USE OF PALYNOLOGIC ASSEMBLAGE-TYPES IN WEALDEN CORRELATION

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ABSTRACT. Analysis of extensive palynologic data from the English Wealden (Early Cretaceous) has enabled a comprehensive set of 17 palynologic assemblage-types to be defined in detail. This has been done in such a way that a rapid preliminary survey of a preparation will enable it to be placed in one of the assemblage-types so that its value for stratigraphic correlation or palaeoecology can be predicted without long and possibly uneconomic use of observation time. With the exception of *Celyphus rallus* gen. and sp. nov. of uncertain affinity, which is described because its presence is important in some assemblages, spore and pollen taxonomy is confined to brief comments on the sense in which some of the genera and species are used here.

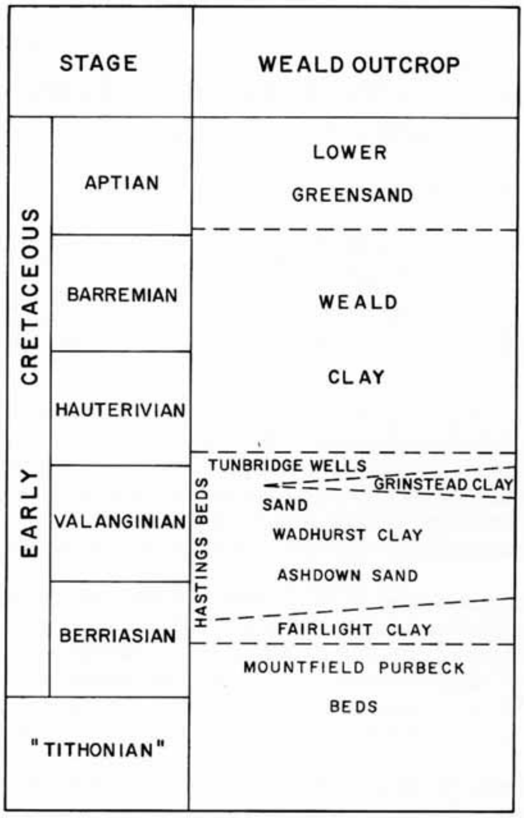
THE method of stratigraphic comparison of palynologic assemblages practised by many palynologists is inadequate and often misleading. The descriptions of many spore and pollen taxa are unsatisfactory, the original concept of a genus or species is frequently distorted by later emendations and attributions to it, and personal opinions have to be interpreted. The ranges of taxa grow both geographically and chronologically. Facies relationships are usually ignored. Dating is, at best, usually possible only to an Age/Stage.

Refinements in the application of palynology to stratigraphic correlation will be possible only when taxa are described and compared more accurately (Hughes and Moody-Stuart 1967*b*, 1969, Hughes 1970) and the effects of the factors which have controlled the distribution of plant microfossils are more fully understood. The recognition of relationships between independent palynomorph taxa and the assemblages in which they occur is obviously necessary and is the subject of this paper.

The first step is to identify and define by their contents kinds of assemblages that are in some degree related to the other characters of the sedimentary rock involved. This has been done for material from the main succession of the Hastings Beds and Weald Clay (Wealden) in the Early Cretaceous of southern England (text-figs. 1-3). The full organic palynomorph content observable with an optical microscope was recorded for 340 productive miospore preparations. Observations on recurrent associations of assemblage characters including abundance, average size, and preservation state of various palynomorphs, led to a grouping of all the assemblages into 17 assemblage-types. The grouping was aided and subsequently confirmed by a cluster analysis procedure.

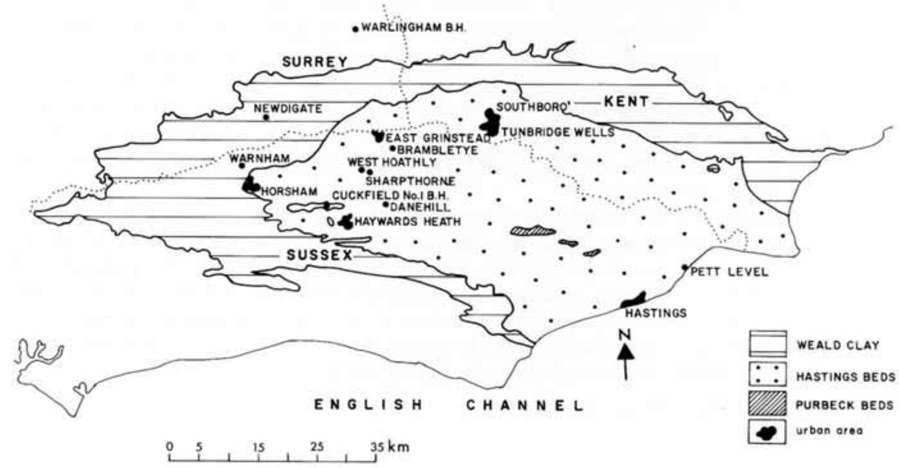
The determination of assemblage-types can now be made by a rapid survey of any preparation from these rocks by comparing its characters with those of the 17 types. As a result, it is now possible to predict, before committing the palynologist to long detailed observation, whether a preparation can contain a certain character. It is thus possible to select preparations (*a*) to avoid waste of time in searching for characters unlikely to be present, and (*b*) positively to search for selected characters thought to be present on evolutionary sequence grounds.

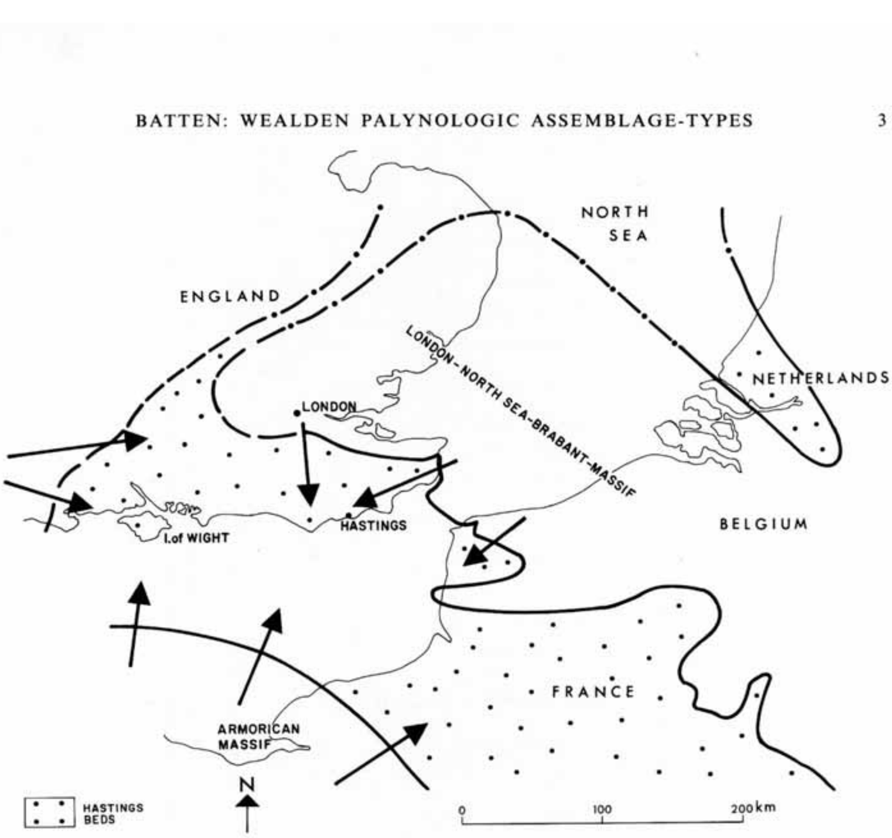
[Palaeontology, Vol. 16, Part 1, 1973, pp. 1–40, pls. 1–2.]



TEXT-FIG. 1. Suggested time-correlation of the Wealden outcrop of south-east England (from Harland *et al.* 1967, and latest published information). Lithologic boundaries appear as broken lines. The Ashdown Sand and Fairlight Clay are often grouped as the 'Ashdown Beds' (Howitt 1964, Gallois 1965, Dines *et al.* 1969); it is probable that the two units are diachronous. The Tunbridge Wells Sand is subdivided into three units (upper and lower sandy members separated by the Grinstead Clay) only in the western part of the High Weald. The formation thicknesses are not to scale. Thicknesses (from Gallois 1965): Ashdown Beds, 152–213 m; Wadhurst Clay, 30–70 m; Lower Tunbridge Wells Sand, 15–46 m; Grinstead Clay, 0–21 m; Upper Tunbridge Wells Sand, 30–76 m; Weald Clay, 122–475 m.

TEXT-FIG. 2. Map showing Purbeck Beds, Hastings Beds, and Weald Clay outcrop in south-east England. Place-names mentioned in text are included.





TEXT-FIG. 3. Inferred extent of the Hastings Beds (modified after Allen 1965, 1967*a*): southern England and part of north-west Europe. The succession is generally thought to have accumulated at the northern end of an elongate subsiding shallow-water essentially non-marine basin (the Anglo-Paris Basin) which ran southwards and connected with the Tethyan Sea in central France. The succession in southern England can be taken, for present purposes, to represent the development of a complex of sandy deltas (probably southward facing), bars and lagoons, and offshore silts and clays (see Allen 1959, 1967*b*).

Although the classification of preparations and the recognition of assemblage-types are primarily intended to provide a basis for improvements in the application of palynology to fine stratigraphy, they also form the main preliminary step towards a plant palaeoecologic study which will require the integration of this information with plant megafossil and other stratigraphic and sedimentologic information. Some assemblage-types here defined cannot be used directly in other geologic periods, but it is hoped that parallels can be produced relatively quickly on similar grounds and that the Wealden types will form a useful basis for comparison.

The development of the assemblage classification and detail of all the assemblage-types is fully worked out here. Comments are provided on the lithologic and stratigraphic distribution of the types within the succession studied. An evaluation of the types by cluster analysis and multidimensional scaling procedures is included.

L E G E N D

KEY CHARACTER ■
IMPORTANT CHARACTER ▮
OTHER ●

RECURRENT ASSOCIATIONS

KEY CHARACTERS	AT	SMOOTH TRILETES			CONCAVISSIMISPORITES	PILOSISPORITES		CICATRICOSISPORITES				ISCHYOSPORITES		TRILOBOSPORITES	GLEICHENIIDITES				TOTAL TRILETES			ARAUCARIACITES			INAPERTUROPOLLENITES			
		C	V	F	C	P	C	P	C	V	F	C	V	C	P	C	V	F	C	V	F	P	C	V	P	C	V	F
POOR GENERAL STATE OF PRESERVATION	1		●	●				●	●						●	●				●	●	●	●			▮	▮	
GOOD GENERAL STATE OF PRESERVATION	2	●	●	●				●	●							●	●			●	●				●	●		
MIOSPORE CONTENT DIVERSE	3		●	●				●	●						●	●					●	●	●		●	●		
SMALL TRILETES DOMINATE TRILETE SPORE CONTENT	4		●	●				●	●						●	●				●	●	●	●		●	●		
LARGE TRILETES DOMINATE TRILETE SPORE CONTENT	5		●	●					▮	▮					●	●					●	●	●		●	●		
BROWN WOOD F	6	●	●	●				●	●						●	●				●	●	●	●		●	●		
INAPERTUROPOLLENITES V OR F	7		●	●				●	●						●	●					●						■	■
PILASPORITES F	8	●	●					●	●										●	●						●		
EXESIPOLLENITES C OR V	9		●	●				●	●						●	●				●	●	●	●		●	●		
CLASSOPOLLIS F	10	●	●					●	●						●	●				●	●	●	●			●		
EUCOMMIIDITES C	11	●	●	●					▮	▮											●	●	●		●	●		
CICATRICOSISPORITES V OR F	12		●	●						■	■										●				●	●		
PILOSISPORITES C	13		●	●			■		▮	▮					●	●					●	●	●		●	●		
TRILOBOSPORITES C	14		●	●				●	●					■	●	●					●	●	●		●	●		
CONCAVISSIMISPORITES C	15		●	●	■	▮	▮		▮	▮					●	●					●				●	●		
ISCHYOSPORITES C OR V	16	●	●	●				●	●	●		■	■							●	●	●	●		●	●		
FAIR GENERAL STATE OF PRESERVATION	17		●	●				●	●						●	●	●	●		●	●	●	●	●	●	●		

KEY CHARACTERS	AT	PILASPORITES			TSUGAEPOLLENITES		BISACCATES			EUCOMMIIDITES		CLASSOPOLLIS				EXESIPOLLENITES			PERINOPOLLENITES	TRILETE SPORE SIZE			MIOSPORE DIVERSITY			INDETERMINABLE MIOSPORES			BROKEN MIOSPORES		PRESERVATION			BLACK WOOD			BROWN WOOD			CUTICLE			MIOSPORE MASSES/TETRADS	
		C	V	F	P	C	C	V	F	P	C	P	C	V	F	P	C	V	P	S	A	L	S	A	L	P	C	F	C	F	B	M	G	P	C	F	P	C	F	P	C	F	P	C
POOR GENERAL STATE OF PRESERVATION	1				●	●	●	●	●			●	●	●							●		▮	▮			●	●	●	●	■					●								
GOOD GENERAL STATE OF PRESERVATION	2				●	●	●	●	●												▮	▮	●	●	●	●	●		●				■		●	●		▮	▮	▮	▮	▮		
MIOSPORE CONTENT DIVERSE	3				●	●	●	●	●	▮	▮	●	●	●							▮	▮			■	●	●		●	●	●	●	●		●	●								
SMALL TRILETES DOMINATE TRILETE SPORE CONTENT	4				●	●	●	●	●											■			▮	▮			●	●	●	●	▮	▮				●								
LARGE TRILETES DOMINATE TRILETE SPORE CONTENT	5				●	●	●	●				●	●	●								■		▮	▮	●	●		●	●		▮	▮		●	●	▮	▮	▮	▮	▮			
BROWN WOOD F	6				●	●	●	●	●			●	●	●							●		●	●	●	●	●		●			▮	▮		●	●			■	▮	▮	▮		
INAPERTUROPOLLENITES V OR F	7						●	●				●	●	●						▮	▮		▮	▮			●	●	●	●	▮	▮				●								
PILASPORITES F	8			■	●		●	●				●	●	●							●		▮	▮		●	●		●			▮	▮	●	●	●		▮	▮		▮	▮	▮	▮
EXESIPOLLENITES C OR V	9				●	●		●	●				▮	▮			■	■		▮	▮		▮	▮			●	●	●	●	▮					●								
CLASSOPOLLIS F	10				●	●	●	●							■					▮	▮		▮	▮			●	●	●	●	▮	▮				●								
EUCOMMIIDITES C	11				●	●		●	●		■					▮	▮			●	●	●	●	●	●	●	●		●	●	●		●		●	●								
CICATRICOSISPORITES V OR F	12						●	●				●	●								●		●	●	●	●	●		●	●	▮	▮				●								
PILOSISPORITES C	13				●	●	●	●													▮	▮		▮	▮	●	●		●			▮	▮		●	●	▮	▮	▮	▮	▮	▮		
TRILOBOSPORITES C	14				●	●		●	●										▮	●	▮	▮		▮	▮	●	●		●	●		▮	▮		●	●	▮	▮	▮	▮	▮	▮		
CONCAVISSIMISPORITES C	15				●	●	●	●				●	●	●							▮	▮		▮	▮	●	●		●	●		▮	▮		●	●	▮	▮	▮	▮	▮	▮		
ISCHYOSPORITES C OR V	16	▮	▮	▮	●	●	●	●													●		▮	▮		●	●		●	●	●		●			●				▮	▮	▮		
FAIR GENERAL STATE OF PRESERVATION	17						●	●	●			●	●	●							●	●	●	●	●	●	●		●	●		■				●	●	●	●	●	●	●		

TABLE 1. Combinations of recurrent associations at the 80% level of affinity which form the bases of ATs 1–17. For abbreviations employed, see Table 2; for use of terms 'wood' and 'cuticle', see 'Development'; for taxonomic usage, see 'Miospore Record'; CVF, SAL, etc. = C, V, or F; S, A, or L.

TABLE 2. Abbreviations employed in text and on tables

AT	assemblage-type; ATs assemblage-types.	
P	< 3%, present	Miospore abundances excluding *Inapertisporites*
C	3- < 15%, common	
V	15- < 30%, very common	
F	30% or more frequent	
P	present	Relative abundances of *Inapertisporites* and of all other entities except for those listed below.
C	common	
F	frequent	

Pyrite corrosion: recorded as P if miospores affected are common or frequent. Fungal remains, rootlets, and other trace fossils, rhizomes and stems *in situ*, ironstones: P if recorded.

Trilete spore size: S = small forms dominate trilete spore content
A = average-sized forms dominant
L = large forms dominant
Miospore diversity: S = little diversity
A = average
L = large
Preservation state: B = poor (bad)
M = fair (mediocre)
G = good
Sorting: B = poor
G = good

Rocks: FC, Fairlight Clay; AS, Ashdown Sand; WC, Wadhurst Clay; TWS, Tunbridge Wells Sand excluding Grinstead Clay; GC, Grinstead Clay; WEC, Weald Clay.

Publication of the detail of their application will, however, for reasons of space, have to be presented later. Details on the materials and methods and brief comments on some of the taxa employed are provided for reference.

Definition of terms. I use the term 'assemblage' to refer to the total organic content of a preparation from a single rock sample. A combination of recurrent associations of assemblage characters forms the basis of an 'assemblage-type'. Some, in particular Soviet, authors employ 'spectrum' for the spores and pollen extracted from a selected sample and use 'assemblage' to refer to the typical spore/pollen spectrum of a given horizon, suite, stage, etc. (Vakhrameev 1970).

THE ASSEMBLAGE-TYPE CLASSIFICATION

The 17 assemblage-types identified from the Wealden are presented on Table 1. Each type consists of a set of recurrent associations for a 'key character' or 'identifier'. For convenience, the types are numbered 1–17. Details are given below in a systematic section which amplifies Table 1.

Method of determination of assemblage-type

Palynologic preparations can be assigned to these assemblage-types after about 10 minutes' examination. The procedure is as follows:

1. Note preservation state, diversity of miospores, average size of trilete spores, and abundance of brown wood; assign preparation to AT1–6, or if in doubt, to AT17.
2. If considered useful, attempt to assign preparation to AT7–16, the more detailed level; in some cases it may not be possible to do so (see Table 6). If necessary,

a rapid count of 100 miospores may be made, only recording the taxa which could be key characters and treating all other taxa as one group. Successful assignment at this level cancels the initial assignment to AT1–6 and 17.

3. The following secondary characters, discussed separately below, can be noted at either stage: *Inapertisporites* F, *Celyphus rallus* C or F, microplankton, microforaminifera, and megaspores C or F. Their identification is not essential for the determination of assemblage-types.

The associations listed for each AT occur in at least 80% of the assemblages I have assigned to that type. An identified assemblage will not, therefore, necessarily display every character listed for the type. Attribution to more than one assemblage-type may be necessary because assemblage character variation is continuous. An order of priority for assemblage-type usage described elsewhere (Batten 1972) is not considered here because it has been found to be too cumbersome for general use.

Table 6 gives data on 100 selected productive samples and the identifications possible. The application of the procedure is considered later (p. 19).

Secondary characters

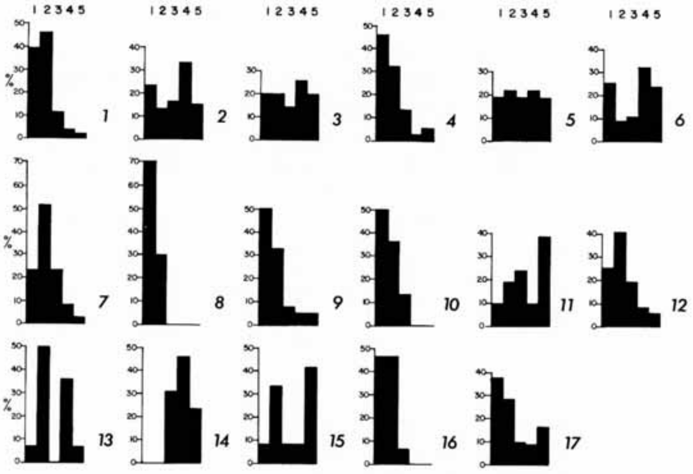
Certain palynomorph groups are considered separately from the classification because: (1) their distribution patterns differ significantly from those of the bulk of the miospores; (2) they occur in a variety of, and therefore superimpose, assemblage-types; and (3) their value in the context of Wealden miospore preparations is primarily palaeoecologic rather than stratigraphic. These groups include megaspores, charalean gyrogonites, seeds, *Botryococcus*, dinoflagellates and acritarchs, microforaminifera, reworked spores, and certain other palynomorphs. Dinoflagellates and acritarchs would probably assume greater importance in assemblage classifications developed for other regions but they are not common enough to have much other than palaeoecologic value in the Wealden.

Five categories of secondary characters which I have found useful to record are those listed on Table 5 together with their recurrent assemblage associations; details are presented for reference below. Their recognition is not, however, essential for and merely refines an identification. The occurrence of secondary characters is recorded for the assemblages listed on Table 6.

RECORD OF ASSEMBLAGE-TYPES

This section is intended to supplement the information given on Table 1 and text-figs. 4 and 5. Details of the assemblage-types are discussed and the key characters and associations which I consider to be important (modified since Batten 1972) are noted; reference to other associations listed on the table and to lithologic and stratigraphic distribution is restricted to information unobtainable or not obvious from the table and text-figures.

All percentages given are accurate to the nearest whole number and are derived from data on 340 productive Wealden miospore preparations (see section below: 'Development'). The number of assemblages on which each assemblage-type is based



TEXT-FIG. 4. Histograms showing relationship between assemblages containing key characters (1–17) and grain size of samples from which they were extracted. % = percentage of total number of preparations of rock samples containing key character. 1 = clay, 2 = fine–medium silt (mostly finely laminated clay/fine silt and medium silt), 3 = medium silt, 4 = medium–coarse silt, 5 = coarse silt and sand.

TEXT-FIG. 5. Histograms showing the frequency of occurrence in the Wealden of assemblages containing the key characters of the 17 assemblage-types. % = percentage of total number of productive samples processed from each formation. Percentages for Weald Clay unreliable because of insufficient data. FC = Fairlight Clay, AS = Ashdown Sand, WC = Wadhurst Clay, TWS = Tunbridge Wells Sand excluding Grinstead Clay, GC = Grinstead Clay, WEC = Weald Clay.

is given on Table 3. For abbreviations employed in the text and on tables and text-figures, see Table 2. Important associations below the 80% level of affinity of selected taxa mentioned in the text are summarized on Table 4.

TABLE 3. Number of assemblages on which each assemblage-type is based

AT	*Number of assemblages*	AT	*Number of assemblages*
1	207	10	22
2	61	11	21
3	70	12	47
4	37	13	14
5	32	14	13
6	68	15	12
7	39	16	15
8	20	17	72
9	40		

TABLE 4. Degrees of association of important taxa with certain assemblage-types, below the 80% level of affinity

Concavissimisporites	> 60% in ATs 13 and 14
Pilosisporites	> 70% in AT14, > 60% in ATs 3 and 5
Verrucosisporites	> 70% in AT11, > 60% in ATs 2 and 3
Staplinisporites	> 60% in ATs 2, 5, and 11
Trilobosporites	> 70% in ATs 3, 11, 13, and 15
Eucommiidites	> 60% in ATs 2, 9, and 14
Cycadopites	> 50% in AT11
Exesipollenites	> 70% in ATs 1, 3, 7, and 10, > 60% in AT6
Schizosporis	> 50% in AT14

AT1

Key character. General state of preservation of miospores poor.

Important associations. Miospore content shows average or little diversity; *Inaperturopollenites* C or V.

Remarks. *Exesipollenites* occurs in 71% of the assemblages referable to AT1. Brown wood occurs in only 37% (C in 14% and F in 4%) and cuticle in 50% (C in 8% and F in < 1%). The preservation state of miospores in assemblages containing an abundance of black wood, but little or no brown wood or cuticle, is generally poor or fair.

The spores of taxa which have been most susceptible to folding, tearing, and corrosion are the thin-walled smooth or lightly sculptured triletes, the thin-walled inaperturates (*Inaperturopollenites* species), and the bisaccates. Many poorly preserved assemblages are composed almost entirely of spores with pale coloured 'thinned' and roughened (pitted/etched) exines. The recognition of various types of corrosion has been employed (unpubl.) to refine assemblage identifications.

Distinction. Well and fairly well preserved assemblages usually occur in association with an abundance of brown wood and/or cuticle and tend to contain a greater variety of miospore taxa than poorly preserved assemblages. The majority of assemblages recorded as showing little diversity are poorly preserved.

Lithologic associations. Assemblages referable to AT1 are most often recovered from (calcareous) fine-medium siltstones, claystones (text-fig. 4), and argillaceous limestones. Those from the fine siltstones and claystones generally contain very flattened miospores but those from limestones and clay (sideritic) ironstones tend to be slightly inflated.

Stratigraphic distribution. Although poorly preserved assemblages are most often recovered from the Wadhurst, Grinstead, and Weald Clays, a high proportion of Tunbridge Wells Sand samples have also yielded them (text-fig. 5); this can be attributed to the fact that many of the samples processed from this unit were well sorted.

AT2

Key character. General state of preservation of miospores good.

Important associations. Trilete miospore content dominated by average sized or large forms; brown wood C or F; cuticle P, C, or F.

Remarks. The miospore content of 49% of the AT2 assemblages is diverse, but shows little diversity in 25%. Brown wood is F in 70%. *Verrucosisporites*, *Staplinisporites*, *Eucommiidites*, and miospore masses and/or tetrads occur in more than 60%. Assemblages in which no spores show signs of corrosion have not been recovered and those with very few corroded forms are exceptional.

Distinction. The usual lack of diversity of miospores and scarcity or absence of brown wood and cuticle in assemblages in which miospores are poorly preserved contrasts with the frequent association of abundances of brown wood and cuticle and the generally greater diversity of the miospore content with well-preserved assemblages. The greater diversity in well-preserved assemblages is partly the result of the fact that it is easier to identify well-preserved miospores than poorly preserved, but it is also frequently a reflection of closer proximity of the depositional environment to source and other factors.

Comparison. Assemblages which contain the identifiers of ATs 5, 6, 8, 13, 14, and 15 are more likely to contain well-preserved miospores than other assemblages.

Lithologic associations. The best-preserved assemblages are most often extracted from sandy siltstones, sandy claystones, and poorly sorted (but not bioturbated) siltstones containing megascopic remains of plants. Many of the others in good condition were extracted from medium and coarse siltstones and very fine sandstones (text-fig. 4). Miospores are frequently preserved in an uncompressed state in these lithologies, probably because they were shielded from compression in the interstices between the grains.

The quantity of plant fragments in a rock can usually be used as an indicator of the state of preservation of miospores which can be expected. Although well-preserved assemblages can be recovered from rock samples lacking megascopic plant remains, any fine-grained sandstone and finer sediment containing F well-preserved megascopic plant fragments (brown wood and/or cuticle) usually contains a spore assemblage that is at least in a fair state of preservation. 84% of the samples which yielded well-preserved assemblages contain megascopic plant fragments and they are C or F in 51%.

AT3

Key character. Miospore content diverse.

Important associations. Trilete spore content dominated by average-sized or large forms; *Eucommiidites* P or C.

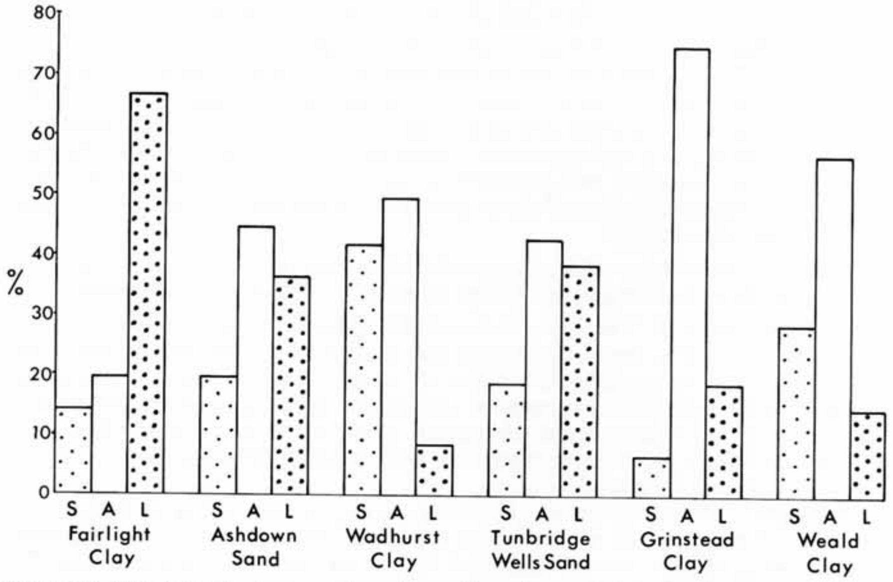
Remarks. Preservation was listed as good or fair for 77% of the assemblages referable to AT3. Both *Exesipollenites* and *Trilobosporites* occur in more than 70%, *Verrucosisporites* occurs in 69%, and *Pilosisporites* in 67%. Further examination of a diverse assemblage after a count of 200 miospores will usually reveal several other taxa which have not already been identified.

Stratigraphic distribution. The mean number of miospore taxa recorded during counts of 200 miospores from FC assemblages is 19, AS is 17, WC 14, TWS 17, GC 16, and WEC 15 (see also text-fig. 6).

AT4

Key character. Small triletes dominate the trilete spore content.

Important associations. Miospore diversity small or average; general state of preservation of miospores poor or fair.



TEXT-FIG. 6. Histograms showing percentage of assemblages from each formation in which the diversity of the miospore content has been recorded as small, average, and large.

Remarks. Cuticle was recorded (P and C) from 40% and brown wood (P and C) from only 19% of the assemblages referable to this AT.

Comparison. Assemblages referable to ATs 7, 9, and 10 are most likely to contain trilete spores dominated by small forms. Many lack or contain very few large and/or heavily sculptured 'fern' spores and megaspores, their bulk being a 'light fraction', *viz.* small and light weight miospores and those which were capable of floating for long periods (e.g. bisaccates).

AT5

Key character. Large triletes dominate the trilete spore content.

Important associations. Miospore diversity average or large; general state of preservation of miospores good or fair; brown wood P, C, or F and cuticle P or C; *Cicatricosisporites* C or V.

Remarks. Brown wood occurs in more than 70%, *Pilosisporites*, *Staplinisporites*, and miospore masses and/or tetrads in more than 60%, and megaspores in 50% of the assemblages referable to this AT.

AT6

Key character. Brown wood F.

Important associations. General state of preservation of miospores good or fair; cuticle P, C, or F.

Remarks. The miospore content of 40% of the assemblages referable to this AT is diverse but 26% of the assemblages show little diversity. Miospore masses and/or tetrads were recorded from 72% and *Exesipollenites* from 66%.

Lithologic associations. 79% of the rock samples from which AT6 assemblages were recovered contain megascopic plant fragments.

AT7

Key character. Inaperturopollenites V or F.

Important associations. Trilete spore content dominated by average-sized or small forms; miospores show average or little diversity; general state of preservation of miospores poor or fair.

Remarks. Exesipollenites occurs in more than 70% and *Inapertisporites* in 59% (F in 26%) of the assemblages referable to this AT. Brown wood and cuticle occur in only 46% and 33% respectively.

AT8

Key character. Pilasporites F.

Important associations. Trilete spore content shows average or little diversity; miospore preservation good or fair; brown wood and cuticle C or F; miospore masses and/or tetrads P or C.

Remarks. Black wood occurs in 85% but is F in only 45% of the AT8 assemblages.

Brown wood occurs in all and is F in 70%. A large proportion of the miospore masses are of *Pilasporites*.

Comparison. Although the general aspect of AT8 is similar to that of ATs 13, 14, and 15, *Pilasporites* is never common in these ATs; it is, however, F in 40% of the assemblages referable to AT16.

Lithologic associations. All assemblages identified as AT8 are associated with *Equisetites* soil beds and fragment partings (Allen 1947, Batten 1968). 70% contain megascopic fragments of (*Equisetites*) plants.

Stratigraphic distribution. AT8 has so far only been recorded from the Wadhurst Clay (text-fig. 5) but it may also occur in both the Grinstead and Weald Clays.

AT9

Key character. *Exesipollenites* C or V.

Important associations. Trilete spore content dominated by average-sized or small forms; miospores show average or little diversity and poor preservation; *Classopollis* C or V.

Remarks. Cuticle was recorded as P or C in 58% of the assemblages referable to this AT but brown wood occurs in only 27%. *Inapertisporites* was recorded from 71% and is F in 21%. *Eucommiidites* occurs in 66%. Pyrite crystals or their relict structures are common or frequent in the exines of miospores in 68%.

AT10

Key character. *Classopollis* F.

Important associations. Trilete spore content dominated by small or average-sized forms; miospores show average or little diversity and poor or fair preservation.

Remarks. The miospore content of 64% of the assemblages referable to this AT show little diversity. Brown wood occurs in only 36% and cuticle in only 23%. *Exesipollenites*, masses or tetrads of *Classopollis*, and pyrite crystals or their relict structures in the exines of miospores occur in more than 70%; *Classopollis* tetrads are C in 18% and F in 14%. *Inapertisporites* occurs in 68% and is F in 36%.

AT11

Key character. *Eucommiidites* C.

Important associations. *Cicatricosisporites* C or V, *Exesipollenites* P or C.

Remarks. *Verrucosisporites*, *Trilobosporites*, and miospore masses and/or tetrads occur in more than 70% and *Staplinisporites* in 67% of the assemblages which can be referred to AT11. Although *Cycadopites* was recorded from only 21% of the 340 productive preparations, it occurs in 57% of AT11 assemblages.

Comparison. The characters of ATs 9 and 14 are closest to those of AT11 and 39% of the AT14 assemblages (all from the Fairlight Clay) contain the identifier of AT11. This overlap is the result of the fact that both *Eucommiidites* and *Trilobosporites* occur together more frequently in abundance in the Fairlight Clay than elsewhere in the succession. Only 5% of the AT9 assemblages contain the identifier of AT11.

Lithologic associations. 62% of the rock samples which yielded AT11 assemblages contain megascopic plant fragments. The one Ashdown Sand and 13 of the 14 Fairlight Clay AT11 assemblages recorded are well or fairly well preserved whereas the 6 Wadhurst, Grinstead, and Weald Clay assemblages are poorly preserved.

AT12

Key character. Cicatricosisporites V or F.

Important associations. General state of preservation of miospores poor or fair.

Remarks. Cicatricosisporites is the most frequently recovered sculptured trilete spore in the Wealden. It occurs in nearly all (99%) productive samples, is C in 68% of these, V in 13%, and F in 1%. Miospore masses and/or tetrads were recorded from 62% of the assemblages referable to this AT; brown wood occurs in 55% and cuticle in 60%.

AT13

Key character. Pilosisporites C.

Important associations. Trilete spore content dominated by average-sized or large forms; miospore diversity average or large; general state of miospore preservation good or fair; brown wood and cuticle P, C, or F; *Cicatricosisporites* C or V.

Remarks. More than 70% of the assemblages referable to this AT are diverse and contain *Trilobosporites. Concavissimisporites*, megaspores and miospore masses and/or tetrads occur in more than 60%.

AT14

Key character. Trilobosporites C.

Important associations. Trilete spore content dominated by average-sized or large forms; miospore diversity average or large; general state of preservation of miospores good or fair; brown wood and cuticle P, C, or F; *Perinopollenites* P.

Remarks. Brown wood was recorded as C or F in 77% of the assemblages identified as this AT. *Pilosisporites* occurs in more than 70%, *Eucommiidites* in 69%, *Concavissimisporites* in 62%, *Schizosporis* (recorded from only 18% of the 340 productive preparations) in 54%, and miospore masses and/or tetrads in 77%.

The association between *Trilobosporites* C and *Perinopollenites* P is partially accounted for by the fact that 62% of the AT14 assemblages came from the Fairlight Clay. Representatives of both genera are recovered more often and are more frequently abundant in the Fairlight Clay than higher in the succession. *Perinopollenites* was recorded from 59% of the productive Fairlight preparations but from only 18% of the total prepared.

Lithologic associations. Megascopic plant fragments are present in 69% of the samples which yielded AT14 assemblages.

AT15

Key character. Concavissimisporites C.

Important associations. Trilete spore content dominated by average-sized or large forms; miospore diversity average or large; general state of preservation of miospores good or fair; brown wood and cuticle P, C, or F; *Pilosisporites* P or C, *Cicatricosisporites* C or V.

Remarks. *Trilobosporites* occurs in more than 70% of the assemblages referable to this AT.

AT16

Key character. *Ischyosporites* C or V.

Important associations. Miospore content shows average or little diversity; cuticle P, C, or F; *Pilasporites* C, V, or F.

Remarks. The miospores are poorly preserved in 47% but well preserved in 33% of the assemblages on which this AT is based.

Comparison. *Pilasporites* F (identifier of AT8) was recorded from 40% of the AT16 assemblages.

Lithologic associations. AT16 assemblages are commonly associated with *Equisetites* soil beds and fragment partings (see AT8).

AT17

Key character. Miospores in a fair state of preservation.

Remarks. Many of the 72 assemblages in which the miospores are in a fair state of preservation contain identifiers of other ATs. AT17 is intended to be a 'portmanteau' type for the inclusion of only those assemblages which cannot be referred to ATs 1–16. Only 3% of the assemblages examined had to be referred to this type.

RECORD OF CATEGORIES OF SECONDARY CHARACTERS

The most important recurrent assemblage associations of the secondary characters at the 80% level of affinity are noted; all are given on Table 5. Lithologic associations and stratigraphic distributions are summarized on text-fig. 7; reference to these aspects here is chiefly restricted to information unobtainable from this text-figure.

S1: *Inapertisporites* F

Important associations. Poorly preserved miospore assemblages in which average-sized or small spores dominate the trilete spore content.

Remarks. The distribution of *Inapertisporites* is not clearly related to kinds of assemblages. It was recorded as F from 38 productive preparations for miospores (26%, 5%, 21%, 36%, 9%, 8%, and 8% of ATs 7, 8, 9, 10, 11, 12, and 15 respectively). Brown wood is F in only 3%, C in 16%, and P in 10% of the assemblages and cuticle is F in only 5%, C in 5%, and P in 23%.

Lithologic associations. The distribution of *Inapertisporites* is irregular. Abundances vary considerably in samples lithologically similar, stratigraphically separated at a single locality by only one or two centimetres. When F (or C), it is usually associated with fine-grained lithologies (clay or medium silt, text-fig. 7). 60% were extracted from fossil rootlet bearing samples.

TABLE 5. Recurrent associations at the 80% level of affinity for secondary characters S1–5. For abbreviations employed, see Table 2; for use of terms 'wood' and 'cuticle', see 'Development'; for taxonomic usage, see 'Miospore Record'. CVF, SAL, etc. = C, V, or F; S, A, or L. § = key character; ▮ = important character; 1 = other.

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                                   RECURRENT ASSOCIATIONS

SMOOTH TRILETES | PILOSISPORITES | CICATRICOSISPORITES | GLEICHENIIDITES | TOTAL TRILETES |
ARAUCARIACITES | INAPERTISPORITES | INAPERTUROPOLLENITES | TSUGAEPOLLENITES | BISACCATES |
EUCOMMIIDITES | CLASSOPOLLIS | EXESIPOLLENITES | CELYPHUS RALLUS | TRILETE SPORE SIZE |
MIOSPORE DIVERSITY | INDETERMINABLE MIOSPORES | BROKEN MIOSPORES | PRESERVATION |
PYRITE CORROSION | BLACK WOOD | BROWN WOOD | CUTICLE | MICROPLANKTON | MICROFORAMS | MEGASPORES

SECONDARY CHARACTERS
                            CVFPCPCVPCVFPCFPCVPCCVFPCPCVFPCCFALSALPCFCFBMGPCFPCFPCFPCFPCF
    INAPERTISPORITES F  S1  .11..11.111111 .1111111..1111....1.▮▮..1111▮....1.............
CELYPHUS RALLUS C or F  S2  .11..11.111111.111...▮▮...11.▮▮§§1.▮▮..1111▮..▮.1.............
         MICROPLANKTON  S3  11....11..1111.11.11111...11.....1..11.1.1111..11.......§§§...
     MICROFORAMINIFERA  S4  .11...1.111111..11...1111111.....1..1111.111.1.11..........§..
    MEGASPORES C or F   S5  .11▮▮11111.1...11...111..11......▮▮.▮▮11.11.▮▮.11▮▮▮▮▮▮▮....§§
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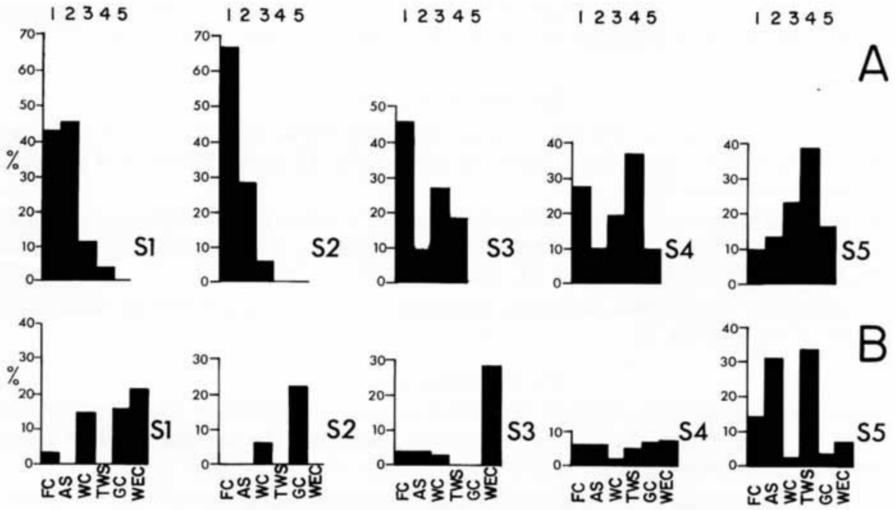


TEXT-FIG. 7. A, Histograms showing relationship between assemblages containing secondary characters (S1–5) and grain size of samples from which they were extracted. % = percentage of total number of preparations of rock samples containing secondary character. 1 = clay, 2 = fine–medium silt (mostly finely laminated clay/fine silt and medium silt), 3 = medium silt, 4 = medium–coarse silt, 5 = coarse silt and sand. B, Histograms showing the frequency of occurrence in the Wealden of assemblages containing secondary (S) characters. % = percentage of the total number of productive samples processed from each formation.

S2: *Celyphus rallus* C or F

Important associations. Poorly preserved miospore assemblages which show average or little diversity, pyrite crystals or their relict structures in the exines of miospores, bisaccates V or F and *Exesipollenites* P or C.

Remarks. C. rallus was recorded as C or F in 18 productive preparations (8%, 18%, 2%, and 17% of AT7, 9, 12, and 16 assemblages respectively).

Lithologic associations. The distribution of *C. rallus* is restricted but irregular. Abundances vary considerably in samples lithologically similar, stratigraphically separated by only one or two centimetres. The productive samples are all medium siltstones and finer grained rocks.

S3: Microplankton

Recurrent associations. The associations listed on Table 4 are unreliable because dinoflagellates and acritarchs have been recorded from only 11 and are abundant in only 2 of the 340 productive preparations.

Remarks. Most forms of Wealden microplankton are attributable to *Palaeoperidinium*, and the acritarch genera *Micrhystridium*, *Baltisphaeridium*, and *Veryhachium*. Of the AT7–16 assemblages, microplankton occur in 5%, 4%, 5%, 10%, 7%, and 15% of those referable to ATs 9, 10, 11, 12, 13, and 14 respectively.

Stratigraphic distribution. Weald Clay preparations are more likely to contain microplankton than preparations of Hastings Beds material (text-fig. 7).

S4: Microforaminifera

Recurrent associations. The associations listed on Table 4 are unreliable because microforaminifera have been recorded from only 11 preparations and are not abundant in any of these.

Remarks. Brown wood occurs in 8 and is F in 5. Cuticle is P in 5. Of the assemblages referable to ATs 7–16, microforaminifera occur in 5%, 5%, 9%, 5%, 4%, 7%, and 8% respectively of ATs 7, 9, 10, 11, 12, 13, and 14.

Stratigraphic distribution. Sporadic occurrences in both the Hastings Beds and Weald Clay (text-fig. 7).

S5: Megaspores C or F

Important associations. Average or diverse miospore assemblage in a good or fair state of preservation. Trilete spore content dominated by average-sized or large forms. *Pilosisporites* P or C, brown wood and cuticle P, C, or F.

Remarks. Megaspores are seldom abundant in preparations for miospores. Abundance (C or F) in a rock sample is usually suggested by the occurrence of only a few specimens in a miospore preparation; when only P in a rock sample an occurrence in a preparation is fortuitous.

Brown wood is F in 40% and C in 33% of the 30 preparations in which megaspores occur. Cuticle is C in 37% but F in only 7%. Abundances of megaspores in rock samples were not suggested for any of the samples from which ATs 1, 8, 10, 11, or

17 were recorded (confirmed after subsequent preparations for large plant microfossils). Of the remaining ATs, megaspores are most often associated with assemblages identified as ATs 2, 3, 5, 6, 13, and 14.

Lithologic associations. Megaspores are most often abundant in medium-coarse and poorly sorted siltstones (text-fig. 7; see also Batten 1969).

Stratigraphic distribution. Fairlight Clay, Ashdown Sand, and Tunbridge Wells Sand samples have been the most productive (text-fig. 7).

EVALUATION

Omissions

Some kinds of assemblages seldom occur in the Wealden succession. One important omission is a set of associations for *Cycadopites*/*Monosulcites* grains. Hughes and Moody-Stuart (1967*a*) reported that *Monosulcites* species are usually associated with inaperturate abundances in higher parts of the Wealden. The low frequency of occurrence of pollen referable to this genus or to *Cycadopites* through the whole of the succession (recorded as P during counts of 200 grains from 18% of the productive preparations, C in only 3 preparations), has, however, prevented the determination of a reliable set of associations for these genera. Greater abundances have been reported elsewhere from the Jurassic (e.g. Couper 1958, Chaloner and Muir 1968) and Early Cretaceous (e.g. Singh 1964).

Taxa of little value

Many of the taxa that have been recorded cannot be considered in the identification procedure because they are seldom common in the Wealden. On the other hand, others which are often abundant (e.g. the bisaccates, *Araucariacites*, *Tsugaepollenites*, and *Gleicheniidites*) have little value because few of their associations are distinct. I had expected 'bisaccates F' to be an identifier of an AT but its usefulness was limited because of the frequency of occurrence of assemblages containing this character (102 of the 340 productive preparations) and because neither its palynologic nor its lithologic associations are distinct (although 28 of the 30 assemblages in which the bisaccates constitute 40% or more came from medium siltstones and finer grained samples).

The only significant associations noted for the other taxa mentioned above are as follows: *Araucariacites* C or V mostly in assemblages containing miospores in a poor or fair state of preservation recovered from the finer grained siltstones; *Tsugaepollenites* C or V mostly in poorly preserved assemblages of average or little diversity; trilete spore content of assemblages containing 5% or more *Gleicheniidites* usually (44 of 45) dominated by average-sized or small forms.

Lithologic and stratigraphic control

The distribution of the assemblage-types is closely related to both lithology and stratigraphy reflecting changes through time of both depositional and source environments. The dominant factor controlling the distribution of plant remains and their preservation in the Wealden was probably a delta complex (text-fig. 3) which would have acted both as the chief source of the material and as a major transport agency. Other factors would have included the geologic and climatic events which affected the water level in the delta and caused changes in the pattern and amount of discharge of the rivers draining into the basin, the relationships between currents in the basin, the rate of deposition of palynomorphs and detrital material, and the degree of reworking.

The relationship between assemblages containing the key characters of the assemblage-types and the average grain-size of the rocks from which they were extracted has been considered in the 'Record of Assemblage-types' and is summarized on text-fig. 4. Some assemblages are more likely to be, or are only associated with fine-grained rocks (maximum average grain-size, medium silt), others are restricted to medium silts and coarser grained rocks, and some distributions show no clear trends (e.g. those of ATs 13 and 15). The last suggests that the assemblage-types are fairly evenly distributed throughout the grain-size range, but it is possible that a trend might have become apparent if the histograms concerned had been based on a greater number of preparations.

Several assemblage-types show a selective distribution in the succession (text-fig. 5). AT10, for example, has so far been recorded only from the more argillaceous formations whereas AT15 has been recovered only from the more arenaceous. AT9 has been recorded most often from the Grinstead Clay, AT12 from the Weald Clay, and ATs 11 and 14 from the Fairlight Clay. ATs 8 and 16 have only been recorded from the Wadhurst Clay. It is likely that AT8 will eventually be recovered from both the Grinstead and Weald Clays; equally, AT16 may well occur elsewhere in the succession. AT8 is usually, and AT16 commonly associated with *Equisetites* soil beds and adjacent strata.

Numerical analysis of relationships

In order to determine the relationships between the assemblage-types, all 340 assemblages on which the classification was based were identified after counts of 200 miospores. The total data on each of the assemblages, and sections of it, were then compared with the data on all the others using coefficients which express relationships of both similarity and difference (see Cheetham and Hazel 1969) followed by cluster analysis and nonmetric multidimensional scaling techniques (Bonham-Carter 1967, Kruskal 1964*a*, *b*). The clusters produced by programs operating on the matrices of coefficients derived were subsequently examined to determine whether they were meaningful in the light of the assemblage identifications (for further details, see Batten 1972).

It was found that most of the assemblages referable to ATs 1, 4, 7, 9, and 10 and most of those identified as ATs 2, 5, 6, 13, 14, and 15 are more closely linked to each other than to those which were identified as the other ATs. These groupings chiefly result from differences in state of preservation of assemblages, diversity of miospore content, abundance of organic matter in rock sample, and grain size of sample. Of the assemblages referable to ATs 3, 11, 12, and 17 (transitional ATs), some are closely linked to the components of the two large groups and some are isolated or constitute (small) clusters which are less well linked to the rest of the set. Assemblages referred to AT8 and most of those identified as AT16 are more closely linked to each other than to any other type.

Examination of the sub-clusters which comprise the major clusters revealed that, for the most part, assemblages referable to particular assemblage-types or to types within the groups mentioned above, tend to be well linked internally in spite of the fact that all the data and not just the recurrent associations of the assemblage-types were taken into account. Some sub-clusters do, however, contain one or two anomalies and some are composed of a variety of (not only transitional) types. Both situations result from the continuous variation of assemblage characters.

The relationships determined here are demonstrated below with the aid of Table 6. This table gives data on 100 selected productive samples. To the right of the data block is a list of the assemblage-types to which the assemblages can be referred. Whilst many can be referred to more than one assemblage-type, the bulk of the multiple assignments are to the general types which take second place to reference to one of the ATs 7–16.

Most are referable to types within the two major groups delimited above, or to an assemblage-type from one of these groups and a transitional form. An assemblage identified as AT13, for example, cannot also normally be referred to types other than ATs 11, 12, 14, or 15. Even when the general assemblage-types are taken into account, reference to ATs 2, 5, or 6 is much more common than to 1 or 4. Similarly an assemblage identified as AT7 is more likely to be also referable to ATs 9 or 10 of the specific and 1 or 4 of the general types than to any of ATs 2, 5, 6, 13, 14, or 15. Atypical groupings do, however, occur (e.g. Table 6, examples 19 and 24).

APPLICATION

In the Wealden

An assemblage-type identification enables an immediate assessment to be made of the potential of an assemblage for either stratigraphic or palaeoecologic purposes. A set of identifications provides a useful record of the general aspect of palynologic preparations in a stratigraphic succession. The use of any stratigraphic marker miospore can now be closely examined in the light of the kinds of assemblages from which it has been recorded. The determination of facies patterns in (local) distributions of kinds of assemblages is facilitated because the assemblage-types reflect both depositional and source environments. Together with plant megafossil and other stratigraphic and sedimentologic information, the assemblage classification procedure provides a basis for more reliable palaeoecologic interpretations than have hitherto been possible. It is now possible to select preparations in which certain characters can be expected or not expected to occur. The type of assemblage which occurs in a given rock type or in a given part of the succession can also be predicted. This allows selective preparations to be made, saving time when large numbers of samples are involved.

On a more specific level, it might, for example, be considered necessary to rely on a certain taxonomic group for correlation, e.g. species of *Trilobosporites*. Preparations which contain, or are likely to contain, these spores in relative abundance can now be selected from a set of identified preparations. Those identified as AT14 can be examined first because *Trilobosporites* species are common in this assemblage-type and are generally well or fairly well preserved. If it is necessary to examine further

TABLE 6. Data on 100 productive samples from the Wealden. Sample numbers on left-hand side of table. Possible identifications on right-hand side; reference to secondary characters is included. Number of samples selected from each formation (Fm) proportional to total prepared from that formation. Samples initially chosen at random from each but numbers then adjusted so that at least two representatives of each AT could be incorporated in table; for localities, see Appendix. Formation boundaries in the Cuckfield No. 1 Borehole given in Gallois (1970); (unregistered) Cuckfield sample numbers prefixed by CUC. The taxa are arranged in the same order as they appear in 'Miospore Record'. A period (.) indicates 'no information' (for columns 1–68 = no information after a count of 200 miospores).

Average grain size: 1 = clay–fine silt; 2 = fine–medium silt (mostly finely laminated clay/fine silt and medium silt); 3 = medium silt; 4 = medium–coarse silt; 5 = coarse silt; 6 = coarse silt–very fine sand; 7 = very fine sand; 9 = fine sand.

		[illegible]	ATs 7–16	ATs 1–6 or 17	S1–5	Fm
1	DJB230	...PF....P....P.P.CP..P.........PC.....P.....PF.P.P.CP...P.....P....SACCM..FCPP..P....1.........P		4		FC
2	DJB21	...PF...P..C..P...CC.P.P..P.PP..CP..P.P.PP...PF.....C...PV.CPPPP....LLCCG.PCF........P4.........C	11,14	2,3,5,6		FC
3	DJB50	.P.PV..P.P.....P..CC...P..P.....PC....P.......F...CPC...PFPCPPPP....ALCCM..F.P...P...P5B.........	11	3		FC
4	DJB27	....F......P..P.PPPC......P..P..P.......P.....F...CPCP.PPVPP.PPPP..PALPCG.PCFP...P.P.P3.........C		2,3,6		FC
5	DJB28	...PF..........P.PC...P........P.....C.P.P..PF...P.C...PVPCP.PPP...ALCCG..CFP........5.........F	11	2,3,6		FC
6	DJB31	....V.........C.C.CV...P..P..P..PP...PCPPC....F.....C...PCPC..P.....ALCCG.PFPC...P.P.P7.........P	11,12	2,3		FC
7	DJB38	....V........PPP.PPPC.P.....P....PC....C.......PF...CPC..PPF.PP.P..P..ALCCG..PFP........P1.........F		2,3,6		FC
8	DJB44	....F....P........PC..P...P......PC...........CF....PC...PVP..CP.....AACCG..C...........1.........P		2		FC
9	DJB46	P...F...PPP...P..PPC...P.........CC...P.PP....PF.P.P.C...PV.P.P.PP.P.ALCFM..FCFP..CC..P4B.........	14	3	5	FC
10	DJB40	...PC.PPP..P..P.PPPC.P.P..P..P..P....P..P.....F...C.P...CF.PPVP.....ALFFMP.FP.........P3.........P		3		FC
11	DJB228	....F....P....P...CC..P.........CP............F...C.C..PPV.P.PPPP...AACCG..CFCP......P4B........F	14	2,6		FC
12	WM1 922	....F.........P...PC..........P.PP............PF...P.V...PC...P..P...LACCM..FCFP..PP...3B...P....C	7	5		FC
13	WM1 910/6	....V...........P..P...P..........P.............V...PPF..PPC.P.VC.....SAFFB..F..........2......P..P	7,9	1,4		FC
14	WM1 900/0–9	..P.F..............C......P.......P............F...PFF...PC...CPP....ASCCB..FP.........P2.......P..	7	1	1	FC
15	DJB73	....F.P..P....P.PPPC......P....P..P..PP.....PF...C.C...PC.C..P.....ALCCM.PCFP...P.P.P6B.........C	11	3,6		AS
16	DJB55	....F..........................C............PF...CPC....F....P.....SSFFB..F.CP.......3G.........		1,4		AS
17	CUC1068	....F.PP..PPP...CPCC.PP....P..P.PP.....PPP....F...C.C..PPVPP.PPP....LLCCG..FFC...CP..P5.........P		2,3,5,6	5	AS
18	CUC1026	....F....P.......P.C............PPP.....P.......F...CPCC.PPVPPPCPC....ALCFM..FFP...C.P.P6.........F		3,6	5	AS
19	CUC1013	....V.P.PP.......P.C..P..........PP...P.P...PP.F...CPC...CVPP.CCP....ALCCG..CFC...CPP.P4......P..P	9	2,5,6	5	AS
20	CUC990A	....F...CP.........PC..P...............P.P.......F...C.C...CC.P.CP.....AACCM..CFP...F.P.P4..P......C		6	5	AS
21	CUC971	...PF....C........CPV............PPP............F...C.P...PC...P......AAPCG..CCF...CPP.P2..........	12,13,15	2	5	AS
22	CUC965	....F....C....P..P.C..P..........PP.......P.....F...C.C...CV..PC.C....AAFFMP.CFC........P5....P....P	15	6		AS
23	CUC943	....F.............PPC...............P...............F...V.C...PV...C.....PASFFB..CFC...P.P.P4.........P		1,6		AS
24	CUC935	....V....C....P..P.C......P....P.......P..P...F...P.VP..CV...VP.....LACFM..FF..........9G.........	7,15	5,6		AS
25	DJB193	..P.F.............PPC...P..P.....PC...PP.P.....F...C.C..PPV.P.PPP....ALPCG.PCFPP........4.........P		2,3,6		AS
26	DJB216	....F....P.C....P.PC..............PC...P..P....PF...P.C...PCP.PP......AAPPG.PCFCP..PPP..6.........		2,6		AS
27	H48/8	P..PF....P.........PPC................P......P......F..VP.P...PC...PP.....AAPCG..FFC...C...P4B........P		2,6	5	AS
28	CUC927	..PPV.....P.....PCPV...P..................PP....F...CCCP..PC..PVP.....ALCFMP.FCP.P.C...P4......P...	12,13	3	3,5	WC
29	CUC918	....C.P.............C...............P.............C....FC..PCV...FP.....ASFCBP.F..P.......F3...P......	10	1	1	WC
30	CUC899/6	P...V...............C...P..........C........P....F...CPCP..CV...VP.....AACCBP.FCP........C1.C.CFPP...		1		WC
31	CUC896	....F...P..........C......P......P.....P.......F...PPVP.P.V..PCCC....AACCBPPFP..........P2..........	7,9	1		WC
32	CUC867	P...F..............C...........P..C..............FP..P.CC..PV...PP....PAAPCBP.FCP.........2.C.CP..P..		1		WC
33	CUC865/6	....C.....PP.......P..........P.................C...P.PF..PCPP.PP.....AAPCGP.CFC........C1.C.FFPP..F	8	2,6		WC

			ATs 7–16	ATs 1–6 or 17	S1–5	Fm
34	CUC863	....V..............P..........................V...C.CC.PCF..PC......LSCFM..CCP.P.....P1....F.....		5	3	WC
35	CUC853	....V..............C...PP.P......P............V...CPCP.PPF...CC....CAAFFBP.FFP.......P1....F..P..	9	1,6	2	WC
36	CUC850/9	....F....P......P..CPPP...P......C............F...CPP...CV..PP.....CAACCBPFF.........P2....F.....		1	2	WC
37	CUC843	....V............P.C.P.P..P...P..P.....P......F...C.CP.PPF..PCPP....AACCMP.F.P.......P1..P....P..		17		WC
38	CUC806	P...F..............C....P........C.....P.....FP..P.CP..PV.P.PP.P....AACCBP.F..........2...F...P..		1		WC
39	CUC801	....F..............C..P...P......P.....P......F...C.CC..PV...C......ASFFBP.F.P........2.C....PP..		1		WC
40	CUC797	....V..............P..........P..P............V...P.CP..CF..PPP.....ASCCBP.F.PP.......2.C........		1		WC
41	CUC794/6	....F..............V......P...P..P............F...CPPP..PV...PP.....ASCCBPPFPP........1....P..PPP	12	1		WC
42	CUC793	...PF...P..........V..PP......P..P...........PF...CCCP..PV...PP.....AACFBP.F.P.......P1.C.....PP.	12	1		WC
43	CUC792	....C..............C..........C..P........P...V...P..F..PC..........ASPCGP.FFC.......P1.C.CP..PP.	8,16	2,6		WC
44	CUC788	..P.V...P..........C......P...P..C............F...C.CV..PF...PP.....AACFBP.FCCP.......1.C.C...PP.		1		WC
45	CUC787	P.P.V.P............C.P....P...P.PC............F...CCCC..PF...P......AACFBP.FCP........2.C.PP.....		1		WC
46	CUC765	....V............P.C.PPP..P....P.P.....P......V...V.CP..VV...CP.....AACCBP.F.P........2...C......		1		WC
47	CUC763	..P.V...P..........C..PP..P......P............F...V.CC..CC...CP.....AACFBP.F.P........1.........P		1		WC
48	CUC752	P...V..............C...P..P...P..CP...........F.....CP..CF...CPP....AACFB..F.P........1...C.....F		1		WC
49	DJB306	....C..............C.............P............V...CPC..P.C...FP.....ASCFMPPF..P......P1..P.......	10			WC
50	DJB314	....V..............C..P..........P............V...C.CP.PCV...VP.....ASCCBP.F.P.......P2G......P..		1		WC
51	DJB318	....C....P.......P.....P..P....PPC............V....CPP..VFP..CC.P...AACCB..F..PP.....P1.......P..	9	1	3	WC
52	DJB324	P...V..P.........P.P.............C............V...C.C...CF.PPVP.P...SACFBP.F.PP.......1........P.		1,4		WC
53	DJB325	....C............................P............C...CCC...CF.PPVCP....SSFFBP.F..P.......1...C.....P	9	1,4		WC
54	DJB349	....F.....P........V..........P..P............F.....CC...V.P.CP.....ASCCB..FCCP.......3...F...PP.	12	1		WC
55	DJB346	....V..............C..........C...............V...P.PF..CV...CP.....ASCCG..PFF.......P1...F.....F	8,16	2,6		WC
56	DJB333	....V..............C......P....P.P............V...CFC...PF.P.VP.....ASCCBP.C..P.......2..........		1	1	WC
57	DJB336	....F.P............C......P...P..P............F...CFV...PVPP.CP.....AACCBP.F.........P1..........	7	1	1	WC
58	DJB355	....F..............C..........P..P............F...PPCC..PF.P.PP.....ASCCBP.F.P.......P2.......PP.		1		WC
59	DJB364	....V..............C..........P...............V...C.CC..CF..PCP.....ASFFB..F.........P2...F.....C		1		WC
60	DJB369	....V..............C......P...P..P............F...C.CC.PPFPPPCP.....AACCB..F.........P2.......P..		1		WC
61	DJB115	....V.P.PP........PC...PP.P...C..........P....F.....CVP..C.P.C......AAFFM..F....C.....1.C........	16		5	WC
62	DJB254	..P.V..PPPP.....P.PC....P........C...........PF...C.CC..CVPP.CP.....ALCCB..F..P.....P2.C.........		1,3		WC
63	DJB262	.P..F...P..........C..........P..P...........PF...CPVC..PVPP.CP.....AACCBP.F..........2...P...P..	7	1		WC
64	DJB276	....F.P.........PC.C..PPP.P...P..P....P.PP...PF...C.CP..PC.P.P......ALCCB..FPP.......P2.....C.P..	13	1,3		WC
65	DJB279	....F..............V.P...........P............F...C.P...PV.P.C......ASCCBP.FP.........2.......P..	12	1		WC
66	DJB120	....V.........P..PPC.P....P...P..C......P.....F...PPCCP.PC...F......AACFB..FCCP......P1.C.P......	10	1		WC

		[illegible]	ATs 7-16	ATs 1-6 or 17	S1-5	Fm
67	DJB291	....F...........PC.V.PP.......P.PP...........F...PPP...PC...C......AAPCMP.FPP.......P2...PPF.P..	12,13			WC
68	DJB294	....V.P.P........P.C.......................V....PCFP.PP..PCP.....LACFM..FCC.......P1.C.C......	8	5		WC
69	DJB347A	..P.V...PP.......PP.C.PPP..P...P..P...........F...P.VP...V.P.CP....PALCCBP.FPP........2.C.........	7	1,3		WC
70	DJB125	....F.P..PPP....C.PP.P....P...V.PP.....P.....PF...PPC...PC.P.CP.....ALCCM..F.P...F...P1.C.....P..	16	3	5	WC
71	DJB352A	....V..............C..............P............V...P.FP.PPF..PCP.P...ASFFB..F..P.......1.C.P...P..	7	1		WC
72	DJB126	....F.C....P..P..P.P.P....P...C.PP...........CF...P.C...PC...C......AACCB..F.P........3.....C....	16	1		WC
73	DJB163	....F.P..PPP.......V.PP.......P...V.....P......F....C......C.P.CC.....SAFFB..F.PP.......3.......PP.	9,12	1,4		WC
74	CUC698	P...F.P..P.........P.C..............PC...PPP......F...C.CP.PPV.P.CP.....LLCCM..FF....P.CPP4......P..P		3,5,6		TWS
75	CUC635/6	P...F...........PP.P.....P...PP.PCP....P.P....F...C.C...CF.P.CP.....ALCCM..FFC........4......P...		3,6		TWS
76	CUC513	..P.F....P.P.....CPP....P.P...PPPP............F...C.C...PV.P.PP.P...LLPCG..CCC...F.PP.4B.........	13	2,3,5	5	TWS
77	CUC499	...PF....P.P....PC.C...P..P....P.C.....PP.....F..PP.C..PPVPP...P....ALPPGP.FP....P.P.P2.........P	13	2,3		TWS
78	CUC443	....C....P.P.....P.P..............P.............C..F..C.........P......ASCCM..FFC...F...P3B........P		6	5	TWS
79	CUC379	....V...PP.P.....PPC..PP.........PP.......P.P..F.PPP.C..PPF...P.P....LLCFM.PFC.P..C.P..2..........		3,5	5	TWS
80	CUC345	....C.P.P..PP......C..PP..........P...P.........V...C.C....F...C.P....AACCBP.F.P...P....3......P..P		1		TWS
81	CUC296	...PF...PP.......PP.C..PP..........C..............F.....V...PVPP.C......AAFFBP.FP...PC.P..3.........P	7	1	4,5	TWS
82	CUC295	....F...............C..PP..........P.....PP.....F...C.C...CV.P.CP.....AACCBP.F.P........2......P...		1		TWS
83	DJB161	P...V...PP..........C.......P...P..P..............F...P.V...CV...C.......SSFFBP.F..P.......2...C......	7	1,4		TWS
84	CUC563	P...C..............P.C...P..P.....PC.....P......V...C.C...CF...CP.....AACCMP.F..........P1...........		17		GC
85	DJB12	....V..............PPC.......P....PP..............F...C.CC.PPF.P.C.......AAFCBP.F...........2......PP..		1		GC
86	DJB137	....V.P..P.P.......PC.P.P..P...P..C.....P......F...P.C..PPF.PPCPPP...ALCCBP.F..........P5.......P..		1,3		GC
87	DJB11	....V...............P..............P..............F...CFC..PPF..PCC....FASCCBP.CPPP.......1...F.P.P..	9	1	1,2	GC
88	DJB143	...PV.P...P...P....C.PP.P.P...P..C...............F...PCCP.P.F.PPCP....CALCFBPPF.PP.......P1...C......		1,3	2	GC
89	DJB9	....V....P....P..P.C...P..PPP...PP..P..........V...C.C...CC.PCF.....PALCCBP.F..P........1.C.F......	10	1,3		GC
90	DJB1	...PF...........PPPC..P.C.P.......P.PPP.........F...CCCP...VP..PP.P..FALCCBP.FPPP.P.....1...CC.....		1,3	2,4	GC
91	DJB3	P...V...PP.P.......PC....P.C...P........P..P....F....CCP..PF..PP.......AAFFBPPF.PP........1.C.F......		1		GC
92	DJB5	P...V..............P.C....P.......P.C.............PF...CCCP..PF.PPCC....PAACCBPPF.PP.......1.C.C......	9	1		GC
93	DJB6	....V.....P.......PPC.P..P.P.P...PC...............F....FC...PF.P.CCP....SACCBP.F.P........1.C.P......	9	1,4	1	GC
94	DJB16	P...F...............P.......P.......C...............PF...PCCC.PPVP..VC......AACCB..F.PP........1..........	9	1		GC
95	DJB17	P...F..P............C....P.P...P..P...............PF.....P...PC.P.CC.....SACCBP.C..........P1...........	9	1,4		GC
96	DJB18	....V....P.......C.V.......P...PPCP.....PPP.P.CF...P.P...PV.PPPP.P...LLCCMP.F.P..PC.P.P4...C.....C	12,13,14	3,5	4,5	GC
97	DJB158	....V.P.P.P..........C..P...P.......C.....C.....PF...PPCP.PPVPCPV.......ALCFBPPCPPPF......1.C.........	11	1,3	3	WEC
98	DJB159	....C.PP.P....P..PPV..PP..P..........PP..C.....CF.....CP..CV.P.C.......ALCFM..F..PC.......1.C.P......	12	3	3	WEC
99	WM212/7	..P.F....P..........F..PP...P.......................F...CFCP..PC...P.......AACCB.PF..........P4........P..	12	1	1	WEC
100	WM1198/5	...PF...........PPPV...PP..................P.....PF...P.C...PV.P.P.......AAPCB..FP.........P3.....PP..P	12	1		WEC

preparations to establish a more complete picture, assemblages identified as ATs 3, 13, and 15 could then be selected because more than 70% of these contain *Trilobosporites* (see 'Record of Assemblage-types' and Table 4). If more preparations are needed, only medium siltstones and coarser grained samples need be considered initially (text-fig. 4).

An examination of assemblages from a larger number of both coarse-grained and Weald Clay samples remains to be accomplished and could lead to the erection of one or two additional assemblage-types; many of the coarse-grained samples proved, as expected, to be devoid of palynomorphs. The sequential appearance and development of recurrent groupings of taxa also need to be fully investigated. It is hoped that eventually it may be possible to identify preparations in which any selected spore, pollen, or other palynomorph species can be expected to occur.

Outside the Wealden

Although it is probable that the assemblage classification cannot be applied in its entirety in (Early Cretaceous) successions outside of the English Wealden, the method of tackling the facies problem can be applied to any rocks containing palynomorphs and many of the associations recognized may provide a useful basis for comparison for both stratigraphic and palaeoecologic purposes.

DEVELOPMENT

The materials and methods employed in the development of the assemblage classification are here described.

Samples

The 340 productive field and borehole samples from southern England were used for the project. They range from Berriasian to Late Barremian/Early Aptian in age (Table 7, text-fig. 1).

TABLE 7. Samples prepared for the microscopic examination of their organic contents

	Total miospore preparations	*Total productive miospore preparations*	*Preparations for larger plant microfossils*
Fairlight Clay	51	36	19
Ashdown Sand	46	36	19
Wadhurst Clay	203	201	22
Tunbridge Wells Sand (excluding GC)	44	21	15
Grinstead Clay	39	32	2
Weald Clay	14	14	3
Total	397	340	80

Preparations

Rock samples weighing about 15 g and from not more than 2 cm stratigraphic thickness were processed for miospores. To enable the assemblages extracted to be compared as accurately as possible, the preparations were carried out in a standard manner using 50% hydrochloric acid, HF, nitric acid or Schulze solution, ammonium hydroxide and zinc bromide (sp. gr. c. 2·2). Oxidation time was kept to a minimum, usually 30 minutes or less in concentrated nitric acid or 5–10 minutes in Schulze solution. The residues were cleared with 5% ammonium hydroxide for 5 minutes. Fine material was removed by short centrifuging. Strew slides were made with Clearcol; Euparal or DePeX sealed the cover-slips to the slides. The method of retrieval and examination of megaspores and other large plant microfossils was as described in Batten (1969).

Documentation of lithologic information

All samples prepared for the microscopic examination of their organic contents were examined under a stereoscopic microscope prior to processing. Abundances of plant megafossils, bivalves, ostracods, and fish remains were estimated and recorded as P, C, or F (Table 2). If present, rootlets and other trace fossils, plant stems and rhizomes *in situ*, and ironstones were recorded as P; abundances were not considered. Information on colour, sorting, cross-bedding, bedding disturbance (bioturbation), slickensiding, presence of pyrite, spherulitic siderite, mica, gastropods, etc., was also documented. The colour of the samples was determined after they had been allowed to dry, by comparing them with the Rock Color Chart (1963) published by the Geological Society of America.

Documentation of palynologic information

Counts. The number of objects that should be counted to ensure that a recorded assemblage is reasonably representative of their distribution in a sample has been considered by several authors both within and outside of the field of palynology. The diversity of the assemblage, the relative abundance of individuals, and particularly the purpose for which the count is required have to be taken into consideration. It is generally known that in a count of *n* grains, the probable error of the recorded number of abundant objects is much lower than that for the rare forms.

Many of the miospores which are stratigraphically useful are uncommon in preparations. It is, therefore, necessary to undertake counts which ensure their adequate representation; a count of 500 miospores is probably best in most cases (cf. Smith and Butterworth 1967, p. 96). For palaeoecologic purposes, however, comparison of only the broad features of palynomorph distribution in beds is the usual aim. There was little advantage in counting more than 200 grains for this study because the characters of an assemblage are established with this number and the occurrence of rare spores, and low percentages can have little value for rapid identification of assemblages, at least for the present, in the Wealden. Broken miospores were included in the counts if they constituted $> 50\%$ of a spore. Tetrads and masses were recorded as single grains only to reduce bias (but their presence in an assemblage was also documented; see p. 28). Unequivocally reworked grains (from Jurassic and older rocks) were recorded separately.

Bias differences can occur between observers when examining the more abundant species, and in the counting of the same worker at different times. The differences arise largely from variations in the procedure adopted for rejecting broken and badly preserved grains (Tomlinson 1957). The possibility of error due to bias can usually be removed by check counting (Smith and Butterworth 1967) but it is sometimes difficult to avoid bias when preparing counts from poorly preserved assemblages because some miospore taxa are more easily recognizable in a poorly preserved state than others. To reduce the possibility of error due to bias and to facilitate comparison of assemblages, I documented the percentages of miospore taxa as P, C, V, and F for < 3%, 3–14·5%, 15–29·5%, and 30% or more respectively (Table 2).

'Fern' spore size index. The maximum diameters of 100 trilete spores were measured from each assemblage and placed in one of three size groupings (small, $< 30\ \mu$m; average, 30–50 μm; and large, $> 50\ \mu$m) following Hughes and Moody-Stuart (1967*b*, 1969). The majority of triletes were referred to the 30–50 μm category.

I considered small triletes to dominate the trilete spore content of an assemblage if either (1) the number of these was greater by more than 15 than the totals of both the average-sized and large spores, or (2) the difference between the totals of small and average-sized spores was 15 or less and if both were greater by more than 15 than the total of large spores. Domination by large triletes was determined in a comparable way.

Miospore diversity. A large number of miospore taxa were recorded during this study but many are rare forms and 44 of the 85 taxa employed in the assemblage comparisons (see 'Evaluation') do not constitute 3% or more of the counts from any palynologic preparation. I therefore considered assemblages from which 13 or fewer taxa were identified during a count of 200 miospores to be those showing little diversity (restricted); from which 20 or more were recorded, to be diverse; and between these limits, to show average diversity. The subdivision is not ideal chiefly because the true diversity of an assemblage may be obscured during a count of 200 by considerable abundances of one or a few taxa. To determine the true diversity in such a case, the exceptionally abundant taxa should be excluded from the count. The numerical limits of the divisions selected were found to be the most reasonable for present data but they will have to be adjusted when future systematic work increases the number of taxa which can be readily identified.

Preservation. The general state of preservation of assemblages was recorded as 'good' (G), 'fair' (M), and 'poor' (B; Table 2). The use of these gradings (they refer more to corrosion than to damage from breakage; see below) has depended to some extent on experience. 'Good' indicates that the majority of spores are well preserved; 'poor', that the majority are poorly preserved; and 'fair' is an intermediate category (indicates that badly damaged (corroded) and well-preserved grains are more or less equally abundant).

The preservation state of, in particular, the common Wealden plant microfossil taxa has been examined. Information was sought regarding the degree of inflation/compression; surface compression (flattening of sculptural elements and crumpling of exine); pitting (whether pits are circular, irregular, or dendritic and whether they are the products of bacterial or fungal attack or the result of diagenesis); modification of exines by pyrite (see Neves and Sullivan 1964; recorded as P if common or frequent); softening and thinning with and without corrosion; breakage and opacity. Some of these effects on the sculptural and structural features of Wealden *Cicatricosisporites* have been demonstrated by Hughes and Moody-Stuart (1969, p. 104, text-fig. 3).

'Degraded' and 'corroded' are terms which have been used by Cushing (1967), Birks (1970), and others to refer to different classes of preservation of deteriorated grains but I have not attempted to distinguish the two.

Wood and cuticle. P, C, and F were used for expressing the relative abundance of black and brown 'wood' and 'cuticle' (Table 2). Black wood (Pl. 1, figs. 1–3) includes both structured (e.g. fibrous, with tracheids) and unstructured plant fragment material. The fragments are usually angular (with sharply defined edges) and platey, but are sometimes splintered. When thin, they are translucent (brownish black–dark brown–medium brown). In reflected light, two kinds are recognizable, one which reflects light and another which is dull black. It has not been possible, however, to make distinctions of this nature in transmitted light. Some is vitrain derived from woody plant tissues and leaves which have been affected by anaerobic decay, diagenesis, and compression, but much is probably fusain (resembles Recent charcoal; see Harris 1958).

Brown wood (Pl. 1, figs. 4–6) includes dark and light brown, reddish brown, and orange fragments of plant material. In transmitted light, distinction from black wood is usually only difficult when the fragments are thick and therefore opaque. Two kinds have been recognized: (1) fragments which lack any recognizable structure and are probably decomposition products of plants; (2) fragments of lignite from tree trunks, branches, and leafy twigs preserved in anaerobic conditions. Brown wood is particularly common in the Fairlight Clay, Ashdown Sand, and Tunbridge Wells Sand.

EXPLANATION OF PLATE 1

All figures ×100. Stage coordinates refer to Leitz Laborlux (L1) microscope, number 557187, Department of Geology, Sedgwick Museum, Cambridge.

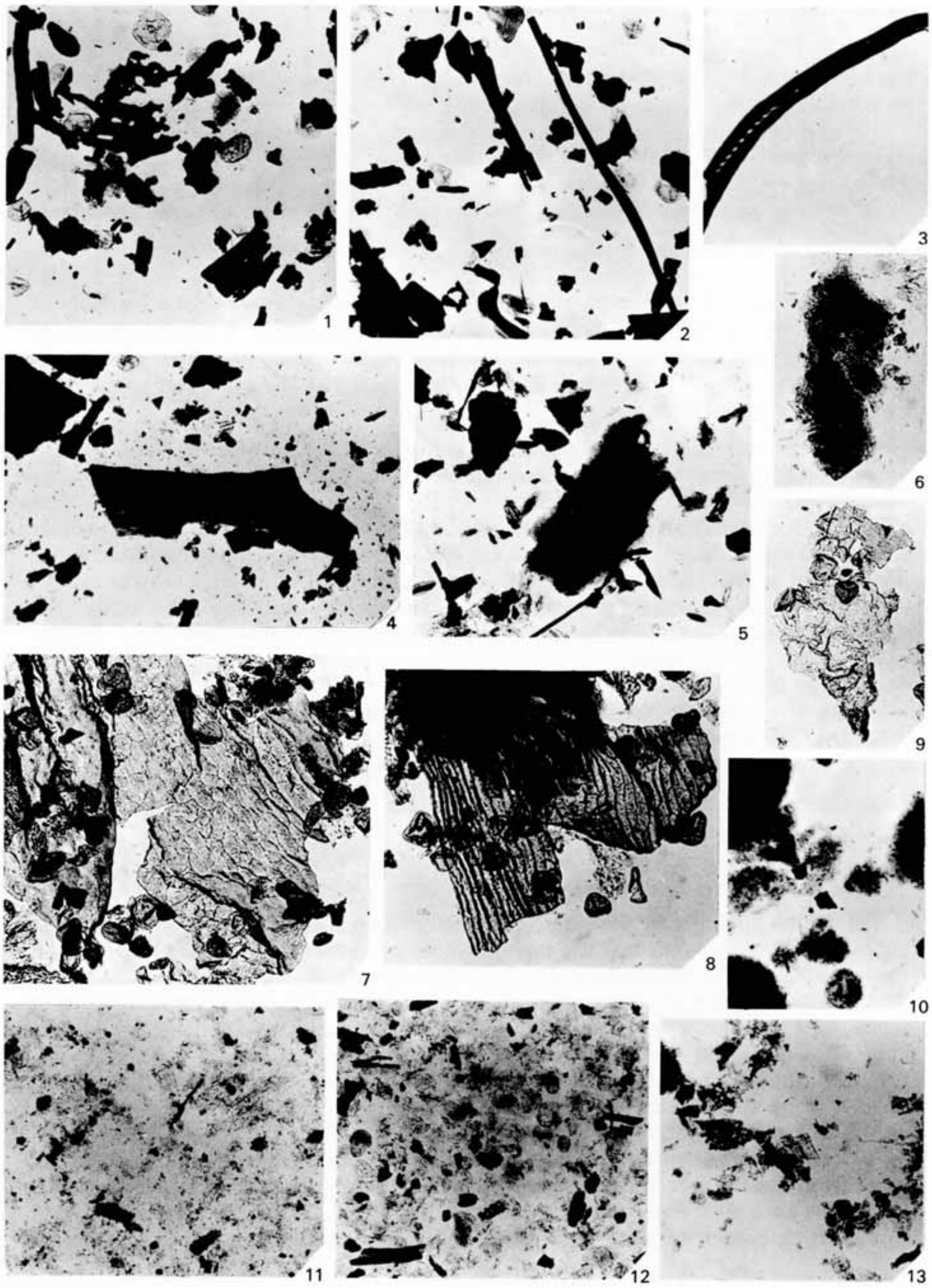
Figs. 1–3. Black 'wood'. 1, Fragments of black wood, some structured (including bordered pits), DJB18, prep. T061/1, L1 51·9 123·5. 2, Black wood fragments, some structured, DJB18, T061/1, L1 48·8 120·8. 3, Bordered pits, CUC799/6, T354/2, L1 50·8 116·4.

Figs. 4–6. Brown 'wood'. 4, All fragments are brown wood, opaque-reddish brown, DJB38, T056/1, L1 40·6 118·9. 5, Large piece in centre of figure and most of the smaller fragments are brown wood, some structured; small fragments with sharp outlines are black wood, DJB51, T025/2, L1 40·9 116·1. 6, Amorphous, light brown, DJB346, T325/1, L1 49·0 113·0.

Figs. 7–9. 'Cuticle.' 7, Large piece, CUC971, T294/2, L1 44·9 122·2. 8, Cuticle and part of *Thomsonia* megaspore, CUC971, T294/2, L1 40·1 121·7. 9, Poorly preserved, mostly unstructured; relict structures of pyrite crystals present but only just visible in figure, CUC971, T294/2, L1 57·8 120·9.

Figs. 10–13. 'Mush.' 10, Mush resulting from faulty preparation technique, CUC799/6, T354/2, L1 48·2 120·1. 11, 'Ghosts' of cuticle together with finely divided organic and mineral debris, DJB160, T145/1, L1 31·8 120·8. 12, Chiefly 'ghosts' of miospores together with mineral debris, DJB334, T350/2, L1 49·5 126·5. 13, Finely comminuted plant fragments and spores, DJB228, T085/1, L1 30·0 120·2.

PLATE 1



BATTEN, Cretaceous palynologie preparations

Cuticle (Pl. 1, figs. 7–9) is used here both for probable epidermal tissue and for the waxy layer formed on the outer layer of epidermal cells. The bulk of the cuticle in Wealden palynologic preparations is probably of gymnospermous origin.

It was difficult to obtain a consistent representation of wood and cuticle in each slide of a preparation, especially when many of the fragments were relatively large. The average size of the fragments is not considered here; it was not recorded unless small or large pieces ($< 75\ \mu$m or $> 200\ \mu$m respectively) were unusually abundant.

Mush. In some assemblages, various homogenized, frequently coagulated, combinations of the following occur, constituting 'mush' (Pl. 1, figs. 10–13: cf. in part 'sapropelic material' in Correia 1971, p. 611): minute fragments of poorly preserved miospores; entire but pale, crumpled 'ghosts' of miospores; small fragments of wood; very pale flimsy structureless tissue, probably partly cuticular–epidermal; finely divided organic (soft tissues of plants and animals) and inorganic (pyritous?) material; and mineral debris.

Other characters. The ratios of determinable to indeterminable grains and broken grains and fragments to entire grains were noted for each assemblage, expressed as percentages and recorded as P ($< 3\%$), C (3–29·5%), or F (30% or more). P, C, and F were also used (Table 2) for expressing the relative abundance of other fossils in the assemblages, namely, *Celyphus rallus* gen. and sp. nov., *Inapertisporites*, spore masses and tetrads, sporangia, megaspores, megaspore fragments, reworked palynomorphs, seeds, charalean gyrogonites, *Dictyothylakos*, dinoflagellates, acritarchs, microforaminifera, and *Botryococcus* (some of these not considered here). Grains referable to *Inapertisporites* were not included in the miospore counts of 200 because they tend to be overlooked on account of their very small size, and when frequent, considerably distort a count. Fungal remains (hyphae and spores) were recorded as P if present; abundances were not considered. Palynomorphs not considered at all include possible animal tissues and algae.

Data storage and handling. The Cambridge Titan computer was used to store and handle both the lithologic and palynologic data.

Determination of assemblage-types

The major difficulty in deriving a practical system for the rapid identification of palynologic assemblages was the large number of variables involved. The data on the preparations for miospores were grouped in various ways. Assemblage characters which I had found were easy to identify and/or appeared to be indicative of certain facies were used as a basis for grouping. The recurrent associations of the other characters displayed by the grouped assemblages were then determined for several levels of affinity. Those at the 70% (0·7) and 80% (0·8) levels of 37 groupings were selected from 69 as potentially useful for assemblage identification (for characters used as a basis for the 37 groupings, see Table 8).

A cluster analysis procedure was then used to facilitate the selection of assemblage-types from this number and at the same time to show the levels of similarity between them. The analysis started with a measure of similarity by comparing the binary data (presence/absence of variables) comprising each pair of objects (potential assemblage-types) and counting the frequency of 'matches' and 'mismatches' between them. A positive match indicated a match of 1 with 1, a negative match, 0 with 0, and a mismatch, 1 with 0.

Because every type of coefficient has some bias which can effect different patterns of clustering, several measures of similarity were used for comparison, including the Simple Matching Coefficient, $\frac{C+A}{N_t+A}$ (see Cheetham and Hazel 1969) and the Jaccard Coefficient $\frac{C}{N_1+N_2-C}$.

A Fortran IV program took the profiles of the 37 potential assemblage-types and computed the similarity coefficient values as a matrix. The values ranged between 1·0 (complete similarity) and 0·0 (complete dissimilarity). A modified version of Bonham-Carter's (1967) Fortran IV cluster analysis program was used to operate on the similarity data matrix using the unweighted pair-group linkage method (Sokal and Michener 1958, Sokal and Sneath 1963; both programs courtesy A. K. Yeats and P. D. Alexander-Marrack, Cambridge). The objects (potential assemblage-types) were related to each other on the basis of their attributes (characters); they were either paired or not paired. The paired categories formed single categories for the next and subsequent computation cycles. New coefficients were computed between the new categories at each cycle. The program printed out the level of similarity of successive linkages and a list of the object names in an order suitable for drawing a dendrogram.

TABLE 8. Characters used as a basis for grouping assemblages. Other characters which occurred in association with these in at least 70% and 80% of the assemblages formed the bases of 37 potential assemblage-types

General state of preservation of miospores good. General state of preservation of miospores poor. Black wood F, brown wood P or not recorded. Brown wood C. Brown wood F. Cuticle C. Cuticle F. Miospore diversity large. Miospore diversity small, poor preservation. Miospore diversity small, good preservation. Small triletes dominate the trilete spore content. Large triletes dominate the trilete spore content. *Concavissimisporites* C. *Pilosisporites* C. *Verrucosisporites* C. *Cicatricosisporites* V or F. *Ischyosporites* C or V. *Trilobosporites* C. *Araucariacites* C. *Araucariacites* V. *Inaperturopollenites* V or F. *Pilasporites* F. *Tsugaepollenites* C or V. *Bisaccates* F. *Eucommiidites* C. *Classopollis* V. *Classopollis* F. *Exesipollenites* C or V. *Inapertisporites* C. *Inapertisporites* F. *Celyphus rallus* C or F. *Microplankton. Microforaminifera. Megaspores* P. *Megaspores* C or F. Light weight megaspores dominate megaspore content. Megaspores mixed.

The clusters produced using the different similarity coefficients were then compared and the number of potential assemblage-types was reduced from 37 to 22. Use of the data derived from comparison of the recurrent associations at the 0·7 level of association was abandoned at this stage in favour of those derived from comparison at the 0·8 level. I then tried to categorize the 340 productive miospore preparations by comparing their characters with those of the 22 potential assemblage-types. 97% were usefully referred to 16 of these (ATs 1–16). The remaining 3% could not be identified and were subsequently referred to a 17th 'portmanteau' type (AT17) erected purely for recording convenience.

MIOSPORE RECORD

Comments are made with regard to the usage, distinction, and comparison of the miospore taxa referred to in the text and listed on Table 6. The authors of both the taxa used and compared are given once only. The Ages/Stages from which the published species (but not genera) referred to were described are given in parentheses after the author(s') name(s) if they were originally described from rocks outside the Cretaceous period. The taxa are arranged in the same order as they are set out on Table 6. The groupings approximately correspond to some of the ranks in the suprageneric classification systems of Potonié (1960, 1966) and Dettmann (1963); these are given in parentheses. Within each grouping the taxa are arranged in alphabetical order.

Systematic and nomenclatural problems raised during the course of this study were numerous despite the fact that for the most part I have dealt only with genera. I have had to use some generic names originally erected to incorporate Palaeozoic species for Wealden spores (e.g. *Granulatisporites*, *Converrucosisporites*, *Verrucosisporites*, *Acanthotriletes*, *Apiculatisporis*, and *Reticulatasporites*). Because they are so greatly separated in time, their use, at least for Late Mesozoic spores, should eventually be discontinued when suitable Mesozoic genera become available (see Hughes 1969). The large volume of literature which has to be perused renders comparison of Palaeozoic with Late Mesozoic taxa impracticable.

(Turma TRILETES Reinsch emend. Dettmann 1963)

(Infraturma LAEVIGATI Bennie and Kidston emend. Potonié 1956)

1. AURITULINASPORITES Nilsson 1958: miospores recorded as *Auritulinasporites* are closely similar to *A. complexis* Burger 1966 and *A. deltaformis* Burger 1966.

2. CONCAVISPORITES Pflug 1952 and in Thomson and Pflug 1953 emend. Delcourt and Sprumont 1955/*Concavisporites jurienensis* Balme 1957: *Concavisporites* was not used unless specimens could be referred to *C. jurienensis* (Jurassic) because of frequent difficulties with reliable determination; they were counted as 'smooth triletes' instead.

3. STEREISPORITES Pflug in Thomson and Pflug 1953.

4. UNDULATISPORITES Pflug in Thomson and Pflug 1953: spores with undulating laesurae almost as long as their radii and with exines which are smooth externally but often irregular (fossulate) internally have been recorded as *Undulatisporites*. The fossulate specimens are similar to *U. pseudobrasiliensis* Krutzsch 1959 (Tertiary), *U. takutuensis* van der Hammen and Burger 1966, and *U. major* Danzé and Laveine 1963 (Jurassic).

5. Smooth triletes: separation of most of the smooth walled trilete spores (*Biretisporites* Delcourt and Sprumont 1955 emend. Delcourt, Dettmann, and Hughes 1963, *Deltoidospora* Miner 1935, *Cyathidites* Couper 1953, *Leiotriletes* Naumova 1937 emend. Potonié and Kremp 1954, *Laroccatriletes* Burger 1966, *Todisporites* Couper 1958, *Triplanosporites* Pflug in Thomson and Pflug 1953, *Dictyophyllidites*, and *Concavisporites* (excluding *C. jurienensis*) etc. is generally not practicable at present because of frequent identification difficulties; although the plants concerned

were many, reliable characters for their separation are few. Observations of some trilete spores which show the outer sculptured layer of the exine partially removed suggests that a few ($< 1\%$) of the miospores recorded as 'smooth trilete' may originally have been sculptured.

(Infraturma APICULATI Bennie and Kidston emend. Potonié 1956)

6. ACANTHOTRILETES Naumova 1937 emend. Potonié and Kremp 1954: I referred to this genus spores which are ornamented with closely spaced, tapered, occasionally blunt-ended spines more than twice as long as their basal diameter. Some are clearly comparable to *Acanthotriletes varispinosus* Pocock 1962.

7. APICULATISPORIS Potonié and Kremp 1956.

8. BACULATISPORITES Thomson and Pflug 1953.

9. CERATOSPORITES Cookson and Dettmann 1958.

10. CONCAVISSIMISPORITES Delcourt and Sprumont 1955 emend. Delcourt, Dettmann, and Hughes 1963: *Concavissimisporites* has, by definition, concave to almost straight sides.

11. CONVERRUCOSISPORITES Potonié and Kremp 1954: I used *Converrucosisporites* for slightly concave to convex sided verrucate spores.

12. CYCLOGRANISPORITES Potonié and Kremp 1954/GRANULATISPORITES Ibrahim 1933 emend. Potonié and Kremp 1954.

13. FORAMINISPORIS Krutzsch 1959: Potonié (1966) is of the opinion that the character which distinguishes this genus from other genera is the presence of foveolae in the exine, provided that they are not of secondary origin. Dettmann (1963), on the other hand, has attributed miospores with a narrow sculptured cingulum to the genus although a cingulum was not diagnosed by Krutzsch. The exines of Wealden specimens referred to the genus lack perforations but are probably slightly thickened equatorially; they resemble the holotype of *F. foraminis* Krutzsch 1959 (Tertiary).

14. KUYLISPORITES Potonié 1956.

15. LEPTOLEPIDITES Couper 1953 emend. Norris 1968.

16. NEORAISTRICKIA Potonié 1956.

17. OSMUNDACIDITES Couper 1953: I included in this genus specimens showing considerable variation in wall thickness and sculpture. Forms with exines less than 1 μm thick, sculptured with small widely spaced grana and occasional bacula, and those with thicker exines possessing closely spaced grana (sometimes with coalescent bases) are grouped together. Most could have been included in the species *O. wellmanii* Couper 1953 (Jurassic). Similar grains but with predominantly baculate sculpture have been included in *Baculatisporites*.

18. PILOSISPORITES Delcourt and Sprumont 1955.

19. VERRUCOSISPORITES Ibrahim 1933 emend. Smith and Butterworth 1967: forms I included in this genus have circular to subcircular ambs. The diagnoses of *Verrucosisporites* and *Converrucosisporites* overlap.

(Infraturma MURORNATI Potonié and Kremp 1954)

20. CICATRICOSISPORITES Potonié and Gelletich 1933: I used *Cicatricosisporites* to incorporate positively and negatively sculptured forms (Hughes and Moody-Stuart 1967*b*) and specimens which possess exinal thickenings (appendices) in equatorial radial regions (= *Appendicisporites* Weyland and Krieger 1953).

21. CORRUGATISPORITES Thomson and Pflug 1953 ex Weyland and Greifeld 1953/ RUGULATISPORITES Thomson and Pflug 1953: spores which could have been referred to *Lycopodiacidites* Couper 1953 emend. Potonié 1956 and to *Trilites* Erdtman 1947 ex Couper 1953 emend. Dettmann 1963 were included here.

22. FOVEOSPORITES Balme 1957/FOVEOTRILETES van der Hammen 1954 ex Potonié 1956/SESTROSPORITES Dettmann 1963.

23. KLUKISPORITES Couper 1958: the diagnoses of *Klukisporites*, *Reticulisporites*, *Lycopodiumsporites*, and *Retitriletes* overlap. I included non-valvate spores with distally foveo-reticulate sculpture and smooth or lightly sculptured proximal surfaces in *Klukisporites*. *Ischyosporites* is valvate.

24. LYCOPODIUMSPORITES Thiergart 1938 ex Delcourt and Sprumont 1955/RETICULISPORITES Potonié and Kremp in Weyland and Krieger 1953: I recorded distally reticulate azonate miospores with membraneous laesurate lips as *Lycopodiumsporites*. *Reticulisporites* differs from *Lycopodiumsporites* in having lower muri.

25. *Reticulisporites semireticulatus* (Burger 1966) Norris 1969 (Jurassic): *Lycopodiumisporites semimuris* Danzé-Corsin and Laveine (in Briche *et al.* 1963; Lower Lias) is similar but the muri are higher (2–4 μm) and generally narrower.

26. RETITRILETES van der Hammen 1956 ex Pierce 1961: I used *Retitriletes* for spores with characters which prohibit their inclusion in other, more commonly used, genera for Mesozoic reticulate spores. Some show characters similar to those of spores which have been referred to, in the literature, as *Dictyotriletes* Naumova 1937 *sensu* Smith and Butterworth (1967).

27. STAPLINISPORITES Pocock 1962/CORONATISPORA Dettmann 1963.

28. TAUROCUSPORITES Stover 1962 emend. Playford and Dettman 1965/POLYCINGULATISPORITES Simoncsics and Kedves 1961 emend. Playford and Dettmann 1965.

29. TRIPARTINA Maljavkina 1949 ex Potonié 1960.

(Infraturma PERINOTRILITI Erdtman 1947)

30. PEROTRILITES Erdtman 1947 ex Couper 1953.

(Infraturma AURICULATI Schopf emend. Dettmann 1963)

31. ISCHYOSPORITES Balme 1957.

32. MATONISPORITES Couper 1958 emend. Dettmann 1963.

33. TRILOBOSPORITES Pant 1954 ex Potonié 1956: spores recorded as *Trilobosporites* had differentially thickened exines and/or larger sculptural elements about the radial regions at the equator.

(Infraturma TRICRASSATI Dettmann 1963)

34. GLEICHENIIDITES Ross 1949 ex Delcourt and Sprumont 1955 emend. Dettmann 1963: I included in this genus forms which could have been included in some of Krutzsch's (1959) subgenera or in *Clavifera* Bolkhovitina 1966. Sculptured forms comparable with *Ornamentifera* Bolkhovitina 1966 (= subgenus *Peregrinisporis* Krutzsch 1959) have not been recovered.

35. *Gleicheniidites apilobatus* Brenner 1963: miospores recorded as this species have differentially thickened distal exines and distal ridges crossing the apical lobes (Kemp 1970). The ridges have been interpreted (Kemp 1970) as upturned margins of the thickening. Reference to *Gleicheniidites* is therefore inaccurate but there is at present no other suitable genus available. *Concavisporites jurienensis* differs in having kyrtomes which extend from the proximal face on to the distal.

(Infraturma CINGULATI Potonié and Klaus emend. Dettmann 1963)

36. CINGUTRILETES Pierce 1961 emend. Dettmann 1963.

37. CONTIGNISPORITES Dettmann 1963.

38. DENSOISPORITES Weyland and Krieger 1953 emend. Dettmann 1963.

39. *Densoisporites velatus* Weyland and Krieger 1953 emend. Krasnova 1961.

(Infraturma PATINATI Butterworth and Williams 1958)

40. PATELLASPORITES Groot and Groot 1962 emend. Kemp 1970: *Patellasporites* was used for spores which are equatorially and distally thickened and strongly sculptured. The distal exine of the type species of this genus (*P. tavaredensis* Groot and Groot 1962) is dissected by narrow canals into areas of exine of varying shape and size. I included here forms which superficially resemble *Bullasporis aequatorialis* Krutzsch 1959 (Tertiary).

(Turma HILATES Dettmann 1963)

41. AEQUITRIRADITES Delcourt and Sprumont 1955 emend. Cookson and Dettmann 1961.

42. COOKSONITES Pocock 1962 emend. Dettmann 1963.

43. COPTOSPORA Dettmann 1963.

44. COUPERISPORITES Pocock 1962 (*C. complexus* (Couper 1958) Pocock 1962).

45. ROUSEISPORITES Pocock 1962.

46. Sculptured triletes indet.

47. Total triletes.

(Turma MONOLETES Ibrahim 1933)

48. MONOLITES Cookson 1947 ex Potonié 1956.

49. MARATTISPORITES Couper 1958.

50. PEROMONOLITES Erdtman 1947 ex Couper 1953.

(Turma ALETES Ibrahim 1933)

51. ARAUCARIACITES Cookson 1947 ex Couper 1953.

52. INAPERTISPORITES van der Hammen 1955 ex Rouse 1959: I used *Inapertisporites*

to incorporate small (7–16 μm diameter), smooth or scabrate, alete, circular to subcircular grains which have an exine 0·5–1·0 μm thick. Most are probably comparable with forms described by Norris as *Inaperturopollenites* sp. (Norris 1969, pp. 597–598; Upper Jurassic).

53. INAPERTUROPOLLENITES Pflug 1952 ex Thomson and Pflug 1953 emend. Potonié 1966: Inaperturates occur in nearly all productive preparations. They are a difficult group to deal with owing to a paucity of characters and a tendency to fold. *Inaperturopollenites* was used here to incorporate all more or less smooth relatively thin walled (exine *c.* 1 μm thick) forms distinct from those referable to *Araucariacites*, *Pilasporites*, *Inapertisporites*, and representatives of the acritarch group.

54. PILASPORITES Balme and Hennelly 1956 (*P. allenii* Batten 1968).

55. RETICULATASPORITES Ibrahim 1933 emend. Potonié and Kremp 1954.

(Turma SACCITES Erdtman 1947)

56. CEREBROPOLLENITES Nilsson 1958 (*C. mesozoicus* (Couper 1958) Nilsson 1958; Jurassic).

57. TSUGAEPOLLENITES Potonié and Venitz 1934 emend. Potonié 1958: considerable confusion exists in the literature with regard to the usage of *Zonalapollenites* Pflug in Thomson and Pflug 1953, *Callialasporites* Dev 1961, *Applanopsis* Döring 1961, *Triangulopsis* Döring 1961, *Cerebropollenites*, and *Tsugaepollenites* for morphologically similar saccate pollen grains (see Potonié 1966, Pocock 1968). The genus *Tsugaepollenites* is used here but not strictly in the sense of Potonié (1958) because *Cerebropollenites mesozoicus* has been recorded separately.

58. Bisaccates (excluding VITREISPORITES): most of the published Late Mesozoic bisaccate species and genera are insufficiently well described (see Kemp 1970) to have much value for stratigraphic purposes in the Wealden. Variations in preservation and orientation continually cause difficulties with identification. The most common forms are *Alisporites* types, e.g. forms similar to *Alisporites thomasii* (Couper 1958) Pocock 1962 (Jurassic) and *A. microsaccus* (Couper 1958) Pocock 1962 (Jurassic) but specimens referable to *Parvisaccites* Couper 1958 (e.g. *P. radiatus* Couper 1958), *Podocarpidites* Cookson 1947 ex Couper 1953, and *Vitreisporites* also occur.

59. VITREISPORITES Leschik 1955 emend. Jansonius 1962.

(Turma PLICATES Naumova emend. Potonié 1960)

60. EUCOMMIIDITES Erdtman 1948 emend. Hughes 1961.

61. CYCADOPITES Wodehouse 1933 ex Wilson and Webster 1946: I recorded all monosulcate grains, including those which could, perhaps, have been included in *Monosulcites* Cookson 1947 ex Couper 1953, as *Cycadopites*. All were elongate to subcircular and had smooth to microgranulate exines.

(Turma POROSES Naumova emend. Potonié 1960)

62. CLASSOPOLLIS Pflug 1953 emend. Reyre 1970.

63. EXESIPOLLENITES Balme 1957: the characters of *Exesipollenites* and *Spheripollenites* Couper 1958 overlap. *Exesipollenites* possesses a circular depression sur-

rounded by an area of exinal thickening; the depression may represent a pore although actual perforation of the exine has not been recorded. According to the original definition, the exine can be smooth or with occasional granules (Balme 1957). *Spheripollenites*, as originally defined, lacks an exinal thickening and, as a result, is more often found in a folded state.

Most of the Wealden forms probably fall within the character range of *E. tumulus* Balme 1957 (Jurassic). Few definitely lack an area of exinal thickening.

Muller (1968) expressed some doubt as to whether *Exesipollenites* can be considered a pollen grain because of the absence of any structural differentiation in the wall and because the circular depression in the wall cannot be considered an aperture. He suggested that its occurrence in floods in Cretaceous marine facies of Sarawak, Malaysia, may be because its origin is planktonic. There is no evidence so far, however, to suggest that Wealden forms referable to the genus have such an origin.

64. PERINOPOLLENITES Couper 1958: grains with a firmly attached but loosely enveloping perine were included in *Perinopollenites*. Reference to *Ballosporites* Mädler 1964 may, however, have been more appropriate for split specimens lacking a pore. Oval, split forms resemble *P. pseudosulcatus* Danzé-Corsin and Laveine 1963 (in Briche *et al.* 1963; Lower Lias).

(MIOSPORES INCERTAE SEDIS)

65. SCHIZOSPORIS Cookson and Dettmann 1959.

66. *Schizosporis parvus* Cookson and Dettmann 1959.

67. *Schizosporis reticulatus* Cookson and Dettmann 1959.

RECORD: INCERTAE SEDIS

Celyphus rallus gen. and sp. nov.

Plate 2, figs. 1–15

Type sample. CUC 869, Cuckfield No. 1 Borehole, Sidnye Farm, Sussex (TQ 2961 2731), depth 869 feet (264·9 m); Wadhurst Clay, Valanginian? Medium to medium dark grey (N5–N4) fine siltstone, slightly calcareous. Preparation T400; 20 mins HNO_3, cleared in dilute NH_4OH, mineral separation, strew slides with Clearcol. AT9:S2,4.

Generic diagnosis. As for specific diagnosis.

Specific diagnosis. Palynomorph body elongate, tapered, with rounded or flattened ends. Mean maximum length of body 55·5 μm, standard deviation 9 μm (100 specimens). Mean maximum width of body 19·5 μm. Body wall 0·5–1·0 μm thick except near the B end (Pl. 2, fig. 1) where it becomes very thin (*c.* 0·25 μm) and is often folded (folds small, narrow, irregular). The B end is open, has a variable outline and frequently appears to have been torn. At the A end (Pl. 2, fig. 1) there is a circular or sub-circular opening (pore) 3–10 μm in diameter, with a smooth (? unthickened) or serrated margin. Unevenly spaced (usually 4–11 μm apart) concentric bands of thin wall may be faintly, sometimes clearly, distinguishable. They are generally 2–4 in number and 0·5–3 μm wide (Pl. 2, fig. 2).

Holotype. Slide preparation T400/6, L1 35·8 127·2; Pl. 2, fig. 5.

Description. The observed limits of the maximum length of the body are 39–74 μm (coefficient of variation 16·2%), and of the maximum width are 16–23 μm. The serrated margins of the pores of some specimens appear to have been the result of expansion and splitting of the pore margin; sometimes the splits continue for up to 25 μm along the length of the body.

Preservation and compression. This palynomorph has been susceptible to corrosion; specimens are commonly pale (thinned) and poorly preserved, and damage by pyrite is common (Pl. 2, fig. 6). Poorly preserved specimens were included in the 100 examined.

Remarks. Specimens are commonly preserved aligned sub-parallel to each other in circular or oval shaped masses (Pl. 2, figs. 9, 11, 12). The A ends face the centre of a mass unless specimens have been dislodged. Individuals separate easily from the masses; perhaps before fossilization they were held together by mucilage. The affinity of the palynomorph is uncertain (? egg cases, ? algae).

Preparations of the same type as used for the recovery of large plant microfossils enabled the recovery of masses larger than those generally seen in preparations for miospores. The holotype specimen is present with topotype specimens in a strew slide of a single preparation. The figured specimens are housed in the palynology collection of the Sedgwick Museum, Cambridge. Representative specimens are also deposited in the Institute of Geological Sciences, Leeds.

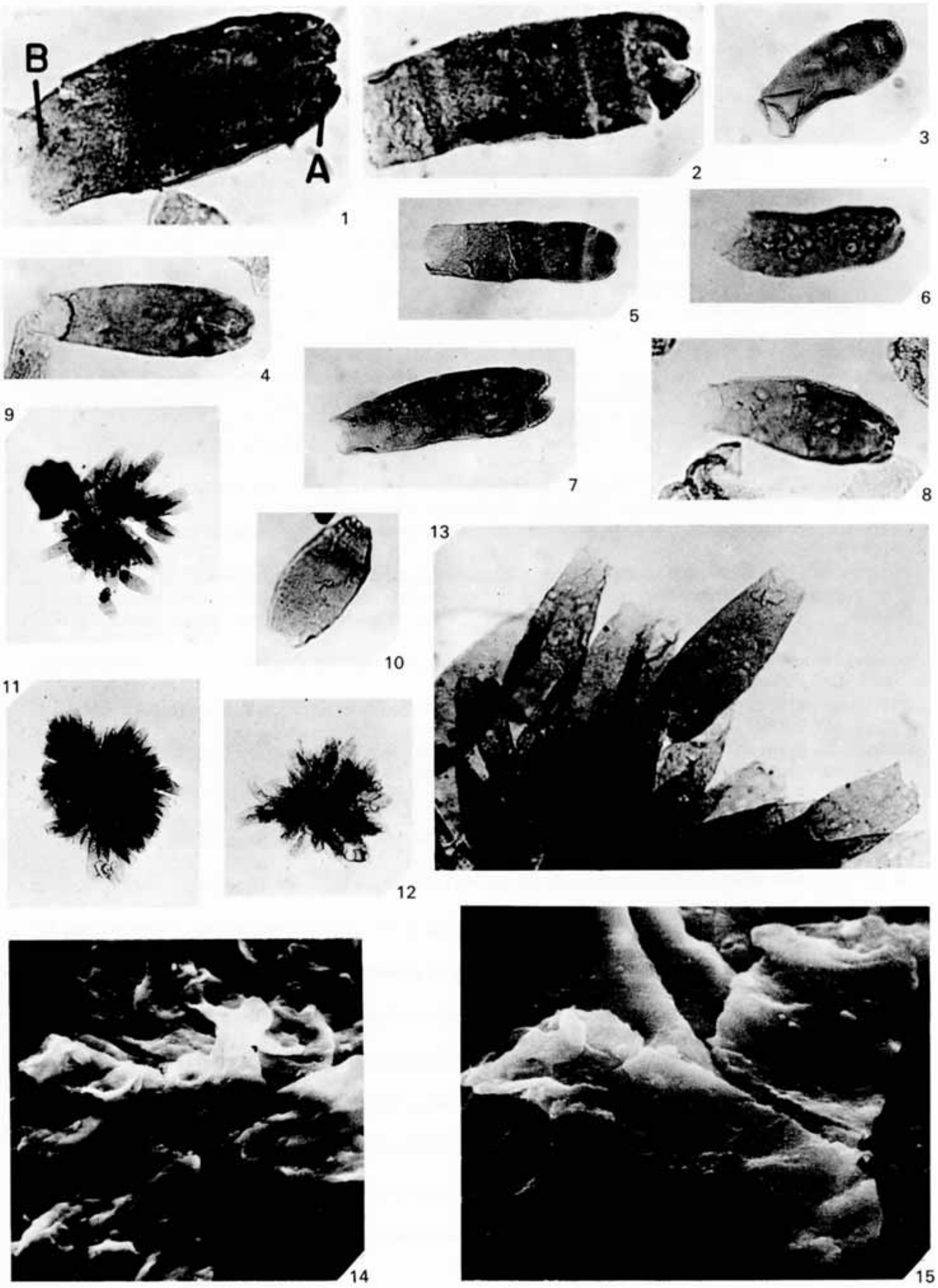
Acknowledgments. The work for this paper was carried out whilst I was in receipt of a N.E.R.C. grant. It is partially based on material from the Cuckfield No. 1, Warlingham, and Whites Bridge boreholes made available to Mr. N. F. Hughes by the Institute of Geological Sciences. I am grateful to the Institute for access to the log of the Cuckfield No. 1 Borehole. I thank Mr. N. F. Hughes and Miss J. E. Hutt for discussion.

EXPLANATION OF PLATE 2

Stage coordinates refer to Leitz Laborlux (L1) microscope, number 557187, Department of Geology, Sedgwick Museum, Cambridge.

Figs. 1–15. *Celyphus rallus* gen. and sp. nov. 1, Indicating A and B ends, T400/6, L1 52·0 119·6, ×1000. 2, Concentric bands of thin wall distinguishable, T400/6, L1 53·1 116·0, ×1000. 3, Pore at A end, B end open, T400/6, L1 53·8 108·9, ×500. 4, Tapered specimen, pore clearly visible, T400/6, L1 22·1 126·9, ×500. 5, Holotype, T400/6 L1 35·8 127·2, ×500. 6, Specimen with pyrite relict structures in wall, T400/6, L1 40·1 128·1, ×500. 7, T400/6, L1 40·2 120·9, ×500. 8, Small pyrite relict structures in wall, T400/6, L1 37·1 127·4, ×500. 9, Mass, several specimens dislodged, T400/4, L1 34·4 115·9, ×100. 10, Small specimen, T400/6, L1 26·9 125·9, ×500. 11, Cohesive mass, T400/4, L1 31·6 120·1, ×100. 12, Poorly preserved mass, T400/4, L1 32·8 114·8, ×100. 13, Part of mass, T400/4, L1 34·3 115·9, ×500. 14, S.E.M. of part of mass, prep. T400, stub (SH)DB 55, ×400. 15, S.E.M. of specimen in mass, prep. T400, stub (SH)DB 55, ×1500. (Scanning electron micrographs courtesy Dept. of Environmental Sciences, U.E.A. Norwich: specimens were mounted on double sided 'Sellotape' and coated with carbon.)

PLATE 2



BATTEN, early Cretaceous palynomorph

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Revised typescript received 20 April 1972

APPENDIX

Localities of samples listed on Table 5

Fairlight Clay (*FC*). 1, FC 'd' (see White 1928), Goldbury Point, near Hastings, Sussex (TQ 8789 1163). 2, FC 'd', in proximity of Fairlight Glen, near Hastings (TQ 8552 1067). 3, as above (TQ 8523 1063). 4–6, as above (TQ 8548 1072). 7, as above (TQ 8548 1073). 8–10, as above (TQ 8533 1070). 11, FC 'b', west of Haddocks Rough, near Hastings (TQ 8818 1222). 12–14, Warlingham Borehole, Surrey (TQ 3476 5719); sample numbers indicate depth.

Ashdown Sand (*AS*). 15, 16, Ecclesbourne Glen, near Hastings (TQ 8372 0996). 17–24, Cuckfield No. 1 Borehole, Sussex, second redrilling (TQ 2961 2731), sample numbers indicate depth, most (rounded) to the nearest foot. 25, east of Haddocks Rough, near Hastings (TQ 8812 1206). 26, west of Ecclesbourne Glen, near Hastings (TQ 8352 0981). 27, near Pett Level, Sussex (TQ 8872 1288).

Wadhurst Clay (*WC*). 28–34, Cuckfield No. 1 Borehole (TQ 2961 2731). 35–45, Cuckfield No. 1 Borehole, first redrilling (TQ 2962 2729). 46–48, Cuckfield No. 1 Borehole, original site (TQ 2962 2729). 49–57, Railway Brickyard, Sharpthorne, Sussex (TQ 3740 3294). 58–60, Freshfield Lane Brickworks, Danehill, Sussex (TQ 3813 2659). 61–72, High Brooms Brick and Tile Company's pit, Southborough, Kent (TQ 5948 4189). 73, Brambletye Bend (A.22), Sussex (TQ 419 363).

Tunbridge Wells Sand (*TWS*). 74–82, Cuckfield No. 1 Borehole (TQ 2962 2729). 83, Philpots Quarry, West Hoathly, Sussex (TQ 3548 3221).

Grinstead Clay (*GC*). 84, Cuckfield No. 1 Borehole (TQ 2962 2729). 85–96, Philpots Quarry, West Hoathly (TQ 3548 3221).

Weald Clay (*WEC*). 97, Warnham brick pit, Sussex (TQ 173 345). 98, Newdigate Brickworks clay pit, Surrey (TQ 204 425). 99, 100, Warlingham Borehole (TQ 3476 5719).