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8 Palynofacies and salinity in the Purbeck and Wealden of southern England

D. J. Batten

Many associations between components of palynological preparations and lithofacies in the Purbeck Beds and Wealden (uppermost Jurassic–Lower Cretaceous) of southern England have been recognised and are progressively being employed to aid the identification of depositional environments. Detailed sampling has led, in particular, to the recovery of numerous assemblages of phytoplankton. All are taxonomically restricted and none has a fully marine aspect. Both numerical and compositional variations suggest near-marine to perhaps only slightly brackish and freshwater conditions of deposition. Selected aspects of these and other palynofacies studies are discussed and illustrated.

Introduction

I first became interested in palynology as a student enrolled in Professor Barnard's MSc course in micropalaeontology at University College London. In common with others on the course, I was given (by Dr, now Professor, W. G. Chaloner) a rock sample from an unspecified locality and asked to prepare it for palynological analysis, write a report on what I found and determine its age. The sample turned out to be from the early Cretaceous Hastings Beds Group of southeastern England (Fig. 8.1). My enthusiasm for this project caused me to follow it up with a study of the facies distribution of British Wealden palynomorphs under the supervision of Dr N. F. Hughes. My interest in palynofacies (palynological facies) has continued ever since and hence seemed an appropriate subject for my contribution to this volume.

The term palynofacies was coined by Combaz (1964). Although criticised by Sigal (1965), subsequent papers by Correia (1967, 1969, 1971), Kieser (1967) and other French workers showed that the identification of the main organic components of sedimentary rocks which comprise palynofacies were of value both in the analysis of source potential for petroleum and for palaeoecology. Hughes saw in palynological facies a means of refining local biostratigraphic correlation and an aid to palaeoenvironmental interpretation (Hughes & Moody-Stuart 1967a,b). As a result, my research on Wealden palynofacies was aimed mainly at finding a means of recognising different kinds of miospore assemblages and correlating these with depositional environments. Papers orientated towards both biostratigraphy and palaeoecology were the end-products (e.g. Batten 1968, 1969, 1973a&b, 1974).

When I began work on Wealden palynomorph distributions (in 1966), literature relating to the subject was very limited in scope. To be sure, palaeoenvironmental conclusions based on spore and pollen associations had been published for Pleistocene to Holocene and some Carboniferous sequences but little was directly relevant to my proposed analysis of the total organic recovery from rock samples as seen in transmitted light. I was, however, able to find useful comparative data in a number of papers on the distribution of phytoclasts in aqueous suspension and Recent sediments, including those by Muller (1959), Rossignol (1961), Cross *et al.* (1966), Groot (1966), Spackman *et al.* (1966), Traverse and Ginsburg (1966) and Williams and Sarjeant (1967), and on pre-Quaternary distributions, e.g. Neves (1958), Tschudy (1961), Smith (1962), de Jekhowsky (1963a&b), Upshaw (1964), Marshall and Smith (1965), Muir (1967), Hughes and Moody-Stuart (1967a), Chaloner (1968) and Chaloner and Muir (1968).

During the past decade, interest in the organic content of sedimentary rocks as seen in transmitted light has increased considerably, mainly in connection with organic maturation and petroleum source potential studies. References to 'visual kerogen analyses' are now commonplace in the petroleum geology literature. Articles in which consideration is given to the relationships between the distribution of organic matter and depositional environments are also beginning to appear more frequently, although only rarely (e.g. Habib 1979) does the subject constitute the main theme. In the light of current interest in the field I take this opportunity both to summarise past work and to discuss some aspects of Purbeck and Wealden (mostly Lower Cretaceous) palynofacies and their palaeoenvironmental significance in the light of new data.

Initially (in 1966–69) I spent much time trying to determine a satisfactory basis on which to distinguish Wealden palynological assemblages. Samples were collected from scattered localities in the Wealden district and selected from a few borehole cores. The majority came from the Hastings Beds Group, and the Wadhurst Clay was studied in detail (Fig. 8.1; Batten 1968). Subsequent work has included an examination of further material from the Hastings Beds, but has been concentrated on the older Purbeck Beds and the younger Weald Clay in the south-east of England and Wealden Marls and Shales of the Isle of Wight (Fig. 8.3). Recurrent associations between palynological entities and depositional environments have received particular attention. This has led to several interesting new discoveries, particularly concerning salinity variations in the Wessex–Weald Basin; some of these are discussed herein.

Previously I have relied largely on verbal description and illustration of selected components to describe palynofacies. I do, however, find that,

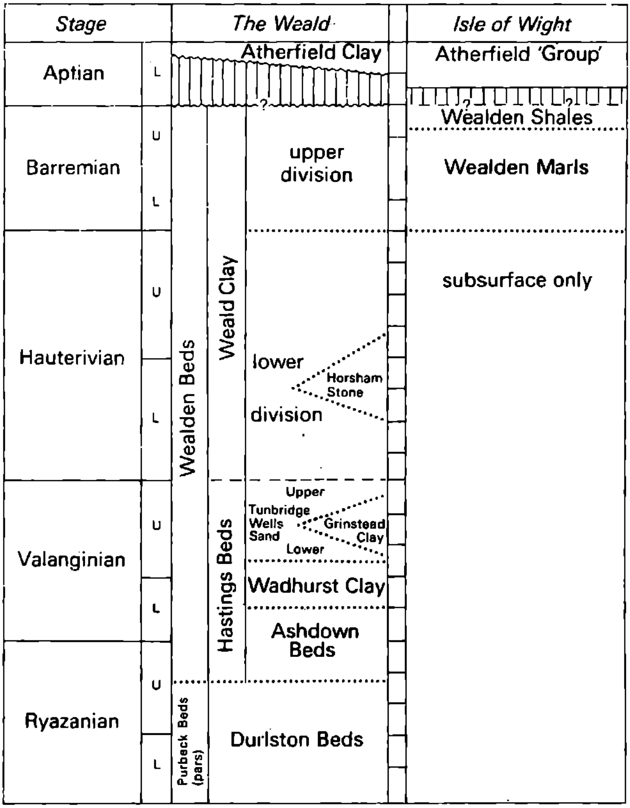

Figure 8.1 Provisional correlation with marine stages of part of the Purbeck Beds, the Wealden and the lowest division of the Lower Greensand of southeastern England and the Isle of Wight (adapted from Rawson *et al.* 1978, Fig. 3).

when accompanied by a few descriptive remarks, photographs showing the main characters have considerable practical value for reference. Although the accumulation of tabulated data is a necessary part of the procedure of organic facies analysis, annotated photographs are at least as convenient to use routinely as tables of relative abundance, if not more so. The discussion which follows is accompanied by a number of illustrations representing just a few of the many preparations which have been examined.

Geology

The uppermost Jurassic–Cretaceous rocks of the UK are mostly restricted in outcrop to the east and south of England, where they represent marginal extensions of three major offshore structures. One of these, the Wessex–

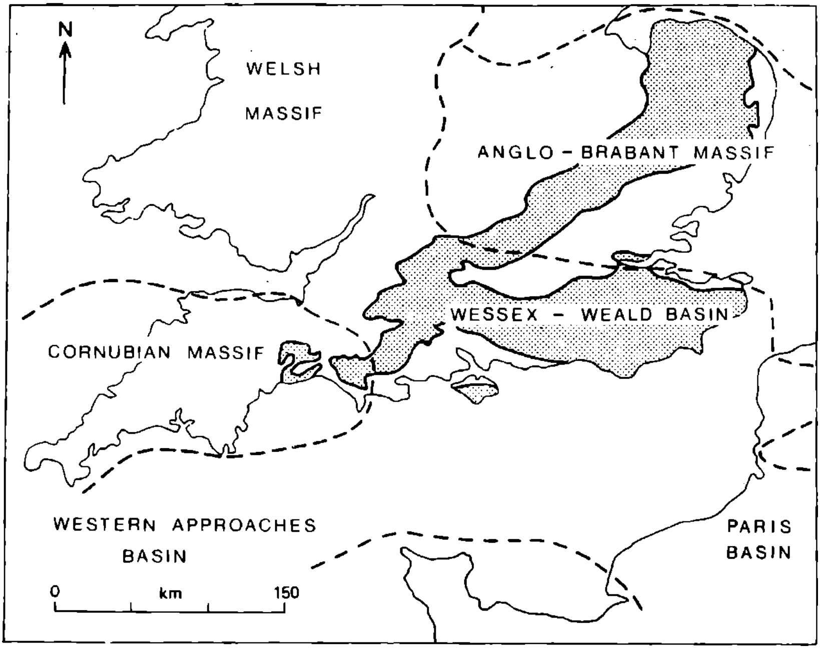

Figure 8.2 Structural setting of the Cretaceous deposits of southern England (adapted from Rawson *et al.* 1978, Figs 1, 2).

Weald Basin to the south of the Anglo-Brabant Massif (Fig. 8.2), was essentially non-marine from early Cretaceous Ryazanian/Berriasian to Barremian times. The base of the Cretaceous in southern England is taken to be the Cinder Beds of the Middle Purbeck (see Anderson & Bazley 1971, Casey 1973). The under- and overlying strata are termed the Lulworth and Durlston Beds respectively (Townson 1975). Whilst these divisions are appropriate for Dorset, they are less satisfactory for the Wealden district where, because the Cinder Beds horizon is not easy to identify (Anderson & Bazley 1971), their use is not accepted by all (see Lake & Holliday 1978). The boundary between the Upper Purbeck and the Wealden Beds in the south-east is gradational and thus also difficult to recognise. This led Allen (1975) to include the 30–70 m or so of Durlston Beds Formation in the Hastings Beds Group, although Rawson *et al.* (1978) maintain their separation (Fig. 8.1).

The overall structure of the Weald is a shallow dome, usually described as an anticlinorium. At its core approximately 70 m of the upper Ashdown Beds are exposed (Lake 1975), but faulting brings the Purbeck Beds to the surface in small inliers in the vicinity of Mountfield, Sussex (Fig. 8.3). The Ashdown Beds Formation comprises part of the Hastings Beds Group, a variable succession of argillaceous and arenaceous units which reaches a maximum thickness of approximately 430 m near the centre of the Weald. The overlying Weald Clay Group consists largely of argillaceous rocks and is

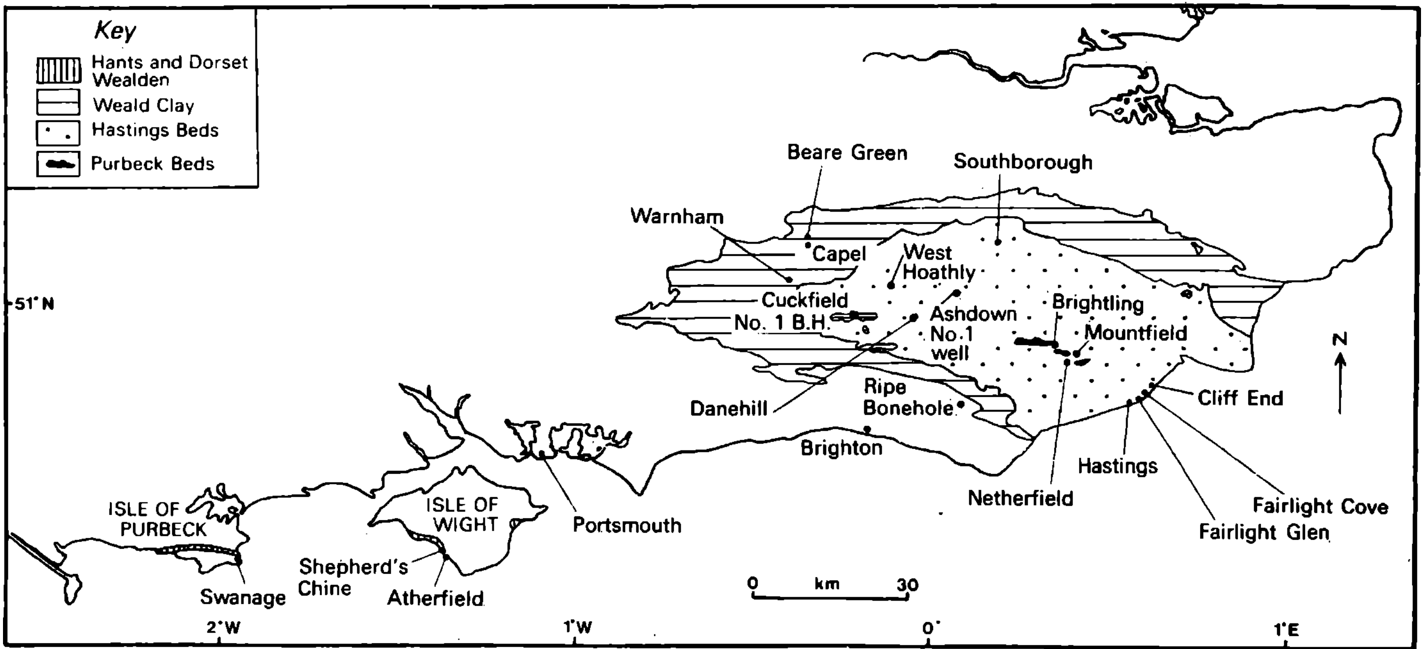

Figure 8.3 Map of southern England showing the areal extent of the Purbeck and Wealden and the places mentioned in the text.

thickest in the western Weald where it may attain 460 m (Thurrell *et al.* 1968, Lake 1975).

To the west of the Wealden district the pre-Aptian Lower Cretaceous succession on the Isle of Wight and in Swanage Bay, Dorset, is of similar thickness to that in the south-east. Although referred to as Wealden, the lithological subdivision of the Wealden district is not recognisable in this region. Further west still it rapidly becomes thinner and more arenaceous. On the Isle of Wight only the top 220 m or so of Wealden strata crop out, the succession being well exposed on the southern coast. The upper 50–60 m belong to the Wealden Shales, the remainder to the Wealden Marls (Fig. 8.1).

Purbeck Beds palynofacies

The Purbeck is made up of sediments which accumulated at a time of major regression following a phase of late Jurassic marine deposition. In Dorset gypsiferous evaporites formed low in the succession, but have since been largely replaced by carbonate and partly removed by solution (West 1975). Evaporites are, however, still present in the Mountfield Purbeck Beds of the Wealden district, where the basal part of the formation comprises some 15–20 m of mudstones, limestones, gypsum and anhydrite (Howitt 1964; Holliday & Shephard-Thorn 1974; Lake & Holliday 1978).

Palynological preparations from the Lower Purbeck in both the Weald and Dorset are usually dominated by *Classopollis* pollen grains, often occurring in tetrads (Pl. 8.1a). Associated palynomorphs tend to be mostly other gymnosperm pollen, particularly bisaccates and *Inaperturopollenites*. The abundance of *Classopollis* in samples adjacent to and within the evaporite beds (Norris 1969; M. A. Partington, in preparation) implies that the pollen grains are derived from a cheirolepidiaceous-dominated vegetation which was able to tolerate dry conditions. The climate may have been fairly arid–warm temperate, perhaps similar to that of present-day northern North Africa. The lowland Dorset vegetation was, at least for some of the time, dominated by trees whose wood has been referred to *Cupressinoxylon* and associated foliage compared with *Cupressinocladus* (Francis 1980) but whose male cones have yielded *Classopollis*. At least some of the plants which flooded these Purbeck lagoons with *Classopollis* seem, therefore, to have been arborescent, but at other times and in other places the Cheirolepidiaceae may also have been represented by shrubs (Batten 1976, Watson 1977).

This evaporite phase was followed by a period of less extreme conditions when a rhythmic series of shales, silts, current-bedded sandstones and limestones was deposited in waters of varying salinity. In the Mountfield area the Middle Purbeck horizon that is equivalent to the Dorset Cinder Beds consists of interbedded mudstones and limestones. These contain an invertebrate macrofauna that includes the bivalve *Praeexogyra* from which it is inferred that salinities were relatively high at this time (Lake & Holliday

1978). At other levels the occurrence of rootlet beds and sandstones which have erosive lower contacts (Allen 1975) implies a freshwater influence on the depositional environment. This is also suggested in palynological preparations by the lack of dinoflagellate cysts and the presence of algal masses of the *Botryococcus* type (Pl. 8.1b–d). Intermediate mildly saline conditions may be indicated by the occurrence of the palynomorph *Celyphus rallus* Batten (see below and Pl. 8.9a) and a few acritarchs and dinoflagellates (under investigation). Both *C. rallus* and *Botryococcus* masses also occur in, and are sometimes important components of, the Purbeck Beds in Dorset.

In addition to these microfossils, the palynomorph assemblages recovered from the Middle–Upper Purbeck in Sussex often contain large numbers of *Classopollis* pollen, though these grains are not quite as numerous as they are in the evaporite beds below. Other gymnosperm pollen, particularly bisaccate and inaperturate species, may also be very abundant (Pl. 8.2a). Pteridophyte spores are moderately varied in their morphology, but overall they are numerically subordinate to gymnospermous grains.

Hastings Beds palynofacies

The Hastings Beds consist mainly of light-coloured fine-grained sandstones and siltstones with subordinate shales and mudstones. The several formations into which the group has been divided vary in thickness and lithological content; whilst not recognisable throughout the district because of facies changes, they are nevertheless mappable over large parts of it. A variety of depositional environments is represented and these have received much attention during the past few decades, notably from Professor P. Allen. Originally thought to represent a deltaic pile, Allen is now of the opinion that the succession is dominated by braided alluvival sand plain and muddy alluvial and lagoonal facies (Allen 1959, 1967, 1975). However, this model has not yet wholly convinced all of those who have specialised in Wealden geology (see Lake 1976, Lake & Young 1978).

Hastings Beds palynofacies seem to show even more variation than the sedimentary facies. I now consider selected aspects of a few of these which are important from the general palaeoenvironmental standpoint.

Some of the best preserved miospore assemblages have been isolated from channel-fill deposits. These are most common in the Ashdown Beds and Tunbridge Wells Sand. Pteridophyte spores tend to dominate the assemblages. Cuticles (Pl. 8.2b), brown-black 'woody tissues' (vitrinite) and other 'humic' matter (Pls 8.2c, 8.6e&f), megaspores (Pl. 8.3a) and other 'large' plant microfossils (Pl. 8.4a–d) may also be abundant. A few channel deposits yield many hundreds of megaspores per 100 g of rock (Pl. 8.3a). The horizons concerned are light-medium to dark grey siltstones bearing plant debris dispersed at all angles. They readily disaggregate in water or in a solution of 'Regent' soft soap.

The composition and preservation of assemblages in channel deposits does, however, vary considerably according to the grain size and sorting of the sedimentary infill, and their general aspect may not be clearly distinct from palynofacies representing other depositional environments.

At outcrop, large parts of the Ashdown Beds and Tunbridge Wells Sand are commonly too coarse grained, well sorted and weathered to be of much palynological interest. However, where more argillaceous facies are developed locally, as in the Ashdown Beds along the coast east of Hastings (Fig. 8.3), miospores are usually recovered in large numbers (Batten 1973a, 1974). The state of preservation of the palynomorphs again varies widely. Although gymnosperm pollen grains are often abundant (Pls 8.3b&5a) the triradiate spore assemblages are more varied, reflecting what must have been a diverse lowland pteridophyte flora. Some are dominated by species or groups suggesting derivation from local vegetation. I have previously considered those in which *Trilobosporites* (Pl. 8.5b–d), *Pilosisporites* (Pl. 8.6a), *Concavissimisporites* (Pl. 8.6d), and *Cicatricosisporites* (Pl. 8.7a) are common to be key forms in the identification of assemblage types (Batten 1973a), but many others not selected for this purpose may also be abundant (e.g. Pl. 8.6b,c,e&f).

By contrast, the Wadhurst and Grinstead Clays yield miospore assemblages which are generally rather poorly preserved and taxonomically, though not numerically, impoverished (Pl. 8.7b&c). Usually gymnosperm pollen grains are dominant, and the triradiate spores are less varied than those of the Ashdown Beds and Tunbridge Wells Sand (Batten 1974). However, beds containing the 'horsetail' *Equisetites in situ* and adjacent horizons do yield rather different and distinctive assemblages (Pl. 8.8a; see also Batten 1968, 1973b), and there are also other preparations of note. A few samples have yielded large numbers of megaspores, mostly of the genus *Minerisporites* (Pl. 8.4k). Many more contain an abundance of *Classopollis* (Pl. 8.8b). By contrast with the Ashdown Beds and Tunbridge Wells Sand, which overall yield fewer pollen grains of this genus, assemblages from the transgressive Wadhurst and Grinstead Clays may be dominated by them. There seems to be a direct correlation between increased *Classopollis* representation and transgressive phases of deposition (Batten 1974; see also Médus & Pons 1967, Hughes & Moody-Stuart 1967a). *Classopollis* recovered from Ashdown and Tunbridge Wells Sand facies might have been produced by plants which coexisted with, but were not dominant in lowland communities. On the other hand, large quantities of *Classopollis* in association with an abundance of bisaccate and other gymnosperm pollen in Wadhurst and Grinstead assemblages may suggest a hinterland source for at least some of the components (Batten 1974).

Superabundance of *Classopollis* has been correlated with arid conditions (Vakhrameev 1970, and others). The overall lessening of the importance of this pollen during the earliest part of the Cretaceous is accompanied by an increase in the diversity of pteridophyte spores. Both phenomena suggest a climatic change to wetter conditions in the Wessex–Weald area which may well have been partly related to increased elevation of the London–Belgium ridge. As Allen (1975, 1976) has pointed out, the nature and extent of the fluvial deposits of the Hastings Beds Group suggest widely fluctuating rainfall.

In addition to the large numbers of degraded palynomorphs that occur in Wadhurst and Grinstead preparations, black wood fragments are also abundant. Some, perhaps much, of this debris may be charcoal produced by fire (Pl. 8.8d; compare with modern fragmented charcoal, Pl. 8.8c). I believe that all the palynological facts support the interpretation of the Wadhurst and Grinstead Clays as largely oxidised transgressive accumulations (Allen 1976). During these periods, the upland relief was low, the basin was subsiding, and the waters shallow and liable to fluctuate in salinity (Anderson *et al.* 1967, Allen *et al.* 1973). Although there is generally little positive evidence of marine influence on the depositional environment in the majority of the Wadhust palynological assemblages that I have examined, raised salinities are suggested by large quantities of dinoflagellate cysts at several horizons and, as noted earlier, it is possible that the occurrence of *Celyphus rallus* is also related to slightly saline phases.

C. rallus is rarely numerous in the Ashdown Beds and Tunbridge Wells Sand, whereas in the Purbeck Beds and in the Wadhurst, Grinstead and Weald Clays it is often present and sometimes abundant (Pl. 8.9a). It may be common in preparations which also contain dinoflagellate cysts. The affinity of this colonial organism remains uncertain (cf. Batten 1973a). I have compared it with various fungal remains and with modern and fossil loricae of presumed folliculinids (spirotrich ciliates). Any resemblance of individual specimens to the latter from offshore Belize (Pl. 8.8b&c) and from the Lower Cretaceous of Gabon (Pl. 8.8d) is probably superficial. Both fungal spores and folliculinids differ from *C. rallus* in the texture and colour of their walls. In transmitted light the outer surface of morphologically similar fungal spores is usually smoother. The Belize microfossils have thin smooth loricae. In thermally immature assemblages, fungal spores are generally darker in colour than associated pollen and spores of vascular plants. Likewise, the Gabonese Cretaceous ?folliculinids are significantly darker than the miospores, and the modern 'tests' have a blue-grey hue.

Indications of marine influence on the depositional environment in the form of dinoflagellate cysts, acritarchs, tasmanitids and foraminiferal linings do occur in the Ashdown Beds and Tunbridge Wells Sands but they are uncommon, and the dinoflagellates are often clearly reworked from older (Jurassic) strata. That the western Weald may have received transgressive saline pulses more frequently than further east (Allen 1976) is at least partly borne out by the recovery of several rich phytoplankton assemblages from the Grinstead Clay in the west. They comprise large numbers of only a few taxa and are not of typical marine aspect. Most of the species recorded to date from both the Wadhurst and Grinstead Clays are referable to the dinoflagellates *Muderongia* (Pls 8.8d, 8.10a), *Cyclonephelium*, and *Can-*

ningia, the acritarchs *Micrhystridium* and *Veryhachium* and to a 'simple sacs' category (cf. below).

Weald Clay palynofacies

The Weald Clay Group consists mainly of clay and silty clay, but also includes beds of sandstone, shelly limestone and clay ironstone. Water depths in the basin may occasionally have been somewhat greater during Weald Clay times than previously although Allen (1975) maintained that they seldom exceeded 2–3 m. The occurrence of mottled clays, suncrack and rootlet horizons, and beds with *Equisetites* and possibly other plants in position of growth (Allen 1959, 1975, Kennedy & MacDougall 1969, and others) lends some support to this suggestion, but they are less common than in the Hastings Beds.

Sedimentation was apparently governed by fluctuating fluvial and marine processes in a steadily subsidising basin. There is both invertebrate and palaeobotanical evidence to suggest that salinities varied more widely than during Hastings Beds deposition. A fossil series which includes *Equisetites, Viviparus, Filosina, Cassiope* and *Praeexogyra* is thought to indicate increasing salinity (see Allen *et al.* 1973, Morter in Worssam 1978). It is thus significant that *Equisetites lyellii* (Mantell) in position of growth is much more common in the Wadhurst than in the Grinstead and Weald Clays, and that *Neomiodon* is replaced by *Filosina* (Casey 1955, Allen 1975) in the lower Weald Clay. In addition most of the non-marine cyprid ostracods which characterise Hastings Beds assemblages are not found in the younger group (Anderson 1967, 1973). Although salinities fluctuated widely, these facts seem to indicate a change to generally more saline conditions of clay deposition, at least during the Hauterivian, in the western part of the Weald. It has long been known that a few horizons near the top of both the lower and upper divisions of the Weald Clay and the Wealden Shales of the Isle of Wight are brackish – marine (see Kilenyi & Allen 1968, Allen *et al.* 1973).

These general conclusions are broadly supported by the palynofloras. The 'marine bands' in the Weald Clay near Capel and Warnham (both Surrey, Fig. 8.3) have yielded large numbers of *Cribroperidinium* (Pl. 8.10b), *Cyclonephelium* cf. *C. distinctum* Deflandre and Cookson (Pl. 8.10d) and *Subtilisphaera terrula* (Davey) (Pl. 8.10e). Adjacent strata yield fewer of these 'marine' forms and varying quantities of an as yet unnamed peridiniacean cyst (Pl. 8.11d), a '*Cleistosphaeridium*' type (Pl. 8.11a), *Muderongia* (Pl. 8.11e), simple sacs (Pl. 8.11b) and *Celyphus rallus*, clearly indicating less saline conditions. Other strata yield only isolated microplankton or are entirely devoid of them.

The miospore assemblages associated with these restricted dinoflagellate 'populations' are normally dominated by bisaccate and other gymnospermous pollen. At best, their state of preservation is generally only fair, probably reflecting both deposition in oxidising environments and reworking. In the context of the latter, it is interesting that an abundance of Jurassic dinoflagellates has been recovered from samples adjacent to calcareous sandstones at Capel which contain burrows identified as *Ophiomorpha* and attributed to callianassid shrimps. This trace fossil has generally been considered to suggest marine conditions, at least during the period represented by the surface from which the burrows originate (Kennedy & MacDougall 1969, Dike 1972, Allen 1975), although its acceptance as a marine indicator has been questioned recently (Stewart 1978).

Other Weald Clay sections of different ages have also yielded numerous dinoflagellates at certain horizons, some of which are new (Pl. 8.11c&f). All will be described formally elsewhere.

Wealden Marls and Shales palynofacies, Isle of Wight

The Wealden Marls of the Isle of Wight (Figs 8.1&3) consist mainly of mottled reddish-purplish brown mudstones with subordinate beds of grey mudstone and siltstone, sandstone, limestone and conglomerate. The bulk is thought to be of fluvial origin (Stewart 1978, Daley & Stewart 1979). The mottled muds and silts are usually devoid of palynomorphs, or yield impoverished assemblages. However the grey argillaceous units are often rich in miospores (Pl. 8.12a) and, as in the Hastings Beds, some of the fine-grained channel deposits contain not only diverse well preserved assemblages but also large quantities of megaspores.

I have seen little palynological evidence of marine influence on the depositional environment except near the top of the formation. The interbedded sandstones and mudstones which make up the highest beds show a variety of sedimentary structures including trace fossils of the *Ophiomorpha* type. On the basis of the ostracod fauna, the presence of charophyte oogonia and sedimentological studies, Stewart (1978) suggested that the burrows were constructed by animals tolerant of low or fluctuating salinities. The recovery of assemblages containing numerous acritarchs and some dinoflagellates from horizons within these beds (Pls 8.11g, 12b&13a) does, however, suggest that at times conditions were more saline than hitherto.

The Wealden Shales are grey to greenish-grey mudstones with subordinate beds of clay ironstone, sandstone and shelly limestone. The grey colour and even bedding contrasts strongly with the variegated and massive marls below. Above the prominent Barnes High Sandstone (White 1921) the mudstones are often finely laminated with silt and rich in ostracods. The occurrence of *Viviparus, Unio, Filosina,* cyprid ostracods, remains of the fish *Hybodus* (Patterson 1966), and ferns (Alvin 1974, D. J. Batten, in preparation) suggests that deposition took place in a lagoon of varying salinity (Stewart 1978) not so very far from which plants were able to maintain a foothold. The Barnes High Sandstone is thought to be a river mouth bar (Daley & Stewart 1979). Near the top of the Wealden Shales, salinities apparently increased because oysters and the gastropod *Cassiope* are found, heralding the onset of the early Aptian marine trangression and deposition of the Lower Greensand.

The palynological assemblages isolated from the Wealden Shales are of varied composition reflecting the fluctuating salinities. As in the Weald Clay, relative abundances of *Cribroperidinium* and *Cyclonephelium* are associated with brackish-marine phases. Occurring with these marine genera and on their own are other plankton which were presumably able to tolerate less saline conditions (e.g. Pl. 8.13a).

Conclusion

The determination of sedimentary environments forms an important part of the research of many sedimentologists, but attention is generally concentrated on sandstones and limestones. I believe that the study of the organic contents of not only shales and siltstones, but also of limestones and the finer sandstones, can significantly aid the interpretation of sedimentary facies. Certainly the examples selected for discussion and illustration in this paper provide a basis for more reliable assessments of Purbeck–Wealden depositional conditions. Although I have not discussed palynofacies relationships in detail, bed by bed, the generalisations made are based on such data.

An important outcome of this work from the palynological viewpoint, on which I have placed some emphasis herein, has been the recognition of non-marine dinoflagellates. Although modern dinoflagellates are widely distributed in both freshwater and marine environments, with a few Tertiary exceptions, virtually all known fossil forms are considered to be marine or brackish-marine. Some Wealden cysts are clearly reworked from older strata (Pl. 8.13d&e). Some are identified as marine species (e.g. *Cyclonephelium distinctum*, *Subtilisphaera terrula*) which were presumably able to tolerate lower salinities. Others are referable to marine genera (e.g. *Muderongia*) but cannot be identified with any known species. Yet others are unknown in marine assemblages and are probably the cysts of dinoflagellates which thrived in brackish and/or fresh water. Not until the Perna Bed of the Lower Greensand was deposited do the assemblages take on a fully marine aspect (Pl. 8.13b,c&f).

Acknowledgements

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References

Allen, P. 1959. The Wealden environment: Anglo-Paris basin. *Phil Trans R. Soc. B* **242,** 283–346.

Allen, P. 1967. Origin of the Hastings facies in northwestern Europe. *Proc. Geol. Assoc.* **78,** 27–105.

Allen, P. 1975. Wealden of the Weald: a new model. *Proc. Geol. Assoc.* **86,** 389–437.

Allen, P. 1976. Wealden of the Weald – a new model. *Reply Proc. Geol. Assoc.* **87,** 433–42.

Allen, P., M. L. Keith, F. C. Tan and P. Deines, 1973. Isotopic ratios and Wealden environments. *Palaeontology* **16,** 607–21.

Alvin, K. L. 1974. Leaf anatomy of *Weichselia* based on fusainized material. *Palaeontology* **17,** 587–98.

Anderson, F. W. 1967. Ostracods from the Weald Clay of England. *Bull. Geol Surv. Gt Br.* **27,** 237–69.

Anderson, F. W. 1973. The Jurassic–Cretaceous transition: the non-marine ostracod faunas. In *The boreal Lower Cretaceous,* R. Casey & P. F. Rawson (eds), 101–10. Liverpool: Seel House Press.

Anderson, F. W. and R. A. B. Bazley 1971. The Purbeck Beds of the Weald (England). *Bull. Geol Surv. Gt Br.* **34.**

Anderson, F. W., R. A. B. Bazley and E. R. Shephard-Thorn 1967. The sedimentary and faunal sequence of the Wadhurst Clay (Wealden) in boreholes at Wadhurst Park, Sussex. *Bull. Geol Surv. Gt Br.* **27,** 171–235.

Batten, D. J. 1968. Probable dispersed spores of Cretaceous *Equisetites. Palaeontology* **11,** 633–42.

Batten, D. J. 1969. Some British Wealden megaspores and their facies distribution. *Palaeontology* **12,** 333–50.

Batten, D. J. 1973a. Use of palynologic assemblage-types in Wealden correlation. *Palaeontology* **16,** 1–40.

Batten, D. J. 1973b. Palynology of early Cretaceous soil beds and associated strata. *Palaeontology* **16,** 399–424.

Batten, D. J. 1974. Wealden palaeoecology from the distribution of plant fossils. *Proc. Geol. Assoc.* **85,** 433–58.

Batten, D. J. 1976. Wealden of the Weald – a new model. Written discussion of a paper previously published. *Proc. Geol. Assoc.* **87,** 431–3.

Batten, D. J. and G. L. Eaton 1980. Dinoflagellates and salinity variations in the Wealden (Lower Cretaceous) of southern England. *5th int. Palynol. Conf., Cambridge,* p. 32 (abstract).

Casey, R. 1955. The pelecypod family Corbiculidae in the Mesozoic of Europe and the Near East. *J. Wash. Acad. Sci.* **45,** 366–72.

Casey, R. 1973. The ammonite succession at the Jurassic–Cretaceous boundary in eastern England. In *The boreal Lower Cretaceous,* R. Casey & P. F. Rawson (eds), 193–266. Liverpool: Seel House Press.

Chaloner, W. G. 1968. The paleoecology of fossil spores. In *Evolution and environment*, 125–38. New Haven, Conn.: Yale University Press.

Chaloner, W. G. and M. D. Muir 1968. Spores and floras. In *Coal and coal-bearing strata*, D. G. Murchison & T. S. Westoll (eds), 127–46. Edinburgh: Oliver & Boyd.

Combaz, A. 1964. Les palynofaciès. *Rev. Micropaléont.* **7**, 205–18.

Correia, M. 1967. Relations possible entre l'état de conservation des éléments figurés de la matière organique (microfossiles palynoplanctologiques) et l'existence de gisements d'hydrocarbures. *Rev. Inst. Fr. Pétrole* **22**, 1285–306.

Correia, M. 1969. Contribution à la recherche de zones favorables à la genèse du pétrole par l'observation microscopique de la matière organique figurée. *Rev. Inst. Fr. Pétrole* **24**, 1417–54.

Correia, M. 1971. Diagenesis of sporopollenin and other comparable organic substances: application to hydrocarbon research. In *Sporopollenin*, J. Brooks, P. R. Grant, M. D. Muir, P. van Gijzel & G. Shaw (eds), 569–620. London: Academic Press.

Cross, A. T., G. G. Thompson and J. B. Zaitzeff 1966. Source and distribution of palynomorphs in bottom sediments, southern part of Gulf of California. *Marine Geol.* **4**, 467–524.

Daley, B. and D. J. Stewart 1979. Week-end field meeting: the Wealden Group in the Isle of Wight. *Proc. Geol. Assoc.* **90**, 51–4.

de Jekhowsky, B. 1963a. Répartition quantitative des grandes groups de "microorganontes" (spores, hystrichosphères, etc.) dans les sédiments marins du plateau continental. *C. R. Somm. Séanc. Soc. Biogéogr.* **349**, 29–47.

de Jekhowsky, B. 1963b. Variations latérales en palynologie quantitative et passage du continental au marin: le Dogger Supérieur du sud-ouest de Madagascar. *Rev. Inst. Fr. Pétrole* **18**, 977–95.

Dike, E. F. 1972. *Ophiomorpha nodosa* Lundgren: environmental implications in the Lower Greensand of the Isle of Wight. *Proc. Geol. Assoc.* **83**, 165–77.

Francis, J. 1980. The Purbeck Forest of the Great Dirt Bed of Dorset. *Int. Palaeobot. Conf. Reading*, p. 19 (abstract).

Groot, J. J. 1966. Some observations on pollen grains in suspension in the estuary of the Delaware River. *Marine Geol.* **4**, 409–16.

Habib, D. 1979. Sedimentary origin of North Atlantic Cretaceous palynofacies. In *Deep drilling results in the Atlantic Ocean: continental margins and palaeoenvironment*, M. Talwani, W. Hay & W. B. F. Ryan (eds), 420–37. Washington, D.C., American Geophysical Union.

Holliday, D. W. and E. R. Shephard-Thorn 1974. *Basal Purbeck evaporites of the Fairlight Borehole, Sussex*. Rep. Inst. Geol Sci. 74/4.

Howitt, F. 1964. Stratigraphy and structure of the Purbeck inliers of Sussex (England). *Q. J. Geol Soc. Lond.* **120**, 77–113.

Hughes, N. F. and J. C. Moody-Stuart 1967a. Palynological facies and correlation in the English Wealden. *Rev. Palaeobot. Palynol.* **1**, 259–68.

Hughes, N. F. and J. C. Moody-Stuart 1967b. Proposed method of recording pre-Quaternary palynological data. *Rev. Palaeobot. Palynol.* **3**, 347–58.

Kennedy, W. J. and J. D. S. MacDougall 1969. Crustacean burrows in the Weald Clay (Lower Cretaceous) of southeastern England and their environmental significance. *Palaeontology* **12**, 459–71.

Kieser, G. 1967. Quelques aspects particuliers de la palynologie du Supérieur du Crétacé Sénegal. *Rev. Palaeobot. Palynol.* **5**, 199–210.

Kilenyi, T. J. and N. W. Allen 1968. Marine-brackish bands and their microfauna from the lower part of the Weald Clay of Sussex and Surrey. *Palaeontology* **11**, 141–62.

Lake, R. D. 1975. The structure of the Weald – a review. *Proc. Geol. Assoc.* **86**, 549–57.

Lake, R. D. 1976. Wealden of the Weald – a new model. Written discussion of a paper previously published. *Proc. Geol. Assoc.* **87**, 827–9.

Lake, R. D. and D. W. Holliday 1978. *Purbeck Beds of the Broadoak Borehole, Sussex*. Rep. Inst. Geol Sci. 78/3, 1–12.

Lake, R. D. and R. G. Thurrell 1974. *The sedimentary sequence of the Wealden beds in boreholes near Cuckfield, Sussex.* Rep. Inst. Geol Sci. 74/2.

Lake, R. D. and B. Young 1978. *Borcholes in the Wealden Beds of ihe Hailsham area, Sussex.* Rep. Inst. Geol Sci. 78/23.

Marshall, A. E. and A. H. V. Smith 1965. Assemblages of miospores from some Upper Carboniferous coals and their associated sediments in the Yorkshire Coalfield. *Palaeontology* **7**, 656–73.

Médus, J. and A. Pons 1967. Étude palynologique du Crétacé Pyrénéo-Provençal. *Rev. Palaeobot. Palynol.* **2**, 111–17.

Muir, M. D. 1967. Reworking in Jurassic and Cretaceous spore assemblages. *Rev. Palaeobot. Palynol.* **5**, 145–54.

Muller, J. 1959. Palynology of Recent Orinoco delta and shelf sediments. *Micropaleontology* **5**, 1–32.

Neves, R. 1958. Upper Carboniferous plant spore assemblages from the *Gastrioceras subcrenatum* horizon, north Staffordshire. *Geol Mag.* **95**, 1–19.

Norris, G. 1969. Miospores from the Purbeck Beds and marine Upper Jurassic of southern England. *Palaeontology* **12**, 574–620.

Patterson, C. 1966. British Wealden sharks. *Bull. Br. Mus. Nat. Hist. (Geol.)* **11**, 281–350.

Rawson, P. F., D. Curry, F. C. Dilley, J. M. Hancock, W. J. Kennedy, J. W. Neale, C. J. Wood and B. C. Worssam 1978. *A correlation of Cretaceous rocks in the British Isles.* Geol Soc. Lond. Sp. Rep. no. 9.

Rossignol, M. 1961. Analyse pollinique de sédiments marins quaternaires en Israël. I. Sédiments Récents. *Pollen Spores* **3**, 303–24.

Sigal, J. 1965. Palynofaciès: un néologisme illogique et superflu. *Rev. Micropaléont* **8**, 59–60.

Smith, A. H. V. 1962. The palaeoecology of Carboniferous peats based on the miospores and petrography of bituminous coals. *Proc. Yorks Geol Soc.* **33**, 423–74.

Spackman, W., C. P. Dolsen and W. Riegel 1966. Phytogenetic organic sediments and sedimentary environments in the Everglades-mangrove complex. Part I: Evidence of a trangressing sea and its effects on environments of the Shark River area of southwestern Florida. *Palaeontographica B* **117**, 135–52.

Stewart, D. J. 1978. *Ophiomorpha:* a marine indicator? *Proc. Geol. Assoc.* **89**, 33–41.

Thurrell, R. G., B. C. Worssam and E. A. Edmonds 1968. *Geology of the country around Haslemere.* Mem. Geol Surv. Gt Br.

Townson, W. G. 1975. Lithostratigraphy and deposition of the type Portlandian. *J. Geol Soc. Lond.* **131**, 619–38.

Traverse, A. and R. N. Ginsburg 1966. Palynology of the surface sediments of Great Bahama Bank, as related to water movement and sedimentation. *Marine Geol.* **4**, 417–59.

Tschudy, R. H. 1961. Palynomorphs as indicators of facies environments in Upper Cretaceous and Lower Tertiary strata, Colorado and Wyoming. In *Guidebook, 13th Annual Field Conference,* 53–9 Geological Association of Wyoming.

Upshaw, C. F. 1964. Palynological zonation of the Upper Cretaceous Frontier Formation near Dubois, Wyoming. In *Palynology in oil exploration. A symposium,* Sp. Publs Soc. Econ. Palaeont. Miner., Tulsa, no. 11, 153–68.

Vakhrameev, V. A. 1970. Range and palaeoecology of Mesozoic conifers, the Cheirolepidiaceae. *Paleont. Zh.* **1**, 19–34. (In Russian.)

Watson, J. 1977. Some Lower Cretaceous conifers of the Cheirolepidiaceae from the USA and England. *Palaeontology* **20**, 715–49.

West, I. M. 1975. Evaporites and associated sediments of the basal Purbeck Formation (Upper Jurassic) of Dorset. *Proc. Geol. Assoc.* **86**, 205–25.

White, H. J. O. 1921. *A short account of the geology of the Isle of Wight.* Mem. Geol Surv. UK.

Williams, D. B. and W. A. S. Sarjeant 1967. Organic-walled microfossils as depth and shoreline indicators. *Marine Geol.* **5**, 389–412.

Worssam, B. C. 1978. *The stratigraphy of the Weald Clay.* Rep. Inst. Geol Sci. 78/11.

Plates

In this and subsequent plate captions in this chapter, stage co-ordinates refer to Leitz Dialux (LD) microscope number 322, Department of Geology and Mineralogy, Aberdeen University.

Plate 8.1 (a) Palynofacies in which degraded *Classopollis* pollen grains are dominant. These occur singly and in tetrads. Pale background detritus is undigested gypsum. Sample DJB 80/M1, a calcareous mudstone containing gypsum from British Gypsum Brightling Mine, Stonehouse ventilation shaft, Lower Purbeck Beds. Preparation MCP 1504.3, LD 34.3 120.9, ×225.

(b) Amorphous organic matter of non-marine (?algal) origin with algae of the *Botryococcus* type. Sample, a shaley mudstone from the Purbeck Beds, depth 219.2 m in Ashdown No. 1 well, drilled during 1954–55 by D'Arcy Exploration Company Ltd. Preparation DB 1197.2, LD 31.9 133.1, ×450.

(c) Alga of the *Botryococcus* type. Sample and preparation as above, LD 32.1 134.0, ×450.

(d) Alga of the *Botryococcus* type. Sample and preparation as above, LD 18.1 122.2, ×450.

Plate 8.2 (a) Palynofacies in which *Classopollis* and other gymnosperm pollen are abundant. Numerous tetrads of *Classopollis*. Much of the black detritus is probably fusinite (inertinite). Sample DJB 80/42, a calcareous shale from above the 'Cinder Bed' horizon, River Line stream section, Netherfield, Sussex. Preparation MCP 903.2, LD 43.3 122.2, ×135.

(b) Cuticle-rich palynofacies recovered from a siltstone in Fairlight Clays facies of the Ashdown Beds Formation on the coast east of the Fairlight anticline, Fairlight Cove. Sample DJB/CE 26, preparation MCP 618.2, LD 33.2 128.0, ×90.

(c) Plant debris/'humic'-rich palynofacies from a siltstone in Fairlight Clays facies, Fairlight Cove as above. Sample DJB/CE 30, preparation MCP 622.2, LD 31.1 124.9, ×90.

Plate 8.3 (a) Palynofacies in which small triradiate spores and megaspores (mostly *Minerisporites alius* Batten) are exceptionally abundant. *Botryococcus* s.l. and other possible freshwater algae referable to *Schizosporis reticulatus* Cookson and Dettmann (and another undescribed species) occur in association. Sample DJB/CE 12 from a channel-fill siltstone in the Ashdown Beds coastal section near Cliff End. Preparation MCP 527.2, LD 37.1 132.9, ×90.

(b) Gymnosperm (bisaccate) pollen-dominated palynofacies from a siltstone in Fairlight Clays facies of the Ashdown Beds coastal section east of the Fairlight anticline, Fairlight Cove. Sample DJB/CE 20, preparation MCP 535.2, LD 36.6 129.2, ×135.

Plate 8.4 (a),(d) Spore mass of *Trilobosporites* sp. Unregistered silty mudstone sample labelled CUC 971 from depth of 296 m in IGS Cuckfield No. 1 borehole, Ashdown Beds (see Lake & Thurrell 1974). (a) ×90; (d) detail, ×180.

(b),(c) Part of a sporangium-bearing smooth-walled triradiate miospores. Sample DJB 174, a siltstone from the Fairlight Clays facies of the Ashdown Beds near Fairlight Glen. (b) ×90; (c) detail, ×225.

(e)–(k) Megaspores.

(e) *Trileites* sp., ×90. Sample DJB 170, a siltstone from the Fairlight Clays facies of the Ashdown Beds near Fairlight Glen as above.

(f),(j) *Arcellites pyriformis* (Hughes), ×45. Sample CUC 971, see explanation of (a),(d) above.

(g),(h) *Hughesisporites galericulatus* (Dijkstra emend. Hughes). (g) ×90; (h) detail, ×225. Sample DJB 170, see explanation of (e).

(i) *Paxillitriletes alatus* (Batten), ×45. Unregistered silty mudstone sample labelled CUC 442 from depth of 134.7 m in IGS Cuckfield No. 1 borehole, Upper Tunbridge Wells Sand (see Lake & Thurrell 1974).

(k) *Minerisporites marginatus* (Dijkstra), ×135, from sample CUC 442 as above.

Plate 8.5 (a) Gymnosperm pollen-dominated palynofacies with algal mass of the *Botryococcus* type. Sample DJB/CE 6, a mudstone from the Ashdown Beds coastal section near Cliff End. Preparation MCP 514.2, LD 41.8 133.8, ×135.

(b),(c) *Trilobosporites* spp. Sample DJB/CE 17, a siltstone from the Ashdown Beds coastal section, Goldbury Point, Fairlight Cove. Preparation MCP 532.2: (b) LD 38.1 126.3; (c) LD 37.7 126.2, both ×450.

(d) Palynofacies in which species of *Trilobosporites* are unusually common. Sample and preparation as above, LD 37.3 126.1, ×135.

Plate 8.6 (a) *Pilosisporites trichopapillosus* (Thiergart) *s.l.* Sample DJB/CE 51, a siltstone from the Ashdown Beds coastal section near Cliff End. Preparation MCP 651.2, LD 34.5, 133.3, ×450.

(b) *Couperisporites* cf.*C. complexus* (Pocock). Sample and preparation as above, LD 21.9 132.2, ×450.

(c) *Triporoletes* sp. Sample and preparation as above LD 35.0 137.1, ×450.

(d) *Concavissimisporites* sp. Sample and preparation as above, LD 24.0 130.1, ×450.

(e) Miospore assemblage dominated by *Gleicheniidites*. Sample DJB/CE 25, a siltstone from Fairlight Clays facies of the Ashdown Beds coastal section east of the Fairlight anticline, Fairlight Cove. Preparation MCP 617.2, LD 29.7 125.2, ×135.

(f) Miospore assemblage dominated by smooth-walled triradiate spores. Sample DJB/CE 50, a siltstone from the Ashdown Beds coastal exposure northeast of Haddock's reversed fault near Cliff End. Preparation MCP 650.2, LD 23.2 122.2, ×135.

Plate 8.7 (a) Miospore assemblage dominated by species of *Cicatricosisporites*. Sample DJB/CE 33, a mudstone containing plant debris from the Fairlight Clays facies of the Ashdown Beds coastal section east of the Fairlight anticline, Fairlight Cove. Preparation MCP 627.2, LD 38.3 132.2, ×135.

(b) Typical Wadhurst Clay palynofacies. Miospores abundant but poorly preserved. Sample DJB 348A, a mudstone from the upper Wadhurst Clay, High Brooms pit, Southborough. Preparation A581.2, LD 36.9 126.8, ×225.

(c) Wadhurst Clay palynofacies with abundant miospores, the majority in a very degraded state. Sample DJB 80/47, a laminated siltstone containing vertebrate debris, upper Wadhurst Clay, Freshfield Lane Brickworks clay pit, Danehill. Preparation MCP 874.2, LD 29.8 121.0, ×135.

Plate 8.8 (a) Palynofacies in which cuticles and other tissues, and presumed spores of *Equisetites*, dominate; recovered from a plant fragment parting in mudstone associated with *Equisetites* in position of growth. Unregistered IGS sample CUC 792D from a depth of approximately 241 m in Cuckfield No. 1 borehole, Wadhurst Clay (see Lake & Thurrell 1974). Preparation T244.3, LD 49.1 129.1, ×135.

(b) *Classopollis*-rich palynofacies. Sample DJB 292, a mudstone from the upper Wadhurst Clay, High Brooms pit, Southborough. Preparation T224/7, LD 36.9 124.1, ×225.

(c) Fragmented modern charcoal. Sample DJB 80/M2, preparation MCP 1430.1, LD 40.2 126.9, ×135.

(d) Grinstead Clay palynofacies in which dinoflagellate cysts are abundant. Sample DJB 79/P3, a silty mudstone from the Lower Grinstead Clay of Philpots Quarry, West Hoathly. Preparation MCP 676.2, LD 35.1 124.4, ×135.

Plate 8.9 (a) *Celyphus rallus* Batten palynofacies. Unregistered IGS sample CUC 869, a mudstone from a depth of 264.8 m in Cuckfield No. 1 borehole, Wadhurst Clay (see Lake & Thurrell 1974). Preparation A281.1, LD 22.9 130.4, ×135.

(b),(c) Presumed folliculinids from bottom sediments, southern end of Tobacco Cay, offshore Belize. Sample/preparation JR 16: (b) LD 32.1 131.0; (c) LD 34.0 119.1; both ×135.

(d) Presumed fossil folliculinids from the Lower Cretaceous of Gabon. Sample/preparation A0757, LD 17.1 125.7, ×135.

Plate 8.10 (a) A ceratiacean cyst of the *Muderongia* type. Sample CSL/P12, a calcareous mudstone from the Lower Grinstead Clay of Philpots Quarry, West Hoathly. Preparation MCP 358.2, LD 29.9, 120.1, interference contrast, ×900.

(b) *Cribroperidinium* sp. Mudstone sample DJB 388, part of a 'marine band' containing the bivalve *Filosina* in the upper part of the lower division of the Weald Clay exposed in the Clockhouse Brickworks pit, Capel. Preparation A699.4, LD 24.1 135.1, ×900.

(c) *Cribroperidinium*-dominated palynofacies from 'marine band' sample DJB 158, a calcareous mudstone containing *Cassiope* from the lower division of the Weald Clay, Warnham Brick pit. Preparation T139.4, LD 11.0 124.9, ×135.

(d) *Cyclonephelium* cf. *C. distinctum* Deflandre and Cookson. Sample DJB 388, details as for (b) above. Preparation A699.4, LD 22.9 134.1, ×900.

(e) Peridiniacean cyst referable to *Subtilisphaera terrula* (Davey). Sample DJB 390, a mudstone from a 'marine band' in the upper part of the lower division of the Weald Clay exposed in the Clockhouse Brickworks pit, Capel. Preparation A701.3, LD 22.3 122.1, interference contrast, ×900.

Plate 8.11 (a) '*Cleistosphaeridium*'. Sample DJB 379, a calcareous shale from the upper part of the lower division of the Weald Clay exposed in Clockhouse Brickworks pit, Capel. Preparation A677.4, LD 46.7 128.6, interference contrast, ×900.

(b) Cyst type A, a 'simple sac' from the same sample and preparation as above, LD 57.8 124.8, ×900.

(c) Cyst type B from a calcareous mudstone sample, IGS Ripe Borehole, depth 170.4–171 m, Weald Clay (see Lake & Young 1978). Preparation MCP 1083.2, LD 28.1 121.7, interference contrast, ×900.

(d) Peridiniacean cyst type A from the same sample and preparation as (a) and (b), LD 43.1 130.2, interference contrast, ×900.

(e) *Muderongia* sp. from calcareous mudstone sample DJB 382, Weald Clay, Capel, see (a). Preparation A680.4, LD 117.7 52.9, interference contrast, ×900.

(f) Peridiniacean cyst type B from a Weald Clay mudstone with silty laminae, Beare Green Brickworks pit. Sample CSL/BG 19, preparation MCP 494.1, LD20.9 129.9, interference contrast, ×900.

(g) *Veryhachium* sp. from a mudstone at the top of the Wealden Marls on the coast northwest of Shepherd's Chine, Isle of Wight. Sample DJB 80/27, preparation MCP 888.2, LD 42.5 122.8, interference contrast, ×450.

Plate 8.12 (a) Diverse assemblage of miospores in varying states of preservation from a siltstone at the top of the Wealden Marls coastal exposure northwest of Shepherd's Chine, Isle of Wight. Sample DJB 80/28, preparation MCP 889.2, LD 41.6 127.2, ×135.

(b) General aspect of the palynofacies in which the *Veryhachium* on Plate 8.11g and Cyst type C (Pl. 8.13a) occur. Preparation MCP 888.2, LD 27.1 126.3, ×135.

Plate 8.13 (a) Cyst type C from sample DJB 80/27 (see explanation of Plate 8.11g for details of section). Preparation MCP 888.2, LD 28.9 128.0, ×450.

(b) *Spiniferites ramosus* (Ehrenberg), Perna Bed (sandstone), basal Lower Greensand, Atherfield Point, Isle of Wight. Sample DJB 80/25, preparation MCP 887.2, LD 21.9 130.1, ×450.

(c) *Protoellipsodinium spinosum* Davey and Verdier, Perna Bed, sample and preparation as above, LD 17.9 131.4, ×450.

(d) *Wanaea fimbriata* Sarjeant reworked from the late Jurassic (probably early Oxfordian) in a laminated muddy siltstone, upper part of the lower division of the Weald Clay, Clockhouse Brickworks pit, Capel. Sample DJB 370, preparation A583.4, LD 38.8 136.9, ×450.

(e) *Gonyaulacysta areolata* Sarjeant reworked from the Jurassic (late Callovian to early Oxfordian). Sample DJB 370 as above, preparation A583.4, LD 57.9 134.6, ×450.

(f) Perna Bed palynofacies; scattered marine dinoflagellate cysts, foraminiferal linings, miospores, brown-black woody and amorphous detritus. Sample DJB 80/25; for locality details see (b) above. Preparation MCP 887.2, LD 30.3 132.9, ×135.

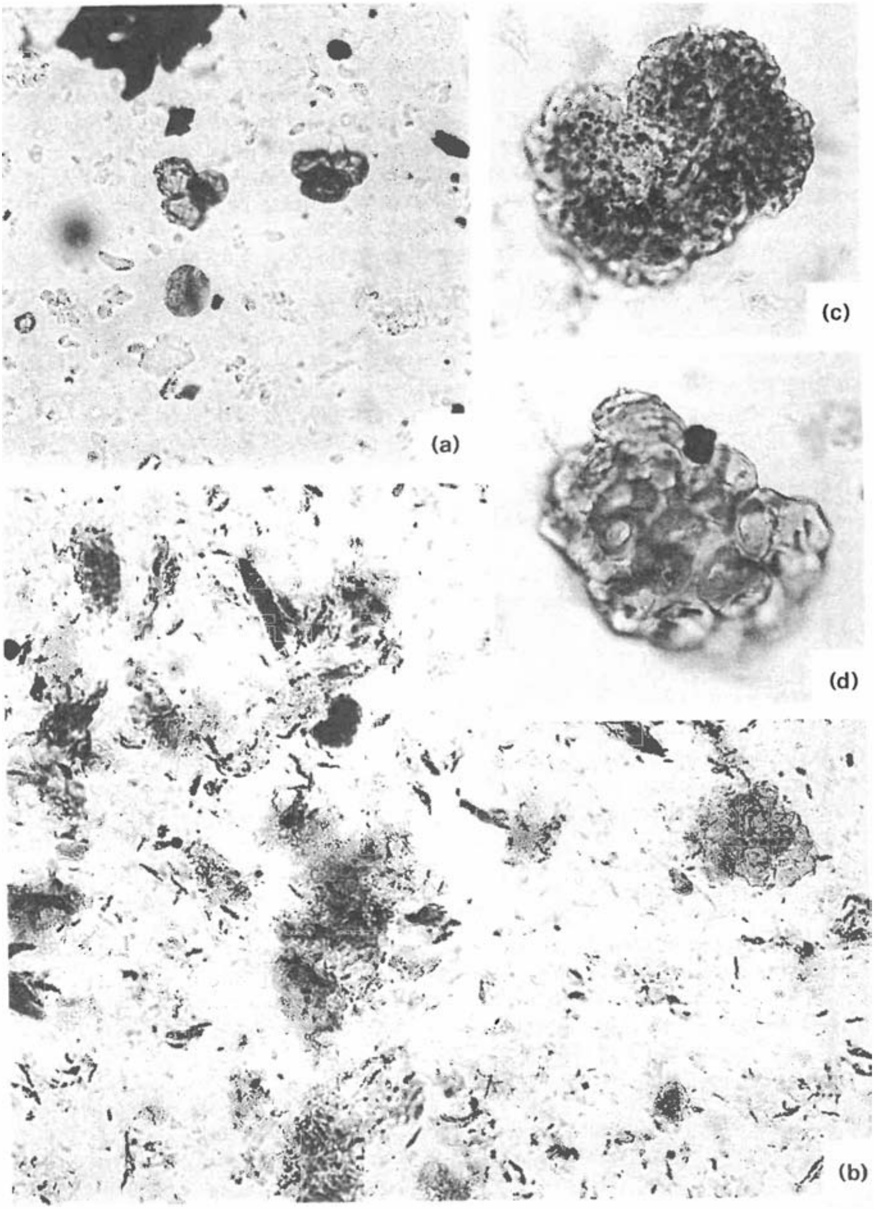


Plate 8.1

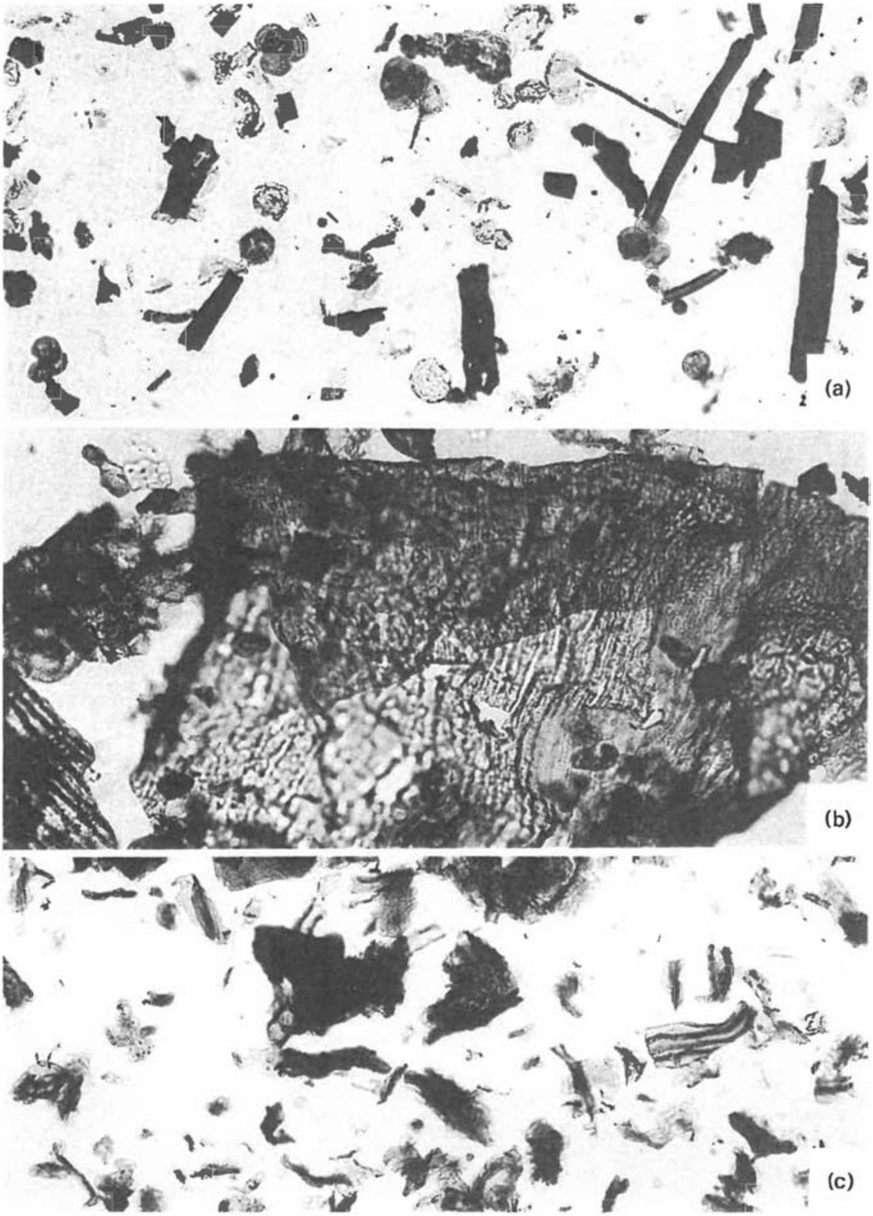
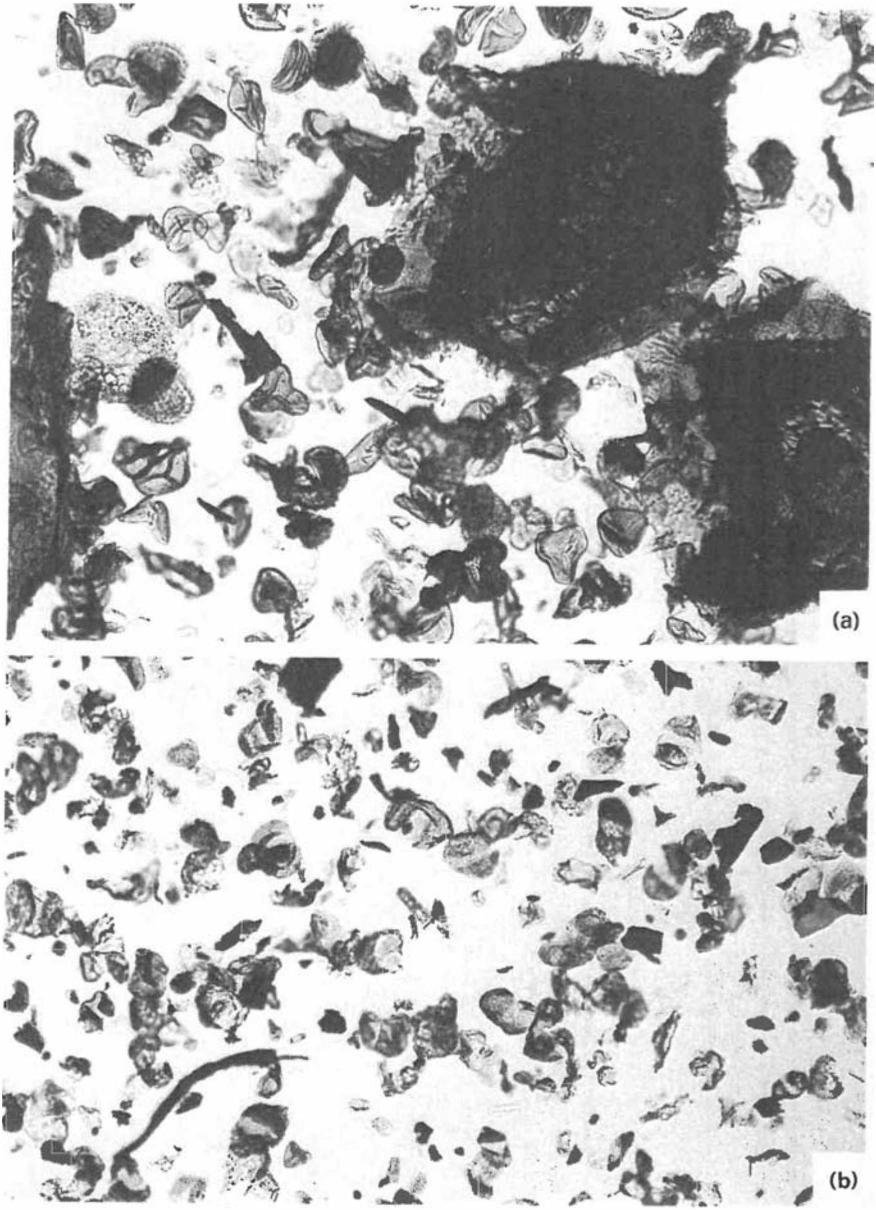


Plate 8.2



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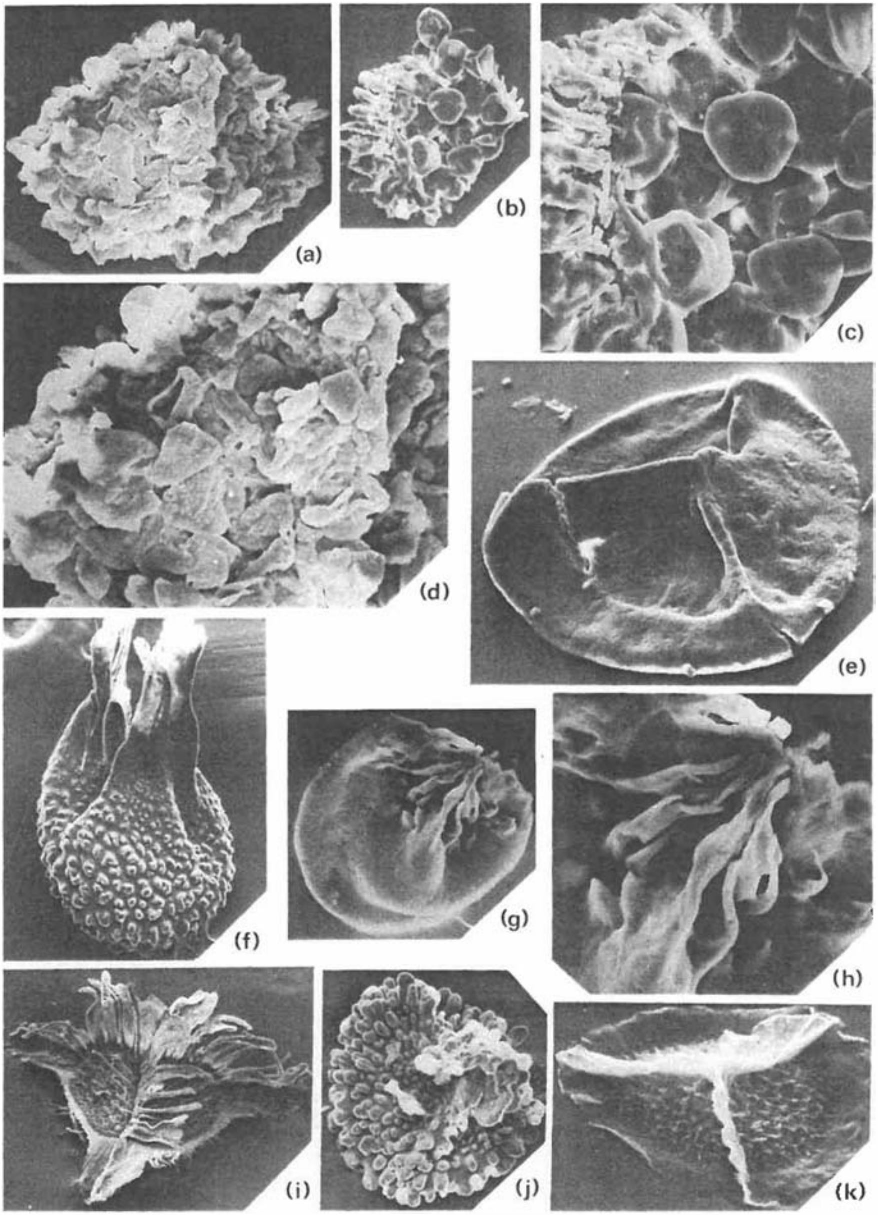

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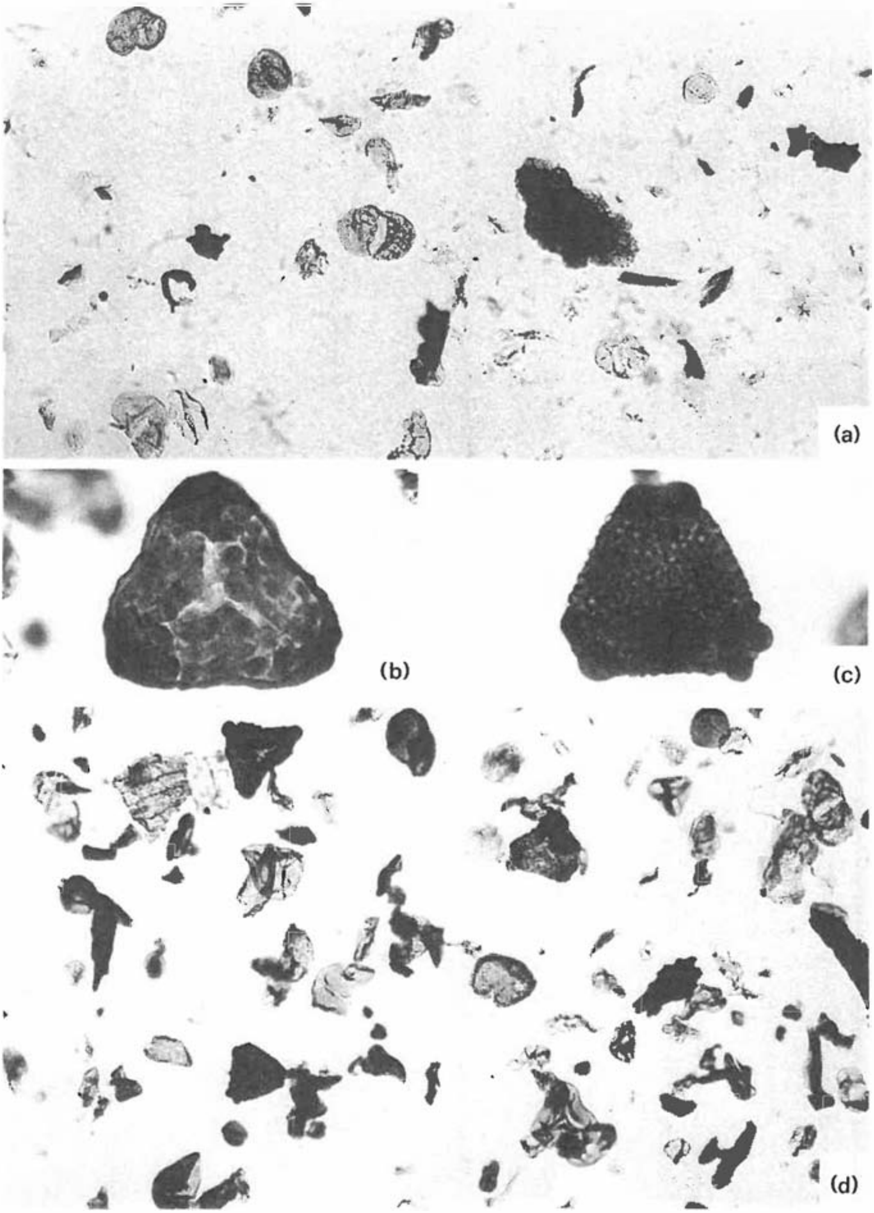

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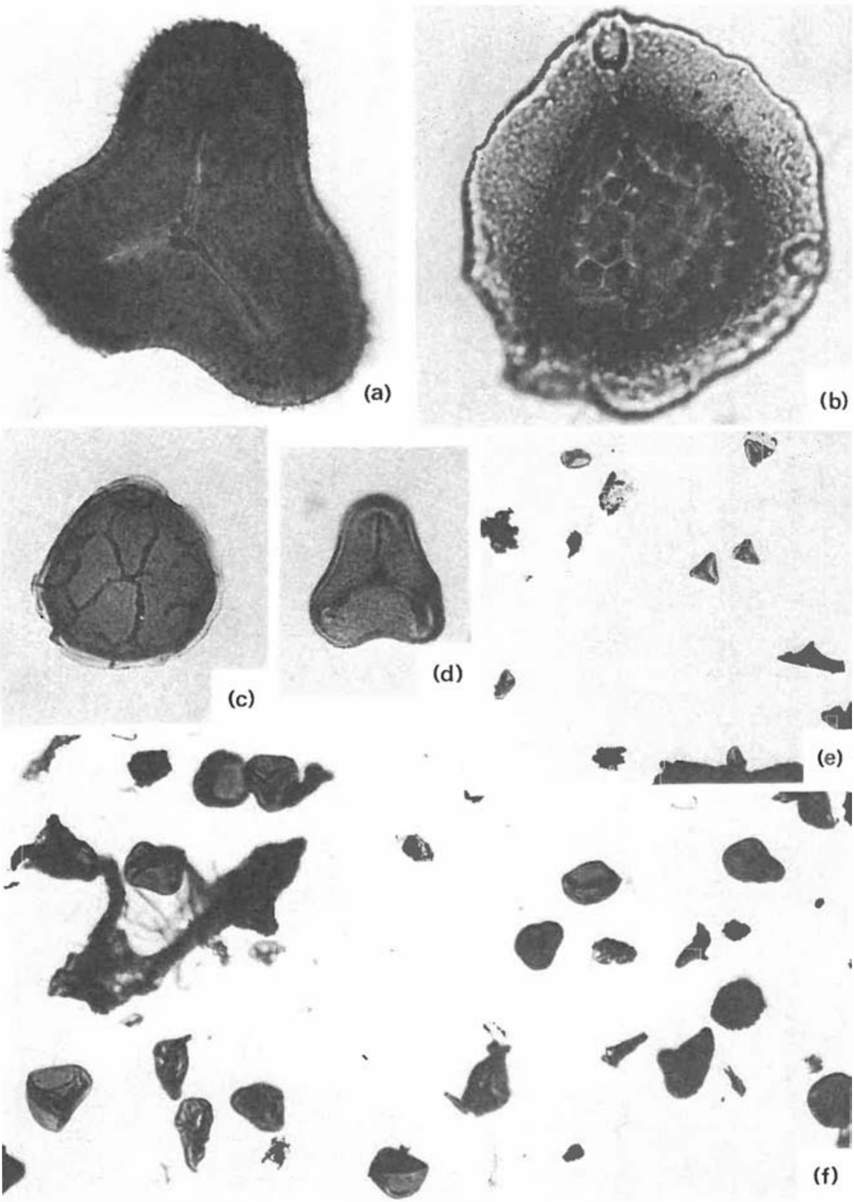
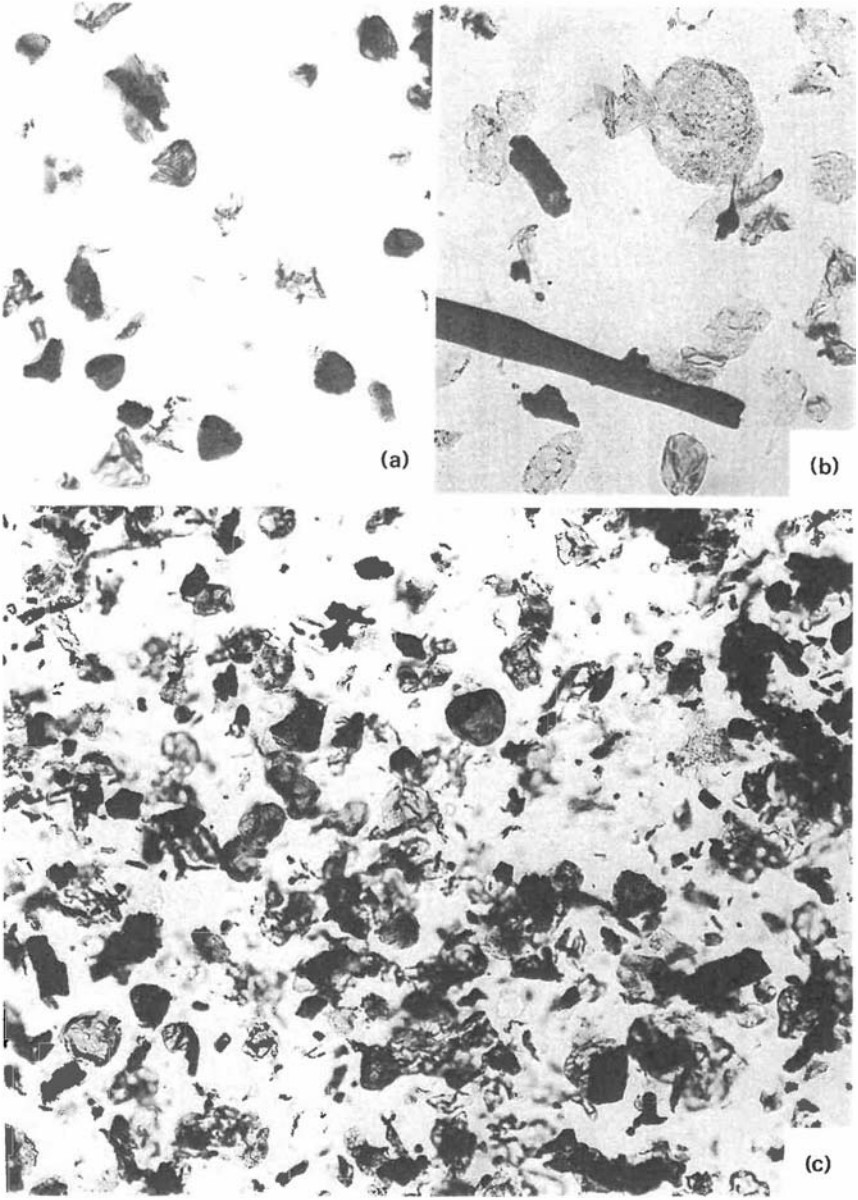


Plate 8.6



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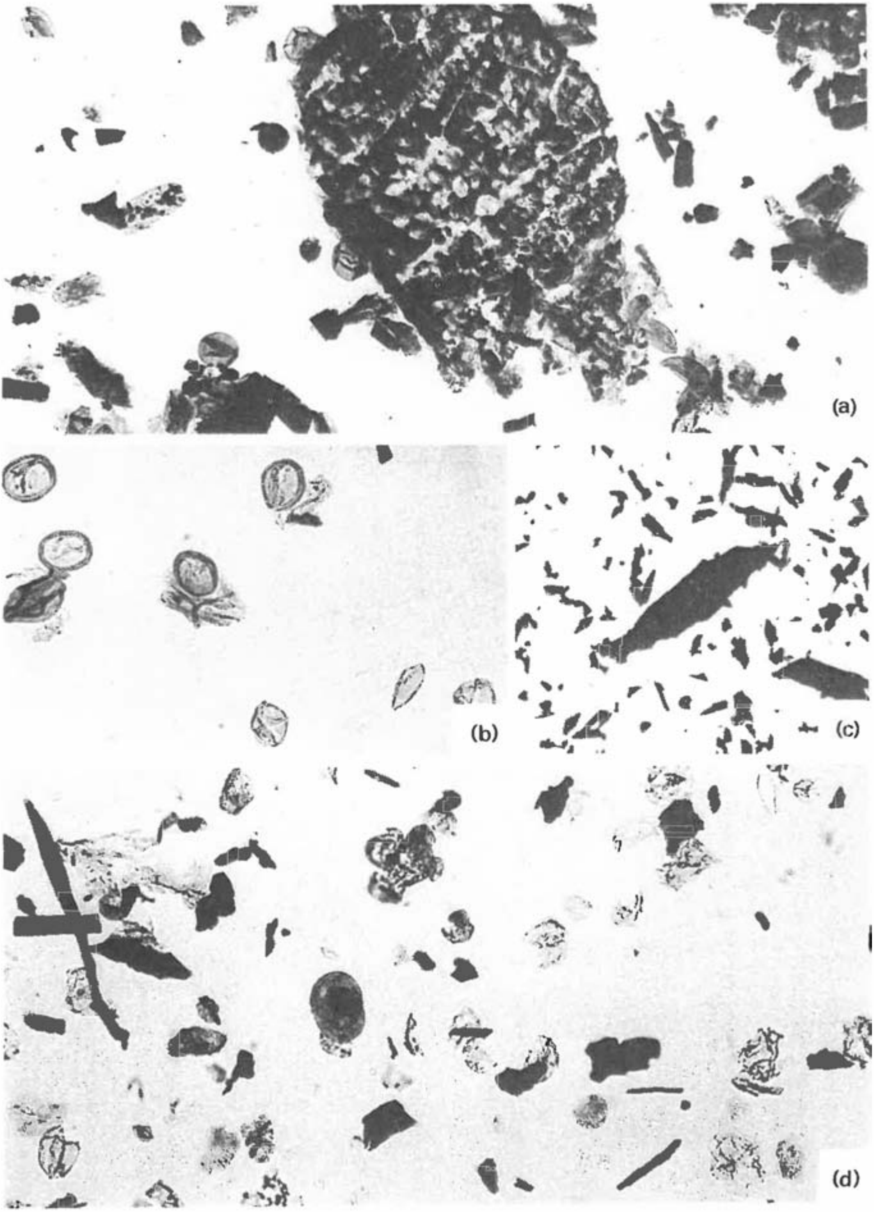

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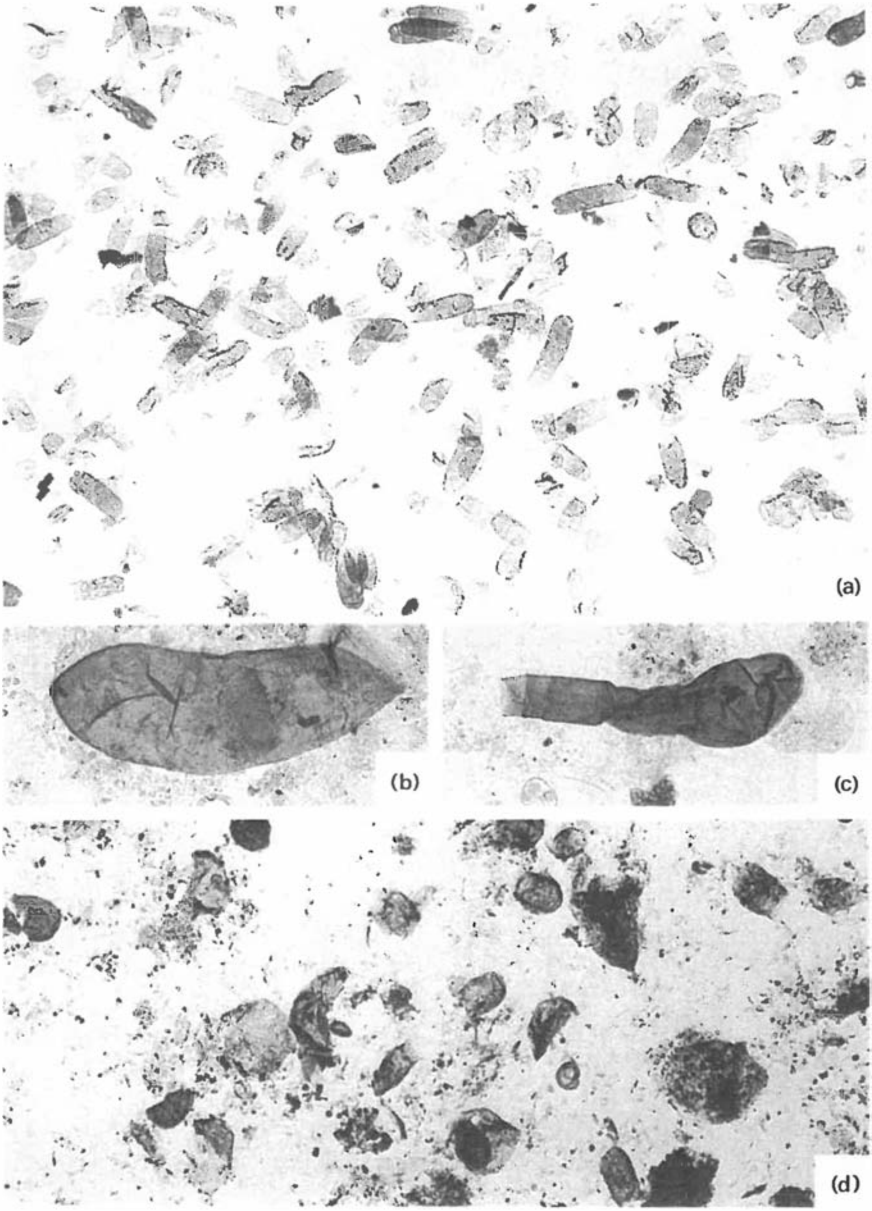

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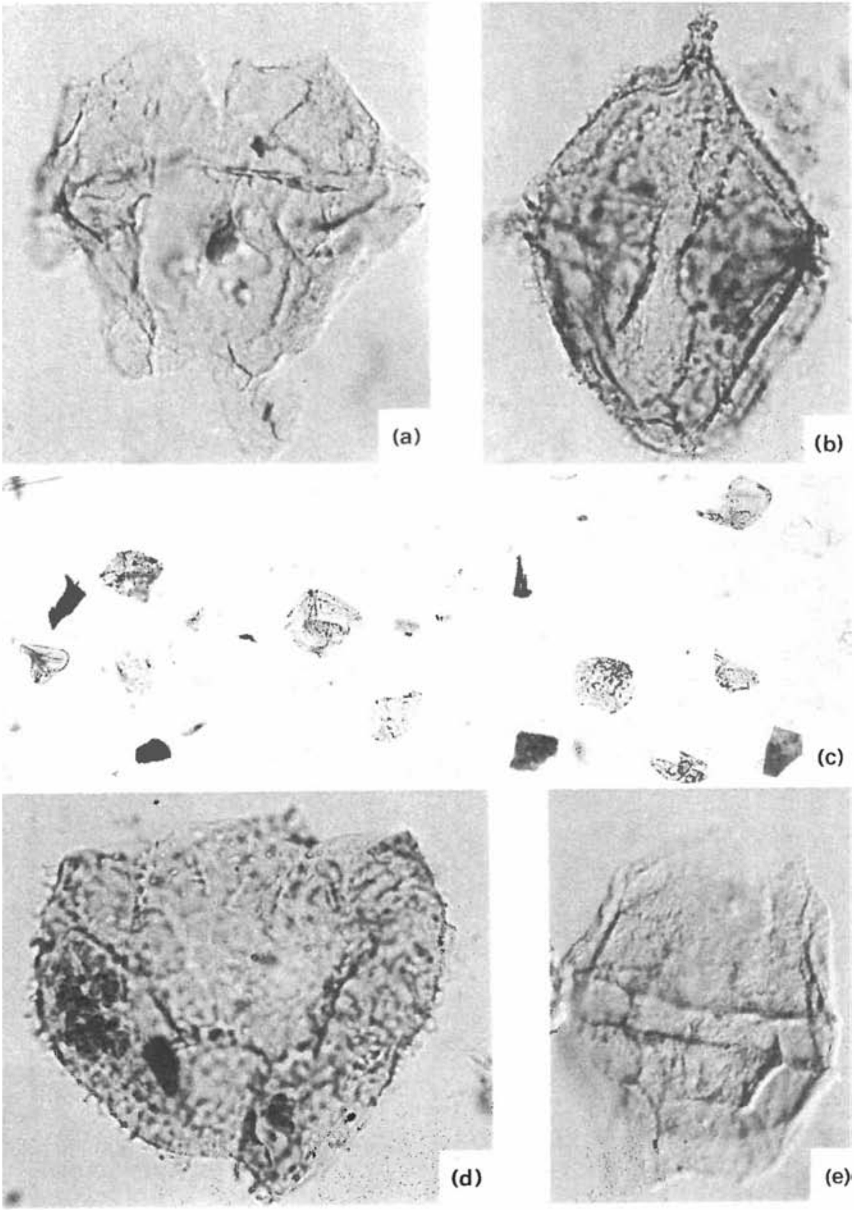

Plate 8.10

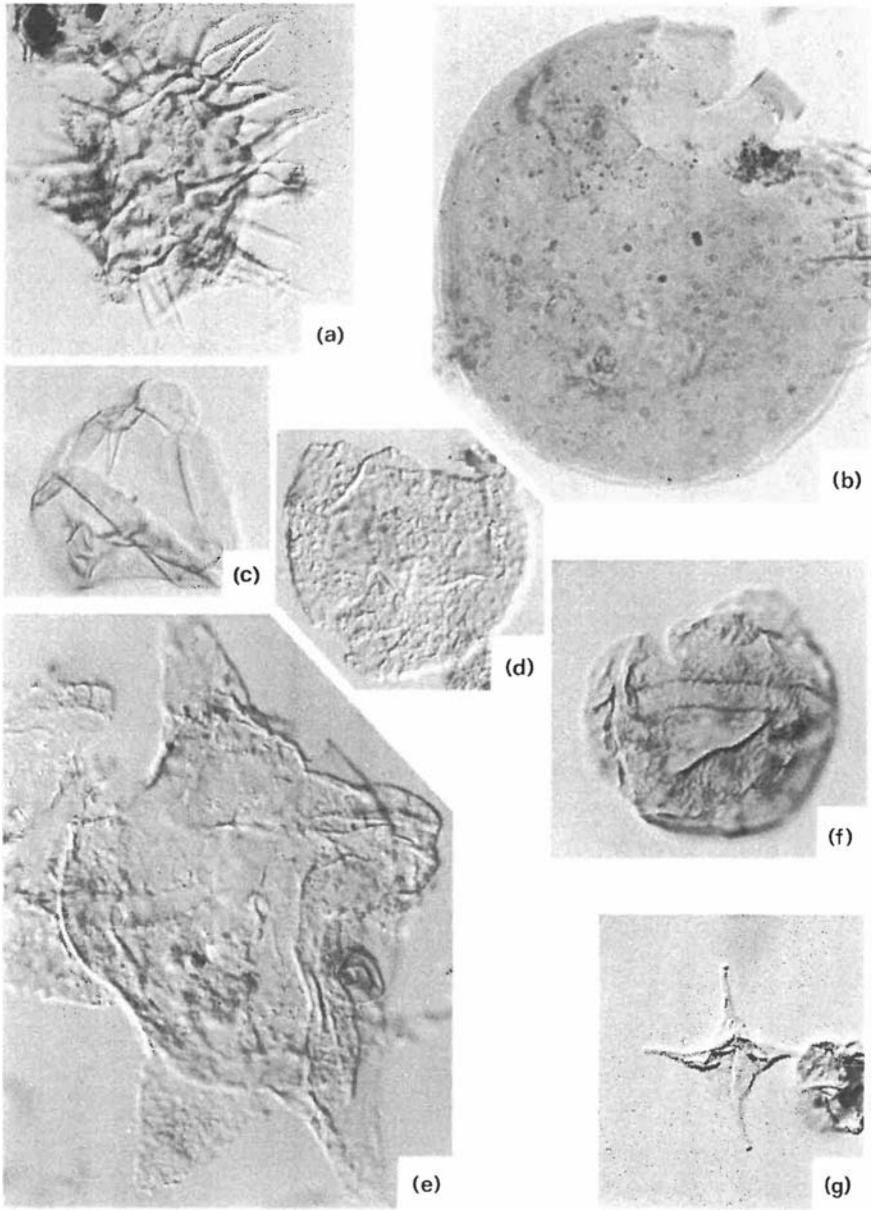

Plate 8.11

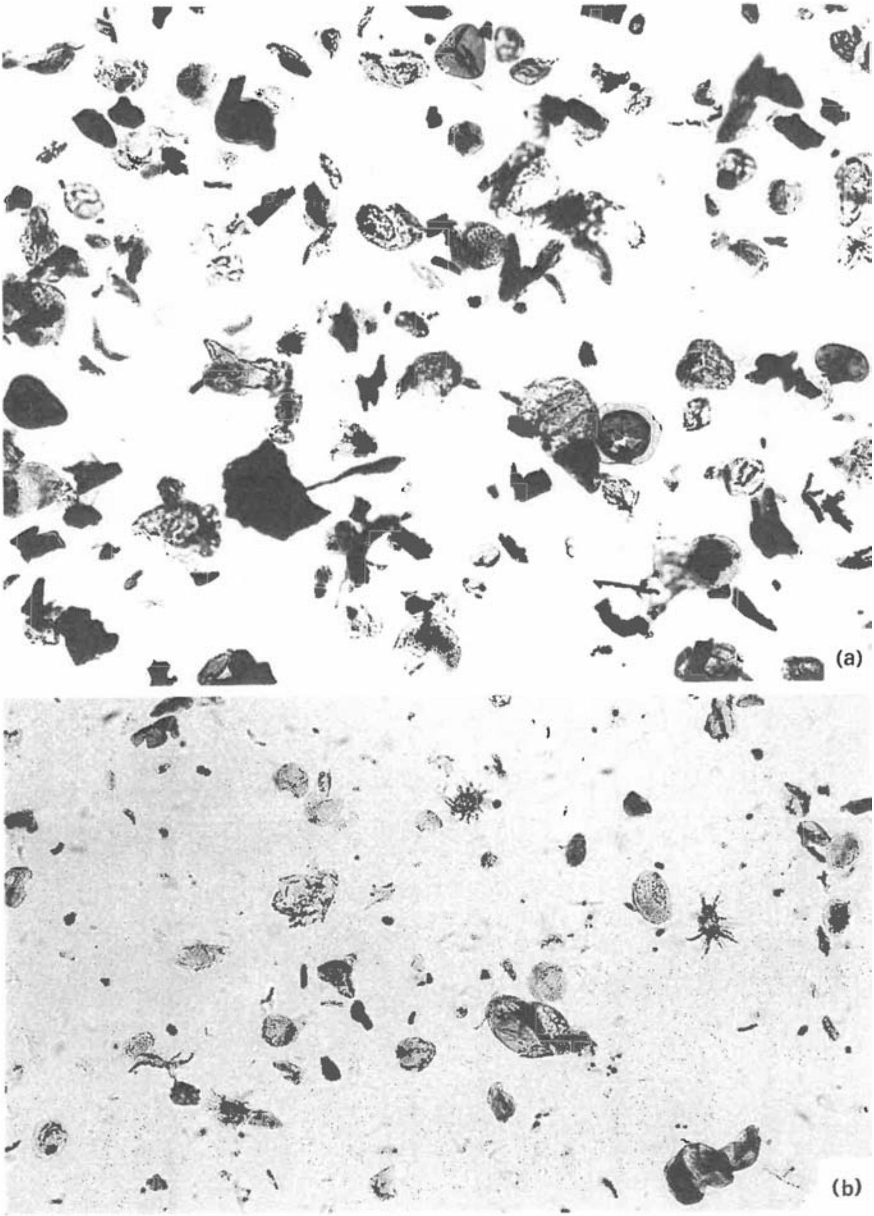

Plate 8.12

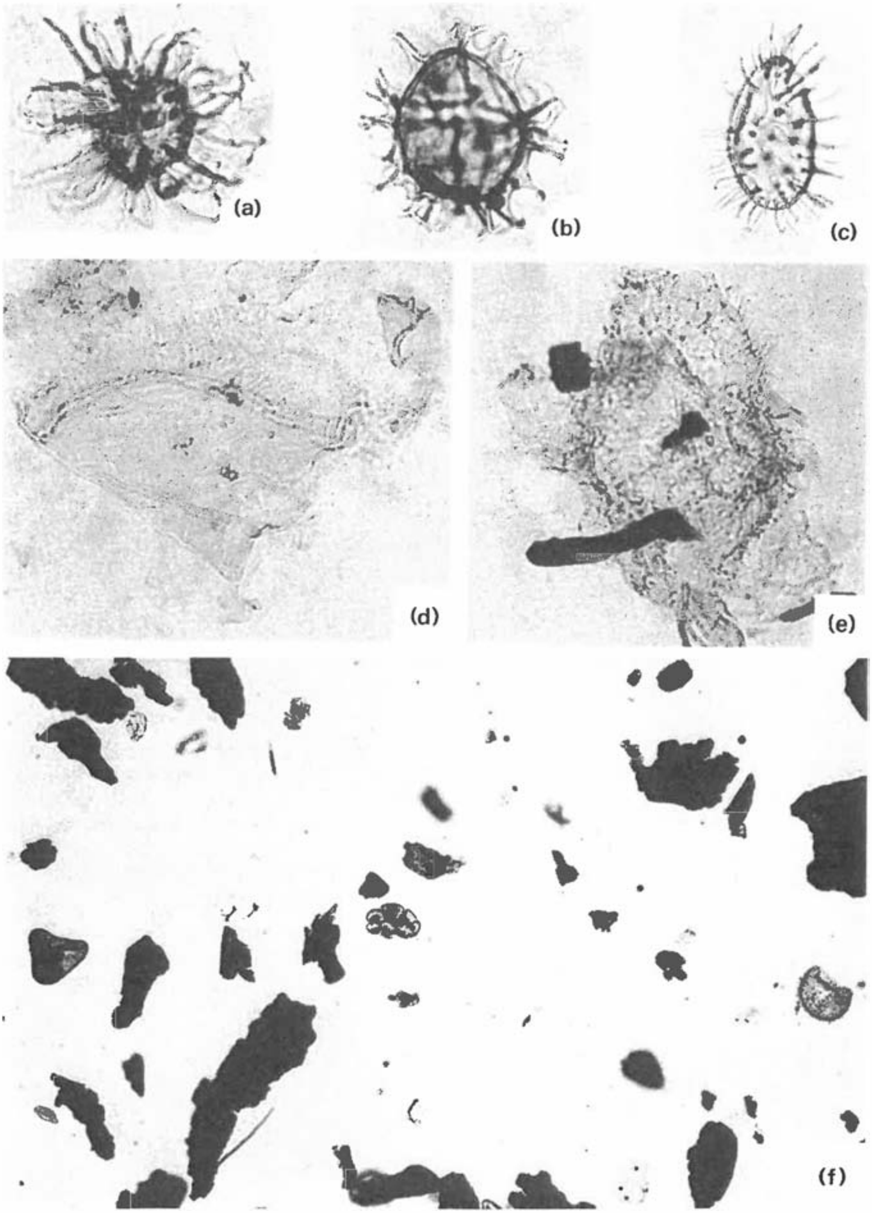

Plate 8.13