Fossil Fishes of Great Britain

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JOINT NATURE CONSERVATION COMMITTEE

Chapter 6

Mid-Devonian fossil fishes sites of Scotland

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INTRODUCTION: PALAEOGEOGRAPHY AND STRATIGRAPHY

Middle Old Red Sandstone sediments accumulated in the tectonically controlled NE–SW-trending Orcadian Basin. This broad structure developed on the margin of Laurussia at about 20° south of the Middle Devonian equator and stretched as far as the Hornelen Basin on the present Norwegian coastline (Figure 6.1). The lower parts of the sequence are lacustrine, but the deposits become more fluvial upwards and laterally towards the margins of the basin, until near the top they are almost entirely fluvial.

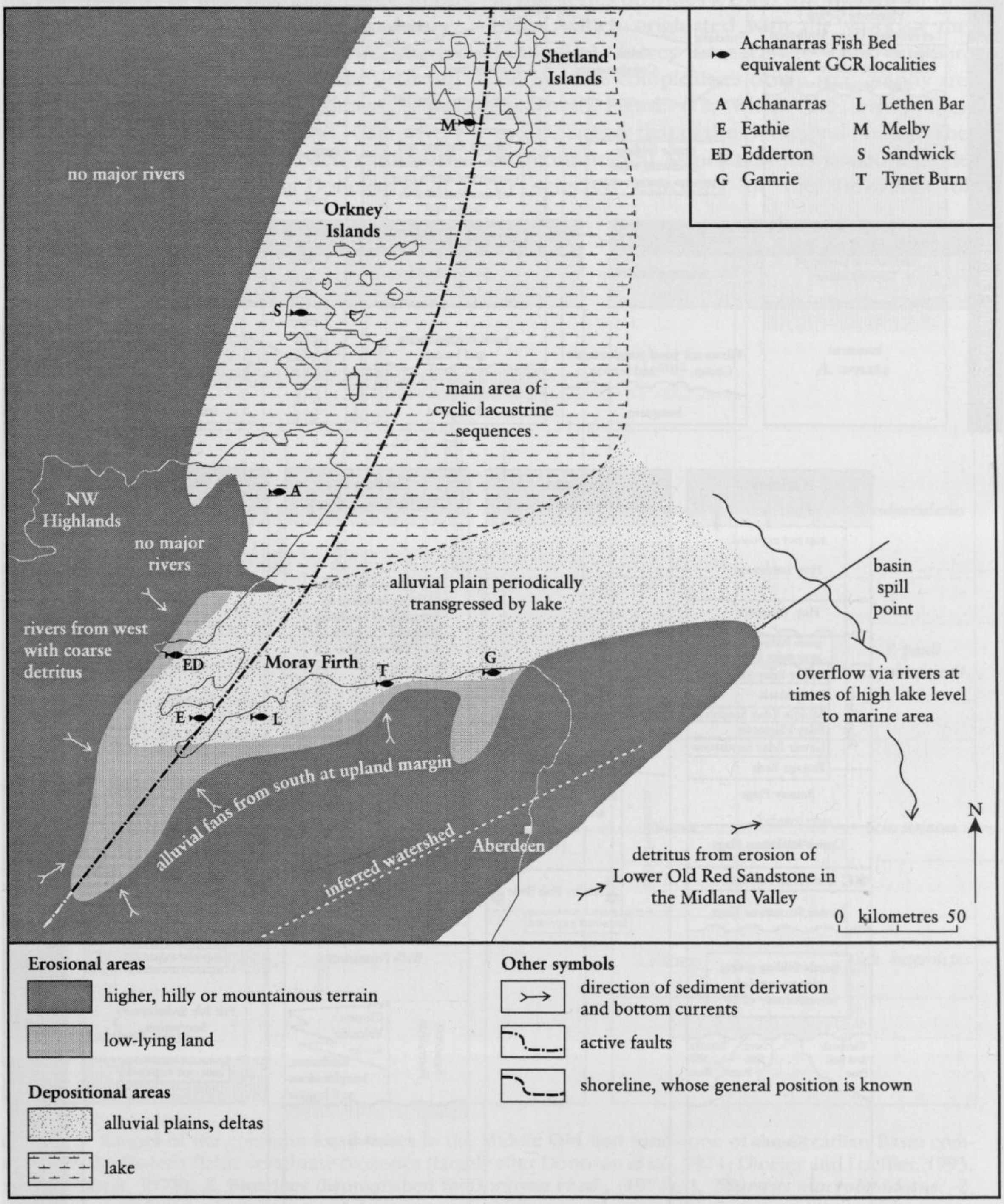

Figure 6.1 Palaeogeography of the Middle Devonian, 380–375 Ma, of Scotland and adjacent North Sea (after Bluck *et. al.*, 1992).

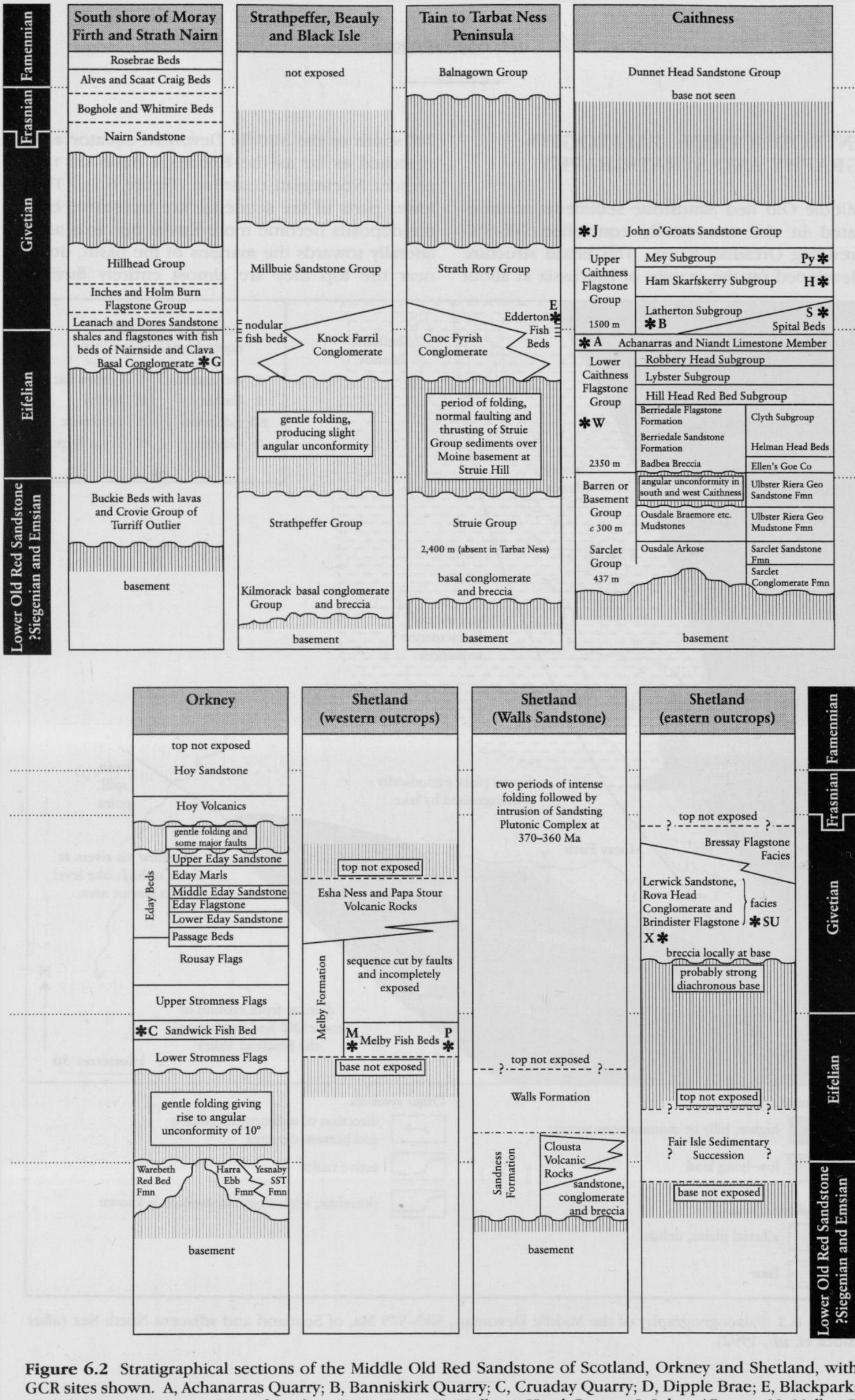

Figure 6.2 Stratigraphical sections of the Middle Old Red Sandstone of Scotland, Orkney and Shetland, with GCR sites shown. A, Achanarras Quarry; B, Banniskirk Quarry; C, Cruaday Quarry; D, Dipple Brae; E, Blackpark; F, Edderton; G, Gamrie, Den of Findon, Tynet Burn; H, Holburn Head Quarry; J, John o'Groats; M, Melby; P, Papa Stour; Py, Pennylands; S, Spital Quarry, Su, Sumburgh Head; W, Weydale Quarry; X, Exnaboe (after Mykura (1991), Donovan *et al.* (1974) and others).

Borehole evidence in the North Sea suggests that at times there may have been access from 'Lake Orcadie' to the Devonian sea to the south, in the vicinity of the present mid-North Sea (Marshall, 1992; Marshall *et al.*, 1996).

In total, the basin infill, the 'Caithness Flagstone Series' reached a thickness of over 5000 m. It rests, in part unconformably, upon the Sarclett Group, Lower Old Red Sandstone, and it is in turn, surmounted by the unconformable Dunnet Head (Sandstone) Group (Upper Old Red Sandstone) in Caithness. It was first detailed by Crampton and Carruthers (1914) but more recently has been studied by T.S. Westoll and his group (e.g. Donovan *et al.*, 1974; Westoll, 1977), who were concerned with the biostratigraphy and sedimentology of these strata, the palaeobiology and taphonomy of the vertebrate faunas, and with the sedimentary tectonics (Rogers and Astin, 1991). Westoll's group, and more recently Trewin, have demonstrated that the succession of vertebrate faunas in this series provides a good chronology for this basin, which originated with the work of the Geological Survey (see Dineley and Loeffler, 1993). The complexities of the stratigraphy are shown in Figure 6.2, where the terminology used is largely that of the Geological Survey. The Palaeontological Association has issued a guide to selected outcrops of the Devonian of

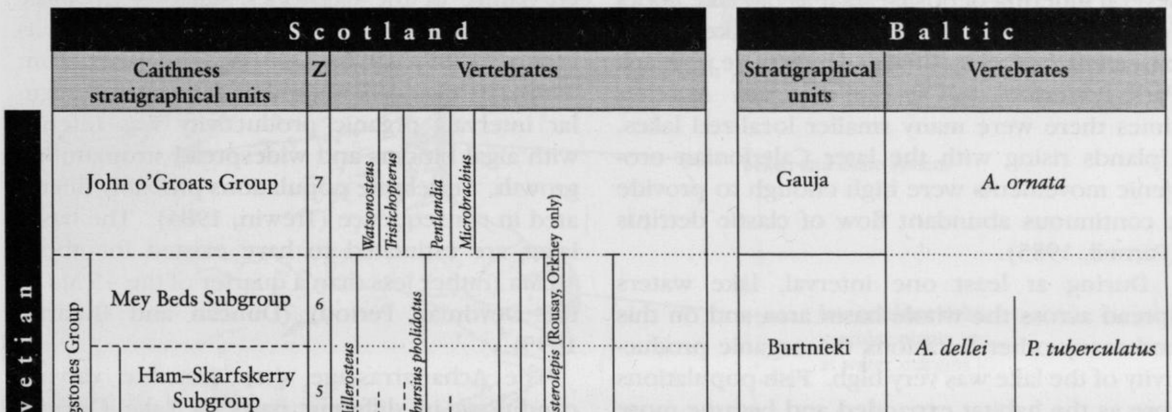

Figure 6.3 Ranges of the common fossil fishes in the Middle Old Red Sandstone of the Orcadian Basin compared with the Eastern Baltic vertebrate biozones (largely after Donovan *et al.*, 1974; Dineley and Loeffler, 1993; and Mark-Kurik, 1978). Z, Biozones distinguished by Donovan *et al.*, (1974): 1, *Thursius macrolepidotus*; 2, *Coccosteus cuspidatus*; 3, *Palaeospondylus gunni*; 4, *Dickosteus threiplandi*; 5, *Asmussia murchisoniana*; 6, *Millerosteus minor*; 7, *Watsonosteus fletti*. A, *Asterolepis*; P, *Psammosteus*; Sch, *Schizosteus*

Scotland, including several of the Middle Old Red Sandstone localities (Friend and Williams, 1978). Trewin and Hurst (1993) have provided a field guide to the geology of eastern Sutherland and Caithness.

The lake transgression appears to have been a relatively rapid event; for example, in Orkney there is a transition from desiccation-cracked sediments into the lower band of the Sandwick Fish Bed over only 1 m of strata (Trewin, 1976). In marginal situations, such as Gamrie, inundation may have occurred later, and probably as pulses, as indicated by more than one fish-bearing horizon at, for example, Edderton, Tynet Burn and in Orkney. The lake spread out over several differing deposits, such as old lake floors (e.g. Achanarras Quarry), marginal lake deltas, basement bedrock, fluvial deposits (e.g. Black Park, Edderton) and aeolian deposits. At other times there were many smaller localized lakes. Uplands rising with the later Caledonian orogenic movements were high enough to provide a continuous abundant flow of clastic detritus (Parnell, 1985).

During at least one interval, lake waters spread across the whole basin area and on this and many other occasions the organic productivity of the lake was very high. Fish populations rose as the habitat expanded and became more favourable. As a consequence on these occasions the abundance of the vertebrates as fossils also rose and the resulting fish beds are important for correlation. The 'Achanarras horizon', named after the most important quarry exposing beds of this fish stratum, is the foremost such marker horizon. It has a large fauna, species of which are widespread and stratigraphically sensitive.

Fish beds occur at many other horizons within the Middle Devonian sequence, but with more limited lateral extent. The vertebrates (gnathostomes mostly) are used for stratigraphy, and seven zones have been determined in Caithness (Donovan *et al.*, 1974) which span from the mid-Eifelian to the mid- or late Givetian in age. Their characteristic faunas are shown in Figure 6.3. The gnathostomes are also important in inter-regional correlations, especially with the eastern Baltic and Russian Platform (Blieck *et al.*, 1988).

ENVIRONMENTS

The water bodies within the Orcadian Basin were lakes fed by streams from the surrounding highlands under a hot climate, varying between humid and arid. The lakes were never deep, were usually highly productive and are presumed to have had a connection with the sea in the south and east. The Achanarras Fish Bed represents stagnant muds deposited at the bottom of a lake covering some 50 000 km^2 (Figure 6.1). It contains well-preserved remains of abundant fishes that lived in the upper waters of the Orcadian Lake, and which eventually sank to the deoxygenated lower layers of the lake. There were no predators or scavengers to disturb the carcasses, and little decomposition to destroy the specimens. The essentially laminated nature of the flagstones suggests rhythmic sedimentation under cyclic climatic conditions (Astin, 1985, 1990; Duncan and Hamilton, 1988). It would be seen that at close and regular intervals organic productivity was intense with algal blooms and widespread stromatolitic growth. Vertebrate populations probably fluctuated in consequence (Trewin, 1984). The basin lakes are estimated to have existed for about 10 Ma (rather less than a quarter of the 45 Ma of the Devonian Period) (Duncan and Buxton, 1995).

The Achanarras-age sites illustrate varying conditions in different parts of Lake Orcadie during approximately the same period of time (Figure 6.4). Achanarras yields the greatest number of species, and is the only site at which it is possible to collect good material of several of these forms. Other sites may be interesting because of the superb state of preservation of their material. Specimens from the Moray Firth are very beautifully preserved within nodules because they were closer to the lake margins where carbonate cements were sufficient to nucleate around decaying fish remains.

FISH FAUNAS

Fossil fishes in the Middle Old Red Sandstone of northern Scotland had obviously been observed by local people for many years, but they were not described in print until the 1820s, after Murchison (1827) visited Caithness. His visit stimulated interest, and large collections were made from the 1830s onwards (Andrews, 1982). Louis Agassiz produced as his first *magnum opus* (1833–1845), a description of the many beautiful specimens in Scottish collections including several Middle Devonian taxa or exam-

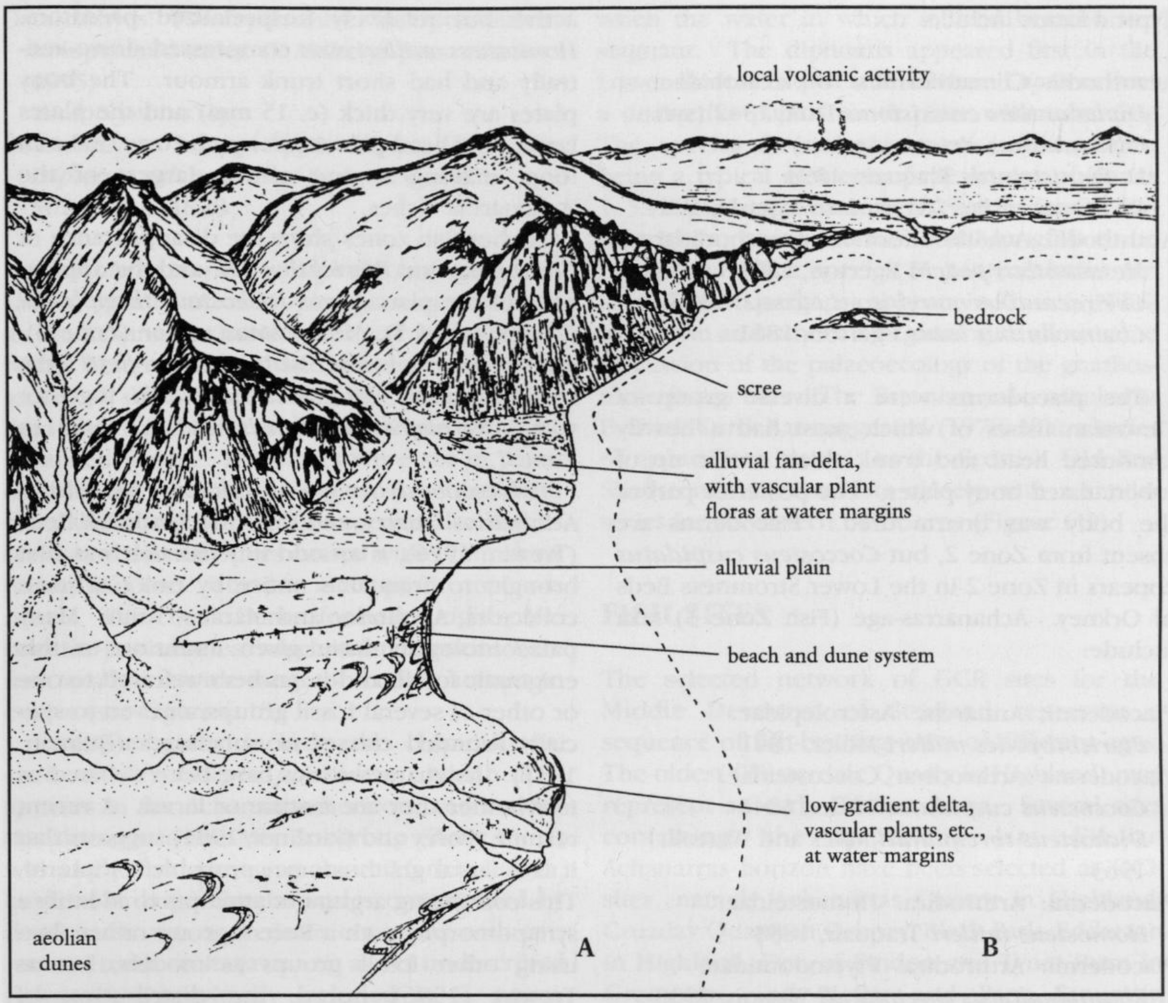

Figure 6.4 Diagrammatic reconstruction of the marginal environments around the Middle Devonian Orcadian Basin of Scotland and the North Sea at a time of high stable water level (after Trewin, 1986). The shallow-water well-oxygenated zone (A) provided a variety of habitats for the fish, which were ultimately preserved in the deeper deoxygenated zone (B).

ples. Hugh Miller, the stone mason and poet who became a popular writer on the history and natural history of Scotland, brought public attention to these fossils between 1841 and 1857, especially in his famous book *The Old Red Sandstone or New Walks in an Old Field*. It ran to seven editions.

The Middle Devonian strata of north and north-east Scotland contain some of the most diverse and best-preserved Palaeozoic fish faunas in the world. Many of the species are unique to the area and were perhaps prevented from migrating by the enclosed nature of the Orcadian Lake. Osteichthyans predominate, but placoderms, aconthodians and agnathans are all represented.

Agnathan fishes are rare in the Scottish Middle Old Red Sandstone, and do not occur at the Achanarras horizon. Only two specimens of *Cephalaspis magnifica* are known, both from Spittal Quarry, a Zone 4 locality. Cephalaspids are well documented elsewhere from the Late Silurian to the Late Devonian (see Chapter 1). The Caithness specimens are remarkably large (up to 600 mm long), as are those in the upper Devonian of eastern Canada.

Acanthodians are common, as complete specimens throughout most of the 'fish zones' (Figure 6.3). Active, predatory gnathostomes, the acanthodians ranged in age from Silurian to Permian, and were at their acme in the Devonian. Many of the acanthodians from the Middle Devonian of Scotland were small fishes and were among the earliest to be described.

Typical forms include:

Acanthodii: Climatiiformes: Diplacanthidae:
Diplacanthus crassisimus Duff, 1842 (syn. *Diplacanthus striatus* Agassiz)
D. tenuistriatus Traquair, 1894
Rhadinacanthus longispinus Agassiz, 1844
Acanthodii: Acanthodiformes: Acanthodidae
Mesacanthus peachi Egerton, 1861
Cheiracanthus murchisoni Agassiz, 1835
Cheiracanthus latus Egerton, 1861

The placoderms were a diverse group of Devonian fishes of which most had a heavily armoured head and trunk shield made up of tuberculated bony plates. The posterior part of the body was unarmoured. Placoderms are absent from Zone 2, but *Coccosteus cuspidatus* appears in Zone 2 in the Lower Stromness Beds of Orkney. Achanarras-age (Fish Zone 3) taxa include:

Placodermi: Antiarchi: Asterolepidae:
Pterichthyodes milleri Miller, 1841
Placodermi: Arthrodira: Coccosteidae:
Coccosteus cuspidatus Miller, 1841
Dickosteus threiplandi Miles and Westoll, 1963
Placodermi: Arthrodira: Homosteidae:
Homosteus milleri Traquair, 1888
Placodermi: Arthrodira: Ptyctodontidae:
Rhamphodopsis threiplandi Watson, 1938

The antiarch *Pterichthyodes milleri* is confined to the Achanarras Horizon. It was about 160 mm long and is virtually the only antiarch in the series. Other antiarchs of the Mid- and Late Devonian epochs were abundant elsewhere throughout the Euramerican province, and latterly the world. The trunk armour supported an armoured and jointed pectoral limb, and the posterior trunk was covered with scales. *Coccosteus cuspidatus*, 400 mm long, is mainly restricted to the Achanarras horizon. It lingered on into the 'Spittal Beds' (Saxon, 1975). This arthrodire, with its heavily armoured head and pectoral region, scaled body and elongated heterocercal tail, is one of the best and longest known in Britain. The headshield was movably articulated with the trunk shield. The jaws bore tooth plates and cusps that provided an effective means of seizing and shearing food. Miles (1969) regarded this level of arthrodire development as fairly advanced and the coccosteids as active but relatively unspecialized predators. *Homosteus milleri* was compressed dorso-ventrally and had short trunk armour. The bony plates are very thick (*c.* 15 mm) and the plates large. The head plus trunk may be over 300 mm long, making it one of the largest of the 'Achanarras' fishes.

Higher fish zones show the disappearance of *Coccosteus* and *Pterichthyodes*, and the appearance of the placoderms *Dickosteus threiplandi* (Zones 4 and 5), *Millerosteus minor* (Zone 6), and two new forms, *Watsonosteus fletti* (the small antiarch), *Microbrachius dicki* together with *Asterolepis orcadensis* and *A. thule* in Zone 7.

Palaeospondylus gunni Traquair, 1890 from Achanarras Quarry, and from the Sandwick Beds (Trewin, 1976), is an odd tiny fish that was first brought to Traquair's notice by two Caithness collectors, Alexander and Marcus Gunn. Many palaeontologists have given attention to this enigmatic fossil, and it has been referred to one or other of several fossil groups, or even to specially founded classes or subclasses (Bulman, 1931). Its characteristics have been debated as to whether they are mature or larval. A recent resumé (Forey and Gardiner, 1981) suggests that it is a larval gnathostome, probably a dipterid. This convincing argument attempts to identify a synapomorphy with a Recent group rather than using other fossil groups as models, but as Trewin (1986) noted, the distribution of *Palaeospondylus* at Achanarras is quite distinct and different from that of other vertebrates. The puzzle remains.

The Osteichthyes (bony fishes), both actinopterygians (ray-finned) and sarcopterygians (lobe-finned), are abundant in the Achanarras horizon. The earliest records of these are from the Late Silurian, but the first complete specimens are found at the Achanarras horizon. Bony fishes from the Scottish Middle Old Red Sandstone include:

Osteichthyes: Actinopterygii: Cheriolepididae
Cheirolepis trailli Agassiz, 1835
Osteichthyes: Sarcopterygii: Holoptychida: Holoptychiidae
Glyptolepis paucidens Agassiz, 1844
G. leptopterus Agassiz, 1844
Osteichthyes: Sarcopterygii: Osteolepidiformes: Osteolepididae
Osteolepis macrolepidotus Agassiz, 1835
Gyroptychius agassizi Traill, 1841

Osteichthyes: Porolepiformes: Holoptychiidae
holoptychiid indet. (P. Ahlberg, pers. comm., 1995)
'*Holoptychius*' sp.
Osteichthyes: Sarcopterygii: Dipnoi: Dipterida
Dipterus valenciennesi Sedgwick and Murchison, 1828

Cheirolepis trailli, perhaps the most primitive known species of actinopterygian, is restricted to the Achanarras horizon. It was long-bodied, with a heterocercal tail and covered with a shagreen of small acanthodian-like scales, rather than the large thick scales common to more advanced forms. The scales were set in rows, each having a peg and socket to articulate with rows above and below. This species also had its scales and dermal bones coated with a thin shiny tissue, ganoine. The jaw mechanism, too, was novel. The cheek bones formed a rigid plate over the jaw muscles, which in later species were free to allow a wide range of feeding actions to evolve (see Figure 6.18).

Sarcopterygians include the rhipidistians, such as *Glyptolepis paucidens*, which first appears in the Achanarras horizon, and continues through to the Mey Subgroup (Zone 6). It was a large fish, averaging about 0.6 m in length, covered in large circular scales ornamented by dentine. It was a predator equipped with two rows of teeth on its jaws. An as yet undescribed holoptychid previously included in *G. paucidens* has a skull length of about 1 m, it is the largest fish in the basin and is very rare. *Osteolepis macrolepidotus*, 0.16 m long on average, is restricted to the Achanarras horizon, but is abundant at some localities (e.g. Cruaday), and rare at others (e.g. Achanarras). *Gyroptychius agassizi* is also virtually confined to the Achanarras horizon. It is 0.3–0.4 m long, and has dorsal fins in a posterior position.

Rhipidistians occur in other Middle Old Red Sandstone fish zones. Species of the osteolepid *Thursius* occur in Zones 1, 2, 5, and 6, *T. macrolepidotus* in the two lower zones, and *T. pholidotus* in the two upper ones. *Osteolepis microlepidotus* is characteristic of Zone 6, and *Tristichopterus alatus* of Zone 7.

The final sarcopterygian group in the Achanarras horizon are the Dipnoi (lungfishes), such as *Dipterus*, which was able to breath air and probably shared this ability with most other sarcopterygians and perhaps basal actionopterygians. They may all have obtained extra oxygen when the water in which it lived became too stagnant. The dipnoans appeared first in the Lower Devonian and still survive. *Dipterus* had a distinctive palatal tooth plate with tubercles. The species *D. valenciennesii* is ubiquitous, being a typical element of the faunas of Zones 1–5. Described as early as 1829 by Sedgwick and Murchison, it was the first fossil lungfish to be recognized. The species *D. platycephalus* (an invalid taxon perhaps) appears in Zone 6. Work by Trewin and others is beginning to allow some discussion of the palaeoecology of the gnathostome fishes here. The Estonian palaeontologist E. Mark-Kurik has suggested (1978) that a series of arthrodiran 'zones' in the Scottish Old Red Sandstone may correlate closely with a similar series in the eastern Baltic area (Figure 6.3).

FISH SITES

The selected network of GCR sites for the Middle Devonian of Scotland represent a sequence of fish-bearing units of different ages. The oldest (Westerdale Quarry in Highland) may represent an early Eifelian fauna. Several sites containing the important late Eifelian Achanarras horizon have been selected as GCR sites, namely Achanarras Quarry in Highland, Cruaday Quarry in Orkney, Black Park, Edderton in Highland, Den of Findon and Tynet Burn in Grampian, and Melby and Papa Stour in Shetland, a wide geographical range of sites of presumably identical age.

The remaining Scottish Middle Devonian fish sites are all probably Givetian in age, and they document sequences of faunal change in some detail. Dipple Brae in Highland is marginally younger than the Achanarras horizon, as are Spittal Quarry and Banniskirk Quarry in Highland. The Caithness Flagstone sequence is continued with progressively younger fish-bearing horizons represented at Holburn Head Quarry, Weydale Quarry, Pennyland and John o'Groats, all in Highland. In Orkney the Sandwick Fish Beds correlate with the Achanarras horizon at Cruaday Quarry. The Cletts, Exnaboe and Sumburgh Head in Shetland both contain fish beds of latest Givetian age.

A new excursion guide to the geology of eastern Sutherland and Caithness covers the outcrops on which many of the following sites are located (Trewin and Hurst, 1993).

WESTERDALE QUARRY (ND 126517)

Highlights

Complete fishes are very common in Westerdale Quarry, Highland. This is a rare inland exposure of one of the earliest occurrences of a fish bed within the Orcadian sediments of the north of Scotland. The quarry is important because of its age, and because of the presence of the early bony (osteichthyan) fishes *Thursius* and *Dipterus* (Figure 6.5A–D).

Introduction

This small, flooded quarry exposes dark grey lacustrine siltstones of Eifelian age. Miles and Westoll (1963) place the Westerdale quarries 'no more than 850 ft below the Achanarras band' on the basis of regional dip. However, inland exposure is very poor in Caithness because of a thick cover of drift, and information from the faunal assemblage at the site is enigmatic, so that the stratigraphical position of the quarry remains uncertain.

Description

Fish specimens occur in a 1 m thick bed of poorly fissile, laminated, calcareous grey siltstone within a sequence of dark grey laminated siltstones with subaqueous shrinkage cracks (Wick Flag type of Crampton and Carruthers, 1914, p. 64). This is detailed in the following section:

	Thickness (m)
Dark grey laminated flagstones with shrinkage cracks	0.9
Light grey laminated siltstone	0.12
Irregular surface	
Light grey, calcareous siltstone, rare fishes	0.25
Mudstone parting	0.01
Dark grey, poorly fissile, varved calcareous siltstone; very fossiliferous, containing much disseminated scale material, plus ?coprolitic concentrations of scales; complete small *Thursius* sp. are common	0.75
Dark grey laminated flagstones, with shrinkage cracks	3+

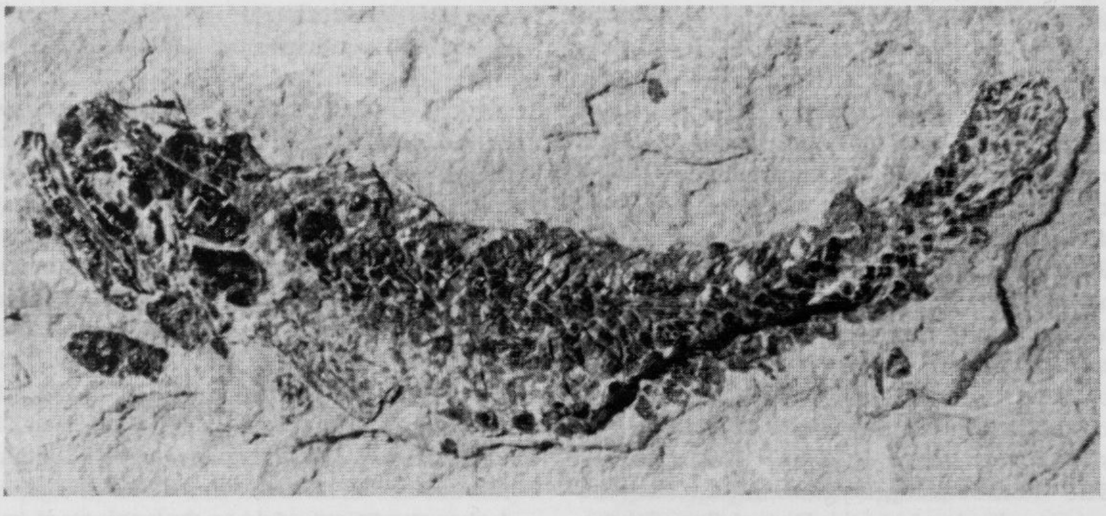

Figure 6.5 Fossil fishes from Westerdale Quarry. (A) The lungfish *Dipterus valenciennesi* Agassiz (Photo: courtesy The Natural History Museum, London, T00826/A), approximately natural size. (Continued on p. 177.)

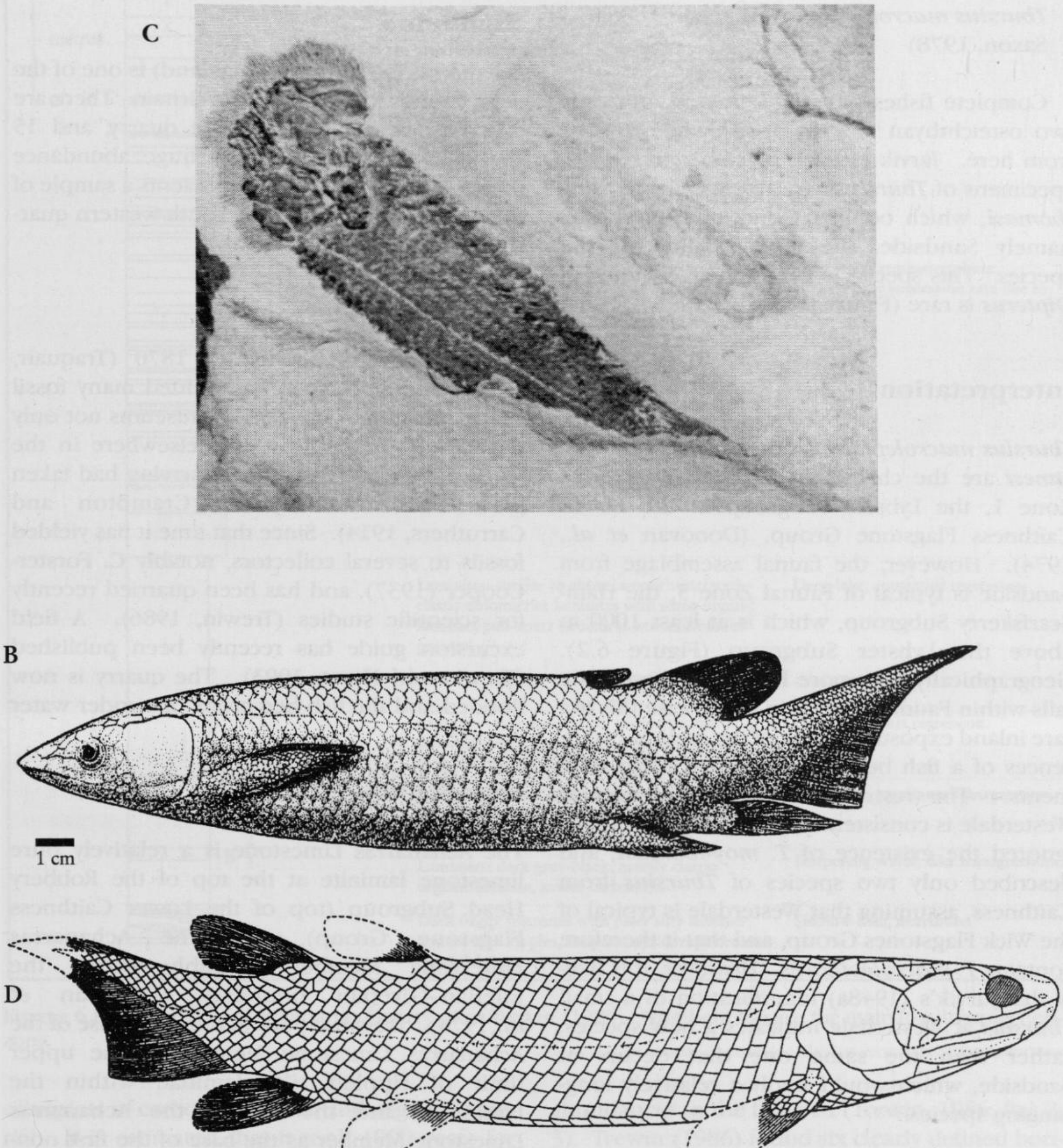

Figure 6.5 – *contd.* Fossil fishes from Westerdale Quarry. (B) *D. valenciennesi* in restoration by Ahlberg and Trewin (1995); (C) the osteolepid *Thursius* (Photo: courtesy The Natural History Museum, London, T00448/A), *c.* 12 cm; (D) *T. macrolepidotus* (Sedgwick and Murchison) (from Jarvik, 1948a).

The beds dip to the north at a low angle, and the fish bed is thus exposed in the north-north-eastern part of the quarry, where a bench has been formed by its removal.

Fauna

Osteichthyes: Sarcopterygii: Dipnoi:
Dipterida: Dipteridae

Dipterus valenciennesii Sedgwick and Murchison, 1828

Osteichthyes: Sarcopterygii: Osteolepiformes: Osteolepidae
Thursius macrolepidotus (Traquair, 1888a; Saxon, 1978)

Complete fishes are very common, but only two osteichthyan species of fish are recorded from here. Jarvik (1948a, p. 212) referred the specimens of *Thursius* to a new species, *T. moy-thomasi*, which occurs at only one other site, namely Sandside, the type locality for the species. This species is common at Westerdale; *Dipterus* is rare (Figure 6.5A–D).

Interpretation

Thursius macrolepidotus and *Dipterus valenciennesi* are the characteristic fossils for Faunal Zone 1, the Lybster Subgroup of the Lower Caithness Flagstone Group. (Donovan *et al.*, 1974). However, the faunal assemblage from Sandside is typical of Faunal Zone 5, the Ham-Scarfskerry Subgroup, which is at least 1000 m above the Lybster Subgroup (Figure 6.2). Geographically, it is more likely that Westerdale falls within Faunal Zone 1, in which case this is a rare inland exposure of one of the earliest occurrences of a fish bed within the Orcadian sediments. The restricted fauna that occurs at Westerdale is consistent with this. Saxon (1978) ignored the existence of *T. moy-thomasi*, and described only two species of *Thursius* from Caithness, assuming that Westerdale is typical of the Wick Flagstones Group, and that it therefore contains *T. macrolepidotus*. However, it is likely that Jarvik's (1948a) identification of a small *Thursius* at Westerdale indicates a new species, rather than the same one that occurs at Sandside, which would imply a relatively long-ranging species.

Conclusion

Westerdale Quarry probably reveals one of the oldest fish-bearing horizons in the Orcadian Basin. Consequently its conservation value lies in its fish fauna, which heralds the beginning of a major phase of fish evolution through the Mid- and Late Devonian in the north of Scotland. The site is still open, and has the potential for further research.

ACHANARRAS QUARRY (ND 150544)

Highlights

Achanarras in Caithness (Highland) is one of the most famous fossil fish sites in Britain. There are many fish-bearing beds in the quarry, and 15 species have been found in huge abundance there. Achanarras Quarry represents a sample of the rich fish fauna from the south-western quarter of the great Orcadian Lake.

Introduction

The quarry was opened in 1870 (Traquair, 1894a) and since then has yielded many fossil fishes, which may be seen in museums not only throughout Britain, but also elsewhere in the world. By 1914, very little quarrying had taken place for several years (Crampton and Carruthers, 1914). Since that time it has yielded fossils to several collectors, notably C. Forster-Cooper (1937), and has been quarried recently for scientific studies (Trewin, 1986). A field excursion guide has recently been published (Trewin and Hurst, 1993). The quarry is now flooded and the fish bed crops out under water (Figure 6.7).

Description

The Achanarras Limestone is a relatively pure limestone laminite at the top of the Robbery Head Subgroup (top of the Lower Caithness Flagstone Group), and the Achanarras Limestone Member probably marks the Eifelian–Givetian boundary (Donovan *et al.*,1974). Trewin (1986) defined the base of the Achanarras Limestone Member as the upper limit of rippled silty laminae within the laminites, and the top of the Achanarras Limestone Member as the base of the first non-laminite bed above the fish bed, a total thickness of 3.6 m (Figure 6.6; Trewin 1993, p. 130). Above the fish bed at Achanarras are thin-layered laminites consisting of alternating microcrystalline carbonate with clastic laminae, which result from sequential annual rhythms in a stratified lake. They appear as a repetition of couplets of thin light and dark laminae, 1–2 mm thick. A third type of lamina is rich in organic material. These are very thin (< 0.1 mm) and are largely of algal origin. The fish bed itself is rather more complicated, being made up in part

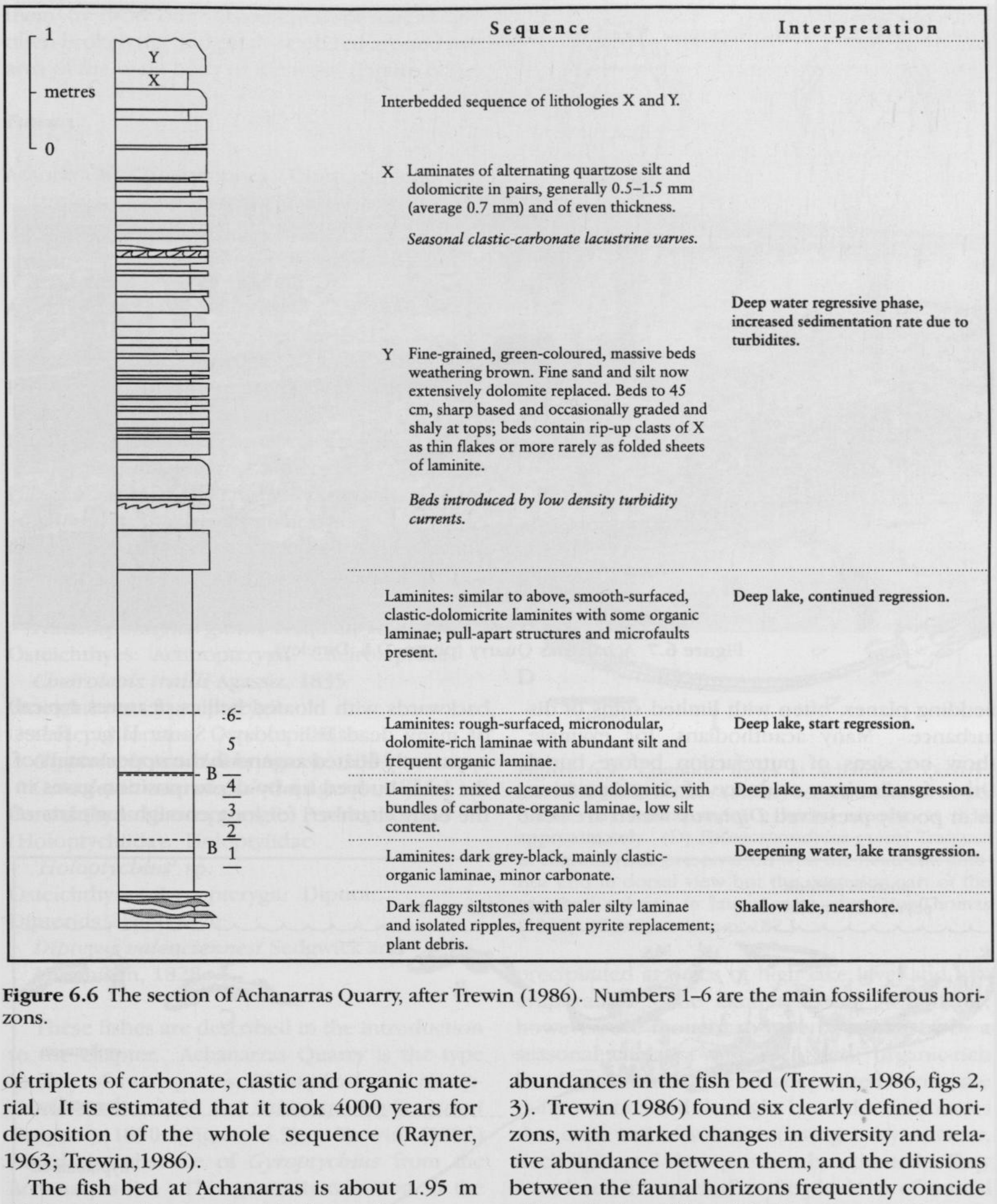

Figure 6.6 The section of Achanarras Quarry, after Trewin (1986). Numbers 1–6 are the main fossiliferous horizons.

of triplets of carbonate, clastic and organic material. It is estimated that it took 4000 years for deposition of the whole sequence (Rayner, 1963; Trewin, 1986).

The fish bed at Achanarras is about 1.95 m thick, and can be examined in the north-east corner of the quarry. The quarry was drained in 1980 and a representative continuous column of rock collected through the full thickness of the fish bed. Etched laminae from the edges of fish-bearing slabs from museum collections could be matched with the patterns exhibited by the total section, and enabled Trewin (1986) to produce detailed information about changing species abundances in the fish bed (Trewin, 1986, figs 2, 3). Trewin (1986) found six clearly defined horizons, with marked changes in diversity and relative abundance between them, and the divisions between the faunal horizons frequently coincide with episodes of low fish abundance. *Dipterus* is abundant at the top and bottom of the bed (Ahlberg and Trewin, 1995); *Osteolepis*, *Glyptolepis*, *Coccosteus* and *Cheirolepis* appear after *Dipterus*, *Pterichthyodes*, *Mesacanthus* and *Palaeospondylus* in the second division, but *Rhamphodopsis* and the larger acanthodians do not enter until near the top of division three.

The fossil fishes tend to lie together on certain

Figure 6.7 Achanarras Quarry (photo: D.L. Dineley).

bedding planes, often with limited signs of disturbance. Many acanthodians, for example, show no signs of putrefaction before burial. Other fossils show evidence of decomposition, as in poorly preserved *Dipterus* which are bent backwards with bloated bellies, features typical of many dead fish today. Some larger fishes apparently floated around in the upper waters of the lake, buoyed up by decomposition gases in the body chamber, for long enough for parts of

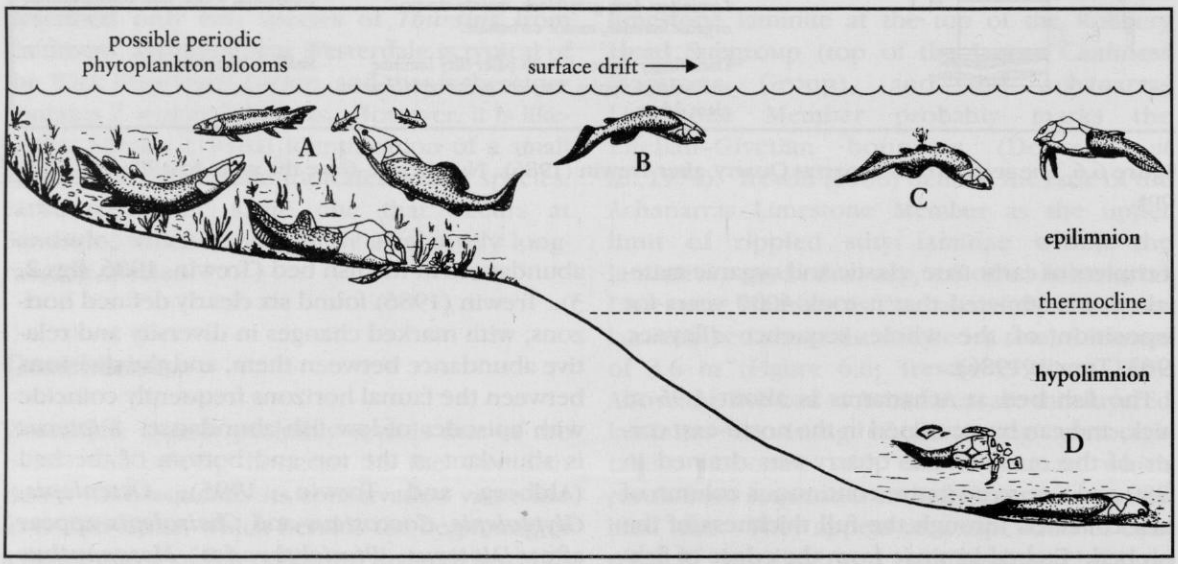

Figure 6.8 Particularly fossiliferous horizons with well-preserved fishes may result from mass mortality events induced by planktonic blooms. The axonic conditions extend throughout the shallow marginal areas (A); following this, carcasses drift into deeper water in a bloated conditions (B); after further decay (C), they sink through the thermocline and are preserved in laminites in the anoxic hypolimnion (D). The depth of the thermocline may have been no more than a few tens of metres (after Trewin, 1986).

them to drop off. Osteolepid specimens are often broken up, and partly scattered around the area of the main body of the fossil (Figure 6.8).

Fauna

Acanthodii: Climatiformes: Diplacanthidae
Diplacanthus striatus
D. tenuistriatus Traquair, 1894
D. (Rhadinacanthus) longispinus (Agassiz, 1844)
Acanthodii: Acanthodiformes: Acanthodidae
Mesacanthus peachi Egerton, 1861
Cheiracanthus murchisoni Agassiz, 1835
Placodermi: Antiarchi: Pterichthyodidae
Pterichthyodes milleri Miller, 1841
Placodermi: Arthrodira: Coccosteidae
Coccosteus cuspidatus Miller, 1841
Placodermi: Arthrodira: Homosteidae
Homosteus milleri Traquair, 1888
Placodermi: Ptychtodontida: Ptychtodontidae
Rhamphodopsis threiplandi Watson, 1938
Incertae sedis
Palaeospondylus gunni Traquair, 1890
Osteichthyes: Actinopterygii: Cheirolepidae
Cheirolepis trailli Agassiz, 1835
Osteichthyes: Sarcopterygii:
Osteolepidiformes: Osteolepididae
Glyptolepis paucidens Agassiz, 1844
Osteolepis macrolepidotus Agassiz, 1835
Osteichthyes: Sarcopterygii: Porolepiformes (Holoptychiida): Holoptyiidae
'*Holoptychius*' sp.
Osteichthyes: Sarcopterygii: Dipnoi:
Dipterida: Dipteridae
Dipterus valenciennesi Sedgwick and Murchison, 1828

These fishes are described in the introduction to the chapter. Achanarras Quarry is the type locality of two species, *Rhamphodopsis threiplandi* Watson, 1938 and *Palaeospondylus gunni* Traquair, 1890 (Figure 6.9). Trewin (1993) noted the absence of *Gyroptychius* from the Achanarras list. This genus is common in the equivalent Sandwick fish bed in Orkney.

Interpretation

Carbonate laminae may have formed as a result of increased pH following photosynthesis, hence causing carbonate (dolomite or calcite) deposition (Donovan, 1975; Trewin, 1986). Studies at Lake Balaton in Hungary indicate that calcite is

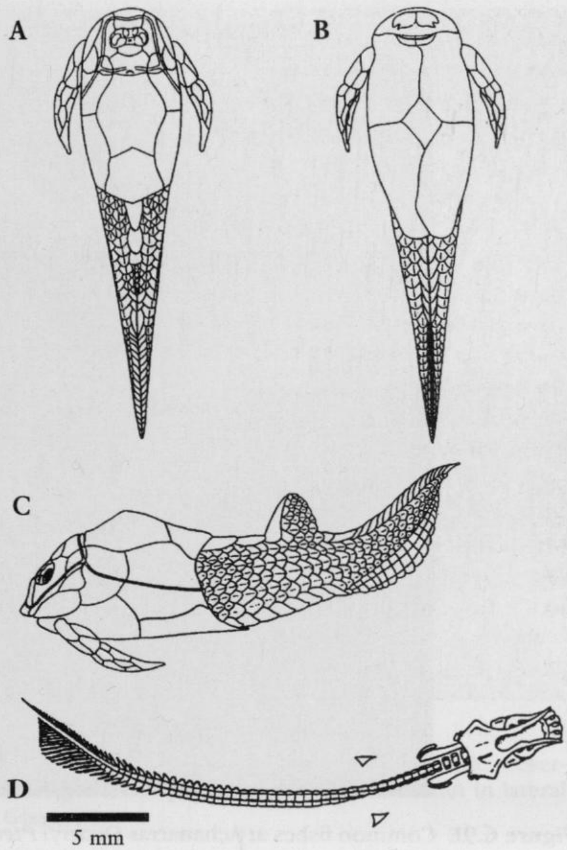

Figure 6.9 Common fishes at Achanarras Quarry: *Pterichthyodes milleri* (Miller) reconstructions in (A) dorsal, (B) ventral and (C) lateral aspects, × 0.33 approximately. (D) *Palaeospondylus gunni* Traquair in characteristic preservation with the head and anterior end in dorsal view but the posterior part of the vertebral column in lateral view, after Moy-Thomas (1940). (Continued on p. 182.)

precipitated at times of high lake level and low evaporation. The laminites from Achanarras, however, are thought to have been caused by a seasonal climate, with each dark organic-rich band representing the silts deposited during the rainy season, and the light band the carbonates that came out of solution during a dry summer. Each light and dark pair can be counted. They have been interpreted as the products of annual algal blooms. Trewin (1986) concluded that the 'calcitic' laminites of the central part of the fish bed represent the period of highest lake level, with greatest faunal diversity because of the stable environments, and the possibility of maximum migration around the lake. He suggested that they are the equivalent of the nodule beds at the basin margins, which must also have been deposited at times of maximum lake extension.

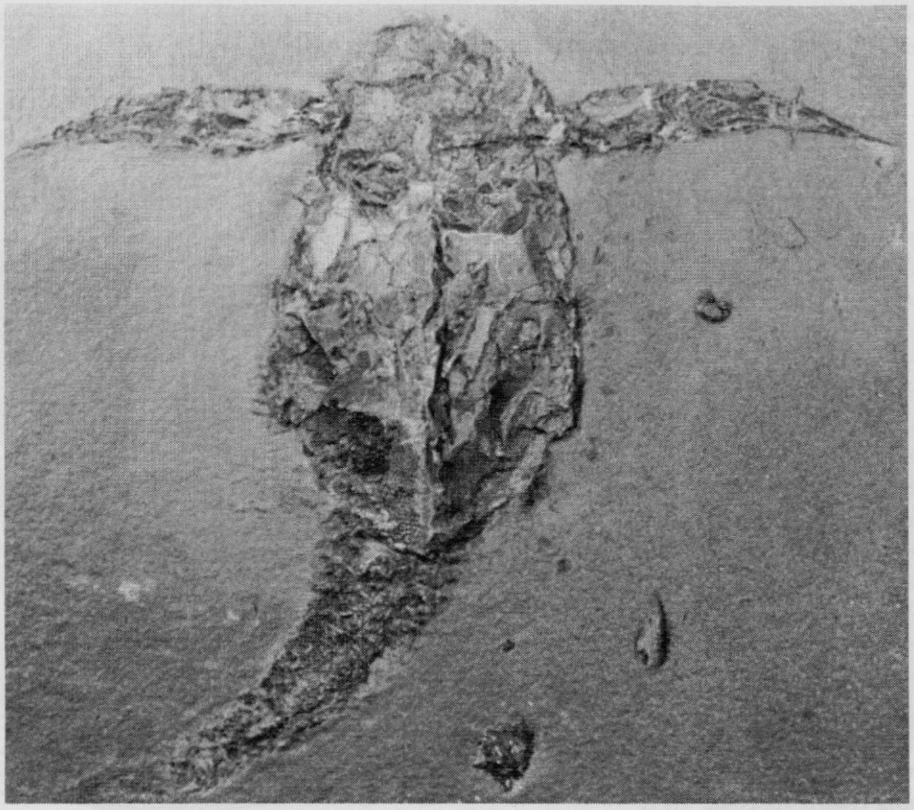

Figure 6.9E Common fishes at Achanarras Quarry: *Pterichthyodes milleri* (Miller). Photograph GLAHM V7015 showing typical compression preservation, *c.* × 0.8 (Photo: courtesy of Hunterian Museum, Glasgow).

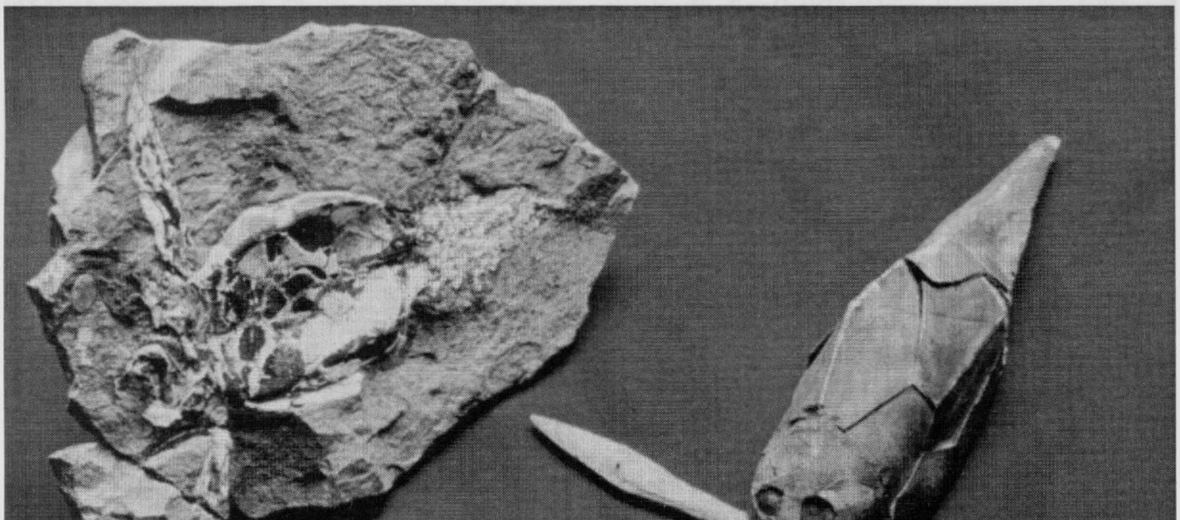

Figure 6.9F Common fishes at Achanarras Quarry: *Pterichthyodes milleri* (Miller), T05399/A, with an early model of the animal, × 0.5 (Photo: courtesy The Natural History Museum, London).

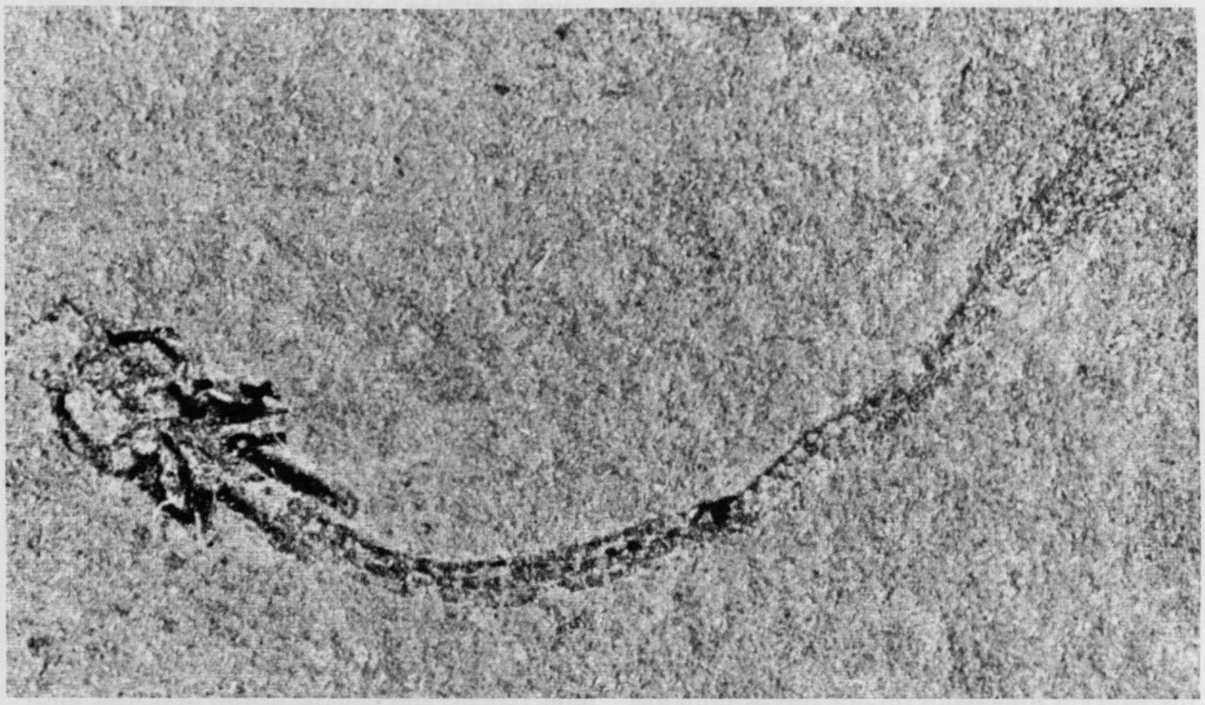

Figure 6.9G Common fishes at Achanarras Quarry: *Palaeospondylus gunni* Traquair in characteristic preservation with the head and anterior end in dorsal view but the posterior part of the vertebral column in lateral view, *c.* × 6 (Photo: courtesy of the Hunterian Museum, Glasgow).

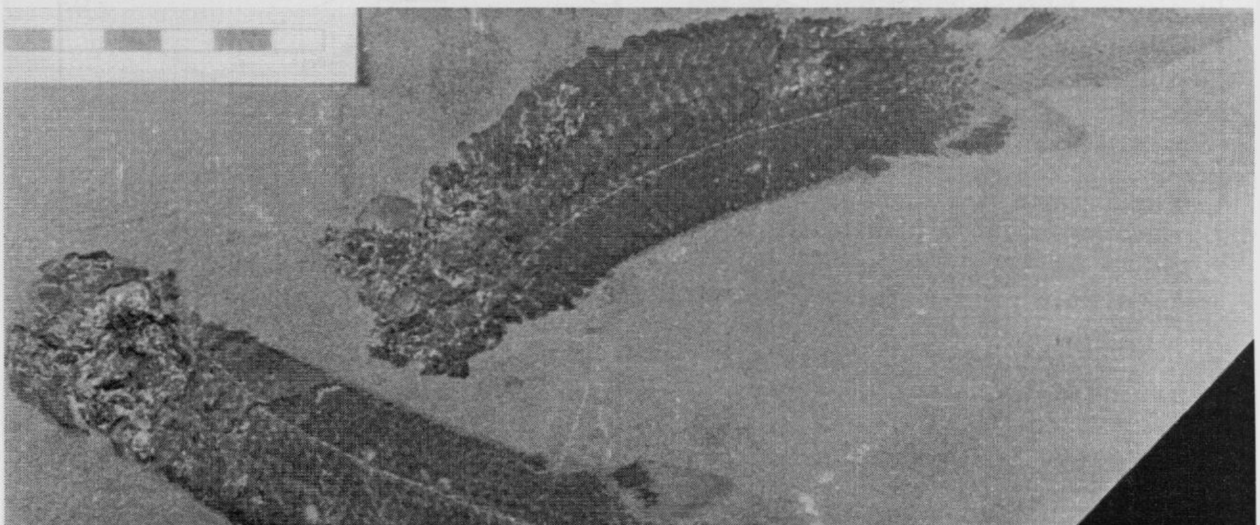

Figure 6.9H Common fishes at Achanarras Quarry: *Dipterus valenciennesi* Agassiz Photograph GLAMH V3656 showing the commonly well-preserved nature of this fossil lungfish, *c.* × 0.75 (Photo: courtesy of the Hunterian Museum, Glasgow).

The fossil fishes tend to lie together on certain bedding planes, representing catastrophes that killed off schools of fish. Postulated causes of mass mortality include not only salinity crises, but also storms stirring up toxic deeper waters, algal blooms leading to eutrophication of surface waters, or shock mixing of cold deep waters with the warmer surface water (Figure 6.8).

There is a series of phases of faunal introduction. *Dipterus* is abundant at the top and the bottom of the fish bed, suggesting that it was the first fish to colonize an area and the last survivor. *Dipterus* may have tolerated lower oxygen levels than the other fishes (Trewin, 1986; Ahlberg and Trewin, 1995) and was environmentally more hardy than the other fishes. *Pterichthyodes*, *Mesacanthus* and *Palaeospondylus* then appear and become abundant within the calcareous laminites of divisions 2, 3 and 4. *Osteolepis*, *Glyptolepis*, *Coccosteus*, and *Cheirolepis* all appear in division 2, but *Rhamphodopsis* and the larger acanthodians do not appear until the top of division 3. In a recent discussion of the palaeoecology of the porolepiform fishes of Scotland, Ahlberg (1992) noted that only adult specimens of *Glyptolepis* are present, and that *G. paucidens* was restricted to the marginal shallow water. A major change occurs at the top of the calcareous laminites, which coincides with the top of division 4. *Palaeospondylus* and *Cheirolepis* disappear, and there is a major expansion of *Coccosteus* in the overlying dolomitic laminites. Other species linger on in small numbers. Thus, changes in conditions which gave rise to dolomite, rather than calcite precipitation, were not equally tolerated by all species. Finally, division 6 contains only *Dipterus* (Figure 6.6).

The Achanarras horizon fauna consists of the same species throughout the area, but significant differences occur in the proportions present at each site, and these may correspond to different ecological areas of the lake. Achanarras Quarry has yielded the greatest number of species, possibly because it was more centrally placed within the lake, whereas sites in the Moray Firth area were on the margin, and contain a sparser fauna (Figure 6.1). The lake margin locations may sample smaller diversities of fish species, but preserve them close to their natural habitats, whereas sites much farther from the lake margins, such as Achanarras Quarry, may show a death assemblage of fishes that had mainly drifted in from some distance, and would therefore include specimens from a larger source area. A similar pattern can be discerned in the fossil plant assemblages from Achanarras horizon sites. The localities bearing the Achanarras fauna were noted by Hamilton and Trewin (1988) as illustrating the major extent of lacustrine spread to the point of basin overflow. The Achanarras Fish Bed is near or at the Eifelian–Givetian boundary (Paton, 1981). The spores of *Dinsosporites devonicus* are abundant in this bed and date it as belonging to the *devonicus–naumovii* Zone of Richardson and McGregor (1986). House (1991, 1996) recently suggested that the Achanarras Fish Bed may represent the mid-Devonian Kacak event. More than 10 Devonian extinction events were marked by reductions or changes in ammonoid faunas worldwide and linked to hypoxic sedimentary events (House, 1985). Sea-level changes, oceanic circulation and extreme climatic factors may all have influenced intense planktonic blooms and deoxygenation of marine and lake waters. The wide spread of the Achanarras Fish Bed and similar horizons with abundant remains in calcareous and carbon-rich seams suggests sharp, brief episodes of environmental change throughout the Orcadian Lake. Resulting mass or increased rates of fish mortality occurred in waters near to, or directly linked to a marine embayment (Marshall, 1992).

Conclusion

The Achanarras Quarry is flooded for most of the time, so the fish bed may not be exposed above the water. Nevertheless, it is world famous as perhaps the richest Old Red Sandstone fish site in Britain. It represents the richest sampling of Middle Devonian fish diversity in the Orcadian Lake, having been located in quiet open waters, removed from the littoral. Many thousands of specimens of fossil fishes, collected over the years, include well-preserved representatives of at least 15 species. Recent sedimentological work has enhanced the conservation value of the site, in linking high-resolution biostratigraphy with models of ancient lake development, and the fluctuations of the fish populations. Exploratory excavations have proved the immense abundance of fish specimens at Achanarras Quarry, and its potential seems undiminished.

CRUADAY QUARRY (HY 246216)

Highlights

Cruaday Quarry, in the Orkney Islands, provides an exposure of the Sandwick Fish Bed, a famous source of fossil fish specimens. The fish fauna is rich here, including 14 or 15 species, and the site has provided crucial evidence for comparisons with the network mainland fish sites of the same age.

Introduction

Cruaday Quarry (Figure 6.10) is a comparatively recent excavation. There is a long history of quarrying in the area for flagstones and roofing tiles, but most of the localities mentioned on the labels of old museum specimens, collected during the 19th century, no longer exist. The exact provenance of material labelled 'Sandwick Fish Bed' is vague. Fossil fishes have been known from the Sandwick area, probably since long before their first published mention – in the First Annual Report of the Orkney Natural History Society, which states that about 100 specimens of fossil fish were exhibited in Stromness Museum in 1837 (in *Orcadian Papers*, 1905, p. xi).

A key figure in the Cruaday story is Professor T.S. Traill of Edinburgh University, who collected many fossil fishes from northern Scotland, particularly Orkney. He corresponded with Agassiz, and in 1832 or 1833 sent him drawings of fossils, and a map showing localities at Skaill, Quoyloo and Breckaness near Stromness (Andrews, 1982). Traill (1834, 1841) described the geology of Orkney and its fossil fishes. The material that he collected, and managed to convey to Edinburgh without loss (see Traill, 1834, p. 646), was sent to Agassiz, who figured type material of new species of fish from Traill's collection from Orkney (Agassiz, 1833–1845), but that material is now lost, presumably because Traill sold his collection to unknown purchasers in 1843 (Andrews, 1982). Clouston (1845) men-

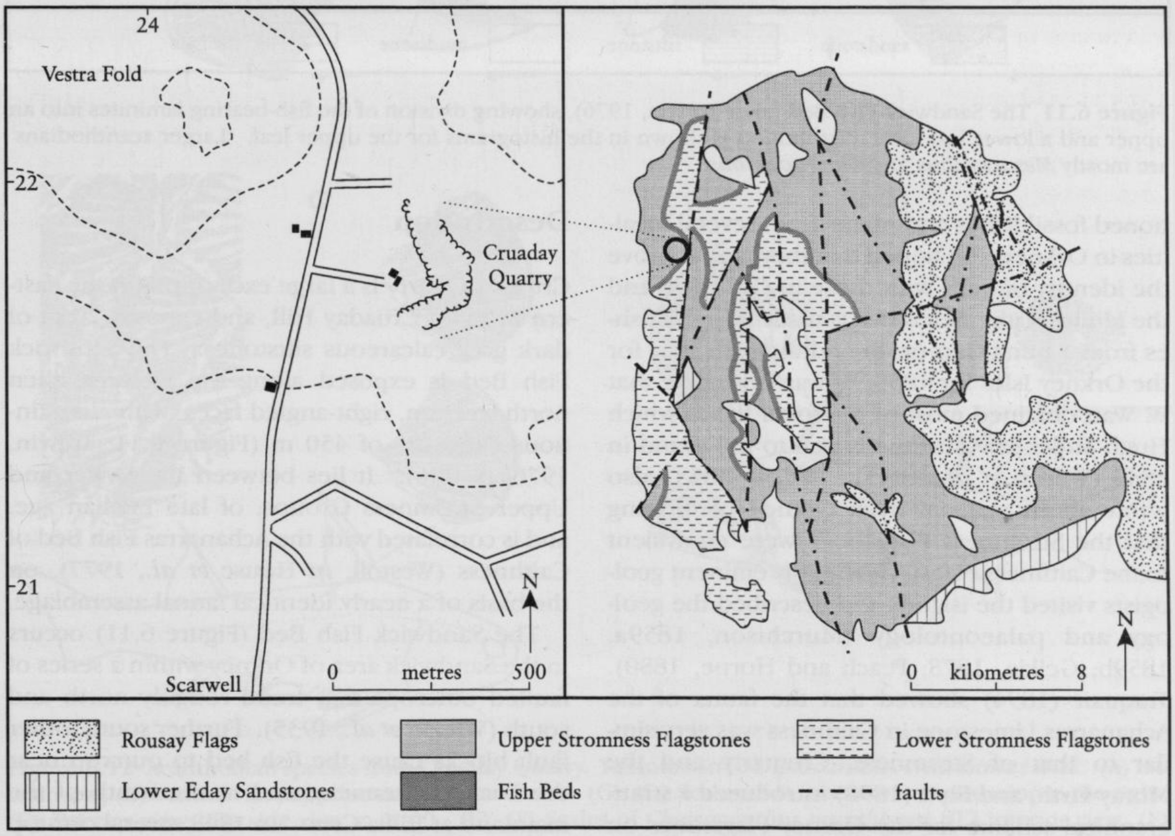

Figure 6.10 Geological sketch map of GCR Site Cruaday Quarry, Mainland, Orkney, based on the Geological Survey Orkney sheet.

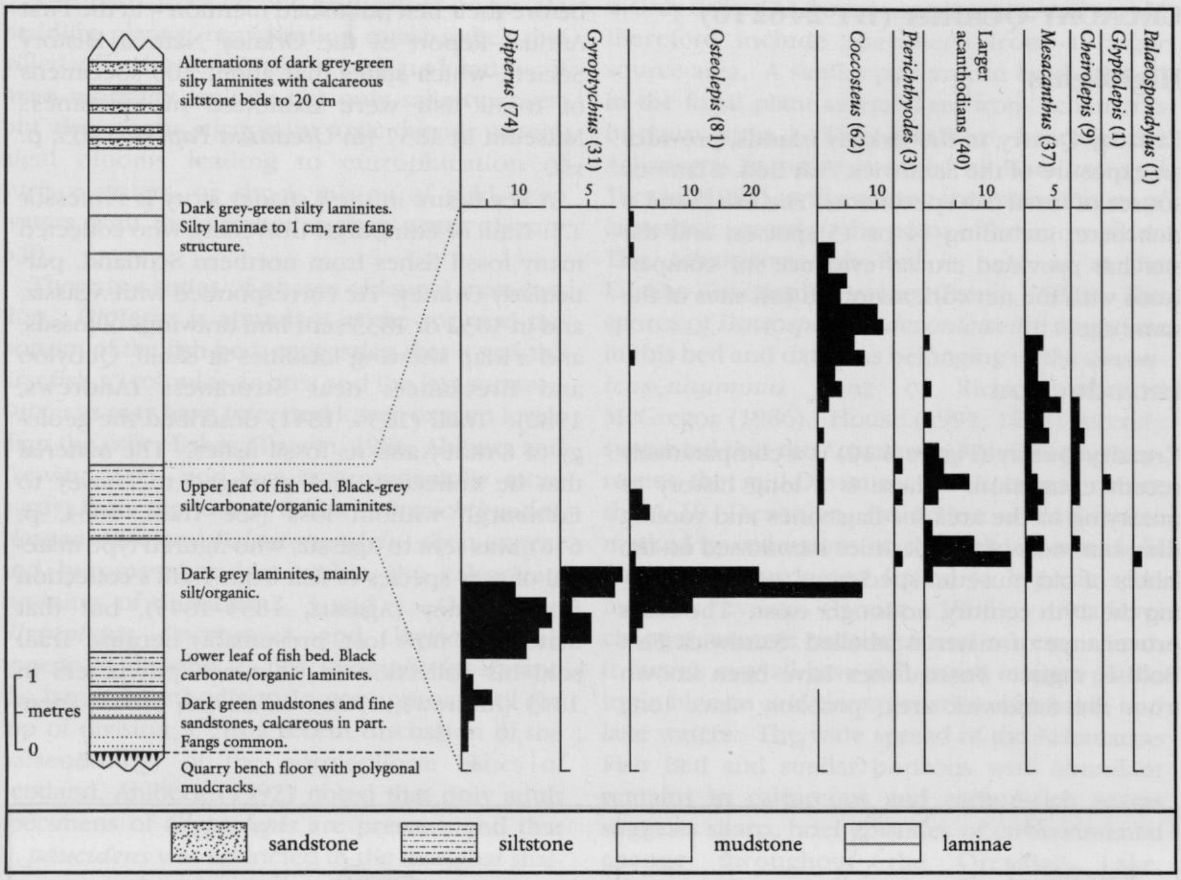

Figure 6.11 The Sandwick Fish Bed (after Trewin, 1976), showing division of the fish-bearing laminites into an upper and a lower leaf. Fish distribution is shown in the histograms for the upper leaf. 'Larger acanthodians' are mostly *Mesacanthus* and *Cheiracanthus*.

tioned fossil fishes and plants from several localities in Orkney, and hoped that they would prove the identity of beds with those in Caithness and the Moray Firth. Reference is made to fossil fishes from Ramna Geo on the Admirality Chart for the Orkney Isles for 1850. It was from here that W. Watt obtained most of the fossil fishes which Hugh Miller saw during his visit to the island in 1848 (Wilson *et al.*, 1935). M'Coy (1854) also wrote about material from Orkney, confirming that the Stromness Flagstones were equivalent to the Caithness Flagstones. Many eminent geologists visited the islands and described the geology and palaeontology (Murchison, 1859a, 1859b; Geikie, 1878; Peach and Horne, 1880). Traquair (1894) showed that the fauna of the Achanarras Limestone in Caithness was very similar to that of Stromness, Cromarty and the Moray Firth, and Flett (1898) introduced a stratigraphical scheme for the Orkney Flagstones on the basis of the fish faunas.

Description

Cruaday Quarry is a large excavation on the eastern brow of Cruaday Hill, and exposes 20 m of dark grey calcareous siltstones. The Sandwick Fish Bed is exposed along the western, then north-western, right-angled faces, with a continuous exposure of 450 m (Figure 6.11; Trewin, 1976, p. 206). It lies between the Lower and Upper Stromness Groups, of late Eifelian age, and is correlated with the Achanarras Fish Bed of Caithness (Westoll, *in* House *et al.*, 1977), on the basis of a nearly identical faunal assemblage.

The Sandwick Fish Bed (Figure 6.11) occurs in the Sandwick area of Orkney within a series of faulted outcrops that trend roughly north and south (Wilson *et al.*, 1935). Further south, other fault blocks cause the fish bed to outcrop near the Loch of Stenness, and in the south of the mainland at Billia Croo. In 1848 several cliff-top quarries yielded a prolific Sandwick Fish Bed fauna (Miller, 1858, pp. 440–5). The fish bed at

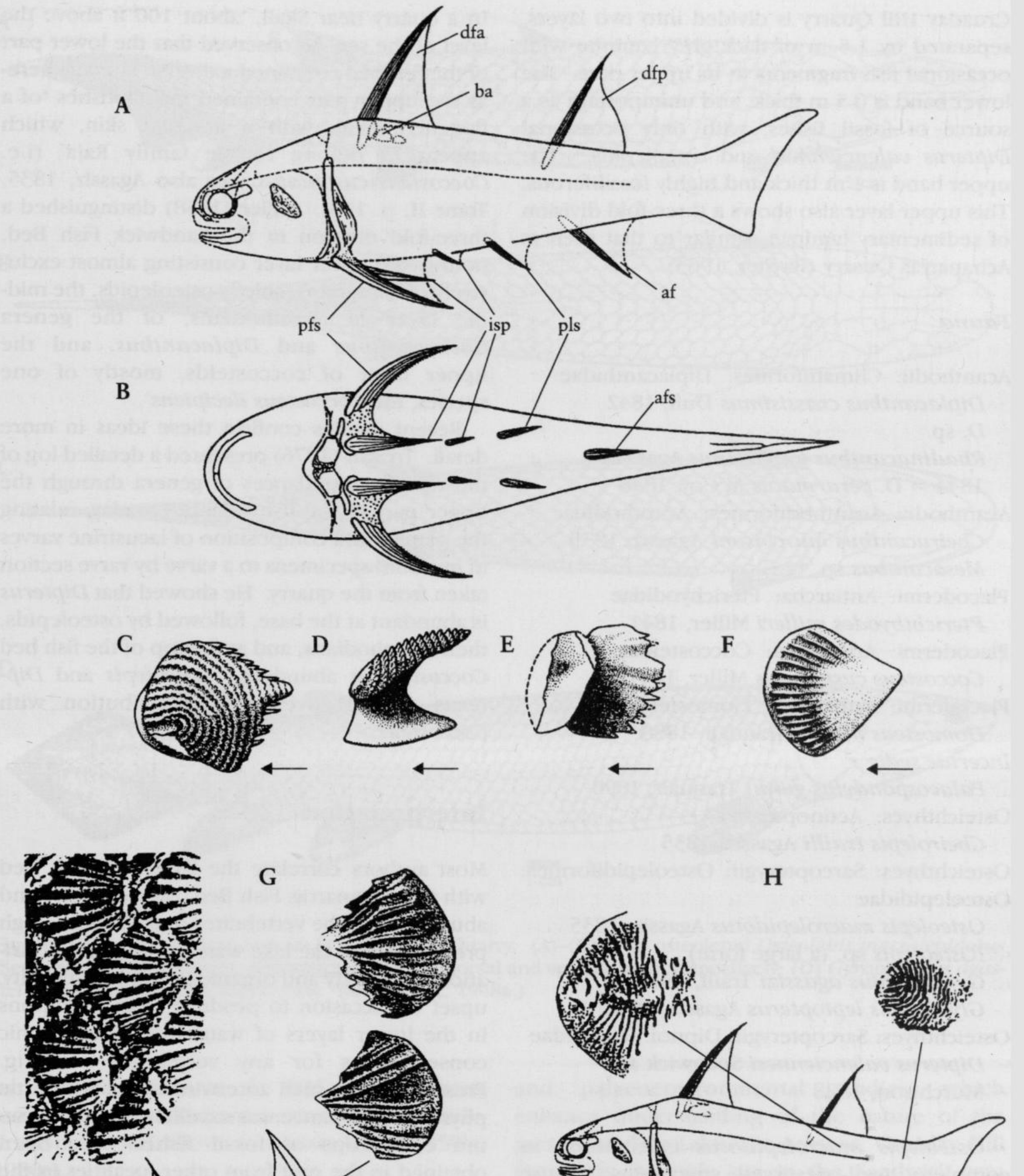

Figure 6.12 Acanthodian species from Cruaday Quarry. Restoration of *Diplacanthus crassisimus* Duff: (A) lateral view; (B) ventral view, approximately natural size. (C), (D) Scales of *D. crassisimus*, posterior to the right: (C) exterior view; (D) side view, *c.* × 60. (E), (F) Scales of *Cheiracanthus murchisoni*; (E) interior view; (F) exterior view, *c.* × 55 (scales from Denison, 1979). (G) *'Rhadinacanthus' Diplacanthus longispinus* Agassiz scales with well-defined ribs and scalloped posterior margin; (H) *Diplacanthus striatus* Duff, scales with fine transverse grooves, (G) and (H) *c.* × 50 (courtesy of V.T. Young).

Cruaday Hill Quarry is divided into two layers, separated by 1.5 m of dark grey laminite with occasional fish fragments in its upper part. The lower band is 0.5 m thick, and unimportant as a source of fossil fishes, with only occasional *Dipterus valenciennesi* and osteolepids. The upper band is 1 m thick and highly fossiliferous. This upper layer also shows a three-fold division of sedimentary laminae, similar to that seen at Achanarras Quarry (Rayner, 1963).

Fauna

Acanthodii: Climatiiformes: Diplacanthidae
- *Diplacanthus crassisimus* Duff, 1842
- *D.* sp.
- *Rhadinacanthus longispinus* Agassiz, 1844 = D. *perarmatus* M'Coy, 1848

Acanthodii: Acanthodiformes: Acanthodidae
- *Cheiracanthus murchisoni* Agassiz, 1835
- *Mesacanthus* sp.

Placodermi: Antiarcha: Pterichyodidae
- *Pterichthyodes milleri* Miller, 1841

Placodermi: Arthrodira: Coccosteidae
- *Coccosteus cuspidatus* Miller, 1841

Placodermi: Arthrodira: Homosteidae
- *Homosteus milleri* Traquair, 1888

Incertae sedis
- *Palaeospondylus gunni* Traquair, 1890

Osteichthyes: Actinopterygii
- *Cheirolepis trailli* Agassiz, 1835

Osteichthyes: Sarcopterygii: Osteolepidiformes: Osteolepididae
- *Osteolepis macrolepidotus* Agassiz, 1835
- ?*Osteolepis* sp. (a large form)
- *Gyroptychius agassizi* Traill, 1841
- *Glyptolepis leptopterus* Agassiz, 1844

Osteichthyes: Sarcopterygii: Dipnoi: Dipteridae
- *Dipterus valenciennesi* Sedgwick and Murchison, 1828

Osteolepis macrolepidotus is common as complete, well-preserved specimens (Figure 6.13), unlike the situation at Achanarras, where it is rare. *Coccosteus cuspidatus* is also very common, and at Cruaday Quarry some bedding planes are covered with complete specimens. Other bedding planes have dense concentrations of acanthodians upon them, particularly *Mesacanthus* sp. (Figure 6.12). The relative abundances of fishes nevertheless vary through the vertical section in the quarry.

Traill (1834) was the first to mention the subdivision of the fauna in the Sandwick fish bed. In a quarry near Skail, 'about 100 ft above the level of the sea' he observed that the lower part of the fish bed contained a diverse fauna, whereas the upper part contained mainly fishes 'of a flattened form, with a granular skin, which appear to belong to the family Raja' (i.e. *Coccosteus cuspidatus*; see also Agassiz, 1835, Tome II, p. 118). Miller (1858) distinguished a three-fold division in the Sandwick Fish Bed, noting 'the lower layer consisting almost exclusively of Dipterians, chiefly osteolepids, the middle layer of acanthodians, of the genera *Cheiracanthus* and *Diplacanthus*, and the upper layer of coccosteids, mostly of one species, the *Coccosteus decipiens*'.

Recent studies confirm these ideas in more detail. Trewin (1976) presented a detailed log of the relative abundances of genera through the upper part of the fish bed at Cruaday, relating the pattern and composition of lacustrine varves in museum specimens to a varve by varve section taken from the quarry. He showed that *Dipterus* is abundant at the base, followed by osteolepids, then acanthodians, and at the top of the fish bed *Coccosteus* is abundant. *Osteolepis* and *Dipterus* do not overlap in distribution with *Coccosteus*.

Interpretation

Most authors correlate the Sandwick Fish Bed with the Achanarras Fish Bed. The diversity and abundance of the vertebrates must indicate high productivity of the lake waters with annual variations in salinity and organic (algal) productivity, upset on occasion to produce toxic conditions in the lower layers of water with catastrophic consequences for any vertebrate entering. Preservation in such an environment with little physical disturbance was excellent. Large museum collections of fossil fishes have been obtained in the past from other localities in the Cruaday area, Quoyloo, Instabillie, Hooveth and a small quarry on the south side of the Hill of Cruaday. Ramna Geo, a nearby coastal exposure, no longer yields the prolific quantity of material which was found there in the 1840s and 1850s. Less prolific quarries in the Sandwick Fish Bed occurred at Gairsty Farm near Tronston, Glebe Quarry, and at the crossroads near Roadside. 'A small quarry, about ¼ mile south-west of Bryameadow, on the south of the Burn of Cruaday' was the most productive local-

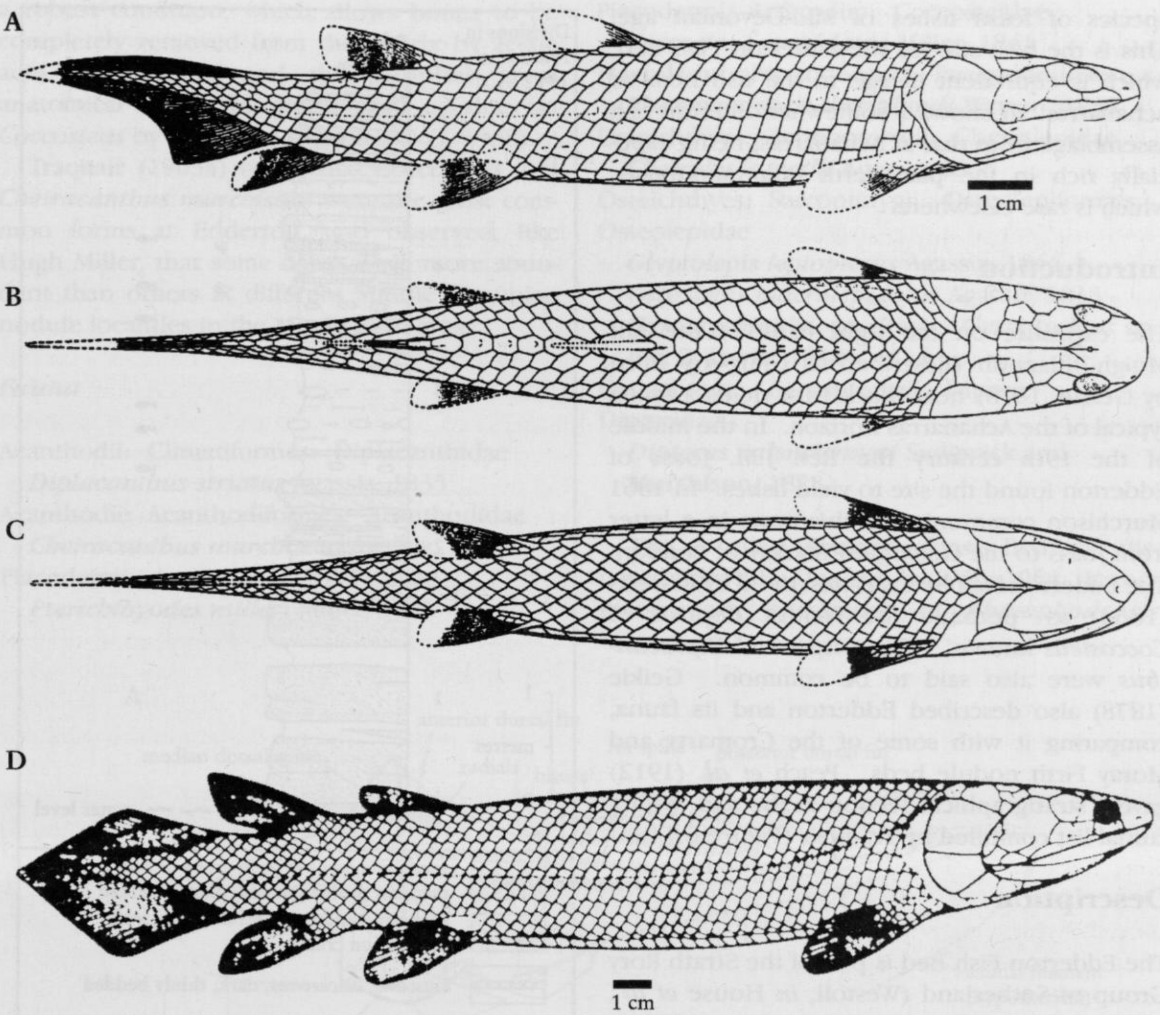

Figure 6.13 Osteichthyan species from Cruaday Quarry. (A)–(C) The osteolepid *Osteolepis macrolepidotus* (Sedgwick and Murchison), restoration in lateral, dorsal and ventral views respectively; (D) *Gyroptychius agassizi* Traill, restoration in lateral view. (After Jarvik, 1948a.)

ity in 1935 (Wilson *et al.*, 1935). All of these localities confirm the areal extent of the conditions described above (see also Jarvik 1950b, 1950c).

Conclusion

Cruaday Quarry is the best site on Orkney showing an Achanarras horizon fish assemblage hence its conservation value. The fauna, consisting of 14 or 15 species of acanthodians, placoderms and osteichthyans, is closely comparable with the fauna from Achanarras itself. Cruaday Hill Quarry has the added advantage, like Achanarras, of recent detailed sedimentological and palaeoenvironmental studies, which enhance understanding of the nature of the great Orcadian Lake. At present, Cruaday Hill Quarry is the only site in the Sandwick area where a diverse fish assemblage can still be collected. All other sites that were productive in the past are no longer accessible.

BLACK PARK, EDDERTON (NH 678832)

Highlights

The Black Park locality, in the Alness–Struie area of the Moray Firth, Highland, has produced species of fossil fishes of Mid-Devonian age. This is the best site for the Edderton Fish Bed, which is equivalent in age to the fish beds at Achanarras. It shows a somewhat different fish assemblage from that at Achanarras, being especially rich in the placoderm *Rhamphodopsis*, which is rare elsewhere.

Introduction

The exposure on the right bank of the Allt Muigh-Bhlaraidh (described as Craig-roy Burn by Geikie, 1878) near Black Park yields a fauna typical of the Achanarras horizon. In the middle of the 19th century the Rev. J.M. Joass of Edderton found the site to yield fishes. In 1861 Murchison communicated this news in a letter from Joass to the Geological Society of London. The Edderton Fish Bed was described by Roberts (1864) as 'perhaps the richest deposit of *Coccosteus* known'. *Glyptolepis* and *Diplacanthus* were also said to be common. Geikie (1878) also described Edderton and its fauna, comparing it with some of the Cromarty and Moray Firth nodule beds. Peach *et al.* (1912) gave a stratigraphical section at the site, with a faunal list compiled by Traquair (Figure 6.14).

Description

The Edderton Fish Bed is part of the Strath Rory Group of Sutherland (Westoll, *in* House *et al.*, 1977). The Strath Rory Group, about 1350 m thick in all, is assumed to be entirely Mid-Devonian in age, and it is separated from the Early Devonian Struie Group by the Polinturk fault and by unconformities, and from the Late Devonian Balnagown Group by an unconformity. The lower part of the Strath Rory Group consists of the Meikle Daan Conglomerate (60 m seen), which is overlain by the Craigroy succession of red and yellow sandstones, often pebbly, and with siltstones and about six horizons of calcareous shales with concretions. One of these nodule beds, near the middle of the sequence, is the Edderton Fish Bed (Figure 6.16), a 2 m thick unit of dark grey and greenish calcareous shales with limestone nodules. The upper part of the nodule bed is the most richly fossiliferous.

About 150 mm above the nodule layer is the *Rhamphodopsis* Bed, a laminated blue-grey shale containing common bituminized flattened specimens of the ptyctodont *Rhamphodopsis*. This is the only site at which this bed occurs.

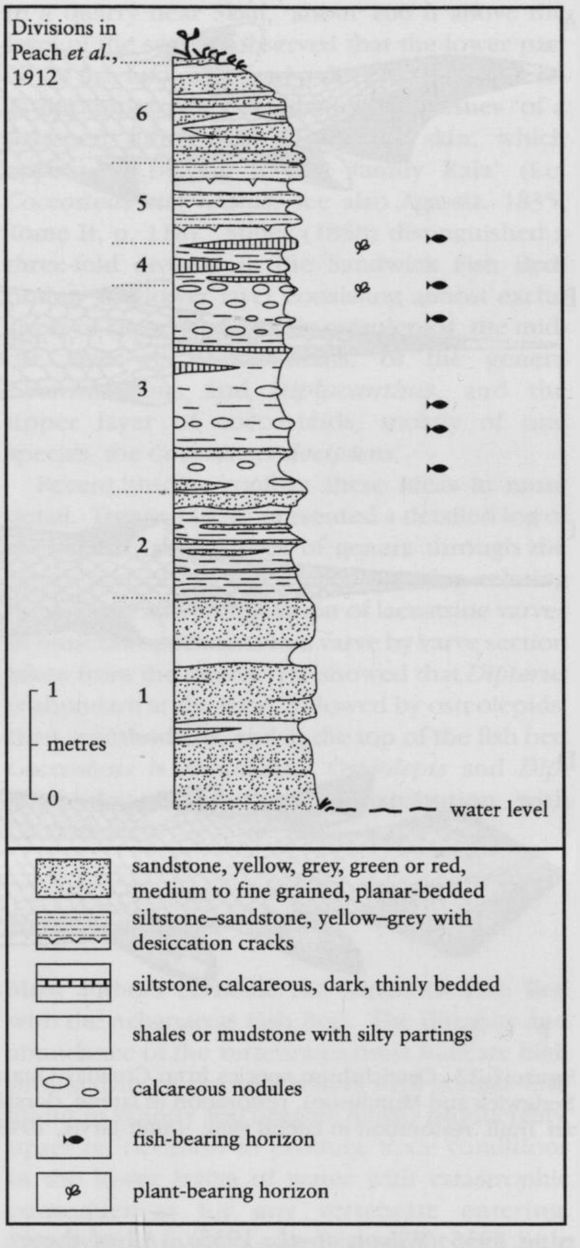

Figure 6.14 The stratigraphical section in the brook at Edderton. The fish are confined to units 2, 3 and 4. (After Peach *et al.*, 1912.)

Fishes in the nodules of the Edderton Fish Bed are usually disarticulated bones, but are well preserved and three-dimensional, unlike the flattened specimens of the same species from Achanarras. Although these specimens may not look so attractive or complete as those from other sites, they allow detailed reconstructions because of the three-dimensional preservation. At Edderton, unlike any other nodule bed locality at this horizon, the bone is preserved in a robust condition, which allows bones to be completely removed from the matrix by acetic acid preparation, and this supplies great anatomical detail for work, such as that on *Coccosteus* by Miles and Westoll (1963, 1968).

Traquair (1905a) noted that *Coccosteus* and *Cheiracanthus murchisoni* were the most common forms at Edderton, and observed, like Hugh Miller, that some fishes were more abundant than others at different Middle Devonian nodule localities in the Moray Firth area.

Fauna

Acanthodii: Climatiformes: Diplacanthidae
Diplacanthus striatus Agassiz, 1835
Acanthodii: Acanthodiformes: Acanthodidae
Cheiracanthus murchisoni Agassiz, 1835
Placodermi: Antiarchi: Asterolepidae
Pterichthyodes milleri Miller, 1841
Placodermi: Arthrodira: Coccosteidae
Coccosteus cuspidatus Miller, 1841
Placodermi: Ptyctodontida: Ptyctodontidae
Rhamphodopsis threiplandi Watson, 1938
Osteichthyes: Actinopterygii: Cheirolepidae
Cheirolepis trailli Agassiz, 1835
Osteichthyes: Sarcopterygii: Osteolepiformes: Osteolepidae
Glyptolepis leptopterus Agassiz, 1844
Osteolepis macrolepidotus Agassiz, 1835
Gyroptychius ?n. sp. (? syn. *Gyroptychius* sp. inc. 2; Jarvik, 1948)
Osteichthyes: Sarcopterygii: Dipnoi: Dipteridae
Dipterus valenciennesi Sedgwick and Murchison, 1828

The so-called '*Rhamphodopsis* Bed' was discovered by R.H. Denison in 1953–1954. It contains many specimens of *Rhamphodopsis*

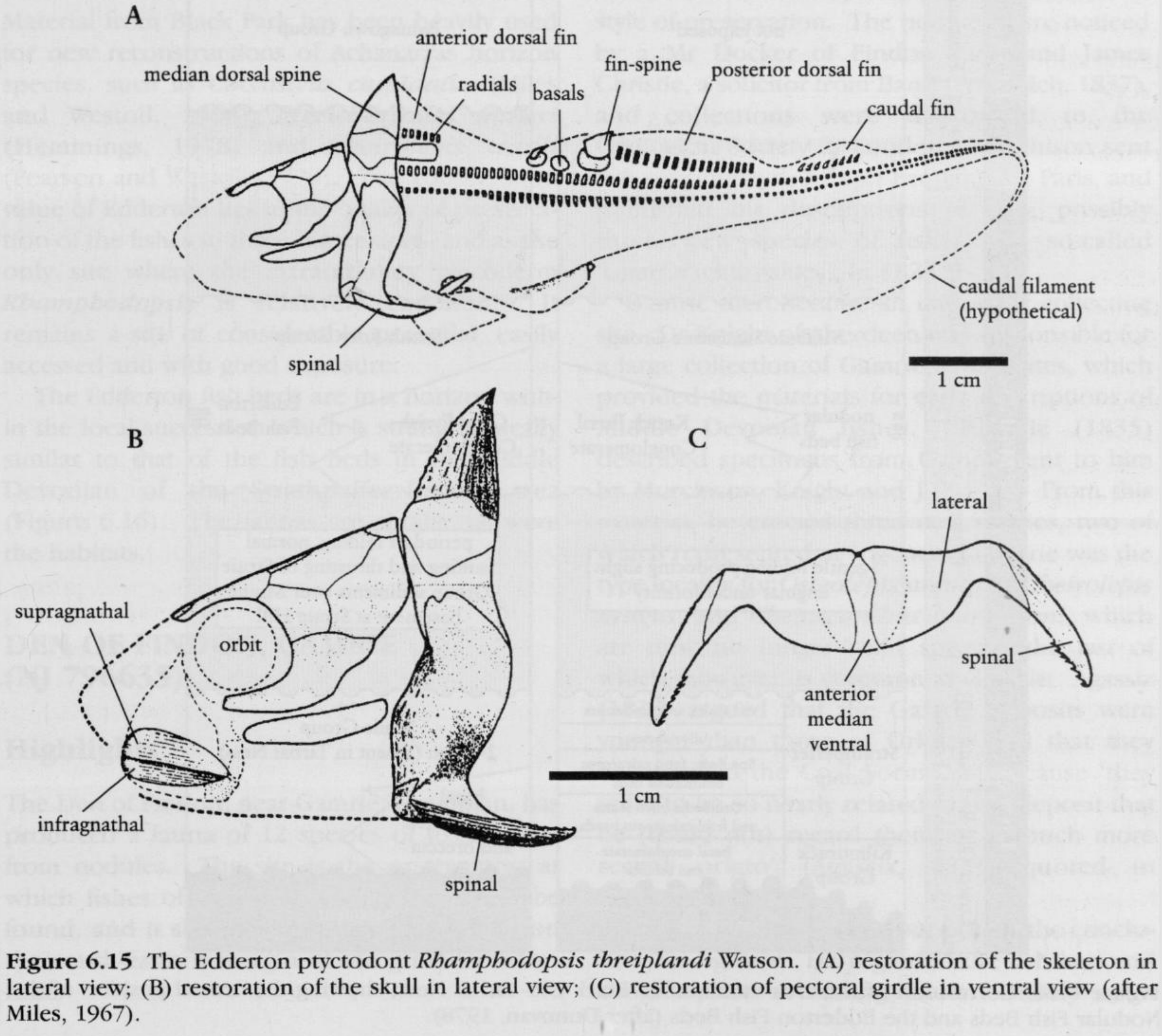

Figure 6.15 The Edderton ptyctodont *Rhamphodopsis threiplandi* Watson. (A) restoration of the skeleton in lateral view; (B) restoration of the skull in lateral view; (C) restoration of pectoral girdle in ventral view (after Miles, 1967).

threiplandi, together with plants and occasional small specimens of *Pterichthyodes milleri*. *Rhamphodopsis threiplandi* (Figure 6.15) had previously only been known from Achanarras Quarry (Watson, 1934), where it is very rare. It also occurs rarely in the nodule beds of Cromarty, Lethen Bar and Tynet Burn. The species was redescribed in the light of this new material by Miles (1967), and was referred to by Ørvig (1960) and Miles and Young (1977). *Rhamphodopsis threiplandi* belongs to an unusual family of small placoderms, the Ptychtodontidae, which are distinguished by their greatly reduced head and trunk armour.

Ptyctodontids are found in the Lower to Upper Devonian of the Russian Arctic, Iran, North America, Europe and Australia, usually as fragments or tooth plates. *Rhamphodopsis*, together with *Ctenurella* from the Upper Devonian of Germany and Australia, are the only two ptyctodont genera that are known from more or less complete specimens.

Interpretation

The fauna in the Edderton vertebrate-bearing layers has a remarkable number of gnathostomes and placoderms of presumed carnivorous habit. The nature of the prey is obscure. The cause(s) of mortality are not known, but seem not to include anoxia. One of the most interesting features about *Rhamphodopsis* is evidence of sexual dimorphism in the pelvic region, with

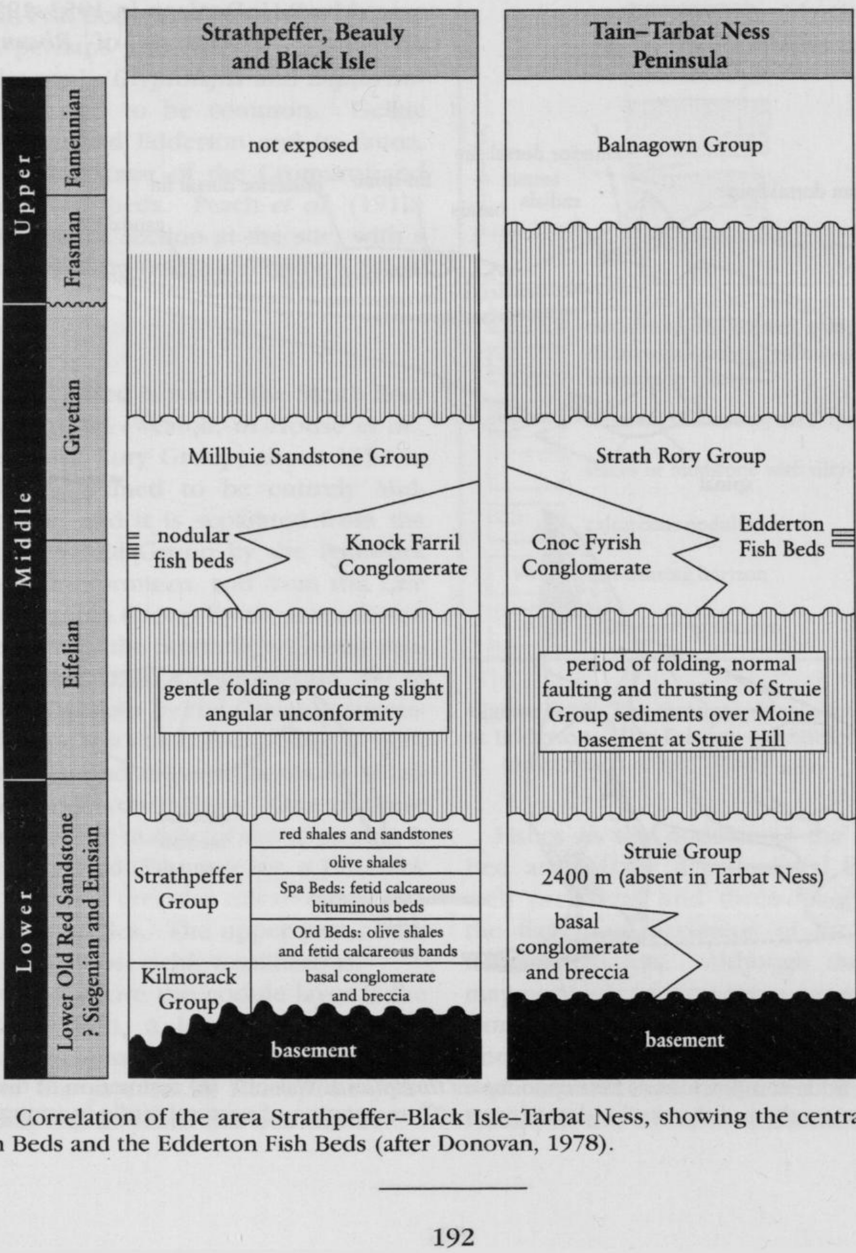

Figure 6.16 Correlation of the area Strathpeffer–Black Isle–Tarbat Ness, showing the central position of the Nodular Fish Beds and the Edderton Fish Beds (after Donovan, 1978).

the presence of claspers in males (Miles, 1967). This is important in evolutionary terms, because claspers are known otherwise only in holocephalans and elasmobranchs. It implies that these ptyctodonts were able to twist about one another during copulation, as do modern-day selachians. The reduced body armour in ptyctodonts in comparison with other placoderms may have permitted such activity. It is also likely that ptychtodonts were ovoviviparous or oviparous, even possibly viviparous. The female's large-scaled pelvic fins may have been associated with some form of parental care or assisted in copulatory grip.

Conclusion

Edderton is not a type locality for any of its fishes, which is an accident of history, in that these species were discovered and described from other sites before Edderton was discovered. Material from Black Park has been heavily used for new reconstructions of Achanarras horizon species, such as *Coccosteus cuspidatus* (Miles and Westoll, 1968), *Pterichthyodes milleri* (Hemmings, 1978) and *Cheirolepis trailli* (Pearson and Westoll, 1979). The conservation value of Edderton lies in the quality of preservation of the fishes in three dimensions, and as the only site where the extraordinary placoderm *Rhamphodopsis* is relatively common. It remains a site of considerable potential, easily accessed and with good exposure.

The Edderton fish beds are in a horizon within the local succession which is stratigraphically similar to that of the fish beds in the Middle Devonian of the Strathpeffer–Beauly area (Figure 6.16). The faunas are similar, as were the habitats.

DEN OF FINDON, GAMRIE (NJ 796635)

Highlights

The Den of Findon, near Gamrie, Grampian, has produced a fauna of 12 species of fossil fishes from nodules. The site is the easternmost at which fishes of the Achanarras horizon can be found, and it shows an example of fish life on the south-eastern margin of the great Orcadian Lake.

Introduction

The Gamrie Fish Bed is the most easterly outcrop of the Achanarras horizon and it yields 12 species of Middle Devonian fishes (see Hamilton and Trewin, 1988, p.590). Specimens from the fish bed were described early in the 19th century, and a great deal of material is now in museums around the world. Murchison came to the site in 1826, during his visit to Scotland, when he first saw Old Red Sandstone fishes in Caithness, but he failed to observe this fish bed. It was discovered during the following winter, when an overflowing mill stream caused a landslip in the blue clays containing the nodules (Murchison, 1828). Impressed by the thick rhomboidal scales and heterocercal tails of one of the Gamrie species (*Osteolepis*), Murchison compared them with the Permian palaeoniscids of Germany (Andrews, 1982), but did not recognize the resemblance between these fossils and those from Caithness, because of differences in style of preservation. The nodules were noticed by a Mr Docker of Findon Farm and James Christie, a solicitor from Banff (Prestwich, 1837), and collections were dispatched to the Geological Society in London. Murchison sent fish specimens to Joseph Pentland, in Paris, and published his descriptions of two, possibly three, new species of fishes, the so-called 'Gamrie ichthyolites', in 1828.

Gamrie then became an important collecting site. Dr Knight of Aberdeen was responsible for a large collection of Gamrie ichthyolites, which provided the materials for early descriptions of Middle Devonian fishes. Agassiz (1835) described specimens from Gamrie sent to him by Murchison, Knight and J. Torrie. From this material, he erected three new species, two of which represented new genera. Gamrie was the type locality for *Osteolepis arenatus*, *Cheirolepis uragus*, and *Cheiracanthus murchisoni*, which are now no longer valid species, the last of which, however, is common at Gamrie. Agassiz (1835) argued that the Gamrie deposits were younger than those of Orkney, and that they belonged to the Coal Formation because 'they seem to be so nearly related to that deposit that he (could not) regard them as of much more recent origin' (Agassiz, 1835, quoted in Andrews, 1982).

Prestwich (1838, 1840) supported the conclusions of Agassiz. He regarded the fish bed and conglomerate as resting unconformably upon the Old Red Sandstone below, and thought that they were probably representatives of the Carboniferous Millstone Grit or Mountain Limestone. This was challenged by Malcolmson (1842) who showed that there was no unconformity. Geikie (1878) described the geology of Gamrie, as did Read (1923). Read also gave a list of species from the fish bed compiled by Traquair (Read, 1923, p. 172). The Gamrie fauna was discussed by Hay-Cunningham (1843), Agassiz (1833–1845), Smith (1851), Gregory (1860), Traquair (1880, 1895), Edward (1889) and Woodward (1891a). Gamrie fishes have also been described repeatedly in the 20th century (Heintz, 1938; Jarvik, 1948a; Miles and Westoll, 1968; Hemmings, 1978; Pearson and Westoll, 1979).

Description

The Middle Devonian Findon Group rests unconformably on the Lower Devonian Crovie Group in the Gamrie–Pennan area (Westoll, *in* House *et al.*, 1977). The basal unit of the Findon Group is a conglomerate, followed by about 2 m of red and grey shales and clays with fossil plants and well-preserved fishes in limestone nodules, and then by reddish and chocolate-coloured breccias. The fish bed is mapped at several places in the Gamrie area, and in the past fishes have been collected from Cushnie Burn and at the head of Pishlinn Burn. Read (1923) stated that Horne also collected fish scales from shales within the conglomerate not far below the fish bed.

The Gamrie fish bed is now rather inaccessible because of the crumbly vertical faces of conglomerate in the ravine, and collections have always been made from the loose nodules which accumulate in the stream bed below the exposure. The section given by Read (1923, p. 171) from the Den of Findon (Figure 6.17) is:

	Thickness
'Bed 7, Breccia	2–15 ft [0.6–4.6 m]
Red clay and shales	2 ft [0.6 m]
Bed 6, Grey clay with ichthyolites	4 ft [1.2 m]

The limestone nodules are restricted to the lower portion of the grey clay. Grey shales with plant remains occur locally above the underlying conglomerates

Bed 5, Conglomerates with intercalations of sandstone	50 ft [15.2 m]'

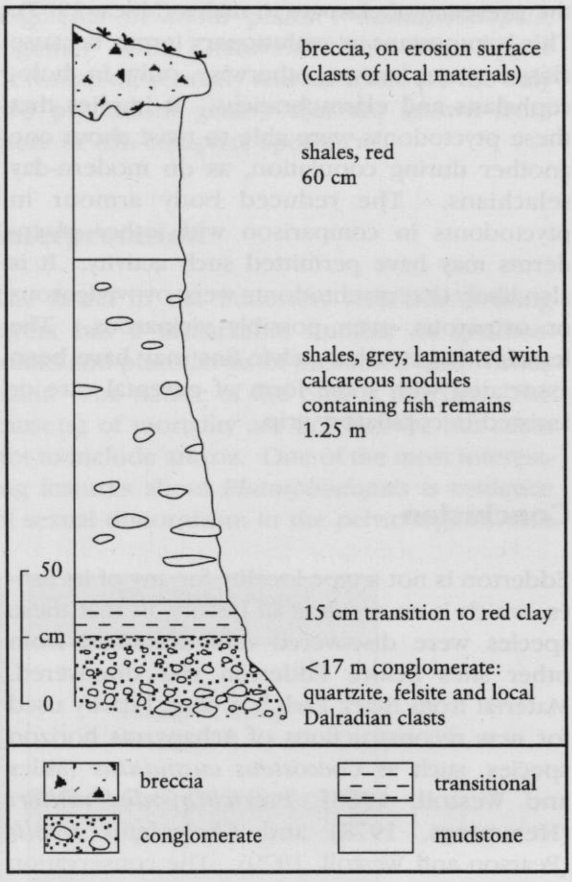

Figure 6.17 Den of Findon section (from Trewin and Kneller, 1987).

The dip is 8° ENE, and the fish bed only crops out near the top on the east side of the ravine, where it can be traced along most of the length of the ravine. Trewin and Kneller (1987) described the section and the preservation of the fishes. Fishes are found in calcareous nodules, which also preserve the fine parallel laminations of the original mud. They are preserved complete, or with only slight disturbance of the carcass, but only the parts that occur within the nodules are fossilized.

Fauna

Acanthodii: Climatiformes: Diplacanthidae
- *Diplacanthus striatus* Agassiz, 1835
- *D. tenuistriatus* Traquair, 1894.
- *D. (Rhadinacanthus) longispinus* (Agassiz, 1844–1845)

Acanthodii: Acanthodiformes: Acanthodidae
- *Cheiracanthus murchisoni* Agassiz, 1835
- *C. latus* Egerton, 1861

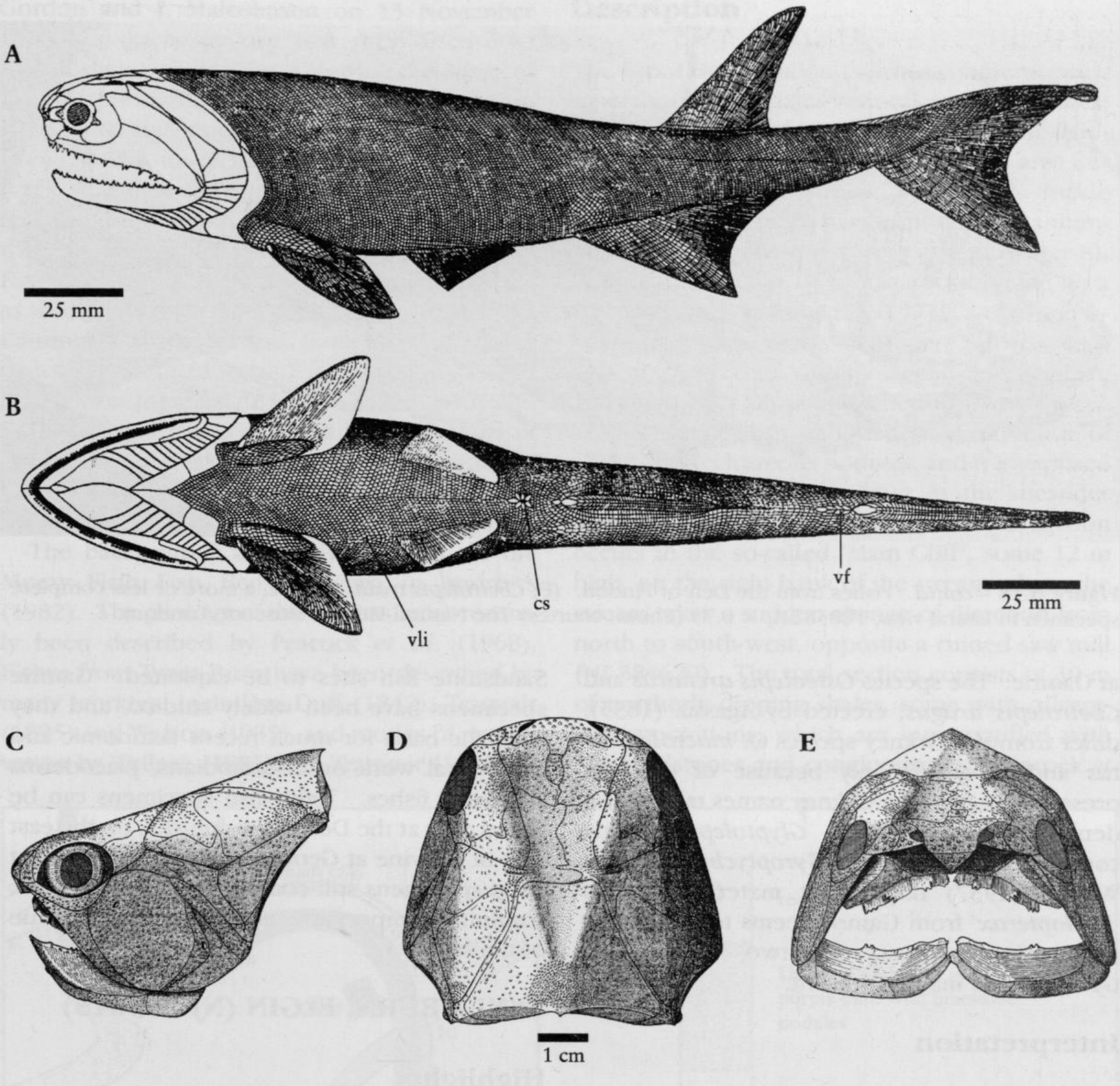

Figure 6.18 Fishes from the Den of Findon. (A), (B) *Cheirolepis trailli* Agassiz, restorations of lateral and ventral views respectively (from Pearson and Westoll, 1979). (C)–(E), *Coccosteus cuspidatus* Agassiz: (C) restoration of the fish head in lateral view; (D) restoration of the head and trunk shields in dorsal view; (E) restoration of the skull in anterior view (after Miles and Westoll, 1968). (Continued on p. 196.)

Placodermi: Antiarchi: Pterichthyodidae
Pterichthyodes milleri Miller, 1841
Placodermi: Arthrodira: Coccosteidae
Coccosteus cuspidatus Miller, 1841
Osteichthyes: Actinopterygii: Cheirolepidae
Cheirolepis trailli Agassiz, 1835
Osteichthyes: Sarcopterygii:
Osteolepidiformes: Osteolepididae
Glyptolepis leptopterus Agassiz, 1844
Osteolepis macrolepidotus Agassiz, 1835
Gyroptychius 2 n. sp.

Acanthodians are common at Gamrie, which is the type locality for *Cheiracanthus murchisoni*, and the source of two of the three syntypes of *Diplacanthus tenuistriatus* (the other is from Orkney). The placoderms *Pterichthyodes milleri* and *Coccosteus cuspidatus* are also common at Gamrie (Figure 6.18). Gamrie is one of only four sites from which specimens of *Pterichthyodes* were good enough for morphometric measurements, which proved that all Scottish *Pterichthyodes* specimens belong to one species, *P. milleri* (Hemmings and Rostron, 1972).

Osteolepis and *Cheirolepis* are relatively rare

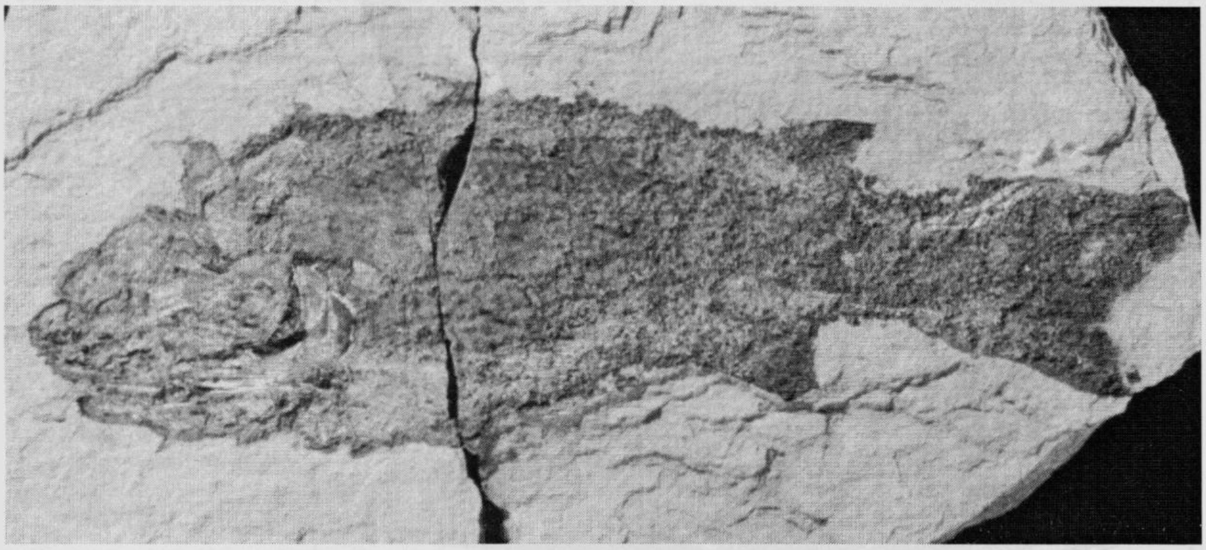

Figure 6.18 – *contd.* Fishes from the Den of Findon. (F) *Cheirolepis trailli* Agassiz, a more or less complete specimen in lateral view, T00382/A, × 0.75 (Photo: courtesy The Natural History Museum, London).

at Gamrie. The species *Osteolepis arenatus* and *Cheirolepis uragus*, erected by Agassiz (1835), differ from the Orkney species *O. macrolepidotus* and *C. trailli* only because of differing preservation, and the Orkney names take precedence (Traquair, 1888b). *Glyptolepis* is fairly common at Gamrie, but *Gyroptychius* is rare. Westoll (1937) noted that material labelled '*Diplopterax*' from Gamrie seems to be distinct from *Gyroptychius*, so two species of *Gyroptychius* may be present.

Interpretation

The evidence at Gamrie (Trewin and Kneller, 1987) indicates that the deposition of the fish bed, over a period of about 4000 years, was followed by uplift and an influx of locally derived breccias. Probably the fish bed was eroded away in many places, leaving the breccia lying directly above the conglomerates, as for example, near The Snook and at Pennan.

There are differences in faunal assemblage between Gamrie and other sites; for example *Dipterus*, which is common elsewhere, is entirely absent from the extensive collections from Gamrie.

Conclusion

The Gamrie fish bed is historically important as one of the first prolific Scottish Old Red Sandstone fish sites to be exploited. Gamrie specimens have been widely studied, and they form the basis for much recent taxonomic and anatomical work on acanthodians, placoderms and bony fishes. Today fish specimens can be found only at the Den of Findon site, on the east side of a ravine at Geordie Craigs, but sufficient good specimens still come to light to justify the continuing importance and conservation value of the site.

TYNET BURN, ELGIN (NJ 383618)

Highlights

Tynet Burn, Grampian, has been a famous source of Mid-Devonian fossil fishes since the 1830s. Up to 16 species of fossil fishes have been found at several levels along the stream section, and they demonstrate the nature of vertebrate life at the time on the southern margins of the great Orcadian Lake (innermost Moray Firth).

Introduction

There are, or were, many Middle Devonian fish sites in the Moray Firth area which have yielded numerous fossils since the 1830s. Most of these lie at the Achanarras level, and they produce similar specimens to those from Achanarras. The fish bed at Tynet Burn was discovered by G.

Gordon and J. Malcolmson on 15 November 1838, on the same day that they discovered Dipple Brae Fish Bed, by 'following the Strata of the Dipple Beds into Banffshire' (Gordon, 1859), although since then these two beds have been shown to represent different horizons. Later, Malcolmson discovered the Lethen Bar fish site (no longer exposed), and concluded that the fishes from the newly discovered Moray Firth fish beds were the same genera and species as those that came from the fish beds in Orkney, Caithness, Cromarty and Gamrie. The specimens were sent to Agassiz for examination and description (Agassiz, 1833–45, 1835, 1840) and a paper about the geology and relationships of the fish beds was prepared by Malcolmson in 1839, but not published until long after his death (Malcolmson, 1842, 1859).

The background and early research on the Moray Firth Fish Beds is given in Andrews (1982). The geology of the site has most recently been described by Peacock *et al.* (1968). Fishes from Tynet Burn have been described by many workers, including Duff (1842), Traquair (1895) and Watson (1935), and modes of preservation by Wallace (1885) and Traquair (1895).

Description

The Tynet Burn section exposes conglomerates, sandstones, and shales with calcareous nodules, all of Mid-Old Red Sandstone age. The Mid-Devonian sequence in the Elgin–Forres area lies unconformably on the Early Devonian Buckie Beds, and is overlain, unconformably by a number of Late Devonian sequences (see Chapter 8). Within the Middle Devonian rocks of the area (Westoll, *in* House *et al.*, 1977) are two fish-bearing levels, those in Tynet Burn, which appear to correlate with the Achanarras horizon, and the higher Dipple Fish Bed (q.v.).

The Tynet Burn fish bed is a sequence of shales with calcareous nodules, and it is exposed behind Lower Mills of Tynet in the meander scars of the incised Tynet Burn. The best section occurs in the so-called 'Main Cliff', some 12 m high, on the right bank of the stream where the stream takes a sudden change of direction from north to south-west, opposite a ruined saw mill (NJ 384620). The total section consists of 30 m of northerly dipping shales, some with calcareous concretions, which are interstratified with red sandstones and conglomerates. Peacock *et*

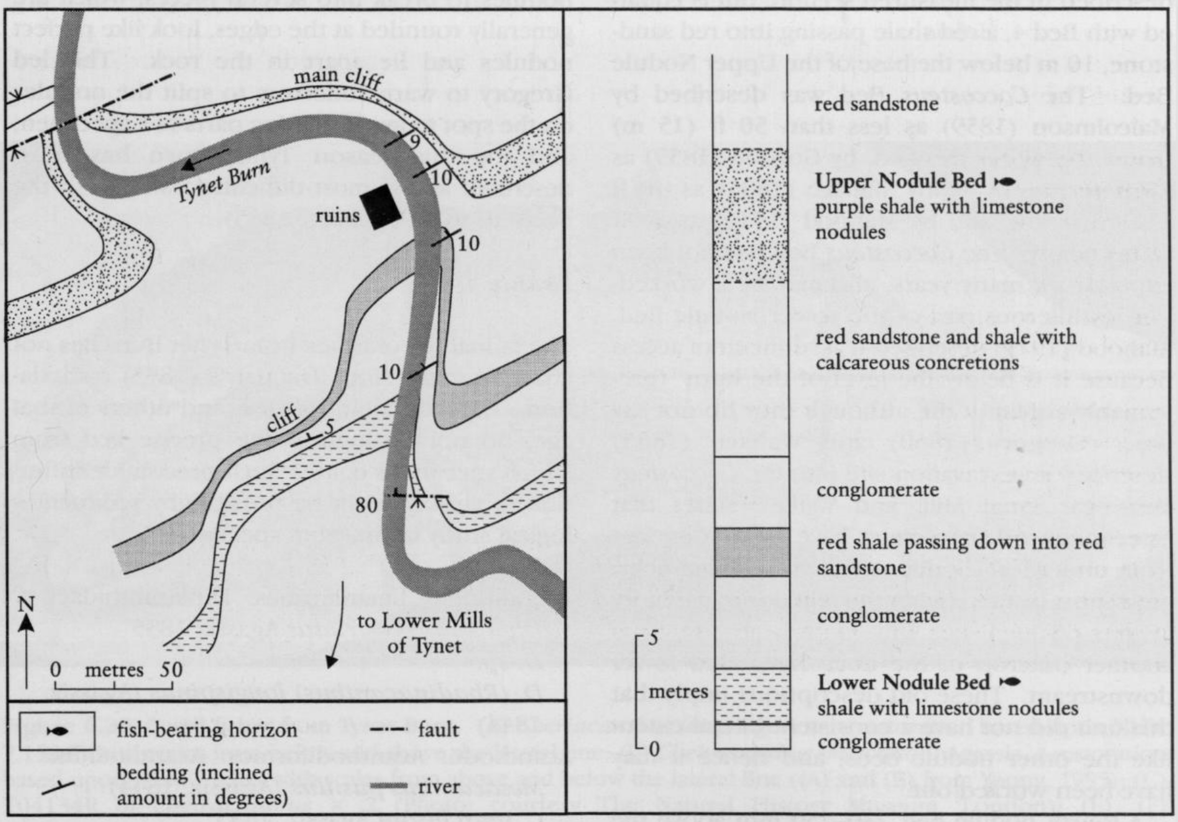

Figure 6.19 Tynet Burn, map of the GCR site and section through the fish-bearing beds.

al. (1968) describe a Lower Nodule Bed and an Upper Nodule Bed, separated by 16 m of sandstones, shales, and conglomerates (Figure 6.19).

The Upper Nodule Bed, 5–7 m thick, outcrops along the top of Main Cliff, rather inaccessibly, and also occurs further downstream in a meander scar in the left bank of the stream (NJ 382620), on the southern side of a series of faults that form the northern boundary of this section. The lower unit of this Upper Nodule Bed is called the '*Osteolepis* Bed' by Mahood (1919). It yields *Cheirolepis*, *Dipterus*, *Pterichthyodes* and *Osteolepis*. The upper unit could be referred to as the Acanthodian Bed because it is very rich in those fishes. It also yields *Pterichthyodes* (Mahood, 1919), '*Diplopterus*' (i.e. *Gyroptychius*) and *Cheirolepis* (Gregory, 1860). Mahood (1919) also distinguished between the two beds on lithological grounds; the Acanthodian Bed is described as 'red clay or shale with cream coloured limestone nodules containing fossils', the *Osteolepis* Bed as a soft shale with nodules.

A third fish bed at Tynet Burn, the *Coccosteus* Bed, may represent partings of the Lower Nodule Bed (Peacock *et al.*, 1968). It is not described in the measured section, but is equated with Bed 4, a red shale passing into red sandstone, 10 m below the base of the Upper Nodule Bed. The *Coccosteus* Bed was described by Malcolmson (1859) as less than 50 ft (15 m) below the upper fish bed, by Gordon (1859) as 20 ft (6 m) below, by Wallace (1885) as 40 ft (12 m) below, and by Mahood (1919) as 20 ft (6 m) below. The *Coccosteus* Bed has not been exposed for many years, and may be a worked-out fossiliferous part of the Lower Nodule Bed. Mahood (1919) described it as 'difficult of access because it is below the level of the burn' (presumably at Main Cliff, although they do not say so). Gregory (1860) and Wallace (1885) described an excavation site into the *Coccosteus* Bed near Tynet Mill, and Wallace states that 'specimens of *Coccosteus* have been dug out from under a thick deposit of gritty conglomerate a short distance from the mill door'. Gregory (1860) distinguishes this excavation site from another outcrop of the *Coccosteus* Bed lower downstream. These old descriptions imply that this unit did not have a consistent lateral extent like the other nodule beds, and hence it may have been worked out.

A fourth nodule bed 230–250 mm above the upper fish-bearing unit in the Upper Nodule Bed was referred to as the 'Dummy-Bed' by Mahood (1919), presumably because of its lack of fossils. However, Malcolmson (1859) gave a section from NJ 384620, which clearly shows three beds of 'shales with ichthyolites'.

The Lower Nodule Bed yielded only unidentifiable fish scales, and *Coccosteus* is the only fish described. Rare specimens of other species may have been found there, since Malcolmson (1859) mentioned a fine specimen of *Dipterus* from a red slatey sandstone in the unit beneath the Upper Nodule Bed. All the other specimens that have been extracted from Tynet Burn are from the two beds of the Upper Nodule Bed, mainly collected from Main Cliff, either from loose nodules lying below the cliff, or *in situ*.

The limestone nodules from Tynet Burn can produce very beautifully preserved fish fossils, and each nodule site has a distinctive colour and mode of preservation. The fishes are stained shades of crimson and lie within pale grey limestone within the flattened fish-shaped nodules. Nodules frequently show veins of sparry calcite with predominantly vertical lineations (Gregory, 1860), possibly related to the tectonic activity that caused local faulting. The veins cause the nodules to break into several pieces, which are generally rounded at the edges, look like perfect nodules and lie apart in the rock. This led Gregory to warn collectors to split the nodules on the spot to avoid missing parts of a specimen, and for this reason Tynet Burn has been described as the most difficult fossil bed of the north to work (Wallace, 1885).

Fauna

The faunal list of fishes from Tynet Burn has not changed much since Traquair's (1895) compilation. Unfortunately, this list, and others of that age, do not distinguish the precise bed from which specimens come. Such precise identification of faunas might be possible by sedimentological study of museum specimens.

Acanthodii: Climatiiformes: Diplacanthidae
- *Diplacanthus striatus* Agassiz 1835
- *D.* sp.
- *D. (Rhadinacanthus) longispinus* (Agassiz, 1844)

Acanthodii: Acanthodiformes: Acanthodidae
- *Mesacanthus pusillus* (Agassiz, 1844)
- *C. murchisoni* Agassiz, 1835
- *C. latus* Egerton, 1861

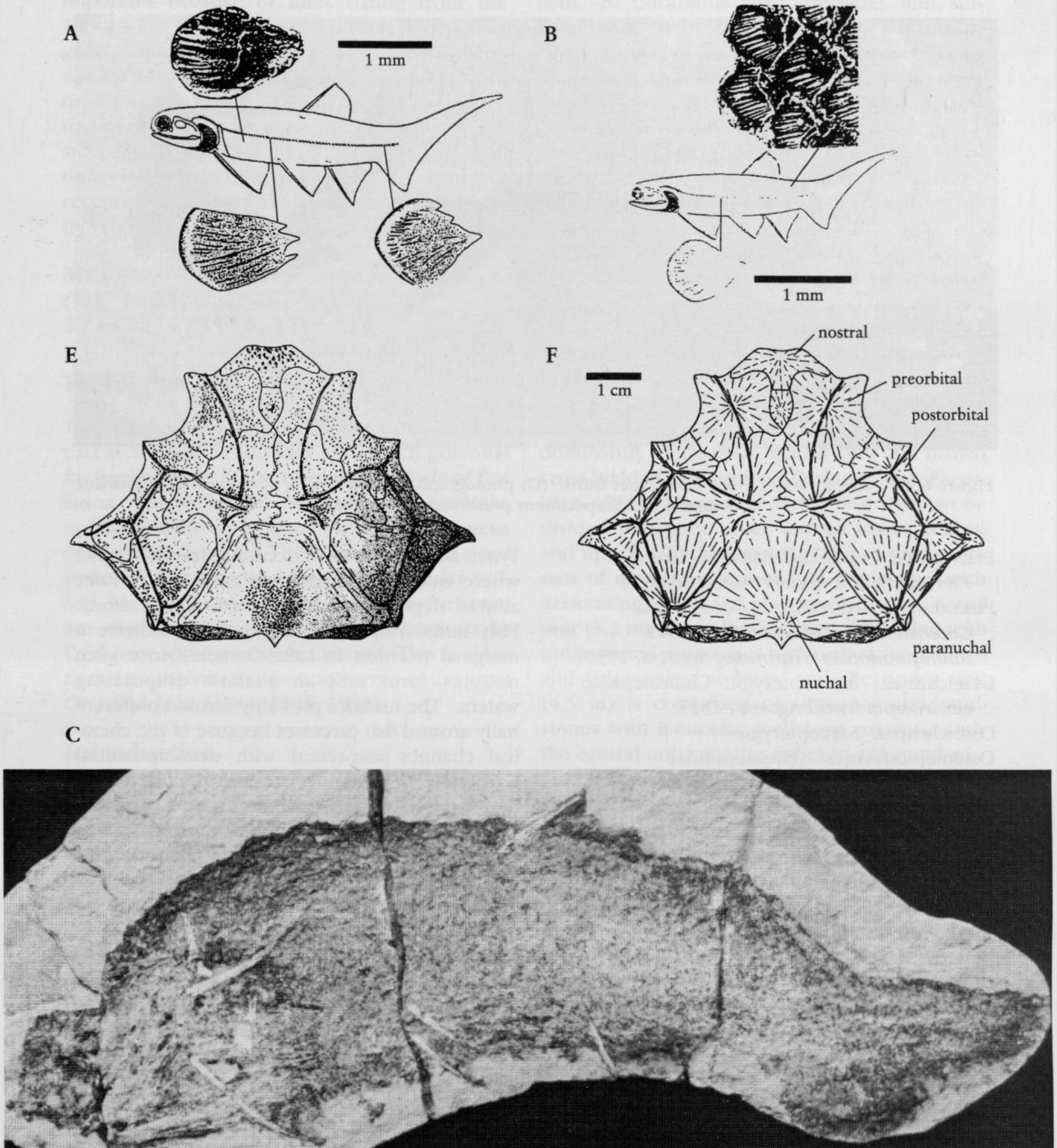

Figure 6.20 Fossil fishes from Tynet Burn. (A) *Cheiracanthus latus* Egerton, a restoration based upon NHM P 15286 with scales from below and above the lateral line; (B) *Cheiracanthus murchisoni* Agassiz, a restoration based upon NHM P 6189 with scales from above and below the lateral line ((A) and (B) from Young, 1995); (C) T04134R of *Cheiracanthus* × 2 (Photo: courtesy The Natural History Museum, London); (E), (F) Reconstructions based on species from Tynet Burn: (E) skull roof with surface ornamentation and lateral line canal grooves; (F) in outline with radiation centres shown. (Part D overleaf.)

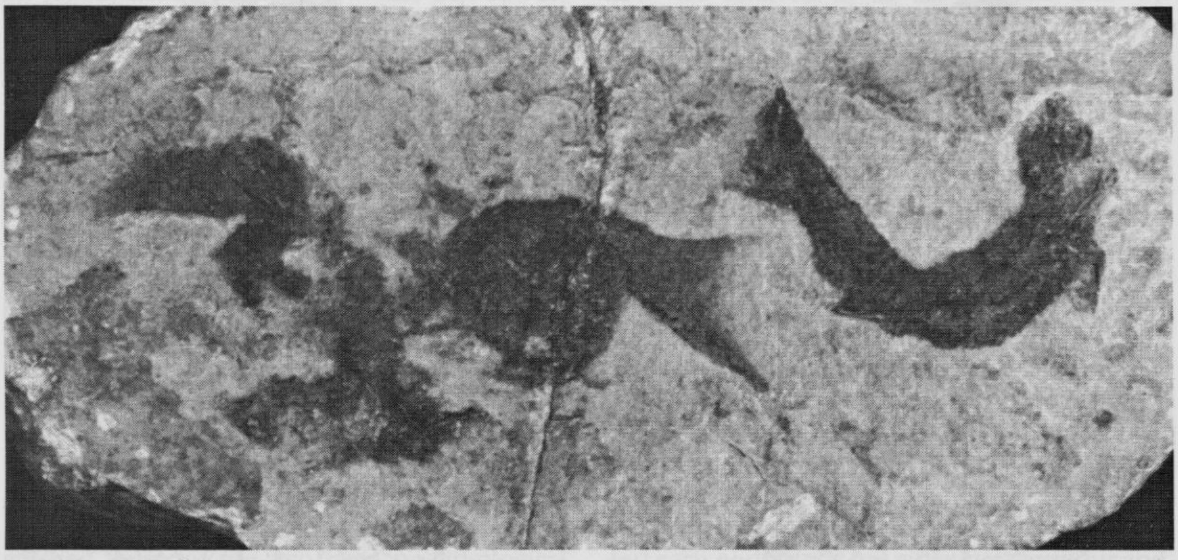

Figure 6.20 – *contd*. Fossil fishes from Tynet Burn. (D) photograph GLAHM V3573, of *Mesacanthus pusillus* (Agassiz) × 2.5, specimens preserved in nodules.

Placodermi: Antiarchi: Asterolepidae
Pterichthyodes milleri Miller, 1841
Placodermi: Arthrodira: Coccosteidae
Coccosteus cuspidatus Miller, 1841
Rhamphodopsis trispinatus Watson, 1938
Osteichthyes: Actinopterygii: Cheirolepidae
Cheirolepis trailli Agassiz, 1835
Osteichthyes: Sarcopterygii:
Osteolepidiformes: Osteolepididae
Osteolepis macrolepidotus Agassiz, 1835
Gyroptychius sp. 1
Gyroptychius sp. 2
Osteichthyes: Sarcopterygii: Porolepiformes:
Holoptychidae
Glyptolepis leptopterus Agassiz, 1844
Glyptolepis paucidens Agassiz, 1844
Osteichthyes: Sarcopterygii: Dipnoi:
Dipterida: Dipteridae
Dipterus valenciennesi Sedgwick and Murchison, 1828

The fish material includes type specimens of *Diplacanthus striatus* and *Rhamphodopsis trispinatus* Watson, 1938, and possibly also *Cheiracanthus latus* Egerton, 1861. It is sufficiently well preserved for Young (1995) to distinguish the scale morphology of several acanthodian species (Figure 6.20).

Interpretation

As Hamilton and Trewin (1988) showed, the Tynet Burn succession accumulated in a zone where coarse fluvial detritus gave way to finer alluvial deposition with lacustrine ingressions. Fish Beds with carbonate nodules indicate a marginal position in Lake Orcadie, since such nodules form only in shallow evaporating waters. The nodules probably formed preferentially around fish carcasses because of the chemical changes associated with decomposition. Carbonate ions migrated towards the fish bodies and invested some of the soft tissues, and the surrounding sediment. Hall and Donovan (1978) concluded that nodules would form during periods of lacustrine regression, when partial carbonate dissolution could have taken place whilst acid oxidizing, or mildly reducing, groundwaters were circulating.

Carbonate nodules are not found at equivalent horizons in Orkney and Caithness, where the fishes are preserved flattened, in flagstones. The localities farther north indicate deeper-water lacustrine sedimentation coupled with more strongly alkaline waters. The Tynet Burn nodules are noticeably flatter than those from other sites.

Conclusion

The conservation value of the three or four fish beds in Tynet Burn results from the production of a rich fauna of acanthodians, placoderms and bony fishes, and the site is historically very important because of finds dating from the 1830s. The quality of preservation is generally good, and specimens from Tynet have been widely used in anatomical and systematic work on Devonian fishes. Collecting at Tynet Burn had been at a halt for some years, because of the steepness and instability of the cliff faces, and difficulty of reaching the fish beds, but was recently resumed on a modest scale by S.P. Wood (N. Trewin, pers. comm.).

MELBY (HU 166560, 167565, 168567, 171572, 173573, 177571)

Highlights

Two fish beds are present with a fauna close to that at Achanarras and they offer much potential for further study of this northernmost site of this fauna. The Melby Fish Beds at several locations in Shetland have produced excellent specimens of about ten species. These are important since some of them, particularly *Pterichthyodes milleri*, are index fossils that show that these strata are the same age as those at Achanarras in Caithness and Cruaday in Orkney. This is close to the northernmost point preserved of the great Orcadian Lake (Astin, 1985, 1990).

Introduction

The Melby Fish Beds were discovered by J. Knox during Geological Survey mapping between 1931 and 1934, and they were described by Watson (1934) and Mykura and Phemister (1976). There are two fish beds, separated by 90 m of predominantly fluvial facies rocks. Spore analysis, and the presence of *Pterichthyodes milleri* (Watson, 1934), confirms that the Melby horizon correlates to the Achanarras horizon (Allen and Marshall, 1981) and is thus of basal Givetian age.

Description

The Melby Fish Beds (Figure 6.21) are in a sequence of sandstones and shales, the Melby Formation, which is an isolated Middle Devonian sequence in West Shetland: there is no Lower or Upper Devonian in the area (Westoll, *in* House *et al.*, 1977). The lower part of the Melby Formation consists of buff and red sandstones, with two outcrops, representing perhaps one or two beds, of calcareous shaly laminites and siltstones, the Melby Fish Beds. Lavas and ignimbrites appear in the upper part of the Melby Formation, and these are overlain by the thick Esha Ness sequence, which is dominated by volcanic rocks. The Foula Beds, on nearby Foula, are similar in age, and consist of 1600 m of sediments, probably deposited in the same basin as the Melby Formation, but the latter are more distal in character.

At first it was thought that only one fish bed was present (Watson, 1934). The area shows considerable folding, thrusting and faulting, and the fish beds show much lateral variation. Later Mykura and Phemister showed that there were in fact two fish beds (Figure 6.21). The Lower Melby Fish Bed is 13 m thick, the Upper 5 m thick, and they are separated by 80–90 m of predominantly arenaceous, mainly buff and brown cross-bedded sandstones (Mykura and Phemister, 1976). The Lower Melby Fish Bed can be divided into three units, termed lower, central and upper. The lower unit, 2.7–3 m thick, consists of mudflat siltstones and mudstones with desiccation cracks and plant remains, the central unit (3.2 m) is grey fissile shales alternating with unlaminated mudstones with carbonate-rich ribs and fish-bearing nodules, and the upper unit (4.5 m) is comprised of siltstones and mudstones with lenticular sandstone masses. Only the central unit contains fishes in any number.

The Lower Melby Fish Bed is exposed at three sites on the coast: Long Rigg (HU 177571), Ayre of Huxter (HU 173573) and Quilva Taing (HU 171572). Ayre of Huxter has the longest exposure, and has been collected most extensively. It is the only Lower Melby Fish Bed site recognized by Watson (1934). Beds at the western end of the exposure at Ayre of Huxter have been disrupted by folds and faulting such that fossils are broken up or lost in some places. The bone itself forms shear planes along which movement took place. Fishes are mainly found within calcareous nodules that occur in the dark grey laminated lacustrine siltstones. Disarticulated pieces mainly of *Coccosteus* exist within the calcareous ribs. Uncommon fragments of fishes also occur in the plant-bearing green-grey siltstones in the top part of the lower unit, and also within the thin siltstones that separate the calcareous bands.

Watson (1934), Mykura and Phemister (1976) and Hemmings (1978) record the following species from the three sites: *Coccosteus* sp. and

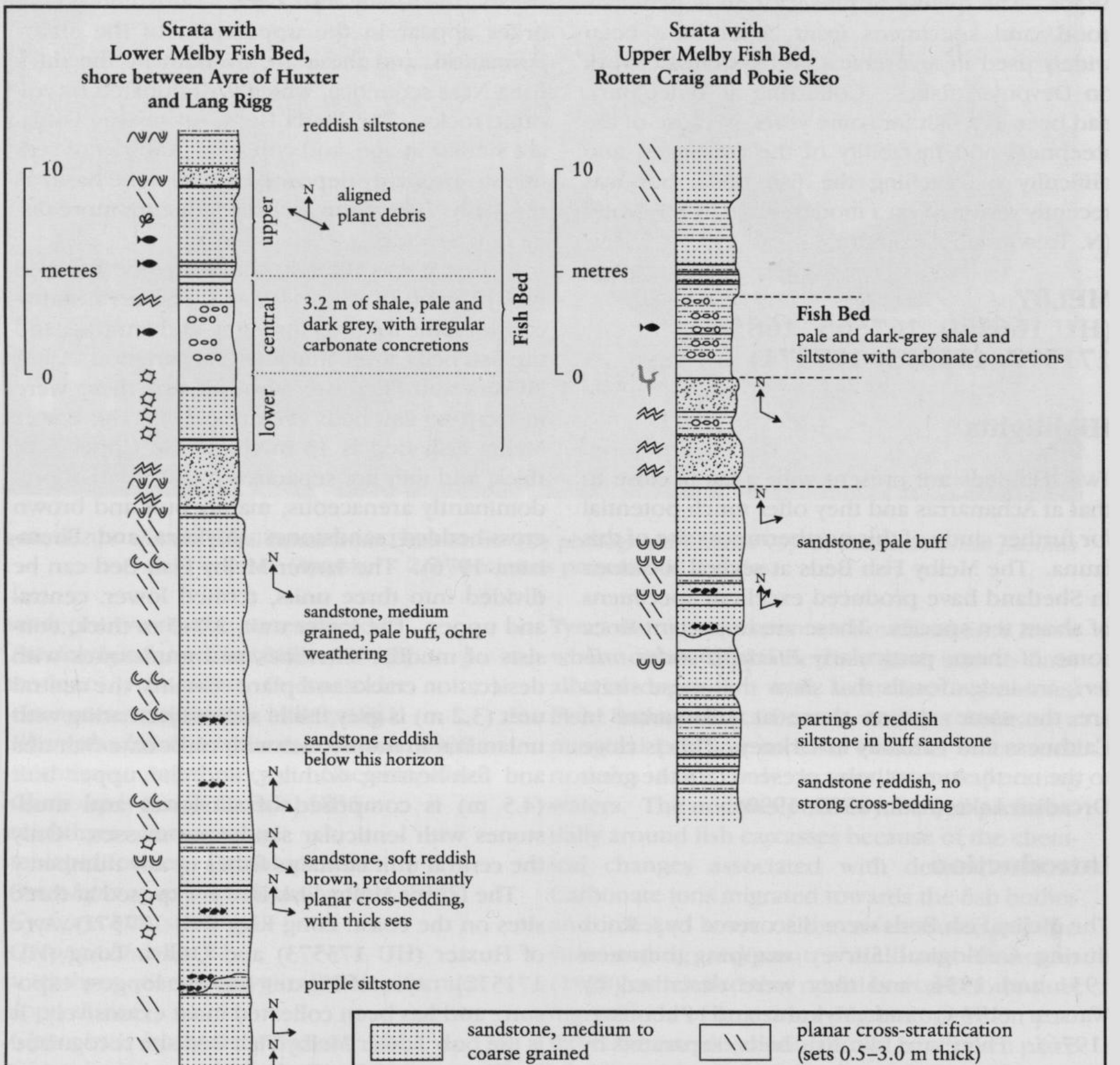

Figure 6.21 **Stratal settings of the Melby Fish Beds (after Mykura and Phemister, 1976).**

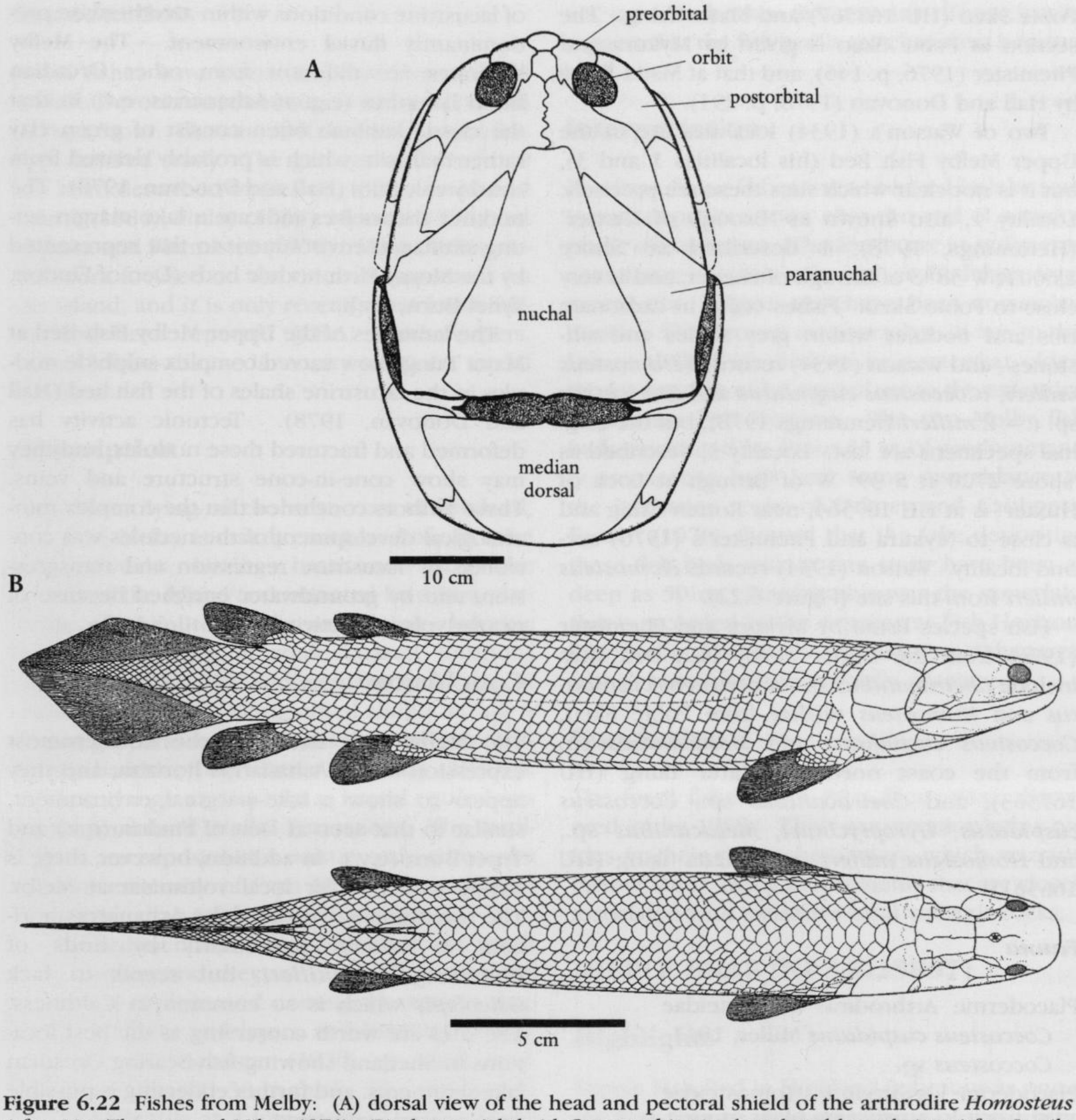

Figure 6.22 Fishes from Melby: (A) dorsal view of the head and pectoral shield of the arthrodire *Homosteus* (after Moy-Thomas and Miles, 1971); (B) the osteichthyid *Gyroptychius* in dorsal and lateral view (after Jarvik, 1948a).

Pterichthyodes milleri from Long Rigg, *Coccosteus cuspidatus*, *Dipterus valenciennesi*, *Glyptolepis* cf. *leptopterus* and *Gyroptychius agassizi* from Ayre of Huxter, and *Coccosteus cuspidatus* Miller 1841, *Dipterus valenciennesi* Sedgwick and Murchison, 1828 and *Gyroptychius agassizi* Traill, 1841 from Quilva Taing. The faunal differences among these sites respond to lateral lithological variations traceable along the Lower Melby Fish Bed, but also probably reflect collecting bias, because Ayre of Huxter is the only one of the three where collecting is easy.

The Upper Melby Fish Bed varies along strike, containing local lenticular masses of siltstone. It is almost continuously exposed along the top of the cliff from Foglabanks (HU 168568) to Rotten Craig (HU 167565), and then is repeated on the upthrown side of an ENE-trending fault. The southermost outcrop is at Matta Taing (HU 166561), where a complete section through the fish bed may be seen, with a 1 m thick lower unit 2.5 m below the main fish bed also available for collection. The most accessible sections are at

Pobie Skeo (HU 168567) and Matta Taing. The section at Pobie Skeo is given by Mykura and Phemister (1976, p. 146), and that at Matta Taing by Hall and Donovan (1978, p. 291).

Two of Watson's (1934) localities are in the Upper Melby Fish Bed (his localities 1 and 3), but it is not clear which sites these are precisely. Locality 1, also known as 'Brough of Huxter' (Hemmings, 1978), is described as 'Shore 1,600 ft W 38° S of Brough of Huxter, and is very close to Pobie Skeo. Fishes occur in carbonate ribs and nodules within grey shales and siltstones', and Watson (1934) recorded *Homosteus milleri*, ?*Coccosteus cuspidatus* and *Pterichthys* sp. (= P. *milleri* Hemmings 1978), but the original specimens are lost. Locality 3, described as 'shore 2720 ft S 39° W of Brough at Loch of Huxter' is at HU 167564, near Rotten Craig and is close to Mykura and Phemister's (1976) second locality. Watson (1934) records *Homosteus milleri* from this site (Figure 6.22).

Fish species listed by Mykura and Phemister (1976) from the Upper Melby Fish Bed sites include *Cheiracanthus* sp., ?*Coccosteus cuspidatus* and *Homosteus milleri* from Pobie Skeo, *Coccosteus cuspidatus* and *Mesacanthus* sp. from the coast north of Matta Taing (HU 167563), and *Cheiracanthus* sp., *Coccosteus cuspidatus*, *Gyroptychius*?, *Mesacanthus* sp., and *Homosteus milleri* from Matta Taing (HU 166561).

Fauna

Placodermi: Arthrodira: Coccosteidae
Coccosteus cuspidatus Miller, 1841
Coccosteus sp.
Placodermi: Arthrodira: Homosteidae
Homosteus milleri Traquair, 1888
Placodermi: Antiarchi: Asterolepidae
Pterichthyodes milleri Miller, 1841
Osteichthyes: Sarcopterygii: Osteolepidae
Dipterus valenciennesi Sedgwick and Murchison, 1828
Acanthodii: Acanthodiformes: Climatiidae
Cheiracanthus sp.
Acanthodii: Acanthodiformes: Acanthodidae
Mesacanthus sp.

Interpretation

The fish beds are thick, pale grey, sandy siltstones and shales with carbonate-rich fish-bearing ribs and nodules and indicate the existence of lacustrine conditions within an otherwise predominantly fluvial environment. The Melby laminites are different from other Orcadian Basin laminites (e.g. at Achanarras; q.v.) in that the clastic laminae often consist of green clay rather than silt, which is probably derived from nearby volcanics (Hall and Donovan, 1978). The nodules themselves indicate a lake margin setting similar in environment to that represented by the Moray Firth nodule beds (Den of Findon, Tynet Burn; q.v.).

The laminites of the Upper Melby Fish Bed at Matta Taing show varved complex sulphide nodules in the lacustrine shales of the fish bed (Hall and Donovan, 1978). Tectonic activity has deformed and fractured these nodules, and they may show cone-in-cone structure and veins. These authors concluded that the complex mineralogical development of the nodules was controlled by lacustrine regression and transgression, and by groundwater enriched because of nearby volcanic activity.

Conclusion

The Melby Fish Beds are the northernmost expression of the Achanarras horizon, and they appear to show a lake-marginal environment, similar to that seen at Den of Findon (q.v.) and Tynet Burn (q.v.). In addition, however, there is strong evidence for local volcanism at Melby. The fish fauna is typical of the Achanarras horizon, as shown particularly by finds of *Pterichthyodes milleri*, but seems to lack *Osteolepis* which is so common in Caithness. The sites are worth conserving as the best locations in Shetland showing fish-bearing Orcadian lake sediments, and further collecting is possible from coastal exposures.

PAPA STOUR (HU 186605)

Highlights

This unusual fossil fish site in Shetland lies in the midst of Devonian-age volcanic rocks. Sandstones formed by denudation of the volcanic landscape entombed rare plants and fishes, and these fossils indicate a Mid-Devonian age, equivalent to the Achanarras horizon, a time of maximum size of the great Orcadian Lake. The site is important for its location with respect to the ancient lake margins, and for the evidence of a mix of volcanic and habitable environments.

Introduction

Fossil fishes have been discovered recently in Middle Devonian sediments on the small island of Papa Stour. The site, and the fishes, await further detailed study. The geology of Papa Stour has been described by Geikie (1878), Peach and Horne (1884), Finlay (1930), Mykura (1976) and Mykura and Phemister (1976). Most of this earlier work focused on the volcanic sequences on the island, and it is only recently that fossil fishes have been reported (J.E.A. Marshall, pers. comm.) from thin sedimentary strata on top of the lavas.

Description

Papa Stour, lying off the west coast of Shetland, opposite Melby, is mainly composed of extrusive igneous rocks, rhyolites, basalts and tuffs. The centre of the island is dominated by a lava platform of rhyolite, with underlying doleritic basalts appearing in some coastal locations (Finlay, 1930). The sedimentary rocks are of minor significance, being noted simply as 'a few feet of grey and red ashy sandstones which overlie the basalts of Papa Stour' by Finlay (1930, p. 673), and regarded by him as lateral equivalents of the mainland Melby Formation. The sandstones are exposed in a narrow strip across the eastern extremity of Papa Stour, closest to the mainland, at an inlet called Housa Voe.

The sedimentary beds lie between the basalt and rhyolite, and they are grey, red, brown and purple in colour, and commonly contain fragments of lava, and layers and lenticles of tuff. Mykura and Phemister (1976) recorded sandstones in a unit 0–30 m thick. The sandstones dip southwards at a low angle (7–12°). These sandstones appear to be the basement beds of the Melby Formation, and they were formed in part by denudation of an earlier Old Red land surface produced by volcanic activity. One sandstone is possibly bioturbated (Mykura and Phemister, 1976, p. 161).

Fauna

Acanthodii: Acanthodiformes
acanthodians indet.
Placodermi: Arthrodira: Coccosteidae
Coccosteus cuspidatus Miller, 1841

A thin bed of black shales, with volcanic detritus, contains broken fish remains. These fossils suggest that the fish bed is at Achanarras horizon level.

Interpretation

The Papa Stour fishes were interred in lake sediments deposited soon after the end of a major phase of volcanism. The fossils are in sediments containing volcanic ash and eroded lava fragments; the habitat may have been somewhat hostile. The deposit may correlate in age to the Lower Melby Fish Bed, or be somewhat older, thus it appears to be equivalent to the extensive Achanarras Fish Horizon. The two Melby fish beds, separated by about 85 m of predominantly arenaceous beds bear some resemblance to the lacustrine rocks of Orkney and Caithness. Fannin (1970) showed that the lake depositing these fish beds may at one stage have been as deep as 50 m. Possibly this was the same lake that is recorded by the Achanarras Fish Horizon. The Melby Fish Beds contain the 'Achanarras fauna', but *Osteolepis* is totally absent.

Conclusion

The fossil fishes from Papa Stour were discovered in the 1980s. Their conservation value resides in their unusual situation, which warrants further study, being in sediments that are closely associated with extensive local volcanic rocks.

DIPPLE BRAE (NJ 33025887)

Highlights

Dipple Fish Bed in Highland is famous as one of the first sites to yield specimens of fossil fishes from the Scottish Old Red Sandstone, with the first finds reported in the 1830s. The fish bed is younger than the widespread Achanarras horizon fauna at nearby Tynet Burn. Seven or eight species of primitive fishes have been extracted from the nodules in the Dipple Brae Fish Bed, and the importance of the site is its age.

Introduction

At Dipple Brae, near Fochabers in Moray (Highland), the Dipple Fish Bed was once quarried for lime, and the remains of these workings can be seen along the north bank of the stream. The Fish Bed was discovered in 1838 by J.G.

Malcolmson (Murchison, 1839; Andrews, 1982), when he located also the fish beds at Lethen Bar, Clune and Tynet Burn. The discoveries by Hugh Miller in Cromarty, plus the founding of the Elgin Museum in 1836, initiated the search for fossil fishes in the Moray area. Malcolmson (1842, 1859) described the specimens, and Gordon (1859) gave more details. Malcolmson and Gordon found that the fishes from Tynet Burn (q.v.) were much better preserved than those at Dipple, and they lost interest in the latter site. Probably Agassiz never saw any material from Dipple, and collectors in the 1830s and 1840s did not detect any differences between the fishes from Dipple and those from the other Moray Firth sites.

There was probably a good exposure of the section at Dipple when it was visited by Malcolmson. He was able to produce a detailed section through the area (Malcolmson, 1859, pl. 11). Later, the outcrop of the fish bed became completely covered with talus from the lime workings, and nodules could only be collected from fields in the neighbourhood (Gregory, 1860). In the 100 years following its discovery, Dipple attracted the attention of Duff (1842), Gordon (1859), Gregory (1860), Wallace (1879), Traquair (1895), Mackie (1902), Mahood (1919) and A.G. Malcolmson (1921). In the 1960s the British Geological Survey reopened the fish bed site and produced a section (Peacock *et al.*, 1968; Figure 6.23).

Description

The Dipple Fish Bed lies higher in the Middle Old Red Sandstone sequence of the Elgin–Forres area than the Tynet Burn Fish Bed (q.v.). It consists of 1.5 m of purple and red shales with limestone nodules, within a sequence of red sandstones and conglomerates of Middle Devonian age (Peacock *et al.*, 1968; Westoll, *in* House *et al.*, 1977).

Before the stratigraphical revision undertaken by Miles and Westoll (1963), it had always been assumed that the Dipple Fish Bed contained the same fauna as the other fish-bearing nodule beds in the area, all equivalent to the Achanarras horizon. Miles and Westoll (1963) proved that *Dickosteus threiplandi* completely replaced *Coccosteus cuspidatus*, a characteristic member of the Achanarras-horizon fauna, and that the Dipple Fish Bed represented a younger horizon, characteristic of Donovan *et al.* (1974) Zone 4.

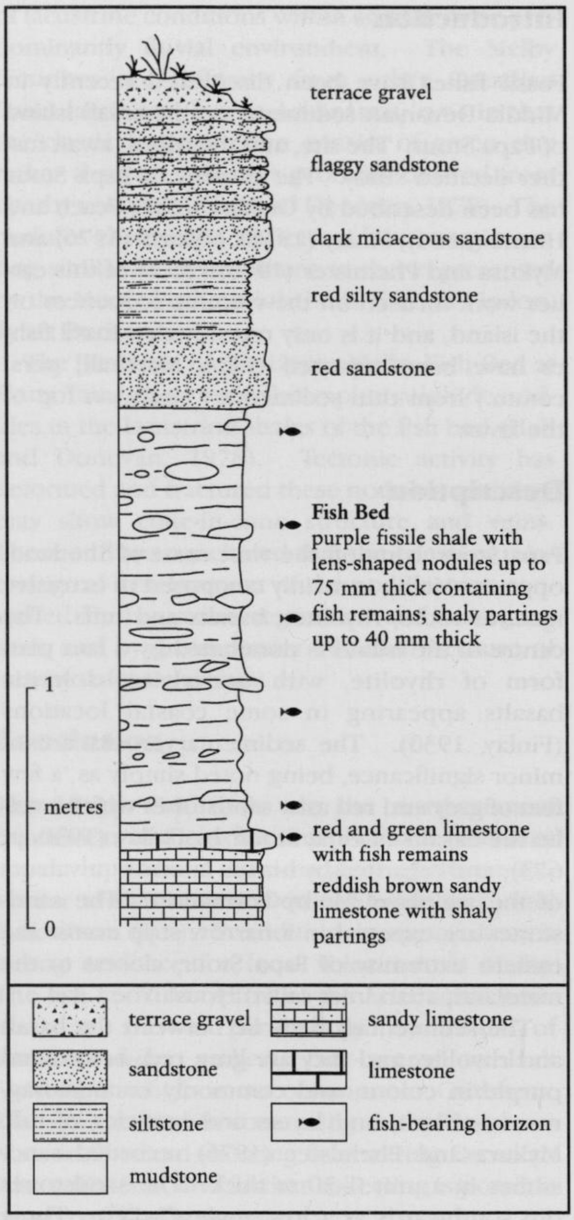

Figure 6.23 Stratigraphical section through Dipple Brae Fish Bed (based on data from M.A. Rowlands MS).

Fauna

The fish fauna consists of the following taxa:

Acanthodii: Acanthiformes: Acanthodidae
Mesacanthus sp. (recorded as *Acanthodes pusillus* by Gregory, 1860)
Placodermi: Arthrodira: Coccosteidae
Dickosteus threiplandi Miles and Westoll, 1963

Placodermi: Arthrodira: Homosteidae
Homosteus sp.,
Osteichthyes: Sarcopterygii: Osteolepiformes
Osteolepis sp. (Thomson, 1964, says that this may be *Gyroptychius* n. sp.)
Ostreichthyes: Sarcopterygii: Dipnoi: Dipteridae
Dipterus sp.

From their discovery, it had been noted that the character of the nodules varied between different Moray Firth sites (Traquair, 1895). Dipple yields nodules that are studded with 'little excrescences' each of which contains a scale and represents the nodule formation around a semi-degraded fossil. Specimens of *Gyroptychius* sp. from the Dipple Fish Bed had been partly disarticulated before burial, but otherwise the quality of preservation was excellent and, among structural details that were present, unique casts of the ethmoid endo-cranial cavity were visible in two specimens, and others showed the arrangement of the small bones of the snout region of the dermal skull roof, which is also very uncommon (Thomson, 1964).

Interpretation

Dipple represents a temporary extension southwards of a lake which formed in Faunal Zone 4 times (Donovan *et al.*, 1974), allowing *Dickosteus*, *Osteolepis* and *Gyroptychius* to enter the area from lake waters farther north. In such an isolated environment new species may ultimately have evolved (Donovan, 1980).

Conclusion

Dipple Fish Bed was always rejected as a poor site by comparison with the other nodule beds of the Moray Firth area which yield beautifully preserved fossil fish. However, it yields a fauna younger than at Achanarras, and contains species that do not occur within the lower nodule beds, hence its conservation value. At Fish Zone 4 (Donovan *et al.*, 1974) there are no other nodule beds, only flattened specimens from flagstone sites in Caithness such as Spittal Quarry. Nodule beds preserve an extensive morphological details of species, an important aspect of this site.

Further collecting at Dipple is likely to reveal interesting fishes, both from the point of view of preservation and also possible differences to typical Zone 4 faunas. Recent excavation has produced well-preserved material, showing the potential of the site (N.J. Hollingworth, pers. comm., 1983).

SPITTAL QUARRY (ND 171541)

Highlights

Spittal Quarry (north-east Caithness, Highland) has produced an important assemblage of fossil fishes of Mid-Devonian age. The fishes are younger than those from Achanarras, and represent a key assemblage for dating. The site produced the first specimens of the placoderm *Dickosteus threiplandi*, as well as rare specimens of the large osteostracan *Cephalaspis magnifica*, a group that is otherwise poorly known from rocks of this age (Figure 6.24).

Introduction

Spittal Quarry exposes lacustrine dolomitic laminites of Givetian age. Fossils are very rare at Spittal, and specimens were found only because of the long phase of over 100 years of quarrying by hand that has turned up occasional fossils. The quarry has been worked for paving slabs since the 1850s (Traquair, 1893), and latterly for luxury objects such as fireplaces and coffee tables. It is still operating. The locality is one of those described in the field guide by Trewin and Hurst (1993).

Description

The strata consist of alternations of dolomitic laminites and fine-grained grey sandstones, of the Latheron Subgroup of the Upper Caithness Flagstone Group and represents beds of 'Faunal Zone 4' (Donovan *et al.*, 1974). The term 'Spittal Beds' was used by Miles and Westoll (1963) for all the Caithness equivalents of the Upper Stromness Flagstones of Orkney, which overlie the Achanarras horizon, but this was rejected by Donovan *et al.* (1974) because the relationships to underlying beds are uncertain at Spittal or other inland quarries.

The few fossils that have come from this site are extremely well preserved. They include plants and fishes, with plant material being rather more common than fish. The fine state of preservation of the fishes allows detailed study of their morphology, which lends them disproportionate importance in anatomical and systematic studies. Fishes from Spittal are housed in the RSM and NHM.

Fauna

The fossil fishes from Spittal Quarry include the following taxa:

AGNATHA
Osteostraci: Cephalaspidiformes:
Cephalaspididae
Cephalaspis magnifica Traquair, 1893

GNATHOSTOMATA
Placodermi: Arthrodira: Homosteidae
Homosteus milleri Traquair, 1888
Placodermi: Arthrodira: Coccosteidae
Dickosteus threiplandi Miles and Westoll, 1963
Osteichthyes: Sarcopterygii: Dipterida:
Dipteriidae
Dipterus sp.

Interpretation

The type specimen of *Dickosteus threiplandi* is a well-preserved and articulated fossil, which is unusual for this type of placoderm. The specimens of *Cephalaspis magnifica* are rarely complete, and in most all that remains are isolated headshields, scattered fragments or bony scales resulting from the break-up of the dead fishes prior to burial.

Cephalaspis magnifica (Figure 6.24B) is a species unique to this quarry, where only two specimens have been found, the first in 1893 (Traquair, 1893) and the second, half a century later. These two specimens are the only known cephalaspid from the Middle Devonian, and the only cephalaspid in Orcadian Lake sediments. They are also the largest cephalaspid (*c.* 350 mm wide headshield compared with a 'normal' range of 40–80 mm). The species is important in bridging a time gap between cephalaspids of the Lower and the Upper Devonian.

Dickosteus threiplandi (Figure 6.24A) is the only species of the genus, and Spittal is the type locality. The fossil was named after Robert Dick (the famous Thurso baker and pioneer geologist), and Major P.W. Murray-Threipland, who discovered the type specimen in 1956 (Miles and Westoll, 1963). *Dickosteus* was over 0.5 m long, which is half as long again as *Coccosteus*. It is

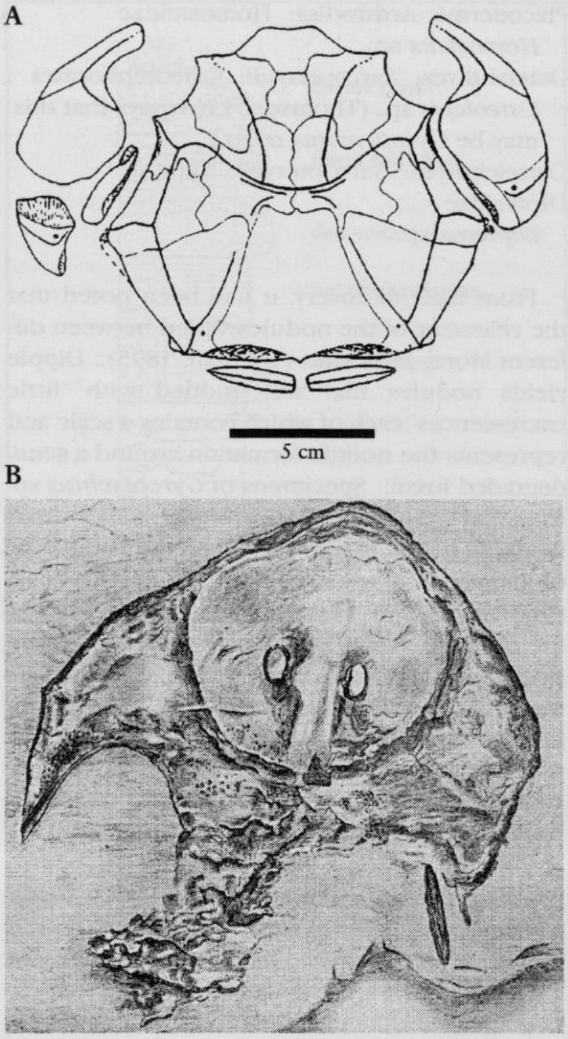

Figure 6.24 (A) The coccosteid arthrodire *Dickosteus threiplandi* Miles and Westoll; outline of the skull roof and cheek bones laid out in a single plane, based on the holotype RSM 1962.4, (after Miles and Westoll, 1963). (B) *Cephalaspis magnifica* Traquair, cephalic shield in ventral view at × 0.23.

the diagnostic fossil for 'Faunal Zone 4' of Donovan *et al.* (1974), and in Caithness is found at the following localities: Spittal, Banniskirk, Stonegun, Amster, Shalmstry, Achscrabster, Forss Hill, Scrabster, Holburn Head and Brims, and in the Stromness Flagstones in Orkney.

Specimens of *Dipterus* from Spittal are usually large individuals. *Dipterus* occurs at many Caithness Flagstone localities. A probable new, and as yet undescribed species of *Dipterus* is also represented in the collection from Spittal.

In 1976 a fish bed was exposed in the base of the quarry. It contained *Dipterus*, and was a true fish laminite. It is possible that this was the top of the Achanarras horizon below. Spittal Quarry is separated from Achanarras Quarry by 2 km of peat- and drift-covered land with no exposure, and the stratigraphical relationship between the two quarries is very uncertain.

Conclusion

The rare fishes from Spittal Quarry, which confer its conservation value, are important for four reasons: (1) their good quality of preservation, (2) the presence of *Dickosteus threiplandi* and other fishes characteristic of Fish Zone 4 of Donovan *et al.* (1974), (3) the fact that Spittal Quarry is the type locality of *D. threiplandi*, and (4) the presence of *Cephalaspis magnifica*, the only known cephalaspid from the Orcadian Basin, and the only one from the Middle Devonian.

BANNISKIRK QUARRY (ND 167568)

Highlights

Banniskirk in Caithness (Highland) is important as the first site where Scottish Old Red Sandstone fossil fishes were found, in 1826. It was visited by many of the leading Victorian geologists, and produced a rich array of fish specimens of various kinds, including placoderms and lungfishes.

Introduction

Banniskirk Quarry was the first quarry to yield Scottish Middle Devonian fossil fishes. In 1826 Matthew Culley, studying rocks in Caithness and Sutherland at Murchison's request, sent some specimens from Banniskirk to the Geological Society in London. Murchison, wishing to obtain an age for the beds in Caithness, passed them to Baron Cuvier in Paris for his opinion, but had not received a reply when he published his paper (Murchison, 1827) on the Brora Coalfield and other northern Scottish strata that included information about fish-bearing sites (Andrews, 1982). Cuvier thought that the Scottish fish specimens (now assigned to *Dipterus*) were analogous to the bony pike of North America, and that the genus was of the Order Malacopterygii abdominales (Agassiz, 1835).

In 1827 fishes were also discovered at Den of Findon, Gamrie (q.v.), and in that year Murchison visited Caithness again, this time with Sedgwick, and they collected more and better fossils. Murchison sent the new material to Paris where, together with the original specimens examined by Cuvier, they were studied by Valenciennes and Pentland. Their descriptions and names for the fossils were published in Sedgwick and Murchison (1828). Valenciennes and Pentland named five species of their new genus *Dipterus*, three of which were synonymized by Pander (1858) in *D. valenciennesi*. Agassiz (1835, p. 24) included all the *Dipterus* material in one species, *Catopterus analis*, but later (Agassiz, 1835, p. 115) called it *D. macrolepidotus* Sedgwick and Murchison, 1828. The early authors made no distinctions between the material from the different sites, and were also unable to determine that the fishes from the Moray Firth fish beds were the same species as those from Caithness because of the very different states of preservation. White (1965, p. 3) stated: 'Unfortunately the provenance of all Sedgwick and Murchison's figured material, now in the collection of the Geological Survey, is not certain. Only one of the specimens, a co-type of *Dipterus macropygopterus* (pl. 15, fig. 2; GS no. 6448) was originally labelled 'Banniskirk', all the others being labelled 'Thurso'. 'Thurso' indeed was used in early days to cover Banniskirk... but it also covered many other quarries in the neighbourhood, and identification of the locality must depend on the recognition of matrix, a very doubtful procedure in these variable rocks'.

Other collectors who visited Banniskirk in the mid-19th century included Robert Dick (the Hugh Miller collection contains specimens from Banniskirk which were probably all collected by Dick) and Charles Peach. The Egerton collection also has material from Banniskirk, which was figured by Murchison (1859) and by Huxley (1861). The Russian collector Hamel made a collection of fishes from Caithness and Orkney in 1842; they were shipped to St Petersburg, Russia, and described by Pander (1857, 1858, 1860) who figured material from Banniskirk. The 19th century collectors benefitted from the fact that flagstones were quarried actively and exported through Thurso Harbour; both the quarry and the flagstone yard were searched for fish specimens.

Description

Stratigraphically, the Banniskirk Quarry lies 'about 120–150 m above the Achanarras band' (Miles and Westoll, 1963), which is in the Latheron Subgroup of the Upper Caithness Flagstone Group, and in Faunal Zone 4 (Donovan *et al.*, 1974), at the boundary between the Eifelian and Givetian (Spittal Beds *sensu* Miles and Westoll, 1963). It is roughly equivalent in age to the beds exposed at Spittal Quarry, though probably a little younger, but is of different lithology. Exposure is very poor in the drift-covered inland area of Caithness, so the stratigraphical relationships between Banniskirk, Spittal and Achanarras Quarries are elusive.

Fauna

Whereas fishes are very rare in the siltstones of Spittal, they are comparatively common in the calcareous laminites of Banniskirk. The full faunal assemblage is poorly known.

Placodermi: Antiarchi: Asterolepidae
?*Pterichthyodes* sp.
Placodermi: Arthrodira: Coccosteidae
Dickosteus threiplandi Miles and Westoll, 1963
Acanthodii sp. et gen. indet.
Osteichthyes: Sarcopterygii: Dipnoi: Diptera
Dipterus valenciennesi Sedgwick and Murchison, 1828

Interpretation

Banniskirk is most important for the common occurrence of *Dipterus*, and occasional acanthodians. The quarry also yields 'excellent material' of *Dickosteus threiplandi* and a specimen from this quarry was figured by Miles and Westoll (1963). *Pterichthyodes* is recorded from Banniskirk in the *Directory of British Fossiliferous Localities* (Anon., 1954), but this cannot be substantiated, and Hemmings (1978) described it as an incorrect determination: there is no specimen to match the record, and *Pterichthyodes* is typical of the underlying Zone 3 (Donovan *et al.*, 1974).

Two forms of *Dipterus* occur in Caithness, as noted by Westoll (1949), one in material from Banniskirk, which he assigned to *Dipterus brachypygopterus* Sedgwick and Murchison, 1828, and all the other material from the Thurso Flagstones, which he called *D. platycephalus* Agassiz. This has been disputed (White, 1965), and all material is currently included in the species *D. valenciennesi* Sedgwick and Murchison, 1828. *Dipterus* may have had a greater tolerance to adverse conditions than other Orcadian Basin species (Donovan, 1980; Trewin, 1986). Hence its occurrence as the most abundant taxon at Banniskirk perhaps suggests occasional stressful conditions.

Conclusion

Banniskirk's conservation value is partly historical as the first site to yield Old Red Sandstone fishes, but it is also particularly important for specimens of the lungfish *Dipterus*, perhaps representing more than one species. Further excavation and assessment of the fauna may reveal evidence of environmental variation during Fish Bed 4 times, since the Banniskirk fauna seems to differ in proportions from the coeval faunas of Dipple Brae and Spittal Quarry.

HOLBORN HEAD QUARRY (ND 080710)

Highlights

Holborn Head Quarry in Caithness (Highland) has produced specimens of 10 or 11 species of fossil fishes, and it is especially well known for the fine, abundant specimens of the small osteolepid *Osteolepis panderi*.

Introduction

In the large disused cliff-top quarry at Ness of Litter, 3 km W of Holburn Head (Figure 6.25), the flags have been quarried down to tough non-fissile siltstones, and the extensive sloping floor of the quarry lies along a single flat bedding plane. This is a common feature of several flagstone quarries, which were worked down bed by bed for paving flags, without the use of explosives. Crampton and Carruthers (1914, pl. 7) showed the quarry in operation early in the 20th century. Trewin and Hurst (1993) have provided an excursion guide. The beds dip at a shallow angle of about 5° to the north-north-east. The taphonomy of these fish beds was recently investigated by Hamilton and Trewin (1994).

Description

The quarry exposes a 6 m high face of carbonate

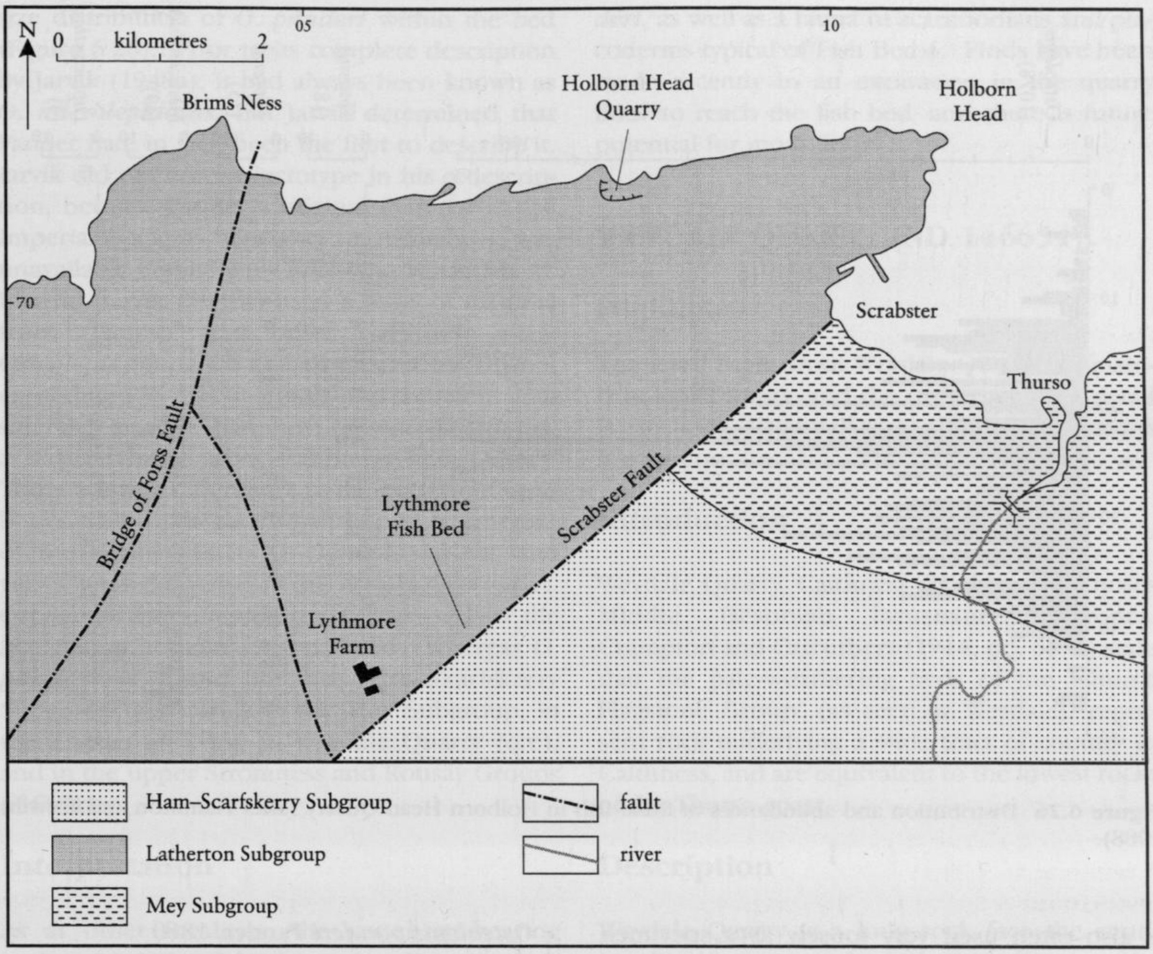

Figure 6.25 Sketch map of the geology of Holborn Head, near Thurso (after Hamilton and Trewin, 1994).

or organic laminated siltstones with subaqueous shrinkage cracks. These are lacustrine sediments from the Ham–Skarfskerry Subgroup of the Upper Caithness Flagstone Group (Donovan *et al*., 1974; Westoll, *in* House *et al*., 1977; Hamilton and Trewin, 1994). The flagstones are thinner-bedded and with lighter weathering colours than those of the underlying Latheron Subgroup, as seen at Banniskirk Quarry (q.v.). Grey and buff sandstones occur in the upper part of the Subgroup. The rocks are of probable mid-Givetian age (Westoll, *in* House *et al*., 1977), as indicated by the fauna that probably belongs to Fish Zone 5 of Donovan *et al*. (1974), as found also at Weydale Quarry (q.v.).

The fish-bearing stratum is 130 mm below the bedding plane which forms the floor of the quarry, and is exposed by a small excavation in the south-east corner of the quarry, near the entrance. The fishes are in a tough, dark brownish grey, calcareous siltstone laminite, and they are difficult to remove. A thickness of 260 mm of fish-bearing siltstones are exposed in the excavation, and the base of the unit is not seen. Fishes are very common throughout the 260 mm thick unit, and they are usually complete, but flattened and poorly preserved. Small attractive complete osteolepids, *Osteolepis panderi*, are very common. Disarticulated skull roofs can also be found and, although less common than complete specimens, their preservation is better. An important addition to knowledge of these strata and their fossil fish is Hamilton and Trewin's (1994) detailed consideration of the taphonomy and palaeoecology.

There are problems in assigning provenances of older museum specimens from this area since the locality label 'Holburn Head' includes several sites of different age, from Brims Hill in the west to the headland of Holburn Head. 'Thurso'

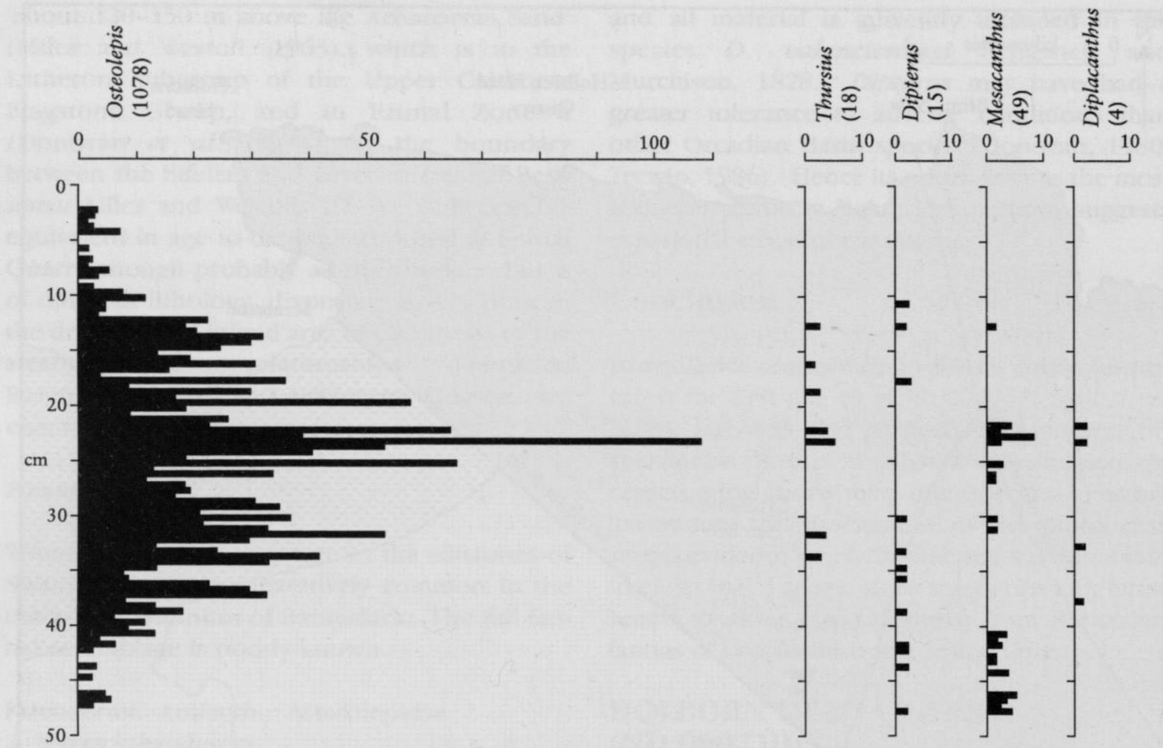

Figure 6.26 Distribution and abundances of fossil fish in Holborn Head Quarry (after Hamilton and Trewin, 1988).

is also often used very loosely as a specimen label (Miles and Westoll, 1963), and can include material from Holburn Head Quarry. Therefore, in the list below, some of the rarer species are queried, and may not be from this site at all.

Fauna

The fish fauna from Holburn Head Quarry includes the remains of active forms most of which were common and widespread throughout the Orcadian Basin.

Acanthodii: Acanthodiformes: Acanthodidae
  Mesacanthus peachi Egerton, 1861
  M. pusillus (Agassiz, 1844)
  ?*Cheiracanthus* sp.
  acanthodian indet.
Placodermi: Arthrodira: Coccosteidae
  Dickosteus threiplandi Miles and Westoll, 1963
Placodermi: Arthrodira: Homosteidae
  ?*Homosteus milleri* Traquair, 1888
Osteichthyes: Sarcopterygii: Osteolepiformes: Osteolepididae
  Osteolepis panderi Pander, 1860
  Gyroptychius agassizi Traill, 1841
  Thursius pholidotus Traquair, 1888
Osteichthyes: Sarcopterygii: Porolepiformes: Holoptychiidae
  Glyptolepis sp.
Osteichthyes: Sarcopterygii: Dipnoi: Dipteridae
  Dipterus cf. *valenciennesi* Sedgwick and Murchison, 1828

Dickosteus threiplandi is a large coccosteid fish with a total length (head plus body) of over 0.5 m. The holotype is from Spittal (q.v.), but a large complete specimen from 'Holburn Head' was described by Miles and Westoll (1963), and specimens of plates from 'Brims' were also figured.

Osteolepis panderi (syn. *O. microlepidotus* Valenciennes and Pentland, 1860) is by far the most common fish at Holburn Head. Hamilton and Trewin (1994) recorded the distribution and abundance of this and four other species throughout the most productive 50 cm of the fish bed at Holborn Head Quarry, and also the size distribution of *O. panderi* within the bed (Figure 6.26). Prior to its complete description by Jarvik (1948a), it had always been known as *O. microlepidotus*, but Jarvik determined that Pander had, in fact, been the first to describe it. Jarvik did not erect a lectotype in his redescription, because Pander's original material in the Imperial Academy of Science, St Petersburg, was unavailable immediately following World War II. Instead, Jarvik (1948a) used a mass of material from 'Thurso' and other Caithness sites. *Osteolepis panderi* is a small species, usually not exceeding 135 mm in length, and therefore considerably smaller than most *O. macrolepidotus*, a close relative from Caithness and Orkney. There are also differences in the pattern of head bones, with numerous small bones at the front of the headshield in *O. macrolepidotus*, and very slight subdivision in this area in *O. panderi*. *Osteolepis macrolepidotus* is restricted to the Achanarras horizon (Saxon, 1978), whereas *O. panderi* is found in the Ham–Skarfskerry Subgroup, and rarely in the Mey Subgroup, in the Thurso area and in Weydale Quarry (q.v.), and in the upper Stromness and Rousay Groups of Orkney.

Interpretation

As at other localities, the vertebrate-bearing rocks are interpreted as lacustrine deposits. Fish fossils are found in a dark-coloured siltstone, which may represent an anoxic phase or a salinity crisis leading to a high fish mortality; mass mortality levels are associated with dolomitic laminae and hence with salinity crises (Hamilton and Trewin, 1994). The dominance of *Osteolepis panderi* may be a reflection of the absence of a large predator, and the lack of juveniles of this species suggests that the young kept to other parts of the lake and so were spared the mass mortality event.

Hamilton and Trewin (1994) plotted the distribution and abundance of the fish within the Holborn Head Quarry fish bed. This band is some 50 cm of dense carbonate or organic laminite, deposited apparently during the deepest part of the lake cycle (Figure 6.26).

Conclusion

The conservation value of Holburn Head Quarry results from the production of excellent specimens of the small osteolepiform *Osteolepis panderi*, as well as a fauna of acanthodians and placoderms typical of Fish Bed 4. Finds have been made recently in an excavation in the quarry floor to reach the fish bed, and there is future potential for more finds.

WEYDALE QUARRY (ND 146654)

Highlights

The fossil fishes from Weydale Quarry are mainly of small forms, and the preservation of detail is excellent. The small sarcopterygian *Osteolepis* is common.

Introduction

Weydale Quarry, Caithness (Highland), exposes Middle Devonian lacustrine flagstones. Crampton and Carruthers (1914, pp. 66–7) state that the pale-weathering beds of the 'Thurso Flagstone Group' (as seen at Weydale), represent rock underlying a wide tract of country in Caithness, and are equivalent to the lowest rocks of the Thurso coast.

Description

Weydale Quarry is a long rock face the stratigraphical position of which is unclear, as the area is obscured by thick deposits of drift, but it must expose either the upper part of the Ham–Skarfskerry Subgroup, or the lower part of the Mey Subgroup of the Upper Caithness Flagstone Group (Donovan *et al.*, 1974). Miles and Westoll (1963) used fossils and the regional dip to place the flagstones in Weydale Quarry about 1250 ft (400 m) above those at Achanarras. The fauna suggests that these beds belong to Fish Zone 5 of Donovan *et al.* (1974), as at Holburn Head Quarry (q.v.).

A faulted outcrop of fish bed, exposed at the northern end of Weydale Quarry, consists of 1.3 m of fish-bearing laminites, the upper and lower portions of which contain mainly fragmentary material, with a central 360 mm of light-grey calcareous laminite that yields complete fishes. Underlying the fish bed are 3 m or more of flagstones with subaqueous shrinkage cracks (Donovan and Foster, 1972). The upper part of the fish bed shows an increase in clastic sedimentation, paralleled by increased fragmentation of fish specimens, and is topped by a thin

(60 mm) calcareous laminated siltstone. The thin siltstone has been overturned and disrupted and has an irregular base upon the fish-bearing laminites. These features may have been produced either by bedding-plane slip prior to consolidation, possibly induced by seismic activity, as suggested by Trewin (1986) for similar structures at Achanarras Quarry, or they may have been dragged over by turbidity currents.

Fauna

Acanthodii: Acanthodida: Acanthodidae
  acanthodian indet.
Placodermi: Arthrodira: Homosteidae
  ?*Homosteus milleri* Traquair, 1888
Osteichthyes: Sarcopterygii: Osteolepiformes: Osteolepididae
  Osteolepis panderi (Pander, 1860)
  Thursius pholidotus Traquair, 1888
Osteichthyes: Sarcopterygii: Dipnoi: Dipteridae
  Dipterus cf. *valenciennesi* Sedgwick and Murchison, 1828

Most of the fishes occur in the central portion of the fish bed where calcareous laminites are developed. *Osteolepis panderi* is the most common species, but *Dipterus valenciennesi* also is abundant. *Osteolepis* occurs mainly within the central portion of the fish bed, and is most abundant in its upper portion. *Dipterus* also occurs most commonly within this bed. *Thursius* sp. was recorded by Saxon (1975), and commonly occurs as fragments throughout the whole fish bed. *Homosteus milleri* is the celebrated '*Asterolepis*' of Hugh Miller (1858). It occurs as large broken lumps of bone, which were once used in Caithness for fuel and would burn with a bright flame (Kinnear, 1893b).

Interpretation

It is likely that *Osteolepis panderi* had a limited geographical range, being known only from the Ham–Skarfskerry and Mey subgroups in north-eastern Caithness and from equivalent strata in Orkney. Weydale and nearby Stonegun are the southernmost sites from which *O. panderi* has been found. The material from Weydale is well preserved, unlike that from Holburn Head Quarry (q.v.), where specimens are flattened and have lost fine detail.

Conclusion

The finds of *Osteolepis panderi* and *Dipterus valenciennesi* give Weydale Quarry its conservation value as they have been useful in anatomical and systematic work because of the good quality of preservation. The dating of the site is difficult, but the fish faunas may be of stratigraphical value.

PENNYLAND (ND 114687–ND 102695)

Highlights

The coastal section at Pennyland in Caithness (Highland) has produced nine species of fossil fishes from high in the Middle Devonian succession. One of the more important fishes from here is the placoderm *Millerosteus minor*.

Introduction

Robert Dick, the Thurso baker, first collected fishes in the area in 1835. He began correspondence with Hugh Miller, and in 1845 sent him a collection of Caithness fish, which included material from 'Thurso'. Some of these were described by Miller (1849). Dick's material went to the RSM, where it was studied by Traquair from 1875 onwards, and Saxon (1978) has given revised faunal lists based on recent collecting. Geological sections of the site are given in Crampton and Carruthers (1914, p. 96), Donovan (1978, p. 46), and Donovan and Sanderson (1979, p. 129).

Description

Middle Devonian flagstones are exposed in a long section on the foreshore between Thurso and Scrabster. The sequence of 150 m of sediments is transitional between the Mey Subgroup of the Upper Caithness Flagstone Group and the John o'Groats Sandstone Group, and is poorly exposed because of faulting.

Donovan and Sanderson (1979) described a total of 20 laminites in the section, of which 16 contain fishes. However, most of these only yield small fragments, and only seven or eight laminites contain complete plates or complete fishes. Where subaqueous shrinkage cracks are well developed within the fish bed, the fossils tend to be entirely fragmentary. Complete head-

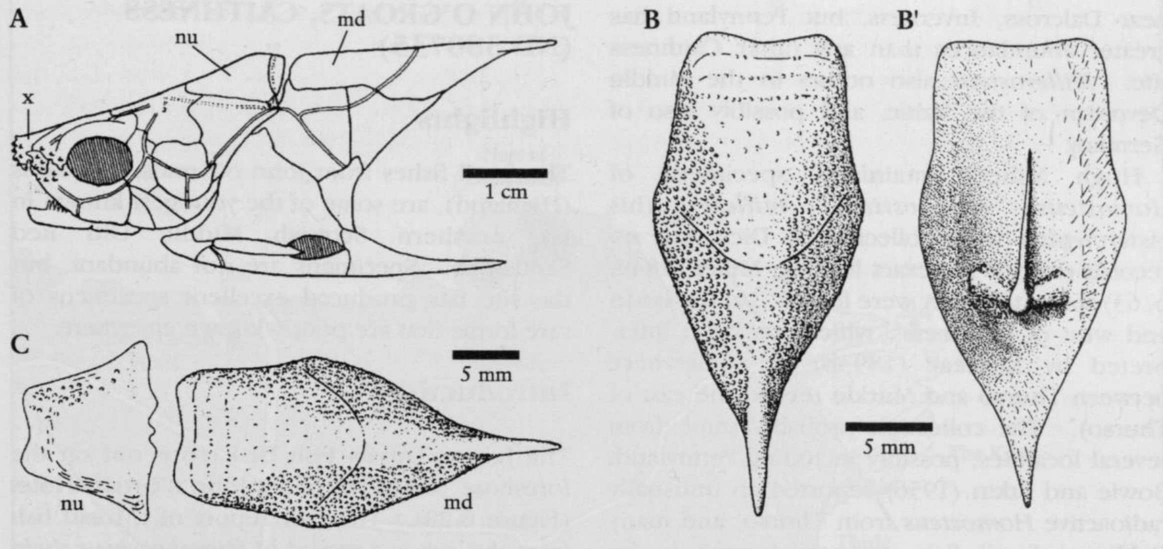

Figure 6.27 The arthrodire *Millerosteus minor* (Miller). (A) Reconstruction in lateral view of the head and thoracic region of this species from the Mey and Ackergill Beds, Thurso Flagstone Group, of Caithness and Orkney (after Desmond, 1974); md, median dorsal plate; nu, nuchal plate; x, rostrum. (B) median dorsal plate, external aspect; (B') median dorsal plate, internal aspect. (C) Nuchal plate, external aspect.

shields and fishes are only found where there has been a thick development of calcareous laminite with no cracks. Some bedding planes are rich in well-preserved heads and plates of fish, with very few finely broken or disarticulated fragments. Complete *Dipterus* are fairly common. Usually *Millerosteus minor* (Figure 6.27) is found as disarticulated, or semi-disarticulated plates, which at Pennyland are very well preserved in the lower part of the section, between ND 113688 and ND 110692. Articulating surfaces and other structures important for reconstructions can be seen in fine detail.

Fauna

Acanthodii: Acanthodiformes: Acanthodidae
Mesacanthus pusillus Agassiz, 1844
Acanthodii: Acanthodiformes: Diplacanthidae
?Rhadinacanthus longispinus Agassiz, 1844 (= Diplacanthus; see Denison, 1979, p. 32)
acanthodian indet.
Placodermi: Arthrodira: Homosteidae
Homosteus milleri Traquair, 1888
Placodermi: Arthrodira: Coccosteidae
Millerosteus minor Miller, 1858
Osteichthyes: Sarcopterygii: Osteolepiformes: Osteolepididae
Osteolepis ?panderi Jarvik, 1948
Osteichthyes: Sarcopterygii: Porolepiformes: Holoptychiidae
Glyptolepis cf. *paucidens* Agassiz, 1844
Thursius pholidotus Traquair, 1888
Osteichthyes: Sarcopterygii: Dipnoi: Dipteridae
Dipterus sp.

A typical Mey Beds fauna can be collected in these fish beds. *Millerosteus minor* is by far the commonest element of the fauna. *Thursius* and *Glyptolepis* occur, and complete specimens of *Dipterus* are fairly common. *Osteolepis* and *Homosteus* are rare. *Asterolepis orcadensis* occurs in Orkney in beds of equivalent age to the upper part of this sequence, but has not yet been discovered on the mainland of Scotland.

Millerosteus minor is a small coccosteid with an average length of 50–64 mm, although larger 150 mm specimens are known (Desmond, 1974) (Figure 6.27). The skull is typically coccosteid in most respects, but retains some primitive features (Denison, 1978). *Millerosteus minor* was named *Coccosteus minor* by Miller (1858), and the type locality is Kirkwall, Orkney. It was redescribed by Woodward (1891a) and Heintz (1938), and the monotypic genus *Millerosteus* was erected by Stensiö (1959); the Family Millerosteidae Stensiö (1963) was not given status by Denison (1978). Desmond (1974) redescribed *M. minor* based mainly on new material from Pennyland and Murkle Bay in Caithness. *M. minor* occurs in the Orkneys (Rousay Beds), Caithness (Mey Beds) and near Dalcross, Inverness, but Pennyland has greater abundances than any other Caithness site. *Millerosteus* also occurs in the Middle Devonian of the Baltic, and possibly also of Germany.

Hugh Miller's mainland specimens of *Homosteus (Homostius) milleri* (his '*Asterolepis*') were collected by Dick, but no records exist of the exact locality; Miller (1849, p. 63) stated that they were found '...in the north and west of Caithness', which has been interpreted by Kinnear (1893b) as somewhere between Thurso and Murkle (i.e. to the east of Thurso). The collection probably came from several localities, possibly including Pennyland. Bowie and Atkin (1956) reported an unusually radioactive *Homosteus* from Thurso, and many Caithness fossil fish are now known to be radioactive.

Interpretation

There is a gradual transition from predominantly lacustrine siltstones upwards into a more fluvially dominated sequence in the John o'Groats Group. Above the lower calcareous laminates, the lacustrine–fluvial cycles become increasingly dominated by fluvial beds represented by cross-bedded sandstones and penecontemporaneously deformed siltstones. Laminites are rarer than lower down in the Caithness Middle Devonian sequence, and they are dominated by subaqueous shrinkage cracks.

Locally *Millerosteus minor* is not present in beds which yield other members of the typical Mey Beds faunal assemblage, possibly because it was more sensitive to environmental controls than other cohabitants of the Orcadian Lake. It may have hunted in shoals (Desmond, quoted in Saxon, 1978).

Conclusion

The Pennyland succession has produced many fossil fish specimens from several horizons. Its importance and conservation value rests in the good-quality material of several species of placoderm and sarcopterygian, and in the fact that these faunas are dated as high in the Givetian, where good fish sites are rarer than for the lower horizons. Exposure is in wave-beaten low cliffs, and new specimens may be found at any time as a result of continuing erosion.

JOHN O'GROATS, CAITHNESS (ND 380735)

Highlights

The fossil fishes from John o'Groats, Caithness (Highland), are some of the youngest known in the northern Scottish Middle Old Red Sandstone. Specimens are not abundant, but the site has produced excellent specimens of rare forms that are poorly known elsewhere.

Introduction

The John o'Groats Fish Bed crops out on the foreshore 365 m NE of the John o'Groats Hotel (Figure 6.28). The first report of a fossil fish from this site is a record of *Microbrachius dicki* by C.W. Peach (1868). Fossils are said to be difficult to obtain from this locality (Westoll, 1948), but complete fishes can be collected, although they do not appear in such rich concentrations here as faunas in the older fish beds of the Caithness Flagstone Groups. An account of the locality is given in Trewin and Hurst (1993).

Description

The fish bed occurs as a thin band within the Last House Formation of the John o'Groats Sandstone Group (Foster, 1972; Donovan *et al.*, 1974) that forms the highest unit of the Middle Devonian in Caithness. The John o'Groats Group is dominated by cross-bedded sandstones, mainly yellow and buff below, reddish above, and which contain channels, evidence of dewatering structures, and grey fissile siltstones with desiccation cracks (Trewin and Hurst, 1993, p. 141).

The John o'Groats Fish Bed is the lowest of three thin silty carbonate laminites. It is faulted by a NE–SW-trending fault with a downthrow of 3.5 m, which displaces the bed north-eastwards on the seaward part of the foreshore (Foster, 1972). A marked notch indicates its outcrop across the foreshore in rocks which dip 20° to the east-north-east. Although scattered unidentifiable fish fragments occur elsewhere, this is the only fish bed within the 610 m of strata that make up the John o'Groats Sandstone Group, and is only exposed at this one locality. Nevertheless, the same fauna can be found in loose blocks on the shore at Gills Bay, where a fish bed presumably lies offshore.

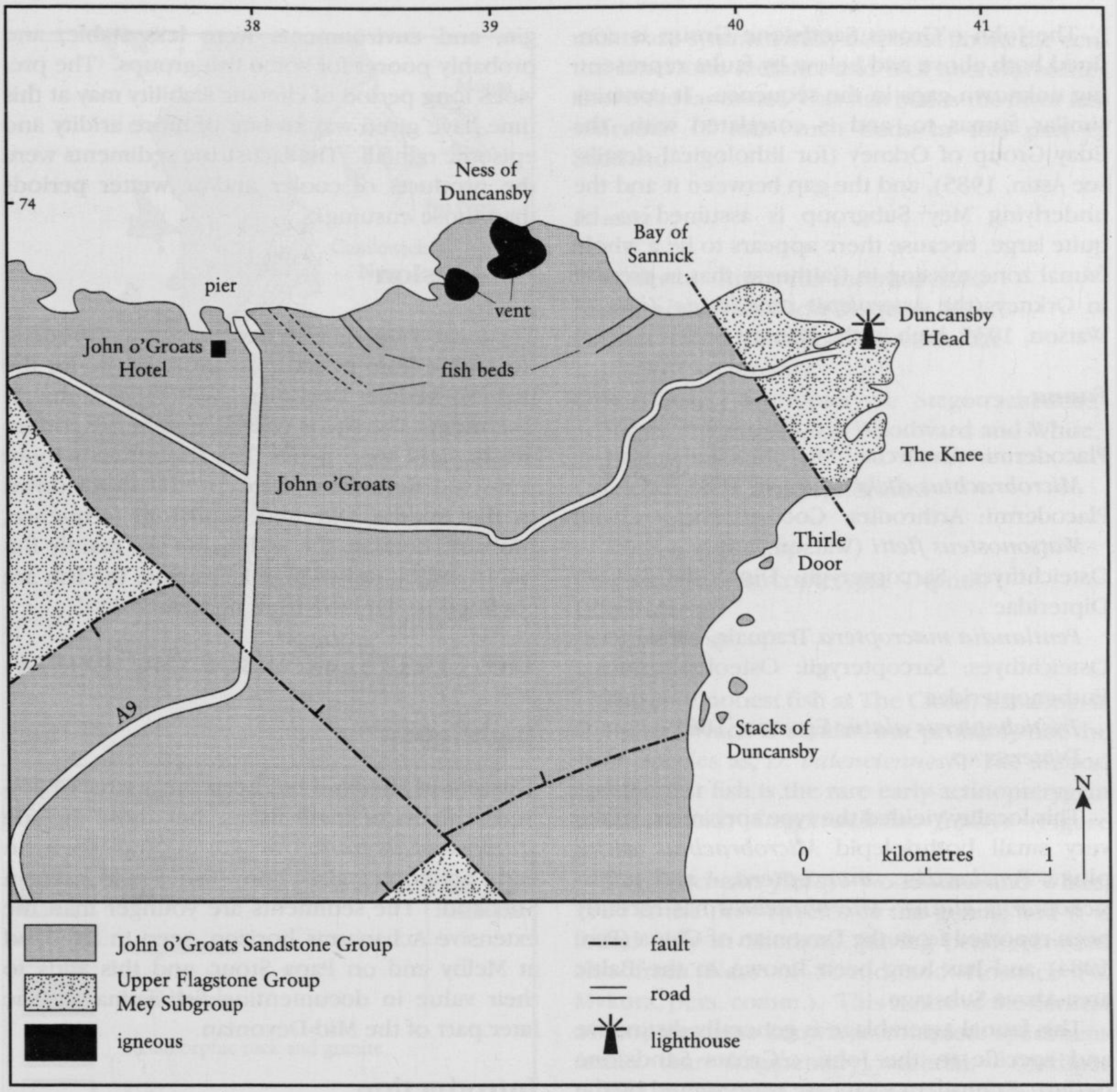

Figure 6.28 Locality map of the John o'Groats area (after Trewin and Hurst, 1993).

A section at the site, measured by M.A. Rowlands, is as follows.

	Thickness (m)
Red mudstones and coarse siltstones (fluvial)	3
Convoluted siltstone; pink weathering	0.6
Red mudstones, fining upwards	0.75
Dark grey, lacustrine varved laminite, becomes siltier upwards; rich in fish fragments, scales and coprolites	0.2
Green-grey mudstone	0.01
Hard light-grey dolostone	0.02
Red and green mudstones	0.04
Dark grey laminated siltstones with dolostone bands	0.37
John o' Groats Fish Bed; light-grey varved laminite, more calcareous at base; scales, fragments, and occasional complete fishes more common in upper part of bed, in siltier and better laminated siltstone	0.25
Convoluted, laminated siltstone with mudcracks and coarse siltstone dyke	0.1
Grey siltstone	0.02
Laminated, calcareous, dark grey siltstone	0.03
Soft bituminous shale	0.07
Dark grey siltstones with subaerial desiccation cracks in upper part, alternating with green mudstones and siltstones	0.08
Alternating red mudstones and thin (*c.* 50 mm), pink siltstones (fluvial)	10 +

The John o'Groats Sandstone Group is confined both above and below by faults representing unknown gaps in the sequence. It contains similar faunas to, and is correlated with, the Eday Group of Orkney (for lithological details, see Astin, 1985), and the gap between it and the underlying Mey Subgroup is assumed to be quite large, because there appears to be a whole faunal zone missing in Caithness that is present in Orkney (the *Asterolepis orcadensis* Zone of Watson, 1935, high in the Rousay Beds).

Fauna

Placodermi: Antiarcha: Microbrachiidae
Microbrachius dicki Traquair, 1888
Placodermi: Arthrodira: Coccosteidae
Watsonosteus fletti (Watson, 1932)
Osteichthyes: Sarcopterygii: Dipterida: Dipteridae
Pentlandia macroptera Traquair, 1889
Osteichthyes: Sarcopterygii: Osteolepiformes: Euthenopteridae
Tristichopterus alatus Egerton, 1861
Dipterus sp.

This locality yielded the type specimens of the very small bothriolepid *Microbrachius dicki*, plus *Pentlandia macroptera*, and *Tristichopterus alatus*. *Microbrachius* has recently been reported from the Devonian of China (Pan, 1984) and has long been known in the Baltic area Abava Substage.

This faunal assemblage is generally distinctive and specific to the John o'Groats Sandstone Group. Equivalent strata are represented by the Eday Flags in Orkney and the Brindister Flags in Shetland, which both contain similar faunas. The assemblage represents Faunal Zone 7 of Donovan *et al.* (1974), the top of the Middle Devonian sequence, and dated as mid- to late Givetian in age.

Interpretation

The lithological sequence has been interpreted as representing a low-angle broad alluvial fan with shallow channels, transgressed periodically by lake waters wherein lived the fish communities. The fauna from the fish bed consists of five species, fewer than in older fish beds of the Orcadian Basin. This may relate to the fact that the strata high in the Middle Devonian sequences are more fluvial than lacustrine in origin, and environments were less stable, and probably poorer for some fish groups. The previous long period of climatic stability may at this time have given way to one of more aridity and episodic rainfall. The lacustrine sediments were the products of cooler and/or wetter periods than those ensuing.

Conclusion

The John o'Groats Fish Bed derives its conservation value from its status as the best site for the highest Middle Devonian fish zone fauna in Caithness. The site is coastal, and hence continues to yield specimens. The fish fauna is more restricted than those encountered lower down in the Middle Old Red Sandstone sequence, probably because the sediments are mainly fluvial in origin, rather than lacustrine; the fish are confined to the lacustrine phases.

THE CLETTS, EXNABOE (HU 399114)

Highlights

This site in Shetland has been the source of limited remains of fossil fishes, but these include *Stegotrachelus finlayi* Woodward and White, an early actinopterygian bony fish found only in Shetland. The sediments are younger than the extensive Achanarras horizon, seen in Shetland at Melby and on Papa Stour, and this adds to their value in documenting fish faunas in the later part of the Mid-Devonian.

Introduction

Exnaboe Fish Bed is a 3 m thick unit of fish-bearing lacustrine limestone laminites within the south-east Shetland Devonian basin of deposition, which outcrops today from Rova Head south to Sumburgh Head in southeast Mainland, and is one of three basins which are juxtaposed in Shetland by major transcurrent faults.

Although fossil fishes have been known from the Middle Devonian of Scotland since 1827, and although the resemblance between the Shetland Flags and those of Orkney and the mainland was generally recognized, fossil fishes were not discovered in Shetland for some time. The first report was of fragments from Bressay (Heddle, 1879). Exnaboe Fish Bed was discovered by T.M. Finlay (1926), and that paper included a report on the fishes by A.S.

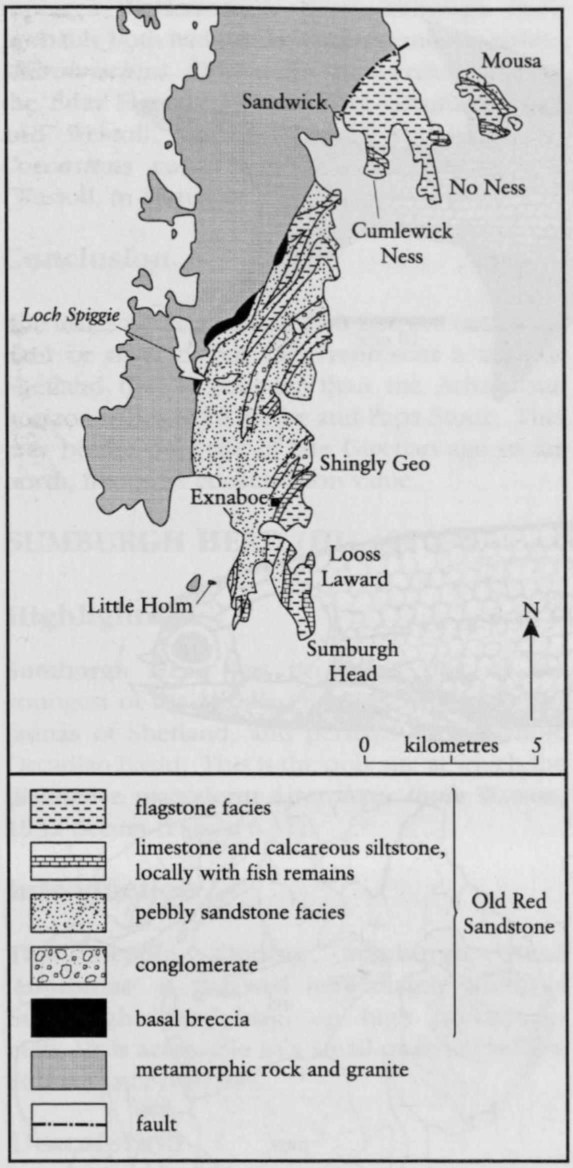

Figure 6.29 Sketch map of the geology of south-east Shetland, including Exnaboe and Sumburgh Head (after Mykura, 1976).

Woodward and E.I. White. The geology of the area has been revised by Wilson and Knox (1936) and Mykura (1976; Figure 6.29).

Description

The Exnaboe Fish Bed falls within the 'Brindister Flags' of Wilson and Knox (1936). The lacustrine facies occurs within thick cross-bedded fluvial sandstones and is mainly represented by horizontally stratified fine sandstones (P.A. Allen, 1981) (Figure 6.29). Allen noted that the sediments are symmetrically disposed about the central limestone member and lack microturbidites above the laminite. This fish bed is the most fossiliferous of four such beds in this part of Scotland.

Fauna

Placodermi: Antiarcha *incertae sedis*
Microbrachius dicki Traquair, 1888
Placodermi: Arthrodira: Coccosteidae
Coccosteus sp. nov.
Osteichthyes: Actinopterygii: Stegotrachelidae
Stegotrachelus finlayi Woodward and White, 1926
Osteichthyes: Osteolepiformes: Eusthenopteridae
Tristichopterus sp.
Osteichthyes: Sarcopterygii: Dipnoi: Dipteridae
Dipterus sp.

The commonest fish at The Cletts, Exnaboe, is *Dipterus*, which is similar, but probably not the same species as, *D. valenciennesi*. The second commonest fish is the rare early actinopterygian (palaeoniscid) *Stegotrachelus finlayi* (Figure 6.30A).

Stegotrachelus finlayi Woodward and White, 1926 is the only species of the genus, and it is found only in Shetland, having been recorded also from Ness of Sound and Hoswick (W. Mykura, pers. comm.). This is one of the earliest actinopterygians known as complete specimens rather than fragmentary material. Gardiner (1963) redescribed the species using newly collected material but in 1984 he concluded that the family Stegotrachelidae Gardiner, 1963, based on the type (Australian) species *Mimia toombsi* Gardiner and Bartram, 1977, contained forms that shared only primitive characteristics with *Stegotrachelus* and that further affinities remained obscure until more is known about this genus.

Interpretation

This is a very similar fauna to that which occurs at John o'Groats, yielding *Microbrachius dicki*, *Watsonosteus fletti*, *Tristichopterus alatus* and *Pentlandia macroptera* (Figure 6.30B). The Exnaboe Fish Bed is probably slightly younger than the John o'Groats and Eday fauna; *Dipterus* sp. replaces *Pentlandia*, and *Coccosteus* sp. nov.

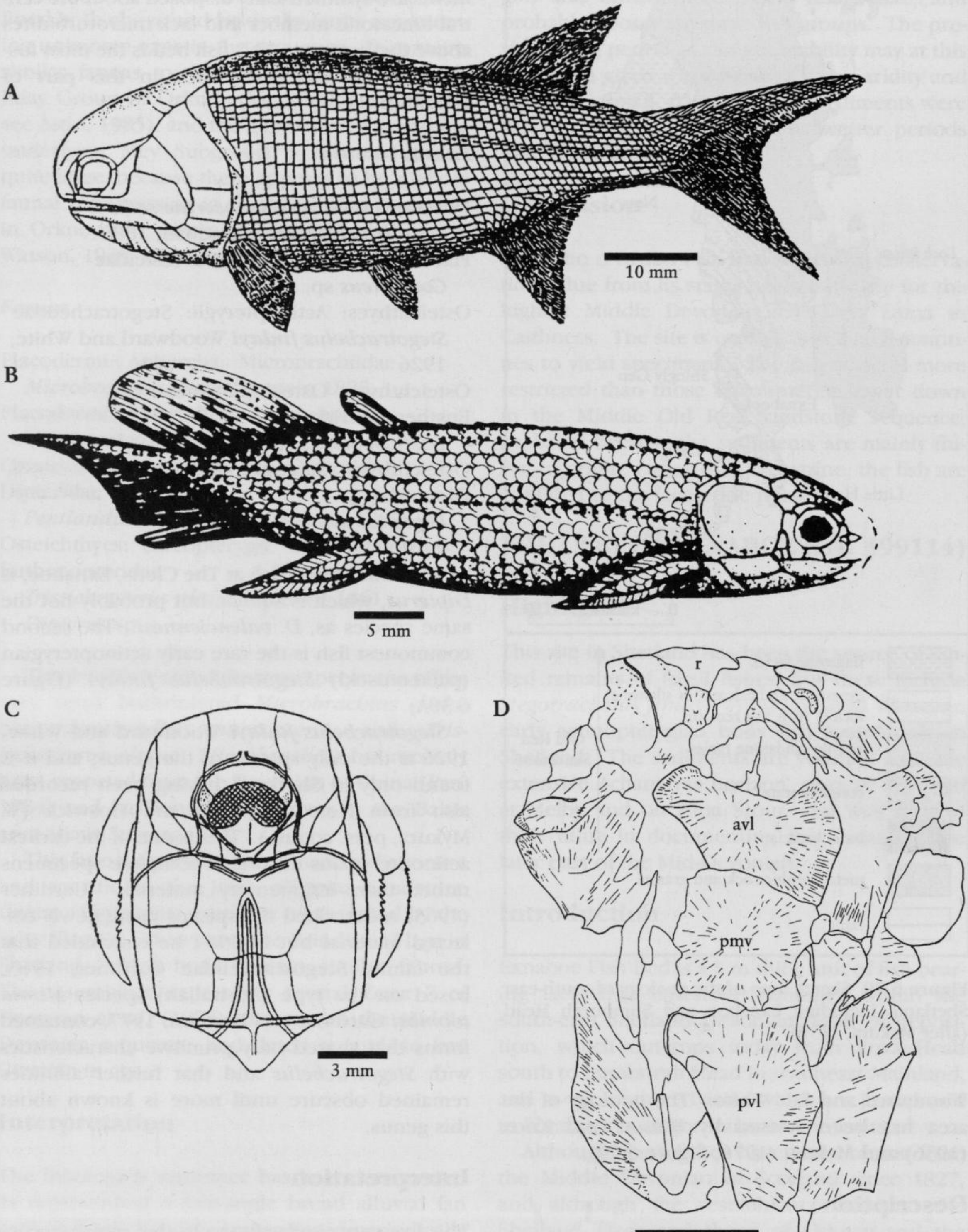

Figure 6.30 Fossil fish found at Exnaboe, Shetland. (A) *Stegotrachelus finlayi* Woodward and White, an early actinopterygian from Exnaboe; (B) *Pentlandia macroptera* Traquair, × 0.5; (C) *Microbrachius dicki* Traquair, reconstruction in dorsal view of the carapace of the smallest antiarch, based largely on RSM 1877.22.4 from John o'Groats and DMSW P 513 from Deerness; (D) *Watsonosteus fletti* (Watson) from Deerness (after Miles and Westoll, 1963); outline drawing of NHM P 11732 in dorsal view; avl, anterior ventro-lateral plate; pmv, posterior ventro-lateral plate; pvl, posterior ventro-lateral plate; r, rostrum.

replaces *Watsonosteus fletti*, although they probably both had similar habitats and life styles. *Microbrachius dicki* suggests correlation with the Eday Flags of Orkney (late Givetian; Miles and Westoll, 1963), but the specimens of *Coccosteus* could represent an earlier age (Westoll, *in* House *et al*., 1977).

Conclusion

The fishes of the Exnaboe Fish Bed are not abundant or diverse, but they represent a unit in Shetland that is younger than the Achanarras horizon fishes from Melby and Papa Stour. This may be the only site of late Givetian age so far north, hence its conservation value.

SUMBURGH HEAD (HU 407078)

Highlights

Sumburgh Head has produced one of the youngest of the Middle Old Red Sandstone fish faunas of Shetland, and perhaps of the whole Orcadian Basin. This is the only site at which the distinctive placoderm *Asterolepis thule* Watson, 1932 occurs (Figure 6.31).

Introduction

The steeply dipping Sumburgh Head 'Limestone' is exposed immediately south of Sumburgh Lighthouse, on high precipitous cliffs. It is accessible in a small quarried hollow at the top of the cliffs.

Description

The Old Red Sandstone clastic rocks at Sumburgh Head (Figure 6.29) are grouped in the Brindister Flags. At this locality, 5 m of south-easterly dipping, fine-grained, thinly bedded and partly laminated calcareous siltstones with some thin bands of dark sandstones are exposed. The siltstones contain abundant plant fragments. In the basal few centimetres of some of the fine sandstone units are patches of coarse gritty sandstone with fish fragments.

Fauna

Placodermi: Antiarchi: Asterolepidae
Asterolepis thule Watson, 1932
Osteichthyes: Sarcopterygii: Osteolepiformes:

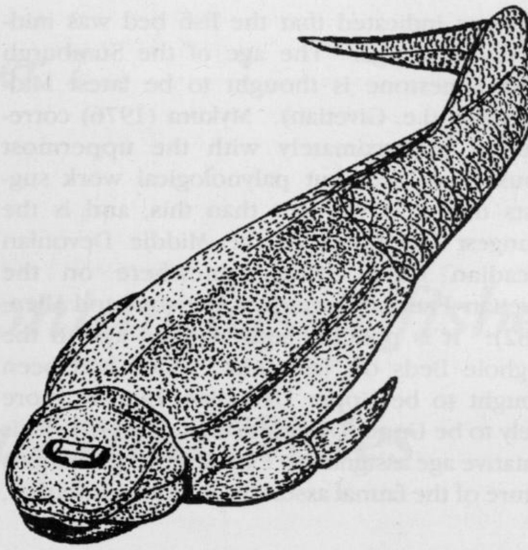

Figure 6.31 The antiarch *Asterolepis thule* Watson from Sumburgh Head, *c*. × 0.2. Reconstruction after Janvier (1996).

Eusthenopteridae
Tristichopterus sp.
Osteichthyes: Sarcopterygii: Dipnoi: Dipteridae
?Dipterus sp.

A specimen of *Asterolepis* was recovered by Geological Survey officers from Sumburgh Head, and named *A. thule* by Watson (1932). The headshield is long (40 mm) and narrow, and Watson (1932) described it as closely allied to *A. ornata* from the Lower Frasnian of the Baltic, and to *A. maxima* from the Frasnian of Nairn (Figure 6.31). Asterolepids occur in the Eifelian of the Baltic, and the Upper Givetian and Lower Frasnian of the Baltic, East Greenland, Spitsbergen, Australia, Nairnshire and the Orkney Islands. Paton (1981) lists from John o'Groats a fragment of *Asterolepis* cf. *thule*, which may be a mis-identification. Sumburgh is therefore the type and only locality for *A. thule*, but *Asterolepis* sp. is recorded from Voe of Cullingsburgh, Bressay, in the lowermost Frasnian (Woodward and White, 1926).

Interpretation

If it had not been for the associated fauna, Watson (1932) would have regarded *Asterolepis thule* as a typical Late Devonian form, but instead he assumed that the presence of *Dipterus* sp. and *Tristichopterus* sp. in lacustrine laminites indicated that the fish bed was mid-Devonian in age. The age of the Sumburgh Head Limestone is thought to be latest Mid-Devonian (i.e. Givetian). Mykura (1976) correlated it approximately with the uppermost Mousa Fish Bed, but palynological work suggests that it is younger than this, and is the youngest fish fauna of the Middle Devonian Orcadian Basin, lying somewhere on the Givetian–Frasnian boundary (Marshall and Allen, 1982). It is possibly equivalent in age to the Boghole Beds of Nairnshire, which had been thought to be Upper Devonian, but are more likely to be Upper Givetian (Westoll, 1979). This tentative age assignment explains the anomalous nature of the faunal assemblage from Sumburgh, which contains Frasnian and Middle Devonian elements.

Conclusion

The fossil fishes from Sumburgh Head are sparse, but they represent an instant in time, perhaps close to the Middle and Upper Devonian boundary, hence the site's conservation value. Two of the fishes are typical of earlier Middle Old Red Sandstone assemblages, but *Asterolepis thule* has more in common with Late Devonian fishes from elsewhere. The fish-bearing rocks at this site are well exposed, and more finds may be made.