FUNGAL SPORES AS PALAEOENVIRONMENTAL INDICATORS OF ANTHROPOGENIC ACTIVITY

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DECLARATION

I declare that I have composed this thesis and that I have conducted the work contained herein.

Ciara Clarke, 3rd July 1994.

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ABSTRACT

Fungal spores often occur in palynological preparations and have been successfully incorporated in both biostratigraphic and palaeoenvironmental investigations. However, the majority of palynologists choose to ignore such microfossils, primarily because of the difficulties relating to their identification. Where they have been used conventional palynological extraction procedures have been implemented in the preparation of samples. The suitability of such techniques for the recovery of fungal palynomorphs has been assumed in many cases.

The objectives of this thesis were to study the effect of different processing techniques on the recovery of fungal palynomorphs, to propose a suitable morphological recording system and to investigate the potential of using fungal palynomorphs as palaeoenvironmental indicators of anthropogenic activity.

Following the specification of a suitable extraction procedure for fungal palynomorphs and an appropriate morphological recording system 215 types were described. These types were encountered in samples from modern and archaeological situations and across a variety of different environments. The types fall into 19 morphological categories as defined in the recording system. Many of the types are restricted to either modern or archaeological sample sets although some are common to both. 96 types are comparable to known fungal taxa, 8 are considered algal in origin, 4 are parasite eggs and 1 has been identified as a rhizopod species. The remaining 106 can only be classified morphologically until they can be related to known taxa.

Although an objective was to employ the Comparative Approach and use the palynomorph assemblages from known modern environments in the palaeoenvironmental interpretation of the archaeological material, it was not feasible. This is principally because of the limited overlap of taxa between modern and archaeological samples and is most likely a reflection of the restricted range of material considered. However, this approach demonstrates a promising future, subject to more extensive sampling regimes.

Palaeoenvironmental interpretation of the archaeological samples was possible using the Indicator Species Approach. The results support and often enhance other forms of palaeoenvironmental analysis and in no instance were contra-indications encountered.

This success testifies to the importance of fungal palynology and the need for continuing research in this area.

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PART 1

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CHAPTER ONE

INTRODUCTION

Palaeoecology is the study and understanding of the relationships between past organisms and the environments in which they lived (Birks and Birks 1980). It is concerned with the reconstruction of past ecosystems from the analysis of the fossilised remains of past organisms.

The objective of this thesis is to assess previous research accessible on fungal spores and to develop and extend these approaches within a palaeoecological context. In doing so, the intention is to evaluate the contributions that dispersed fungal spores can make to the elucidation of anthropogenic activities from archaeological deposits.

FUNGAL SPORES IN PALYNOLOGY

Palynology is the study of dust-sized, organic-walled, micro-organismic remains in the size range 5µm to 500µm (Traverse 1988). It is a term coined in 1944 by Hyde and Williams to replace `Pollen Analysis' and denoted the study of pollen and plant spores, including their morphology, methods of dispersal and their application to geological, ecological and evolutionary problems (Hyde and Williams 1944). Hence, pollen grains and plant spores are the original palynomorphs. Now, in addition to pollen and plant spores palynology also includes the study of chitinous fungal bodies and fungal spores, chitinozoans, scolecodonts, microscopic colonial algae, dinoflagellate cysts, microforaminiferal test linings and acritarchs. Palynomorphs are composed of very resistant organic polymers, usually sporopollenin, chitin or pseudochitin.

Pollen and spores of vascular plants are the most abundant type of fossil preserved in terrestrial Quaternary sediments (Cushing & Wright 1967) and pollen analysis has a long history of successful use in palaeoecological investigations. Initial studies focused on large scale climatic reconstructions, eg von Post (1918). The success of such early investigations prompted the application of the technique to smaller scale, more local environmental questions. The outcome was encouraging and now many other identifiable microfossils also have a proven track record in palaeoecological

investigations within the Quaternary. Plant macrofossils, insect remains and diatoms are among the most notable. Fungal spores have, to date, received little attention despite the fact that they commonly occur in conventional pollen preparations.

ORIGINS OF FUNGAL SPORES

Before advancing any further it is appropriate at this point to consider the fungi themselves - the organisms responsible for spore production.

Broadly speaking a fungal spore is a nucleate portion delimited from the thallus, characterised by cessation of cytoplasmic movement, small water content and slow metabolism, lack of vacuoles. It is specialised for dispersal, reproduction or survival (Gregory 1966). Fungal spores have in common with plant spores only that they are detached reproductive cells. They can be produced by sexual or asexual means and some fungi do not produce spores at all but reproduce vegetatively by means of their hyphae only.

`Fungi' is a term which has been used in a wide sense to include the Mycetozoa (Slime Moulds) and also in a narrower sense excluding them. The exclusion of the latter can be justified by the fact that in some members of the class the feeding stage is amoeboid and, therefore, characteristic of the Animal Kingdom. However, for the purpose of this study the Mycetozoa will be considered since they form spores which are capable of being preserved as palynomorphs.

The Kingdom Fungi can be divided into five main classes. The classes are:

1. Phycomycotina
2. Ascomycotina
3. Basidiomycotina
4. Deuteromycotina
5. Mycetozoa

Individual members of each class have the potential to bear anything from one to several different types of spores. Spores of a single taxon can be produced by sexual or/and asexual means. The fungi are reproductively quite heterogenous and,

consequently, fungal spores are much more diverse in origin than other diaspores. The types of spore which can be produced by each class are summarised below in Table 1.1. For a more thorough account of the types of spore produced within each class see Appendix 1.

Table 1.1 Spore types produced within each Class of the Fungi.

CLASS	Sexual Spore	Asexual Spore
PHYCOMYCOTINA		
Order Zygomycotina	**Zygospore**	**Sporangiospore**
		Chlamydospore
Order Oomycotina	**Oospore**	**Oospore**
		Zoospore
Order Chytridiomycotina	**Resting Spore**	**Zoospore**
ASCOMYCOTINA	**Ascospore**	**Conidium**
BASIDIOMYCOTINA	**Basidiospore**	**Conidium**
DEUTEROMYCOTINA		**Conidium**
MYXOMYCOTINA	**Myxomycete Spore**	

WHY HAVE PALYNOLOGISTS DISREGARDED FUNGAL SPORES?

The taboo which surrounds fungi in many cultures and is a connotation originating from their connections to fairies, witchcraft, black magic and pagan rituals (see Cooke 1977; Emboden 1979; Ramsbottom 1953) is likely to be a contributory factor to the lack of attention to fungi and as a result also to fungal spores. For example, three strange properties of basidiomycete fruiting bodies are the ability to form fairy rings, the phenomenon of luminescence and the possession of complex biochemical compounds that are capable of inducing hallucinations if ingested. Each of these attributes has given rise to beliefs which spring from their apparently supernatural nature. In the case of the hallucinogenic fungi there is convincing evidence that widespread religious practices have been based on their controlled use. Additionally, and apart from the deadly nature of some of them, the fungi are often associated with putrescence and decay; fruiting bodies are often slimy, with dark or unnaturally vivid colours and can be foul smelling. Physically offensive objects are often allied with evil and forces of darkness by humans. Hence, there has been a certain reticence towards the study of the fungi.

More importantly, fungal spores are not readily identifiable. Many fall into the category of *incertae sedis* microfossils, meaning that they are of unknown or uncertain affinity; Varma and Rawat (1963) encountered diporate spores with restricted stratigraphic ranges in Tertiary sediments of India but did not distinguish the palynomorphs as fungal spores. Even when they are recognised as fungal spores, identification may be dependent, to a large extent, on knowledge of the parent fungus, e.g. spores of the Sordariaceae, and sometimes even its host, e.g. in the case of rust spores. The taxonomy of any biological group is largely dependent upon an investigation of the morphological characters available for study and although fungal spores are often considered in the taxonomy of the fungi this is largely as a supplement to other taxonomic criteria. On the whole, in their dispersed and isolated state, they lie in a taxonomic no-man's land.

In the past Quaternary palynologists have not dealt with such *incertae sedis* microfossils. After all, why should they have considered taxonomically complicated microfossils when they had a wealth of more easily identifiable material to contend with, providing them with ample challenges? *Incertae sedis* microfossils have traditionally been the domain of Pre-Quaternary palynologists and the emphasis has

been, in general, form taxonomic and biostratigraphical. Fungal palynomorphs have, therefore, not been given due consideration in Quaternary studies and with respect to palaeoenvironmental investigations.

Quaternary and Pre-Quaternary palynology have traditionally been conducted as semi-independent disciplines. Quaternary palynologists consider identifiable microfossils and their known modern ecological and sociological preferences, while Pre-Quaternary palynologists focus principally on the form classification of *incertae sedis* microfossils and their locations and restrictions in the geological column.

Conventional Quaternary palaeoecological techniques are now well established and confidence in these techniques encourages palynologists to explore the potential of new palaeoecological techniques. This brings Quaternary palynologists into the unchartered territory of *incertae sedis* microfossils, such as fungal spores. To give adequate consideration to fungal spores within the Quaternary, it is necessary to consider them as candidates for Form Taxonomy, an approach which is traditionally pre-Quaternary.

PREVIOUS PALAEOMYCOLOGICAL INVESTIGATIONS

Although the procedures for interpreting dispersed fungal spores have not yet fully evolved, spores have, nonetheless, been retrieved from throughout the fossil record. In addition to spores, a wealth of other fungal remains has been recovered including hyphae, fructifications, rhizomorphs and sclerotia. There is fossil evidence of the fungi spanning geological time from the Proterozoic to the present. The first appearance of fossil fungi in the late Precambrian was in the form of coenocytic, hyphae-like filaments associated with algae. *Eomycetopsis* Schopf, the earliest named fungus, appears to have been a widespread component of marine stromatolites, accompanying blue-green algae and the earliest eukaryotic green algae (Schopf 1970). The fungal nature of *Eomycetopsis* is questioned by some (Awramik *et al* 1975), and a more convincing late Precambrian fungus is the ascus-like microfossil of uncertain systematic position (Schopf and Barghoon 1969), which closely resembles intercalary oogonia of modern Saprolegniaceae (Pirozynski and Malloch 1975).

Since the 1820s fossil fungi of various ages have been reported sporadically in the literature. Reviews by Seward (1898), Meschinelli (1902) and Pia (1927), of these early studies, demonstrated that they emphasised descriptive taxonomy and varied widely in the reliability of their identification and interpretation. Many of the fossils they included were subsequently excluded from the fungi altogether or reclassified in other fungal groups. Twenty years later Wolf and Wolf (1947) published an updated list of fossil fungi and then, three decades later, Tiffney and Barghoorn (1974) provided the next detailed review of the fossil fungi organised to show the geological distribution of each major group. Previous to this Dilcher (1965) pioneered the move away from mere taxonomic and stratigraphic studies and angled an investigation towards the relationship between the fungus and its biotic environment.

Although diversity, taxonomy and stratigraphy remain important themes in palaeomycology today, the relationship between fossil fungi and their biotic and abiotic environments is now also considered. The potential of fossil fungi in disciplines such as sedimentology, palaeoecology, palaeontology and evolutionary studies has been established. New fossil fungi are being described frequently from throughout geological time worldwide and the major groups of fungi are recognised from relatively early in geological time. Barghoorn and Tyler (1965) reported aseptate hyphae resembling the phycomycetes from the middle Precambrian, ascomycetes have been recovered from the late Precambrian (Schopf & Barghoorn 1969) and Dennis (1969) identified clamp connections typical of the basidiomycetes from the Pennsylvanian. However, the number of fossil fungi which have been extensively studied are few and those which have been studied from a biological perspective even fewer.

Fungal spores are amongst the many fungal remains which have been recovered as fossils. Attempts to specifically identify isolated, fossil fungal spores were neglected until 1966, when Frederick Wolf commenced a study on the spores of East African lake sediments (Wolf 1966a, 1966b, 1967a, 1967b, 1967c, 1967d; Wolf and Cavaliere 1966). Previously, van der Hammen was one of the first palynologists to consider fungal spores and he recorded them in broad morphological classes (see Chapter Two) but he made no attempt to formally identify them. Other palynologists also recognised fungal spores in their preparations and expressed the need for palaeomycological studies, for example, Ogden (1965). Wolf, however, pioneered the link between dispersed fungal spores and the present ecologies of their parent

fungi. This approach was underpinned by his recognition of the similarity between fossil fungal spores and spores of present day genera and species.

The first fossil fungal spore to which a specific name was allocated with any kind of certainty was *Tetraploa aristata* from Lake Bujuku (Wolf and Cavaliere 1966). Spores from Lake Bujuku sediments were morphologically identical to spores of the modern species *T. aristata*. A further example where fossil spores were attributed to known taxa is the endomycorrhizal genus *Endogone* (Wolf 1969). *Endogone* is a fungal genus which ranges from the Devonian (Butler 1938-39) to the present with no apparent morphological alteration. It is considered that the morphologically conservative nature of these spores, and other fossil spores which can be identified to known taxa, could provide an important link with the past as living witnesses of former environments.

Wolf realised the potential of fungal spores in palynological studies but considered the paucity of available mycological information a limiting factor. Wolf also thought it correct to name fossil fungi according to contemporary taxonomic affinities, (Wolf 1969), contrary to the conventions of the time. Seward (1933) had expressed disapproval of such a procedure arguing that such a double use of the same term would lead to confusion between botany and palaeobotany. Ultimately Wolf hoped to use fungal spore analysis alongside pollen analysis to aid in the interpretation of floristic changes but he found that evidence to support the anticipated complementary associations of pollen and fungal spores was not apparent (Wolf 1968a).

W.C. Elsik began incorporating fungal spores in Pre-Quaternary palynological studies in the late sixties. His interests in the subject continue through to the present, although he has recently retired. Initially Elsik focused on the mycostratigraphic value of fungal spores (Elsik 1969, 1970, 1974, 1976, 1979, 1980, 1981, 1990). Previous mycostratigraphic workers, such as Varma and Rawat (1963), were uncertain of the affinity of the material that they were describing although they found diporate spores with restricted vertical ranges and wide horizontal distributions in Tertiary sediments of India. Elsik, however, was aware of the fungal nature of the microfossils and seven of the thirteen spores showing restricted stratigraphic distribution in the study of Varma and Rawat were subsequently identified by Elsik as being fungal spores (Elsik 1968). Other succesful mycostratigraphic studies include those conducted by Fournier *et al* (1970), Jansonius (1976), Norris (1986).

Elsik recognised the rapid evolution of some of the spores during the Cenozoic with many forms useful for marking boundaries such as the top of the Paleogene. He noted that many Cenozoic forms are distinct from extant taxa having ranges that are potentially very useful stratigraphically. He also observed that spore profiles fluctuated with large scale climatic changes (Elsik 1969) and phased in a biological dimension by incorporating fungal spores in palaeoenvironmental studies Elsik (1986a, 1986b).

Elsik, like Wolf, recognised the possible links to modern genera of many fossil fungal spores and carried out studies of distributions of fungal palynomorphs in modern sediments (Elsik 1986b). He proposed a modified form classification system to that of van der Hammen and Saccardo (Elsik 1976b), (see Chapter Two) and predicted that in time many of the forms described in this system would be attributed to known taxa. He suggested that the known habitat and host preference of many of the identified forms could conceivably be used to deduce the environmental conditions of similar fossil fungal spore floras (Elsik 1986b), thereby, acknowledging the importance of studies on modern samples.

Van Geel began to record fungal and many other types of *incertae sedis* microfossils from Holocene palynological preparations in the 1970s in an attempt to maximise the total information available from analyses (see Chapter Two). He recorded the forms encountered within a type system. He then attempted to relate types encountered to known taxa and infer ecological information about the fossil samples from what is known of the ecology of the modern taxa. This approach has been productive, particularly with respect to fungal spores, (Van Geel 1972, 1978, 1986; Van Geel and Anderson 1988; Van Geel *et al* 1981; Van Geel *et al* 1983a, 1983b; Van Geel *et al* 1986). For example, Van Geel (1978) identifies his Type 3B as being *Pleospora* sp. *Pleospora* spp. typically occur on dead plant remains. This environment is concurrent with the relatively dry, ombrotrophic peat conditions from which the spores were recovered. Successful interpretations like these emphasise the benefits of comparative studies between modern and fossil material. At a less specific level the ratio of fungal cells (spores and hyphae) and pollen grains from peat deposits has been used as an index of moisture. Van Geel (1972), Huikari (1956) and Aartolahti (1965) have shown that higher percentages of fungal spores, as compared with the number of pollen grains, are indicative of moist conditions at the time of peat formation. Van

Geel has also shown that certain unidentifiable fungal spores show a clear connection with peat-forming vegetation (Van Geel 1972).

Van Geel also succeeded in detecting complementary associations of pollen and fungal spores (Van Geel 1986), a phenomenon which Wolf (1968a) had anticipated, but failed to elicit. Van Geels' success resulted from looking at deposits which are considered to contain palynomorphs from a more local source than lakes, such as those studied by Wolf. He found that the distance between forest site and deposit greatly influenced the frequency records of fungal spores and that spores were absent from relatively large lakes (Van Geel 1987).

In summary, these palaeomycological investigations have highlighted that on the one hand there is a remarkable similarity between fossil fungal spores and present genera and species, but that there are also many more stratigraphically restricted forms. Stratigraphically restricted forms are of benefit in mycostratigraphic studies where evolution and extinctions come into effect, and the limited range of certain spores can be used to correlate and date sequences. However, it is the potential of the more conservative forms which will be explored in this study, which covers an archaeological time period and deals with palaeoecological reconstruction. Within this timescale it is highly unlikely that evolution and extinction are relevant, therefore geologically restricted forms should not occur. Previous palaeomycological investigations highlight the advantages of the comparison of fossil and known material by incorporating knowledge of the ecologies of the modern taxa in palaeoenvironmental interpretations. This approach will be incorporated in these investigations of fungal spores as palaeoenvironmental indicators of anthropogenic activities.

PALAEOENVIRONMENTAL POTENTIAL

In the knowledge that it is possible to make connections between the present and the past using fungal spores what kind of palaeoenvironmental information can we expect to obtain from such dispersed spores?

The fungi are devoid of chlorophyll and hence cannot produce their own food, i.e. they are heterotrophic. They are dependent on scavenging for their survival. Thus, at

its simplest level, the presence of fungal spores in a deposit is indicative of the former existence of fungal sporocarps inhabiting a source of organic matter, either locally or at a distance. Taphonomic processes are complex and beyond the scope of this study. Spore discharge in the fungi is predominantly ballisitic (Ingold 1965; Simons 1993) and once the spores are airborne, as with pollen, prevailing local and atmospheric conditions determine their plights (Tauber 1965, Gregory 1945). However, from studies on lake deposits, eutrophic to mesotrophic bogs, carr peat and raised bogs, Van Geel (1986, 1987) observed that almost all fungi and fungal spores appeared to occur *in situ*. Taphonomic processes in the present study are more complicated due to the presence and actions of humans. Chapter Five considers this issue in more detail.

The habitat ecology of the fungi today shows that while some fungi have quite a general distribution others are more habitat specific, having more specialised physiological requirements. It is the detection of these more ecologically restricted forms in the palynological record which could be of significance in palaeoenvironmental studies.

Many fungi can utilise cellulose and hemicellulose, and a very few, mainly basidiomycetes and a few ascomycetes can utilise lignin. These three compounds are the primary constituents of wood and so such fungi are of paramount importance in the decomposition of wood (Ingold 1988). The fossil presence of such fungi in the palynological record could, therefore, be interpreted as indicative of the former existence of wood in the vicinity.

Leaf litter also forms an ideal medium for fungal growth and has a large flora of microscopic and macroscopic fungi. There are fungal species which show a preference for a particular kind of leaf litter. Detection of spores of such fungi in the palynological record could assist in resolving the nature of a former woodland. Each type of woodland tends to have a distinctive assemblage of the larger fungi growing on the ground. This is partly due to the preference of certain species for specific types of leaf litter; but mainly such large ground-dwelling wood fungi relate to the fact that the these fungi are in symbiotic association with particular trees. This relationship between fungus and tree is known as mycorrhizal. Such fungal spores could also supplement the pollen record in diagnosing locally wooded areas and the

technique could potentially be fine tuned to detect different kinds of woodland from the fungal remains recovered.

In pastures fungal species tend to be distinctive and the larger species are inclined not to be common to both grasslands and woods (Ingold 1988). Especially ectomycorrhizal types are absent. More particularly toadstools are often associated with dung and there is a well known flora that develops on the dung of specific herbivores. The succession of fungal fruiting bodies on dung is well known (Harper & Webster 1964). Many species express a preference for dung of a particular kind of herbivore (Lundqvist 1972; Mirza 1963). Spores of such dung fungi recorded from archaeological contexts may help identify the former usage of structures.

Compost heaps, damp hay stacks and manure heaps are all self-heating systems which encourage a distinctive fungal flora as the temperature rises above 30^{0}C. Most of the fungi involved cannot grow below 20^{0}C but grow vigorously between 35 and 45^{0}C. Such fungi could also provide useful information if they were detected in archaeological deposits.

Fungi are also the principal pathogens of higher plants. There are five broad categories of plant pathogenic fungi (Ingold 1988). The first category embraces those fungal pathogens which attack the underground parts of the plant and are soil-borne, second are those fungi which attack the trunks and limbs of trees and the third and largest group the fungi causing the diseases of foliage and of herbaceous stems. These are especially important in relation to food plants such as cereals and potatoes and have been detected and identified from archaeological deposits (Aaronson 1989). The fourth group attack the floral parts of plants and the fifth and final group concern the fungal rots which destroy the fruit of plants.

Their parasitic activities also extend to other organisms. Some attack insects and others attack small animals. There are even some fungi which attack other fungi (Ellis & Ellis 1988).

Any pronounced change in a habitat means that other species of fungi will appear there. Thus, for example, after a fire, certain species not previously found sporulating in the habitat are almost certain to occur on the charred debris and on the ashes

around and under partly burned stumps and logs. In brief, any factor which changes the conditions in an ecosystem will most likely have an effect on at least some of the fungi living there and a distinct change in the fungal flora may be apparent. If such changes could be detected in the fungal spore record from archaeological contexts, they could be interpreted, for example, as changes in the use of a building.

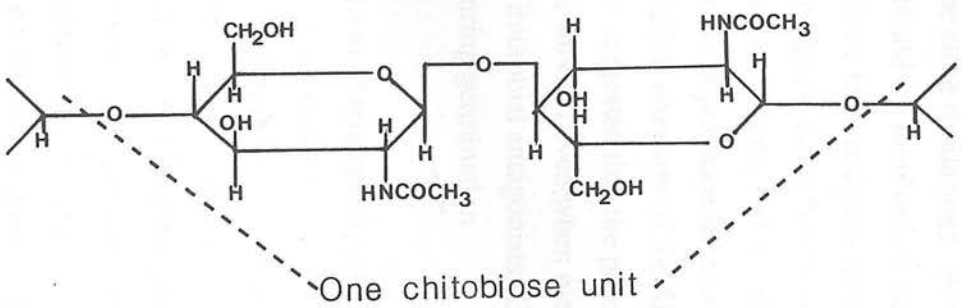
The soft parts of fungi are highly unlikely to persist into the fossil record, although there are many exceptions including those detailed byWatling (1974) and Watling and Seaward (1976). Our knowledge of their former existence is determined predominantly by those parts which survive most frequently; namely hyphal fragments and spores. Hyphal fragments, for the most part, give little insight into the nature of the parent fungi while the spores, being morphologically more variable and distinctive, yield more information as to the nature of the parent fungi.

WALL COMPOSITION

Where fungal spores have been considered palynologically they have been recovered using standard palynological techniques and are often considered as a supplement to conventional pollen analysis. However, a more detailed look at the differences between fungal spore walls and pollen grain walls casts some doubt on the validity of such recovery procedures for fungal spores.

Fungal spores are generally regarded by palynologists as being composed predominantly of chitin, although Traverse (1988) considered this perspective to be based on the knowledge that chitin does occur in the fungi and is a resistant substance. He suggested that it would be worthwhile to investigate the assumption that resistant-walled fungal structures are really always chitinous. Wolf (1966a) also suggested that the chitinous nature of fungal palynomorphs warranted investigation.

Chitin is a complex C-H-O compound, see Fig. 1.1. It is closely related to cellulose, differing from it by having a nitrogenous group. It has similar physical properties to



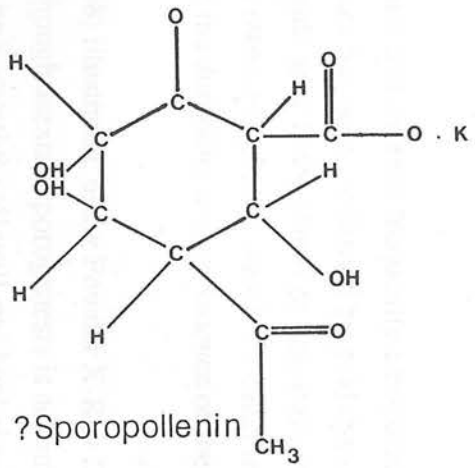


Fig. 1.1. Chemical structure of Chitin and sporopollenin.

the sporopollenin which constitutes the fundamental structure of the resistant walls of dinoflagellate cysts, acritarchs, plant spores and pollen grains.

In fact research indicates that chitin is frequently a constituent of fungal spore walls; its ubiquitous occurrence has been confirmed by gold cytochemistry (Chamberland *et al* 1986; Bonfante-Fasola *et al* 1986; Harris & Szaniszlo 1986; Grandmaison *et al* 1988). There are also other compounds which are often incorporated into the walls that also play a role in the durability and persistence of the spores.

Bartnicki-Garcia (1968) illustrated, using Powder X-Ray Diffraction and Infrared Spectroscopy, that although asexual sporogenesis is accompanied by the retention of the basic structure of the vegetative cell wall and hyphal walls, spore walls revealed differences that were largely quantitative. Among the qualitative changes recorded were the deposition of melanin in the spore walls and the absence of phospho-glycoprotein. In some species glucans are generated *de novo* during sporogenesis but reversion to the basic structure occurs on germination. Melanin and the lignin of higher plants bear some close similarities. Both are oxidised phenolics with hydrophobic properties and are involved in the reduction of wall permeability (Young and Ashford, 1992). Apart from reducing permeability of cell walls, melanins contribute to resistance against other factors of the environment including irradiation and biological degradation (Willets, 1971). Melanins when complexed with chitins of fungal walls are inhibitors of polysaccharides (Bull, 1970) and therefore provide structural protection against enzymes of the fungus itself and of antagonistic micro-organisms. It has been suggested that the presence of melanins in sclerotial walls may be responsible for their survival even when medullary hyphae have been completely lysed by the action of microbial antagonists (Coley-Smith 1980) and after sclerotia have been degraded during germination.

In recent years, the advent of modern techniques allowing the accurate identification of various compounds at the molecular level has contributed to a surge of interest in the cell wall chemistry of fungi (Molano *et al* 1980; Bullock *et al* 1983; Benhamou *et al* 1990; Young & Ashford 1992). Papers dealing with the ultrastructural localisation of polysaccharides in the walls of fungal mycelium started to increase dramatically in number after the initial demonstration that substances such as lectins, enzymes and antibodies, when complexed to gold as an electrondense marker, were of essential value in elucidating the wall topochemistry. The investigation of the chemical

composition of the spore wall has received less attention. A lot of the information available has been derived from enzymatic digestions and X-Ray diffraction (Chu & Alexander 1972; Aronson 1981) and more recently through the use of gold-complexed probes (Bonfante-Fasola *et al* 1986; Grandmaison *et al* 1988; Berg *et al* 1988; Benhamou 1989). Results from these studies have demonstrated a remarkable difference in wall composition between spores and mycelia of even the same fungus confirming the earlier claims of Bartnicki-Garcia (1968).

Since the advent of the probe for detecting *in situ* ß-1, 4-glucan containing molecules a new wave of investigation has begun. One such study revealed that ß-1, 4-glucan rich molecules were found to be associated with conidial walls of a range of fungi - *Trichoderma viride*, *Fusarium oxysporum f. sp. radicus lycospersii*, *Verticillium albo-atrum*, *Penicillium thomii* and *Ophiostoma ulmi* (Benhamou *et al* 1989). Differences in cell wall composition between conidia and mycelium were reflected by the absence of ß-1, 4-glucan containing molecues in the vegetative walls. The presence of molecules with ß-1, 4-linkages in conidia is, therefore, most likely contributory to reinforcement of the wall architecture. These revelations suggest that spore walls may be more resistant then walls of purely vegetative structures and, consequently, they are more likely to be recovered as palynomorphs.

Palynologically it is considered that fungal spores behave in the same way as pollen grains and plant spores simply because they occur in conventional palynological preparations. In fact the wall chemistry of pollen grains is very different from that of fungal spores. In pollen grains the primary division in wall chemistry is between the intine and the exine. The intine is generally pectocellulosic and resembles the primary wall of somatic cells. The exine is sporopolleninous (Zetsche 1932) with small quantities of polysaccharides (Rowley *et al* 1981). Sporopollenin was first observed by John (1814) and was later characterised by Berzelius in the 1930s (see Zetsche & Huggler 1928). Sporopollenin refers to the general class of resistant exine materials and in fact defines a range of compounds. It is variable either in the relative proportions of different moieties or in the degree of cross-linking, or in the extent of masking of reactive groups. It has been suggested that sporopollenin is possibly the most inert organic compound known (Traverse 1988). Like chitin it is a C-H-O compound, see Fig. 1.1, and although characterisation of the structural formula is difficult, largely because of its inert nature, it is likely to be of the carotenoid-terpenoid sort and a copolymer of ß-carotene, a xanthophyll and fatty acids (Traverse

1988). However, the involvement of carotenoid derivatives in sporopollenin is questionable (Guildford *et al* 1988). In addition to sporopollenin, pollen grains may contain some or all of the following - carbohydrates, fibre residue, mineral elements, proteins and nucleic acids, amino acids, organic acids, callose, vitamins, hormones, steroids, carotenoids, flavanoids and up to 50% water at time of shedding in some grains.

The chemistry of the fungal spore wall is thus markedly different from that of the pollen grain. In retrospect, the possession of different wall chemistries is hardly surprising since fungal spores and pollen grains are produced in different biological Kingdoms and for different reasons, although the fundamental one is procreation. Many fungal spores are produced specifically to tide the fungus over periods of adverse conditions or indeed are required as part of their normal lifecycle to undergo some extreme form of duress, such as passing through the intestine of a herbivore (Massee & Salmon 1901). Resilience of such fungal spores is a prerequisite for survival. Comparatively speaking pollen has a much easier task and is not subject to the same tests of endurance.

These differences in wall chemistry, however, cast doubt on the application of conventional palynological extraction procedures to fungal spores. How can recovery of two chemically distinct suites of microfossils be optimally obtained by a single technique? They also raise speculation as to whether or not the limits of environmental criteria which define the preservation of the two suites of microfossils overlap for all or just part of their ranges. Elsik (in Traverse 1988, p. 306) commented indirectly on the physical implications of the differing wall compositions of the two palynomorph groups by noting that in some sediments it seemed that fungal spores were preserved better than sporopolleninous palynomorphs and also that the reverse could occur. Traverse (1988) also remarked on the tendency for some chitinous palynomorphs to be more resistant to both chemical and biological attack and to colour change on carbonisation than sporopolleninous palynomorphs. It would seem that their preservation overlaps for just part of the range but that there are circumstances which favour preservation of either fungal spores or pollen grains.

It is therefore, important at the outset to consider fungal palynomorphs in isolation and, most importantly, independently from pollen grains and plant spores. It cannot be assumed that to treat them as pollen is either acceptable or unacceptable. The very

fact that fungal spores are recovered by techniques designed to extract pollen indicates that there is a common palynological territory. However, it may well be that conventional extraction techniques do not optimise recovery of fungal spores. It is known that fungal spores are recovered through these techiques, but perhaps modified techniques would enhance their recovery. One of the first steps in the investigation of fungal spores as palaeoenvironmental indicators of anthropogenic activity is to develop a technique to maximise their recovery.

CONCLUSION

This chapter has examined previous research accessible on dispersed fungal spores. Reviews of previous work on fungal spores in palynology indicate the benefits of adopting a form taxonomic approach to recording dispersed fungal spores within Quaternary investigations, in order to faciltate palaeoenvironmental investigations. Modern habitat ecologies of the fungi suggest a potential for palaeoecological resolution if the spore record is a reflection of prevailing environmental conditions. However, in order to maximise the contribution fungal spores could provide as palaeoecological tools it is necessary to examine spore recovery methods, particularly in the light of what is known of the differences in wall chemistry between pollen grains and fungal spores.

THE APPROACH IN THIS STUDY

In view of these points this investigation will take a threefold approach.

First, since no universal system currently exists for the systematic recording of dispersed fungal spores it is considered necessary to devise one. In Chapter Two previous approaches to the classification of fungal spores are reviewed. In the light of these points a new system for the recording of dispersed fungal spores is proposed. This system is used thereafter throughout these investigations.

Second, it is essential to examine how fungal palynomorphs respond to conventional palynological extraction procedures. In Chapter Three the outcome of subjecting fungal spores to a range of conventional extraction procedures is noted and discussed.

As a result modifications are proposed to standard techniques to optimise the recovery of fungal spores.

Finally, using the recording system and the appropriate technique, fungal spores from modern samples are extracted and recorded in order to ascertain suites of microfossils presently associated within specific agricultural or/and ecological parameters. Further samples from a range of archaeological sites, which have been investigated by other environmental techniques or/and where other lines of evidence suggest the former anthropogenic activities on the site, are then investigated. Chapter Four describes these sites, both modern and archaeological, and the nature of the samples studied. All fungal spores recovered feature in the catalogue which constitutes Part Two of this thesis.

In Chapter Six multivariate analysis will be used to test whether local environmental variables pertaining to anthropogenic activities can be used to explain the distribution of the fungal spores within modern samples. From this information the potential for using modern samples as reference material for interpreting archaeological deposits can be assessed.

Where there is knowledge of a modern comparative for fossil spores this can be utilised in inferences as to the palaeoenvironment that is indicated. This approach is covered in Chapter Seven.

From this information the suitability of incorporating fungal palynology in archaeological investigations can be assessed in a preliminary fashion. Approaches which may lead to enhancing the technique are proposed.

CHAPTER TWO

FUNGAL SPORES IN CLASSIFICATION

Fungal spores have been employed extensively in the classification of the fungi. In some cases, particularly amongst the Agaricales, they are even diagnostic to generic and species level (Pegler & Young 1971), while Saccardo (1882 - 1886) devised a system for classifying the Ascomycetes and Fungi imperfecti to species level on the basis of spore characteristics alone. However, no uniform system for the classification and identification of all dispersed fungal spores exists and from a palynologist's perspective this limits their utility as a source of knowledge. In addition, some of the characteristics used for classifying fresh material could conceivably be lost by the time spores have become incorporated into the fossil record. This makes systems for classifying fresh material, such as those referred to above, impractical when fossil material is being considered.

The objectives of this chapter are to review the ways in which dispersed fungal spores have been considered in the past and to propose a universal system for recording all fungal palynomorphs. This recording system could eventually be used in constructing diagnostic keys to dispersed fossil fungal spores. Construction of such a key would, however, require consideration of a very large number of spores and the task is outwith the scope of this study. The intentions of this thesis are, simply, to lay the foundations for such an approach.

Through the use of the system that has been devised all fungal spores recovered through the course of these investigations can be allocated to morphological categories. This facilitates comparison of material variously described by other fungal palynologists and should make such comparisons more straightforward in future.

All spores encountered are featured in a catalogue which constitutes Volume Two of this thesis. Each record is accompanied by a spore description and, where appropriate, comparisons to known taxa and other spores and associated environmental/palaeoenvironmental information.

PREVIOUS APPROACHES TO FUNGAL SPORE CLASSIFICATION

In the late ninteenth century Saccardo (1882 - 1886) classified Ascomycetes and Fungi Imperfecti according to the shape, colour and septation of their spores. On the

basis of these criteria he divided them into 7 morphological groups of supra-generic rank:

1. *AMEROSPORAE* - monocellate, (aseptate) spores.

2. *DIDYMOSPORAE* - dicellate, monoseptate spores.

3. *PHRAGMOSPORAE* are spores having two or more transverse septa.

4. *DICTYOSPORAE* - spores divided by intersecting septa in more than one plane i.e. Muriform.

5. *SCOLECOSPORAE* - spores resembling *Amerosporae* but with or without septa and a length:width ratio greater then 15:1.

6. *STAUROSPORAE* - spores with or without septa and having more than one axis. The axes are not curved through more than 180°. Protuberances are present and greater than 1/4 spore body length.

7. *HELICOSPORAE* - spores with or without septa, with a single usually elongated axis curved through at least 180° but may describe one or more complete rotations in two or three dimensions. Any protuberances other than setulae are less than 1/4 spore body length.

For colourless or hyaline spores the categories were prefixed by HYALO - and pigmented by PHAEO - except for the *Amerosporae* which became *Hyalosporae* and *Phaeosporae* respectively.

Even with a rudimentary knowledge of fungi it should be possible to categorise spores of the Ascomycetes and Fungi Imperfecti according to Saccardo's system. However, other classes of fungi or fungal palynomorphs are not accounted for and, in addition, the use of colour as such an important taxonomic character is based on assumptions that may not hold true, especially where fossil material is concerned. There is evidence to suggest that the colour of spores may be affected by conditions of preservation such as thermal maturation, oxidation state, processing techniques and even nature of embedding substrate (Traverse 1988; Wolf 1966a); this colour variation is certainly the case for pollen and other classes of palynomorphs (Traverse 1988). Unpublished observations of W.C. Elsik referred to by Traverse (1988 p. 433) suggest that the colour changes in chitinous fungal spores, resulting through thermal maturation, are slower to happen than changes in pollen and other sporopolleninous palynomorphs.

A subsequent scheme for classifying isolated fossil fungal spores was proposed in the middle of this century by Thomas van der Hammen, (van der Hammen 1954a, 1954b, 1956). This system takes a form-taxonomic approach to the classification of fossil fungal spores.

The *Botanical Code of Nomenclature* (which governs the naming of fungi) recognises a special category for fossil plants - the *form-genus* - under which species may be recognised and given names (Jeffrey 1989). This is because fossil plants usually occur as detached organs or fragments of organs rather than as complete organisms. The same is true of dispersed fungal spores which are seldom found attached to the sporocarp. A form-genus may be unassignable to a family, but may be referable to a taxon of higher rank. It may include fossils superficially similar but in fact representing widely different taxa of family and higher rank. Unless a spore is found actually attached to the parent material, which is but rarely the case, it is frequently impossible to tell to which fungal genus a spore may correspond. The code permits the use of form-genera as means of reference to such isolated and unassignable parts.

Form-genera are also adopted for some extant taxa of fungi imperfecti where, for example, only the anamorph (asexual stage) is evident and assignation to known genera requires knowledge of the teleomorph (sexual stage) e.g. *Penicillium* (Carmichael *et al* 1980).

In the form classification of van der Hammen all fossil spores of supposed fungal origin are given the terminal *sporites*. Spores are then divided into groups according to the number of apertures, the number of septa and the number of spores united, leaving also a category for those that could not easily be assigned with certainty to any of the other categories. He proposed 8 form genera in total :

1. MONOPORISPORITES
2. DIPORISPORITES
3. TRIPORISPORITES
4. POLYPORISPORITES
5. INAPERTISPORITES
6. PLURICELLAESPORITES
7. POLYADOSPORITES
8. INCERTISPORITES

These descriptions of fossil fungal spores are valid according to the rules established by the *International Code of Botanical Nomenclature*. However, prior use of the term *sporites* as a generic suffix for spores of pteridophyte and bryophyte origin makes this convention impractical. To overcome this Clarke (1965) proposed the term *sporonites* for new generic names.

There are, however, ambiguities within this system ; for example whether to call a multicellate spore with two apertures a *Diporisporites* or a *Pluricellaesporites* or whether to call an inaperturate, multicellate spore an *Inapertisporites* or a *Pluricellaesporites,* etc., i.e. which spore characteristics are dominant.

Some more recent approaches to recording fungal palynomorphs have tended to emphasise ecological in addition to taxonomical information. Van Geel (1978, 1979, 1981, 1986) records many kinds of Quaternary *incertae sedis* microfossils which are predominantly of fungal origin in a `type' system. The use of `type' here is unrelated to the taxonomic meaning of the word. It refers to not accurately identifiable, more or less homogenous categories of microfossils as far as a distinction of a particular element is feasible. These types can be considered to be provisional form species designated by van Geel. The type numbers are sequential upon recovery and do not imply any relationship between the fossils. Van Geel considers assemblages of micro- and macrofossils of diverse taxonomic affinities, and in addition to considering the assemblages as a whole, he employs the assistance of numerous specialists in mycology, algology and invertebrate zoology for the identification of individual types. He attempts to relate as many as possible to living species thereby enhancing environmental interpretation.

This work is of exceptional value. Its applications to the wider field of palynology could potentially be improved if the recorded microfossils were allocated to morphological categories. This would facilitate access to the data by other palynologists, and also provide them with some incentive to record fungal types, which they encounter within the same framework. However, since van Geel concerns himself with not only fungal and algal remains but also with microfossils of, for example, zoological origin and with macrofossils the task of developing a single classification system becomes more complex.

Contemporaneously with van Geel, Elsik (1976a) proposed the following *form-classification* for dispersed pre-Quaternary fungal spores:

ORDER	*Sporae dispersae*
FAMILY	*Monocellae*
	Monodicellae
	Dicellae
	Tricellae
	Tetracellae
	Multicellae
	Cellae indeterminatae

The additional characters of aperture, shape and surface ornament are used to define genera within the proposed families: such characters are also useful in keying to form-genera. This system encourages palynologists to record fungal spores as it permits instant allocation of a spore to a category on the basis of the number of cells present. It is simple and uncomplicated. However, cell number (or septal number) often varies, even within spores of the same species. In addition, over 60 % of the spore types recovered throughout the course of this investigation were monocellate (or aseptate), see Volume Two. This means that the Family Monocellae comprise over 60% of the fungal types encountered; a more even distribution of types throughout the system is more desirable.

Coles (1989) proposed a recording system whereby fungal and algal palynomorphs encountered could be grouped on the basis of four orders of characteristic in addition to ecological information. However, this system although it records all the morphological information required about the palynomorphs is rather complicated, and for the purposes of constructing a morphological key simplification and restructuring is required and reallocation of emphasis to different morphological characteristics.

PROPOSED CLASSIFICATION SYSTEM

The recording system proposed here is a unification of the main principles of Saccardo, van der Hammen, van Geel, Elsik and Coles. Each fungal palynomorph encountered is, first of all, assigned to a morphological class on the basis of its apertures and septation. Thereafter, other morphological details are recorded which can subsequently be applied in the definition of further morphological divisions.

Additionally, palynological and/or ecological associations are noted as are comparisons and contrasts to other specimens.

In the proposed classification system septal number is combined with aperture number to define a new set of morphological classes. These characteristics have been selected because they are quantitative and therefore objective. In addition, they are generally easy to determine using light microscopy. They are also the main features which Saccardo, Van der Hammen and Elsik chose for their spore divisions. Thus, they are suitable for first order division. This system has the advantage of spreading the distribution of types more evenly across the different categories than if septal number alone was used as in Elsik (1976a).

By constructing a matrix which displays the number of apertures on the horizontal axis and the number of septa on the vertical axis then 20 compartments each with a unique number of apertures and septa results (see Fig. 2.1). Each compartment has an individual three letter code which describes its arrangment of aperture number and cell number, for example, an aseptate/inaperturate spore would have the code ASI (AS= ASeptate + I=Inaperturate).

Cell number and septal number are directly related and relay the same information. However, the use of septal number as opposed to cell number has been adpoted simply to minimise any confusion likely to arise over the biological interpretation of the word `cell '.

Subsequent refinements and divisions to form generic and species level can be based on the following spore characteristics:

1. Aperture details
2. Septal details
3. Shape and symmetry
4. External appendages/processes
5. Surface ornamentation
6. Wall structure
7. Colour
8. Stain uptake

These traits should be recorded in a format which facilitates construction of a morphological key when a sufficient corpus of spores has been described (see Fig. 2.4).

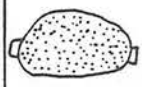
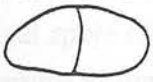
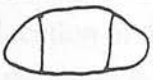
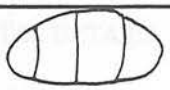
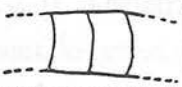
NO. OF APERTURES / NO. OF SEPTA	 INAPERTURATE	 MONO-APERTURATE	 DI-APERTURATE	 POLYAPERTURATE
 ASEPTATE	ASI	ASM	ASD	ASP
 MONOSEPTATE	MOI	MOM	MOD	MOP
 DISEPTATE	DII	DIM	DID	DIP
 TRISEPTATE	TRI	TRM	TRD	TRP
 MULTISEPTATE	MUI	MUM	MUD	MUP

Fig. 2.1 Matrix illustrating morphological categories for recording dispersed fungal spores.

SPORE CHARACTERISTICS

APERTURE DETAILS

For the nature of the apertures the terminology of Elsik (1983) has been adopted. He illustrates six representative types of pores based on pore modification. Four of them are also used in describing pores of pollen (1. perforate, 2. simple, 3. annulate, 4. invaginate) while the remaining two (5. pore chamber and 6. compound pore chamber) are exclusive to fungal spores. The term aperture as opposed to pore was preferred since a pore in a pollen grain is not necessarily analogous to a pore in a fungal spore (See Fig. 2.2). It should be noted that from this author's observation apertures in fungal palynomorphs are not always very obvious and are easily overlooked particularly in some of the large, ellipsoid, thick-walled specimens where the location of the aperture is polar, the aperture is extremely small, <1µm diameter and the spore favours an equatorial orientation.

SEPTAL DETAILS

For the septal details once again the terminology of Elsik 1983 has been adopted (see Fig. 2.3). The arrangment of the septa can be either transverse or longitudinal and, if present, longitudinal septa can be either Regular (aligned) or Irregular (offset). The locations of all septa are recorded. It should be noted that there is a possibility that septa may be lost through fossilisation or laboratory processing (Elsik, 1979). In addition, the following septal details may not always be evident with light microscopy. However, they should be noted if possible.

Individual septa may be described as entire, having a septal aperture, having a septal flap or being irregularly ruptured. The term *entire septum* is an additional septal type to those of Elsik 1983. If a septal pore is present it may be described as simple annulate, with a plug or with an apeture cap. Where the septa break near their attachment to the spore wall a septal scar may remain which can be described as a septal groove or a septal ridge.

Sometimes only *shadow bands* occur which may be indicative of incomplete septa.

SHAPE

Shape is often an important diagnostic feature for many spores. However, there are several published terminologies for shape (see Kremp, 1965: Ainsworth and Bisby 1971) and as a result there are in several cases synonyms for the same shape. In

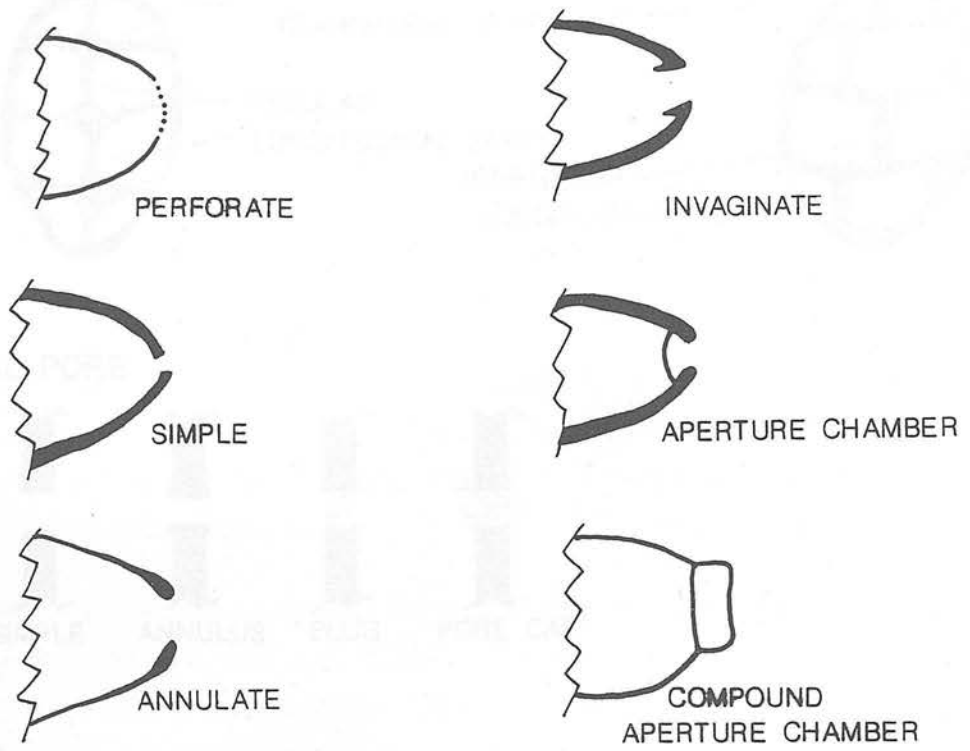
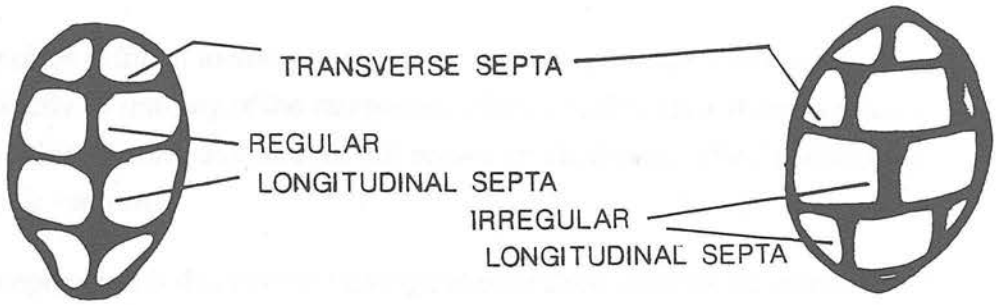
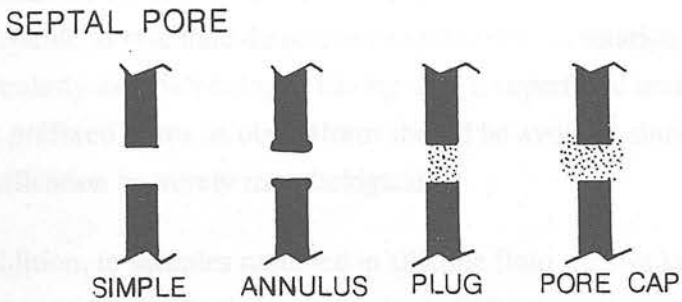
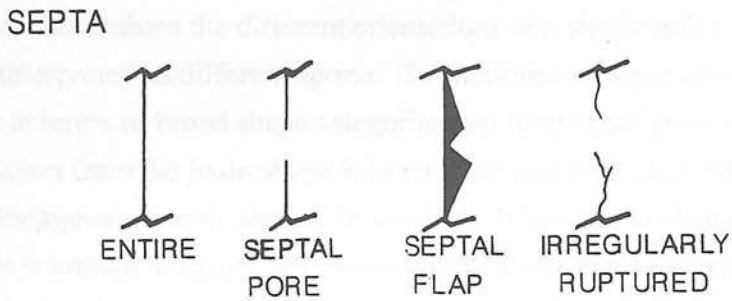


Fig. 2.2 Aperture types (after Elsik 1983).







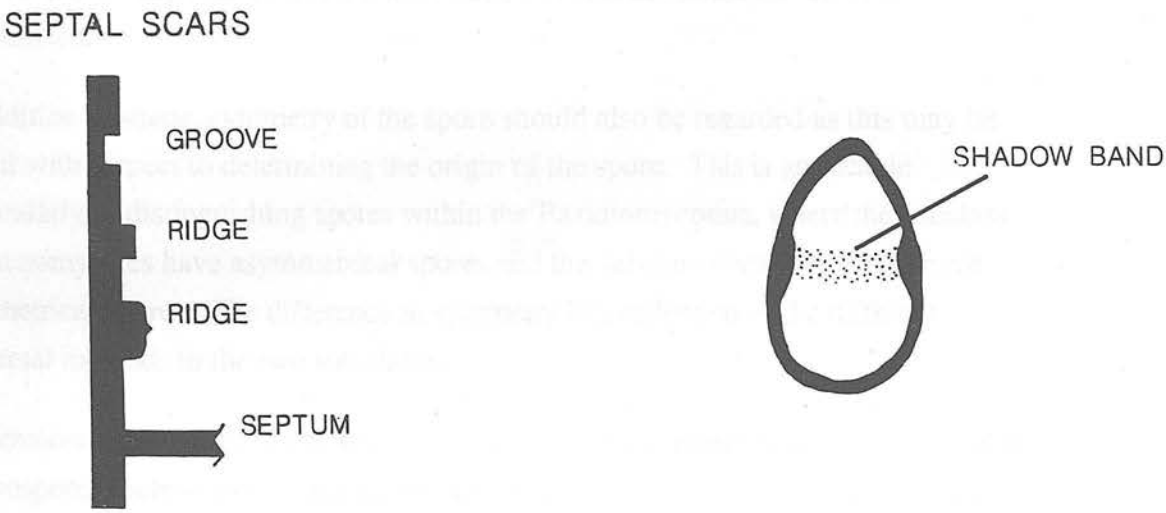


Fig. 2.3 Septal details of fungal spores (after Elsik 1983).

addition it is often difficult to assign a particular spore to a definite shape category as it may not exactly fit into any of the categories. Thus, deciding on a shape is often a difficult and subjective decision and for this reason an illustration or/and photograph of each spore is essential.

A further complication is that defining a shape may be dependent on the orientation of the spore e.g. Pyriform and Obpyriform are morphologically identical and the distinction between them is purely a matter of orientation. Since it is frequently impossible to orientate dispersed fungal spores in relation to the parent material, particularly as a palynologist having only a superficial understanding of mycology, such prefixed terms as obpyriform should be avoided since it is intended that this classification be purely morphological.

In addition, in samples mounted in silicone fluid (or similar viscous mounting media) the shape of individual spores can look different as the specimen is rolled about. Therefore, the possibility exists that in specimens mounted in fixed media or preserved in two-dimensions the different orientations of a single spore could be confused for and interpreted as different spores. To minimise this risk spores should be described only in terms of broad shape categories and terms such as subfiliform, where the deviation from the main shape is in terms of an apiculus or other form of external appendage or process, should be avoided. Where more than one orientation of the spore is known it should be drawn and described in all the orientations. Consequently, any approach based on spore shape should be treated with extreme caution and its importance in the classification of spores should not be over-emphasised.

In addition to shape, symmetry of the spore should also be regarded as this may be useful with respect to determining the origin of the spore. This is applicable particularly to distinguishing spores within the Basidiomycotina, where the subclass Hymenomycetes have asymmetrical spores and the subclass Gasteromycetes have symmetrical spores. The difference in symmetry is a reflection of the different dispersal methods in the two sub classes.

Dimensions are also noted and any useful descriptive terminology applicable, such as dictyospore, scolecospore, staurospore and helicospore may be adopted. The longest axis of the spore is governed by measurement `a' and the next longest axis by measurement `b', certain spores will also have a third measurement `c'.

EXTERNAL APPENDAGES/PROCESSES

This category accounts for any protrusions present. It will encompass hilar appendages, attachment scars, foot cells, corona .....etc. A brief outline of the nature of the appendages along with their distribution and numbers should also be recorded.

Ultimately it should prove possible to categorise such external appendages in the same manner as aperture and septal details.

SURFACE ORNAMENTATION

The terminology of Iversen and Troels-Smith 1950 for the surface ornanmentation of pollen has been adopted simply because there is no comprehensive published terminology dealing exclusively with the surface ornamentation of fungal spores, known to the author, which does not require transverse sections. Additionally, the terminology of the Iversen and Troels-Smith scheme is familiar to palynologists.

This terminology comprises twelve sculpture types: psilate, foveolate, scabrate, verrucate, gemmate, baculate, clavate, echinate, rugulate, striate, reticulate and fossulate. Ainsworth and Bisby (1961) recognised the sculpture types foveolate, verrucate, echinate, striate, reticulate and punctate as the basic types occurring in fungal spores. Punctate is a form of foveolate where individual elements are smaller. The Troels-Smith terminology may therefore be adequate, despite the fact that wall structure and wall chemistry of pollen differ markedly from those of fungal spores as outlined in Chapter One. However, in addition to these basic types tuberculate ornamentation was encountered in this investigation, for example see Part Two Type ASI 002.

For terms such as foveolate, verrucate, clavate...etc, there are conventions as to how in detail they may be used. Where individual sculpture elements can be clearly seen their distribution can be quantified by counting the number of sculpture elements in quarter of one surface of the spore if radially symmetrical or half of one surface of the spore if bilaterally symmetrical, then multiplying by 8 or 4 respectively to get an approximation for the distribution over the total surface area. If the spore is asymmetrical or the ornamentation is not uniformly distributed then it may not be possible to quantify the ornamentation. However, emphasis should not be placed on the distribution of ornamentation since differences thereof may simply be representative of intra-specific variation.

WALL STRUCTURE

This characteristic should be treated with the same caution as the presence of septa since some of the inner less resistant walls may be lost in the process of fossilisation (Elsik 1979) or extraction (Elsik 1979). This may create artificial discrepancies between modern and fossil material. In addition, it is often difficult to discern the number of wall layers without sectioning: this is particularly true where some of the very dark-walled spores are concerned where they are virtually opaque even at very high illuminations. However, where possible, the number of wall layers and their distribution and dimensions are recorded.

COLOUR

Colour of palynomorphs is not a very reliable characteristic, as mentioned in Chapter One. This reservation applies especially with respect to pre-Quaternary material. Colour could be described using e.g. a Munsell colour chart but because if its inconsistency and unreliability as a diagnostic feature less rigorously defined variations on grey, brown and yellow...etc should be adequate.

STAIN UPTAKE

This characteristic may be useful in confirming the suspected biologic affinities of certain spores. However, the deterministic reactions to specific stains of fresh spore material have not been demonstrated in the fossil record. Fossil spores take up biological stain only if they have been oxidised (Elsik in Traverse 1988, p.306) and whether or not they then react in the same manner as fresh material has not been tested.

Therefore, as judged from previous work stain uptake is of little significance, on the whole, for the purpose of classification of dispersed fungal spores.

Safranin, a common palynological stain may, however, be of value in distinguishing between fungal and algal material as fungal material does not generally absorb safranin whereas algal material does. However, some fungal material does absorb safranin as can be seen from examples in this study e.g. Type MOI 005 and Type MOI 007, see Part Two. Therefore, the absorption of safranin should not be considered as confirmation of non-fungal status for any palynomorph. It may be that many more fungal spores absorb safranin than previously considered but that the colour staining is masked by the already dematiaceous nature of the walls.

OTHER INFORMATION

In addition to recording the preceeding morphological information for each new spore type encountered the following information should also be recorded:

1. Sample number, slide number and England finder reference.

2. Extraction/concentration techniques employed and mounting medium.

3. Comparable spores recorded previously or/and comparison to published material.

4. Ecology - if the environment of deposition of the palynomorph is known.

5. Location.

6. Additional notes.

7. Analyst and date.

USE OF THE PROPOSED SYSTEM

The entire system has been designed so that each new palynomorph encountered can be recorded on both sides of a single A4 sheet - the morphological characteristics on one side and all other information on the reverse; see Fig. 2.4. Each new palynomorph recorded is given a type number at the time of recording - names can be designated at a later date. The type number is composed of a three letter code and a number. The three letter code refers to the state of apertures and septation of the spore, i.e. the morphological category (described earlier in this chapter) and the number is designated as each new spore is encountered within each morphological category.

When an appropriate number and range of spore types have been recorded using the system, construction of the morphological key can begin and form-taxa described. With time it is likely that many of the spore types will be assigned to known fungal taxa. However, as mentioned previously, this will not be possible in all cases and many types will retain their form-classification.

The system is intended to be flexible and through use any limitations or necessary changes can be dealt with and modifications implemented.

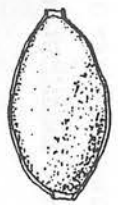
TYPE NAME unknown

TYPE NUMBER ASD 005

MORPHOLOGICAL CLASS
ASD

APERTURE DETAILS:
present ☑
absent ☐
Type Pore Chambers
Location On opposite poles
Size 2½ µm diameter

GROSS MORPHOLOGY:
Shape oval
Drawing



Dimensions a. 31µm b. 16µm c.
Range 30 - 41 µm 16 - 24µm

SEPTAL DETAILS: present ☐ absent ☑ longitudinal ☐ transverse ☐ regular ☐ irregular ☐
Septal Pore present ☐ absent ☐ Type of pore
Nature of septa Location of septa

EXTERNAL APPENDAGES/PROCESSES: present ☐ absent ☑
Nature Number
Location

SURAFCE ORNAMENTATION: present ☐ absent ☑
Ornamentation Dimensions
Distribution

WALL STRUCTURE:
No. of wall layers One
Distribution Thinning at Pore Chambers
Dimensions Approx. 1µm

COLOUR: Dark Brown

STAIN None used
Diagnosis ——

DETAILS OF SAMPLE

Sample Number HB91J.07 Slide Number 2
England Finder Ref. E41/3

Nature of Sample Mor Humus
Location of sample site Galashiels, Borders Region
Grid Reference NT4936
(Provisional) Age Recent

Extraction/Concentration Techniques used
KOH/HF/Acetolysis

Mounting Medium 6.000 c.s. Silicon fluid

DETAILS OF SPECIMEN

Palynological Association/ Ecology
Ash Woodland

Frequency of Occurence very rare

Comparisons Van Geel, B., 1978; p. 81.

Additional Notes

Analyst CC

Date 27/09/92

Fig 2.4 Format of recording sheet with working example

LIMITATIONS OF THE SYSTEM

One limitation of the system which came to attention early in its use was the fact that some fungal palynomorphs have inconsistent morphologies. This is applicable particularly to palynomorphs which take the form of long single rows of cells. In many cases it is not possible to ascertain whether or not these are fragments of spores or of hyphae. To overcome this, all palynomorphs of this form are referred to collectively as `Toruloid fragments' because of their resemblance to the genus *Torula* (Crane & Schoknecht 1981). This alleviates the unproductive tedium of describing and recording such variable fragments each time they are encountered.

The same principle has been applied to agglomerations of small round cells having an average diameter of 9µm. Such cells are also often found in isolation, and usually, single cells and agglomerations occur in the same sample. All such forms have been collectively referred to as `Phomoid' because of their resemblance to the genus *Phoma* (Boerema 1976).

More compact agglomerations of cells also sharing uncharacteristic morphology and of larger size than phomoid agglomerations have been grouped together as `aggregations'. Some of the spores initially assigned to this category were subsequently identified as bulbils and papulospores, as is discussed in Part Two. Plate 2.1 illustrates some examples of such forms of palynomorphs.

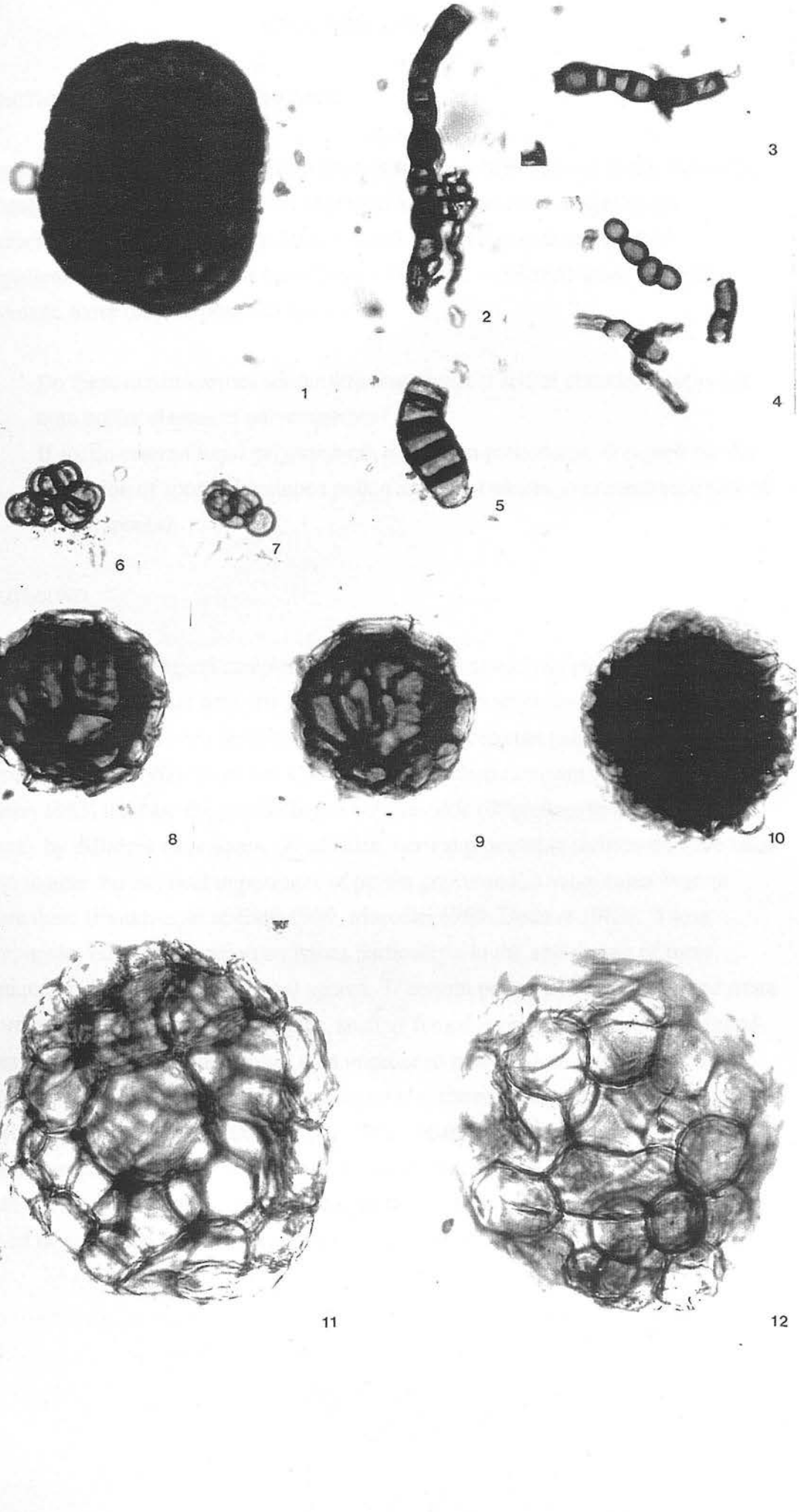
CONCLUSION

A morphological recording system for the classification of dispersed fungal palynomorphs has been proposed and its use described. This system permits recording of both modern and fossil fungal palynomorphs within a single framework. Additionally, it enables recording without *a priori* knowledge as to the origin of the microfossil and facilitates eventual construction of a morphological key.

Plate 2.1

Fig. 1. Chlamydosporic aggregation. Figs. 2-5. Toruloid fragments. Figs. 6-7. Phomoid agglomerations. Figs. 8-9. High and low focus of chlamydosporic aggregations later identified as Papulospores. Fig. 10. Chamydosporic aggregation later identified as a Bulbil. Figs. 11-12. High and low focus of chlamydosporic aggregations later identified as papulospores.

PLATE 2.1



CHAPTER THREE

EXTRACTION OF FUNGAL PALYNOMORPHS

Conventional palynological extraction procedures have been applied to the recovery of fungal spores. A close look at the chemical wall structure of fungal spores illustrates the differences between fungal spores and wall chemistry of other sporopolleninous palynomorphs (see Chapter One). A number of issues arise from this remark, these may be posed as questions:

> Do these dissimilarities confer different physical and/or chemical properties onto unlike classes of palynomorphs?
>
> If so, do conventional palynomorph extraction procedures, designed for the extraction of sporopolleninous pollen and plant spores, maximise recovery of fungal spores?

BACKGROUND

Traditionally, palynological samples were prepared by acetolysis preceded by digestion in Hydrofluoric acid (HF) if minerogenic. However, over the years several other techniques have been devised to extract and concentrate palynomorphs from sediments (Brown 1960, Hunt and Coles 1988). Limited comparative studies (Dodson 1983) indicate the probability of considerable differences in the efficiency of recovery by different techniques. In addition, certain processing techniques have been shown to alter the physical appearance of pollen grains and in some cases even to rupture them (Funkhauser & Evitt 1959, Marceau 1969, Dodson 1983). These discrepancies raise some important issues particularly in the application of these techniques to the recovery of fungal spores. If certain pollen and spore taxa and more importantly other palynomorph groups, such as fungal spores, are selectively altered or lost through different techniques then in order to maximise the potential it is important to determine which technique optimises the recovery of the specific palynomorph group under consideration. This is particularly relevant to fungal spores in the knowledge of the differences in wall composition between pollen and fungal spores already discussed in Chapter One. In this instance the aim is to define a method of extraction which maximises the recovery of fungal spores.

EXPERIMENTAL DESIGN

Three different extraction techniques incorporating a varied range of procedures were chosen. The techniques all commence with the pretreating of the samples in alkali to disaggregate humic rich sediments and dissolve humic colloids, followed by sieving to remove the larger pieces of debris. Two of the techniques employ the widely used 5% Potassium Hydroxide (KOH) alkali pretreatment while the third technique incorporates a reputedly gentler acting base, 5% Ammonium Hydroxide (NH_4OH), (Elsik, pers. comm). In all three techniques sieving was through nested 180µm and 10µm mesh sieves. The residue from the 180µm mesh sieve was discarded and that of the 10µm mesh sieve was retained and subjected to the subsequent procedures in the extraction techniques.

The first technique is the traditional Hydrofluoric Acid (HF) maceration followed by Acetolysis. The second technique uses heavy liquid of specific gravity 2.0 and varying centrifugation speeds and times to separate off the palynomorph fraction. The third technique, the one with the NH_4OH pretreatment, works on the same principle as gold-panning. It can be considered chemically as the least harsh of the three techniques and involves swirling a water-diluted solution of the sample on a large clock glass on the assumption that the palynomorph fraction will remain in suspension while the heavier mineral debris will sink when the clock glass is gently swirled. The palynomorph fraction in suspension can then be poured off and the process repeated with the sink. A more complete outline of each procedure is given below. The final residue from all three techniques was dehydrated using Tertiary Butyl Alcohol (TBA) and stored in phials with silicone oil of 6,000 centistokes (cs) viscosity.

Two palynomorph groups are considered, pollen and spores constituting one and fungal spores the other; the purpose being to compare the reactions of pollen and fungal spores to the same palynological extraction procedures and consequently to establish which technique maximises the recovery of fungal spores.
By subjecting each of three different substrates listed below to all three different processing techniques and recording the assemblages of the two different palynomorph groups recovered, the effect of each processing technique on samples and their palynomorph groups could be ascertained.

NATURE OF SAMPLES

The samples chosen for investigation were collected in June 1991 from two organic regime farms in the Borders Region: namely Holybush Farm in Galashiels, Roxburgh

District and Godscroft farm in Duns, Berwick District see Fig. 4.1. The samples are 1. HB91J.11 - Mor Humus from a mixed deciduous woodland (Holybush), 2. HB91J.1/2 - Deep Litter from a cow byre (Holybush) and 3. GC91J.07 - Soil from a field under permanent pasture (Godscroft). These samples were selected because it is thought that they are representative of situations likely to have analogues in archaeological studies and also because preliminary examination showed them to contain abundant and diverse assemblages of fungal palynomorphs and pollen. For more detailed information on the sampling localities and the individual samples see Chapter Four.

METHODOLOGY

The samples were placed in manila envelopes and thoroughly dried in an oven in order to assist homogenisation using mortar and pestle. Homogenistation consisted of coarsely grinding the samples in order to break up any clumps. Then each sample was mixed thoroughly before sub-sampling. Five subsamples of each sample were processed by each technique. Each sub-sample was taken by displacing $1cm^3$ of water in a graduated polypropylene centrifuge tube.

Because the focus of the comparison is between palynomorph recovery from subsamples of a single sample treated by different processing techniques the addition of exotic markers was not considered necessary as each sample effectively acts as its own standard. There is no comparison between samples, only within.

EXTRACTION TECHNIQUES

TECHNIQUE A - HF MACERATION /ACETOLYSIS

The samples were boiled in 5% KOH for 15 minutes followed by sieving through nested 180 µm and 10 µm mesh sieves. The residue on the 180 µm mesh sieve was discarded while that of the 10 µm mesh sieve was retained for subsequent stages in the extraction procedure, since that is the fraction likely to contain any palynomorphs. The samples were then centrifuged at 3,000 rpm for 5 minutes and the supernatant was decanted and discarded. 6 mls of 40% HF were added to each sample in a polythene tube which was then placed in a boiling water bath for one hour. The samples were centrifuged while the HF was still hot and the supernatant was neutralised and disposed of carefully. The pellet was resuspended in Hydrochloric Acid (HCL) and warmed in a water bath before washing twice with distilled water. The pellet was then suspended in 6 mls of Glacial Acetic Acid (Ch_3COOH), mixed well, centrifuged and the supernatant decanted. Next 6mls of acetolysis mixture were added to each of the tubes and they were placed in a boiling water bath for no more

than 2 minutes. Acetolysis mixture consists of 9 parts Acetic Anhydride to 1 part concentrated Sulphuric Acid (H_2SO_4). After 2 minutes the tubes were filled up to two thirds capacity with glacial acetic acid and centrifuged. The supernatant was decanted and the process repeated. The samples were then rinsed twice with distilled water followed by dehydration using TBA. They were stored in silicone fluid prior to mounting.

TECHNIQUE B - HEAVY LIQUID FLOTATION.

The samples were boiled in 5% KOH for 15 minutes followed by sieving through nested 180 µm and 10 µm mesh sieves and as in Technique A the residue of the 10 µm mesh sieve was retained while that of the 180 µm mesh was discarded. The samples were then rinsed with distilled water, rinsed twice with ethanol and after the second ethanol supernatant had been decanted the tubes were filled with acidified Zinc Chloride ($ZnCl_2$) of specific gravity 2 (acidified by adding a few drops of 10% HCl to the Zinc Chloride solution). Each tube was then centrifuged at 500 rpm for 25 minutes, followed by a centrifugation at 2,500 rpm for 10 minutes. The supernatant containing the palynomorphs was then poured off, diluted by at least four and recentrifuged at 3,000 rpm for 2 to 3 minutes or until a pellet had formed. The samples were then washed in 10% HCl to prevent formation of a precipitate and dehydrated using TBA before storage in small labelled phials in silicone fluid.

TECHNIQUE C - SIEVING AND SWIRLING

The samples were boiled in 5% NH4OH for 15 minutes followed by sieving through nested 180 µm and 10 µm mesh sieves. The residue on the 180 µm mesh sieve was discarded while that on the 10 µm mesh was retained. Then the 10 µm sieve residue was washed onto a 220mm diameter clock glass. A gentle swirling motion allows silt and fine sand to fall out of suspension, whilst pollen, spores and other microfossils remain in suspension and can be poured off. These `floats' are returned to the sieve, whilst the `sinks' are repeat swirled. The sinks were examined microscopically to check that palynomorphs were not being discarded and the process of sieving and swirling was repeated until a clean preparation was obtained. The preparations were then dehydrated using TBA and stored in small labelled phials in silicone fluid.

MOUNTING METHODS

Silicone fluid of 6,000cs (centistokes) viscosity was used in place of the more frequent 1,250 cs fluid, for storing and mounting of residues, as there is less likelihood of the palynomorphs moving around under the coverslip when the viscosity

is higher. This makes it easier to relocate specific palynomorphs, in particular fungal palynomorphs which require detailed examination, description, illustration, photographing and measurement within the recording system detailed in Chapter Two.

METHODS

Total palynomorph counts of a minimum of 300 pollen grains per sample were achieved in most cases. In cases where this was not possible because of the paucity of palynomorphs, then at least one compete slide was logged and an endeavour to reach a minimum sum of 100 was the target.

Fungal palynomorphs encountered were recorded on a scale of occurrence. Those occurring between 1 and 3 times (per slide or per 300 pollen grains) are designated as rare, between 4 and 9 times as frequent and more than 10 times as abundant. The recovery and abundance from replicates of each sample can be seen in Figs 3.1 to 3.3.

The ratio of pollen to fungal spores recovered by each sample was used as a means of assessing how consistent replicates of a single sample were. The 95% confidence intervals of the standard errors of the means were calculated and the smaller the confidence interval then the more consistent are the replicates. The results of this can be seen in Fig. 3.4.

The fungal and algal palynomorphs encountered can be categorised into five groups based on the fact that each group behaved more or less as a unit. The groups are:

1. Small round to oval palynomorphs 10 - 25 µm diameter; palynomorphs falling into this category are prefixed by `S'.
2. Thick-walled, dematiaceous, elongated fungal spores; prefixed by `T'.
3. Endogonaceous palynomorphs; prefixed by `E'..
4. Other fungal sporocarps; prefixed by `O'.
5. Algal cysts; prefixed by `A'.

	1	2	3	4	5
A-ASI 014	F		F		F
E-ASI 020	R		F		
O-MUI 016			R		R
S-ASI 003	R	R			
S-ASI 008	A	A	A	A	A
S-ASI 009					R
S-ASI 011	F			R	
S-ASI 012		R			R
S-ASI 036	A	A	A		F
S-ASI 042	F	F	A	F	A
S-ASM 001	A	F	F	F	
T-ASD 002	F			R	
T-ASD 005	F	A	A	F	F
T-ASD 008	F	R	F	F	F
T-ASI 037	R	R	R	F	F
T-ASM 015	F	R	F	F	F
T-ASM 020	A	A	A	A	A
T-DII 002			R	F	R
T-DII 003			R		
T-DII 005	R	R		R	R
T-DII 011	R		R		
T-DIM 003		F	R	R	R
T-MUD 001		R			R
T-MUI 003					R
T-TRD 001	F	R	F	F	F
T-TRI 004					R
T-TRI 005				R	

TECHNIQUE A

A= Abundant
F= Frequent
R= Rare

	1	2	3	4	5
A-ASI 046			R	R	
A-ASI 055	F	F	F		R
A-ASM 014			R		
A-ASM 032	R	R		F	F
A-DIM 003		R			
E-ASI 020			R		
E-ASI 028			R	F	
E-ASO 031		R	R		
O-ASM 018	F	A	F	A	R
O-ASM 019	F	F	F	A	F
O-MUI 016	F	A	F	A	F
S-ASI 008		R	F	R	R
S-ASI 036				R	
S-ASM 001	R	F		A	R
T-ASD 005		R	R		
T-ASI 037	R			F	
T-ASM 015			R		
T-ASM 020					R
T-ASM 029	R		R		
T-ASM 031	R	R		R	R
T-TRD 001		R			

TECHNIQUE B

	1	2	3	4	5
A-ASI 055	R				R
A-ASM 014		R		R	
A-ASM 022	A	A	A	A	A
A-ASM 032	A	A	A	A	A
A-ASM 033	R	F	F	F	
E-ASI 020	F	R	F		R
E-ASM 019	F	F			
O-ASM 016	R		R	R	F
O-ASM 018		R		R	
O-MUI 016	F	F	F		
S-ASI 003	R				F
S-ASI 008	F	A	F	F	A
S-ASI 036	F	F	F	R	F
S-ASI 041		R			
S-ASI 047		R			
S-ASM 001	A	F	A	R	R
S-ASM 004		R			
T-ASI 037	R	R	R	R	
T-ASM 006					R
T-DIM 001	R		R		
T-DIM 003	R	R			
T-MUI 003		R			
T-TRD 001		R			

TECHNIQUE C

Fig. 3.1 Occurrence of fungal palynomorphs from subsamples of permanent pasture prepared by techniques A,B and C.

	1	2	3	4	5
A-ASM 004	F	F	F		F
E-ASI 020		R	R	R	R
S-ASI 001		R			
S-ASI 003	F	R		R	R
S-ASI 008	F	F	A	A	F
S-ASI 011					R
S-ASM 001		F	R		F
S-ASM 006					R
S-ASM 009	A	A	A	A	A
S-ASM 010	R	R			
S-MOI 005		R			R
T-ASD 002	R	R		R	R
T-ASD 009	R				R
T-ASI 037	R	F	F	F	F
T-ASI 042	A	A	A	A	A
T-ASM 011		R			
T-ASM 015	A	A	A	A	A
T-DII 008	A	F	F		F
T-MOM 001					R
T-MUI 003	R	R			
T-MUP 001				R	

TECHNIQUE A

A= Abundant
F= Frequent
R=Rare

	1	2	3	4	5
E-ASI 020	F		R		F
E-ASM 019		R	R	F	R
O-ASM 018		R		R	
S-ASI 042	F	F	R	R	R
S-ASI 047		R			R
S-ASM 001	F	F	R		R
T-ASD 003	R		R		F
T-ASD 005		R			
T-ASI 048	R				R
T-ASI 055		R			R
T-ASM 020		R	R	F	
T-DII 008	R	R		R	

TECHNIQUE B

	1	2	3	4	5
A-ASM 014					R
A-ASM 022	F	R	F	R	R
E-ASI 020	F	F	F	F	F
O-ASI 040			R		
S-ASI 001					R
S-ASI 003				R	R
S-ASI 036	F	R	R		
S-ASI 041			R		
S-ASI 042	R				
S-ASM 010		R		R	F
S-MUI 004	R				
T-ASD 002			F		
T-ASD 003				R	R
T-ASI 037					R
T-ASM 006			R		
T-ASM 007			R		
T-ASM 009	R		F		
T-ASM 012			R		
T-ASM 015		R	R		R
T-ASP 001			R		
T-ASP 002					R
T-MUI 003	R				
T-MUI 007		R			
T-TRI 001			R		

TECHNIQUE C

Fig. 3.2 Occurrence of fungal palynomorphs from subsamples of mor humus prepared by techniques A,B and C.

	1	2	3	4	5
O-ASI 043		R			
O-MUI 016			A		
S-ASI 001	A	A	A	F	A
S-ASI 003	A	A	A	A	A
S-ASI 004			F	R	F
S-ASI 008	F	A	F	A	A
S-ASI 009			R	F	
S-ASI 014	R				
S-ASI 038	R				
S-ASM 001	A	F	A	F	
S-ASM 003	R			R	R
S-ASM 004	R				
S-DII 001				R	
T-ASD 002		R			
T-ASI 037	R		R		F
T-MOI 001	A	R			
T-MOI 004		R	R		
T-MUI 001	R				R
T-MUI 002	R				
T-MUI 005		R			
T-MUI 006		R			
T-TRI 002	R				

TECHNIQUE A

	1	2	3	4	5
O-ASI 043			R		
O-ASI 056	A	A	A	A	A
O-MUI 016	A	A	A	A	A
S-ASI 003	A	F	F	F	A
S-ASI 008	F	R	F		F
S-ASI 014	A	A	A	A	A
S-ASI 035			R	F	
S-ASM 001	F		R		R
T-ASI 037			R	R	
T-ASI 042	F				
T-MUI 006			R	R	

TECHNIQUE B

A = Abundant
F = Frequent
R = Rare

	1	2	3	4	5
O-ASI 010		R	_	_	_
S-ASI 003	R	R	_	_	_
S-ASI 008	R		_	_	_
T-ASM 006	R		_	_	_

TECHNIQUE C

Fig. 3.3 Occurrence of fungal palynomorphs from subsamples of cow byre material prepared by techniques A, B and C.

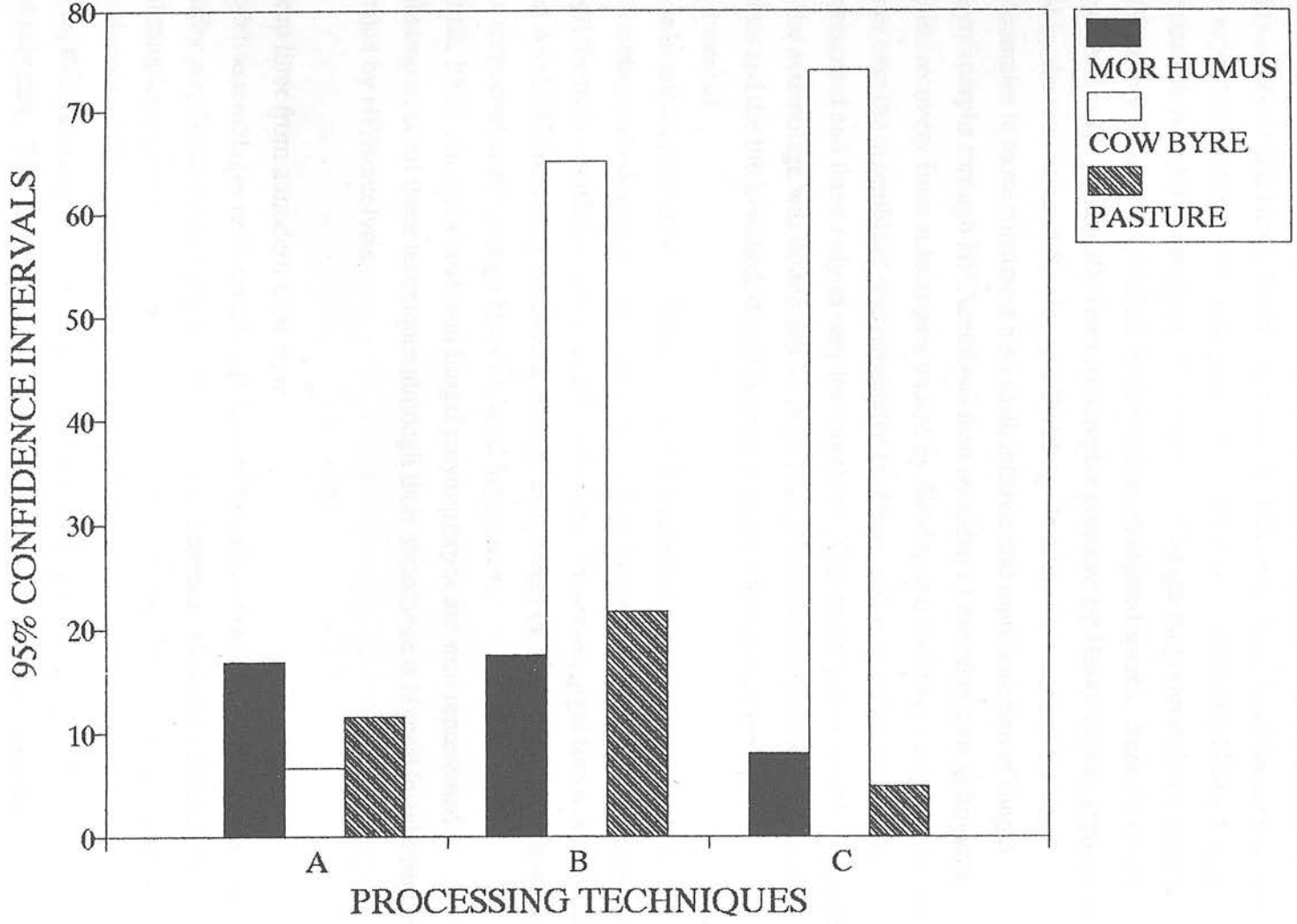


Fig. 3.4 95% confidence intervals of standard errors of the means.

Plates 3.1 and 3.2 illustrate the five classes of palynomorphs under consideration here.

RESULTS

Mixed Deciduous Woodland Mor Humus

Pollen recovery was good from both subsamples prepared by the techniques of HF/Acetolysis and Heavy Liquid Separation. However, fungal palynomorphs were not recovered in nearly the same quantities or diversity of forms by Heavy Liquid Separation as by HF/Acetolysis. The majority of fungal palynomorphs recovered by HF/Acetolysis are thick-walled, dematiaceous, elongated spores. Such forms are recovered only sporadically from subsamples prepared by Heavy Liquid Separation and by the technique of Sieving and Swirling. In addition, recovery between subsamples is more consistent both in abundance and representation of fungal palynomorphs through HF/Acetolysis than by either of the other two techniques. Pollen recovery from subsamples treated by Sieving and Swirling was poor. In the latter case the assemblage was dominated by *Pinus* with only a few other taxa represented and these only in very low numbers. The fungal palynomorph component of the assemblage was dominated by large Endogonaceous palynomorphs and algal forms and the thick-walled, dematiaceous, elongated forms were only poorly represented.

In subsamples recovered by Heavy Liquid Separation the fungal palynomorph assemblage was dominated by large types such as Endogonaceous palynomorphs and algal forms in addition to other fungal sporocarps. However, algal forms ASM 022 and ASM 033 frequently recovered through the process of Sieving and Swirling were not recovered at all through Heavy Liquid Separation.

Small, 10-25 µm round and oval fungal palynomorphs are well represented in subsamples of all three techniques although their abundance is highest in subsamples treated by HF/Acetolysis.

Deep litter from a modern Cow Byre

Pollen assemblages recovered by all three techniques were dominated by Poaceae, hardly surprising considering the nature of the substrate. However, three of the subsamples treated by Sieving and Swirling were barren. The two which were productive yielded a total of four fungal types and these only in very low abundance. Thus, this technique is not successful in this case, probably because of the nature of the substrate. The substrate, being composed primarily of straw and dung, makes the liberation of constituent palynomorphs dependent on the initial pretreatment breaking down the matrix. If palynomorphs are not liberated in the beginning then subsequent

stages in the extraction process are effectively redundant. The use of NH_4OH as a pretreatment may be a contributing factor to its effectiveness and perhaps a better result would have been obtained by using a harsher pretreatment such as KOH. Subsamples prepared by Sieving and Swirling will not be considered further.
Pollen assemblages did not vary significantly between HF/Acetolysis and Heavy Liquid Separation although HF/Acetolysis produces higher abundances. Obviously acetolysis is more effective at attacking the substrate, thereby liberating more palynomorphs than Heavy Liquid Separation. However, the fungal palynomorph assemblage was significantly different between the two, with the greatest diversity of forms recovered by HF/Acetolysis. Many are only single occurrences which results in replicate samples being inconsistent. There are only a few types which are regularly recovered from replicate samples. These are small, round to oval forms, 10-25 µm in diameter. Subsamples recovered by Heavy Liquid Separation do not have the same incidence of singly occurring types as those recovered by HF/Acetolysis but yet parallel samples are still inconsistent. This may be as a result of over-representation of ASI 014 and ASI 003 since when they are excluded from the palynomorph sum the ratio of pollen to fungal palynomorphs becomes more constant. ASI 014 are borne within sporocarps of MUI 016 while the origin of ASI 003 is uncertain although it is suspected that they may come from within the true Endogonaceae.
MUI 016, both whole and ruptured, occur more frequently in subsamples prepared by Heavy Liquid Separation than by HF/Acetolysis. The increase in numbers of ruptured specimens could be partly or wholly responsible for the higher number of ASI 014. Alternatively, it is possible that acetolysis destroys dispersed ASI 014 although they were found dispersed in subsamples processed by HF/Acetolysis. This could have occurred due to the parent sporophores rupturing at a stage post-acetylation
Although fungal sporocarps are encountered occasionally in subsamples by HF/Acetolysis they are much more abundant in those processed by Heavy Liquid Separation. ASI 010 does not occur at all in subsamples processed by HF/Acetolysis while MUI 016 occurs only rarely.

Permanent Pasture Soil

Pollen was recovered in abundance from subsamples processed by both HF/Acetolysis and Heavy Liquid Separation while subsamples treated with Sieving and Swirling were poor in pollen. Fungal palynomorph assemblages recovered by HF/Acetolysis were consistent in their representation and abundance between parallel subsamples as were assemblages from parallel subsamples treated with Heavy Liquid Separation. However, assemblages recovered by HF/Acetolysis and Heavy Liquid Separation were different from each other. Fungal palynomorph assemblages recovered in

parallel subsamples treated by Sieving and Swirling were inconsistent in both occurrence and abundance. There was a high incidence of taxa occurring singly which is contributory to this. Most of the singly occurring taxa were Endogonaceous palynomorphs and large algal forms. Contrastingly, ASM 022 is abundant in subsamples treated by Sieving and Swirling but absent from subsamples treated by Heavy liquid Separation.

Subsamples recovered by Heavy Liquid Separation exhibit the lowest diversity in types but the incidence of singly occurring types is also low and so there is consistency between parallel subsamples in both occurrence and abundance. Once again this method produces higher numbers of the Endogonaceous palynomorphs than subsamples recovered by HF/Acetolysis, although not as high as from those recovered by Sieving and Swirling. Additionally, recovery and abundance of other sporocarps is best from subsamples recovered by the technique of Heavy Liquid Separation.

DISCUSSION

It seems that small, round to oval fungal palynomorphs in the size range 10-25 µm behave in a similar manner to plant spores and pollen in all of the techniques tested. However, other fungal palynomorphs do not conform with this observation. Endogonaceous palynomorphs, other sporocarps and other larger and more buoyant forms are lost through the process of HF/Acetolysis. Thick-walled, dematiaceous, elongated forms are lost through the process of Heavy Liquid Separation whilst only the more buoyant forms as is also the case with the more buoyant forms of pollen such as *Pinus* are reliably and consistently recovered through the process of Sieving and Swirling. Thus, it seems that the technique of Sieving and Swirling biases recovery in favour of larger and more buoyant forms of both pollen and fungal palynomorphs while Heavy Liquid Separation biases recovery predominantly against the fungal palynomorph component.

The morphology of the Endogonaceous palynomorphs and of the algal forms, large and rounded, may result in their being lost in discarded supernatant during centrifugation. This phenomenon was observed by Jemmet and Owen (1990) in relation to *Tsuga* pollen, a large and spherical form, in which up to 65% were lost to the supernatant during centrifugation. It may account for the apparent under representation of these forms through the technique of HF/Acetolysis since centrifugation is carried out between most of the stages in this extraction procedure. There may also be an element of over representation of large, rounded forms in samples prepared by Sieving and Swirling and by Heavy Liquid Separation since these techniques depend to a large extent on buoyancy for palynomorph recovery.

It seems that the reverse is true of the thick-walled, dematiaceous, elongated fungal palynomorphs which settle out of suspension although they fall within the size range of most pollen grains encountered. This is most likely to be due to an intrinsic difference in their morphologies or/and densities to that of pollen grains and plant spores which can remain suspended.

Payak (1964) determined the specific gravities of a range of fungal spores using a method suggested by Buller (1909). It was found that fungal spore specific gravities range from 0.807 for some uredospores to 1.44 for spores of *Lycoperdon* species. However, Mc Callan (1958) holds the view that the specific gravities of most fungal spores fall at around 1.1. It should be noted that such measurements have been conducted on only a small number of fungi and Gregory (1961) believes the densities of thin-walled, hyaline spores are low and often corresponding to that for water. However, the fact that many of the spores in samples from this study are lost in suspension of specific gravity 2 indicates that such forms have, in fact, higher specific gravities. Therefore, it is likely that the range of fungal spore specific gravities is more extensive than reported in the literature. This makes it unlikely that a single solution could be successfully employed in the heavy liquid extraction of a diverse and random sample of fungal spores.

This argument suggests that gravity separation techniques applicable to pollen recovery are unsuitable for representative recovery of fungal palynomorphs.

Algal form ASM 022, often recovered in considerable quantities in subsamples prepared by Sieving and Swirling was not recovered in subsamples processed by either of the other two techniques. The same is true of algal form ASM 033 which is recovered by Sieving and Swirling but not by Heavy Liquid Separation or HF/Acetolysis. It is not unusual to find such algal forms destroyed by acetolysis since they are often cellulose in composition. However, it would be anticipated that they would be recovered in subsamples prepared by Heavy Liquid Separation. Their absence in these subsamples suggests that they may fall out of suspension in $ZnCl_2$ or that they are destroyed at some stage by some process in the extraction procedure. It is unlikely because of their shape that they would fall out of suspension and although the possibility that their destruction is as a result of $ZnCl_2$ exists, it is more likely that they are destroyed by alkali pretreatment using KOH, whereas NH_4OH being gentler may not damage them.

None of the techniques tested seemed to cause notable deterioration to any of the fungal palynomorphs. This may indicate that fungal spores are less susceptible to process induced deterioration than pollen and plant spores. Although Wolf (1966a)

noted that acetolysis was responsible for darkening hyaline spores this was not evident from these samples where hyaline spores were often recovered from acetolysed samples. Van Geel (1972) also remarked that the colour of fungal cell walls is little altered by acetolysis.

An important point which is revealed through this investigation is that in some cases processing techniques should be modified according to the nature of the virgin sample and that by doing so the outcome can be considerably enhanced. However, in practice a lot more bias may be introduced by adopting this approach. Since all samples are not being treated in the same way the outcome may be, in part, a reflection of the different processing techniques employed and this could introduce discrepancies into the results. There is also the other side to the argument that if techniques are not tailored to individual samples then potentially valuable information may be lost, which could also introduce inaccuracies to the results.

In practice, in Quaternary palynology it is not often that the nature of the samples will vary as much as in this investigation and samples would generally be more homogenous, e.g. from a soil core. Additionally, palynology of surface sediment samples is not a very common practice. Surface samples for pollen investigations generally take the form of moss polsters (Wright 1967). Where sediments are being considered most fossil and subfossil material would have been broken down naturally, to a greater extent, so that initial chemical pretreatments should be more effective and the problem, therefore, less pronounced.

Thus, there is no ideal approach but the safest and most scientific approach is to treat all samples in the same way.

CONCLUSIONS

Ideally the extraction procedure is required to give optimal recovery of fungal spores but also adequate recovery of pollen grains and plant spores. This is because many palynologists consider the analysis of non-pollen palynomorphs primarily as a supplementary source of information. This practice will undoubtedly continue until other forms of palynological analysis have become established. Although this thesis is concerned only with the analysis of non-pollen palynomorphs, the wider convention of recording the fungal spores encountered within a count of 300 pollen grains has been adopted; the reasons for doing so are discussed in Chapter Five.

Of the three techniques tested, HF/Acetolysis is the most effective at extraction and concentration of both classes of palynomorphs. However, there are apparent losses of Endogonaceous palynomorphs, other fungal sporocarps and large buoyant forms among the fungal component and potential losses of buoyant forms among the pollen component (Jemmet and Owen 1990). Ideally, these losses should be minimised. There are many possible approaches to overcome this problem, for example, experimenting with longer centrifugation times or faster speeds or experimenting with alternative forms of oxidation which could be carried out in sintered funnels, thereby reducing the required number of centrifugations.

By far the simplest approach is to reduce the specific gravity or alter the surface tension of the sample in the test tube, prior to centrifugation. This can easily be done by spraying the suspension with ethanol and then centrifuging as normal and it is the approach which has been adopted for all subsequent palynological extractions throughout this study. All samples in this study were prepared using exactly the same extraction procedure.

PLATES 3.1 AND 3.2

(see catalogue for actual dimensions of specimens)

Plate 3.1

Images 1, 2, 3, 7, 8, 9, 10. Thick-walled, dematiaceous palynomorphs,

Images 4-6. Small, round to oval fungal palynomorphs

Image 11. Endogonaceous palynomorph

Image 12. Other fungal sporocarp.

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PLATE 3.1


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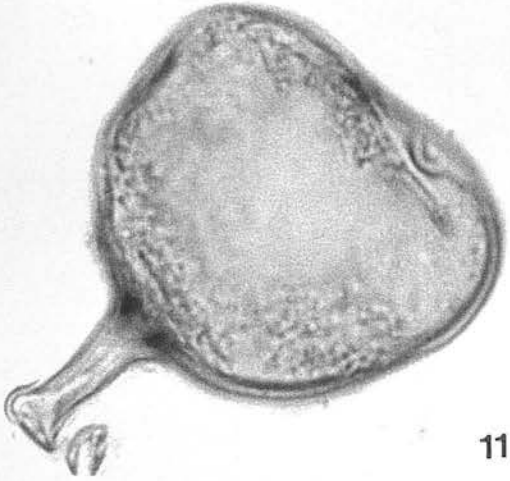
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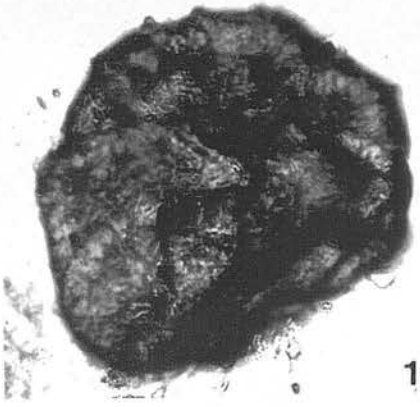
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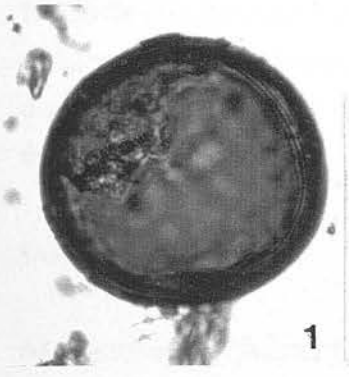
Plate 3.2

Image 1. Endogonaceous palynomorph

Images 2-4. Algal palynomorphs

Image 5. Other fungal sporocarps

PLATE 3.2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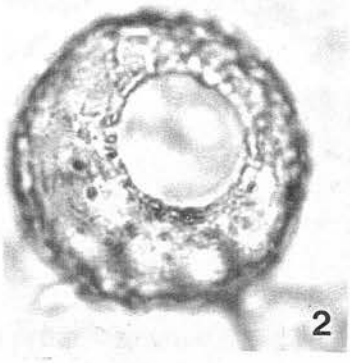
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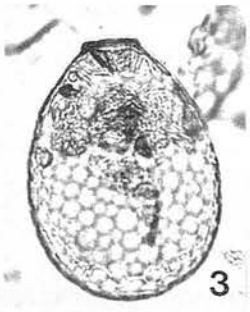
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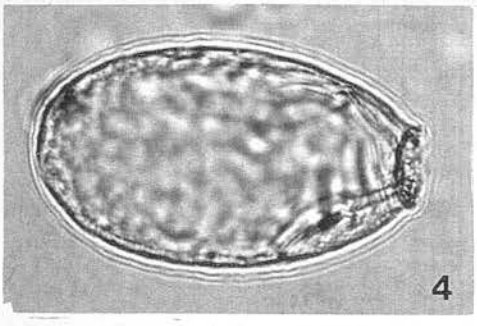
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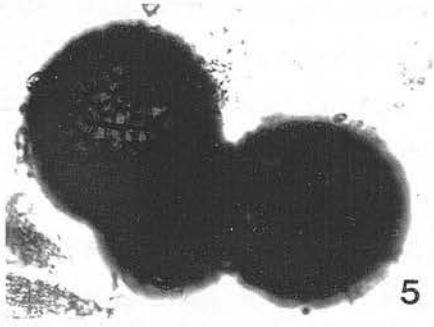
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CHAPTER FOUR

SITE DESCRIPTIONS

This chapter describes the sites from which samples were taken to investigate the potential of fungal spores as palaeoenvironmental indicators of anthropogenic activity. It also details the nature of the samples from each of these sites. The Chapter is divided into two sections; the first dealing with the modern sites and their samples and the second dealing with the archaeological sites and their samples. Fig. 4.1 illustrates the location of all sites.

SAMPLING STRATEGY

As discussed in Chapter One, a prime objective of this study is the investigation of the suites of organic walled microfossils presently associated with specific agricultural or/and ecological parameters with a view to using this material as reference material for the interpretation of archaeological palynomorph assemblages. In order to do this samples were required from both modern and archaeological situations. Organic regime farms and prehistoric analogue farms were considered appropriate to establish the reference material of modern agricultural and ecological situations. Since use of artificial chemicals is controlled and minimised on organic regime farms it is assumed that they are more closely related to prehistoric situations than non organic regime farms. The same argument can be applied to prehistoric analogue farms.
Selection of archaeological sites followed less stringent criteria. An attempt was made to include sites across a range of periods and a range of environments.

SAMPLING METHODS

Modern samples were taken using a trowel - approximately $10cm^3$ of material were removed from the surface of each deposit. Samples were bagged and frozen on the same day. Archaeological samples were provided in the form of air dried material for samples from Balbridie and Lairg; refrigerated soil samples in the case of Buiston and Tuquoy; and a frozen core in the case of Bharabhat.
All frozen samples were defrosted overnight before processing according to the procedure outlined in Chapter Three.

MODERN SITES

Godscroft farm, Duns

NT7463

This is a hill farm situated just outside Duns in Berwickshire. It is predominantly an arable farm but with some sheep, cattle and pigs. In addition there is a range of fowl- ducks, geese and hens- wandering around amongst the farm buildings and a hen house with roosts and egg boxes. The following samples were taken for the analysis of the fungal spore content.

SAMPLES

GC92F.01 : Surface soil from permanent pasture field, grazed by cattle and sheep. Sample collected in February 1992.

GC92F.02 : Surface soil from permanent pasture field, grazed by cattle and sheep. Sample collected in February 1992.

GC92F.03 : Surface soil from wheat field. Sample collected in February 1992.

GC92F.09 : Surface soil from winter barley field. Sample collected in February 1992.

GC92F.11 : Debris from hen house floor. Floor covered in rolled oats mixed with droppings and straw. Sample collected in February 1992.

GC92F.12 : Debris from pig house with concrete floor. This building has also been used to house calves and probably sheep at some point. The floor is a sea of muck which is likely an accumulation of deep litter straw. In addition to access by pigs a range of other animals including hens, ducks, geese, cats and dogs were encountered on sampling visits to the farm. Sample collected in February 1992.

GC92F.14 : Debris from pig house with earth floor. As with sample GC92F.12, this building has also been used to house calves and probably sheep at some point. The floor is a sea of muck which is most likely an accumulation of deep litter straw. In addition to

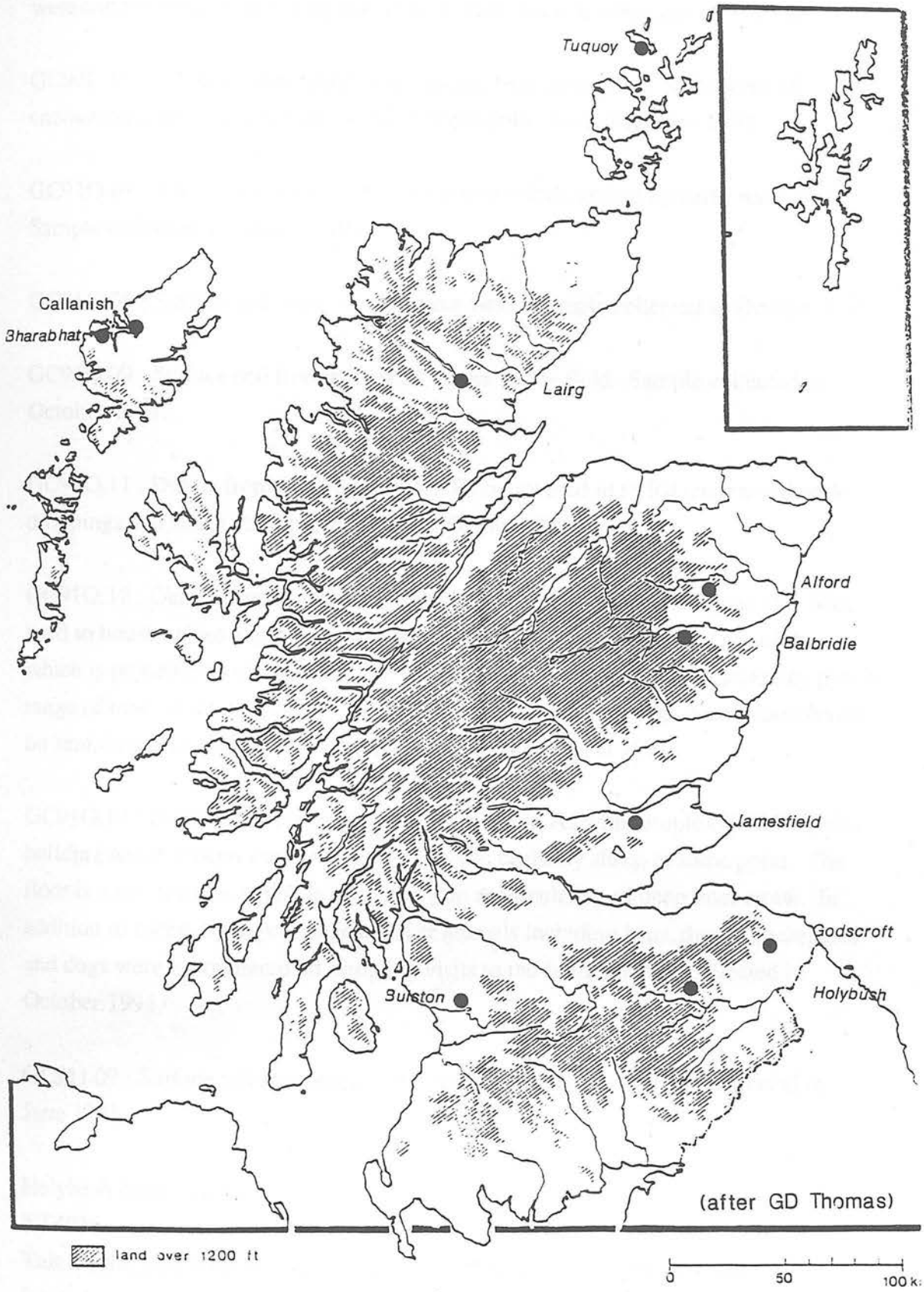


Fig. 4.1 Location of all sampling sites.

access by pigs a range of other animals including hens, ducks, geese, cats and dogs were encountered on sampling visits to the farm. Sample collected in February 1992.

GC92F.15 : Soil from pigs' yard. Pigs, ducks, hens, sheep, and cattle were all encountered roaming about this yard. Sample collected in February 1992.

GC91O.01 : Surface soil from permanent pasture field, grazed by cattle and sheep. Sample collected in October 1991.

GC91O.05 : Surface soil from harvested oat field. Sample collected in October 1991.

GC91O.09 : Surface soil from harvested winter barley field. Sample collected in October 1991.

GC91O.11 : Debris from hen house floor. Floor covered in rolled oats mixed with droppings and straw. Sample collected in October 1991.

GC91O.12 : Debris from pig house with concrete floor. This building has also been used to house calves and probably sheep at some point. The floor is a sea of muck which is probably an accumulation of deep litter straw. In addition to access by pigs a range of other animals including hens, ducks, geese, cats and dogs were encountered on sampling visits to the farm. Sample collected in October 1991.

GC91O.14 : Debris from pig house with earth floor. As with sample GC92F.12, this building has also been used to house calves and probably sheep at some point. The floor is a sea of muck which is most likely an accumulation of deep litter straw. In addition to access by pigs a range of other animals including hens, ducks, geese, cats and dogs were encountered on sampling visits to the farm. Sample collected in October 1991.

GC91J.09 : Surface soil from field under permanent pasture. Sample collected in June 1991.

Holybush farm, Galashiels
NT4936
This a 1000 acre farm with approximately 100 head of cattle and 400 head of sheep, located just outside Galashiels. Some arable cultivation is also practised on this farm. Amongst the farm buildings were cattle byres, covered hay and straw sheds and a

pony stable. The following samples were taken for the analysis of fungal spore content.

SAMPLES

HB92M.01 : Floor of winter cattle byre. Sample collected in March 1992.

HB92M.02 : Floor of winter cattle byre. Sample collected in March 1992.

HB92M.03 : Hay from floor of covered hay store. Sample collected in March 1992.

HB92M.05 : Well-rotted straw from floor of straw store. Sample collected in March 1992.

HB92M.07 : Bedding from horse stable - a mixture of peat and wood-shavings. Sample collected in March 1992.

HB92M.12 : Surface soil from manured meadow. Sample collected in March 1992.

HB92M.14 : Surface soil from permanent pasture field. This field has not been ploughed since before the First World War, long term phosphate is applied every three to four years. Both sheep and cattle graze on the pasture. Sample collected in March 1992.

HB92M.16 : Surface soil from barley field. Sample collected in March 1992.

HB91O.01 : Floor of winter cattle byre. Sample collected in October 1991.

HB91O.03 : Hay from floor of covered hay store. Sample collected in October 1991.

HB91O.04 : Hay from floor of covered hay store. Sample collected in October 1991.

HB91O.07 : Bedding from horse stable - composed of peat and wood shavings. Sample collected in October 1991.

HB91O.14 : Soil from permanent pasture field. This field has not been ploughed since before the First World War. Cattle and sheep graze on the pasture. Sample collected in October 1991.

HB91O.16 : Surface soil from harvested barley field. Sample collected in October 1991.

HB91J.1/2 : Floor of winter cattle byre. Sample collected in June 1991.

HB91J.11 : Mor humus from mixed deciduous woodland at upslope end of permanent pasture field. Sample collected in June 1991.

Jamesfield farm, Newburgh, Fife
NO2318
This is a 180 acre organic regime farm. It is divided into three experimental plots. Two thirds of the farm are given over to the production of organic meat and the remainder to a range of vegetables including; potatoes, brussel sprouts, carrots and onions. This farm has been organic since the 1980s.
The following samples were taken for analysis of fungal spore content:

SAMPLES
JF91J.01 : Surface of sheep field. Sample collected in June 1991.

JF91J.03 : Surface of barley field. Sample collected in June 1991.

JF91J.05 : Bedding from cow stall. Consisting of straw, cows had only been present for a few days. Sample collected in June 1991.

JF91J.06 : Hay from floor of hay shed. Sample collected in June 1991.

Highland Pony Stud, Alford
NJ5715
This is a small ca 50 acre highland pony stud farm in Alford in the Don Valley. The owners have been in possession for about 20 years and during this time the land has not been farmed intensively. Although the predominant stock are ponies, sheep and goats have been kept at various stages and the deposits examined in this study were from locations in which sheep, goats and ponies had been kept.

The following samples were taken for analysis of the fungal spore content.

ABP1 : Deep litter from pony byre. Sample taken from indoor byre in a damp area below open roof ventilation.

ABP3 : Deep litter from pony byre. Sample taken from indoor byre in a damp area below open roof ventilation.

ABPS1 : Outdoor midden used by ponies and sheep. A permanent outdoor midden on which hay is fed to the animals in winter. This midden has been accumulating for at least 15 years.

ABPS2 : Outdoor midden used by ponies and sheep. A permanent outdoor midden on which hay is fed to the animals in winter. This midden has been accumulating for at least 15 years.
It is interesting to note that the midden reputedly yielded a tasty crop of field mushrooms - *Agaricus campestris* - in 1992 before the samples were taken.

ABGS1 : Deep litter from goat and sheep byre. Sample taken from a dry area away from open roof ventilation.

ABGS2 : Deep litter from goat and sheep byre. Sample taken from a dry area away from open roof ventilation.

ABGS3 : Deep litter from goat and sheep byre. Sample taken from a dry area away from open roof ventilation.

Callanish farm, Callanish, Isle of Lewis
NB2132
This is a 200 acre property immediately adjacent to the Callanish Standing Stones on the Isle of Lewis. The experimental plots from which samples were taken had been abandoned for several years but had last been planted with cereal crops.
The following samples were taken for the analysis of the fungal spore content.

CA91G.02 : Surface soil from abandoned crop plot (experimental plot 1). Sample collected in August 1991.

CA91G.03 : Surface soil from abandoned crop plot (experimental plot 2). Sample collected in August 1991.

CA91G.05 : Surface soil from abandoned crop plot (experimental plot 3). Sample collected in August 1991.

CA91G.07 : Surface soil from small, ungrazed enclosure (around automatic weather station). Sample collected in August 1991.

Fungal spores were extracted and recorded from all of these samples and are catalogued in Part Two of this Dissertation.

Balbridie, Kincardine and Deeside District, Grampian Region
NO7395
This is an isolated rectangular structure 24 X 12 m in overall dimensions. It has a range of internal features and bowed gable-ends, which may be of typological significance. Surviving features indicate that this site represents a single wooden hall which was roofed. A significant discovery during excavation was that the structure had been burnt down (Fairweather & Ralston 1993).
The site is situtated on a fluviglacial terrace immediately south of the river Dee and east of Banchory. The site was originally thought to be of Pictish age but radiocarbon dates on wood, charcoal, cereal grains and plant macrofossils centred between 3100 bc. and 2700 bc. It offers the largest assemblage of carbonised, Neolithic grain known from the British Isles, some 20,000 cereal grains have been counted to date (Fairweather and Ralston 1993).
Fig 4.2 shows a plan of the excavated structure.

Five samples from this site were selected for investigation of the fungal spore content therein. One of the samples was barren. All samples come from the fills of features. The samples are;

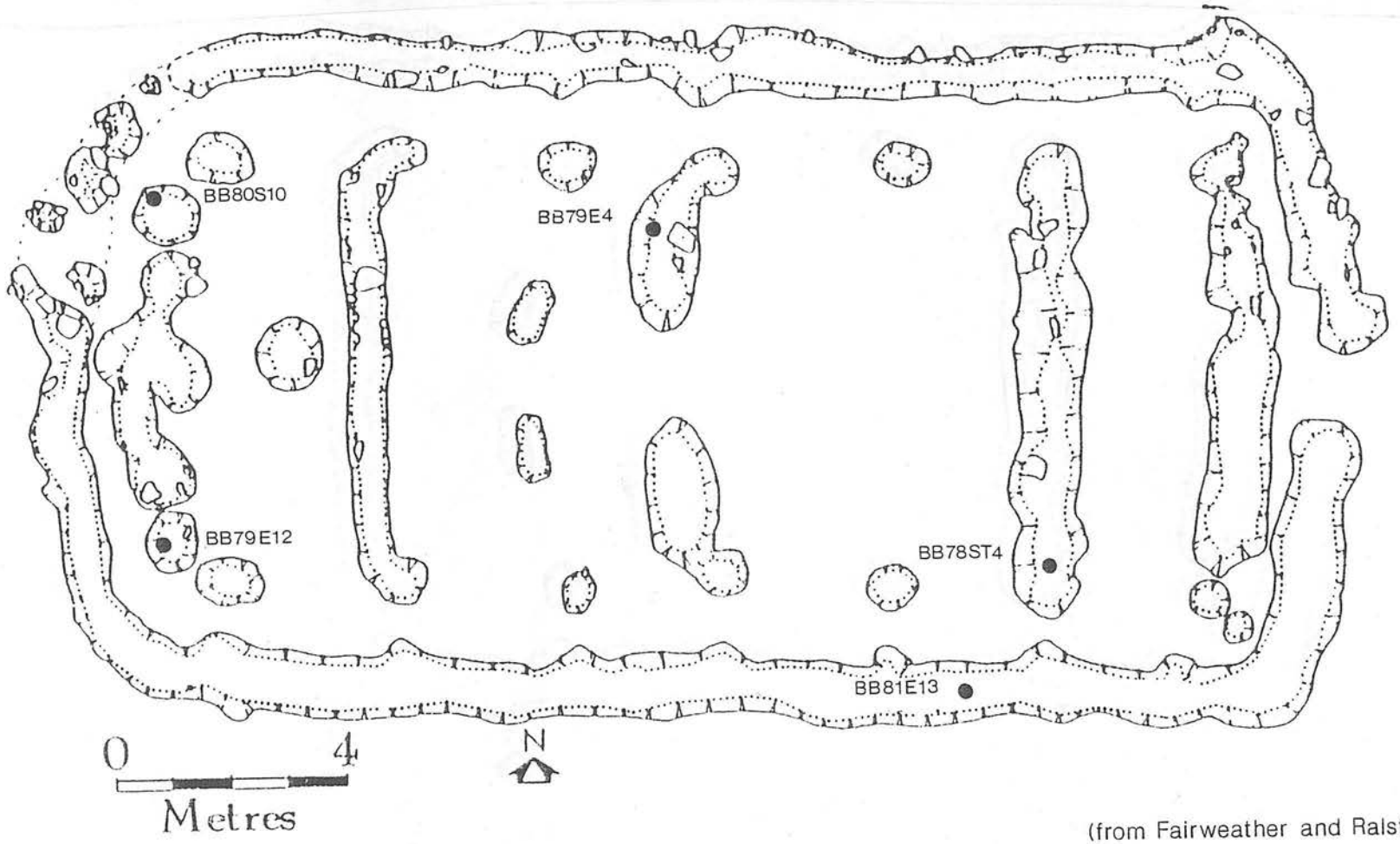
BB 78 ST4 : this sample is from the rim of the construction trench as it survived inside the building. It is therefore likely to produce indications relating to the use of the building.

BB 79 E4 : this sample was collected between two plan levels in one of the main internal divisions within the building. Preliminary palynological investigations showed this sample to be barren and so it was not considered further.

BB 79 E12 : this sample comes from apparent turf packing in one of the individual postholes inside the building towards its west end.

BB 80 S10 : this sample comes from one of the individual postholes inside the building at its northwest corner.

BB 81 E13 : this sample comes from turf in the north half (longitudinal section) of the outer wall on the south side of the building.



(from Fairweather and Ralston 1993)

Fig. 4.2 Plan of the timber hall at Balbridie.

Sample locations ●

Dun Bharabhat, Isle of Lewis

NB9835

This site is a dun with a causeway located in Loch Bharabhat, Cnip. The site is approached by the causeway which is 20 metres long leading out from the western shore of the loch. Underwater excavations, surprisingly, revealed a submerged dun adjacent to the higher dry dun but 2 metres lower (Dixon and Harding 1988). The dry dun is iron-age. The features of the underwater building appear undisturbed and the organic material is abundant and exceptionally well preserved. Straw and heather layers enclosed by the submerged building have been interpreted as undisturbed occupation and floor levels (Dixon and Harding 1988). Within these layers peat is interspersed with layers of ash and lenses of clay. Deposits of dung are easily recognisable and heather stems are still brittle (Dixon 1989). A number of cut wooden artefacts, a creel, a wooden dish and other organic materials such as insect remains were uncovered along with a range of pottery, metal, bone and antler objects (Dixon 1989, 1990). These deposits continue down beyond 1.5 metres until a layer of loose white sand overlying an apparent cobblestone floor is encountered. Below this cobbled surface lies another deep layer of peat. There is evidence that this layer represents cut turfs laid as a floor. Below this layer is a layer of boulders interpreted as either an intermediate foundation layer or as a supporting layer to raise the area around the edge of the floor. Fig 4.3 shows the nature of the underwater structure and its relationship to the adjacent dry structure.

The samples in this study were taken from a core extending through the organic deposits of the underwater structure as far as the cobbled surface. The location of the core can be seen in fig. 4.3. Samples were taken according to the stratigraphy of the core which is illustrated in fig. 4.4. 12 samples in total were examined. The location of each sample is illustrated on the plan.

Radiocarbon dates from the organic deposits range from 2000+/- 50 BP to 2140 +/- 50 BP (Dixon pers. comm.).

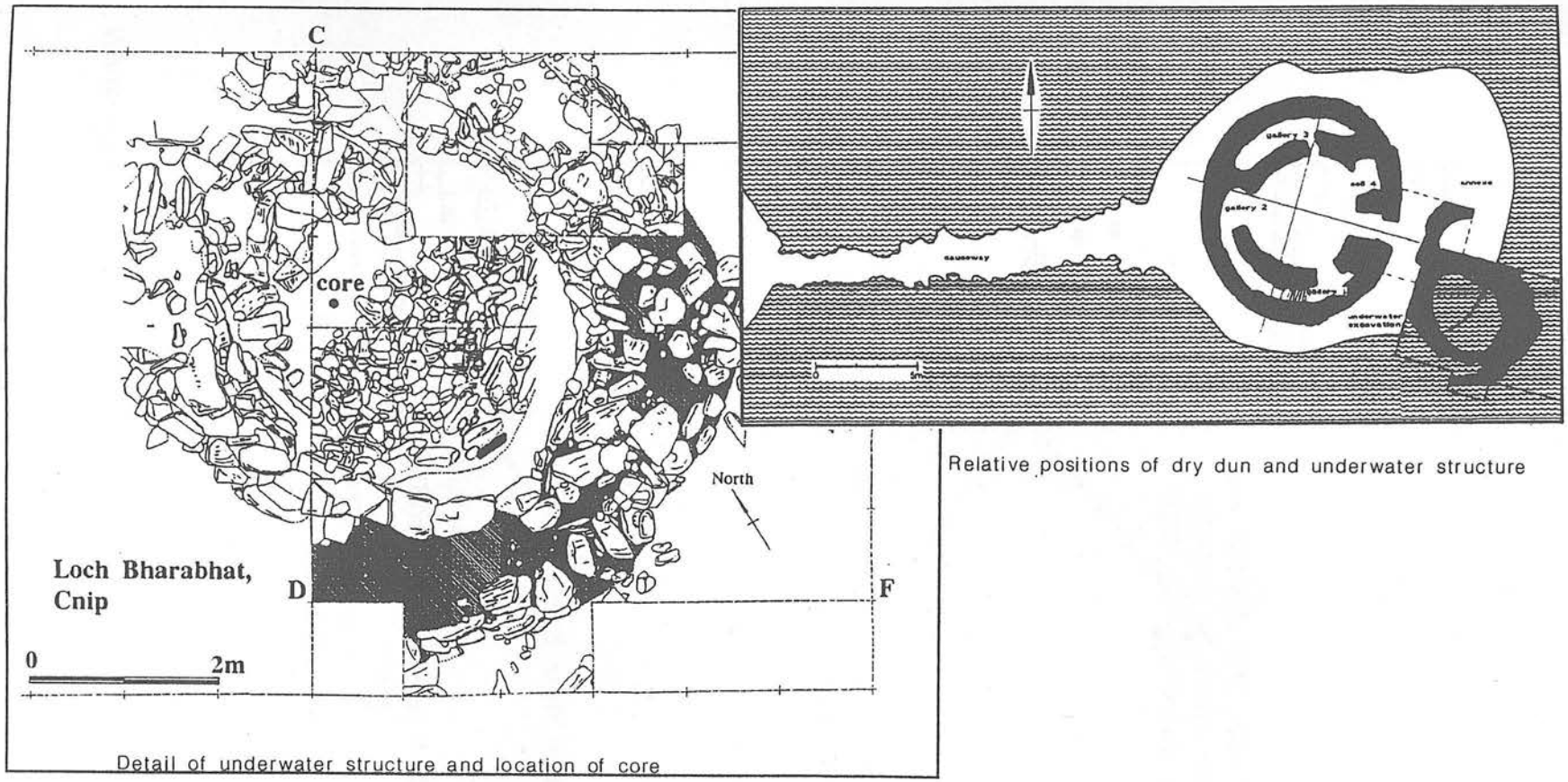


Fig. 4.3 Detail of underwater structure and its relationship to the adjacent dry dun at Bharabhat.

(after GD Thomas)

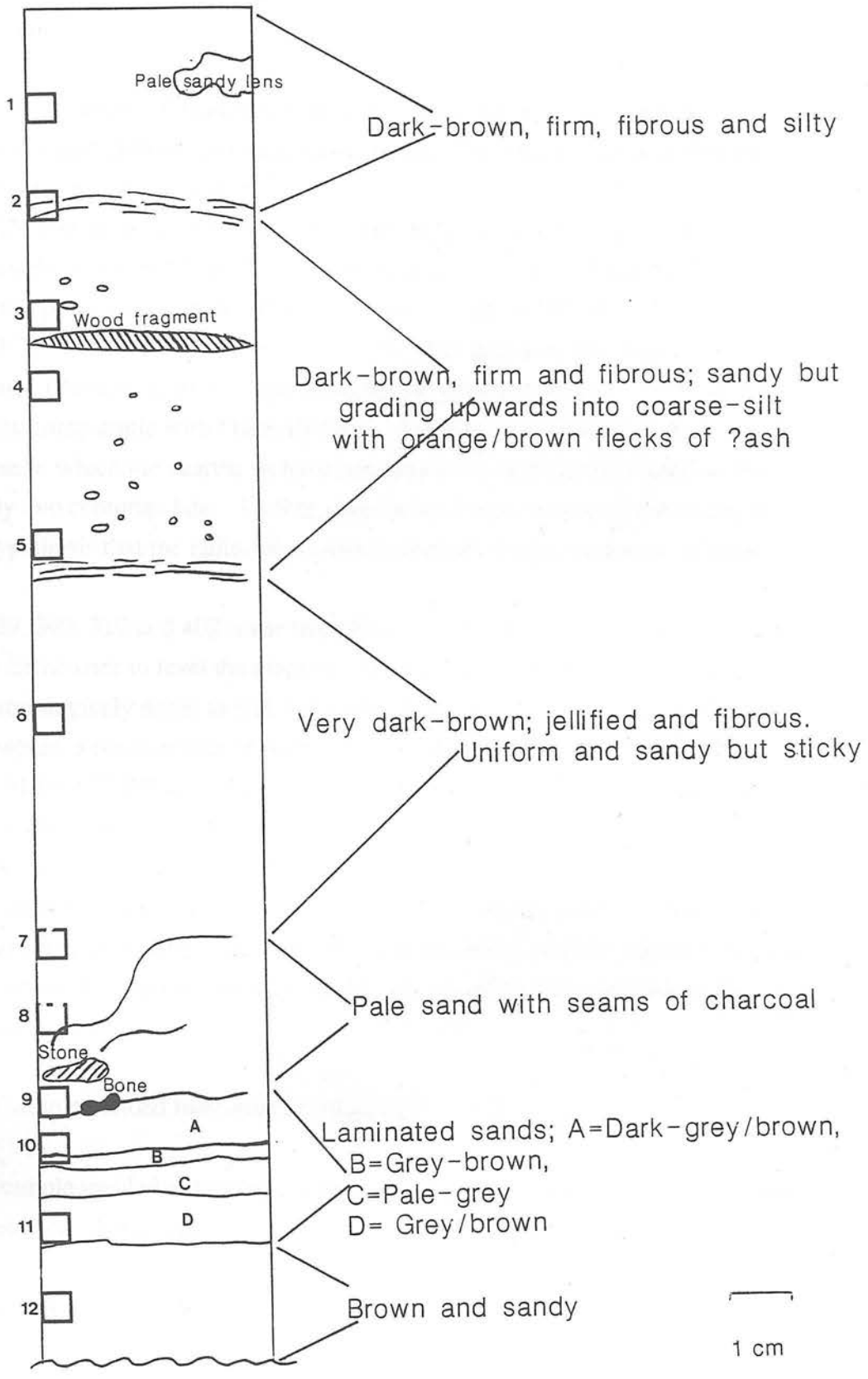


Fig. 4.4 Stratigraphy of the core from Bharabhat and location of the samples studied.

Buiston Crannog

NS 4144

This is an Early Historic Crannog (Crone 1991). Nine samples from this site were chosen for investigation of the fungal spore conten. The samples range across three different phases of the excavation.

Samples 234 and 48 come from Phase III. This phase comprises a series of superimposed hearths and floors, rapidly succeeding each other. Charcoal from a hearth in this phase produced a radiocarbon date of 1680 +/- 50 BP.

Samples 327, 316 and 341 come from Phase IV. The dating of this phase is problematic. Charcoal from the uppermost hearth produced a date of 1640 +/- 50 BP, broadly comparable with Phase III dates. However, the foundation planks of the roundhouse in which the hearths sit have been dendrochronologically dated to 594 AD, nearly two centuries later. Further samples have been submitted for dating to test the hypothesis that the radiocarbon date is aberrant due to the use of residual wood.

Samples 39, 309, 310 and 402 come from Phase V. These are all deposits within the palisaded framework to level the crannog. The palisaded framework has been dendrochronologicaly dated to 608 AD so the deposits were dumped soon after that date. However, a plank retrieved from one of the dump deposits was radiocarbon dated to 1610 +/- 70 BP indicating that much of the rubbish used to level the crannog may have come from earlier phases.

Fig 4.5 shows the excavated structure in plan.

All of the samples were selected on the strength of the results from the fossil insect assemblages (carried out by M.H. Dinnin). Samples which yielded indicators of dung, hay, byre material or animals were favoured. The tentative identifications of the samples are as follows ;

39 : This sample yielded indicators of stored hay.

48 : This sample yielded indicators of dung; in addition, the fauna of rotting hay was well represented. It has tentatively been identified as a byre deposit.

234 : This sample was taken from outside the enclosure.

309 : This sample yielded indicators of mouldy stored hay.

310 : Diptera analysis elicited indicators of rotting plant material or/and dung and of rotting hay. It is considered that this deposit may be dumped flooring from a byre.

316 : This sample yielded indicators of mouldy stored hay.

327 : This sample yielded indicators of sweet plant material such as mouldy hay. It also contained a sheep ectoparasite and *Damalina* louse which is parasitic on sheep, goats, cattle and horses.

341 : This sample yielded indicators of dung and a sheep ked.

402 : It is thought that this sample may represent a byre deposit.

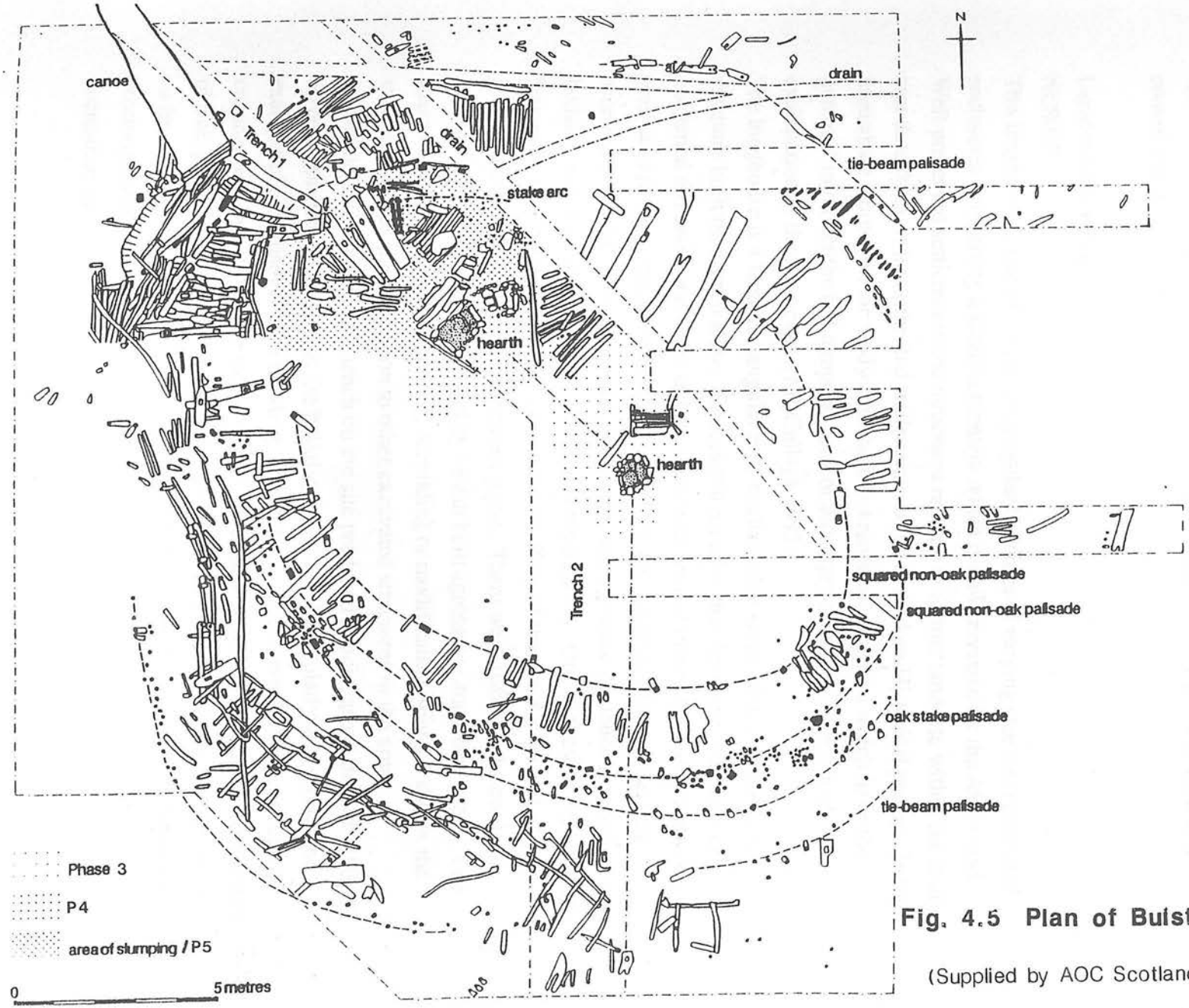


Fig. 4.5 Plan of Buiston crannog.

(Supplied by AOC Scotland Ltd)

309 : This sample yielded indicators of mouldy stored hay.

316 : This sample yielded indicators of mouldy stored hay.

234 : This sample yielded no indicators of agricultural activity and was used as a control sample.

Longhouse at Lairg
NC8030

This longhouse is one of several rectangular buildings of varying size and associated enclosures comprising a small settlement which is now traversed by the A836 road. Well-preserved settlements and structures relating to former land-use within the study area date from, at least, the 2nd millennium bc up to the late-Historical period. In the immediate vicinity of the study area there is a range of structures which have the potential to reflect the full temporal span of sedentary subsistence and ritual exploitation of the landscape (Mc Cullagh 1992).

The longhouse is a large rectangular post-mediaeval or early modern domestic structure built on a steep slope. Excavation revealed that the house was built of combined sod and stone walls and may have had wattled inner face walls. The walls were slightly bow-shaped in plan. The entrance was southwest facing and was accessed by a well-built stone path. Internally, there is some evidence that the building was partitioned into two or three compartments. One of these compartments featured a long central drain, which divided the floor of the downslope end of the house, and issued through the northwest gable. There were two hearths on the internal floor surface, and a secondary hearth built against the southeast gable. The structure exhibited signs of periodic rebuilding or modification. Fig 4.6 shows the structure in plan and in relation to other excavated structures in the area.

A sample taken from a trial tench on the site produced a radiocarbon date of 350 +/- 50 bp. This date suggests that the building might be a particularly well-preserved example of a mediaeval farm building, or have been a mediaeval building occupied continuously into the early modern period. The latter is more likely, given the number of well-preserved adjacent house sites. However, the results of the excavation have so far not borne out either version of the hypothesis: though construction cannot be precisely dated, the evidence of finds in particular points to an early modern occupation date.

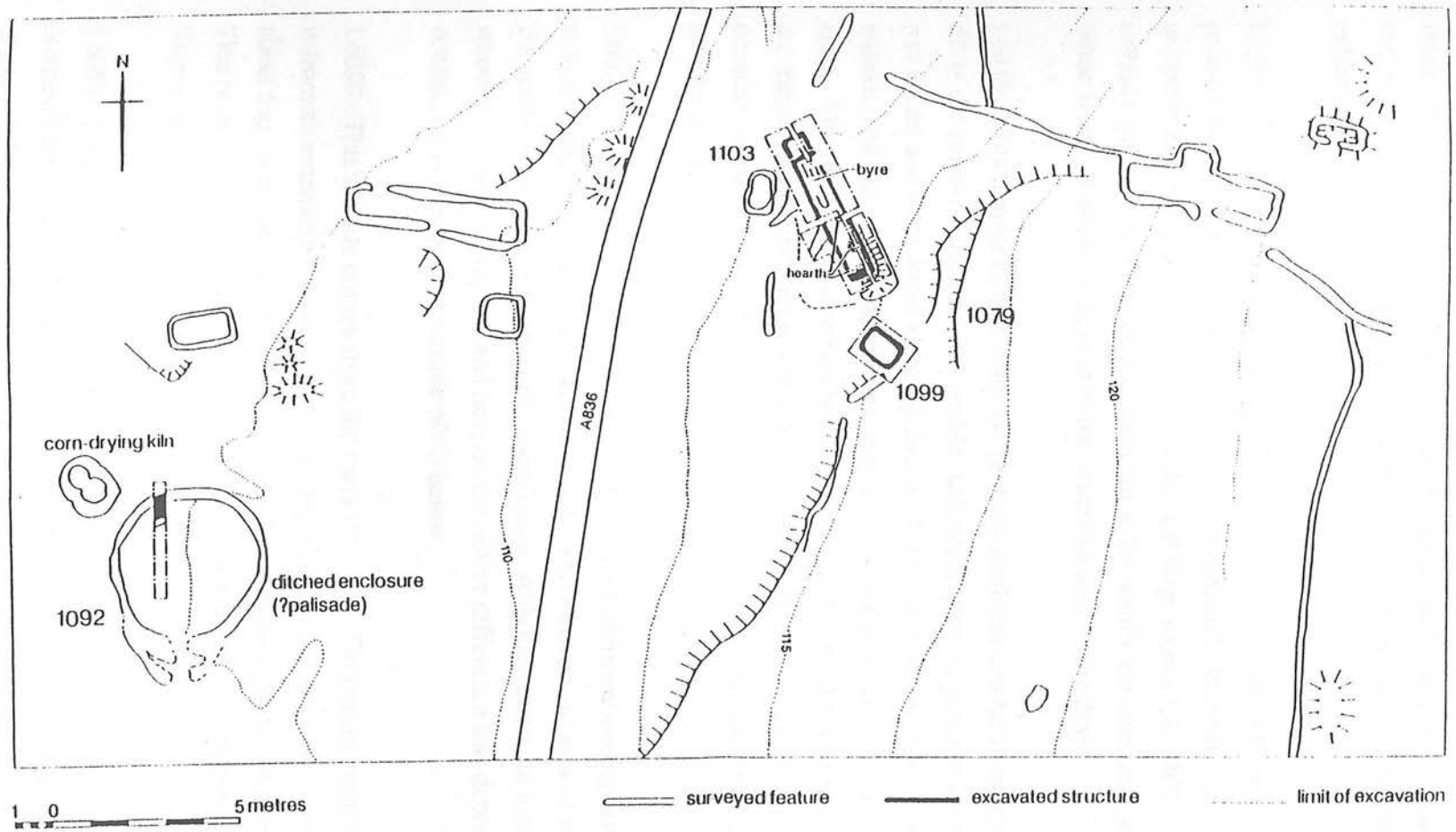


Fig. 4.6 Plan of the longhouse at Lairg showing other surveyed and excavated structures in the area.

(Supplied by AOC Scotland Ltd)

The following samples were examined for fungal spore assemblages:

L6073 : This sample comes from the primary or early hearth in the house floor. It is a small spread of hearth debris consisting of compacted lenses of charcoal-rich yellow, red and black sand. The drift material and bedrock beneath this deposit is brightly reddened.

L6108 : This sample comes from the primary earth cut central floor drain. The primary drain cut (6118) is partly filled by a loose, dark, fine silty sand with moderate to frequent charcoal and frequent medium and large stones (30 - 40%). This fill extends out over the edge of the drain cut at the southwest side, to overspread the house floor. It does not appear at the northeast side of the drain.

L6119 : This sample comes from the primary earth cut central floor drain. The lower fill of the primary drain cut is a friable, soft orange/brown sandy loam silt, with iron pan lenses and occasional charcoal flecks. It occupies the southwest side of the drain bottom, and has perhaps been truncated at some point by emptying or cleaning of the drain. The fill is partly overlain by lenses of natural subsoil subsided from the sides of the trench (indicating that it was open for some time at this level) and by a spread of occupation material which overspreads the floor at the southwest and partly extends into the drain.

L6011 : This sample comes from the early internal sediments/occupation spreads. It is from a small spread of pale grey sandy silt which covers an area of about 1sq. m at the centre of the house floor in the south quad. Although charcoal has not been recovered from this deposit and despite the colour difference this deposit is considered as identical to sample 6050 below.

L6050 : This sample comes from the early internal sediments/occupation spreads. It is from an extensive spread of mottled, grey/black sandy silt which covers an area of about 5sq. m in the centre of the house floor, predominantly in the north quadrant. This layer is up to 0.02m thick and is stone-free, but contains frequent charcoal fragments.

L6089 : This sample comes from the early internal sediments/occupation spreads. It is a small lens of black, charcoal-rich soil which lies within or on the surface of deposit 6050 (above), at the intersection of the baulks near the centre of the house floor.

L6109 : This sample comes from the early internal sediments/occupation spreads. It is a thin spread of grey, fine silty sand with frequent charcoal flecks covering an area of less than 1sq. m. It abuts the inner southwest wall face in the west quad, and extends from there into the edge of the central floor drain.

L6057 : This sample comes from the occupation spreads/rake-out at the northwest gable. It is a spread of red/brown mottled sandy loam, with fine rootlets and occasional charcoal covering about 8sq. m, at the northwest, downslope end of the house.

L6058 : This sample comes from the occupation spreads/rake-out at the northwest gable. It is a similar layer to 6057 (above) and immediately underlies it. The distinction between these two layers is slight and depends upon marginal colour changes.

L6112 : This sample comes from the occupation spreads/rake-out at the northwest gable. It refers to the part of sample 6057 (above) which lies on the west side of the central baulk.

L6084 : This sample comes from the occupation spreads/rake-out at the northwest gable. It refers to the part of sample 6057 which lies on the east side of the central baulk.

L6097 : This sample comes from the re-cut stone-lined central floor drain. It is recorded as infill around the stones of the northeast side of the drain, where it partly covers the drain stones, but extends over a smaller area beyond the drain edge.

L6075 : This sample comes from the secondary hearth in the house floor. It underlies some stoney debris and is a small deposit of hearth debris partly excavated at the junction of the median baulks near the centre of the house floor. It consisted of a saucer-shaped fill of fine lenses of orange ash and black charcoal.

L6029 : This sample comes from the secondary hearth and constitutes a small spread of mottled orange/grey ash overspreading the floor of the secondary hearth. The spread is interpreted as possible peat ash, though charcoal is also present.

L6129 : This sample comes from deposits interpreted as possible floor deposits. It is a large spread of compact orange/brown, stone-free sandy loam with occasional charcoal and thin iron pan lenses, on the interior of the house in the south quadrant.

L6014 : This sample comes from later internal sediments/occupation spreads. It is a small spread of very dark peaty soil in the north quadrant and abuts the house wall internally.

Tuquoy, Orkney
HY4543

The site at Orkney is located on the northern Orkney island of Westray, on the south shore of the Ness of Tuquoy (Ritchie 1993). Trial excavations centred around four substantial, externally plastered stone walls representing part of a late Norse hall. The hall had been superseded by other late Norse and Mediaeval buildings. Progressive excavation revealed a substantial pit which appeared to have been dug into windblown sand in the east although the original depth of its west edge had been obscured by the insertion of later walling and other deposits. A 0.60 mdepth of extremely compacted, waterlogged organic material was discovered within the pit and butted against the east wall. A radiocarbon determination of AD 885 +/- 65 was obtained from a sample taken from within the pit.

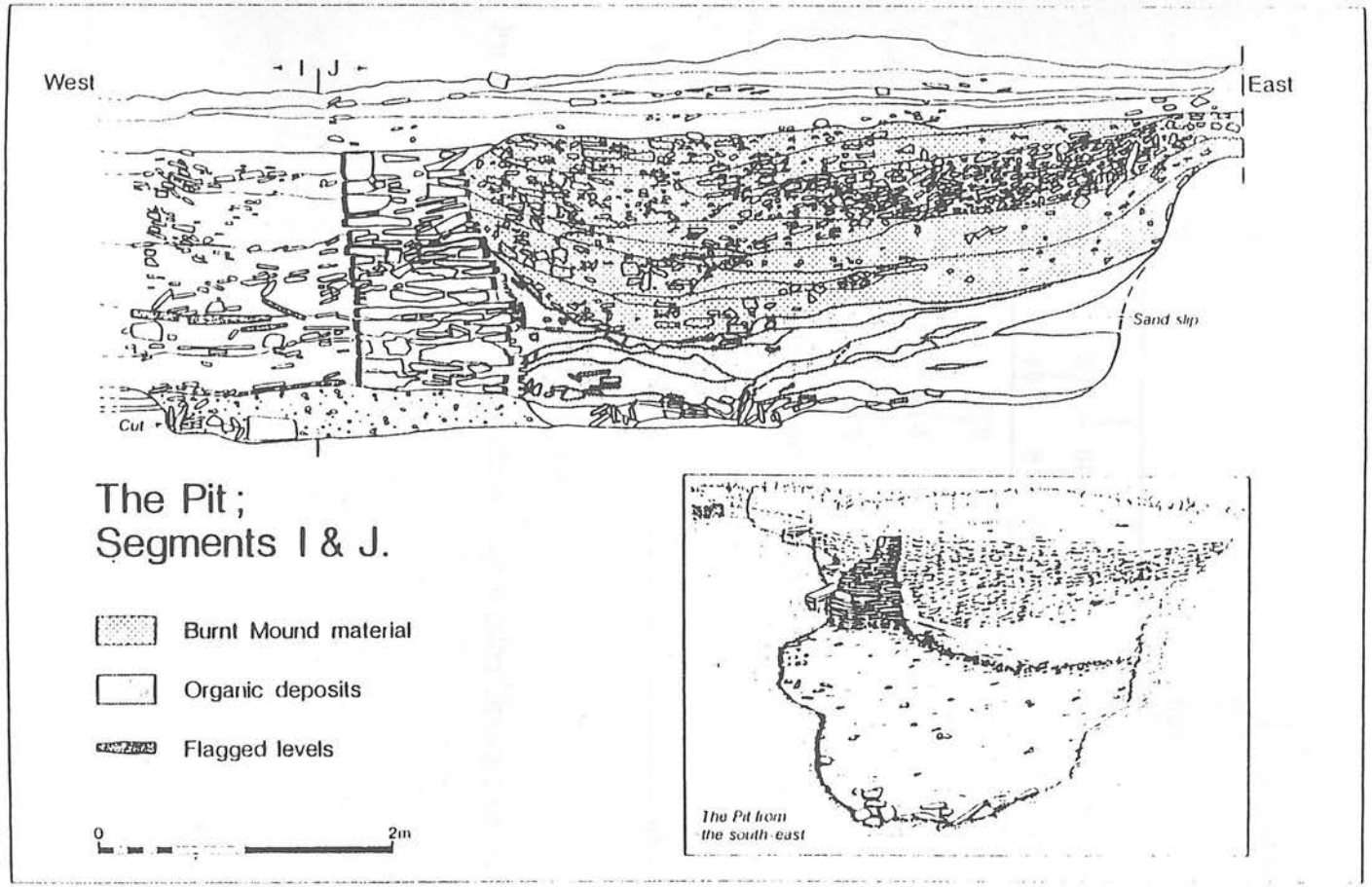
The material from the pit appears to consist of a mixture of animal dung, straw and grey ash. At different levels it also contained varying quantities of unburnt wood, fungi, grasses, insects, marine shells and shell sand in addition to microscopic remains. The wood comprises mostly off-cuts, presumably from the manufacture of planks. It also contains some fragmentary artefacts, including part of a decorated handle.

This material has been interpreted as representing predominantly redeposited byre refuse. The product of layers of animal bedding constituting grass, short heath, dry mould, household ashes and dung accumulated in the byre from overwintering animals. This conclusion has been reached predominantly on the basis of the Coleoptera (carried out by Jon Sadler)and Diptera (carried out by Peter Skidmore) analyses, both of which indicate that dung, peat, hay, manure and seaweed were being regularly dumped onto an area of wet ground. The parasitological analysis (carried out by Andrew K.G. Jones and Colin Nicholson) yielded no direct indicators that animal dung was present but the triturated nature of some of the plant fragments suggest that they may have passed through the gut of a herbivore. In addition, secondary thickening annuli and fragments of spiral thickening of xylem vessels which

are commonly present in animal faeces were pesent in the samples. Analysis of the charred plant remains (carried out by Sheila Boardman and Sandra Nye) do not indicate any catastrophic destruction of the buildings or parts of the site by fire at Tuquoy suggesting that material probably became charred in household fires or domestic ovens. The wood analysis (carried out by Anne Crone) indicates a community that were exploiting all available wood resources on the island - from driftwood to scrub willow and birch, in addition to imported pine baulks from Norway or mainland Scotland. The presence of roughcuts and unfinished objects thrown away in the pit testifies to the presence of an active domestic industry. The pollen analysis (carried out by Richard Tipping) yielded evidence of cereals, arable weeds and pastoral species indicating that the settlement at Tuquouy was evidently a farming community.

Usually byre material would have been transferred outside to a dunghill or compost midden for further fermentation and its deposition here, in a waterlogged pit, is anomalous.

The radiocarbon date and the nature of this material suggest that there may have been a ninth to tenth century Viking settlement, complete with byres, in the immediate vicinity, to which the late Norse to Mediaeval site to the west was the successor.



(Supplied by Historic Scotland)

Fig. 4.7 The nature of the pit at Tuquoy and its relationship to the environs.

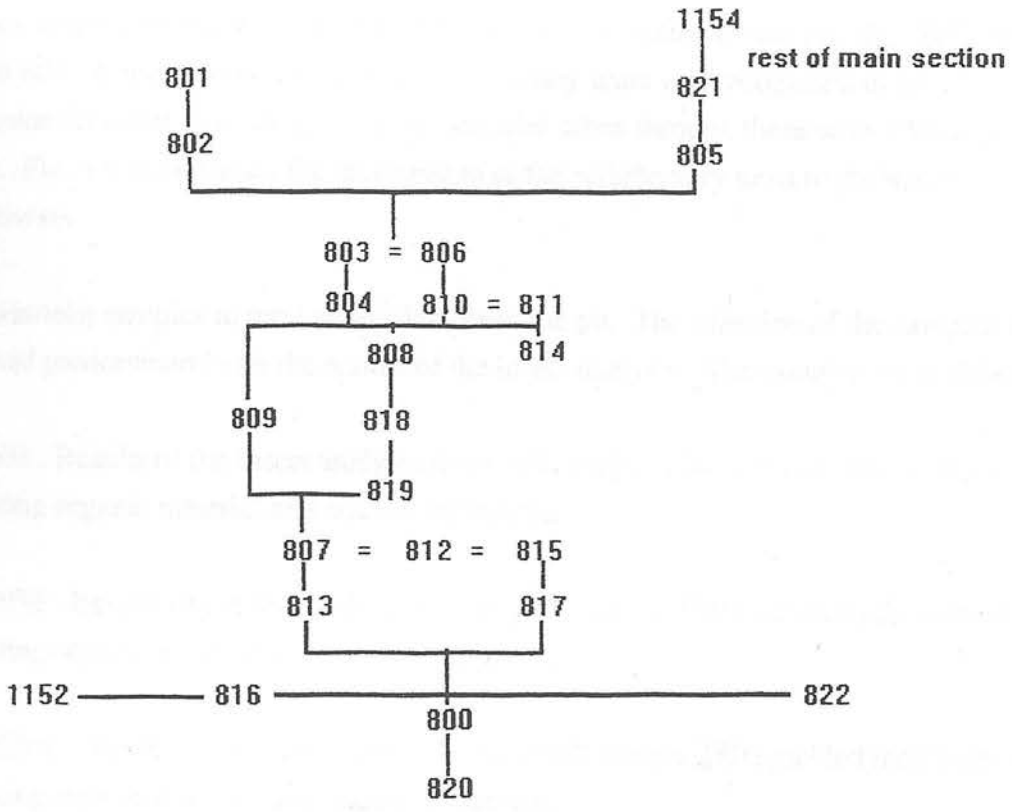


Fig. 4.8 The stratigraphy of the pit fills at Tuquoy (after Tipping pers. comm.).

The pit to the east of the wall continued to be used. Its upper layers comprise a 1.40 m depth of burnt stones and peat ash presumably the debris from water-heating activities. This typical burnt mound material dates from the Norse period or later. Immediately west of the wall, late Norse or mediaeval walls and flagged levels were inserted within the area of the original pit, the flagging butted against the west face of the earlier wall; and associated midden site deposits survived. Fig. 4.7 illustrates the nature of the pit and its relationship to the environs.
Four major contexts were identified during the excavation of this pit; 813, 807, 804 and 803. A more complex series of sedimentary units was recognised in the cleaned section face and so a column section was also taken through these with a 50cm peat tin. Fig. 4.8 summarises the relationship of the sedimentary units to the major contexts.

Seventeen samples in total were taken from the pit. The selection of the samples was based predominantly on the results of the insect analysis. The samples are as follows :

T803 : Results of the insect analysis from bulk sample T803 yielded indicators of rotting organic material and aquatic influences.

T8038 : Results of the insect analysis from bulk sample T803 yielded indicators of rotting organic material and aquatic influences.

T8036C : Results of the insect analysis from bulk sample T803 yielded indicators of rotting organic material and aquatic influences.

T8036D : Results of the insect analysis from bulk sample T803 yielded indicators of rotting organic material and aquatic influences.

T804 : Results of the insect analyis yielded indicators of rotting organic matter, aquatic and aquatic marginal influences, in addtion to indicators of open dry grassland, open wet grassland and open eurytope environments.

T8057 : Results of the insect analysis on the bulk sample T805 yielded indicators of pests, rotting organic matter, dung and aquatic and marsh influences. In addition indicators of open dry grassland, open wet grassland and eurytope indicators were encountered.

T8141A : This sample contained insect indicators of pests, human parasites, rotting organic material, aquatic and marsh influences, in addition to indicators of open dry grassland, open wet grassland and open eurytope assemblages.

T815 : Analysis of the fossil insect assemblage revealed indicators of pests, human and animal parasites, rotting vegetation, aquatic and marsh influences in addition to open dry grassland, open wet grassland and eurytope assemblages.

Results of the analysis of fungal spore content of the modern samples are discussed in Chapter Six and results from the archaeological samples are discussed in Chapters Six and Seven. All spores are catalogued in Volume Two.

CHAPTER FIVE

INTRODUCTION

This Chapter considers the following issues in relation to the recovery of fungal spores from anthropogenic deposits;

i. Taphonomic processes.

ii. Palynomorph sum

iii. Nature of palynomorph data.

The recording methods are discussed and a summary of the results is presented. Following the discussion, approaches to analysis of the data are proposed and reference is made to succeeding Chapters.

TAPHONOMIC PROCESSES

As mentioned in Chapter One, observations by van Geel (1986) suggest that fungi and fungal spores occur apparently *in situ* in lake deposits, eutrophic to mesotrophic bogs, carr peat and raised bogs. Dispersal mechanisms in the fungi are predominantly ballistic (Ingold 1965; Simons 1993) - once local and atmospheric conditions determine the fate of the spores (see Tauber 1965; Gregory 1945; Hirst 1953; Hirst and Stedman 1967; Hirst *et al* 1967). Fungal spores are frequently recovered in air samples both indoors (Lethonen *et al* 1993; Pasanen *et al* 1992) and outdoors (Hudson 1973; Nussbaum 1991; Pady and Kramer 1967; van der Werff 1967); it is likely that these spores will settle out, under favourable conditions (Gregory 1945), and become incorporated into deposits. There is, therefore, the potential for spores to occur in deposits where the parent fungi are not present and, although many may occur *in situ* as noted by van Geel, allocthonous fungal palynomorphs cannot be disregarded.

Taphonomy of fungal spores is complex and beyond the scope of this study. Owing to the presence and actions of humans in the material considered in the case studies taphonomic processes are further complicated. In this investigation, where the deposits are recovered predominantly from within humanly influenced milieux, it is likely that the local fungal palynomorph source compares with that of a small hollow or closed canopy see Bradshaw (1981). In addition there are potentially many sources of non-local palynomorphs which are more difficult to qualify. These result from activities such as;

the deliberate movement of material into and out of the structures by humans,

and contamination from external sources by the activities of humans and of animals. Both local and non-local palynomorphs would be mixed in the deposits and it would be difficult to provenance the sources.
In addition , reworking of material and hence of fungal spores is also a possibility. Such questions, although important, do not form the focus of this study. It is frequently impossible to trace the path of material from origin to present location particularly when there is conscious transport by humans involved.

For the purpose of these investigations taphonomic processes are effectively only incidental because they are likely to be masked by multiplicity of function. This is because it is a combination of events conducted within a structure which characterise the environment and hence the palynomorph record. The transport of the materials is not the issue, it is their ultimate presence that is important. Because of the localisation of activities within structures it is assumed that the greatest representation of palynomorphs will reflect and characterise the uses of the sites.

PALYNOMORPH SUM

The paucity of knowledge on the distribution of fungal palynomorphs raises questions with respect to the palynomorph counting procedures to be employed. These principally concern determination of the fungal palynomorph sum that needs to be attained to be representative of a sample, assuming that their deposition is homogenous enough to have characteristic assemblages? Opinions of statistically significant pollen counts vary and sums ranging from 250 to 1000 have been deemed appropriate by various authors. Dimbleby (1957,1961) considers a pollen sum of 300 to be representative of any particular sample; using this pollen sum as a datum the fungal spores recovered within this count were considered for palaeoenvironmental interpretation.
In order to test the validity of this procedure data previously considered in Chapter Three were used. Chapter Three dealt with the effects of different processing techniques on palynomorph recovery and concluded that of the techniques tested the standard procedure of HF/Acetolysis gave the maximum and least impaired recovery of fungal palynomorphs. The raw data consist of palynomorph counts of 5 replicate subsamples of each sample processed by each technique. These data provide the opportunity to explore what happens when the fungal spore count of a sample is increased. Data from both the mor humus and permanent pasture samples processed by HF/Acetolysis were used since this technique gave the most consistent results; and these samples had high numbers of different spore types.

Figs. 5.1 and 5.2 show the relationship between the total count and the number of different types. These Figures illustrate that by increasing the total count the numbers of different types also increase. However, the majority of the types which occur most frequently are recovered from the first sample and the other types only have sporadic occurrences (see Figs. 5.3 and 5.4). These results suggest that considering the fungal spore assemblage which is encountered within 300 pollen grains is effective, in these samples, at characteristing the dominant components of the fungal spore assemblage from a sample. From this it can be assumed by extension that in most cases this counting procedure should be adequate. However, in cases where pollen has deteriorated and fungal spores have persisted compromises will have to be established. If fungal spores can be successfully incorporated in postulating former environmental conditions on this basis then more rigorous statistical tests can be used to standardise counting procedures and maximise available information.

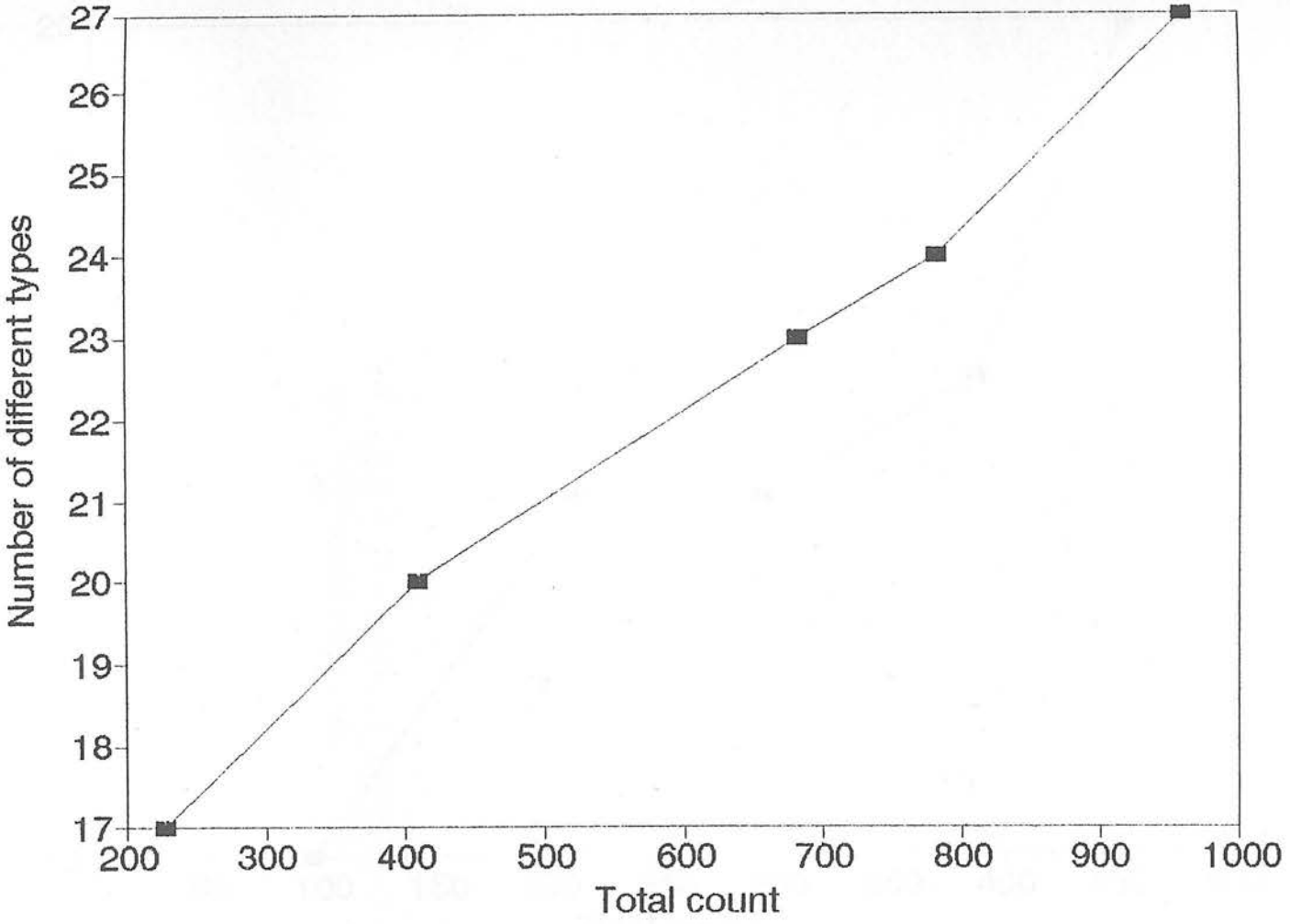


Fig. 5.1 Number of types in relation to total count from mor humus sample.

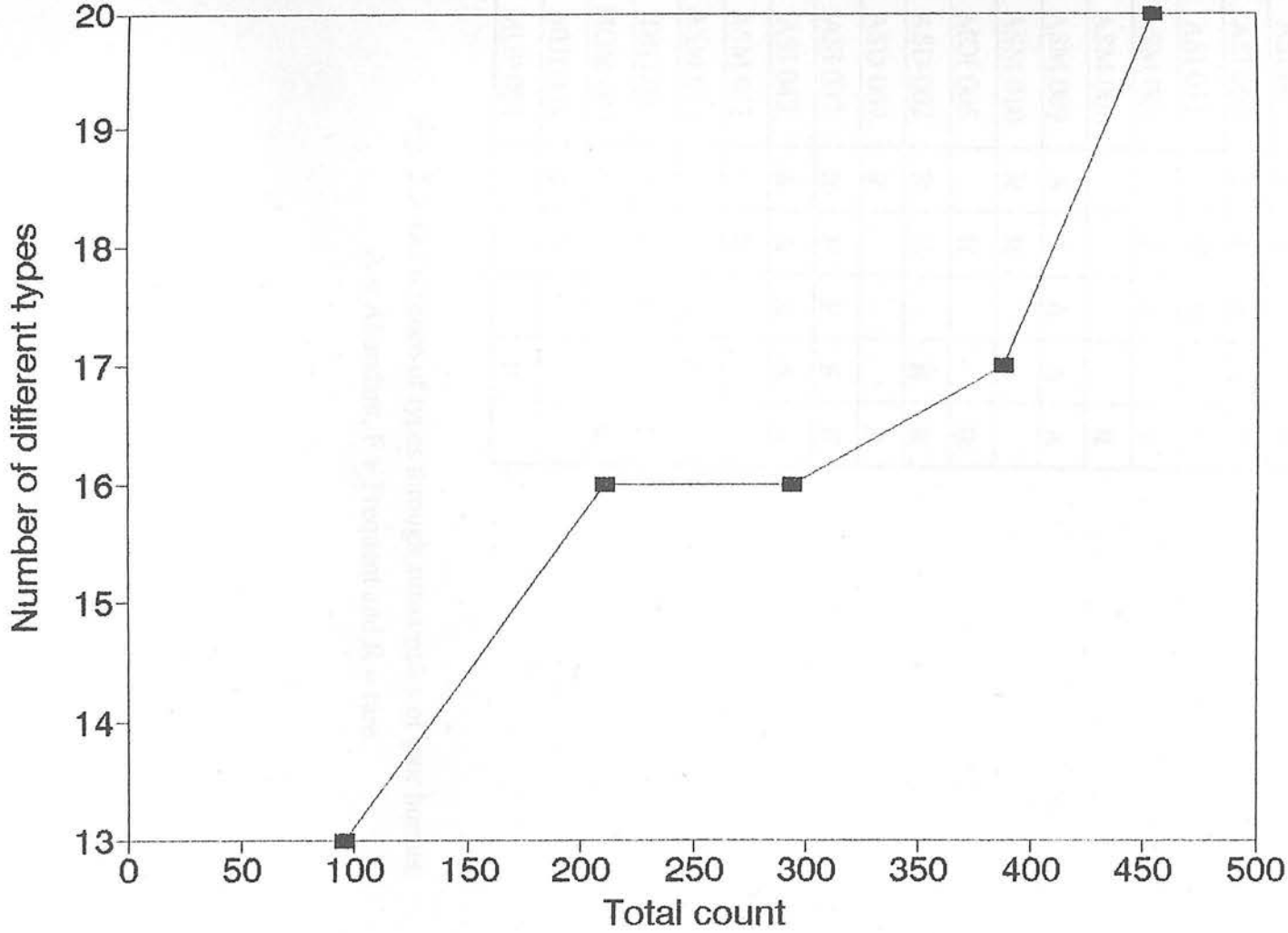


Fig 5.2 Number of different types in relation to total count from pasture sample.

	1	2	3	4	5
ASM 004	F	F	F		F
ASI 020		R	R	R	R
ASI 001		R			
ASI 003	F	R		R	R
ASI 008	F	F	A	A	F
ASI 011		F	R		F
ASM 001		F	R		F
ASM 006					R
ASM 009	A	A	A	A	A
ASM 010	R	R			
MOI 005		R			R
ASD 002	R	R		R	R
ASD 009	R				R
ASI 037	R	F	F	F	F
ASI 042	A	A	A	A	A
ASM 011		R			
ASM 015	A	A	A	A	A
DII 008	A	F	F		F
MOM 001					R
MUI 003	R	R			
MUP 001				R	

Fig. 5.3 Occurrence of types through subsamples of mor humus.
A = Abundant, F = Frequent and R = rare.

	1	2	3	4	5
ASI 014	F		F		F
ASI 020	R		F		
MUI 016			R		R
ASI 003	R	R			
ASI 008	A	A	A	A	A
ASI 009					R
ASI 011	F			R	
ASI 012		R			R
ASI 036	A	A	A		F
ASI 042	F	F	A	F	A
ASM 001	A	F	F	F	
ASD 002	F			R	
ASD 005	F	A	A	F	F
ASD 008	F	R	F	F	F
ASI 037	R	R	R	F	F
ASM 015	F	R	F	F	F
ASM 020			R	F	R
DII 002			R	F	R
DII 003			R		
DII 005	R	R		R	R
DII 011	R		R		
DIM 003		F	R	R	R
MUD 001		R			R
MUI 003					R
TRD 001	F	R	F	F	F
TRI 004					R
TRI 005				R	

Fig. 5.4 Occurrences of types through subsamples of permanent pasture.
A = Abundant, F = Frequent and R = Rare.

NATURE OF PALYNOMORPH DATA

Due to the heterogenous nature of the individual modern samples, their content ranging from soil to straw, the convention of spiking the samples with an exotic marker in order to ascertain absolute counts of palynomorphs was not adopted. It was considered that this procedure would not enhance the available information, because in effect it would prove counterproductive. 1g of soil and 1g of straw possess considerably different densities and coupled to the fact that none of the samples from modern sites were taken from a stratigraphic column, the process of obtaining absolute counts by exotic markers becomes redundant. Only one set of samples from the archaeological sites was taken from a stratigraphic column. These are the samples from the dun at Loch Bharabhat. These samples were spiked and absolute data were calculated for these samples.

The emphasis of this work will thus be based on presence/absence data and on percentage values of fungal palynomorphs.

Complications arise when dealing with percentage data with regard to the categories *Toruloid fragments* and *Phomoid* since they are effectively non-quantifiable palynomorphs (see Chapter Two). This is because they are not whole and often consist of fragments broken off a much larger corpus. To overcome introducing unnecessary bias into percentage values as a result of this, both categories were excluded from the overall fungal palynomorph sum. They were considered, instead, in terms of presence/absence only. The categorisation of these types is, admittedly, subjective but it would be difficult to objectify, accurately such incomplete and nonquantifiable palynomorphs.

METHODS

Palynomorphs were extracted from the samples according to the procedure outlined in Chapter Three. Residues were stored and mounted in silicone oil of 6,000 cs, coverslips of 20mm x 20mm were used for all slides. They were tacked at the corners with nail varnish so that when pressure was applied to the coverslip the palynomorphs could roll about allowing observations to be made on equatorial, polar and other orientations of the spores.

Slide logging was carried out on an Olympus BH2 series light microscope fitted with 10X oculars and a 40X objective. Critical identifications were made with a 100X oil immersion objective. Whole numbers of slides with regularly spaced traverses across the coverslip were counted for each sample to avoid errors associated with the non random distribution of palynomorphs.

RESULTS

215 fungal taxa (detailed in Part Two) were recovered throughout the course of this study.

Of these:

99 are limited to modern samples and 74 are restricted to archaeological samples.

42 are common to both modern and archaeological samples.

96 are comparable to known fungal taxa.

8 are considered to be algal in origin.

1 is a rhizopod.

4 have been identified as parasite eggs.

106 have no known modern comparatives.

The restriction of some taxa to either modern or archaeological samples is not necessarily significant. It is likely that it is an artificial fact, reflecting the limited nature of the sampling. Additionally, it is likely that with time modern comparatives will be proposed for many of the taxa which at the time of this thesis have not yet been encountered.

DISCUSSION

There are three approaches which can be adopted in the reconstruction of former environmental conditions using microfossils, which include fungal spores. The approaches are the Statistical Approach, the Indicator Species Approach and the Comparative Approach (Birks & Birks 1980).

The statistical approach involves delimitation of recurrent groups of fossils and is not widely used in Quaternary studies because of the potential for making use of modern analogues.

The Indicator species and the Comparative approaches are widely used in Quaternary studies. Both of these approaches are considered in this study.

THE COMPARATIVE APPROACH

This involves the characterisaton of a range of modern ecological systems by means of contemporary microfossils and then the comparison of these spectra with fossil spectra (Wright 1967; Birks & Birks 1980). If the two spectra are similar then it can be concluded that they are derived from within similar ecological parameters. In this way a modern analogue can be suggested for the fossil spectrum.

In these investigations multivariate analysis was implemented in testing the comparative approach, in particular to ascertain whether fungal spore assemblages from modern samples are governed by discernable environmental criteria. This topic is dealt with in Chapter Six.

THE INDICATOR SPECIES APPROACH

This approach can be defined as the extension backwards in time of known sociological and ecological preferences of individual taxa (Iversen 1964; Birks & Birks 1980). The strength of the indicator species approach, in this study, depends on the detection of suites of indicator taxa with similar known ecological preferences from within the same sample. This approach is dependent to a large extent on comparison of recovered spores to descriptions and illustrations of spores through the literature to gain insight to their ecological tolerances. In this study specific identifications can be coupled to morphological comparison of fossil taxa to unidentifiable taxa from modern samples whose ecological preferences can be tentatively inferred from their modern occurrences. This approach is tested in Chapter Seven.

CHAPTER SIX

THE COMPARATIVE APPROACH

The comparative approach involves the characterisation of a range of modern ecological systems by means of contemporary microfossils and then the comparison of these spectra with fossil spectra (Wright 1967; Birks & Birks 1980). If the fossil and modern assemblages are similar in their palynomorph composition or/and proportions, this may indicate that the spectra were produced under similar environmental conditions. In this way a modern analogue can be proposed for the fossil assemblage. If, on the other hand, modern and fossil spectra cannot be matched then it can be concluded that either the fossil assemblage has no modern analogue or the modern spore data are incomplete and more extensive modern comparatives are required.

OBJECTIVES

In this study the aim is to test whether the comparative approach, when applied to exclusively modern situations, is effective at matching fungal spore assemblages from different samples sharing the same ecological criteria; for example, to examine whether samples from cattle byres on different farms had comparable fungal spore assemblages. This line of enquiry extends the original definition of the approach somewhat as it is not comparing modern to fossil assemblages but rather modern to other modern assemblages. However, the principles of the approach remain intact, with the objective being to match assemblages from similar known environments.
The rationale behind the initial comparison of modern to modern is as follows:
It is difficult to apply the comparative approach to anthropogenic situations since the parameter of human activity leads to an exponential increase in potential sources of variation. This has been recognised as a problem with Holocene pollen investigations of northwest Europe. Present day flora, vegetation and landscapes, of northwest Europe, have been so heavily influenced over the millennia by humans that pollen spectra can be expected to have little or no similarity to early- or mid-Holocene fossil assemblages (Gaillard *et al* 1992).
Human interference results in corruption of naturally occurring biological associations and also in the deliberate mixing of products of different activities; for example manuring fields with byre deposits mixes the products of pasture and byre material. This reduces the chances of matching spore assemblages, from anthropogenic situations, as a result of the influence of humans. If the comparison was between

entirely naturally occurring situations, the chances of detecting comparatives would most likely be greater.

However, recent research by Gaillard *et al* (1992) has shown that it is possible in some cases to successfully apply the comparative approach in Holocene pollen studies. They used a form of multivariate analysis called Canonical Correspondence Analysis (CCA) to explore and test patterns of modern pollen variation, and to derive environmental reconstructions from fossil pollen data. More information on the technique of CCA is given below.

The success of these preliminary investigations of Gaillard *et al* suggest that it may be worthwhile investigating the applicability of this technique to other Holocene situations, such as those considered in this study. By restricting the initial samples to modern contexts of known ecological status, the opportunity exists to interpret results in the light of what is known of the ecologies of the samples and thereby, to assess the value of the technique.

If modern assemblages are governed by known environmental parameters, then the projection of the approach backwards in time to archaeological deposits, can be considered. The exploratory nature of this procedure ismanifest. If, however, modern samples from similar ecological situations do not contain comparable spore assemblages then there is little point in projecting the application backwards in time as there would be effectively no template provided by modern material to use as a basis. If this is the case then alternative exploratory procedures need to be investigated. With respect to this study, even if the assemblages in modern samples are governed by known environmental criteria, it will not be possible to use these data, more than tentatively, in the interpretation of fossil assemblages. This is because only approximately 20% of taxa are common to both modern and fossil samples so that the interpretation would be based on only 20% of the total species represented. However, if the modern species composition is statistically related to environmental variables then future research should include building up more extensive data sets whereby comparisons of modern and fossil assemblages would be more plausible.

IMPLEMENTING THE APPROACH

In many applications of the comparative approach, fossil and modern spectra have been visually compared e.g. Mc Andrews (1966), Davis (1967) and Birks (1973). However, where numerous samples are involved the task becomes arduous, and bias can easily be introduced in attempting to find a match between modern and fossil spectra. Numerical methods of analysis enable large data sets to be considered and eliminate subconscious bias in the matching procedure (Birks & Gordon 1985).

There are many methods of numerical analysis available and the choice is dependent on the nature of the data under consideration and the questions being posed. Since Gaillard *et al* succeeded in their approach to a similar problem using the program CANOCO, it was decided to use this program.
CANOCO is a FORTRAN programme for canonical community ordination by (partial) (detrended) (canonical) correlation analysis, principal components analysis and redundancy analysis. Correspondence analysis and canonical correspondence analysis were considered appropriate techniques to carry out investigations on these data.

CORRESPONDENCE ANALYSIS

Correspondence analysis is an ordination technique which attempts to derive a set of ordination-axis scores for species and for sites in such a way that the correlation between species and site scores is maximised (Jongman *et al* 1987).
It has two underlying assumptions. First, it assumes that the species have unimodal responses (bell shaped response curves) to the environment. Second, it assumes that there is some underlying structure in the data, i.e. that species composition is governed by a few unknown environmental variables (latent variables) according to a simple response model. Correspondence analysis is capable of detecting the underlying data structure. It is termed a form of indirect gradient analysis since the interpretation of the ordination axes is typically achieved with the help of external knowledge and data on environmental variables.

CANONICAL CORRESPONDENCE ANALYSIS

Canonical correspondence analysis is a form of direct gradient analysis whereby the axes are constrained as linear combinations of environmental variables. This gives a simultaneous ordination of species and sites, with the site scores constrained to be linear combinations of the environmental variables and the species scores weighted averages of the site scores. This technique considerably extends the analytical power of ecological ordination and eliminates the guesswork stage of straightforward Correspondence Analysis.
The data in this study can be considered fundamentally as a collection of response variables and explanatory variables; the response variables being samples and their fungal spore composition (or species), and the explanatory variables being a set of environmental variables relating to the samples.

Both forms of analysis have the option of detrending to eliminate the arch effect. The arch effect is a mathematical artefact corresponding to no real structure in the data (Hill & Gauch 1980).

METHODOLOGY

There is one principal question to be asked of the data in this investigation:

> Do certain samples produce statistically distinctive fungal spore assemblages which can be related to recorded environmental variables?

This question deals with the characterisation of modern anthropogenic situations in terms of fungal spore assemblages. The response to this question should determine whether or not it is worthwhile considering incorporating modern fungal spore/environment relations in the interpretation of fossil fungal spore data.

As outlined in Chapter Five, the data is this study will be considered in terms of presence/absence and percentages only. For the purpose of testing for the major gradients and their relation to recorded environmental variables in modern samples both forms of data can be investigated. However, if the comparison was between modern and fossil spore spectra, at present only presence/absence data could justifiably be considered. This is because:

1. In comparing modern and fossil spectra the comparison is between the components of the spectra which are common to both modern and fossil samples only. Consideration of taxa occurring exclusively in either modern or fossil samples would introduce an imbalance in the data.
   Since percentage data are based on entire assemblages, by comparing only selected components of assemblages this means that percentage data are no longer an accurate reflection of the population and should be disregarded.
2. Additionally, spore recoveries undertaken for this study indicate a greater diversity of taxa from modern samples. Can this be interpreted as an indication that many forms do not persist into the fossil record? If this is the case then it fortifies the argument against the consideration of percentage data when comparing modern and fossil spectra, since if there is selective degradation of certain spore categories in operation then original proportions will not necessarily be represented in the fossil assemblages.
   In any case it is likely that time-averaging will alter the relative proportions of taxa in assemblages and since not enough is currently known on this subject,

particularly with respect to fungal spores, it would be unwise to assume that relative proportions were constant between modern and fossil samples.

These points are speculative at this stage but should be contemplated since they affect the ways in which the modern data are to be considered numerically. The potential changes and losses from modern to fossil spectra with respect to species composition and proportions indicates that investigation of the modern data should initially be in terms of both percentage and presence/absence terms.

ANALYSIS

Two data matrices of the modern samples and their species compositions were constructed in Cornell condensed format (see ter Braak 1987-1992). One matrix contained the data in percentage form and the other the data in presence/absence form. Using the programme CANOCO, a CA was run on the percentage data matrix to explore the major patterns in the data in their percentage form.

RESULTS OF CA ON MODERN PERCENTAGE DATA

The eigenvalues for the first four ordination axes were unusually high (see Table 6.1 below). An eigenvalue is a measure of the importance of the axis (also known as an eigenvector) and corresponds to the maximised dispersion of the species scores on the ordination axis (Jongman *et al* 1987). The eigenvalues of CA all lie between 0 and 1, and the closer to 1 then the more important the axis.

Table 6.1
Eigenvalues of first four ordination axes after carrying out a correspondence analysis on modern percentage data.

	AX1	AX2	AX3	AX4
Eigenvalue	0.843	0.685	0.669	0.645

These unusually high eigenvalues suggest that there may be some form of block or near block structure or diagonal structure in the data, particularly since the eigenvalue of the first ordination axis is so close to 1.

Data are said to have block structures if their sites and species can be divided into clusters, with each cluster of species occurring in a single cluster of sites. CA is particularly good at detecting block structures (Jongman *et al* 1987).
In diagonal structures most of the abundance values for species can be arranged in a band along the diagonal after the data have been arranged according to the score of the species and sites on the first CA axis. Such a structure in a table confirms that species show bell-shaped curves against the environmental variable controlling the first CA axis, over the sites in which the species occur (Jongman *et al* 1987). A matrix which displays rows ordered so that the non-zero entries in each of the columns are fully contiguous is said by Kendall to be in the Petrie form (Doran & Hodson 1975). A Petrie matrix is an incidence matrix that has a block of consecutive ones in every row; the matrix is two-way Petrie if it also has a block of ones in every column, the block in the first column starting in the first row and the block of the last column ending in the last row (Jongman *et al* 1987).

If the structure is a block structure then the immediate assumption is that sampling location could be responsible for this apparent block structure, i.e. each sampling locality has a corresponding suite of species which occur in all samples from that particular locality.
In order to test this assumption a table of variables was drawn up. These variables relate to the location of the samples and basically labels the samples by sampling locality. CANOCO allows two ways of testing for the significance of these variables on the data. Either the matrix of variables can be considered in terms of covariables or it can be considered in terms of environmental variables.
By considering the sampling localities as covariables it is possible to conduct a `partial ordination' on the data. In such a partial ordination the effects of the covariables can be separated from those of other sources of variation and the effects of the covariables partialled out. The resulting ordination axes then represent the residual variation after the effects of the covariables have been partialled out.
If the variables are to be considered as environmental variables then it is necessary to run a CCA. In this analysis the ordination axes are constrained as linear combinations

of the environmental variables. The variation explained by the sampling localities can thereby be imposed onto the first ordination axis.

The first approach, considering location as covariables was considered.

TESTING FOR BLOCK STRUCTURES

Results of Partial Ordination and CCA of modern percentage data.
When the partial ordination was carried out ordination of the residual variation still demonstrated extremely high eigenvalues, (see Table 6.2).

Table 6.2
Eigenvalues of first four ordination axes after carrying out a partial analysis to test for block structures.

	AX1	AX2	AX3	AX4
Eigenvalue	0.814	0.641	0.642	0.584

This suggests that sampling locality does not explain the apparent structure in the data. Additionally, colinearity was detected amongst the covariables indicating that some of them have similar effects on the ordination.

If, however, the data are in a diagonal structure it may indicate that different assemblages of taxa occur in each sample, although individual taxa may occur across a range of samples. If this is the case it may impply either that the fungal spore sum of each sample is perhaps not high enough to constitute a representative sample or that the distribution of fungal spores is so localised that there is an almost unique assemblage exclusive to each and every sample.

TESTING FOR DIAGONAL STRUCTURES

Table 6.3 shows the data in a matrix form arranged according to the scores of species and samples on the first CA axis. As can be seen, the data can be organised in an approximately Petrie form matrix. This confirms that the species show bell-shaped

curves against the environmental variable controlling the first CA axis, over the sites in which the species occur (Jongman *et al* 1987). It also illustrates how samples at opposite ends of the axis have little in common.
Furthermore, it can be seen from the matrix that there are bands of species which occur almost throughout the samples, amongst them:

ASI 042
ASI 003
ASD 001
ASM 001
Phomoid agglomerations
Toruloid fragments.

However, if the species composition is explained perfectly by the ordering of the sites and species along the first axis then the importance of the second axis should be zero. The second axis has in fact an eigenvalue of 0.6855. This may be a manifestation of the arch effect (Jongman *et al* 1987). In order to minimise the arch effect DCA (Detrended Correspondence Analysis) was run on the data.

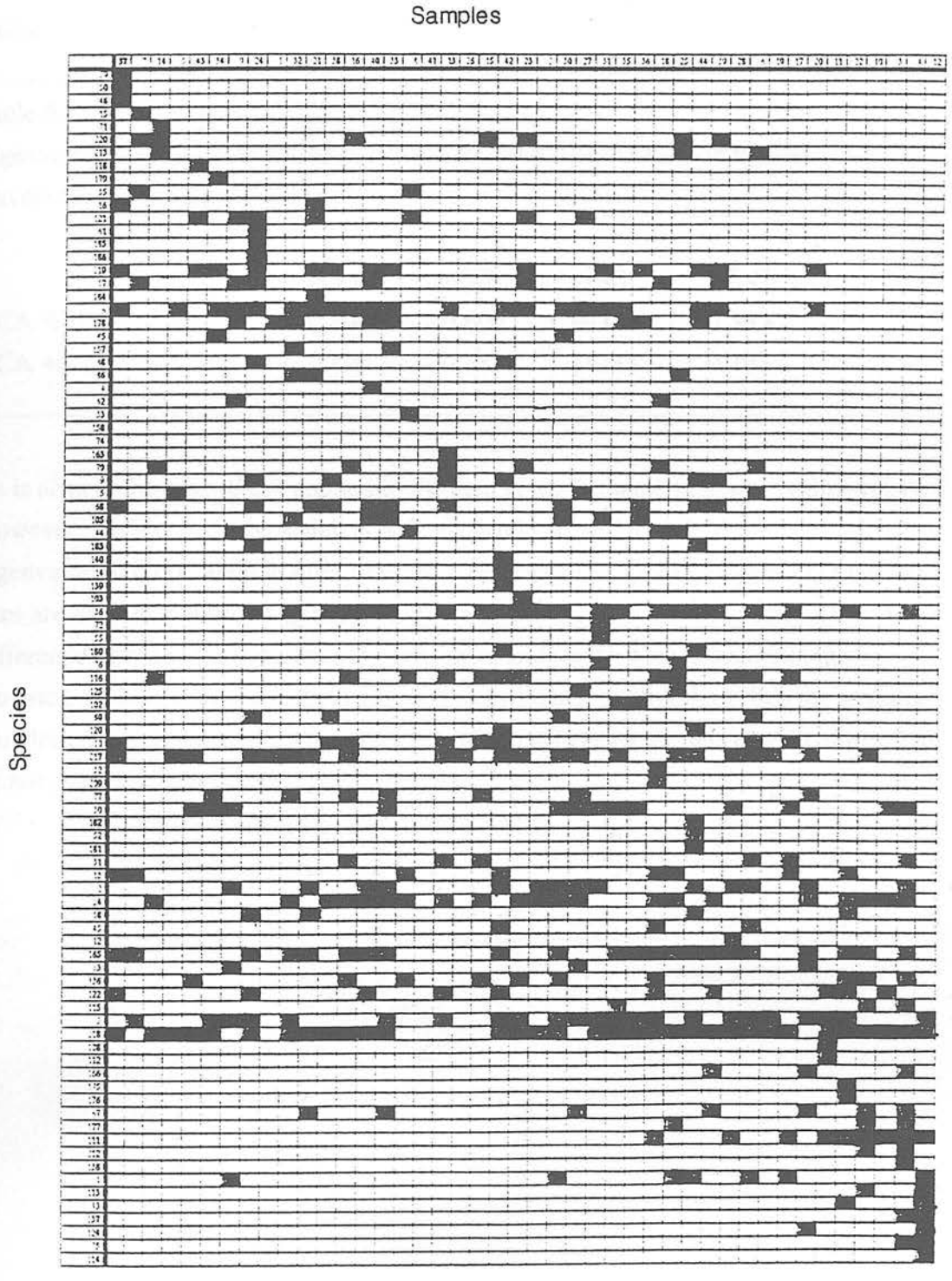


Table 6.3 Samples and species arranged according to their scores on the first CA axis - shows approximate diagonal arrangement

When DCA was run on the modern percentage data the first four eigenvalues were as follows.

Table 6.4
Eigenvalues of first four ordination axes after carrying out DCA on modern percentage and modern presence/absence data.

	AX1	AX2	AX3	AX4
DCA % data	0.843	0.660	0.562	0.345
DCA +/- data	0.493	0.382	0.245	0.193

As is always the case, DCA applied to the data gives the same first eigenvalue as CA. However, the second axis, which is now uncorrelated with the first axis, has an eigenvalue of 0.660 and the third axis has an eigenvalue of 0.562 suggesting that these axes are responsible for a significant amount of the variation in the species data. The difference between the eigenvalues of the third and fourth axes is such that the variation explained by the fourth axis can be considered negligible. When the samples are plotted in relation to their scores on the first two axes their distribution appears to be nonrandom, (see Fig 6.1).

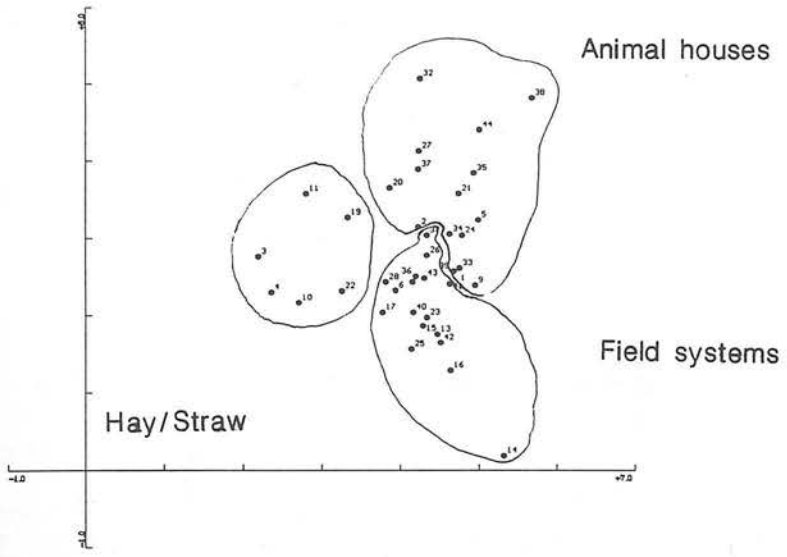


Fig 6.1 Scatter plot of ordination of samples on first and second CA axes - % data.

It seems that the first CA axis may be some kind of a gradient relating to the complexity of the samples, in that there is a cluster of samples associated with stored hay and straw at one extreme, then the samples grade to byre-type deposits where hay and straw are mixed with animal dung and at the other extreme the samples are from field systems and presumably incorporate a mixture of byre material, soil and arable crop; for a key to the numerical codes of the samples see Appendix 2. The second CA axis appears to be ordinating samples according to the extent of influence animals have in the sample. For example the cluster of samples closest to the X-axis include samples from barley fields, pasture fields and hay and straw stores whilst samples such as pig houses, cattle byres, pony and sheep byres and horse stables ordinate higher up along the Y-axis.

The same overall trends were observed when the same analysis was carried out on the data in presence/absence form, (see Fig. 6.2.).

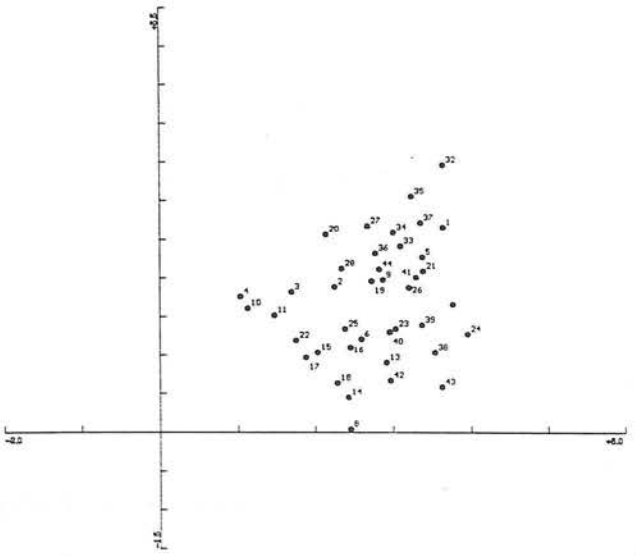


Fig 6.2 Scatter plot of sample ordination on first and second CA axes - +/- data.

However, the eigenvalues of the first two ordination axes were not as high as when percentage data were considered and the dispersion along the axes was not as great as when relative data were ordinated.

As the first two CA axes can apparently be interpreted in terms of broad environmental parameters, a matrix was constructed linking samples to more controlled environmental criteria to see if this could be invoked in refining the ordination of the samples. The matrix labels the sites according to a set of environmental variables related to the anthropogenic activities on the sites. The environmental variables chosen relate directly to the dominant activities operating on the samples, for example the animals which inhabit the source or the nature of arable cultivation. This matrix is summarised in Table 6.5. In order to test the significance of these variables on the data a CCA was conducted.

Table 6.5 Environmental variables used to constrain first canonical axis.

CA	Cattle
SH	Sheep
PI	Pigs
HO	Horses/Ponies
PC	Pigs/Cattle
GS	Goat/Sheep
PS	Pony/Sheep
CC	Cereal Crop
HE	Hens

CCA ON MODERN DATA

When a CCA was run on the percentage data, using the matrix of site activities as environmental variables to constrain the first axis, the eigenvalue of the first CCA axis is 0.516 suggesting that these environmental variables are responsible for a significant amount of variation along this axis. However, they do not explain as much of the variation as the first CA axis which has a considerably higher eigenvalue (0.8431 as opposed to 0.516). A similar result was obtained when CCA was run on the presence/absence data. Table 6.6 presents the eigenvalues of the first four ordination axes following CCA on both modern and percentage data. In both cases the first CCA axis has the highest eigenvalue implying that this axis explains most of the variation in both data sets.

Table 6.6
Eigenvalues of first four ordination axes resulting from CCA on modern percentage and modern presence/absence data.

	AX1	AX2	AX3	AX4
CCA % data	0.516	0.402	0.360	0.326
CCA +/- data	0.309	0.228	0.211	0.199

When the samples were plotted on the first two ordination axes the pattern of their distribution differed between the percentage and the presence/absence data (see figs 6.3 and 6.5). Furthermore the most important environmental variables also differed between percentage and presence/absence data (see Figs 6.4 and 6.6). This suggests that in constraining the first axis in terms of selected environmental variables

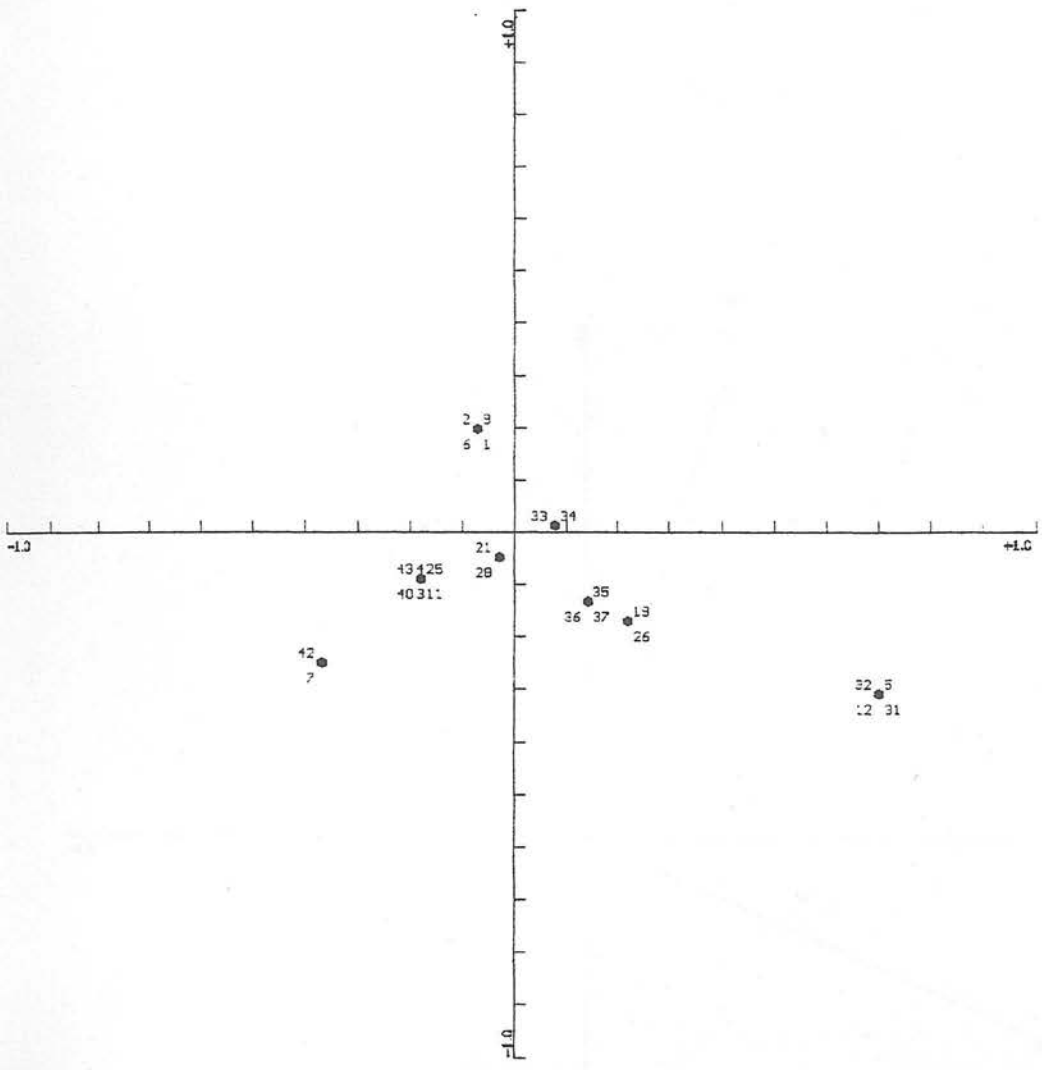


Fig. 6.3 Ordination of samples on the first two canonical axes following CCA on % data.

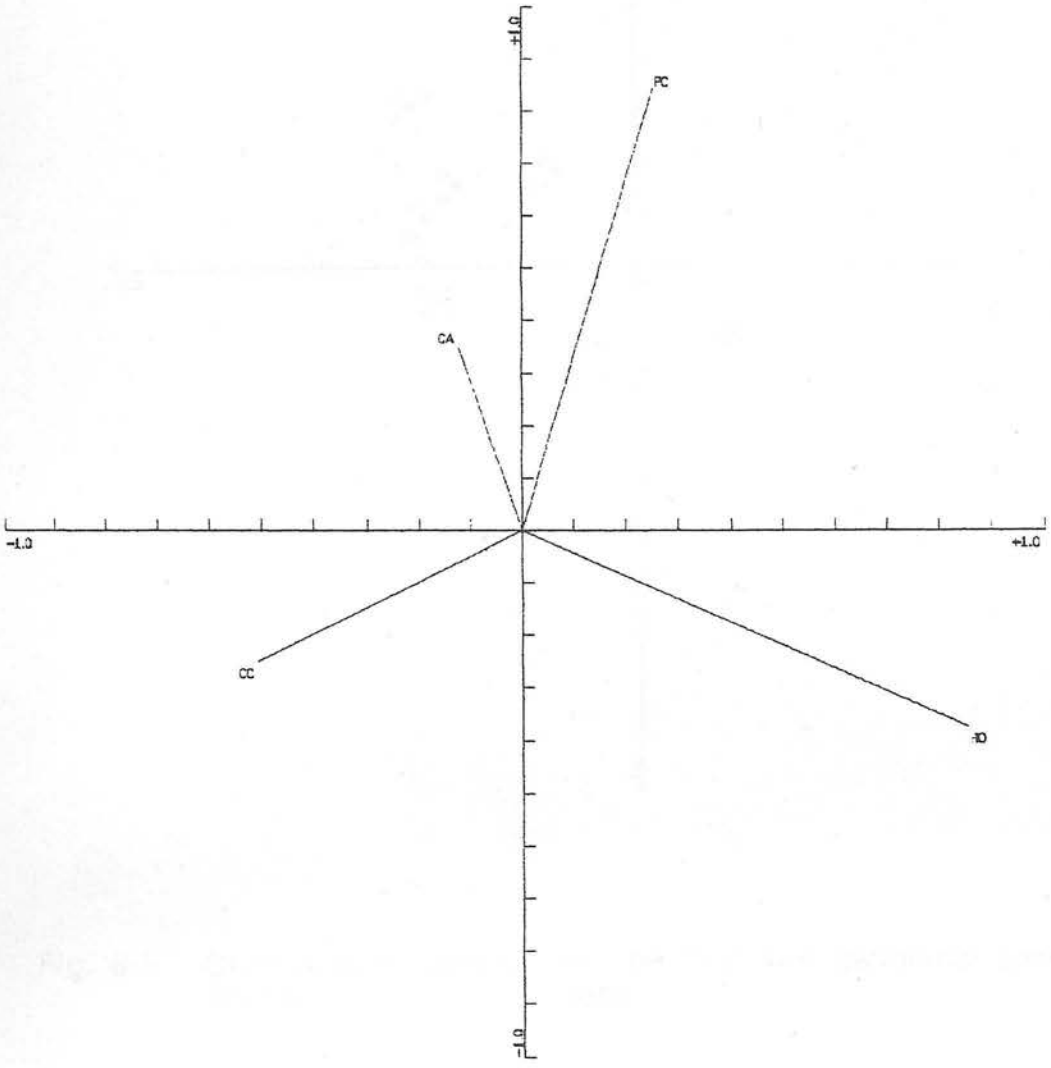


Fig. 6.4 The most important environmental variables following CCA on % data - the longer the arrow the more important the variable.

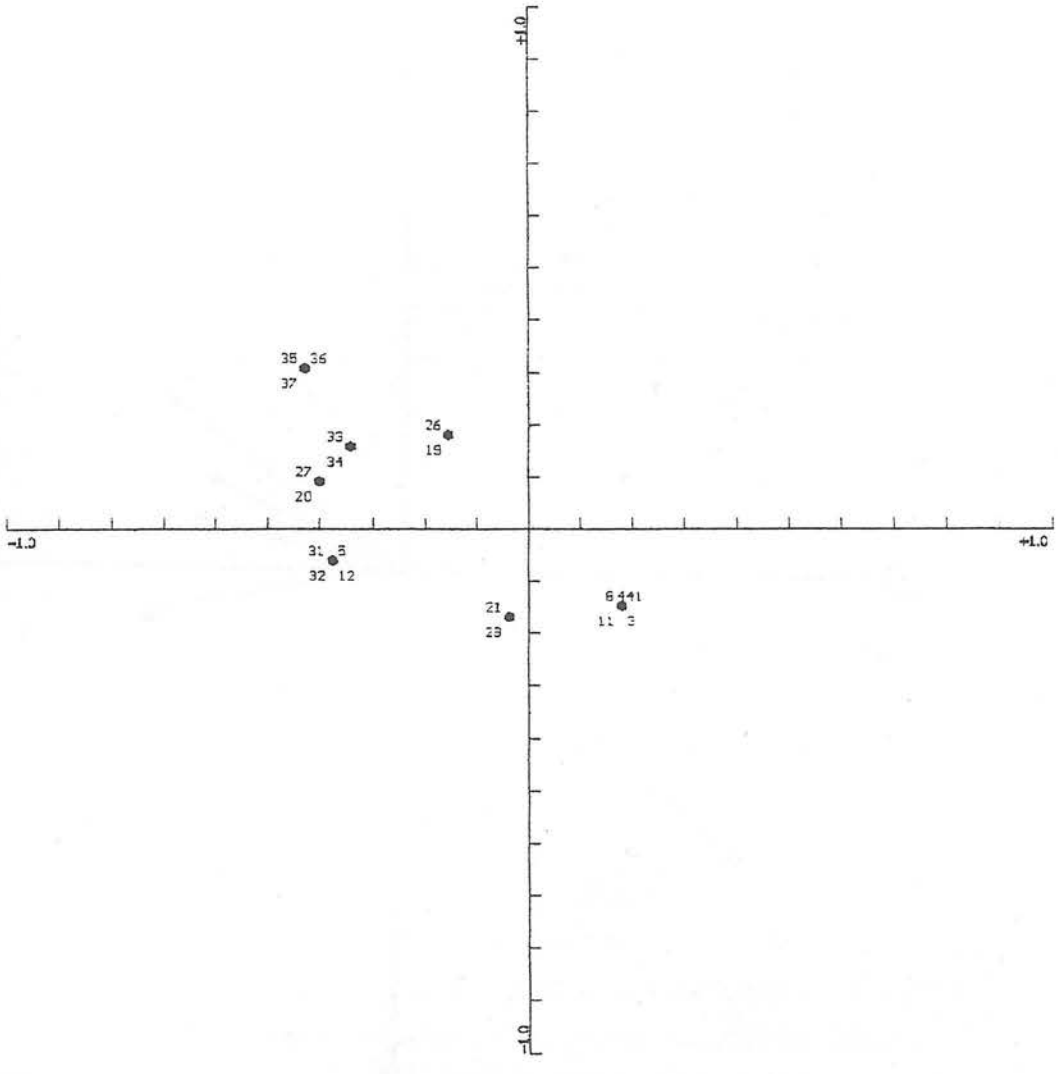


Fig. 6.5 Ordination of samples on the first two canonical axes following CCA on +/-data.

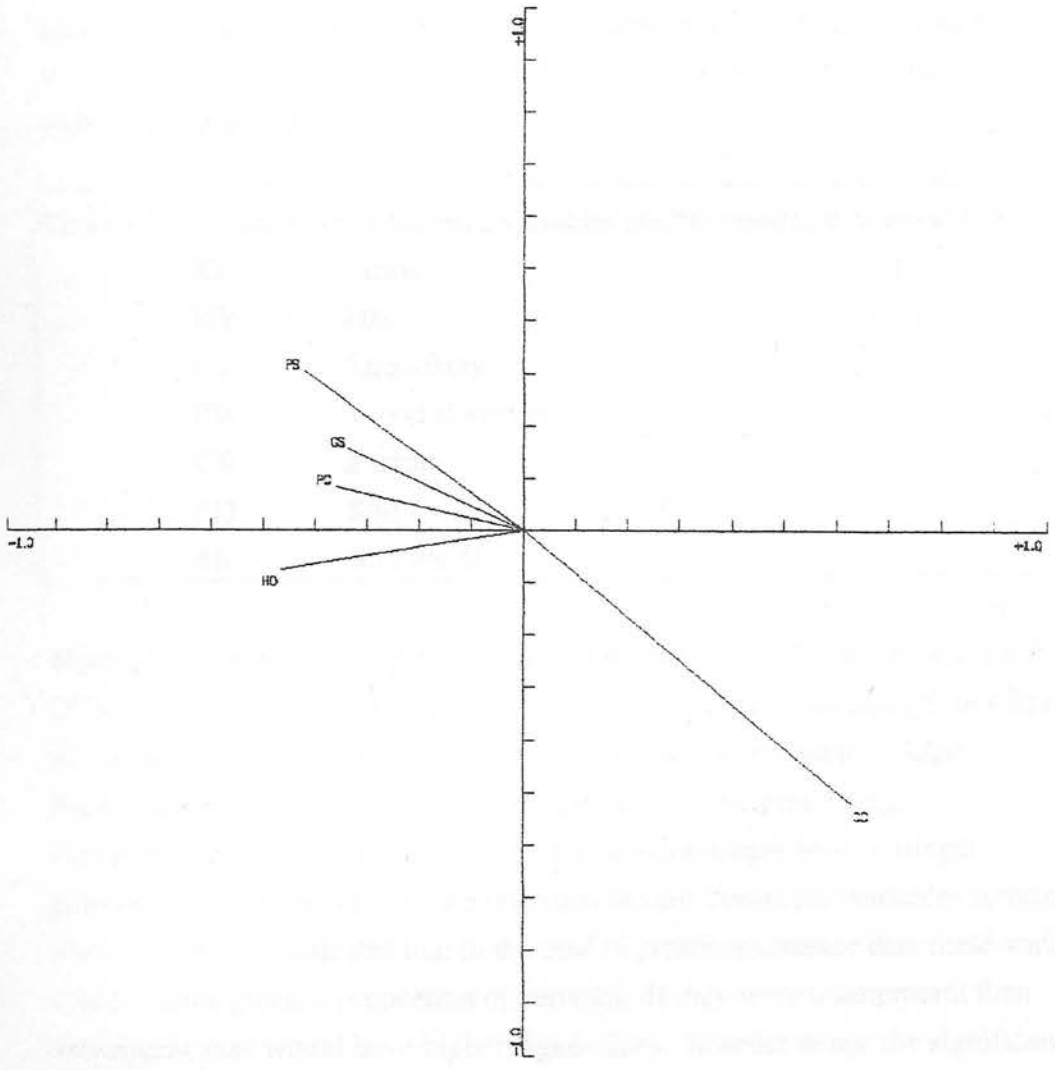


Fig. 6.6 The most important environmental variables following CCA on +/- data. The longer the arrow the more important the variable.

important information is being distorted because there is a continuum between sample ordination of percentage and presence/absence data following DCA.
The eigenvalue of the second CCA axis is significantly high in the case of the percentage data, demonstrating that a considerable amount of the variation can also be explained in terms of this axis. In order to try to interpret this axis a second table of environmental variables was drawn up relating to the next most obvious ecological parameter which is considered to be the substrate of the samples, for example whether the matrix was predominantly soil, straw, wood-shavings.....etc. Table 6.7 summarises these data.

Table 6.7 Secondary environmental variables used to constrain canonical axis.

ST	Straw
HY	Hay
SY	Straw/Hay
PW	Wood shavings
GR	Pasture
SO	Soil
SS	Straw/soil

When a CCA was run using this matrix as the environmental variables to fix the first CCA axis it was found that, surprisingly, these parameters had negligible variance on the ordination. Since there are no other obvious environmental variables interpretation of subsequent axes is not possible for the time being.
However, these results do suggest that the relative proportions of fungal palynomorphs within samples are related to the environmental variables summarised in Table 6.5. It also indicates that in the case of presence/absence data these variables explained the greatest proportion of variation. If they were unimportant then subsequent axes would have higher eigenvalues. In order to test the significance of these results, a Monte Carlo Permutation test was executed on the data.

MONTE CARLO PERMUTATION TESTS

Monte Carlo permutation tests investigate the statistical significance of the effects of the environmental variables on the ordination. The tests are carried out by randomly permuting the sample numbers in the environmental data which are randomly linked to the species data and calculating test statistics on the random data sets generated (ter

Braak 1987-1992). CANOCO has an option at the end of each analysis to carry out these tests.

In both the percentage data and the presence/absence data the results of the Monte Carlo permutation tests indicate that the effect of the environmental variables on the first canonical axis is not statistically significant at the 95% level since $P > 0.05$.

CONCLUSION

The results of DCA confirm that the ecological criteria appear to influence the fungal spore assemblages of samples. However, it seems that although similar patterns, apparently related to environmental variables, are detected when data are considered in both percentage and purely presence/absence terms following DCA, this phenomenon is not replicated when the axes are constrained in terms of known environmental variables. Following CCA the importance of the first axis declines (the eigenvalues decrease) suggesting that the selected environmental variables are not the most important influence on the data sets and Monte Carlo permutations confirm that the environmental variables are not statistically significant. Additionally the environmental variables (as determined by the positions of the arrows for environmental variables) which are most important to the ordination of the relative data are not the same as those for the presence/absence data. Furthermore the relative positions of samples in ordination diagrams of the first two canonical axes are different for percentage and presence/absence data while following DCA the overall relationship is maintained although distances differ.

These results suggest that at present fungal spore assemblages in samples can only be attributed to very broadscale environmental control. It is possible that further work may elicit more about the relationships to and nature of the environmental variables. This relationship between fungal spore assemblage and broad environmental parameters implies that the application of the comparative approach to the interpretation of fossil data has a promising future if refinements can be made. Unfortunately, owing to the limited sampling regime and the restriction of many taxa to either modern or fossil samples, with only 20% being common to both, the comparative approach is rendered invalid for this study. It cannot be considered further through these investigations. Instead the application of the indicator species approach will be tested. Chapter Seven deals with this issue.

CHAPTER SEVEN

THE INDICATOR SPECIES APPROACH

The Indicator Species Approach can be defined as the extension backwards in time of known sociological and ecological preferences of individual taxa (Iversen 1964; Birks & Birks 1980). The key assumption of this approach is that the ecological tolerances of the taxa involved have not undergone significant change through time. There is no direct means of testing this assumption. However, if groups of taxa occur together in the past in the same way as they do in the present then it reinforces the assumption that their ecological behaviour has not changed significantly. The coexistence through time of certain pollen taxa has been demonstrated (Anderson 1961; Iverse the n 1954, 1964; Janssen 1972; Birks 1973). The longterm coexistence has not so far been demonstrated in the fungal spore record but the phenomenon has not yet been investigated.

Since the fungi are heterotrophic organisms, they are opportunistic and their presence is determined particularly by the presence of their host substrate. They are host as opposed to habitat specific and their sociological associations are less pronounced than those of other organisms, such as plants. More importantly, the impact of human interference in naturally occurring associations, as referred to in the preceding chapter makes it difficult to investigate the associations of species from anthropogenic situations. It is, however, unlikely that the ecological tolerances of species will have changed radically over the timescale of this investigation, which considers samples from the Holocene. The strength of the indicator species approach, in this study, depends on the detection of suites of indicator taxa with similar known ecological preferences from within the same sample.

If a particular species is ecologically homogenous, and ecologically distinct from taxonomically related species, then it is of potential value as an indicator species. Greig-Smith (1964) has demonstrated this with respect to plants. If the species is ecologically heterogenous then ecoTypes rather than species are the best indicators of environmental conditions: Hanson and Churchill (1961) have demonstrated the utility of this approach with respect to plants. Fungi have received less attention in this field and although Hawksworth (1973) has reported the existence of ecoTypes amongst the lichens (fungal-algal symbionts) this phenomenon has not been demonstrated amongst the fungi. This does not preclude its existence.

Because of the limitations of our existing knowledge of fungal spore morphology most of the taxa encountered can only be identified to family or generic level, and to ecologically broad and diverse categories. Some have been identified to species level wherby more precise ecological inferences can be made. However, mycological research and the literature it generates is not geared towards species identification on the basis of spore morphology and such taxonomic precisions will be infrequent at this stage of fungal spore palynology; it is doubtful whether spore morphology under light microscopy could ever serve to distinguish between ecoTypes of a single species should they exist. In any case, reported ecological information is often paltry with the emphasis being on taxonomy or evolutionary aspects. Therefore, in this study a high degree of ecological resolution is not anticipated using the indicator species approach; rather, the aim is to test whether it is possible to resolve the nature of deposits to ecologically broad categories. If this is possible then suggestions can be proposed as to means of achieving higher degrees of resolution, through ecological and spore morphological researches in the future.

OBJECTIVES

As with the comparative approach, the first stage is to investigate whether the indicator species approach, when applied first of all to modern samples reflects the known ecologies of the samples. If this is the case, then it can be assumed that fungal spores are an indication of prevailing environmental conditions in anthropogenic deposits. If this is confirmed then the projection of the application backwards in time to archaeological deposits is validated, whereby suggestions on the palaeoenvironmental conditions of the contexts can be proposed.

THE INDICATOR SPECIES APPROACH AND MODERN SAMPLES

Of the 57 Types present in modern samples which are comparable to known taxa, the known ecological preferences of all of them concur with the nature of the environment from which they were collected. For example, Type ASI 002 has been identified as *Histoplasma capsulatum*; this fungus requires soil enriched with bird droppings to exist upon (Cooke 1977) and in almost all of the samples from where it was recovered compressed, pelleted bird droppings had been used as a source of phosphate enrichment for the soil. Another example is that of Type DII 003, identified as *Brachysporium* sp.; this Type was recovered from a sample of mor humus which is in accordance with the known ecological requirements of rotten wood and bark as substrate material for species of *Brachysporium* (Ellis 1966). There are

many other examples which have been summarised in Table 7.1 and detailed in Part Two, a catalogue of all the spores encountered throughout these investigations. It contains spores from modern samples with their known ecological requirements (in addition to spore recoveries from archaeological contexts). This catalogue is fully referenced.
This result confirms the application of the indicator species approach to fungal spore assemblages in modern samples and establishes an incentive to apply the technique to archaeological situations.

SUPPLEMENTARY INFORMATION

Along with the indicator species approach, a supplementary source of information may be considered in the palaeoenvironmental interpretations of the archaeological samples. This method is tangential to both the comparative and indicator species approaches. However, it is considered alongside the indicator species approach since, like this approach, interpretation is dependent on individual taxa rather than on assemblages, as in the comparative approach. It is applicable only to the 42 taxa which occur in both modern and archaeological samples. It involves considering the nature of the deposits where particular taxa occur in modern samples. Without needing specifically to identify the taxa, knowledge of the nature of the modern sample can then be incorporated in explaining the fossil occurrence of the taxa. This source of information should be used in supporting results provided by identifiable taxa. It should not be used in isolation since it is possible that foreign Types could be incorporated into deposits; basing hypotheses solely on such Types could thus result in erroneous deductions.

SAMPLES

Samples from five archaeological sites were considered; their short titles are Balbridie Hall, Dun Bharabhat, Buiston Crannog, Longhouse at Lairg and Pit at Tuquoy. Descriptions of these sites and the nature of the samples are detailed in Chapter Four.

Summary information on taxonomic and ecological details of taxa encountered at each is presented in this Chapter. More detailed morphological, taxonomical and ecological information is presented in Part Two of this thesis. Photographs of many of the Types can also be found in this catalogue.

Table 7.1 Identifiable types from modern samples with their known summary ecologies and the nature of the samples in which they occur.

TYPE	I.D.	SUMMARY ECOLOGY	NATURE OF MODERN SAMPLE TYPE OCCURS IN
ASI 002	Histoplasma capsulatum	Soil enriched with bird droppings	Soil enriched with pelleted bird droppings
ASI 012	Lycoperdon/Myxomycete	Widespread/damp conditions	Pasture or crop fields
ASI 014	Ampelomyces quisqualis	On powdery mildews	Earth floor of pig house
ASI 020	Endogonaceae	Soil	Pasture or crop fields
ASI 035	Cladosporium	Mainly plant pathogens	Samples containing wheat or straw
ASI 037	Sordariaceae	Dung, vegetation, seeds and burnt ground	Widespread
ASI 039	Sordariaceae	Dung, vegetation, seeds and burnt ground	Soil from barley field
ASI 042	Sporormia	Dung, grass debris and old wood	Widespread
ASI 048	Apiosordaria verruculosa	Unknown	Pasture field
ASI 052	Sordariaceae	Dung, vegetation, seeds and burnt ground	Pig yard and horse stable
ASI 054	Sordariaceae	Dung, vegetation, seeds and burnt ground	Pasture or crop field
ASI 060	Melampsora	Willow and Poplar trees	Abandoned crop field
ASM 001	Nigrospora	Vegetation	Widespread
ASM 002	Bolbitiaceae/Coprinaceae	Wood, dung, plant remains, pastures and heaths	Pony byre
ASM 008	Sordariaceae	Dung, vegetation, seeds and burnt ground	Harvested oat field
ASM 009	Bolbitiaceae/Coprinaceae	Wood, dung, plant remains, pastures and heaths	Cattle byre and barley field
ASM 012	Sordariaceae	Dung, vegetation, seeds and burnt ground	Pasture
ASM 014	Centropyxis ecornis	Water and mosses, damp conditions	Widespread, seems linked to hay or/and straw
ASM 015	Sordariaceae	Dung, vegetation, seeds and burnt ground	Widespread, seemslinked to cereal crops
ASM 016	Microthyriaceae	On leaves and stems	Mor humus
ASM 018	Microthyriaceae	On leaves and stems	Harvested barley field
ASM 019	Microthyriaceae	On leaves and stems	Mor humus and pasture field
ASM 021	Sordariaceae	Dung, vegetation, seeds and burnt ground	Sheep pasture
ASM 024	Sordariaceae	Dung, vegetation, seeds and burnt ground	Harvested barley field and pony byre
ASM 025	Sordariaceae	Dung, vegetation, seeds and burnt ground	Widespresd, seems linked to presence of animals
ASM 029	Sordariaceae	Dung, vegetation, seeds and burnt ground	Pony byre and abandoned crop field
ASM 031	Sordariaceae	Dung, vegetation, seeds and burnt ground	Mor humus
ASM 054	Ureda	Plants	Sheep and goat byre
ASD 001	Chaetomium/Lophotrichus	Cellulose - straw, paper and cloth	Widespread, seems linked to the presence of hay/straw or/and dung
ASD 002	Sordariaceae	Dung, vegetation, seeds and burnt ground	Widespread, seems linked to the presence of cereal crops
ASD 004	Sphaerodes	Dung	Cow byre
ASD 005	Sordariaceae	Dung, vegetation, seeds and burnt ground	Mor humus and permanent pasture
ASD 006	Sordariaceae	Dung, vegetation, seeds and burnt ground	Mor humus
ASD 007	Sordariaceae	Dung, vegetation, seeds and burnt ground	Mor humus
ASD 012	Xylaria	Wood	Pig yard
ASD 013	Xylaria	Wood	Straw, hay and barley
ASD 016	Sordariaceae	Dung, vegetation, seeds and burnt ground	Barley field
ASD 020	Sphaerodes	Dung	Pig house with earth floor
MOI 001	Cladosporium	Mainly plant pathogens	Cow byre
MOI 006	Brachysporium	Wood	Mor humus
MOI 008	Delitschia	Dung	Barley field and pig house
DII 003	Brachysporium	Wood	Mor humus
DII 004	Brachysporium	Wood	Mor humus
DII 011	Apical conidiophore	Unknown	Mor humus
DIM 001	Brachysporium	Wood	Mor humus
TRI 007	Cladosporium	Mainly plant pathogens	Straw and a horse stable
TRI 010	Chaetosphaerella	Branches and twigs	Barley field
TRD 001	Brachysporium	Wood	Mor humus
MUI 001	Helminthosporium	Grassland	Pasture field
MUI 002	Stagonospora	Grassland	Cattle byre
MUI 006	Alternaria	Leaves, stems, seeds and flowers	Hay
MUI 007	Bactrodesmium	Wood	Pasture field
MUI 011	Pleospora	Dead plant remains	Hay
MUI 016	Ampelomyces quisqualis	On powdery mildews	Straw, hay, goat and sheep byre and pasture
MUI 020	Alternaria	Leaves, stems, seeds and flowers	cattle byre
MUP 001	Asterosporium	Trees	Mor humus
MUP 003	Papulospora	Widespread	Barley field

The ecological information available on Types is incorporated in the interpretations of the samples from each site; these interpretations follow.
To avoid unecessary repetition the implications of Type ASI 012 are summarised here. This Type is widespread and occurs in many of the archaeological samples across a range of sites. It is comparable morphologically to two previously published Types, namely:

1. type 181 of van Geel *et al* (1983b) - where it was found to be associated with open-water, eutrophic conditions.

2. *Lycoperdon*-Type of Elsik (1986) where it is considered to be a spore of the puffball genus *Lycoperdon.*

More details on this Type are given in Part Two. In summary it is not possible to distinguish between puffball spores and Myxomycete spores without knowledge of the sterigmata. Therefore, the uncertainity of the identification of this spore Type means that it is of little significance in palaeoecological interpretations despite its ubiquity.

BALBRIDIE HALL

Five samples from Balbridie Hall were examined, see Chapter Four for details of individual samples.

RESULTS

Sample BB79 E4 was barren and will not be considered further. Amongst the other samples palynomorphs were not abundant and a minimum spore sum of fifty fungal palynomorphs was achieved for each sample, by counting several slides. This is a deviation from the procedure outlined in Chapter Five, i.e. to consider the fungal palynomorphs represented within a minimum pollen sum of 300. However, because of the low numbers and poor preservation of pollen grains it was not practical to adopt the standard procedure in the case of the Balbridie samples.
Preservation was average but not good or exceptional for fungal spores. Some of the spores were fractured and some exhibited corrosion but most were in a state of preservation which would facilitate identification, as far as identification of such microfossils is possible.

Fifteen Types in total were recovered from the samples. Table 7.2 charts the occurrences of taxa through the samples. Of these fifteen Types, nine are comparable to modern taxa. These are illustrated in Table 7.3 along with a summary of their ecological preferences.
The remaining taxa recovered from Balbridie have not, so far, been connected in any way to known taxa. For the time being they can make no contribution, in terms of the indicator species approach, to palaeoecological interpretations of the site.

The Aggregations encountered in these samples resemble spores of the genus *Stephylium*, a genus usually found associated with decaying vegetation (Wiltshire 1938).

Table 7.2 Occurrence of types through the samples from Balbridie.

	BB78ST4	BB79E12	BB80S10	BB81E13
AGG REG	X	X	X	
ASD 001	X			X
ASD 036		X		
ASD 037		X		X
ASD 038		X		X
ASI 012	X			
ASI 068	X	X	X	X
ASM 001	X			
ASM 051		X		
ASM 053			X	
ASM 054	X			
ASP 006			X	
DII 010				X
MOI 005	X	X	X	X
TOR FRA				X

Table 7.3 Type codes with their comparatives and summary ecologies.

Type Code	Known Comparative	Summary Ecology
AGG REG	**? Stemphylium**	**Decaying vegetation**
ASD 001	**Chaetomium/Lopotrichus**	**Cellulose - straw, paper, cloth**
ASD 038	**Ustulina deusta**	**Parasitic on deciduous trees**
ASM 001	**Nigrospora**	**Grassland**
ASM 051	**Sordariaceae**	**Dung, vegetation, burnt ground**
ASM 053	**Ascomycotina**	**Widespread**
ASM 054	**Ureda**	**Parasitic on vegetation**
ASP 006	**Gelasinospora ?cerealis**	**Dung, vegetation, ?wheat and oats**
MOI 005	**Delitschia**	**Dung**

BB78 ST4

This sample contains spores comparable to those of the modern genera *Stemphylium, Chaetomium/Lophotrichus*, *Nigrospora*, *Ureda* and *Delitschia*. All except *Delitschia* occur on vegetation or decaying vegetation. *Delitschia* is known to occur almost exclusively on herbivore dung; one species has been reported from dog faeces. Excavation suggests that this sample is likely to be associated with the use of the building and results of the fungal spore analysis are in accordance with the hypothesis that the building was, in part, a grain store. *Chaetomium/Lophotrichus* could have existed on straw and chaff associated with grain or perhaps on the cellulose component of the grain itself. *Ureda* could have been parasitic on the growing crop and *Nigrospora* could also have existed on the growing crop. *Stemphylium* may be associated with the decay of the grain while *Delitschia* could be indicative of the presence of rodents or other small mammals inhabiting the building and exploiting the availability of an abundant supply of food.

BB79 E12

This sample contains spores comparable to those of the modern genera *Stemphylium* and *Delitschia* and the modern family Sordariaceae, in addition to an unidentifiable basidiospore. Spores of *Stemphylium* Type dominate the assemblage. It lacks any direct indicators of grain or straw, although it has yielded a spore of the Sordariaceae. The Sordariaceae have been known to occur on seeds and therefore, possibly grain. However, this sample does not yield any particularly diagnostic spores. Spores of *Stemphylium* are present in three out of the four samples studied while spores of *Delitschia* are present in all of the samples. These Types can be considered as indicative of the background presence of decaying vegetation and animals - factors that apply to almost any archaeological situation.

BB80 S10

This sample contains spores comparable to those of the modern genera *Stemphylium, Gelasinospora* and *Delitschia*. Spores of *Stephylium* Type dominate the assemblage. Spores of *Gelasinospora* are considered to be spores of the species *G. cerealis* because of their morphological and size similarities to described and illustrated spores (Dowding 1933). *Gelasinospora* spp. occur on dung and vegetation but spores of *G. cerealis* occur on the crown of wheat and oats. There is a possibiity that these spores existed on stored grain.

BB81 E13

This sample contains spores comparable to those of the modern genera *Chaetomium/Lophotrichus* and *Delitschia*, in addition to an unidentifiable basidiospore. *Chaetomium/Lophotrichus* suggests the presence of straw. Little else can be said about this sample although the absence of *Stemphylium* Type makes it unique amongst these samples, a factor which may be of significance.

CONCLUSION

The fungal spore Types encountered in four samples from Balbridie have been documented. Using these taxa in the indicator species approach palaeoecological suggestions have been made as to the nature of the samples.

It would seem that the spore content in all of the samples reflects the presence of vegetation. Three of the spore Types identified as Sordariaceae, *Gelasinospora* and *Delitschia* can also be indicative of the presence of dung. However, recoveries of Sordariaceae and *Delitschia* are rare. *Gelasinospora* Types could also reflect the presence of seeds or of burnt ground. *Delitschia* is more intrinsically linked to the presence of dung, perhaps, in this case, of small mammals. It is thought that the spores of *Gelasinospora* recovered may be of a form which occurs on cereal crops.

DUN BHARABHAT

Twelve samples from Dun Bharabhat were examined. These were taken from a core at strategic positions relating to the stratigraphy, see Chapter Four.

RESULTS

Palynomorphs were abundant and exceptionally well preserved - both pollen and fungal spores. In each case it was possible to attain a pollen sum of 300, although in some of the sandier subsamples at the base of the core it took several slides to achieve this sum.

60 different Types in total were recovered from the subsamples. 37 are comparable to known taxa, while inferences about 8 of the Types can be made on the basis of their occurrences in modern samples. One further Type is considered to be of algal origin. The remaining 14 have not so far been connected in any way to known taxa or known environments. For the time being the latter can make no contributions in terms of the indicator species approach to palaeoecological interpretations of the site.

Table 7.4 charts the occurrence of Types through the core; while Table 7.5 summarises the ecologies of known comparative taxa and of unknown taxa which occur in modern samples. Fig. 7.1 illustrates the relative flux of key Types through the samples. Absolute spore values were calculated and are tabulated in Table 7.6: however the changing nature of the sediment through the core is reflected in these values and downweights their significance in terms of possible ecological interpretations.

DISCUSSION

Bharabhat 1

This sample contains spores comparable to those of the modern genera *Chaetomium/Lophotrichus*, *Nigrospora* and *Cladosporium*. It also contains Type ASI 012. In addition it contains Type ASI 008 a Type which occurs in modern samples and may be related to the presence of animals or/and dung.

The presence of *Chaetomium/Lophotrichus* suggests the presence of straw, while *Nigrospora* and *Cladosporium* could also have existed on this substrate.

Table 7.4 Occurrence of types through the samples from Bharabahat.

	BHAR 1	BHAR 2	BHAR 3	BHAR 4	BHAR 5	BHAR 6	BHAR 7	BHAR 8	BHAR 9	BHAR 10	BHAR 11	BHAR 12
AGG REG		X	X				X	X			X	
ASD 001	X	X		X							X	
ASD 017	X					X					X	
ASD 024			X									
ASD 026					X	X						
ASD 027		X										
ASD 028											X	
ASD 029							X					
ASD 030									X			
ASD 032								X			X	
ASI 003		X	X	X								
ASI 008	X	X	X	X	X	X	X	X	X	X	X	X
ASI 012	X	X			X	X	X	X	X		X	X
ASI 015								X				
ASI 035					X							
ASI 042			X					X		X		
ASI 069	X											
ASI 070									X			
ASI 071											X	
ASI 072				X							X	X
ASI 073							X					
ASI 074											X	
ASI 220			X					X	X	X	X	X
ASM 001	X	X	X		X	X	X			X	X	
ASM 002	X	X	X		X	X	X			X	X	
ASM 005											X	
ASM 014			X		X			X			X	
ASM 015								X		X		
ASM 036								X		X		
ASM 047									X			
ASM 048						X					X	
ASM 050											X	
ASP 001										X		
ASP 005	X							X	X			
ASP 006			X	X		X	X					
ASP 007										X		
ASP 010											X	
DII 002						X						
DII 008				X							X	
DII 009											X	
DIM 002						X	X	X	X		X	
MOD 001						X						
MOI 004				X						X	X	
MOI 005											X	
MOI 010				X							X	
MOI 011				X	X		X	X			X	
MOI 012											X	
MOI 013											X	
MUI 004			X					X		X		
MUI 016	X					X						
MUM 001								X				
PHO MOI			X	X		X	X	X		X	X	
TOR FRA	X	X	X	X	X	X	X		X	X	X	
TRI 001							X					
TRI 006								X			X	
TRI 007	X											
TRI 010											X	
TRI 012				X	X	X	X				X	
TRI 013							X			X		
TRM 001		X	X	X	X	X		X	X	X	X	X

Table 7.5 Type codes with their comparatives and summary ecologies - Bharabhat samples.

TYPE CODE	COMPARATIVE	SUMMARY ECOLOGY
ASD 001	Chaetomium/Lophotrichus	Cellulose - straw, paper, cloth
ASD 017	Sordariaceae	Dung, vegetation
ASD 024	Sordariaceae	Dung, vegetation
MOD 002	Delitschia	Dung
ASI 020	Endogonaceae	Soil
ASD 026	Sordariaceae	Dung, vegetation
ASD 027	Neurospora	Fire
ASD 028	Parasite egg	Dung
ASD 030	Sordariaceae	Dung, vegetation
ASD 031	Sordariaceae	Dung, vegetation
ASI 003	From modern samples	Widespread
ASI 008	From modern samles	?Dung
ASI 012	Type 181 (Van Geel 1983) Lycoperdon-type (Elsik 1986)	Associated with Eutrophic conditions by Van Geel (1983)
ASI 015	?Algal in origin	Soil
ASI 020	Endogonaceae	Soil
ASI 035	Cladosporium sp.	Preominantly from vegetation
ASI 037	Sordariaceae	Dung, vegetation
ASI 042	Sporormia	Dung, grass debris and wood
ASI 072	Sordariaceae	Dung, vegetation
ASI 073	Basidiomycotina	Widespread
ASM 001	Nigrospora sp.	Grassland
ASM 002	Coprinaceae/Bolbitiaceae	Dung, vegetation
ASM 005	From modern samples	Soil
ASM 014	Centropyxis ecornis	Wet conditions
ASM 015	Sordariaceae	Dung, vegetation
ASM 047	Bolbitiaceae/Coprinaceae	Dung,vegetation
ASM 048	Microthyriaceae	Leaves, stems, bark and on other fungi
ASM 029	Sordariaceae	Dung, vegetation
ASM 050	Sordariaceae	Dung, vegetation
ASP 001	Gelasinospora sp.	Dung, vegetation
ASP 006	Gelasinospora ?cerealis	Dung, vegetation, wheat and oats
ASP 007	Gelasinospora	Dung, vegetation
ASP 010	Sordariaceae	Dung vegetation
DIM 002	From modern samples	Pasture field
MOI 004	From modern samples	?Dung
MOI 005	From modern samples	?Cereals
MOI 011	Type 140 of Van Geel (1983) identified as Nectria	Eutrophic wet conditions
MOI 013	Reticellites houstonii (Elsik et al 1986)	Unknown
MUI 004	Bulbil	Unknown
MUI 016	Ampelomyces quisqualis	On powdery mildews
MUM 001	From modern samples	?Hay and straw
TRI 006	From modern samples	?Dung
TRI 007	Cladosporium sp.	Predominantly from vegetation
TRI 010	Chaetosphaerella sp.	On diatrypaceous fungi
TRI 012	Meliola niessleana	Parasitic on plants

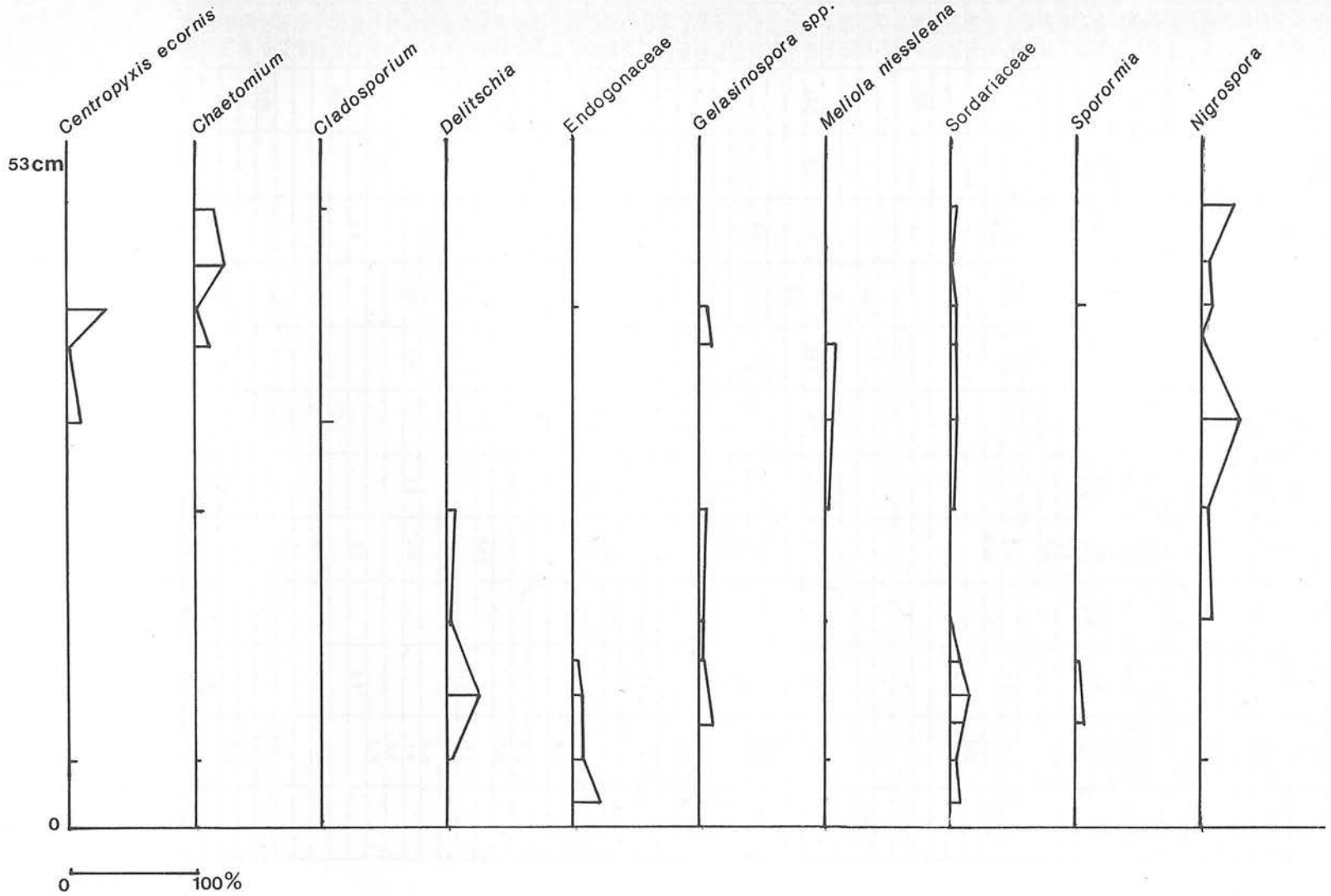


Fig. 7.1 Relative flux of key types through the samples from Bharabhat.

Table 7.6 Absolute values for types recovered from the samples at Bharabahat.

	BHAR 1	BHAR 2	BHAR 3	BHAR 4	BHAR 5	BHAR 6	BHAR 7	BHAR 8	BHAR 9	BHAR 10	BHAR 11	BHAR 12
ASD 001	6.25	25.9		1.8							0.3	
ASD 017	2.08					4.5					0.14	
ASD 024			0.96									
ASD 025						9.1	4.6		3.5		0.14	
ASD 026					1.9	2.3						
ASD 027		3.7										
ASD 028											0.14	
ASD 029							1.2					
ASD 030									1.2			
ASD 031								0.45				
ASD 032								0.9			0.14	
ASI 003		29.6	3.8	0.3							1.1	
ASI 008	6.25	25.9	0.96	1.2	3.8	47.7	37.9	1.4	2.3	0.9	1.05	0.2
ASI 012	8.3	18.5			11.1	4.5	4.8	17.2	2.3		3.2	1.1
ASI 015								2.3				
ASI 029								0.45				
ASI 035					5.6							
ASI 042			1.9					0.45		0.3		
ASI 064			0.96					0.45	1.2		1.25	0.64
ASI 065											0.14	
ASI 066										0.3	3.8	
ASI 068												
ASI 069	2.8											
ASI 070									1.2			
ASI 071											0.97	
ASI 072				0.6							0.3	0.2
ASI 073							1.2					
ASI 074											0.14	
ASM 001	12.5	3.7	2.9		16.7	4.5	63.2			0.6	1.55	
ASM 002				0.3								
ASM 005											0.14	
ASM 014			9.6		5.6			0.9			0.97	
ASM 015								0.45		0.3		
ASM 036								3.6		0.3		
ASM 047									1.2			
ASM 048						2.3					0.14	
ASM 049								0.45				
ASM 050										0.3		
ASP 001										0.3		
ASP 005	8.3							0.45	1.2			
ASP 006			0.96	1.2		6.8	6.9	0.45				
ASP 007										0.3		
ASP 010											0.14	
DII 002						6.8						
DII 008				1.5							0.14	
DII 009											0.14	
DIM 002						38.6		0.45				
MOI 004				1.2						0.6	0.3	
MOI 005											0.45	
MOI 010				0.3							0.14	
MOI 011				0.3	1.9		1.2	0.9			1.4	
MOI 012											3.6	
MOI 013											0.14	
MUI 004			4.8					2.7		0.3		
MUI 019	2.08					2.3						
MUM 001								0.45				
TRI 001							3.5					
TRI 006								0.45			1.1	
TRI 007	2.08											
TRI 010											0.14	
TRI 012				0.9	1.9	6.8	1.2				0.14	
TRI 013							2.3			0.3		
TRM 001		3.7	3.8	3.3	9.3	47.7		2.3	1.2	1.2		1.1

Bharabhat 2

This sample contains spores comparable to those of the modern genera *Chaetomium/Lophotrichus*, *Neurospora* and *Nigrospora*. It also contains Type ASI 012. In addition it contains Type ASI 003, a form which is widespread amongst modern samples and Type ASI 008 which also occurs in modern samples and may be related to the presence of animals or/and dung.

Chaetomium/Lophotrichus suggests that straw may have been a constituent of this deposit, while *Nigrospora* could also have existed on this substrate. *Neurospora* has been associated with fire by van Geel (1986) and could represent ash being incorporated into the deposit.

Bharabhat 3

This sample contains Types comparable to those of the modern genera *Sporormia* and *Nigrospora*; the modern species *Centropyxis ecornis* (Rhizopod) and *Gelasinospora ?cerealis* in addition to a fungal bulbil. It also contains spores of the family Sordariaceae. Also present are the following: Type ASI 003, a form which is widespread amongst modern samples and Type ASI 008 which also occurs in modern samples and may be related to the presence of animals or/and dung.

Nigrospora suggests the presence of hay or/and straw, while *G. cerealis* may be an indication that cereal grains were present. The presence of Sordariaceae is likely to be related to either decaying vegetation or a source of dung; the presence of Type ASI 008 favours the Sordariaceae having dung as a host. *Sporormia* may indicate the presence of dung, or grass debris or wood. Although van Geel *et al* (1983b) associate the presence of *Centropyxis ecornis* with wet conditions, in the majority of the modern samples in this study where the rhizopod occurred, hay or/and straw were present. From this evidence it would appear that hay or/and straw were almost definitely constituents of this deposit and it is possible that animals or/and dung were also present. The ecological significance of the fungal bulbil is unknown.

Bharabhat 4

This sample contains spores comparable to those of the modern genera *Chaetomium/Lophotrichus* and *Nectria*; the modern species *Gelasinospora ?cerealis* and *Meliola niessleana*; and the modern families Bolbitiaceae/Coprinaceae and Sordariaceae. It also contains Type ASI 003, a form which is widespread amongst modern samples; Type ASI 008, which also occurs in modern samples and may be related to the presence of animals or/and dung; and Type MOI 004 is also present and thought to be related to the presence of animals or/and dung in modern samples.

Chaetomium/Lophotrichus suggests the presence of straw; *M. niessleana*, although known to be parasitic on plants, has been found by van Geel to be associated in particular with *Calluna vulgaris* (van Geel 1978, van Geel *et al* 1988), other known hosts are species of *Vaccinium* (Erikkson 1974). The known presence of heather in these deposits favours this as being the host plant for the fungus. Sordariaceae and Bolbitiaceae/Coprinaceae spores imply either the existence of dung or/and decaying vegetation, while Types ASI 008 and MOI 004 support the likely presence of dung. *G. ?cerealis* suggests that cereal grains may have been present.

Bharabhat 5

This sample contains spores comparable to the modern genera *Cladosporium*, *Nigrospora* and *Nectria*; the modern family Sordariaceae; and the modern species *Meliola niessleana* and the rhizopod *Centropyxis ecornis*. It also contains Type ASI 008, which also occurs in modern samples and may be related to the presence of dung; and Type ASI 012.

The presence of *Cladosporium* and *Nigrospora* in conjunction with *C. ecornis* suggests the presence of hay or/and straw. *M. niessleana* indicate the likely presence of heather; while *Nectria* may be an indicator of wet conditions. The recovery of spores of the Sordariaceae indicate the presence of dung or/and decaying vegetation; Type ASI 008 suggests that the substrate may include dung.

Bharabhat 6

This sample contains spores comparable to the modern genera *Chaetomium/Lophotrichus*, *Delitschia* and *Nigrospora*; the modern families Sordariaceae and Microthyriaceae; and the modern species *Gelasinospora ?cerealis* and *Ampelomyces quisqualis*. It also contains Type ASI 008, which also occurs in modern samples and may be related to the presence of dung; and Type ASI 012.

The presence of *Chaetomium/Lophotrichus* and *Nigrospora* indicate the presence of hay or/and straw while *Delitschia* indicates the presence of dung. Type ASI 008 supports the existence of dung. *G. ?cerealis* suggests that cereal grains may have been present. *A. quisqualis* could have existed on these hosts. The Sordariaceae indicate the presence of dung or/and decaying vegetation while the Microthyriaceae indicate the presence of vegetation.

Bharabhat 7

This sample contains spores comparable to those of the modern genera *Delitschia*, *Nigrospora* and *Nectria*; the modern species *Meliola niessleana* and *G. ?cerealis*; in

addition, Type ASI 008, which also occurs throughout modern samples and may be related to the presence of animals or/and dung; and Type ASI 012.
The presence of spores of *Delitschia* indicates the presence of dung and *Nigrospora* suggests the influence of grassland vegetation. *Meliola niessleana* suggests the likely presence of heather; while *G. ?cerealis* suggests that cereal grains may have been present. The recovery of spores of the genus *Nectria* may be an indication of wet conditions..

Bharabhat 8

This sample contains spores comparable to those of the modern genera *Sporormia* and *Nectria*. It contains the modern rhizopod species *Centropyxis ecornis* and the fungal species *G. ?cerealis*. In addition it contains spores of the families Sordariaceae and Endogonaceae, in addition to a fungal bulbil. It contains Type ASI 012. Type ASI 008, which occurs throughout modern samples and may be related to the presence of dung, and Type MUM 001 which is linked to the presence of hay and straw in modern samples were also recovered.
Centropyxis ecornis suggests the presence of hay or/and straw; Type MUM 001 lends support to this hypothesis. *G. ?cerealis* suggests that cereal grains may have been present. The presence of the Sordariaceae indicate the presence of decaying vegetation or/and dung; the recovery of Type ASI 008 supports this argument. *Sporormia* may indicate the presence of dung, grass debris or wood. The presence of spores of the Endogonaceae indicate that soil or/and plant roots form part of this deposit. *Nectria* may be an indication of wet conditions. The ecological significance of the presence of Type ASI 12 and of the fungal bulbil Type, if any, is unknown.

Bharabhat 9

This sample contains spores comparable to the modern genera *Delitschia* and *Coprinus*; the modern families Sordariaceae and Endogonaceae. It also contains Type ASI 008, which also occurs in modern samples and is thought to be associated with the presence of animals or/and dung, and Type ASI 012. *Delitschia* and *Coprinus* in this sample indicate the presence of dung; the presence of Type ASI 008 supports this hypothesis. Spores of the Sordariaceae are indicators of dung or/and decaying vegetation. Recoveries of spores of the Endogonaceae suggest that soil or/and plant roots were incorporated in this deposit.

Bharabhat 10

This sample contains spores comparable to the modern genus *Sporormia*, *Nigrospora* and *Gelasinospora*. Spores comparable to those within the family Sordariaceae were recovered. A Type of fungal bulbil was also present. Type ASI 008 is present, this also being recovered from modern samples where it is thought to be associated with the presence of dung.

Nigrospora suggests the presence of vegetation, probably of the grassland Type and possibly from hay or/and straw. Recoveries of spores of the *Gelasinospora* spp. and Sordariaceae indicate the existence of decaying vegetation or/and dung. *Sporormia* may indicate the presence of dung, grass debris or wood. The ecological affinity of the fungal bulbils is unknown.

Bharabhat 11

This sample contains spores comparable to the modern genera *Chaetomium/Lophotrichus*, *Delitschia*, *Nigrospora* and *Chaetosphaerella*; and to the modern families Sordariaceae, Endogonaceae and Microthyriaceae. It also contains the rhizopod *Centropyxis ecornis* and a parasite egg. Additionally, it contains spores of the modern species *Meliola niessleana*.

Type MOI 011 is comparable to Type 141 of van Geel *et al* (1983a) and has been identified as *Nectria*.

Type ASI 003 has been found across a range of modern samples; Type ASI 008, is thought to be related to the presence of animals or/and dung in modern samples; Type ASM 005 is thought to be related to the presence of cereals in modern samples; Type MOI 013 is comparable to *Reticellites houstonii* of Glass *et al* (1986); the ecological tolerances of this Type are presently unknown.

Type MOI 005 is thought to be related to the presence of cereals in modern samples; - all these Types occur in this sample.

Chaetomium/Lophotrichus, *Nigrospora* and *C. ecornis* indicate that straw or/and hay were likely components of this deposit. M. *niessleana* suggests the presence of heather while *Chaetosphaerella*, which exists on small branches or twigs could have existed on these hosts. The presence of Microthyriaceae is diagnostic of the existence of vegetation. Spores of the Sordariaceae suggest the presence of dung or/and decaying vegetation. The recovery of *Delitschia* and of parasite eggs indicate that dung is a constituent of this deposit. Endogonaceae indicate that soil or/and plant roots are also components. *Nectria* is considered by van Geel to be an indication of eutrophic wet conditions; this fungus may have flourished on the aquatic substratum around the dun site.

Bharabhat 12

This sample contains spores comparable to the modern families Sordariaceae and Endogonaceae. It also contains spores of Type ASI 008, a Type thought to be related to the presence of dung in modern samples and Type ASI 012.

Spores of the Sordariaceae indicate the presence of dung or/and decaying vegetation while the Endogonaceae are typically recovered from soil or/and plant roots.

CONCLUSIONS

The analysis of the fungal spore assemblages through this core suggest that it may be a Type of byre deposit with straw or/and hay and heather as livestock bedding material. There is evidence of hay or/and straw from recoveries of *Chaetomium/Lophotrichus* and *Nigrospora* spores and the rhizopod *C. ecornis*; decaying vegetation or/and dung from occurrences of spores of the Sordariaceae and *Gelasinospora* spp.; and *Calluna* or *Vaccinium* Type vegetation from occurrences of *M. niessleana* all the way through the deposit. This is in accordance with findings of the excavation which uncovered layers of straw, heather and dung.

In the lower levels, samples 7 to 12, the presence of spores of *Delitschia* are indicative of the presence of dung and this is substantiated by the concomitant recovery of a parasite egg. *Delitschia* is an obligate dung fungus which is almost exclusively restricted to herbivore dung, although one species inhabits dog faeces although it is not restricted to it. Specific identification of the *Delitschia* spores recovered from these samples was not possible. However, their recovery supports the hypothesis that the dung deposits are derived from animals rather than humans. From Fig. 4.1 it is obvious that the occurrence of *Delitschia* coincides with the presence of spores of the Endogonaceae and to relative increases in the proportions of the Sordariaceae and *Gelasinospora* spp.

This suggests that the expansion in Types of Sordariaceae and species of *Gelasinospora*, both facultative dung inhabitors, may be intrinsically linked to the presence of dung. Fig 4.2 shows the increase in the numbers of different Types of Sordariaceae through the column and the general trend is an increase in Types towards the basal samples where spores of obligate dung fungi are present.

Spores of the Endogonaceae are indicative of soil or/and plant roots and also strongly associated with the presence of *Delitschia* spores, and the relative increases in Types of spores of the Sordariaceae and *Gelasinospora* spp. Soil may have been deliberately introduced or may have found its way in on the roots of heather or other plants, or in the hooves of animals.

In the upper levels of the core, samples 1 to 6, there is no irrefutable evidence to suggest the presence of animals. However, there are Types of Sordariaceae present which occur in both upper and lower levels and have been tentatively associated with dung in the lower levels. In addition relative proportions of *Chaetomium/Lophotrichus* spores and of the rhizopod *C. ecornis*, both considered as indicators of straw or/and hay, are higher in the upper levels.

It does seem, on the basis of the fungal spore analysis, that from sample 6 upwards it is likely that the function of the structure changed or at least that it was less intensively used. As there is no evidence of obligate dung fungi the possibility exists that the straw and heather in these upper levels could be derived from collapsed roof-thatch material.

BUISTON

Nine samples from Buiston crannog were examined; refer to Chapter Four for details thereof. Comparison of results of fungal spore analysis to Diptera analysis was possible. The Diptera analysis was carried out by M.H. Dinnin for AOC Scotland Ltd.

RESULTS

Palynomorphs were present but not in great abundance and preservation was adequate to permit identification. In four of the samples a pollen sum of 300 was not attained because of the paucity of pollen; instead a sum of only 100 was reached.

50 fungal Types in total were recovered from the samples. 33 are comparable to known taxa or to previously described Types. In addition, inferences about the ecological preferences of 9 other taxa could be made on the basis of their occurrences in modern samples. Table 7.7 charts the occurrence of Types encountered through the Buiston samples while Table 7.8 lists Types of known affinity and their comparatives and summary ecologies.

DISCUSSION

B39

This sample contains spores comparable to the modern genera *Chaetomium/Lophotrichus*, *Sporormia* and *Brachysporium*; to the families Sordariaceae and Endogonaceae; and to the Class Basidiomycotina. In addition it contains Type ASI 003, a form found to be widespread amongst modern samples; Type ASI 008 also recovered from modern samples where it is thought to be related to the presence of animals or/and dung; and Type ASM 035 which is also widespread amongst modern samples.

Chaetomium/Lophotrichus indicates the presence of straw or/and hay - this concurs with the fossil insect analysis of this sample which yielded indicators of stored hay. Sporormia may indicate the presence of dung, or grass debris or wood.

Brachysporium suggests the presence of rotten wood or bark, while the presence of spores of the Sordariaceae indicate either decaying vegetation or/and dung. The recovery of spores of the Endogonaceae indicate that soil or/and plant roots were constituents of this deposit.

Table 7.7 Occurrence of types through the samples from Buiston.

	B39	B48	B234	B309	B310	B316	B327	B341	B402
AGG REG	X			X	X	X	X		X
ASD 001	X	X			X	X		X	
ASD 010	X								
ASD 013						X			
ASD 016			X						
ASD 017	X								
ASD 024		X							
ASD 033				X					
ASD 034				X					
ASD 035						X			X
ASI 003	X				X		X	X	X
ASI 008	X	X			X	X		X	X
ASI 012		X	X	X	X	X	X	X	X
ASI 020	X	X	X				X		X
ASI 027							X		
ASI 031							X		
ASI 037				X	X				
ASI 042	X	X		X	X				X
ASI 054				X					
ASI 067	X								
ASI 072			X					X	
ASI 073				X		X			
ASM 001		X	X	X	X				
ASM 002		X							
ASM 005		X			X				
ASM 013	X								X
ASM 014			X			X		X	
ASM 015					X	X			
ASM 018						X		X	
ASM 021				X					
ASM 026			X						
ASM 029		X		X		X			
ASM 035	X								
ASM 041					X				
ASM 044		X			X				
ASM 045		X							
ASM 051				X					X
ASP 006				X					
DIM 003	X								
MOI 002					X				
MOM 002				X					
MUI 008					X				
MUI 009					X				
MUM 002				X					
PHO MOI	X	X	X		X	X	X	X	
TOR FRA		X	X	X	X	X	X	X	X
TRI 006				X					
TRI 008						X			
TRI 014						X			
TRM 002				X					

Table 7.8 Identifiable types from Buiston with their known comparatives and summary ecologies

Type code	KNOWN COMPARATIVE	SUMMARY ECOLOGY
ASD 001	Chaetomium/Lophotrichus	Cellulose - straw, paper, cloth
ASD 010	Basidiomycotina	Widespread
ASD 013	From modern samples	?Straw, hay and soil
ASD 016	Sordariaceae	Dung, vegetation
ASD 017	Sordariaceae	Dung, vegetation
ASD 024	Sordariaceae	Dung, vegetation
ASD 035	Cladosporium	Predominantly from vegetation
ASI 003	From modern samples	Widespead
ASI 008	From modern samples	?Dung
ASI 012	Type 181 of Van Geel (1983) Lycoperdon-type of Elsik (1986)	Type 181 associated with open water, eutrophic conditions
ASI 020	Endogonaceae	Soil
ASI 037	Sordariaceae	Dung, vegetation
ASI 042	Sporormia	Dung, grass debris and wood
ASI 054	Sordariaceae	Dung, vegetation
ASI 072	Sordariaceae	Dung, vegetation
ASI 073	Basidiomycotina	Widespread
ASM 001	Nigrospora	Grassland
ASM 002	Bolbitiaceae/Coprinaceae	Vegetation, dung
ASM 005	From modern samples	?Soil
ASM 013	Sordariaceae	Dung, vegetation
ASM 014	Centropyxis ecornis	Wet conditions
ASM 015	Sordariaceae	Dung, vegetation
ASM 018	Microthyriaceae	Leaves, stems, bark and other fungi
ASM 021	Sordariaceaae	Dung, vegetation
ASM 026	Sordariaceae	Dung, vegetation
ASM 029	Sordariaceae	Dung, vegetation
ASM 035	From modern samples	Widespread
ASM 041	Sordariaceae	Dung, vegetation
ASM 044	Sordariaceaae	Dung, vegetation
ASM 045	Microthyriaceae	Leaves, stems, bark and other fungi
ASM 029	Sordariaceae	Dung, vegetation
ASM 051	Sordariaceae	Dung, vegetation
ASP 006	Gelasinospora ?cerealis	Dung, vegetation, ?wheat and oats
DIM 003	Brachysporium	On rotten wood and bark
ASI 020	Endogonaceae	Soil
MOM 002	Brachysporium	Rotten wood and bark
MUI 008	Tetraploa aristata	Leaves and stems
MUI 009	From modern samples	?Hay and straw
MUM 002	From modern samples	?Soil
TRI 006	From modern sampes	?Dung
TRI 008	From modern samples	?Straw
TRI 014	Spadicoides	Dead wood

B48

This sample contains spores comparable to the modern genera *Chaetomium/Lophotrichus*, *Sporormia* and *Nigrospora*; the modern families Endogonaceae, Sordariaceae, Bolbitiacea and Microthyriaceae. In addition it contains Type ASI 008, a Type recovered from modern samples where it is thought to be related to the presence of animals or/and dung; and Type ASM 005 which is considered to be related to the presence of soil from its occurrence throughout the modern samples.

Chaetomium/Lophotrichus and *Nigrospora* indicate that straw or/and hay are likely components of this deposit - this is in accordance with the fossil insect assemblage which yielded fauna of rotting hay. Spores of the Sordariaceae and Bolbitiaceae/Coprinaceae indicate the presence of decaying vegetation or/and dung - this also parallels the insect analysis which, in addition to indicators of rotting hay, yielded indicators of dung; Type ASI 008 lends support to this observation. *Sporormia* may indicate the pesence of dung, or grass debris or wood. The recovery of Microthyriaceae supports the existence of vegetation in the deposit. The presence of spores of the Endogonaceae suggest that soil or/and plant roots form part of this deposit; Type ASM 005 supports this hypothesis.

B234

This sample contains Types comparable to the modern genus *Nigrospora*; the modern families Sordariaceae and Endogonaceae; and the rhizopod *Centropyxis ecornis*. In addition it contains Type ASI 012.

The presence of *Nigrospora* indicates the influence of grassland vegetation, while the Endogonaceae indicate the presence of soil or/and plant roots. Sordariaceae suggest the presence of dung or/and decaying vegetation and *Centropyxis ecornis* could indicate the presence of hay or/and straw. This sample was intended as a control sample since the insect analysis did not recover any indications of anthropogenic activity. The fungal spore analysis does not show any over-ruling evidence for intensive anthropogenic activity. The results could be interpreted as being representative of an open grassland vegetation, although the recovery of *C. ecornis* suggests that straw or hay may have been present.

B309

This sample contains Types comparable to the modern genera *Nigrospora*, *Sporormia* and *Brachysporium*; the modern species *Gelasinospora ?cerealis*; and the modern family Sordariaceae. It also contains a spore of the Class Basidiomycotina. In addition it contains Type ASI 012. It also contains Type MUM 002, a Type which is

thought to be associated with soil from its occurrence in modern samples; and Type TRI 006 which is thought to be associated with animals or/and dung from its occurrence throughout modern samples.
Nigrospora suggest that straw or/and hay may have been present, while *Brachysporium* indicates the existence of rotten wood or bark. Sordariaceae spores indicate the presence of decaying vegetation or/and dung. All of the above support the results of the fossil insect assemblage which yielded indicators of mouldy stored hay. The presence of *G. cerealis* suggests that cereal grain may have been present. *Sporormia* suggests that dung, or grass debris or wood may have been present.

B310

This sample contains Types comparable to the modern genera *Chaetomium/Lophotrichus, Sporormia* and *Nigrospora*; the modern species *Tetraploa aristata*; and the modern family Sordariaceae. It also contains Type ASI 003, a Type which is widespread in modern samples; Type ASI 008, which is thought to be associated with the presence of animals or/and dung from its occurrence in modern samples; Type ASM 005 which is thought to be associated with the presence of soil from its occurrence in modern samples; and Type MUI 009 which also occurs in modern samples where it is thought to be related to the presence of hay and straw. *Chaetomium/Lophotrichus*and *Nigrospora* indicate that straw or/and hay were likely to be components of this deposit; Type MUI 009 supports this statement. *Sporormia* indicates that dung, or grass debris or wood may have been present. *Tetraploa aristata* indicates the presence of leaves or stems. Sordariaceae spores indicate the presence of dung or/and decaying vegetation. All of the above agree with the results of the insect analysis which yielded indicators of rotting plant material or/and dung and those of rotting hay.

B316

This sample contains Types comparable to the modern genera *Chaetomium/Lophotrichus*, *Cladosporium*, *Xylaria* and *Spadicoides*; the modern families Sordariaceae and Microthyriaceae; the rhizopod species *Centropyxis ecornis*. It also contains a representative of the Class Basidiomycotina. Type ASI 012 was also recovered. It also contains Type ASI 008, which occurs in modern samples where it is thought to be associated with the presence of dung; Type TRI 008 which occurs in modern samples where it is thought to be associated with the presence of straw; and Type ASD 013 which occurs in modern samples in association with straw or/and hay or/and soil.

Chaetomium/Lophotrichus and *Cladosporium* indicate the likely presence of straw or/and hay; the recovery of *C. ecornis* supports this probability. The presence of TRI 008 and ASD 013 also lend support to this hypothesis. The above observations are in accordance with the results of the insect assemblage analysis which yielded indicators of mouldy stored hay. The presence of the Sordariaceae suggests that dung or/and decaying vegetation form part of this deposit. The Microthyriaceae support the presence of vegetation. The presence of *Spadicoides* and *Xylaria* indicates the presence of wood.

B327

This sample contains Types comparable to the modern genus *Inocybe*; and the modern family family Endogonaceae. It also contains Type ASI 003, which is widespread in modern samples and Type ASI 012.

The presence of the Endogonaceae suggest that soil or/and plant roots are components of this deposit while Inocybe indicates the presence of humus or/and wood. The ecological significance, if any, of Type ASI 012, is unknown as previously remarked.

B341

This sample contains Types comparable to the modern genus *Chaetomium/Lophotrichus*; the modern families Sordariaceae and Microthyriaceae; and the rhizopod species *Centropyxis ecornis*. It also contains Type ASI 012, this Type is comparable to Type 181 of van Geel *et al* (1983b) where it is associated with open water, eutrophic coditions; and to *Lycoperdon*-Type of Elsik (1986) which is considered to be a spore of the puffball genus *Lycoperdon*. It also contains Type ASI 003, a Type which is widespread throughout modern samples and Type ASI 008 which occurs in modern samples where it is thought to be related to the presence of animals or/and dung.

Chaetomium/Lophotrichus and *C. ecornis* suggest the presence of straw or/and hay; Type ASI 008 supports the existence of dung. Microthyriaceae indicate the presence of vegetation while spores of the Sordariaceae indicate the presence of dung or/and decaying vegetation. Analysis of the fossil insect assemblage yielded indicators of dung and also a sheep ked. Results of the fungal spore analysis fall within these parameters.

B402

This sample contains Types comparable to the modern genera *Cladosporium* and *Sporormia*; the modern families Endogonaceae and Sordariaceae. It also contains

Type ASI 012, this Type is comparable to Type 181 of van Geel *et al* (1983b) where it is associated with open water, eutrophic conditions; and to *Lycoperdon*-Type of Elsik (1986) which is considered to be a spore of the puffball genus *Lycoperdon*. In addition it contains Type ASI 003, which is widespread in modern samples and Type ASI 008, which also occurs within modern samples where it is thought to be associated with the presence of dung.

Cladosporium indicates the likely presence of straw or/and hay. Spores of the Sordariaceae indicate the presence of dung or/and decaying vegetation. *Sporormia* may indicate the presence of dung, grass debris or wood. The presence of the Endogonaceae indicates the presence of soil or/and plant roots in the deposit. The ecological significance of Type ASI 012 is unknown.

CONCLUSIONS

From these results it seems likely that straw or/and hay, and decaying vegetation or/and dung were ubiquitous amongst these samples. There is also evidence of rotten wood in some of the samples as determined by the presence of spores of *Brahysporium*.

Although species of the Sordariaceae are facultative dung fungi, it is almost certain that some of them did exist on this host in these samples since the Diptera analysis yielded indicators of dung.

In all cases the fungal spore analysis agreed with results of the Diptera analysis and in some cases fungal spores provided additional information. For example, in many samples both fungal spore and Diptera analysis suggest the presence of rotting vegetation or/and dung. It is possible in the case of the Diptera analysis to ascertain the presence of mouldy stored hay while fungal spore analysis can also reveal the presence of hay or/and straw although no indications that it was mouldy are currently known. Fungal spores can, however, indicate more about the precise nature of the vegetation. For example, *Tetraploa aristata* indicates the presence of leaves or/and stems while *Brachysporium* spp. indicate the presence of decaying wood.

LAIRG

Twelve samples from the longhouse at Lairg were examined; refer to Chapter Four for details thereof.

RESULTS

Pollen was abundant and well preserved in most samples. Only four samples failed to produce pollen sums of 300. However, fungal spores were not present in great numbers or diversity.

21 different fungal Types were recovered from the samples. Of these, 9 are comparable to known taxa or to previously described Types. In addition knowledge of the ecological preferences of 4 taxa could be included on the basis of their distribution in modern samples. Table 7.9 charts the occurrence of Types through the samples at Lairg while Table 7.10 presents Types of known affinity with their comparatives and summary ecologies.

DISCUSSION

L6014

This sample contains Types comparable to the modern genus *Nigrospora*. It also contains Type ASI 012; and Type ASI 008 which occurs in modern samples where it is thought to be associated with the presence of dung.

The presence of *Nigrospora* suggests the influence of grassland vegetation. The ecological significance of Type ASI 012 is unknown. Little else can be deduced about the nature of this sample on the basis of the fungal spore analysis. Excavation suggests this deposit represents late internal sediments/occupation spread.

L6050

This sample contains Types comparable to the modern genus *Nigrospora*. It also contains Type ASI 012.

The presence of *Nigrospora* suggests the influence of grassland vegetation. Little else can de deduced about the nature of this sample on the basis of the fungal spore analysis. Excavation suggests that this sample represents early internal sediments/occupation spread.

Table 7.9 Occurrence of types through the samples from Lairg.

	L6014	L6050	L6057	L6075	L6084	L6097	L6108	L6075	L6112	L6119	L6129	L6137
AGG REG			X		X			X	X			X
ASD 019									X			
ASD 022									X			
ASD 023			X									
ASD 026												X
ASD 029											X	
ASI 004					X							
ASI 008	X						X		X			
ASI 012	X	X	X		X	X			X	X		
ASI 020					X					X		X
ASI 042			X	X	X	X						X
ASI 061					X							
ASM 001	X	X			X					X		X
ASM 005									X			
ASP 006												X
ASP 008			X									
MOD 001					X	X						
MOI 005					X							
MOI 011											X	
MOI 014												X
TOR FRA											X	

Table 7.10 Identifiable types from Lairg with their known modern comparative taxa and summary ecologies.

Type code	COMPARATIVE	SUMMARY ECOLOGY
ASD 019	From modern samples	?Soil
ASD 022	From modern samples	?Soil
ASD 023	Chaetomium	Cellulose - straw, paper, cloth
ASD 026	Sordariaceae	Dung, vegetation
ASI 004	From modern samples	?Soil
ASI 008	From modern samples	?Dung
ASI 012	Type 181 of Van Geel (1983) Lycoperdon-type of Elsik (1986)	Type 181 found in open water, eutrophic conditions
ASI 042	Sporormia	Dung, grass debris and wood
ASI 061	From modern samples	?Soil
ASM 001	Nigrospora	Grassland
ASM 005	From modern samples	?Soil
ASP 006	Gelasinospora ?cerealis	Vegetation, dung, ?wheat and oats
ASP 008	Sordariaceae	Dung, vegetation
ASI 020	Endogonaceae	Soil
MOI 005	From modern sampes	?Cereals
MOI 011	Type 140 of Van Geel (1983) identified as Nectria	Associated with eutrophic, wet conditions

L6057

This sample contains Types comparable to the modern genera *Chaetomium/Lophotrichus* and *Sporormia*; and to the modern family Sordariaceae. It also yielded Type ASI 012.

The recovery of spores of *Chaetomium/Lophotrichus* indicates the presence of hay or/and straw. The presence of the Sordariaceae indicates the presence of dung or/and rotting vegetation. *Sporormia* suggests the presence of dung, or grass debris or wood. Excavation suggests this deposit is an occupation spread/rake out.

L6075

This sample is almost barren, containing only Aggregations and *Sporormia*. This Type normally occurs in deposits where hay and/or straw are components although it is associated with dung, grassland debris and old wood in modern deposits. Nothing else can be inferred of the ecology.

The sample was excavated from the secondary hearth set in the house floor.

L6084

This sample contains Types comparable to the modern genera *Sporormia* and *Nigrospora*; and the modern family Endogonaceae. It contains Type ASI 012. In addition it yielded Type ASI 061 which is thought to be associated with soil from its occurrence in modern samples and Type MOI 005 which also occurs in modern samples where it is thought to be associated with cereal crops.

Spores of *Nigrospora* suggest that hay or/and straw were likely components of this context. *Sporormia* suggests that dung, or grass debris or wood may have been present. The presence of the Endogonaceae suggest that soil or/and plant roots were incorporated into the matrix and the presence of Type ASI 061 supports this. From excavation it is considered that this sample is an occupation spread/rake out.

L6097

This sample contains Types comparable to the modern genus *Sporormia*; and to Type ASI 012.

The presence of Sporormia may be indicative of the existence of the presence of dung, grass debris or wood in this deposit. This sample was excavated from the re-cut, stone-lined central floor drain.

L6108

This sample contains a Type ASI 008, which occurs in modern samples where it is thought to be associated with the presence of dung.
This sample was excavated from the primary earth-cut central floor drain.

L6112

This sample contains Type ASI 012. It also contains Type ASI 008, which occurs in modern samples where it is thought to be associated with the presence of dung; Type ASD 019, which occurs in modern samples where it is thought to be associated with the presence of soil; Type ASD 022, which also occurs in modern samples and is thought to be associated with the presence of soil; and ASM 005 which occurs in modern samples and like the previous two, is also thought to be related to the presence of soil.
This sample was excavated from the northwest, gable end and is considered to represent occupation spread/rake out.

L6119

This sample contains Types comparable to the modern genus *Nigrospora*; the modern family Endogonaceae; and Type ASI 012.
The recovery of *Nigrospora* suggests the influence of grassland vegetation while the presence of the Endogonaceae indicate the presence of soil or/and plant roots.
This sample was excavated from the primary central floor drain.

L6129

This sample contains Type MOI 011, comparable to Type 140 of van Geel *et al* (1983a), which has been identified as *Nectria* sp. It has been found to be associated with the presence of fire by van Geel *et al* (1983a).
Excavation suggests that this context may represent a possible floor deposit.

L6137

This sample contains Types comparable to the modern genera *Sporormia* and *Nigrospora*; the modern species *Gelasinospora ?cerealis*; and the modern families Sordariaceae and Endogonaceae.
The presence of *Nigrospora* may be indicative of the occurrence of hay or/and straw. Spores of the Sordariaceae indicate the presence of dung or/and decaying vegetation. Fragments of Sporormia may be indicative of the presence of wood or grass debris or wood. The recovery of the Endogonaceae indicate the presence of soil or/and plant roots. *G. cerealis* may be an indication that cereal grains were present.

The paucity of spore material recovered from these samples is reflected in the conclusions that can be drawn. Little can be intimated other than the possibility that hay or/and straw were present in some samples, that soil was a constituent in some samples and that decaying vegetation or/and dung were also components of some samples.

TUQUOY

Seventeen samples were examined from the pit at Tuquoy; refer to Chapter Four for details thereof. Comparison of fungal spore analysis to macrofossil, pollen, sedimentological, parasites, insect analyses and wood was possible. The macrofossil analysis was carried out by Sheila Boardman and Sandra Nye, pollen and sedimentological analysis by Richard Tipping, parasite analysis by Andrew K.G. Jones and Colin Nicholson, insect analysis by Jon Sadler and Peter Skidmore and wood analysis by Anne Crone. All analyses were conducted on behalf of Historic Scotland.

RESULTS

Palynomorph abundance and preservation varied. A pollen sum of 300 was attained in only five of the samples.

37 fungal morphoTypes in total were recovered from the samples. 20 are comparable to known taxa and a further 7 can be included in palaeoenvironmental interpretations on the strength of their occurrences in modern samples. Table 7.11 charts the occurrence of recovered Types through the samples at Tuquoy, while Table 7.12 presents Types of known affinity with their comparatives and summary ecologies.

DISCUSSION

T803

This sample contains Types comparable to the modern family Sordariaceae; Type ASI 008, a Type which occurs in modern samples where it is thought to be related to the presence of animals or/and dung; and the rhizopod *Centropyxis ecornis*.
Spores of the Sordariaceae indicate the presence of dung or/and decaying vegetation; the recovery of Type ASI 008 favours the presence of dung. *C. ecornis* may be an indicator of the presence of hay or/and straw.
This is in accordance with results of the insect analysis which yielded indicators of rotting organic matter or/and dung.

T8036c

This sample contains a single spore of unknown affinity.

Table 7.11 Occurrence of types through the samples from Tuquoy.

	T803	T8036c	T8036d	T8038	T804	T8054a	T8056b	T8057	T806	T808	T810	T813	T814	T8141a	T8141b	T8141c	T815
ASD 001			X	X				X		X	X			X			
ASD 013											X						
ASD 017	X																
ASD 023			X														
ASD 035								X									
ASI 003						X			X	X	X						
ASI 008	X		X		X												X
ASI 012											X	X		X	X		
ASI 037			X											X			
ASI 039			X														
ASI 041			X														
ASI 042			X														
ASI 020								X				X		X	X		
ASI 073											X						
ASI 074												X					
ASI 075	X																
ASI 076		X				X	X										
ASI 078											X						
ASI 079										X							
ASM 001			X				X			X							
ASM 014	X		X	X		X	X	X			X						
ASM 025			X														
ASM 029			X														
ASM 035								X				X					
ASM 036						X								X			
ASM 039			X														
ASM 040			X														
ASM 052				X													
ASP 006															X		
AGG REG							X				X				X		
DIM 003							X										
MOI 004														X			
MUI 016											X			X			
MUM 001															X		
PHO MOI	X		X			X			X		X						X
TOR FRA	X		X			X							X	X	X	X	
TRM 001														X			

Table 7.12 Identifiable types from Tuquoy with their known comparatives and summary ecology.

Type code	COMPARATIVE	SUMMARY ECOLOGY
ASD 001	Chaetomium/Lophotrichus.	Cellulose - straw, paper,cloth
ASD 013	From modern samples	?Straw, hay, soil
ASD 017	Sordariaceae	Dung, vegetation
ASD 035	Sordariaceae	Dung, vegetation
ASI 003	From modern samples	Widespread
ASI 008	From modern samples	?Dung
ASI 012	Type 181 of Van Geel (1983) Lycoperdon-type of Elsik (1986)	Type 181 associated with open water, eutrophic conditions
ASI 020	Endogonaceae	Soil
ASI 037	Sordariaceae	Dung, vegetation
ASI 039	Sordariaceae	Dung, vegetation
ASI 041	From modern samples	?Soil
ASI 042	Sporormia	Dung, grass debris and wood
ASI 073	Basidiomycotina	Widespread
ASI 078	Inocybe sp.	Wood
ASI 079	Sordariaceae	Dung, vegetation
ASM 001	Nigrospora sp.	Grassland
ASM 014	Centropyxis ecornis	Wet conditions
ASM 025	Sordariaceae	Dung, vegetation
ASM 029	Sordariaceae	Dung, vegetation
ASM 035	From modern sample	Widespread
ASM 039	Blastospore	?Soil
ASM 052	Parasite egg	Animal dung
ASP 006	Gelasinospora ?cerealis	Dung, vegetation, ?wheat and oats
DIM 003	Brachysporium	Rotten wood and bark
MOI 004	From modern samples	?Dung
MUI 016	Ampelomyces quisqualis	On powdery mildews
MUM 001	From modern sample	?Hay and straw

T8036d

This sample contains Types comparable to the modern genera *Chaetomium/Lophotrichus*, *Sporormia* and *Nigrospora*; to the modern family Sordariaceae; Type ASI 008, a Type which occurs in modern samples where it is thought to be related to the presence of animals or/and dung and Type ASI 041, a Type which also occurs in modern samples where it is thought to be related to the presence of soil. It also contains the rhizopod *Centropyxis ecornis*. In addition it contains a fungal blastospore of unknown ecological affinity.

The recovery of spores of *Chaetomium/Lophotrichus* and *Nigrospora* along with *C. ecornis* indicate that straw or/and hay were almost certainly components of this deposit. The Sordariaceae indicate the presence of dung or/and decaying vegetation. *Sporormia* indicates the resence of dung, grass debris or wood. These results are in accordance with the analysis of the insect material which yielded indicators of rotting organic material and open dry grassland.

T8038

This sample contains a Type comparable to the modern genus *Chaetomium/Lophotrichus*; in addition to the rhizopod *Centropyxis ecornis*, and a parasite egg.

The presence of *Chaetomium/Lophotrichus* and *C. ecornis* suggest that straw or/and hay were components of this deposit; while the recovery of a parasite egg suggests that animals or/and dung were present.

T804

This sample contains Type ASI 008, a Type which occurs in modern samples where it is thought to be related to the presence of animals or/and dung. On the basis of the fungal spore analysis little can be inferred on the ecology of this deposit.

T8054a

This sample contains Type ASI 003, a Type which is widespread in modern samples; in addition to the rhizopod *Centropyxis ecornis*.

The presence of *C. ecornis* suggests that straw or/and hay may have been present.

T8056b

This sample contains Types comparable to the modern genera *Nigrospora* and *Brachysporium*; in addition to the rhizopod *Centropyxis ecornis*.

The presence of *Nigrospora* suggests the influence of grassland vegetation; the presence of *Brachysporium* is an indication that rotten wood or bark were in existence while *C. ecornis* suggests that straw or/and hay may have been present. Results of the insect analysis revealed among other things the presence of rotting organic matter and the influence of open dry and open wet grasslands.

T8057

This sample contains Types comparable to the modern genus *Chaetomium/Lophotrichus*; and the modern families Sordariaceae and Endogonaceae. It also contains Type ASM 035 which is widespread amongst modern samples, in addition to the rhizopod *Centropyxis ecornis*.
Chaetomium/Lophotrichus is an indicator of straw or/and hay while the presence of *C. ecornis* supports this hypothesis. The recovery of spore of the Sordariaceae suggests the likely presence of dung or/and decaying vegetation. The Endogonaceae indicate the presence of soil or/and plant roots.
Results of the insect analysis revealed amongst other things the presence of rotting organic material and dung.

T806

This sample contains Type ASI 003, a Type which occurs in modern samples where its distribution is widespread. On the basis of the fungal spore analysis little can be inferred on the ecology of this deposit.

T808

This sample contains Types comparable to the modern genera *Chaetomium/Lophotrichus* and *Nigrospora*; and the modern family Sordariaceae. In addition it contains Type ASI 003, which is widespread in modern samples.
The presence of *Chaetomium/Lophotrichus* and *Nigrospora* suggest the existence of straw or/and hay; while the presence of the Sordariaceae indicates the presence of dung or/and decaying vegetation.
Results of the insect analysis revealed, amongst other things, the presence of rotting organic material and dung.

T810

This sample contains Types comparable to the modern genera *Chaetomium/Lophotrichus, Inocybe* and *Xylaria*; the modern species *Ampelomyces quisqualis* and an unidentifiable spore of the class Basidiomycotina. In addition it contains the rhizopod *Centropyxis ecornis*. It also contains Type ASD 013, a Type

which has been recovered from straw or/and hay or/and soil in modern samples; Type ASI 003, which is widespread in modern samples; and Type ASI 012.
The presence of *Chaetomium/Lophotrichus*, *C. ecornis* and Type ASD 013 suggest that straw or/and hay were present. *A. quisqualis* could also have existed on this substrate. The recovery of *Inocybe* indicates the presence of humus or wood while the presence of *Xylaria* indicates the presence of wood.
Results of the insect analysis yielded indicators including those of human and animal parasites, rotting organic material and dung.

T813

This sample contains Types comparable to the modern family Endogonaceae. It also contains Type ASM 035, which is widespread amongst modern samples; and the non diagnosticType ASI 012.
The presence of the Endogonaceae indicate that soil or/and plant roots form part of this deposit.
Results of the insect analysis yielded indicators of animal parasites, rotting organic matter, aquatic, aquatic marginal and marsh influences - there is no evidence from the fungal spore analysis to support these results.

T814

This sample only contains aggregations. No ecological insight can be obtained from this information.

T8141a

This sample contains Types comparable to the modern genus *Chaetomium/Lophotrichus*; the modern families Sordariaceae and Endogonaceae; and the modern species *Ampelomyces quisqualis*. It also contains Type MOI 004 which has been recovered from modern samples where it is thought to be associated with the presence of animals or/and dung. In addition it contains Type ASI 012.
Chaetomium/Lophotrichus suggests the presence of straw or/and hay. The Sordariaceae indicate the presence of dung or/and decaying vegetation; while the Endogonaceae indicate the presence of soil or/and plant roots. *A. quisqualis* is widespread and could have existed on these substrates.
Analysis of the insect assembage revealed, among other things, the presence of human parasites, rotting organic matter and dung.

T8141b

This sample contains Types comparable to the modern species *Gelasinospora ?cerealis*; and the modern family Endogonaceae. In addition it contains Type ASI 012. It also contains Type MUM 001, a Type which has been recovered from modern samples where it is thought to be related to the presence of hay or/and straw. *G. ?cerealis* suggests that cereal grains may have been present. The Endogonaceae indicate the presence of soil or/and plant roots.
Among the indicators recovered from analysis of the insect assemblage were those of rotting organic matter.

T8141c

This sample only contains Toruloid fragments. No ecological postulations can be put forward.

T815

This sample contains Types ASI 008, a Type which has been recovered from modern samples where it may be related to the presence of animals or/and dung. Little can be said about the ecology of this sample on the basis of the fungal spore assemblage.

CONCLUSIONS

Fungal spore assemblages from these samples suggest the ubiquitous occurrence of hay or/and straw and of decaying vegetation through recoveries of *C. ecornis*, *Chaetomium/Lophotrichus*, *Trichocladium* and *Nigrospora* and of spores of the Sordariaceae. The concomitant occurrence of *Chaetomium/Lophotrichus* and a parasite suggest that at least some of the deposits represent dumped byre material; the *Chaetomium/Lophotrichus* indicating the presence of hay/or and straw and the parasite egg indicating the presence of animal dung. Recoveries of spores of wood decay fungi such as *Brachysporium* indicate that wood was also incorporated into the pit. These results are in accordance with those of the analysis of the insect and pollen assemblages and also support the presence of wood off-cuts in the matrix.

From these case-studies it is apparent that analysis of fungal spores can provide an insight as to the nature of anthropogenic deposits if ecologies of known fungal taxa are utilised. In addition, results confirm and often enhance other forms of palaeoenvironmental investigations. For example, the presence of decaying vegetation or/and dung is often suggested by both diptera and fungal spore analyses and the existence of wood off-cuts in deposits supports the recovery of spores of wood decay fungi.

A major restraint to the progression of this technique is the nature of the mycological literature which on the whole does not focus on morphology of isolated fungal spores or high resolution ecological information. Chapter Eight suggests means of enhancing the technique in the future.

CHAPTER EIGHT

CONCLUSIONS

The aims of this dissertation were;

i. To devise a morphological recording system for dispersed fungal spores and *incertae sedis* microfossils, the ultimate objective being to construct a morphological key to their identification.

ii. To determine an appropriate extraction technique to maximise the recovery of fungal spores from sediments.

iii. To ascertain whether fungal spore assemblages from modern anthropogenic situations are governed by known environmental criteria.

iv. To assess the potential for implementing fungal spores in the interpretation of assemblages from archaeological deposits.

RECORDING SYSTEM

A morphological recording system for dispersed fungal spores was proposed in Chapter Two and was utilized successfully throughout the course of these investigations. Morphological categories of spores were determined on the basis of the number of septa and the number of apertures. These morphological categories form the framework for the catalogue in which all spores recovered in this study are represented (Volume Two). Distinctions between individual types in each category are made on the nature of septa and apertures, shape, size and symmetry, external appendages/processes, surface ornamentation, wall structure, colour and stain uptake. The most frequently used criteria to distinguish between types in each category were shape, size and symmetry, external appendages and processes and wall structure. The nature of the apertures and of the septa were considered only occasionally. The majority of types had simple apertures, while annulate and aperture chambers were much less frequently encountered. Perforate, invaginate and compound aperture chambers were not found at all. The majority of septa were entire septa. Where septal pores were present only simple pores were recognised.

The small range of potential variation in aperture and septal details encountered in this study is most likely a reflection of the limited amount of material sampled. It exemplifies the need to examine material from a much wider range of samples. When a more comprehensive corpus of spores has been described the construction of a key can be taken forward.

EXTRACTION TECHNIQUE

Following a series of experiments which are detailed in Chapter Three the application of gravity separation techniques to the recovery of fungal spores was deemed inappropriate. Recovery of such palynomorphs was maximal when the procedure of KOH/HF/Acetolysis, with the additional stage of spraying the surface of each tube with ETOH between centrifugations, was adopted. This additional stage reduces the surface tension and assists sedimentation of the more buoyant forms.

ENVIRONMENTAL CRITERIA AND MODERN SAMPLES

Through the application of program CANOCO to assemblages from modern samples the command of environmental influences was confirmed. However, because of the limited sampling less than 20% of the described types are common to both modern and archaeological samples. This inhibits comparison of modern and fossil assemblages and means that in this study modern analogue samples cannot be directly implemented in the interpretation of fossil data.
Nevertheless, these results suggest an encouraging prospect for the comparative approach in the use of fungal spores as palaeoenvironmental indicators of anthropogenic activity subject to more extensive work.

INTERPRETATION OF ARCHAEOLOGICAL SAMPLES

The interpretation of the archaeological samples was possible in terms of the indicator species approach. Results from a series of case-studies indicate that ecological knowledge on fungi can successfully be incorporated in reconstructing humanly

influenced palaeoenvironments on the basis of dispersed fungal spores. In instances where different forms of palaeoenvironmental techniques had previously been applied to the deposits the outcome of the fungal spore analyses can confirm and often enhance these other results. In no case were counter-indications revealed. This indicates the benefits of coordinated research projects.

Knowledge on spore morphologies of known taxa and ecological information are considered to be limiting factors to this approach.

Furthermore the differences in range and abundances of spore types from different archaeological samples reflects the exigency to conduct investigations into preservation criteria controlling fungal spores.

FUTURE WORK

With respect to the indicator species approach it should be remembered that while many spores encountered through the course of these investigations are comparable to spores of known fungal taxa, in order to verify these identifications it would be necessary to isolate the fungus and study it critically. This is not possible with spores from archaeological deposits which are likely to be inviable or spores rendered inviable through chemical extraction procedures. Tentative identifications could in future be followed up by detailed examination of the spores of known living taxa and their comparison with fossil spores. This would require accessing formally identified fresh, or dried material and making spore mounts for direct comparison. Further collaboration with Edinburgh Royal Botanic Garden would enable continuing contact with expert mycologists and access to herbarium collections. To refine taxonomic precision on groups of spores such as the Sordariaceae, spore morphological studies on living taxa could prove particularly beneficial, since it is known that some members of this family may be restricted to the dung of a single type of herbivore.

An area worthy of investigation for the improvement of the comparative approach is to examine the consistency of assemblages in similar environments from different locations. Although this was explored in this thesis on a broad scale it would be advantageous to focus more specifically on a more limited range of environmental situations from more numerous localities. The possibility exists that because of the

opportunistic nature of the fungi particular environments are inhabited by only some of a whole range of potential colonisers; as the range of potential colonisers is so wide assemblages from different localities with similar environments may not necessarily resemble each other. This could be contributory to the apparent restriction of some species to either the modern or fossil record in this study. More work on modern and fossil situations would assist in the clarification of this point.

In addition, further work should encompass studies on preservation criteria for this category of organic-walled microfossil. Taphonomic processes also warrant consideration as does attention to what constitutes a statistically significant assemblage.

The reconstructions and interpretations presented in this thesis should be considered as working hypotheses. These working hypotheses will undoubtedly be modified and ameliorated as further sites are considered and as morphological, palaeoecological and ecological knowledge of dispersed fungal spores accumulates. Nonetheless, the palynological applications of dispersed fungal spores in Quaternary deposits have improved significantly since the 1960's. This study has proved that fungal spores have a worthy position as palaeoenvironmental indicators and their implementation to the elucidation of anthropogenic activities from archaeological deposits merits continuing research.

PART TWO

This catalogue presents 215 morphotypes which were encountered through the course of investigating the potential of fungal spores as palaeoenvironmental indicators of anthropogenic activity. Each type record is accompanied by taxonomic and ecological information where available and by the occurrence of each type throughout the samples in this study (samples are detailed in Chapter Four and summary information can be found in Appendix 2).

It should be noted that since all the modern samples in this investigation come from farms it is probable that the presence of dung and straw are ubiquitous because of the widespread practice of muck-spreading. It is likely that fungi, and consequently their spores, associated with dung and straw will therefore also be widespread throughout the modern samples.

All fungal spores recovered from both modern and archaeological samples are featured in this catalogue. A summary of the nature of individual samples is included at the end of this catalogue. For a more detailed account of the nature of individual samples refer to Chapter Four, Part One of this thesis.

Of the 215 types recovered;

99 occur only in modern samples,

74 occur only in archaeological samples

42 are common to both

96 are comparable to known fungal taxa

8 are thought to be of algal origin

4 are parasite eggs

1 is a rhizopod species.

The remaining 106 will be retained within the confines of an exclusively morphological classification system, until such a time as they can be related to known taxa.

While a number of the spores encountered are comparable morphologically to spores of known fungal taxa, in order to verify many of these determinations it would be necessary to isolate the fungus and study it critically. Obviously this is not possible with spores which have been chemically extracted, as in these samples. The spores, if not previously inviable, would undoubtedly have been killed by the extraction procedures employed.

Therefore, there are some identifications which must be regarded as tentative. While there is greater certainty about the identification of some of the morphologically more distinctive spores, there are many spores which have been equated with known fungi which could, in fact, be representative of several independent fungal taxa.
Some of the identifiable spores encountered could be identified only to suprageneric level. In particular, spores of the Sordariaceae *sensu lato* and the Endogonaceae constitute a large proportion of the aforementioned spores. Spores of the Sordariaceae *sensu lato* demonstrated a wide degree of morphological variation in shape, size and number of apertures, but the smooth-walled spores of this family did not exhibit enough variation to permit identification beyond the family level, at this stage of investigation. However, smooth-walled members of this family are considered as discreet taxa on the basis of their characteristic morphologies. With time, and with studies on the spore morphology of known taxa, it may be possible to determine described types to generic and maybe even specific level.
Spores of the Endogonaceae differed predominantly in size and colour and there were no clear cut morphological boundaries in spores recovered, simply a size gradation. Spores of the Endogonaceae were not, therefore, considered as discreet taxa.
More information on the sordariaceous and endogonaceous spores is given below.

Spores of the Sordariaceae

Among the identifiable spores frequently encountered in this study are the Sordariaceae *sensu lato*. All members of the family have dark spores- exceptions being *Cercophora, Bombardia* and *Tripterospora* as their spores are physiologically mature and discharged at their hyaline stage but which do darken with maturity. The one-chambered spore type prevails in the group although two-chambered spores are also common and consist of an upper pigmented chamber or spore head and a basal hyaline pedicel.
To many mycologists the hallmark of sordariaceous spores is the presence and nature of the gelatinous equipment, a fact that has caused other morphological features to have been neglected as taxonomic criteria. The gelatinous equipment of such spores will be lost through time and as the material becomes fossilised, thereby weighting the importance of other more persistent morphological criteria for taxonomic identifications

in the fossil and subfossil record. Also of note is the hyaline pedicel of some spores, this hyaline pedicel is not as resistant as the upper pigmented sporehead and is not often recovered in situ in the fossil record (Van Geel 1978).

Other distinctions can be made within the family based on the shape of the sporehead which varies much in form although most of its shapes can be derived from the ellipsoid. Spore types of the following genera *Podospora, Bombardia, Cercophora, Tripterospora* and *Strattonia* characteristically exhibit at least one truncated apex. This flattened pole marks the existence of a former pedicel. The feature is more obvious in some species than in others but it is rarely a feature, so far as I can see, in other Sordariaceous genera such as *Anapodium, Zygospermella, Jugulospora* or *Apodospora.* If spores of *Bombardia, Cercophora* and *Tripterospora* were to remain hyaline it would theoretically be possible to differentiate between these spores and spores of *Podospora* and *Strattonia* by virtue of their pigmentation. However, although the pigmentation occurs very late in the spore development of these hyaline spores, and indeed has not yet been detected in some species (Lundqvist 1972), when the material being considered is of an archaeological age immaturity of the spores can be eliminated and distincton between such spore types on the basis of pigmentation becomes redundant. Thus, realistically at this stage, it is not possible to distinguish between dispersed spores of the genera *Podospora, Bombardia, Cercophora, Tripterospora* and *Strattonia.* They are all spores of the Sordariaceae *sensu lato* with *Bombardia* and *Cercophora* belonging to the sub family Lasiosphaeriaceae and *Podospora, Tripterospora* and *Strattonia* belonging to the sub family Podosporoideae.

Most species of Sordariaceae have smooth spores and the ornamentation, of those spores which do possess it, is diagnostic often to generic level. For example *Copromyces* exhibits a verrucose surface, *Echinospora* and *Apiosordaria* bear spines while *Gelasinospora, Diplogelasinospora* and *Anixiella* are pitted. However, the smooth spores cannot yet be resolved beyond the family level.

Thus spores of the Sordariaceae can be considered as discreet taxa, although for the time being those which cannot be identified beyond the family level are considered as

ecologically homogenous. With time and with more focused studies on the spore morphologies of this family it may prove possible to resolve them to generic level or beyond, thereby greatly enhancing the ecological resolution attainable through the palynology of such dispersed fungal spores.

Spores of the Endogonaceae

Although keys to the Endogonaceae have been based on the morphology of the spores (Mosse & Bowen 1968, Hall & Fish 1979), some of the diagnostic characteristics can be lost through fossilisation or/and processing. Among the aforementioned morphological features are the nature of attachment to the parent hyphae, pattern of spore contents, relative positioning of spore walls and colour of spores; these characters are unlikely to be reliable in the fossil record. The parent hyphae are often broken off so close to the spore that the nature of attachment is indiscernible (personal observation), the spore contents, even if they managed to persist into the fossil record, would certainly be destroyed by processing techniques. Finally, as mentioned in Chapter Three, some wall layers do not persist into the fossil record and colour is not a good characteristic for divisions.

The wall structures used in taxonomy are those relatively easily observed by light microscopy in good, well-preserved specimens (Walker 1983) - even in unprocessed, recent material spore walls of older specimens of the Endogonaceae may be lost (Hall & Abbott 1991). Additionally most species in the Endogonaceae have several walls surrounding the contents of their spores and the arrangement of these walls may only become apparent upon crushing (Walker 1983). Recent descriptions of species in the Endogonaceae have increasingly relied upon spore wall structure for separation of species within a genus (Ferrera and Herrera 1981; Nicolson and Schenck 1979; Rose, Daniels and Trappe 1979; Schenck and Smith 1982; Walker and Trappe 1981) - this is not practical to palynological applications.

The characters which are persistent are size and shape. However, Mosse and Bowen (1968) consider that absolute size is not a good criterion for identification since spores differ significantly in size diverging by up to 50% in populations of the same spore types. Dispersed Endogonaceae spores do not, therefore, demonstrate enough morphological

variation to consider them as discreet taxa. Thus all endogonaceous spores recovered in these studies are considered as a single type and as being ecologically homogenous.

The spores treated herein are arranged in groups according to the recording system detailed in Chapter Two, where categories are defined according to the number of apertures and septa of the spores. Aseptate inaperturate spores are listed first, then aseptate monoaperturate spores etc. Spores are arranged numerically according to their type codes within each category. This grouping is simply one of convenience; no relationship is suggested between taxa in each group. Plates are located to the back of the volume. The number and percentage of types in each group are as follows:

TYPE CODE	NO. TYPES	% TYPES
ASI	52	25
ASM	46	20
ASD	37	18
ASP	10	4.5
MOI	14	6.5
MOM	2	1
MOD	2	1
MOP	0	
DII	11	5
DIM	3	1.5
DID	0	
DIP	0	
TRI	12	5.5
TRM	2	1
TRD	1	0.5
TRP	0	
MUI	14	6.5
MUM	2	1
MUD	2	1
MUP	2	1

Three other categories were also considered. These encompass morphologically inconsistent types and sub-division within the categories was only possible in exceptional cases.

AGG REG	1	0.5
TOR FRA	1	0.5
PHO MOI	1	0.5

ASEPTATE INAPERTURATE SPORES

Types with aseptate inaperturate spores represent the largest group amongst the fungal spores encountered, 52 in total constituting 25%. Of these 14 have comparatives with known fungal taxa, while it is considered that 3 are possibly algal in origin. 25 occur only in modern samples, 14 occur only in archaeological samples while 13 are common to both.

ASI 001 (Plate 1, fig. 1)

Description: Spherical spores, aseptate, inaperturate and smooth. Single walled, wall up to 1µm thick, hyaline. Ranging in size from 8µm to 12µm in diameter.

Occurrence: MODERN SAMPLES - HB91O.01, HB91O.07, GC92F.03, GC91O.09, ABP1, JF91J.03.

Known Comparative(s): None

Ecology: The common denominator of the modern samples this type occurs in seems to be cereals. All samples either contain hay or/and straw or are from the surface soil of a cereal field.

ASI 002 (Plate 2, fig. 2, fig. 3, fig. 4, fig. 5, fig. 6)

Description: Spherical spores, aseptate, inaperturate, tuberculate. Single walled and hyaline to grey in colour. Some with attachment scar in the form of a foot cell still apparent. Up to 25µm in diameter.

Occurrence: MODERN SAMPLES - HB92M.02, HB92M.05, HB92M.12, HB91O.01, GC92F.12, GC92F.14, GC91O.12, GC91O.14, ABP1, ABP3, ABPS2, CA91G.07.

Known comparative(s): *Histoplasma capsulatum*, *Histoplasma* Darling (1906).

Ecology: This fungus only grows on soil that is enriched by the droppings of birds or bats and is common in and around poultry houses and within caves. *Histoplasma capsulatum* is the organism responsible for the disease Histoplasmosis which is endemic in the United States and also occurs around the world in both temperate and tropical zones (Cooke 1977). Inhaled spores give rise to yeast like chambers which show preference for the tissues of the lungs but can also infest the spleen, liver, kidneys and bone marrow. Some forms of infection can be fatal.

A feature of Histoplasmosis is that it tends to have a village or rural distribution and this is related to the occurrence of suitable habitats which are capable of supporting growth and sporulation of *H. capsulatum* (Cooke 1977). The samples in this study, in *which H. capsulatum* spores occur, come predominantly from farms which are known to use compressed, pelleted bird droppings as a source of phosphate enrichment for the soil. The soil would therefore be enriched with bird droppings providing ideal conditions for the growth and sporulation of the organism.

Other tuberculate spores morphologically identical to those of *H. capsulatum* exist in soil under similar conditions (see Gaur & Lichtwardt 1980).

ASI 003 (Plate 1, fig. 7)

Description: Spherical spores, aseptate and inaperturate. Spore surface of a mottled appearance. Single walled, wall up to 1µm thick. Pale brown in colour. Up to 7µm in diameter.

Mottled appearance of spore surface may represent an insipient ornamentation.

Occurrence: MODERN SAMPLES - HB92M.07, HB92M.12, HB92M.14, HB91O.01, HB91O.04, HB91O.07, HB91O.14, GC92F.09, GC92F.11, GC92F.12, GC92F.14, GC92F.15, GC91O.01, GC91O.05, GC91O.12, GC91O.14, ABP1, ABP3, ABPS1, ABPS2, ABGS1, ABGS2, ABGS3, JF91J.01, JF91J.03.

ARCHAEOLOGICAL SAMPLES - B39, B310, B316, B327, B341, B402, T805/4A, T806, T808, T810, BH03, BH04, BH11.

Known comparative(s): ?

Ecology: This type occurs across a range of samples with no apparent common denominator.

ASI 004 (PLate 1, fig. 8)

Description: Spherical spores, aseptate and inaperturate. Surface foveolate, individual elements < 1µm in diameter. Overall `dimpled' appearance. Single wall < 1µm thick, pale brown. Ranging from 8µm to 12µm in diameter.

Occurrence: MODERN SAMPLES - CA91G.07.

ARCHAEOLOGICAL SAMPLES - L6084.

Known comparative(s): None

Ecology: Small, presently ungrazed enclosure around weather station at Callanish.

ASI 008 (Plate 1, fig. 9)

Description: Spherical to subspherical spores, aseptate and inaperturate with smooth wall. Single wall < 1µm in diameter. Brown in colour and ranging in size from 8µm to 23µm diameter.

Occurrence: MODERN SAMPLES - HB92M.07, HB91O.01, HB91O.14, GC92F.02, GC92F.12, GC92F.14, GC91O.01, GC91O.05, GC91O.12, ABP1, ABP3, ABPS1, ABPS2, ABGS1, ABGS2, CA91G.02, CA91G.03, CA91G.05, CA91G.07, CA91G.07, JF91J.01, JF91J.03.

ARCHAEOLOGICAL SAMPLES - B39, B48, B310, B316, B341, B402, L6014, L6108, L6112, T803, T803/6D, T804, T815, BH01, BH02, BH03, BH04, BH05, BH06, BH07, BH08, BH09, BH10, BH11, BH11, BH12.

Known comparative(s): None

Ecology: This type occurs across a range of modern samples, all of which have or have had animals present. It may be associated with the dung of animals. The animal presence include: horses, cattle, pigs, sheep and goats.

ASI 009 (Plate 1, fig. 10)

Description: Spherical to subspherical spores, aseptate and inaperturate with smooth walls. Bears an attachment scar seen in equatorial orientation as two short appendages <1µm in length and about 1µm apart. Single wall < 1µm thick, dark brown. Ranging from 9µm to 11µm in diameter.

Occurrence: MODERN SAMPLES - HB91J.11, GC91J.09, HB91J.1/2.

Known comparative(s): None

Ecology: Occurs in a range of samples with no apparent common denominator.

ASI 010 (Plate 1, fig. 11, fig. 15)

Description: Subspherical, aseptate, inaperturate bodies with a densely verrucate and irregular surface. Often folded or/and compressed distorting original shape. Thick walled, up to 2µm. Verrucae often seen to be elongating, forming what appear to be diverticulae. Brown. Ranging from 88µm to 127µm at longest axis.

Occurrence: MODERN SAMPLES - HB91J.1/2.

Known comparative(s): None

Ecology: Occurs only in one sample taken from a winter cow byre.

ASI 011

Description: Spherical, aseptate, inaperturate spores with a dense covering of baculae. Each bacula up to 1µm in length and <1µm in width. Single walled < 1µm thick, brown. Ranging from 8µm to 14µm in diameter, excluding baculae.

Occurrence: MODERN SAMPLES - HB91O.14, GC91O.05, CA91G.03, CA91G.05, JF91J.03.

Known comparative(s): None

Ecology: Occurs in a range of modern samples all being fields either under crop or permanent pasture. This may, therefore, be a soil borne organism.

ASI 012 (Plate 1, fig. 12, fig. 13, fig. 14)

Description: Spherical, aseptate, inaperturate spores with a dense covering of echinae. Each spine up tp 3.5µm in length and < 1µm in width. Single walled < 1µm thick, yellow to pale brown. Ranging from 11µm to 16µm in diameter, excluding ornament.

Occurrence: MODERN SAMPLES - HB92M.12, HB91O.14, GC92F.01, GC92F.02, GC92F.03, CA91G.02, CA91G.03, JF91J.01, JF91J.03.

ARCHAEOLOGICAL SAMPLES - B48, B234, B309, B310, B316, B327, B341, B402, L6014, L6050, L6057, L6084, L6097, L6112, L6119, T810, T810, T813, T814/1A, T814/1B, BB78ST4, BH01, BH02, BH05, BH06, BH07, BH08, BH09, BH11, BH12.

Known comparative(s): Resembles Type 181 of Van Geel *et al* (1983b). Also resembles *Lycoperdon*-type of Elsik (1986). It could, alternatively, be a spore of the Myxomycetes. The distinguishing factor between spores of the myxomycetes and of *Lycoperdon* spp. is that *Lycoperdon* spp. would have sterigmata marking the point of attachment to the parent material; myxomycete spores would not have such an attachment. However, this attachment if present would not necessarily persist into the fossil or subfossil record making it impossible to distinguish between spores of *Lycoperdon* spp. and of the myxomycetes in the absence of sterigmata.

Ecology: Type 181 is common in stagnant shallow open water, eutrophic conditions (van Geel *et al* 1983), this makes it more likely to be a aspore of the myxomycetes in this case since slime moulds favour wet environments. *Lycoperdon* contains about 50 cosmopolitan species commonly known as puffballs and widespread in fields and woodland. In this study ASI 012 was recovered from a range of modern samples all being either pasture or crop fields. It is possibly belonging to the genus *Lycoperdon.*

ASI 013

Description: Subspherical, aseptate, inaperturate bodies with a granulate surface and a sparse but regular covering of baculae, 30 baculae per quarter surface area. Baculae up to 2µm high and 1µm in width. Single walled, 1µm thick, hyaline. Ranging in size from 28µm X 26µm, to 29µ X 28µm, excluding ornament.

Occurrence: MODERN SAMPLES - HB91J.11.

Known comparative(s): None

Ecology: This type was only recovered from mor humus.

ASI 014 (Plate 1, fig. 18)

Description: Round to ovoid spores, aseptate and inaperturate. Walls smooth. Single walled, wall < 1µm in diameter and grey to pink in colour. Size range 8µm X 6µm to 12µm X 8µm.

Occurrence: MODERN SAMPLES - GC91O.14.

Known comparatives: These spores occur within sporocarps of *Ampelomyces quisqualis*. *Ampelomyces* Ces. ex Schecht. (1852).

Ecology: *A. quisqualis* is an example of a fungus which grows on another fungus. It is common on the mycelial mat of powdery mildews (Ellis & Ellis 1988), which themselves are plant parasites. In this study ASI 014 spores were only recovered from debris on the earth floor of a pig house.

ASI 015

Description: Subspherical, aseptate, inaperturate bodies with smooth surfaces. Often folded and compressed, thereby distorting original shape. Single wall < 1µm thick, hyaline to pink. Ranging from 42µm X 38µm to 50µm X 39µm.

Occurrence: MODERN SAMPLES - HB92M.14, HB92M.16, GC92F.03, GC92F.09, GC92F.15, GC91O.09, CA91G.02, JF91J.01, JF91J.03.

ARCHAEOLOGICAL SAMPLES - BH08.

Known comparative(s): May be algal in origin due to absorption of safranin.

Ecology: In this study type ASI 015 only occurred in deposits composed predominantly of soil, either pasture or arable fields or areas where pigs and fowl roamed.

ASI 017 (Plate 1, fig. 17)

Description: Sub circular, discoid body. Aseptate and inaperturate with irregular radial striations extending almost to circumference. All striations do not originate from the locus. Single wall < 1µm thick, pale brown. 35µm X 33µm diameter.

Occurrence: MODERN SAMPLES - HB92M.14, GC92F.03.

Known comparative(s): None

Ecology: Both deposits in this study where type ASI 017 occurred are fields, one under permanent pasture and the other a cereal crop field.

ASI 018 (Plate 1, fig.19, fig. 20, fig. 21)

Description: Spherical, aseptate, inaperturate spore with baculate surface. Bacula uniform in size, < 1µm in height and width, never touching. Single wall, < 1µm thick. Up to 10µm in diameter.

Occurrence: ARCHAEOLOGICAL SAMPLES - CA91G.02.

Known comparatives(s): None

Ecology: Occurs in soil from an abandoned crop field at Callanish, Isle of Lewis.

ASI 019 (Plate 1, fig. 22)

Description: Spherical, aseptate, inaperturate spore. The surface is dissected into numerous polygonal plates, approximately 24 plates per hemisphere, ornamentation on each plate is scabrate. Murae between adjacent plates 1µm thick. Single wall < 1µm thick, yellow to pale brown. 31µm diameter.

Occurrence: MODERN SAMPLES - GC92F.14.

Known comparative(s): None

Ecology: Occurs in debris from pig house with earth floor.

ASI 020 (Plate 2, fig. 1, fig. 2, fig. 3, fig. 4, fig. 5, fig. 6)

Description: Spherical to subspherical, aseptate inaperturate spores with smooth surface. Each spore has a suspensor denoting former attachment to the sporocarp or to other spores. Single wall ranging in dimensions from < 1µm to 5µm thick; wall ranging in colour from hyaline to dark brown. Ranging in size from 20µm in diameter to 65µm X 55µm. Occasional specimens exhibit perforated walls.

Occurrence: MODERN SAMPLES - HB92M.14, HB91O.16, GC92F.02, GC91O.01, GC91O.09, CA91G.05, JF91J.01, JF91J.03.

ARCHAEOLOGICAL SAMPLES - B39, B48, B234, B316, B402, L6084, L6119, L6137, T813, T814/1A, T814/1B, BH03, BH08, BH09, BH10, BH11, BH12.

Known comparative(s): Endogonaceae type.

Ecology: Characteristically soilborne fungi. In this study occurrences of the Endogonaceae were all from fields either under pasture or under cereal crops.

ASI 035

Description: Elongated, aseptate, inaperturate spore with scabrate surface. Ornamentation concentrated about transverse median area of spore giving the impression of a shadow band. Single wall layer < 1µm in diameter. 14µm X 5µm to 17µm X 7µm.

Occurrence: MODERN SAMPLES - HB92M.03, HB92M.05, HB91O.01, GC92F.03, GC91O.12, GC91O.14, ABP1, ABP3, ABPS2, ABGS1, ABGS2, ABGS3, JF91J.05.

ARCHAEOLOGICAL SAMPLES - BH05.

Known comparative(s): *Cladosporium* Link (1815).

Ecology: Recovered from leaves, stems and fruits, dead stumps, wood pulp, dead organic material, decaying leaves and stems with many species being plant pathogens. Some species have also been recovered from non-plant material e.g. *C. herbarum* also recorded from meat - Massee (1912) and Brookes and Hansford (1923) isolated this fungus from `Black spot' in frozen meat in cold stores. *C. spaherospermum* has been isolated from diseased human nails and skin. Some species are `hyperparasites' i.e. they parasitise other fungi which are themselves also parasitic.

In this study all recoveries were from samples likely to have had wheat or straw either growing, or in use as bedding or fodder.

ASI 037 (Plate 1, fig. 23)

Description: Ellipsoidal, aseptate, inaperturate spore with one trucated apex and a smooth surface. Spore symmetrical. Truncation slight. Single wall, 1µm thick, brown. 18µm X 7µm to 32µm to 23µm.

Occurrence: MODERN SAMPLES - HB92M.05, HB92M.12, HB91O.14, GC92F.01, GC92F.02, GC92F.03.

ARCHAEOLOGICAL SAMPLES - B309, B310, T803/6D, T814/1A.

Known comparative(s): Sordariaceae type.

Ecology: Members of this family are predominantly fimicolous and herbicolous, i.e. grow on dung or vegetation (Lundqvist 1972). Sordariaceae have also been found on seeds (Cain & Groves 1948) and in association with burnt ground (Petersen 1970).

Type ASI 037 was recovered in this study from a range of modern samples with no obvious common denominator.

ASI 038 (Plate 1, fig. 24)

Description: Irregularly ellipsoidal, aseptate, inaperturate spore with echinate surface. Echinae uniform but sparse in distribution, < 1µm in length and width. Single wall < 1µm thick, grey to brown. 9µm X 5µm.

Occurrence: MODERN SAMPLES - GC92F.09, GC92F.15.

Known comparative(s): None

Ecology: Both samples in this study yielding type ASI 038 had in common the fact that the matrix was composed predominantly of soil, one sample from a barley field and one sample from a yard where pigs range.

ASI 039 (Plate 1, fig. 24)

Description: Ovoid, aseptate, inaperturate spore with smooth surface. Tapered pole slightly truncate. Opposite pole irregular in shape often umbonate. Single wall > 1µm thick, brown to black. 25µm X 15µm to 33µm X 25µm.

Occurrence: MODERN SAMPLES - HB92M.16.

ARCHAEOLOGICAL SAMPLES - T803/6D.

Known comparative(s): Sordariaceae type.

Ecology: Members of this family are predominantly fimicolous and herbicolous, i.e. grow on dung or vegetation (Lundqvist 1972). Sordariaceae have also been found on seeds (Cain & Groves 1948) and in association with burnt ground (Petersen 1970). Recovered in this study from the surface soil of a field under barley.

ASI 040 (Plate 1, fig. 26)

Description: Subspherical, aseptate, inaperturate body with an irregular, sparsely foveolate wall. Elements up to 1µm in diameter. Thick walled and opaque, dark brown. 70µ X 59µm in size. Wall dimensions indeterminable due to opacity. Would require sectioning or finding a broken specimen to measure wall thickness.

Occurrence: MODERN SAMPLES - GC91J.07.

Known comparative(s): None

Ecology: Recovered in this study from a field under permanent pasture.

ASI 041 (Plate 2, fig. 7)

Description: Irregular, disc-like body having one to three emergent flagellum-like appendages from one plane. Each appendage up to 2µm thick tapering to a point, or branching to tapered points. Length variable. Main body coarsely granular in places, hyaline elsewhere. 11µm X 15µm to 10µm X 24µm in size.

Occurrence: MODERN SAMPLES - HB92M.14, HB92M.16.

ARCHAEOLOGICAL SAMPLES - T803/6D.

Known comparative(s): None

Ecology: Recovered in this study from samples having in common that they are soil based.

ASI 042 (Plate 2, fig. 8)

Description: Rectangular and triangular, aseptate, inaperturate spores with smooth surfaces. All corners rounded. It is thought that the triangular spores represent the peripheries, while the rectangular chambers represent the intermediate chambers of phragmospores which have split into their constituent chambers. This fractionation could either occur naturally soon after sporulation or it could reflect degeneration as a

result of preservation or processing. Single wall < 1µm thick, brown. 11µm X 7µm to 21µm X 11µm.

Occurrence: MODERN SAMPLES - HB92M.02, HB92M.05, HB92M.12, HB91O.14, GC92F.01, GC92F.02, GC92F.03, GC92F.09, GC92F.15, GC91O.01, GC91O.05, GC91O.09, ABP1, ABPS1, ABPS2, ABGS2, CA91G.02, CA91G.03, CA91G.05, CA91G.07, JF91J.01, JF91J.03.

ARCHAEOLOGICAL SAMPLES - B39, B48, B309, B310, B402, L6057, L6073, L6084, L6097, L6137, T803/6D, BH03, BH08, BH10.

Known comparative(s): *Sporormia* de Not. (1854)

Ecology: Occurring predominantly on dung but also isolated from grass debris and old wood (Cannon *et al* 1985).

Recovered in this study from a range of samples, many having an abundance of hay or/and straw and some being pasture fields.

ASI 043 (Plate 2, fig. 11, fig. 12)

Description: Subspherical, aseptate, inaperturate bodies with a coarse reticulation and occasional verrucae. Luminae up to 3µm in diameter, adjacent luminae separated by murae 1µm thick. Verrucae emerge from dissecting murae. Verrucae up to 1µm thick. Yellow to brown. 72µm X 90µm in size.

Occurrence: MODERN SAMPLES - HB91J.1\2.

Known comparative(s): None

Ecology: Recovered from a cow byre sample.

ASI 044 (Plate 2, fig. 9)

Description: Subspherical palynomorph consisting of an inner body and an outer body. Inner body subspherical, aseptate, inaperturate with scabrate to granulate surface. Single wall, < 1µm thick, brown to yellow. 13µm X 7µm. Outer body surrounding inner body; subspherical, inaperturate body with single wall, < 1µm thick, hyaline. 15µm X 7µm. Point of attachment between two bodies, if any, unclear.

Occurrence: MODERN SAMPLES - HB91J.1/2.

Known comparative(s): None

Ecology: Recovered from a cow byre sample.

ASI 046

Description: Large, irregular shaped, folded body with clavate surface. Individual elements up to 2µm in length and 1µm in width at widest point. Distribution approximately 25 per quarter surface area. Single wall, < 1µm thick, hyaline. 78µm along longest axis.

Occurrence: MODERN SAMPLES - HB91J.11.

Known comparative(s): None

Ecology: Recovered only from mor humus.

ASI 047 (Plate 2, fig. 13)

Description: Ellipsoidal, aseptate, inaperturate spore with echinate surface. Double-walled, inner wall < 1µm thick and appears dehisced forming a central corpus. Central corpus 19µm at longest axis and green to brown. Outer wall < 1µm thick and bearing dense covering of echinae, hyaline. Echinae up to 2µm in length and 1µm in width and each one tapering to a sharp point. Overall spore length (excluding echinae) 19µm X 23µm.

Occurrence: MODERN SAMPLES - GC91J.07.

Known comparative(s): None

Ecology: Recovered from a field under permanent pasture.

ASI 048 (Plate 2, fig. 14)

Description: Ovoid, aseptate, inaperturate spore with verrucate surface and a foot chamber. Ornamentation dense. Single wall approximately 1µm thick, brown. Foot chamber single walled, < 1µm, hyaline. 20µm X 13µm.

Occurrence: MODERN SAMPLES - GC91J.07.

Known comparative(s): *Apiosordaria* v. Arx and W. Gams (1967)

A. verruculosa.

Ecology: According to Lundqvist (1972) most records of this species reflect the distribution and not the ecology and practically nothing is known of the spontaneous appearance of *A. verruculosa* under natural conditions.

Recovered in this sample from a field under permanent pasture.

ASI 049 (Plate 2, fig. 10)

Description: Reniform, aseptate, inaperturate spores with smooth walls. Axis curved, Single wall 1µm thick, brown. 12µm X 4.5µm.

Occurrence: MODERN SAMPLES - HB91J.11.

Known comparative(s): None

Ecology: Recovered in this study only from samples of mor humus.

ASI 052 (Plate 3, fig. 1)

Description: Ovoid, aseptate, inaperturate spore with smooth surface. Symmetrical. Single wall > 1µm thick, brown to black. 45µm X 35µm.

Occurrence: MODERN SAMPLES - GC92F.15, HB91O.07.

Known comparative(s): Sordariaceae type.

Ecology: Pig yard. Members of this family are predominantly fimicolous and herbicolous, i.e. grow on dung or vegetation (Lundqvist 1972). Sordariaceae have also been found on seeds (Cain & Groves 1948) and in association with burnt ground (Petersen 1970).

Recovered in this study from samples which have in common the presence of animals. One sample being a pig yard and the other being a horse stable.

ASI 053 (Plate 3, fig. 2)

Description: Spores clavate, aseptate, inaperturate and smooth. Single wall < 1µm thick, brown. Size range 10µm X 9µm to 13µm X 10µm.

Occurrence: MODERN SAMPLES - HB92M.16, HB91O.01, GC92F.09, GC91O.09.

Known comparative(s): None

Ecology: Recovered in this study predominantly in samples from barley field soil. Also found in one sample from a cattle byre.

ASI 054 (Plate 3, fig. 11)

Description: Ovoid, aseptate, inaperturate spore with truncate pole and microverrucate surface. Truncate pole appears to represent a point of former attachment to a ?basal appendage, as the margin is irregular and frayed in appearance. Uniform, dense covering

of microverrucae on surface. Single wall 1µm thick, brown. 19µm X 14µm to 22µm X 15µm.

Occurrence: MODERN SAMPLES - HB92M.12, GC92F.09, JF91J.03.

ARCHAEOLOGICAL SAMPLES - B309, BB78ST4.

Known comparative(s): Sordariaceae type. These spores resemble Type 169 of Van geel *et al* 1983b. They differ from those of Van Geel in that an apical aperture was not observed. All showed remains of a ?basal appendage. Van Geel considers that these ascospores were probably produced by a member of the Sordariaceae related to the genus *Tripterospora* Cain (1956).

Ecology: Members of this family are predominantly fimicolous and herbicolous, i.e. grow on dung or vegetation (Lundqvist 1972). Sordariaceae have also been found on seeds (Cain & Groves 1948) and in association with burnt ground (Petersen 1970).

Recovered in this study from samples of crop or pasture fields.

ASI 055

Description: Amb irregular due to folding and compression but proboably originally spherical, aseptate, inaperturate. Dense covering of small gemmae. Individual elements <1µm in width and height. Single wall <1µm thick, yellow-grey to hyaline. 105µm at maximum diameter.

Occurrence: MODERN SAMPLES - HB91J.11, GC91J.07.

Known comparative(s): Probably algal in origin.

Ecology: Recovered in this study from mor humus and a field under permanent pasture.

ASI 058 (Plate 3, fig 3, fig. 4.)

Description: Spherical to ellipsoidal, aseptate, inaperturate spores with echinate surface. Single wall < 1µm thick and hyaline, bearing echinae. Echinae, uniform in size, up to 2µm in length and tapering to a point. 12µm X 12µm to 15µm X 11µm.

Occurence: MODERN SAMPLES - CA91G.02.

Known comparative(s): None

Ecology: Occurring in surface soil from an abandoned crop field. Sheep roam freely across the site.

ASI 059 (Plate 3, fig. 5, fig. 9)

Description: Limoniform, aseptate, inaperturate spore with reticulate surface. Both polar areas tapering to a point. Reticulation open, reticulation coarsest around equatorial region with luminae decreasing in size towards the poles. Single wall, 1µm thick, brown. 17µm X 12.5µm.

Occurrence: MODERN SAMPLES - CA91G.02.

Known comparatives: None

Ecology: Occurring in surface soil from an abandoned crop field. Sheep roam freely across the site.

ASI 060 (Plate 3, fig. 6)

Description: Ellipsoidal, aseptate, inaperturate spore with verrucate surface. Individual elements small < 1µm in width and height and sparse, never touching. Single wall 1µm thick, hyaline. 16µm X 10µm.

Occurence: MODERN SAMPLES - CA91G.02.

Known comparative(s): *Melampsora* Cast. (1843)

Ecology: *Melampsora* spp. belong to the Uredinales or rusts. These fungi are parasitic on plants. *Melampsora* spp. are particularly common on willow and poplar trees (Grove 1913).

Occurring in surface soil from an abandoned crop field. Sheep roam freely across the site.

ASI 061 (Plate 3, fig. 10)

Description: Aseptate, inaperturate spore with smooth surface. Asymmetrical. One pole truncated the other pole umbonate, and terminating in a rounded apiculus. Some specimens exhibited a small, simple aperture at the apex of the apiculus. Truncate pole appears to represent point of former attachment as the margin is irregular and frayed in appearance. Single wall, < 1µm thick, brown. 16µm X 12µm to 18µm X 13µm.

Occurrence: MODERN SAMPLES - JF91J.03.

ARCHAEOLOGICAL SAMPLES - L6084.

Known comparative(s): None

Ecology: Occurring in the surface soil from a barley field.

ASI 062 (Plate 3, fig. 7, fig. 8)

Description: Reniform, aseptate, inaperturate spore with echinate surface. Appearing subcircular in polar orientation. Irregular and sparse distribution of echinae, tending to clump together in patches. Individual elements small, up to 1 µm in length and < 1µm in width. Single wall < 1µm thick, brown to black. Overall dimensions 13µm X 8µm to 17µm X 9µm.

Occurrence: MODERN SAMPLES - JF91J.06.

Known comparative(s): None

Ecology: Occurring in hay.

ASI 063 (Plate 3, fig. 3)

Description: Ellipsoidal, aseptate, inaperturate spore with reticulate surface. Luminae irregular in size, up to 2.5µm diameter. Thick murae, up to 1.5 µm, separate adjacent luminae. Wall thick and opaque, dimensions indiscernible. Overall the spores have a somewhat carbonised appearance. 11µm X 9 to 12µm X 11µm.

Occurrence: MODERN SAMPLES - HB91O.01, GC92F.12, GC91O.12.

Known comparative(s): None

Ecology: Occurring in samples from the floor of a pig house and also from a cattle byre. Samples have in common the presence of animals.

ASI 067

Description: Oval, aseptate, inaperturate spore with rugulate surface. Single wall, 1µm thick, pink to brown. 20µm X 14µm.

Occurence: ARCHAEOLOGICAL SAMPLES - B39.

Known comparative(s): None

Ecology: Affinity unknown.

ASI 068 (Plate 3, fig. 14, fig. 15, fig. 16, fig. 17, fig. 18)

Description: Irregular in shape but frequently variations on spatulate; aseptate, inaperturate, asymmetrical spore with smooth surface. Occasional specimens exhibit a simple aperture, < 1µm in diameter, at the tapered apex. Single wall, 1µm thick, brown to black. 21µm X 16µm to 28µm X 23µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - BB78ST4, BB79E12, BB80S10, BB81E13, BH09.

Known comparative(s): None

Ecology: Recovered from samples taken from a Neolithic grain store. Affinity unknown.

ASI 069 (Plate 3, fig. 19)

Description: Subspherical, aseptate, inaperturate spore with tuberculate surface. Tuberculae dense and very tightly packed. Individual elements approximately uniform in dimensions, up to 3µm in length and up to 1µm in width. Double-walled. Innerbody subspherical, 6µm in diameter, brown. Outer wall 3µm thick and bearing the tuberculae, brown. Overall dimensions, including tuberculae, 12µm in diameter.

Occurrence: ARCHAEOLOGICAL SAMPLES - BH01.

Known comparative(s): None

Ecology: Affinity unknown.

ASI 070 (Plate 3, fig. 20)

Description: Aseptate, inaperturate spore with truncated apex and scabrate to verrucate surface. Tapered pole umbonate terminating in a small round ended apiculus. Ornamentation uniform. Single wall < 1µm thick, brown. 20µm X 11µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - BH09.

Known comparative(s): Sordariaceae type. Resembles Type 169 of Van Geel *et al* (1983b). They differ from those of Van Geel in that an apical aperture was not observed. All showed remains of a ?basal appendage. Van Geel considers that these ascospores were probably produced by a member of the Sordariaceae related with the genus *Tripterospora*.

Tripterospora Cain (1956).

Ecology: Members of this family are predominantly fimicolous and herbicolous, i.e. grow on dung or vegetation (Lundqvist 1972). Sordariaceae have also been found on seeds (Cain & Groves 1948) and in association with burnt ground (Petersen 1970).

ASI 071 (Plate 3, fig 21)

Description: Subspherical, aseptate, inaperturate spore with smooth walls. Double-walled, inner wall > 1µm thick, outer wall < 1µm thick and loosely covering inner body, yellow brown. 50µm X 55µm in size.

Occurrence: ARCHAEOLOGICAL SAMPLES - BH11.

Known comparative(s): None

Ecology: Affinity unknown.

ASI 072 (Plate 3, fig. 22)

Description: Oval, aseptate, inaperturate, symmetrical spore with smooth surface. Occasional specimens found having a single simple aperture, < 1µm diameter, located towards one of the poles. Single wall < 1µm thick, brown. 31µm X 18µm to 42µm X 20µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - B234, B341, BH04, BH11, BH12.

Known comparative(s): Sordariaceae type.

Ecology: Members of this family are predominantly fimicolous and herbicolous, i.e. grow on dung or vegetation (Lundqvist 1972). Sordariaceae have also been found on seeds (Cain & Groves 1948) and in association with burnt ground (Petersen 1970).

ASI 073 (Plate 3, fig. 29, 33)

Description: Spores oval, asymmetrical, aseptate and inaperturate with smooth walls. Single wall up to 1µm thick, pale brown. Size range 13µm X 6µm to 19µm X 12µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - B309, B316, T810, BH07.

known comparative(s): This is considered a spore of the Class Basidiomycotina because of its asymmetry.

Ecology: Affinity unknown.

ASI 074 (Plate 3, fig. 25, fig. 26)

Description: Spherical, aseptate, inaperturate spore with a densely pilate ornament, regular arrangement. Pilae up to 2µm long and emerging from a 2µm thick single wall, yellow to hyaline. 18µm diameter.

Occurrence: ARCHAEOLOGICAL SAMPLES - T813, BH11.

Known comparative(s): None

Ecology: Affinity unknown.

ASI 075 (Plate 3, fig. 30, fig. 31,fig. 32)

Description: Spherical, aseptate, inaperturate spore with a reticulate surface. Reticulation uniform on one surface. Luminae up to 2.5µm in width. On opposite surface luminae decrease in size away from centre. Single wall, 1µm thick, brown. 20µm in diameter.

Occurrence: ARCHAEOLOGICAL SAMPLES - T803.

Known comparative(s): Resembles spores of the Lycopodiaceae but no trilete mark was apparent. It is therefore considered as an *incertae sedis* microfossil.

Ecology: Affinity unknown.

ASI 076 (Plate 3, fig. 27, fig. 28)

Description: Spherical, aseptate, inaperturate spore with a dense covering of irregular baculae. Individual elements 1µm in length and 1µm in width. Single wall, 1µm thick, hyaline. 13µm in diameter, excluding ornament.

Occurrence: ARCHAEOLOGICAL SAMPLES - T803/6C, T805/4A, T805/6B.

Known comparative(s): None

Ecology: Affinity unknown.

ASI 077 (Plate 3, fig 23)

Description: Lobed, aseptate, inaperturate spore with smooth surface. Up to 8 lobes emerging from a spherical central body. Lobes up to 3µm in height and width. Spherical body up to 7µm in diameter. Single wall, < 1µm thick, brown.

Occurrence: ARCHAEOLOGICAL SAMPLES - B327.

Known comparative(s): *Inocybe* (Fr.) Fr. (1863)

Ecology: Living on humus or wood, mainly ectomycorrhizal (Moser 1978).

ASI 078 (Plate 3, fig. 24)

Description: Lobed, aseptate, inaperturate spore with smooth surface. Up to 12 lobes emerging from an irregularly subspherical central body. Central body approximately 15µm in diameter. Individual lobes up to 4µm in height and 2.5µm in width. Single wall, < 1µm thick, brown.

Occurrence: ARCHAEOLOGICAL SAMPLES - T810.

Known comparative(s): *Inocybe* (Fr.) Fr. (1863)

Ecology: Living on humus or wood, mainly ectomycorrhizal (Moser 1978).

ASI 079 (Plate 4, fig. 19)

Description: Ovoid, aseptate, inaperturate spore with one truncated pole and smooth surface. Truncated pole elongated slightly distorting oval shape. Single very thick wall, dimensions indeterminable due to opacity, brown to black. 33µm X 24µm to 40µm X 23µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - T808.

Known comparative(s): Sordariaceae type.

Ecology: Members of this family are predominantly fimicolous and herbicolous, i.e. grow on dung or vegetation (Lundqvist 1972). Sordariaceae have also been found on seeds (Cain & Groves 1948) and in association with burnt ground (Petersen 1970)

ASEPTATE MONOAPERTURATE SPORES

Types with aseptate inaperturate groups constitute the second largest group amongst the fungal spores encountered, 46 in total, making up 20%. Of these 24 are comparable to known fungal taxa while it is considered that 5 could possibly be algal in origin, and that 2 are parasite eggs. 20 occur only in modern samples, 14 occur only in archaeological samples while 12 are common to both.

ASM 001 (Plate 4, fig. 1)

Description: Spherical to subspherical, aseptate monoaperturate fungal spore with smooth wall. Simple aperture, < 1µm in diameter is often surrounded by a dark circular patch. Outline often sligtly flattened around area of aperture. Single wall < 1µm thick and sometimes thickening slightly around aperture, brown. 15µm to 24µm in diameter.

Occurrence: MODERN SAMPLES - HB92M.02, HB92M.05, HB92M.12, HB92M.16, HB91O.03, HB91O.14, HB91O.16, GC92F.01, GC92F.02, GC92F.09, GC92F.12, GC92F.15, GC91O.01, GC91O.09, GC91O.12, ABP1, ABPS1, ABPS2, CA91G.03, CA91G.05, CA91G.07.

ARCHAEOLOGICAL SAMPLES - B48, B234, B309, B310, L6014, L6084, L6119, L6137, T803/6D, T805/6B, BB78ST4, BH01, BH02, BH03, BH05, BH06, BH07, BH10, BH11, BH11,

Known comparative(s): *Nigrospora* Zimm. (1902). Also frequently recovered from Prequaternary deposits and named *Exesisporites neogenicus* by Elsik (1969).

Ecology: *Nigrospora* ccurs on many different kinds of plants and is especially common on *Oryza*, has also been isolated from air and soil (Ellis 1971).

Type ASM 001 occurs across a range of modern samples, many of which have or have had the presence of hay or/and straw either in the form of bedding, fodder or manure (in the form of byre deposits).

ASM 002 (Plate 4, fig. 2)

Description: Ovoid, aseptate, monoaperturate. Spore axis asymmetrical. Simple aperture located at one pole, aperture 1µm in diameter. Hilar appendage located at

opposite pole, offset. Hilar appendage measuring 2µm X 1µm. Single wall, 1µm thick, brown. Size range 10µm X 9µm to 16µm X 9µm.

Occurrence: MODERN SAMPLES - ABP3.

ARCHAEOLOGICAL SAMPLES - BH04.

Known comparative(s): Bolbitiaceae and Coprinaceae.

Ecology: Bolbitiaceae typically occur on the ground in woods, pastures, heaths; on dung and on plant remains, refuse materials and on wood; often in gardens, farmyards and green houses (Watling 1982). They are saprophytes.

Coprinaceae typically occur on the ground, in woods, pastures, heaths etc and on dung, and on plant remains and refuse material (Orton and Watling 1979).

Differences between spores of these families are predominantly on the basis of colour, the spores of Coprinaceae being darker than those of the Bolbitiaceae. Since colour is not a favourable diagnostic feature (see Chapter Two) distinctions between spores of these two families are tentative and often impossible. Hence, these spores are referred to as Bolbitiaceae/Coprinaceae type.

Occurring in this study in a modern sample from a pony byre.

ASM 003 (Plate 4, fig. 3)

Description: Spherical, aseptate, monoaperturate spore. Aperture protruding 1µm from circumference and 1µm in diameter. Single wall < 1µm thick. 8µm diameter.

Occurrence:MODERN SAMPLES - HB91J.1/2.

Known comparative(s): None

Ecology: Occurring in a modern sample from a cattle byre.

ASM 004 (Plate 4, fig. 4, fig. 5)

Description: Ovoid, aseptate, monoaperturate spore, surface scabrate. Spore axis asymmetrical. Simple aperture 1µm in diameter located at pole. Surface uniformly scabrate. Single wall < 1µm, brown. Size range 10µm X 9µm to 12µm X 7µm.

Occurrence: MODERN SAMPLES - HB92M.14, HB92M.12, HB91O.01, GC92F.09, GC91O.01, GC91O.05, CA91G.05, CA91G.05, CA91G.07.

Known comparative(s): None

Ecology: Recovered from a range of modern samples mainly fields under pasture or a cereal crop and also from a cattle byre.

ASM 005 (plate 4, fig. 6)

Description: Ovoid, aseptate, monoaperturate spore. Surface smooth. Simple aperture located at one pole and 1µm in diameter. Single wall 1µm thick, brown. 12µm X 8µm.

Occurrence: MODERN SAMPLES - GC92F.14, GC92F.15, GC91O.05.

ARCHAEOLOGICAL SAMPLES - B48, B310, L6112, BH11,

Known comparative(s): None

Ecology: Recovered from a pig house, a pig yard and in the surface soil from a harvested oat field.

ASM 006 (Plate 4, fig. 7)

Description: Subspherical, aseptate, monoaperturate spore. Simple aperture located at tapered pole and 2µm in diameter. In equatorial orientation amb appears concave at pore. Single wall <1µm thick. 9µm X 7µm.

Occurrence: MODERN SAMPLES - HB91J.11, HB91J.1/2, GC91J.07.

Known comparatives: ?

Ecology: Recovered from a sample of mor humus, a cow byre and a field under permanent pasture.

ASM 007 (Plate 4, fig. 15)

Description: Ovoid, aseptate, monoaperturate spore. Surface densely baculate. Narrowest pole elongated distorting oval shape. Axis symmetrical. Simple aperture located at narrowest pole and 1µm in diameter. Entire surface covered in a dense carpet of small baculae. Individual elements < 1µm in height and width. Dark brown. 22µm X 17µm.

Occurrence: MODERN SAMPLES - GC91J.07.

Known comparative(s): None

Ecology: Occurring in soil from a field under permanent pasture.

ASM 008 (Plate 4, fig. 8)

Description: Ellipsoidal, aseptate, monoaperturate spore with single truncated apex and smooth surface. Truncate apex having simple aperture up to 3µm in diameter. Opposite pole irregular in shape and often umbonate. Single wall, dimensions indeterminable due to opacity, brown to black. 22µ X 14µ to 33µm X 15µm.

Occurrence: MODERN SAMPLES - GC91O.05.

Known comparative(s): Sordariaceae type.

Ecology: Members of this family are predominantly fimicolous and herbicolous, i.e. grow on dung or vegetation (Lundqvist 1972). Sordariaceae have also been found on seeds (Cain & Groves 1948) and in association with burnt ground (Petersen 1970).

Ecology: Occurring in modern samples from this study in soil from a harvested oat field.

ASM 009 (Plate 4, fig. 9, fig. 10)

Description: Ellipsoidal, aseptate, monoaperturate, asymmetrical spore with one truncated pole. Surface smooth. Simple aperture located at truncated pole. Hilar appendage located at opposite pole, offset. Hilar appendage 1µm X 1µm. Single wall < 1µm thick, yellow to brown. Size range 13µm X 7µm to 15µm X 8µm.

Occurrence: MODERN SAMPLES - HB91O.01, GC92F.09.

Known comparative(s): Bolbitiaceae and Coprinaceae.

Ecology: Bolbitiaceae typically occur on the ground in woods, pastures, heaths; on dung and on plant remains, refuse materials and on wood; often in gardens, farmyards and green houses (Watling 1982).

Coprinaceae typically occur on the ground in woods, pastures, heaths etc, on dung, plant remains and refuse material (Orton and Watling 1979).

Differences between spores of these families are predominantly on the basis of colour, the spores of Coprinaceae being darker than those of the Bolbitiaceae. Since colour is not a favourable diagnostic feature (see Chapter Two) distinctions between spores of these two families are tentative and often impossible. Hence, such spores are referred to as Bolbitiaceae/Coprinaceae type.

Occurring in this study in a sample from a cattle byre and in soil from a winter barley field.

ASM 010 (Plate 4, fig. 11)

Description: Ellipsoidal, aseptate, monoaperturate spore. Smooth surface. Simple aperture located at one pole, < 1µm diameter. Single wall < 1µm diameter, brown. 8µm X 6µm.

Occurrence: MODERN SAMPLES - HB91J.11, GC91J.07, HB91J.1/2.

Known comparative(s): None

Ecology: Occuring in a sample of mor humus, a cow byre and a field under permanent pasture.

ASM 011 (Plate 4, fig. 12, fig. 13)

Description: Ovoid, aseptate, monaperturate spore. Surface verrucate. Compound aperture located at tapered pole. Verrucae up to 1µm diameter and < 1µm in height, < 1µm apart. Double wall, inner wall < 1µm thick, outer wall 1µm thick. Brown. 13µm X 8µm.

Occurrence: MODERN SAMPLES - GC91J.07.

Known comparative(s): None

Ecology: Occurs in field under permanent pasture.

ASM 012

Description: Ovoid, aseptate, monoaperturate, asymmetrical spore with single truncated apex and smooth surface. Truncated apex bearing simple aperture up to 1.5µm in diameter. Opposite pole tapering gradually to narrow rounded end, off central longitudinal axis. Single wall < 1µm thick, brown. 10µm X 6µm.

Occurrence: MODERN SAMPLES - GC91J.07.

Known comparative(s): Sordariaceae type.

Ecology: Members of this family are predominantly fimicolous and herbicolous, i.e. grow on dung or vegetation (Lundqvist 1972). Sordariaceae have also been found on seeds (Cain & Groves 1948) and in association with burnt ground (Petersen 1970).

Occurs in this study in a field under permanent pasture.

ASM 013 (Plate 4, fig. 14)

Description: Subovoid, aseptate, monoaperturate, symmertical spore with ?corroded wall surface. Ovoid shape distorted by slight rounded protrusion at tapered pole bearing the aperture. Aperture < 1µm in diameter. Single wall appearing slightly foveolate, but apparent ornamentation may be as a result of corrosion, wall < 1µm thick. 13µm X 8µm to 15µm X 11µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - B402.

Known comparative(s): Sordariaceae type.

Ecology: Members of this family are predominantly fimicolous and herbicolous, i.e. grow on dung or vegetation (Lundqvist 1972). Sordariaceae have also been found on seeds (Cain & Groves 1948) and in association with burnt ground (Petersen 1970).

ASM 014 (Plate 4, fig. 16, fig. 17)

Description: Often crumpled and folded but probably originally subspherical. Aseptate, monoaperturate body with a regularly arranged granulate surface. Opercular aperture up to 20µm in diameter, some specimens still have opercular piece intact. Single wall < 1µm thick, brown. Largest diameter measured 70µm.

Occurrence: MODERN SAMPLES - HB92M.05, HB910.03, GC92F.12, GC92F.14, GC91O.12, ABPS2, CA91G.05.

ARCHAEOLOGICAL SAMPLES - B234, B316, B341, T803, T803/6D, T803/8, T805/4A, T805/6B, T805/7, T808, T810, BH03, BH05, BH08, BH11.

Known comparative(s): Comparable to Type 530 of Van Geel *et al* (1983b). Van Geel identifies this type as the rhizopod *Centropyxis ecornis*.

Ecology: The known habitat of *C. ecornis* is water and mosses growing in extremely wet conditions. Van Geel *et al* (1983b) considers that its presence in his samples represents allochthonous material. Occurring in this study in a range of modern and archaeological samples. Most of the modern samples, (except one), have in common the presence of hay or/and straw.

ASM 015 (Plate 4, fig. 1)

Description: Ovoid, aseptate, monoaperturate, symmetrical spore with narrowest pole elongated and truncated. Smooth surface. Truncated pole bearing simple aperture < 1µm in diameter. Single wall 1 - 1.5µm thick, brown. 20µm X 10µm to 36µm X 18µm.

Occurrence: MODERN SAMPLES - HB91O.16, GC92F.14, GC91O.05, ABP1, ABPS2, ABGS3, CA91G.02, CA91G.03, CA91G.05, CA91G.07.

ARCHAEOLOGICAL SAMPLES - B310, B316, BH08, BH10,

Known comparative(s): Sordariaceae type.

Ecology: Members of this family are predominantly fimicolous and herbicolous, i.e. grow on dung or vegetation (Lundqvist 1972). Sordariaceae have also been found on seeds (Cain & Groves 1948) and in association with burnt ground (Petersen 1970). Recovered in this investigation from a range of modern samples all having cereals as a common denominator, either in the form of a crop or as bedding or fodder.

ASM 016 (Plate 6, fig 8)

Description: Subcircular fruit body 65µm X 84µm, applanate. Wall composed of radially arranged septa 1µm to 2µm wide. Septa meandering in outline and often branching. Centrally located aperture or ostiole, 15µm in dimateter. Single wall, < 1µm thick, brown.

Occurrence: MODERN SAMPLES - HB91J.11.

Known comparative(s): Microthyriaceae, *Microthyrium* Des. (1841). Possibly ?*Stomiopeltis* sp., comparable to Type 8F of van Geel (1978). *Stomiopeltis* Theiss. (1914).

Ecology: The Microthyriaceae and similar fungi all occur in the same kind of habitats. Elsik (1978) reports that all the Microthyriaceae mimics are found living only on leaves and stems of live plants, while, Ellis (1976) agrees that most are saprophytic on leaves and stems but that a few occur on dead wood bark and others are said to be parasitic on other fungi. In many taxa, in order to facilitate identification to species level, it is necessary to know the numerical spore content of the asci and dimensions and descriptions of the ascospores. In order to determine species to variety knowledge of the host is necessary (Ellis 1976).

Modern microthyriaceous fungi are mainly tropical in distribution. The most important environmental factor determining their distribution is not temperature but precipitation (Elsik 1978). Their occurrences can be correlated to those parts of the world with an annual precipitation of not less than 1000 mm, hence species are indigenous to temperate latitudes as in Britain (Ellis 1976) and North America (Arnaud 1918; Popov 1960).

Such fungi were among the first fungal groups seen in palynologic residues to be accepted as unquestionably in situ due to the growth habit of extant species (Elsik 1978). Recovered in this investigation from mor humus.

ASM 017

Description: Subellipsoidal, aseptate, monoaperturate body with smooth surface. Opercular aperture up to 4µm in diameter and located at one pole. Single wall layer < 1µm thick, yellow to grey. 54µm X 33µm.

Occurrence: MODERN SAMPLES - HB91J.11.

Known comparative(s): None

Ecology: Recovered in this investigation from mor humus.

ASM 018 (Plate 6, fig. 9, fig. 10)

Description: Subcircular fruit body up to 95µm in diameter, applanate. Wall composed of numerous radiating files of regular rectangular cells. Central annulate aperture or ostiole, 17µm in diameter. Cells around aperture appear thicker, darker and smaller in size. Annulus 3µm thick. Two walls, one upper and one lower, up to 1µm thick, brown.

Occurrence: MODERN SAMPLES - HB91O.16.

ARCHAEOLOGICAL SAMPLES - B316, B341.

Known comparative(s): Microthyriaceae type. Comparable to Type 8E of van Geel (1978).

Ecology: The Microthyriaceae and similar fungi all occur in the same kind of habitats. For detailed ecology see ASM 016 above.

Recovered in this investigation from a harvested barley field.

ASM 019

Description: Subcircular fruit body up to 68µm in diameter, applanate. Wall composed of radially arranged septa, some originating from ostiole and extending as far as circumference; others originating at irregular distances between ostiole and circumference and extending for irregular distances. Centrally located annulate aperture, or ostiole, 13µm in diameter. Annulus 4µm thick. Single wall up to 1µm thick, brown.

Occurrence: MODERN SAMPLES - HB91J.11, GC91J.07.

Known comparative(s): Microthyriaceae type.

Ecology: The Microthyriaceae and similar fungi all occur in the same kind of habitats. Elsik (1978) reports that all the Microthyriaceae mimics are found living only on leaves and stems of live plants, while, Ellis (1976) agrees that most are saprophytic on dead leaves and stems but that a few occur on dead wood bark and others are said to be parasitic on other fungi. In many taxa, in order to facilitate identification to species level, it is necessary to know the numerical spore content of the asci and dimensions and descriptions of the ascospores. In order to determine species to variety knowledge of the host is necessary (Ellis 1976).

Modern Microthyriaceous fungi are mainly tropical in distribution. The most important environmental factor determining their distribution is not temperature but precipitation (Elsik 1978). Their occurrences can be correlated to those parts of the world with an annual precipitation of not less than 1000 mm, hence species are indigenous to temperate latitudes as in Britain (Ellis 1976) and North America (Arnaud 1918; Popov 1960).

Such fungi were among the first fungal groups seen in palynologic residues to be accepted as unquestionably in situ due to the growth habit of extant species (Elsik 1978).

Recovered in this sample from mor humus and from a permanent pasture field.

ASM 020 (Plate 4, fig. 20)

Description: Often crumpled and folded but probably originally subellipsoidal in shape. Aseptate, monoaperturate body with smooth surface. Annulate aperture located at one pole and 3µm in diameter, annulus 2 -3 µm thick and resembling a collar. Single wall layer < 1µm thick, grey to brown and transparent. 24µm X 15µm.

Occurrence: MODERN SAMPLES - HB91J.11, GC91J.07.

Known comparative(s): Probably algal in origin.

Ecology: Recovered in these samples from mor humus and from a permanent pasture field.

ASM 021 (Plate 4, fig. 21)

Description: Ellipsoidal, aseptate, monoaperturate, symmetrical spore with broad, truncated apex and smooth surface. Tapered apex bearing small, < 1µm diameter, simple aperture. Single wall 1µm thick, brown. 19µm X 12µm to 40µm X 23µm.

Occurrence: MODERN SAMPLES - JF91J.01.

ARCHAEOLOGICAL SAMPLES - B309,

Known comparative(s): Sordariaceae type.

Ecology: Members of this family are predominantly fimicolous and herbicolous, i.e. grow on dung or vegetation (Lundqvist 1972). Sordariaceae have also been found on seeds (Cain & Groves 1948) and in association with burnt ground (Petersen 1970). Recovered in this investigation from a sheep pasture.

ASM 022 (Plate 6, fig. 7)

Description: Oval, aseptate monoaperturate body. Wall hyaline, occasional specimens demonstrated a faint hexagonal reticulation on surface. Polar aperture opercular in nature and up to 4µm in diameter. 18µm X 12µm to 26µm X 17µm

Occurrence: GC91J.09, HB91J.11.

Known comparative(s): Probably algal in origin.

Ecology: Recovered from permanent pasture and mor humus samples. Affinity unknown.

ASM 023 (Plate 4, fig. 23)

Description: Subovoid, aseptate, monaperturate body with smooth surface. Aperture located at one pole and always taking the form of a split up to 2µm in length. Single wall layer < 1µm thick, pink and transparent. 15µm X 10µm to 17µ X 11µm in size.

Occurrence: MODERN SAMPLES - HB92M.05, HB91O.07.

Known comparative(s): Nature of aperture and absorption of safranin suggest that this form is likely to be algal in origin.

Ecology: Recovered in this study from a hay store and from a horse stable.

ASM 024

(Plate 4, fig. 24)

Description: Ellipsoidal, aseptate, monoaperturate spore with smooth surface. Aperture simple, 1µm diameter and located 4µm below pole. Single wall < 1µm thick, brown. 40µm X 20µm.

Occurrence: MODERN SAMPLES - GC91O.09, ABP3.

Known comparative(s): Sordariaceae type.

Ecology: Members of this family are predominantly fimicolous and herbicolous, i.e. grow on dung or vegetation (Lundqvist 1972). Sordariaceae have also been found on seeds (Cain & Groves 1948) and in association with burnt ground (Petersen 1970).

Recovered in this investigation from surface soil of a harvested barley field and from a pony byre.

ASM 025 (plate 4, fig. 25, fig. 26)

Description: Ovoid to round, aseptate, monoaperturate spore with smooth surface. Tapered pole umbonate. Rupture below pole may once have been an aperture (rupture not present on all specimens). Simple aperture < 1µm in diameter located a few µm above opposite pole. Single wall, dimensions indiscernible due to opacity, brown. 34µm X 24µm.

Occurrence: MODERN SAMPLES - GC92F.01, GC92F.02, GC92F.12, GC91O.12, ABPS1, ABPS2, ABGS1.

ARCHAEOLOGICAL SAMPLES - T803/6D,

Known comparative(s): Sordariaceae type.

Ecology: Members of this family are predominantly fimicolous and herbicolous, i.e. grow on dung or vegetation (Lundqvist 1972). Sordariaceae have also been found on seeds (Cain & Groves 1948) and in association with burnt ground (Petersen 1970).

Recovered in this study from a range of samples all having in common the presence of animals. This form could be associated with the dung of animals - horses, pigs, sheep and goats.

ASM 026 (Plate 4, fig. 22)

Description: Round to ellipsoidal, aseptate, monoaperturate spore with smooth surface. Simple aperture located a few µm below pole and 1µm in diameter. Wall thick, dimensions indiscernible due to opacity, brown. 30µm diameter.

Occurrence: ARCHAEOLOGICAL SAMPLES - B234.

Known comparative(s): Sordariaceae type.

Ecology: Members of this family are predominantly fimicolous and herbicolous, i.e. grow on dung or vegetation (Lundqvist 1972). Sordariaceae have also been found on seeds (Cain & Groves 1948) and in association with burnt ground (Petersen 1970).

ASM 027 (Plate 5, fig. 16)

Description: Irregular flattened body always variously crumpled and folded with a smooth surface. Annulate aperture up to 3µm in dimater. Annulus < 1µm in diameter. Single wall < 1µm thick, pink to brown and transparent. 15µm X 10µm to 20µm X 19µm.

Occurrence: MODERN SAMPLES - HB91O.14, HB91O.16, GC92F.09, GC91O.01, GC91O.05.

Known comparative(s): Probably algal in nature since safranin has been absorbed.

Ecology: Recovered in these samples from the surface soil of fields either under permanent pasture or a cereal crop.

ASM 029 (Plate 5, fig. 2, fig. 3, fig. 4)

Description: Ovoid, aseptate, monaperturate spore with truncated pole and smooth surface. Simple aperture < 1µm in diameter, located a few µm below tapered pole. Aperture often difficult to detect, visibility dependent on orientation of spore. Spore symmetrical. Single wall < 1µm thick, brown. 30µm X 19µm to 46µm X 20µm.

Occurrence: MODERN SAMPLES - ABP1, ABP3, CA91G.03.

ARCHAEOLOGICAL SAMPLES - B48, B309, B316, T803/6D, BH08.

Known comparative(s): Sordariaceae type.

Ecology: Members of this family are predominantly fimicolous and herbicolous, i.e. grow on dung or vegetation (Lundqvist 1972). Sordariaceae have also been found on seeds (Cain & Groves 1948) and in association with burnt ground (Petersen 1970). Recovered in these samples from a pony byre and an abandoned crop field.

ASM 031

Description: Ovoid, aseptate, monoaperturate spore with smooth surface. Simple aperture, 1.5µm in diameter located a few µm above transverse median of spore. Single wall < 1µm thick, brown. 20µm X 12µm.

Occurrence: MODERN SAMPLES - HB91J.11.

Known comparative(s): Sordariaceae type.

Ecology: Members of this family are predominantly fimicolous and herbicolous, i.e. grow on dung or vegetation (Lundqvist 1972). Sordariaceae have also been found on seeds (Cain & Groves 1948) and in association with burnt ground (Petersen 1970)

Recovered in these samples from mor humus.

ASM 032 (Plate 5, fig. 1)

Description: Spherical, aseptate, monoaperturate body with reticulate surface. Operculate, annulate aperture up to 15µm in diameter. Annulus up to 2µm thick. Some specimens still had opercular piece intact. Surface microreticulate, luminae < 1µm diameter. Single wall < 1µm thick, hyaline. 35µm to 47µm diameter.

Occurrence: MODERN SAMPLES - HB91J.11.

Known comparative(s): Possibly algal in origin or may be a rotifer cyst. Opercular aperture characteristically algal.

Ecology: Recovered in these samples from mor humus.

ASM 033 (plate 5, fig. 8)

Description: Ovoid, aseptate, monoaperturate body with a coarse, reticulate, surface. Annulate aperture located at tapered pole and 20µm in diameter. Annulus 1µm thick and resembling a collar. Luminae of reticulum heterogenous in size and shape but often geometric. Single wall 1µm thick, hyaline. 83µm X 62µm in size.

Occurrence: MODERN SAMPLES - HB91J.11.

Known comparative(s): Probably algal in origin because of nature of operculum.

Ecology: Recovered in modern samples from mor humus.

ASM 034

Description: Subspherical, aseptate, monoaperturate body with scabrate surface. Aperture located at one pole and up to 3µm in diameter. Some specimens still have hyaline foot chamber attached around aperture. Single wall, uniformly scabrate, 1.5µm thick, yellow to brown. Individual elements up to 1µm in width. Wall 1.5µm in width. Size range 17µm X 15µm to 21µm X 18µm.

Occurrence: MODERN SAMPLES - ABP1, ABGS1.

ARCHAEOLOGICAL SAMPLES - B316.

Known comparative(s): None

Ecology: Recovered in modern samples from byre deposits; one deposit from a pony byre and the other from a sheep and goat byre.

ASM 035 (Plate 5, fig. 6, fig. 7)

Description: Subspherical, aseptate, monoaperturate body with scabrate surface. Aperture located at one pole and up to 2µm in diameter. Some specimens still had hyaline foot chamber attached around aperture. Single wall uniformly punctate, and 1.5µm thick, brown. Individual punctae < 1µm diameter. 15µ X 14µ to 21µm X 16µm.

Occurrence: MODERN SAMPLES - GC92F.14, GC91O.09, ABPS1.

ARCHAEOLOGICAL SAMPLES - B39, T805/7, T813.

Known comparative(s): None

Ecology: Recovered in this study from a pig house, a harvested winter barley field and a pony and sheep outdoor midden.

ASM 036

Description: Truncate, ellipsoidal spore, aseptate with aperture located at truncate pole. Surface smooth to faintly reticulate. Simple aperture 4µm in diameter. Single wall layer 2µm thick, pale brown. 15µm X 12.5µm to 23µm X 16µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - T805/4A, T814/1A, BH08, BH10.

Known comparative(s): None

Ecology: Affinity unknown.

ASM 039

Description: Ovoid, aseptate, monoaperturate spore. Double walled, both walls < 1µm thick, brown. Inner wall smooth and uniform, outer wall appears wrinkled over inner one. 24µm X 16µm.

Occurrence: MODERN SAMPLES - GC91O.05.

ARCHAEOLOGICAL SAMPLES - T803/6D.

Known comparative(s): None

Ecology: Occurring in surface soil from a harvested oat field.

ASM 040

Description: Ellipsoidal, aseptate, monoaperturate spore with smooth surface. Aperture located at one pole, pole slightly umbonate. Aperture 1µm in diameter. Single wall < 1µm, brown. 7µm X 5µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - T803/6D.

Known comparative(s): None

Ecology: Affinity unknown.

ASM 041 (Plate 5, fig. 5)

Description: Subovoid, aseptate, monoaperturate, asymmetrical spore with smooth wall. Ovoid shape distorted by tapered pole which swings off the central longitudinal axis forming a short rounded apex. Simple aperture, 1µm in diameter located at opposite pole. Single wall 1µm thick and thickening slightly internally into the polar aperture, brown. 32µm X 18µm to 27µm X 19µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - B310.

Known comparative(s): Sordariaceae type.

Ecology: Members of this family are predominantly fimicolous and herbicolous, i.e. grow on dung or vegetation (Lundqvist 1972). Sordariaceae have also been found on seeds (Cain & Groves 1948) and in association with burnt ground (Petersen 1970).

ASM 043 (Plate 5, fig. 13)

Description: Ellipsoidal, aseptate, monoaperturate body with granular surface. One pole having an extended `neck', giving body an overall flask-like shape. Simple aperture,

10µm in diameter located at end of neck. Single wall, 2µm thick, yellow to brown. Apparent granulation may be as a result of corrosion. 66µm X 38µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - B39.

Known comparative(s): Parasite egg.

Ecology: Associated with dung.

ASM 044 (Plate 5, fig. 9, fig. 10)

Decsription: Oval, septate, monoaperturate, symmetrical spore with smooth surface. Both poles truncated. One pole umbonate and bearing a simple aperture < 1µm in diameter and located off centre. Opposite pole having an irregular margin. Single wall 1µm thick, brown. 19µm X 10µm to 22µm X 11µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - B48, B310.

Known comparative(s): Sordariaceae type.

Ecology: Members of this family are predominantly fimicolous and herbicolous, i.e. grow on dung or vegetation (Lundqvist 1972). Sordariaceae have also been found on seeds (Cain & Groves 1948) and in association with burnt ground (Petersen 1970).

ASM 045 (Plate 6, fig. 11, fig. 12)

Description: Subcircular fruit body 55µm X 39µm, applanate. Wall composed of numerous radially arranged septa, all extending from ostiole to circumference. Occasional intersecting septa occur, forming cells. Centrally located aperture or ostiole, 8µm wide, with occasional hyphae emerging from its margin. Single wall, < 1µm thick, brown.

Occurrence: ARCHAEOLOGICAL SAMPLES - B48.

Known comparative(s): Microthyriaceae type.

Ecology: The Microthyriaceae and similar fungi all occur in the same kind of habitats. Elsik (1978) reports that all the Microthyriaceae mimics are found living only on leaves and stems of live plants, while, Ellis (1976) agrees that most are saprophytic on dead leaves and stems but that a few occur on dead wood bark and others are said to be parasitic on other fungi. In many taxa, in order to facilitate identification to species level, it is necessary to know the numerical spore content of the asci and dimensions and

descriptions of the ascospores. In order to determine species to variety knowledge of the host is necessary (Ellis 1976).

Modern Microthyriaceous fungi are mainly tropical in distribution. The most important environmental factor determining their distribution is not temperature but precipitation (Elsik 1978). Their occurrences can be correlated to those parts of the world with an annual precipitation of not less than 1000 mm, hence species are indigenous to temperate latitudes as in Britain (Ellis 1976) and North America (Arnaud 1918; Popov 1960). Such fungi were among the first fungal groups seen in palynologic residues to be accepted as unquestionably in situ due to the growth habit of extant species (Elsik 1978).

ASM 047 (Plate 5, fig. 14, fig. 15)

Description: Ellipsoidal, aseptate, monoaperturate, asymmetrical spore with smooth surface. Simple aperture, 1µm in diameter offset from one pole. Single wall 1µm thick, brown. 10µm X 7µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - BH09.

Known comparative(s): Coprinaceae and Bolbitiaceae

Ecology: Bolbitiaceae typically occur on the ground in woods, pastures, heaths; on dung and on plant remains, refuse materials and on wood; often in gardens, farmyards and green houses (Watling 1982). They are saprophytes.

Coprinaceae typically occur on the ground, in woods, pastures, heaths etc and on dung, and on plant remains and refuse material (Orton & Watling 1979).

Differences between spores of these families are predominantly on the basis of colour, the spores of Coprinaceae being darker than those of the Bolbitiaceae. Since colour is not a favourable dignostic feature (see Chapter Two) distinctions between spores of these two families are tentative and often impossible. Hence, these spores are referred to as Bolbitiaceae/Coprinaceae type.

ASM 048 (Plate 6, fig. 13)

Description: Irregularly circular fruit body 45µm X 40µm, applanate. Wall composed of numerous radiating files of regular rectangular cells with very thick walls, up to 3.5µm. Single centrally located aperture or ostiole, 4µm in diameter. Single wall 1µm thick, brown.

Occurrence: ARCHAEOLOGICAL SAMPLES - BH06, BH11.

Known comparative(s): Microthyriaceae type.

Ecology: The Microthyriaceae and similar fungi all occur in the same kind of habitats. Elsik (1978) reports that all the Microthyriaceae mimics are found living only on leaves and stems of live plants, while, Ellis (1976) agrees that most are saprophytic on dead leaves and stems but that a few occur on dead wood bark and others are said to be parasitic on other fungi. In many taxa, in order to facilitate identification to species level, it is necessary to know the numerical spore content of the asci and dimensions and descriptions of the ascospores. In order to determine species to variety knowledge of the host is necessary (Ellis 1976).

Modern Microthyriaceous fungi are mainly tropical in distribution. The most important environmental factor determining their distribution is not temperature but precipitation (Elsik 1978). Their occurrences can be correlated to those parts of the world with an annual precipitation of not less than 1000 mm, hence species are indigenous to temperate latitudes as in Britain (Ellis 1976) and North America (Arnaud 1918; Popov 1960). Such fungi were among the first fungal groups seen in palynologic residues to be accepted as unquestionably in situ due to the growth habit of extant species (Elsik 1978).

ASM 050 (Plate 5, fig. 11, fig. 12)

Description: Ovoid, aseptate, monoaperturate spore with both poles truncated and a smooth surface. Spore symmetrical. Tapered end of spore having broadest pole measuring 3µm across. Simple aperture 1µm in diameter located 3.5µm below broadest pole. Opposite pole narrower 2µm and slightly umbonate. Thick walled, dimensions indiscernible due to opacity. 37µm X 21µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - BH10.

Known comparative(s): Sordariaceae.

Ecology: Members of this family are predominantly fimicolous and herbicolous, i.e. grow on dung or vegetation (Lundqvist 1972). Sordariaceae have also been found on seeds (Cain & Groves 1948) and in association with burnt ground (Petersen 1970).

ASM 051 (Plate 6, fig. 2)

Description: Ovoid, aseptate, monoaperturate spore with truncated apex and smooth surface. Tapered pole truncated and bearing a compound aperture measuring 2µm X 2µm. Single wall < 1µm thick, brown. 24µm X 14µm to 30µm X 23µm.
Occurrence: ARCHAEOLOGICAL SAMPLES - B309, B402, BB79E12.
Known comparative(s): Sordariaceae.
Ecology: Members of this family are predominantly fimicolous and herbicolous, i.e. grow on dung or vegetation (Lundqvist 1972). Sordariaceae have also been found on seeds (Cain & Groves 1948) and in association with burnt ground (Petersen 1970).

ASM 052 (Plate 5, fig. 17, Plate 6, fig. 1)
Description: Ovoid, aseptate, monoaperturate body with smooth surface. Narrowest pole elongated and bearing an opercular aperture. Aperture 7µm in diameter. Single wall approximately 1µm thick and thickening slightly at pole opposite aperture. 19µm x 17µm to 26µm X 21µm.
Occurrence: ARCHAEOLOGICAL SAMPLES - T803/8.
Known comparative(s): Parasite egg.
Ecology: Associated with dung.

ASM 053 (Plate 6, fig. 3, fig. 4)
Description: Cymbiform, aseptate, monoaperturate spore with smooth surface. One pole truncated the other pole tapering to a simple aperture 1.5µm in diameter. Single wall, < 1µm thick, yellow to brown. 22µm X 7µm.
Occurrence: ARCHAEOLOGICAL SAMPLES - BB80S10.
Known comparative(s): Ascomycotina type.
Ecology: Affinity unknown.

ASM 054 (plate 6, fig. 5, fig. 6)
Description: Subspherical, aseptate, monoaperturate
Occurrence: MODERN SAMPLES - ABGS2, ABGS3.
Known comparative(s): *Ureda* sp.

Ecology: *Ureda* is a genus within the Uredinales or rusts. These fungi are parasitic on plants and are often host specific. Speciation of the spores is dependent on knowledge of the host

(Grove 1913).

Occurring in this investigation from a sheep and goat byre deposit.

ASEPTATE DIAPERTURATE SPORES

Types that possess aseptate diaperturate spores constitute the third largest group of fungal spores encountered, making up 18%. Of these 16 are comparable to known fungal taxa, while it is considered that 2 are parasite eggs. 16 occur only in modern samples, 17 occur only in archaeological samples while 4 are common to both.

ASD 001 (Plate 7, fig. 1)

Description: Limoniform, aseptate, diaperturate, flattened spores with smooth walls. Simple aperture located at each pole, poles umbonate. Single wall, < 1µm thick, light grey-brown to dark brown. 10µm X 8µm to 14µm X 10µm.

Occurrence: MODERN SAMPLES - HB92M.05, HB92M.12, HB92M.14, HB91O.03, GC92F.02, GC92F.09, GC92F.12, GC92F.14, GC92F.15, GC91O.05, GC91O.09, GC91O.14, ABP1, ABP3, ABPS1, ABPS2, ABGS2, ABGS3, CA91G.02, CA91G.05, CA91G.07, JF91J.01, JF91J.03.

ARCHAEOLOGICAL SAMPLES - B39, B48, B310, B316, B341, T803/6D, T803/8, T805/7, T808, T810, T814/1A, BB78ST4, BB81E13, BH01, BH02, BH04, BH11.

Known comparative(s): *Chaetomium /Lophotrichus* type.

Ecology: *Chaetomium* Kunze (1814), cosmopolitan on dung, straw, wet paper, cloth, cotton fibres, many cellulolytic and some mycotoxic. However, according to (Ellis & Ellis 1988), *Chaetomium* spp. are rarely found on dung except for when it is mixed with straw. In the fifty years up until 1988, 11 species had been found associated with dung but most of them only once or twice (Ellis and Ellis 1988). *Lophotrichus* R. Benj. (1949), has similar ecological amplitude (Cannon *et al* 1985).

Recovered, in this study, from a wide range of modern samples, the common ecological denominator possibly being that of the presence of straw or/and dung.

ASD 002 (Plate 7, fig. 2)

Description: Ellipsoidal, aseptate, diaperturate spore with smooth surface. Simple aperture located at each pole and each aperture measuring 2µm in diameter. Single wall 1µm thick, brown. 15µm X 9.5µm to 16µm X 10.5µm.

Occurrence: MODERN SAMPLES - HB92M.05, GC92F.12, CA91G.05.

Known comparative(s): Sordariaceae type.

Ecology: Members of this family are predominantly fimicolous and herbicolous, i.e. grow on dung or vegetation (Lundqvist 1972). Sordariaceae have also been found on seeds (Cain & Groves 1948) and in association with burnt ground (Petersen 1970)
Recovered from a range of modern samples all which could have cereals in common, either in the form of animal bedding, fodder or a growing crop.

ASD 003 (Plate 7, fig. 3, fig. 4, fig. 5)

Description: Aseptate, diaperturate spore with murate wall. Apertures simple, located on opposite poles, 5µm diameter. Murae running from pole to pole but interrupted, 2-3µm thick. Overall the spore has a ribbed appearance. Single wall, 2µm thick, brown. 45µm X 22µm to 50µm X 25µm.

Occurrence: MODERN SAMPLES - GC91J.07.

Known comparative(s): None

Ecology: Occurring in samples from a permanent pasture field.

ASD 004

Description: Oval, aseptate, diaperturate spore with reticulate surface. Annulate apertures located at each pole, 3.5µm wide with an annulus of 2µm thick. Reticulation heterogenous with luminae up to 2µm wide, covering entire surface. Single wall, 1µm thick, brown. 31µm X 16µm.

Occurrence: MODERN SAMPLES - HB91J.1/2.

Known comparative(s): *Sphaerodes* Clem. 1909. *S. fimicola*

Ecology: Recovered from a cow byre sample.

ASD 005 (Plate 7, fig. 6, fig. 13)

Description: Oval, aseptate, diaperturate spore with smooth surface. Apertures in the form of aperture chambers and located at the poles. Each aperture 2.5µm wide. Single wall, 1µm thick and thinning into aperture chambers, brown. 31µm X 16µm to 37µm X 17µm.

Occurrence: MODERN SAMPLES - HB91J.11, GC91J.07.

Known comparative(s): Comparable to type 55 of Van Geel (1978). Possibly an ascospore of *Sordaria* Ces. and de Not. (1863) species.

Ecology: Occurs in mesotrophic conditions (Van Geel, 1978).

Recovered, in this study, from a mor humus and a permanent pasture sample.

ASD 006

Description: Ovoid, aseptate, diaperturate spore with smooth surface. Apertures simple, < 1µm diameter. One located at truncated pole the other 3µm below opposite pole. Single wall < 1µm thick, brown. 16µm X 10µm.

Occurrence: MODERN SAMPLES - HB91J.11.

Known comparative(s): Sordariaceae type.

Ecology: Members of this family are predominantly fimicolous and herbicolous, i.e. grow on dung or vegetation (Lundqvist 1972). Sordariaceae have also been found on seeds (Cain & Groves 1948) and in association with burnt ground (Petersen 1970).

Recovered from a mor humus sample.

ASD 007 (Plate 7, fig. 17, fig. 18)

Description: Ellipsoidal, aseptate, di- to tetra-aperturate spore with smooth surface. One simple aperture at each pole, < 1µm diameter. Up to two other simple apertures located randomly elsewhere on spore body, up to 1.5µm in diameter. Single wall 1µm thick, brown. 23µm X 12µm to 25µm X 12µm.

Occurrence: MODERN SAMPLES - HB91J.11.

Known comparative(s): Sordariaceae type.

Ecology: Members of this family are predominantly fimicolous and herbicolous, i.e. grow on dung or vegetation (Lundqvist 1972). Sordariaceae have also been found on seeds (Cain & Groves 1948) and in association with burnt ground (Petersen 1970).

Recovered from a mor humus sample.

ASD 008 (Plate 7, fig. 16)

Description: Fusiform, aseptate, diaperturate spore with smooth surface. Annulate apertures located at the poles and approximately 1µm in diameter, annulus 1µm thick. Single wall 1µm thick, brown. 11µm X 4.5µm.

Occurrence: MODERN SAMPLES - HB91J.11.

Known comparative(s): None

Ecology: Recovered in this study from a sample of mor humus.

ASD 009 (Plate 7, fig. 11, fig. 12)

Description: Sigmoidal, aseptate, diaperturate spore with smooth surface. Simple apertures located at poles, 2µm in diameter. Single wall, < 1µm thick, yellow to brown. 36µm X 14µm to 38µm X 14µm.

Occurrence: MODERN SAMPLES - GC91J.07, HB91J.11.

Known comparatives: None

Ecology: Recovered in this study from a mor humus sample and a sample from a permanent pasture field.

ASD 010 (Plate 7, fig. 9)

Description: Irregularly limoniform, aseptate, diaperturate spore with faintly reticulate surface. Shape asymmetrical. Simple polar apertures, < 1µm in diameter. One pole umbonate with aperture located off the central axis. Opposite pole having centrally located aperture. Single wall, 1µm thick, brown. 12µm X 7µm to 15µm X 7µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - B39.

Known comparative(s): Basidiomycotina type.

Ecology: Affinity unknown.

ASD 011 (Plate 7, fig. 10)

Description: Oval, aseptate, diaperturate body with truncated poles and smooth wall. Simple apertures, 7µm in diameter located at the poles. Single wall, 1µm thick, brown. 54µm X 30µm.

Occurrence: MODERN SAMPLES - GC92F.15.

Known comparative(s): Parasite egg.

Ecology: Associated with dung.

Recovered from the soil in a yard where pigs roam.

ASD 012 (Plate 7, fig. 7)

Description: Ovoid, aseptate, diaperturate spore with irregular surface. Simple aperture, 1µm in diameter located at each pole. Two walls, the inner wall being smooth and < 1µm thick, the outer wall loosely covering the inner wall, making contact with inner wall randomly and irregularly, giving an overall wrinkled appearance to the spore. Outer wall, < 1µm thick, brown. 18µm X 9µm.

Occurrence: MODERN SAMPLES - GC92F.15.

Known comparative(s): *Xylaria* Hill ex Gray (1821)

Ecology: Species of *Xylaria* typically occur on wood substrates (Cannon *et al* 1985). Recovered from the soil in a yard where pigs roam.

ASD 013 (plate 7, fig. 8)

Description: Suboval, aseptate, diaperturate spore with smooth surface. Shape asymmetrical. Both poles umbonate and having a simple central aperture, < 1µm in diameter. Single wall, 1µm thick, brown. 18µm X 9µm to 19µm X 9µm.

Occurrence: MODERN SAMPLES - HB92M.05, HB91O.03, GC91O.09.

ARCHAEOLOGICAL SAMPLES - B316, T810.

Known comparative(s): *Xylaria* Hill ex Gray (1821)

Ecology: Species of *Xylaria* typically occur on wood substrates (Cannon *et al* 1985). Recovered in this investigation from straw, hay and the soil from a barley field.

ASD 014

Description: Ovoid, aseptate, diaperturate spore with smooth surface. Simple aperture, < 1µm diameter located at widest pole, off centre. Opposite pole having central annulate aperture 1.5µm in diameter; annulus 1µm thick. Single wall < 1µm thick but thickening to 1µm at annulus. 9µm X 7µm to 15µm X 8µm.

Occurrence: MODERN SAMPLES - HB92M.01, ABPS1, ABPS2, ABGS2, ABGS3, CA91G.07.

Known comparative(s): None

Ecology: Recovered from a range of modern samples all having in common the presence of one or more of the following animals; cattle, horses, sheep, goats.

ASD 015

Description: Oval, aseptate, diaperturate spore with smooth surface. Two simple apertures, 1µm in diameter located at random over the surface of the spore usually one per hemisphere. Single wall, 1µm thick, brown. 14µm x 11µm.

Occurrence: MODERN SAMPLES - ABGS1.

Known comparative(s): None

Ecology: Occurring in a goat and sheep byre.

ASD 016 (Plate 7, fig. 14)

Description: Subellipsoidal, aseptate, diaperturate spore with truncated pole and smooth surface. Simple aperture 1.5µm in diameter located at each pole. Pole opposite truncated pole slightly umbonate. Single wall, dimensions indiscernible due to opacity, brown. 15µm X 7µm to 43µm X 20µm.

Occurrence: MODERN SAMPLES - JF91J.03.

ARCHAEOLOGICAL SAMPLES - B234.

Known comparative(s): Sordariaceae type.

Ecology: Members of this family are predominantly fimicolous and herbicolous, i.e. grow on dung or vegetation (Lundqvist 1972). Sordariaceae have also been found on seeds (Cain & Groves 1948) and in association with burnt ground (Petersen 1970). Recovered from the surface soil of a barley field.

ASD 017

Description: Limoniform, aseptate, diaperturate spore with smooth surface. Simple aperture < 1µm in diameter located at each pole. Single wall 1µm thick, brown. 24µm X 17µm to 30µm X 20µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - B39, T803, BH01, BH06, BH11.

Known comparative(s): Sordariaceae type. Resembles *Chaetomium* type. but differs by having a much thicker wall.

Ecology: Members of this family are predominantly fimicolous and herbicolous, i.e. grow on dung or vegetation (Lundqvist 1972). Sordariaceae have also been found on seeds (Cain & Groves 1948) and in association with burnt ground (Petersen 1970).

ASD 018 (Plate 7, fig. 15, fig. 20)

Description: Oval, aseptate, inaperturate spore with smooth surface. Simple aperture 1µm in diameter located at tapered pole, projecting 1µm. Opposite pole bearing simple aperture < 1µm in diameter, located off centre. Single wall, < 1µm thick, brown. 18µm X 11µm.

Occurrence: MODERN SAMPLES - JF91J.06.

Known comparative(s): None

Ecology: Recovered from a sample of hay.

ASD 019 (Plate 7, fig. 19, fig. 24)

Description: Oval, aseptate, diaperturate spore with smooth surface. Simple aperture, 1µm diameter located at each pole. Single wall, < 1µm thick, grey to brown. 18µm X 10µm to 28µm X 8µm.

Occurrence: MODERN SAMPLES - GC91O.05.

ARCHAEOLOGICAL SAMPLES - L6112.

Known comparative(s): None

Ecology: Recovered from the surface soil of a harvested oat field.

ASD 020 (Plate 7, fig. 21, fig. 26)

Description: Limoniform, aseptate, diaperturate spore with reticulate surface. Both poles umbonate. Simple aperture, 1µm diameter located at each pole. Single wall, < 1µm thick, brown to black. 13µm x 9µm.

Ocurrence: MODERN SAMPLES - GC92F.14.

Known comparative(s): *Sphaerodes* Clemm. (1909), ascospore

Ecology: Found on old dung of sheep (Ellis and Ellis 1988).

Recovered from the debris of a pig house with an earth floor.

ASD 021 (Plate 7, fig. 27)

Description: Subspherical, aseptate, diaperturate spore with smooth surface. Annulate aperture, 2µm in diameter with annulus of 1.5µm, located at each pole. Single wall, 1µm thick, brown. 19µm in diameter (excluding polar annuli).

Occurrence: MODERN SAMPLES - GC91O.05.

Known comparative(s): None

Ecology: Recovered from the surface soil of a harvested oat field.

ASD 022 (plate 7, fig. 22, fig. 23)

Description: Pyriform, aseptate, diaperturate spore with reticulate surface. Simple aperture, 1µm in diameter located at each pole. Luminae of reticulum < 1µm in width and up to 1µm in length. Murae separating luminae up to 1µm thick. Single wall, 1µm thick, brown. 13µm X 9µm to 21µm X 11µm.

Occurrence: MODERN SAMPLES - GC91O.05.

ARCHAEOLOGICAL SAMPLES - B48, L6112.

Known comparative(s): None

Ecology: Recovered from the surface soil of a harvested oat field.

ASD 023

Description: Limoniform, aseptate, diaperturate spore with truncated poles and smooth surface. Simple aperture, 1µm in diameter located at each pole. Single wall, < 1µm thick, brown. 13µm X 6µm to 15µm X 9µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - L6057, T803/6D.

Known comparative(s): *Chaetomium/Lophotrichus* type. Differs to ASD 001 in having truncated poles, and not being flattened.

Ecology: *Chaetomium* Kunze (1817), cosmopolitan on dung, straw, wet paper, cloth, cotton fibres, many cellulolytic and some mycotoxic. However, according to Ellis and Ellis (1988), *Chaetomium* spp. are rarely found on dung except for when it is mixed with straw. In the fifty years up until 1988, 11 species had been found associated with dung but most of them only once or twice (Ellis and Ellis 1988). *Lophotrichus* R. Benj. (1949) has similar ecological tolerances (Cannon *et al* 1985).

ASD 024

Description: Ovoid, aseptate, diaperturate spore with truncated pole and smooth surface. Both poles umbonate, truncated pole to a greater extent than opposite pole which has a small rounded apex. Simple aperture < 1µm diameter located at each pole. Single wall > 1µm thick, brown. 50µm X 32µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - B48, BH03.

Known comparative(s): Sordariaceae type

Ecology: Members of this family are predominantly fimicolous and herbicolous, i.e. grow on dung or vegetation (Lundqvist 1972). Sordariaceae have also been found on seeds (Cain & Groves 1948) and in association with burnt ground (Petersen 1970)

ASD 026 (Plate 7, fig. 28)

Description: Ellipsoidal, aseptate, diaperturate spore with smooth wall. Simple aperture located at each pole. One aperture 1µm in diameter and the other < 1µm in diameter. Single wall, 1µm thick, and thickening slightly inwards to both apertures, brown. 23µm X 12µm to 27µm X 16µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - L6137, BH05, BH06.

Known comparative(s): Sordariaceae type.

Ecology: Members of this family are predominantly fimicolous and herbicolous, i.e. grow on dung or vegetation (Lundqvist 1972). Sordariaceae have also been found on seeds (Cain & Groves 1948) and in association with burnt ground (Petersen 1970).

ASD 027 (Plate 7, fig. 29)

Description: Oval, aseptate, diaperturate spore with striate surface. Simple, protruding pores, 1.5µm in diameter located at each pole. Striae running from pole to pole, not extending as far as margins. Striae up to 2µm apart. Single wall approximately 1µm thick. 27µm x 19µm.

Occurrence: ARCAHEOLOGICAL SAMPLES - BH02.

Known comparative(s): *Neurospora* Shear and B. Dodge (1927). Type 55C of Van Geel (1978, 1986).

Ecology: Van Geel (1986) links the presence of *Neurospora* spp. with the incidence of local bog fire.

ASD 028 (plate 7, fig. 34)

Description: Subrectangular, aseptate, diaperturate body with smooth surface. Corners rounded and tapering slightly inwards. Simple aperture , 6µm across located at the widths of the rectangle. Single wall, 3µm thick and thickeneing into the apertures, yellow to brown. 50µm X 27µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - BH11.

Known comparative(s): Parasite egg.

Ecology: Associated with the presence of dung.

ASD 029 (Plate 8, fig. 1)

Description: Ovoid, aseptate, diaperturate spore with smooth surface. Both poles umbonate. Simple aperture located centrally at each pole. Aperture at broadest pole 2µm in diameter, and aperture at narrowest pole 1µm in diameter. Single wall, 1.5µm thick, brown to black. 32µm x 22µm to 39µm X 21µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - L6129, BH07.

Known comparative(s): None

Ecology: Affinity unknown

ASD 030 (Plate 7, fig. 32, fig. 33)

Description: Ellipsoidal, aseptate, diaperturate spore with smooth wall. Specimen slightly crumpled so symmetry of spore indeterminable. Simple aperture < 1µm diameter located at each pole. Single wall < 1µm thick, brown. 31µm X 16µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - BH09.

Known comparative(s): Sordariaceae type.

Ecology: Members of this family are predominantly fimicolous and herbicolous, i.e. grow on dung or vegetation (Lundqvist 1972). Sordariaceae have also been found on seeds (Cain & Groves 1948) and in association with burnt ground (Petersen 1970)

ASD 031 (Plate 8, fig. 11)

Description: Ovoid, aseptate, diaperturate spore with truncated pole and smooth surface. Tapered pole being truncate and having simple aperture < 1µm in diameter. Opposite pole also having simple aperture < 1µm in diameter. Single wall 1.5µm thick, and thickening slightly into aperture on truncated apex, brown. 27µm X 18µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - BH08.

Known comparative(s): Sordariaceae type.

Ecology: Members of this family are predominantly fimicolous and herbicolous, i.e. grow on dung or vegetation (Lundqvist 1972). Sordariaceae have also been found on seeds (Cain & Groves 1948) and in association with burnt ground (Petersen 1970).

ASD 032 (Plate 8, fig. 2)

Description: Oval, aseptate, diaperturate spore with smooth surface. Both poles umbonate. Simple aperture 1µm in diameter located at each pole. Single wall, 2µm thick and thinning to 1µm towards poles, brown. 32µm X 17µm to 33µm X 19µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - BH08, BH11.

Known comparative(s): None

Ecology: Affinity unknown.

ASD 033 (Plate 8, fig. 7, fig. 8)

Description: Limoniform, aseptate, diaperturate spore with smooth surface. Both poles umbonate, one pole protruding more than the other and curving away from central axis. Simple aperture, < 1µm in diameter located at each pole. Single wall, < 1µm thick, brown. 22µm X 12µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - B309.

Known comparative(s): None

Ecology: Affinity unknown.

ASD 034 (Plate 8, fig. 5, fig. 6)

Description: Fusiform, aseptate, diaperturate spore with smooth surface. Simple aperture, < 1µm in diameter located at each pole. Single wall, < 1µm thick, brown. 54µm X 18µm to 60µm X 24µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - B309.

Known comparative(s): None

Ecology: Affinity unknown.

ASD 035 (Plate 8, fig. 3)

Description: Ovoid, aseptate, diaperturate spore having a truncated pole and a smooth wall. Tapered pole being truncate and having a simple aperture < 1µm in diameter.

Opposite pole also having a simple aperture < 1µm in diameter. Single wall < 1µm thick, brown. 28µm X 18µm to 38µm X 21µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - B316, B402, T805/7.

Known comparative(s): Sordariaceae type.

Ecology: Members of this family are predominantly fimicolous and herbicolous, i.e. grow on dung or vegetation (Lundqvist 1972). Sordariaceae have also been found on seeds (Cain & Groves 1948) and in association with burnt ground (Petersen 1970).

ASD 036 (Plate 7, fig. 30, fig. 31)

Description: Oval, aseptate, diaperturate spore with broad truncated poles. Occasional specimens having only one truncated pole, the other pole being rounded and also bearing an aperture. It is thought that such forms represent peripheral cells of the same form. Simple aperture, < 1µm in diameter, located at the centre of each truncated pole. Single wall, 1µm thick, yellow to brown. 12µm X 10µm to 14µm X 11µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - BB79E12.

Known comparative(s): None

Ecology: Affinity unknown.

ASD 037 (Plate 8, fig. 4)

Description: Pyriform, aseptate, diaperturate spore with smooth surface. Shape asymmetrical. Broadest pole truncated. Simple aperture, < 1µm in diameter located at each pole. In some specimens aperture represented by a polar thinning. Single wall, dimensions indiscernible due to opacity, brown to black. 70µm X 33µm to 100µm x 58µm

Occurrence: ARCHAEOLOGICAL SAMPLES - BB79E12, BB81E13.

Known comparative(s): None

Ecology: Affinity unknown.

ASD 038 (Plate 8, fig. 9, fig. 10)

Description: Fusiform, aseptate, diaperturate spore with smooth surface. Asymmetrical. Simple aperture, < 1µm in diameter located at each pole. Single wall, 1µm thick, grey to light brown. 27µm X 7µm to 30µm X 7µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - BB79E12, BB81E13.

Known comparative(s): *Ustulina deusta* = Type 44 of van Geel (1978). *Ustulina* Tul. and C. Tul. (1863).

Ecology: Weak parasites on deciduous trees (Van Geel 1986, 1978).

ASEPTATE POLYAPERTURATE SPORES

Aseptate, polyaperturate spores constitute 4.5 % of the types encountered, 10 in total. Of these 4 are comparable to known fungal taxa, while it is considered that 1 is algal in origin. 4 occur only in modern samples and 6 occur only in archaeological samples.

ASP 001 (Plate 8, fig. 15)

Description: Oval, aseptate polyaperturate spore. Spore surface foveolate, individual eleemts simple apertures, approximately 48 apertures per 1/4 surface area. Each aperture < 1µm diameter. Single wall, 1µm thick. 12µm X 7µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - BH10.

Known comparatives: *Gelasinospora* Dowding (1933). Amongst the spores of the Sordariaceae *sensu stricto* are the *Gelasinospora*, *Sordaria* and *Copromyces*. Spores of *Gelasinospora* were encountered frequently in the course of this investigation and three discreet taxa were recognised - ASP 001, ASP 006 and ASP 007. These spores are charactersised by their pitted surfaces.

Ecology: Members of this family are predominantly fimicolous and herbicolous, i.e. grow on dung or vegetation (Lundqvist 1972).

ASP 002 (Plate 8, fig. 17, fig. 18)

Description: Pentaradiate, aseptate, penta-aperturate spore with smooth surface. Simple aperture, < 1µm diameter, located at the apex of each `arm'. Spore appearing triangular in polar orientation and tetra-radiate in equatorial orientation. Single wall, < 1µm thick, brown. Median height 8µm.

Occurrence: MODERN SAMPLES - GC91J.07.

Known comparative(s): None

Ecology: Recovered in this study from a field under permanent pasture.

ASP 003 (Plate 8, fig. 22, fig. 23)

Description: Oval, aseptate, tetra-aperturate spore with smooth surface. 3 simple apertures located equidistant from each other around long axis of spore, fourth aperture located in polar position (long axis = equator). All apertures borne on the end of short

protruding arms approximatley 2µm in length and width. Single wall, < 1µm thick, brown. 7µm X 5µm.

Occurrence: MODERN SAMPLES - HB91J.1/2.

Known comparative(s): None

Ecology: Recovered in a litter sample from a cow byre.

ASP 004

Description: Oval, aseptate polyaperturate spore. Surface pitted with numerous heterogenous, simple apertures 1-1.5µm in diameter, arrangement irregular. Thick wall, dimensions indiscernible due to opacity. 62µm X 20µm.

Occurrence: MODERN SAMPLES - GC92F.02.

Known comparative(s): None

Ecology: Recovered in the soil from a permanent pasture field.

ASP 005 (Plate 8, fig. 16)

Description: Subspherical, aseptate, penta- to octa-aperturate spore with smooth surface. Most specimens having 5 apertures, 3 equatorial and 2 polar to heteropolar. All apertures simple, 1µm in diameter. Single wall approximately 1.5µm thick, yellow to brown. 11µm X 9µm to 13µm X 9µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - BH01, BH08, BH09.

Known comparative(s): None

Ecology: Affinity unknown.

ASP 006 (Plate 8, fig. 19, fig. 20, fig. 21, fig. 24, fig. 25)

Description: Oval to ellipsoidal, aseptate, polyaperturate spore. May have an annulate aperture at one or both poles although this feature is not always obvious, polar apertures up to 3µm wide and 2µm thick. Surface pitted with numerous homogenous simple apertures, up to 2µm in diameter, arrangement apparently regular. Approximately 28 apertures per 1/4 spore surface area. Single wall, < 1µm thick, brown. 25µm X 20µm to 30µm X 20µm

Occurrence: ARCHAEOLOGICAL SAMPLES - B309, L6137, T814/1B, BB80S10, BH03, BH04, BH06, BH07, BH08.

Known comparative(s): *Gelasinospora* Dowding (1933). It is thought that spores of ASP 006 are *G. cerealis*. In *G. cerealis* the spores are much wider in proportion to their length than other species of *Gelasinospora* and pitting in this species is sometimes closer than in, for example *G. tetrasperma.*

Ecology: *G. cerealis* was originally isolated from the crown of wheats and oats in Manitoba (Dowding 1933).

ASP 007 (Plate 8, fig. 12)

Description: Ovoid, aseptate, polyaperturate spore. Apertures, simple, < 1µm diameter regularly arranged all over spore surface. Wall 1.5µm thick, brown. 20µm X 11µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - BH 10.

Known comparative(s): *Gelasinospora* Dowding (1933).

Ecology: Members of this family are predominantly fimicolous and herbicolous, i.e. grow on dung or vegetation (Lundqvist 1972).

ASP 008 (Plate 8, fig. 13, fig. 14)

Description: Subspherical, aseptate, polyaperturate body with 10-lobed margin. Simple, 6µm diameter, apertures located regularly over the surface . Single wall, < 1µm diameter, pink. 21µm diameter.

Occurrence: ARCHAEOLOGICAL SAMPLES - L6057.

Known comparative(s): Possibly algal in origin since it has absorbed safranin.

Ecology: Affinity unknown.

ASP 009

Description: Triangular, aseptate, triaperturate spore with smooth surface. Simple aperture, < 1µm in diameter located at each apex. Single wall, 1µm thick, brown. Each arm of the triangle measuring 10µm.

Occurrence: MODERN SAMPLES - HB91J.11.

Known comparative(s): None

Ecology: Recovered in a sample of mor humus.

ASP 010 (Plate 9, fig. 1, fig. 2)

Description: Ovoid, aseptate, triaperturate spore with smooth surface. One simple aperture located at tapered pole. Up to two other apertures located randomly on spore body, these apertures 1.5µm to 2µm in diameter. Single wall, 1µm thick, brown. All specimens rescovered measuring 23µm X 13µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - BH11.

Known comparative(s): Sordariaceae type.

Ecology: Members of this family are predominantly fimicolous and herbicolous, i.e. grow on dung or vegetation (Lundqvist 1972). Sordariaceae have also been found on seeds (Cain & Groves 1948) and in association with burnt ground (Petersen 1970).

MONOSEPTATE INAPERTURATE SPORES

Monoseptate, inaperturate spores constitute 6.5% of the spores encountered through the course of this investigation, 14 types in total. 3 of the types are comparable to known taxa. 6 occur only in modern samples, 6 occur only in archaeological samples while 2 are common to both.

MOI 001 (Plate 9, fig. 3)

Description: Irregular, monoseptate, inaperturate spore with verrucate surface. Septum median, transverse, < 1µm thick, no septal plate visible. Occasional specimens exhibited an additional two shadow bands one each side of median septum. Verrucae distributed irregularly over the entire surface, individual elements < 1µm in both width and height. Single wall, < 1µm thick, grey to brown. Ranging in size from 8µm X 4µm to 17µm X 6µm.

Occurrence: MODERN SAMPLES - HB91J.1/2.

Known comparative(s): *Cladosporium* Link (1815)

Ecology: Recovered from leaves, stems and fruits, dead stumps, wood pulp, dead organic material, decaying leaves and stems with many species being plant pathogens. Some species have also been recovered from non-plant material e.g. *C. herbarum* also recorded from meat - Massee (1912) and Brookes and Hansford (1923) isolated this fungus from `Black spot' in frozen meat in cold stores. *C. sphaerospermum* has been isolated from diseased human nails and skin. Some species are `hyperparasites' i.e. they parasitise other fungi which are themselves also parasitic.

Recovered in a litter sample taken from a cow byre.

MOI 002

Description: Monoseptate, inaperturate spore with faintly scabrate surface. Septum transverse, median and no spetal plate apparent. Spore outline constricted about septum. Single wall, < 1µm thick, brown. 24µm X 9µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - B310.

Known comparative(s): None

Ecology: Affinity unknown.

MOI 003

Description: Monoseptate, inaperturate, asymmetrical, elipsoidal spore with scabrate surface and hilar appendage. Transverse, median septum, 1µm thick. Hilar appendage offset from one of poles protruding < 1µm. Single wall 1µm thick, brown. Hyaline to faintly scabrate. 10µm X 5µm.

Occurrence: MODERN SAMPLES - JF91J.03.

Known comparative(s): None

Ecology: Recovered from the surface soil in a barley field.

MOI 004 (Plate 9, fig. 4)

Description: Irregularly ellipsoidal to subellipsoidal, monoseptate, inaperturate spore with smooth surface. Asymmetrical. Median, transverse, entire septum. Single wall < 1µm thick, brown. 8µm X 5µm to 17µm X 7µm.

Occurrence: MODERN SAMPLES - HB92M.07, HB92M.12, HB92M.16, HB91O.01, GC92F.14, GC91O.01, GC91O.05, GC91O.12, JF91J.05.

ARCHAEOLOGICAL SAMPLES - B310, T814/1A, BH04, BH10, BH11.

Known comparative(s): None

Ecology: Occurring across a range of samples from modern sites most of them having one or more of the following animals; horse, cattle, pigs. Three of the samples were from field samples; one a permanent pasture field, one a barley field and the final one a wheat field.

MOI 005 (Plate 9, fig. 5)

Description: Fusiform, monoseptate, inaperturate spore with smooth surface and tapered apices. Median, transverse, entire septum < 1µm thick. Single wall < 1µm thick, pink. 12µm X 4.5µm to 13µm X 6µm.

Occurrence: MODERN SAMPLES - HB92M.03, HB91O.04, HB910.14, GC92F.09, GC92F.15, GC91O.05, CA91G.02, CA91G.05, CA91G.07, JF91J.03.

ARCHAEOLOGICAL SAMPLES - L6084, BB78ST4, BB79E12, BB80S10, BB81E13, BH11.

Known comparative(s): None

Ecology: Recovered from a range of modern samples mostly in connection with cereal crops, in the form of hay and straw or soil from fields under cultivation. One sample from a field under permanent pasture and one sample from a pig yard also yielded this type.

MOI 006 (Plate 9, fig. 6)

Description: Ovoid, monoseptate, inaperturate spore with smooth surface and attachment scar in the form of a foot chamber. Median transverse septum with central, septal aperture, < 1µm in diameter. Foot chamber located at tapered pole and up to 2µm in length. Single wall < 1µm thick, brown. 16µ X 9µm to 21µ X 15µm.

Occurrence: MODERN SAMPLES - HB91J.11.

Known comparative(s): *Brachysporium* Sacc. (1880)

Ecology: Species of *Brachysporium* typically occur on rotten wood or bark (Ellis 1966). Recovered in this study from a sample of mor humus.

MOI 007 (Plate 9, fig. 8, fig. 9)

Description: Spherical, monoseptate, inaperturate spore with smooth surface and foot chamber. Septum dividing spherical body from foot chamber, septum entire. Single wall, 1µm thick, dark brown and opaque. Foot chamber having single wall < 1µm thick, pink and transparent. Spherical body 8µm diameter, foot chamber 2µm X 3µm.

If foot chamber was lost could be e.g., an ASM 001.

Occurrence: MODERN SAMPLES - HB91O.07.

Known comparative(s): None

Ecology: Recovered from a sample of bedding from a horse stable.

MOI 008 (Plate 9, fig. 10)

Description: Elongate, ellipsoidal, monoseptate, inaperturate spore with smooth to faintly scabrate surface. Septum transverse, median, 1.5µm thick, no septal plate visible. Spore outline constricted about median septum. Poles tapering to sharp apices. Single wall, < 1µm thick, brown. 28µm X 9µm to 47µm X 15µm.

Occurrence: MODERN SAMPLES - GC92F.12, GC91O.09, GC91O.12.

Known comparative(s): *Delitschia* Auersw. (1866)

Ecology: Herbivore dung, except for *D. canina* which grows on dog faeces (Ellis & Ellis 1988).

Recovered in this study from a barley field and from two samples within a pig house.

MOI 009

Description: Monoseptate, inaperturate spore with smooth surface. Amb constricted about median, transverse septum. Double walled. Outer wall thick, 1.5µm, brown. Inner wall 1.5µm thick, brown. Inner and outer walls apparently not in contact, at least 4µm apart. 35µm X 26µm by 26µm at median constriction.

Occurrence: MODERN SAMPLES - HB910.16.

Known comparative(s): None

Ecology: Occurring in a barley field.

MOI 010 (Plate 9, fig. 7)

Description: Oval, monoseptate, inaperturate spore with smooth surface. Septum transverse, median and having a large, 1µm diameter, central aperture. Occasional diseptate forms recovered. Both poles tapering to a blunt apex. Single wall, < 1µm thick, brown. 11µm X 7µm to 14µm X 11µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - BH04, BH11.

Known comparative(s): None

Ecology: Affinity unknown.

MOI 011 (Plate 9, fig. 12, fig. 13, fig. 14, fig. 15, fig. 16)

Description: Irregularly oval, monoseptate, inaperturate spore with striate surface. Septum transverse, median and entire. Occasional triseptate specimens recovered, having one median septum and one either side of the median. Double walled. Inner wall smooth and uniform, < 1µm thick, brown. Outer wall very fine and loosely covering inner wall making spore outline irregular. Outer wall contacting inner wall for short irregular distances along the longitudinal axis giving spore a slightly striate appearance. Outer wall < 1µm thick and hyaline to brown. 32µm X 15µm to 45µm X 24µm

Occurrence: ARCHAEOLOGICAL SAMPLES - L6119, BH04, BH05, BH07, BH08, BH11.

Known comparative(s): (Fr.) Fr. (1849). Similar in morphology to Type 140 of Van Geel *et al* (1983a) but specimens of this study were greater in size and contact between inner and outer walls in van Geel's Type 140 was for short distances both along the longitudinal and transverse axes. These differences could reflect interspecific variation.
Ecology: Occurring on wood, bark, stems and other fungi (Cannon *et al* 1985). Type 140 found by Van Geel *et al* (1983a) to be of regular occurrence in deposits formed under eutrophic wet conditions.

MOI 012 (Plate 9, fig. 11, fig. 18)
Description: Irregularly oval, monoseptate, inaperturate spore with granulate surface. Septum transverse, median and entire with central septal aperture < 1µm in diameter. Spore outline constricted about median septum. Poles varying from rounded to tapering. Occasional specimens bearing randomly located apertures 1µm in diameter. Single wall 1µm thick, brown. 30µm X 18µm to 35µm X 19µm.
Occurrence: ARCHAEOLOGICAL SAMPLES - BH11.
Known comparative(s): None
Ecology: Affinity unknown.

MOI 013 (Plate 9, fig. 21)
Description: Irregularly oval, monoseptate, inaperturate spore with reticulate surface. Septum transverse, median and entire. Spore outline constricted about septum. Reticulation uniformly distributed, luminae irregular but all < 1µm in diameter. Single wall 1.5µm thick, brown. 24µm X 15µm.
Occurrence: ARCHAEOLOGICAL SAMPLES - BH11.
Known comparative(s): Resembles *Reticellites houstonii* (Glass *et al* 1986), recovered from Middle and late Eocene strata of the Gulf Coast. However, differs from the above in size, the specimen from this study was smaller, and also in that a polar aperture was not observed. However, Glass *et al* mention that the aperture may not always be evident. Additionally, only one wall layer was evident in this specimen while the fossil specimens demonstrated two wall layers.
Ecology: Affinity unknown.

MOI 014 (Plate 9, fig. 19, fig. 20)

Description: Irregularly ellipsoidal, monoseptate, inaperturate spore with smooth walls. Septum transverse, median, 2µm thick; no septal plate. Amb consricted about median septum. Single wall < 1µm thick, brown. 46µm X 30µm to 49µm X 35µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - L6137.

Known comparative(s): None

Ecology: Affinity unknown.

MONOSEPTATE MONOAPERTURATE SPORES

Monoseptate, monoaperturate spores account for 1% of the fungal types encountered, 2 types in total. Neither of these are comparable to known taxa. 1 occurs only in modern samples, the other occurs only in archaeological samples.

MOM 001 (Plate 9, fig. 25)

Description: Oval, monoseptate, monoaperturate spore with smooth surface. Septum transverse, median; no septal plate apparent. Simple protruding aperture located at one pole. Aperture 1.5µm in diameter. Single wall, < 1µm thick, brown. 8µm X 6µm to 10µm X 6µm.

Occurrence: MODERN SAMPLES - GC91J.07.

Known comparative(s): None

Ecology: Recovered in a sample from a field under permanent pasture.

MOM 002 (Plate 9, fig. 22)

Description: Oval, monoseptate, monoaperturate spore with smooth surface. One pole umbonate and bearing simple, central aperture, 2µm in diameter. Septum transverse, median and having a simple, central aperture < 1µm in diameter. Single wall, 1.5µm thick., brown. 30µm X 20µm to 33µm X 19µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - B309.

Known comparative(s): *Brachysporium* Sacc. (1880).

Ecology: Species of *Brachysporium* typically occur on rotten wood or bark (Ellis 1966).

MONOSEPTATE DIAPERTURATE SPORES

2 monoseptate, diaperturate forms were recovered. 1 of these is comparable to a known fungal taxon. Both of them occur only in archaeological samples.

MOD 001 (Plate 9, fig. 23, fig. 24)

Description: Monoseptate, diaperturate didymospore with smooth walls. Asymmetrical. Each pole truncated; simple aperture, < 1µm in diameter located in the centre of each polar plate. Median transverse septum 1µm thick. Septal plate not apparent. Spore outline constricted about septum. Single wall 1µm thick, brown. 45µm X 16µm to 57µm X 20µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - L6084, L6097.

Known comparative(s): None

Ecology: Affinity unknown.

MOD 002

Description: Oval, monoseptate, diaperturate spore with faintly scabrate surface. Septum transverse, median and 1.5µm thick, no septal plate evident. Simple aperture, < 1µm in diameter located at each pole. Single wall, < 1µm thick, brown. Occasional specimens have apparently two walls, the outer wall being a very fine and incomplete periphragm. 31µm X 18µm to 36µm X 16µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - BH06, BH07, BH09, BH11.

Known comparative(s): *Delitschia* Auersw. (1866).

Ecology: Frequently found on herbivore dung. Exception *D. canina* which is found on dog faeces as well as on cow and sheep dung (Ellis and Ellis 1988).

DISEPTATE INAPERTURATE SPORES

Diseptate, inaperturate spores constitute 5% of the types encountered. Of these only 1 was comparable to a known fungal taxon. 7 occur only in modern samples while 4 occur only in archaeological samples.

DII 001

Description: Oval, diseptate, inaperturate spore umbonate at both poles, with smooth surface. One median septum and one septum located halfway between median septum and polar region. Septa < 1µm thick, septal plates not apparent. Single wall, < 1µm , brown. 8µm X 5µm

Occurrence: MODERN SAMPLES - HB91J.1/2.

Known comparative(s): None

Ecology: Recovered from a sample taken from a cow byre.

DII 002

Description: Elongated ovoid, diseptate, inaperturate spore with smooth surface. Septa transverse, entire, and located either side of the median. Single wall, < 1µm thick, brown. 19µm X 8µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - BH06.

Known comparative(s): None

Ecology: Affinity unknown.

DII 003 (Plate 10, fig. 1)

Description: Ovoid, diseptate, inaperturate spore with smooth surface. Septa located towards tapered pole. First septum 4µm from pole and 2µm thick, second septum 4µm behind first and < 1µm thick. Area between pole and first septum hyaline, rest of spore having single wall, < 1µm thick and brown. 32µm X 20µm.

Occurrence: MODERN SAMPLES - HB91J.11.

Known comparative(s): *Brachysporium* Sacc. (1880).

Ecology: Species of *Brachysporium* typically occur on rotten wood or bark (Ellis 1966). Recovered from a sample of mor humus.

DII 004 (Plate 10, fig. 7)

Description: Fusiform, dispetate, inaperturate spore with smooth surface. Tapered pole umbonate. Septa located either side of the median. Chamber between umbonate pole and first septum hyaline. Other chambers brown. Single wall, < 1µm thick. 17µm X 7µm.

Occurrence: MODERN SAMPLES - HB91J.11.

Known comparative(s): *Brachysporium* Sacc. (1880).

Ecology: Species of *Brachysporium* typically occur on rotten wood or bark (Ellis 1966). Recovered from a sample of mor humus.

DII 005

Description: Pyriform, dispetate, inaperturate spore with smooth surface. Septa, transverse, entire, < 1µm thick, and located towards narrow pole. Single wall, < 1µm thick, brown. 29µm X 14µm to 30µm X 15µm.

Occurrence: MODERN SAMPLES - HB91J.11.

Known comparative(s): None

Ecology: Recovered from a sample of mor humus.

DII 006 (Plate 10, 2)

Description: Ovoid, dispetate, inaperturate spore with scabrate surface. Septa transverse, < 1µm thick, no septal plates evident. Septa located away from tapered pole. Single wall, < 1µm thick, brown. 37µm X 18µm to 43.5µm X 18µm.

Occurrence: MODERN SAMPLES - ABPS1, ABPS2.

Known comparative(s): None

Ecology: Recovered from an outdoor pony and sheep midden.

DII 007 (Plate 10, fig. 3)

Description: Dispetate, inaperturate spore with smooth surface. Septa transverse, no septal plates evident, located either side of the median, 1µm thick. Both poles rounded. Single wall, 1-1.5µm thick, brown. 41µm X 19µm.

Occurrence: MODERN SAMPLES - JF91J.01.

Known comparative(s): None

Ecology: Recovered from the surface soil of a sheep pasture.

DII 008 (Plate 10, fig. 5)

Description: Irregularly fusiform, diseptate, inaperturate spore with smooth surface. Septa transverse, each one having a centrally located simple aperture < 1µm in diameter. Septa located either side of the median. Occasional specimens having only a single centrally located septum. Single wall, < 1µm thick, brown. 25µm X 10µm to 36µm X 13µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - BH04, BH11.

Known comparative(s): None

Ecology: Affinity unknown.

DII 009 (Plate 10, fig. 6)

Description: Ovoid, diseptate, inaperturate spore with smooth wall. Septa transverse, 1µm thick and having simple centrally located aperture. Septa located either side of the median. Single wall < 1µm thick in chamber between tapered pole and first septum and 1µm thick in other chambers, dark pink to brown. 21µm X 12µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - BH11.

Known comparative(s): None

Ecology: Affinity unknown.

DII 010 (Plate 10, fig. 4)

Description: Oval, diseptate, inaperturate spore with truncated apex. Tapering pole truncated. Septa transverse, 4µm thick and having a centrally located septal aperture. Septa dividing the spore into 3 chambers of equal length. Single wall, < 1µm thick, brown. 55µm X 34µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - BB81E13.

Known comparative(s): None

Ecology: Affinity unknown.

DII 011

Description: Ovoid, diseptate inaperturate spore with smooth surface. Septa transverse and in the form of shadow bands; one median septum and the other halfway between the median and the proximal pole. Mycelium still attached to the proximal pole, thereby indicating orientation of the spore. Single wall, < 1µm thick, brown. 24µm X 14µm to 30µm X 15µm (excluding mycelia).

Occurrence: MODERN SAMPLES - HB91J.11.

Known comparative(s): The dark coloured mycelium suggest that the spore is not germinating, therefore, this spore could be an apical conidium. This type is comparable to Type 10 of Van Geel (1972). Van Geel also considers it to be a conidiophore bearing a conidium.

Ecology: Found by Van Geel (1972, 1978b) to be associated with thin root fragments of Ericales, probably *Calluna vulgaris*. It is interpreted as an indicator of locally dry conditions, the drier the conditions the more conidia are liberated because of the decomposition of the roots. It is thought that it may also play a role in the process of root decomposition.

Recovered in this investigation from a sample of mor humus.

DISEPTATE MONOAPERTURATE SPORES

Diseptate, monoaperturate spores constitute 1.5% of the types encountered. Of these none are comparable to known taxa. 1 occurs only in modern samples while 2 occur only in archaeological samples.

DIM 001

Description: Subovoid, diseptate, monoaperturate, asymmetrical spore with smooth surface. Simple apical aperture located at apex of tapered pole, < 1µm in diameter. Septa transverse, 3µm thick, entire. Septa located either side of median. Single wall, 2µm thick, brown. 18µm X 11µm.

Occurrence: MODERN SAMPLES - HB91J.11.

Known comparative(s): *Brachysporium* Sacc. (1880).

Ecology: Species of *Brachysporium* typically occur on rotten wood or bark (Ellis 1966). Recovered in this investigation from a sample of mor humus.

DIM 002

Description: Fusiform, diseptate, monoaperturate spore with smooth walls. Pole bearing simple aperture tapered, opposite pole rounded. Aperture < 1µm in diameter. Septa transverse, located either side of median, < 1µm thick, septal plates not evident. Single wall, < 1µm thick, brown. 20µm X 8µm.

Occurrence: MODERN SAMPLES - HB91O.14.

ARCHAEOLOGICAL SAMPLES - BH06, BH08.

Known comparative(s): None

Ecology: Recovered from the soil of a field under permanent pasture.

DIM 003 (Plate 10, fig. 8)

Description: Ovoid, diseptate, monoaperturate spore with smooth wall. Septa transverse; one median septum and the other septum a few µm below the narrowest pole, pole truncated. Septal plates bearing a central septal aperture < 1µm in diameter. Simple aperture 2µm in diameter at narrowest pole. Compartment bearing aperture

hyaline, central compartment light brown, remaining compartment dark brown. Single wall, < 1µm thick. 12µm X 8µm to 12µm X 9µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - B39, T805/6B.

Known comparative(s): *Brachysporium* Sacc. (1880).

Ecology: Species of *Brachysporium* typically occur on rotten wood and bark (Ellis 1966).

TRISEPTATE INAPERTURATE SPORES

Triseptate, inaperturate spores constitute 6.5% of the types encountered. Of these 7 are comparable to known taxa. 4 occur only in modern samples, 4 occur only in archaeological samples while 4 are common to both.

TRI 001

Description: Oval, triseptate, inaperturate spore with scabrate surface. Septa transverse; one median septum and two septa to the same side of the median. Spore outline concave between median septum and septum directly above, rounding to the apex thereafter. Third septum 3µm below apex. Septa 1µm thick, septal plates not evident. Single wall, < 1µm thick, brown. 20µm X 11µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - BH07.

Known comparative(s): None

Ecology: Affinity unknown.

TRI 002

Description: Triseptate, inaperturate spore. Takes the form of two spheres connected at the median septum, each sphere has a small, up to 4µm diameter, chamber attached at pole opposite median septum. Peripheral chambers scabrate in appearance, central chambers smooth. Single wall, < 1µm thick, grey to brown. Central chambers ranging from 8µm to 13µm diameter.

Occurrence: MODERN SAMPLES - HB91J.1/2.

Known comparative(s): None

Ecology: Recovered, in this study, from a sample taken from a cow byre.

TRI 004 (Plate 10, fig. 10)

Description: Discoid, triseptate inaperturate spore with smooth surface. Circular outline interrupted by protruding ?hilar appendage which extends approximately 2µm beyond circumference and tapers to a point. One median septum which dissects the spore across the diameter, 2 radial septa, one each side of the median but arrangement irregular so radial septa do not meet in centre. Spore dissected into 4 approximately equal quarters.

Single wall 1µm thick, brown. 14µm diameter with ?hilar appendage extending 2µm beyond circumference.

Occurrence: MODERN SAMPLES - HB91J.11.

Known comparative(s): None

Ecology: Recovered from a sample of mor humus.

TRI 005

Description: Reniform, triseptate, inaperturate spore with smooth surface. Septa transverse, one median septum and one each side of the median. Peripheral septa sloping gently towards median septum and approximately equidistant from it. Single wall, < 1µm thick, brown. 15µm X 7µm.

Occurrence: MODERN SAMPLES - HB91J.11.

Known comparative(s): None

Ecology: Recovered from a sample of mor humus.

TRI 006 (Plate 10, fig. 17)

Description: Fusiform, triseptate, inaperturate spore with faintly scabrate surface. Spore outline constricted about septa. Septa transverse. All chambers approximately the same length, peripheral chambers tapering to a rounded apex. Single wall, < 1µm thick, pink to brown. 14µm X 5µm to 27µm X 8µm.

Occurrence: MODERN SAMPLES - HB92M.05, HB92M.16, HB91O.03, GC92F.01, GC92F.02, GC92F.09, GC92F.15, GC91O.01, ABP1, JF91J.05.

ARCHAEOLOGICAL SAMPLES - B309, BH08, BH11.

Known comparative(s): None

Ecology: Recovered from a range of modern samples with the only apparent common ecological denominator, being that of animal dung.

TRI 007 (Plate 10, fig. 11)

Description: Oval, triseptate, inaperturate spore with scabrate to microverrucate surface. One pole truncated, probably representing point of attachment to conidiophore. Septa transverse, regular; one median septum and one either side of median. Peripheral

chambers slightly longer than central chambers. Single wall, < 1µm thick, pink to brown. 15µm X 7µm to 22µm X 6µm.

Occurrence: MODERN SAMPLES - HB92M.05, HB91O.07.

ARCHAEOLOGICAL SAMPLES - BH01.

Known comparative(s): *Cladosporium* Link (1815).

Ecology: Recovered from leaves, stems and fruits, dead stumps, wood pulp, dead organic material, decaying leaves and stems with many species being plant pathogens. Some species have also been recovered from non-plant material e.g. *C. herbarum* also recorded from meat - Massee (1912) and Brookes and Hansford (1923) isolated this fungus from `Black spot' in frozen meat in cold stores. *C. sphaerospermum* has been isolated from diseased human nails and skin. Some species are `hyperparasites' i.e. they parasitise other fungi which are themselves also parasitic.

Recovered, in this study, from a sample of straw and from a horse stable.

TRI 008 (Plate 10, fig. 9)

Description: Triseptate, inaperturate spore with verrucate surface. Spore outline much constricted where septa intersect the circumference giving an overall clover shape. Septa radial and froming a Y shape. Single wall up to 1µm thick. Maximum diameter 13µm.

Occurrence: MODERN SAMPLES - HB92M.05.

ARCHAEOLOGICAL SAMPLES - B316.

Known comparative(s): None

Ecology: Recovered from a sample of straw.

TRI 009

Description: Discoid, triseptate, inaperturate spore with smooth surface. Septa arranged radially and forming a Y. Some constriction of spore outline where septa intersect the circumference. Septa 1µm thick. Single wall, < 1µm thick, brown. 16µm to 19µm in diameter.

Occurrence: MODERN SAMPLES - JF91J.03.

Known comparative(s): None

Ecology: Recovered from the surface soil of a barley field.

TRI 010 (Plate 10, fig. 13, fig. 14)

Description: Fusiform, triseptate, inaperturate spore with smooth surface. Symmetrical. All chambers approximately the same length. Septa. transverse, < 1µm thick, no septal plates visible. Central chambers brown and apparently thicker walled than peripheral hyaline chambers. All walls < 1µm thick. 29µm X 8µm.

Occurrence: MODERN SAMPLES - JF91J.03.

ARCHAEOLOGICAL SAMPLES - BH11.

Known comparative(s): *Chaetosphaerella* E. MÜller and C. Booth (1972).

Ecology: Frequently found growing on stromata of diatrypaceous fungi, especially *Diatrype stigma* and *Eutypa flavovirens* (Ellis and Ellis 1988).

Recovered, in this study, from the surface soil of a barley field.

TRI 012 (Plate 10, fig. 15, fig. 16, fig. 22)

Description: Elongate, triseptate, inaperturate spores with smooth surface. Asymmetrical, having one margin of the longitudinal axis almost straight. Median, transverse septum and two septa either side at equal distance from the median septum. Peripheral chambers approximately 2/3 the length of central chambers. Septa 2µm thick, no septal plates visible. Single wall 1µm thick, brown. 37µm X 14µm to 47µm X 15µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - BH04, BH04, BH05, BH06, BH07, BH11.

Known comparative(s): *Meliola niessleana*, *Meliola* Fr. (1825).

Ecology: Meliolaceae are obligate and oligophagous parasites on green plants (Hansford, 1961). *M. niessleana* is the only British species of *Meliola* and is associated with *Vaccinium vitis-idaea* (Dennis 1968), and Eriksson (1974) found *M. niessleana* associated with several species of *Vaccinium*. Van Geel (1978, 1988) found spores identified as *M. niessleana* associated with *Calluna vulgaris*. He suggested *that M. niessleana* or a closely allied species, or a physiological race slightly different from the recent ones, was probably a common parasite in peat bogs during the Atlantic to Subatlantic period (Van Geel 1978).

TRI 013 (Plate 10, fig. 19)

Description: Triseptate, inaperturate spores with faintly scabrate surface. Symmetrical. One median, transverse septum and two septa either side equidistant from the median, septa < 1µm thick. Septal plates not evident except occasionally in median septum where it is ruptured forming flaps. Spore constricted at median septum. Peripheral chambers < 1/2 length of central chambers and tapering sharply on both sides towards the poles. Central chambers only bearing ornament, peripheral chambers smooth. Single wall, < 1µm thick, brown. 42µm X 18µm to 46µm X 17µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - BH07, BH10.

Known comparative(s): None

Ecology: Affinity unknown.

TRI 014 (Plate 10, fig. 18)

Description: Ovoid, triseptate, inaperturate spore with smooth surface. One median septum and two either side. Septa equidistant from each other and having simple central aperture, < 1µm in diameter. Septa 1.5µm thick. Peripheral chambers, < 1/2 the length of central chambers. Single wall 2µm thick, brown. 67µm X 15µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - B316.

Known comparative(s): *Spadicoides* S. Hughes (1958).

Ecology: Species of *Spadicoides* have been recovered from the dead wood of various trees including Douglas fir, larch, oak, poplar and spruce; specimens seen from Czechoslavakia, Engand, France, Italy and U.S.A. (Ellis 1963).

TRISEPTATE MONOAPERTURATE

2 trispetate, monoaperturate spores were recovered. Neither of these have, so far, been comparable to known fungal taxa. Both of them occur only in archaeological samples.

TRM 001 (Plate 10, fig. 20)

Description: Elongate, triseptate, monoaperturate spore with smooth surface. Septa transverse, entire and located at irregular intervals across the longitudinal axis of the spore. Individual septa up to 1µm thick. Occasional specimens having 4 septa were recovered. Simple aperture, < 1µm in diameter located at narrowest pole. Single wall, < 1µm thick, brown. 19µm X 8µm to 26µm X 9µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - T814/1A, BH02, BH03, BH04, BH05, BH06, BH08, BH09, BH10, BH11, BH12.

Known comparative(s): None

Ecology: Affinity unknown.

TRM 002 (Plate 10, fig. 21)

Description: Triseptate, monoaperturate spore with smooth wall. Septa transverse, with centrally located septal apertures < 1µm in diameter. Individual septa up to 1.5µm thick. Spore outline constricted about septa. Specimens with only 2 septa were also recovered. Aperture chamber located at one pole. Chamber 4µm in diameter. Where chamber is absent spore appears inaperturate. Single wall, 2µm thick, brown. 30µm X 15µm to 40µm X 23µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - B309.

Known comparative(s): None

Ecology: Affinity unknown.

TRISEPTATE DIAPERTURATE SPORES

Only 1 triseptate, diaperturate spore was recovered it has not, so far, been comparable to known taxa. It occurs only in modern samples.

TRD 001 (Plate 10, fig. 23, fig. 24, fig. 25, fig 26)

Description: Trispetate, diaperturate spore with smooth surface. Septa transverse, one median and one each side of the median. Peripheral chambers 2/3 the length of central chambers. Single wall, < 1µm thick. Central cells brown, peripheral cells hyaline. 20µm X 11µm to 25µm X 15µm.

Occurrence: MODERN SAMPLES - HB91J.11, GC91J.07.

Known comparative(s): *Brachysporium* Sacc. (1880).

Ecology: Species of *Brachysporium* typically occur on rotten wood or bark (Ellis 1966). Recovered from a sample of mor humus.

MULTISEPTATE INAPERTURATE SPORES

Multiseptate inaperturate spores constitute 6.5% of the fungal types encountered, 14 types in total. Of these 8 are comparable to known fungal taxa. 10 occur in modern samples only, 2 occur in archaeological samples only while 2 are common to both.

MUI 001 (Plate 11, fig. 1)

Description: Fusiform, pentaseptate, inaperurate spore with rounded ends and a smooth surface. Septa transverse, no septal plates evident, 1µm thick; situated at irregular intervals across the longitudinal axis of the spore. Single wall, < 1µm thick, brown. 27µm X 8µm.

Occurrence: MODERN SAMPLES - GC91O.01.

Known comparative(s): *Helminthosporium* Link (1809).

Ecology: Occurs on dead stems, twigs and branches of herbaceous species (Ellis 1971). Recovered in a surface soil sample from a field under permanent pasture.

MUI 002 (Plate 11, fig. 5)

Description: Fusiform, hexaseptate, inaperturate spore with tapered ends and a smooth surface. Septa transverse, no septal plates evident, < 1µm thick; situated at irregular distances across the longitudinal axis of the spore. Single wall, < 1µm thick. 33µm X 5µm.

Occurrence: MODERN SAMPLES - HB91J.1/2.

Known comparative(s): *Stagonspora* (Sacc.) Sacc. (1884).

Ecology: Occurs predominantly of leaves and stems of *Carex* and *Phragmites* spp. (Ellis 1971).

Recovered from a litter sample taken from a cattle byre.

MUI 003 (Plate 11, fig. 2, fig. 3)

Description: Chain-like spore composed of individual chambers, rectangular in shape, each one measuring approximately 4µm in length by 5µm in width. Each chamber having dense covering of microechinae, < 1µm in height and width. Single wall, < 1µm, brown. Largest chain recovered consisting of 8 chambers.

Occurrence: MODERN SAMPLES - ABP1, ABP3, ABPS1, ABPS2, ABGS3, CA91G.07.

Known comparative(s): None

Ecology: Recovered from litter and midden deposits of the following animals; horses, sheep and goats.

MUI 004 (Plate 11, fig. 6, fig. 10, Plate 13, fig. 10)

Description: Spherical to pyramidal agglomeration of heterogenous cells, individual cells up to 7µm in diameter. Each cell having a single wall, < 1µm thick, hyaline to grey. Overall dimensions 22µm X 24µm.

Occurrence: ARCHAEOLOGICAL SAMPLES - BH03, BH08, BH10.

Known comparative(s): Bulbil type. Bulbils are commonly produced by the genera *Burgoa* and *Minimedusa*. The presence of colourless, raspberry-like balls composed without recognisable order of numerous small chambers that expand synchronously into individuated bubbles is immediately diagnostic of the genus Burgoa (Weresub & Leclair 1971). This description fits type MUI 004. Even when during active mycelium production, bulbils at any stage may become swathed in hyphae, their fundamental homogeneity and developmental process remain clear.

However, the breakdown in precision of the pattern for development of thallodic propagules is probably common in fungi and chains of indefinitely swollen chambers aggregating into more or less discrete propagules are known in groups besides *Burgoa*.

Resembles type MUP 003, (*Papulospora* type), but differs by having no structural differentiation between central and sheathing cells.

Ecology: Unknown.

MUI 005 (Plate 11, fig. 4)

Description: Club-shaped, inaperturate phragmospore, having a maximum of 7 septa. Septa may be entire, ruptured or in the form of shadow bands. Narrowest pole blunt ended, widest pole round ended. 39µm X 6µm.

Occurrence: MODERN SAMPLES - HB91J.1/2.

Known comparative(s): None

Ecology: Recovered from a litter sample taken from a cow byre.

MUI 006 (Plate 11, fig. 7)

Description: Club-shaped, inaperturate phragmospore having a maximum of 7 septa and a faintly scabrate surface. Spore outline often constricted about septa. Single wall, < 1µm thick, yellow to brown. 37µm X 9µm.

Occurrence: MODERN SAMPLES - HB91O.04.

Known comparatives: *Alternaria* Nees (1816).

Ecology: Occurs on leaves, stems, petals and seeds of a range of plants and has also been isolated from soil (Ellis 1976).

Occurring in a hay sample.

MUI 007 (Plate 11, fig. 13)

Description: Fusiform, inaperturate spore with 5 transverse septa. Septa entire, < 1µm thick and located approximately equidistant from each other along the length of the spore. Both poles rounded. One peripheral chamber slightly smaller than all the other chambers. Single wall, < 1µm thick, brown. 15µm X 6µm.

Occurrence: MODERN SAMPLES - GC91J.07.

Known comparative(s): *Bactrodesmium* Cooke (1883).

Ecology: Occurring on dead branches or wood (Ellis 1976).

Recovered in a surface soil sample in a field under permanent pasture.

MUI 008 (Plate 11, fig. 15)

Description: Multiseptate, inaperturate spore with verrucose surface. Spore consisting of 3 (-4) columns of 2 or 4 chambers. Each column terminating in a septate appendage. Septate appendages not bearing ornament but having smooth surface. Single wall, < 1µm thick, brown. 30µm X 14µm, excluding septate appendages which have broken and therefore accurate measurements cannot be recorded.

Occurrence: ARCHAEOLOGICAL SAMPLES - B310.

Known comparative(s): *Tetraploa aristata*, *Tetraploa* Berk. and Broome (1850). Type 89 of van Geel (1978).

Ecology: *T. aristata* is a widespread fungus usually found on leaf bases and stems just above the soil. Known host plants are *Ammophila*, *Carex*, *Cladium*, *Cyperus*, *Dactylis*, *Deschampsia*, *Juncus*, *Phaseoulus*, *Phragmites* and *Triticum* (van Geel 1978).

MUI 009 (Plate 11, fig. 8, fig. 9)

Description: Filiform, inaperturate, multiseptate spore with smooth surface. Septa transverse, entire and approximately equidistant from each other along length of the spore. Both poles rounded. Single wall, < 1µm thick, pink to brown. Variable numbers of septa on different spores. Specimens measuring up to 50µm in length and 5µm in width.

Occurrence: MODERN SAMPLES - HB92M.03, HB92M.05, HB91O.03, HB91O.04, HB91O.07, GC92F.03, GC92F.09, GC92F.15, GC91O.14.

ARCHAEOLOGICAL SAMPLES - B310.

Known comparative(s): None

Ecology: Recovered from a range of modern samples. All samples could have hay or/and straw incorporated in them.

MUI 011 (Plate 11, fig. 11, fig. 12)

Description: Oval, inaperturate, multiseptate spore with smooth surface. Recovered specimens had 5 transverse septa and some specimens had one longitudinal septum. Spore outline constricted slightly at transverse septa, which are located approximately equidistant from each other along length of spore. Longitudinal septum, when present, follows axis of spore but does not extend into peripheral chambers, peripheral septa mark boundary of longitudinal septum. Single wall, < 1µm thick, pink to brown. 13µm X 6µm to 16µm X 6µm.

Occurrence: MODERN SAMPLES - HB91O.04.

Known comparative(s): *Pleospora* Rabenh. ex Ces. and de Not. (1863). *Pleospora* spp. have been identified from the Dutch Holocene (Van Geel 1978), East African lake sediments (Wolf 1966a, 1966b) and from river deposits in Zambia (Elsik 1986).

Ecology: *Pleospora* spp. occur typically on dead plant remains (van Geel 1978). Recovered from a sample of hay.

MUI 013 (Plate 11, fig. 14)

Description: 5 to 7 chambered, inaperturate spore with smooth surface. Individual chambers gradually decrease in size towards one pole. The peripheral chamber is

significantly smaller to the others. Both peripheral chambers have rounded poles. Some septa may be represented by shadow bands. Single wall < 1µm. 23µm X 7µm to 32µm X 8µm.

Occurrence: MODERN SAMPLES - HB91O.03, HB91O.07.

Known comparative(s): None

Ecology: Recovered, in this investigation, from a sample of hay and from a horse stable.

MUI 016 (Plate 12, fig. 10, fig. 11)

Description: Subspherical, multiseptate, inaperturate sporocarp with smooth walls. Septa longitudinal and transverse, irregular; dissecting the surface into numerous heterogenous plates. Single-walled, 1µm thick, brown. Sporocarp containing numerous small spores of type ASI 014. Overall dimensions 62µm X 54µm.

Occurrence: MODERN SAMPLES - HB92M.05, HB91O.03, ABGS2, JF91J.01.
ARCHAEOLOGICAL SAMPLES - T810, T814/1A, BH01, BH06.

Known comparative(s): *Ampelomyces quisqualis*, *Ampelomyces* Ces. ex Schlecht. (1852).

Ecology: *A. quisqualis* is an example of a fungus which grows on another fungus. It is common on the mycelial mat of powdery mildews (Ellis & Ellis 1988), which themselves are plant parasites.

Recovered, in this study, from straw, hay, a goat and sheep byre and a sheep pasture.

MUI 018 (Plate 11, fig. 16, fig. 17; Plate 12, fig. 1, fig. 2)

Description: Ovoid, inaperturate spore, tri- to tetraseptate with umbonate poles and a scabrate surface. Septa transverse and entire. One median septum and one septum at each pole located at area of greatest constriction. One specimen was found having a fourth septum a few µm above one of the polar septa. Ornamentation scabrate to microverrucate and uniform in distribution. Single wall 1µm thick, brown. 45µ X 19µm to 54µ X 24µm.

Occurrence: MODERN SAMPLES - GC92F.02.

Known comparative(s): None

Ecology: Recovered from the soil of a field under permanent pasture.

MUI 020 (Plate 12, fig. 5)

Description: Pyriform, multiseptate, inaperturate spore with smooth surface. Septa predominantly transverse, with occasional longitudinal septum. Transverse septa located at regular intervals across the longitudinal axis of the spore. Longitudinal septa located at central longitudinal axis and not exceeding the boundaries of the transverse septa. Single wall, < 1µm thick, hyaline to pink. 27m x 8µm.

Occurrence: MODERN SAMPLES - JF91J.05.

Known comparative(s): *Alternaria* Nees (1816).

Ecology: Occurring predominantly on leaves, stems, seeds and flowers of a range of plants (Ellis 1976).

Recovered from the bedding in a cattle stall.

MULTISEPTATE MONOAPERTURATE SPORES

Only 2 multiseptate, monoaperturate types were encountered. So far, known comparatives have not been established for either of them. Both of them occur in modern and archaeological samples.

MUM 001 (Plate 12, fig. 3)

Description: Irregularly cymbiform, multiseptate, monaperturate spore with smooth walls. Recovered specimens possessed 9 septa. Septa transverse, entire and located at regular intervals across the longitudinal axis, individual septa up to 1µm thick. Annulate aperture 2µm in diameter located at apex; annulus 1µm thick. Single wall 1.5µm thick and thickening slightly at intersection with septa making spore outline irregular. 52µm X 9µm.

Occurrence: MODERN SAMPLES - HB92M.05, HB91O.03.

ARCHAEOLOGICAL SAMPLES - T814/1B, BH08.

Known comparative(s): None

Ecology: Recovered from a hay and a straw sample within this study.

MUM 002 (Plate 12, fig. 4)

Description: Cymbiform, multiseptate, monoaperturate spore with smooth walls. Specimens recovered possessed up to 6 septa. Septa transverse, entire and located at regular intervals across the longitudinal axis, individual septa up to 2µm thick. Simple aperture 3µm in diameter located at apex. Single wall, 2µm thick, brown. 58µm X 15µm to 95µm X 17µm. Overall dimensions appear to be proportional to number of septa.

Occurrence: MODERN SAMPLES - HB92M.12, HB91O.16, GC91O.09.

ARCHAEOLOGICAL SAMPLES - B309.

Known comparative(s): None

Ecology: All occurrences, in this study, were from soil samples from fields; two barley fields and one manured meadow.

MULTISEPTATE DIAPERTURATE SPORES

Only 2 multiseptate, diaperturate spores were encountered. One of them has only tentatively been assigned to this category as it was an incomplete specimen but had a characteristic morphology. Comparable known taxa have not, so far, been established for either of these types. Both of them only occur in modern samples.

MU?D 001 (Plate 12, fig. 7)

Description: Specimen incomplete but presumed to have two apertures. Multiseptate spore with smooth walls. Septa transverse, located at regular intervals across longitudinal axis. No septal plates evident. Polar region elongated and bearing simple aperture, 5µm in diameter. Single wall, < 1µm thick, brown. Overall length 40µm, overall width 13µm.

Occurrence: MODERN SAMPLES - HB91J.11.

Known comparative(s): None

Ecology: Recovered from a sample of mor humus.

MUD 002

Description: Fusiform, tetraseptate, diaperturate spore with smooth surface. Septa transverse, no septal plates evident. One septum located at 2µm to either side of the median, remaining septa located at 2 µm below each pole. Invaginate aperture, 1.5µm in diameter, located at each pole. Single wall, 1µm thick, brown. 13µm X 5µm.

Occurrence: MODERN SAMPLES - HB91J.11.

Known comparative(s): None

Ecology: Recovered from a sample of mor humus.

MULTISEPTATE POLYAPERTURATE SPORES

Only 2 multiseptate, polyaperturate spores were recovered. Both of these are comparable to known taxa. Both occur only in modern samples.

MUP 001 (Plate 12, fig. 8)

Description: Multiseptate, polyaperturate spore with faintly scabrate surface. Consisting of 4 septate columns; each column having 2 to 3 septa and terminating in an invaginate aperture, 3.5µm in diameter. Columns arranged in several planes but uniting in centre. Single wall, < 1µm thick, brown. ongest axis 40µm.

Occurrence: MODERN SAMPLES - HB91J.11.

Known comparative(s): *Asterosporium* Kunze (1819)

Ecology: Occurring on trees (Sutton 1980).

Recovered from a sample of mor humus.

MUP 003 (Plate 13, figs.8, 9, 11, 12)

Description: Multiseptate, multiaperturate body with a smooth surface. Consisting of a ball of chambers differentiated into a core of one to several enlarged, presumably germinable, central chamber(s), with wall more or less thickened and pigmented and surrounded by a sheath of chambers abruptly smaller and thinner-walled. In some specimens many of the chambers possess a simple aperture, < 1µm in diameter. Overall dimensions 48µm in maximum diameter.

Occurrence: MODERN SAMPLES - GC92F.09.

Known comparative(s): *Papulaspora* Preuss (1851).

Resembles type MUI 004, (Bulbil), but differs in the fact that in papulaspores there is a structural differentiation between central and sheathing chambers, such a structural differentiation is not evident in bulbils. Papulaspores are thallodic propagules i.e. pertaining to or belonging to a thallus. It is used to convey the idea that these propagules are produced by forms currently classifiable among Mycelia sterilia. It is a Form genus restricted to species producing papulaspores as recognsed by their early development whether or not central and sheathing chambers are distinguishable at maturity (Weresub & LeClair 1971).

Ecology: On wood, soil, litter and other substrates. (Carmichael *et al* 1980).

Recovered from a sample of surface soil from a winter barley field.

PHOMOID (Plate 13, fig. 6, fig. 7)

Description: This is a term used to describe agglomerations of small, round cells. Each cell has an average diameter of 9µm. Such cells are often found in isolation, and usually single cells and agglomerations and occur in the same sample. They have been so called because of their resemblance to the genus *Phoma* (Boerema 1976).

Occurrence: MODERN SAMPLES - HB92M.01, HB92M.07, HB92M.12, HB92M.14, HB91O.03, HB91O.14, GC92F.02, GC92F.11, GC92F.12, GC92F.14, GC91O.01, GC91O.05, GC91O.09, GC91O.11, GC91O.12, GC91O.14, ABP1, ABPS1, ABGS2, CA91G.02, JF91J.01, JF91J.03, JF91J.05.

ARCHAEOLOGICAL SAMPLES - B234, B310, B327, B341, T803, T803/6D, T805/4A, T810, T815, BB78ST4, BH03, BH04, BH06, BH08, BH10, BH11,

Ecology: Affinity unknown.

TORULOID FRAGMENT (Plate 13, fig. 2, fig. 3, fig. 4, fig. 5)

Description: This is a term which has been applied to fungal palynomorphs which take the form of long single rows of cells. In many cases it is not possible to ascertain whether these fragments represent spores or hyphae. To overcome this they have been collectively referred to as Toruloid Fragments because of their resemblance to the genus *Torula* (Crane & Schoknecht 1981).

Occurrence: MODERN SAMPLES - HB92M.02, HB92M.03, HB92M.05, HB92M.12, HB91O.03, HB91O.04, HB91O.07, HB91O.16, GC92F.02, GC92F.03, GC92F.09, GC92F.11, GC92F.14, GC92F.15, GC91O.01, GC91O.05, GC91O.09, GC91O.14, ABP1, ABP3, ABPS1, ABPS2, ABGS1, ABGS2, ABGS3, CA91G.02, CA91G.03, CA91G.05, CA91G.07, JF91J.01, JF91J.03, JF91J.05.

ARCHAEOLOGICAL SAMPLES - B234, B309, B310, B316, B327, B341, B402, L6119, T803, T803/6D, T805/4A, T810, T814, T814/1A, T814/1B, T814/1C, BB81E13, BH02, BH03, BH04, BH05, BH06, BH07, BH08, BH09, BH10, BH11,

Ecology: Affinity unknown

AGGREGATION (Plate 13, fig.1 (Aggregation), figs. 8, 9 (Papulospore), fig 10 (Bulbil), figs. 11, 12 (Papulospore))

Description: This term is used to describe aggregations of cells which appear to form a regular structure. Some forms initialy ascribed to this category were subsequently relegated to the categories of Bulbil and Papulospore.

Occurrence: MODERN SAMPLES - GC92F.12, GC92F.14, GC91O.01, GC91O.05, ABP3, ABPS2, ABGS1, ABGS3, CA91G.03, CA91G.05, CA91G.07, JF91J.05.

ARCHAEOLOGICAL SAMPLES - B234, B309, B310, B316, B316, B402, L6057, L6084, L6075, L6112, L6137, T810, T814/1B, BB78ST4, BB79E12, BB80S10, BH02, BH03, BH07, BH08, BH11,

Known comparative(s):

Ecology: Affinity unknown, except in the case of Papulospores (see MUP 003).

PLATES

(ALL SPECIMENS MAGNIFIED BY x1000)

Image 1. ASI 001

Images 2-6. ASI 002

Image 7. ASI 003

Image 8. ASI 004

Image 9. ASI 008

Image 10. ASI 009

Images 11, 15. ASI 010

Images 12-14. ASI 012

Image 16. ASI 015

Image 17. ASI 017

Image 18. ASI 014

Images 19-21. ASI 018

Image 22. ASI 019

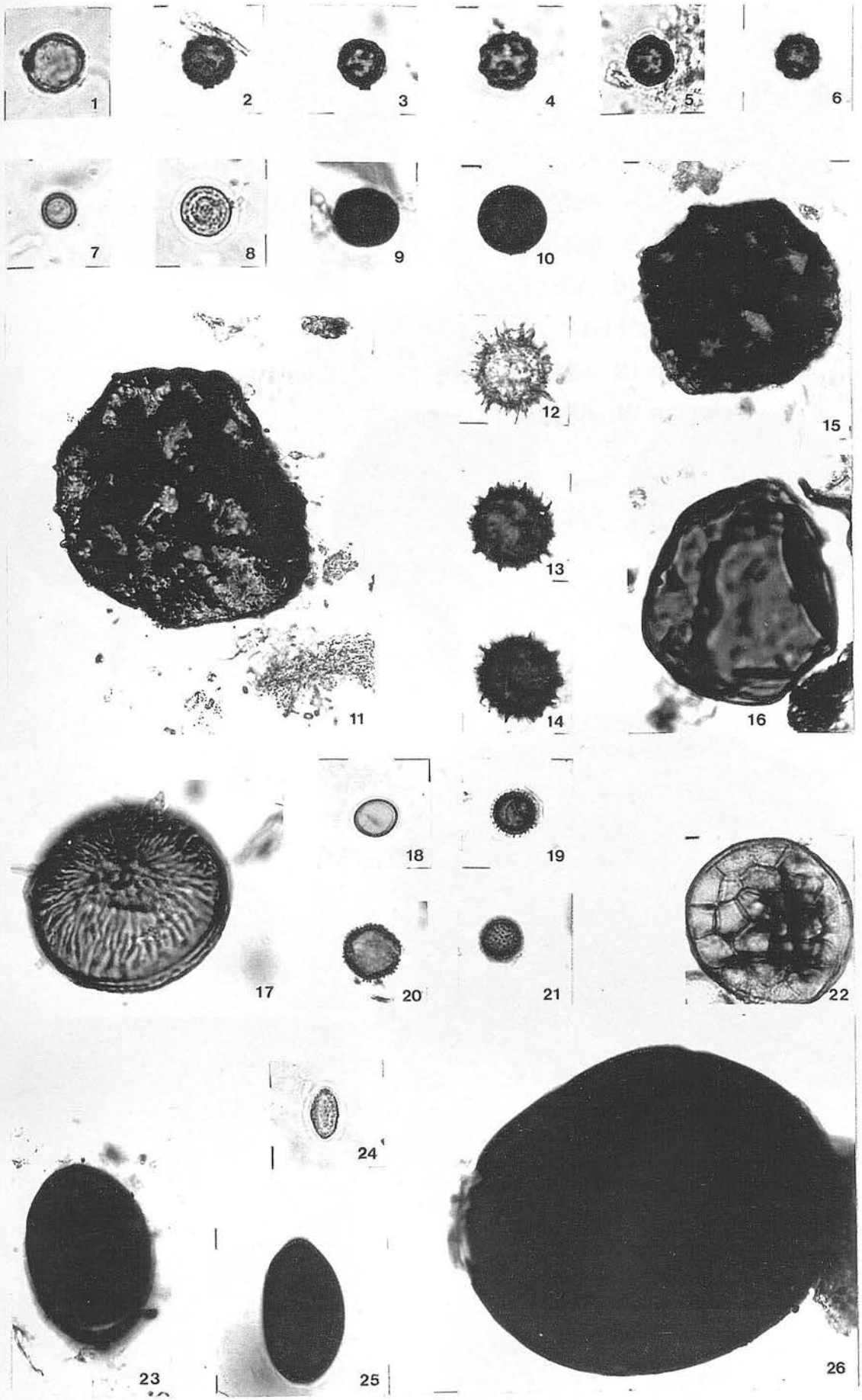
Image 23. ASI 037

Image 24. ASI 038

Image 25. ASI 039

Image 26. ASI 040.

PLATE 1



Images 1-6. ASI 020

Image 7. ASI 041

Image 8. ASI 042

Image 9. ASI 044

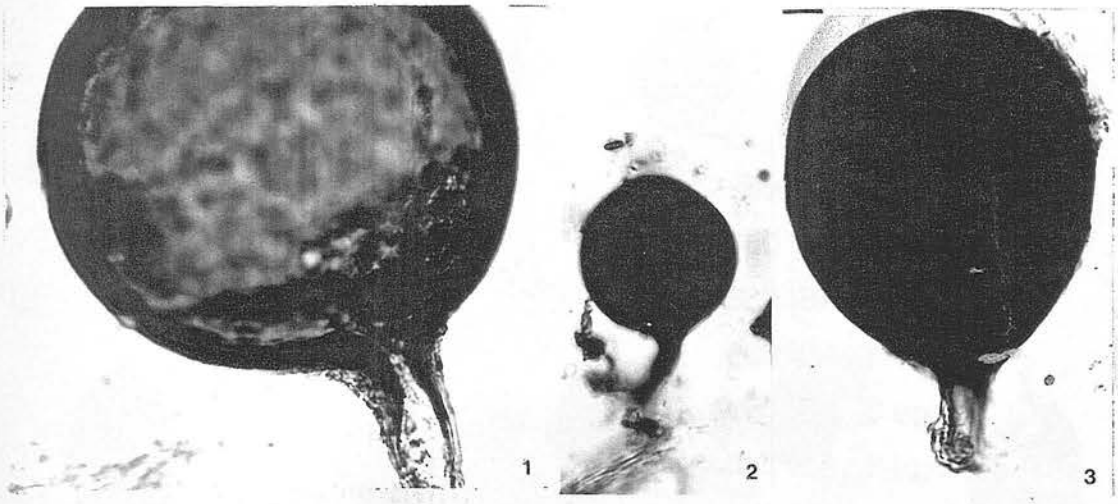
Image 10. ASI 049

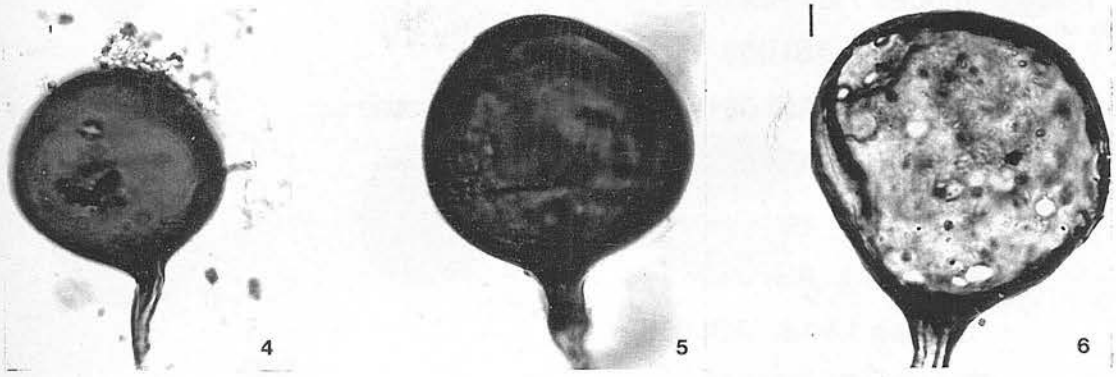
Images 11-12. ASI 043

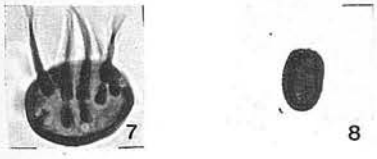
Image 13. ASI 047

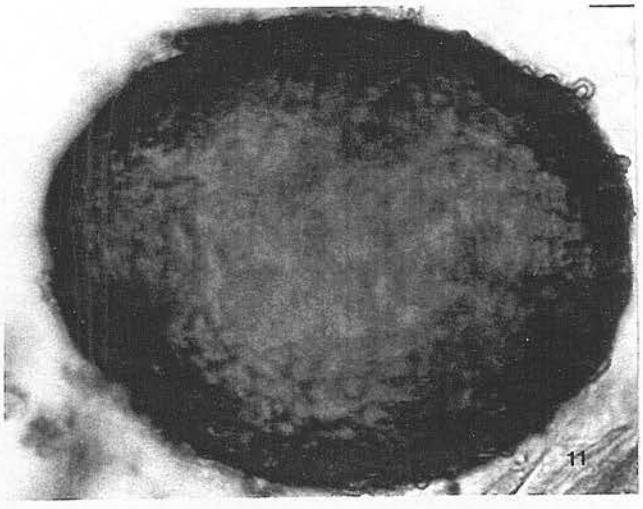
Image 14. ASI 048.

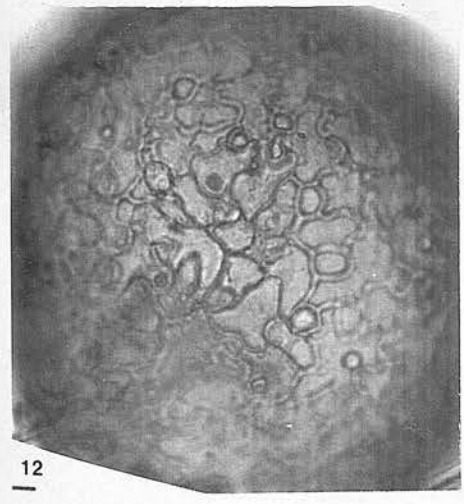
PLATE 2

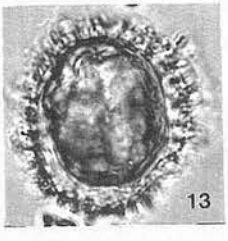












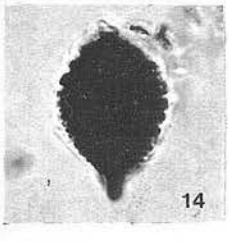


Plate 3

Image 1. ASI 052

Image 2. ASI 053

Image 3. ASI 058

Image 4. ASI 038

Image 5. ASI 059

Image 6. ASI 060

Images 7-8. ASI 062

Image 9. ASI 059

Image 10. ASI 061

Image 11. ASI 054

Image 12. ASI 067

Image 13. ASI 063

Images 14-18. ASI 068

Image 19. ASI 019

Image 20. ASI 070

Image 21. ASI 071

Image 22. ASI 072

Image 23. ASI 077

Image 24. ASI 078

Images 25-26. ASI 074

Images 27-28. ASI 076

Images 29,33. ASI 073

Images 30-32. ASI 075.

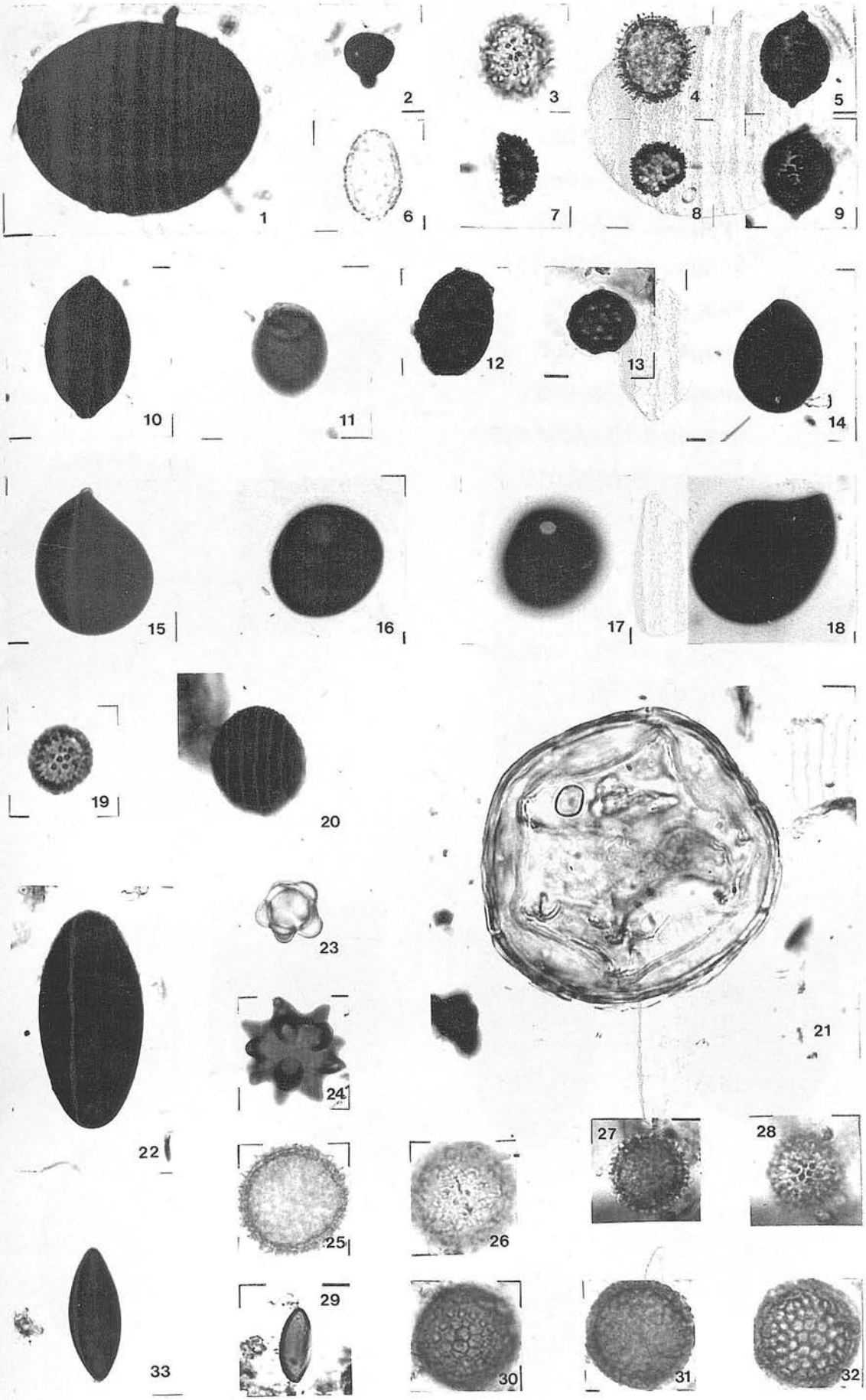

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Image 1. ASM 001

Image 2. ASM 002

Image 3. ASM 003

Images 4-5. ASM 004

Image 6. ASM 00

Image 7. ASM 006

Image 8. ASM 008

Images 9-10. ASM 009

Image 11. ASM 010

Images 12-13. ASM 011

Image 14. ASM 01

Image 15. ASM 007

Images 16-17. ASM 014

Image 18. ASM 015

Image 19. ASI 079

Image 20. ASM 020

Image 21. ASM 02

Image 22. ASM 026

Image 23. ASM 023

Image 24. ASM 024

Images 25-26. ASM 025.

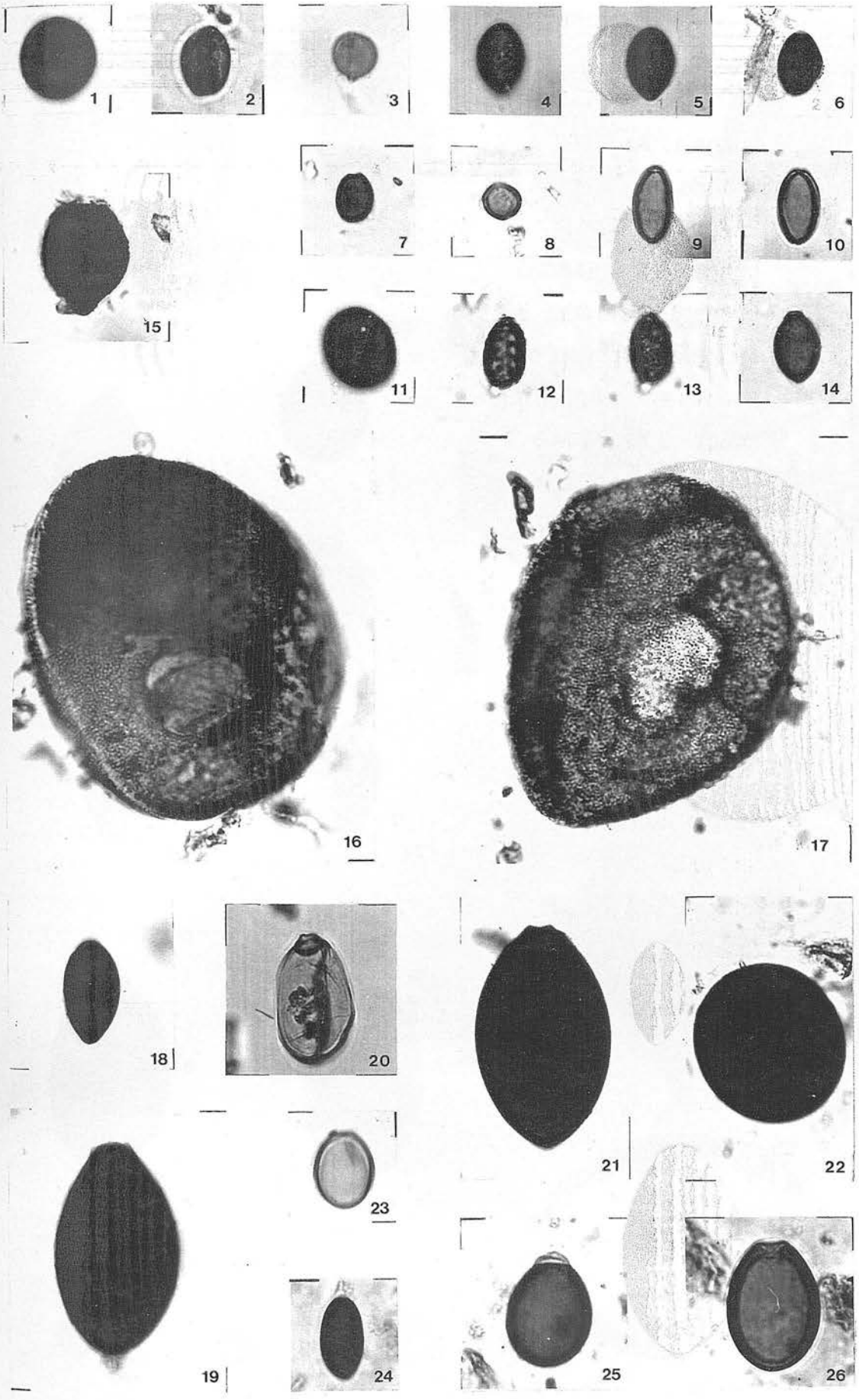
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Image 1. ASM 032

Images 2-4. ASM 29

Image 5. ASM 041

Images 6-7. ASM 035

Image 8. ASM 033

Images 9-10. ASM 044

Images 11-12. ASM 050

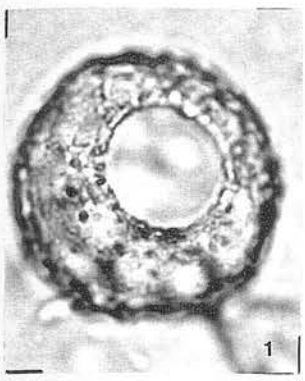
Image 13. ASM 043

Images 14-15. ASM 047

Image 16. ASM 027

Image 17. ASM 052.

PLATE 5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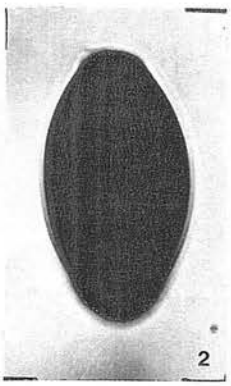
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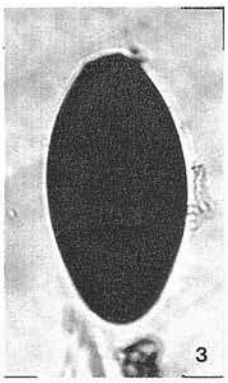
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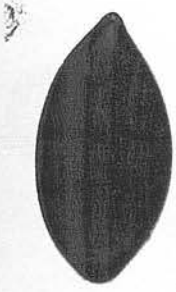
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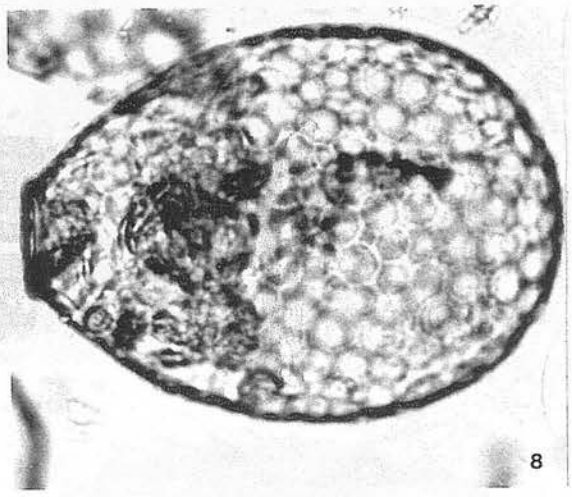
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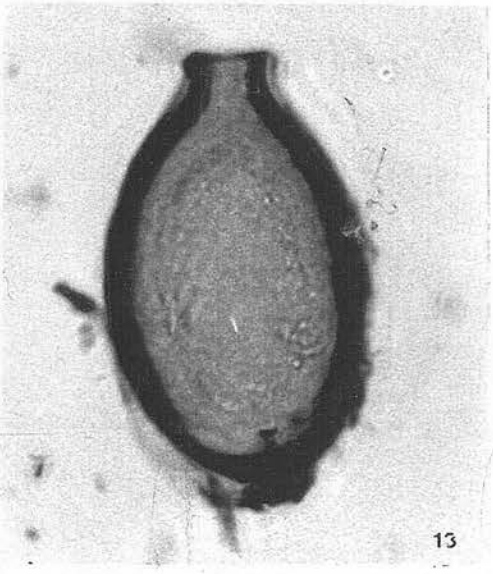
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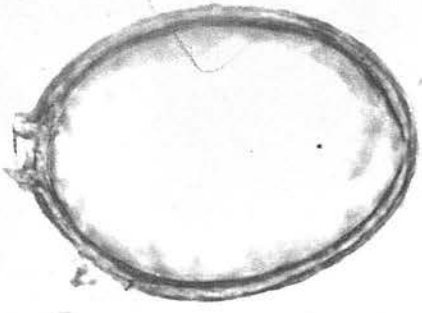
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Plate 6

Image 1. ASM 052

Image 2. ASM 051

Images 3-4. ASM 053

Images 5-6. ASM 054

Image 7. ASM 022

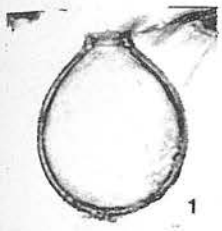
Image 8. ASM 016

Images 9-10. ASM 018

Images 11-12. ASM 045

Image 13. ASM 048.

PLATE 6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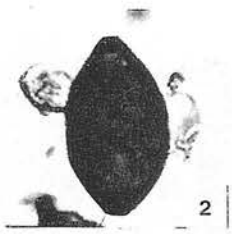
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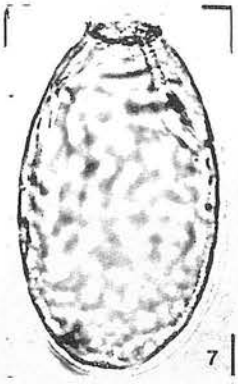
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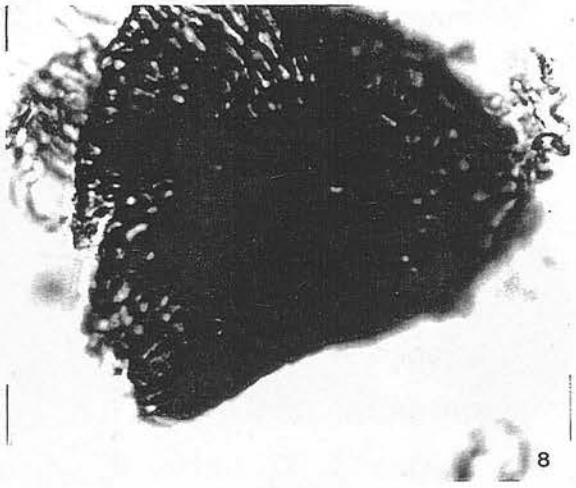
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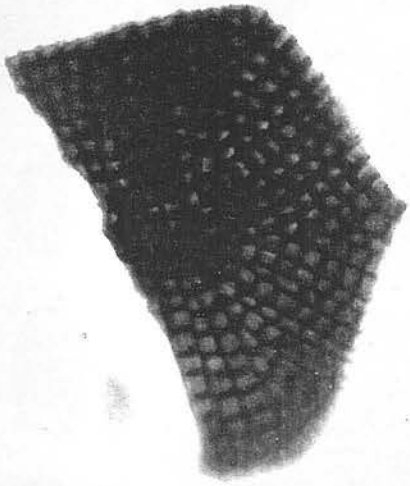
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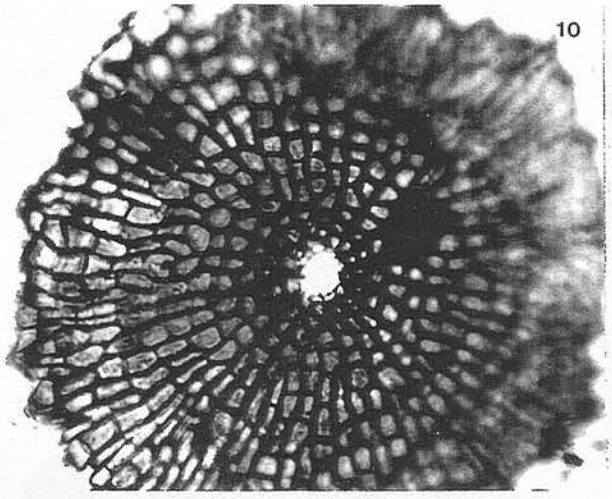
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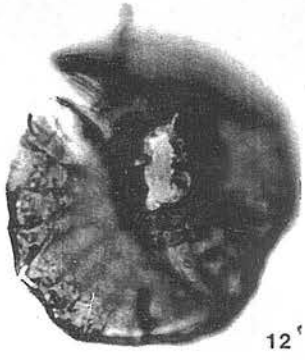
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Plate 7

Image 1. ASD 001

Image 2. ASD 002

Images 3-5. ASM 003

Images 6, 13. ASM 005

Image 7. ASM 012

Image 8. ASM 013

Image 9. ASM 010

Image 10. ASM 011

Images 11-12. ASM 009

Image 14. ASM 016

Images 15, 20. ASM 018

Image 16. ASM 008

Images 17-18. ASD 007

Images 19, 24. ASM 009

Images 21, 26. ASM 022

Images 22-23. ASM 022

Image 25. ASM 023

Image 27. ASM 021

Image 28. ASM 026

Image 29. ASM 027

Images 30-31. ASM 036

Images 32-33. ASM 030

Image 34. ASM 028.

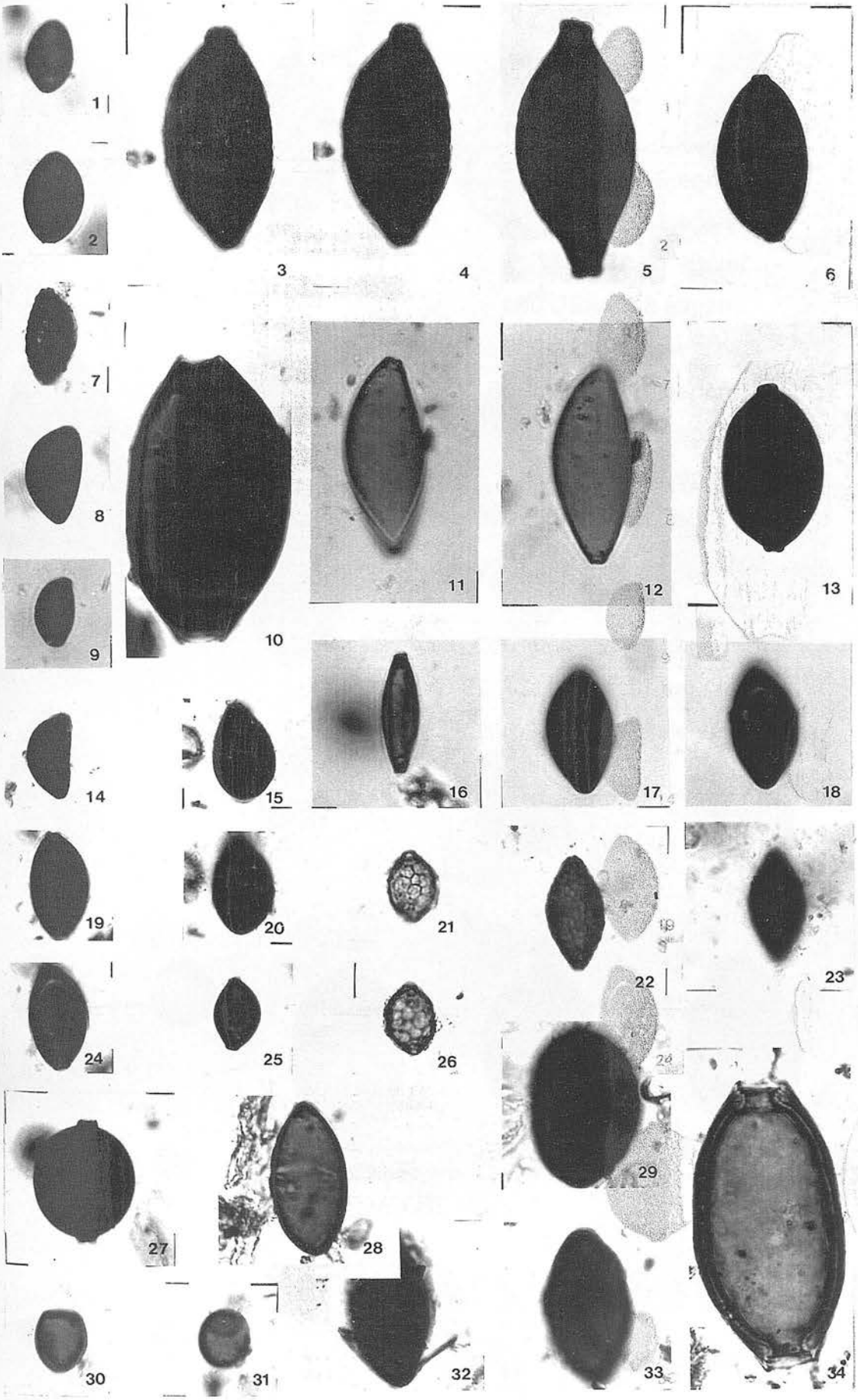
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Image 1. ASD 029

Image 2. ASD 02

Image 3. ASD 035

Image 4. ASD 037

Images 5-6. ASD 034

Images 7-8. ASD 033

Images 9-10. ASD 038

Image 11. ASD 031

Image 12. ASP 007

Images 13-14. ASP 008

Image 15. ASP 001

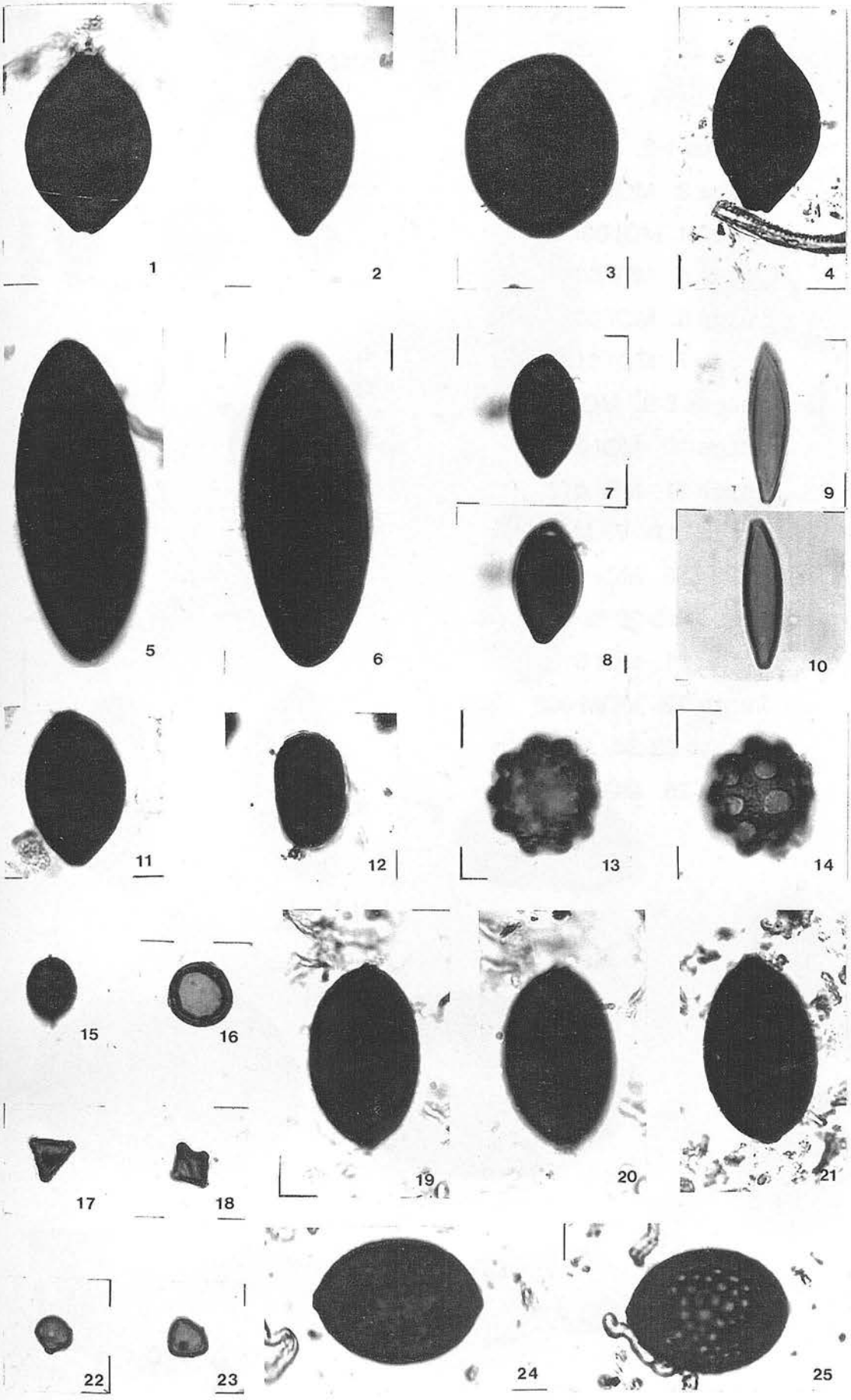
Image 16. ASP 005

Images 17-18. ASP 002

Images 19, 20, 21, 24, 25. ASP 006

Images 22-23. ASP 003.

PLATE 8



Images 1-2. ASP 010

Image 3. MOI 001

Image 4. MOI 004

Image 5. MOI 005

Image 6. MOI 006

Image 7. MOI 010

Images 8-9. MOI 007

Image 10. MOI 008

Image 11. MOI 012

Images 12-17. MOI 011

Image 18. MOI 012

Images 19-20. MOI 014

Image 21. MOI 013

Image 22. MOM 002

Images 23-24. MOD 001

Image 25. MOM 001.

PLATE 9

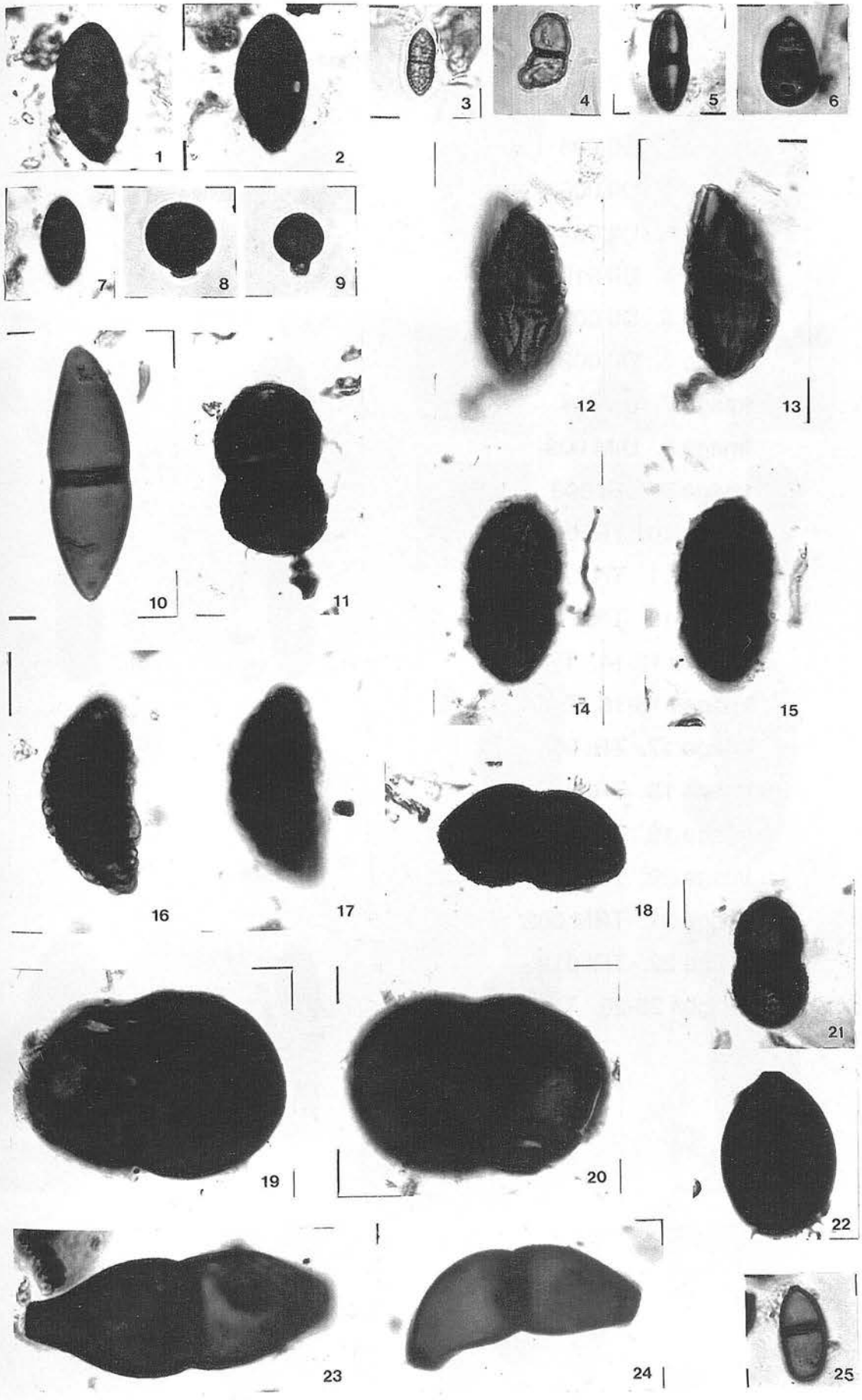


Image 1. DII 003

Image 2. DII 006

Image 3. DII 007

Image 4. DII 010

Image 5. DII 008

Image 6. DII 009

Image 7. DII 004

Image 8. DIM 003

Image 9. TRI 008

Image 10. TRI 004

Image 11. TRI 007

Image 12. TRM 001

Images 13-14. TRI 010

Images 15-16. TRI 012

Image 17. TRI 006

Image 18. TRI 014

Image 19. TRI 013

Image 20. TRM 001

Image 21. TRM 002

Image 22. TRI 012

Images 23-26. TRD 001.

PLATE 10

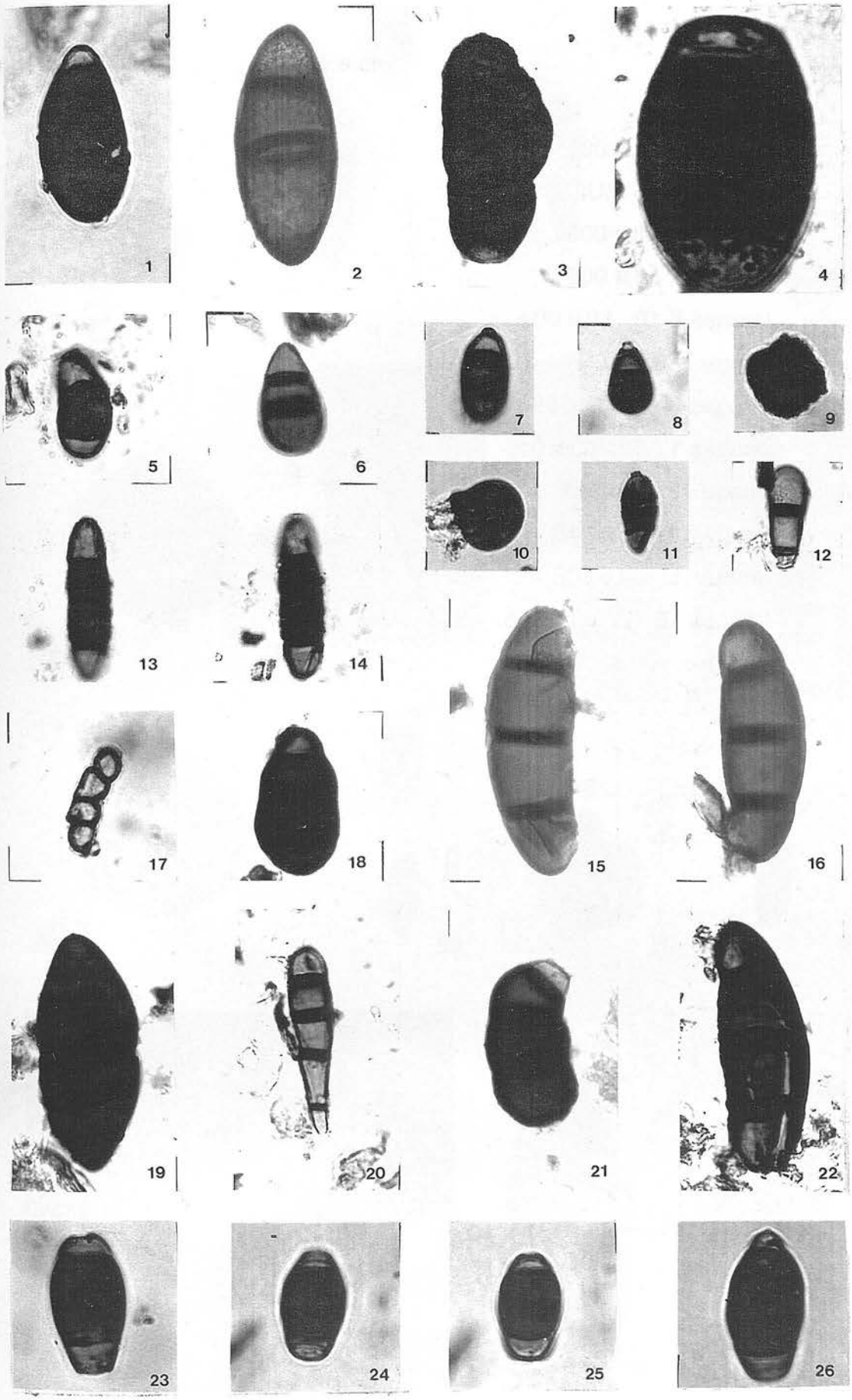


Plate 11

Image 1. MUI 001

Images 2-3. MUI 003

Image 4. MUI 005

Image 5. MUI 002

Images 6,10. MUI 004

Image 7. MUI 006

Images 8-9. MUI 009

Images 11-12. MUI 011

Image 13. MUI 007

Image 14. MUI 013

Image 15. MUI 008

Images 16-17. MUI 018.

PLATE 11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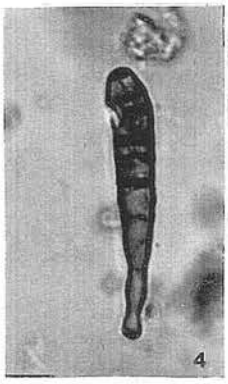
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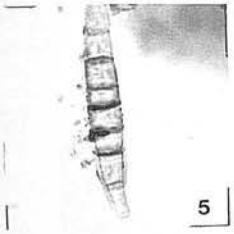
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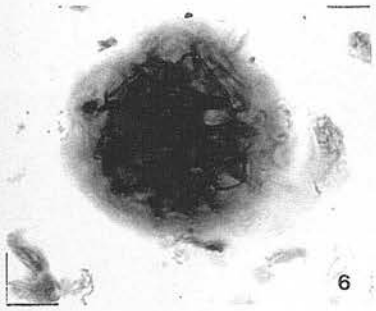
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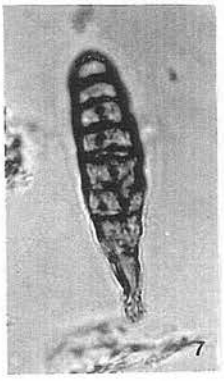
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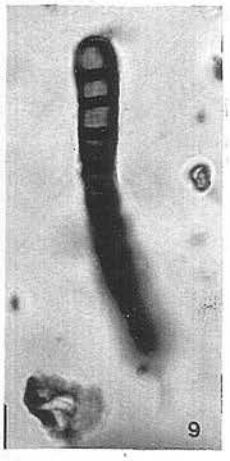
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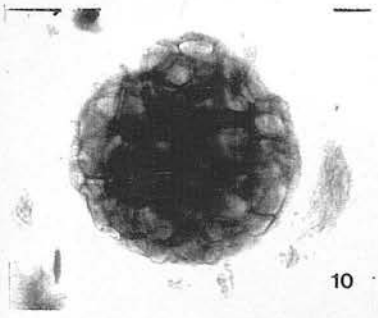
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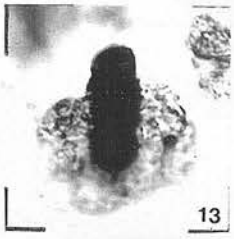
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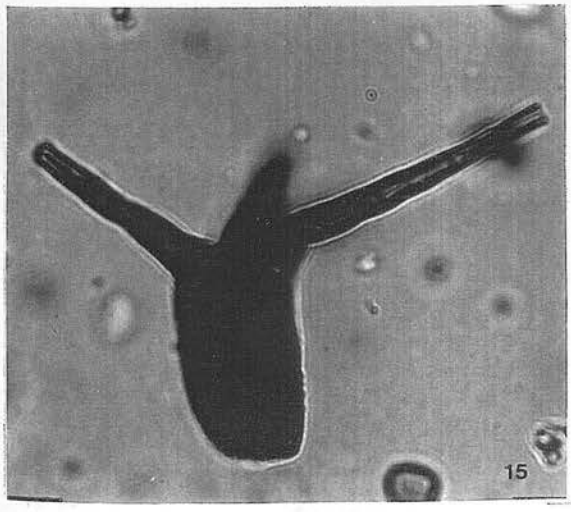
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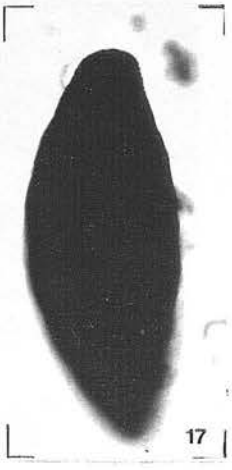

17

Plate 12

Image 1. MUI 018

Image 2. MUI 019

Image 3. MUM 001

Image 4. MUM 002

Image 5. MUI 020

Image 6. MUD 002

Image 7. MUD 001

Images 8 - 9. MUP 001

Images 10-11. MUI 016.

PLATE 12

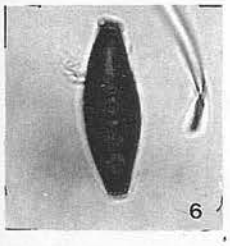

1


2


3


4


5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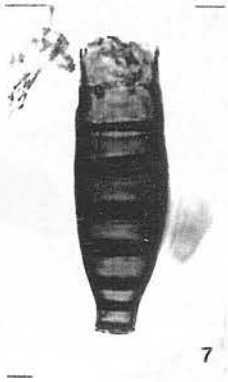
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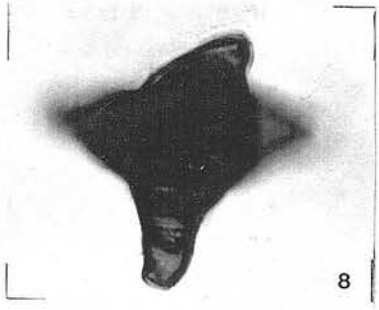
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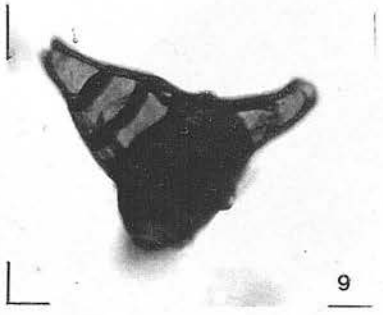
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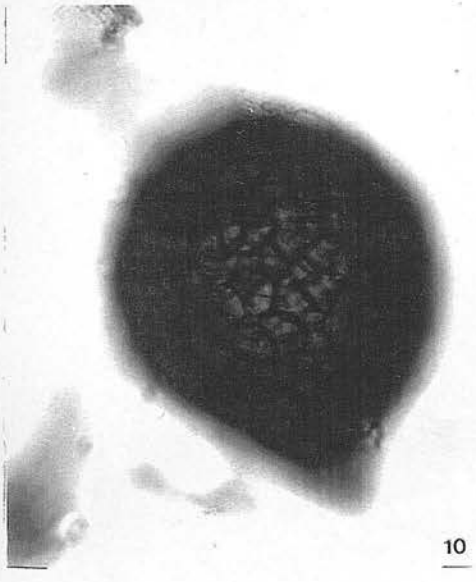
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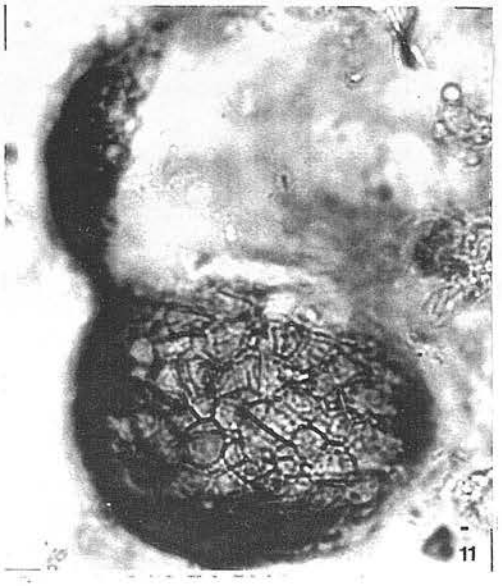

11

Plate 13

Image 1. Aggregation

Images 2-5. Toruloid fragments

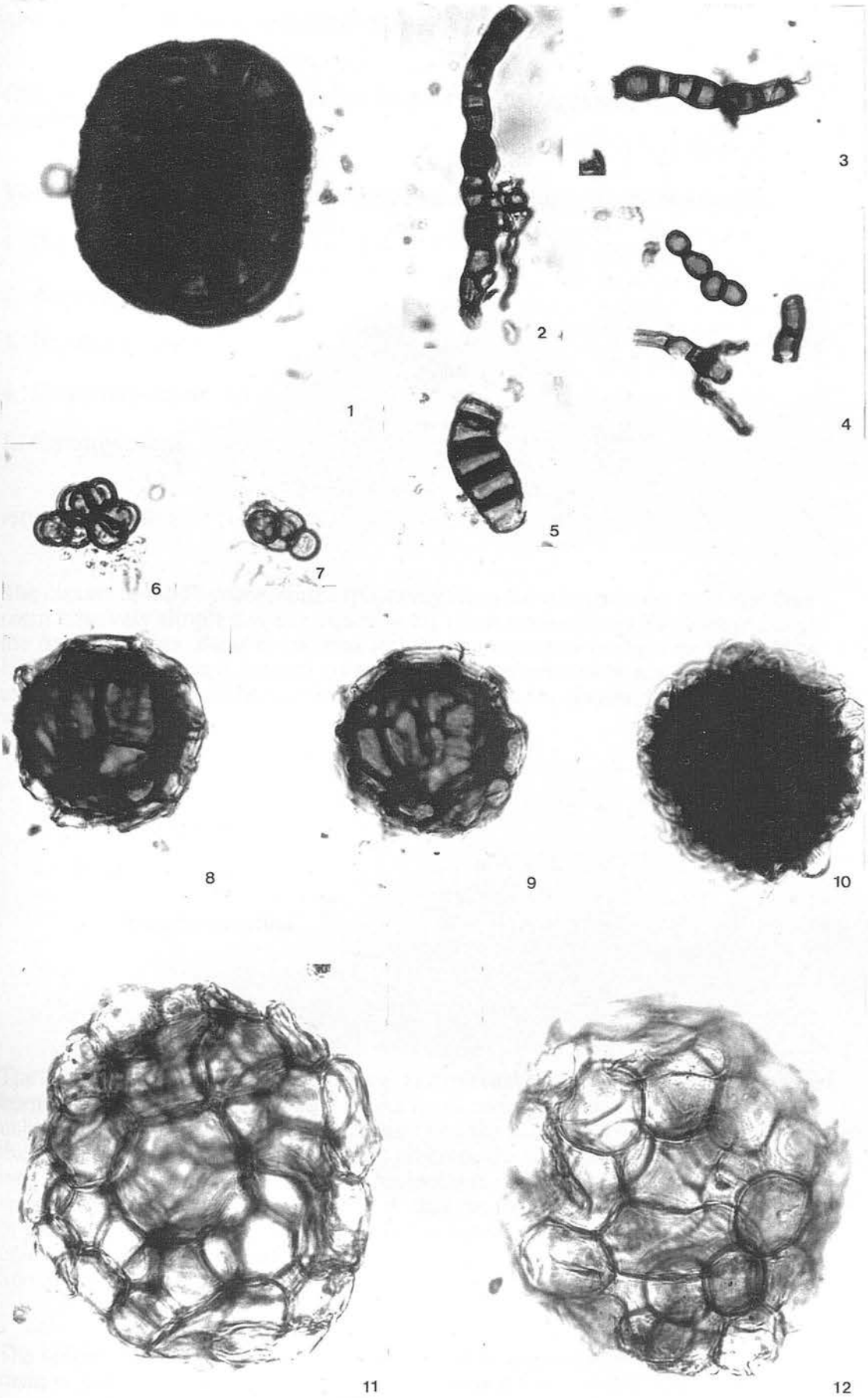
Images 6-7. Phomoid agglomerations

Images 8-9. Papulospore

Image 10. Bulbil

Images, 11-12. Papulospore.

PLATE 13



APPENDIX 1 - THE FUNGI AND SPORE PRODUCTION

Chapter One, Table 1.1. summarises the points of this appendix which are most significant to this study.

The Kingdom Fungi can be divided into five main classes. These classes are;

1. Phycomycotina
2. Ascomycotina
3. Basidiomycotina
4. Deuteromycotina
5. Myxomycotina

PHYCOMYCOTINA

The classes in the Phycomycotina (phycomycetes) have in common only that they seem relatively simple and consequently are often referred to as The Lower Fungi - the Ascomycotina, Basidiomycotina and Deuteromycotina being referred to as the Higher Fungi. There is general agreement that Phycomycotina is an unnatural assemblage and should be split into a number of smaller classes, the most important of which are:

1. Zygomycotina
2. Oomycotina
3. Chytridiomycotina

The Zygomycotina produce both sexual and asexual spores. The asexual spores are borne in sporangia which develop on the tip of sporangiophores - long and unbranched hyphae which grow in the air (a hypha is one of the filaments of the fungal thallus or mycelium). As development proceeds the tip of the sporangiophore swells into the incipient sporangium. In this, cytoplasm and nuclei accumulate and then the sporangium is delimited by a septum. Within the sporangium the multinucleate mass of protoplasm cleaves into a large number of equal portions in some species uninucleate but in most with several nuclei. These portions are the young spores - the Sporangiospores, each of which develops a surrounding wall.

The sexual spores are formed when two hyphae of opposite strains i.e. `+' and `-' form more or less equal gametangia which fuse to form a thick-walled Zygospore.

Some members of the Mucorales - one of the three orders recognised within the Class Zygomycotina - produce Chlamydospores. These are formed in an intercalary position as short, somewhat swollen portions delimited on either side by cross-walls. The chlamydospore is an asexual resting spore with a firm, resistant wall and a store of fatty reserve. Chlamydospores are perennating rather than disseminating in function.

The characteristic feature of Oomycotina is oogamous sexual reproduction with one or more eggs being formed in a spherical oogonium. The mycelium is non-septate with diploid nuclei and meiosis occurs in the developing oogonium and antheridium to give haploid sexual nuclei. The fertilized egg, Oospore, secretes a smooth, thickish wall and is a resting spore. This sexual behaviour in the production of oospores is typical but in some species a proportion of the oogonia contain oospores formed apogamously without the mediation of the antheridia.

Another feature of Oomycotina is that nearly all produce asexual spores that are Zoospores. A zoospore is a uninucleate spore without a cell wall which can exist only in water, where it swims by means of one or two flagellae. In Oomycotina the zoospores are always biflagellate. They are produced in zoosporangia - these are segments of the hyphae delimited by a basal cross-wall and containing a multinucleate mass of colourless protoplasm which eventually cleaves into a large number of naked uninucleate zoospores. When mature they are released and swim about for a period before encysting. It may emerge and form secondary or subsequent cysts (depending on the species), but at some point it will germinate like a normal fungal spore to establish a mycelium.

The characteristic feature of Chytridiomycotina is asexual reproduction by uniflagellate zoospores. In addition many form resting spores often associated with a sexual process.

It will be principally spores of the sexual stages of such fungi which will provide any insight as to the nature of palaeoenvironments. This is because spores of the asexual stages are often morphologically indistinctive, in addition to being less resistant than the more resilient resting structures.

ASCOMYCOTINA

The Ascomycotina (ascomycetes) is the largest class of fungi, if Ascolichens are included, and despite a considerable range of forms the class seems to be a natural one. Its' members are characterised by having Asci (singular ascus). The ascus is a special type of sporangium which usually contains eight ascospores. Development is highly distinctive - the young ascus has two haploid nuclei which fuse to form a diploid one. This undergoes meiosis forming four haploid nuclei each of which normally divides mitotically. Ascospores are organised around the individual nuclei but some protoplasm (epiplasm) is left outside the ascospores. At maturity the ascus bursts squirting its spores into the air.

A great many have an additional asexual means of reproduction by conidia - asexual spores. In some the accessory spore form has become dominant and the ascus stage is rarely formed.

Sexual ascospores are likely to provide the best source of palaeoenvironmental information. This is because they are generally morphologically more distinctive than spore of other classes of fungi (personal observation) and often have thick, dark walls. The pigments reponsible for wall colouration, often melanins, may provide resilience against degradation (Willets 1971, Bull 1970). In addition, within this study, they are the spores most commonly identifiable to known taxa and such fungi are often ecologically restricted.

BASIDIOMYCOTINA

Most of the large and conspicuous fungi found in fields and woods belong to the Basidiomycotina (basidiomycetes). The class also contains many microfungi including two large and economically important orders of obligate plant parasites:- rusts and smuts. The distinctive feature of this group is the Basidium (plural Basidia), a special type of sporangium which produces it's spores externally.

Mushrooms, shell fungi and puffballs are classified as homobasidiomycetes. these propagate by basidiospores borne externally on a club-shaped basidium. Rusts, smuts and also jelly fungi are also classified as heterobasidiomycetes.

Up to a point there is a close parallel between the development of the ascus and that of the basidium. The young basidium like the ascus has two haploid nuclei which fuse and the resultant diploid nucleus undergoes meiosis to give four haploid nuclei which pass into the developing basidiospores. The basidiospores, unlike the ascospores are produced externally.

Spores of the homobasidiomycetes are characteristically 1-celled, globose, angular to sausage-shaped with walls smooth or ornamented by projections ranging from fine echinulations to coarse lobes. They are asymmetrical, a reflection of their mode of dispersal. Graham (1962) considered basidiospores to be potentially useful both mycostratigraphically and in palaeoenvironmental studies, and illustrated their morphological variability amongst modern samples. However, despite their abundance in the present day they do not figure prominently in the fossil record (Pirozynski 1976). Many are hyaline and thin-walled and are readily destroyed by acetolysis (Graham 1962). It is likely that on the whole they will provide less palaeoecological information than spores of the ascomycetes. However, it is hoped that spores of the heterobasidiomycetes such as plant pathogenic fungi may be detected. There is reliable evidence of ancient rust spores from Cretaceous and late sediments (Popov 1959, Bradley 1931, Ramanujan and Ramachar 1963, Wolf 1969b, Popov and Rybakova 1970, Benes and Kraussova 1963).

In addition, quite a number form additional asexual spores - conidia.

DEUTEROMYCOTINA

The Deuteromycotina also known as Fungi Imperfecti or deuteromycetes include the species of fungi for which there is no known sexual stage so that they cannot be placed with confidence in other classes. Most reproduce by conidia although others are purely mycelial developing no spores. Such forms are referred to as Mycelia sterilia. Purely conidial fungi are thought to be represented by ascomycetes and basidiomycetes which have lost the ascus or basidium stage completely or in which it has not yet been discovered.

Similar spore morphologies in this class are often common to many taxa and it is unlikely that such spores will be informative as palaeoenvironmental indicators. Often the classification of taxa is dependent, in part, on the mode of spore production and therefore it is not the spores *per se* but rather the way in which they are produced which is of taxonomic significance. The mode of spore production may be reflected in the spore morphology but it is unlikely that this will provide sufficient information for any degree of taxonomic precision.

Palaeoecological information from spores of this class is dependent, as with all spores, on the more morphologically distinct taxa many of which occur on plant material, for example *Tetraploa aristata* and *Alternaria* spp.

Some fungi may have more than one imperfect state.

MYCETOZOA

The slime moulds or mycetozoa all have in common a uninucleate amoeboid stage in their lifecycle from which can develop a multinucleate or multicellate stage which can in turn give rise to a fruiting body containing dormant spores. The fruiting body resembles those produced by the lower fungi and this combination of protozoan and fungal characteristics is the cause of much taxonomic confusion. There are two main forms of slime moulds; the acellular slime moulds and the cellular slime moulds. The lifecycle of the acellular slime moulds comprises a unicellular amoeboid stage, a multinucleate plasmodium stage and a sporulation stage. The processes by which the amoebae form plasmodia differs for different species and are in many cases unknown. The stimuli which lead the plasmodium to form fruiting bodies also differ in different species although lack of food and changes in light intensity are often important. The fruiting bodies are dry, brittle and immobile structures which contain thousands of uninucleate spores, each of which is surrounded by a thick cell wall which renders it resistant to drought. The spores can be readily dispersed by wind and rain. When moistened each spore germinates to give rise to a uninucleate amoeba which feeds on bacteria, grows, multiplies and thus completes the lifecycle.

The Cellular Slime Moulds (Acrasiales) resemble the Myxomycetes in having a microscopic amoeboid phase in their lifecycle but these amoebae never fuse to form a multinucleate plasmodium. Instead when food sources are depleted they converge about a central point to form a multicellular aggregate often referred to as a `pseudoplasmodium' or `grex'. The grex is motile with a definite shape and after a period of time stops moving, rounds up and develops into a fruiting body. The component cells of the grex become either the stalk or the spore cells of the fruiting bodies. The spores like those of the Myxomycetes are surrounded by a thick cell wall, which renders them resistant to desiccation and are dispersed by wind and rain. The

life-cycle is completed when each spore germinates in the presence of bacteria to give rise to another amoeba.

Mycetozoan spores are not frequently recovered and the existing fossil records of such spores are inconclusive. Pirozynski (1976) believes that the Carboniferous spores identified as being of the myxomycetes by Cash and Hick (1879) and Renault (1896), show insufficient detail for identification. Graham (1971) considers spores of the slime moulds to be morphologically distinctive and sufficiently resistant to persist into the fossil record, while Martin and Alexopoulos (1969) are of the opinion that such spores are not morphologically distinctive. In brief, there is much confusion about the morphology and palynological potential of these spores. It is likely that myxomycete spores and spores of some basidiomycetes such as Lycoperdon spp. could easily be confused. Distinction would be dependent on detection of sterigmata for confirmation of the basidiomycete status. However, if the sterigmata was lost through fossilisation or processing then distinction between the two types of spore would be impossible. Future resolutions are dependent on the close collaboration of palynologists and mycologists.

APPENDIX 2 - SAMPLE REFERENCES AND SUMMARY INFORMATION.

More detailed information on samples is available in Chapter Four. This Appendix serves as a quick reference guide.

MODERN SAMPLES

1. HB92M.01	Floor of winter cattle byre.
2. HB92M.02	Floor of winter cattle byre.
3. B92M.03	Hay from floor of covered hay store.
4. HB92M.05	Well-rotted straw from floor of straw store.
5. HB92M.07	Bedding from horse stable.
6. HB92M.12	Surface soil from manured meadow.
7. HB92M.14	Surface soil from permanent pasture field.
8. HB92M.16	Surface soil from barley field.
9. HB910.01	Floor of winter cattle byre.
10. HB91O.03	Hay from floor of covered hay store.
11. HB91O.04	Hay from floor of covered hay store.
12. HB91O.07	Bedding from horse stable.
13. HB91O.14	Soil from permanent pasture field.
14. HB91O.16	Surface soil from harvested barley field.
15. HB91J.1/2	Floor of winter cattle byre.
16. HB91J.11	Mor humus from deciduous woodland.
17. GC92F.01	Surface soil from permanent pasture field.
18. GC92F.02	Surface soil from permanent pasture field.
19. GC92F.03	Surface soil from wheat field.
20. GC92F.09	Surface soil from winter barley field.
21. GC92F.11	Debris from hen house floor.
22. GC92F.12	Debris from pig house with concrete floor.
23. GC92F.14	Debris from pig house with earth floor.
24. GC92F.15	Soil from pigs yard.

25. GC91O.01	Surface soil from permanent pasture field.
26. GC91O.05	Surface soil from harvested oat field.
27. GC91O.09	Surface soil from harvested winter barley field.
28. GC91O.11	Debris from hen house floor.
29. GC91O.12	Debris from pig house with concrete floor.
30. GC91O.14	Debris from pig house with earth floor.
31. GC91J.09	Soil from pasture field.
32. ABP1	Deep litter from highland pony byre.
33. ABP3	Deep litter from highland pony byre.
34. ABPS1	Outdoor midden, highland pony and sheep.
35. ABPS2	Outdoor midden, highland pony and sheep.
36. ABGS1	Deep litter from goat and sheep byre.
37. ABGS2	Deep litter from goat and sheep byre.
38. ABGS3	Deep litter from goat and sheep byre.
39. CA91G.02	Surface soil from abandoned crop field.
40. CA91G.03	Surface soil from abandoned crop field.
41. CA91G.05	Surface soil from abandoned crop field.
42. CA91G.07	Surface soil from small, ungrazed enclosure.
43. JF91J.01	Surface soil from sheep field.
44. JF91J.03	Surface soil from barley field.
45. JF91J.05	Bedding from cattle stall.
46. JF91J.06	Hay from hay shed floor.

BB78ST4	From rim of construction trench inside building.
BB79E12	From turf packing in internal posthole.
BB80S10	From internal posthole.
BB81E13	From turf in outer wall.
BH1	3 - 4 cm interval from core.
BH2	7.5 - 8.5 cm interval from core.
BH3	11 - 12 cm interval from core.
BH4	14 - 15 cm interval from core.
BH5	20 - 21 cm interval from core.
BH6	27 - 28 cm interval from core.
BH7	36 - 37 cm interval from core.
BH8	39 - 40 cm interval from core.
BH9	42 - 43 cm interval from core.
BH10	44 - 45 cm interval from core.
BH11	47 - 48 cm interval from core.
BH12	50.5 - 51.5 cm interval from core.
B39	Tentative stored hay deposit.
B48	Tentative byre deposit.
B234	Sample external to archaeological enclosure.
B309	Tentative mouldy, stored hay deposit.
B310	Tentative byre floor deposit.
B316	Tentative mouldy, stored hay deposit.
B327	Indicators of animal dung and sheep present.
B402	Tentative byre deposit.
L6014	Internal sediment, occupation spread.
L6029	Secondary hearth, ash spread.
L6050	Early internal sediment, occupation spread.

L6057	Occupation spread, rake-out.
L6073	Early hearth debris
L6075	Secondary hearth debris.
L6084	Central drain, soil spread.
L6097	Central, soil spread.
L6108	Primary central drain, soil spread.
L6109	Early internal sediment, soil spread.
L6112	Threshold drain, soil spread.
L6119	Central drain soil spread.
L6129	Possible floor surface, soil spread.
L6137	Occupation spread, soil layer.
T805	From pit at Tuquoy.
T803/6C	From pit at Tuquoy.
T803/6D	From pit at Tuquoy.
T808/8	From pit at Tuquoy.
T804	From pit at Tuquoy.
T805/4A	From pit at Tuquoy.
T805/6B	From pit at Tuquoy.
T805/7	From pit at Tuquoy.
T806	From pit at Tuquoy.
T808	From pit at Tuquoy.
T810	From pit at Tuquoy.
T813	From pit at Tuquoy.
T814	From pit at Tuquoy.
T814/1A	From pit at Tuquoy.
T814/1B	From pit at Tuquoy.
T814/1C	From pit at Tuquoy.
T815	From pit at Tuquoy.

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