Stonehaven, Aberdeenshire

[NO 881 866]

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Introduction

This site is located in the north-easternmost part of the Midland Valley of Scotland, immediately south of where the Highland Boundary Fault intersects the coastline (see (Figure 2.5)). The most important part of the site concerning the present volume centres on Cowie Harbour, a kilometre north of Stonehaven town (Figure 2.30). However, strata that put the site into geological, tectonic and palaeoenvironmental context are exposed over about 2.0 km, from Stonehaven Harbour in the south to Craigeven Bay in the north (see MacGregor, 1968; Dineley, 1999a). The rocks along this stretch of coast are referred largely to the Stonehaven Group, which forms the lowest part of the Old Red Sandstone, with the whole of the latter in the Midland Valley reaching its greatest thickness, some 8 kin, in this region. The Old Red Sandstone is largely of Devonian age, but the deposits of the Stonehaven Group were laid down in mid-Silurian times, around 422 million years ago.

The geology of this area has been described in detail or put into context by Hickling (1908), Campbell (1911, 1912a, 1912b, 1913), Carroll (1995), Trewin and Thirlwall (2002), Browne *et al.* (2002) and Browne and Barclay (2005a, 2005b). The site was also included in the field guide to accompany the 1978 International Symposium on the Devonian System by Armstrong *et al.* (1978), and the guides covering Fife and Angus by MacGregor (1968), and the Aberdeen area by Gillen and Trewin (1987). Discussion of the sedimentology has been presented in modern times by Armstrong *et al.* (1978), Gillen and Trewin (1987), Phillips and Carroll (1995), Robinson *et al.* (1998) and Browne and Barclay (2005b). The relative age of the Stonehaven Group has been the subject of successive revisions, largely on the basis of arthropods and then palynomorphs, through the work of Campbell (1912a, 1912b), Lamont (1952), Hanken and Størmer (1975), Marshall (1991) and Wellman (1993).

The palaeobiota associated with the Old Red Sandstone of the Midland Valley of Scotland has had world renown since the pioneering researches of Hugh Miller (1841) and the Swiss palaeontologist and glaciologist Louis Agassiz (1844). They focussed particularly upon the remarkable agnathan fish fauna but also included notices of the accompanying arthropods and plants. The arthropods from the Stonehaven area — eurypterids, myriapods and a species of uncertain affinity — have been the subject of comment since the time of Campbell (1912a). Recent research by Almond (1985, 1986) and by Anderson and Wilson (2002) has assessed the most important components of this fauna, the fossil myriapods. These include the earliest known millepedes, one species of which represents a fully terrestrialized example and the earliest known land animal.

Other aspects of the strata exposed at Stonehaven are also significant and have been included, under the site name 'The Toutties', in the GCR volumes on Devonian stratigraphy (Barclay *et* ed., 2005) and fossil fishes (Dineley and Metcalf; 1999).

Description

The early stratigraphical framework of Campbell (1911, 1912a, 1912b, 1913) for his 'Stonehaven beds' has been somewhat revised in modem times. The Stonehaven Group, as now termed, includes the successive Cowie and Carron formations according to Armstrong and Paterson's 1970 classification. Donovan (in Armstrong *et al.,* 1978) then outlined several constituent members, which were subsequently formalized in Gillen and Trewin (1987). Further stratigraphical refinement of the group by Carroll (1995), which was adopted by Browne and Barclay (2005b) and which is used herein, saw among other changes the introduction of the terms Cowie Sandstone and Carron Sandstone formations.

The 730 m thick Cowie Sandstone Formation is exposed on the foreshore for some 500 m between Cowie Harbour and near Ruthery Head in the north-east, where it rests unconformably on the Cambro-Ordovician Highland Border Series close to the Highland Border Fault. Inland intermittent outcrop of this formation has been mapped over 13 km to the west, on the north-west limb of the Strathmore Syncline. The formation, which is represented by about 450 metres of beds at The Toutties, is subdivided into six members (Armstrong *et al.,* 1978; Carroll, 1995; Browne and Barclay, 2005b; (Figure 2.30) and (Figure 2.31).

The unconformity at the base of the Cowie Sandstone Formation is exposed in steeply dip ping (70–80°) and structurally disturbed strata. A thin and locally derived basal breccia of the lowest, Purple Sandstone Member, containing clasts of spilite, black shale and jasper, can be seen resting on weathered and reddened slaty rocks of the Highland Border Series. In total this member comprises about 93 m of medium-grained sandstones, the basal 60 m of which (the Basal Breccia Member of Armstrong *et al.,* 1978) are pebbly and conglomeratic, and low in the unit there is an andesitic lava horizon.

The succeeding Castle of Cowie Member is made up of 75 metres of medium-grained sandstones, red siltstones and sandy siltstones. Soft brown, grey and green sandstones, which contain calcareous nodules, volcaniclastic material and, locally, pebbles, form the next, Brown and Grey Sandstone Member. Overlying the latter are 12.5 m of conglomerates that are interbedded with tuffaceous sandstone, and which comprise the Cowie Harbour Conglomerate Member (the Volcanic Conglomerate Member of Armstrong *et al.,* 1978). The succeeding Red Sandstone Member is about 16 m thick, with medium-grained, cross-bedded sandstones together with tuffaceous sandstones that exhibit convolute bedding. The youngest, Cowie Harbour Siltstone Member (the Dictyocaris Member of Armstrong *et al.,* 1978), consists of 60 m plus of interbedded sandy siltstone and fine-grained sandstone, mostly showing planar lamination, but with some cross-lamination, small-scale ripples, and convolute de-watering structures.

The Cowie Harbour Fish Bed, a reddish sandy mudstone, occurs among a sequence of grey sandstones and fissile siltstones and mudstones near the base of the Cowie Harbour Siltstone Member. Other elements of the biota occur in this member in grey mudstones, which are intercalated with sandy siltstones and red sandstones with convolute dewatering structures, one such horizon above the fish bed yielding arthropods (Browne and Barclay, 2005b).

The Carron Sandstone Formation, some 820 m thick and unfossiliferous, comprises mainly brown, reddish-brown and grey, medium-grained sandstones that locally are pebbly and have a considerable volcanic component. They are thinly bedded in the lower part of the formation, and trough cross-bedded in the upper part. The formation is seen overlying the Cowie Harbour Siltstone Member at low tide at The Toutties (Carroll, 1995). The succeeding Dunnottar–Crawton Group lies with slight unconformity on the Carron Sandstone Formation. It is some 1600 m in thickness and in its basal part comprises the 60 m thick Downie Point Conglomerate.

From a palaeontological standpoint the main interest lies in the Cowie Harbour Fish Bed and adjacent strata, which were first described in 1911 by Campbell. Macconochie had previously collected fossils from this part of the sequence for the Geological Survey in 1881, but the first agnathan fish were not found until 1912 (Campbell, 1912a,b). The fish, *Hemiteleaspis heintzi, Traquairaspis campbelli* and *Birkenia* sp., are uncommon. They are complemented by rare plant fragments, and a diverse fauna of arthropods which historically have been recorded as the phyllocarid *Ceratiocaris* sp., the eurypterids *Nanahughmilleria norvegica* (Kiaer, 1911) and *Pterygotus* sp., the enigmatic *Dictyocaris slimoni* Salter, 1860, the myriapods *Archidesmus* sp. and a species that possibly belongs to *Kampecaris* (Campbell, 1913; Størmer, 1935; Westoll, 1951, 1977; Armstrong and Paterson, 1970; Hanken and Størmer, 1975; Almond, 1985; Dineley, 1999a; Browne and Barclay, 2005b). Recently, millipedes from the Palaeozoic of Scotland have been re-assessed on the basis of existing and new material, and the new species *Albadesmus almondi, Cowiedesmus eroticopodus* and *Pneumodesmus newmani* established, all of them from the Cowie Sandstone Formation of Cowie Harbour (Wilson and Anderson, 2004; (Figure 2.32), (Figure 2.33), (Figure 2.34)).

For many years the fossiliferous deposits of the Cowie Formation were thought to be 'Downtonian' in age, that is approximating to the P■ídolí Series (upper Silurian) of current usage, on the basis of a comparison of the fish and arthropods with those from Old Red Sandstone successions elsewhere, especially the Welsh Borderland. Lamont (1952) was one of the first to question this correlation and to suggest that the deposits and their fauna, along with similar fossils

from the southern part of the Midland Valley of Scotland, might be of an older, late Llandovery to early Wenlock age. Work by Hanken and Størmer (1975) on eurypterids of the Ringerike region, Norway, where *N. norvegica* also occurs, and comparison of the eurypterid–vertebrate fauna from there with that from Estonia, suggested that that part of the (Figure 2.34) *Pneumodesmus newmani* Wilson and Anderson, 2004; holotype, National Museums of Scotland, Edinburgh, NMS G. 2001.109.1; Cowie Harbour Siltstone (Dictyocaris) Member, upper Wenlock or lower Ludlow Series, Silurian, Cowie Harbour, Stonehaven. (a) Photograph, dorsolateral view, anterior to the right. (b) interpretive drawing (modified). AB, Anterior Bar; Ap, appendages; CS, coxal socket; Sp, Spiracle; St, Sternite. (From Wilson and Anderson, 2004, figs 9.2 and 9.3.)

Ringerike sequence was early Ludlow in age, and thus by implication that the 'Stonehaven beds' were also. The relatively recent recovery from the Cowie Sandstone Formation of a palynomorph assemblage consisting of cryptospores, trilete spores and dispersed plant fragments has provided new age constraints for this unit (Marshall, 1991; Wellman, 1993). This assemblage can be assigned to the *Artemopyra brevicostata* (*?E.* cf. *protophanus*)–*Hispanaediscus verrucatus* (*c.f. S. verrucatus*) Assemblage Biozone of Richardson and MacGregor (1968). Such an assignment, involving in part a comparison of the Stonehaven spore assemblage with those from Welsh Borderland type Silurian sections, indicates the Cowie Sandstone Formation to be of late Wenlock (early Homerian) or possibly earliest Ludlow (earliest Gorstian) age.

The Carron Sandstone Formation may be significantly younger than the Cowie Sandstone Formation, Marshall *et al.* (1994) claiming that there is a break in sedimentation between them, based on differences in mineralogical composition, palaeomagnetism and burial history. It should also be noted that although Campbell (1911) originally placed the boundary between his Stonehaven beds and the overlying Dunnottar Group at the base of the Downie Point Conglomerate, later (Campbell, 1913) he suggested that this boundary should be moved downwards to a point in the succession where there is a gap in exposure (near the mouth of the River Carron), which would thus include in the Dunnottar–Crawton Group at least 100 m of sandstones that he formerly included in his Stonehaven beds. Of further relevance here is modern work that has shown that the sandstones immediately below the Downie Point Conglomerate have more of a link with those of the Dunnotar–Crawton Group sandstones than they do with deposits of the Stonehaven Group underlying them (see Armstrong *et al.,* 1978; Gillen and Trewin, 1987). Thus the Carron Sandstone Formation might be best considered with the overlying Dunnottar–Crawton Group, though on mapping grounds the base of the Dunnottar Conglomerate is a key horizon (Trewin and Thirlwall, 2002).

Interpretation

The Stonehaven Group represents the fill of the Stonehaven Basin, which was controlled by strike-slip faulting (Bluck, 2000, 2001). One interpretation of the relationship between the Cowie Sandstone and Carron Sandstone formations argues for the Cowie Sandstone Formation to be the fill of a separate sub-basin and not to be, like the Carron Sandstone Formation, a part of the major fining upward sequence of the Lower Old Red Sandstone. The junction between these two formations would thus be a major stratigraphical and structural discontinuity. Others record a transitional boundary between the two formations (see Carroll, 1995; Phillips and Carroll, 1995; Trewin and Thirlwall, 2002; Browne and Barclay, 2005b).

The dominant palaeocurrent direction in both the Cowie and Carron formations has been given in one study as trending to the north-west with a metamorphic source terrane lying to the south-east (Robinson *et aL,* 1998), whereas other work indicates transport to the ESE at the base of the Cowie Sandstone Formation, and to the south-west at other times during the deposition of this unit (Gillen and Trewin, 1987).

The sediments of the Purple Sandstone and Grey Sandstone members of the Cowie Sandstone Formation are indicative of a braided river complex, and were laid down on the lower part of alluvial fans (Armstrong *et al.,* 1978; Phillips and Carroll, 1995; Browne and Barclay, 2005b). The Castle Cowie Member sediments have been interpreted as channelized sandstone and floodplain argillite deposits of a sinuous river system. Bedload-dominated, braided streams provided the material that make up the Cowie Harbour Conglomerate and the Red Sandstone members. Fluvial channel, floodplain and lacustrine processes are invoked for deposition of the sediments of the Cowie Harbour Siltstone Member. The horizontally laminated and cross-bedded sandstones that comprise the major part of this unit have been interpreted as

the distal deposits of turbidity currents brought into the lake from a fluvial source. Periodically, the lake appears to have been deep and stratified, with anoxic bottom conditions, as evidenced by the finer-grained carbonaceous siltstones that are devoid of wave ripples or trace fossils.

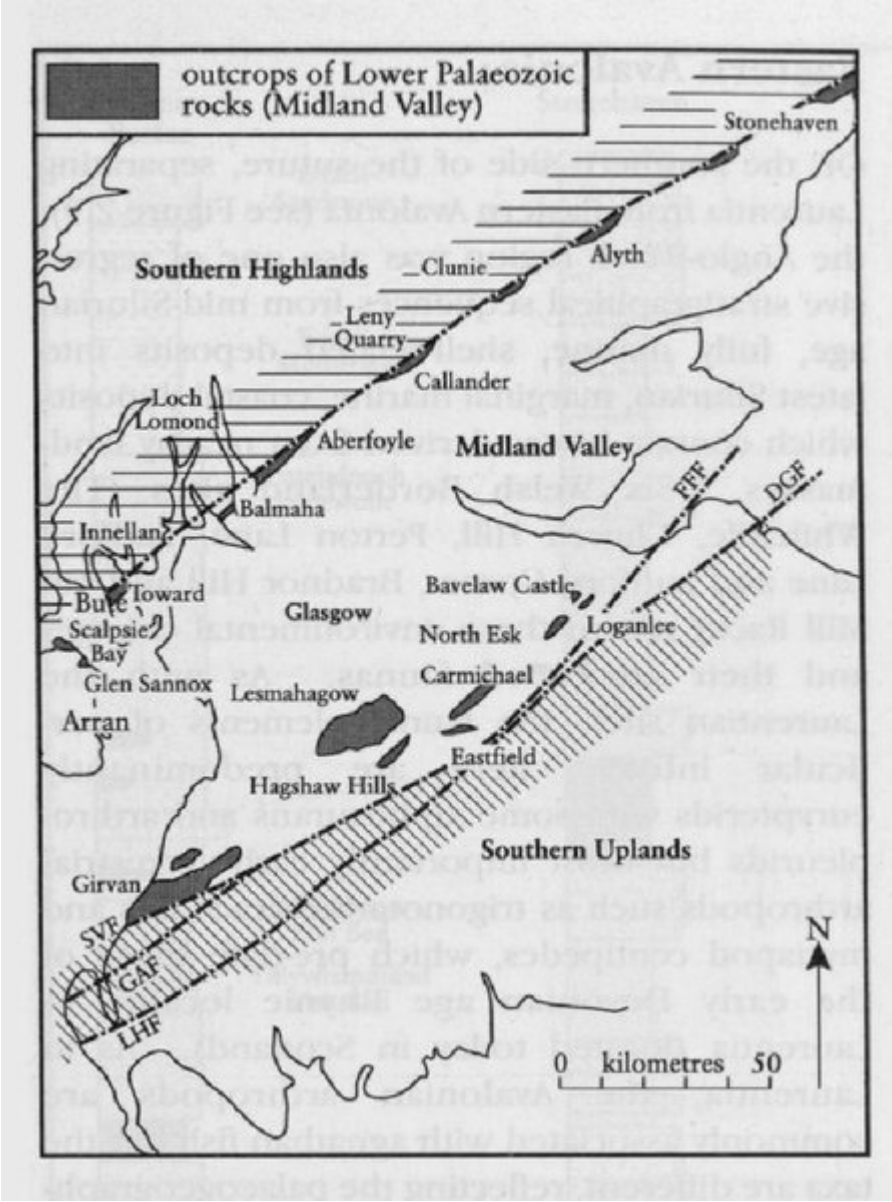
With reference to the arthropods from the Stonehaven area, the *Kampecaris* (*?*) sp. described by Størmer (1935) was suggested by Almond (1985) to be a new genus though he did not allocate it to any major group. The kampecarids as a whole were considered by Almond (1985) to be a discrete group possibly most closely related to the millipedes (Diplopoda); they occur in a number of Old Red Sandstone facies rocks of P■ídolí to Pragian age in Scotland and the Welsh Borderland. The record of *Archidesmus* sp. from Stonchaven was not commented on by Almond (1985), nor by Wilson and Anderson (2004), though the latter authors considered the genus to be a millipede containing only *Archidesmus macnicoli* from the Lower Devonian of the Midland Valley (see Turin Hill site report herein). *Cowiedesmus eroticopodus, Albadesmus almondi,* and *Pneumodesmus newmani* were all regarded as archipolypodan millipedes and each assigned to their own new monotypic genus (Wilson and Anderson, 2004). The presence of spiracles in *P. newmani* represents the earliest evidence globally for a tracheal respiratory system, and thus air breathing and land dwelling, in any animal. Trace fossil — as opposed to body fossil evidence suggests that arthropod terrestrialization had begun even earlier, by Ordovician times at least Oohnson *et al.,* 1994; MacNaughton *et al.,* 2002).

Myriapods are found elsewhere in the GCR network of Siluro-Devonian arthropod sites, at Ludford Lane and Ludford Corner (upper Silurian) in the Welsh Borderland, and Turin Hill and Rhynie (both Lower Devonian in age) in the Midland Valley of Scotland and the Grampians respectively. Other arthropod sites in the Midland Valley are those of Gutterford Burn in the Pentland Hills, and Slot Burn and Dunside in the Lesmahagow inlier, which have all yielded important eurypterid material.

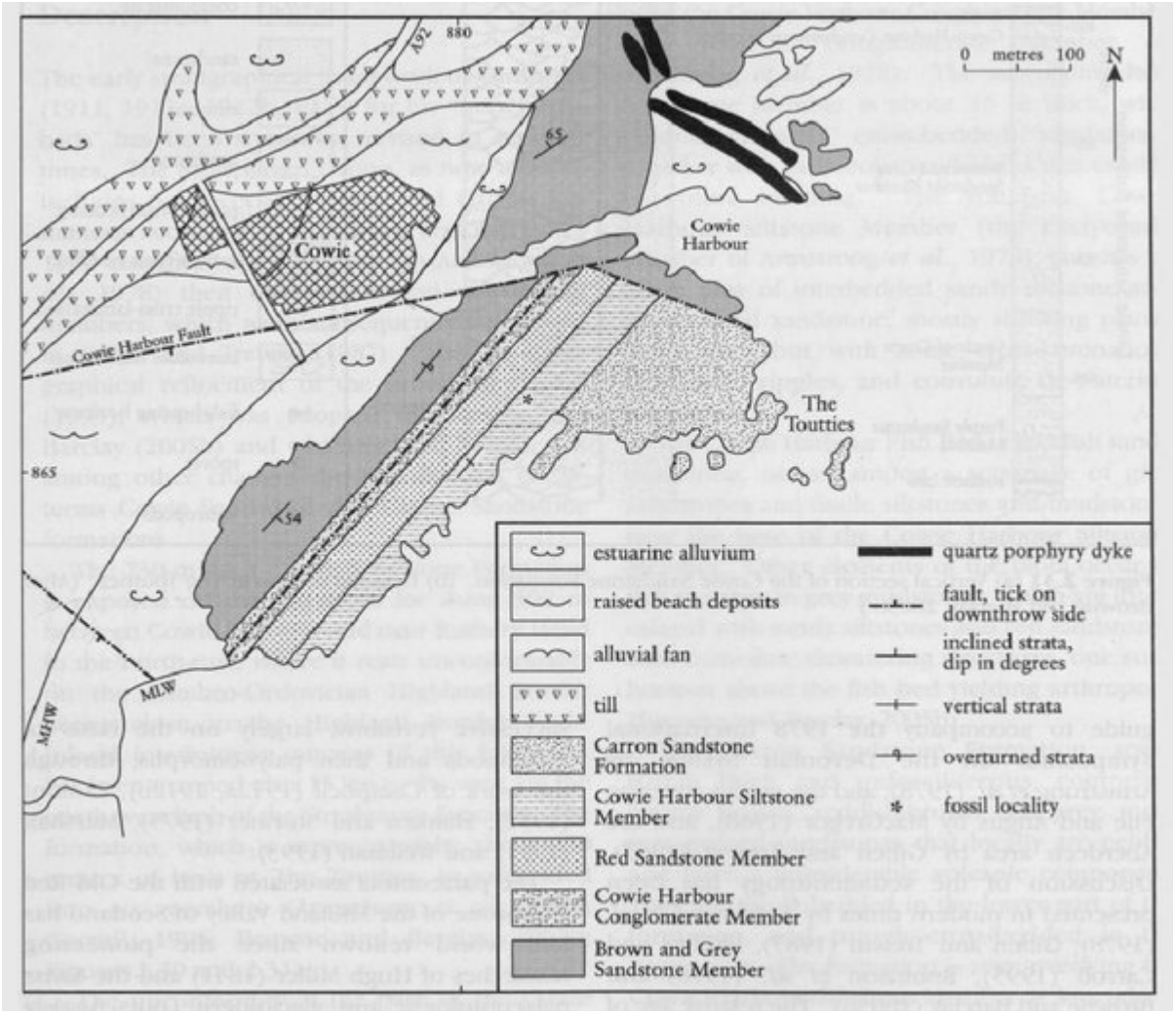
Conclusion

This site contains rocks that form the base of the Old Red Sandstone in the Midland Valley of Scotland and are of late Wenlock or earliest Ludlow age. The millipede species from here represent the earliest in the geological column. Also material of one of them preserves spiracles, indicating a tracheal respiratory system and making it the earliest known fully terrestrialized animals. Other arthropod elements include eurypterids, which have been used to help give a relative age to the host sediments, and the enigmatic *Dictyocaris.* All of these factors make the site of international importance.

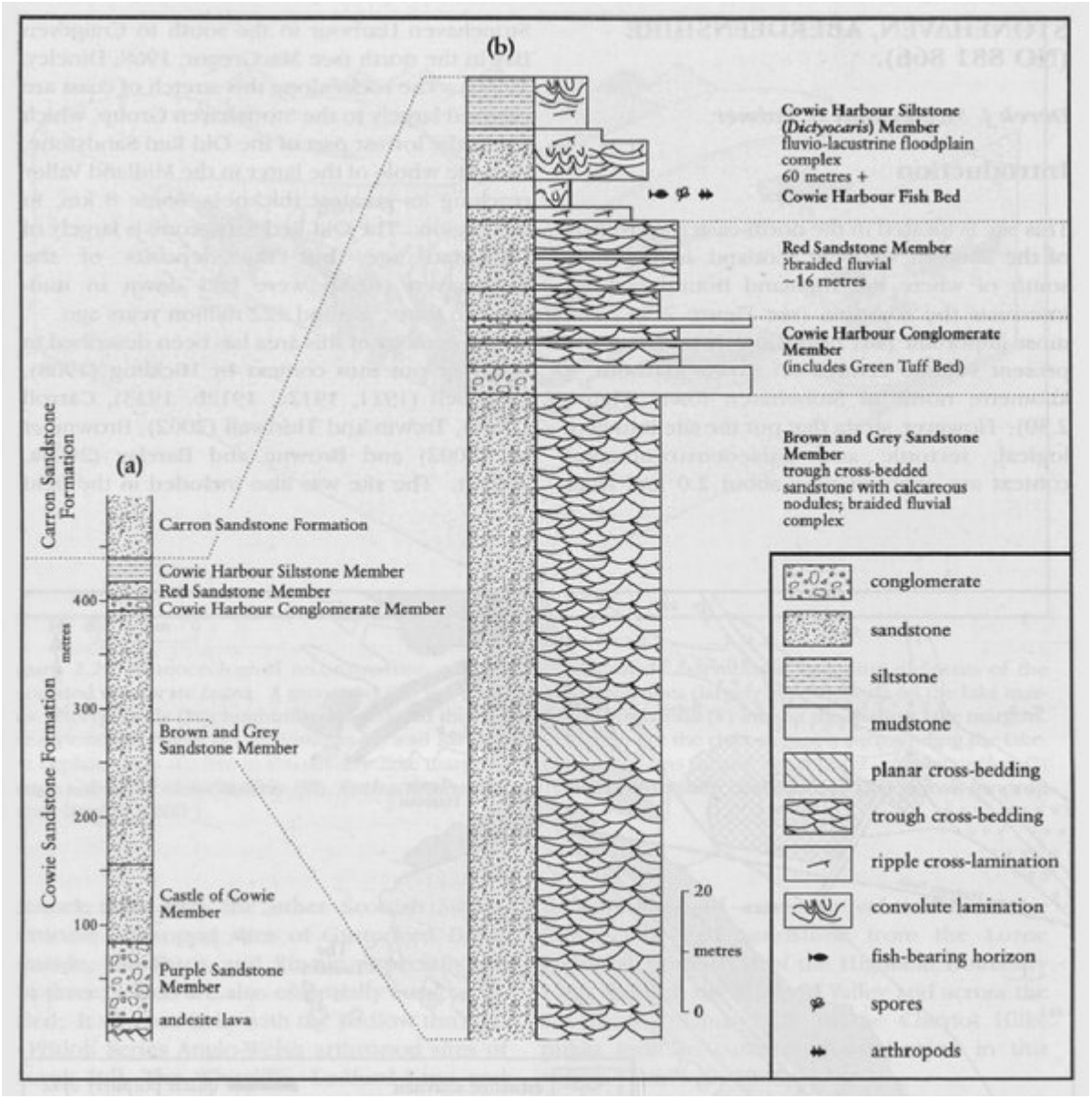
References



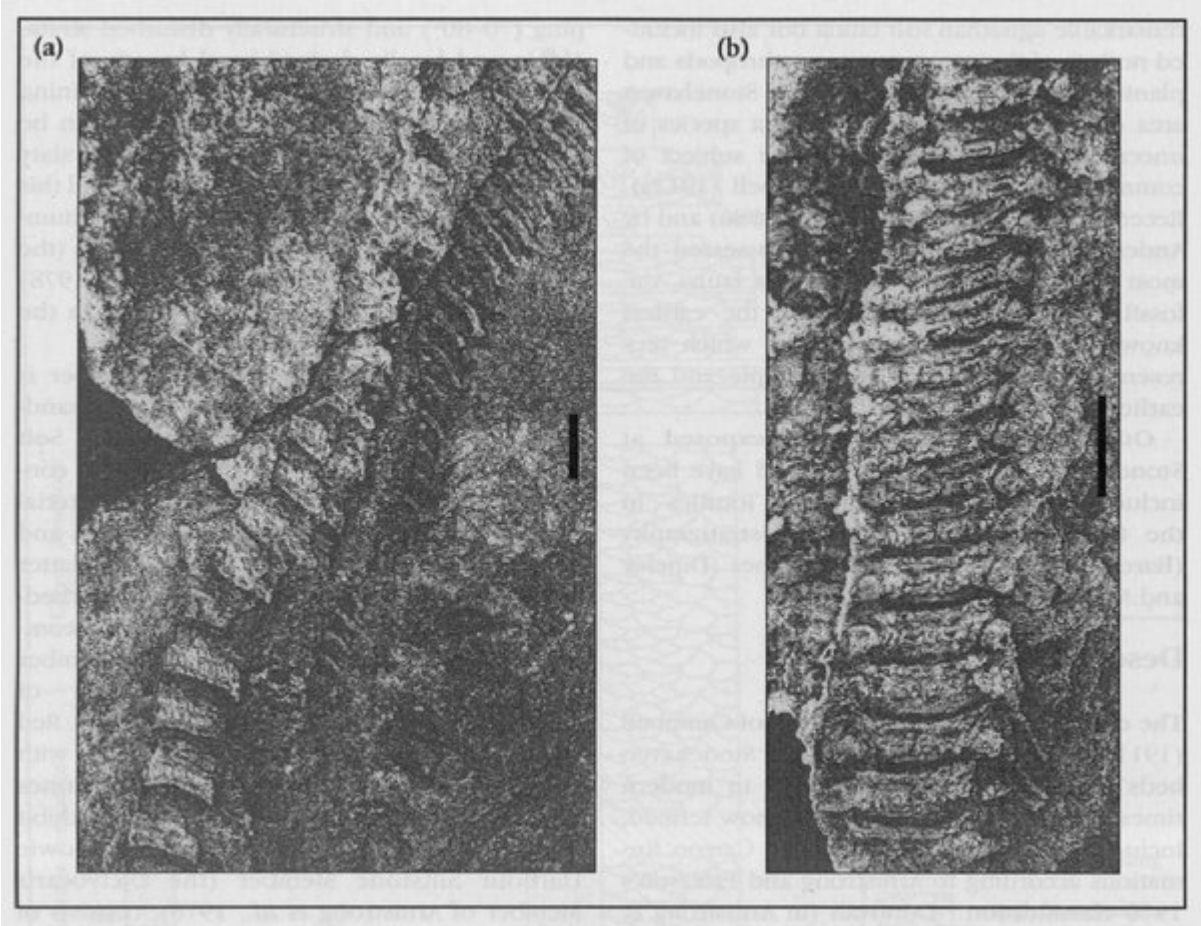
(Figure 2.5) Location of the main Silurian inliers of the Midland Valley of Scotland, and faults. SVF Stinchar Valley Fault; GAF Glen App Fault; LHF Leadhills Fault; FFF Firth of Forth Fault; DGF Dunbar–Gifford Fault; HBF Highland Boundary Fault. (After Palmer, 2000 and Bluck, 2002.)



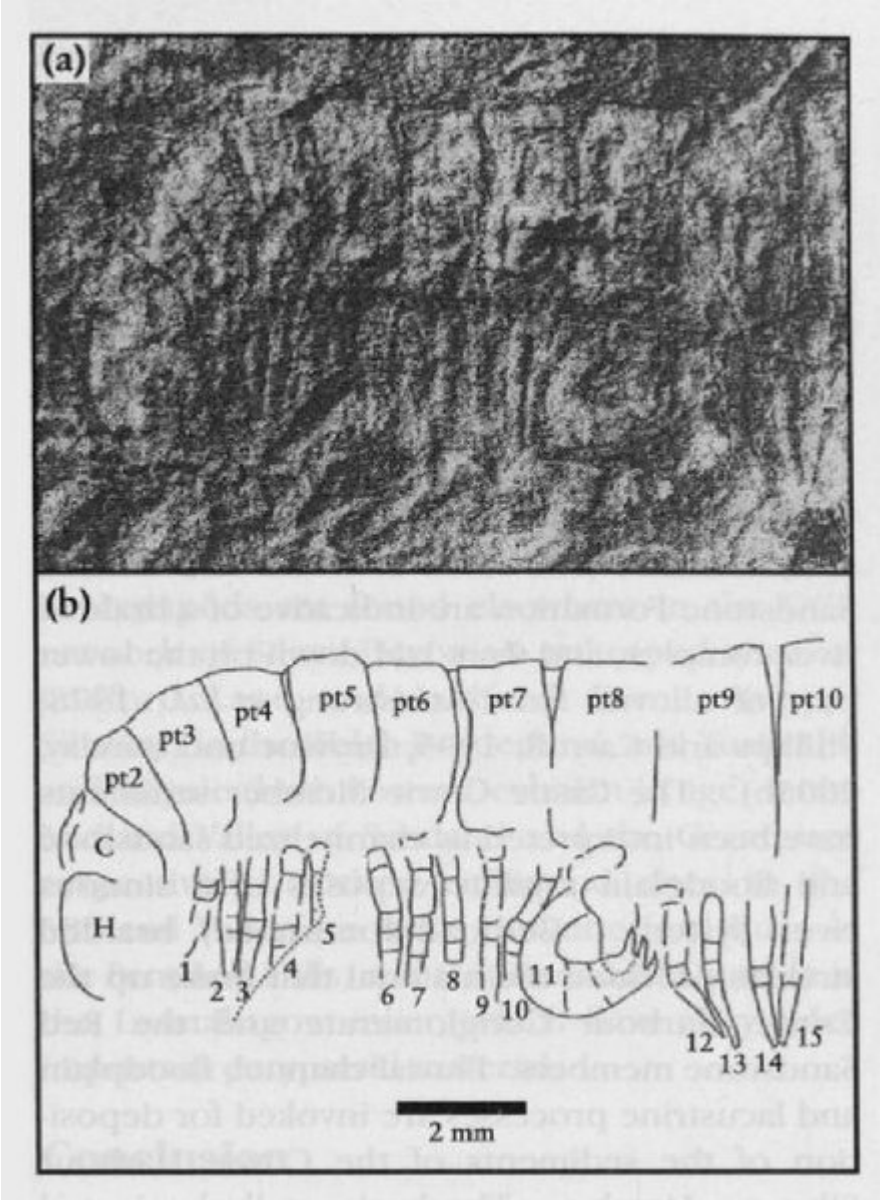
(Figure 2.30) Geological sketch map of The Touties area. (After Browne and Barclay, 2005b.)



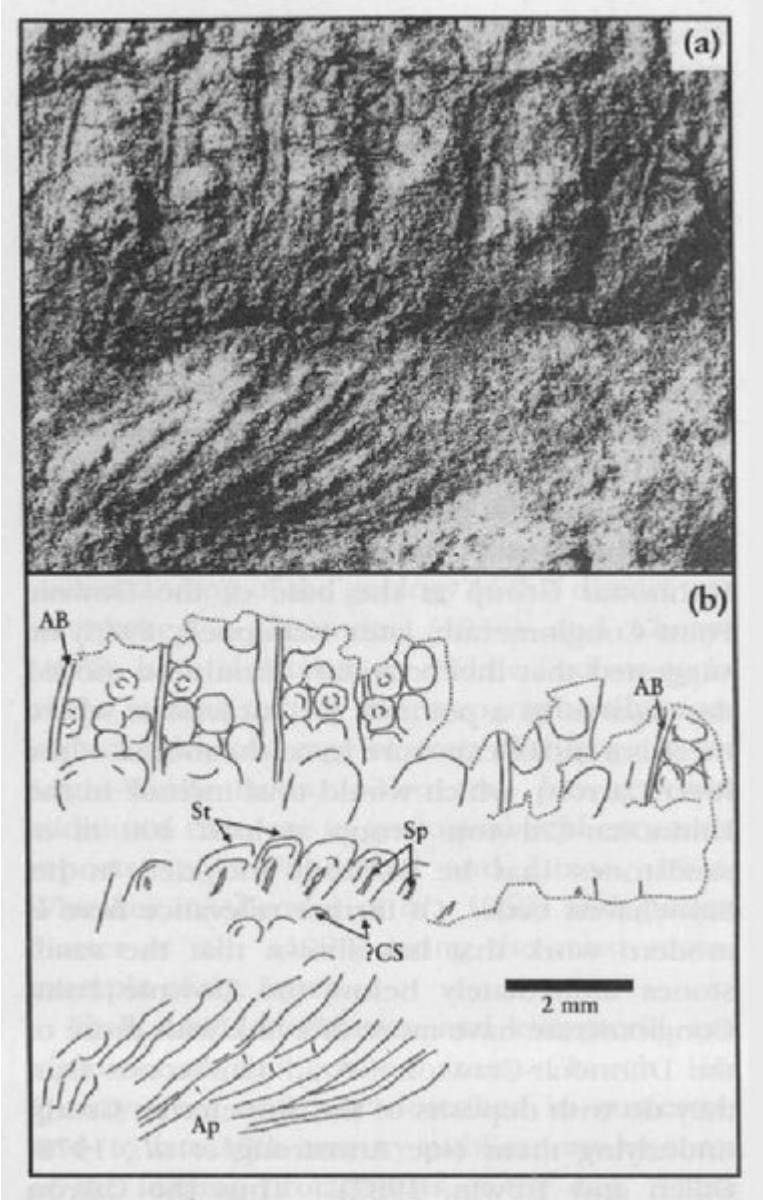
(Figure 2.31) (a) Vertical section of the Cowie Sandstone Formation. (b) Detailed section at The Mimics. (After Browne and Barclay, 2005b.)



(Figure 2.32) Albadesmus almondi Wilson and Anderson, 2004; holotype, Australian Museum, Sydney, F.64847a; Cowie Harbour Siltstone (Dictyocaris) Member, upper Wenlock or lower Ludlow Series, Silurian, Cowie Harbour, Stonehaven. (a) Photograph, dorsal view of entire specimen with tergites and sternites slid apart, anterior towards the top. (b) Latex mould of sternites with paramedian pores and lateral coxae. Scale bars are 2 mm. (From Wilson and Anderson, 2004, figs 8.1 and 8.3.)



(Figure 2.33) Cowiedesmus eroticopodus Wilson and Anderson, 2004; holotype, Australian Museum, Sydney, F.64845a; Cowie Harbour Siltstone (Dictyocaris) Member, upper Wenlock or lower Ludlow Series, Silurian, Cowie Harbour, Stonehaven. (a) Photograph, lateral view of anterior part of specimen. (b) Interpretive drawing (modified). C, collum; H, head; pt2—pt10, pleurotergites, with a modified leg associated with pt8. (From Wilson and Anderson, 2005, figs 7.2 and 7.3.)



(Figure 2.34) Pneumodesmus newmani Wilson and Anderson, 2004; holotype, National Museums of Scotland, Edinburgh, NMS G. 2001.109.1; Cowie Harbour Siltstone (Dictyocaris) Member, upper Wenlock or lower Ludlow Series, Silurian, Cowie harbour, Stonehaven. (a) Photograph, dorsolateral view, anterior to the right. (b) Interpretive drawing (modified). AB, Anterior Bar; Ap, appendages; CS, coxal socket; Sp, Spiracle; St, Sternite. (From Wilson and Anderson, 2004, figs 9.2 and 9.3.)