MIOSPORES FROM THE PURBECK BEDS AND MARINE UPPER JURASSIC OF SOUTHERN ENGLAND

by GEOFFREY NORRIS

ABSTRACT. Miospores from the marine Upper Jurassic and from the non-marine Purbeck Beds (Tithonian–Berriasian) of southern England are described and illustrated. Three principal palynologic suites embracing a total of 77 species (13 of which are new) are recognized, each delimiting broadly similar spore-pollen assemblages. Suite A characterizes the Upper Kimmeridgian (rotunda and pallasioides zones), the Portlandian, and the basal Lower Purbeck Beds. Suite B characterizes the remaining Lower Purbeck and the lower part of the Middle Purbeck. Suite C occupies the remaining Middle Purbeck and all of the Upper Purbeck. The Purbeck Beds of central Sussex correlate palynologically with some of the Middle and the Upper Purbeck of Dorset and with the Serpulite and Wealden 1 to 4 of north-central Germany and Holland. The lower limit of palynologic Suite C approximately coincides with a possible Jurassic–Cretaceous boundary. The successive palynologic suites represent a progressive diversification of the spore-pollen flora derived from principally gymnosperm-pteridophyte vegetation. Although filicalean spores are the most diverse elements in the assemblages as a whole, coniferalean pollen species are the most persistent as well as the numerically dominant elements. Bryophytic and cycadalean elements remain unimportant throughout.

THIS paper describes miospore assemblages from the Purbeck Beds of southern England and from the Upper Kimmeridgian and Portlandian marine sediments exposed on the Dorset coast. Couper (1958) made an extensive study of British Jurassic and Lower Cretaceous miospores but examined only a few samples from the Purbeck Beds of Durlston Bay, Dorset and Mountfield, Sussex and three palynologic assemblages from the Kimmeridgian of Scotland. He demonstrated that significant differences exist between miospore assemblages from various Jurassic and Cretaceous stages and formations but did not attempt detailed subdivision and correlation of the Upper Jurassic. Lantz (1958*b*), however, attempted a palynologic subdivision of the English Upper Jurassic in a limited study. Hughes (1958) demonstrated a relatively detailed miospore zonation of both marine and non-marine Lower Cretaceous sediments and correlated the Wealden with the marine stages by this means. Recently, Hughes and Moody-Stuart (1969) have noted a new method to correlate palynologically the Lower Cretaceous of southern England.

The present study examines the stratigraphic value of miospores for zonation and correlation of strata developed close to the Jurassic–Cretaceous boundary in southern England and for age determination of the Purbeck Beds and equivalent strata in Dorset and Sussex.

STRATIGRAPHY AND LOCATION OF SAMPLES

The stratigraphy of the sections is summarized in text-fig. 1. Location of the sections examined are indicated in text-fig. 2. Precise stratigraphic positions of the samples within these sections are given in the Appendix to Norris (1963). Reference should be made to Arkell (1947) for a detailed account of the stratigraphy and structural setting where also a full list of references to major works on the geology of the Dorset area may be found.

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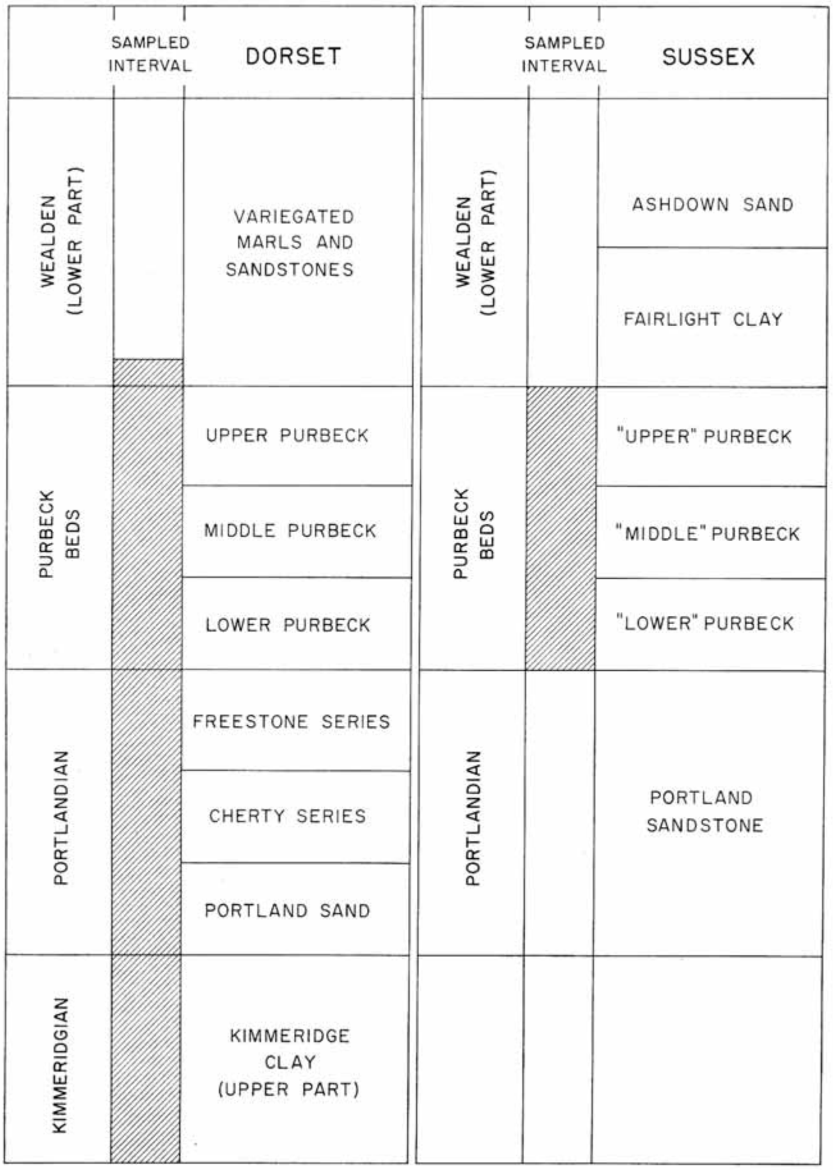
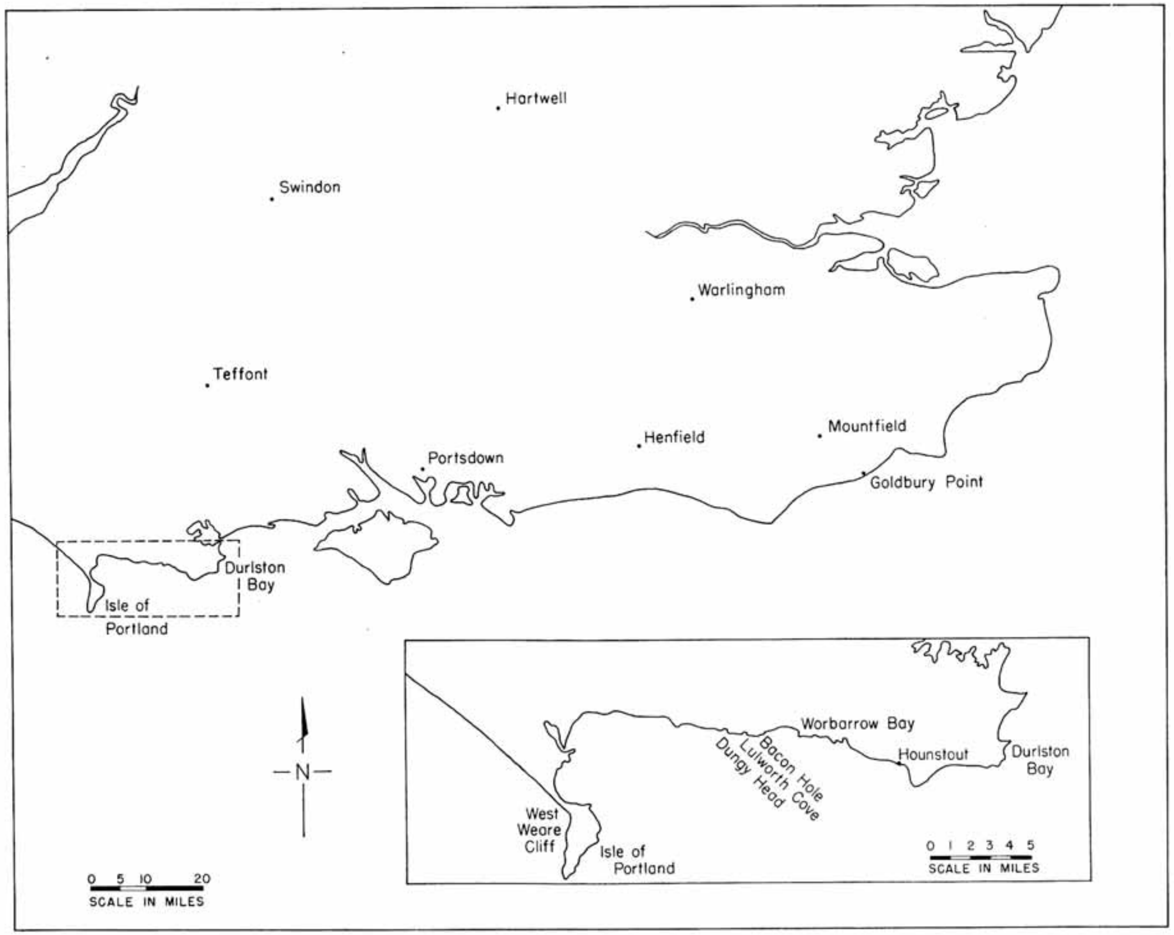


TEXT-FIG. 1. Generalized succession of strata close to the Jurassic–Cretaceous boundary in Dorset and Sussex. Correlations are not implied between the two areas.



TEXT-FIG. 2. Locality map of Kimmeridgian, Portlandian, and Purbeck sections examined in southern England, plus other areas mentioned in the text. Inset map shows localities on the Dorset coast within the area enclosed by a broken line on the main map.

Samples were selected on the basis of lithologies most suitable for palynomorph preservation in each section. In general, the samples from the Kimmeridge Clay are shales or silty shales and those from the Portland Sand are siltstones or fine-grained sandstones. Clastic material is almost entirely lacking in the Portland Stone and all samples from here are relatively pure limestones. Samples from the Purbeck Beds are more varied but in general grey and brown shales, silty shales, and clays yielded the best assemblages. Of the carbonate rocks in the Purbeck Beds, argillaceous limestones are the most satisfactory for palynologic examination.

TABLE 1

Zonal classification of the Portlandian and upper part of the Kimmeridgian in Dorset, with thicknesses of respective rock divisions exposed at West Weare Cliff (Isle of Portland) and Hounstout (Isle of Purbeck). The strata comprising the upper two Portlandian zones constitute the Portland Stone and those of the lower two zones the Portland Sand. Numbers of samples examined are indicated.

Stage	*Zone*		*Rock Units*		
			Isle of Portland		*Isle of Purbeck*
Portlandian					
	Titanites titan	Barren	Freestone Series 25 ft.	Not sampled	Freestone Series 50 ft.
	Kerberites okusensis		Cherty Series 60 ft. Basal Shell Bed 6 ft.		Cherty Series 65 ft.
	Glaucolithites gorei	22 samples	Portland Clay 14 ft. West Weare Sandstone 40 ft. Exogyra Bed 8 ft. Upper Black Nore Beds 35 ft. Black Nore Sandstone 6 ft. Lower Black Nore Beds 25 ft.	9 samples	Black Sandstones and Parallel Bands 44 ft. St. Alban's Head Marls 45 ft. White Cementstone 2 ft. Emmit Hill Marls 30 ft. Massive Bed 6 ft.
	Zaraiskites albani				
Kimmeridgian					
	Pavlovia pallasioides	12 samples	Kimmeridge Clay 100+ ft.	10 samples	Hounstout Marl 50 ft. Hounstout Clay 30 ft. Rhynchonella Marls 20 ft. Lingula Shales 40 ft. Rotunda Clays and Nodules 98 ft. Crushed Ammonoid Shales 108 ft.
	Pavlovia rotunda	Not sampled	(Not exposed at West Weare Cliff)		

Marine Upper Jurassic

(*a*) *Hounstout* (*Isle of Purbeck*). A complete succession from the Upper Kimmeridgian to Portlandian, as shown in Table 1, is exposed in the face of Hounstout and surrounding cliffs at Chapman's Pool, Emmit Hill, Pier Bottom, and St. Alban's Head on the Isle of Purbeck (Arkell 1935, 1947). Number of samples collected is shown in Table 1.

Arkell's (1935, 1947) zonal classification of the Kimmeridgian and Portlandian is followed, with modifications suggested by House (1958 *a*, *b*), and is also shown in Table 1. The top two ammonite zones of the Kimmeridge clay were examined in this study so that the typical shaley facies of the Kimmeridgian would be included.

(*b*) *West Weare Cliff* (*Isle of Portland*). A continuous succession from Kimmeridge Clay to Portland Stone is exposed in the cliffs on the west side of the Isle of Portland as shown in Table 1 (Arkell 1933, 1935; House 1958*a*). The number of samples used is also shown in the Table.

Purbeck Beds

The lower boundary of the Purbeck Beds in southern England is delimited by Portlandian sediments which belong to different zones in different areas (Arkell 1953, Taitt and Kent 1958, Falcon and Kent 1960). The Purbeck Beds are terminated by the incoming of the Wealden facies (Allen 1955). Arkell (1947, 1956) used 'Purbeckian' as a stage of the Jurassic system, basing it on three ostracod zones recognizable in the Purbeck Beds. However, the Purbeckian of north-west Europe is now considered as a predominantly freshwater and continental facies developed at the top of the Jurassic and the base of the Cretaceous (Maubeuge 1962, Oertli 1963), and to avoid confusion the term will not be used.

It has been customary in British stratigraphy for more than a century to use the term 'Purbeck Beds' for all those continental, freshwater, brackish, estuarine, lagoonal or partly marine, usually fine-grained and calcareous sediments developed above the Portland Beds in southern England (Fisher 1856, Bristow 1857, Topley 1875, Woodward 1895, Arkell 1933, Howitt 1964). The desirability of using the same rock unit name for similar sediments from widely separated localities is questionable. The term Purbeck Beds is used in this study for all areas because it is still in widespread use. The erection of other formational names requires more intensive work on the detailed stratigraphy at each locality than was attempted here. The present work on the Purbeck palynologic assemblages may help to resolve some problems of the stratigraphy and correlation of the Purbeck Beds.

In a later section, reference will be made to the 'Purbeckian' of France and Switzerland developed in and around the Jura Mountains (Arkell 1956, Donze 1958). To avoid confusion and to remove any connotation of time-concordance, these sediments will be informally termed, for purposes of discussions, the 'Swiss Purbecks', 'French Purbecks', or 'Jura Purbecks', depending on the context.

Some sections of the Purbeck Beds in southern England have been zoned using ostracods. The history of the zonal classification of the Purbeck Beds has been given by Anderson (1958, 1962), the later reference with particular regard to the Upper Purbeck. Anderson (1940) proposed a more detailed subdivision of the Purbeck Beds than the original tripartite division of earlier workers. This was subsequently revised by Sylvester-Bradley (1949) and Anderson (1958). In consequence, the limits of the Lower, Middle, and Upper divisions have undergone considerable fluctuations. Anderson (1958) proposed 6 ostracod zones of which the lower 2 define the Lower Purbeck, the succeeding 3 the Middle Purbeck, and the highest zone characterizes the Upper Purbeck (Table 2). The limits of these three divisions now correspond exactly to those used by Bristow (1857).

(*a*) *Dorset Coast*. The type section of the Purbeck Beds is exposed on the north limb of the Purbeck anticline in Durlston Bay. There is a general attenuation of the Purbeck Beds westwards from Durlston Bay (390 ft.), Worbarrow Bay (290 ft.), Bacon Hole (250 ft.) to Lulworth Cove (179 ft.) (see Howitt 1964, fig. 7). Purbeck assemblages have not been recovered westwards beyond Lulworth Cove. The detailed stratigraphy of the Purbeck Beds has been described by Fisher (1856), Bristow (1857), and Damon (1884). Bristow's sections have usually been taken as a basis for later work, but his rock units have been emended by Woodward (1895), Strahan (1898), and Arkell (1933). Some workers still use Bristow's rock unit nomenclature in preference to Arkell's. The two schemes are compared in Table 2, where also the ostracod zones of Anderson (1958) are indicated.

TABLE 2

Ostracod zonal classification of the Purbeck Beds from Anderson (1958), with Arkell's and Bristow's alternative stratigraphic nomenclature of the Dorset Purbeck sections; the Mountfield Purbeck is from Howitt (1964) including his suggested lithologic correlations with Dorset.

Zones	*Dorset*		*Mountfield, Sussex*
	Bristow 1857	*Arkell 1953*	
Upper Purbeck	Upper Cypris Clay and Shales	Viviparus Clays	
Cypridea setina		Marble Beds and Ostracod Shales	Greys Limestone Series
	Unio Beds	Unio Beds	
	Upper Broken Shell Limestone	Broken Shell Limestone	
Middle Purbeck	Chief Beef Beds	Chief Beef Beds	Shales with Beef and Clay Ironstone
Cypridea propunctata	Corbula Beds	Corbula Beds	
	Scallop Bed		
Cypridea fasciculata	Intermarine Beds	Upper Building Stone	Arenaceous Beds
	Cinder Beds	Cinder Bed	Cinder Beds
	Cherty Freshwater Beds	Lower Building Stone	Plant and Bone Beds
Cypridea granulosa	Marley Freshwater Beds	Mammal Bed	
Lower Purbeck	Soft Cockle Beds	Marls with Gypsum and Insect Beds	Blue Limestone Series
Fabenella boloniensis	Hard Cockle Beds		
	Cypris Freestone		Rounden Greys
'Cypris' purbeckensis	Broken Beds	Broken Beds	Main Gypsiferous Beds
	Soft Cap	Caps and Dirt Beds	
	Hard Cap		

Four Purbeck localities were examined along the Dorset Coast. The type section at Durlston Bay was examined in most detail. One hundred and twenty samples were collected from the 390-ft. section of Lower, Middle, and Upper Purbeck at this locality. Of the 85 samples treated for palynomorphs, 69 yielded assemblages.

At Worbarrow Bay, 18 samples were collected, 15 were processed, and 12 yielded palynomorphs in the 290-ft. section.

At Bacon Hole, 73 samples were collected from the 250-ft. Purbeck section. 47 samples were processed and 37 of these yielded palynomorphs.

At Lulworth Cove, 30 samples were collected from the 179-ft. section. Of these, 17 samples were processed for palynomorphs but only 5 yielded assemblages. The poor yield at Lulworth may be related to the increased proportion of carbonates at this locality compared with areas further east. Limestone proved to be generally barren of palynomorphs. For the same reason, sections of the Purbeck Beds developed close to the edge of the basin at Teffont in the Vale of Wardour (Andrews and Jukes-Browne 1894), at Swindon, Wiltshire (Sylvester-Bradley 1941), and at Hartwell, Buckinghamshire (Ballance 1963) all proved to be barren of palynomorphs and are not considered further here.

(*b*) *Mountfield, Sussex.* Purbeck Beds are brought to the surface in Sussex along the central line of the Wealden dome in the Brightling anticline (Edmunds 1954). The lower part of the Purbeck Beds is known in subsurface sections in the mine of Gyproc Ltd., at Mountfield and in various boreholes. The stratigraphy, compiled from surface and subsurface sections, has been summarized by Topley (1875), White (1928), and Allen (1960*b*). A more detailed account has been given by Howitt (1964). The general succession of the Purbeck Beds in the vicinity of the mine is shown in Table 2.

At Mountfield, 31 samples were collected between the lowest gypsum seam, at the base, and the Greys Limestone Series at the top of the section, a total of almost 400 ft. (Howitt 1964). These samples were from surface outcrops and from subsurface sections in the mine and from Gypsum Mines borehole M 64 (grid reference TQ 716187). Further details of this borehole are given in Appendix 1 of Norris (1963). Of the 23 samples processed from Mountfield, 21 yielded palynomorphs.

(*c*) *Warlingham Borehole, Surrey.* Preliminary accounts of the succession in this borehole have been published in the *Summary of Progress of the Geological Survey* (1957, p. 29; 1958, p. 48). The Purbeck–Wealden junction has been placed at 1,892 ft. on the basis of ostracod faunas and the top of the Middle Purbeck at 1,935 ft. (Anderson 1962; Howitt 1964, p. 105). The top of the Portland Beds is recognized at 2,150 ft. but below 2,040 ft. there appears to be a repetition of lithological and faunal types in the Purbeck Beds, which is attributed to reversed faulting.

Twenty-three core samples between 1,900 and 2,027 ft. in the borehole were examined for palynomorphs. Of these, 18 yielded assemblages.

Fairlight Clay

On the coast east of Hastings, the Fairlight anticline brings the Fairlight Clay to the surface (Edmunds 1954). The Fairlight Clay is the lowest Wealden formation and is generally thought to pass laterally north and westwards into, and to be overlain by, the Ashdown Sand (Allen 1960*a*). The complete Fairlight Clay succession has been described by Topley (1875) and by White (1928), who believed that the Purbeck Beds underlie this section, close to the surface on the crest of the anticline. Allen (1955) stated that the Upper Purbeck–Wealden junction as defined by ostracods is probably situated low down in the Fairlight Clay near the base of the Wealden as traditionally defined, i.e. the base of the Fairlight Clay. A series of calcareous clays and limestones developed between 949 and 1,080 ft. in the Henfield borehole and regarded as equivalent to the basal portion of the Fairlight Clay (on ostracod faunas) '. . . could equally well be classed with the Purbeck . . .' (Taitt and Kent 1958, p. 12). The lateral change of facies at this horizon promotes the possibility that the lower part of the Fairlight Clay on the Sussex coast may be a lateral equivalent of part of the Purbeck Beds of Dorset. Allen (1960*b*, p. 7) noted 'The problem of how far the Purbeckian extends upwards (if at all) into the Fairlight facies of the Wealden remains unsolved.' A detailed palynologic study of the entire Fairlight Clay sequence would be desirable to determine its probable equivalence to the Purbeck but was not attempted in the present study. The preliminary results of a study by Hughes and Moody-Stuart (1969) using a new correlation method, however, suggest that the Fairlight Clay is in fact a lateral facies equivalent of the upper Middle and Upper Purbeck.

EXTRACTION OF PALYNOMORPHS

Most samples examined in this study were grey or brown fine-grained clastic rocks but a few limestones were represented. These samples were prepared by first crushing about 5 gm. (20–50 gm. in the case of limestones) to pass through a 1-mm. mesh sieve. Carbonates were removed with cold dilute hydrochloric acid. Silica and silicates were dissolved in hot 50% hydrofluoric acid (40–60 minutes treatment was sufficient). By-products from this reaction are finely crystalline or in part colloidal, gelatinous white, pink, or brown precipitates usually occurring as a distinct layer or intimately mixed with the organic residue. This by-product was reported by Norem (1953) to be composed of either aluminium fluosilicates or a mixture of double fluorides of calcium, magnesium, sodium, and potassium. It interferes with subsequent preparation procedures and consequently must be removed after hydrofluoric acid treatment by repeated washing and dissolution in hot 25% hydrochloric acid.

The organic residue remaining was treated with 20 kHz ultrasound for 20–30 seconds using a generator with a 60-W power output and a magnetostrictive transducer coupled to a steel probe with a 1:1 end area ratio. The probe tip has an acoustic power output of 2·74 W/cm^2. Acoustic treatment was used to disperse the finely divided organic material which characterized most residues. This finely divided material was removed from each residue after ultrasonic treatment by repeated short centrifugation in water with a few drops of non-ionic detergent added (Funkhouser and Evitt 1959). Ultrasonic treatment was used before oxidation of the residues because spores and pollen are more fragile to ultrasound after oxidation (McIntyre and Norris 1964).

Most samples were not highly carbonaceous and the residues did not require more than a few minutes oxidation in concentrated nitric acid or Schulze's solution. Humic material remaining after oxidation was rare in most samples, but when present dilute ammonium hydroxide removed it effectively. Safranine-O was used to stain some palynomorph assemblages. Residues were mounted in glycerine jelly and stored in a mixture of glycerine and water with phenol added to prevent microbial attack.

Rock samples used in this study are stored in the Sedgwick Museum, Cambridge. Full locality details are listed for all samples in Appendix 1 of Norris (1963). Type material currently in the palynology collection of the Department of Geology, University of Toronto, will be transferred to the Sedgwick Museum for permanent storage.

SYSTEMATIC PALYNOLOGY—SPECIES LIST

The species mentioned in the following list occur in the marine Upper Jurassic and Purbeck Beds. The species are listed morphographically using Dettmann's (1963) modified scheme. Where applicable the original author's name is followed by the plate and figure number of the illustrations given in this paper. New species and new combinations are treated thoroughly in the following section on Systematic Descriptions. The stratigraphic significance of all species is discussed in a later part of the paper.

Turma TRILETES
Suprasubturma ACAVATITRILETES
Subturma AZONOTRILETES
Infraturma LAEVIGATI

Cyathidites australis Couper 1953; Plate 102, fig. 1.
Cyathidites minor Couper 1953; Plate 102, figs. 2, 3.
Deltoidospora rafaeli Burger 1966; Plate 102, fig. 11.
Deltoidospora psilostoma Rouse 1959; Plate 102, fig. 8.
Dictyophyllidites harrisii Couper 1958; Plate 102, figs. 9, 10.
Dictyophyllidites equiexinus (Couper) Dettmann 1963; Plate 102, figs. 4, 5.
Stereisporites antiquasporites (Wilson and Webster) Dettmann 1963; Plate 102, figs. 13, 14.
Concavisporites juriensis Balme 1957; Plate 102, figs. 6, 7.
Divisisporites sp. cf. *D. euskirchenensis* Thomson and Pflug 1952; Plate 102, fig. 17.

Infraturma APICULATI

Acanthotriletes varispinosus Pocock 1962; Plate 102, fig. 12.
Osmundacidites wellmanii Couper 1953; Plate 102, fig. 18.
Baculatisporites comaumensis (Cookson) Potonié 1956; Plate 102, figs. 15, 16.
Converrucosisporites variverrucatus (Couper) comb. nov.; Plate 102, fig. 19.
Leptolepidites psarosus sp. nov.; Plate 103, figs. 2–5.
Leptolepidites epacrornatus sp. nov.; Plate 103, figs. 6–9, 11.
Rubinella major (Couper) comb. nov.; Plate 103, fig. 10.
Pilosisporites trichopapillosus (Thiergart) Delcourt and Sprumont 1955; Plate 103, fig. 1.
Pilosisporites delicatulus sp. nov.; Pl. 103, figs. 12–18; Plate 104, figs. 1, 2.

Infraturma MURORNATI

Cicatricosisporites australiensis (Cookson) Potonié 1956.
Cicatricosisporites purbeckensis sp. nov.; Plate 104, figs. 5–11.
Cicatricosisporites angicanalis Döring 1965; Plate 104, figs. 12–13; Plate 105, figs. 1, 2.
Cicatricosisporites brevilaesuratus Couper 1958; Plate 105, fig. 3.
Reticulisporites semireticulatus (Burger) comb. nov.; Plate 105, figs. 4, 5.
Lycopodiacidites cerniidites (Ross) comb. nov.; Plate 105, figs. 6, 7.
Lycopodiumsporites austroclavatidites (Cookson) Potonié 1956; Plate 105, figs. 8, 9.
Klukisporites pseudoreticulatus Couper 1958; Plate 105, fig. 11.
Microreticulatisporites diatretus sp. nov.; Plate 105, figs. 12–15.
Foveosporites canalis Balme 1957; Plate 106, fig. 3.
Tripartina sp.; Plate 105, fig. 10.

Subturma ZONOTRILETES
Infraturma AURICULATI

Trilobosporites bernissartensis (Delcourt and Sprumont) Potonié 1956; Plate 106, figs. 1, 2.
Trilobosporites apiverrucatus Couper 1958; Plate 107, figs. 9, 14.
Trilobosporites obsitus sp. nov.; Plate 106, figs. 7, 8.
Trilobosporites domitus sp. nov.; Plate 106, figs. 9, 10, 12, 13.
Appendicisporites potomacensis Brenner 1963; Plate 107, figs. 1–4, 7, 10.
Plicatella abaca (Burger) comb. nov.; Plate 106, figs. 4–6, 11; Plate 107, figs. 5, 6.

Infraturma CINGULATI

Foraminisporis wonthaggiensis (Cookson and Dettmann) Dettmann 1963; Plate 107, figs. 11, 13.
Contignisporites dorsostriatus (Bolchovitina) Dettmann 1963; Plate 107, fig. 12.
Duplexisporites problematicus (Couper) Playford and Dettmann 1965.

Infraturma TRICRASSATI

Gleicheniidites senonicus Ross 1949; Plate 107, figs. 16, 17.
Sestrosporites pseudoalveolatus (Couper) Dettmann 1963; Plate 108, fig. 5.
Coronatispora valdensis (Couper) Dettmann 1963; Plate 108, figs. 1, 2.

Suprasubturma PERINOTRILETES

Densoisporites perinatus Couper 1958; Plate 108, figs. 3, 4, 6.
Heliosporites sp.; Plate 108, figs. 7, 8, 10, 11.

Turma HILATES

Aequitriradites spinulosus (Delcourt and Sprumont) Cookson and Dettmann 1961; Plate 108, fig. 9.
Couperisporites complexus (Couper) Pocock 1962; Plate 108, fig. 13.
Januasporites tumulosus sp. nov.; Plate 108, fig. 12; Plate 109, figs. 2–4, 7.

Turma MONOLETES
Suprasubturma ACAVATOMONOLETES
Subturma AZONOMONOLETES
Infraturma SCULPTATOMONOLETI

Marattisporites scabratus Couper 1958; Plate 109, figs. 5, 6.

Anteturma POLLENITES
Turma SACCITES
Subturma MONOSACCITES
Infraturma SACCIZONATI

Cerebropollenites mesozoicus (Couper) Nilsson 1958; Plate 109, figs. 11, 12.

Subturma DISACCITES

Alisporites bilateralis Rouse 1959; Plate 109, figs. 14, 15.
Abietineaepollenites minimus Couper 1958; Plate 109, fig. 13.
Vitreisporites pallidus (Reissinger) Potonié 1960; Plate 109, figs. 8–10.
Podocarpidites sp. cf. *P. ellipticus* Cookson 1947; Plate 109, figs. 16, 17.
Parvisaccites radiatus Couper 1958; Plate 109, figs. 18, 19; Plate 9, fig. 1.

Subturma POLYSACCITES

Callialasporites sp. cf. *C. trilobatus* (Balme) Sukh Dev 1961; Plate 110, fig. 8.
Callialasporites dampieri (Balme) Sukh Dev 1961 emend.; Plate 110, figs. 2, 3.
Callialasporites obrutus sp. nov.; Plate 110, figs. 6, 7.
Callialasporites sp.; Plate 110, figs. 4, 5.

Turma ALETES

Infraturma PSILONAPITI

Inaperturopollenites dubius (Potonié and Venitz) Thomson and Pflug 1953; Plate 110, figs. 9, 10; Plate 111, fig. 19.
Inaperturopollenites sp.; Plate 110, figs. 11, 12.

Infraturma GRANULONAPITI

Araucariacites australis Cookson 1947; Plate 110, fig. 17.
Spheripollenites subgranulatus Couper 1958; Plate 110, fig. 13.

Infraturma SPINONAPITI

Peltandripites tener sp. nov.; Plate 110, figs. 18, 19.

Infraturma RETICULONAPITI

Undulatasporites araneus sp. nov.; Plate 110, figs. 14–16; Plate 111, figs. 2–10.

Turma PLICATES

Subturma PRAECOLPATES

Eucommiidites troedssonii Erdtman 1948; Plate 111, figs. 13, 14, 16.
Eucommiidites minor Groot and Penny 1960; Plate 111, fig. 15.

Subturma MONOCOLPATES

Cycadopites sp. cf. *C. nitidus* (Balme) comb. nov.; Plate 111, figs. 11, 12.
Cycadopites carpentieri (Delcourt and Sprumont) Singh 1964; Plate 111, fig. 18.
Monosulcites sp. aff. *M. minimus* Cookson 1947; Plate 111, fig. 17.

Turma POROSES

Subturma MONOPORINES

Exesipollenites scabrosus sp. nov.; Plate 111, figs. 20–2.
Perinopollenites elatoides Couper 1958; Plate 112, figs. 6, 7.

MIOSPORES INCERTAE SEDIS

Classopollis torosus (Reissinger) Balme 1957; Plate 112, figs. 1–5.
Classopollis echinatus Burger 1965; Plate 112, figs. 8–13.
Classopollis hammenii Burger 1965; Plate 112, figs. 14–16; Plate 113, figs. 1–4.
Schizosporis reticulatus Cookson and Dettmann 1959; Plate 113, figs. 5, 8.
Schizosporis spriggi Cookson and Dettmann 1959; Plate 113, figs. 6, 13.
Schizosporis parvus Cookson and Dettmann 1959; Plate 113, fig. 7.
Sigmopollis callosus sp. nov.; Plate 113, figs. 9–12.

SYSTEMATIC DESCRIPTIONS

Turma TRILETES
Suprasubturma ACAVATITRILETES
Subturma AZONOTRILETES
Infraturma LAEVIGATI
Genus DIVISISPORITES Thomson and Pflug 1952
Divisisporites sp. cf. *D. euskirchenensis* Thomson and Pflug 1952

Plate 102, fig. 17

Description. Spores radiosymmetric, complexly trilete. Amb triangular convex to irregularly sub-circular. Laesurae long, simple, straight but dichotomozing up to the third order, reaching or almost reaching the equator. Both proximal and distal surfaces scabrate to granular. Granules usually low (occasional up to 1 μ high), closely spaced, up to 2 μ in diameter. Occasional verrucae developed at the equator up to 3 μ high and 10 μ or more in width. Exine 3–5 μ in total thickness; endexine distinct and 0·5–1 μ thick.

Dimensions (3 specimens). Equatorial diameter: 53–69 μ.

Distribution. Upper Purbeck, Dorset.

Remarks. These specimens differ from *D. euskirchenensis* by the possession of a thicker exine, more complexly divided laesurae, and verrucae at the equator. Insufficient specimens were available to erect a new species. Lower Cretaceous specimens originally assigned to *D. euskirchenensis* by Cookson and Dettmann (1958) are now included in *Rouseisporites radiatus* Dettmann (1963), which is distinct in structure from the present specimens.

Infraturma APICULATI
Genus CONVERRUCOSISPORITES Potonié and Kremp 1954
Converrucosisporites variverrucatus (Couper) comb. nov.

Plate 102, fig. 19

1958 *Concavisporites variverrucatus* Couper, p. 142, pl. 22, figs. 4–5.

Remarks. This species is removed from *Concavisporites* because of the lack of curvaturae, and recombined with *Converrucosisporites* on the basis of shape and ornament.

Genus LEPTOLEPIDITES Couper 1953 emend. Norris 1968

Leptolepidites psarosus sp. nov.

Plate 103, figs. 2–5

Holotype. GN 109B/1, 40.4 124.5. Sample 59–1–6 (dark grey shale), Middle Purbeck, Chief Beef Beds, Durlston Bay (from the top of Bed 75, Bristow 1857).

Diagnosis. Spores radiosymmetric, trilete, amb rounded triangular to circular. Laesurae simple, reaching the equator, usually indistinct. Proximal face entirely granulate, or only on the contact areas. Distal face with closely spaced verrucae. Exine thin in between the projections.

Description. Laesurae straight, reaching or almost reaching the equator, occasionally quite distinct but usually difficult to see. Granules on proximal face rounded or polygonal, 1–2 μ in diameter, dense, occasionally joining up to give a sub-rugulate sculpture, rugulae about 4 μ long. When only contact faces are granular there is a distinct levigate zone separating them from the verrucate distal ornament.

Distal verrucae 3–13 μ in diameter, 1–5 μ high, rounded sub-circular, rounded polygonal, irregular or elongated. Solitary rugulae up to 17 μ long and about 5 μ wide may be interspersed among the verrucae. Verrucae closely packed forming a distinct negative reticulum with grooves about 0·5 μ wide but varying slightly. The distal verrucae may encroach to a variable extent on to the proximal face up to the contact areas.

Exine between projections less than 0·5–1 μ in thickness. Exine on proximal face less than 0·5 μ in thickness.

Dimensions. Equatorial diameter: 20–44 μ (holotype, 39 μ).

Distribution. Middle and Upper Purbeck, Dorset, Sussex, and Surrey.

Remarks. Distinguished from *Converrucosisporites proxigranulatus* Brenner (1963) by the more densely packed distal verrucae and by the presence of rugulae.

EXPLANATION OF PLATE 102

All figures ×750 unless otherwise stated.

Figs. 1–3. *Cyathidites* spp. 1, *C. australis* Couper, GN 161/1, 32.0 127.4. 2–3, *C. minor* Couper. 2, GN 317/2, 44.2, 128.5. 3, GN 138/2, 58.2 123.1.

Figs. 4, 5, 9, 10. *Dictyophyllidites* spp. 4–5, *D. equiexinus* (Couper) Dettmann. 4, GN 146/1, 24.7 128.3. 5, GN 161/2, 53.0 117.7. 9–10, *D. harrisii* Couper. 9, GN 316/1, 32.6 114.9. 10, GN 316/1, 58.0 124.8.

Figs. 6, 7. *Concavisporites juriensis* Balme. 6, GN 142/2, 43.1 112.5. 7, GN 142/1, 40.1 119.6.

Figs. 8, 11. *Deltoidospora* spp. 8, *D. psilostoma* Rouse. 1113–13C, 38.3 116.9. 11, *D. rafaeli* Burger, GN 262/2, 32.2 107.5.

Fig. 12. *Acanthotriletes varispinosus* Pocock, GN 188/1, 44.0 114.5; ×1250.

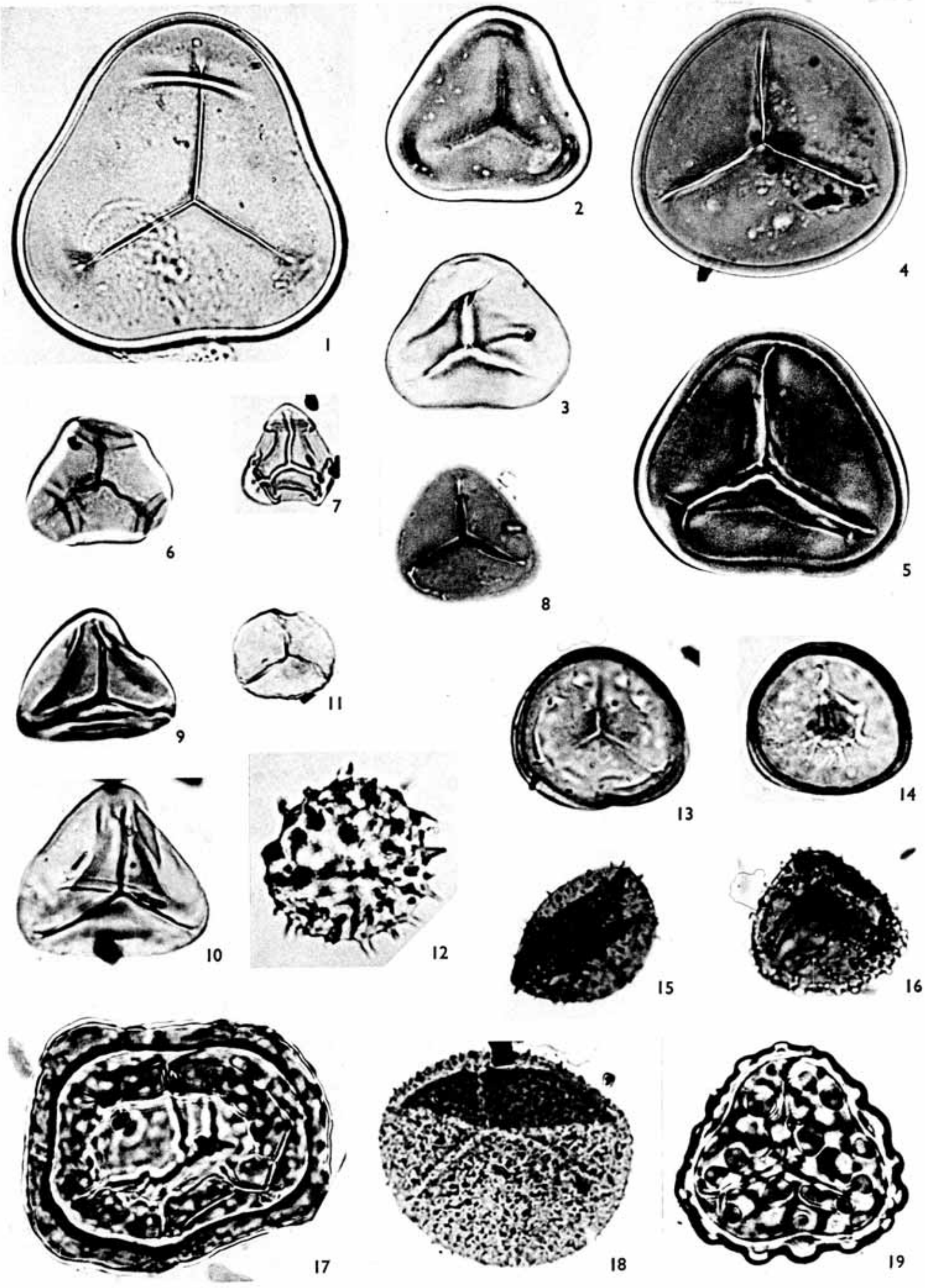
Figs. 13, 14. *Stereisporites antiquasporites* (Wilson and Webster) Dettmann. 13, GN 476/1, 51.8 112.5; ×1250. 14, GN 187/1, 29.5 108.6; ×1250.

Figs. 15, 16. *Baculatisporites comaumensis* (Cookson) Potonié. 15, 1113–18C, 22.6 118.9. 16, GN 432/2, 46.9 104.3.

Fig. 17. *Divisisporites* sp. cf. *D. euskirchenensis* Thomson and Pflug, GN 345/1, 117.3 56.2.

Fig. 18. *Osmundacidites wellmanii* Couper, GN 316/1, 22.2 106.6.

Fig. 19. *Converrucosisporites variverrucatus* (Couper) comb. nov., GN 338/3, 50.9 124.1.



NORRIS, Late Jurassic and Purbeck miospores

Leptolepidites epacrornatus sp. nov.

Plate 103, figs. 6–9, 11

Holotype. Slide GN 147/1, 27.8 119.1. Sample 60–5–22 (dark grey-brown shale), Upper Purbeck, Marble Beds and Ostracod shales, Durlston Bay (6 ft. below the top of Bed 84, Bristow 1857).

Diagnosis. Spores radiosymmetric, trilete. Amb rounded triangular to circular. Laesurae long but not reaching equator, simple or labiate. Proximate face levigate to subgranular. Distal face verrucate with occasional echinate projections. Exine thin.

Description. Laesurae simple or with very narrow lips less than 0·75 μ wide, straight or sinuous. Ornament of proximal face very much reduced with respect to distal ornament, but distal ornament encroaches on to proximal face at apices. Distal verrucae regularly or irregularly rounded or elongate, 2–3 μ in diameter, sometimes reaching 5 μ long, up to 1 μ high and spaced about 1 μ apart. Exine 0·25–0·5 μ.

Dimensions. Equatorial diameter: 12–22 μ (holotype 20 μ).

Distribution. Middle and Upper Purbeck, Dorset, Sussex, and Surrey.

Genus *Rubinella* (Maljavkina 1949) Potonié 1960

Rubinella major (Couper) comb. nov.

Plate 103, fig. 10

1958 *Leptolepidites major* Couper, p. 141, pl. 21, figs. 7–8.

Description. Spores radiosymmetric, trilete. Amb rounded triangular or occasionally almost circular. Laesurae long, simple, not reaching the equator, rather indistinct. Both proximal and distal surfaces ornamented with closely spaced or touching, almost spherical, irregularly rounded or elongated verrucae. Verrucae 2–10 μ in diameter, 1–5 μ high. Exine thickness between verrucae 1–2·5 μ.

Dimensions. Equatorial diameter: 39–80 μ.

Remarks. It proved impossible to split off the larger specimens as a distinct species and consequently all are included in one species with a larger size range than that indicated by Couper in his original description. The species is transferred to *Rubinella* because of the comprehensive verrucate sculpture. *Leptolepidites* is characterized by verrucae on the distal face only (Norris 1968).

Genus PILOSISPORITES Delcourt and Sprumont 1955

Pilosisporites delicatulus sp. nov.

Plate 103, figs. 12–18; Plate 104, figs. 1, 2

Holotype. GN 428/1, 46.0 128.4 Sample 61–7–5 (buff lignitic clay), Upper Purbeck 7 ft. above *Paludina* Clays, Bacon Hole (middle of Bed 26 described in Norris 1963).

Diagnosis. Spores radiosymmetric, trilete. Amb triangular convex with broadly rounded apices, occasionally becoming almost circular. Laesurae short, one-third to one-half of the spore radius, straight, simple, frequently indistinct. Both proximal and distal surfaces scabrate and covered with irregularly distributed echinulate processes. Processes hair-like, very narrow, straight or curved, simply terminated or briefly bifurcate, 2–5 μ long, spaced 1–2 μ apart at the equator but up to 5 μ apart at the poles. Exine 0·5–1 μ thick.

At high magnifications (greater than 1,000 diameters) the exine is seen to be distinctly microreticulate. Lumina of reticulum less than 0·25 μ in diameter and muri also very narrow. Echinulate processes very narrow and consequently indistinct. Occasionally the bases of the processes may widen up to 0·5 μ and can be seen to be hollow.

Dimensions. Equatorial diameter: 28–40 μ (holotype 30 μ).

Distribution. Upper Purbeck of Dorset.

Remarks. This species is easily overlooked on account of its delicate ornament, or it may be confused with *Stereisporites antiquasporites* (Wilson and Webster) Dettmann.

Infraturma MURORNATI

Genus CICATRICOSISPORITES Potonié and Gelletich 1933

Cicatricosisporites purbeckensis sp. nov.

Plate 104, figs. 5–11

Holotype. Slide GN 145/1, 38.8 121.9. Sample 60–5–16 (grey, slightly calcareous shale) Upper Purbeck, Marble Beds and Ostracod Shales, Durlston Bay (Bed 84 of Bristow 1857).

Diagnosis. Spores radiosymmetric, trilete. Amb. triangular. Laesurae long, straight, simple or labiate. Proximal face levigate. Distal face with 3 or 4 triangular sets of widely spaced ribs running more or less parallel to equator. Ribs narrow and uneven in width, height, and spacing.

Description. Laesurae simple or bordered by very narrow lips about 0·5 μ wide, reaching equator. Distal ribs straight or sinuous, occasionally bifurcating, 0·25–1 μ wide, 0·5–1 μ high, spaced 0·5–2 μ apart (4 ribs and intervening lumina measure 9–12 μ). Ribs project at apices but not on sides of amb. Distal ribs encroach on to proximal face at apices. Ribs are characteristically uneven in width with swollen nodes at irregular intervals along their length. Exine about 1 μ thick, with a very thin layer of endexine distinguishable.

Dimensions. Equatorial diameter 30–48 μ (holotype 47 μ).

Distribution. Lower, Middle, and Upper Purbeck of Dorset and Sussex.

EXPLANATION OF PLATE 103

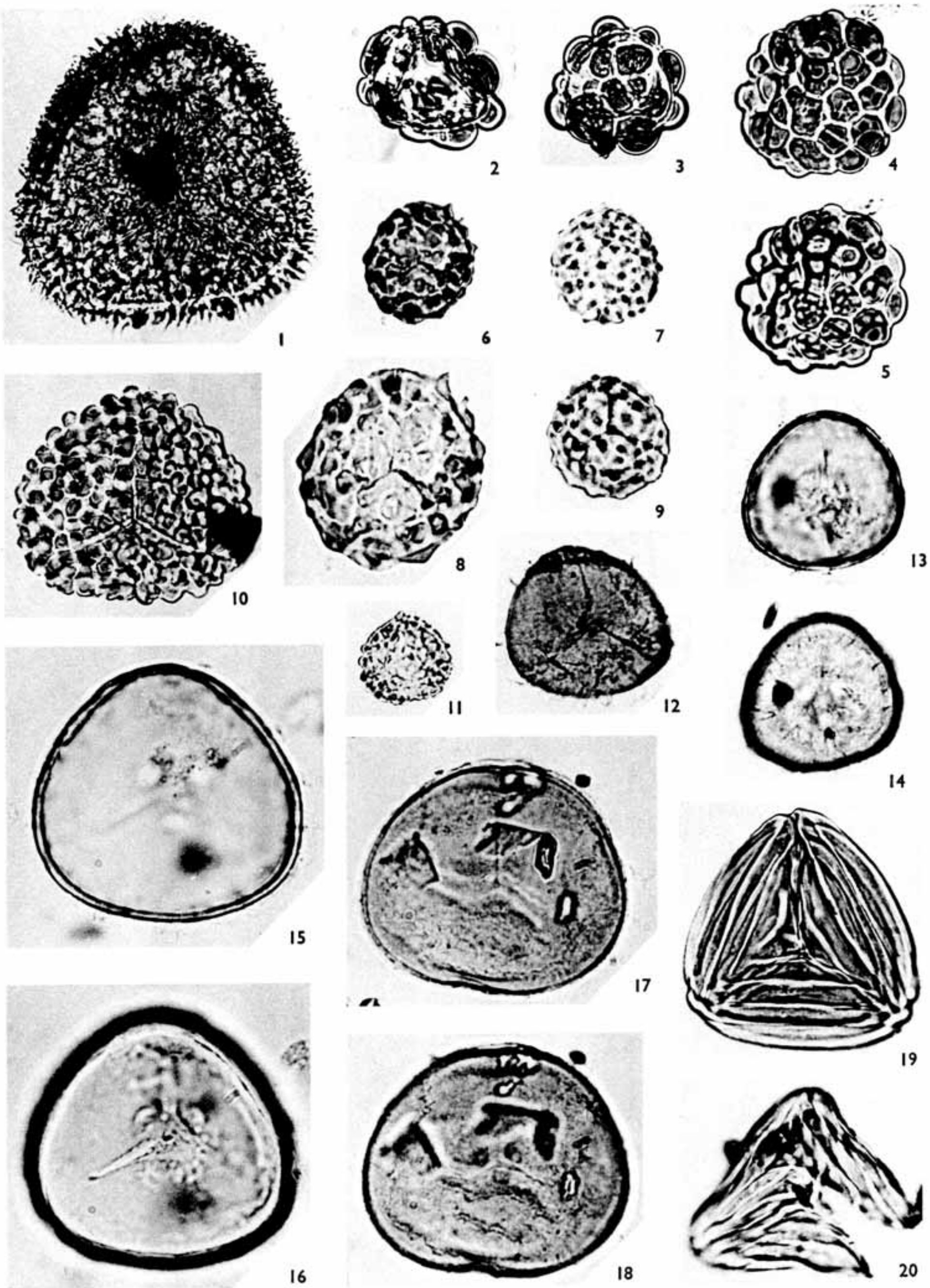
All figures × 750 unless otherwise stated.

Figs. 1, 12–18. *Pilosisporites* spp. 1, *P. trichopapillosus* (Thiergart) Delcourt and Sprumont, GN 338/2, 30.6 117.4. 12–18, *P. delicatulus* sp. nov. 12, proximal surface, GN 427/1, 56.6 124.9. 13–14, Holotype, median focus and distal surface respectively, GN 428/1, 46.0 128.4. 15–16, Holotype, median focus, and distal surface respectively. × 1,250. 17–18, Proximal and distal surfaces respectively, GN 338/2, 119.7 22.2; × 1,250.

Figs. 2–9, 11. *Leptolepidites* spp. 2–5, *L. psarosus* sp. nov. 2, Proximal surface, GN 428/1, 128.5 37.0. 3, Distal surface, GN 338/3, 36.2 1.262. 4–5, Holotype, proximal and distal surfaces respectively, GN 109B/1, 40.4 124.5. 6–9, 11, *L. epacrornatus* sp. nov. 6, 8, Holotype, × 750 and × 1,250 respectively, GN 147/1, 27.8 119.1. 7, GN 146/2, 52.6 125.3. 9, GN 146/2, 52.7 125.5. 11, GN 190/3, 41.6 108.9.

Fig. 10. *Rubinella major* (Couper) comb. nov., GN 255/1, 41.7 119.4.

Figs. 19, 20. *Cicatricosisporites australiensis* (Cookson) Potonié. 19, GN 142/1, 54.8 108.7. 20, GN 315/3, 45.5 122.8.



NORRIS, Late Jurassic and Purbeck miospores

Remarks. Distinguished from other species of *Cicatricosisporites* by means of the narrow ribs of uneven width and spacing.

Genus RETICULISPORITES Pot. and Kremp in Weyl. and Krieger 1953
Reticulisporites semireticulatus (Burger 1966) comb. nov.

Plate 105, figs. 4, 5

1966 *Lycopodiumsporites semireticulatus* Burger, p. 247, pl. 14, fig. 4.

Remarks. The concave amb and low muri place this species in the genus *Reticulisporites*.

Genus LYCOPODIACIDITES (Couper 1953) Potonié 1956
Lycopodiacidites cerniidites (Ross 1949) comb. nov.

Plate 105, figs. 6, 7

1949 *Lycopodium cerniidites* Ross, p. 30, pl. 1, figs. 1–2.
1955 *Lycopodiumsporites cerniidites* (Ross) Delcourt and Sprumont, p. 32.

Remarks. The distal surface is rugulate, not reticulate, thus placing this species in *Lycopodiacidites*. There appears to be a morphological transition between those forms of *L. cerniidites* (Ross) with more regularly arranged regulae, to forms of *Coronatispora valdensis* (Couper) Dettmann with poorly developed circum-equatorial ridges. However the latter species has a very much greater stratigraphic and geographic distribution in the sediments examined and it is likely that each species was derived from different sources, their morphological similarity being only apparent. *Reticulatisporites pudens* Balme from the Lower Cretaceous of Western Australia is similar but much smaller and carries an imperfect reticulum on the distal face.

Genus MICRORETICULATISPORITES (Knox 1950) Potonié and Kremp 1954
Microreticulatisporites diatretus sp. nov.

Plate 105, figs. 12–15

Holotype. Slide GN 148/1, 33.2 125.6. Sample 60–5–24 (grey shaley clay), Upper Purbeck Unio Beds, Durlston Bay (Bed 82 of Bristow 1857).

Diagnosis. Spores radiosymmetric, trilete. Amb rounded triangular. Laesurae one-half to one-third of the spore radius in length, usually with narrow lips. Both proximal and distal surfaces ornamented with a perfect microreticulum with rather variable circular to polygonal lumina never exceeding 2 μ in diameter. Exine 1–2 μ thick interradially, thinning to 0·75–1 μ at apices.

Description. Amb occasionally elongated along one median. The trilete scar is rather variable in development, occasionally being simple or indistinct. Muri of the microreticulum 0·5–1 μ wide, 0·3–1·5 μ in height, of slightly variable width usually widening at the junctions. Lumina 0·5–2 μ in diameter, rounded or rounded-polygonal, varying in spacing from moderately widely spaced pits to closely spaced rounded-polygonal lumina. The lumina of the proximal reticulum may be slightly radially attenuated, particularly near the ends of the laesurae.

Dimensions. Equatorial diameter: 30–40 μ.

Distribution. Middle and Upper Purbeck, Dorset and Sussex.

Remarks. Distinguished from *Foveotriletes subtriangularis* Brenner 1963 by the microreticulate ornament on both surfaces rather than foveolate ornament primarily developed on the distal surface.

Genus TRIPARTINA Maljavkina 1949 ex Potonié 1960

Tripartina sp.

Plate 105, fig. 10

Description. Spores radiosymmetric, trilete. Amb triangular, usually concave or straight-sided, slightly undulating. Laesurae long, reaching the equator, with lips about 2 μ wide. Proximal surface unornamented. Distal surface with irregular radial grooves 0·5–2 μ wide, spaced 1–2 μ apart, occasionally anastomosing or coalescing with adjacent grooves. Both proximal and distal face may be slightly undulose. Exine 1–2 μ thick.

Dimensions. Equatorial diameter 24–46 μ.

Distribution. Middle and Upper Purbeck of Dorset, Sussex, and Surrey.

Remarks. This species is distinguished from *T.* sp. cf. *T. variabilis* Maljavkina described by Dettmann (1963) from the Australian Cretaceous by the more broadly rounded apices and less dense distal ornament.

Subturma ZONOTRILETES

Infraturma AURICULATI

Genus TRILOBOSPORITES Pant 1954 ex Potonié 1956

Trilobosporites obsitus sp. nov.

Plate 106, figs. 7, 8

Holotype. Slide GN 163/2, 59.2 127.5. Sample 60–5–1 (buff, silty, calcareous clay), Upper Purbeck, Unio Beds, Durlston Bay (Bed 80 of Bristow 1857).

Diagnosis. Spores radiosymmetric, trilete. Amb triangular. Laesurae long, usually simple, but rather variable. Both proximal and distal faces verrucate, but sculpture sparse and more reduced on distal face. Apices each carry a very large and prominent thickening which is circular in equatorial view and is restricted to the apical equatorial region. Exine thick.

EXPLANATION OF PLATE 104

All figures ×750 unless otherwise stated.

Figs. 1, 2. *Pilosisporites delicatulus* sp. nov. 1, Median focus, GN 338/2, 122.3 23.0; ×1,250. 2, Proximal surface, GN 428/2, 31.4 108.3; ×1,250.

Figs. 3–13. *Cicatricosisporites* spp. 3, 4, *C. australiensis* (Cookson) Potonié, Distal and proximal surfaces respectively; GN 146/2, 32.0 111.8. 5–11, *C. purbeckensis* sp. nov. 5, Proximal surface, GN 153/2, 29.3 119.7. 6, Holotype, median focus, GN 145/1, 38.8 121.9. 7, Median focus, GN 146/2, 20.9 113.2. 8, Median focus, GN 146/2, 44.7 108.2. 9, Equatorial view, GN 153/1, 21.9 109.0. 10, Equatorial view, GN 142/2, 23.2 126.7. 11, Distal surface, GN 147/2, 32.5 125.6. 12–13, *C. angicanalis* Döring, proximal and distal surfaces respectively, GN 163/2, 40.8 122.7.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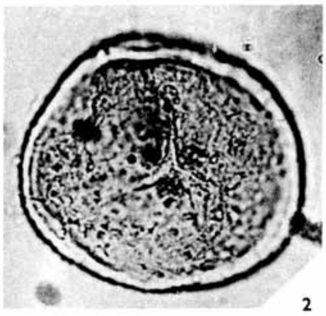
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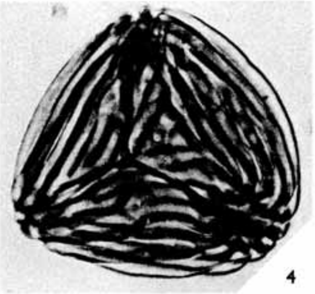
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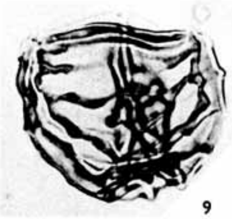
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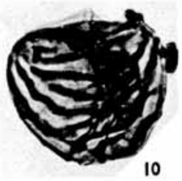
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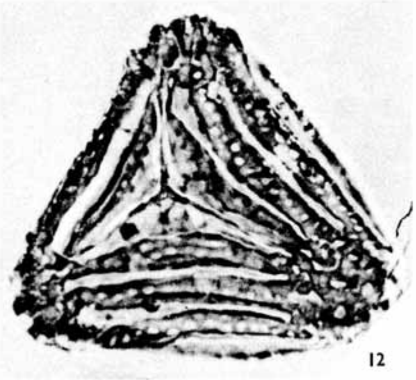
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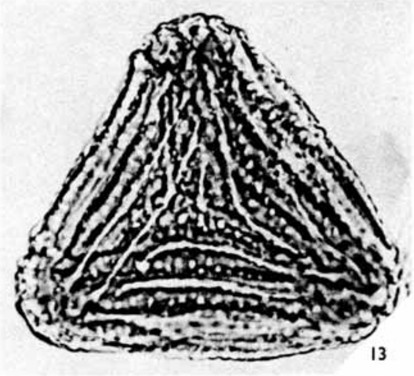
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NORRIS, Late Jurassic and Purbeck miospores

Description. Amb with roughly straight or slightly concave sides which are undulating because of verrucate ornament. Apices rounded and extended by the apical projections. Laesurae may be narrowly labiate, two-thirds or more of radius in length, occasionally reaching the equator. Proximal face with dense, rounded, or irregular verrucae, 6–12 μ in diameter, 2–3 μ high, and spaced up to 3 μ apart. Occasionally they may fuse into large indistinct rugulae. Distal ornament variable, ranging from low, indistinct, sparse irregular granules about 3 μ in diameter to rounded, low or high sparse verrucae up to 11 μ in diameter. Apical thickenings usually restricted to the equator but occasionally extending about 4 μ towards the polar areas. Exine thickness 8–10 μ over the apical thickening which is 14–20 μ wide and has a rounded aspect in equatorial views. Endexine 0·75–1·5 μ thick. Ektexine 1·5–3 μ thick between the projections.

Dimensions. Equatorial diameter 56–69 μ (holotype 63 μ).

Distribution. Upper Purbeck, Dorset.

Trilobosporites domitus sp. nov.

Plate 106, figs. 9, 10, 12, 13

Holotype. Slide GN 345/1, 57.0 111.7. Sample 60–19–3 (grey calcareous marl), Upper Purbeck, Upper Cypris Clays and Shales, Bacon Hole (6 in. above Bed 1 of Arkell 1933).

Diagnosis. Spores radiosymmetric, trilete. Amb triangular, concave. Laesurae long, straight, labiate, commissures raised. Both proximal and distal faces entirely covered in closely spaced, low, irregular granules. Exine at apices undulating and usually slightly thickened in the equatorial region here, but these thickenings not extending polewards as distinct valvae. Exine thicker on proximal than distal face.

Description. Laesurae almost reach the equator, raised 1·5–2·5 μ high at the centre and provided with narrow (1 μ) tapering lips along at least half their length. Scabrate to sub-granular ornament on both proximal and distal surfaces. Granules rather irregular in outline, very low, 0·25–1 μ in diameter and spaced not more than 0·5 μ apart. The exine becomes rather undulating around the apices tending to assume a low, poorly developed, verrucate ornament, and also is slightly thickened. Exine 2–4 μ thick, increasing at apices to between 4 and 7 μ. Exine on proximal face distinctly thicker than on distal face, about 6 μ at the centre. Endexine 0·25–0·5 μ thick. Occasionally the exine is slightly thickened interradially at the middle of the concave sides. Both proximal and distal faces convex, proximal face rather flatter than distal.

Dimensions. Equatorial diameter: 56–80 μ (holotype 65 μ).

Distribution. Upper Purbeck, Dorset.

Genus PLICATELLA Maljavkina 1949

Plicatella abaca (Burger) comb. nov.

Plate 106, figs. 4–6, 11; Plate 107, figs. 5, 6

1966 *Cicatricosisporites abacus* Burger, p. 242, pl. 7, fig. 3.

Distribution. Middle and Upper Purbeck, Dorset, Sussex, and Surrey.

Remarks. This species is transferred to *Plicatella* on account of the apical thickenings at the equator. The distinction of *Plicatella*, characterized by weak apical thickenings, from *Appendicisporites*, with more prominent apical thickenings, is arbitrary but a convenient procedure. Hughes and Moody-Stuart (1969) have questioned the validity of the genus *Plicatella* on the basis of observations on associated spores of Cretaceous schizeaceous ferns. They have noted that occasional apical thickenings occur in populations of *Cicatricosisporites*-type spores. These thickenings may be in part the result of compression in the equatorial plane. Dispersed spores, however, are difficult to relate to associated spore populations. *Plicatella abaca* has a distinctive morphology and distribution and appears to be a discrete group. Consequently it is maintained as a distinct spore species.

Suprasubturma PERINOTRILITES

Genus HELIOSPORITES Schulz 1962

Heliosporites sp.

Plate 108, figs. 7, 8, 10, 11

Description. Spores radiosymmetric, trilete, zonate, consisting of a central body and an outer more complex layer. Amb of outer layer, excluding the zone, convex triangular with broadly rounded apices. Amb of inner body convex triangular with more sharply rounded or pointed apices. Inner body excentrically placed in relation to outer layer. Laesurae of inner body long, straight, simple, reaching the equator, occasionally indistinct. Laesurae of outer layer long, sinuous, labiate, reaching equator and frequently the outer zone. Lips 1 μ wide, slightly tapering, with fibrilar structure similar to that of outer layer. Equatorial zone 4–7 μ wide, roughly parallel to amb of outer layer, 2 μ thick and tapering very slightly towards its outer edge which is smooth except for occasional projecting spines from the dorsal surface. Entire distal surface of outer layer, including the distal surface of the zone, ornamented with irregularly distributed spines, 3–5 μ high, bases roughly circular and 3–6 μ wide, spaced 4–7 μ apart (tips spaced 8 μ apart), tapering rapidly at base but more gradually towards tips which are pointed, truncate or occasionally bifurcate. Exine of inner layer levigate, 0·25 μ or less in thickness, apparently of simple, undifferentiated structure, frequently folded, particularly near equator. Outer layer including zone, spines, and trilete mark with a fibrilar structure. Fibrils about 0·25 μ thick and anastomosing to form a 'three-dimensional'

EXPLANATION OF PLATE 105

All figures ×750.

Figs. 1–3. *Cicatricosporites* spp. 1–2, *C. angicanalis* Döring. 1, Proximal surface, GN 140/2, 42.6 128.5. 2, Distal surface, GN 145/2, 48.0 128.6. 3, *C. brevilaesuratus* Couper, GN 265/1, 39.8 112.9.

Figs. 4, 5. *Reticulisporites semireticulatus* (Burger) comb. nov. 4, Median focus, GN 189/2, 46.0 122.5. 5, Distal surface, GN 195/1, 21.1 110.8.

Figs. 6, 7. *Lycopodiacidites cerniidites* (Ross) comb. nov. 6, Proximal surface, GN 147/1, 29.8 128.2. 7, Distal surface, GN 421/1, 111.8 60.8.

Figs. 8, 9. *Lycopodiumsporites austroclavatidites* (Cookson) Potonié. 8, Proximal surface, GN 147/2, 43.4 128.2. 9, Distal surface, GN 154/1, 29.2 127.8.

Fig. 10. *Tripartina* sp., distal surface, GN 182/3, 26.0 101.4.

Fig. 11. *Klukisporites pseudoreticulatus* Couper, GN 148/1, 45.3 119.5.

Figs. 12–15. *Microreticulatisporites diatretus* sp. nov. 12, Holotype, proximal surface, GN 148/1, 33.2 125.6. 13, Distal surface, GN 341/2, 26.8 121.6. 14, GN 145/1 121.3 39.2. 15, Proximal surface, GN 153/2, 34.7 111.8.


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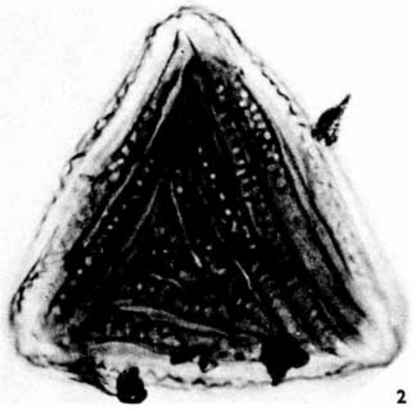
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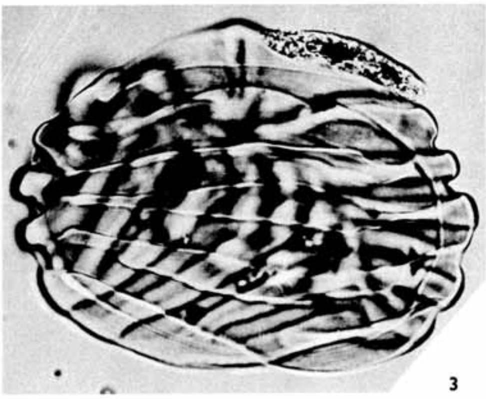
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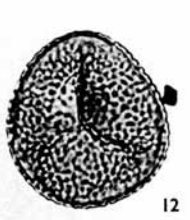
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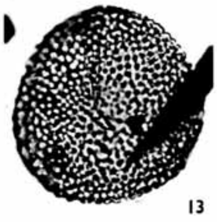
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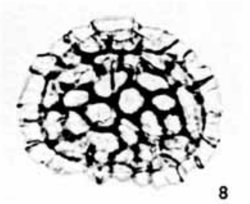
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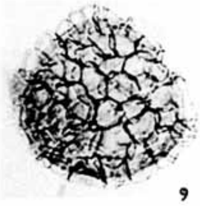
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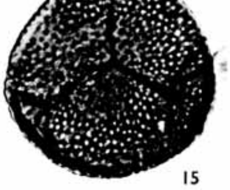
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NORRIS, Late Jurassic and Purbeck miospores

reticulum with lumina 0·25–1 μ in diameter. Outer layer very thin on proximal surface where its fibrilar nature is difficult to determine. The outer layer is 1–2 μ thick at equator and on distal surface.

Dimensions. Equatorial diameter (including zone): 30–42 μ.

Distribution. Upper Purbeck, Dorset.

Remarks. Insufficient material was available to erect a new species. It was considered appropriate to describe the specimens in detail, however, because they are extremely distinctive and possibly of stratigraphic importance.

These specimens are tentatively referred to *Heliosporites*. Schultz interpreted the type material of this genus as possessing a distal perispore. He did not distinguish a zone. This latter feature, together with the restriction of the spinose ornament to the distal surface, suggests affinities with the genus *Styxisporites* Cookson and Dettmann. This genus, however, does not possess a central spore body.

Considerable difficulty was encountered in interpreting the structure of these specimens owing, firstly, to the indistinct appearance of the central body; secondly, to the thinness of the proximal surface of the outer layer; and thirdly, to the fibrilar nature of this layer and the zone. All these features make elucidation of the equatorial structure, in particular, very difficult. Consequently this interpretation must be considered tentative until further specimens are available. In view of this uncertainty these specimens and the type material of *Heliosporites* may ultimately prove to have a similar structure. If this is so, these specimens are distinguished from the Lower Jurassic *Heliosporites altmarkensis* Schulz by their rather small size, thinner exine of the inner spore body, and rather shorter distal spines which are not truncated.

Turma HILATES

Genus JANUASPORITES (Pocock 1962) Singh 1964

Januasporites tumulosus sp. nov.

Plate 108, fig. 12; Plate 109, figs. 2–4, 7

Holotype. Slide GN 421/1, 55.5 123.3. Sample 61–6–2 (grey, clayey shale), Upper Purbeck, *Paludina* Clays, Lulworth Cove, Dorset (from 2 ft. 6 in. below the highest *Viviparus* limestone).

Diagnosis. Spores radiosymmetric, probably trilete, with a distinct central body. Amb rounded triangular to circular or oval. Inner body thicker and ornamented with a perfect polygonal microreticulum and usually carrying a large circular aperture on one face. Outer layer is very thin and loosely fitting around the antapical face, projecting beyond the central body at the amb and ornamented with irregularly distributed granules which are distinctly raised on hollow protuberances. Exine layers usually very thin and of indeterminate thickness.

Description. Exine is composed of two distinct layers, an inner thicker and an outer, thinner membraneous layer almost completely enclosing the inner body. The inner layer bears an irregular but perfect polygonal micro-reticulum; muri 0·25–0·75 μ wide; lumina 1–3 μ wide and of polygonal shape but occasionally irregularly rounded. Reticulum always present at centre of antapertural face but usually becoming indistinct towards edges, sometimes showing a trilete distribution by development of stronger, elongated lumina along 3 rays. The outer layer is very thin and is covered with rounded granules about 1–2 μ high and varying from 0·5–2 μ in diameter. Granules are distinctly raised on protuberances of the outer layer giving a characteristic L–O–L pattern in surface view. Granules spaced 1–2 μ apart and irregularly distributed. Occasional gemmate or papillate projections may be distributed amongst the granules. Outer layer loosely lies over the antapertural face and projects 1–6 μ from the amb. It occasionally encroaches up to the edges of the aperture but usually becomes indistinct on the apertural face.

Inner layer about 0·25 μ thick but usually indeterminate; outer layer of exine very thin with no distinguishable optical section visible under oil immersion, excluding the thickened granules.

Dimensions. Maximum equatorial diameter: 47–62 μ (holotype 47 μ). Minimum equatorial diameter: 32–52 μ (holotype 33 μ).

Distribution. Middle and Upper Purbeck, Dorset.

Remarks. The outer layer of *Januasporites* is not referred to in the description as either a perine or a saccus since the stratification of the inner layer is not visible. This outer layer is only loosely attached on the antapertural face but becomes closely attached to the apertural face at or just beyond the amb.

Anteturma POLLENITES

Turma SACCITES

Subturma DISACCITES

Genus PODOCARPIDITES (Cookson 1947) ex Couper 1953

Podocarpidites sp. cf. *P. ellipticus* Cookson 1947

Plate 109, figs. 16, 17

Distribution. Kimmeridgian and Portlandian of Dorset. Lower, Middle, and Upper Purbeck of Dorset, Sussex, and Surrey.

Subturma POLYSACCITES

Genus CALLIALASPORITES (Sukh Dev 1961) Potonié 1966

Callialasporites sp. cf. *C. trilobatus* (Balme 1957) Sukh Dev 1961

Plate 110, fig. 8

Description. Spores radiosymmetric, alete, with a distinct central body. Amb of central body rounded triangular, surrounded by a distinctly trilobed equatorial saccus constricted

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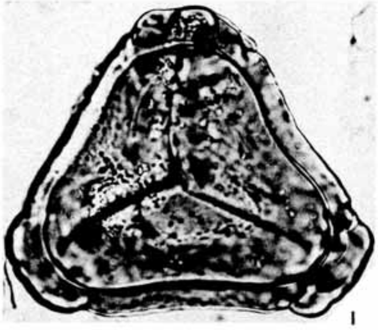
EXPLANATION OF PLATE 106

All figures ×750.

Figs. 1–2, 7–10, 12–13. *Trilobosporites* spp. 1–2, *T. bernissartensis* (Delcourt and Sprumont) Potonié. 1, Median focus, GN 345/1, 47.3 127.4. 2, Distal surface, GN 163/2, 51.0 122.9. 7–8, *T. obsitus* sp. nov. 7, Holotype, median focus, GN 163/2, 59.2 127.5. 8, Median focus, GN 163/2, 24.2 114.7. 9–10, 12–13, *T. domitus* sp. nov. 9, Holotype, proximal surface, GN 345/1, 57.0 111.7. 10, Median focus, GN 345/1, 57.4 120.6. 12, Equatorial view, GN 345/1, 51.6 116.5. 13, Median focus, GN 345/1, 38.4 127.8.

Fig. 3. *Foveosporites canalis* Balme, GN 168/1, 107.6 22.3.

Figs. 4–6, 11. *Plicatella abaca* (Burger) comb. nov. 4, Median focus, GN 145/2, 49.0 12.49. 5, Median focus, GN 212/2, 45.9 126.1. 6, GN 261/1, 46.6 116.0. 11, Equatorial view, GN 212/2, 40.4 126.4.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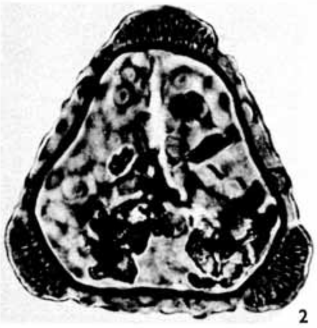
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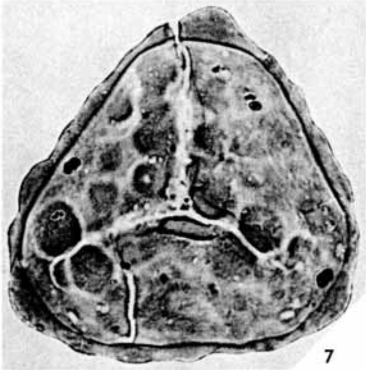
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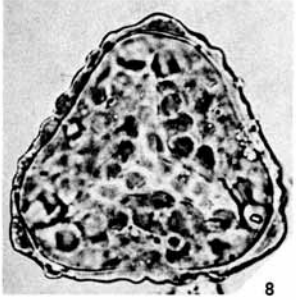
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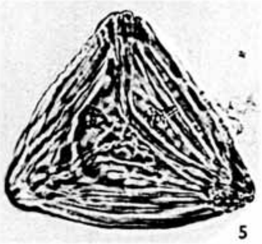
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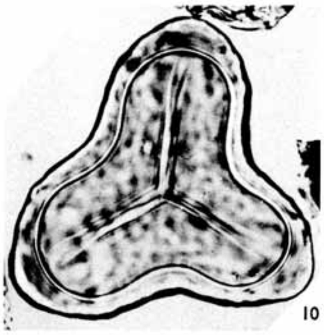
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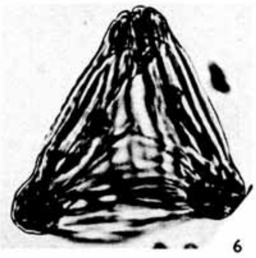
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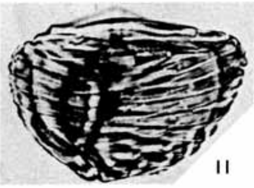
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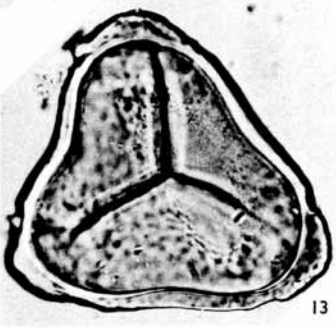
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NORRIS, Late Jurassic and Purbeck miospores

at the apices of the central body. Exine scabrate or indistinctly wrinkled. Saccus 8–10 μ wide. Exine of saccus and central body indistinct and thin.

Dimensions. Equatorial diameter 50–51 μ.

Distribution. Middle and Upper Purbeck, Dorset and Sussex.

Remarks. These grains differ from *C. trilobatus* (Balme) Sukh Dev in the scabrate rather than rugulate central body and in the overall smaller size. \

Callialasporites dampieri (Balme 1957) Sukh Dev emend.

Plate 110, figs. 2, 3

1937 *Nelumbium* type Simpson, p. 673, fig. 2a.
1957 *Zonalapollenites dampieri* Balme, p. 32, pl. 8, figs. 88–90.
1958 *Zonalapollenites* cf. *trilobatus* Balme; Hughes and Couper, p. 1482, fig. 1 (e).
1958 *Zonalapollenites dampieri* Balme (partim); Lantz, p. 925, pl. 3, fig. 34.
1958 *Zonalapollenites trilobatus* Balme (partim); Lantz, p. 925, pl. 4, fig. 37.
1961 *Callialasporites dampieri* (Balme) Sukh Dev, p. 48.
1962 *Pflugipollenites dampieri* (Balme) Pocock, p. 72.

Restated diagnosis. Spores radiosymmetric, alete, with a distinct central body. Central body amb circular to rounded triangular. One face of central body distinctly convex. Equatorial saccus surrounds central body and imparts a circular outline to the entire spore. Saccus attached by a narrow area at the equator of the central body, about one-fifth to one-seventh of the total diameter in width but decreasing and becoming irregularly constricted at the apices of the central body. The saccus is never constricted so much as to completely separate into three distinct lobes. Saccus usually carries delicate radial folds which may pass into rugulate folds on the attachment area, but is never folded on the centre of the spore body. Saccus and spore body scabrate to subgranular. Saccus wall about 1 μ thick. Exine of central body 0·25–0·5 μ thick.

Description. Attachment area of saccus 2–8 μ wide, distinct or indistinct, sometimes with a wrinkled appearance due to folding. Bladder usually 8 μ wide between apices but varying from 4–13 μ. Constrictions at apices reduce bladder width to the range 1–8 μ, but these are not equal and all three are not necessarily developed on any one spore.

Dimensions. Equatorial diameter: 47–69 μ.

Distribution. Kimmeridgian, Portlandian, Lower, Middle, and Upper Purbeck of Dorset, Sussex and Surrey.

Remarks. C. dampieri (Balme) is similar to *C. trilobatus* (Balme). Balme (1957) noted the similarity but in his description of *C. dampieri* did not mention any constrictions of the saccus, which however, are clearly shown in his photographs (pl. 8, figs. 88–90). In the present material the sacci are always constricted to a variable degree, frequently deeply, in three places. The more deeply constricted examples are very similar to *C. trilobatus*, particularly as Balme described the bladders of this species to occasionally coalesce to form one trilobate bladder. The central body, however, is always scabrate to subgranular rather than rugulate, the latter ornament being characteristic of *C. trilobatus*.

C. dampieri is here emended to include forms in which the bladder is constricted to a variable degree at the apices of the central body but never sufficiently deeply to clearly delimit three bladders as are found in *C. trilobatus*. It is distinguished from *C. trilobatus* by this character, by the scabrate to subgranular rather than rugulate central body, by the narrow attachment areas of the bladders to the central body, and by the restriction of the rugulate folds to this area.

Thus emended it embraces forms variously attributed to or compared with *C. dampieri* (Balme) and *C. trilobatus* (Balme) by Lantz (1958*b*) and Hughes and Couper (1958). Some of these trilobed, but not trisaccate forms have a clear rugulate central body (e.g. Lantz 1958, pl. 4, fig. 40) and on this character are best left in *C. trilobatus*. In his original description of *C. dampieri*, Balme noted that 'some specimens show vestigial triradiate markings' although these were not illustrated. Saccate grains with trilete scars of various types and development have been illustrated by Hughes and Couper (1958) and Lantz (1958*b*) and attributed to Balme's species of *Zonalapollenites*. It seems advisable to remove these from *Callialasporites dampieri* (Balme) and *C. trilobatus* (Balme) to genera of the Triletisacciti since some of the trilete marks illustrated by these authors appear to be quite well developed and not vestigial.

EXPLANATION OF PLATE 107

All figures ×750.

Figs. 1–4, 7, 10. *Appendicisporites potomacensis* Brenner. 1, 2, Median focus and distal surface respectively, GN 427/1, 48.0 117.6, 3, Proximal surface, GN 265/1, 122.3 44.1. 4, Median focus, GN 265/1, 50.2 111.0. 7, Median focus, GN 265/1, 48.2 123.4. 10, Median focus, GN 138/2, 50.0 102.6.

Figs. 5, 6. *Plicatella abaca* (Burger) comb. nov., distal and proximal surfaces respectively, GN 145/2, 45.5 108.4.

Fig. 8. *Duplexisporites problematicus* (Couper) Playford and Dettmann, GN 109B/1, 44.2 128.6.

Figs. 9, 14. *Trilobosporites apiverrucatus* Couper. 9, Proximal surface, GN 338/1, 34.9 124.5. 14, Proximal surface, GN 341/1, 116.8 25.8.

Figs. 11, 13. *Foraminisporis wonthaggiensis* (Cookson and Dettmann) Dettmann. 11, GN 428/1, 58.3 110.7. 13, GN 428/1, 44.6 114.0.

Fig. 12. *Contignisporites dorsostriatus* (Bolchovitina) Dettmann, GN 163/2, 32.4 119.1.

Fig. 15. *Coronatispora valdensis* (Couper) Dettmann; Damaged specimen showing structure of distal surface, GN 154/1, 27.2 127.8.

Figs. 16, 17. *Gleicheniidites senonicus* Ross. 16, GN 146/2, 37.4 124.4. 17, GN 147/2, 28.2 116.9.

EXPLANATION OF PLATE 108

All figures ×750 unless otherwise stated.

Figs. 1, 2. *Coronatispora valdensis* (Couper) Dettmann. 1, Proximal surface, GN 187/2, 47.4 125.3. 2, Distal surface, GN 152/1, 42.5 112.3.

Figs. 3, 4, 6. *Densoisporites perinatus* Couper. 3, Proximal surface, GN 262/1, 41.5 123.3. 4, Median focus, GN 338/1, 52.8 111.2. 6, Median focus, GN 338/3, 50.4 127.9.

Fig. 5. *Sestrosporites pseudoalveolatus* (Couper) Dettmann, GN 257/1, 44.1 116.4.

Figs. 7, 8, 10, 11. *Heliosporites* sp., Median foci. 7, GN 338/2, 37.1 110.7. 8, GN 427/2, 34.9 112.6. 10, GN 338/2, 44.9 117.4. 11, GN 262/1, 53.3 114.2.

Fig. 9. *Aequitriradites spinulosus* (Cookson and Dettmann) Cookson and Dettmann, GN 428/2, 50.5 124.7.

Fig. 12. *Januasporites tumulosus* sp. nov., holotype, distal surface; GN 421/1, 55.5 123.3; ×1,250.

Fig. 13. *Couperisporites complexus* (Couper) Pocock; distal surface, GN 265/1, 59.0 115.3.


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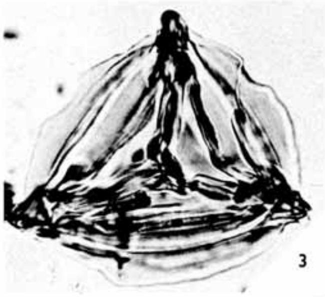
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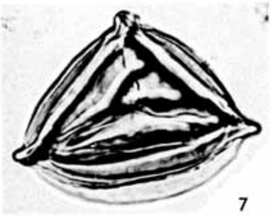
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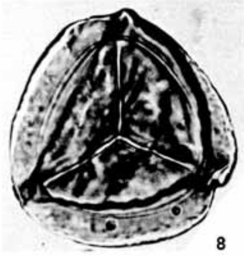
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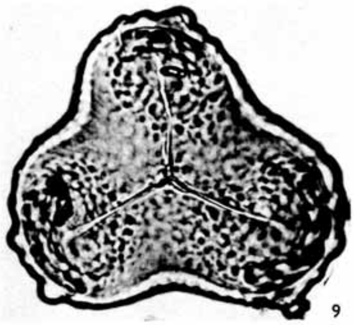
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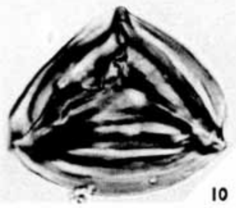
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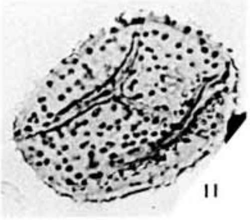
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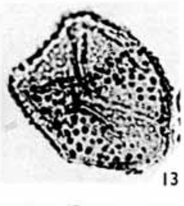
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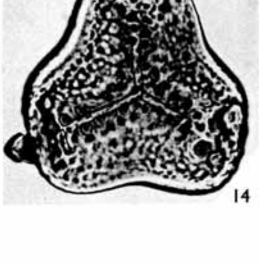
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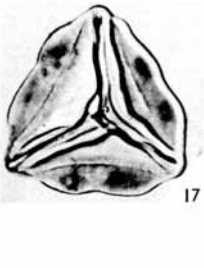
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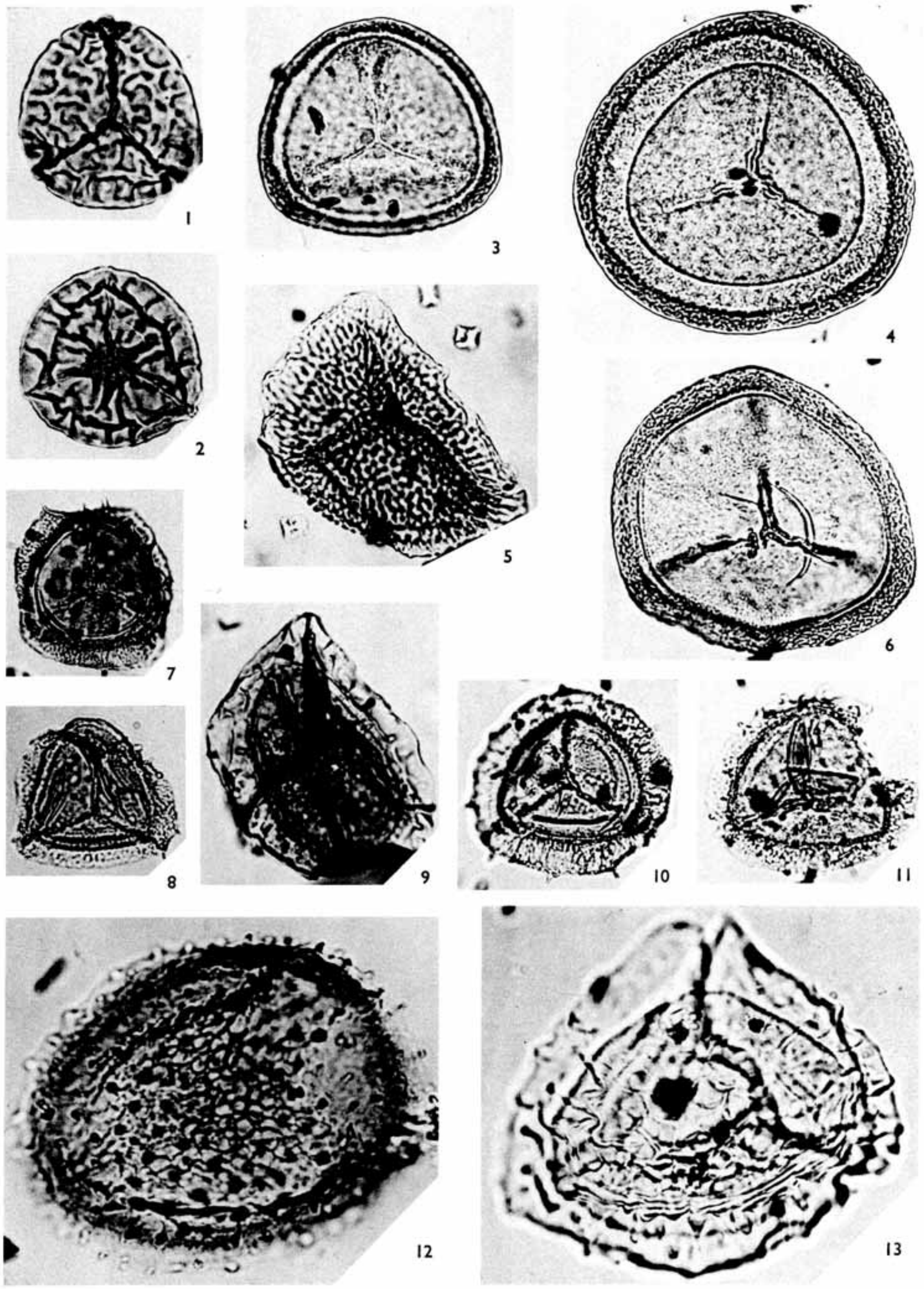
NORRIS, Late Jurassic and Purbeck miospores



NORRIS, Late Jurassic and Purbeck miospores

Callialasporites obrutus sp. nov.

Plate 110, figs. 6, 7

Holotype. Slide GN 148/1, 48.4 109.6. Sample 60–5–24 (grey, shaley clay), Upper Purbeck, Unio Beds, Durlston Bay (from Bed 82 of Bristow 1857).

Diagnosis. Spores radiosymmetric, alete, with a distinct central body. Amb of central body circular to oval, surrounded by a saccus imparting an irregularly circular outline to the entire spore. Central body outline not clear, saccus not distinctly attached to it. Saccus very thin, standing out from central body one-tenth to one-twelfth of the total diameter, scabrate to sub-granular, carrying coarse and also fine radial folds on equatorial bladder, these passing into irregular rugulate folds on central body. Central body granular to rugulate, finer sculpture elements at poles. Exine of central body (?endoexine) thin, about 0·25 μ or less in thickness. Bladders (?ektexine) also thin, about 0·25 μ thick.

Description. Bladders very narrow, usually about 5 μ wide but varying 4–9 μ. Bladder folded coarsely and approximately radially. Central body usually indistinct.

Dimensions. Equatorial diameter (including sacci): 38–69 μ (holotype 61 μ). Central body diameter: 29–44 μ (holotype 44 μ).

Distribution. Kimmeridgian, Dorset. Lower, Middle, and Upper Purbeck, Dorset, Sussex, and Surrey.

Remarks. *Callialasporites obrutus* sp. nov. is distinguished from *Zonalapollenites segmentatus* Balme by the possession of a very thin-walled central body.

Callialasporites sp.

Plate 110, figs. 4, 5

Description. Spores radiosymmetric, trilete, with a narrow equatorially attached saccus. Laesurae long, sinuous, labiate, 1–2 μ wide reaching beyond amb of central body and occasionally reaching amb of the saccus when they fan out into folds. Amb of both saccus and central body circular to rounded triangular. Saccus scabrate but thrown into rugulate, rather than irregular folds where attached to central body. Saccus projects evenly beyond amb of central body a distance equal to one-sixth to one-tenth of the total diameter (4–8 μ). Saccus almost unfolded or carrying rather coarse, irregular radial rugulate folds up to 2 μ wide and 4 μ long.

Dimensions. Equatorial diameter (including sacci): 39–64 μ.

Distribution. Portlandian, Dorset. Middle and Upper Purbeck, Dorset and Surrey.

Remarks. Apart from the prominent trilete mark, this species is similar to *Callialasporites obrutus* sp. nov. in possessing an equatorial, radially folded bladder which is attached to a rugulate central body.

Turma ALETES

Infraturma PSILONAPITI

Genus INAPERTUROPOLLENITES (Pflug ex Thomson and Pflug 1953) Potonié 1958

Inaperturopollenites sp.

Plate 110, figs. 11, 12

Description. Spores small, spheroidal or occasionally of irregular shape owing to folding, inaperturate. Exine relatively thick and rigid, unfolded or carrying short arcuate folds. Exine 0·25–1 μ in thickness, usually about 0·75 μ.

Dimensions. Diameter: 9–15 μ.

Distribution. Kimmeridgian and Portlandian of Dorset and Sussex. Lower, Middle, and Upper Purbeck of Dorset, Sussex, and Surrey.

Infraturma SPINONAPITI

Genus PELTANDRIPITES Wodehouse 1933

Peltandripites tener sp. nov.

Plate 110, figs. 18, 19

Holotype. Slide GN 316/1, 42.0 123.7. Sample WM 2024/2 (grey, calcareous shale), Middle Purbeck, Warlingham borehole, Surrey.

Diagnosis. Spores radiosymmetric, inaperturate, spherical, folded, entirely covered in

EXPLANATION OF PLATE 109

All figures ×750.

Fig. 1. *Couperisporites complexus* (Couper) Pocock; distal surface, GN 338/1, 43.4 111.0.

Figs. 2–4, 7. *Januasporites tumulosus* sp. nov. 2, 3, Holotype, median focus and distal surface respectively; GN 421/1, 55.5 123.3. 4, Median focus, showing circular aperture; GN 345/1, 41.51 28.5. 7, Median focus, GN 138/2, 40.4 117.2.

Figs. 5, 6. *Marattisporites scabratus* Couper. 5, Polar view, GN 163/2, 51.2 111.5. 6, Equatorial view, GN 147/1, 27.8 119.0.

Figs. 8–10. *Vitreisporites pallidus* (Reissinger) Potonié. 8, GN 138/2, 28.0 122.0. 9, GN 154/2, 45.7 121.7. 10, GN 153/2, 30.7 113.5.

Figs. 11, 12. *Cerebropollenites mesozoicus* (Couper) Nilsson. 11, GN 152/1, 38.1 117.9. 12, GN 152/1, 48.0 111.1.

Fig. 13. *Abietineaepollenites minimus* Couper, GN 265/2, 46.4 111.3.

Figs. 14, 15. *Alisporites bilateralis* Rouse. 14, GN 143/2, 42.6 120.8. 15, GN 259/2, 28.6 127.2.

Figs. 16, 17. *Podocarpidites* sp. cf. *P. ellipticus* Cookson. 16, GN 431/1, 118.8 39.3. 17, GN 421/1, 47.5 123.1.

Figs. 18, 19. *Parvisaccites radiatus* Couper. 18, Oblique polar view, GN 146/2, 37.0 124.3. 19, Oblique equatorial view, GN 186/2, 49.5 112.6.

EXPLANATION OF PLATE 110

All figures ×750 unless otherwise stated.

Fig. 1. *Parvisaccites radiatus* Couper, equatorial view, GN 138/2, 50.8 128.2.

Figs. 2–8. *Callialasporites* spp. 2–3, *C. dampieri* (Balme) Sukh Dev. 2, 1113–13C, 44.2 119.4, 3. GN 421/1, 46.6 119.3. 4–5, *C.* sp. 4, GN 152/1, 29.5 123.2. 5, GN 152/2, 36.1 121.8. 6–7, *C. obrutus* sp. nov. 6. Holotype, GN 148/1, 48.4 109.6. 7, GN 431/1, 23.9 118.2. 8, *C.* sp. cf. *C. trilobatus* (Balme) Sukh Dev, GN 255/2, 49.7 120.2.

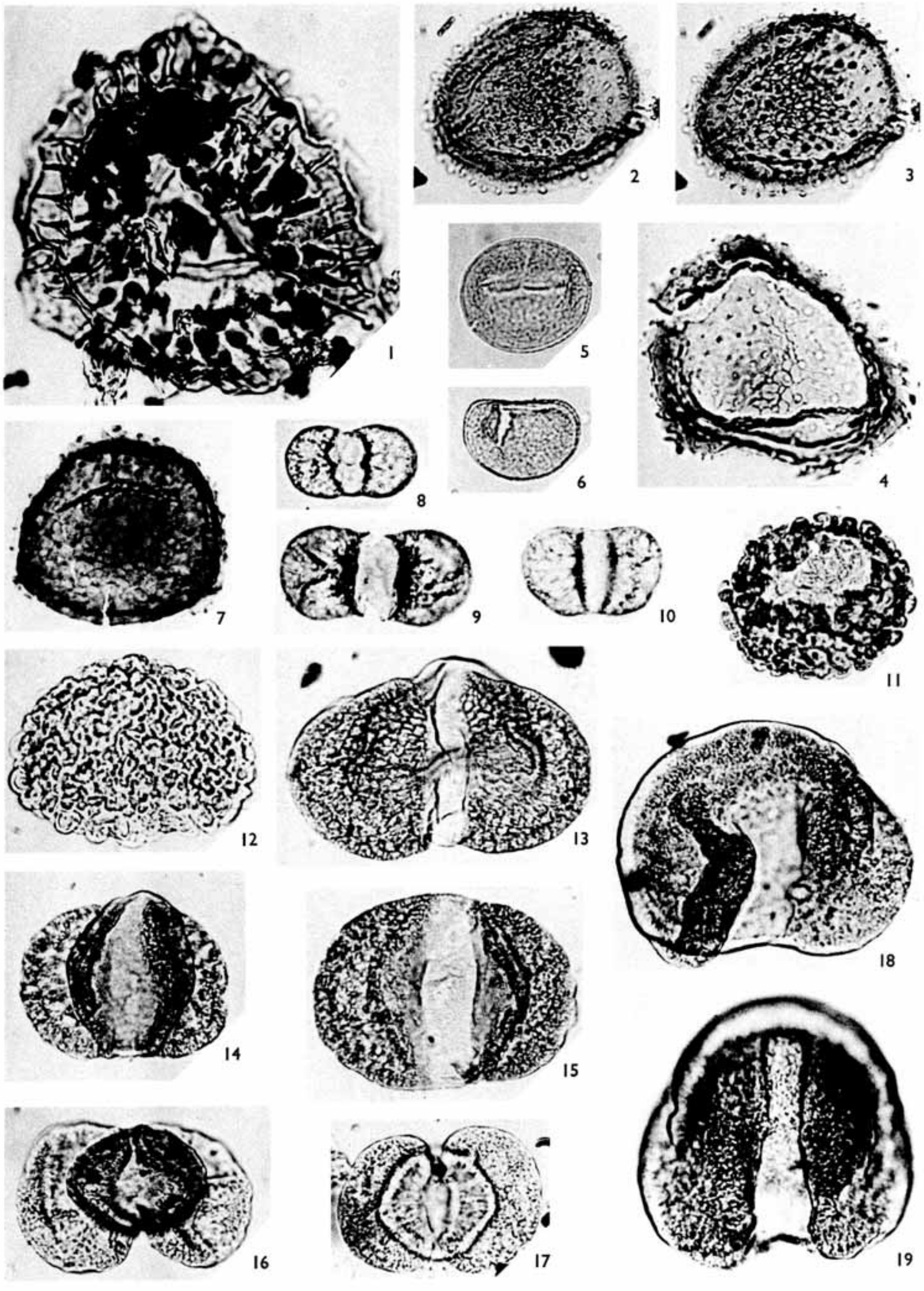
Figs. 9–12. *Inaperturopollenites* spp. 9–10, *I. dubius* (Potonié and Venitz) Thomson and Pflug. 9, GN 196/1, 56.8 127.7. 10, GN 345/1, 35.9 108.6. 11–12, *I.* sp. 11, GN 272/1, 44.9 117.0; ×1,250. 12, GN 421/1, 39.1 120.4; ×1,250.

Figs. 13. *Spheripollenites subgranulatus* Couper, GN 482/1, 34.6 109.3.

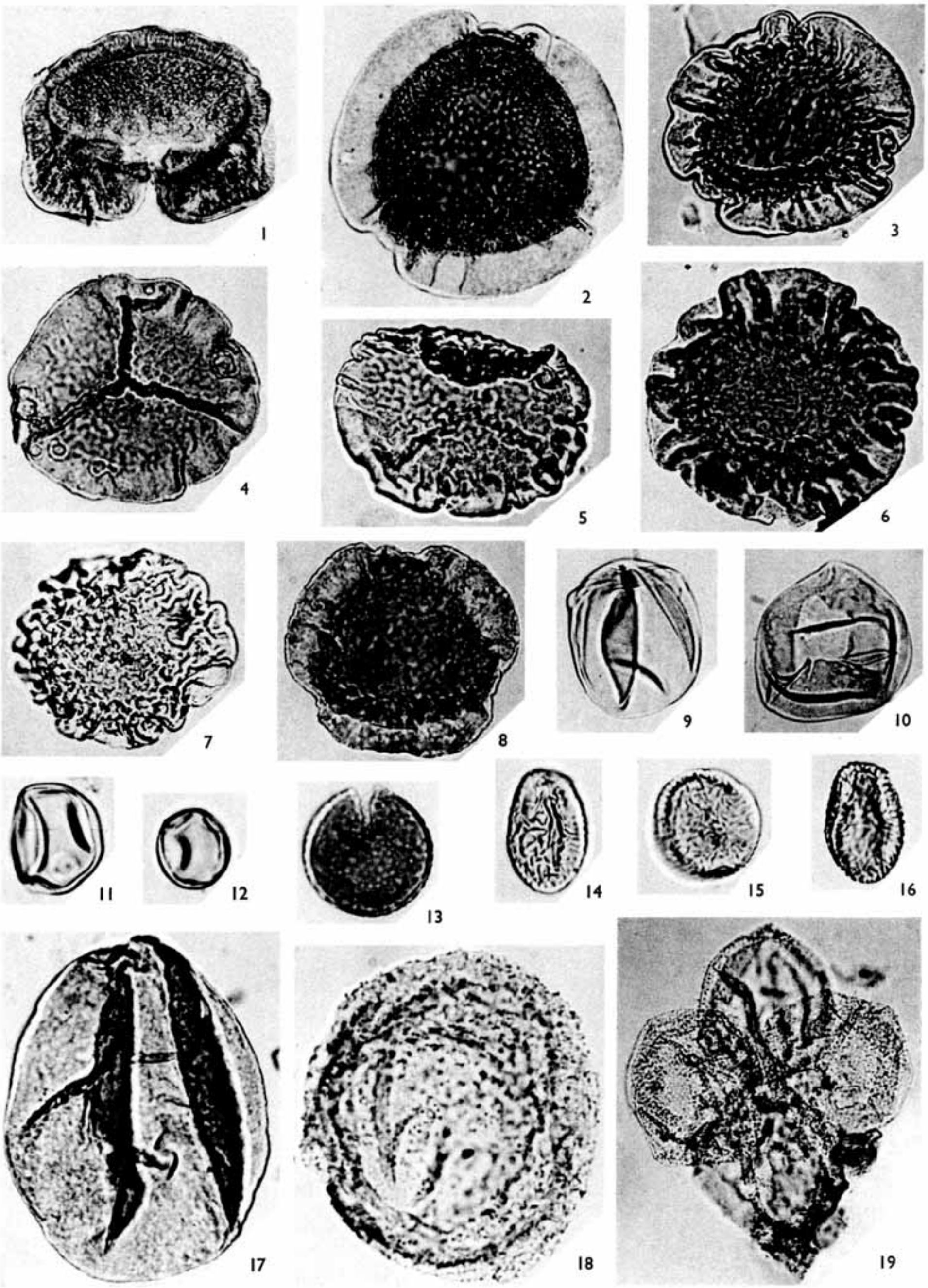
Figs. 14–16. *Undulatasporites araneus* sp. nov. 14, 16, High and median foci respectively, GN 421/2, 43.2 126.8. 15, High focus, GN 421/2, 47.1 110.0.

Fig. 17. *Araucariacites australis* Cookson, GN 265/2, 46.6 119.8.

Fig. 18, 19. *Peltandripites tener* sp. nov. 18, Holotype, GN 316/1, 42.0 123.7; ×1,250. 19, Tetrad, GN 281/1, 46.4 115.0.



NORRIS, Late Jurassic and Purbeck miospores



NORRIS, Late Jurassic and Purbeck miospores

short, closely spaced, irregularly distributed spines. Exine very thin, usually less than 0·25 μ in thickness.

Description. Grains always carry many arcuate and crescentic folds. Spines 0·75–1 μ long, usually about 0·25 μ wide but occasionally up to 1 μ wide, spaced irregularly 0·25–1 μ apart. In some corroded specimens some of the spines are reduced to low granules. Rarely the grains occur in tetrads. Sometimes the grains are ruptured in an arcuate fashion. Optical section of exine indistinct, occasionally reaching about 0·25 μ thick but never thicker.

Dimensions. Maximum diameter: 33–55 μ (holotype 50 μ).

Distribution. Kimmeridgian and Portlandian, Dorset. Lower and Upper Purbeck, Dorset.

Remarks. This species is easy to confuse with some acritarchs with short processes. It is only distinguished with difficulty but is clearly a pollen grain on account of its occurrence in tetrads.

Peltrandripites tener is distinguished from *Araucariacites australis* Cookson by its smaller size, much thinner exine, and clearly echinulate rather than granular ornament.

Infraturma RETICULONAPITI

Genus UNDULATASPORITES Leschik 1955

Undulatasporites araneus sp. nov.

Plate 110, figs. 14–16; Plate 111, figs. 2–10

Holotype. Slide GN 345/1, 25.3 107.2. Sample 60–19–3, (grey calcareous marl), Upper Purbeck, Upper Cypris Clays and Shales, Bacon Hole (6 in. above Bed 1 of Arkell 1933).

Diagnosis. Spores radiosymmetric, alete. Amb circular to oval. Exine very thin and ornamented with irregular rugulae coalescing into a very imperfect, irregular microreticulum consisting of narrow muri of constant width, and elongated irregular lumina with a radially elongated arrangement towards the periphery. Exine 0·25–1 μ thick, possibly tectate.

Description. Muri and rugulae 0·25–1 μ wide, of constant width along their length, 0·25 μ or less up to 0·5 μ high. Luminae 0·5–1 μ wide and up to 3 μ long, tortuous and bounded by anastomosing muri which show both angular and rounded bends in their courses. Spores sometimes show concentric folds close to the periphery.

Dimensions. Maximum equatorial diameter: 21–30 μ (holotype 26 μ).

Distribution. Upper Purbeck, Dorset.

Remarks. Undulatasporites araneus sp. nov. is distinguished from *Undulatasporites anguineus* Leschik by the overall smaller size, thinner exine, and shorter rugulae.

Turma PLICATES

Subturma MONOCOLPATES

Genus CYCADOPITES Wodehouse 1933 ex Wilson and Webster 1946

Cycadopites sp. cf. *C. nitidus* (Balme 1957) comb. nov.

Plate 111, figs. 11, 12

1957 *Entylissa nitidus* Balme, p. 30, pl. 6, figs. 78–80.
1962 *Ginkgocycadophytus nitudus* (Balme) de Jersey, p. 12.

Distribution. Kimmeridgian, and Portlandian, Dorset. Lower, Middle, and Upper Purbeck, Dorset and Surrey.

Remarks. These grains have a slightly greater over-all size range (18–39 μ long; 13–27 μ broad) than those described by Balme but also differ in their tectate and scabrate to infrapunctate exine (rather than 'smoothly or faintly granulate'). The exine, however, has a granular appearance in some corroded specimens. Balme (1957) believed that *C. nitidus* was derived from plants of cycadalian or bennettitalian affinities. The stratification of the exine of the present grains is not in conflict with this. Pollen grains of the modern genera *Bowenia*, *Cycas*, and *Macrozamia* belonging to the Cycadaceae and are illustrated by Erdtman (1957, figs. 10, 17, 46). All have tectate exines with rod-like elements supporting the tectum and closely resemble *C.* sp. cf. *C. nitidus*. The exines of some of the modern forms are distinctly crassitegellate whereas the tectum of *C.* sp. cf. *C. nitidus* is frequently seen to be just thinner than the gap between it and the endexine but merging into a crassitegellate exine.

Turma POROSES
Subturma MONOPORINES
Genus EXESIPOLLENITES Balme 1957
Exesipollenites scabrosus sp. nov.

Plate 111, figs. 20–2

Holotype. Slide GN 316/1, 45.5 109.5. Sample WM 2024/2 (grey calcareous shale), Purbeck Beds, Warlingham borehole.

Diagnosis. Spores radiosymmetric, monoporate. Amb rounded triangular to circular. Both proximal and distal faces rather flattened. Distal face with a circular thickening around the centre with an over-all diameter about half the equatorial diameter. At the distal pole at the centre of the thickening is a rather thinner, distinctly depressed circular

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EXPLANATION OF PLATE 111

All figures × 1,250 unless otherwise stated.

Fig. 1. *Peltandripites tener* sp. nov., GN 281/1, 54.5 121.1.

Figs. 2–10. *Undulatasporites araneus* sp. nov. 2–3, High and median foci respectively, GN 341/1, 27.8 128.0. 4–5, Holotype, high and median foci respectively, GN 345/1, 25.3 107.2. 6–7, GN 345/1, 30.5 112.4. 8, High focus, GN 345/1, 107.3 25.9. 9, Median focus, GN 421/1, 56.1 127.6. 10, GN 345/1, 24.3 108.9.

Figs. 11, 12. *Cycadopites* sp. cf. *C. nitidus* (Balme) comb. nov. 11, GN 338/3 49.4 119.8; × 750. 12, GN 196/1 43.0 109.3; × 750.

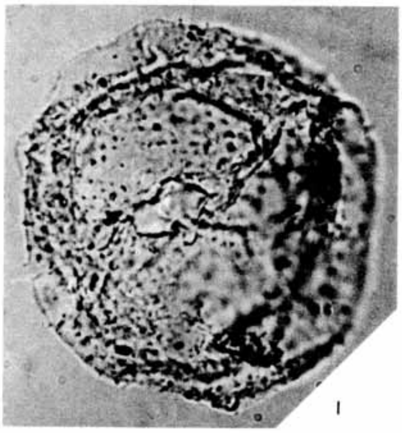
Figs. 13–16. *Eucommiidites* spp. 13–14, 16, *E. troedssonii* Erdtman, × 750. 13, GN 163/2, 40.3 109.9. 14, GN 163/2, 48.7 125.9. 16, GN 148/1, 38.1 117.2. 15, *E. minor* Groot and Penny, GN 345/1, 25.9 107.4; × 750.

Fig. 17. *Monosulcites* sp. aff. *M. minimus* Cookson, GN 344/1, 39.2 128.6; × 750.

Fig. 18. *Cycadopites carpentieri* (Delcourt and Sprumont) Singh, GN 184/1, 41.9 108.8; × 750.

Fig. 19. *Inaperturopollenites dubius* (Potonié and Venitz) Thomson and Pflug, GN 153/2, 23.2 122.1; × 750.

Figs. 20–22. *Exesipollenites scabrosus* sp. nov. 20, GN 316/1, 109.3 45.3; × 750. 21–2, Holotype, distal surface, × 750 and × 1,250 respectively; GN 316/1, 45.5 109.5.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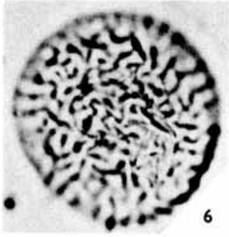
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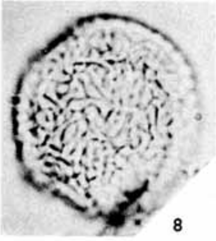
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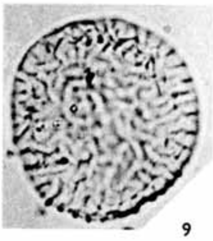
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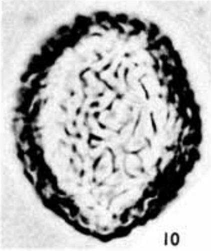
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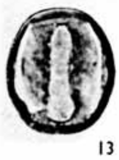
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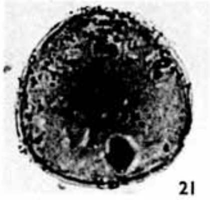
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NORRIS, Late Jurassic and Purbeck miospores

pore. Exine tectate, microreticulate, consisting of inwardly projecting elements. Occasional scattered, irregular granules may occur on both faces. Exine just under 1 μ in thickness.

Description. Distal thickening distinct but not sharply delimited at its periphery, 11–17 μ in diameter (just greater or just less than half the equatorial diameter). Distal pore at centre of distal thickening circular, depressed 1·5–3 μ, 1–8 μ in diameter (one-twelfth to two-thirds the diameter of the distal thickening).

Microreticulate ornament developed over entire surface of grain, including the distal pore and thickening, occasionally indistinct or scabrate. When well developed the muri of the microreticulum are about 0·25 μ wide and the lumina are about 0·25 μ in diameter. This tectate ornament may be accompanied by scattered groups of irregular granules up to 1 μ in diameter developed on the outer surface of the tectum. The tectate nature of the exine is usually quite clear even though delicately marked. The inwardly projecting elements of the ektexine are usually only seen as faint radial structures between the tectum and endexine. The radial elements may become so faint as to simulate a simply cavate exine.

Exine 0·25–1 μ in total thickness. Endexine 0·25 μ or less in thickness, occasionally not clearly distinct from the ektexine.

Folding seldom occurs owing to the flattened nature of the spore but the amb is occasionally irregularly crumpled.

Dimensions. Equatorial diameter: 23–36 μ (holotype 36 μ). Polar diameter: 4–6 μ (holotype 6 μ).

Distribution. Kimmeridgian and Portlandian of Dorset and Sussex. Lower, Middle, and Upper Purbeck of Dorset, Sussex, and Surrey.

Remarks. Exesipollenites scabrosus is distinguished from *Exesipollenites tumulus* Balme by the tectate nature of the thinner exine and by the microreticulate ornament. No spheroidal forms with a triangular polar thickening which Balme (1957) found associated with *E. tumulus* were found associated with *E. scabrosus*. The Lower Jurassic assemblage in which *E. tumulus* occurred also contained abundant *Classopollis* (Balme 1957, p. 41) as do the present samples in which *E. scabrosus* occurs.

MIOSPORES INCERTAE SEDIS

Genus SIGMOPOLLIS Hedlund 1965

Sigmopollis callosus sp. nov.

Plate 113, figs. 9–12

Holotype. Slide GN 383/1, 48.7 108.3. Sample 60–19–22 (buff calcareous sandstone), Middle Purbeck Corbula Beds, Bacon Hole (from the base of Bed 60 of Bristow 1857).

Diagnosis. Spores spheroidal. One face carries a distinct, markedly sinuous split in the exine. Entire surface of grain ornamented with low bifurcating rugulae which do not project at the amb. Exine about 1 μ thick.

Description. Grains seldom folded and consequently more or less perfectly spherical owing to the relatively thick and rigid exine.

Splitting is almost invariably developed and often takes an inverted S-shaped course across the entire face. It does not appear to be associated with a thinning of the exine and in optical section is seen to be a simple break perpendicular to the surface of the grain.

Rugulae 1–2 μ long, up to 0·25 μ wide, branching and occasionally partly forming an imperfect microreticulum, usually not projecting at the amb but in a few specimens giving the outline a slightly irregular appearance. Exine 0·75–1·25 μ thick.

Dimensions. Diameter: 11–14 μ (holotype 14 μ).

Distribution. Middle and Upper Purbeck, Dorset, Sussex, and Surrey.

Remarks. *Sigmopollis callosus* is distinguished from *Spheripollenites subgranulatus* Couper by the much thicker, more rigid exine, by the distinct rugulae which do not project at the amb, and by the distinct sinuous rupture occurring on one face.

The split in the exine is considered to be significant (possibly connected with germination) rather than fortuitous owing to its constant and similar development in most grains examined. Since it is not associated with any thinning of the exine it cannot be considered a colpus. It is similar to a monolete mark but is not associated with a differential raising of the surface of the exine and appears to transgress the entire exine thickness from the inner to the outer surface. Probably it is best considered an alete grain.

STRATIGRAPHIC PALYNOLOGY

All the samples examined from the Purbeck Beds and Upper Jurassic with few exceptions are dominated either by *Classopollis torosus* or *Inaperturopollenites dubius*. These two species together usually constitute at least 70% and occasionally more than 90% of the total spore-pollen flora. The relative abundance of these two species may have palaeoecologic significance. They are of little use, however, for delimiting assemblages

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EXPLANATION OF PLATE 112

All figures × 1,250 unless otherwise stated.

Figs. 1–5, 8–16. *Classopollis* spp. 1–5, *C. torosus* (Reissinger) Balme. 1, Tetrad, GN 164/1, 43.9 128.5; × 750. 2–3, Median and high foci respectively showing grain with endexine separated from ektexine; GN 414/5, 49.5 125.2. 4, Equatorial view, GN 97C/1, 43.1 107.8; × 750. 5, polar view, GN 316/3, 37.6 128.0; × 750. 8–13, *C. echinatus* Burger. 8, Polar view, GN 316/1, 41.9 129.1. 9, Oblique polar view, GN 316/1, 58.9 124.6. 10, Polar view, GN 316/1, 37.0 124.3. 11, Equatorial view, GN 203/1, 31.2 128.7. 12–13, Equatorial view, median and high foci respectively; GN 97C/1, 53.8 108.5. 14–16, *C. hammenii* Burger. 14, Equatorial view, GN 316/1, 29.2 125.7. 15, Equatorial view, GN 162/2, 41.9 128.7. 16. Oblique equatorial view, GN 97C/2, 47.1 126.7.

Figs. 6, 7. *Perinopollenites elatoides* Couper. 6, GN 259/2, 50.8 118.1; × 750. 7, GN 190/3, 42.5 108.5; × 750.

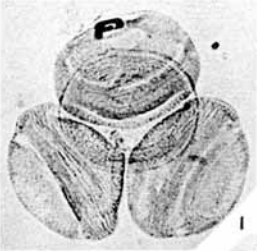
EXPLANATION OF PLATE 113

All figures × 1,250 unless otherwise stated.

Figs. 1–4. *Classopollis hammenii* Burger. 1, 2, Equatorial view, low and median foci respectively; GN 316/1, 32.0 128.5. 3, Polar view, GN 154/1, 52.7 120.3. 4, Oblique polar view, GN 316/1, 40.9 129.5.

Figs. 5–8, 13. *Schizosporis* spp. 5, 8, *S. reticulatus* Cookson and Dettmann. 5, GN 260/1, 43.3 116.3; × 350. 8, GN 259/1, 53.7 127.9; × 350. 6, 13, *S. spriggi* Cookson and Dettmann. 6, GN 265/1, 46.2 116.5; × 350. 13, GN 163/1, 51.6 117.6; × 350. 7, *S. parvus* Cookson and Dettmann, GN 154/1, 47.8 125.6; × 750.

Figs. 9–12. *Sigmopollis callosus* sp. nov. 9–11, Holotype, low, median and high foci respectively, GN 383/1, 48.7 108.3. 12, High focus, GN 383/1. 37.5 108.7.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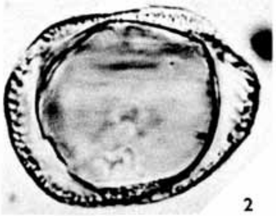
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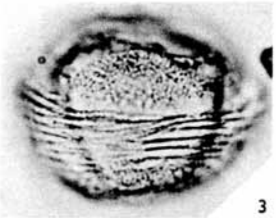
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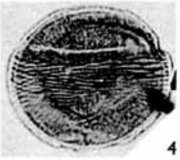
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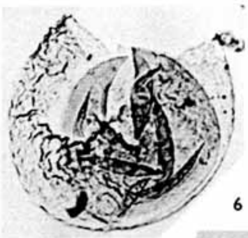
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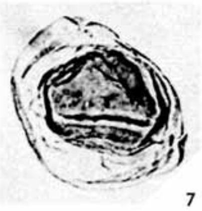
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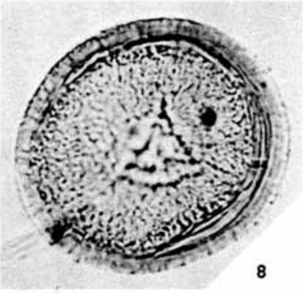
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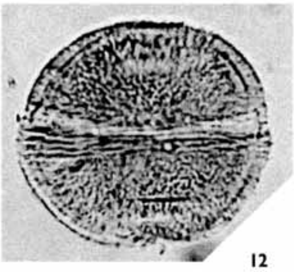
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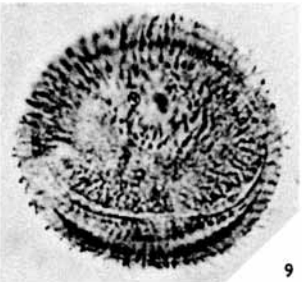
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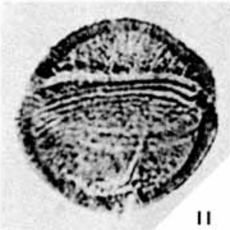
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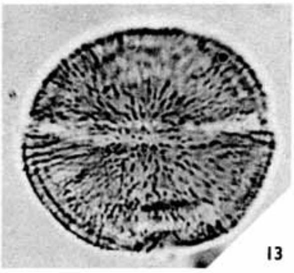
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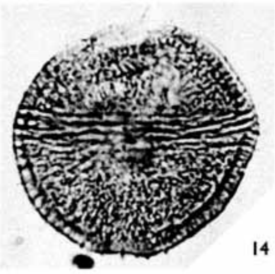
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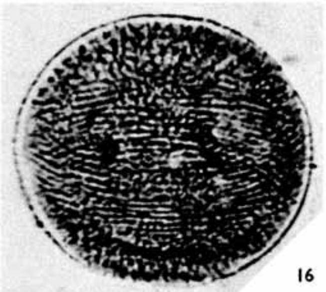
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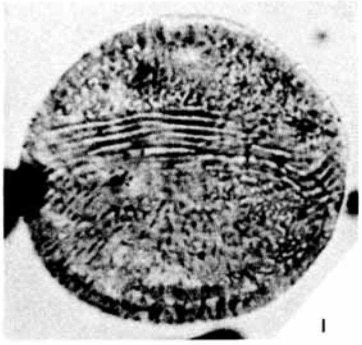
NORRIS, Late Jurassic and Purbeck miospores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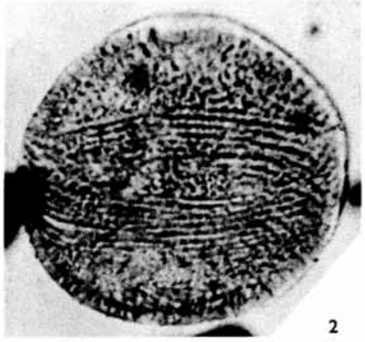
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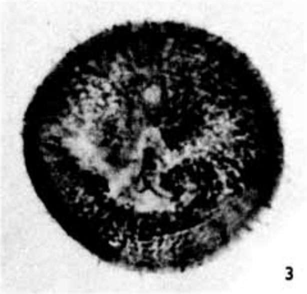
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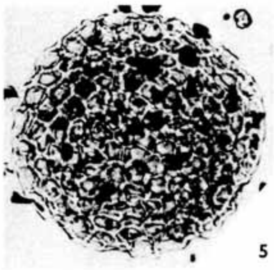
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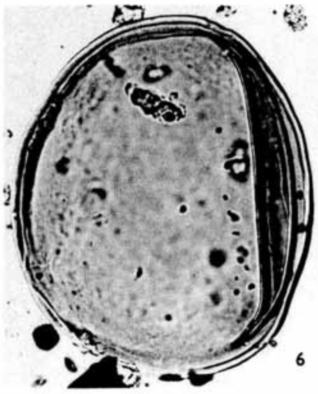
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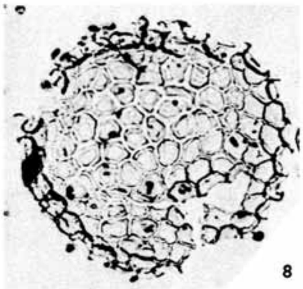
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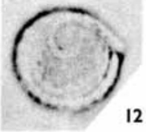
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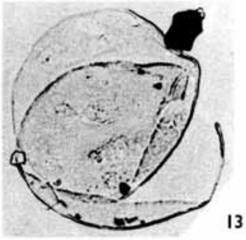
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NORRIS, Late Jurassic and Purbeck miospores

for stratigraphic purposes. On the other hand, the constituent species of the remaining fraction of the miospore samples are very diverse and may be used to define spore-pollen suites which appear to have stratigraphic significance. Suites have been recognized by study of samples collected in sequences. They delimit broadly similar spore-pollen samples, presumably derived from the same vegetational unit or units. They are described on the basis of their *persistent* species (those present in about 50% or more of the constituent samples in a suite) and *spasmodic* species (those occurring in less than half of the samples on which the suite is recognized). The composition of the suites is shown in text-fig. 3.

Marine Upper Jurassic Assemblages

The Upper Kimmeridgian and Portlandian of the Dorset coast and the Portland Sand of Sussex have similar miospore assemblages which are included in one miospore suite (Suite A). The basal Purbeck of Durlston Bay is also marine or brackish and is characterized by the same Suite.

Suite A is restricted in composition, most assemblages consisting of 10–15 species (listed in text-fig. 3). None of the species show restricted ranges within the intervals examined. All species occur in the overlying Purbeck Beds. The extension of their ranges into lower strata is not known in detail, owing to lack of adequate studies in the lower horizons of the Kimmeridgian, but more than half the species comprising Suite A have been reported from the Lower, Middle and Upper Jurassic of Britain by Couper (1958), Lantz (1958*b*), and Wall (1965).

The restricted nature of assemblages constituting Suite A is probably the result of the combination of several factors. Both the Upper Kimmeridgian and Portlandian comprise marine sediments deposited in an offshore environment. Considerable sedimentary sorting of the miospores by both wind and water is likely and may have resulted in only a fraction of the total available spore-pollen population from the adjacent land areas reaching the depositional site. This relative impoverishment may have been accentuated by the extremely limited flora that occupied coastal sites at that time as evidenced by the overlying Lower Purbeck assemblages.

At West Weare Cliff (Isle of Portland) Suite A occurs up to and including the Basal Shell Bed. Samples above this bed from the Cherty Series and Freestone Series did not yield palynologic assemblages. Suite A occurs in Portlandian samples from the West Weare Sandstone, Upper Black Nore Beds, Black Nore Sandstone, and Lower Black Nore Beds. Samples from the Exogyra Bed, the lower part of the West Weare Sandstone and upper part of the Upper Black Nore Beds were not available. At Tar Rocks below West Weare Cliff, Suite A characterizes the Kimmeridgian pallasioides zone to at least 135 ft. below the lowest row of nodules in the Black Nore Sandstone.

At Hounstout, Suite A characterizes similar horizons in the Lower Portlandian and Upper Kimmeridgian. The highest occurrence of Suite A collected at this locality was immediately below the Lower Parallel Band of the St. Albans Head Marls. Suite A characterizes the Portlandian and Upper Kimmeridgian below this, comprising the remainder of the St. Albans Head Marl, Emmit Hill Marl, Hounstout Marl, Hounstout Clay, Rhynchonella Marl, Lingula Shale, Rotunda Clays and Nodules, and the highest 20 ft. of the Crushed Ammonoid Shales, below which samples were not collected.

At Durlston Bay, the only Purbeck assemblage obtained below the base of the Marls

SPECIES	SUITE A	SUITE B	SUITE C	
1 GLEICHENIIDITES SENONICUS	——	——	——	1
2 ALISPORITES BILATERALIS	——	——	——	2
3 VITREISPORITES PALLIDUS	——	——	——	3
4 CEREBROPOLLENITES MESOZOICUS	——	——	——	4
5 INAPERTUROPOLLENITES DUBIUS	——	——	——	5
6 ARAUCARIACITES AUSTRALIS	——	——	——	6
7 PERINOPOLLENITES ELATOIDES	——	——	——	7
8 CLASSOPOLLIS TOROSUS	——	——	——	8
9 CLASSOPOLLIS ECHINATUS	——	——	- - -	9
10 INAPERTUROPOLLENITES SP.	——	- - -	- - -	10
11 EXESIPOLLENITES SCABROSUS	——	- - -	——	11
12 PODOCARPIDITES SP. CF. ELLIPTICUS	- - -	——	——	12
13 EUCOMMIIDITES TROEDSSONII	- - -	——	——	13
14 CLASSOPOLLIS HAMMENII	- - -	——	- - -	14
15 CYATHIDITES MINOR	- - -	- - -	——	15
16 CICATRICOSISPORITES AUSTRALIENSIS	- - -	- - -	——	16
17 CORONATISPORA VALDENSIS	- - -	- - -	——	17
18 DICTYOPHYLLIDITES EQUIEXINUS	- - -	- - -	——	18
19 CALLIALASPORITES DAMPIERI	- - -	- - -	——	19
20 DELTOIDOSPORA PSILOSTOMA	- - -	- - -	——	20
21 OSMUNDACIDITES WELLMANII	- - -	- - -	——	21
22 LYCOPODIUMSPORITES AUSTROCLAVATIDITES	- - -	- - -	——	22
23 KLUKISPORITES PSEUDORETICULATUS	- - -	- - -	——	23
24 RUBINELLA MAJOR	- - -	- - -	- - -	24
25 RETICULISPORITES SEMIRETICULATUS	- - -	- - -	- - -	25
26 ABIETINEAEPOLLENITES MINIMUS	- - -	- - -	- - -	26
27 CALLIALASPORITES SP.	- - -	- - -	- - -	27
28 CALLIALASPORITES OBRUTUS	- - -	- - -	- - -	28
29 PELTANDRIPITES TENER	- - -	- - -	- - -	29
30 CYCADOPITES SP. CF. C. NITIDUS	- - -	- - -	- - -	30
31 DICTYOPHYLLIDITES HARRISII	- - -	- - -	- - -	31
32 EUCOMMIIDITES MINOR	- - -		- - -	32
33 ACANTHOTRILETES VARISPINOSUS		- - -	——	33
34 CICATRICOSISPORITES PURBECKENSIS		- - -	——	34
35 PLICATELLA ABACA		- - -	——	35
36 PARVISACCITES RADIATUS		- - -	——	36
37 DELTOIDOSPORA RAFAELI		- - -	- - -	37
38 CONVERRUCOSISPORITES VARIVERRUCATUS		- - -	- - -	38
39 LEPTOLEPIDITES PSAROSUS		- - -	- - -	39
40 MICRORETICULATISPORITES DIATRETUS		- - -	- - -	40
41 CICATRICOSISPORITES AUSTRALIENSIS		- - -	- - -	41
42 COOPERISPORITES COMPLEXUS		- - -	- - -	42
43 SPHERIPOLLENITES SUBGRANULATUS		- - -	- - -	43
44 CYCADOPITES CARPENTIERI		- - -	- - -	44
45 SCHIZOSPORIS SPRIGGII		- - -	- - -	45
46 CONCAVISPORITES JURIENSIS			- - -	46
47 STEREISPORITES ANTIQUASPORITES			- - -	47
48 LEPTOLEPIDITES EPACRORNATUS			- - -	48
49 DIVISISPORITES SP. CF. EUSKIRCHENENSIS			- - -	49
50 BACULATISPORITES COMAUMENSIS			- - -	50
51 PILOSISPORITES TRICHOPAPILLOSUS			- - -	51
52 PILOSISPORITES DELICATULUS			- - -	52
53 LYCOPODIACIDITES CERNIIDITES			- - -	53
54 CICATRICOSISPORITES BREVILAESURATUS			- - -	54
55 CICATRICOSISPORITES ANGICANALIS			- - -	55
56 TRIPARTINA SP.			- - -	56
57 FOVEOSPORITES CANALIS			- - -	57
58 CONTIGNISPORITES DORSOSTRIATUS			- - -	58
59 DUPLEXISPORITES PROBLEMATICUS			- - -	59
60 APPENDICISPORITES POTOMACENSIS			- - -	60
61 TRILOBOSPORITES BERNISSARTENSIS			- - -	61
62 TRILOBOSPORITES APIVERRUCATUS			- - -	62
63 TRILOBOSPORITES OBSITUS			- - -	63
64 TRILOBOSPORITES DOMITUS			- - -	64
65 FORAMINISPORIS WONTHAGGIENSIS			- - -	65
66 SESTROSPORITES PSEUDOALVEOLATUS			- - -	66
67 DENSOISPORITES PERINATUS			- - -	67
68 HELIOSPORITES SP.			- - -	68
69 AEQUITRIRADITES SPINULOSUS			- - -	69
70 JANUASPORITES TUMULOSUS			- - -	70
71 CALLIALASPORITES SP. CF. TRILOBATUS			- - -	71
72 MARATTISPORITES SCABRATUS			- - -	72
73 UNDULATASPORITES ARANEUS			- - -	73
74 MONOSULCITES SP. AFF. MINIMUS			- - -	74
75 SCHIZOSPORIS RETICULATUS			- - -	75
76 SCHIZOSPORIS PARVUS			- - -	76
77 SIGMOPOLLIS CALLOSUS			- - -	77

TEXT-FIG. 3. Composition of microfloral suites showing persistent species (unbroken lines) and spasmodic species (broken lines). N.B. Range in entry 16 is correct, and not that in entry 41.

with Gypsum and Insect Beds belongs to Suite A. This assemblage which was obtained from a horizon 3 ft. below the top of the Broken Beds, contains dinoflagellate cysts (Norris 1965*b*) suggesting marine conditions of deposition, as suggested independently by Brown (1964) using petrologic criteria.

Marine plankton. The spore-pollen assemblages of Suite A are accompanied by a large proportion of dinoflagellate cysts and acritarchs; Norris (1965) has described a few of these species. The relative numerical abundance of microplankton in the marine Upper Jurassic (expressed as a ratio—number of microplanktonic forms/number of miospores) varies from 0·2 to 1·0. The relative diversity of marine Upper Jurassic microplankton species compared with miospore species (expressed as a ratio) varies between 0·6 and 3·0. In contrast the saline horizons in the Purbeck Beds containing microplankton have relative numerical abundances of microplankton that rarely exceed 0·01 and relative diversities of microplankton that never exceed 0·2 and frequently are less than 0·1.

Purbeck Assemblages

The Purbeck miospore assemblages of Dorset, Sussex, and Surrey can be grouped into two suites of distinctly different composition.

Suite B. This Suite (see text-fig. 3) is similar to Suite A in terms of most of the commoner constituents; however, *Classopollis echinatus* and *Inaperturopollenites* sp. occur less frequently, and *Podocarpidites* sp. cf. *P. ellipticus*, *Araucariacites australis* and *Perinopollenites elatoides* more frequently. *Eucommiidites minor* occurs in Suites A and C but is unknown in Suite B. Suite B is distinguished from Suite A by the presence of the following rarely occurring species:

Acanthotriletes varispinosus, *Converrucosisporites variverrucatus*, *Leptolepidites psarosus*, *Microreticulatisporites diatretus*, *Cicatricosisporites purbeckensis*, *Plicatella abaca*, *Couperisporites complexus*, *Cycadopites carpentieri*, *Schizosporis spriggi*, *Parvisaccites radiatus*.

On the Dorset Coast, Suite B characterizes most of the Lower Purbeck and the lower part of the Middle Purbeck. At Durlston Bay, Suite B occurs up to Bristow's (1857) Bed 53 in the Upper Building Stone, 17 ft. below the base of the Corbula Beds. At Bacon Hole Suite B occurs up to the top of the Marly Freshwater Beds (Bristow's Bed 42). Its lowest occurrence is not clearly defined at Bacon Hole where palynologic assemblages are rare in the Lower Purbeck. At Durlston Bay, however, Suite B definitely occurs down to the base of the Marls with Gypsum and Insect Beds. Suite A occurs almost to the top of the Broken Beds.

At Mountfield, Suite B characterizes the 4 gypsum seams at the bottom of the Purbeck sequence, the highest sample containing Suite B assemblages occurring at the top of No. 1 seam.

In the Warlingham borehole, Suite B does not occur above 2,022 ft. but the section was not examined below 2,027 ft. and so its lowest occurrence was not determined.

Suite C. This suite is similar to Suite B in terms of most of the persistent species (text-fig. 3) but contains these additional persistent species (some of which, however, occur rarely in other suites):

Cyathidites minor, *Klukisporites pseudoreticulatus*, *Cicatricosisporites australiensis*, *Cicatricosisporites purbeckensis*, *Plicatella abaca*, *Coronatispora valdensis*, *Parvisaccites radiatus*.

Suite C contains all the rare species that characterize Suite B but also contains the 32 additional spasmodic species listed in text-fig. 3.

Suite C occurs in the upper part of the Middle Purbeck and the Upper Purbeck of the Dorset Coast. At Durlston Bay, this Suite ranges from a horizon 15 ft. below the top of the Upper Building Stone (Bristow's Bed 55) to the highest sample examined, a bed of limestone at the top of the Marble Beds and Ostracod Shales. The Viviparus Clays are no longer exposed at this locality. At Bacon Hole the lowest occurrence of Suite C is from near the base of the Corbula Beds (from the bottom of Bristow's Bed 60). The interval from the base of the Corbula Beds to the highest occurrence of Suite B close to the lower middle Purbeck junction is barren of miospores. Consequently the exact delimitation of Suites B and C at this locality cannot be determined accurately. Suite C occurs up to the highest sample examined from Bacon Hole, a silty clay in Wealden arenaceous facies about 8 ft. above the top of the Upper Purbeck Paludina Clays. The latter is delimited from the basal Wealden by the incoming of sandstone.

At Lulworth Cove, Suite C occurs in the Paludina Clays but its lowest occurrence has not been determined at this locality because of the lack of assemblages. Suite C is not known at Worbarrow Bay, also because of lack of palynomorph assemblages in the Upper Middle and Upper Purbeck.

At Mountfield, Suite C occurs from 13 ft. above the top of No. 1 gypsum seam throughout the remaining 'Middle' and 'Upper' Purbeck to the highest sample examined in the lower half of the Grey Limestone Series exposed in the River Line south-west of the gypsum mine (Howitt 1964, p. 86).

In the Warlingham borehole, Suite C occupies the interval from 2,004 ft. to the highest sample examined at 1,900 ft.

DISCUSSION OF ASSEMBLAGES AND SUITES

The three suites represent a progressive diversification of the plant microfossil assemblages (text-fig. 3). Species of Suite A are drawn from a total of 32 species. Most assemblages constituting Suite A are composed of 10–15 species. Suite B is represented by a total of 42 species, although each assemblage in this suite usually consists of less than 10 species with occasionally up to 22 species present. Suite C is the most diverse, being represented by a total of 73 species; most assemblages of Suite C contain 15–30 species although this number can be (rarely) as low as 4 or as high as 42.

Each successive suite is characterized by the entrances of new forms. There are no well-marked extinctions although local ranges may be restricted in some sections. Most of the characteristic new forms of each suite are rare types. This leads to difficulties in assigning some samples to a suite, but the use of sequential samples has allowed a more meaningful evaluation of the absence of rare types in a sample.

This progressive diversification of the assemblages may be the result of evolution, sedimentation, local phytogeography, or changing environments. The distribution and ranges of characteristic species within each Suite is not constant from section to section, which suggests that factors other than evolution and extinction are important in determining individual ranges. For example, *Pilosisporites delicatulus* is characteristic of Suite C in Dorset but is unknown in Sussex and Surrey. Thus local palaeoecologic control may be severe and does not allow the use of individual miospores for minutely detailed stratigraphic correlation, although the use of miospores for general correlative purposes is possible as set out below.

There is no apparent relationship between the miospore Suites and the numerical dominants in each section. Either *Classopollis torosus* or *Inaperturopollenites dubius* may dominate the assemblages constituting Suite A. At Durlston Bay and in the Warlingham borehole Suite B is characterized by relative abundances of *Classopollis torosus* greater than 50%. At Bacon Hole and Mountfield, *C. torosus* dominates the lower assemblages of Suite B but *I. dubius* becomes important in the higher assemblages of this Suite. Suite C is characterized by an abundance of *I. dubius* at Durlston Bay and in the Warlingham borehole. At Bacon Hole and Mountfield either *I. dubius* or *C. torosus* may dominate the Suite C assemblages. Many assemblages in Suite B and C are characterized by the freshwater chlorophycean alga, *Botryococcus*, presumably reflecting the dominantly non-marine conditions of deposition.

Botanical considerations. It is possible to assign many dispersed spore and pollen species from the Jurassic and Cretaceous to natural plant orders and families (Potonié 1962, Brenner 1963, Dettmann 1963, Pocock 1962, Singh 1964, Norris 1967). Species constituting Suites A, B, and C are distributed amongst natural plant taxa at the ordinal or higher levels as follows:

BRYOPHYTA: *Stereisporites antiquasporites*, *Foraminisporis wonthaggiensis*, *Aequitriradites spinulosus*, *Couperisporites complexus*.

PTERIDOPHYTA: *Inaperturopollenites dubius* (pars). Lycopodiales: *Acanthotriletes varispinosus*, *Lycopodiacidites cerniidites*, *Lycopodiumsporites austroclavatidites*, *Foveosporites canalis*, *Sestrosporites pseudoalveolatus*, *Densoisporites perinatus*. Filicales: *Cyathidites minor*, *C. australis*, *Osmundacidites wellmanii*. *Baculatisporites comanumensis*, *Converrucosisporites variverrucatus*, *Leptolepidites psarosus*, *Rubinella major*, *Pilosisporites trichopapillosus*, *Cicatricosisporites australiensis*. *C. purbeckensis*, *C. angicanalis*, *C. brevilaesuratus*, *Klukisporites pseudoreticulatus*, *Trilobosporites bernissartensis*, *T. obsitus*, *T. domitus*, *Appendicisporites potomacensis*, *Plicatella abaca*, *Gleicheniidites senonicus*, *Marattisporites scabratus*. Pteridophyta incertae sedis: *Deltoidospora rafaeli*, *D. psilostoma*, *Concavisporites juriensis*, *Divisisporites* sp. cf. *D. euskirchenensis*, *Pilosisporites delicatulus*, *Reticulisporites semireticulatus*, *Microreticulatisporites diatretus*, *Tripartina* sp., *Heliosporites* sp., *Contignisporites dorsostriatus*, *Coronatispora valdensis*, *Januasporites tumulosus*.

CYCADOPHYTA: *Vitreisporites pallidus*, *Cycadopites* sp. cf. *C. nitidus*, *C. carpentieri*.

CONIFEROPHYTA. Coniferales: *Cerebropollenites mesozoicus*, *Alisporites bilateralis*, *Abietineaepollenites minimus*, *Podocarpidites* sp. cf. *P. ellipticus*, *Parvisaccites radiatus*, *Callialasporites* sp. cf. *C. trilobatus*, *C. dampieri*, *C. obrutus*, *C.* sp., *Inaperturopollenites dubius* (pars), *Araucariacites australis*, *Spheripollenites subgranulatus*, *Perinopollenites elatoides*. Coniferophyta incertae sedis: *Eucommiidites troedssonii*, *E. minor*, *Exesipollenites scabrosus*, *Classopollis torosus*, *C. echinatus*, *C. hammenii*.

SPORES AND POLLEN INCERTAE SEDIS: *Inaperturopollenites* sp., *Peltandripites tener*, *Undulatasporites araneus*, *Monosulcites* sp. aff. *M. minimus*, *Schizosporis reticulatis*, *S. spriggi*, *S. parvus*, *Sigmopollis callosus*.

From the above list it is evident that the assemblages spanning the Jurassic–Cretaceous boundary in southern England as a whole represent principally pteridophyte–gymnosperm vegetation. Lycopsids are less important than filicalean elements but some of the pteridophyte spores of uncertain affinities may belong to this group. Bryophytes and cycads are both relatively unimportant groups.

Ascending the sequence from the Upper Kimmeridgian to the Upper Purbeck there is a progressive diversification of the spore-pollen assemblages. Suite A consists principally of coniferalean elements with a few filicalean, lycopsid, and other pteridophyte species. In Suite B conifers remain important but pteridophytes begin to diversify. Bryophytes appear in Suite B as rare elements. In Suite C conifers remain the most diverse persistent elements but pteridophytes are the most diverse of the spasmodic species. Bryophytes are commoner here than in Suite B but are still rare. Cycadophytes are rare elements in all the suites. The numerical dominants in all the suites, *Classopollis torosus* and *Inaperturopollenites dubius*, are both coniferalean species but some of the inaperturate grains could be derived from equisetalean plants (Batten 1968).

CORRELATION AND AGE OF THE PURBECK BEDS

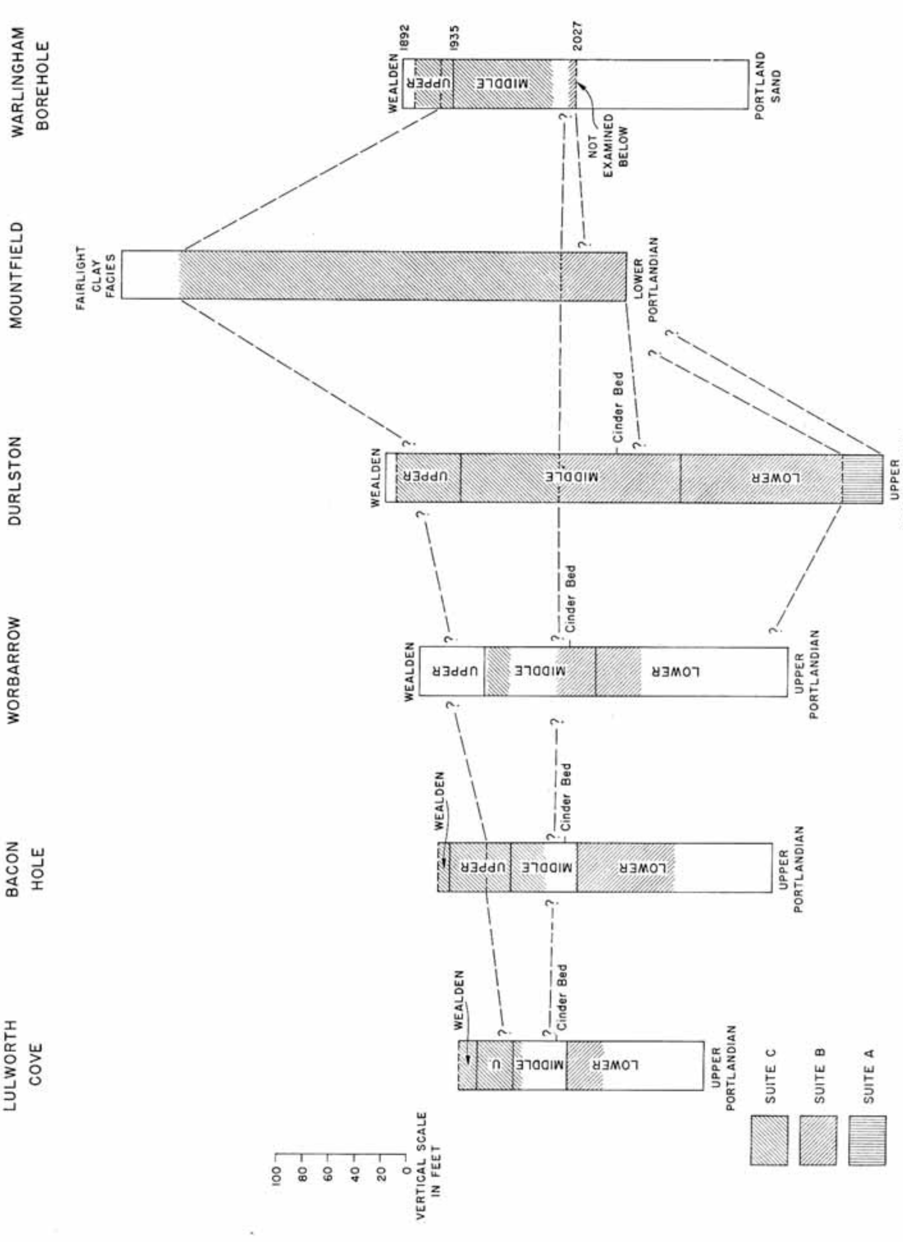
Correlation

It is difficult to select 'index' forms or key species (Couper 1958) but the suites recognized on the basis of several species are presumably time concordant.

Correlation of the Purbeck Beds and equivalent strata in southern England on the basis of palynologic suites is shown in text-fig. 4. At Durlston Bay, Suite B is present from the top of the Broken Beds (samples from the Caps and Dirt Beds below did not yield palynomorphs) to the upper part of the Upper Building Stones. Suite C occupies the remainder of the Upper Building Stone to the top of the Marble Beds and Ostracod Shales. In Bacon Hole the boundary between Suites B and C occurs at a similar stratigraphic position, i.e. at the approximate level of the Scallop Beds (of Bristow's 1857 terminology). Due to the westward attenuation of the strata, however, the B/C boundary is approximately 15 ft. above the Cinder Bed at Bacon Hole whereas the equivalent interval at Durlston is almost double that thickness.

Samples from the major part of the Purbeck Beds at Worbarrow Bay and at Lulworth Cove were too sparse (perhaps due to the large amounts of limestone in the sections) to locate the boundary between Suites B and C. At Mountfield, however, this boundary is well marked in the subsurface section of the Purbeck Beds just above the No. 1 gypsum seam approximately 50–60 ft. above the base of the section. This contrasts with the position of the B/C boundary approximately 260 ft. above the base at Durlston Bay. Thus the four gypsum seams and intercalated shales at the base of the Mountfield Purbeck would appear to be either a condensed sequence equivalent to the Lower and much of the Middle Purbeck of Dorset (some 260 ft.), or there is a hiatus between the underlying Portlandian and the lowest Purbeck at Mountfield which seems more likely for the following reasons.

Although the Purbeck of Dorset is apparently conformable with the underlying Upper Portlandian, in other areas there is some evidence to suggest that the Upper Portlandian is absent. In the Henfield borehole of Sussex, 2 ft. below the base of the Purbeck Beds, faunas occur indicating the Lower Portlandian albani zone (Taitt and Kent 1958). In the Portsdown borehole the Purbeck Beds rest on Portlandian equivalent to the top of the Portland Sand (Lower Portlandian) in Dorset. At Mountfield the arenaceous sediments immediately underlying the Purbeck Beds have yielded dinoflagellates characteristic of the top part of the Lower Portlandian gorei zone in Dorset (Norris 1963). Falcon and Kent (1960, p. 13) presented additional evidence from boreholes in southern England and stated that there is 'no evidence of the occurrence of Upper Portland anywhere in the Wealden area, there being a non-sequence at the base of the Purbeck'. Taitt and Kent



TEXT-FIG. 4. Palynologic correlation of the Purbeck Beds in southern England.

(1958) also ascribed this break to a non-sequence due to a regional movement causing a cessation of deposition since there are no signs of erosion and the break is of a uniform nature. The occurrence of Lower Portlandian pebbles within the Lower Purbeck of Dorset (Woodward 1895), the erosion of the Portland Beds prior to deposition of the Purbeck Beds in the Aylesbury district (Woodward 1895), and the presence of derived Kimmeridgian and Portlandian pelecypods from the basal Purbeck Beds of Swindon similar to forms from the south of England and the Boulonnais (Arkell 1941) indicate the possible existence of a pre-Purbeck unconformity.

The correlation of the Purbeck at Mountfield is particularly interesting whatever the reason for the absence of marine Upper Portlandian at this locality. Details of Purbeck ostracod faunas are not available. Howitt (1964) used lithologic criteria for correlation of the Purbeck sequence of the Mountfield inlier. He assigned this relatively thick sequence to the conventional tripartite subdivision: the 'Lower' Purbeck consists largely of gypsum and limestone; the 'Middle' Purbeck consists of shale, some marine limestone and arenaceous horizons; the 'Upper' Purbeck contains freshwater limestones, shales, and calcareous sandstones. A different correlation is suggested on the basis of miospores (text-fig. 4). Suite B characterizes the gypsiferous series at the base plus a few feet of overlying shale as detailed in the previous section. Suite C occupies the remaining Mountfield Purbeck to the middle of the Greys Limestone Series. This suggests that the entire gypsiferous series at Mountfield is equivalent to the Middle Purbeck rather than to the Lower Purbeck of Dorset as suggested by Howitt (1964). It is difficult to determine how much of the Durlston Suite B is represented at Mountfield. There appear to be no breaks in sedimentation within Suite B strata which suggests in view of their thin development that only the upper part of Suite B is represented, i.e. equivalent to part of the lower Middle Purbeck. The correlation of the higher assemblages of Suite C is difficult. *Cicatricosisporites angicanalis*, a distinctive species of limited stratigraphic range, is restricted to the upper part of the Upper Purbeck in Dorset. At Mountfield, *C. angicanalis* occurs in one sample of the Greys Limestone suggesting a correlation with the upper part of the Upper Purbeck of Dorset. Thus if this correlation is correct, sedimentation of the upper part of the Middle Purbeck (above the Cinder Bed) and the Upper Purbeck proceeded at less than half the rate at Durlston Bay (183 ft.) compared with the equivalent interval at Mountfield (396 ft.).

Age

At the type locality on the Dorset Coast the Purbeck Beds overlie with apparent conformity the uppermost Portlandian. The Upper Portlandian has been correlated with the Middle Tithonian of the continent by Arkell (1956) on the basis of the contained ammonite faunas. Presumably the Upper Tithonian is represented by at least part of the Purbeck sequence in Dorset. The top of the Purbeck Beds is delimited by the incoming of coarse, clastic arenaceous and carbonaceous sediments of Wealden facies which have not been precisely dated but in the past have been generally assumed to be basal Cretaceous (Allen 1955).

Ostracods have been used to correlate the Purbeck Beds of southern England (Anderson 1958) and similar European formations (Anderson 1962, Arkell 1956, Bartenstein and Burri 1955). Age determinations of the Purbeck Beds, however, rest principally on occurrences of ammonites (Arkell 1956). Arkell's arguments for a Late Tithonian age for the Purbeck Beds have been reviewed and revised by Donze (1958) who suggested that the ammonites indicate either a Late Tithonian or Berriasian age for the French Purbeck.

The Jura Purbecks have been correlated with the Lower and Middle Purbeck by F. W. Anderson using ostracods (Arkell 1956). Their Berriasian and possibly Late Tithonian age is not inconsistent with other stratigraphic and palaeontologic evidence from underlying and overlying deposits in this region. Arkell (1956) has noted that undated limestones underlie the ammonite-bearing and other sequences of the French Purbecks. Only the lower part of the thick limestones underlying the Jura Purbecks contain ammonites and these indicate the Kimmeridgian gravesiana zone. The higher part of this limestone sequence is customarily referred to as 'Portlandian' but diagnostic fossils are lacking. The limestones overlying the French Purbecks are assigned to the Berriasian with little or no palaeontologic evidence but are overlain by undoubted Valanginian. The limestones and marls overlying the Jura Purbecks are considered to be Berriasian on insecure evidence (Bartenstein and Burri 1955) and the one diagnostic ammonite has been compared to a Valanginian form (Arkell 1956). The remaining fauna is not diagnostic.

Similar correlations to the above for the Swiss and French Purbecks have been suggested by other workers using fossils other than ammonites. Bartenstein and Burri (1955) correlated the Swiss Purbecks with the Serpulite and Wealden 1 of NW. Germany and with the higher Lower Purbeck and lower Middle Purbeck of England using ostracods and charophytes. Donze (1958) correlated the French Purbecks with a regression in the Berriasian of the 'fosse vocontienne' (indicated by microfaunal and algal changes) and with the Lower Purbeck and part of the Middle Purbeck of Dorset (using ostracods). Palynologic correlations differ slightly: these suggest a correlation of the Serpulite and Wealden 1 of Germany and Holland with the upper Middle Purbeck and part at least of the Upper Purbeck. Thus the Berriasian regressive facies in the West Tethys may correlate with the Lower Purbeck and lower Middle Purbeck or with the upper Middle Purbeck and Upper Purbeck. Bartenstein (1959, 1962) extended the Berriasian correlation of the French Purbecks to the Jura Purbecks. He confirmed that probably only the lowest part of the Swiss 'Berriasian' overlying the Jura Purbecks is to be correlated with the top of the type Berriasian, most of the remainder being of Valanginian age.

Thus on the evidence from ammonites and using ostracods to correlate to the west Tethyan region, the Purbeck Beds in Dorset appear to span the Jurassic–Cretaceous boundary occupying the interval Late Tithonian–Berriasian (text-fig. 5).

Assignment of the upper part of the Purbeck Beds to the Lower Cretaceous is also suggested by palaeobotanical arguments. Hughes (1958) studied megaspores from the English Wealden and compared them with those from Dutch and German sequences. The lowest Wealden formation in the type area is the Fairlight Clay of the Sussex Coast. The Fairlight Clay is believed to immediately overlie or be a partial facies equivalent of some of the Purbeck (Allen 1960 *a*, *b*) but the base of this formation is not exposed and so exact relationships cannot be confirmed. Overlying the Fairlight Clay is the Ashdown Sand which Hughes (1958) correlated with the Lower Valanginian of the Netherlands from the occurrence in both of *Thomsonia* megaspore floras. Hughes also noted that *Thomsonia* floras are known from the German Wealden 4 and 5. The beds below the

Thomsonia horizon of the Lower Valanginian of the Netherlands contain *Pyrobolospora pyriformis* (Dijkstra) Hughes which is known only in the Fairlight Clay in England. These lower beds in the Netherlands are probably Berriasian or partly Lower Valanginian, suggesting a similar age for the Fairlight Clay. The Upper Purbeck is a facies equivalent of the Fairlight Clay, as suggested by Hughes and Moody-Stuart's (1969) correlation of the Lower Fairlight Clay with the upper Middle and Upper Purbeck using a new palynologic method. This indicates that the upper Middle and Upper Purbeck may also be Lower Cretaceous (?Berriasian) in age. The uppermost Purbeck Beds at Bacon Hole contain megaspores at some horizons (see Appendix 1 in Norris 1963). More intensive study of these megaspores may help to resolve the point.

Jurassic–Cretaceous boundary in southern England

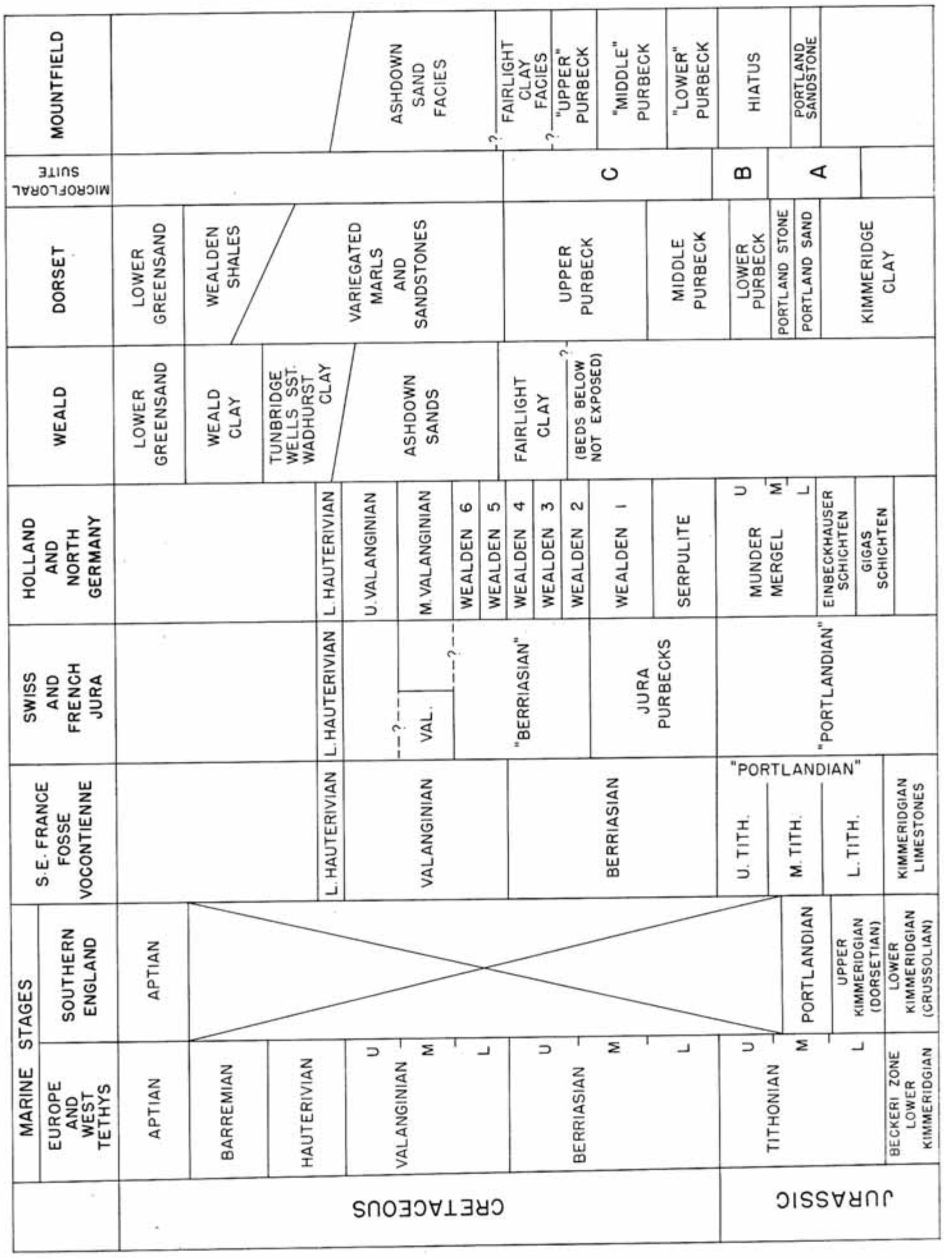
As reviewed above, the Purbeck Beds on the Dorset Coast appear to occupy the Upper Tithonian–Berriasian interval and hence straddle the Jurassic–Cretaceous boundary which is conventionally placed between the Tithonian and Berriasian stages (Arkell 1956). These stages are based on ammonite faunas occurring in marine limestones of south-east France. Correlation with non-marine and transitional strata is difficult, being based on sparse ammonite-bearing marine intercalations together with the use of non-marine fossils to extend these age determinations into other areas of non-marine rocks. In southern England (Dorset) this has led to a situation in which it is possible to say that the lower part of the Lower Purbeck is probably Upper Tithonian and that the higher part of the Upper Purbeck is Berriasian (perhaps Upper Berriasian). But it is not possible to place the Jurassic–Cretaceous boundary precisely. Casey (in Howitt 1964, p. 109) has discussed some of the problems involved in locating the base of the Cretaceous in England. He suggested tentatively that the Cinder Bed of Dorset might be taken to mark the Jurassic–Cretaceous boundary. Casey considered this to be a convenient procedure because he thought the Cinder Bed to be the most extensive of several saline horizons in the Purbeck of England. Furthermore Casey pointed out that the flooding of the Wessex Basin that led to deposition of the Cinder Bed and supposed correlative horizons was perhaps linked with the Osterwald phase of Saxonian folding in north Germany that immediately preceded deposition of the Serpulite (a possible correlative of the Cinder Bed), and whose effects might be traced in the Spilsby Sea deposits further north. If the Cinder Bed is taken to mark approximately the base of the Cretaceous, the base of miospore Suite C occurs just above the Jurassic–Cretaceous boundary (text-fig. 4). At Mountfield, the Jurassic–Cretaceous boundary on palynologic evidence would be placed at about the top of the Main Gypsiferous Beds. Hence the gypsiferous series at Mountfield appear to correlate at least in part with the Cinder Bed of Dorset (text-fig. 4). This is considerably different from the correlations suggested by Howitt (1964) who equated the gypsiferous series at Mountfield with the gypsum developed in the middle of the Lower Purbeck at Durlston, more than 100 ft. below the Cinder Bed. Howitt correlated the Cinder Bed of Dorset with a 5-ft. marine limestone containing *Ostrea distorta*, 182 ft. above the top of the Main Gypsiferous Beds. This 5-ft. limestone in fact would correlate with a horizon in the Chief Beef Beds at Durlston, assuming the palynologic correlation is correct and sedimentation was twice as rapid at Mountfield compared with Durlston (see the preceding sections). Dinoflagellate cysts and acritarchs occur in samples from the Chief Beef Beds of Durlston Bay (Norris 1963) suggesting marine influence at these horizons and supporting the above correlation. Dinoflagellate cysts and acritarchs also occur in small quantities in the Main Gypsiferous Beds of Mountfield but comparisons with acid-insoluble microfossil assemblages from the Cinder Bed of Dorset is not possible because this limestone bed has proved to be barren of palynomorphs. If the microfloral correlation is correct it suggests that the entire Purbeck sequence in Sussex is Early Cretaceous in age (text-fig. 5), accepting Casey's selection of the Cinder Bed in Dorset as a marker horizon for the base of the Cretaceous. More detailed work is required in the Mountfield area to refine the correlations suggested here.

COMPARISON WITH OTHER JURASSIC AND CRETACEOUS ASSEMBLAGES

Britain

Couper (1958) noted that the spore-pollen assemblages from the Kimmeridgian of Brora (Scotland) are impoverished in both number of species and specimens and in general are similar to Oxfordian assemblages from Yorkshire and to Middle Callovian assemblages from Brora. Although details on only three Kimmeridgian assemblages, one Oxfordian assemblage, and one Callovian assemblage are available, the data are sufficient to make a general comparison. All these Upper Jurassic assemblages (the Callovian is classed variably as either Middle or Upper Jurassic by different workers) are characterized by the dominance of *Abietineaepollenites minimus* and *Abietineaepollenites microalatus* Couper. This contrasts sharply with Suite A in the Upper Kimmeridgian and Portlandian of Dorset in which *Classopollis torosus* and *Inaperturopollenites dubius* are dominants or co-dominants. Couper's Callovian, Oxfordian, and Kimmeridgian assemblages are clearly distinguished from the Dorset Upper Jurassic assemblages by the presence of *Sestrosporites irregulatus* (Couper) Dettmann, *Cingulatisporites dubius* Couper, and *Pteruchipollenites microsaccus* Couper. These three species are unknown in the Upper Kimmeridgian, Portlandian, or Purbeck Beds of southern England. Of the approximately twenty remaining species in Couper's assemblages, a little more than half are pteridophyte spores, just less than half are conifer grains and the rest are cycads or pteridosperms. All of these occur in younger strata but the following are absent in Suite A: *Cyathidites australis* Couper, *Dictyophyllidites harrisii* Couper, *Densoisporites perinatus* Couper, *Duplexisporites problematicus* (Couper) Playford and Dettmann; the distance of the parent vegetation from the site of marine deposition in Dorset may have been important in determining what miospores entered the sediment. With the onset of estuarine and non-marine conditions in southern England in the Upper Tithonian and Lower Cretaceous these species presumably were able to reach the depositional sites more easily. Species present in Suite A which are not known in Couper's Middle or Upper Jurassic assemblage include *Exesipollenites scabrosus* sp. nov., *Inaperturopollenites* sp., *Classopollis echinatus*, *Classopollis hammenii*, *Rubinella major*, *Reticulisporites semireticulatus*, *Klukisporites pseudoreticulatus*, *Cicatricosisporites australiensis*, *Coronatispora valdensis*, *Podocarpidites* sp. cf. *P. ellipticus*, *Callialasporites dampieri*, *Callialasporites obrutus*, *Callialasporites* sp., *Peltandripites tener*, *Eucommiidites minor*, *Cycadopites* sp. cf. *C. nitidus*.

Couper (1958) and Hughes (1958) summarized the main differences between the



TEXT-FIG. 5. Correlation chart of strata close to the Jurassic–Cretaceous boundary in north-west Europe.

Wealden microflora and the Purbeck assemblages known at that time. Many of their conclusions are invalidated by the present study. Of the six species stated to characterize the Wealden, five are now known to occur in the Purbeck or Upper Jurassic (particularly in Suite C but some also in Suites A and B), viz. *Trilobosporites apiverrucatus*, *Parvisaccites radiatus*, *Appendicisporites potomacensis* (= *A. tricornitatus* of Couper 1958 in part), *Cicatricosisporites brevilaesuratus*, and *Coronatispora valdensis*. *Concavisporites punctatus* was reported by Couper (1958) and by Hughes (1958) to range down to the base of the exposed Fairlight Clay and this species is not known in the Purbeck Beds. Apart from this species, however, the Fairlight Clay assemblages are closely similar to those of Suite C, as far as it is possible to judge from Couper's descriptions. The numerical dominants in the Fairlight Clay, however, are quite different: about 70% of the grains are filicalean spores and the remainder are *Abietineaepollenites*, contrasting with the abundance of *Inaperturopollenites dubius* in the Upper Purbeck. The possibility that the Fairlight Clay at least in part is a lateral facies equivalent of the upper part of the Purbeck Beds should be considered in view of recent palynological correlations suggested by Hughes and Moody-Stuart (1969). Numerical differences could be due to the clastic facies of the Fairlight Clay compared with the finer grained lithologies in the Purbeck (limestone and shale).

Germany and Holland

Comprehensive accounts of the palynology of strata close to the Jurassic–Cretaceous boundary have been given by Döring (1965) for north-central Germany and by Burger (1966) for the eastern Netherlands. Several difficulties, however, are involved in making comparisons with other areas. Strata close to the British Jurassic–Cretaceous boundary show relatively restricted spore-pollen assemblages. This is due either to distance from the site of the vegetation in the case of the marine sediments or to the apparently restricted and perhaps specialized nature of the coastal vegetation in the case of the estuarine and non-marine sediments. The assemblages described from the continent appear to be more diverse which in part may be a taxonomic effect due to the less conservative approach to miospore variability adopted by those continental workers. But much of this diversity appears to be a real reflection of richer parent vegetation. Detailed comparisons of individual ranges of miospores between Britain and the Dutch and German localities is not appropriate for stratigraphic purposes in this case because palaeophytogeography or palaeoecology appear to have been important in controlling miospore distribution. A general comparison of the continental palynologic sequences with the palynologic suites recognized in southern England may yield more meaningful results.

Burger (1966) studied two cored sections of uppermost Jurassic and lowermost Cretaceous strata located on the western edge of the Lower Saxon Basin in the Twente area of Holland. He recognized 9 pollen zones spanning the higher Upper Malm (conventionally placed in the Tithonian, e.g. Arkell 1956) and the predominantly non-marine 'Wealden' up to the next fully marine horizon in the Middle Valanginian. Burger noted that his 9 pollen zones based on appearances and disappearances of miospore species may have only local significance. Of the 88 species occurring in the Dutch sequence, only 29 species are common to the Upper Jurassic–Purbeck sequence in England. All but 6 of these species range from Upper Malm to Middle Valanginian. Of the 6 species of restricted range, all are present in the Upper Malm but do not occur higher than the lower part of the Middle Valanginian. Thus the following 29 species occur from Upper Malm to the base of Middle Valanginian sediments in Holland and also occur in the Upper Kimmeridgian–Purbeck of England:

Cyathidites minor, *C. australis*, *Deltoidospora rafaeli**, *Concavisporites juriensis***, *Dictyophyllidites equiexinus*, *Osmundacites wellmanii*, *Rubinella major*, *Lycopodiumsporites austroclavatidites*, *Coronatispora valdensis*, *Reticulisporites semireticulatus*, *Plicatella abaca**, *Trilobosporites bernissartensis***, *T. apiverrucatus***, *Gleicheniidites senonicus*, *Callialasporites dampieri*, *C. trilobatus***, *Abietineaepollenites minimus*, *Parvisaccites radiatus**, *Vitreisporites pallidus*, *Cerebropollenites mesozoicus*, *Eucommiidites troedssonii*, *E. minor*, *Monosulcites minimus***, *Araucariacites australis*, *Spheripollenites subgranulatus**, *Perinopollenites elatoides*, *Classopollis torosus*, *C. echinatus*, *C. hammenii*.

Twenty of the species in the above list occur in Suites A, B, or C in England. Species marked * occur only in Suites B and C and species marked ** occur only in Suite C. Two of the latter in England are comparable with but not identical to the Dutch forms (*Callialasporites trilobatus* and *Monosulcites minimus*). Thus apart from the presence of *Trilobosporites apiverrucatus*, *T. bernissartensis*, *C. trilobatus*, and *Monosulcites minimus* the species from the Upper Malm that also occur in England suggest a correlation with Suite B. If the presence of the few Suite C species is considered significant, a correlation of this sequence with Suite C is indicated. But approximately forty other species also occur in the Upper Malm of Holland that are not known in the Kimmeridgian–Purbeck sequence of England. Of particular significance amongst these forms is *Peromonolites asplenioides* Couper. This species was reported by Couper (1958) to occur in the higher parts of the Wealden but not in the Fairlight Clay, Ashdown Sand, Wadhurst Clay or Tunbridge Wells Sand (i.e. this species occurs in the Barremian–Aptian using Hughes 1958 correlation). In view of the local variations in entrances of particular species, evidence from one species alone is not usually adequate for stratigraphic correlation. However, the presence of this species down to the Upper Malm together with the evidence from the microfloras reviewed above suggests that the Dutch Upper Malm microflora is probably no older than Suite C of England and may be younger.

Döring (1965) gave details of the stratigraphic ranges of 109 spore species (mostly trilete) in 7 boreholes penetrating strata close to the Jurassic–Cretaceous boundary from an area about 50 miles east of Hamburg, Germany. His section extended from the Upper Malm (Serpulite) to Wealden G which Döring equated with Wealden 5 and 6 of the standard NW. German sequence i.e. immediately underlying the Middle Valanginian. Only 12 of these species are known in Suites A, B, and C of England and of these, the following range from Upper Malm to Wealden G:

Dictyophyllidites equiexinus, *Osmundacidites wellmanii*, *Pilosisporites trichopapillosus*, *Klukisporites pseudoreticulatus*, *Coronatispora valdensis*, *Trilobosporites bernissartensis*, *Cerebropollenites mesozoicus*.

In England all these species occur in Suites A, B, and C except *Trilobosporitites bernissartensis* and *Pilosisporites trichopapillosus* which only occur in Suite C, suggesting a correlation of the Upper Malm (Serpulite) with Suite C. This correlation is reinforced by the entrance in Wealden A (overlying the Serpulite) of *Duplexisporites problematicus*, *Aequitriradites radiatus*, and *Cicatricosisporites angicanalis*. All these species appear in England in Suite C. *Trilobosporites apiverrucatus* does not appear in the German sequence until Wealden G however, compared with Suite C in England. Thus on the basis of trilete spores, the Serpulite and Wealden A (= Wealden 1) of Germany correlate with Suite C of England. Correlations between the English, Dutch, and German sequences are shown in text-fig. 5, incorporating palynologic correlations in the scheme based on ostracods by Anderson (1955, 1962).

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GEOFFREY NORRIS
Department of Geology
University of Toronto
Ontario, Canada

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