THE ZONATION OF THE YORKSHIRE JURASSIC FLORA

TOM M. HARRIS
University of Reading

ABSTRACT

There has been no recent attempt to zone the great flora of the Bathonian and Bajocian of Yorkshire. The plant-bearing rocks are divided into four, and after investigation of new localities it has been found that there is little zonation, but floral changes do occur. The lowest and highest zones are characterized by the relative abundance of one group of species; the two middle zones are characterized by the relative abundance of another group. There is thus a fluctuation and return in the flora.

INTRODUCTION

THE Lower Oolite Flora of Yorkshire has been a standard flora since Brongniart began its scientific description over a century ago. Several authors added to Brongniart's work and in 1900 Seward wrote his catalogue, a work which is both the culmination of the old period of research and the start of the new.

After 1900 a large number of papers were written on individual species, nearly all using Nathorst's maceration methods, but there has been little attempt to review the whole flora. For purposes of correlation the flora has been taken as a unit though it has long been recognized that it ranges through a series of strata. I myself am working towards a general revision of the flora; I have also been examining its stratigraphic relations and although this side also will not be completed for some years, I am satisfied that certain general results are established and these are now given.

In my field work I have aimed at studying the area extensively to supplement the intensive work of others on the best localities. I have no doubt I would have obtained more specimens of palaeobotanical value by limiting my attention to the well-known best localities, but the other method has its advantages being, indeed, indistinguishable from a holiday.

GENERAL STRATIGRAPHY

The general stratigraphic relations of the Yorkshire plant-bearing beds are set forth in many works; the fullest detail is given by Fox Strangways (1892) and the best recent account in Arkell (1933). It is agreed that the accepted name of the plant-bearing series "the Estuarine series" is unfortunate, and based on a mistake, the deposits not being Estuarine at all but laid down by fresh water on a delta. These Deltaic rocks are divided by three marine transgressions into four stages, the two lowest being called "Lower Estuarine", the next Middle Estuarine and next and top the Upper Estuarine. This division is unhappy and Hemingway (1949) has just proposed a new scheme of naming, which has, however, already met criticism (SYLVESTER BRADLEY, 1949). I cannot say whether Hemingway's scheme will be accepted, but I use it here because it fits palaeobotanical needs.

The old system of naming the Yorkshire Lower Oolites (Bathonian and Bajocian stages) and that of Hemingway are compared below.

Hemingway's new terms only affect the non-marine Deltaic or Estuarine rocks.

Old names	*New names*
Callovian (Marine macrocephalus zone)	
Upper Estuarine	Upper Deltaic
Grey or Scarborough Limestone (Marine, *blagdeni* zone)	
Middle Estuarine	Gristhorpe series of the Middle Deltaic
Millepore Bed and Whitwell Oolite (Marine, perhaps discites zone)	
Lower Estuarine	Sycarham series of the Middle Deltaic
Eller Beck Bed and Hydraulic Limestone (Marine, not yet zoned)	
Lower Estuarine	Lower Deltaic
Dogger (Marine, age varied, *murchisoni* zone or older)	

THE OUTCROP

The outcrop of the Deltaic rocks extends along the coast from Gristhorpe to Loftus and some 40 miles inland. At least 99 per cent of it is covered by soil and I had limited my work to natural exposures or artificial ones made by others.

The chief natural exposures are in the sea cliffs ; the famous localities being on the beaches. Much of the cliffs is quite inaccessible, but great blocks continually fall and give good material. Inland, there are two important localities caused by recent landslides and very many small sections in the streams.

Artificial exposures are fewer now than a century ago because of the extinction of all industry except farming. The Upper Liassic alum pits (and certain iron-stone workings) are so large that fresh rock is still available. About 1,000 small sandstone quarries are scattered over the moors and were used for building walls and farms. Many must have yielded plants, but they are now so weathered that I only found them in about one in twenty quarries. The old coal, and "soft jet" pits scattered over the moors are more useful. Their depth varies from 20 to 120 ft. (as I have proved by plumming) and although nearly all have fallen in around the shaft, there is a heap of muddy shale most of which must have been closely associated with the coal. At a depth of two feet this shale is little weathered and yields very good plants. As there are over 2,000 of these coal pits, I have not sampled every one but have taken a few in each group.

The war has left plenty of bomb craters caused by enemy action as well as entrenchments and the like, but for some reason I have seldom obtained useful specimens from them. More useful are road banks and railside sections, and in particular the little erosion gulleys caused by farm tracks up escarpments.

It has been my aim to visit every exposure of Deltaic rocks in the outcrop. So far I have covered about two-thirds of the area and must have walked well over a thousand miles over the moors and along small streams. The maceration of all material collected has been completed, but about half the species still await description.

THE PLANT BEDS

Some 240 different beds yielding determinable plants are now known. I distinguish the following five types of beds, though it must be made clear that they intergrade.

1. Truly autochthonous beds (i.e. beds with plants preserved in the position of growth). Such beds consist of the roots and lower 1 m. or so of the stem of *Equisetites columnaris* which are frequent in the Lower Deltaics, but not known above, though the species remains common. They seem to consist of an *Equisetum* swamp suddenly overwhelmed by sand through a river diversion.

Truncated root beds, however, occur at all stages in the series; thus at Cloughton Wyke over half the section of the Gristhorpe series consists of them. Many of these roots seem to belong to *E. columnaris* but other species occur. These beds represent an old land (or swamp) surface occupied by vegetation but with the upper parts removed by erosion through river diversion. Geologists have noted these root beds in Yorkshire, but without clearly distinguishing them from beds of Equisetean stems. Similar beds are abundant in other Deltaic areas and I have noted them repeatedly in Greenland, in other parts of England and in the Rajmahal Hills of India. I think that many of the tiny coal seams in the Deltaic series represent the continued accumulation of *Equisetum* stems in a marsh, for the coal yields *Equisetum* cuticles in millions. Other coal seams are, however, formed from logs of trees with more or less of *Equisetum* and leaf material. Such coal seams are allochthonous, though their material may have come from fairly near.

2. Lagoon and sluggish river channel beds. The prevailing sediment is fine mud. The richest is the Gristhorpe Bed but other plant beds approach this type. Here there is a mixture of large delicate leaves which plainly have not been carried far by water, with some water-worn material. The frequent association of leaves with their reproductive organs suggest that the plant of origin grew near at hand and on this account the Gristhorpe Bed has even been termed autochthonous. I think, however, that the term is better used in its strict sense.

3. River channel beds, the prevailing sediments being fine sand. The richest is the Whitby plant bed. Such beds differ from those of group 2 in having a higher proportion of water-worn plants, but even here good leaves occur and are often associated with their appropriate reproductive organs; types 2 and 3 in fact intergrade.

4. Drifted plant beds, the prevailing sediment being sand (e.g. Black's drifted plant bed at Scalby Wyke, BLACK, 1929).

Here all but the smallest plants are severely water-worn and such fossils as fern leaf fragments devoid of lamina are common. There are often many pieces of water-worn wood. This type intergrades with 3.

5. Redeposited plant beds. Such beds have not been described, but are in my opinion very common or even prevalent. The characteristic fossils are tough cuticles, often already macerated at the time of preservation and with the upper and lower sides already separated. Such uncutinized fossils as fern rachises are not prominent and are perhaps absent entirely.

We know that the erosion channels of the delta were shallow in relation to the thickness of the Deltaic series, so we may presume that the redeposited fossils are from beds of only slightly older age. I imagine shallow river channels wandering over the face of the land and continually cutting away and redepositing nearly all the surface. Only unrotted plant material, i.e. cuticle, would survive and be redeposited.

Derived fossils (in the ordinary sense) are also met, for example sandstones containing fragments of carboniferous coal yielding well-known coal measure megaspores.

TYPES OF PLANTS

The flora of the autochthonous Equisetites beds and of the lagoon and river channel beds is known from the work of Seward and others. It must, however, be emphasized that even in these beds many determinable microfossils occur and in the far more numerous drifted and redeposited beds they are almost the only ones available. The microfossils I have used so far are the larger ones — pieces of leaves, seeds and Lycopod megaspores. I have neglected small spores though they are numerous. I have also neglected wood. Wood is preserved as a bituminous coal (soft jet) or as pieces of fusain or charcoal; true petrified wood is rare. I have also neglected the smaller microfossils because it seems to me they involve more uncertainty than the larger microfossils and hand specimens. Even without woods and small microfossils the investigation promises to last many more years.

ZONATION OF THE FLORA

Although Phillips made a start with careful collecting, his work was buried under an accumulation of badly collected material. Museums are full of professionally collected specimens with no label or even a wrong label. It was only in comparatively recent years that Thomas (1913) collected and listed species in certain Lower Deltaic localities and Black (1929) in Upper Deltaic ones, but neither dealt with the zonation of the whole flora.

Any such study has indeed been difficult because knowledge of the flora has been based on a very few localities and it was impossible to disentangle zonation from mere local peculiarities. One large part of the series (Sycarham series) had no recorded flora. Each of the four main divisions of the Deltaic series has now plants from a good many localities, but their richness is far from equal. The Gristhorpe series is the richest, then the Lower Deltaic, then the Upper Deltaic and the Sycarham series is the poorest, both in number of localities and in number of species.

TYPES OF PLANT DISTRIBUTION

As far as I have been able to tell, the flora of the Deltaic series is more or less evenly distributed horizontally over the whole area. While it was known from but few localities, their strong local peculiarities of flora seemed to suggest that a certain plant was northern, another southern, and so on, but the study of more numerous localities has largely discounted this.

Another point that may be made is that no fine zonation, such as occurs in the Ammonites, appears in this flora. Each of Hemingway's four named stages of the Deltaic has its floral peculiarities, but I could find no sign at all of real difference between the upper and lower parts of any one of these stages. If such zonation is to be established, different methods must be used.

Another general observation is that each local plant bed may have strongly marked peculiarities. Thus I have several times found a rare species (i.e. one with few or no other localities) in local abundance, its fragments in thousands dominating a few cm. of shale. I think indeed that this uneven occurrence is quite normal in Deltaic floras, but it seems that relative abundance of a species in a single bed is dangerous evidence to use in correlation.

There is, however, another way in which ' frequency ' can be used and in this different

sense I believe it has zonal significance. Thus suppose for example that a certain rock series is represented by 97 localities from which determinable plants have been obtained. A species found in all would have 100 per cent of its possible ' frequency ', how abundant it was in each locality would not matter. Using the term ' frequency ' in this special sense a species has been found to vary in its frequency. Thus for *Pachypteris lanceolata* we have the following figures :

	%
Upper Deltaic : 8 locs of a possible 45	18
Middle Deltaic, Gristhorpe series : 4 locs of a possible 83	5
Middle Deltaic, Sycarham series : 2 locs of a possible 18	10
Lower Deltaic : 14 locs of a possible 97	14

The species is clearly commoner in the first and fourth. It is clear that for this use of frequency one must have plenty of localities and also that they should, in the main, be investigated in a reasonably consistent manner. Disproportionately prolonged work on the localities of a particular stage would no doubt raise its figures ! Apart from the rare species, whose range and frequency are necessarily ill known, the flora can be divided on its range and frequency into the following parts :

1. A few species range the whole series without any striking change in abundance. *Brachyphyllum mamillare* is an example and also *Coniopteris hymenophylloides* but that is an aggregate of many varieties differing considerably in both sterile and fertile leaves. There are also several microfossils such as the megaspore *Triletes sparassis* Murray which is one of the frequent fossils throughout, being met in larger or smaller numbers in about a third of the localities at each stage.

2. There are a few common species which range the lower three series but so far as we know are absent from Upper Deltaic. *Equisetites columnaris* is the most striking example ; its cuticle can be detected in nearly every maceration of fossiliferous shale from the three lower, but I have not yet found it in the Upper Deltaic.

3. There are a few species which seem confined to the Lower Deltaics, and though moderately frequent, they have not yet been met in any of the other three divisions. None of these is particularly common, but one *Sphenobaiera pecten* Harris has now a dozen localities to its credit and another *Pachyderphyllum* Thomas has half a dozen. There are also a few megaspores (not yet described) in this group.

4. There is quite a large group of species which occur commonly in the Lower Deltaic, are rare in the next two divisions but are common again in the Upper Deltaic. Some of these, like *Pachypteris lanceolata*, are very frequent indeed in the upper and lower but present, though rare, in the two middle ones. Several megaspores have this distribution. Others like *Stenopteris nana*, *Pseudoctenis oleosa* are rare in both Upper and Lower Deltaics and so far have not been discovered in the two middle divisions. Rather common species with this sort of distribution are *Ptilophyllum pectinoides*, *Zamites gigas*, *Baiera gracilis*, *B. furcata*.

5. There is a considerable group of species which are more or less abundant in the two middle divisions, but much rarer or absent above and below. Several undescribed megaspores belong to this group, but the most remarkable is an undescribed conifer with a very beautiful cuticle. Fragments of this are found in 33 per cent of the localities of the stages of the Middle Deltaics — but so far only known from 12 per cent in Lower Deltaic and 4 per cent in the Upper Deltaic. It is a striking thing that a fossil which has been met as fragment so many times should never yet have been seen as a macrofossil — can it have been an inland growing species ?

The groups 1, 2 and 3 perhaps call for little comment as such groups are to be expected in a gradually changing flora. It is, however, a little remarkable that there are no complementary groups to 2 and 3 beginning, say, in the Gristhorpe series, and passing on into the Upper Deltaic. The groups 4 and 5, which imply a fluctuation and the restoration in the nature of the flora, were quite unexpected by me.

The only floral succession I have previously studied was in the Greenland Rhaetic-Liassic (Harris, 1935) where at about the end of Rhaetic times there was a rapid, though not quite sudden, change in what had been a stable flora which gave place to another stable flora. From what we know of other areas where a similar change seems to have occurred, there was no restoration of the Rhaetic species ; and also we know

that once the Rhaetic species disappeared, they were gone entirely and not merely relatively rare. From the point of view of the use of fossil plants for zonation, this is very simple. The fluctuation in the flora of the Yorkshire Deltaics is, so far as I know, without parallel in the older formations; but there are plenty of parallels in recent periods, especially the Quarternary where it is well known and even occurred repeatedly. The explanation given for these changes in the Quarternary is that they reflect a fluctuation of climate occurring with a period much less than that of the life period of species.

If such a climatic fluctuation occurred in England in the Bathonian and Bajocian, I know of no other evidence for it; nor do the plants seem to provide any evidence about its nature.

At each stage there were plants with tough, xeromorphic leaves, intermediate plants and delicate looking ones along with large numbers of swamp Equisetales. No change of proportions of such elements is obvious. Indeed, if any climatic change did occur, it should have been a rather slight one in view of the continued abundance of certain species.

Such a fluctuating change in a flora is clearly a less reliable index for correlation than the sustained change which separates the Rhaetic from the Lias. It is indeed doubtful if it is to be relied on at all for correlation. I do, however, suggest that it might occur elsewhere and its possible occurrence should be borne in mind when plant zonation is being established.

It would seem, therefore, that, apart from a small group of species confined to the first stage in the Lower Deltaic, the flora should be taken as a whole for purposes of correlation. The early authors, who without regard to possible floral succession did this, did right.

REFERENCES

ARKELL, W. J. (1933). The Jurassic System of Great Britain. *Oxford*.

BLACK, M. (1929). Drifted Plant beds of the Upper Estuarine series of Yorkshire. *Q.J. Geol. Soc.* **85** (4): 389.

FOX STRANGWAYS, C. & BARROW, G. (1892). The Jurassic Rocks of Britain. **1** and **2**, Yorkshire. *Mem. Geol. Surv.*

HARRIS, T. M. (1935). The Fossil Flora of Scoresby Sound, East Greenland. *Medd. Om Groenland.* **112** (2).

HEMINGWAY, J. E. (1949). A Revised Terminology and Subdivision of the Middle Jurassic Rocks of Yorkshire. *Geol. Mag.* **67**.

PHILLIPS, J. (1829, 1875). Illustrations of the Geology of Yorkshire, Pt. I, the Yorkshire Coast (1st Edition 1829, 3rd Edition 1875). *York*.

SEWARD, A. C. (1900). Catalogue of the Mesozoic Plants. The Jurassic Flora 1. British Museum (Natural History). *London*.

SYLVESTER BRADLEY, P. C. (1949). Letter to *Geol. Mag.* **86** (4): 263.

THOMAS, H. H. (1913). The fossil flora of the Cleveland district of Yorkshire 1. The flora of Marske Quarry. *Q.J. Geol. Soc.* **69**: 223.