Proceedings of the Geologists' Association 124 (2013) 215–262

Contents lists available at SciVerse ScienceDirect

Proceedings of the Geologists' Association

journal homepage: www.elsevier.com/locate/pgeola

The Dalradian rocks of the Highland Border region of Scotland

P.W. Geoff Tanner [a], Christopher W. Thomas [b], Anthony L. Harris [c], David Gould [d], Ben Harte [e], Jack E. Treagus [f,1], David Stephenson [b,*]

[a] Department of Geographical and Earth Sciences, University of Glasgow, Gregory Building, Lilybank Gardens, Glasgow G12 8QQ, United Kingdom
[b] British Geological Survey, Murchison House, West Mains Road, Edinburgh EH9 3LA, United Kingdom
[c] Department of Earth, Planetary and Marine Sciences, Cardiff University, Park Place, Cardiff CF10 3YE, United Kingdom
[d] Formerly British Geological Survey, Edinburgh, United Kingdom
[e] School of GeoSciences, University of Edinburgh, West Mains Road, Edinburgh EH9 3JW, United Kingdom
[f] 15 Raynham Avenue, Didsbury, Manchester M20 6BW, United Kingdom

ARTICLE INFO

Article history:
Received 15 December 2011
Received in revised form 8 July 2012
Accepted 14 July 2012
Available online 22 November 2012

Keywords:
Geological Conservation Review
Highland Border region
Dalradian Supergroup
Lithostratigraphy
Structural geology
Metamorphism

ABSTRACT

The Highland Border region is defined here by the outcrop of the Southern Highland Group that lies north-west of the Highland Boundary Fault and runs from Stonehaven south-west to the Isle of Bute, and thence to the Campbeltown peninsula. The late-Neoproterozoic to early-Ordovician rocks of the Dalradian Supergroup in this region form a stratigraphical and structural entity that encompasses the >300 km-long surface traces of both the Tay Nappe (D1–D2) and the Highland Border Downbend (D4). The least deformed and metamorphosed Southern Highland Group rocks occur along the south-east margin of the region and are in continuity with the younger, newly recognized Trossachs Group, which has therefore been assigned to the Dalradian Supergroup. The earliest (D1) structures in the Dalradian rocks are dominant close to the Highland Boundary Fault but are successively overprinted northwards by D2, D3 and D4 structures and fabrics, here represented by a series of zones near-parallel to the Highland Boundary. Regional metamorphism increases progressively away from the Highland Boundary Fault and ranges from greenschist to upper amphibolite facies (sillimanite zone). Three fundamental features of deformed and regionally metamorphosed rocks worldwide were first recognized in this area: the 'stretching lineation' by Clough in 1897; the concept of regional metamorphic 'Barrovian zones' by Barrow in 1901; and the 'facing direction' of folds by Shackleton in 1958. The Highland Border region has acquired international recognition for research undertaken into the origin and mode of emplacement of the Tay Nappe, one of the largest recumbent folds known worldwide. This structure provides a framework for linking together most of the GCR sites in this paper.
© 2012 Natural Environment Research Council. Published by Elsevier Ltd on behalf of The Geologists' Association. All rights reserved.

Contents

* Corresponding author. Tel.: +44 0131 667 1000.
E-mail address: dst@bgs.ac.uk (D. Stephenson).
[1] Formerly Department of Earth Sciences, University of Manchester, United Kingdom.

0016-7878/$ – see front matter © 2012 Natural Environment Research Council. Published by Elsevier Ltd on behalf of The Geologists' Association. All rights reserved.
http://dx.doi.org/10.1016/j.pgeola.2012.07.013

1. Introduction (P.W.G. Tanner and J.E. Treagus)

The Highland Border region is defined here as the outcrop of the Southern Highland Group that is bounded to the north-west by its contact with the outcrop of the Argyll Group, and to the south-east by an ill-defined and much disputed contact with the Cambrian to Ordovician Highland Border Complex (Johnson and Harris, 1967; Tanner, 1995, 1997, 1998; Tanner and Pringle, 1999; Bluck and Ingham, 1997; Harris et al., 1998; Bluck, 2000; Tanner and Sutherland, 2007). Both the Southern Highland Group and the Highland Border Complex outcrops are truncated to the south-east by a major structural discontinuity, the Highland Boundary Fault.

The Dalradian rocks of this area form a single narrow outcrop, up to 35 km wide and 280 km long, extending from Kintyre to Stonehaven (Fig. 1). They consist of a rather monotonous pile of metagreywackes, over 5 km thick, with relatively thin units of slaty pelite that were once quarried for roofing slate at a number of localities such as Arran, Aberfoyle and Dunkeld. Volcaniclastic beds, commonly known as 'green beds', occur in the lower part of the sequence. Despite the uncertainty about its upper boundary, the Southern Highland Group in this outcrop forms a discrete unit in terms of its depositional history, structure, and regional metamorphism. It consists of a series of deep-sea fan turbidites that pass upwards into a passive-margin sequence, the sedimentary edifice being contained within a single major fold structure, the Tay Nappe.

The Tay Nappe is a large, early fold that was flat-lying, or recumbent, following the D2 deformation and was then folded by the Highland Border Downbend (F4) along a line close to, and parallel with, the south-eastern limit of the Highland Border region (Fig. 1). The lower, inverted limb of this fold occupies most of the Highland Border region and the main hinge-zone crops out between Arran and Callander. Farther to the north-east, beyond Dunkeld, it is either truncated by the Highland Boundary Fault or buried beneath an unconformable cover of Siluro-Devonian sedimentary and volcanic rocks of the Old Red Sandstone Supergroup and hence is not exposed.

Most of the Dalradian rocks are affected by up to four superimposed phases of deformation (D1–D4), the first three of which are attributed to the main mid-Ordovician Grampian Event of the Caledonian Orogeny and the last possibly to a mid-Silurian event. The Grampian deformation was accompanied by regional metamorphism that reached a peak in the upper amphibolite facies (sillimanite zone). Migmatites, arising from partial melting, occur in the highest grade rocks, and the regional metamorphic minerals include chlorite, biotite, garnet, chloritoid, staurolite, kyanite, and sillimanite (see the *Glen Esk* GCR report). The regional metamorphism reached its peak some 470 Ma ago, at around D2–D3, and it is thought that the growth of the mineral assemblages in each zone occurred during a relatively brief period (Oliver et al., 2000; Baxter et al., 2002).

A further compelling reason for considering this outcrop of the Southern Highland Group as a separate region is that it displays a structural unity throughout its length. This is defined in plan view by: the NE-trending axial traces of the Tay Nappe (D1 and D2) and the Highland Border Downbend (D4) (Fig. 1); the line marking the onset in a north-westerly direction of intense D2 reworking of bedding and the S1 fabric; and, less exactly, the traces of the biotite and garnet isograds.

This intensively studied region is now achieving international status as a model for short-lived orogenesis (less than 10 Ma) in which the unusually rapid rise in temperature of the deforming rock mass probably resulted from advective heat introduced via circulating fluids from contemporaneous intrusions (Atherton and Ghani, 2002; Dewey, 2005). This was aided by the loading and blanketing effects of an ophiolite nappe, which was emplaced over the Dalradian sedimentary rocks prior to the Grampian Event (Tanner, 2007; Henderson et al., 2009; Chew et al., 2010; Cutts et al., 2011). Although some of the first radiometric ages from these rocks, especially K-Ar ages on slaty pelites and on white micas, gave ages of over 500 Ma, these are now considered to be unreliable, and there is no tangible evidence that a late-Neoproterozoic orogeny affected the Dalradian prior to the Grampian Event (cf. Hutton and Alsop, 2004, 2005; and see Tanner, 2005).

Examples of seminal studies carried out in the Highland Border region that have gained international recognition as being unique in their field include:

(i) first use of minor structures in structural interpretation, and the recognition of polyphase deformation (Cowal peninsula; Clough, in Gunn et al., 1897) (see Section 1.2.3; Fig. 5). This approach is exemplified by the three GCR sites in the south-west (*Ardscalpsie Point*, *Cove Bay to Kilcreggan* and *Portincaple*), and especially by the three GCR sites around Dunkeld (*Little Glen Shee*, *Craig a'Barns* and *Rotmell*) that have been grouped together with this purpose in mind.

(ii) formulation of the concept of zones of metamorphic grade, and the recognition of the Barrovian and Buchan types of metamorphism (Barrow, 1912). The geology of the area in which this work was carried out is described in the *Glen Esk* GCR site report, which includes illustrations of the key Barrovian mineral assemblages.

(iii) introduction of the concept of structural facing in polyphase terrains to facilitate understanding of the structural evolution of an area, and to demonstrate the existence of a major fold, the Tay Nappe (Shackleton, 1958). This theme is central to many of the GCR site reports in this paper and Shackleton's work features particularly strongly in the *Duke's Pass* GCR site report and in the reports of the three GCR sites around Dunkeld.

The Trossachs area, which includes the *Bealach nam Bo* and *Duke's Pass* GCR sites, is now part of the first National Park to be established in Scotland. In the 19th Century it attracted many famous painters, including Constable, Millais and Turner, and the poet Wordsworth. But it is John Ruskin, founder member of the Pre-Raphaelite movement, who has left us the legacy of the beautiful drawing reproduced in Fig. 3. Ruskin was inspired by the

Download English Version:

https://daneshyari.com/en/article/4734702

Download Persian Version:

https://daneshyari.com/article/4734702

Daneshyari.com