The Toutties, Aberdeenshire

[NO 881 866]

Potential ORS GCR site

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Introduction

The Toutties GCR site on the foreshore at Cowie Harbour north of Stonehaven, Aberdeenshire (Figure 3.8) has been long known for the fossil fish specimens from the Cowie Harbour Fish Bed and the arthropods from the overlying mudstones. The fish are described in the companion GCR volume on fossil fishes (Dineley and Metcalf, 1999). The site has recently gained international prominence with the discovery of fossil terrestrial millipedes, including a new air-breathing species, *Pneumodesmus newmani* (Wilson and Anderson, 2004). Traditionally referred to the 'Downtonian' (P■ídolí), recent palynological evidence (Marshall, 1991; Wellman, 1993) suggests a mid-Silurian (Late Wenlock–Early Ludlow) age for the beds. Although controversial (Dineley, 1999b), this dating makes the strata among the oldest Old Red Sandstone lithofacies in Britain and the terrestrial diplopod the earliest air-breathing animal of any kind recorded in the geological column. The strata are near-vertical to overturned, lying on the north-west limb of the asymmetric Strathmore Syncline. They belong to the Cowie Sandstone Formation and Carron Sandstone Formation of the Stonehaven Group (Figure 3.9).

Description

The geology of the site has been described by Armstrong *et al.* (1978b), Gillen and Trewin (1987) and Carroll (1995a). Trewin and Thirlwall (2002) provided a summary. Dineley (1999b) described the fossil fishes and summarized the early work on the fauna. The Cowie Sandstone and Carron Sandstone formations consist mainly of cross-bedded and horizontally laminated, quartzo-feldspathic sandstones. There are numerous intercalations of silty mudstone and siltstone in the Cowie Sandstone Formation and abundant fragments of volcanic rock in the overlying Carron Sandstone Formation. Robinson *et al.* (1998) reported that the sandstones in both formations show a dominant palaeocurrent direction to the northwest and contain detrital garnets indicating a metamorphic source terrane to the south-east. In contrast, Gillen and Trewin (1987) reported palaeocurrent indicators in the Cowie Sandstone Formation showing transport to the ESE near the base and to the south-west in the remainderof the formation. The Cowie Sandstone Formation is late Wenlock to early Ludlow in age (Marshall, 1991; Wellman, 1993), but the Carron Sandstone Formation may be significantly younger, Marshall *et al.* (1994) arguing that there is a break in sedimentation between them, with differences in mineralogical composition (Armstrong *et al.,* 1978b), palaeomagnetism (Sallomey and Piper, 1973) and burial history.

The Cowie Sandstone Formation consists of dull red, purple, grey, buff and yellow, cross-bedded and flat-bedded, medium-grained, quartzo-feldspathic sandstones with intercalations of red, purple and grey siltstone and mudstone. It is exposed at The Toutties and northwards from Cowie Harbour to the unconformity with the Highland Border Complex at Ruthery Head close to the Highland Boundary Fault. About 450 m of beds are present at The Toutties, where faulting may attenuate the succession (Figure 3.9). The formation is subdivided into six members, the names of Donovan (in Armstrong *et al.,* 1978b) as amended by Carroll (1995a) being used in the following description.

The two lowermost members (Purple Sandstone and Castle of Cowie members) crop out to the north of The Toutties site. The Purple Sandstone Member (as re-defined by Carroll, 1995a) consists of about 93 m of purple, medium-grained, trough cross-bedded, quartzo-feldspathic sandstones. The basal 60 m of the member are pebbly and conglomeratic (the Basal Breccia Member of Armstrong *et al.,* 1978b) and contain an andesite lava flow. The overlying Castle of Cowie Member comprises 75 m of interbedded medium-grained, quartzo-feldspathic sandstones, red siltstones and sandy siltstones.

Within and just to the north of the site, over 240 m of soft, brown, grey and green, locally pebbly, trough cross-bedded, quartzo-feldspathic sandstones with common calcareous nodules constitute the Brown and Grey Sandstone Member. The sandstones contain a greater proportion of lithic clasts in comparison with the sandstones of the underlying members. Lenses of breccia containing rip-up siltstone clasts up to cobble size are locally abundant and volcaniclastic material makes its first appearance in the succession.

The Brown and Grey Sandstone Member is overlain by 12.5 m of conglomerates and interbedded green tuffaceous sandstone (the Cowie Harbour Conglomerate Member of Carroll, 1995a and the Volcanic Conglomerate Member of Armstrong *et al.,* 1978b). The conglomerates consist of well-rounded pebbles and cobbles generally up to 10 cm, but with some boulders, of acid volcanic rocks. The unit is variable along strike (Gillen and Trewin, 1987), Carroll (1995a) noting that it consists of three structural blocks bounded by strike parallel (?reverse) faults at Cowie Harbour. The lower block contains two broadly upward-fining sequences in which an irregular erosion surface is overlain by poorly sorted pebbly, coarse- to very coarse-grained volcaniclastic sandstone, which passes upwards over about 7 m into medium-grained volcaniclastic sandstone. The contact between the lowermost conglomerate and the underlying Brown and Grey Sandstone Member is repeatedly displaced eastwards (dextrally) by small syndepositional faults. Beds in the lower part of the member are overstepped by the overlying massive and trough-cross-bedded medium-grained volcani-clastic sandstone. A short break in exposure marks a line of truncation of bedding, the presence of fragments of fractured, soft, sandy fault breccia in this gap suggesting that a near-strike-parallel fault cuts the section here, possibly causing some tectonic attenuation. The upper contact is a gradual transition from medium-grained, green volcaniclastic sandstone into the overlying red sandstone.

The Red Sandstone Member comprises about 16 m of red, lithic, medium-grained, cross-bedded sandstones and tuffaceous sandstones with common convolute bedding. Trough cross-bedding indicates palaeocurrents towards the south-west. In the western part of the Stonehaven area, westwards from Tewel [NO 826 855], a thicker succession of massive and thinly planar-bedded, medium-grained, lithic sandstone may be an indication of varying rates of subsidence across the basin (Carroll, 1995a).

The Cowie Harbour Siltstone Member of Carroll (1995a) (the *Dictyocaris* Member of Armstrong *et al.,* 1978b) consists of interbedded sandy siltstone and planar-bedded, fine-grained sandstone. Both lithologies are predominantly planar laminated, but small-scale cross-lamination is also present, mainly in asymmetrical, current-generated ripples. Symmetrical, wave-generated ripples and convolute de-watering structures occur on the upper surfaces of sandstone beds directly overlain by siltstone.

The Cowie Harbour Fish Bed (Figure 3.10) lies in a succession of intercalated grey sandstones and fissile siltstones and mudstones at the base of the Cowie Harbour Siltstone Member. The other biota occur in grey beds intercalated with sandy siltstones and red sandstones with convolute de-watering structures. Planar lamination predominates, but small-scale ripple lamination occurs locally (Figure 3.9), (Figure 3.10). The fish bed and adjacent strata are truncated by a NW-trending fault at the northern end of the outcrop, where they are displaced eastwards to below low-tide level in Cowie Harbour. Abundant remains of *Dictyocaris slimoni* and other arthropods including *Archidesmus* sp., *Kampecaris?, Ceratiocaris* sp., *Hughmilleria norvegica* and *Pterygotus* sp. (Campbell, 1913; Westoll, 1951, 1977) have been recovered from a bed of grey mudstone. Cephalaspids were found in a reddish sandy mudstone (the Cowie Harbour Fish Bed) below (see Dineley (1999b) for references). The fish fauna includes the anaspid *Birkenia* sp., the holotype of the cephalaspid *Hemiteleaspis heintzi* and the holotype of *Traquairaspis campbelli,* a heterostracan of which this is the only species.

Three new species of fossil millipedes (*Albadesmus almondi, Cowiedesmus eroticopodus* and *Pneumodesmus newmani*)discovered recently at the site are of international importance, particularly in view of the fact that *Pneumodesmus newmani* is the earliest-known record of a fully terrestrial, air-breathing species (Wilson and Anderson, 2004).

The junction between the Cowie Harbour Siltstone Member and the overlying Carron Sandstone Formation is exposed at low tide at The Toutties (Carroll, 1995a). The Carron Sandstone Formation consists predominantly of brown, dull reddish brown and grey, locally pebbly, medium-grained, lithic sandstones with a substantial volcanic content locally. The sandstones are thinly bedded and weakly planar laminated in the lower part of the formation in and adjacent to the GCR site, and trough cross-bedded in the upper part near Downie Point to the south of Stonehaven Harbour.

Interpretation

The Stonehaven Group is interpreted as the fill of a pull-apart basin (the Stonehaven Basin) controlled by strike-slip faulting (Bluck, 2000, 2001). In contrast to the Crawton and Strathmore basins, there is no broad upward-fining trend to the sedimentary basin-fill and conglomerates are rare. Vitrinite reflectivities of the Stonehaven Group (represented here by the Cowie Sandstone Formation) are compatible with a maximum burial of 3–5 km (Marshall *et al., 1994).* This, along with the distinctive structure, sediment dispersal pattern, petrography and palaeomagnetism, supports the suggestion of Marshall *et al.* (1994) that the Cowie Sandstone Formation was the fill of a separate strike-slip sub-basin, and not part of the general fining-upward Lower Old Red Sandstone megacycle of which the Carron Sandstone Formation is a part. In this interpretation, the junction between the Cowie Sandstone and Carron Sandstone formations is a major structural and stratigraphical discontinuity (Trewin and Thirlwall, 2002). However, Carroll (1995a) and Phillips and Carroll (1995) record a transitional boundary, invoking the development of forced folds by continuous sedimentation and deposition in a strike-slip basin (cf. Christie-Blick and Biddle, 1985; Serrane, 1992). In this model, the bedding in the older deposits adjacent to the basin margin is progressively rotated, resulting in them retaining a structurally high position. Hence the Cowie Sandstone Formation could have been marginal to the supposed Crawton Basin deposits, as indicated by present outcrop distribution, and have been buried at shallow depth, as indicated by the vitrinite reflectivity data of Marshall *et al.* (1994).

The sandstones of the Purple Sandstone Member and Brown and Grey Sandstone Member are interpreted as the deposits of a braided river complex (Armstrong *et al.,* 1978b). Phillips and Carroll (1995) interpreted the sediments to have been laid down by small, bedload-dominated, braided streams on the lower part of alluvial fans, with some sheet-flood deposits in the Purple Sandstone Member. Based on palaeocurrents, the drainage was lateral (towards the ENE) in the Purple Sandstone Member and longitudinal (south or SSW) in the Brown and Grey Sandstone Member. The interbedded sandstones and argillaceous rocks of the Castle of Cowie Member are interpreted as the channelized and floodplain deposits respectively of a sinuous (?meandering) river system with longitudinal flow to the south-west. The Cowie Harbour Conglomerate Member was deposited from bedload-dominated, braided streams either on a distal alluvial-fan or braidplain, with transport to the ENE. Marked scouring at channel bases suggests higher flow energies than those of the streams that deposited the other members of the formation. Phillips and Carroll (1995) suggested that deposition of this thin unit might be linked to the appearance of a small volcanic cone on the braidplain. A return to a bedload-dominated, braided stream environment is suggested by the Red Sandstone Member. Palaeocurrents indicate derivation from the north-east (Gillen and Trewin, 1987; Phillips and Carroll, 1995). Sedimentation by fluvial channel, floodplain and lacustrine processes were responsible for the deposition of the Cowie Harbour Siltstone Member. Phillips and Carroll (1995) interpreted the horizontally laminated and cross-bedded sandstones that form most of the member as distal deposits of turbidity currents that introduced fluvial sediment into the lake. The finer-grained, carbonaceous siltstones lack wave ripples and trace fossils, suggesting that the lake was deep and stratified periodically, with anoxic bottom conditions.

The fish and arthropod fauna of the Cowie Harbour Fish Bed were formerly considered to be of late Silurian–early Devonian ('Downtonian') age (now the P■ídolí Series) (Campbell, 1913; Denison, 1956; Westoll, 1951, 1977). However, Lamont (1952) advised caution in the age dating and correlation of the fauna, on the basis of similar faunas of probable late Ilandovery to early Wenlock age in the southern part of the Midland Valley. Hanken and Stormer (1975) later suggested an early Ludlow age for the eurypterid arthropods. Marshall (1991) and Wellman (1993) provided palynological evidence of a late Wenlock or early Ludlow (mid-Silurian) age. On this basis, the site is only one of two, the other being in Pennsylvania, that has yielded late Wenlock palynomorphs from continental Old Red Sandstone facies.

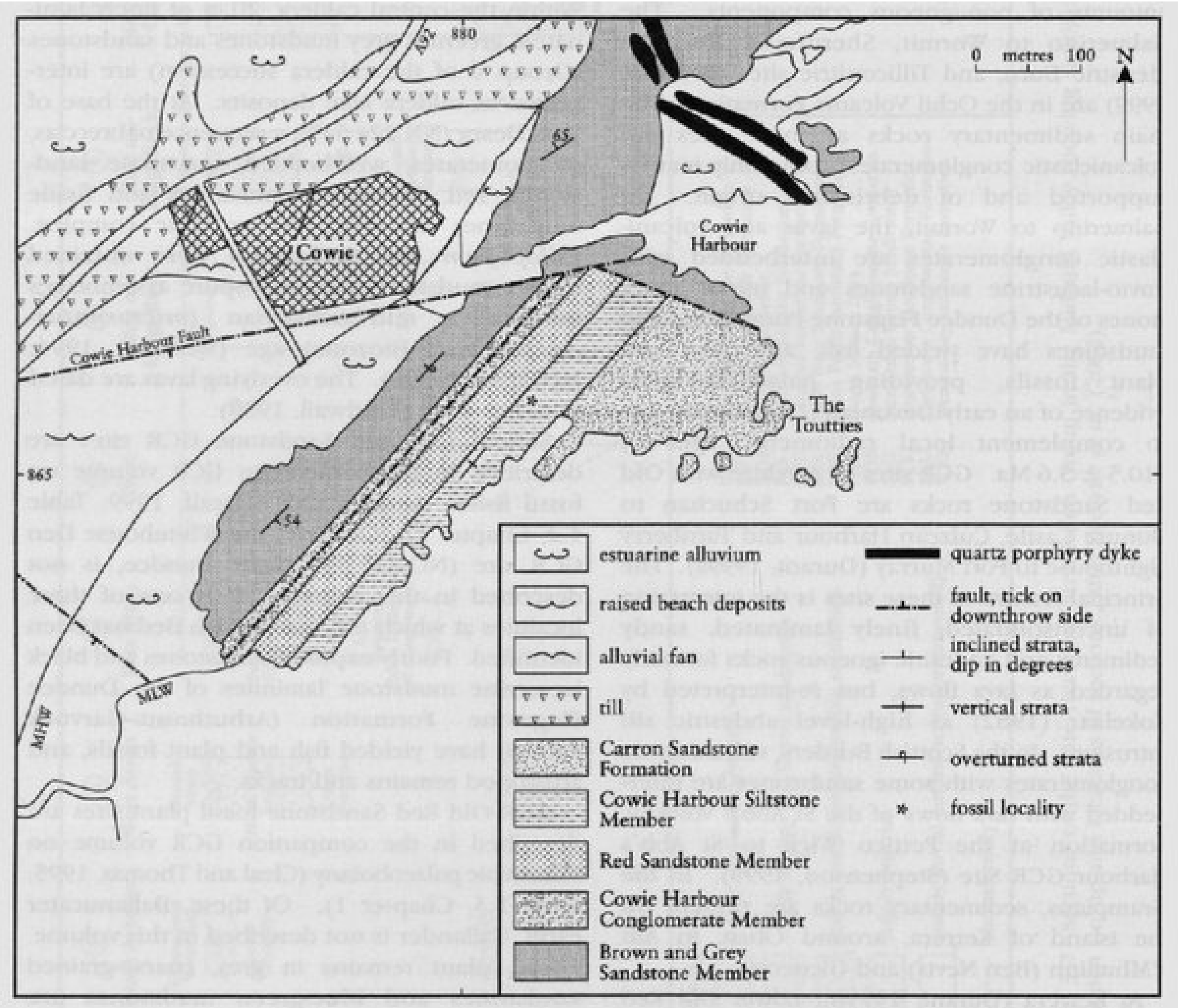
The Toutties site is important because it is comparable with the red-bed successions of the Silurian inliers in the southern Midland Valley, in which the Silurian rocks are overlain unconformably by Lower Old Red Sandstone of latest Silurian to early Devonian age. A late Wenlock (Homerian) to Ludlow (Gorstian) age for the Cowie Harbour Siltstone (*Dictyocaris*)Member, as proposed by Marshall (1991) and Wellman (1993), implies that *Traquairaspis campbelli* is substantially older than had previously been thought, and of similar age to the heterostracans of the Cape Phillips Formation and Cape Storm Formation in the Canadian Arctic (Dineley, 1999b). It also implies that the site provides, in the discovery of the fully terrestrial millipede *Pneumodesmus newmani,* the earliest evidence of air-breathing in any animal of any kind (Wilson and Anderson, 2004).

Conclusions

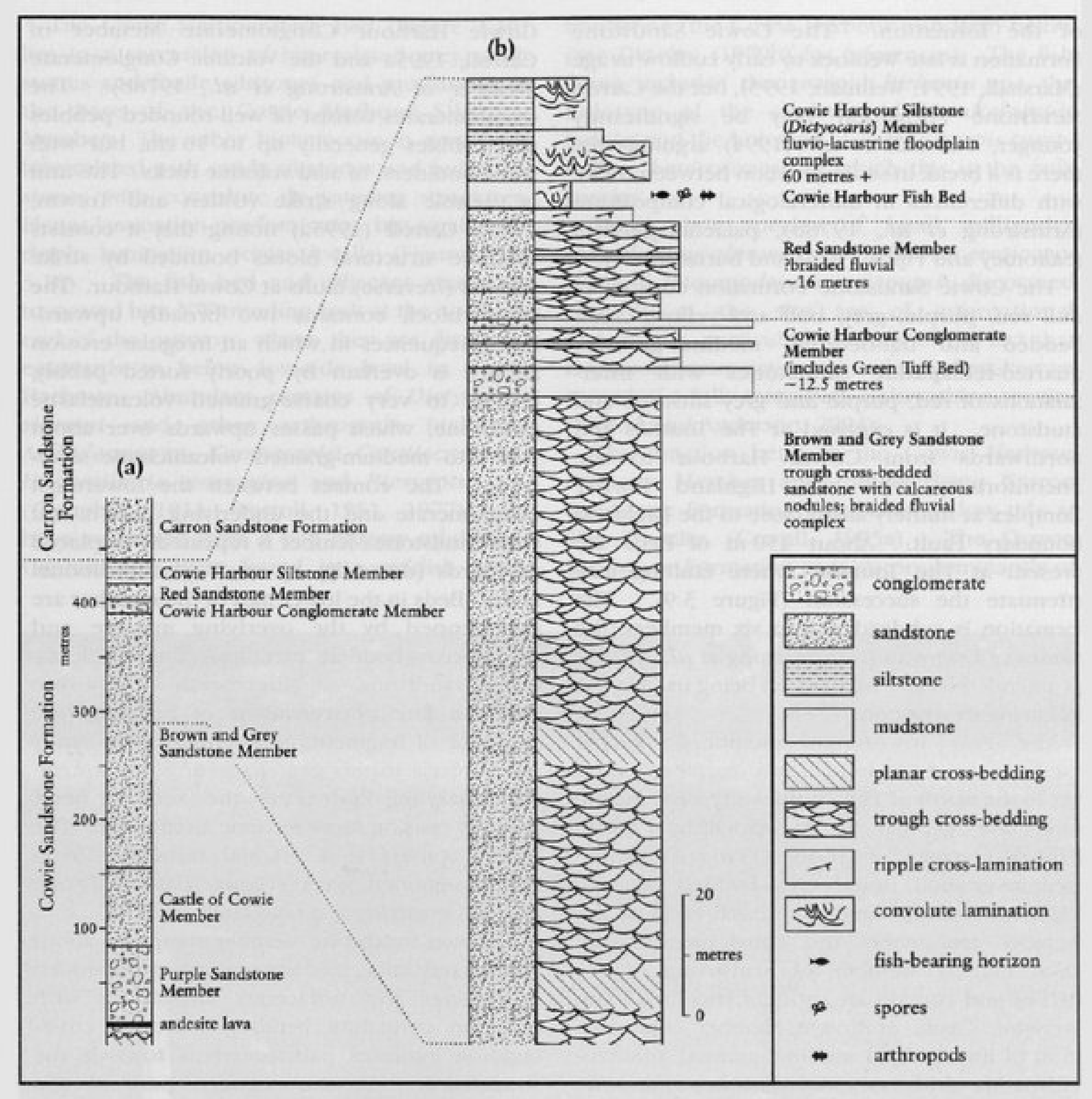
The site's international importance lies in its freshwater fauna of fish, arthropods and newly discovered millipedes, and in its late Wenlock to early Ludlow palynomorphs, which date the rocks as some of the oldest Old Red Sandstone fades recorded. The unique heterostracan fish *Traquairaspis campbelli* is unknown elsewhere, with similar heterostracans providing a link with the Canadian and Baltic provinces. Recent discoveries of new species of fossil millipedes add a new dimension to the site's importance, particularly in the presence of the oldest record anywhere in the world of a fully land-based, air-breathing animal.

The section is also important in the evidence it provides into an understanding of the early development of the Midland Valley. The Stonehaven Basin appears to have been an early pull-apart basin formed before the development of the larger Strathmore Basin. The site offers opportunity for further research into its unique fauna and microflora and into the relationship between the Cowie Sandstone Formation and the overlying Carron Sandstone Formation.

References



(Figure 3.8) Geological sketch map of the area of The Toutties GCR site. After British Geological Survey, 1: 10 000 Manuscript Map NO 88NE (1996).



(Figure 3.9) (a) Vertical section of the Cowie Sandstone Formation; and (b) detailed section at The Toutties. Based on Armstrong et al. (1978b) and Dineley (19996).

(Figure 3.10) Cowie Harbour Fish Bed [NO 8813 8667]. Fissile mudstones and siltstones with thin ripple-laminated sandstone. (Photo: BGS No. D2455, reproduced with the permission of the Director, British Geological Survey, © NERC.)