# *Mesozoic and Tertiary Palaeobotany of Great Britain*

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## Chapter 4

# The Jurassic palaeobotany of southern England

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## INTRODUCTION

During most of the Jurassic Period, southern England was covered by an area of shallow sea between the islands of Cornubia and Armorica and the Anglo-Brabant landmass (see Figure 3.2). The strata of this period thus provide an excellent record of marine faunas, especially invertebrates, but are generally impoverished in plant macrofossils. However, there are a few exceptions, most notably in the Middle Jurassic Stonesfield and Cotswold 'Slate' facies, and in the Upper Jurassic Purbeck facies, and these are the subject of this chapter. Although none of the sites can be compared in preservation or diversity of the floras with those of the Yorkshire Jurassic succession, they reflect rather different types of vegetation and thus provide a valuable complement to the Yorkshire sites.

## HISTORY OF RESEARCH

Despite their relatively poor preservation, the Jurassic floras of southern England have attracted a considerable amount of scientific attention in the past, especially during the 19th century. This is probably because of their geographical proximity to some of the main centres of palaeobotanical research in those days, most notably London and Oxford.

William Buckland, Professor of Mineralogy at Oxford between 1813 and 1845, generated much of the early interest in the Jurassic palaeobotany of southern England (Andrews, 1980). His direct contribution to the science was on the bennettite stumps preserved on the Isle of Portland (Buckland, 1828, 1836). However, more important was his involvement with a group of palaeobotanists active in the early 19th century, some of whom were permitted to publish descriptions of specimens in his collection. This included some of the leading pioneers of scientific palaeobotany, such as Adolphe Brongniart, Kaspar von Sternberg and John Lindley (for details of these publications, see the Stonesfield GCR site report). As a result, Stonesfield in particular became one of the best-known Jurassic floras in the world.

Buckland's successor at Oxford, John Phillips, continued to study the Mesozoic palaeobotany of southern England, especially in the vicinity of Oxford. He made few novel contributions to the subject, but in 1855 and 1877 he published the first attempts at a monographic treatment of the Stonesfield flora. Also active at this time was William Carruthers of the British Museum (Natural History), who had access to the extensive collections of these floras that by then had been accumulated. He published a number of papers on both the Stonesfield and Portland floras (Carruthers, 1867a,c, 1869, 1870a).

Towards the end of the 19th century and in the early 20th century, Albert Seward was the leading Mesozoic palaeobotanist in Britain. He rarely went into the field himself, but, at least for the Middle Jurassic floras of southern England, this was of little consequence because the opportunities to collect had by then all but disappeared. His major contribution was to synthesize the existing collections, most notably those of the British Museum (Natural History). The resulting catalogue is far more than just a list of the species; it is a comprehensive monograph on these floras (Seward, 1904).

Following Seward, relatively little attention was given to these floras. Mabel Kendall (1947, 1948, 1949) published on some conifer remains from various localities in southern England, and Peter Barnard (1968) reviewed a few conifer cones from Stonesfield, but little else seems to have been accomplished. This was partly because collecting from many of these sites had become difficult or impossible, and partly because the fossils could not match the Yorkshire Jurassic floras with their cuticles preserved intact. Recently, however, there has been a resurgence in interest. For the Middle Jurassic material, this has been a direct result of GCR work, since it became evident that a proper assessment of the significance of the floras, such as that from Stonesfield, necessitated a full monographic revision. Cleal and Rees (1998) summarized this work and a full account is now in preparation. For the Upper Jurassic material, recent interest has increased largely through the efforts of J. Francis, who has studied the in-situ fossil forests of the Isle of Portland and the adjacent parts of the Dorset coast (Francis, 1983, 1984).

## PALAEOGEOGRAPHICAL SETTING

The general palaeogeographical setting of Britain during the Jurassic Period is summarized in Chapter 3 and need not be repeated here. Much of southern Britain during the Jurassic Period was an area of shallow marine shelf. The geology here thus tends to be dominated by marine clastic and carbonate deposits. Drifted plant remains are known from the Lower Jurassic Series, the middle of the Bathonian Stage and the Oxfordian Stage, the second of these providing the most extensive floras. The Bathonian floras would seem to represent coastal plain and mangrove vegetation from the adjacent lands, probably mainly the Anglo-Brabant landmass. Towards the end of the Jurassic Period, there was a marked marine regression that culminated in the non-marine conditions seen in the Lower Cretaceous Series of southern England. In very late Jurassic times, the seas had shallowed sufficiently for coastal forests to develop periodically. These probably grew on the margins of hypersaline lagoons.

During the Middle Jurassic Epoch, the climate of southern England was probably similar to that of Yorkshire (a humid, subtropical climate). In the Late Jurassic Epoch, however, conditions became more seasonal. A Mediterranean-type climate, with hot, dry summers and cooler, wetter winters prevailed during the latest Jurassic and earliest Cretaceous times.

## STRATIGRAPHICAL BACKGROUND

The Jurassic geology of southern England was summarized by Cope *et al.* (1980a,b). Sediments accumulated in the region (Wessex Basin *sensu lato*) from the Permian Period to the Late Cretaceous Epoch. Today, the marine Jurassic rocks exposed there provide one of the finest sections seen anywhere in the world. During the Jurassic Period, present-day Dorset lay at the western end of a basinal sea covering the Wealden district of south-east England and the English Channel (Callomon and Cope, 1995). The deposits are a mixture of the limestones that dominate to the south and the predominantly siliciclastic sediments that prevail to the north. Ammonites occur from the base of the Lias upwards through much of the section, apart from most of the Bathonian. As a result, biostratigraphical correlation of the Jurassic rocks of the region is generally precise.

Just two parts of the succession are relevant to this chapter. The Great Oolite Group of the Cotswolds is a highly varied interval of mainly shallow marine deposits (Figure 4.1). Most of the plant (and terrestrial vertebrate) fossils occur in a facies known as the Stonesfield 'Slate'. Poor exposure of these beds has always made detailed correlations of these beds difficult and as a result, their position within the stratigraphical column has been somewhat controversial. Until recently, the most widely held view was that the facies comprised a discrete unit within the Sharp's Hill Formation (e.g. Sellwood and McKerrow, 1974). However, boreholes drilled in the Stonesfield area have now proved that it occurs at several levels within the Great Oolite (Boneham and Wyatt, 1993). At Stonesfield itself, the fossiliferous 'slates' are mainly in the Taynton Limestone Formation, whereas further west in Gloucestershire they are in the underlying Charlbury Formation. Both of these formations are in the lower part of the middle Bathonian succession.

The Upper Jurassic succession is well exposed along the cliffs in Dorset enabling changes in facies and thickness to be measured over long distances. Deposition in the area of present-day Dorset gradually changed. Sea-level rises throughout the Oxfordian led to the widespread mudrocks of the Oxford Clay and the limestones and sands of the Corallian Beds. A series of sedimentary cycles followed, the mudstone clays, bituminous mudstones and limestones of the overlying Kimmeridge Clay representing progressive oxygen depletion leading to complete anoxia at the end of each cycle (Oschmann, 1988). Silt and then carbonate sedimentation in the shallower seas of Portlandian times followed. Continued shallowing of the sea eventually led to the termination of marine sedimentation and the spread of Purbeck facies over the whole area (Wimbledon, 1987). The basin was now smaller and connection to the Bristol Channel area was closed. Even though there was probably connection to the Paris Basin, the rate of evaporation of the shallow water within it was high, and led to intermittently hypersaline conditions. This produced the conditions necessary for fossilizing the coniferous trees that grew around the basin. The forests were rooted in shallow soils that are now preserved as the 'Dirt Beds' in the lower Purbeck Formation (Figure 4.2). Although most of the Purbeck is now regarded as part of the Lower Cretaceous succession, these basal beds are probably still within the topmost Jurassic Portlandian Stage (Wimbledon in Calloman and Cope, 1995).

## JURASSIC VEGETATION IN SOUTHERN ENGLAND

The Jurassic vegetation of southern England is

| Chronostratigraphic units | | | | Lithostratigraphic units | | |
|---|---|---|---|---|---|---|
| **Stage** | **Substage** | **Zone** | **Subzone** | **Formation/Member** | | **Group** |
| Bathonian | Upper Bathonian | *Clydoniceras (Clydoniceras) discus* | *C. (C.) discus* | Lower Cornbrash | | Great Oolite Group |
| | | | *C. (C.) hollandi* | Forest Marble | | |
| | | *Oxycerites orbis* | | not represented | | |
| | | *Procerites hodsoni* | | White Limestone | Bladon Member | |
| | | | | | Ardley Member | |
| | Middle Bathonian | *Morrisiceras (Morrisiceras) morrisi* | | | Shipton Member | |
| | | *Tulites (Tulites) subcontractus* | | Hampen Marly Formation | | |
| | | | | Taynton Limestone Formation | | |
| | | *Procerites progracilis* | | Charlbury Formation | | |
| | Lower Bathonian | *Asphinctites tenuiplicatus* | | Sharp's Hill Formation | | |
| | | *Zigzagiceras (Zigzagiceras) zigzag* | *Oppelia (Oxycerites) yeovilensis* | Chipping Norton Limestone Formation | | |
| | | | *M. (Morphoceras) macrescens* | Clypeus Grit | | Inferior Oolite |
| | | | *P. (Parkinsonia) convergens* | | | |

**Figure 4.1**. Summary of the stratigraphical divisions in the Great Oolite Group of the Cotswolds. (After Boneham and Wyatt, 1993.)

broadly similar in composition to that of Yorkshire (see Chapter 3). Gymnosperms, in particular bennettites and conifers, dominate the floras. Representatives of other seed plants tend to be rarer (cycads, caytonias, corystosperms, ginkgos) than in Yorkshire or absent altogether (czekanowskias). Clubmosses and horsetails are absent and ferns rare. In the Middle Jurassic Epoch, this may partly be because of their lower preservation potential; the floras are preserved as drifted fragments in marine deposits, in which only the more robust plants would normally survive. However, it may also reflect the fact that the original vegetation of southern England occupied coastal fringes whereas in Yorkshire it clothed a delta.

A notable addition to the Middle Jurassic floras here, by comparison with Yorkshire, is the enigmatic plant that bore leaves known as *Pelourdea*. When originally found, they were interpreted as large, deciduous leaflets from bennettite or cycad fronds (*Zamites*), even though no other bennettite or cycad was known to have them. However, more complete material from the Triassic strata of North America (Ash, 1987), has since demonstrated that the leaflets

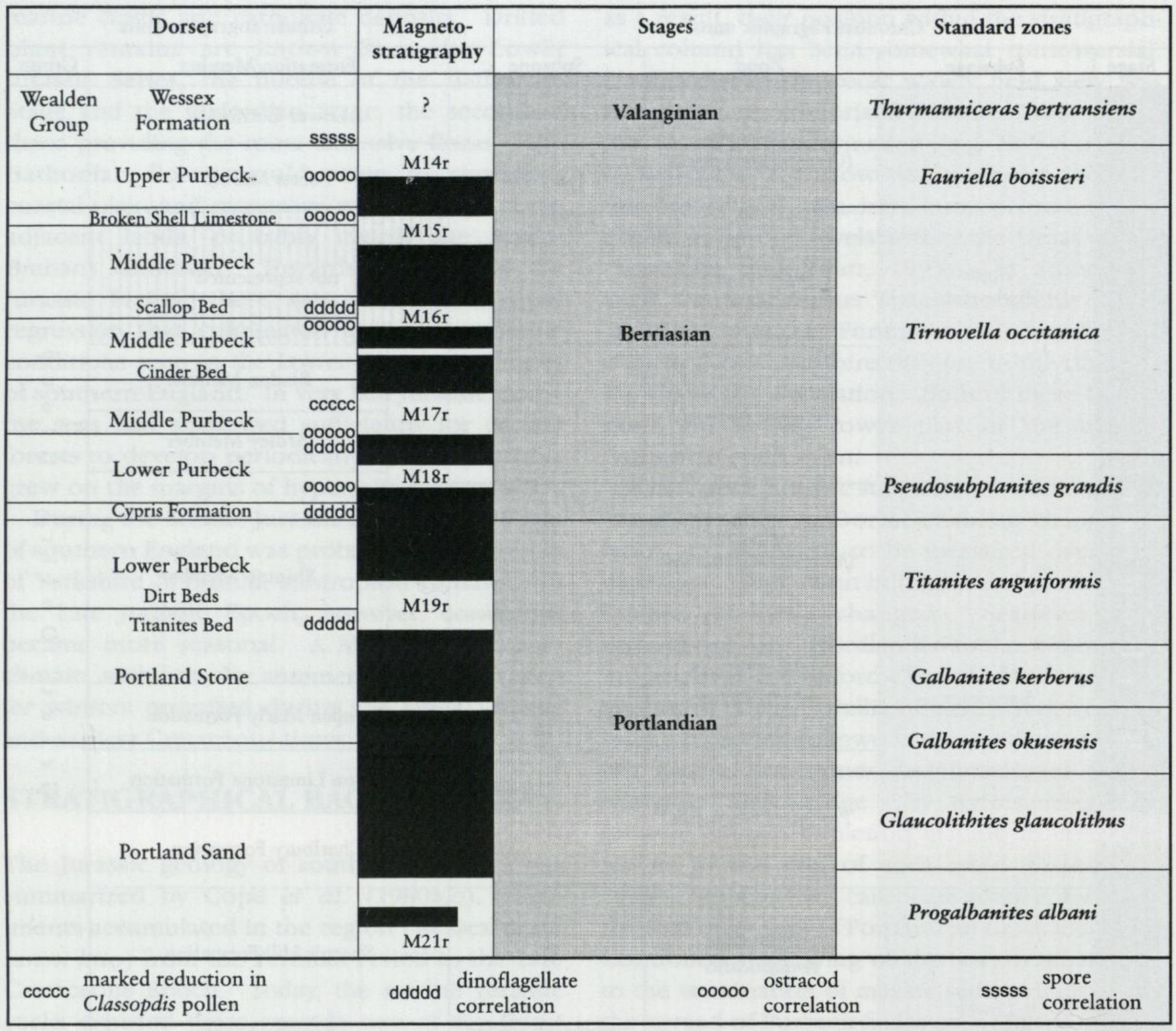


**Figure 4.2.** Summary of Jurassic–Cretaceous boundary interval in Dorset. (After Wimbledon in Calloman and Cope, 1995.)

are in fact complete leaves and that the plant probably had a habit similar to that of the living angiosperm *Dracaena*, which is not much more than half a metre high (Figure 4.3). The affinities of this plant remain an enigma, although the American examples were associated with gnetalean 'flowers' (Cornet, 1995).

Another enigmatic plant from these Middle Jurassic deposits is represented by a single leaf (part and counterpart) known as *Phyllites*, reported from Stonesfield by Seward (1904). Despite its rarity, it has attracted attention because it looks so remarkably angiospermous. However, there is no other good evidence of angiosperms in rocks of this age, the oldest known macrofossil being from deposits of supposed Late Jurassic age in China (Sun *et al.*, 1998). The attribution of such an isolated leaf must therefore remain questionable.

The conifers in these floras are represented mainly by cheirolepidiacean and, to a lesser extent, araucariacean remains. Our knowledge of the habit of the cheirolepidiacean conifers has benefited considerably from the work of Francis (1983, 1984) on the Upper Jurassic fossil forests of the Purbeck Dirt Beds of Portland (Figure 4.4).

## PALAEOBOTANICAL SITES IN THE JURASSIC OF SOUTHERN ENGLAND

Except for the stratigraphically highest rocks, plant fossils in the Jurassic rocks of southern England are mainly drifted, poorly preserved

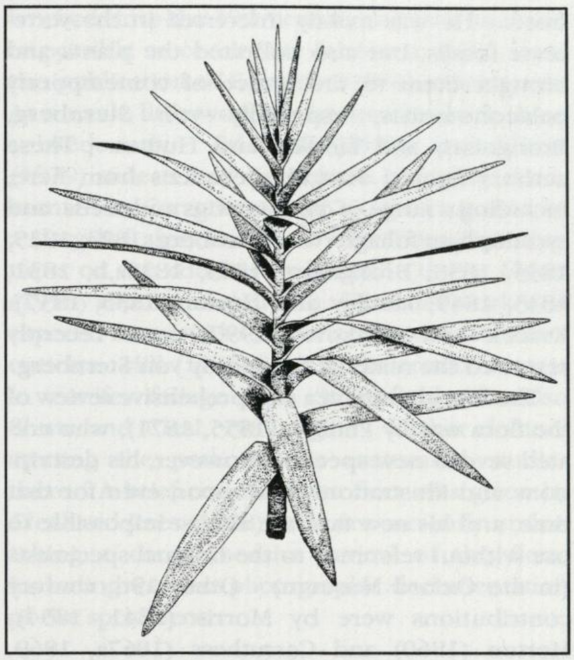

**Figure 4.3.** Reconstruction of the plant that bore the leaves known as *Pelourdea*, × 0.1. This was based on fossils from the Upper Triassic rocks of North America, but it is assumed that the plant represented in the Middle Jurassic floras of southern England was broadly similar. (Redrawn from Ash, 1987.)

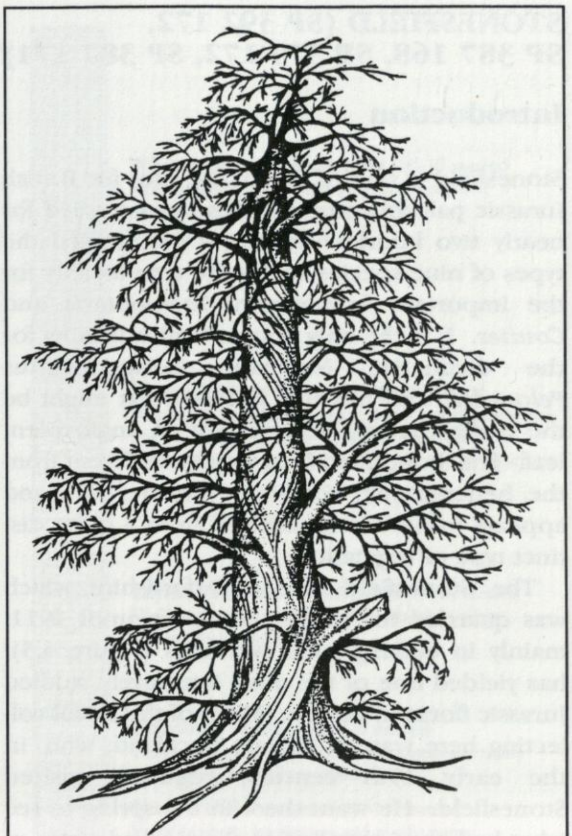

**Figure 4.4.** Reconstruction of a cheirolepidiacean conifer, a tall forest tree. (Redrawn by Annette Townsend from an original by Pauline Dean, and based on the work of J.E. Francis.)

fragments. The Lower Lias around Lyme Regis has over the years yielded some better-preserved material including cuticles (De la Beche, 1824; Woodward, 1893; Seward, 1904; Kendall, 1948), but they are so rare that it has been decided not to select this as a GCR Mesozoic palaeobotany site. Kendall (1948) also reported conifers from the Lower Lias of Warwickshire, but these were from museum specimens and the localities no longer exist.

As noted earlier, Middle Jurassic plant macrofossils are mainly restricted to the tilestones known as the Stonesfield and Cotswold 'Slates'. The classic site for such floras is Stonesfield, which has yielded by far the most diverse assemblage. However, the exposures are underground, in mines from which it is now difficult to collect. The Huntsman's Quarry at Eyford, Gloucestershire, has, therefore, also been selected, because the 'slates' crop out at the surface here. Plant fragments have been reported from other Middle Jurassic sites, most notably in the Forest Marble Formation (upper Bathonian) of Oxfordshire, which has yielded coniferous remains (Kendall, 1952), but the fossils are rare and usually poorly preserved. As a result, none of these localities merits selection for the GCR.

Mainly coniferous remains have been reported from the Upper Jurassic Oxford Clay, most notably from Christian Malford, in Wiltshire (Carruthers, 1869; Kendall, 1947), but the exposure no longer exists. There is also a record of rare plant remains from the Kimmeridge Clay near Weymouth (Carruthers, 1869). The only significant palaeobotanical sites in the Upper Jurassic rocks of southern England that still exist are the 'fossil forest' localities in the Dirt Beds of the Purbeck Limestone Formation. These can be seen in several places, one of the best sites being in Lulworth Cove. However, it is on the Isle of Portland where they can be best studied, and it is here that the representative GCR site has been identified.

## STONESFIELD (SP 392 172, SP 387 168, SP 379 172, SP 387 171)

### Introduction

Stonesfield is one of the classic sites for British Jurassic palaeobotany and has been studied for nearly two hundred years. It has yielded the types of nine species and is the type locality for the important form-genera *Taeniopteris* and *Conites*. It is the only known British locality for the distinctive Mesozoic foliage genus *Pelourdea*, and has also yielded what might be the earliest known example of an angiosperm leaf. The Stonesfield flora is quite different from the better-known Yorkshire Jurassic flora and appears to have been derived from a quite distinct type of vegetation.

The 'Stonesfield Slate' of Oxfordshire, which was quarried for roofing stone up until 1911, mainly in underground workings (Figure 4.5), has yielded one of the most intensively studied Jurassic floras in Britain. Much of the initial collecting here was by William Buckland, who, in the early 19th century, regularly visited Stonesfield. He went there in the spring to see what had been revealed in the worked stone of the previous year, after weathering the winter's frosts. He was mainly interested in the vertebrate fossils, but also collected the plants and brought them to the notice of contemporary palaeobotanists, especially von Sternberg, Brongniart, and Lindley and Hutton. These authors figured several specimens from here, including a range of conifer twigs and seeds, and cycadophyte foliage (von Sternberg, 1823, 1825, 1833, 1838; Brongniart, 1823, 1828a,b, 1831, 1833, 1849; Lindley and Hutton, 1835, 1837). Kvaček and Straková (1997) have recently reviewed the material figured by von Sternberg.

The first attempt at a comprehensive review of the flora was by Phillips (1855, 1871), who created several new species. However, his descriptions and illustrations were poor, even for that time, and his new taxa are almost impossible to use without reference to the original specimens (in the Oxford Museum). Other 19th century contributions were by Morris (1841, 1854), Horton (1860) and Carruthers (1867a, 1869, 1870a). However, the landmark study was by Seward (1904), whose monograph of the British Mesozoic plant fossils (excluding those from Yorkshire) in the collections of the British Museum (Natural History) documented all the known specimens from Stonesfield.

The tilestones at Stonesfield have not been

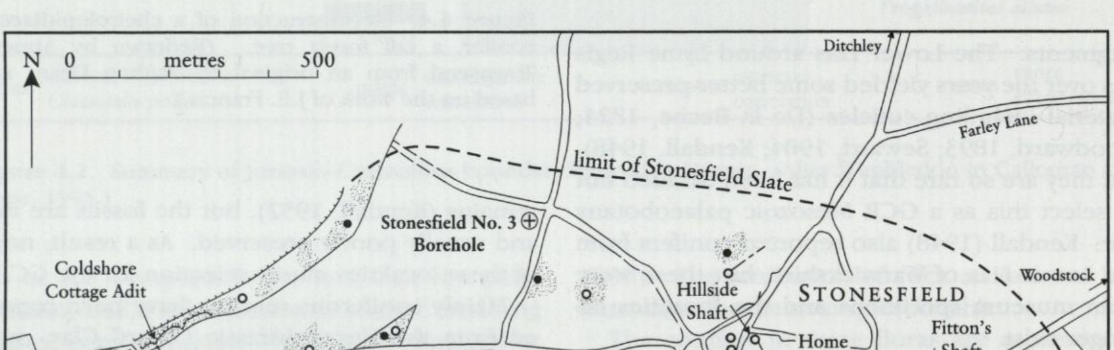


**Figure 4.5** Map of the area around Stonesfield village, showing the principle working for the Stonesfield 'Slate'. (After Boneham and Wyatt, 1993.)

worked since the 19th century and so it has been impossible to obtain any further material since the publication of Seward's (1904) monograph. As a result, little work on the flora has been done subsequently. Edwards (1928) and Elliott (1979) redescribed a specimen originally documented by Carruthers (1867a), showing it to be a dasyclad alga, and there have been contributions on the conifers by Kendall (1949), Florin (1958) and Barnard (1968). Kendall's work is of especial interest as she managed to obtain some cuticles. Hill (1986, fig. 9.3) illustrated stomata in conifer foliage from Stonesfield (see also Shute and Cleal, 1987, fig. 3), further demonstrating the potential for anatomical studies there. A brief review of the flora was given by Cleal and Rees (1998), who are currently undertaking a comprehensive review of the flora, including the first photographic documentation of the specimens.

## Description

### *Stratigraphy*

The 'Stonesfield Slate' comprises tilestones that vary from calcareous sandstone to siltstone with impersistent oolitic laminae. They have a characteristic fine, horizontal lamination that allowed the splitting of the 'slates'. The association of marine and non-marine animal fossils and terrestrial plant fossils suggests that the sediments accumulated in shallow marine conditions in a narrow gulf that extended north-east from the main basin in the south (Sellwood *et al.*, 1986).

Poor exposure has hindered the geological study of these deposits. However, understanding of it improved dramatically after a series of boreholes was drilled during the early 1990s (Boneham and Wyatt, 1993). It had been thought that the 'Stonesfield Slate' was a discrete member of the Sharp's Hill Formation (Great Oolite Group) but the boreholes showed that it is in fact a facies occurring at different levels within the lower Great Oolite (Figure 4.6). The mined tilestones from which plant fossils have been recovered occur at three levels within the Taynton Limestone Formation. They have yielded ammonites of the *Procerites progracilis* Zone, hence placing them in the lower part of the Middle Bathonian Stage (Torrens in Cope *et al.*, 1980a).

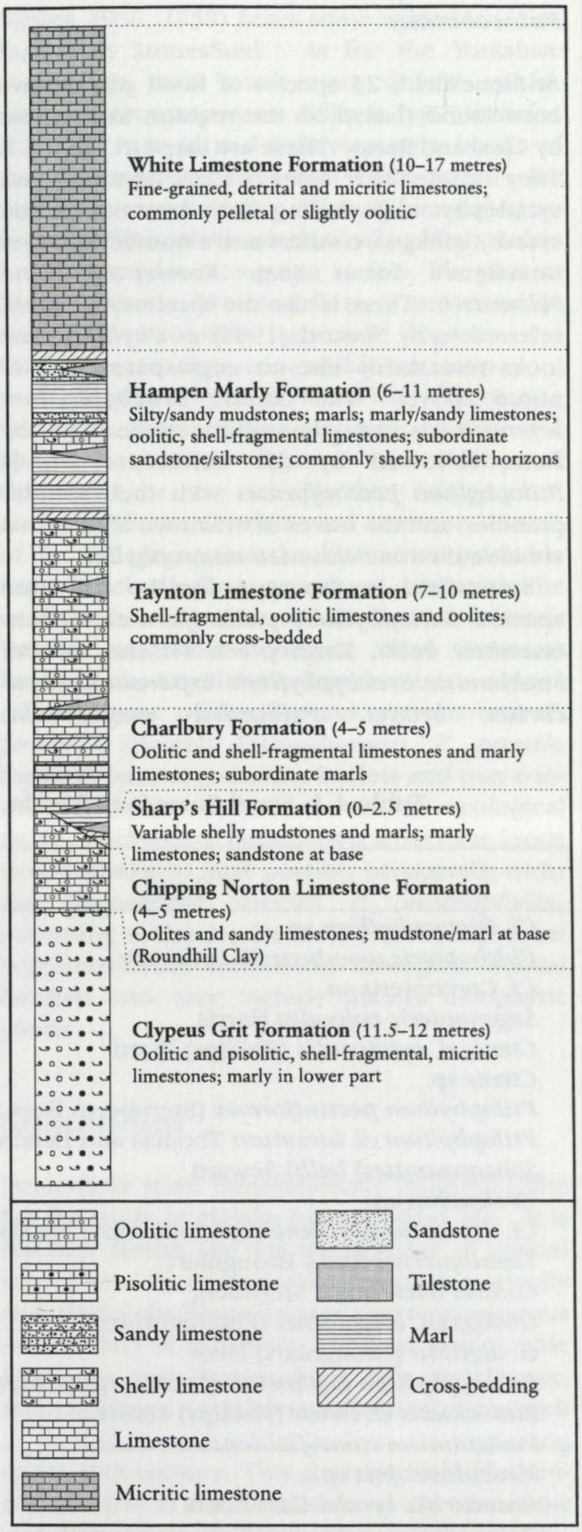


**Figure 4.6** Generalized sequence through the Great Oolite Group of the Stonesfield area, showing the different levels at which the Stonesfield 'Slate' facies is developed (After Boneham and Wyatt, 1993.)

### *Palaeobotany*

At Stonesfield, 23 species of fossil plants have been found (based on the revision in progress by Cleal and Rees). These are listed in Table 4.1. They include the remains of ferns, caytonialeans, cycadophytes (including both bennettites and cycads), ginkgos, conifers and a number of as yet unassigned forms (e.g. *Komlopteris* and *Pelourdea*). There is also the specimen of a leaf, referred to by Seward (1904) as *Phyllites*, that looks remarkably like an angiosperm leaf, as noted above. The conifer *Brachyphyllum expansum* is the commonest element in the flora, followed by the bennettite fronds *Ptilophyllum pectiniformes* with their slender pinnules, and the leaves of unknown affinity that are identified as *Pelourdea macrophylla*.

Stonesfield is the type locality for nine species: *Ptilophyllum pectiniformes*, *Sphenozamites*? *bellii*, *Taeniopteris vittata*, *Conites bucklandii*, *Brachyphyllum expansum*, *Araucarites brodei*, *Pelourdea megaphylla*, *Pachypteris macrophylla* and *Carpolithes diospyriformis*. It is also the type locality for two form-genera. One of these, *Taeniopteris*, is a widely used name for entire, cycadophyte leaves that cannot be assigned to either bennettites or cycads. The other, *Conites*, is an earlier synonym of *Bucklandia* Presl in Sternberg, which is a widely used name for bennettite stems.

The fossils are preserved as impressions (*sensu* Shute and Cleal, 1987), sometimes picked out by iron staining or other mineralization. Cuticles have so far been found only in some conifer foliage (Kendall, 1949). One conifer shoot has also yielded evidence of epidermal structure impressed on secondary mineralization (e.g. Hill 1986).

## Interpretation

Stonesfield has yielded by far the most diverse and best-preserved fossil flora from the 'Stonesfield Slate'-like facies in southern

**Table 4.1** Fossil floras found in the Middle Jurassic strata of southern England.

| | Stonesfield | Huntsman's Quarry |
|---|---|---|
| Cf. *Dictyophyllum* sp. | × | |
| *Phlebopteris woodwardii* Leckenby | × | |
| Cf. Coniopteris sp. | × | × |
| *Sagenopteris colpodes* Harris | × | × |
| *Ctenis* cf. *sulcicaulis* (Phillips) Ward | × | |
| *Ctenis* sp. | × | |
| *Ptilophyllum pectiniformes* (Sternberg) Rees and Cleal | × | |
| *Ptilophyllum* cf. *hirsutum* Thomas and Bancroft | × | |
| *Sphenozamites*? *bellii* Seward | × | × |
| ?*Weltrichia* sp. | × | |
| Cf. *Ctenozamites leckenbyi* (Leckenby) Nathorst | × | |
| *Taeniopteris vittata* Brongniart | × | × |
| *Conites bucklandii* Sternberg | × | |
| *Ginkgo* aff. *longifolius* (Phillips) Harris | × | |
| *G. digitata* (Brongniart) Heer | | × |
| *Brachyphyllum expansum* (Sternberg) Seward | × | × |
| *Elatocladus* cf. *laxus* (Phillips) Harris | × | |
| *Podozamites stonesfieldensis* Seward | | × |
| *Masculostrobus* sp. | × | |
| *Araucarites brodei* Carruthers | × | × |
| *Pelourdea megaphylla* (Phillips) Seward | × | × |
| *Pachypteris macrophylla* (Brongniart) Cleal and Rees | × | |
| *Komlopteris speciosa* (Ettingshausen) Cleal and Rees | × | × |
| *Carpolithes diospyriformis* Sternberg | × | × |
| *C. conicus* Lindley and Hutton | | × |
| *C.* spp. | × | |

England. The only other comparable flora has been found in the stratigraphically older Charlbury Formation at Huntsman's Quarry in Gloucestershire. A comparative analysis between these two floras is given in the account of the latter site (see also Table 4.1).

Brongniart (1828a) suggested that the Stonesfield flora was broadly similar to that found in the Yorkshire Jurassic strata, and this view has become well established. At first sight it seems significantly impoverished, compared with the more than 200 species in Yorkshire. This is mainly because of the difficulty that there has always been in collecting material from Stonesfield, and the fact that it occurs in relatively coarse-grained, marine deposits; the latter factor probably explains the paucity of ferns. There are nevertheless some notable absentees that are not so easily dismissed, such as the horsetails, which are the most abundant recognizable fossils in large parts of the Yorkshire Jurassic succession (Harris, 1961a). Ginkgoalean foliage is also common in Yorkshire (Harris *et al.*, 1974), but is represented at Stonesfield by just one poor specimen.

More important are the taxa found at Stonesfield but not in Yorkshire. Especially significant is *Pelourdea*, which is one of the most common foliage fossils at Stonesfield. The (relatively) common seeds called *Carpolithes diospyriformis* also have no equivalent in Yorkshire and *Komlopteris* is so far unreported from there, although it is very similar to such species as *Pachypteris papillosa*, which are common. The apparent absence of *Sphenozamites* from Yorkshire may have to be reconsidered in the light of its resemblance to *Otozamites*.

One of the reasons for the differences in comparison between the Stonesfield and Yorkshire floras may be the environmental setting. The latter represents mainly swamp elements in a fluvio-deltaic setting whereas the Stonesfield flora was probably derived from mangrove-like vegetation (mainly *Ptilophyllum*-bearing bennettitaleans) growing along coastal fringes, behind which were periodically drowned lowlands covered mainly by cheirolepidiacean forests. The preferred habitat of the third most common component of the Stonesfield flora, *Pelourdea*, is unknown but probably represents plants that grew either in these lowlands with the conifers, or in drier, marginal habitats.

The Early Jurassic flora of the Venetian Alps of Italy (de Zigno, 1856–1885; Grandori, 1913; Wesley, 1956, 1958) bears some resemblance to that from Stonesfield. As for the Yorkshire assemblage, it is much more diverse, which makes direct comparison difficult, but *Pelourdea* is known from it, and *Sphenozamites* is one of the commonest bennettite frond-types. De Zigno also recorded (but did not illustrate) specimens of *Pachypteris macrophylla*. What makes the comparison interesting is that, like that at Stonesfield, the Venetian flora is preserved in marine (or possibly lagoonal) deposits and therefore represents comparable vegetation.

Also similar are French floras found in marine Oxfordian–Kimmeridgian deposits, as reviewed by Barale (1981). There is no evidence of *Pelourdea* or any comparable foliage, but cheirolepidiacean remains are common. Some of the foliage appears to be indistinguishable from *Brachyphyllum expansum*, although the associated cones (*Masculostrobus dorchensis* Barale) are more elongate than those at Stonesfield. No *Ptilophyllum* has been reported, but some of the *Zamites* present (e.g. *Z. feneonis* (Pomel) Ettingshausen, *Z. pumilo* Saporta) have very slender leaflets and may conceivably have occupied a similar ecological niche. *Pachypteris desmomera* from near Lyons is very similar to (and possibly conspecific with) the Stonesfield species *P. macrophylla*. According to Barale, the French floras represent vegetation from temporarily emergent, coastal habitats and may include mainly halophytic plants.

## Conclusions

Stonesfield is an internationally important site for the study of Middle Jurassic plant life. It is the best British site for the remains of coastal vegetation. Its composition contrasts markedly with that of the better-known, contemporaneous swamp flora of Yorkshire. Although comparable floras are now known from Italy and France, there has been a much longer history of research at Stonesfield, extending back to the beginning of the 19th century. This gives Stonesfield a central position in any discussion on the taxonomy and nomenclature of these types of plant fossils. The flora mainly represents a mixture of mangrove vegetation dominated by bennettites, and lowland forests dominated by conifers, which grew along the southern coast of Britain some 170 Ma ago.

## HUNTSMAN'S QUARRY (SP 125 255)

### Introduction

This is the only plant-bearing site within the Middle Jurassic Eyford Member ('Cotswold Slates') of the Charlbury Formation in Gloucestershire that still exists. Although less diverse than the slightly younger Stonesfield succession in Oxfordshire, it has yielded some species not found in Oxfordshire and thus expands our knowledge of the Middle Jurassic floras of southern Britain.

The so-called 'Cotswold Slate' of Gloucestershire was for a long time regarded as equivalent to the 'Stonesfield Slate' of Oxfordshire. It has yielded a fossil flora that has a number of taxa in common with the latter, but it is now recognized to be stratigraphically lower (Boneham and Wyatt, 1993). Plant fossils are known from the Eyford area and Sevenhapton Common, both of which are between Stow-in-the-Wold and Cheltenham in the Cotswolds. However, exposures of these beds still exist only in the Eyford area, of which Huntsman's Quarry is the best.

There has been no systematic survey of the Eyford flora in recent years. Strickland and Buckman (1844) provided a list of species, and Seward (1904) included them in his review of what he called 'Stonesfield Slate' (i.e. including the 'Cotswold Slate'). The most intensive collecting here appears to have been undertaken in the mid-19th century by a local amateur, Edward Witts, the curate at the nearby village of Stanway. His collection is now in Gloucester Museum and Savage (1961) gave a list of the plant species preserved there.

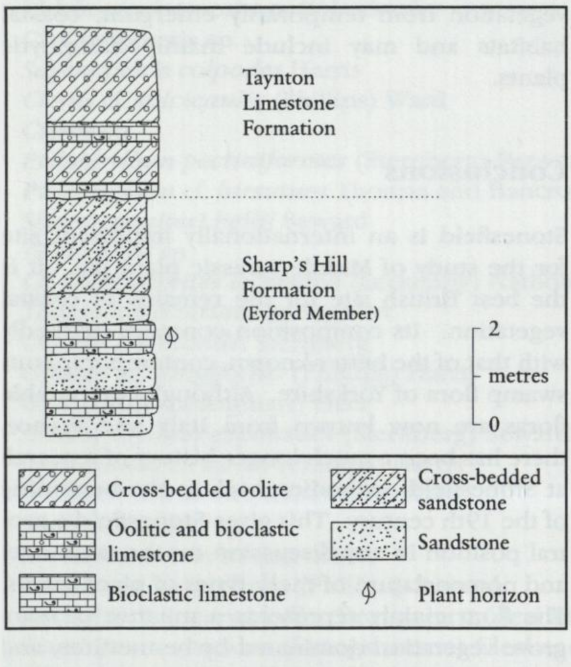


**Figure 4.7** Generalized sequence of the Great Oolite Group exposed at Huntsman's Quarry. (After Mudge, 1995.)

### Description

#### *Stratigraphy*

Richardson (1929), Ager *et al.* (1973) and Mudge (1995) have described the geology of this quarry, where 4.9 m of sandstones and bioclastic limestones of the Eyford Member are overlain by 3.5 m of oolitic limestones of the Taynton Formation (Figure 4.7). Many authors have assigned the Eyford Member, the formal name for beds traditionally known as the 'Cotswold Slate', to the Sharp's Hill Formation (e.g. Sellwood and McKerrow, 1974). However, it is now included within the Charlbury Formation, which Boneham and Wyatt (1993) established for a distinctive set of lithologies between the Sharp's Hill and Taynton Limestone Formations. From the comments made by Richardson (1929), the fossiliferous tilestones were probably in the limestone unit that he termed 'Pendle', about 3 m below the top of the Eyford Member.

#### *Palaeobotany*

Twelve species of plant macrofossil have been reported from Huntsman's Quarry, all preserved as impressions (*sensu* Shute and Cleal, 1987), sometimes picked out by iron staining or other mineralization. A list of species is shown in Table 4.1. The most common remains are conifer foliage (*Brachyphyllum*) and, to a lesser extent, cone scales (*Araucarites*). There are also remains of ferns, caytonialeans, cycadophytes and ginkgos, as well as a number of forms of unknown affinities (e.g. *Pelourdea*).

### Interpretation

The Eyford flora from Huntsman's Quarry is clearly very similar to that of Stonesfield. On the face of it, the assemblage is less diverse but this may just be because not so much collecting has been done here. Many of the species absent from the Eyford flora are, after all, represented at Stonesfield by only one or two specimens. However, there is one notable absentee, the cycadophyte *Ptilophyllum pectiniformes*, which is an abundant component of the Stonesfield flora. As suggested above, *P. pectiniformes* may have grown as coastal mangrove-like vegetation, which might not have extended further west in Gloucestershire.

Taxa present at Eyford but not at Stonesfield are *Ginkgo digitata*, *Podozamites stonesfieldensis* and *Carpolithes conicus*. The *Ginkgo* is represented by several quite well-preserved specimens that, although not yielding cuticles, are very similar to specimens from Yorkshire. Interestingly, Harris *et al.* (1974) stated that *G. digitata* is relatively rare in most of the Yorkshire localities but seems to be one of the commoner plants at Eyford.

Rarer is what Seward (1904) named *Podozamites stonesfieldensis*, an unfortunate (but nevertheless valid) species epithet as it appears to be absent from the Stonesfield flora. Seward argued that these fossils are the remains of conifer foliage because of their similarity to the leaves of living *Agathis*, although he recognized that this was a highly speculative suggestion in the absence of cuticles and evidence of attachment to stems. There is also the possibility of confusion with *Lindleycladus*, which again can only be distinguished from *Podozamites* if cuticles are available (Harris, 1979a).

Isolated seeds referrable to *Carpolithus conicus* are known from a number of Jurassic localities in southern England, but not Stonesfield. Seward (1904) thought that they were most likely to be derived from cycads, although they are also similar to the seeds of living *Ginkgo*.

## Conclusions

Huntsman's Quarry is the only remaining site within the Middle Jurassic 'Cotswold Slate' (Eyford Member) that has yielded plant fossils. The flora is very similar to that found in the approximately coeval Stonesfield flora, being dominated by conifers. However, it lacks evidence of the mangrove-like vegetation found abundantly at Stonesfield (principally *Ptilophyllum*). On the other hand, it contains a few species that are absent from Stonesfield, most notably *Ginkgo digitata*. Huntsman's Quarry therefore enhances considerably our understanding of the vegetation that clothed southern Britain during the Middle Jurassic Epoch, about 170 Ma ago.

# MAGGOT, KINGBARROW AND WAYCROFT QUARRIES (SY 691 728, SY 692 731 AND SY 696 729)

## Introduction

Sites on Portland (Figure 4.8) afford the best opportunity to examine the trees of the basal Purbeck (latest Jurassic age) 'fossil forest'. This forest was formed primarily of cheirolepidiaceous conifers, whose silicified in-situ boles and fallen trunks and branches can be seen in the fossil soils known as 'dirt beds' and overlying beds. Bennettitaleans up to 1.18 m tall were also present. The plants and the sediments in which they are found are of considerable value for reconstructing latest Jurassic palaeoenvironments in southern England.

The Purbeck Limestone Formation ('Purbeck Beds') of southern England have long been known to yield in-situ remains of arborescent plants. Buckland (1828, 1836), Fitton (1836), Carruthers (1870a) and Seward (1897b) described the bennettitalean stems that have been preserved, and more recently Francis (1983, 1984) investigated one of the coniferous species. The Isle of Portland is the best area to study them because of the extensive quarrying of the underlying Portland Stone Formation for building stone, which is still continuing (Figure 4.9).

## Description

### *Stratigraphy*

The Upper Jurassic Series in southern Britain ranges from the Kellaways Beds to the Purbeck Beds. The lower Purbeck Beds of Dorset are the uppermost deposits of the Jurassic System, and lie within the Portlandian Stage. The Purbeck Beds are present over much of the Isle of Portland, and extend as a broad band from Swanage in the east to Portesham in the west via Lulworth Cove where the 'fossil forest' level is preserved. They also occur at a few inland sites.

The term 'Portlandian' was first used with reference to the Portland Stone, which is an important building and facing stone. Until fairly

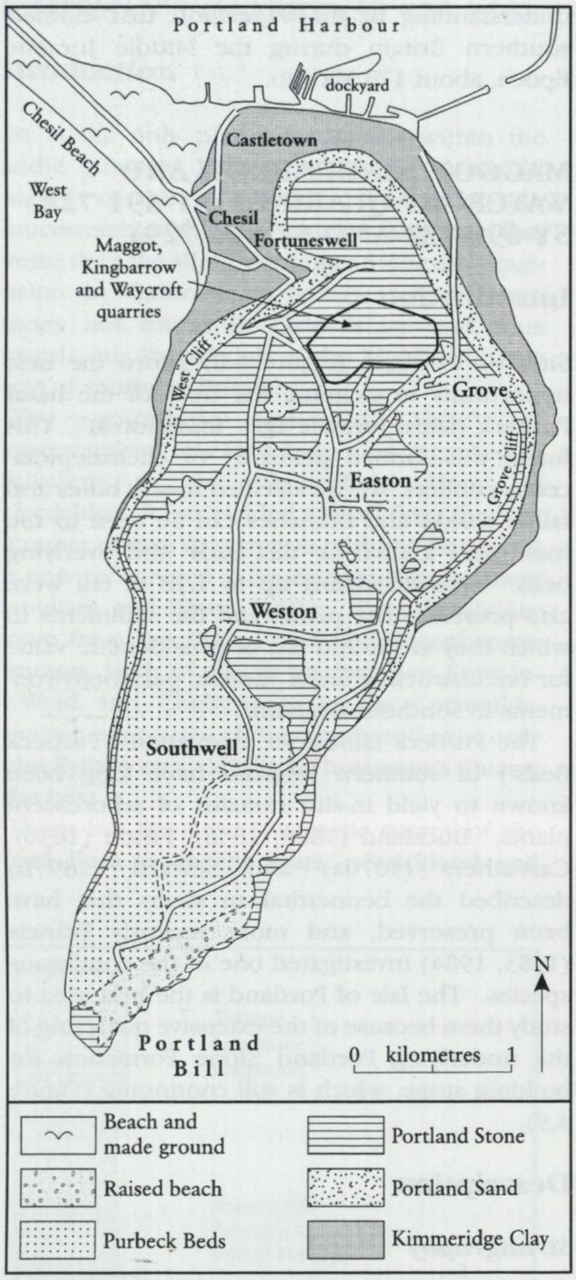


**Figure 4.8** The Isle of Portland, showing the position of Maggot Quarry, Kingbarrow Quarry and Waycroft Quarry. (After House, 1993.)

recently it was used synonymously with 'the Portland Beds'. However, according to Wimbledon (in Cope *et al.*, 1980a), the Portlandian, as the topmost Jurassic stage, encompasses everything between the top of the Kimmeridgian Stage and the base of the Cretaceous System (base Berriasian Stage). For decades, the boundary between the Jurassic and Cretaceous systems was accepted, somewhat arbitrarily, to be at the base of the mid-Purbeck Cinder Bed, but recent studies (e.g. Wimbledon and Hunt, 1983; Allen and Wimbledon, 1991; Feist *et al.*, 1995) suggest that it is low down in the Lower Purbeck (Lulworth Formation). As noted earlier, the 'fossil forests' of Portland and Lulworth are found in the basal Purbeck (Figure 4.10). They are, therefore, late Portlandian in age.

## Palaeobotany

The quarries are famous for the silicified stumps and branches of the cheirolepidiaceous conifer ***Protocupressinoxylon purbeckensis*** Eckhold, which have been most recently studied by Francis (1983, 1984; Figure 4.11). Most of the stumps are rooted ***in situ*** and many are encircled by algal stromatolites (Figure 4.12). The algae grew when the trees were drowned by rising water. In some cases the stromatolites completely covered the stumps, but in others the trunks have almost gone (in some cases removed by collectors) leaving the raised circular stromatolites (burrs) on their own. Small holes in the limestone surrounded by narrow circles of stromatolites mark the original positions of branches. Francis (1984) mapped the positions of stromatolite burrs on Portland and calculated the original density of trees to vary between one tree in 15 $m^2$ to one in 54 $m^2$, trunks on average being spaced between 3 and 5 m apart. This suggests an open forest, much more open than modern *Taxodium* swamp forests, although the relative age of the trees needs to be taken into account. Some were dead stumps that became encased by the stromatolites. Large silicified trunks lying close to them support this interpretation. The silicified wood shows fairly well-defined growth rings with very narrow mean-ring widths ranging from 0.05 mm to a maximum of 4.44 mm (Francis, 1984).

The Isle of Portland has also been famous for its cycadeoid stems ever since Buckland (1828, 1836) first described their occurrence, followed by Carruthers (1870a). Seward (1897b) described a particularly well-preserved specimen, 1.18 m tall and 1.7 m in girth, to which he gave the new name *Cycadeoidea gigantea*. It is elliptical in cross-section, measuring 0.41 m × 0.19 m. Its surface is covered with diamond-shaped ridges, which are the petrified ramenta

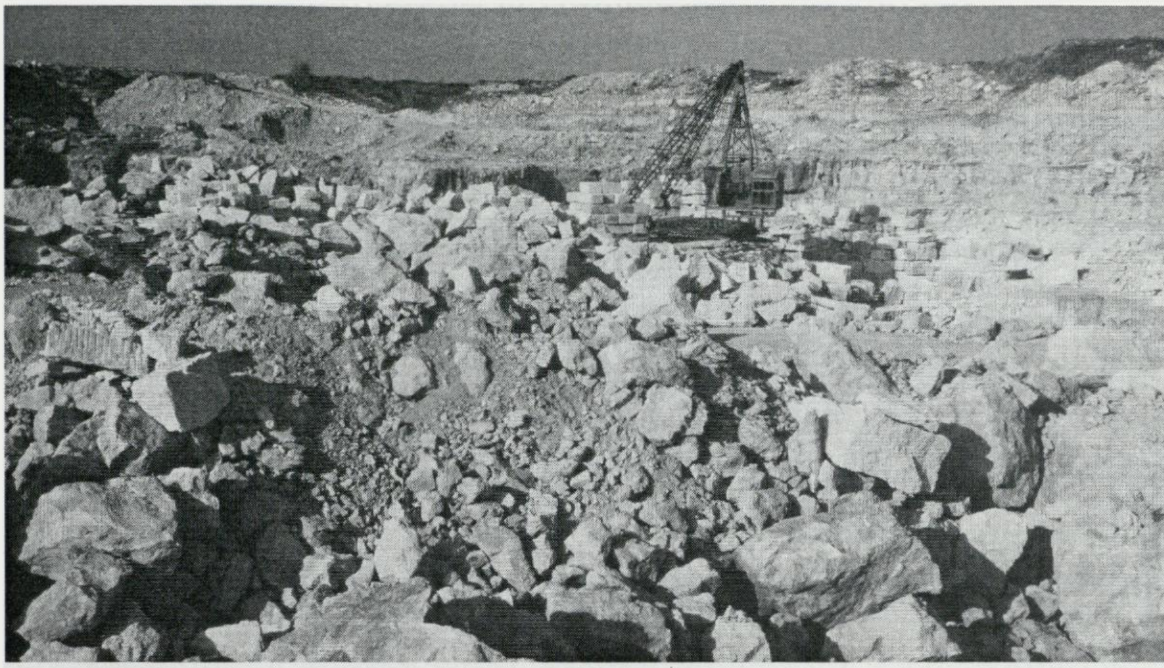

**Figure 4.9** Kingbarrow Quarry. Quarrying on Portland Bill exposes the almost horizontally bedded basal Purbeck Beds of the Upper Jurassic Series. (Photo: B.A. Thomas.)

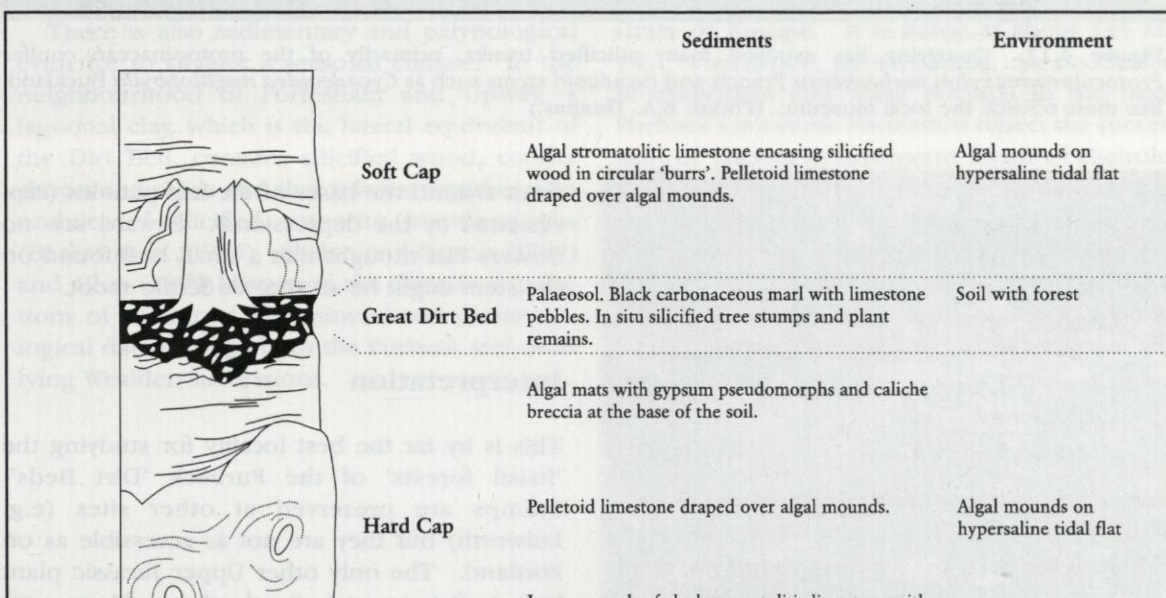


**Figure 4.10** Schematic section through the Lower Purbeck strata of the Isle of Portland, showing the position of the Great Dirt Bed with the fossil forest. (After Francis, 1983.)

**Figure 4.11** Quarrying has exposed many silicified trunks, primarily of the protopinacean conifer *Protocupressinoxylon purbeckensis* Francis and cycadeoid stems such as *Cycadeoidea megalophylla* Buckland, like these outside the local museum. (Photo: B.A. Thomas.)

from around the bases of the leaf petioles (represented by the depressions). Seward saw no flowers but thought that a small bud found on the stem might be an aborted fertile shoot.

## Interpretation

This is by far the best locality for studying the 'fossil forests' of the Purbeck 'Dirt Beds'. Stumps are preserved at other sites (e.g. Lulworth) but they are not as accessible as on Portland. The only other Upper Jurassic plant beds in Britain are in Scotland (see Chapter 5), but these are rather older (Kimmeridgian) and yield compression fossils. Late Jurassic floras are

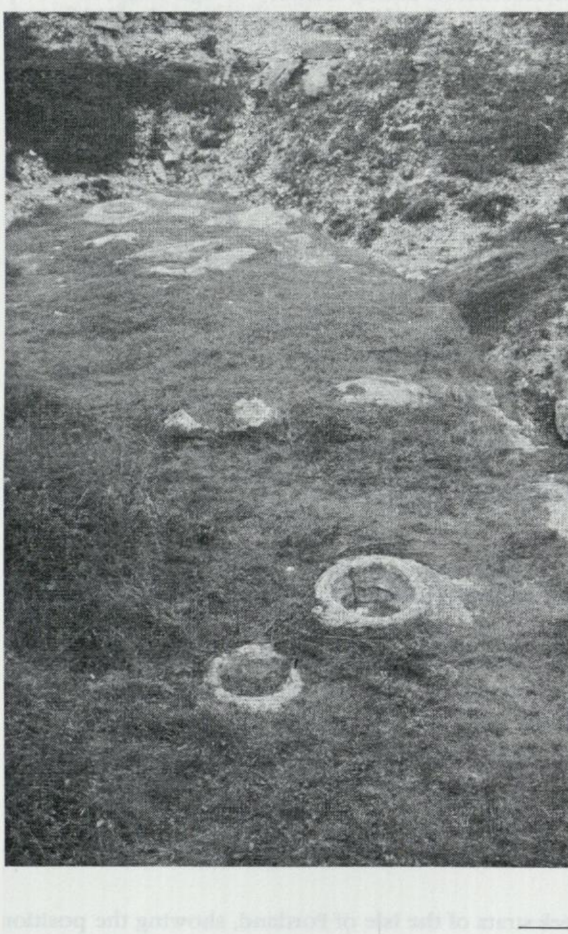

**Figure 4.12** Stromatolite Burrs. These open rings of stromatolite algal growth are found in the Soft Cap Limestone on Portland. They formed around the bases of conifer trees that were rooted in what is now known as the 'Great Dirt Bed', when the forests were drowned by rising water levels. Sometimes silicified trunks remain within stromatolite rings and occasionally tree stumps were completely covered by this growth. The majority are, however, open 'doughnut-shaped' rings that were left after the encased trees subsequently rotted away. (Photo: B.A. Thomas.)

generally very rare in Europe and none appears to be Portlandian (Tithonian) in age (Vakhrameev *et al.*, 1978).

Francis (1984) has interpreted these 'fossil forests' as the remains of cheirolepidiaceous gymnosperm trees that grew on the fringes of a shallow, hypersaline lagoon that covered much of southern England during the latest part of the Jurassic Period. The trees appear to have been adapted to growing in a semi-arid environment, as indicated by the growth rings in the wood. These vary in width, but all are narrow. The trees were probably very sensitive to climatic variations. The factor most likely to have affected growth would have been rainfall and, hence, the availability of water. The preservation of the wood was by quartzine, which is chalcedony that formed very slowly. It is often associated with evaporitic environments and high pH values. The source of the silica is not known although it might have come from the dissolution of detrital quartz.

There is also sedimentary and palynological evidence to suggest a seasonal climate. In the neighbourhood of Portesham and Upway, a lagoonal clay, which is the lateral equivalent of the Dirt Bed, contains silicified wood, conifer shoots and seeds and charophytes together with nodules of silicified evaporite pseudomorphs (Barker *et al.*, 1975). Sladen and Batten (1984) and Allen (1998) discussed the climatic implications of combined clay mineral and palaeontological data through both the Purbeck and overlying Wealden successions.

All this information suggests that the marginal and variable climate was probably of Mediterranean-type, with warm, wet winters. The summers would have been hot and arid, stimulating the formation of evaporites. Francis (1984) suggested that intermittent dry spells could have interrupted the growing season for days or even months to produce the 'false' rings seen within the early wood of the growth rings. She further proposed that an analogous modern environment for both the forests and the seasonal lagoonal sediments is to be found on Rottnest Island, near Perth in Western Australia. Here natural stands of the conifer *Callitris preissii* grow close to small ephemeral lakes.

## Conclusions

Maggot, Kingbarrow and Waycroft quarries yield the only conveniently examinable examples of a fossil forest known from the uppermost Jurassic strata of Europe. It is dated at about 145 Ma (W.A. Wimbledon, pers. comm.). An association of evaporites and fossil remains in the basal Purbeck Limestone Formation reflect the succession of mature gymnosperm forest of cheirolepidiaceous conifers growing on the margins of a shallow, variably saline, sometimes hypersaline lagoon. Narrow rings in the wood indicate marginal and highly irregular growth conditions for the trees. The Purbeck climate was probably of Mediterranean-type with hot, arid summers and wet winters.