Mesozoic and Tertiary Palaeobotany of Great Britain

C.J. Cleal

Department of Biodiversity and Systematic Biology,
National Museums and Galleries of Wales,
Cardiff, UK

B.A. Thomas

Welsh Institute of Rural Studies,
University of Wales Aberystwyth,
Aberystwyth, UK

D.J. Batten

Institute of Geography and Earth Sciences
University of Wales Aberystwyth,
Aberystwyth, UK

and

M.E. Collinson

Geology Department,
Royal Holloway University of London,
Egham, UK

GCR Editor: **D. Palmer**

JOINT NATURE CONSERVATION COMMITTEE

Chapter 5

The Jurassic palaeobotany of Scotland

B.A. Thomas and D.J. Batten

INTRODUCTION

For most of the Jurassic Period, Scotland was an upland area where there was little or no build-up of sediment to form a stratigraphical and palaeobotanical record (see Figure 3.2). Sediment did, however, accumulate around the eastern and western coastal areas, and this has preserved a partial record of the vegetation growing in the vicinity, at least for the Middle and Late Jurassic epochs. The floras are not as diverse or well preserved as those from Yorkshire, nor have they been subjected to investigation over as long a time as those in southern England. Nevertheless, they are of interest with respect to both their species composition and their preservation. Many differ in age (Kimmeridgian to Portlandian) from the other British floras.

HISTORY OF RESEARCH

A number of early records of plant fossils from the Jurassic strata of Scotland were made by König in Murchison (1827) and Lindley and Hutton (1832). However, there was little palaeobotanical research in the Scottish academic institutions during the 19th century. Much of the early work was done by amateurs. Most notable among these was the stonemason, turned popular scientist and charismatic preacher, Hugh Miller (1857, 1861), some of whose specimens were described by Richards (1884). Some floras were also described by geologists in their stratigraphical studies, such as Judd's (1873) description of the Brora flora in his review of the Mesozoic stratigraphy of Scotland. The only other notable 19th century record of plants from Brora was by Carruthers (1870a).

During the early 20th century, the Scottish plant fossils started to attract the attention of specialist palaeobotanists. Stopes (1907) published a detailed account of the Brora assemblage, and Seward (1911) and Seward and Bancroft (1913) did the same for other Sutherland floras. For many years these remained the definitive accounts. Little more was published apart from a brief description of fossils from Brora by Harris and Rest (1966). Recently, however, palaeobotanists from Utrecht have been re-examining the floras, the results of which have been published in a series of papers (van der Burgh, 1987; van der Burgh and van Konijnenburg-van Cittert, 1984; van Konijnenburg-van Cittert and van der Burgh, 1989, 1996).

The west of Scotland has only one locality for Jurassic plant fossils. This newly discovered site at Bearreraig on the Trotternish Peninsula of the Isle of Skye has yielded well-preserved plants in calcitic and sideritic nodules (Bateman and Morton, 1994; Dower and Bateman, 1998; Bateman *et al.*, in press).

PALAEOGEOGRAPHICAL SETTING

During the Jurassic Period, most of Scotland was part of the Scottish Landmass and a centre of erosion rather than deposition (see Figure 3.2). However, there are important successions of this period in the Inner Hebrides and along a narrow western strip of the mainland coast. These range from Hettangian to Kimmeridgian in age (Morton and Hudson, 1995). On the eastern side of the country, there is some evidence of non-marine deposition in the Early and Middle Jurassic epochs, but most of the succession is offshore. Only the relatively small area around Golspie and Brora has any onshore exposure. A major marine transgression took place at the start of the Callovian, possibly triggered by tectonic activity in the North Sea. This resulted in flooding of what is now known as the Moray Firth Basin and the development of shallow marine sedimentary sequences along a narrow strip of the Sutherland coast.

Late Jurassic global palaeogeography was not significantly different from that of the Middle Jurassic Epoch (see Figure 3.1) except for the expansion southwards of the arid region into southern Africa and southern South America. It was a time of marked climatic warming that in the Northern Hemisphere resulted in a northwards movement of the main floristic boundaries (Vakhrameev, 1991). Vakhrameev placed the Scottish Late Jurassic floras in their own floristic province, (the 'Scottish Province'), which he interpreted as being intermediate between the Siberian and the more typical Euro-Sinian floras such as found in southern Europe.

STRATIGRAPHICAL BACKGROUND

The Jurassic stratigraphy of Scotland has been summarized by Cope *et al.* (1980a,b). Jurassic deposits in the Moray Firth Basin of Sutherland range in age from late Sinemurian to early Pliensbachian (early Jurassic) at Dunrobin Bay

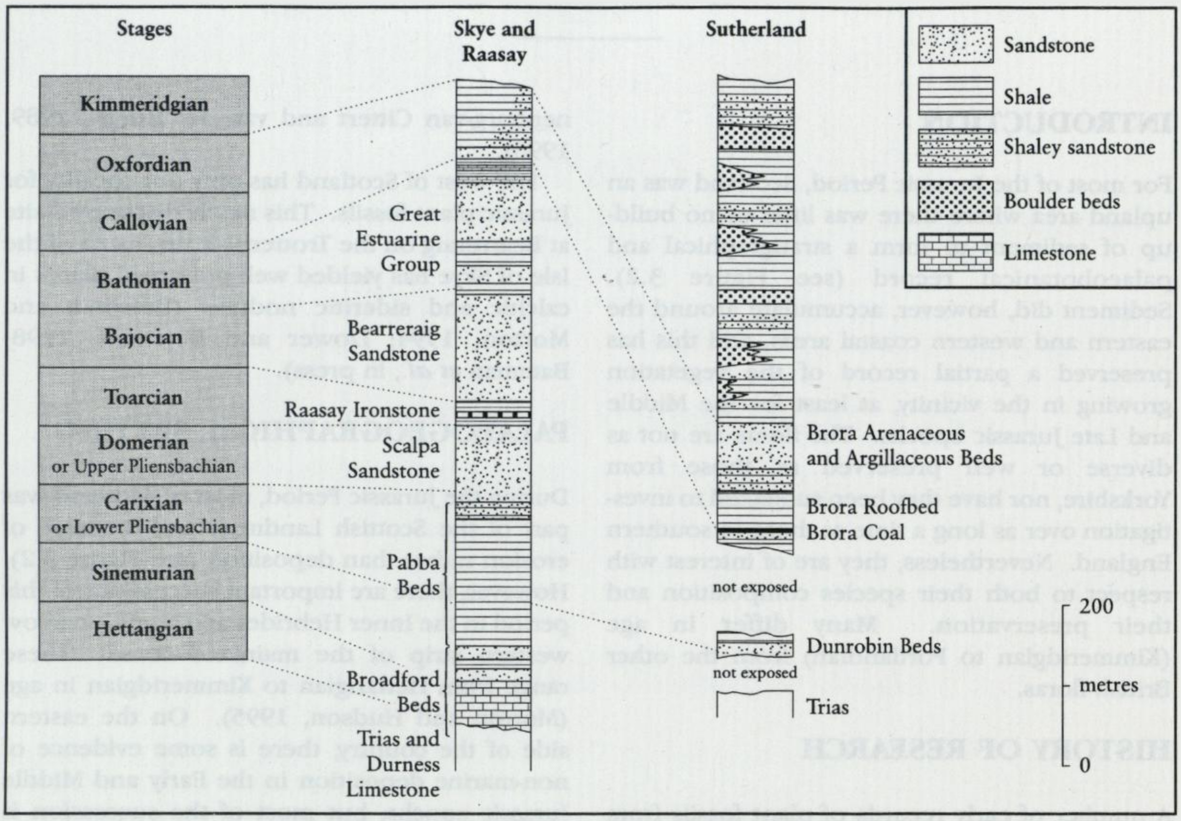

Figure 5.1 Correlation of Jurassic rocks in the northern Inner Hebrides and Sutherland. (After Hallam, 1983.)

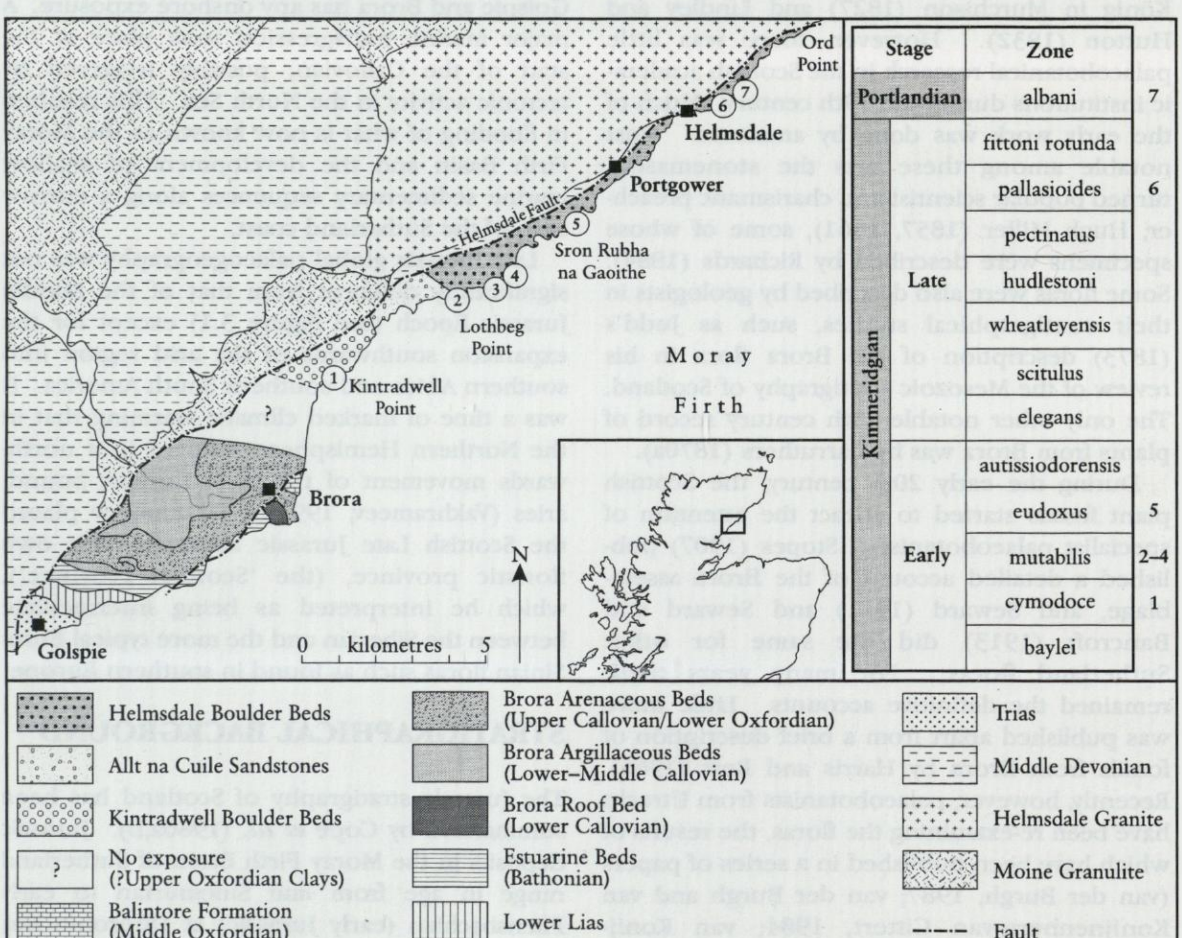

Figure 5.2 Location and relative stratigraphical positions of the main Kimmeridigian and Portlandian palaeobotanical localities along the Sutherland coast. (Adapted from Pickering, 1984, and van Konijnenburg-van Cittert and van der Burgh, 1996.)

Farm, near Golspie, through Bathonian at Brora to Early Portlandian at Navidale (Figures 5.1 and 5.2). They form the only accessible part of the extensive Jurassic deposits in the North Sea Basin. The western margin is clearly delineated by the Helmsdale Fault (Johnson and Mykura, 1989). The beds are largely covered by moraine and are exposed only along the coast, and in river sections and disused quarries.

Morton and Hudson (1995) gave a detailed account of the Hebridean sequence. The deposits are mainly shallow marine, except for the Great Estuarine Group, which is lagoonal. However, it is the Bearreraig Sandstone, which underlies the Great Estuarine Group, that has yielded plant fossils.

JURASSIC VEGETATION IN SCOTLAND

The composition of the vegetation during the Jurassic Period was broadly similar to that in Yorkshire (see Chapter 3). Ferns and bennettites are especially abundant in the fossil record, while drought-resistant conifers with *Brachyphyllum* foliage are relatively rare. Czekanowskias occur in the Upper Jurassic strata. These are otherwise unknown from northern temperate latitudes (Vakhrameev, 1991).

PALAEOBOTANICAL SITES IN THE JURASSIC ROCKS OF SCOTLAND

Plant fossil assemblages are now known from ten localities, four of which are included here as GCR sites together with one potential site (Lothbeg Point). Two are Middle Jurassic in age: Bearreraig (Aalenian–Bajocian) and Brora (Bathonian). As these are unique localities, they have been selected as GCR sites.

The commonest plant remains in the Scottish Jurassic strata are Kimmeridgian in age. They are known from a series of coastal localities, which become slightly younger from south to north: Kintradwell and Eathie are in the *cymodoce* Zone; Lothbeg Point, Craikaig Links and Kilmote are middle Kimmeridgian; and Culgower is in the *mutabilis* Zone (Figure 5.2). Culgower is the best known for adpression fossils, and Eathie for petrifactions; therefore these have been selected as GCR sites. However, the newly discovered Lothbeg Point plant bed provides a significant comparison with Culgower and thus also merits selection for the GCR.

The overlying upper Kimmeridgian–Portlandian (Volgian) succession also includes several known palaeobotanical localities, notably at Helmsdale and Navidale. The latter was originally thought to be Kimmeridgian but palynological evidence has shown it to be younger (Riley, 1980). However, neither is deemed to now yield plant fossils of sufficient interest to justify selection as a GCR site.

The depositional environments of the plant assemblages varied considerably, reflecting taphonomic more than any innate floral differences within the region. That at Brora was lagoonal in origin with an in-situ build up of plant growth and deposition to give coal. Some, such as at Culgower, represent a nearby vegetation with some upland elements washed in. Others, such as at Lothbeg Point, represent drifted plant remains that are found in association with marine indicators. From the evidence of these different assemblages, van Konijnenburg-van Cittert and van der Burgh (1996) have interpreted the ecology of the Kimmeridgian flora as plants growing along and near to river banks, with their debris accumulating in deltas or being transported out to sea. They grouped the plants according to the most probable occurrence: brackish areas or saltmarsh (five species); freshwater swamp (five species); moist lush vegetation (the richest in species); upland forest (a few species) and heath (only two species).

The plant fossils from Bearreraig, Eathie and Helmsdale are rather different in that they are preserved as permineralizations. Those at Bearreraig and Eathie are in calcareous nodules, while the Helmsdale fossils are fragments of wood.

BRORA (NC 896 029–NC 904 033)

Introduction

The coastal exposures at Brora are of Bathonian age. They yield a well-preserved, but fragmentary, flora of at least 12 species that is of considerable research potential.

The Brora region was referred to by geologists even before Murchison (1827) because of the economic importance of workable coal and building stone. Coal extraction began here in 1529 and the first pit was sunk in 1598. Since then, coal has been mined periodically until the last pit closed in 1974 (Owen, 1995). Plant fossils were first described by König in Murchison (1827) and Nicol (1844), and then by Judd (1873) in his memoir on the secondary rocks of Scotland. However, only *Equisetites columnaris* was named. The assemblage was not described in detail until Stopes (1907) revisited the site. The most recent contribution was by Harris and Rest (1966) who examined cuticle fragments macerated from the coal.

Description

Stratigraphy

The beds exposed at Brora range from Bathonian to Callovian in age, although the palaeobotanical interest is limited to the Brora Coal Formation (named by Neves and Selley, 1975), which is Bathonian in age (Figure 5.3). Hurst (1981) later divided the formation into the Doll Member with its fluvial succession of channel sandstones and floodplain mudstones, and the overlying Inverbrora Member of dark shales with thin coals, bituminous shales and some shell beds of lagoonal origin. The lagoonal area is thought to have extended parallel to the Helmsdale Fault system and was probably invaded periodically by the sea from the north-east (Trewin, 1993). The recovery of the dinoflagellate cyst *Tubotuberella* cf. *dangeardii* Sarjeant in the topmost shell bed has permitted the whole of the Brora Coal Formation to be dated as Bathonian, with the boundary between it and the overlying Callovian being placed at the roof of the coal. The exposure comprises the only rocks that can be compared closely, with regard to sedimentology and palynofacies, to the economically important sedimentary rocks in the Moray Firth and further into the North Sea.

Palaeobotany

The plants are drifted fragments found in association with the fresh–brackish water crustacean

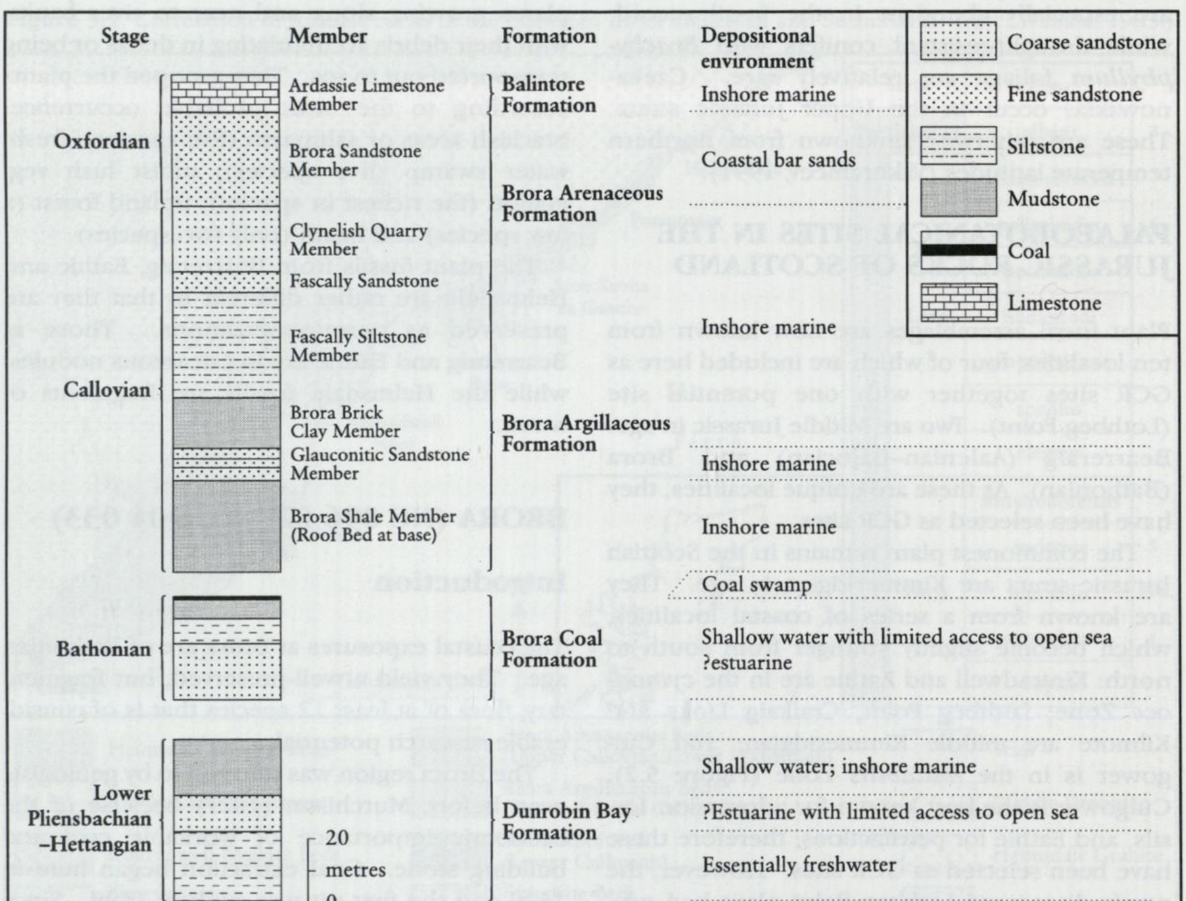

Figure 5.3 Generalized sequence of Jurassic strata in the Brora outlier. (After Lam and Porter, 1977.)

Euestheria. Stopes recorded the following species:

Equisetales: *Equisetites beanii* Bunbury, *Equisetites broraensis* Stopes, *Equisetum columnaris* Brongniart (Harris)
Filicales: *Coniopteris hymenophylloides* Brongniart, *Coniopteris quinqeloba* Phillips, *Todites williamsonii* Brongniart, *Cladophlebis denticulata* Brongniart, *Dictyophyllum* sp.
Cycadales: *Zamites* sp.
Bennettitales: *Otozamites* sp.
Ginkgoales: *Ginkgo digitata* Brongniart
Pinales: *Cheirolepis* sp.

Interpretation

The Bathonian assemblage at Brora is the youngest Jurassic flora in the area. No detailed assessment of the plants has been made for 90 years so the site has, therefore, considerable research potential.

The assemblage is very similar in composition to those of some sites in the Yorkshire Jurassic succession. It is dominated by pteridophytes and contains very few gymnosperms. This suggests that it largely represents vegetation growing fairly close to the site of deposition, most probably in a freshwater swamp. There is no seat earth below the coal, which led Trewin (1993) to infer that the coal formation was initiated by plant material that drifted into a lagoon too deep to allow plants to root. Stopes counted the individuals of each species and deduced from this that *Equisetum columnaris* and *Ginkgo digitata* were the most numerous of the plants. This, however, tells us very little about the original vegetation other than that *Equisetum columnaris* probably grew in quantity close to the area of deposition. The larger, but less perfectly known, *Equisetites beanii* is a distinct species that is never found mixed with *E. columnaris*. It must have grown away from the edges of the watercourses that fed the area of sedimentation. Stopes described *Equisetum brorarensis* (as it is preferably named) from small round discs representing nodal diaphragms dispersed from the disintegrating stems. Their size distinguishes them from the other two species. They may represent the remains of plants growing some distance from the area of sedimentation.

The *Ginkgo* leaves are the best-preserved fossils in this assemblage and agree entirely with those found in Yorkshire. Most are deeply bilobed although Stopes found one or two small unlobed leaves. She prepared cuticles from these leaves and showed that the stomata are confined to the lower surfaces. Harris *et al.* (1974) took a different view and suggested that the leaves are very similar in form and epidermal structure to his *Sphenobaiera gyron* from Broughton (Hasty) Bank.

Most of the plant remains are poorly preserved, suggesting that they had been transported to the site of deposition. *Ginkgo* leaves do not decay rapidly and appear to fossilize well, so they could also have been blown, or washed, in, from quite a distance. The comparatively few specimens of *Zamites* and *Otozamites* again suggest that they came from some distance away.

The Brora coal does not crop out on the beach, but a study of it does have a bearing on our understanding of the flora growing in the area at that time. Harris and Rest (1966) macerated coal from the Brora mine that was still operative at the time. They found the most abundant plant material to be fusainized conifer wood, which must have been washed down after forest fires to become deposited in a moderately deep lagoon. Most of the coal was formed from such wood. Anaerobic conditions would have prevailed, allowing the debris to build up. Rootlets from a dirt band within the coal suggest that swamp conditions subsequently spread over the lagoon, leading to the accumulation of plant debris that included *Equisetum*. There were also small fragments of the bennettitalean *Pterophyllum cycadites*, which probably grew on the banks of rivers. The other species, found only occasionally, were most probably carried down greater distances by rivers. Harris and Rest listed the following plants from the coal: stem cuticles of *Equisetum* cf. *columnare*, *E.* cf. *laterale* and *E.* sp. indet.; pteridophyte wood as fusain; leaf fragments of the cycad *Pterophyllum cycadites* Harris and Rest (also found in the Yorkshire Jurassic succession; see Table 3.1); *Czekanowskia* sp. indet.; conifer wood of many kinds as fusain; and leaf cuticles of the conifer *Farndalea fragilis* Bose. This last species is perhaps the most widespread of all the Yorkshire Jurassic plants, being always present as scattered fragments in bulk maceration of rock. However, it has never been found as a recognizable hand specimen, suggesting that it must have grown on land either far up river or away from water courses, being washed down only in times of flood and deposited as scattered and finely broken fragments. This species can almost certainly be found in the rocks exposed on the beach.

Harris and Rest also reported 'fibrous brown sacs'. Manum *et al.* (1991) have interpreted similar sacs as reproductive cocoons of annelid worms.

They also gave brief descriptions of several megaspores identified by W.G. Chaloner. The currently accepted names (Batten and Kovach, 1990) are as follows: *Minerisporites richardsonii* (Murray) Potonié emend. Harris, *Paxillitriletes phyllicus* (Murray) Hall and Nicolson, *Bacutriletes corynactis* (Harris) Marcinkiewicz, and *Triletes murrayi* Harris. These megaspores might easily be recovered from rocks exposed on the beach.

Conclusion

The Bathonian assemblage at Brora is the youngest Jurassic flora in the Moray Forth Basin. Although small, it has many similarities with those of the Yorkshire Jurassic succession. It is a nationally important site of great potential research value.

CULGOWER BAY (NC 991 117)

Introduction

This is by far the most significant Late Jurassic flora in Britain, and it rates as one of the most important in Europe. It has yielded over 50 species of plants, including conifers, ginkgos, bennettites and ferns, the latter being particularly abundant and well preserved. They include several species recorded only from this locality and others recorded from only two or three of the other Sutherland floras.

The flora was discovered in the 19th century by an amateur palaeontologist, Marcus Gunn, who was to have collaborated with Albert Seward in describing the material. However, Gunn's death prevented this from happening and his collection was not described until Seward (1911) and Seward and Bancroft (1913) published their more general study on the Sutherland Jurassic flora. No further work appeared in print until that of van der Burgh (1987) and van Konijnenburg-van Cittert and van der Burgh (1989, 1996), upon which this account is based.

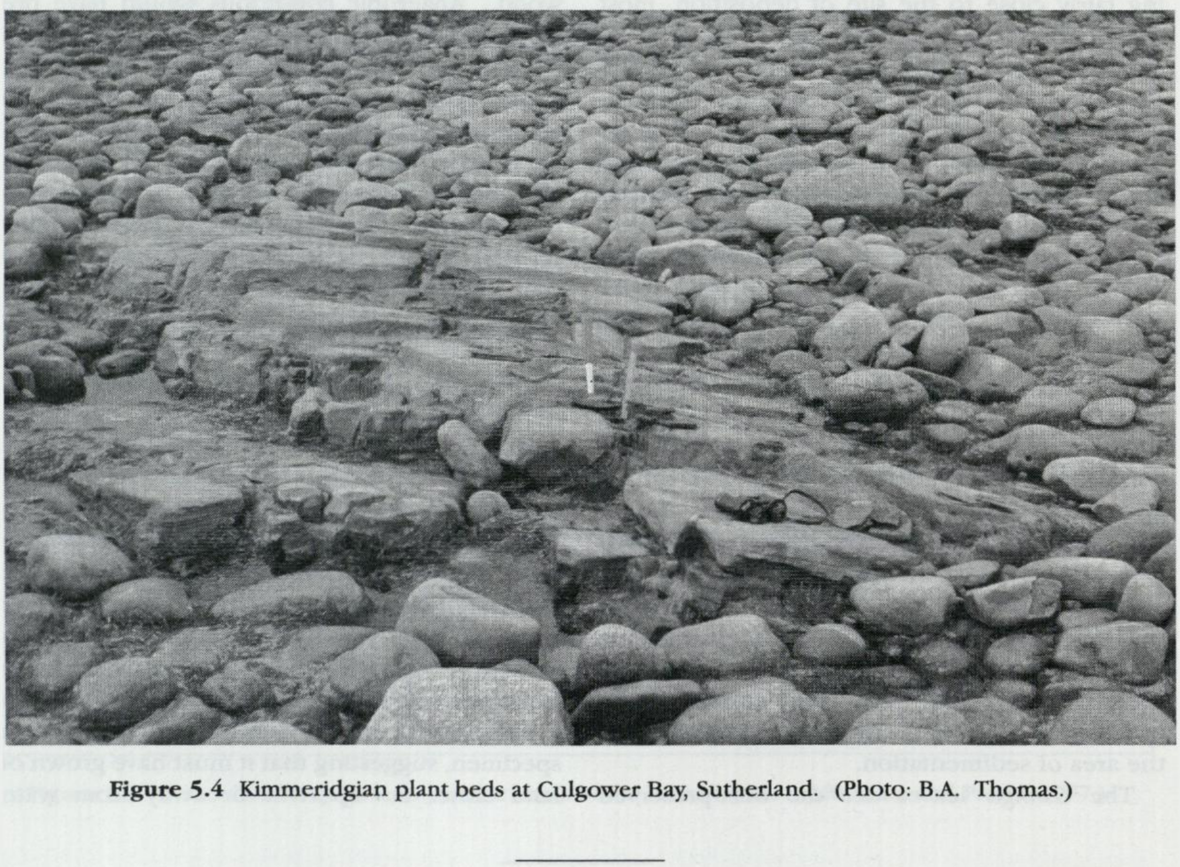

Figure 5.4 Kimmeridgian plant beds at Culgower Bay, Sutherland. (Photo: B.A. Thomas.)

Table 5.1 Floral composition of Lothbeg Point and Culgower Bay. The abundance of fossils is given as follows: +, 1–5 specimens; ++, 6–10 specimens; and +++, >10 specimens. Data from dispersed cuticles have been taken into account (from van Konijnenburg-van Cittert and van der Burgh, 1996).

	Lothbeg	Culgower
SPHENOPHYTA		
EQUISETALES		
Equisetum sp.	+	
PTERIDOPHYTA		
Angiopteris boweri (Seward) van Konijnenburg-van Cittert and van der Burgh	+	++
Aspidistes thomasii Harris	+	+
Asplenium rigidum Vassilevskaja		+
Coniopteris setacea Vakhrameev		+
Gleichenia boodlei		+
G. cycadina (Schenk) Seward	+++	+++
Hausmannia buchii (Andrä) Seward	+++	+
H. dichotoma Dunker	++	++
Matonidium goeppertii (Ettingshausen) Schenk	++	+
Phlebopteris dunkeri (Schenk) Schenk	+	+++
Sphenopteris onychyopsis Seward		+
Sphenopteris sp.	+	+
Selleyopteris morayensis van Konijnenburg-van Cittert and van der Burgh		+
Todites denticulatus (Brongniart) Krasser	++	+
T. williamsonii (Brongniart) Seward	+	++
GYMNOSPERMOPHYTA		
CAYTONIAS		
Sagenopteris phillipsii (Brongniart) Presl	+	+++
PTERIDOSPERMS		
Cycadopteris jurensis (Kurr) Hirmer	+	
Dichopteris pomelii (Saporta) Seward		+
Pachypteris lanceolata Brongniart	++	+++
CYCADALES		
Nilssonia brevis Brongniart		+
N. orientalis Heer	+	++
Pseudoctenis eathiensis (Richards) Seward	++	++
BENNETTITALES		
Pterophyllum cycadites Harris and Rest	+	++
P. thomasii Harris	+	+
Pterophyllum/Otozamites		+
Williamsonia sp.		+
Zamites buchianus (Ettingshausen) Seward		+
GINKGOALES		
Baiera cf. *muensteris* (Presl *in* Sternberg) Saporta		+
Ginkgo sp.	+	
Sphenobaiera longifolia (Pomel) Florin		+
CZEKANOWSKIALES		
Czekanowskia rigida Heer	+++	+
Phoenicopsis gunnii Seward	++	+
PINALES		
Araucarites milleri Carruthers		+
Brachyphyllum eathiensis Seward		++
Elatides curvifolia (Dunker) Nathorst	+	+++
(with attached male and female cones)		+
Elatocladus jeffryi (Seward) van Konijnenburg-van Cittert and van der Burgh		+
Masculostrobus zeilleri (Seward)		+
Podozamites sp.		++
Tritaenia scotica van der Burgh and van Konijnenburg-van Cittert	+++	+++

Description

Stratigraphy

The Kimmeridgian succession of the Sutherland coast is dominated by bituminous shales with a fauna, including ammonites, that indicates deposition in a fairly deep shelf-sea. The Boulder Beds, which are interbedded with these shales, range from 1 to nearly 10 m in thickness. They consist of sandstones with boulders, and contain animal remains that indicate shallow water sedimentary environments. The age of the Boulder Bed succession has been determined principally from the ammonites, and the plant fossils at Culgower lie within the *Aulacostephanus exodus* Zone.

The Boulder Beds probably accumulated initially as a submarine fan, from which blocks of sediment slid relatively slowly down the submarine scarp. During deposition in the Culgower area the fault scarp was near sea level and covered by a vegetated delta (Neves and Selley, 1975; Johnson and Mykura, 1989).

Today the Kimmeridgian beds form a low-lying platform stretching out to sea from the base of low cliffs (Figure 5.4). The strata are much faulted and contorted, with a seaward dip and a strike that is roughly coincident with the coastline. The richer plant beds are at the northern end of the bay.

Palaeobotany

A list of the 36 species from Culgower Bay is given in Table 5.1 (see also Figure 5.5). Of these, the ferns *Gleichenites boodlii* and *Selleyopteris morayensis*, and the conifers *Araucarites milleri* and *Masculostrobus zeilleri* are known only from this locality. There are also specimens referred to simply as *Williamsonia* sp., *Otozamites* sp., *Brachyphyllum* sp., *Podozamites* sp. and *Elatocladus* sp., which might yet be determined as new species limited to Culgower. The fern *Sphenopteris onychyopsoides* is known only from Culgower, Lothbeg and Crakaig. The czekanowskialean *Phoenicopis gunnii* and the conifer *Taxodiophyllum scoticum* have been found only at this locality and the nearby Lothbeg Point, while the conifer *Taxites jeffreyi* is known only from Culgower and Eathie.

The fossils are preserved in a coarse calcareous sandstone, which has not led to good preservation. Nevertheless, the more robust cuticles of some seed plants survive and can be prepared. Dispersed cuticles have also been extracted from sediments at Culgower Bay and Lothbeg Point as part of a small palynofacies study (van Konijnenburg-van Cittert and van der Burgh, 1996). Some could not be determined to species level because they were fragments of the less characteristic species of such genera as *Nilssonia* and *Pseudoctenis* (Figure 5.5). Others of the genera *Czekanowskia* and *Phoeniciopsis* were far too small to be assigned to species with any degree of certainty.

Specimens of *Masculostrobus* and the male cone of *Elatides curvifolia* (Figure 5.5) have yielded pollen grains.

Interpretation

This important Upper Jurassic palaeobotanical site has yielded an exceptional fossil flora of Kimmeridgian (Late Jurassic) age, with over 50 species of conifers, ginkgos, bennettites and ferns. The assemblage is an interesting mixture of characteristically Early–Middle Jurassic and Early Cretaceous elements, and is thus transitional between typical Jurassic and Cretaceous floras. Many of the species have a wide geographical distribution, but others are more restricted and/or otherwise only known from such regions as Spitzbergen, Australia and the Far East. Several have been recorded only from this locality and others from only two or three of the Sutherland coast exposures.

Van Konijnenburg-van Cittert and van der Burgh (1989, 1996) suggested that the relatively large size of the fragments found at Culgower indicates a site of deposition close to the shore, possibly in a shallow basin within a delta. The deposits include boulder beds that are thought to have slid down the slope of one of the regional faults, stretching and cracking the larger leaves in the process. The authors' ecological analysis of the flora has suggested a lush river-border vegetation with many ferns and gymnosperms making up over half of the assem-

Figure 5.5▸ Representative plant fossils from the Kimmeridgian of Culgower Bay. Upper left, *Pachypteris lanceolata* Brongniart (pteridosperm), × 0.5. Upper right, *Phlebopteris dunkeri* (Schenk) Schenk (fern), × 1. Lower left, *Elatides curvifolia* (Dunker) Nathorst (conifer), × 1. Lower right, *Pseudoctenis eathiensis* (Richards) Seward (cycad), × 0.5. (Photos: J.H.A. van Konijnenburg-van Cittert.)

blage. This riparian habitat merged into both freshwater backswamps, with *Elatides curvifolia* and *Taxodiophyllum scoticum*, and into upland forest, with plants such as *Aspidistes thomasii*, *Elatocladus* sp. and *Phoenicopis gunnii*. The influence on the fossil assemblage of the only heathland plant, *Phlebopteris dunkeri*, and salt-marsh plants such as *Gleichenites cycadina*, *Hausmannia buchii*, *H. dichotoma* and *Pachypteris lanceolata*, are restricted, although the latter obviously less so.

Conclusions

The Culgower assemblage is the most important Kimmeridgian (Late Jurassic) flora in Britain and possibly Europe, providing a valuable insight into the vegetation growing here 140 Ma ago. Of the nearly 40 species that have been found, four are unique to the site and several others may also eventually prove to be so. The large assemblage is less affected by taphonomic sorting than assemblages at the other Sutherland sites and therefore gives a fuller picture of the flora that existed at the time.

LOTHBEG POINT (NC 962 096) Potential GCR Site

Introduction

The section exposed at Lothbeg Point (Figure 5.6) has yielded an assemblage of well-preserved, but fragmentary plants including a new conifer, *Taxodiophyllum scoticum*. It occurs within marine deposits containing a rich marine fauna, which suggests that the plants drifted into this environment. The Lothbeg Point site makes an interesting comparison with the nearby flora at Culgower.

The site was first described in 1984 by van der Burgh and van Konijnenburg-van Cittert, some five years after the GCR site selection programme had been completed for the palaeobotany of the Scottish Jurassic Series. However, the flora encountered at this locality is clearly of considerable importance and merits inclusion in the GCR network that represents the Jurassic palaeobotany of Scotland.

Figure 5.6 Plant beds exposed on the foreshore of Lothbeg Point (Photo: J.H.A. van Konijnenburg-van Cittert.)

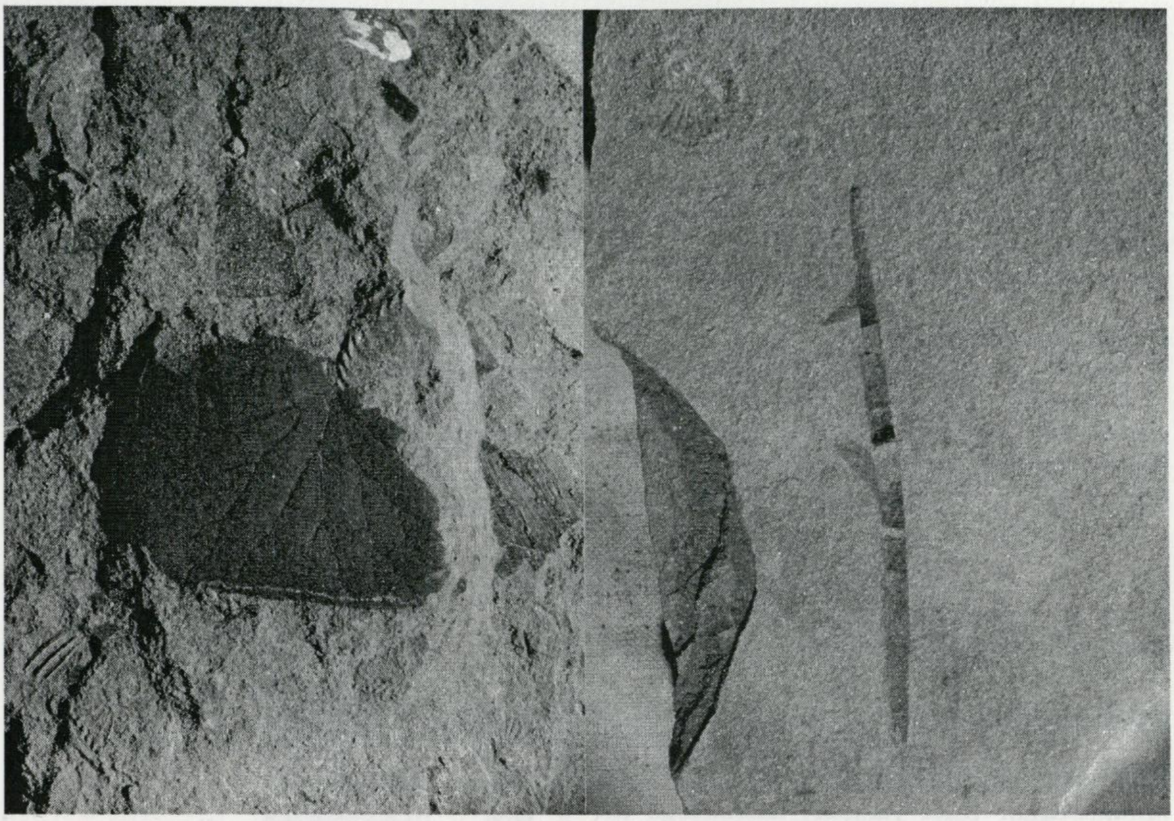

Figure 5.7 Representstive plant fossils from the Kimmeridgian of Lothbeg Point. Left, ***Hausmannia buchii*** (Andrä) Seward (fern). Right, ***Tritaenia scotica*** van der Burgh and van Konijnenburgh-van Cittert (conifer). Both about natural size. (Photos J.H.A. van Konijnenburg-van Cittert.)

Description

Stratigraphy

These Jurassic marine deposits are dark grey shales containing the remains of numerous cephalopods, bivalve molluscs and plant fragments. They are dated as early Kimmeridgian on the basis of the occurrence of the ammonite ***Aulacostephanoides*** cf. ***mutabilis*** J. Sowerby (Lam and Porter, 1977; van der Burgh and van Konijnenburg-van Cittert, 1984). The unusual depositional environment of these plant-bearing beds was shown by Neves and Selley (1975) to be a submarine delta involving turbidity flows, resulting in subwave-base marine muds (now shales) interbedded with boulder beds and sand flows.

Palaeobotany

Twenty-six plant taxa are known from Lothbeg Point (van der Burgh and van Konijnenburg-van Cittert, 1984); a complete list is given in Table 5.1 (see also Figure 5.7). Although fragmentary, the plants are all well preserved. The ferns have very distinct veins and the gymnosperms good cuticles, which can be easily prepared for microscopic examination. The conifer species *Taxodiophyllum scoticum* was described from here on the basis of over 70 specimens of simple, flat, linear, single-veined leaves with characteristic epidermal features.

Interpretation

Of the 26 taxa at Lothbeg Point, eight also occur in the plant beds of the Yorkshire Jurassic succession and a further four have near relatives there. Six of the 26 also occur in Lower Cretaceous, Wealden, deposits of south-east England and another five have near relatives there.

The fossils must have been transported by rivers that shed their load into the sea. Van der Burgh and van Konijnenburg-van Cittert have analysed the flora according to the methodology described by van der Burgh (1993). Their table shows high numbers for brackish and freshwater swamps, medium figures for moist lush vegetation and heath, and low figures for upland forest. The comparatively high figure for heathland is certainly attributable to the good preservation and easy recognition of the fusainized leaf fragments of the fern *Phlebopteris dunkeri*.

Conclusions

The Lothbeg Point section yields an unusual assemblage of well-preserved fragments of plants in marine shales that also contains a rich fauna. It is an important site for comparison with the nearby exposure at Culgower.

EATHIE FISHING STATION (NH 779 635)

Introduction

This site has yielded a well-preserved Kimmeridgian (Late Jurassic) assemblage of conifers, bennettites and cycads. Significantly, the fossils are preserved as permineralizations, showing fine detail of their internal cell structure. They include some of the best examples of bennettite flowers ever to have been found as well as some finely preserved conifer cones. Remarkably the flora has not been studied since the early 20th century and is in serious need of revision.

Miller (1857) first described the plant petrifactions at Eathie and his specimens are now nearly all in the collections of the Royal Scottish Museum, Edinburgh. Richards (1884) published a short account on Miller's cycadean species, but it was not until early in the 20th century that they were looked at again by Seward (1911, 1912) and Seward and Bancroft (1913). There has been little attempt to re-examine this site and its fossils, which is rather remarkable in view of the small number of petrifaction sites that exist in rocks of this age.

Description

Stratigraphy

The exposed succession here is summarized in Figure 5.8. Cope *et al.* (1980a) dated it as Kimmeridgian, based on the work of Waterstone (1951) and Ziegler (1962). There are green mudstones at the base with some thin limestone nodules and bands that belong to the *Rasenia cymodoce* Zone. The plant petrifactions most probably come from this part of the succession. The higher beds yield a fauna of *Amoebites* and raseniids characteristic of the upper part of the *R. cymodoce* Zone and the basal *Aulacostephanoides mutabilis* Zone. Fossiliferous nodules, containing the ammonite *Pictonia baylei*, have also been found 10 km to the north of Eathie, indicating that the basal Kimmeridgian strata are preserved offshore in this region.

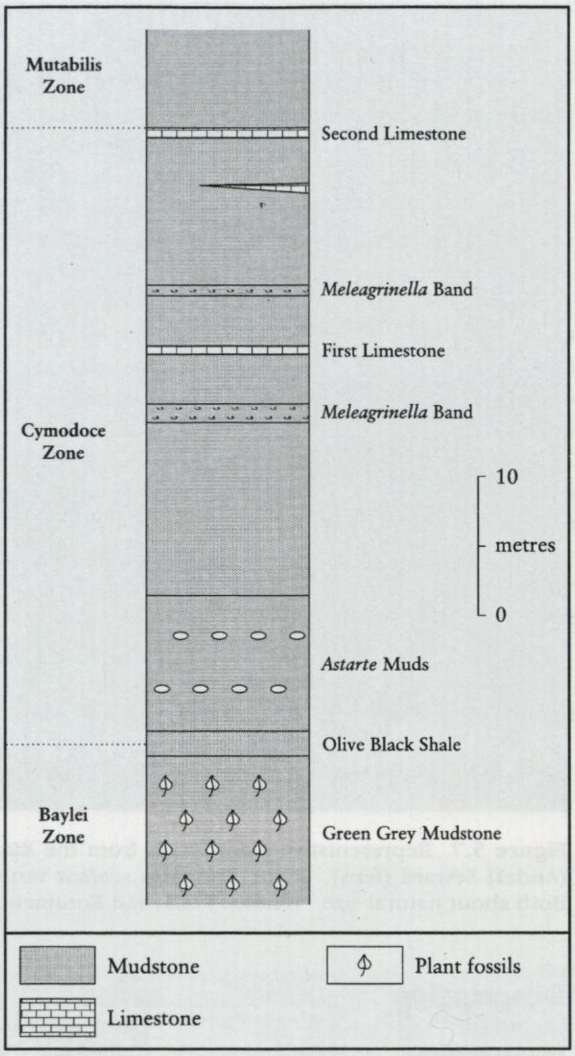

Figure 5.8 Generalized sequence of Kimmeridgian rocks exposed near Eathie, showing position of plant bed. (After Gitmez and Sarjeant, 1972.)

Palaeobotany

The plant fossils are preserved as petrifactions and reveal a considerable degree of anatomical detail (Figure 5.9). Miller considered that he had three species of conifer cones and a number of different conifer shoots. Seward (1911) named the shoots as his new species *Taxites jeffryi*. Others Seward named as *Elatides curvifolia* (Dunker) Nathorst, and *Sphenolepidium* cf. *kurrianum* Dunker, although it is not clear if these come from Eathie. He also named isolated cone scales as *Araucarites milleri* after Miller. Miller's imbricated stem (Miller, 1857, fig. 149) was described by Seward and Bancroft (1913) as a new species, *Brachyphyllum eathiense*. In the

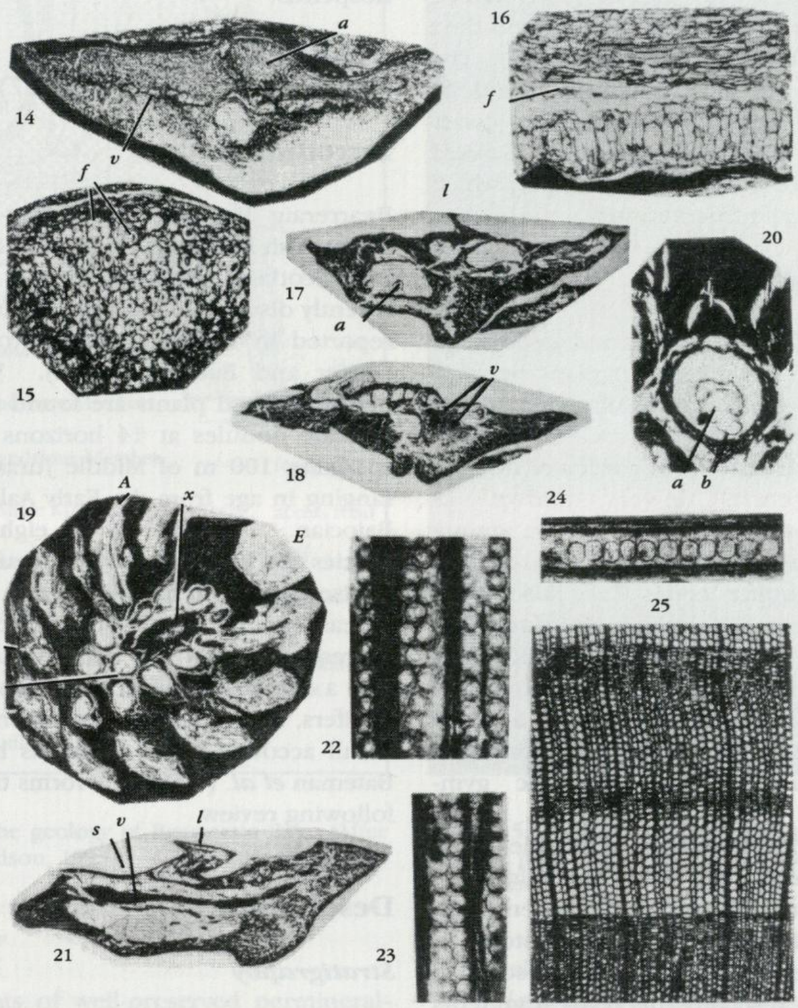

Figure 5.9 Petrified plants from Scotland as figured by Seward and Bancroft 1913. The gymnosperm cones *Conites juddii* Seward and Bancroft were collected by Hugh Miller at Eathie Bay in weathered calcareous nodules. Parts 14–16 are of a section of a cone scale showing crushing of parenchyma at *a*, thick fibres or idioblasts at *f* and an almost continuous line of vascular stands stretching across the cone scale at *v*. Part 14 × *c*.4, Part 15 × 15, Part 16 ×18. Part 19 is an oblique longitudinal section of a cone with secondary xylem (*x*), × *c*.1. The obliquely cut cone scale A, enlarged in Part 21, shows a vascular strand (*v*) and a ligular outgrowth (*l*) with *s* indicating the likely position of the missing seed. The transversely cut cone scales B (enlarged in Part 17 × 3) and C (enlarged in Part 18 × 3) show the ligule (*l*), vascular bundles (*v*) and more crushed parenchyma (*a*). In the cavity of cone scale D (enlarged in Part 20 × 3.5) the identity of the structure marked as *a* and *b* are still speculative. The single specimen of gymnosperm wood, *Cedroxylon hornei* Seward and Bancroft, comes from Helmsdale, near the northern limit of the Jurassic rocks in Sutherland. In transverse section growth rings of tracheids are clearly visible, Part 25 × 25. Longitudinal sections show bordered pits approximately 20 μm in diameter, Parts 22–24 × 150.

same paper, they named Miller's conifer cones as two new species, *Masculostrobus woodwardii* and *Conites juddii* (the latter in four forms).

Miller described cycad-like foliage under the name of *Zamites pectinata* and figured two cones that he thought might belong to a cycad intermediate between the fertile apices of *Cycas revoluta* and the cones of *Zamia pungens*. One of his leaves (Miller, 1857, fig. 133) was named *Zamites eathiensis* by Richards (1884) and then *Pseudoctenis eathiensis* by Seward (1911). The other (fig. 134) was named *Nilssonia orientalis* Heer by Seward (1911). The cycad-like cones were described in another paper by Seward (1912) as *Williamsonia pecten* (Phillips), which is in fact a bennettite fructification.

Interpretation

The site has yielded a well-preserved assemblage of Kimmeridgian (Late Jurassic) plant petrifactions, consisting of the remains of conifers, bennettites and cycads. They preserve fine detail of the internal cell structure. Of particular interest are the bennettite flowers known as *Williamsonia scotica* Seward, which are among the best-preserved examples of such organs. Well-preserved conifer cones have also been described from here, including *Maculastrobus woodwardii* and *Conites juddii*. The flora has not been studied since the early 20th century and is in serious need of revision. It is a site of considerable potential for understanding the detailed structure of the Mesozoic gymnosperms.

The permineralized plants at Eathie must have been fragments that were carried into the sediments now represented by the green mudstones. Carbonates forming the limestone in bands within the mudstones would also have penetrated and preserved the plant fragments and formed nodules around them.

The flora is difficult to compare directly with the other Scottish Jurassic assemblages because it has been preserved in a different way. The only other locality where there are permineralized plants is at Helmsdale. Unlike the other localities, Eathie is dominated by both bennettites and conifers.

Conclusion

Eathie Fishing Station is an outstanding site for Kimmeridgian permineralized plants with four species of gymnosperms having been named from here. The presence of permineralized *Williamsonia* flowers and bennettite leaves, as well as conifer shoots, and cones makes it an extremely valuable succession for the study of these plants and is a site worthy of future investigation, especially for understanding the detailed structure of the Mesozoic gymnosperms.

BEARRERAIG (NG 518 524–NG 518 527)

Introduction

Bearreraig Bay is on the east coast of the Trotternish Peninsula on the Isle of Skye, north-west Scotland (Figures 5.10 and 5.11). It is a recently discovered palaeobotanical site that was reported by Bateman and Morton (1994) and Dower and Bateman (1998). Well-preserved permineralized plants are found in calcitic and sideritic nodules at 14 horizons at Bearreraig spanning 100 m of Middle Jurassic sediments ranging in age from the Early Aalenian to Early Bajocian. A minimum of eight whole-plant species are known from 15 organ species: one equisetalean, four filicalean ferns, one cycad and at least one bennettite and one conifer. These represent at least two distinct plant communities: a coastal–deltaic community dominated by conifers, and an inland vegetation rich in ferns. A full account of the flora has been given by Bateman *et al.* (2000) and forms the basis of the following review.

Description

Stratigraphy

The plant fossils come from 14 horizons in a 120-m-thick central portion of the Bearreraig Sandstone Formation (Figure 5.12). The detailed stratigraphy is based upon abundant and well-preserved ammonites and bivalves in calcareous nodules. By this means, Morton (1990) dated the plant-bearing section as from the *Ludwigia murchisonae* Zone (early Aalenian) at the base of the Ollach Sandstone Member to the *Witchellia laeviuscula* Subzone (early Bajocian) in the middle of the Holm Sandstone Member.

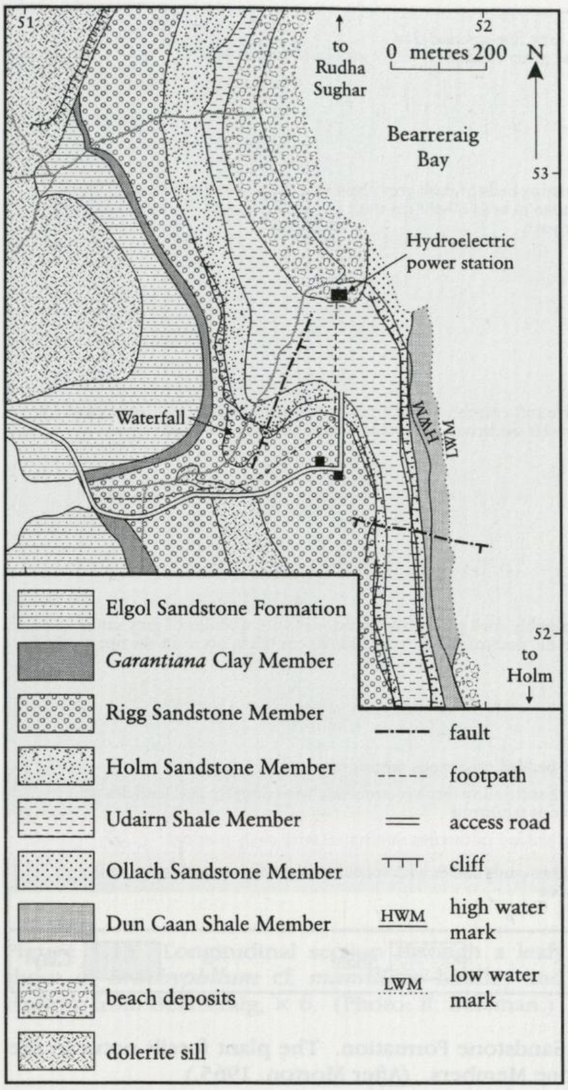

Figure 5.10 The geology of Bearreraig Bay. (After Morton and Hudson, 1995.)

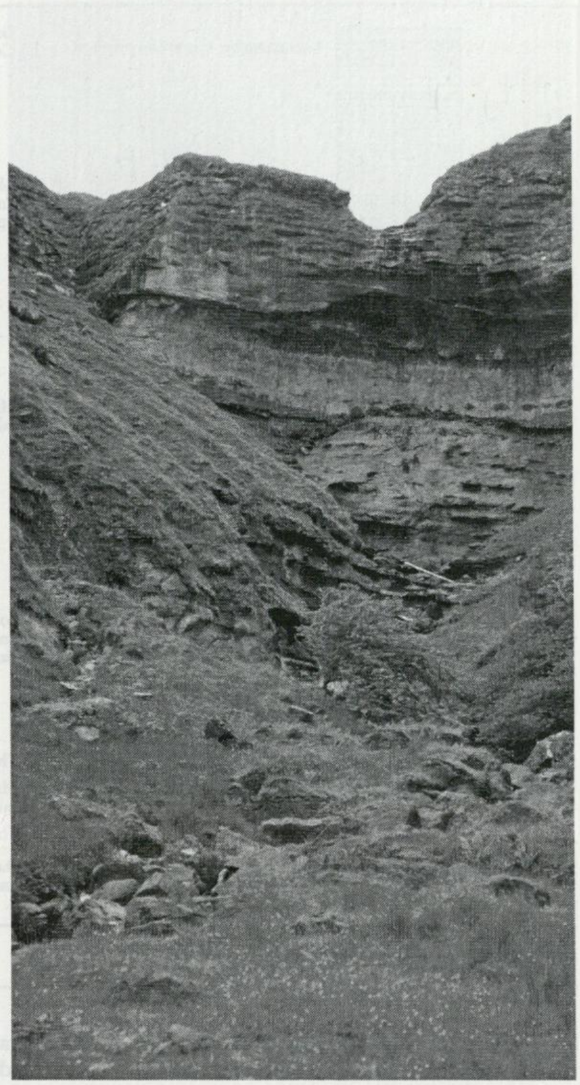

Figure.5.11 View of the upper part of the Middle Jurassic plant beds at Bearreraig Bay, Skye. (Photo: R. M. Bateman.)

Palaeobotany

Small fragments of well-preserved permineralized land plants are present in the calcareous nodules (Bateman *et al.*, 2000). They were prepared for detailed examination by sectioning and cellulose acetate peeling. The ferns are fusainized (charcoalified), which enabled them to be examined by SEM, thereby revealing intricate anatomical details. The plant fossils so far recorded by Bateman *et al.* (in press) are as follows:

Equisetales: *Equisetum* cf. *columnare* Brongniart (a large pyritized rhizome).

Filicales: charcoalified fragments of *Cladophlebis denticulatus* (Brongniart) Fontaine, *Coniopteris* cf. *hymenophylloides* (Brongniart) Seward, *Hausmannia buchii* (Andrä) Seward, *H. dichotoma* Dunker, *Phlebopteris woodwardii* Leckenby.

Cycadales: *Nilssonia* cf. *tenuinervis* Seward.

Bennettitales: *Cycadolepis* sp., *Otozamites* cf. *penna* Harris, *Ptilophyllum* cf. *pecten* (Phillips) Harris, *P.* cf. *pectinoides* (Phillips) Morris, ovules and cone fragments.

Conifers: *Brachyphyllum* cf. *mamillare*

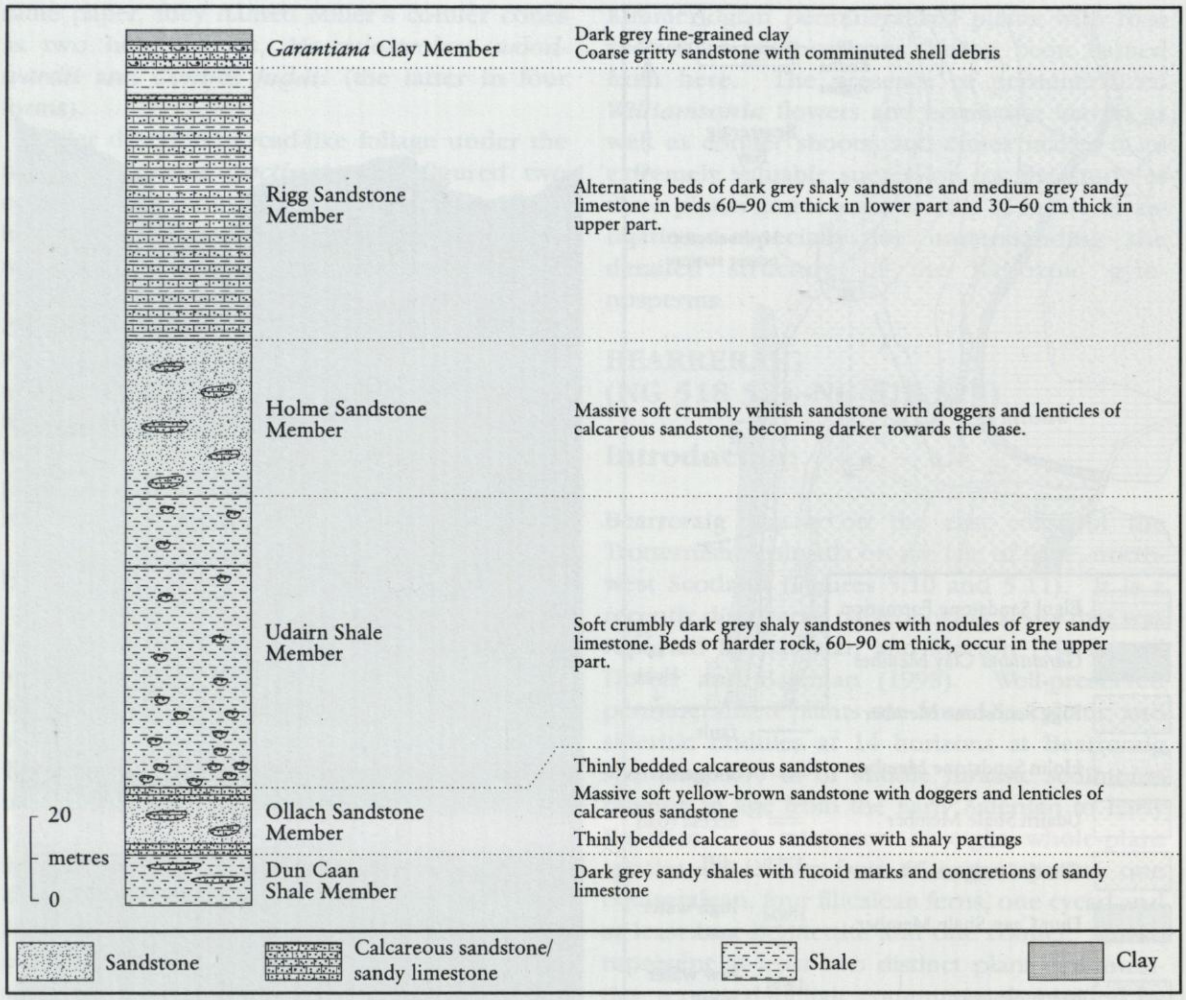

Figure 5.12 Generalized section through the Bearreraig Sandstone Formation. The plant fossils occur in the Ollach Sandstone, Udairn Shale and lower Holme Sandstone Members. (After Morton, 1965.)

Lindley and Hutton, female cones and isolated ovule scales of araucarian affinity, cf. *Taxodioxylon* sp. (Figures 5.13 and 5.14).

Bateman *et al*. (2000) interpret these fragments as most likely to have come from a minimum of eight and a maximum of 11 whole plant species. However, even though the assemblage is small it is diverse and encompasses eight or nine families in five orders. Plant microfossils and cuticles have also been recovered from the inorganic matrix by maceration. Riding (1991) described 17 morphospecies of dinoflagellate cysts from the section.

Interpretation

Permineralized Jurassic floras are globally rare and only one other reasonably extensive assemblage has been reported in Britain, from the Lower Jurassic succession at Eathie (Seward and Bancroft, 1913), as noted previously. The other important features of the Bearreraig plants are not only that Middle Jurassic floras in any state of preservation are uncommon but also that the assemblage immediately pre-dates and resembles the classic Yorkshire Jurassic floras described by Harris and others (see Chapter 3).

The plant fossils are clearly all allochthonous in origin, being very fragmentary and in marine deposits. The Bearreraig Sandstone Formation was deposited by tidal sand waves that migrated northwards parallel to the east. The plant debris accumulated some 25–30 km from the nearest land. Most would have decayed on the sea floor. Only those fragments that were closely associat-

Figure 5.13 Longitudinal section through a leafy shoot of *Brachyphllum* cf. *mamillare* Lindley and Hutton, from Bearreraig, × 6. (Photo: R. Bateman.)

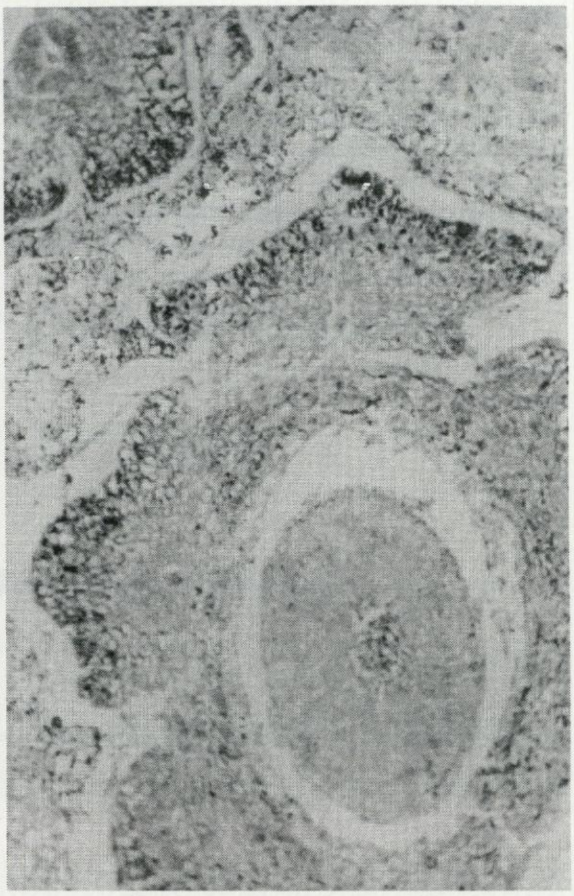

Figure 5.14 Transverse section through a leafy shoot of *Brachyphyllum* cf. *mamillare* Lindley and Hutton, from Bearreraig, × 12. The section shows the stem surrounded by fleshy leaves. (Photo: R. Bateman.)

ed with mollusc shells were preserved. Decay and dissolution of some of the shells led to local re-precipitation of authigenic calcite nucleating around the remaining shells and infiltrating any associated plant remains. Dower and Bateman (1998) suggested that such permineralization was most probably rapid because there appears to be little evidence of chemical or biological degradation in conditions that were unlikely to have been anoxic. Also since the ferns arefusainized, it is unlikely that degradation would have occurred anyway. Bateman and Morton (1994) suggested that the plants were carried as rafts for great distances before becoming waterlogged and sinking to the ocean floor.

Although the number of species is low there is some evidence of the communities from which they came. The single large pyritized fragment of *Equisetum* almost certainly originated from a plant growing on a riverside. The charcoalified nature of the fern fragments suggests derivation from plants that grew inland on relatively dry heaths that were subject to periodic burning. The presence of *Phlebopteris* is especially significant because Harris (1961a) had previously argued that it grew in such fire-affected situations.

Bateman *et al.* (2000) suggest that the abundance of *Brachyphyllum* reflects seaward habitats (possibly intertidal) of the parent plants on the deltas. The domination of the araucarian *B.* cf. *mamillare* in both megafossil and microfossil assemblages suggests that it was more abundant and closer to the watercourses than the cheirolepidiacean *B.* cf. *crucis*. The few cycadophytes suggests that they were either rarer components of the delta community or that they lived in drier habitats further away from the watercourses.

Nearly all the species had thick fleshy leaves with thick cuticles and sunken stomata suggesting xeromorphy. However, Bateman *et al*. (2000) quite rightly point out that such leaves might have been selectively preserved, therefore biasing our views on both species and morphological make-up of the living communities.

Conclusion

The Bearreraig assemblage is a rare Middle Jurassic flora immediately pre-dating the classic compression floras described from Yorkshire. It provides a rare opportunity for studying the anatomy of Middle Jurassic plants and thus significantly improve our understanding of the vegetation of this period.