoun Castle, there is a much simpler replacement of the original chiastolite porphyroblasts.

The regional study of Beddoe-Stephens (1990) placed quantitative pressure and temperature constraints on the observed metamorphic reactions on both sides of the Portsoy–Duchray Hill Lineament. Values were calculated from various thermodynamic calibrations based upon reactions between commonly occurring minerals. Both thermal and barometric ‘breaks’ are clearly seen at the lineament. East of the lineament, where only andalusite and sillimanite occur, pressures never exceeded 4.5 kbar and temperatures of up to 660°C are recorded. West of the lineament, where kyanite occurs either as the sole aluminosilicate phase or as a replacement of andalusite, pressures of 7.5 to 8.5 kbar are recorded close to the lineament and these increase to over 9 kbar farther west. There is also a corresponding temperature increase from 500°C to 600°C westwards from the lineament. A sample from close to Auchindoun Castle, some 4.5 km to the north-west of the Portsoy–Duchray Hill Lineament, gave values of 8.5 kbar and 605°C. Compositional zoning in garnet crystals enables the pressure–temperature path that the rock has experienced during the growth of the garnet to be modelled. Using this method, samples from immediately west of the lineament have shown an increase in pressure of about 2 kbar, associated with only minor heating, which was sufficient to account for the observed inversion of andalusite to kyanite.

From detailed studies such as that of Beddoe-Stephens (1990), associated with previous work based largely on the coastal sections (e.g. Harte and Hudson, 1979; Hudson, 1985; Baker, 1987), it has been possible to deduce a sequence of structural and metamorphic events to account for all of the features described above. The development of andalusite, characteristic of high-temperature, low-pressure metamorphism, clearly extended westwards from the Buchan area, across the position of the Portsoy–Duchray Hill Lineament as is shown by the relics of andalusite, for example in the Auchindoun area. The andalusite–kyanite isograd of Chinner and Heseltine (1979) marks the western limit of this original andalusite, which might have developed at least in part in response to high heatflow associated with the emplacement of basic magma in the Buchan Block at around 470 Ma.

Subsequent to the development of andalusite, the rocks immediately to the west of the lineament underwent a pressure increase of up to 2 kbar that transformed the andalusite to kyanite and it is these peak metamorphic conditions that are recorded by the calculated pressure and temperature values of Beddoe-Stephens (1990). Ashcroft *et al.* (1984) suggested that it was subvertical shear movements along the Portsoy–Duchray Hill Lineament after the emplacement of the basic magmas, with relative uplift to the west, that brought up the higher grade rocks. However, Baker (1987) and Beddoe-Stephens (1990) refined this to suggest that westerly or north-westerly directed thrusting across the lineament emplaced a thick upper Dalradian sequence of the Buchan Block above older rocks to the west, which were hence subjected to increased overburden pressure and near-isothermal compression. Although this explanation has been generally accepted, there is little stratigraphical evidence for overthrusting and the Dalradian stratigraphy seems to young consistently from west to east across the Portsoy–Duchray Hill Lineament with no repetition (Fettes *et al*., 1991). Hence Dempster *et al.* (1995) have offered the alternative suggestion that the pressure increase was due to magmatic loading caused by emplacement of the basic magmas.

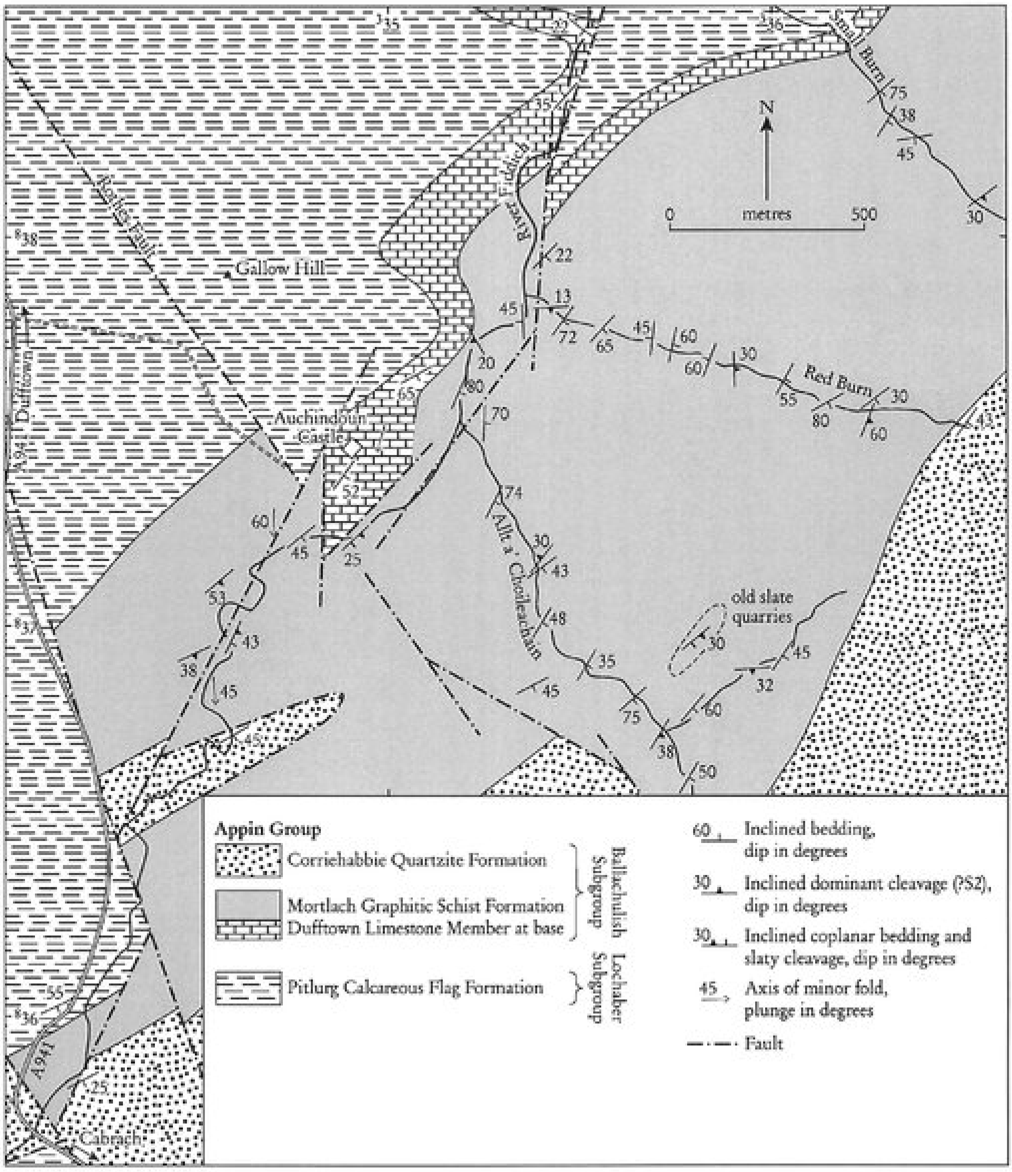
The present steep attitude of the shear-zones along the Portsoy–Duchray Hill Lineament is probably attributable to subsequent late folding and crustal warping, during D3 and later events, resulting in exhumation of strata from deeper levels on the western side. This uplift must have been relatively rapid in order to have preserved the mineral relationships without further retrograde reactions taking place, and this is nowhere more true than at Auchindoun Castle.

12.4 Conclusions

Metamudstones (pelites) in the banks of the River Fiddich, below Auchindoun Castle, contain prominent minerals that provide a fascinating insight into the history of deformation and regional metamorphism in Dalradian rocks of the North-east Grampian Highlands. Rectangular white cross-sections are easily visible in hand specimen. Some have a dark ‘cross’ due to inclusions of graphite and their overall appearance is characteristic of chiastolite (a variety of the aluminium silicate, andalusite). However, thin sections reveal that the original andalusite has been replaced by kyanite, identical in composition to andalusite but stable under higher pressure conditions. These are exceptionally clear examples of a feature that has great significance in the understanding of metamorphic terranes and hence could be said to have international importance.

Detailed mineralogical studies have enabled the temperature and pressure at the peak of metamorphism to be calculated and, when combined with similar determinations throughout the region, these data reveal significant differences in metamorphic history between rocks on either side of the N–S-trending Portsoy–Duchray Hill Lineament. It has been suggested that this is due to a considerable thickness of low-pressure–high-temperature rocks from the Buchan Block in the east having been overthrust westwards, increasing the overburden pressure on the rocks below and hence causing the low-pressure andalusite to recrystallize as the high-pressure form of aluminium silicate, kyanite.

References



(Figure 6.23) Map of the area around Auchindoun Castle, Glen Fiddich from BGS 1:10 000 sheets NJ33NW (1993) and NJ33NE (1993). The Portsoy Lineament lies some 4.5 km to the south-east of the castle. Most of the exposures of pelites in this area show square cross-sections of chiastolite in hand specimen and thin sections reveal that this has been replaced by kyanite (Figure 6.24).

(Figure 6.24) Chiastolite (=andalusite) porphyroblasts pseudomorphed by fan-like sheaves of kyanite in a sample of pelite from the Mortlach Graphitic Schist Formation close to Auchindoun Castle. The original ‘crosses’ formed by graphite inclusions in the chiastolite are still clearly visible. (from Beddoe-Stephens, 1990, figure 2a). (Photo: BGS No. P 254543, reproduced with the permission of the Director, British Geological Survey, © NERC.)