TITLE

The Palynology, Palynofacies and Palaeoenvironment of the early Cretaceous Weald clay of Southeast England.

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THE PALYNOLOGY, PALYNOFACIES AND PALAEOENVIRONMENT OF THE EARLY CRETACEOUS WEALD CLAY OF SOUTHEAST ENGLAND

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FRONTISPIECE

class REPTILIA
subclass ARCHOSAURIA
order ORNITHISCHIA
suborder ORNITHOPODA
family IGUANODONTIDAE (Huxley 1869)

IGUANODON

(= IGUANOSAURUS, SPHENOSPONDYLUS, THEROSAURUS.)

(RIGHT FEMUR)

Specimen collected from
Redlands Brick Company Beare Green pit, Surrey, England,
31 July 1979

1. Anterio-left lateral aspect.
2. Left (inside) lateral aspect.
3. Right (outside) lateral aspect.
4. Posterior aspect.

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THE PALYNOLOGY, PALYNOFACIES AND PALAEOENVIRONMENT OF THE EARLY CRETACEOUS WEALD CLAY OF SOUTHEAST ENGLAND

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ABSTRACT

This study attempts to show that cluster groupings of rock samples based on spore/pollen content in the Weald Clay represent particular palaeoenvironments. Palynofacies defined for such cluster groupings appear to bear some relationship to actual palaeoecological communities of parent plants that formed the flora of the Weald Clay braidplain. The relationship appears to be stronger using cluster groups derived from presence/absence data, rather than percentage frequency data. Both these types of cluster groups were combined in a matrix to define further groups based on both methods. Such groups can be called palynofacies. They have been found to be independently characterised by particular lithologies, kerogen types and algal assemblages, suggesting that they do represent fidelity to a biocoenosis of parent plants. Consideration of factors such as the occurrence of marine and aquatic freshwater elements, and spore/pollen diversity, have allowed the palynofacies to be related to a palaeoenvironmental trend, partly controlled by salinity. Pioneer plant communities near the strandline, intermediate communities,and mature, species-rich communities of drier uplifted areas nearer to the sediment source-lands, can be recognised.

Once palaeoenvironmental parameters have been attached to particular palynofacies, samples can be placed back in stratigraphic order to plot a depositional environmental sequence for each sample locality. In the case of the Warnham samples, a marine transgression has been indicated followed by gradual regression by braidplain progradation. This is probably a cyclic pattern and offers a different interpretation from that presently accepted. The accepted Wealden cyclothem suggests that a cycle commenced with renewed alluvial inflow into the basin due to rejuvenation of the source-lands, followed by gradual marine transgression as clastic supply into the basin slowly diminished with erosion of the source.

A broad correlation of two cores from Chailey has been achieved, using the palynofacies sequence of each.

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THESIS LAYOUT

This thesis is mainly a palynofacies study of the Weald Clay,using data generated by a cluster analysis computer programme of spore/pollen data. The cluster groupings generated are interpreted in terms of palaeoenvironments during the Early Cretaceous deposition of the Weald Clay.

Chapter One introduces the geology of the Wealden Series, giving particular emphasis to palaeoenvironmental conclusions obtained from a variety of published sources. Chapter Two leads straight in to the quantitative (multivariate) and qualititative (binary) methods of data collection and analysis, and provides detailed descriptions of the palynofacies characteristics of the derived cluster groupings. Brief palaeoenvironmental conclusions are given as appropriate on the binary and multivariate data with these descriptions. Chapter Three is reserved for the main palaeoenvironmental conclusions obtained by combining the binary and multivariate data to produce a series of numbered palynofacies. These palynofacies are then used to interpret the palaeoenvironmental sequence at each sampled locality. Chapter Four provides for the taxonomy of all the various palynomorph types. Descriptions are not exhaustive as this study is not intended to be taxonomic, but allows palaeoenvironmental parameters to be discussed for each taxon. Chapter Five are conclusions.

A series of appendices is included at the end dealing with biostratigraphy of the Weald Clay, reworked palynomorphs, corrosion patterns of palynomorphs, fluorescence characteristics, and insect debris encountered during routine logging of Weald Clay samples. The appendices make use of the derived palynofacies defined during the course of the study, where possible.

CHAPTER 1 INTRODUCTION

1.1 GEOLOGICAL INTRODUCTION

1.1 (a) General historical background

The history of palaeontological studies of the Wealden rocks goes back a long way. In the early 1800's Mantell was amassing large collections of vertebrate bones, but at this time the number of recorded fossil plant species was very low. Palynology had barely begun at this time. The publication in 1838 by Ehrenberg of descriptions of Cretaceous palynomorphs in flakes of flint from Germany was one of the very earliest ever palynological publications. The Rufford collection of fossil plants was acquired by the British Museum of Natural History and was described by Seward in the late 1800's and early 1900's, which significantly raised the number of described plant taxa. More recent work on Wealden palaeobotany has been carried out by Watson (1969), Hughes (1975a,b), Harris (1976, 1981) and Alvin (1971, 1974, 1982).

Other fossil plant remains in the form of rootlet beds and plant debris beds, yielding cuticle fragments, have been described from the Wealden rocks (Batten,1968 and Oldham,1976). Microfossil plant remains in the form of megaspores have been described and used in stratigraphy and palaeoenvironments, (Dijkstra ,1951 ; Hughes,1958 ; Batten, 1969, 1974).

Palynology is the study of miospores, dinoflagellate cysts, fungal spores and comminuted plant debris in the form of kerogen fragments. This is the basis of the present study, and has a fairly wide and up to date literature for the Wealden, both as stratigraphic and palaeoenvironmental studies, following numerous papers by Hughes, Hughes & Moody-Stuart, Norris & Batten. Early Cretaceous palynology papers including some on 'Wealden' facies from other parts of the world have been published by Brenner, Dörhöfer, Singh, Dettmann, Cookson & Eisenack, Pocock, Kemp, Delcourt, Playford, Couper, Debout, Srivastava and many others. Lists of all these papers with year of publication are too numerous to include here, but many of the important ones are summarized below.

The Wealden rocks have yielded good ostracod assemblages that have been studied by Anderson (1940, 1967, 1985) and Kilenyi & Allen N.W. (1968).

The Wealden rocks also have an extensive literature on sedimentology largely by virtue of numerous papers by Allen, P published between 1948 and 1981 (see bibliography) as well as work by Taylor (1963), Kirkaldy (1939, 1947), Macdougal & Prentice (1964) and Stewart (1981). Ideas on the sedimentological setting of the Wealden rocks in these papers have changed from lacustrine to deltaic to 'braidplain' at present. The latest concept of a braidplain is followed in the present study as this interpretation is favoured by the data in this study.

Outside of the type area of the Weald, Late Jurassic/Early Cretaceous freshwater-brackish 'Wealden facies' are recognised from many areas in Europe; Germany, Holland, France, Denmark, Sweden and Spain. Also other parts of the world; U.S.A., Brazil, The Cameroons, Gabon, Canada, Manchuria, Mongolia, Lebanon, Algeria, Tunisia, Ghana, Angola and Nigeria.

In 1953 Couper produced a monograph of Cretaceous and Tertiary spores and pollen from New Zealand, one of the first modern postwar biostratigraphical and palaeoenvironmental studies on palynomorphs of this age. Couper (1958) extended these studies to the British Mesozoic. Balme (1957) described spores and pollen grains from the Mesozoic of Western Australia. Cookson & Dettmann (1957) described Early Cretaceous spore assemblages from Eastern Australia. Cookson (1958, 1959, 1961) provided additional palynostratigraphic and taxonomic information on the Early Cretaceous of Australia. Early Cretaceous spores were described from Germany by Weyland & Greifeld (1953). Wealden facies were first examined for spores and pollen by Delcourt & Sprumont (1955). Hughes (1958) first attempted to date the English Wealden by palynological correlation with the Early Cretaceous of Lincolnshire and the Netherlands. Pocock (1962, 1964) described in detail the Late Jurassic/Early Cretaceous spores and pollen of the Western Canada plains, comparing them with sections in Europe and Australia. Brenner (1963) described in detail Early Cretaceous spores from Maryland, the first such study published in the U.S. . Papers by Döring (1964, 1965, 1966) added to descriptions of Early Cretaceous palynomorphs. Döring (1965, 1966) subdivided the Wealden of Germany into seven zones based on miospore content, Dettmann (1964) monographed Early Cretaceous microfloras from S.E.Australia. Burger (1966) described Jurassic/Cretaceous palynomorphs from the Netherlands. Singh (1964, 1971) described in detail the microfloras from East-central and North-west Alberta. Hughes & Moody-Stuart (1966, 1967, 1969) and Hughes & Croxton (1973) developed a new method of describing schizaeaceous spores of the genus Cicatricosisporites, termed biorecords, from both Early Cretaceous plant fructifications and dispersed spores from the English Wealden, for improved biostratigraphical correlation. Norris (1967) described Early Cretaceous spores and pollen from Central Alberta. Norris (1968, 1969) looked at palynological assemblages across the Jurassic/Cretaceous boundary in Southern England. Further Early Cretaceous spore assemblages from Southern England were described by Kemp (1970) and from Saskatchewan and Manitoba by Playford (1971). Burger (1976) described new Early Cretaceous miospore taxa from Queensland, Australia. Papers by Batten (1973 a, b, 1974) described palynological assemblages from the English Wealden and employed palynofacies analysis within the Hastings Beds sediments. Dörhofer & Norris (1977) examined possible evolutionary lineages within Jurassic/Cretaceous palynofloras. Recently further stratigraphic data on Early Cretaceous miospores has been provided by Batten (1978, 1984), Dörhofer (1979), Srivasta (1981) and Bebout (1981).

1.1(b) The age and stratigraphic setting of the Wealden Group

The Wealden Group, comprising the Hastings Beds Formation overlain by the Weald Clay Formation, is the major sedimentary pile laid down during the Early Cretaceous of Southern England. It ranges in age from the Late Ryazanian to top Barremian (Hughes,1958; Rawson,et al,1978) and Southern England is the type area of it. The underlying Purbeck formation is considered to be Ryazanian in age. The Weald Clay itself is thought to encompass all of the Hauterivian and Barremian (text-fig.1.2).

The Weald Clay is conformably overlain by the Lower Greensand (Aptian), the boundary marked by bored non-sequence. The Hastings Beds overlie conformably the Purbeck, but with no well defined non-sequence leading to difficulty in precise location of the boundary (Allen,1955). The Purbeck/Wealden boundary lies just above the Jurassic/Cretaceous boundary.

The withdrawal of the Jurassic sea was not uniform; periodic transgressions occurred within the overall regression. One of these is marked by the mid Purbeck cinder bed of Dorset, thought to originate from the transgression of a northern sea. This may correlate with the Whitchurch Sands, 75 miles away along the west outcrop of the Cretaceous. Casey(1963) considered a nodule bed separating the Lower and Upper Spilsby sandstone a correlative of this, though it is now considered to be younger. The cinder bed is now generally taken to indicate the Jurassic/Cretaceous boundary (Rawson & Riley,1982; Wimbledon & Hunt,1983).

The change from the Jurassic to the Cretaceous, though gradual, was quite profound, involving a regional regression to leave large areas of dry land and isolated marine basins as well as swampy areas of varying brackish/freshwater. The regional stratigraphic control provided by ammonites in the Jurassic was therefore lost; what isolated marine areas remained developed their own provincial faunas. While the Wealden basin became brackish/freshwater, the province to the north of the London-Brabant Massif (Londinia, sensu Allen, P.) became boreal marine (Snettisham Sea sensu Allen,P.) known as the Spilsby Basin of Lincolnshsire and Norfolk, accumulating shallow marine deposits (Spilsby Sandstone and Sandringham Sands). Further north from the Spilsby Basin, across the Market Weighton swell, another marine basin accumulated the Speeton Clay sequence at this time. Casey (1962 a, b & 1963) has shown from a study of Craspedites ammonite faunas, that the Spilsby Sandstone commenced deposition during the Portlandian(Late Jurassic) and boreal conditions including the Tealby Series overlying the Spilsby Sandstone existed up to and including the Aptian. The sequence is very condensed compared to the Purbeck and Wealden, however. In North Yorkshire the Speeton Clay succession (c. 300') forms a quite different facies of shallow marine clays that represents a very slow sedimentation rate despite the presence of many non-sequences, spanning the entire Early Cretaceous.

The Wealden beds of the type locality are not necessarily of uniform age. For instance around the edge of the basin the top of the Wealden Group is younger than in the centre, with the overlying beds also being younger in age; Late Aptian on the southern edge of the London Platform and Middle Aptian in Dorset. Wealden outliers around Oxford and Swindon are Late Wealden or Early Aptian in age.

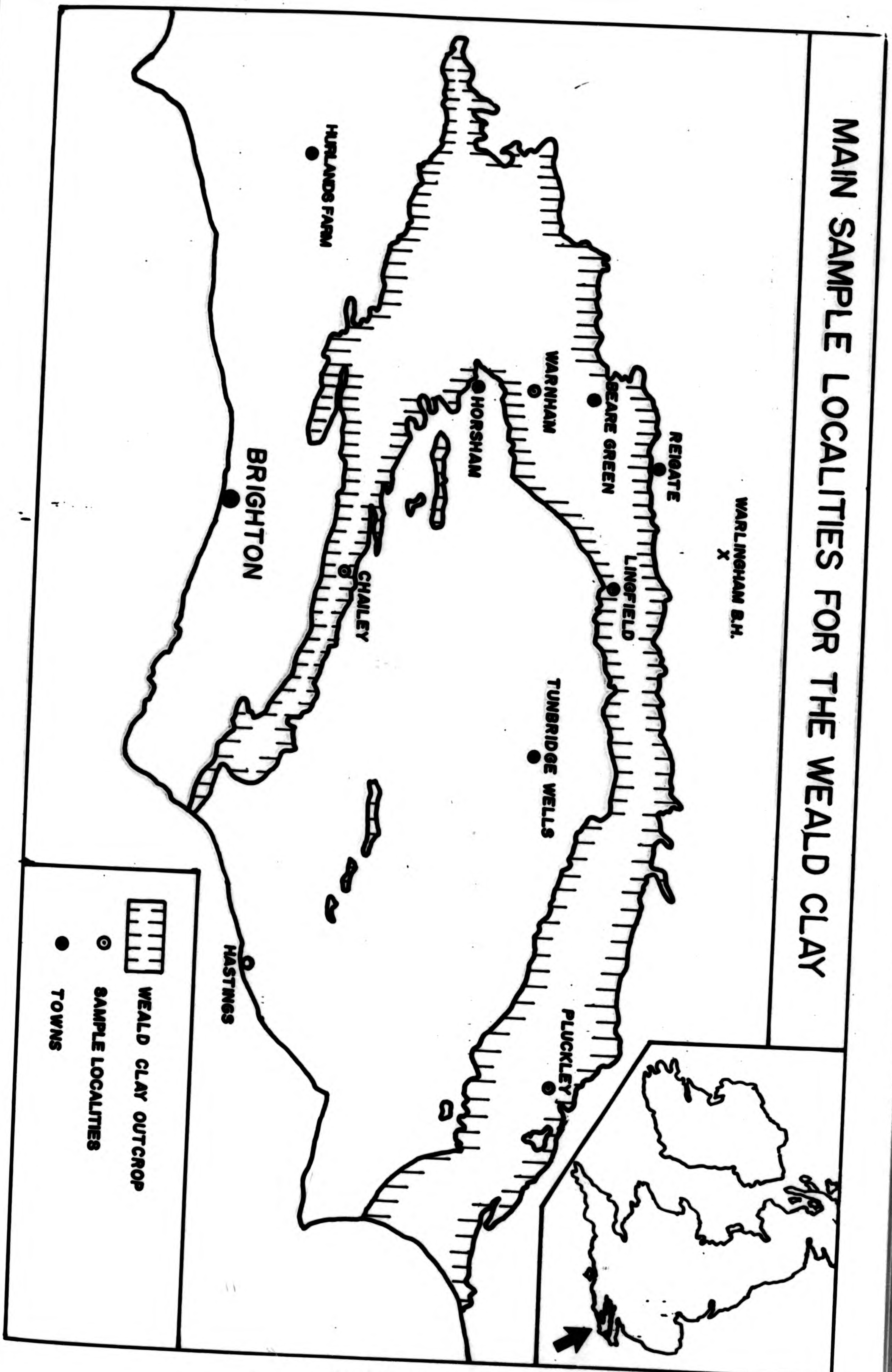
The Wealden beds of the Isle of Wight form a different facies with Wealden Shales & Wealden Marls coeval with the upper division of the Weald Clay.

1.1 (c) The stratigraphy of the Weald Clay

The Weald Clay crops out in a deep east-west crecentic band formed by the two limbs of the east-west trending Wealden anticline in Southern England. It is surrounded by the Lower Greensand and Late Cretaceous chalk escarpments that form the North and South Downs, that on a clear day provide vantage points for views across a substantial part of the Weald (text-fig.1.1).

The western outcrop of the Weald Clay is much thicker than in the east, reaching maximum development west of Horsham (450m) where the outcrop is more than 20 miles across. The limbs of the anticline narrow eastwards, the northern limb reaching the coast at Romney Marsh, the southern limb coming down to the sea between Eastbourne and Pevensey. In the Maidstone area the Weald Clay is about 75 m thick (Worssam, 1963) in the Lewes area and north of Eastbourne, it is 180 m in thickness, while around Hythe it is 400 m. Small inliers in the Lower Greensand occur near Dorking, Guildford and Maidstone, with outliers near Tenterden and Cuckfield. In the Warlingham borehole the Weald Clay is 175 m in thickness. To the north east of Reigate the Lower Greensand oversteps the Weald Clay onto Jurassic.

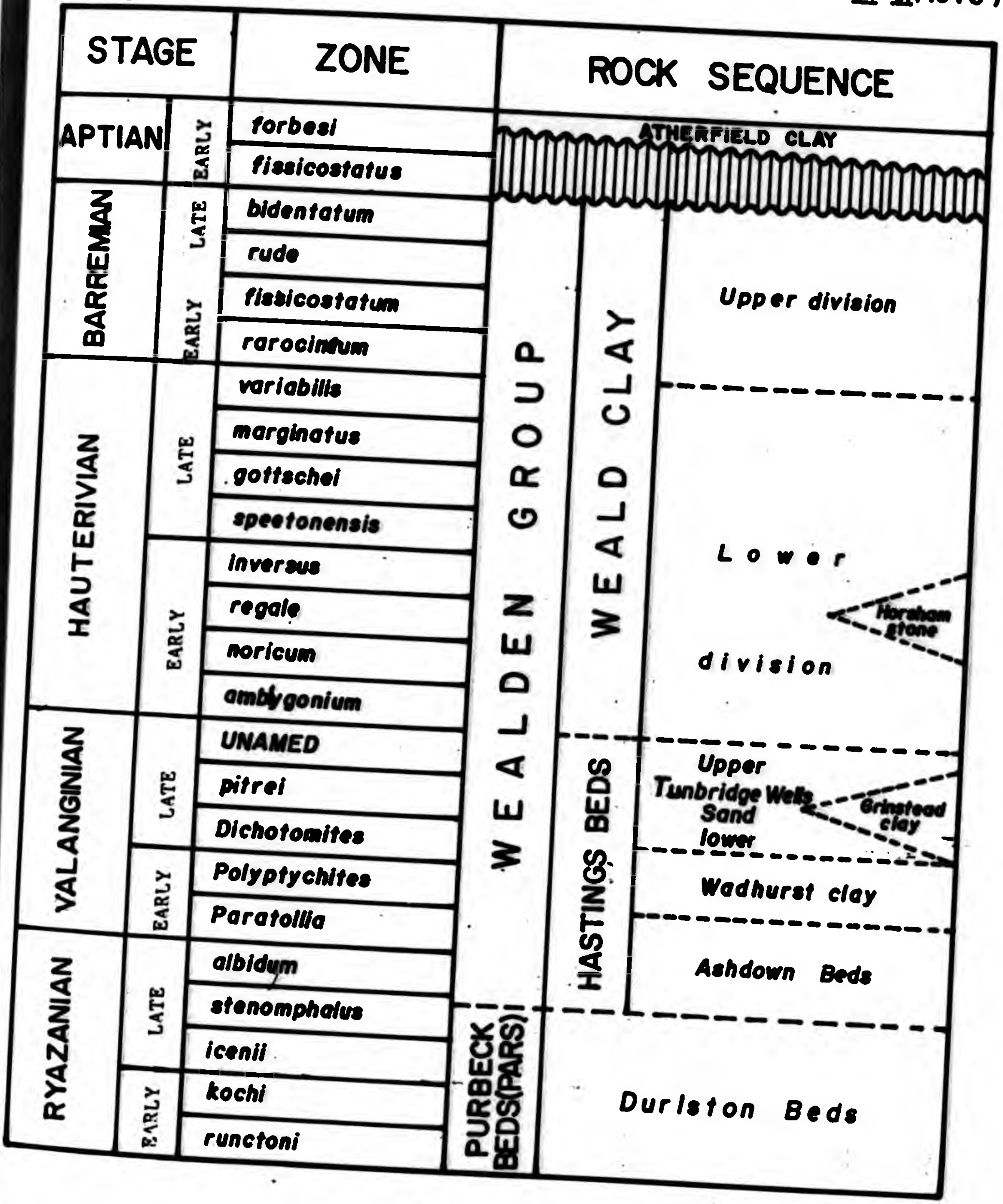
In 1822 Mantell made the first subdivision of the Weald Clay (or Oaktree Clay), recognising the Petworth or Sussex marble overlain by blue and lead coloured clay, passing into marble. Ferguson (1926) divided the Horsham Stone into three subdivisions; calcareous sandstone, fissile sandstone and thick bedded sandstone. A detailed subdivision of the Weald Clay working on the whole outcrop rather than part of it, was produced by Topley (1875). He produced a succession of seven beds with


MAIN SAMPLE LOCALITIES FOR THE WEALD CLAY

Text-fig. 1.1

STRATIGRAPHIC RELATIONSHIPS OF ROCK SEQUENCES (RYAZANIAN —APTIAN) FOR THE WEALDEN OF THE WEALD.

(After Rawson *et al.* 1978)



Text-fig. 1.2

intervening clays as follows:

7. Sand
6. Limestone 'Sussex marble'(Large Paludina)
5. Sand and sandstone with Calcareous
4. Limestone (Large Paludina)
3. Limestone (Small Paludina)
2. Sand and sandstone
1. Horsham stone

Topley did not consider the clays in his subdivision. Allen, P. (1947) divided the Weald Clay into three groups; a lower buff clay (43 m), middle variegated clays, shales and shaley limestones and sandstone (250 m) and an upper group of stiff blue clay weathering yellow (107 m). Reeves (1949, 1958, 1969) traced horizons of red clay over wide tracts of countryside, mainly for structural purposes, and also produced a threefold subdivision based on these red clays. The most recent detailed work on the stratigraphy of the Weald Clay is by Worssam & Morter (1978) based on detailed mapping by the Geological Survey and using information from boreholes. They have shown Topley's original seven-fold subdivision to be broadly applicable. These authors have provided a useful summary of the main Weald Clay lithologies:- clays, sandstones and pebble beds, limestones and ironstones. The sandstones are mostly about 3 m in thickness, considered by Allen (1975) to represent channel-fills this thickness representing the depth of erosion of the channels. The old lithological terms '*Paludina*' and '*Cyrena*' limestones are still used for mapping purposes, but the present generic names of the shells composing them are *Viviparus* and *Filosina* respectively. These limestones are never more than

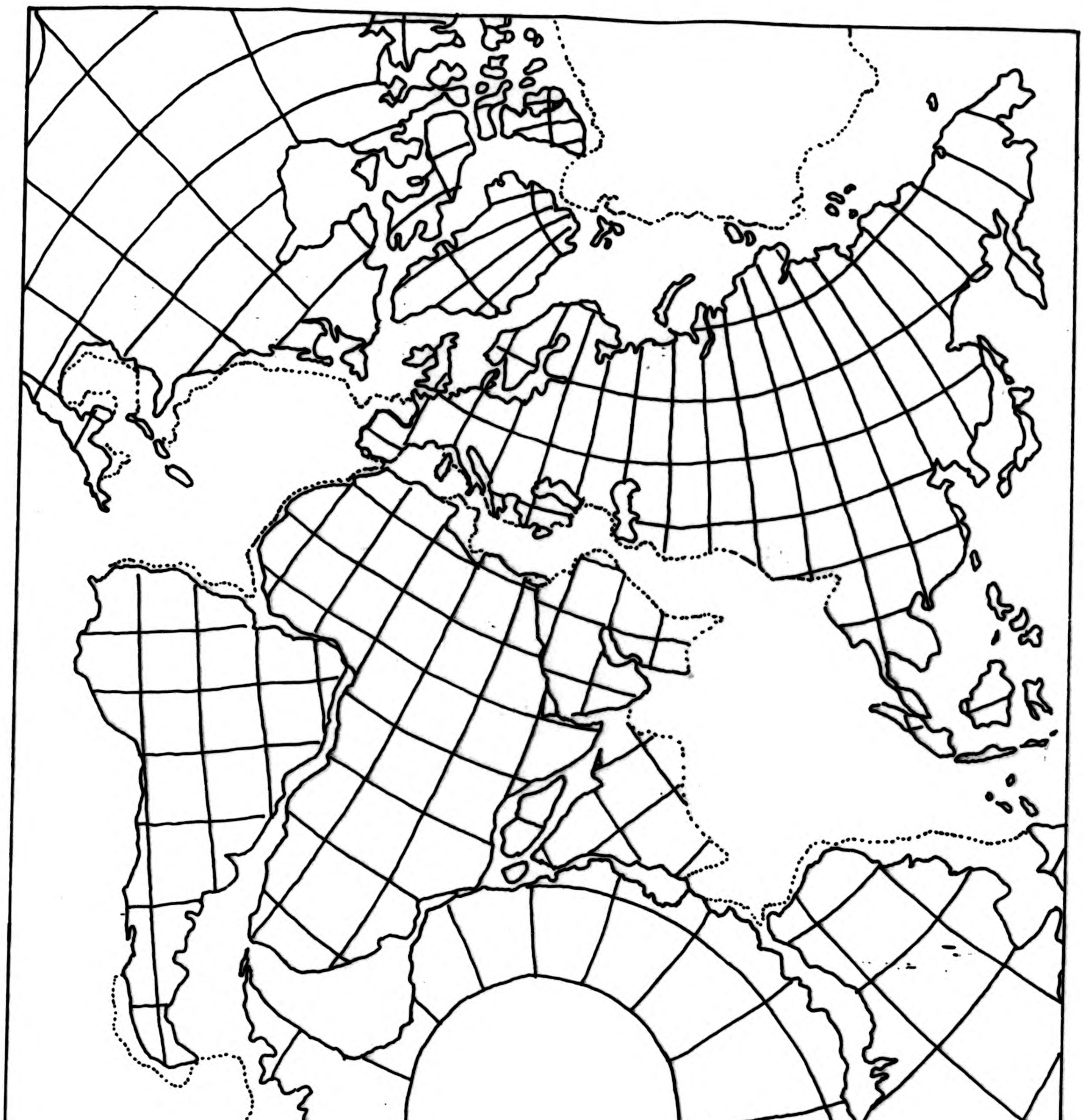
30 cm in thickness, usually around 5 cm. The ironstones are most common near the top of the Weald Clay and formed the basis of an iron industry from the sixteenth to eighteenth centuries. Laminated silty clay, greenish-grey in colour weathering pale grey to yellow, form the predominant Weald Clay lithology. Red clays associated with rootlet beds probably indicate oxidation at the time of deposition, by local uplift. The clays are mixed with quartz silt by bioturbation making them very valuable for brick making. Present day brickworks provide many fresh quarry sections for sample collecting, as used in the present study (text-fig. 1.1).

1.1 (d) Palaeogeography & palaeoclimatology in Wealden times

At the end of the Jurassic 135 million years ago the North Atlantic had opened significantly, but it was still quite small (see text-fig. 1.3, Smith et al., 1973). The Eurasian landmass was rotating so that the Eastern end of the Tethys Sea was closing. According to Allen (1975),the Wealden detritus formed on the 'trailing edge' of the Eurasian landmass. Allen (1972) notes the affinity of Wealden detritus to Cornubia,Amorica and N.W. Iberia. Anderson (1973) records Cypridean ostracod faunas of the Jurassic/Cretaceous boundary in two zones of a circumpolar belt indicating the equator to have been north of its present position, also indicated by palaeomagnetic evidence. A palaeolatitude of 35°N is suggested by plate tectonic reconstruction (Smith, Briden & Drewry, 1973).

Deposition of evaporites and algal limestones suggests that the climate was near subtropical (like the climate of present day Mediterranean - North Africa). Warm temperate subtropcal conditions are also indicated by the oxygen isotope ratios of Allen, Tan and Deines (1973). Small leaf size compared to the Middle Jurassic of Yorkshire has been used as evidence to support this conclusion. The Wealden sediments contain many thick arenaceous horizons and the whole Wealden Group is quite thick, which is evidence that relief and therefore rainfall over the London massif were quite high, causing rapid erosion and run-off. Sladen & Batten (1984) suggest from combined clay mineral studies and palynofacies that a change in climate from semi-arid to humid temperate with much increased rainfall occurred over the Jurassic-Createaceous transition in Southern

Plate Tectonic Reconstruction for the Early Cretaceous
(After Smith, Briden and Drewry, 1973)



Text-fig. 1.3

England. A warm temperature of 20 - 25°C is suggested, dropping to 10°C in cool spells, with "no more than a few light frosts annually". The evidence from these authors also indicates that relief of the source lands was of prime importance in determining the amount of rainfall and thus run-off, leaching and erosion. The heavy rain was periodic, indicated by features of the clay mineralogy and also the sediments themselves (Allen,1981). Also there is evidence of forest fires, presumably happening during dry spells (Harris, 1981), and palaeobotanical evidence of xeromorphic adaptation in the Wealden plant Weichselia (Alvin,1974). Allen (1967) indicates that a structural hinge existed between the basin and the source lands allowing frequent rejuvenation of the London massif, thus maintaining its elevation for continued erosion. Pebble provenance studies of Allen (1967) indicate Lower Palaeozoic, Carboniferous and Jurassic sediments to have formed the source lands. By Weald Clay times the London massif had become much eroded, though its configuration remained the same as during earlier Hastings Beds times. Allen (1975) traces the origin of a lot of the Weald Clay detritus as coming from the west (Upland Cornubia). Reworked ?Lower Palaeozoic acritarchs, Carboniferous spores (Plate 27,figs.16 - 46) and Jurassic dinoflagellates (Plates 31, 32, 33, 34 & 35) have been recorded in the present study.

1.1 (e) The sedimentology of the Wealden Group

Allen (1975) described the Wealden Group as "rapid and repetitive transformations of a fresh-brackish mudswamp into an extensive sandplain". The fresh-brackish mudswamp is represented by the Grinstead Clay and Wadhurst Clay members of the Hastings Formation, and the overlying Weald Clay formation itself. Allen (1981) describes the mudswamp facies as pro-fan brackish lagoons and bays of a meanderplain. The sandplain facies (comprising the Ashdown Sand and Tunbridge Wells Sand of the Hastings Formation) is subdivided into three zones; a proximal fan-apex zone (not preserved), a medial braidplain zone of sheet sands and a distal interfan zone comprising meanderplain and lacustrine palaeoenvironments.

As described in section 1.1 (d), controls on sedimentation were local depending on rejuvenation and rainfall over the source land area. During high relief and high rainfall the sandplain facies were laid down with rapid influx of coarse detritus within braided channels maintaining dominantly freshwater conditions. When the relief of the source lands was low (due to erosion and downfaulting), rainfall was lower as well as clastic supply and freshwater alluvial input. This meant that the braidplain gave way to a meanderplain (that existed in the distal parts of the sandplain phase) over most of the basin. The lower input of freshwater into the basin allowed marine waters to invade, mostly through gaps in the downwarped source lands to the northern boreal sea. This was particularly marked during deposition of the Weald Clay when the London massif had become very degraded and most of the coarse detritus had its origin to the west

(Cornubia of Allen). "The scene is a watery mudplain with occasional sandy channels and numerous semi-permanent lakes" (Allen, 1981). Allen(1975) also notes that as most coarse detritus within the Weald Clay (eg.the Horsham Stone) was derived from the west, and marine incursions were from the north and west, there is a differentiation in facies to the east, where input of coarse material and salinity variation was much less.

Within all the Wealden Group deposits water level was always shallow and liable to exposure, as shown by suncracks, footprints, occasional contemporaneous oxidation of the clays and soilbeds. However sedimentation, though sometimes slow, was never terminated long enough for coals to develop, though vegetation within the basin on areas of temporary _terra firma_ must have been well developed (see section 1.1 (f)). The regime of fairly continuous freshwater sedimentation, rare brackish marine inundation and lack of tidal reworking is very significant from a palynological viewpoint. It means that the _in situ_ preservation potential of the palynomorph assemblages will be much higher than in a deltaic/estuarine-marginal marine environment, though downstream reworking will still be evident.

1.1 (f) Salinity fluctuations within the Wealden Group

The delicate balance between freshwater alluvial input and brackish/marine incursion is an important part of the palaeoenvironment of the Wealden Group, particularly the argillaceous parts, and under this heading, particularly so in the deposition of the Weald Clay.

In the early 1800's the Wealden Group was considered to be entirely marine until the work of Sowerby, Mantell and Fitton recognised freshwater shells very different from those in the Lower Greensand. Since then sedimentology has shown red shale, sandstone and soil beds, all indicative of freshwater. Patterson (1966) described a freshwater Hybodont Elasmobranch (Shark) fauna from a Wealden bone bed near Henfield. Allen, Tan & Deines (1973) used carbon isotope ratios in Wealden carbonates in infer salinity changes. The work of these authors as well as Prentice (1969) suggests that the sand units of the Weald Clay were most saline and the Viviparus infracretacicus & V. fluviorum with Unio were least saline. Evidence presented in the present study (see section 3.4 (b)) is the opposite, that the Viviparus (large 'Paludina') limestone are the most brackish/marine influenced facies and the sandstones the most freshwater. Other invertebrate gastropod and bivalve shells indicative of higher salinities include Filosina, Cassiope, Ostrea, Nemocardium, Procerithium, Mytilus, Gerrillia, Melania and Paraglauconia (Worssam & Morter, 1978).

The best evidence of alternating brackish/marine influence conditions within the Wealden comes from examination of the ostracod assemblages (Anderson in Worssam,1963; Thurrel et al.

1968; Shephard-Thorn et al.1966 and Anderson 1967, 1971 and 1985).Alternations are seen between more saline 'S-phase' assemblages and more freshwater 'C-phase' assemblages with Cypridea spp.. The publication by Anderson(1985) of a complete sequence of 98 Purbeck and Wealden faunicycles of salinity controlled ostracod assemblages is a culmination of previous work. Work completed in the present study (see section 3.4 (b)) done prior to Anderson's paper corroborates his salinity changes within the Henfield phase of the Weald Clay. Ostracod work has also been done by N. W. Allen(1970) and Kilenyi & Allen (1968)

Other salinity indicators within the Wealden include freshwater Chara gyronites , (Tappan , 1980) remains of the horsetail plant Equisetites (Batten,1968) and megaspores produced by aquatic freshwater plants (Batten,1969). Other fossil remains of Echinoids, Cirripeds and Foraminifera are indicative of marine influence. A few records of dinoflagellate cysts (Batten,1981 and Hughes & Harding, 1985) suggest marine or brackish/marine influence. The trace fossil Ophiomorpha (produced by the burrowing decapod Callianassa) is recorded in the Wealden marls of the Isle of Wight. This has traditionally been taken as a marine indicator though Stewart (1978) shed doubts on this.

Work on the palaeobotany of the Cheirolepidiaceae and the palynology of its pollen (Classopollis) by Hughes & Moody-Stuart (1967), Batten (1973, 1974 & 1976), Hughes (1975a,b,c), Alvin (1982), Francis (1983) and Batten & Sladen (1984), suggests that this Wealden plant and its abundant pollen can be used to indicate raised salinities. The present study shows that spore/pollen assemblages and kerogen types are partly controlled by salinity changes across the Weald Clay basin.

1.1 (g) Plant communities of the Wealden

The rapidly deposited clays and sands with unleached minerals and nutrients, well-watered by frequent rain, with many streams for easy seed dispersal together with a warm atmosphere, would have made the Wealden Basin a tempting site for colonisation by higher plants. Herbaceous plants and trees probably germinated easily on the rich mud flats and sand bars. However the transient nature of the environments, subject to rapid erosion and marine inundation would have prevented the communities developing very far. Nevertheless, one could expect that particular associations of plants would have favoured the more marine influenced facies, others the drier uplifted ones. Plant communities nearer to the hinterland at slightly higher elevation would have been different from those close to the strandline, if such could have been discerned in the gradation of salinities. The sandier lithologies would have provided less nutritious substrates than the muddy ones.

The horesetail reedswamp plant Equisetites lyellii ~~has~~ been recorded extensively (Allen 1941, 1975, 1976; Harris, 1976; Batten, 1968) as a possible first coloniser of sand bars and muds. This plant is quite common in soil beds of the Wadhurst Clay (Batten,1974). Alvin (1971, 1974) has described the Wealden plant Weichselia that first appears in the Tunbridge Wells Sand and may also have been a first coloniser of the sand bars (Batten, 1974). The ubiquitous Classopollis plants have already been mentioned in Section 1.1 (f). Though many authors have found their cuticles and pollen in association with halophytic facies, Batten (1974) mentions their possible association with upland habitats. Chaloner (1984) considered that Classopollis was probably derived from a variety of related species that were adapted to many different palaeoenvironments.

Batten (1974) considered that abundant bisaccate pollen was produced by conifers growing mostly at raised elevations within the basin and the source land mass. Good evidence for this is that bisaccate pollen are more common in transgressive facies such as the Wadhurst and Grinstead Clays when the flora of the Wealden basin (mostly ferns) was destroyed. This would have allowed pollen of the hinterland flora to become relatively more dominant in palynological assemblages.

Most of the plant groups recorded from the Weald Clay are known only from dispersed miospores, though the Fairlight Flora of the Hastings Formation is well represented by macroplant remains (see Hughes, 1975c). The main object of the present study is to look in detail for recurrent associations between spore/pollen taxa. The object is then to see if such associations (or assemblages) can be related to palaeoenvironment given the regime of comparatively good preservation potential of the Weald Clay sediments that were not greatly reworked or mixed once laid down. Apart from the cases already mentioned, these spore/pollen taxa have not left macroplant remains in the Weald Clay. It is possible that work on other Mesozoic formations where spore/pollen taxa as well as macroplant material with fructifications occur will eventually elucidate the nature of the parent plants of these spores and pollen, as has been done with Classopollis (Alvin, 1982; Francis, 1983).

1.2 PALYNOLOGICAL METHODS

1.2 (a) Components of a palynological assemblage

The isolation of organic material (O.M.) from a sedimentary rock leaves a finely comminuted acid resistant residue. It is quite likely that some of the O.M. is dissolved by the strong acids so that the residue, known as kerogen, is not 100% representative of the original O.M. . For this reason kerogen has been defined (Durand,1980) as "the fraction of sedimentary O.M. which is insoluble in the usual organic solvents" . These solvents include chloroform, benzene and methonal-benzene below 80°. The soluble fraction of the sedimentary O.M. is termed bitumen.

A brief description is given here of the main kerogen types encountered together with their environmental implications. Environmental inferences come from previously published literature as well as data from the present study.

i) Humic material: This includes all kerogen types derived from cellular woody plant tissues or cellular non-woody shoots, stems and leaves. Comparatively small amounts of these tissues are encountered in the Weald Clay rocks, as prior to the development of Angiosperms at this time, trees (conifers) tended to be confined to the source uplands well away from the basin. The braidplain would have supported abundant ferns and fern allies, mainly shrubs but some larger tree ferns, none of which laid down woody tissues.

ii) Fusinite: The commonest form of humic material encountered in the Weald Clay, this material is almost completely opaque black in colour and normally shows cellular structure as regular perforations or forms angular oblong shaped fragments (see Plate 76, figs.1-13; Plate 70, figs.5,8,9 & 10; Plate 63, figs.1,2, 5 & 6; Plate 77, figs.1-11). Fusinite that shows good cellular structure is thought by most authors (Cope, 1980; Batten, 1974; Harris, 1958, 1981) to be produced by incomplete natural burning of plant tissues to form charcoal, which cannot be further broken down by bacteria. This idea is in keeping with the volume of fusinite that occurs in sediments of low thermal maturity as seen from the spore colour index, indicating that it must be produced prior to deposition. Fusinite (or inertinite) can be produced by oxidative degradation of woody tissues by bacteria, but in this case cellular structure tends not to be maintained, which supports the forest fire theory. Harris (1981) described fossil fern leaves preserved as fusinite from Beare Green that probably grew locally rather than being transported as they were unfragmented. However the material did tend to be washed into channels. Fine fusinite fragments in the present palynological preparations could have partly originated from local ferns as well as from coniferous trees of the source lands. Evidence presented in this study does show the fusinite proportion to be generally higher in channel sediments or those considered to have been laid down closest to the source lands. Likewise fusinite proportions are much lower in the palynofacies considered associated with lakes or the shoreline, more distal with respect to the source land mass.

iii) Vitrinite: Also included in the humic category, this material is generally quite rare in the Weald Clay. It includes O.M. that usually shows good cellular structure, but is not opaque, but orange-brown in colour, (Plate 68, figs.1-7; Plate 69, figs.1,3,6 & 7). It probably occurs where plant tissues were fortuitously buried or deposited in anoxic ponds or lakes, thus being saved from oxidative degradation. This material did not occur sufficiently frequently in great enough abundance to provide palaeoenvironmental information.

iv) Semifusinite: This material is intermediate between vitrinite and fusinite, often appearing as irregularly shaped black fragments with orange translucent rims. Much of it in the Weald Clay may have been derived from oxidative degradation of plant tissues. Semifusinite was not common enough to provide palaeoenvironmental information.

v) Fine amorphous organic matter: This material forms a finely divided groundmass of opaque grey material in some Weald Clay samples. Sometimes it forms subrounded hollow 'amorphous masses' (Plate 78, figs.1-9). These structures superficially resemble Botryococcus (Plate 78, fig.10), but are easily distinguished using fluorescence. Amorphous masses may be artificially produced during maceration. Bubbles of gas produced during long HF treatment may concentrate fine material on their outer surface that might adhere and remain intact. The origin of this material is not certain, but it may be from a variety of sources, fine grained inertinite as well as algal debris and other degraded kerogen. Its relevance in the palynofacies analysis is that it must be laid down under very quiet water conditions as it is so fine grained, so may be associated with standing water bodies such as ponds or lakes. Evidence is presented in the present study that specific spore pollen palynofacies are associated with it that supports this environmental inference.

Batten & Sladen (1984) equated amorphous organic matter with anoxic lacustrine conditions, though Hughes & Harding (1985) saw no reason for this association where Botryococcus was absent.

vi) Amorphous liptinite: This material has a translucent membraneous texture and is strongly autofluorescent (Plate 90, figs. 1-3). It is probably aquatic marine in origin, as evidence presented in the present study equates it with strongly marine influenced palynofacies.

vii) Palynomorphs: Palynomorphs are part of the kerogen assemblage, though they are usually treated separately. In the present study palynomorphs include spores, gymnosperm pollen, algal cysts, dinocysts, fungal material and chitinous foraminiferal linings. Specific environmental inferences from these individual taxa are dealt with in the ensuing chapters.

1.2 (b) Principles of Palynological slide preparation

Palynological slide preparation techniques are fairly simple, and apart from slight differences the same basic method is used the world over. The technique of maceration is based on the principle that palynomorphs preserved in sedimentary rocks are composed of a material that is of great chemical strength though it is physically quite fragile. The rock matrix in which they are enclosed is of high physical strength but is chemically very weak in the face of strong acids (HCl, HF) that leave palynomorphs untouched. A collective name given to the material comprising spore, pollen and dinocyst walls is sporopollenin (Brooks, 1971). This is one of the most resilient complex organic materials known. Palynomorphs are usually preserved by being compressed flat from their original general spherical bag shape, once the inner protoplasm has decayed. They are flexible enough to assume the shape of the pore spaces between clastic grains without suffering much degradation. Degradation can occur by the secondary growth of pyrite and other minerals within the sporopollenin wall.

Even in a fairly rich sample, palynomorphs and other organic material (O.M.) comprise only a small percentage of the total volume of the rock, except of course in coals. Once the rock matrix has been dissolved this small organic residue must be concentrated together. This is done by simple wet sieving using very fine nylon meshes (c. 10u mesh) that retain the bulk of the material. From an original fairly large rock sample (say match-box size) the small amount of O.M. residue can be pipetted onto a slide with a mounting medium for examination.

Techniques to improve the concentration of palynomorphs over dispersed O.M. fragments can be used. These include use of oxidising agents (eg.fuming HNO_3) to dissolve O.M. fragments (palynomorphs are largely unaffected by these agents if used carefully), use of the higher specific gravity of dispersed O.M. over palynomorphs ('panning' using a large watch glass or centrifugation in a heavy liquid such as zinc chloride) and the greater fragility of solid O.M. fragments over membraneous palynomorphs when subjected to ultrasonic treatment. These techniques are used to improve the recovery of palynomorphs by selectively removing the dispersed O.M. . However the original dispersed O.M. is also required for study. Two slide preparations are normally made, one before carrying out concentration of the palynomorphs, that represents all the O.M. from the rock in its original form for kerogen percentage, colour, size and shape studies. The other made after concentrating the palynomorphs is for relative abundance studies of palynomorph taxa and palynomorph taxonomy.

CHAPTER 2

QUANTITATIVE AND QUALITATIVE ANALYSIS OF WEALD CLAY PALYNOLOGY DATA

2.1 INTRODUCTION

2.1 (a) Counting method

Prepared slides of all rock samples were systematically counted to a maximum of 200 spore/pollen grains, and the remainder of the slide scanned for species present that were not recorded during the count. Counting was helped by the use of a swift 'automatic point counter' model C which allows ten separate items to be totalled at the same time, and provides an automatic cut-out and buzzer system once the full 200 total has been reached.

Slides were logged by starting with a horizontal traverse through the centre followed by successive traverses adjacent to this until the total was reached. A record was kept of the total and fractional number of traverses required for the 200 total. Logging was carried out using the x20 microscope objective with ordinary light or phase contrast illumination, going to x100 oil immersion for identification of a grain once located.

All slides were separately logged under ultraviolet illumintion for autofluorescent palynomorphs that were found to be not normally visible in ordinary light or phase contrast illumination. Due to the generally much smaller size and greater abundance of these palynomorphs compared to the normal pollen and spores observed in ordinary light, a single traverse through the centre of the slide using the x40 objective was made. This allowed the proportion of autofluorescent palynomorphs to be compared directly with those counted in ordinary light, by multiplying the actual numbers of each type by the number of traverses required to count 200 grains in the first count, then multiplied by two to compensate for the higher magnification of x40. Numbers of autofluorescent palynomorphs are therefore recorded as absolute numbers of individuals per 200 palynomorphs identified in normal illumination.

Spore/pollen count data was acquired on 211 Weald Clay samples, which was then subjected to cluster analysis. The cluster analysis program employed was CLUSTAN (Wishart,1978).

2.1 (b) Elements of spore/pollen assemblages for statistical analysis.

From the outset of counting of Weald Clay palynomorph assemblages, it was evident that some forms occurred much more frequently than others, and that generally the abundant and rarer forms remained consistently so in most samples. Many of the palynomorphs were identified to well defined species, while other identifications could only be made to generic level. Most of the forms recorded as being most common were assigned to these broader less well defined groups. Some assemblages contained palynomorphs of poor preservation that could only be assigned to generic level. For the purposes of statistical analysis, palynomorphs were separated into 87 different types including specific and generic groups. These are as follows:

Taxon code	Taxon name
01	*Cyathidites* spp.
02	*Dictyophyllidites* spp.
03	*Cicatricosisporites* spp.
04	*Gleicheniidites* spp.
05	*Classopollis* spp.
06	*Tsugaepollenites* spp.
07	*Alisporites* type
08	*Podocarpidites* type
09	*Cedripites* type
10	*Celyphus rallus*
11	*Vitreisporites pallidus*
12	Foraminiferal lining
13	*Microthyriaceae*

Taxon code	Taxon name
14	Schizosporis spp.
15	Pluricellaetes
16	Trilobosporites canadensis
17	Trilobosporites bernissitartensis
18	Trilobosporites apiverrucatus
19	Trilobosporites spp.
20	Pilosisporites trichopapillosus
21	Pilosisporites verus
22	Pilosisporites notensis
23	Pilosisporites cf. notensis
24	Pilosisporites spp.
25	Matonisporites phleberopteroides
26	Concavissimisporites variverrucatus
27	Concavissimisporites spp.
28	Calamospora type
29	Todisporites spp.
30	Biretisporites spp.
31	Concavisporites jurienensis
32	Undulatisporites undulapolus
33	Spheripollenites psilatus
34	Deltoidospora spp.
35	Coronatispora valdensis
36	Reticulisporites spp.
37	Klukisporites spp.
38	Lycopodiumsporites marginatus
39	Lycopodiumsporites austroclavitides
40	Lycopodiumsporites spp.
41	Foveotriletes spp.
42	Foveosporites spp.

43 *Foraminisporis assymmetricus*
44 *Ischyosporites* spp.
45 *Kuylisporites lunaris*
46 *Sestrosporites pseudoalveolatus*
47 *Lycopodiacidites baculatus*
48 *Contignisporites* sp.
49 *Antulsporites* sp.
50 *Distaltriangulisporites* sp.
51 *Polycingulatisporites* spp
52 *Leptolepidites* spp.
53 *Verrucosisporites* spp.
54 *Cingulitriletes* sp.
55 *Couperisporites* sp.
56 *Cooksonites* sp.
57 *Krauselisporites* sp.
58 *Aequitriradites* spp.
59 *Rugubivesiculites* sp.
60 *Cerebropollenites mesozoicus*
61 *Acanthotriletes varispinosus*
62 *Cicatricosisporites australiensis*
63 *Cicatricosisporites augustus*
64 *Cicatricosisporites minor*
65 *Cicatricosisporites hughesi*
66 *Cicatricosisporites potomacensis*
67 *Cicatricosisporites hallei*
68 *Cicatricosisporites pseudotripartites*
69 *Cicatricosisporites annulatus*
70 *Appendicisporites jansonii*
71 *Appendicisporites potomacensis*
72 *Appendicisporites tricornitatus*
73 *Appendicisporites problematicus*

74	Appendicisporites sellingii
75	Appendicisporites trichacanthus
76	Appendicisporites spp.
77	Costatoperforosporites spp.
78	Triporoletes sp.
79	Regresporites sp.A
80	Reticulatisporites castellanus
81	Lycopodiacidites spp.
82	Selaginella type
83	Januasporites sp.
84	Stereisporites antiquasporites
85	Densoisporites spp.
86	Foraminisporis spp.
87	Tigrisporites scurrandus

The numbered order in which these types have been presented corresponds to the coding sequence that each type was given for data processing using CLUSTAN. (For taxonomic assignment of these palynomorphs to the form generic turma scheme, see pollen diagrams, enclosures 1 & 2). It will be noted that forms 10 and 12-15 are not spores or pollen, falling into the category of 'other palynomorphs'. Forms 06, 07, 08, 09, 11, 59, 60 and probably 05 are gymnosperm pollen, while the rest are spores, mostly of pteridophytes.

These 87 palynomorph types do not correspond exactly with all of the forms described in the systematics section of this study, being generally broader generic groups. They form the basis of the binary and multivariate cluster analysis groups which have been defined in this study, and associations of them are described later as individual palynofacies.

The palynomorph Celyphus rallus (Batten,1973) was found to be very abundant in many samples, such that it totally dominated some assemblages. Celyphus rallus is not a pollen or spore, probably having aquatic affinities as an algal structure(Batten & Van Geel,1985). The presence of C. rallus in the palynomorph assemblage can therefore be thought of as an independent influence. In order that abundant C. rallus did not 'over-ride' the spore/pollen assemblage, but was itself also included as a taxon of great palaeoecological importance when very abundant, assemblages containing a great abundance of Celyphus rallus were counted twice. The first count included all taxa present and the second was the same ignoring C. rallus. In this way, the relative percentages of spores and pollen could not be disrupted by an over-abundance of C. rallus in the count. This procedure applied to the following samples:

W60 W23
W52 W14
W47 W20
W36

This second count was not carried out on all samples rich in C. rallus, but those that did receive a second count also provided a useful control group. A great dominance of C. rallus will be sufficient to form a cluster group of its own, based on multivariate data, but discounting C.rallus the spore/pollen assemblages alone will define to which group each sample is clustered. Thus the two counts have been treated as separate rock samples.

Some samples were found to be barren of spores and pollen though they contained rich liptinitic kerogen, as follows:

W69
W63
W62
W61
W33
W34

These samples were encoded into the cluster analysis even though zero data was available, as a clear control group that could be expected to cluster together as a very close association.

The total number of rock samples encoded for CLUSTAN from all sample localities was 211.

2.1 (c) Data collection.

Relative frequencies of individual taxa in the 200 count were converted to percentage frequencies by halving the totals of each taxon. Single occurrences were kept as 1% (encoded as -1). Coding sheets were filled out for each rock sample with the taxon code followed by the percentage frequency. Data for each rock sample were separated using an identifier -1000, -1000.

All of the rock samples were given a separate code number for statistical analysis, different from their collection sample number. These are as follows:

1-115	Warnham samples
116-133	Lingfield samples
134-154	Beare Green samples
155-190	Chailey samples
191-199	Hurlands Farm samples
200-208	Pluckley samples
209-208	Nutfield samples
211	Cranleigh sample

Before these data were fed into CLUSTAN, a complete matrix of all percentage frequencies of 87 individual taxon for all samples was obtained as a printout for checking that all numbers applied to the correct sample and taxon.
On completion of this the matrix was then run for binary and multivariate analysis in CLUSTAN.

2.2 STATISTICAL METHODS

2.2 (a) Introduction

An extensive literature exists on statistical methods applicable to geological and palynological problems. One up to date text book that I have drawn from in this study is John C. Davis "Statistics and Data Analysis in Geology". (John Wiley & Sons , 1976). This text carries an extensive bibliography of most of the major references on statistics in geology. A key bibliography of palynological papers that make use of statistics has been provided by Frederiksen (1974 and 1985).

Cluster analysis is only one of several statistical methods that are available. There is not room here for an extensive review of the literature on cluster analysis but mention will be made in this chapter of a few papers that I have made use of in its preparation. Aside from the statistical methods, of greater importance is work done on modern environments that has shed light on the distribution patterns of palynomorphs in various sedimentary settings. Work of this kind is essential in providing an objective framework in which theoretical problems and patterns produced by statistical methods can be discussed. There is a huge literature produced by Quaternary palynologists and geographers on pollen profiles and their interpretation in the light of the modern pollen rain. The fine detail of this work is possible because most of the pollen can be related to present day plants whose palaeoecology is known in detail, and usually the present day geography is not greatly different from that during the Quaternary. Two papers that can be mentioned as providing key information on modern environments applicable to geological settings are Kuyl, Muller & Walterbolk, (1955) and Davey (1971).

Cluster analysis has been extensively used by palynologists for biostratigraphical problems and in numerical taxonomy, neither of which are applicable to the present study that is only concerned with palaeoecology.

2.2 (b) Cluster analysis

Most papers and publications on cluster analysis in geology describe cluster analysis as a classification process "...of putting similar objects into an unknown number of distinct categories, with the objects in each category being more similar to each other than to the objects in all the other categories." (Parks, 1966). "Cluster analysis is an exploratory method for helping to solve classification problems. Its use is appropriate when little or nothing is known about the category structure in a body of data" (Wishart, 1978). Clapham(1970) states that the "... simplest, and most easily visualizable means of presenting matrices is through the dendrogram. Dendrograms are graphic records of the highest level of inter-relationship, or bonding, between pairs or groups of individuals."

Most authors allude to the problems with this kind of cluster analysis. Kaesler(1969) considers that "Its major disadvantage is that because dendrograms produced by cluster analysis are two-dimensional representations of multidimensional configurations, distortion may be introduced by averaging during cluster analysis. Another possible source of distortion is lack of inherent hierarchical structure among the entities being classified". Kauffman & Hazel(1973) have referred to distortions added to a dendrogram by averaging, calling it "down the dendrogram distortion". More distortion is added as new components join those already clustered. They note that cluster analysis is most useful when compact groupings exist in the data, but not so when the data matrix structure is a subtle gradation of loosely compacted groups. It has also been noted that once an item has been linked in to another in the dendrogram it is then removed from being able to be compared with anything else subsequently. Clapham (1970) considers dendrograms to be a "weak method that uses only a small amount of available information, and because there is no internal corroboration of inferred groups, either through use of negative bonds to check relationships between groups or through interpretation of different factors. It may be an extremely effective means of illustrating relationships between entities but it should be used in conjunction with other methods for maximum utility and accuracy". Most authors agree cluster analysis using dendrograms is a very convenient graphic display. Parks (1966) summarizes as follows:

1. Cluster analysis is a useful technique for analysing large tables of data where many different measurements are made on each of many samples.
2. Cluster analysis results are easily understood and interpreted because the results are in the form of a two-dimensional hierarchical diagram.
3. Cluster analysis reveals "natural groupings" and further allows the observer to pick off groups at any desired level of similarity.

Davis (1976) has discussed the problem of distortion by averaging. This distortion is introduced by averaging of the two values between two entities when a third item is linked to them. Evaluation of this distortion can be made by examining the 'cophenetric variables'. This is a matrix composed of apparent correlations contained on the dendrogram (ie. averaged ones) which can be compared with the actual values in the matrix to see the amount of distortion. Correlation and distance coefficients can also be used. Averaging of items within a cluster is called the pair group method. Single linkage clustering can be done where an object becomes linked to a cluster based on its similarity with any one single item already in the cluster rather than the average of all. This therefore allows linkage at higher levels. Where averaging is used, this is known as weighted technique. With averaging, objects already in a cluster are treated as one item, ie. individually each object in the cluster is of low importance, and lower with the greater number of objects clustered. A new object to be clustered thus has much higher importance being on its own. Unweighted average methods avoid this difficulty by weighting each cluster in proportion to the number of objects in it. This is done by correlating the new object with the sum of the original values of all the objects in the cluster, each divided by the number of samples in the cluster. This would allow each object in the cluster equal influence in the cluster group in proportion to the value of each. Objects that enter the cluster later thus have less influence on the cluster than those entering earlier unlike the weighted methods that give greater influence to objects that cluster later on.

It is thus apparent that the structure of the dendrogram can be greatly affected depending on the method employed. According to Davis (1976) experience has shown that weighted pair-group methods are superior to single linkage or unweighted average methods.

The CLUSTAN program used in this study is an integrated package of FORTRAN IV programs for the collective study and use of various cluster analysis and other multivariate methods. For the details on the various methods, procedures and options available see Wishart(1978) (the CLUSTAN manual). The program as used employs Ward's method to optimise the error sum of squares by hierarchical fusion.

2.3 RAW DATA

2.3 (a) Form of computer print-out

The palynological data was processed in two separate ways through CLUSTAN. One cluster analysis was based on binary presence/absence data, where the numeric variables (relative frequencies of individual taxa in any one sample) were ignored, and the occurrence of any taxon recorded as 1 for its presence and 0 for its absence. This type of cluster therefore gives equal weight to very abundant as to very rarely occurring taxa. A dendrogram was produced as a print-out, which grouped together the most similar rock samples at a very low coefficient of 0.001, up to coefficient 2.809 where all the samples clustered together as one group. Intermediate between these values at coefficient 0.711, the CLUSTAN program recognised 10 clusters as a convenient grouping of all 211 samples. These 10 clusters are indicated by alternate shading of a drafted copy of the dendrogram print-out (see text-fig. 2.1), and they have been designated with the capital letters A-J.

The CLUSTAN program also provided a breakdown of the rock sample and species content of each cluster. This came in the form of a list, which for each individual cluster gave four pieces of data :

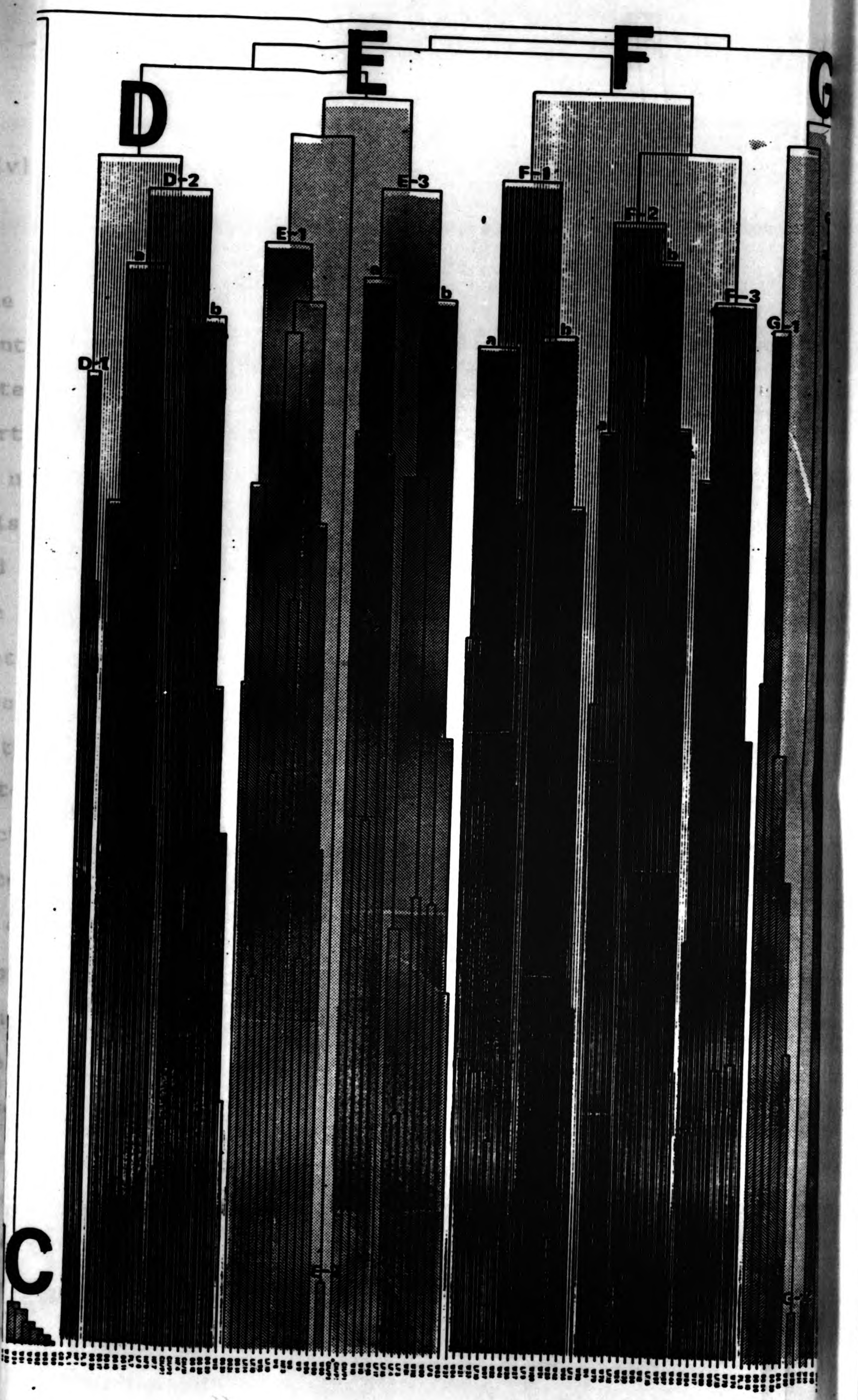
(i) The number of cases (or number of rock samples in that cluster)

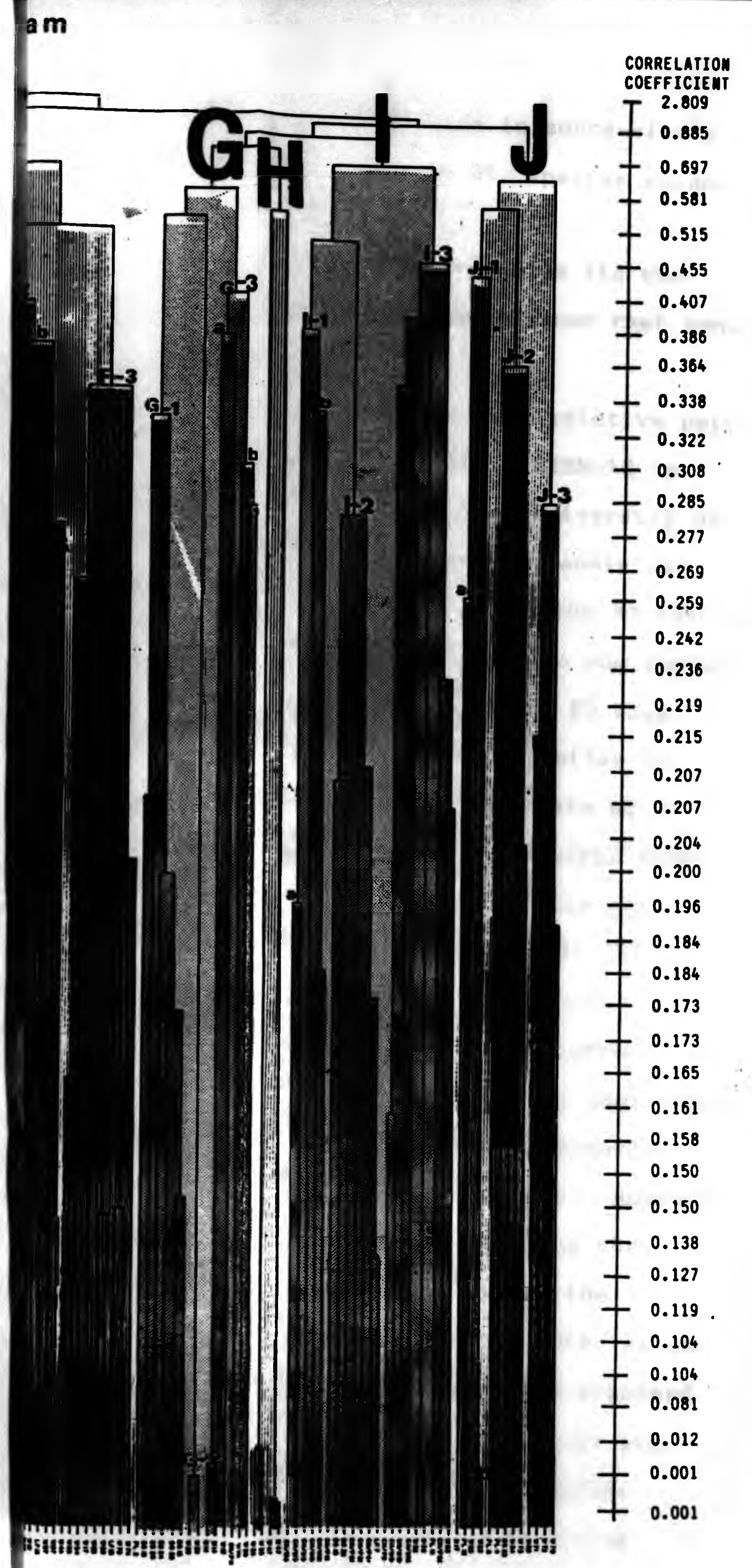
(ii) The case numbers (ie. the code numbers of each of the samples in that cluster)

(iii) The binary variable frequencies (ie. a list of the number of species in the cluster that occur in 100% of the rock


B
D
A
B-1
D-2
B-3
A-b
a
D-1
A-a
a
B-2
b
C

Binary dendrogram



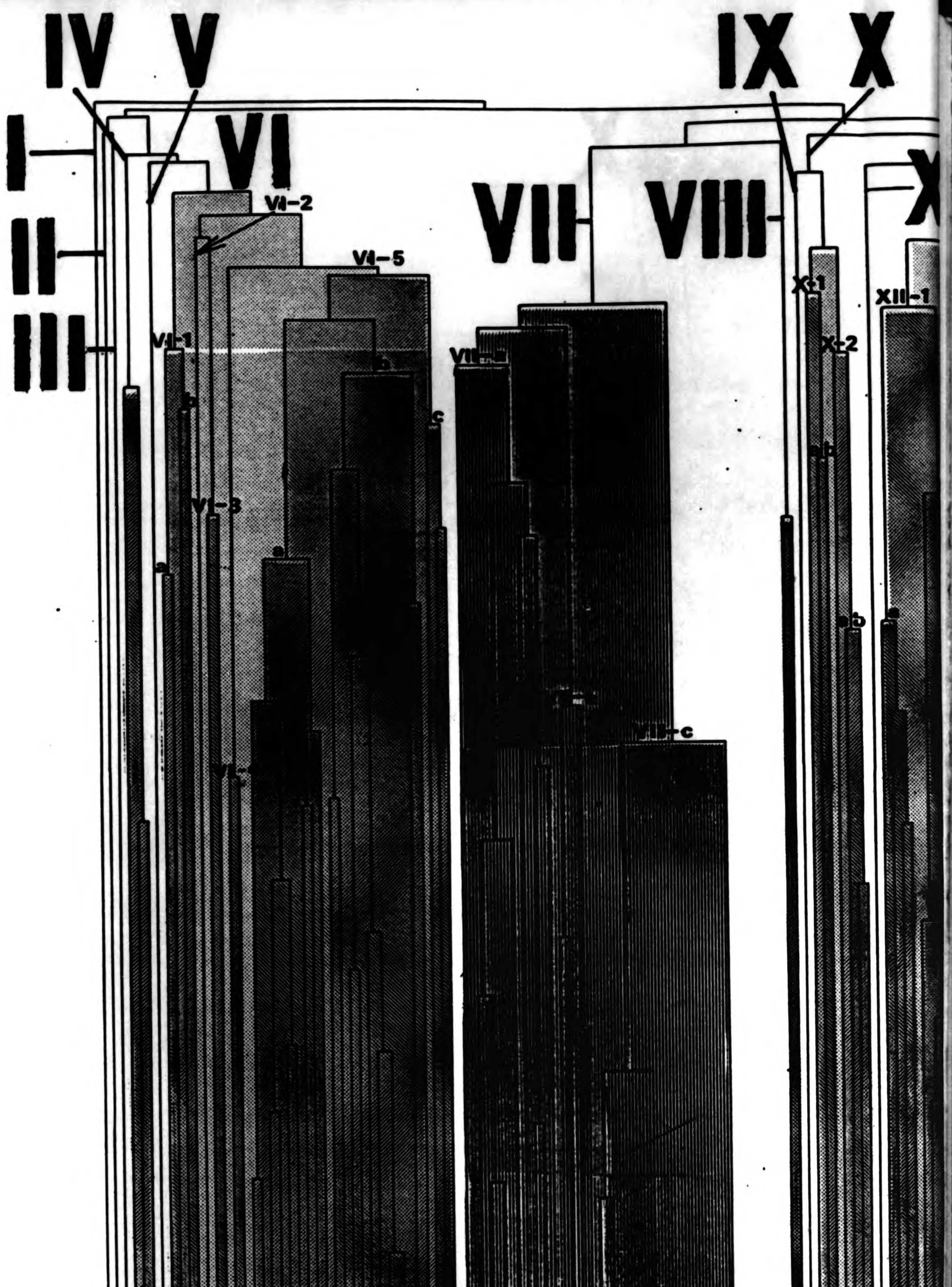

am
CORRELATION COEFFICIENT
2.809
0.885
0.697
0.581
0.515
0.455
0.407
0.386
0.364
0.338
0.322
0.308
0.285
0.277
0.269
0.259
0.242
0.236
0.219
0.215
0.207
0.207
0.204
0.200
0.196
0.184
0.184
0.173
0.173
0.165
0.161
0.158
0.150
0.150
0.138
0.127
0.119
0.104
0.104
0.081
0.012
0.001
0.001
G
H
I
J
F-3
G-1
G-3
I-1
I-2
I-3
J-1
J-2
J-3
a
b

Text-fig. 2.1

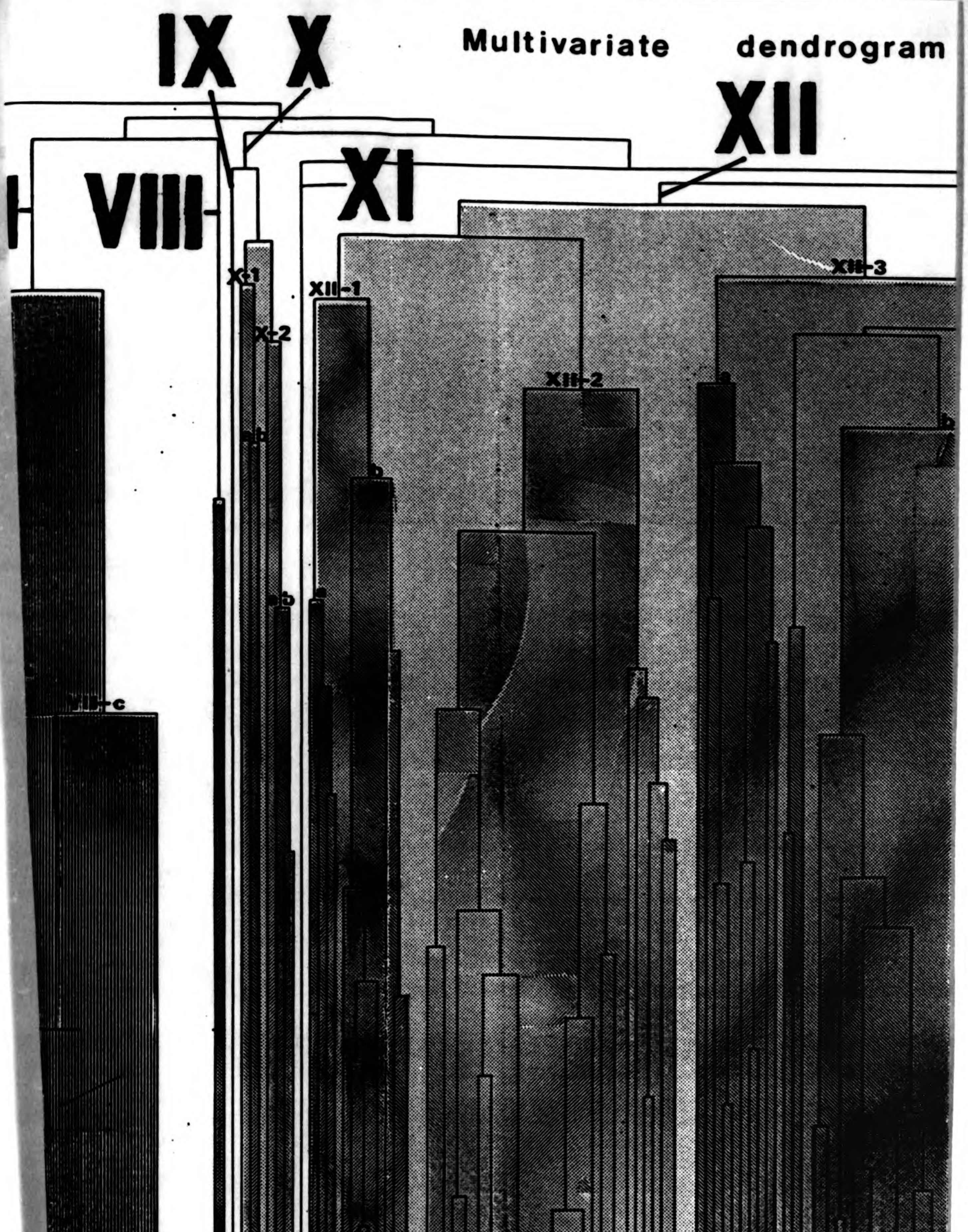
samples clustered, the number of species in successively less than 100% of the samples (down to 0%, species absent in all samples of that cluster) .

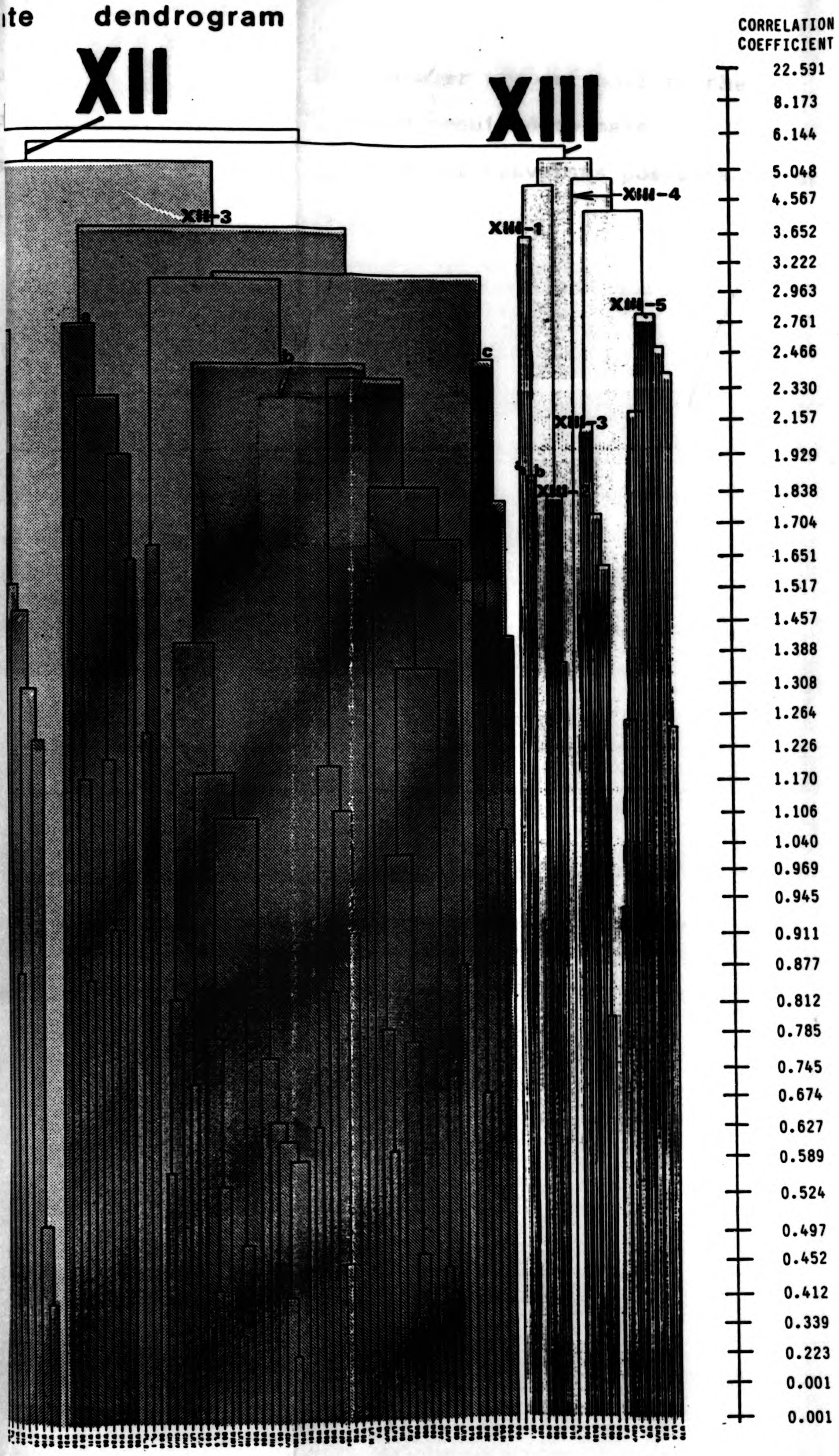
(iv) The percentage occurrence for binary variables (ie the actual percentage of all samples of that cluster that contain each taxon, from 1-87).

The second cluster analysis was based on the full relative percentage count data. However the computer (DEC SYSTEM-10 updated February 1978, computer centre, James Cook University of North Queensland) did not have sufficient core to handle all 87 numeric variables (ie.percentage frequencies of the 87 taxa). This did not matter as all 87 taxa never occurred in one sample, and even the most varied assemblage contained below 80 taxa. The cluster analysis gave a dendrogram print-out similar to that provided for the binary data, but additional data at a specified coefficient level was not provided. A drafted copy of the dendrogram is given on text-fig. 2.2. . Samples are listed at the bottom end of the dendrogram adjacent to those to which they are most closely related in the cluster analysis, at coefficient 0.001. All of the samples are finally grouped as one at the top end, at coefficient 22.591. The only additional information provided by the print-out was a list of numeric means and standard deviations of the first 74 species. However some of the values given are negative ones, indicating that presence outside the 200 count, which had been given the identifier -1 had been taken 'literally' by the computer as an actual numeric value. This list of numeric means and standard deviations is therefore mostly meaningless. (For future procedure, the problem of giving a numeric value to a species occurrence outside the 200 count could be solved by giving


IV
V
IX
X
I
VI
II
III
VI-2
VI-5
VI-1
b
c
VI-3
a
VII
VIII
X-1
X-2
XII-1
VIII-c

Multivariate dendrogram




ıte dendrogram
XII
XIII
XII-3
XIII-1
XIII-4
XIII-5
XIII-3
XIII-2
a
b
c
b
CORRELATION COEFFICIENT
22.591
8.173
6.144
5.048
4.567
3.652
3.222
2.963
2.761
2.466
2.330
2.157
1.929
1.838
1.704
1.651
1.517
1.457
1.388
1.308
1.264
1.226
1.170
1.106
1.040
0.969
0.945
0.911
0.877
0.812
0.785
0.745
0.674
0.627
0.589
0.524
0.497
0.452
0.412
0.339
0.223
0.001
0.001

Text-fig. 2.2

such occurrences a fractional number proportional to the number of traverses of the slide required to make the 200 count as a fraction of the total number of traverses possible on one slide).

2.3 (b) Data collection from dendrograms

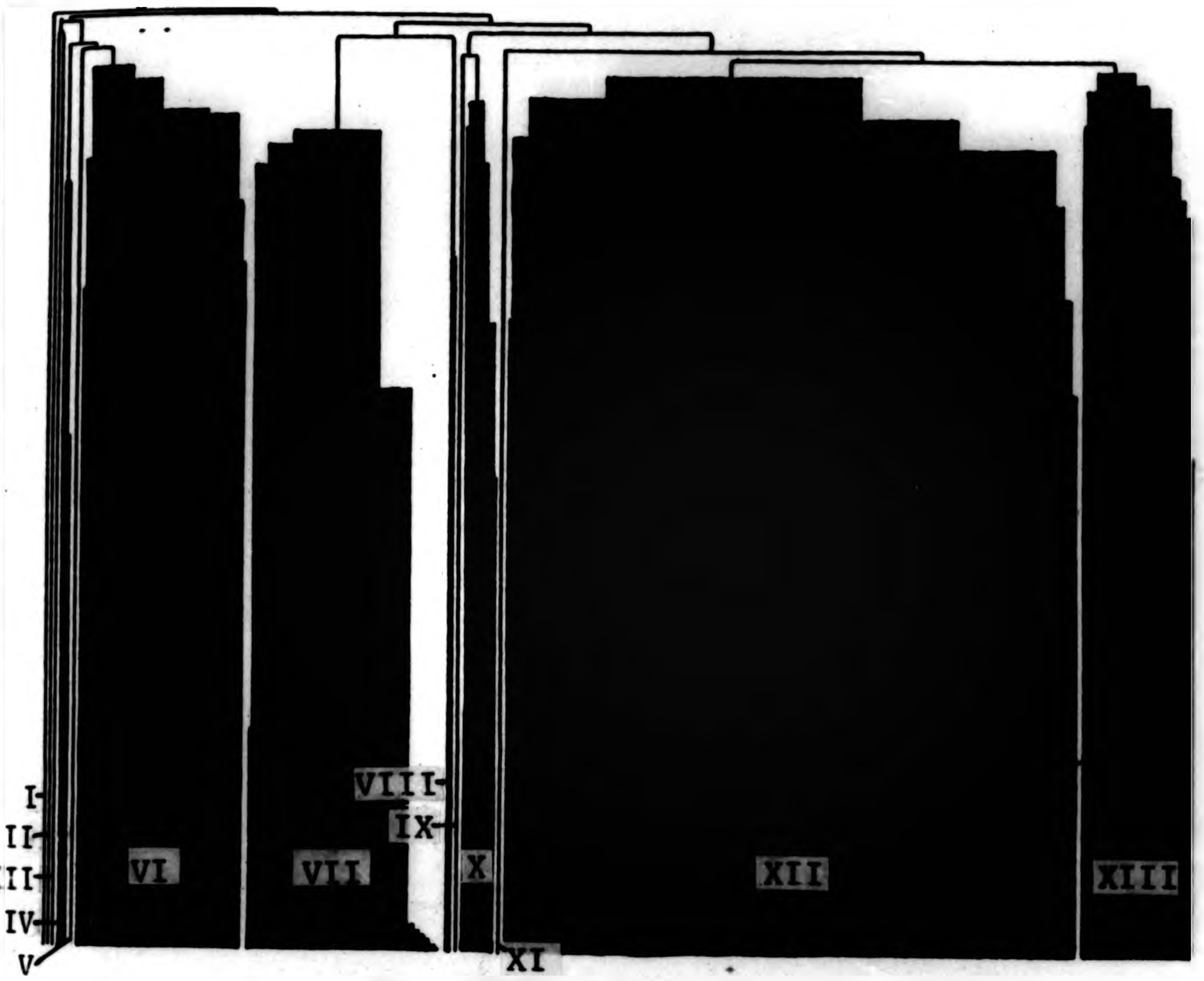
As stated in the previous section, the binary analysis dendrogram provided 10 clear-cut clusters at coefficient 0.7111 that were defined by number of cases, case numbers, binary variable frequencies and percentage occurrence for binary variables of each. However the numeric variable analysis (multivariate) dendrogram did not provide any group of clear-cut clusters. Before proceeding any further, cluster groups must therefore be allocated to the dendrogram. If a similar coefficient level (0.7111) to the binary dendrogram were used here, the dendrogram forms 159 clusters. This high number of clusters compared to only 10 on the binary analysis dendrogram at this coefficient clearly reflects the greater dissimilarity of palynological assemblages of rock samples when numeric frequency of individual taxa is taken into account. These 159 clusters are too many to provide any meaningful analysis of the whole data set, being only just less thn half the total number of unclustered rock samples.

On the other hand the dendrogram could be taken at the coefficient 6.360 where 10 clusters occur. A severe difficulty arises here also, as these 10 clusters are all very uneven with about 80% of the data set grouped in two clusters and the remaining 20% spread through the other eight. This is not a meaningful separation of the data set either. By way of compromise it was decided to take intermediate coefficient levels at coefficient 2.0 (2.011), 3.0 (2.963), 4.0 (3.997) and 5.559 (ie near 6.0). The respective number of clusters of the data set at each of these levels is 58, 35, 24 and 13. By designating the 13 main clusters I - XIII, each with subgroups 1, 2, 3 etc for the 24 cluster level, sub-subgroups a, b, c etc for the 35 cluster level , and sub,sub-subgroups i, ii, iii etc for the 58 cluster level it is possible to stress the bigger cluster groups or smaller ones as desired at the same time. A breakdown of the various clusters and subclusters is given on text-fig.2.2. The 10 binary cluster groups were also broken down into subgroups (or 'subclusters') where the 'cut-off' point of the dendrogram produced 24 and 36 subclusters at coefficients 0.470 and 0.386 respectively. These positions were only arbitrarily arrived at, where they produced convenient numbers of subcluster groups comparable with the multivariate ones. In practice with the succeeding palynofacies analysis it has been found to be of very great value to be able to emphasize both the main clusters and subclusters within them at the same time. Binary subclusters are shown on text-fig. 2.1.

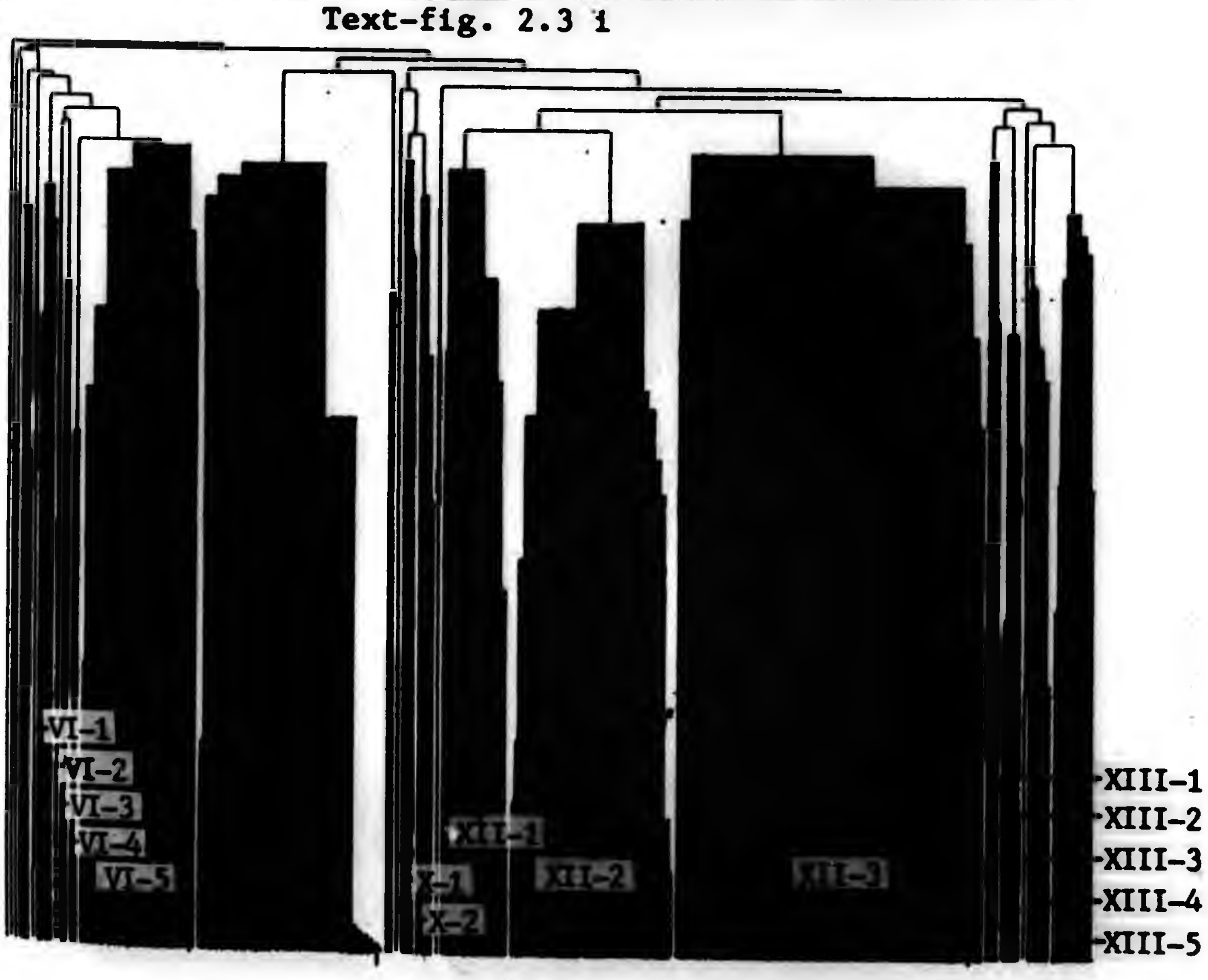
A series of diagrams showing the multivariate cluster groups at various coefficient levels (shaded black for clarity) is given on text-fig. 2.3 i - iv. A similar diagram of the binary cluster groups at various coefficient levels is given on text-fig. 2.4 i - iii. Clapham(1970)has used the term "phenon" levels (quoted from Sokal and Sneath,1963) for the arbitrary definition of clusters from a dendrogram.

The multivariate cluster groups

i 13 clusters at coeff. 4.0 (3.997)
ii 24 " " " 3.0 (2,963)



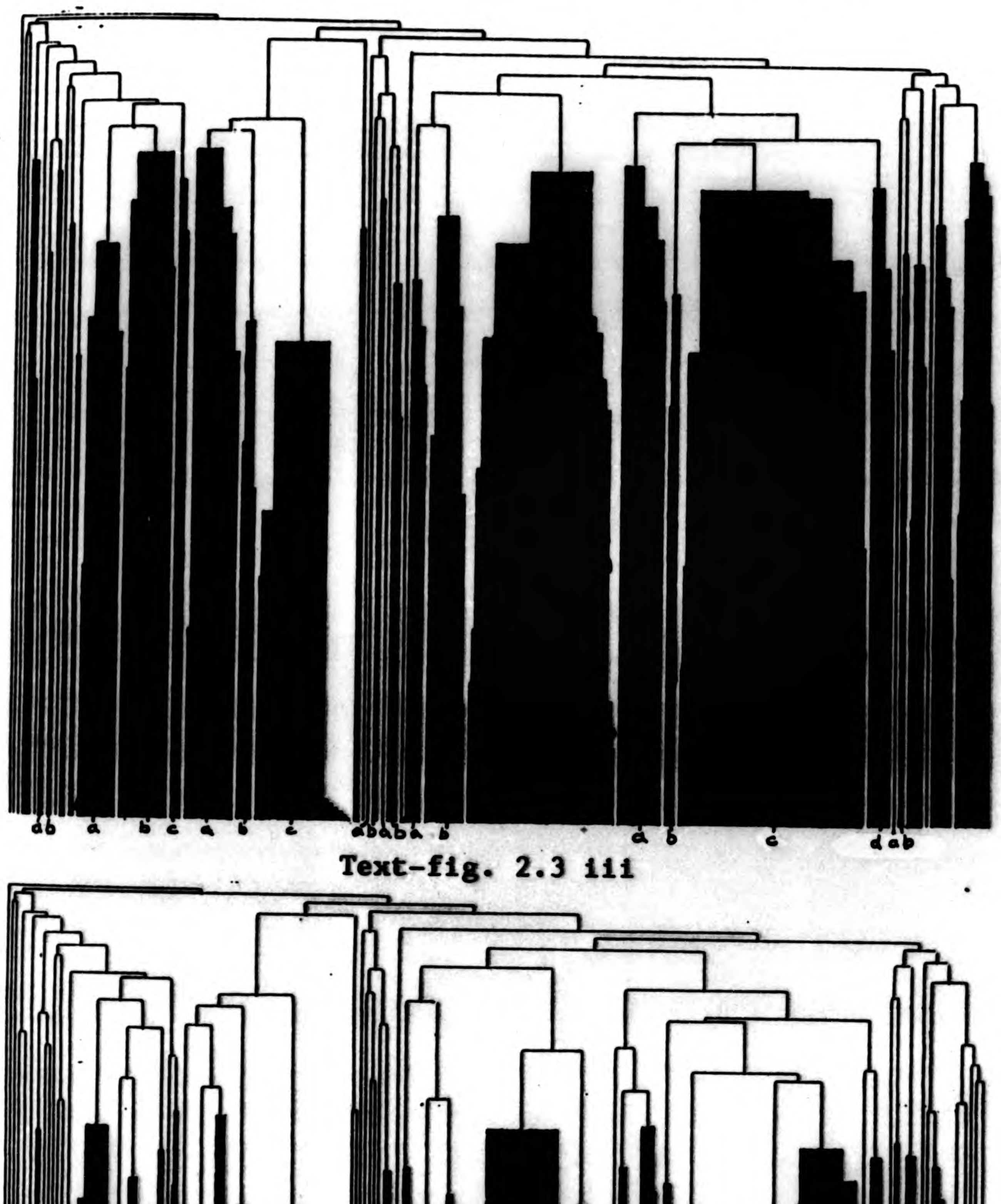
Text-fig. 2.3 i



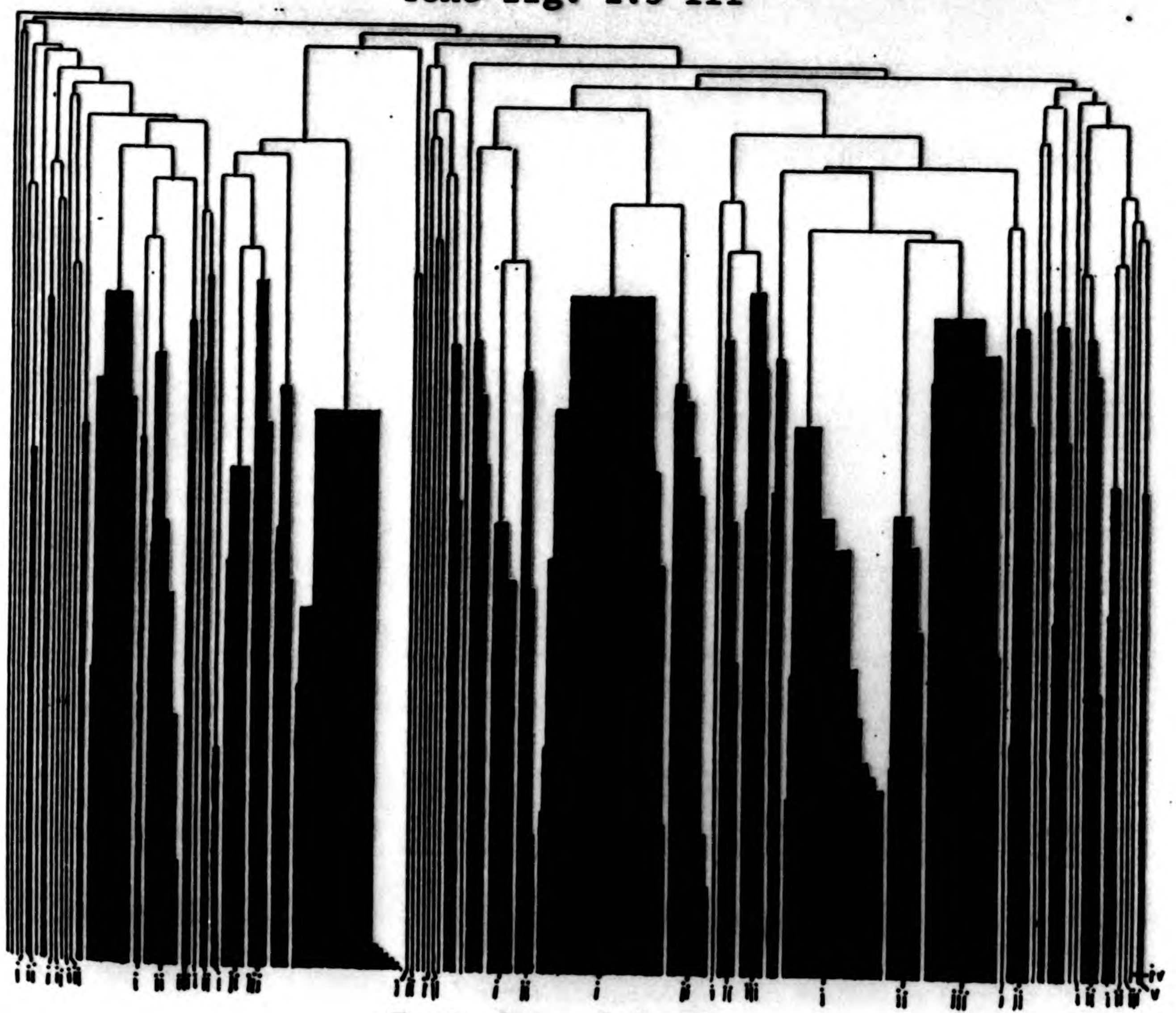
Text-fig. 2.3 ii

The multivariate cluster groups

iii 36 clusters at coeff. 3.0 (2.963)
iv 58 " " " 2.0 (2.011)

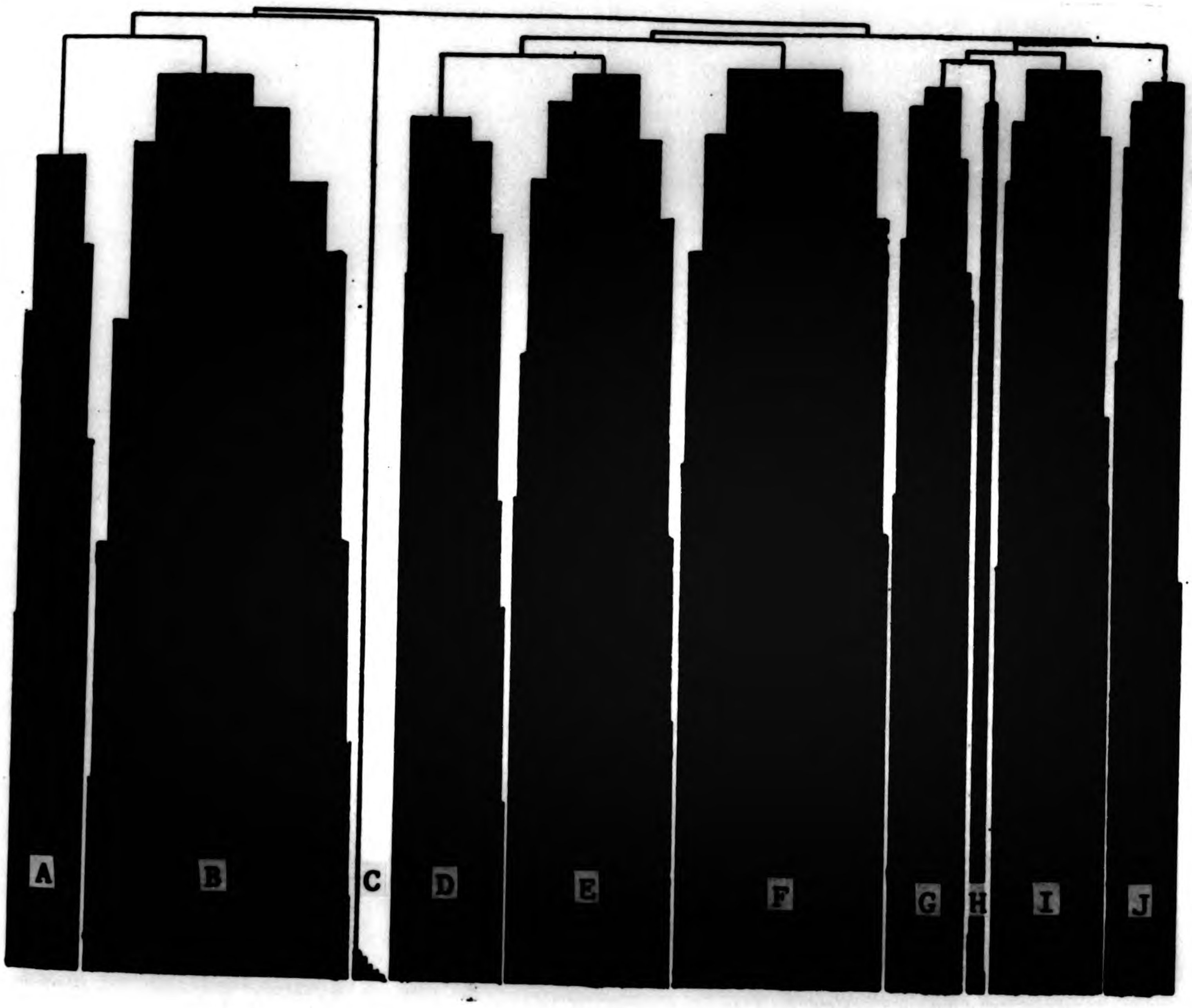


Text-fig. 2.3 iii



Text-fig. 2.3 iv

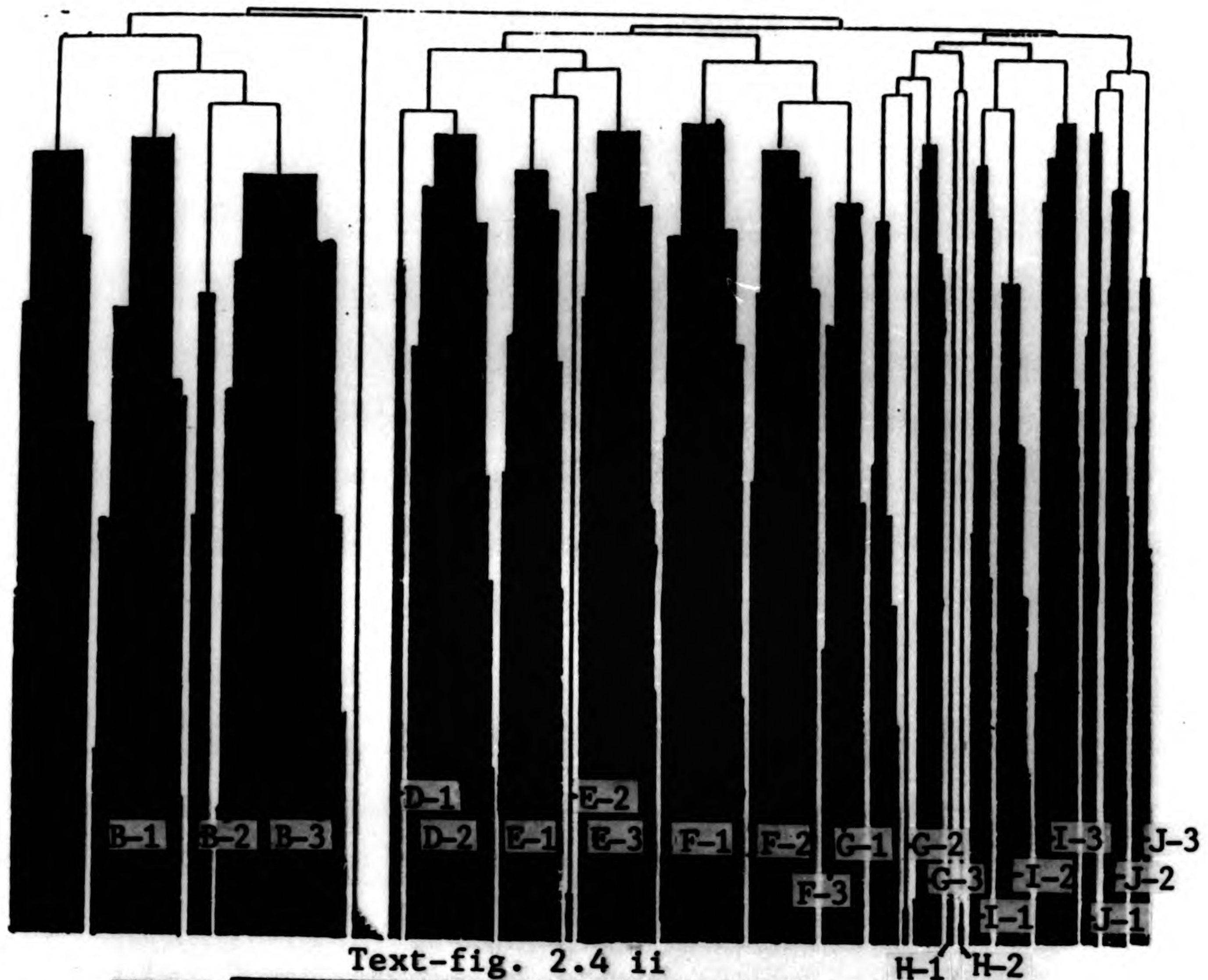
The 10 binary (presence/absence) cluster groups



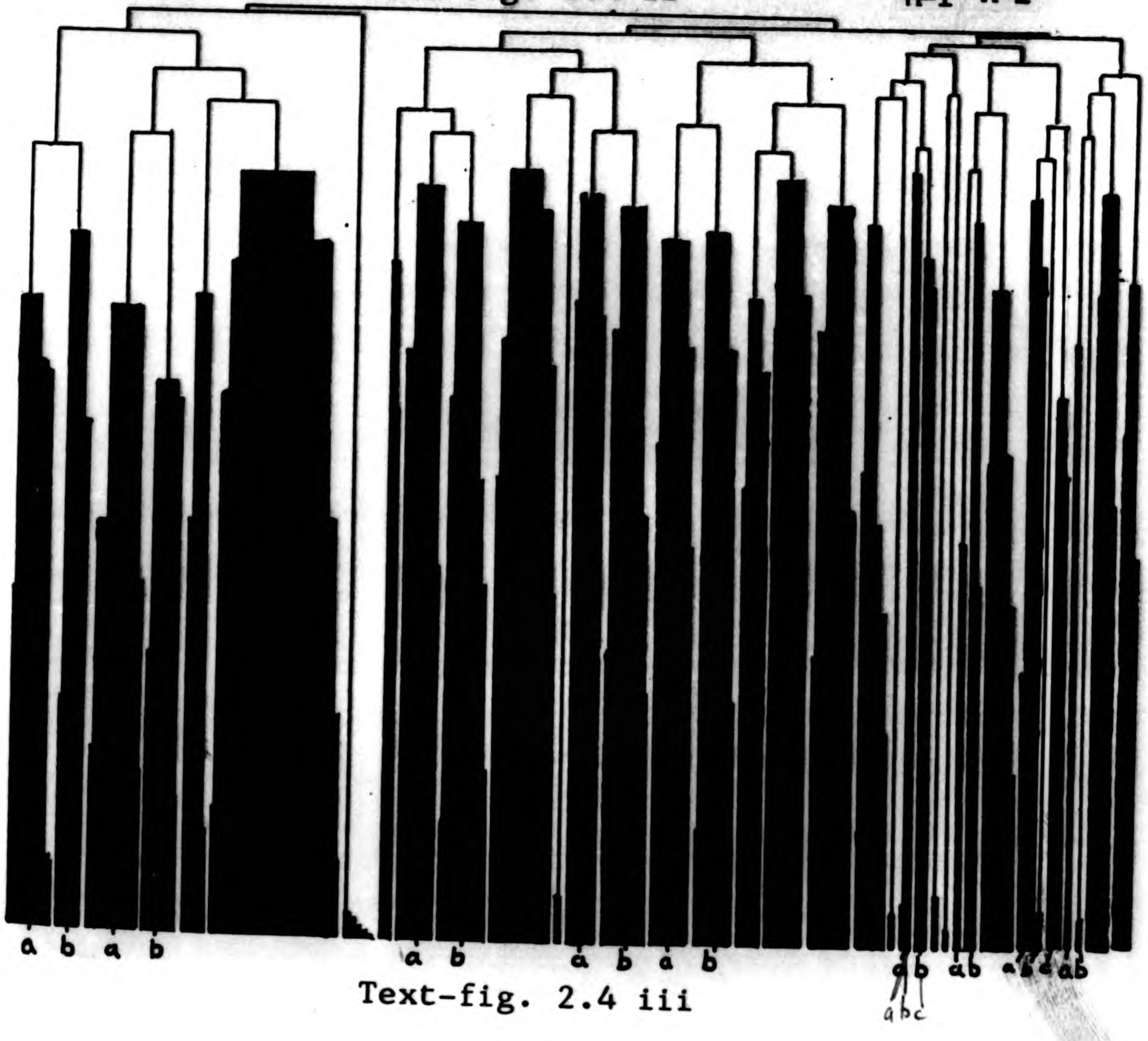
Text-fig. 2.4 i

The binary cluster groups

ii 24 clusters at coeff. 0.470
iii 36 " " " 0.386



Text-fig. 2.4 ii



Text-fig. 2.4 iii

2.4 BINARY CLUSTER GROUPS

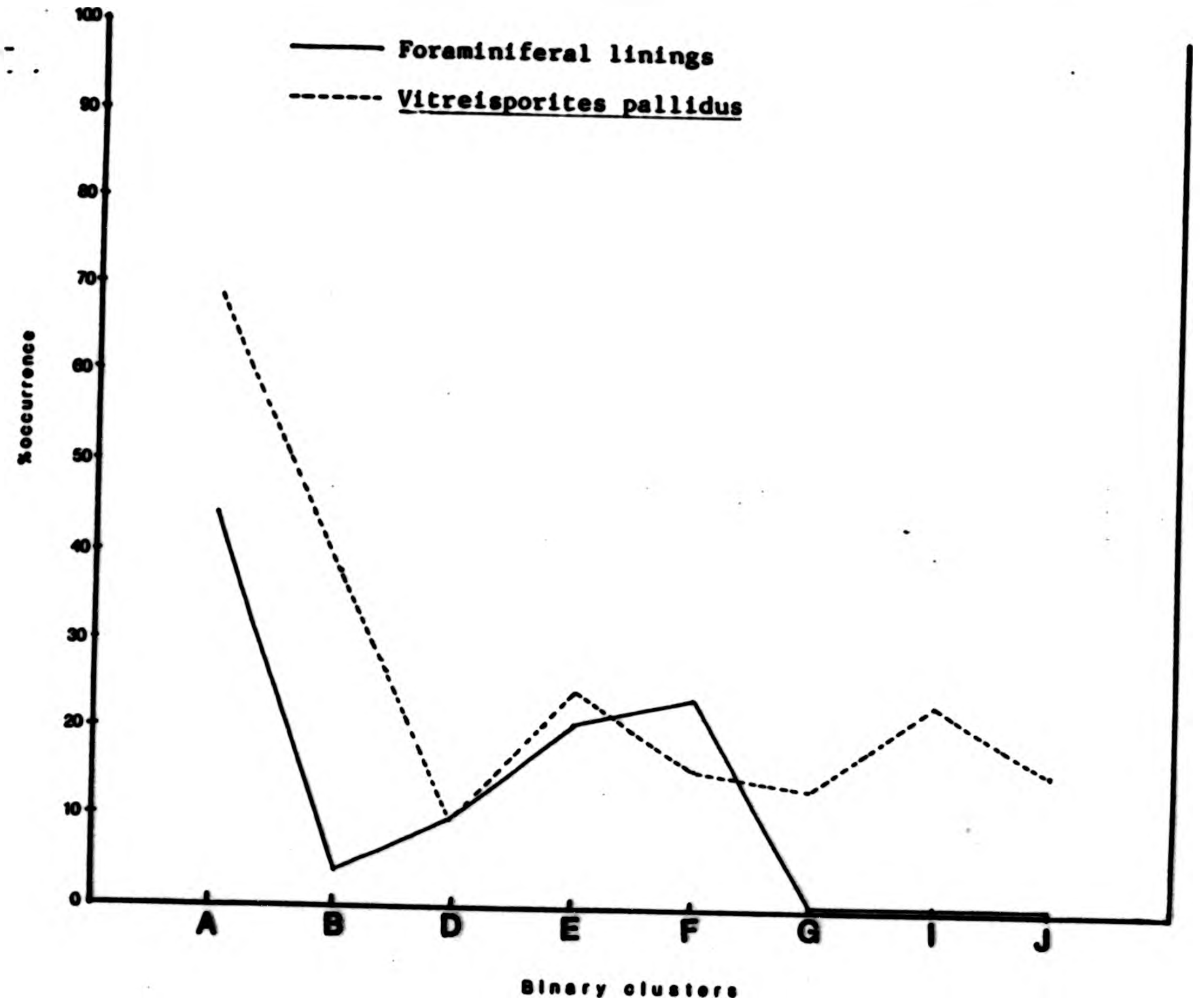
2.4 (a) Introduction

In this section each binary cluster group will be described in detail under separate headings of spore/pollen assemblage, lithology, fluorescent algal assemblage and others if applicable. It is important to bear in mind that the cluster groups have been erected solely by cluster analysis of the spore/pollen assemblages. Parameters such as kerogen type, lithology and fluorescent algae are described only by the association that they show with individual cluster groups that have already been established on spore/pollen character. Close reference to the palynofacies diagrams(enclosures 3 & 4) is necessary in reading this section, in order to see associations between different parameters. These diagrams provide a visual summary of all the data relevant to this section. The cluster analysis has done no more than rearrange the sample set out of stratigraphic order so that samples with the most similar spore/pollen assemblage (by presence/absence) are arranged side by side. Foraminiferal linings, Microthyriaceae, Pluricellaesporites, Celyphus rallus and Schizosporis are included under the heading of spore/pollen for the purposes of the cluster analysis.

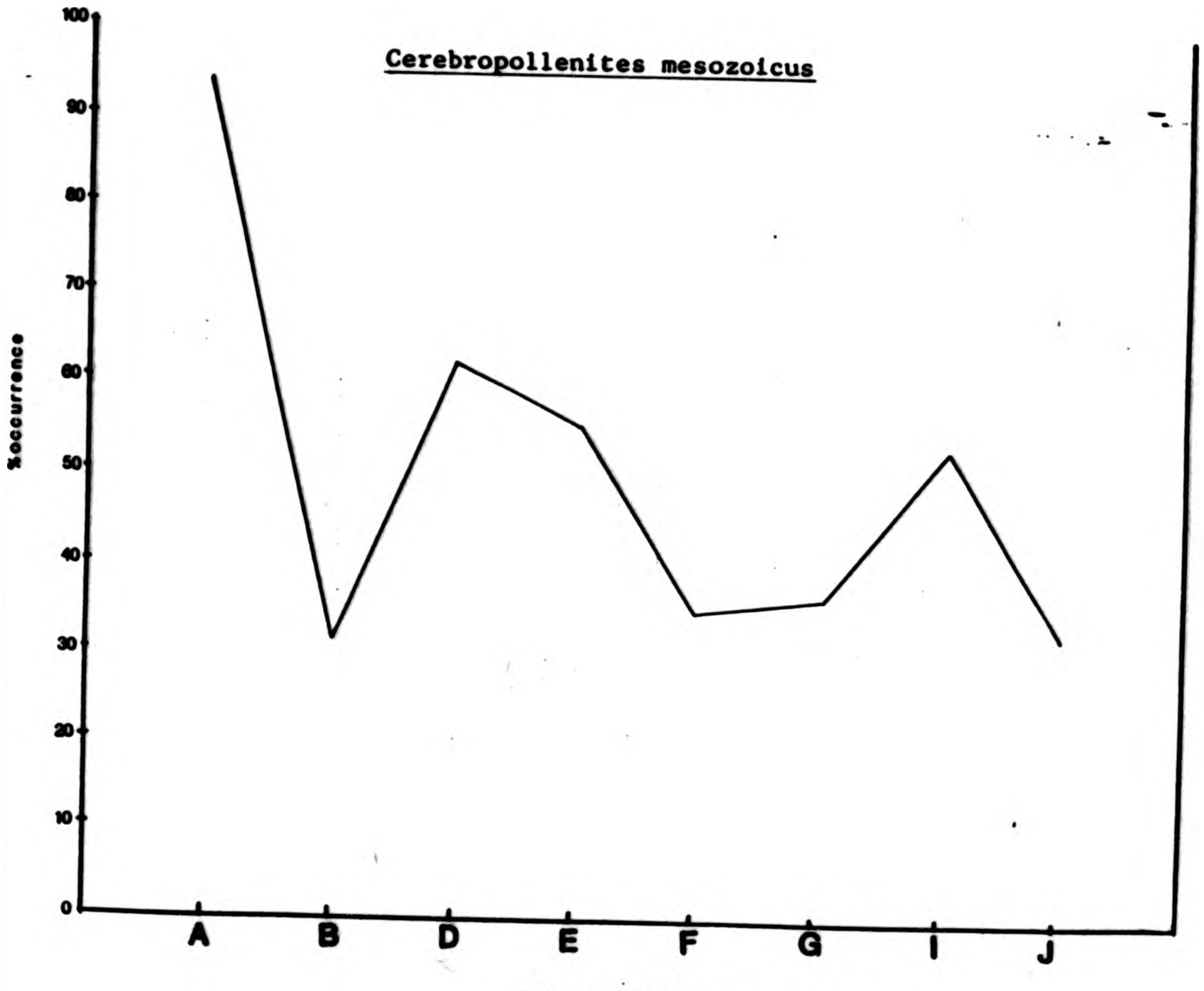
Spore/pollen assemblages upon which the clusters are based, provide little palaeoenvironmental information as knowledge on the palaeoecology of their parent plants is limited. However much more is known concerning palaeoenvironments from work on kerogen type, marine and freshwater microplankton and lithology. By 'keying' these parameters into the cluster groups using the palynofacies diagram then trends revealed by these parameters allow palaeoenvironmental conclusions to be made for the various spore/pollen assemblages represented by individudal cluster groups. Features of overlap or association of these parameters between cluster groups will be additionally significant. Associations between cluster groups based on spore/pollen assemblages will be discussed in section 2.4 (d) as this has bearing on the palaeoecology of the parent plants of the spore/pollen taxa once some idea of the palaeoenvironmental conditions for individual cluster groups is known.

Percentage occurrence traces (text figs. 2.5 i-xxx) showing the occurrence level of individual spore/pollen taxa within individual cluster groups, have been used in this section. These diagrams show the mean occurrence of a taxon throughout all the samples in a given cluster group. Where the number of samples in a cluster group is high then the importance of a given number of occurrences of a particular taxon may be much less than the same number of occurrences amongst a much lower sample total. The palynofacies diagrams allow all the assemblage characteristics of the samples in the cluster to be viewed at once. This allows subclusters to be identified that have their own assemblage characteristics apart from the overall group characters. The palynofacies diagram allows apparently lower percentage occurrence values of particular taxa, caused by a larger number of samples in the group, to be recognised. It has generally been found to be the case that for example a 27% occurrence

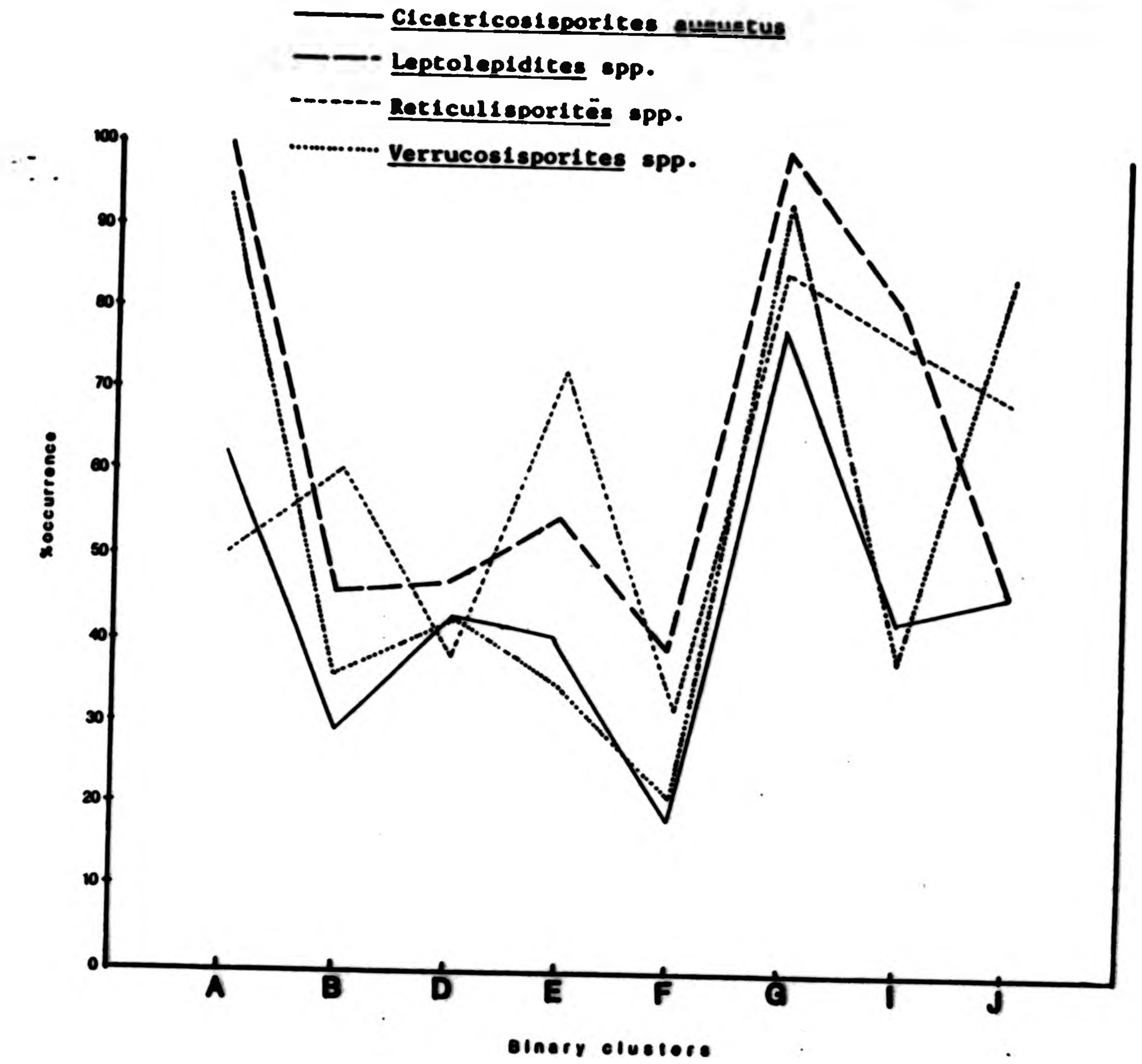
Percentage occurrence traces (P.O.T.'s) of spore/pollen taxa within the binary cluster groups. - Text-fig. 2.5 i-xxx



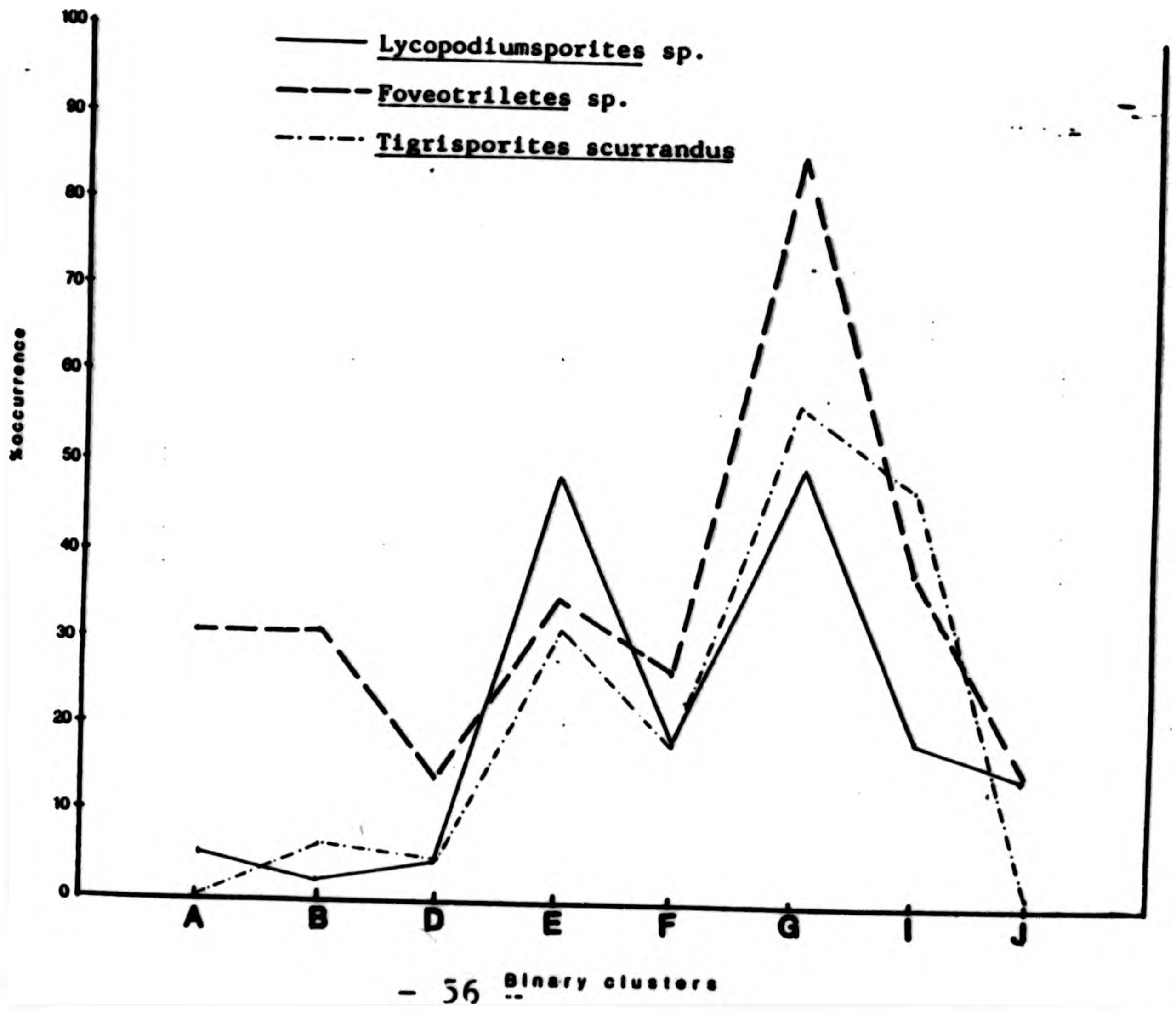
i



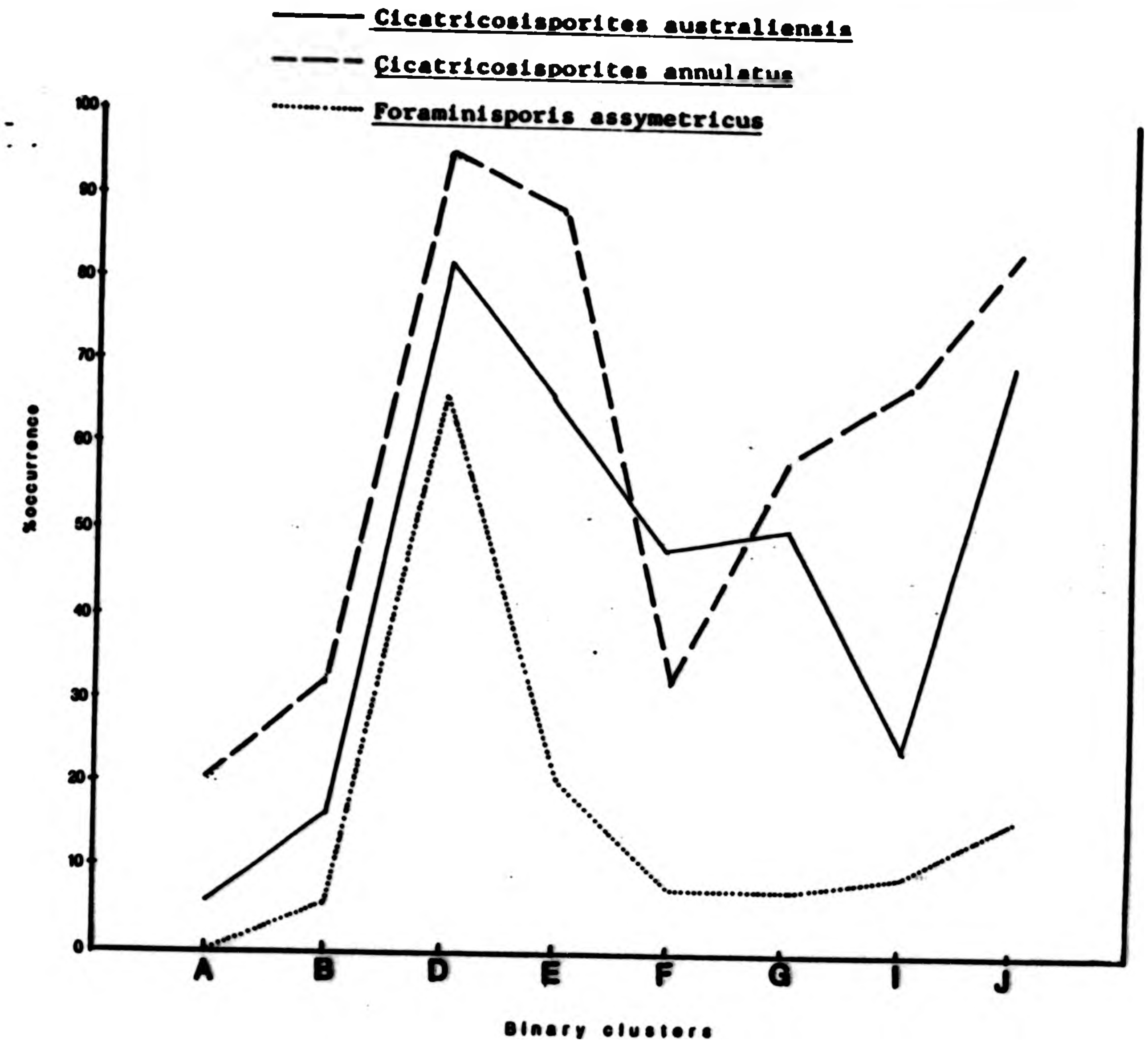
ii


Cicatricosisporites augustus
Leptolepidites spp.
Reticulisporites spp.
Verrucosisporites spp.
%occurrence
100
90
80
70
60
50
40
30
20
10
0
A
B
D
E
F
G
I
J
Binary clusters

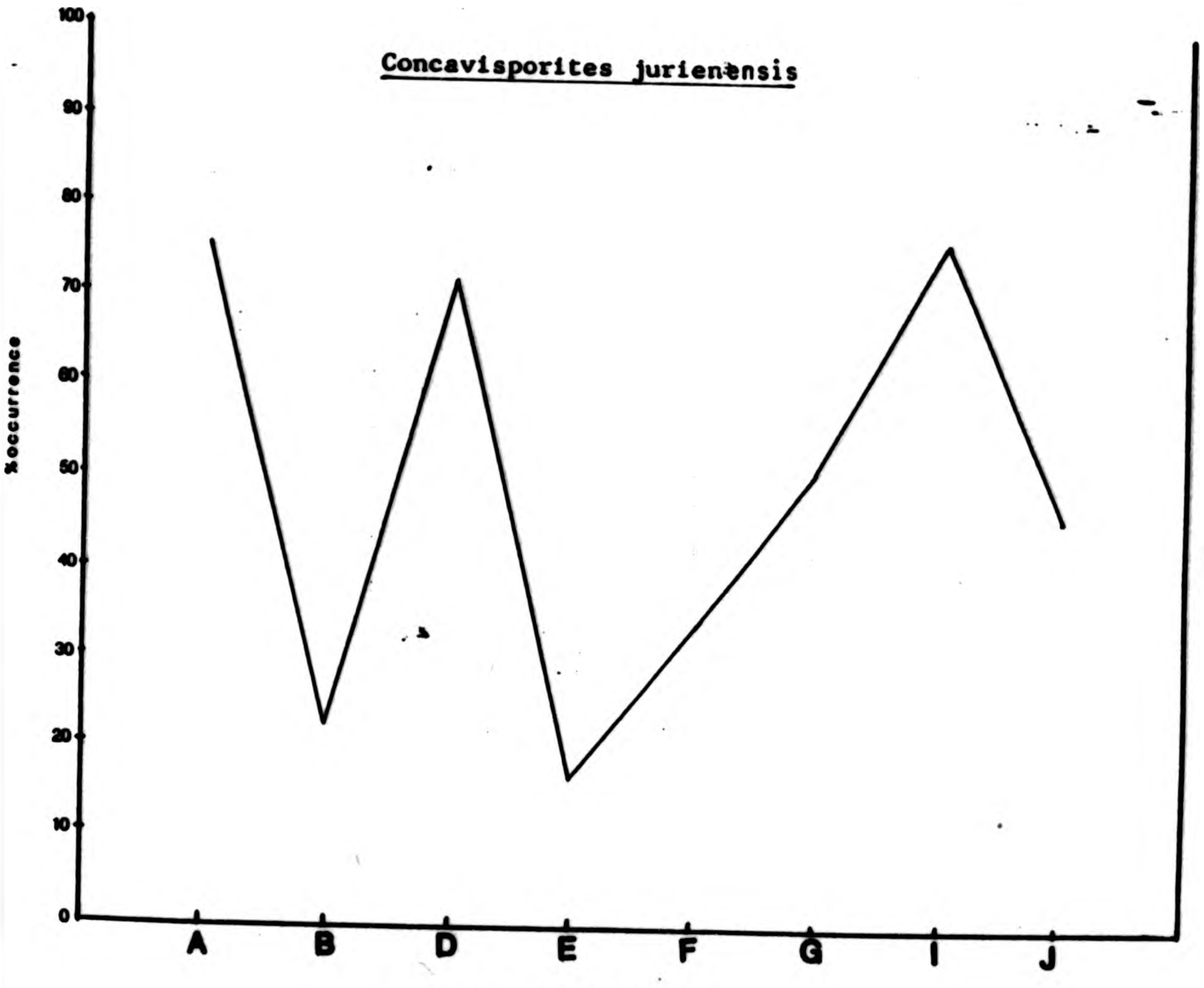
iii


Lycopodiumsporites sp.
Foveotriletes sp.
Tigrisporites scurrandus
%occurrence
100
90
80
70
60
50
40
30
20
10
0
A
B
D
E
F
G
I
J
Binary clusters

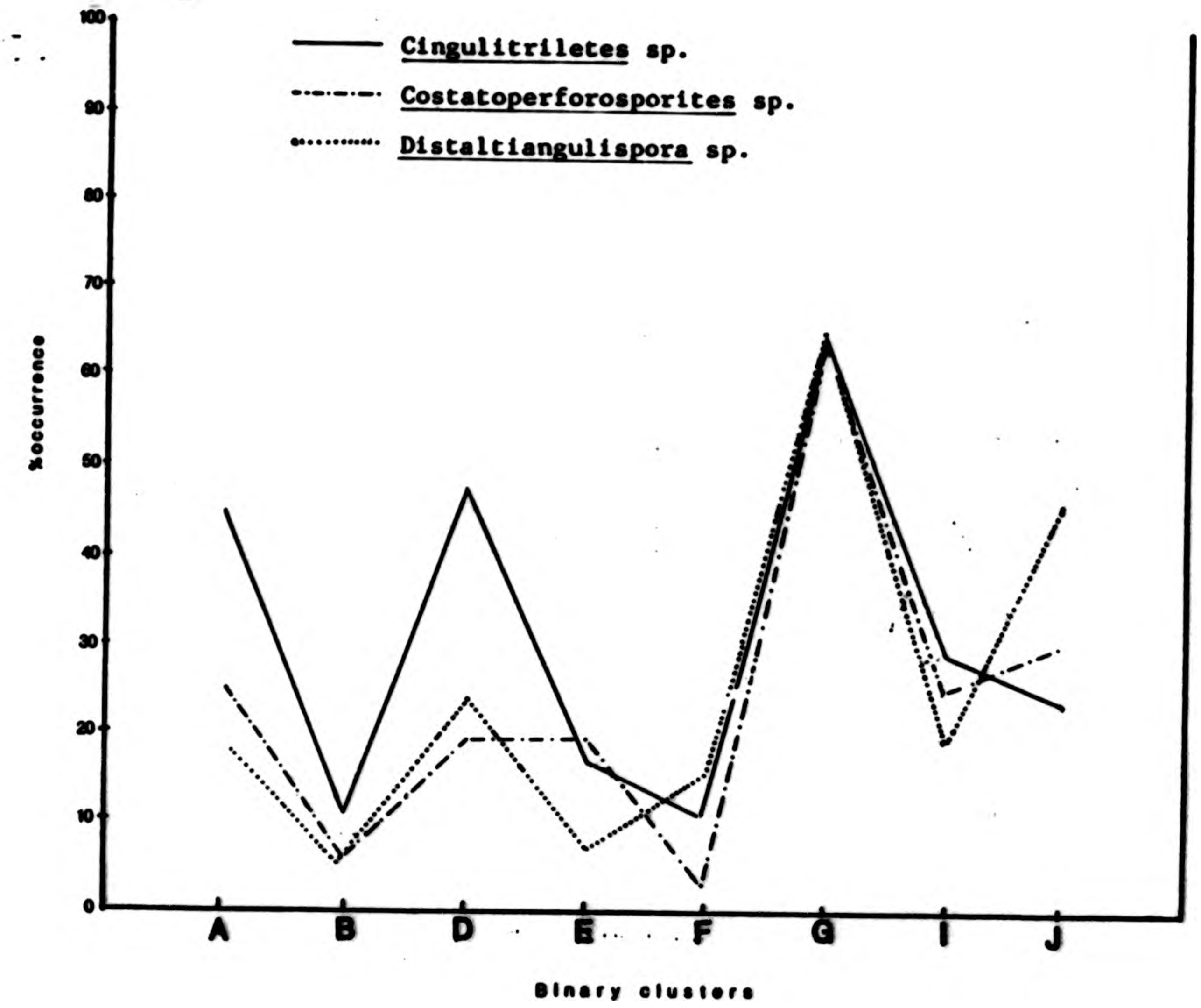
iv


Cicatricosisporites australiensis
Cicatricosisporites annulatus
Foraminisporis assymetricus
%occurrence
100
90
80
70
60
50
40
30
20
10
0
A
B
D
E
F
G
I
J
Binary clusters

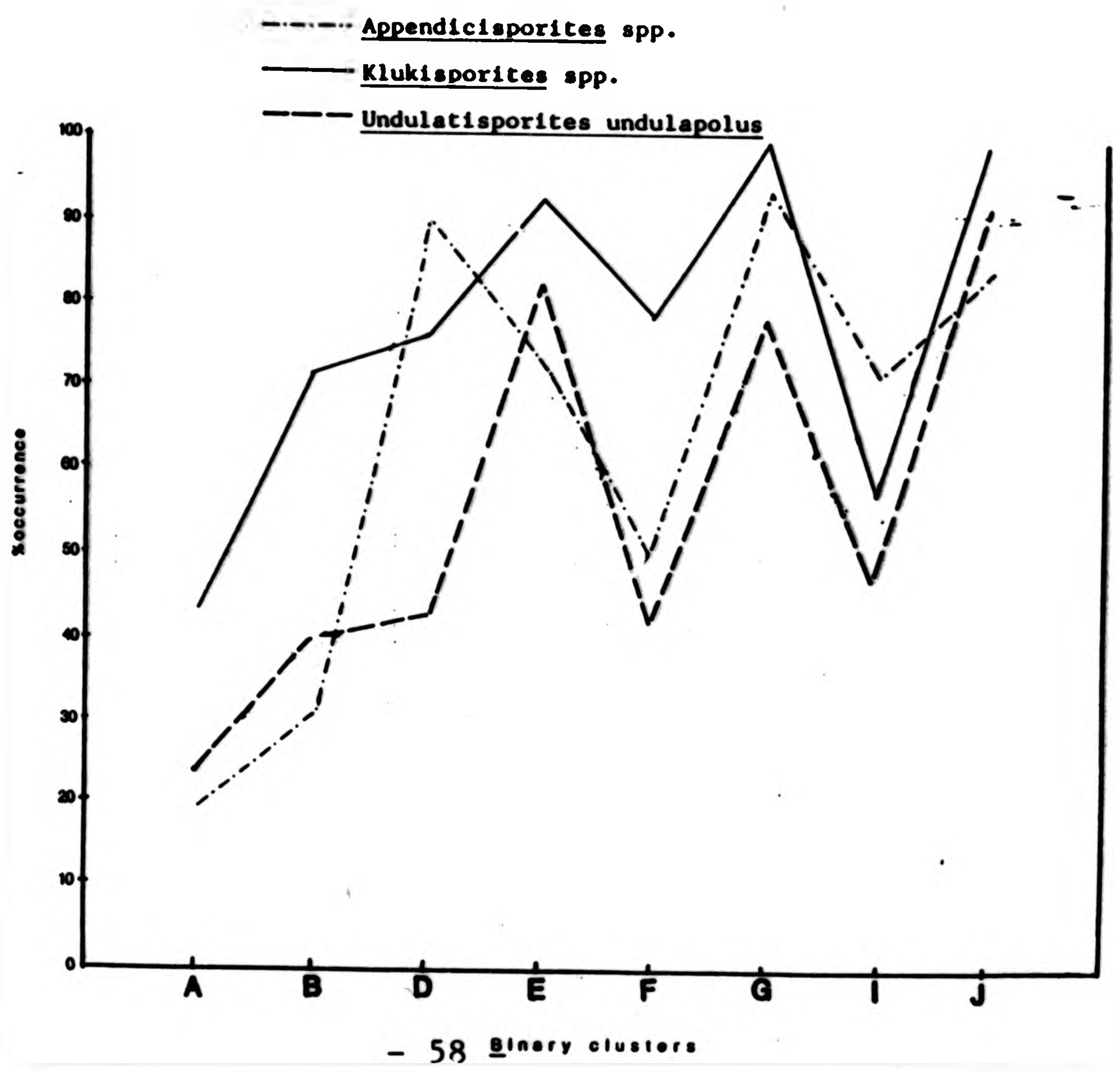
v


Concavisporites jurienensis
%occurrence
100
90
80
70
60
50
40
30
20
10
0
A
B
D
E
F
G
I
J
Binary clusters

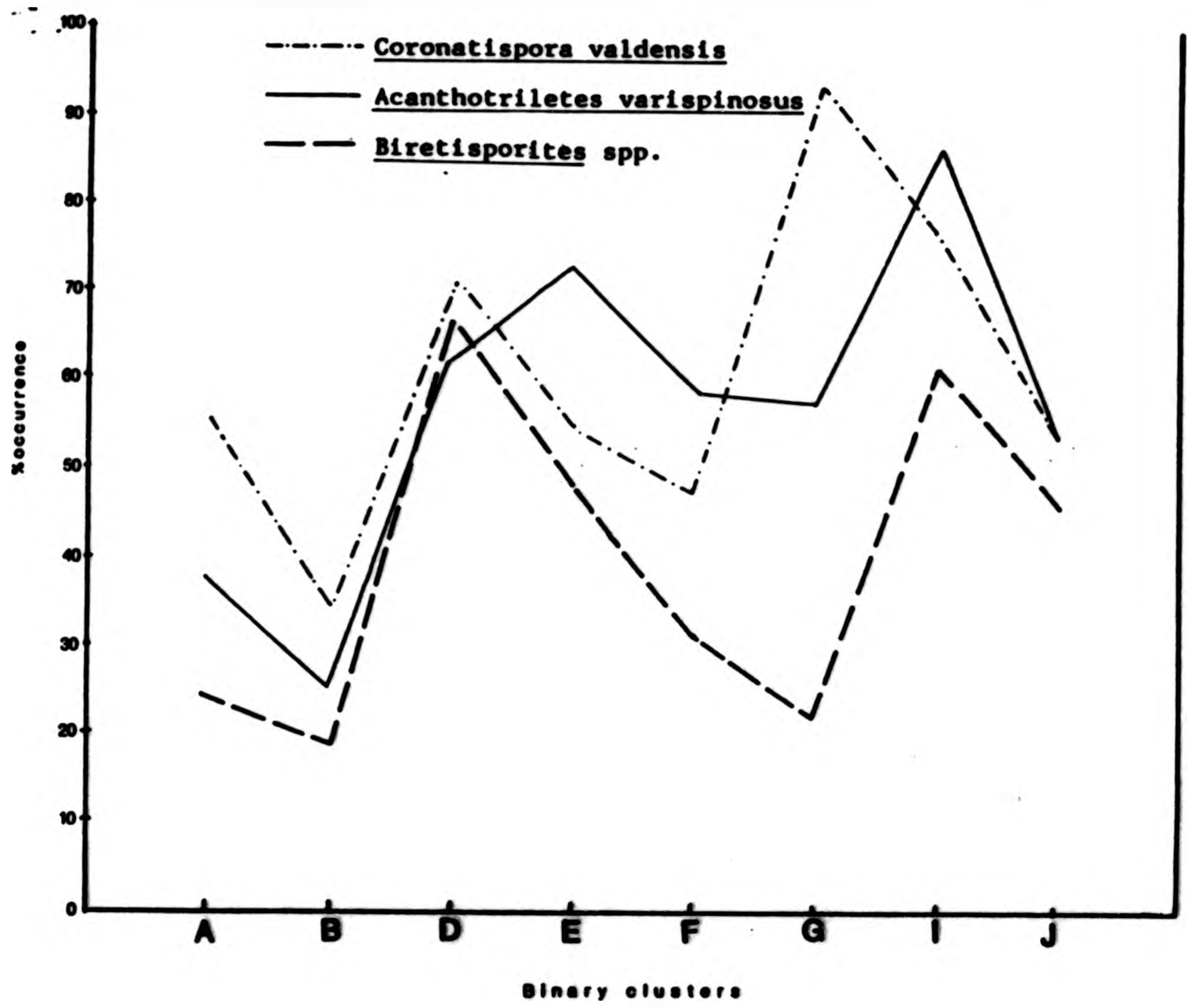
vi


Cingulitriletes sp.
Costatoperforosporites sp.
Distaltiangulispora sp.
%occurrence
100
90
80
70
60
50
40
30
20
10
0
A
B
D
E
F
G
I
J
Binary clusters

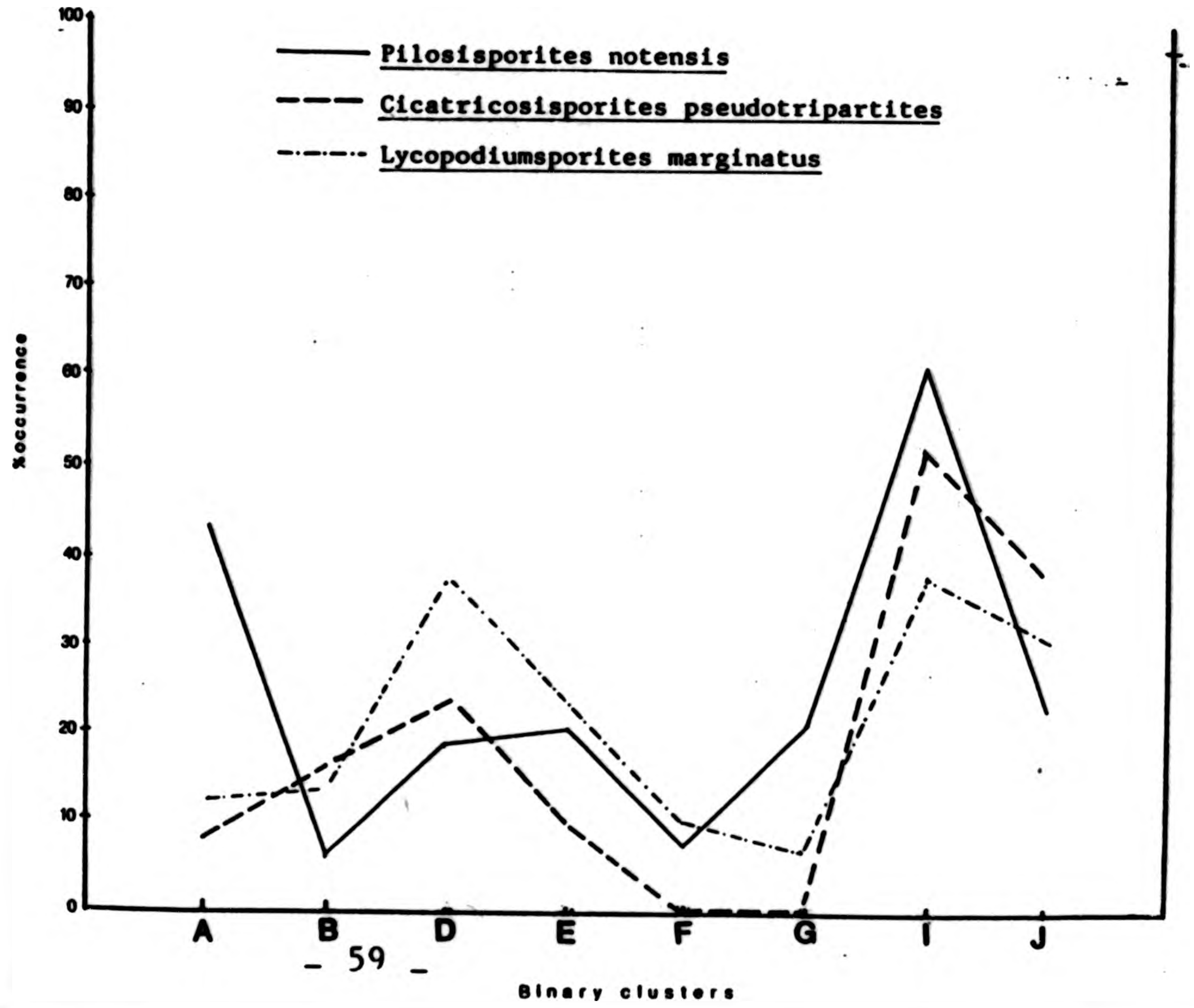
vii


Appendicisporites spp.
Klukisporites spp.
Undulatisporites undulapolus
%occurrence
100
90
80
70
60
50
40
30
20
10
0
A
B
D
E
F
G
I
J
Binary clusters

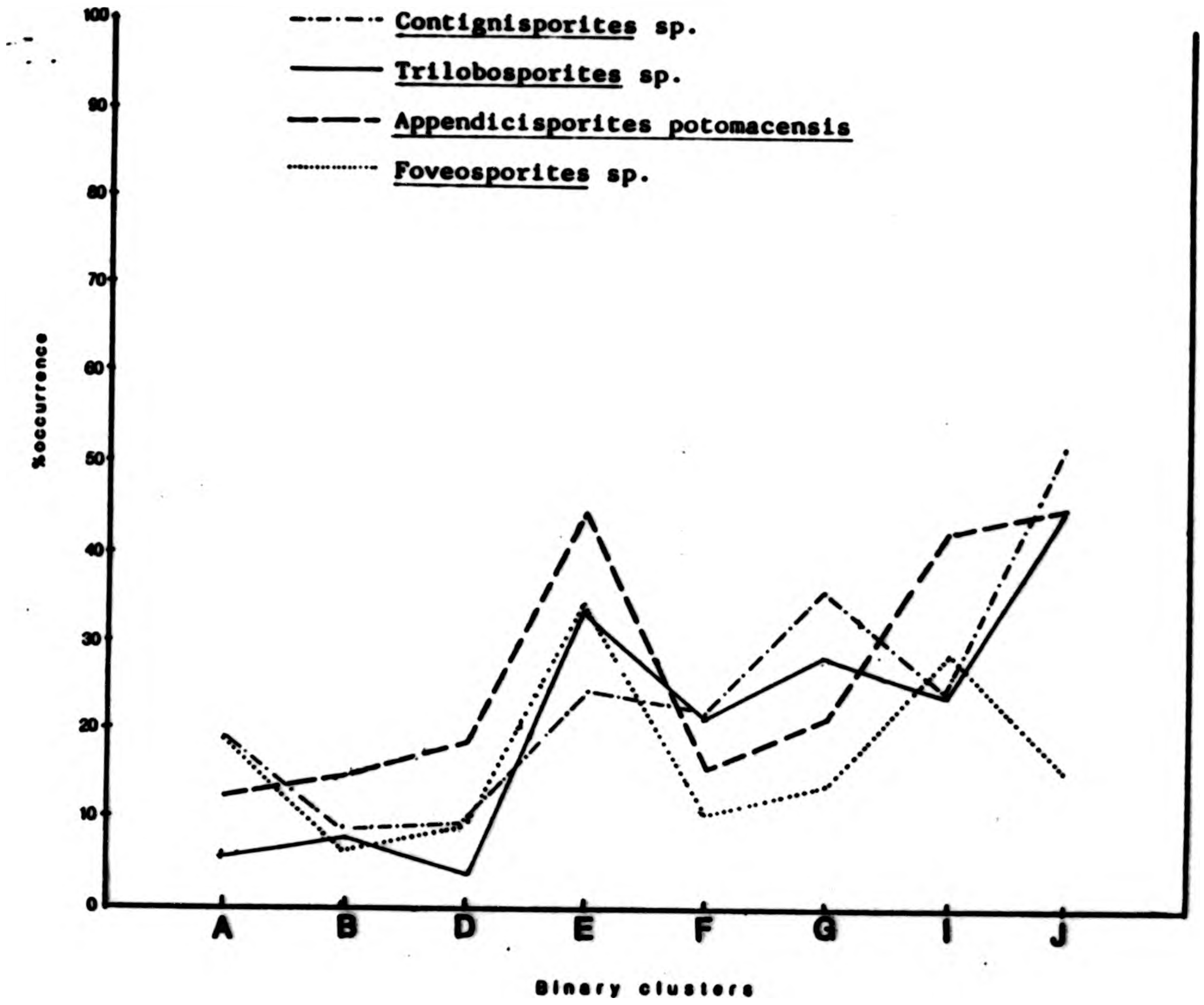
viii


Coronatispora valdensis
Acanthotriletes varispinosus
Biretisporites spp.
% occurrence
0
10
20
30
40
50
60
70
80
90
100
A
B
D
E
F
G
I
J
Binary clusters

ix

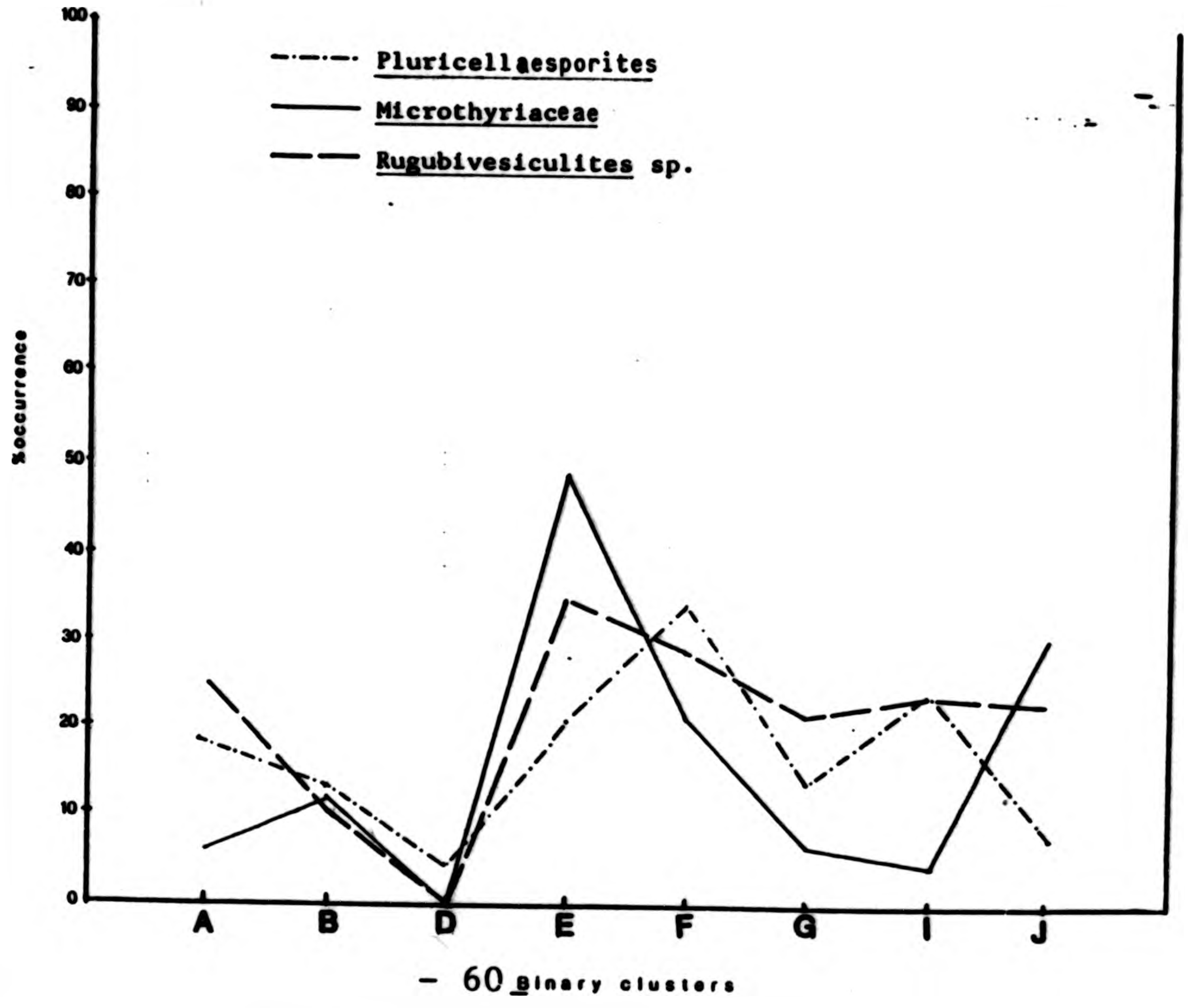

Pilosisporites notensis
Cicatricosisporites pseudotripartites
Lycopodiumsporites marginatus
% occurrence
0
10
20
30
40
50
60
70
80
90
100
A
B
D
E
F
G
I
J
Binary clusters

x



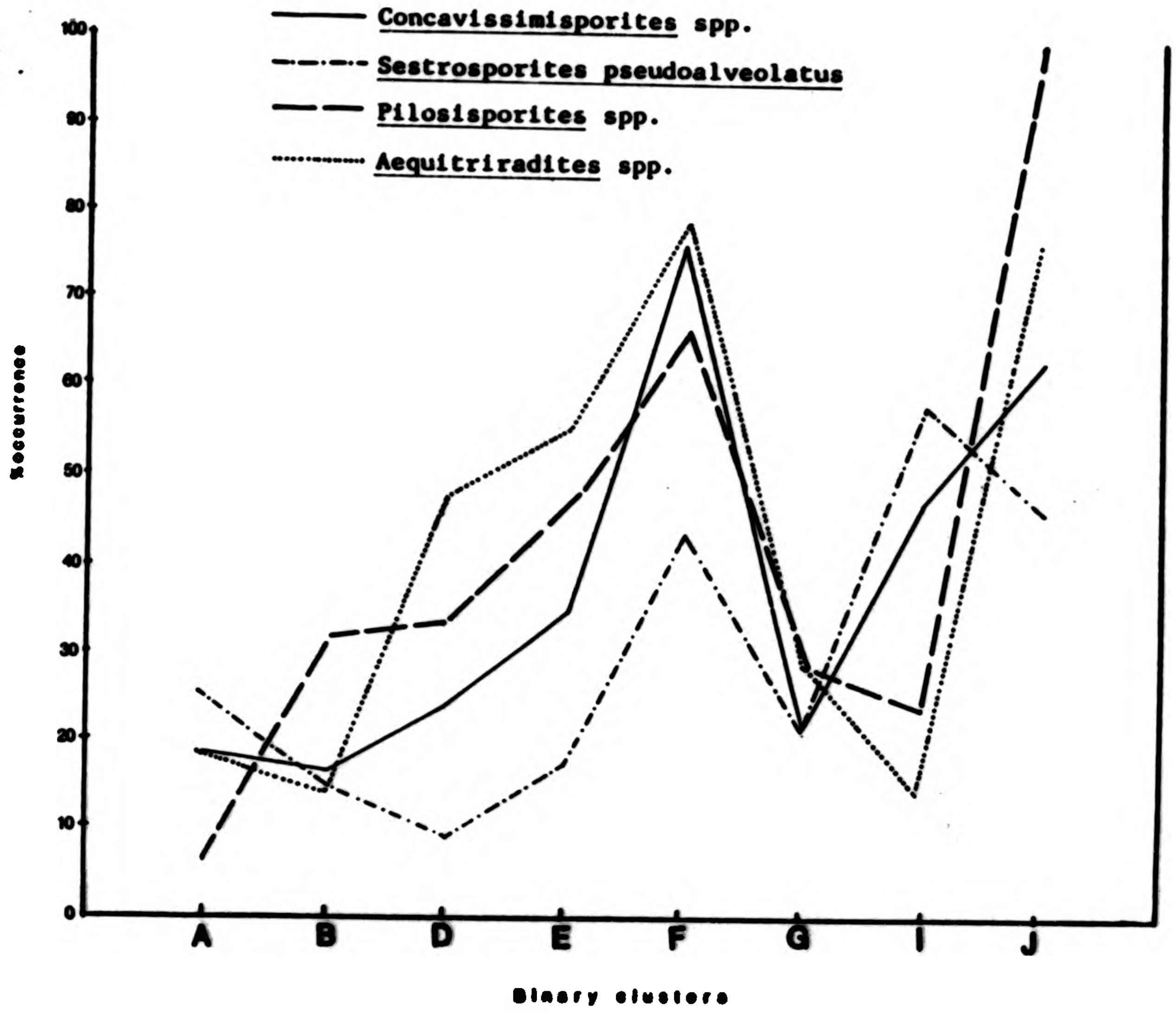
Contignisporites sp.
Trilobosporites sp.
Appendicisporites potomacensis
Foveosporites sp.
% occurrence
0
10
20
30
40
50
60
70
80
90
100
A
B
D
E
F
G
I
J
Binary clusters

xi

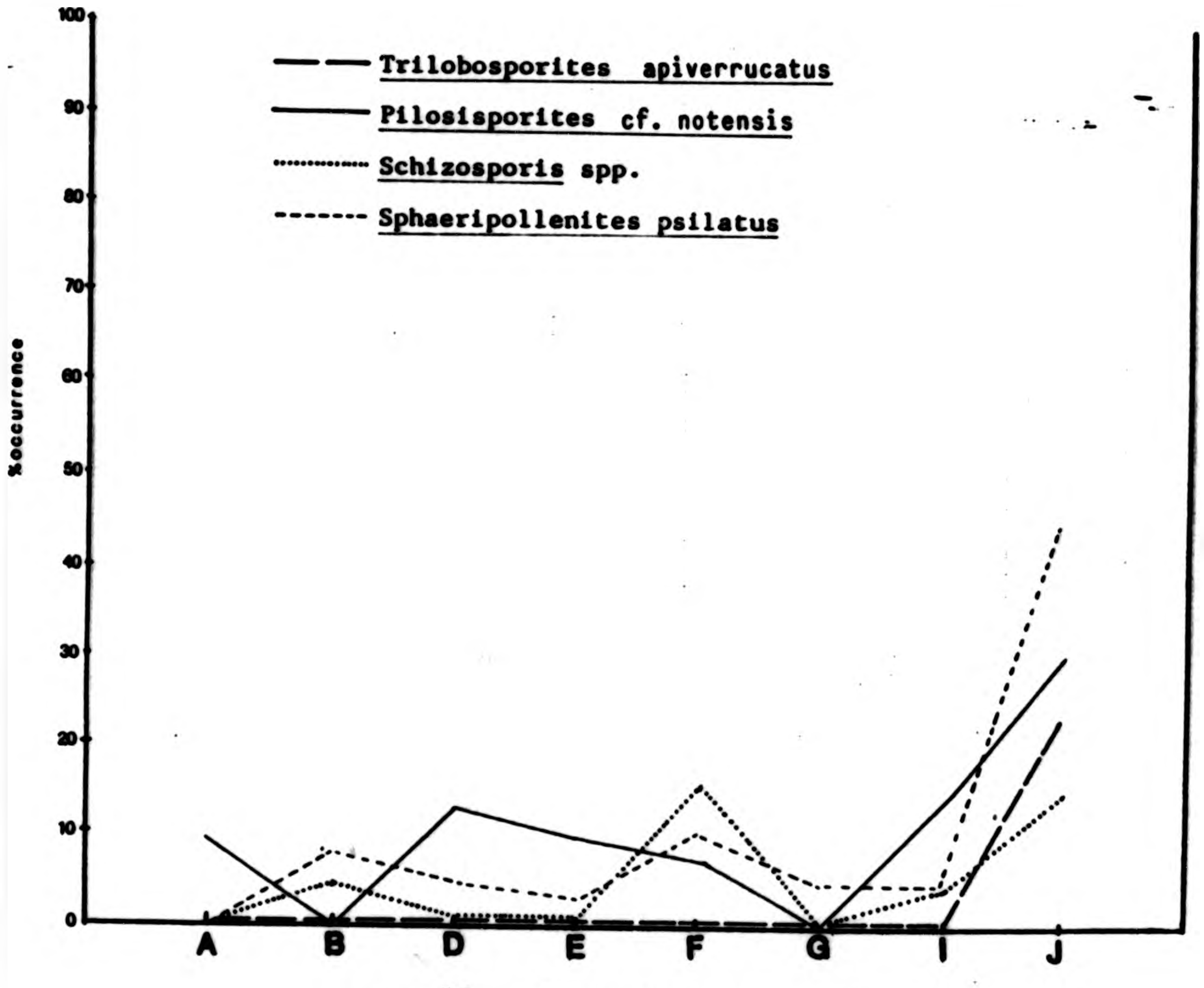


Pluricellaesporites
Microthyriaceae
Rugubivesiculites sp.
% occurrence
0
10
20
30
40
50
60
70
80
90
100
A
B
D
E
F
G
I
J
Binary clusters

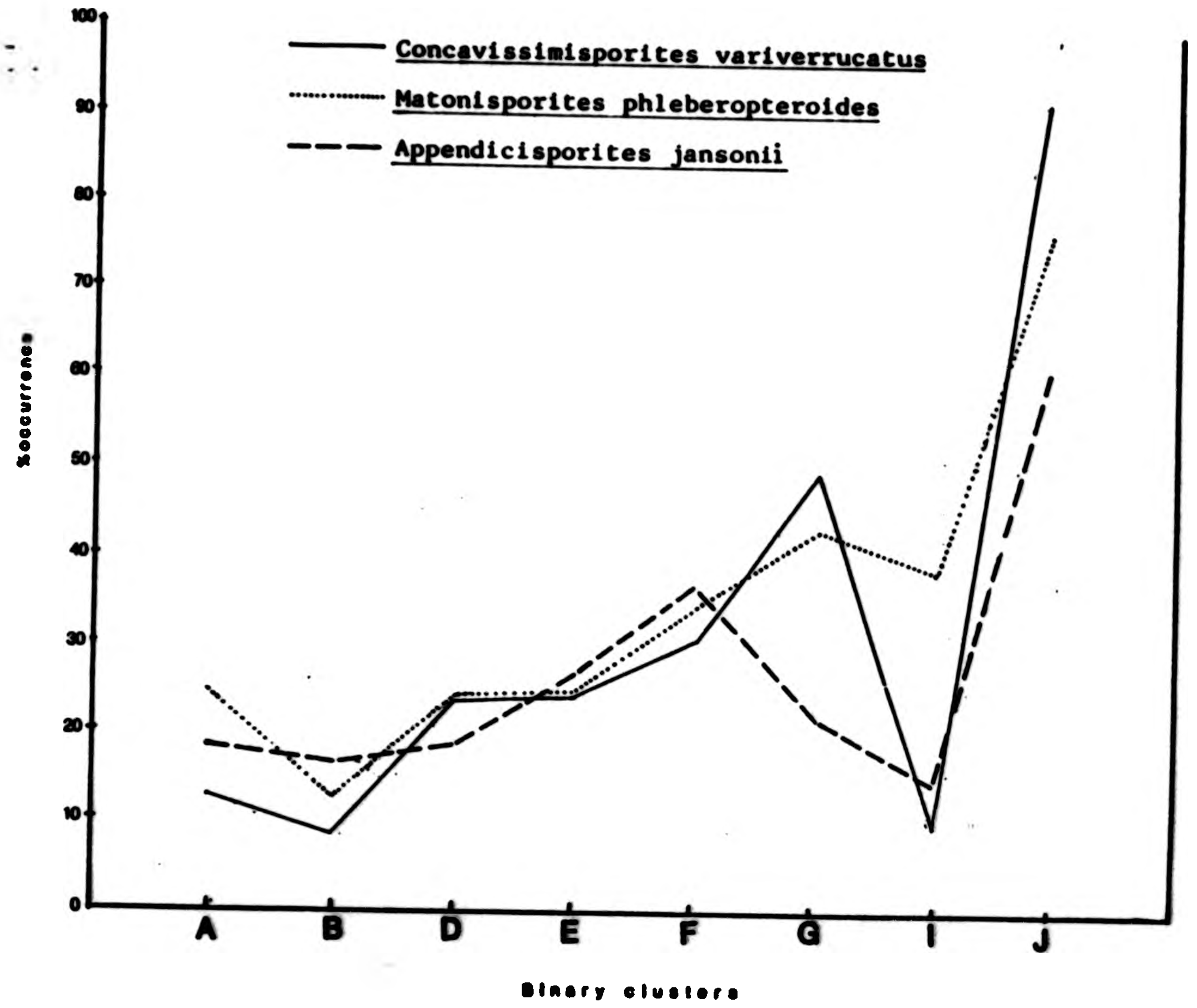
xii


Concavissimisporites spp.
Sestrosporites pseudoalveolatus
Pilosisporites spp.
Aequitriradites spp.
100
90
80
70
60
50
40
30
20
10
0
%occurrence
A
B
D
E
F
G
I
J
Binary clusters

xiii

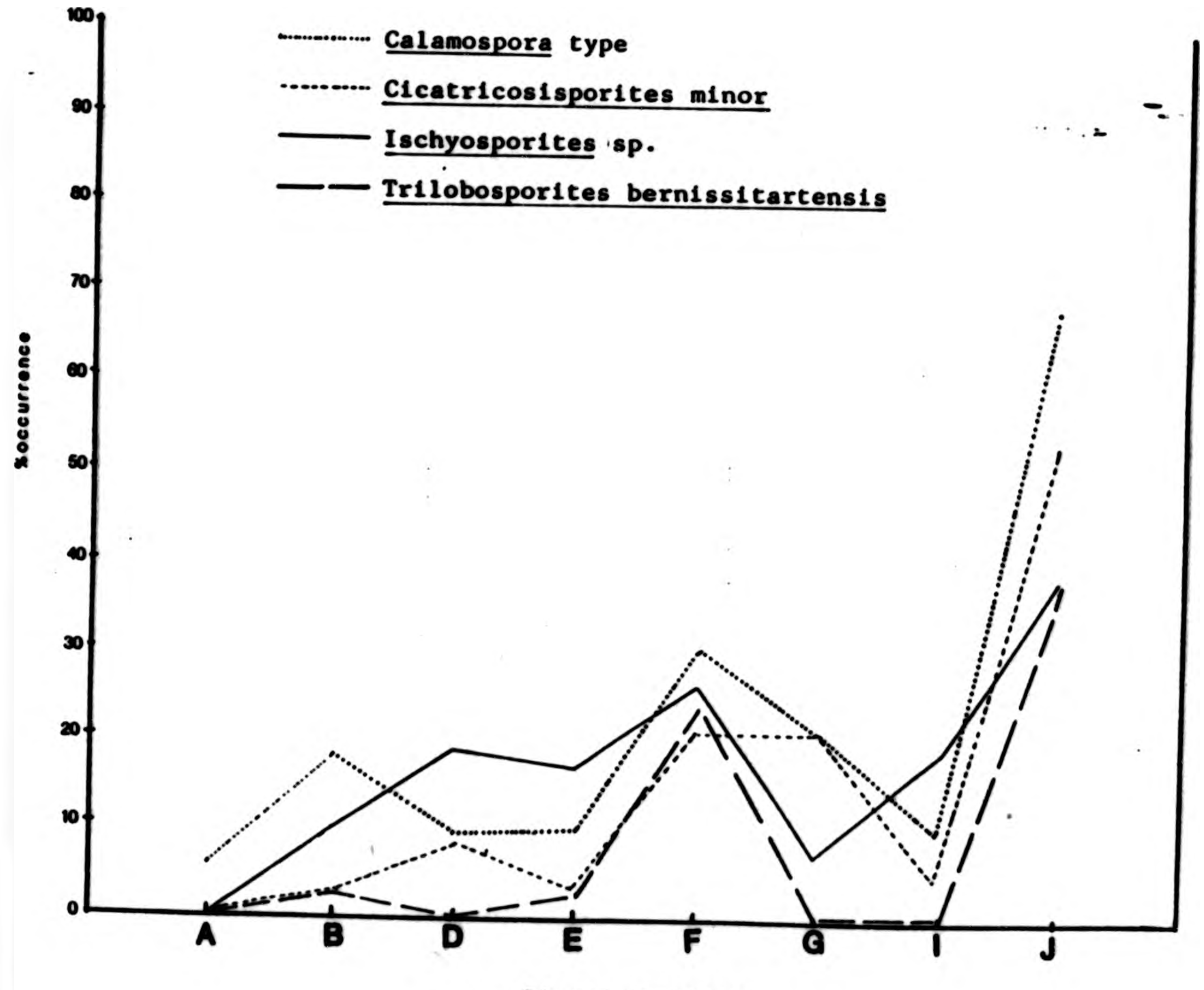

Trilobosporites apiverrucatus
Pilosisporites cf. notensis
Schizosporis spp.
Sphaeripollenites psilatus
100
90
80
70
60
50
40
30
20
10
0
%occurrence
A
B
D
E
F
G
I
J
Binary clusters

xiv



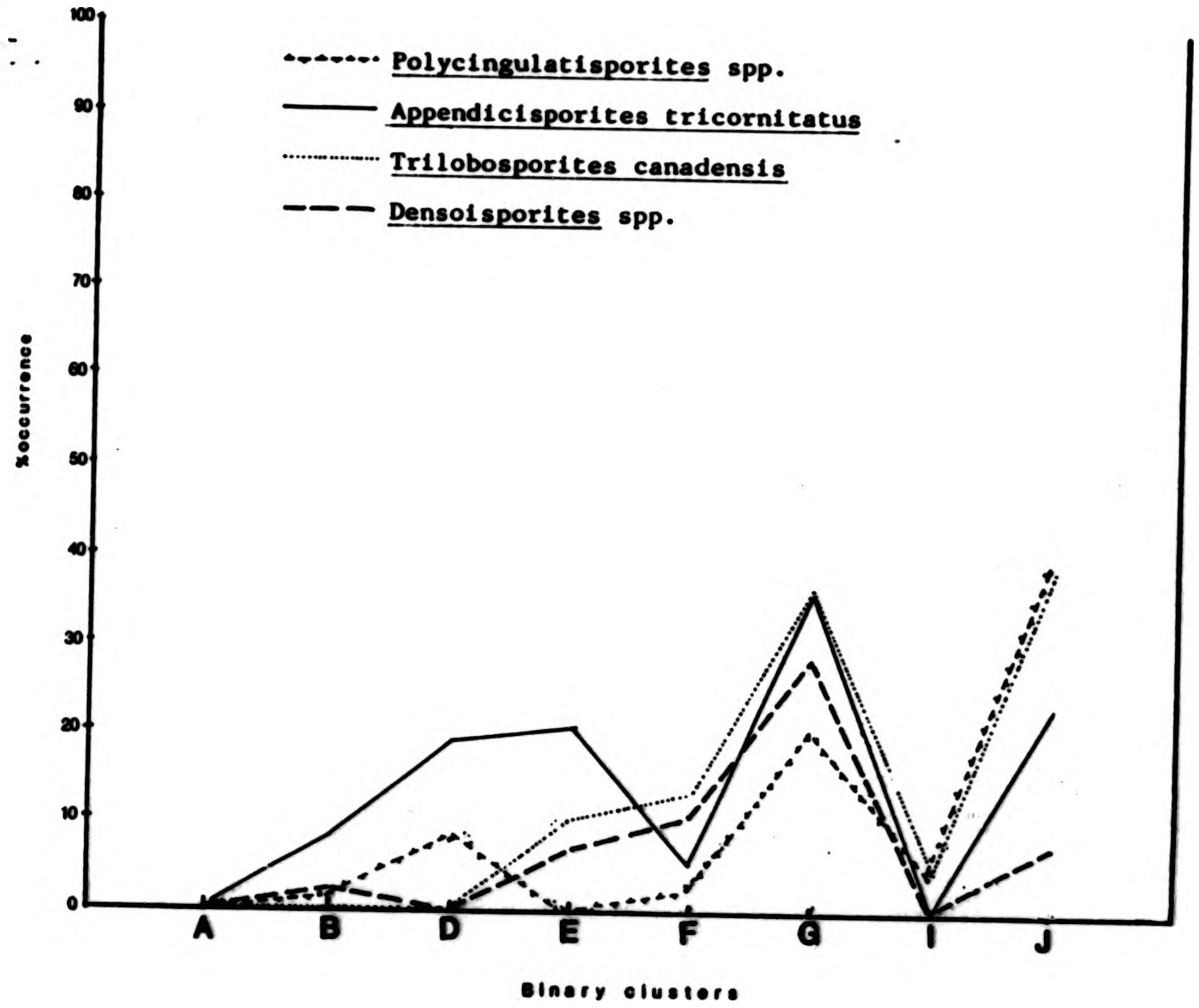
Concavissimisporites variverrucatus
Matonisporites phleberopteroides
Appendicisporites jansonii
%occurrence
0
10
20
30
40
50
60
70
80
90
100
A
B
D
E
F
G
I
J
Binary clusters

xv

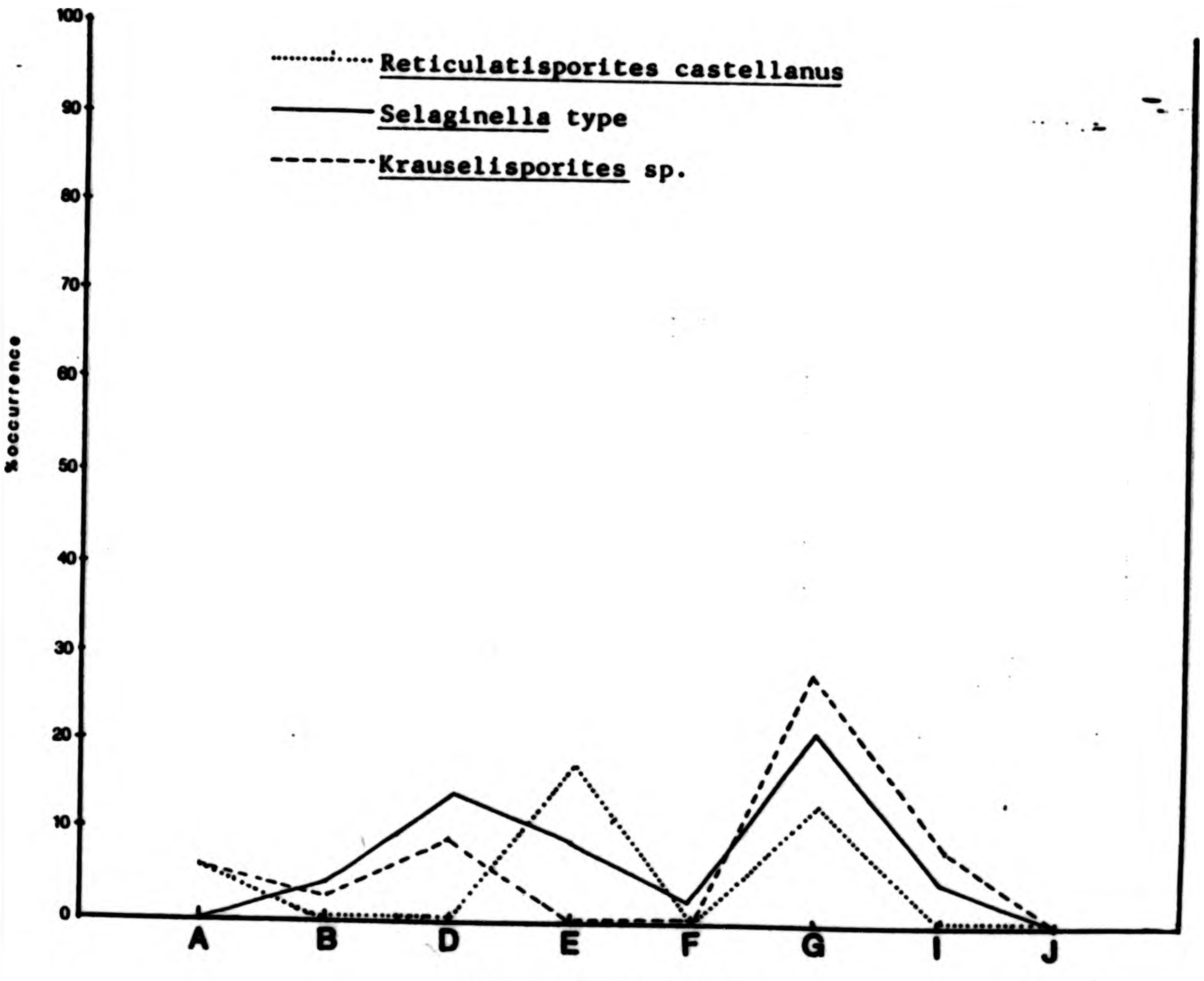


Calamospora type
Cicatricosisporites minor
Ischyosporites sp.
Trilobosporites bernissitartensis
%occurrence
0
10
20
30
40
50
60
70
80
90
100
A
B
D
E
F
G
I
J
Binary clusters

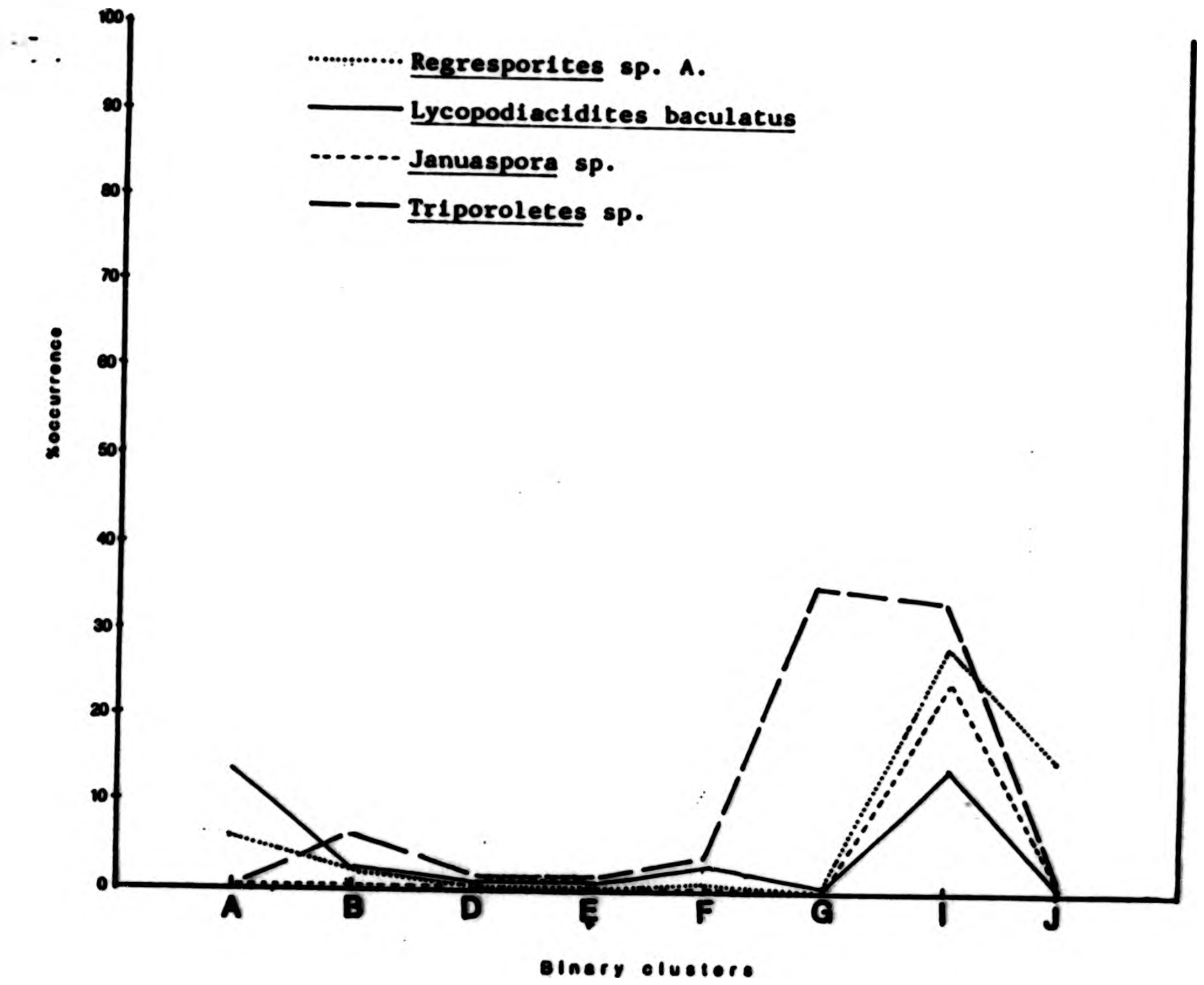
xvi


Polycingulatisporites spp.
Appendicisporites tricornitatus
Trilobosporites canadensis
Densoisporites spp.
%occurrence
100
90
80
70
60
50
40
30
20
10
0
A
B
D
E
F
G
I
J
Binary clusters

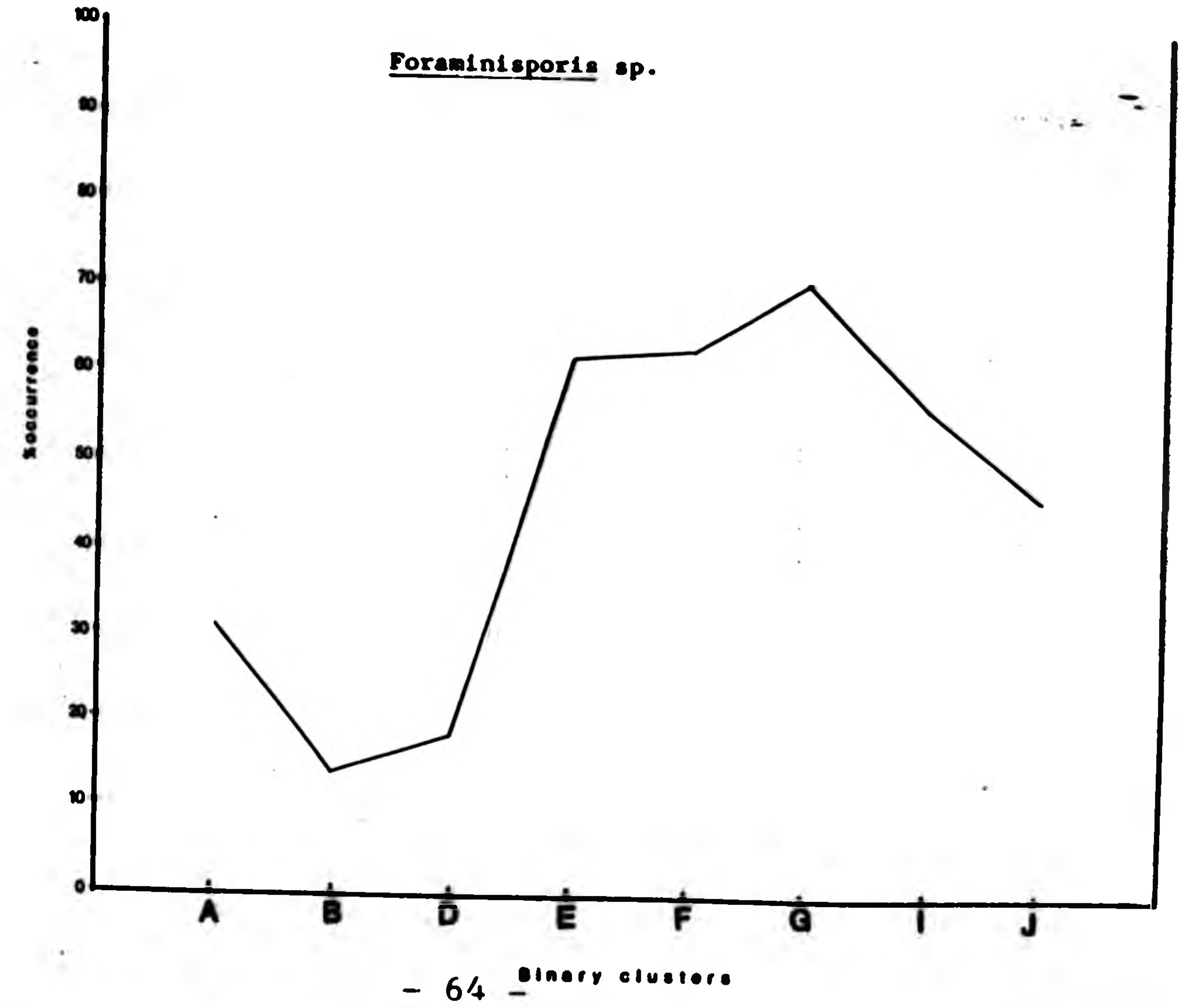
xvii


Reticulatisporites castellanus
Selaginella type
Krauselisporites sp.
%occurrence
100
90
80
70
60
50
40
30
20
10
0
A
B
D
E
F
G
I
J
Binary clusters

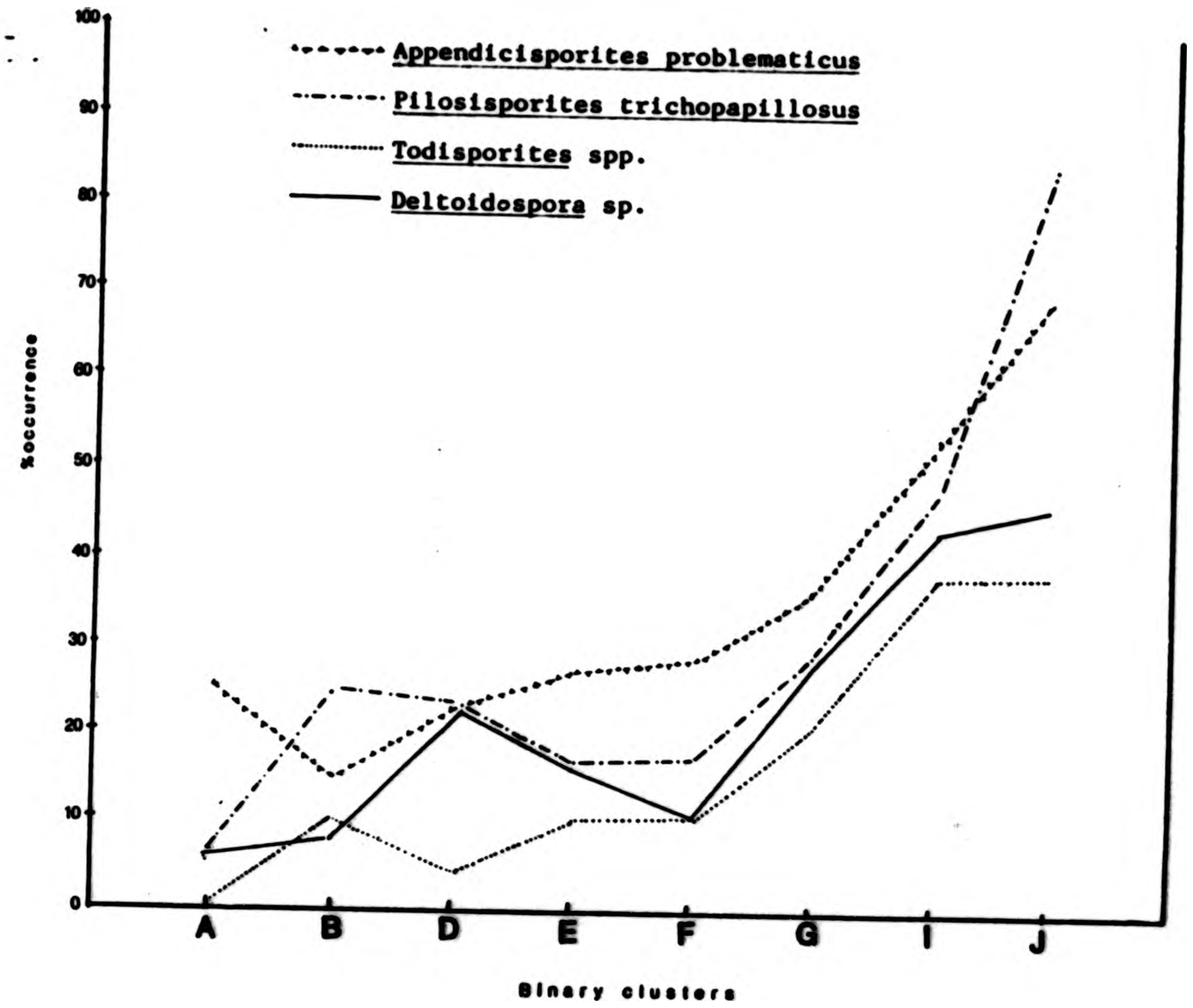
xviii


Regresporites sp. A.
Lycopodiacidites baculatus
Januaspora sp.
Triporoletes sp.
%occurrence
0
10
20
30
40
50
60
70
80
90
100
A
B
D
E
F
G
I
J
Binary clusters

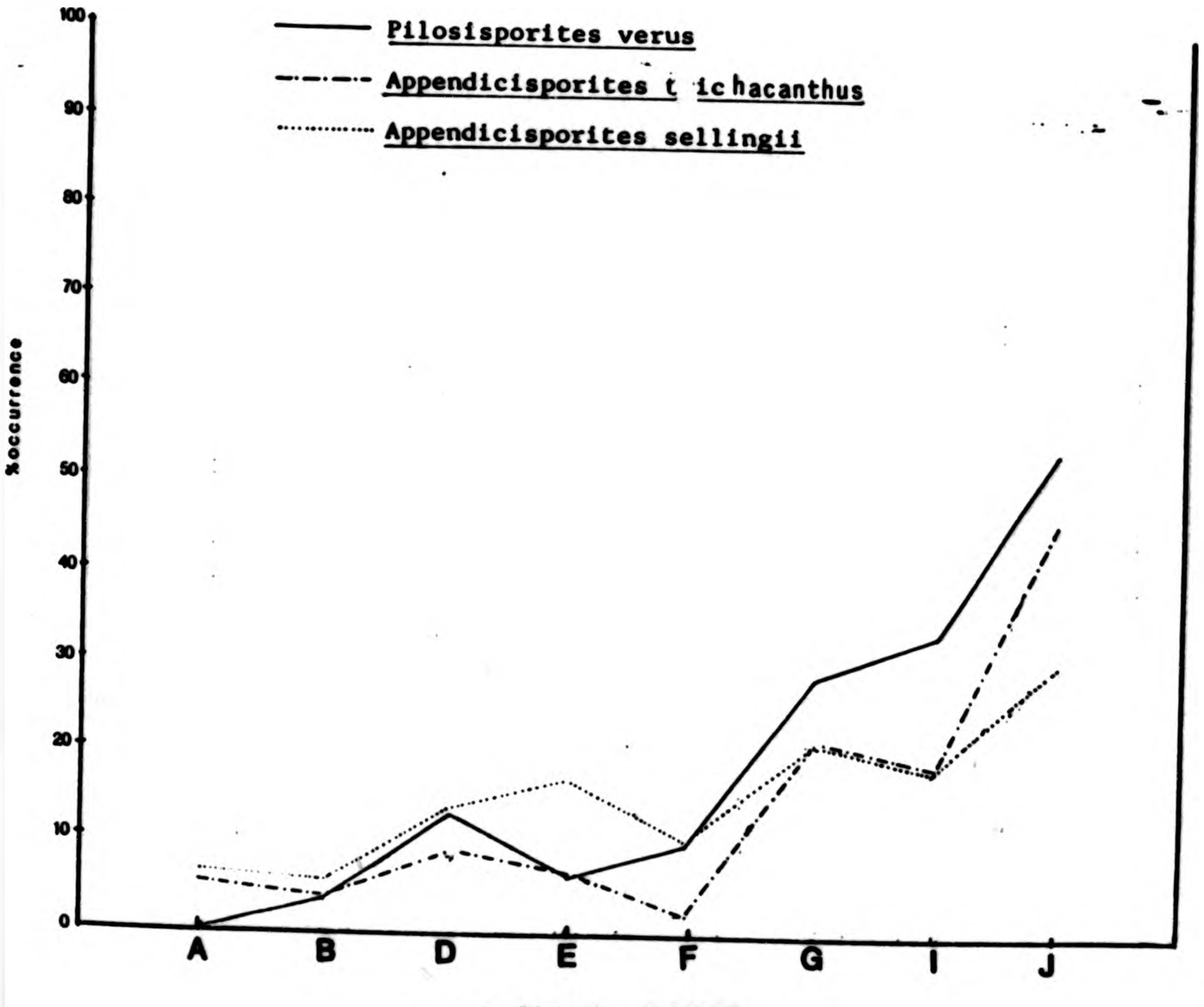
xix


Foraminisporis sp.
%occurrence
0
10
20
30
40
50
60
70
80
90
100
A
B
D
E
F
G
I
J
Binary clusters

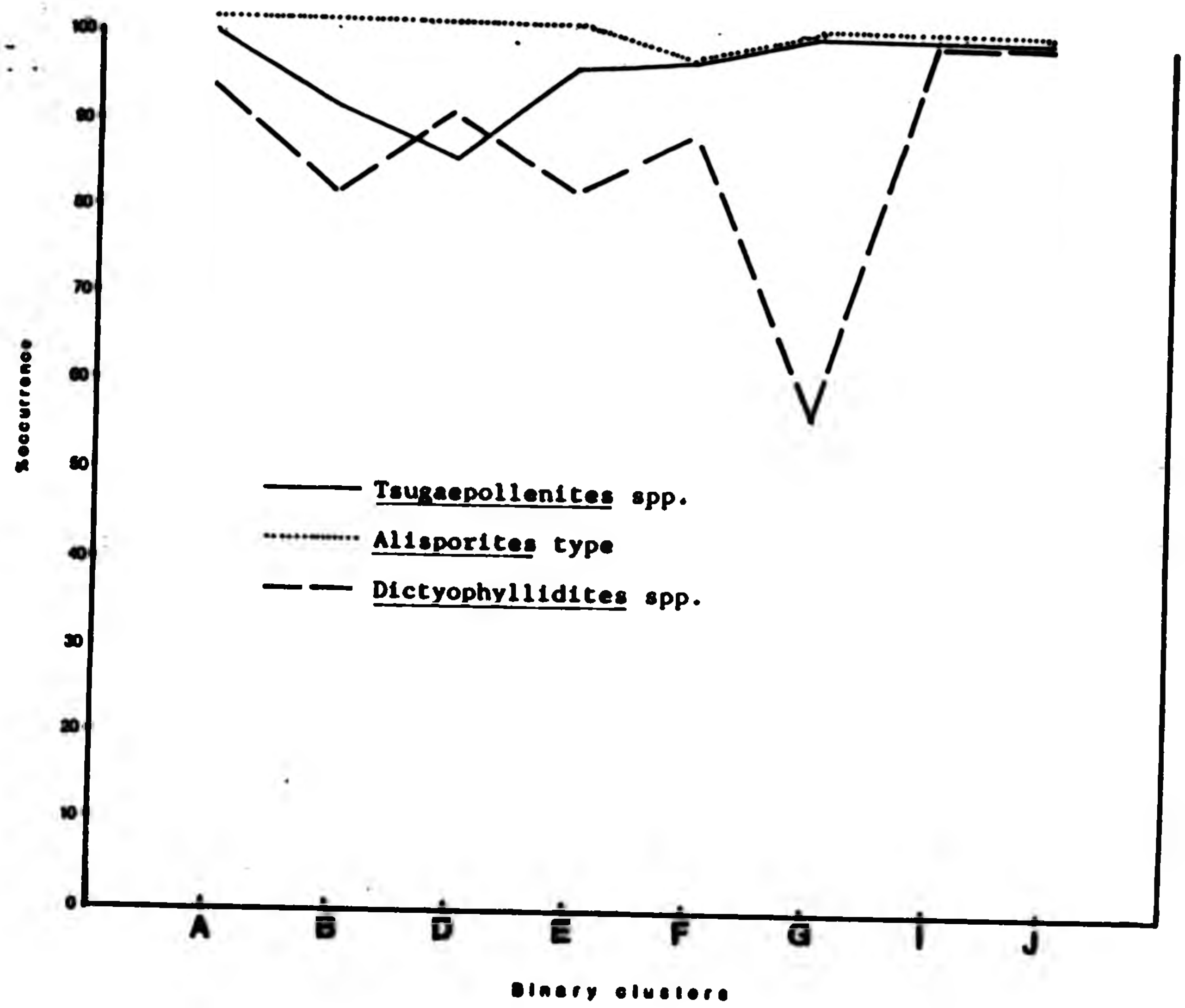
xx


Appendicisporites problematicus
Pilosisporites trichopapillosus
Todisporites spp.
Deltoidospora sp.
%occurrence
100
90
80
70
60
50
40
30
20
10
0
A
B
D
E
F
G
I
J
Binary clusters

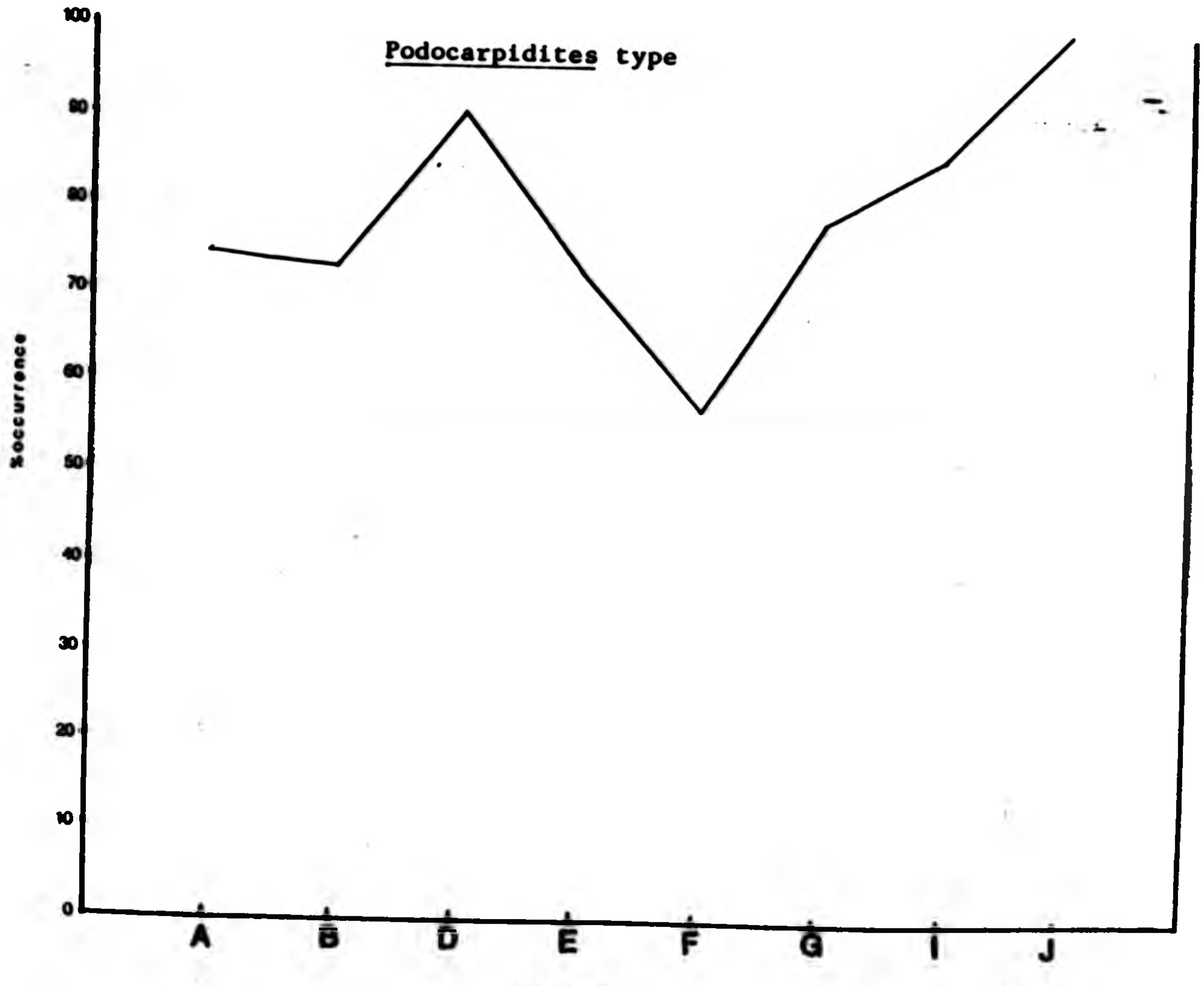
xxi


Pilosisporites verus
Appendicisporites trichacanthus
Appendicisporites sellingii
%occurrence
100
90
80
70
60
50
40
30
20
10
0
A
B
D
E
F
G
I
J
Binary clusters

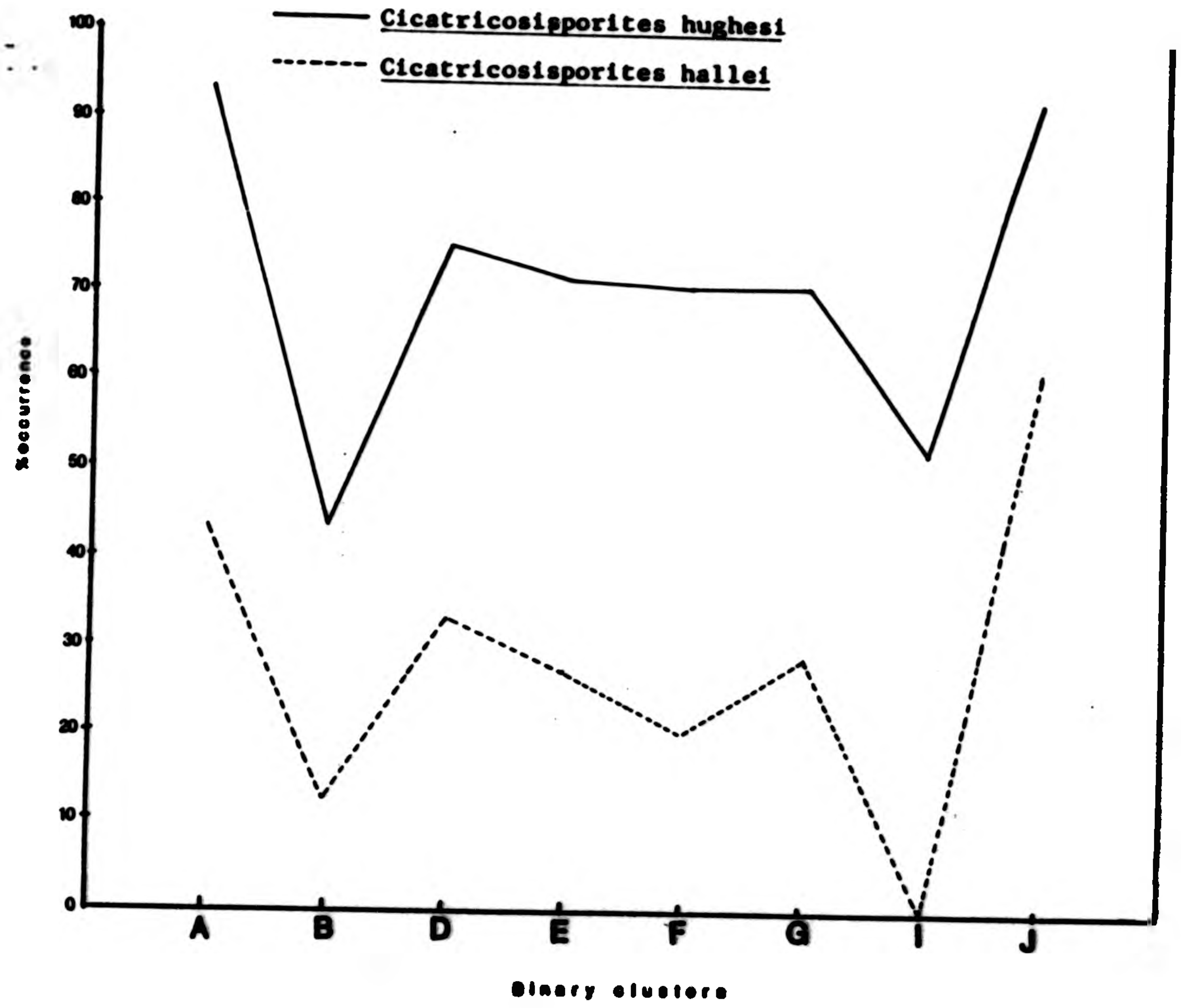
xxii


100
90
80
70
60
50
40
30
20
10
0
%occurrence
Tsugaepollenites spp.
Alisporites type
Dictyophyllidites spp.
A
B
D
E
F
G
I
J
Binary clusters

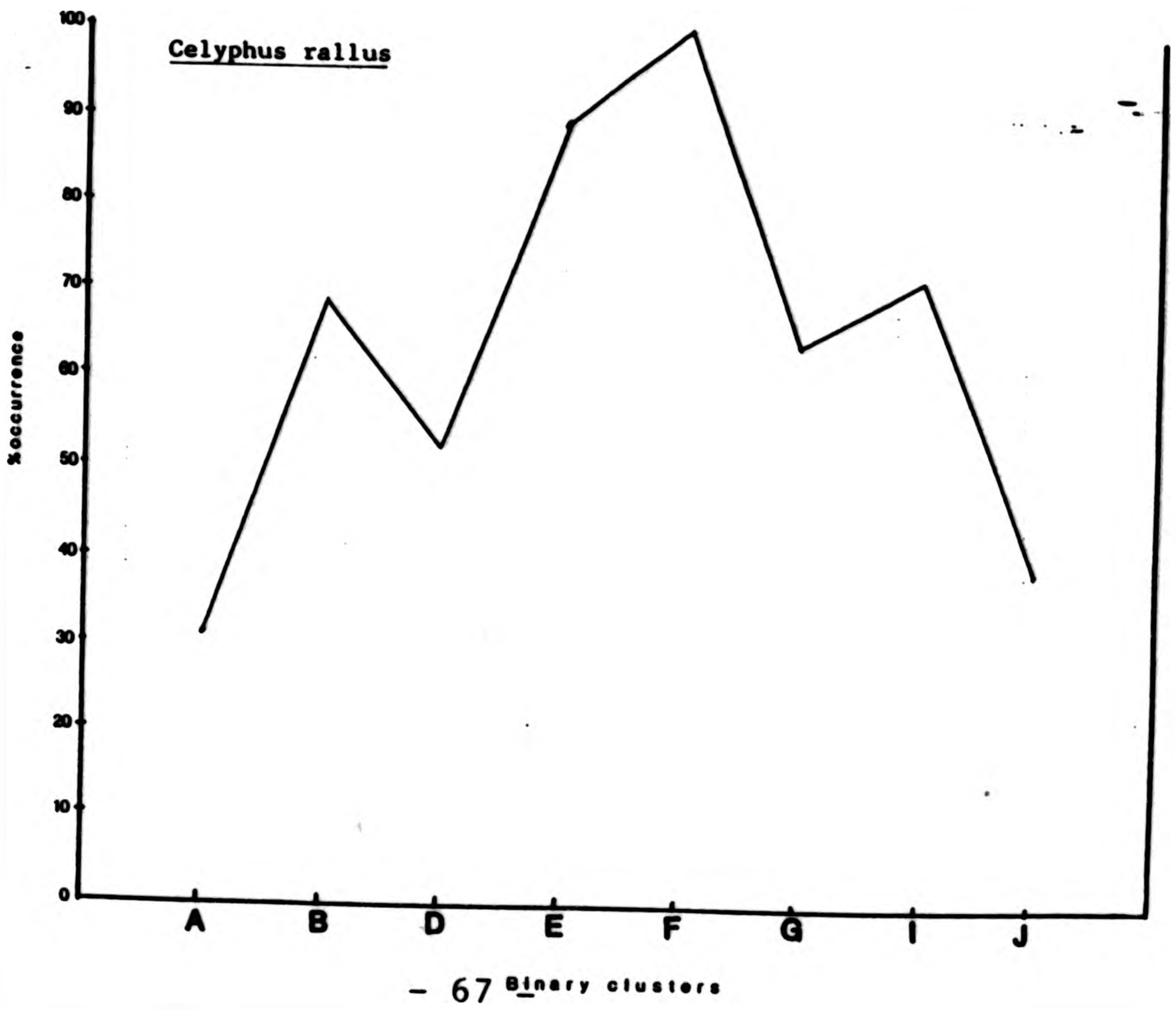
xxv


100
90
80
70
60
50
40
30
20
10
0
%occurrence
Podocarpidites type
A
B
D
E
F
G
I
J
Binary clusters

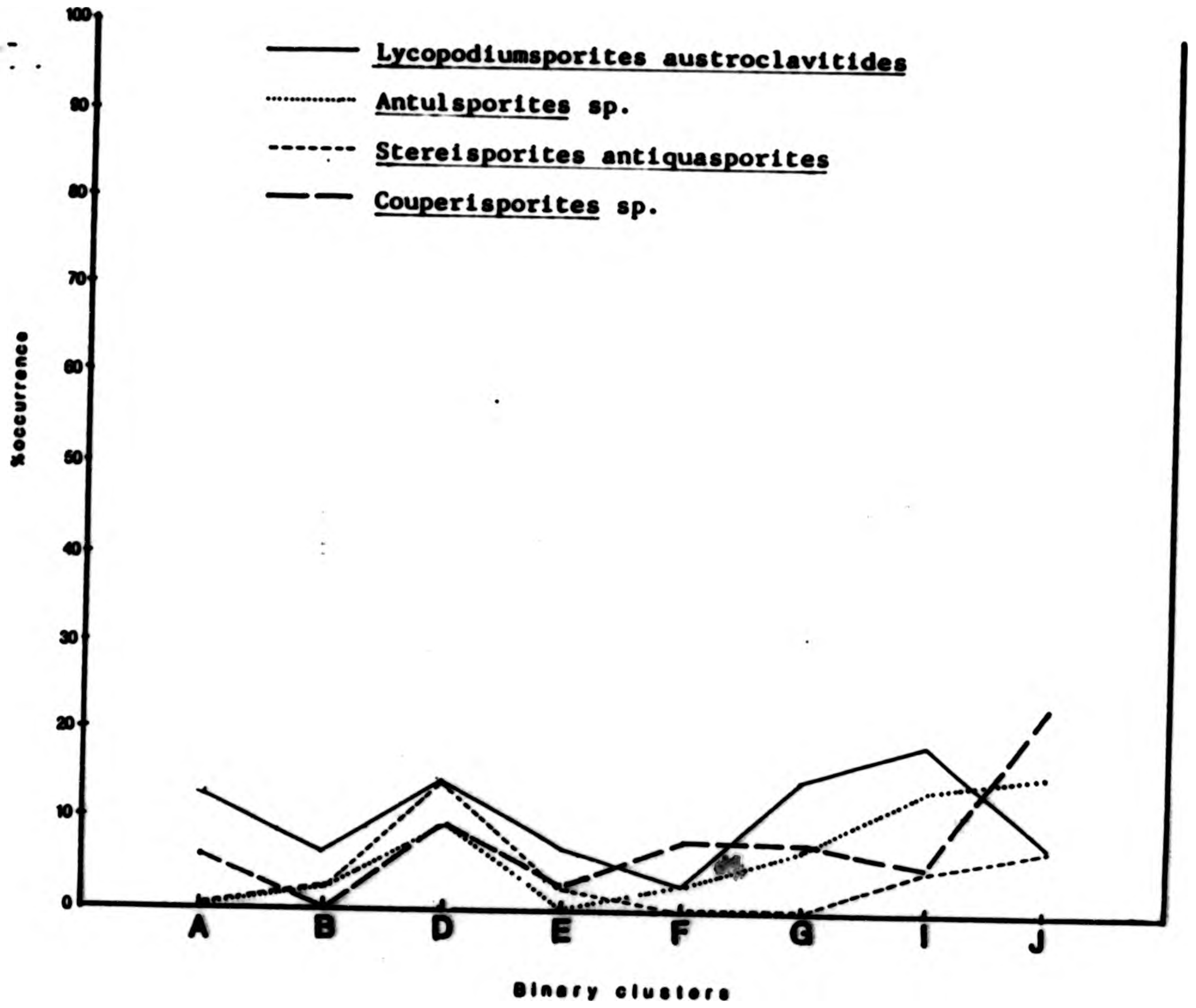
xxvi


Cicatricosisporites hughesi
Cicatricosisporites hallei
%occurrence
100
90
80
70
60
50
40
30
20
10
0
A
B
D
E
F
G
I
J
Binary clusters

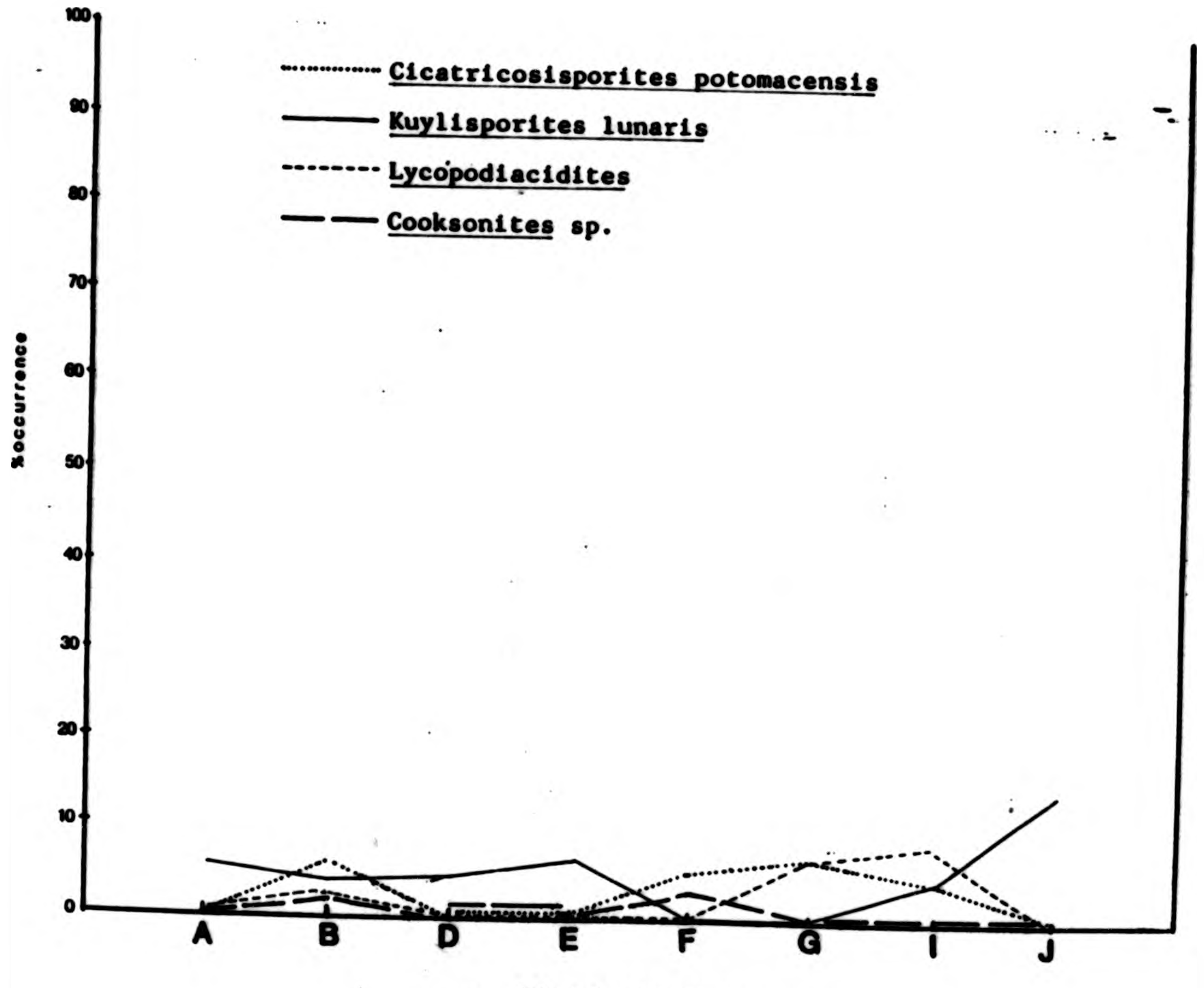
xxiii


Celyphus rallus
%occurrence
100
90
80
70
60
50
40
30
20
10
0
A
B
D
E
F
G
I
J
Binary clusters

xxiv



xxvii



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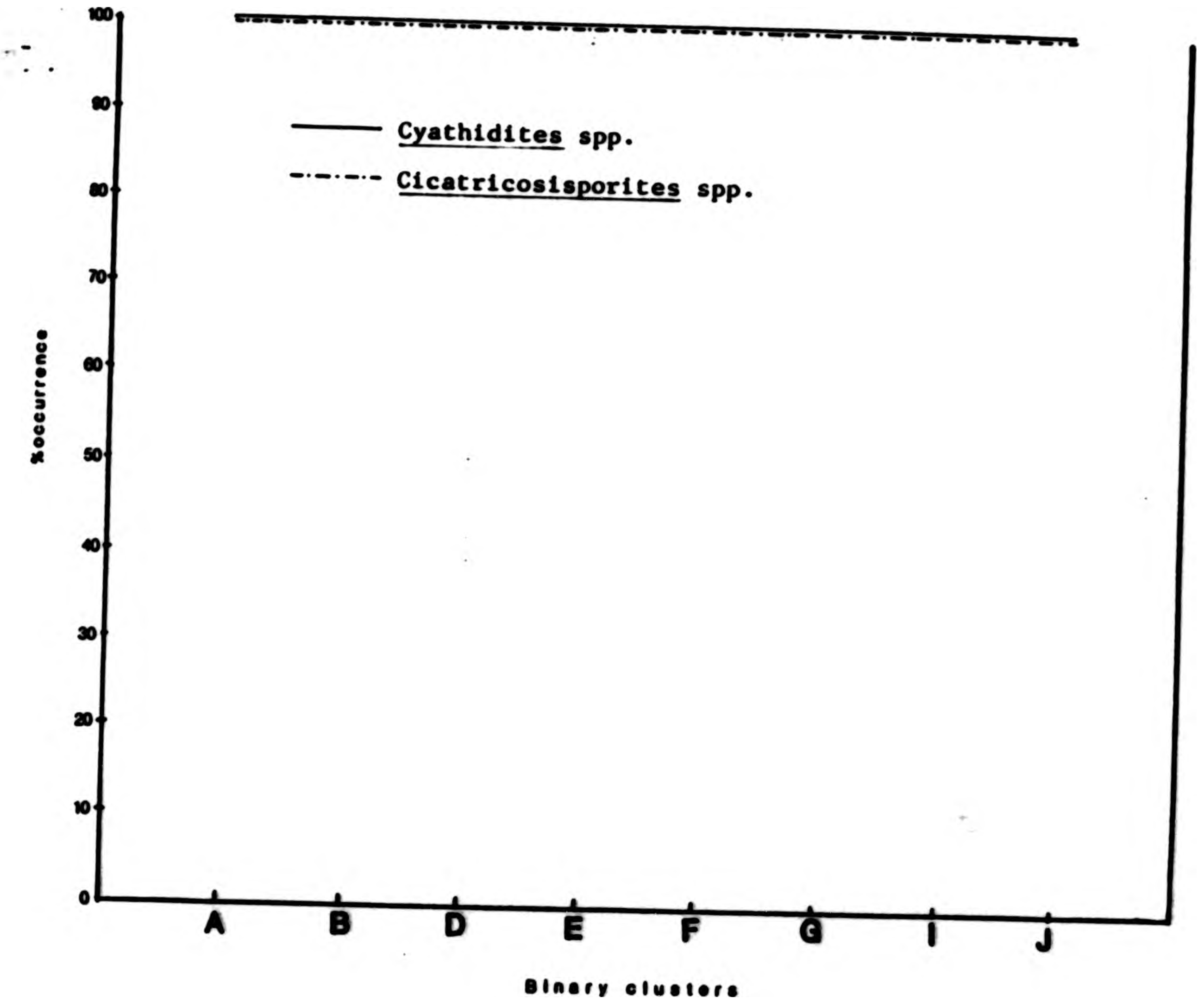
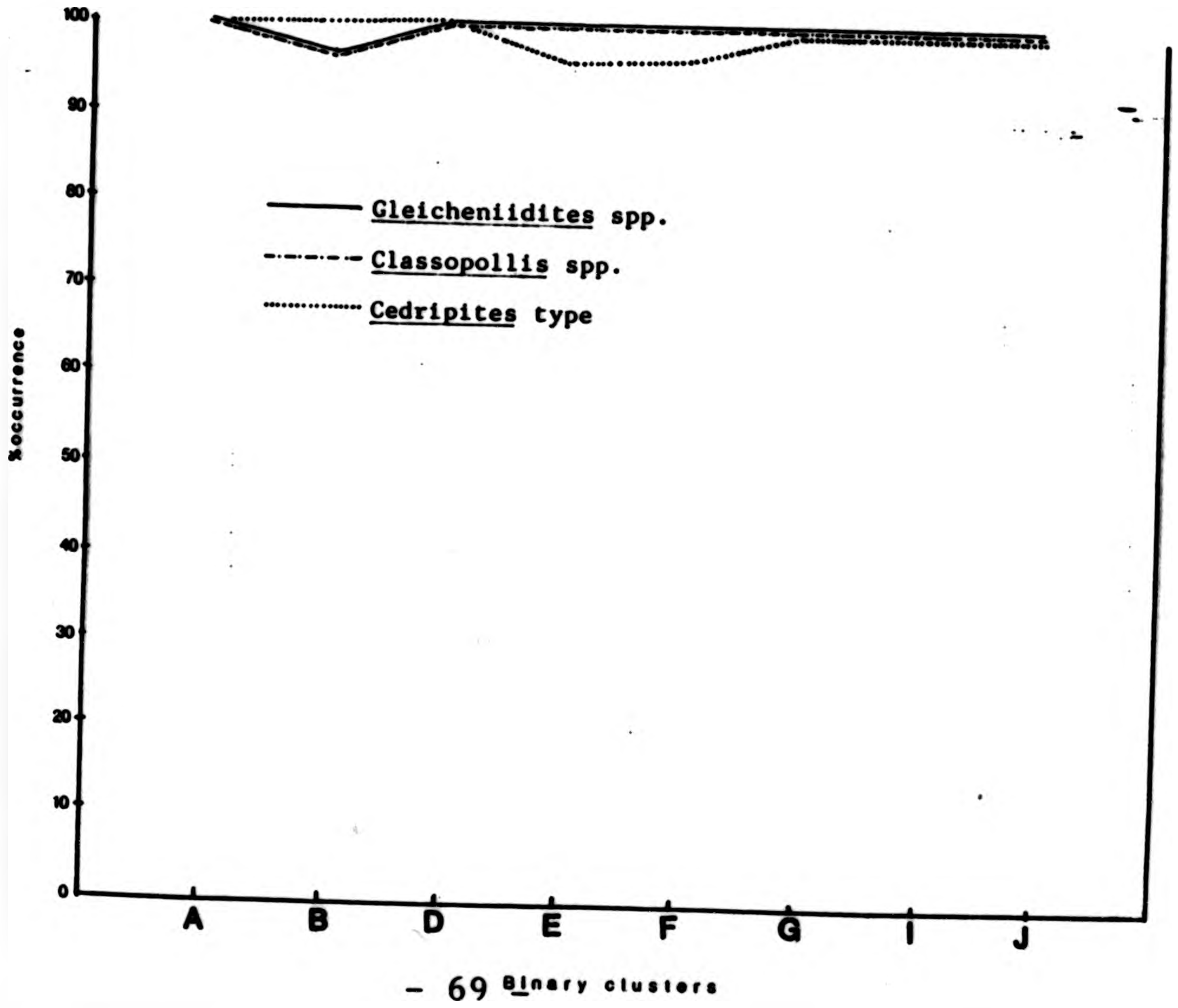


100
90
80
70
60
50
40
30
20
10
0
%occurrence
Cyathidites spp.
Cicatricosisporites spp.
A
B
D
E
F
G
I
J
Binary clusters

xxix



100
90
80
70
60
50
40
30
20
10
0
%occurrence
Gleicheniidites spp.
Classopollis spp.
Cedripites type
A
B
D
E
F
G
I
J
Binary clusters

xxx

of an individual taxon present in 13 samples out of 48 in a cluster group, does tend to group together as a subcluster. Subclusters have been particularly emphasised in the description to follow, when they coincide with coefficients at the 24 and 36 cluster level. In several instances such subclusters have been found to coincide closely with subclustering of the kerogen and/or fluorescent algal assemblage. Many of the fluorescent algae referred to have not been previously described. They have been given informal names for the purposes of this study. These are, 'Colonial Spiny Masses', 'Spiny Tetrads', 'Minute Leiospheres', 'Segmented Alga type 1', 'Segmented Alga type 2', 'Laevigate Algal Cysts', 'Granulate Algal Cysts', 'Large Thick Walled Cysts' and 'Very Small Spiny Acritarchs'. Descriptions and photographs of these and other taxa are provided in chapter 4.

At the end of each description of assemblage characteristics for each cluster group, palaeoenvironmental inferences are discussed.

2.4 (b) Cluster group characteristics

CLUSTER GROUP A

Spore/pollen assemblage

This group contains the highest records of foraminiferal linings together with *Cerebropollenites mesozoicus* and *Vitreisporites pallidus*. Distinct occurrences of *Leptolepidites* spp., *Verrucosisporites* spp., *Concavisporites juriensis*, *Pilosisporites notensis* and *Cicatricosisporites hughesi* are also to be seen. The Auriculati, Cingulati and Hilates as well as species of *Appendicisporites* are distinctly low in abundance, and this group contains the largest number of totally absent species amongst all the binary cluster groups.

Subcluster A-a contains consistent occurrences of *Klukisporites* sp., *Costatoperforosporites* spp., *Matonisporites phleberopteroides* and Foraminiferal linings, all of which are absent or rare in subcluster A-b. Subcluster A-b itself contains consistent *Contignisporites* sp. and *Celyphus rallus*, that are rare or absent in A-a.

Kerogen assemblage

This group is particularly distinct in showing generally high abundances of amorphous liptinite. Fusinite is generally very low in abundance.

Lithology

A high percentage of limestones are found in this group together with fish osteocytes. Non laminated mudstones generally comprise the remaining lithologies and iron staining is very rare in this group.

Fluorescent algal assemblage

This group is distinct in showing consistently high records of Laevigate Algal Cysts, Colonial Spiny Masses and Segmented Alga type 1. Spiny Tetrads and *Scenedesmus* are moderate to common, while acritarchs (*Veryhachium* spp, *Baltisphaeridium* spp. and *Micrhystridium* spp.) are of general low occurrence.

Subcluster A-a shows these characteristics much more strongly than A-b, where *Veryhachium* spp are more prominent and laevigate algal cysts less so.

Others

One sample in this group (W.94) contained currence of *in situ* dinocysts of *Muderongia simplex*. Most other records of dinocysts are either from the transitional Weald Clay/Atherfield Clay samples (Hurlands Farm), comprise the Incertae Sedis type 1 group of simplified morphology (chapter 4)or are reworked from older rocks.

Palaeoenvironmental remarks

The strong positive correlation of foraminiferal linings together with fish osteocytes and rare marine dinoflagellates (*Muderongia simplex*) indicates a marine influence to the depositional environment represented by the spore/pollen assemblage of this cluster group. The general lack of iron staining in this group, which is evidence of pedogenesis (Worssam & Morter, 1978) supports this conclusion. The low percentages of fusinite together with high incidence of limestones in this group suggests that sedimentation rate was low.

The distinct association of amorphous liptinite with this cluster group suggests that it is probably marine derived. Likewise the strong association of Laevigate Algal Cysts and Segmented Alga type 1 with this cluster group suggests that these are marine derived. The generally low records of Veryhachium spp. particularly in subcluster A-a where foraminiferal linings are prominent suggests that this is a non-marine taxon.

CLUSTER GROUP B

Spore/pollen assemblage

The spore/pollen assemblage of this cluster group, which comprises the largest number of samples in any of the groups, (48), is distinct in not showing any uniquely commonly occurring species. The group also shows the lowest number of totally absent species, but the highest frequency of rarely occurring taxa. This is in part due to the large number of samples in the group. It is notable that species of Cicatricosisporites, Appendicisporites and the Auriculati, Cingulati and Hilates are distinctly rare.

Subclusters within this group can be more easily characterised. Subcluster B-1-a shows consistent Undulatisporites undulapolus and Cicatricosisporites augustus is distinctly absent compared to the rest of the group. Subcluster B-1-b contains consistent Leptolepidites spp., Verrucosisporites spp. and Kuylisporites lunaris. Celyphus rallus and Reticulisporites spp. are distinctly rare in this subcluster. Subcluster B-2 contains common Cicatricosisporites annulatus and C. pseudotripartites as well as Reticulisporites spp. in common with subcluster B-3, which also yielded common C. hughesi and C. mesozoicus as well as moderate Pilosisporites trichopapillosus.

Kerogen assemblage

The most distinctive feature of this cluster group is the prominence of fine amorphous (grey) organic matter. Subcluster B-1-a is separated from the rest of the cluster groups in not showing prominent grey organic matter, but is generally dominated by fusinite and palynomorphs. The subcluster comprising B-1-b, B-2 and B-3 shows a particularly strong association with grey organic matter that is not seen elsewhere.

Lithology

This group shows a high proportion of limestones together with non-laminated mudstones.

Fluorescent algal assemblage

The two subclusters defined by kerogen type are also well defined by the fluorescent algal assemblage. Subcluster B-1-a contains very few algae, notably Veryhachium spp. are totally absent. The subcluster comprising B-1-b, B-2 and

B-3 contains large numbers of fluorescent algae, particularly of Veryhachium spp. Colonial Spiny Masses and Segmented Alga type 1 are moderate to common in occurrence. Laevigate Algal Cysts are prominent in subcluster B-3.

Palaeoenvironmental remarks

This cluster group shows three distinctive features that have some bearing on the palaeoenvironment. Firstly, Segmented Alga type 1 are of moderate occurrence throughout this group. This microplankton is particularly common in cluster group A but is rare or absent in the rest of the cluster groups. The moderate occurrence of limestones and fish debris in cluster group B is also similar to cluster group A. Cluster group A provided evidence of marine influence. Secondly, cluster group B shows no commonly occurring spore/pollen taxon. It also shows a particularly low number of totally absent species, even when the high number of samples here present has been taken into account (see section 2.4 (d)). The number of rarely occurring taxa is however very high (also taking into account the high number of samples present.) In my opinion this suggests that the spore/pollen taxa are derived from many distant sources and that a local flora is not strongly represented. In essence a good variety of spore/pollen taxa from many different sources is represented with no dominant autochthonous element. Thirdly, cluster group B has prominent amorphous grey organic matter. This character is the main feature of this cluster group that distinguishes it from all the others, so it is probably autochthonous.

A brackish lagoonal or lacustrine environment is invoked as the principal palaeoenvironment represented in cluster group B. This accounts for the absence of an *in situ* flora in the waterlogged conditions, where current activity was much reduced preventing winnowing of fine amorphous grey organic matter, probably formed by *in situ* decomposition. Proximity to the sea is suggested by the partial overlap of this group with group A 'marine' parameters.

CLUSTER GROUP C

This group of seven samples was included in the cluster analysis as a control group which were barren of spores and pollen, and could be expected to form a close clustering group. The absence of spores and pollen is probably due to non preservation, which may be associated with alkaline conditions in the palaeoenvironment, reflected by the prominence of limestone lithologies.

CLUSTER GROUP D

Spore/pollen assemblage

This cluster group is mainly distinguished from all others by the common occurrence of *Foraminisporis assymetricus* that is only a rare component of other groups. (On the palynofacies diagram this taxon is included in the larger generic group of *Foraminisporis* spp.). Other commonly occurring taxa are *Biretisporites* spp., *Cicatricosisporites australiensis*, *C. annulatus*, *Appendicisporites* spp., *Coronatispora valdensis*, *Aequitriradites* spp., *Concavisporites* *jurienensis* and *Cerebropollenites mesozoicus*.

Subcluster D-1 contains only a very few samples and is characterised by occurrences of normally rare taxa. These include *Cicatricosisporites minor*, *Appendicisporites tricacanthus*, *Krauselisporites* sp. and *Couperisporites* sp.. Subcluster D-2 is distinct in showing a higher occurrence of large trilete spores, the apiculati *Pilosisporites* spp., *Concavissimisporites* spp, and the auriculati *Matonisporites phleberopteroides* and *Ischyosporites* spp.. Subcluster D-2-b contains a distinct occurrence of *Distaltriangulispora* sp.

Kerogen assemblage

This cluster group shows a generally high proportion of fusinite with palynomorphs and algal cysts of secondary importance. Fusinite is most prominent within subclusters D-1 and D-2-a. In subcluster D-2-b, fusinite is of less importance, with moderate occurrences of amorphous liptinite and fine amorphous (grey) organic matter to be seen.

Lithology

A very high proportion of mudstones are found in this cluster group. Iron oxide staining is particularly rare.

Fluorescent algal assemblage

Fluorescent algae are particularly uncommon in this cluster group. Colonial Spiny Masses are notably rare. Acritarchs of *Baltisphaeridium* spp. and Segmented Alga type 2 are important in this group.

Others

The dinocyst Incertae Sedis type 1 is important in this cluster group. One sample (HF.1) contains prominent marine dinocysts. This sample is from a transitional upper Weald Clay/lower Atherfield Clay sequence.

Palaeoenvironmental remarks

Marine indicators of the type seen within cluster group A are present but not common in this group. A few samples contain amorphous liptinite and/or Laevigate Algal Cysts and in these cases Veryhachium acritarchs are very low in number, an antipathetic relationship already noted for cluster group A. Generally raised fusinite content in this group is thought to indicate greater proximity to the hinterland and thus distinctly freshwater conditions of deposition, but where the ground was drier, with lesser development of standing water resulting in diminished importance of algal cysts in this cluster group. The particular association of Incertae Sedis type 1 dinocysts and Segmented Alga type 2 is characteristic of the Beare Green samples and probably only reflects local freshwater conditions, (see page 381).

CLUSTER GROUP E

Spore/pollen assemblage

This cluster group is characterised by common (50%) Microthyriacites leaf fungi together with bisaccate pollen of Rugubivesiculites sp., and spores Reticulisporites spp., Lycopodiumsporites sp., Cicatricosisporites australiensis

C. annulatus, Undulatisporites undulapolus, Klukisporites spp., Acanthotriletes varispinosus, and Appendicisporites potomacensis. Other important taxa include Reticulatisporites castellanus, Celyphus rallus, Cerebropollenites mesozoicus and Aequitriradites sp..

Two subclusters can be distinguished within this group, that comprising E-1, E-2 & E-3-a, and E-3-b. Subcluster E-1/E-2/E-3-a contains all of the above taxa in abundance while A. varispinosus, Microthyriacites sp. and Contignisporites sp. are absent and U. undulapolus and C. rallus rare, in subcluster E-3-b.

Kerogen assemblage

The kerogen assemblage of this cluster group is generally dominated by fusinite, with algal cysts and palynomorphs comprising the remainder. Semifusinite is moderately prominent in this cluster group.

Lithology

The lithologies within this group mainly comprise mudstones.

Fluorescent algal assemblage

The fluorescent algal assemblage, including Pediastrum sp., Botryococcus, Colonial Spiny Masses and Veryhachium spp. are particularly common in this cluster group. The two subclusters E-1/E-2/E-3-a and E-3-b distinguished on spore/pollen assemblage can also be recognised here. Subcluster E-3-b has a markedly reduced fluorescent algal assemblage compared to E-1/E-2/E-3-a.

Others

Dinocysts of Incertae Sedis type 1 are significant in the subcluster E-1/E-2/E-3-a of this cluster group.

Palaeoenvironmental remarks

The palynofacies represented by this cluster group is distinctly freshwater in aspect. Indications of marine influence such as prominent amorphous liptinite are rare. One sample (HF.3) that shows a high percentages of this maceral together with Laevigate Algal Cysts comes from the transitional Weald Clay/Atherfield Clay sequence where marine conditions are known to be more prominent. The strong representation of Veryhachium spp., Pediastrum and Botryococcus, all aquatic freshwater algae, indicates the dominance of freshwater conditions. The reduced occurrence of fluorescent algae in subcluster E-3-b coinciding with reduced variety in the spore/pollen assemblage may reflect drier conditions in the palaeoenvironment.

CLUSTER GROUP F

Spore/pollen assemblage

This cluster group contains the most prominent representation of Celyphus rallus together with important occurrences of Pluricelleites sp., Concavissimisporites spp, Pilosisporites spp., Aequitriradites spp., Schizosporis spp., Appendicisporites jansonii, Trilobosporites bernissitartensis, Ischyosporites spp., Calamospora type and Foraminisporis spp.

Subcluster F-1-a is separated from the rest of cluster group F in containing consistent Undulatisporites undulapolus and Appendicisporites potomacensis. Subcluster F-1-b contains consistent foraminiferal linings together with prominent Leptolepidites spp.. The muronati are comparatively rare within this subcluster. Subcluster F-2 contains prominent Cicatricosisporites annulatus, Distaltriangulispora sp., Trilobosporites bernissitartensis and Ischyosporites spp.. Subclusters within F-2 are distinguishable, F-2-a with consistent Concavisporites jurienensis and Appendicisporites spp. and F-2-b with consistent Rugubivesiculites sp. and Celyphus rallus, where this latter form is numerically very abundant within individual samples of the subcluster. Subcluster F-3 contains consistent Appendicisporites sp. and only rare Foraminisporis spp..

Kerogen assemblage

This cluster group contains the most prominent and consistent representation of fusinite amongst the whole data set. Amorphous liptinite and grey amorphous material are rare. Moderate occurrences of algal cysts and palynomorphs are additionally to be seen.

Lithology

Lithologies within this cluster group are varied, with no one type dominant.

Fluorescent algal assemblage

Records of fluorescent algae are generally low in this group.

Most consistently present throughout the cluster group are Botryococcus sp. and Colonial Spiny Masses. The subcluster F-2-b contains higher and more consistent records of fluorescent algae than other parts of this cluster group.

Palaeoenvironmental remarks

The palaeoenvironment represented by the palynofacies of this cluster group is dominantly freshwater. Foraminiferal linings are important only in subcluster F-1-b which has only very rare records of Veryhachium spp. and Botryococcus , suggesting marine influence. However in this instance amorphous liptinite is not important in the kerogen fraction. Fusinite is prominent throughout this cluster group indicating general proximity of this palynofacies to the source of this material which is thought to be the hinterland massif. The depositional site must lie well within the basin of deposition where marine influences were comparatively minor and infrequent.

CLUSTER GROUP G

Spore/pollen assemblage

The spore/pollen assemblage of this cluster group is particularly distinctive. It differs from all the other groups in showing a strong positive association of Costatoperforosporites sp., Distaltriangulispora sp., Foveotriletes sp. and Tigrisporites scurrandus.

Other important taxa include Leptolepidites sp, Verrucosisporites sp., Reticulisporites sp., Cicatricosisporites augustus, Concavissimisporites variverrucatus, Klukisporites spp, *Appendicisporites* spp., *Undulatisporites undulapolus* and *Cingulitriletes* sp., together with normally rare Hilates, *Densoisporites* sp., *Krauselisporites* sp. and *Triporoletes* sp..

Subclusters are not well defined, except for *Concavisporites jurienensis* and *Acanthotriletes varispinosus* being more common in G-1 while *Lycopodiumsporites* spp, *Appendicisporites problematicus* and *Trilobosporites canadensis* are particularly common in G-3.

Kerogen assemblage

Palynomorphs as a kerogen maceral are the most dominant element in this group. Fusinite is generally more abundant in subcluster G-1.

Lithology

Mudstones, mostly non-laminated are particularly dominant amongst the lithologies of this group.

Fluorescent algal assemblage

Fluorescent algae of all types are particularly common within this group particularly the freshwater algae *Pediastrum* and *Scenedesmus*. However the acritarchs *Micrhystridium* sp. and *Baltisphaeridium* sp. are almost absent. Segmented Alga type 2 are abundant in a few samples within subcluster G-1, though algae in general are distinctly less common in this subcluster.

Palaeoenvironmental remarks

The palaeoenvironment represented by this cluster group is dominantly freshwater. The abundance of fluorescent algae suggests that an aquatic element is important here, probably as stagnant ponds away from watercourses as suggested by the low percentages of fusinite. The prominence of the freshwater algae Scenedesmus and Pediastrum, whose modern analogues thrive in freshwater lacustrine conditions, favours this interpretation. Subcluster G-1 with higher fusinite and fewer algae may represent current activity in a watercourse.

CLUSTER GROUP H

This cluster group comprises only two samples that have similar characteristics to those described for group G, of which this cluster group can be considered a part, and to which it is most closely related by CLUSTAN.

CLUSTER GROUP I

Spore/pollen assemblage

This cluster group is characterised by the moderate to common ocurrence of Biretisporites spp., Concavisporites jurienensis, Pilosisporites notensis, Acanthotriletes varispinosus, Lycopodiumsporites marginatus, Cicatricosisporites pseudotripartites, Appendicisporites potomacensis, Matonisporites phleberopteroides, and Sestrosporites pseudoalveolatus. Other important taxa include Cerebropollenites mesozoicus, Reticulisporites sp., together with the normally rarely occurring Lycopodiacidites baculatus, Januaspora sp. and

Triporoletes sp..

Subclusters within this group can be defined. Subcluster I-1 contains distinctly persistent Regresporites sp. A, Januaspora sp. and Triporoletes sp.. Subcluster I-2 bears consistent Tigrisporites scurrandus. Subcluster I-3 bears generally consistent Auriculati that are very rare or absent in the rest of this cluster group.

Kerogen assemblage

No distinctive overall characteristic of the kerogen assemblage is to be seen in this cluster group. However subcluster I-1 contains prominent palynomorphs with low records of fusinite. Subcluster I-2 contains prominent fusinite and algal cysts. Subcluster I-3 contains low records of fusinite but prominent amorphous liptinite and fine amorphous organic matter.

Lithology

Lithologies within this group are dominated by laminated and non-laminated mudstones.

Fluorescent algal assemblage

Fluorescent algae are generally low in abundance, particularly Veryhachium acritarchs. Fluorescent algae are generally fewer in subcluster I-1, though slightly more are to be seen in I-2 which contains isolated peaks of Baltisphaeridium sp. with Colonial Spiny Masses in sample CH/P.58 and Laevigate Algal Cysts with Colonial Spiny Masses in sample CH/P.38. Subcluster I-3 contains only moderate occurrences of fluorescent algae while Scenedesmus and Pediastrum are distinctly absent. Sample CH/M.36 contains a distinct peak in Segmented Alga type 1.

Palaeoenvironmental remarks

The palaeoenvironment represented by this cluster group of spore/pollen taxa shows distinct variation indicated by the kerogen and fluorescent algal assemblages. Both freshwater and marine influences can be discerned. Drier non-marine conditions are reflected by the scarcity of fluorescent algal cysts and low percentages of fusinite in subcluster I-1. Increased fusinite content in I-2 together with moderate numbers of fluorescent algal cysts suggests aquatic conditions associated with watercourses. Marine influences are suggested in I-3 by the presence of amorphous liptinite, prominent Segmented Alga type 1 in one sample (CH/M.36), and an absence of Pediastrum and Scenedesmus .

CLUSTER GROUP J

Spore/pollen assemblage

This group is separated from all the others by the variety of commonly occurring taxa, some of which are rarities within the whole batch of samples. Most notable within this group is the high concentration of Apiculati together with other large trilete spores of the Auriculati. Several species within the Muronati are prominent here, including Klukisporites sp, Cicatricosisporites minor, C. hughesi, C. hallei, Appendicisporites jansonii and A. problematicus. Within the Cingulati all taxa are of moderate importance with Contignisporites sp. distinctly so. Bisaccate pollen are very important together with Sphaeripollenites psilatus and Aequitriradites sp..

Subclusters within this group are based on small differences in importance of some of the above mentioned taxa. J-1 contains slightly greater numbers of Muronati, J-2 contains consistent Costatoperforosporites sp. (absent in J-1 and J-3) and J-3 contains generally important occurrences of Rugubivesiculites sp. and Sphaeripollenites psilatus, fewer Apiculati and rare Cingulati.

Kerogen assemblage

The kerogen assemblage of this group is very distinctive in containing very prominent fusinite and palynomorphs. Algal cysts are of moderate importance while amorphous liptinite and amorphous grey material are almost completely absent.

Lithology

This group contains almost exclusively non-laminated mudstones and sandstones.

Fluorescent algal assemblage

Except for a very few cases, fluorescent algae are absent or present in very low abundances in this group.

Palaeoenvironmental remarks

This cluster group shows the most varied and diverse association of fern spores, particularly the large trilete forms of the Apiculati and Auriculati. This rich association of taxa probably represents a much more mature community of plants than that represented by the other cluster groups. In my opinion this indicates that the community has had longer to develop and must exist in a much more stable environment with a richer soil. This can only be raised parts of the depositional plain or parts of the hinterland itself. This interpretation is supported by the distinct lack of marine indicators in this cluster group, eg. a total absence of foraminiferal linings and very rare amorphous liptinite. The one sample (W.68) that contains amorphous liptinite, also contains ostracods. This is probably caused by local reworking. This cluster group also shows a high proportion of fusinite indicating its proximity to the hinterland. A generally drier, more elevated palaeoenvironment is supported by the distinct rarity of fluorescent algal cysts .

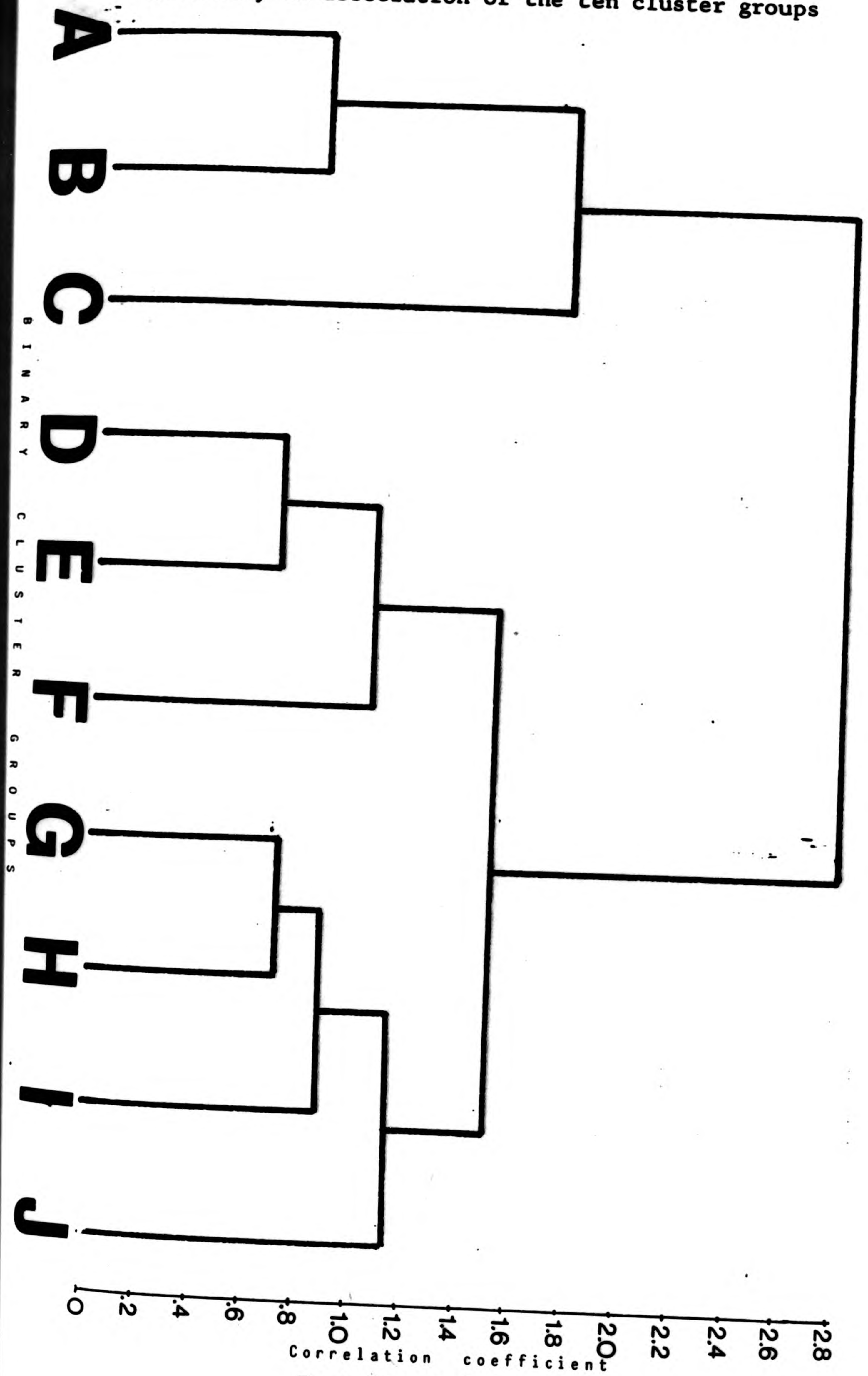
2.4 (c) Discussion

The previous section has shown that the 10 binary cluster groups can be quite well defined by their particular spore/ pollen assemblages. Evidence that these assemblages are not random, and do indicate a certain degree of genuine palaeo-ecological association in the Weald Clay palaeoenvironment is provided by distinct and characteristic kerogen types, lithologies and fluorescent algal assemblages in association with these spore/pollen cluster groups. Frederiksen (1985) has called the measure of degree to which a taxon is restricted to a particular community, environment of depostion lithofacies etc, the fidelity. In my opinion the fidelity of the binary cluster groups is quite high. This must indicate that the preservation potential of the Weald Clay palynofacies is high. This is to be expected given the particular nature of the Weald Clay braidplain, where sedimentary accumulation could occur everywhere from the most distal to the most proximal facies with respect to the strandline. This good preservation potential (ie. in the sense of fidelity, not exine degradation) is probably a rarity in deltaic environments that are so important in many fossil and modern depositional settings, where freshwater spore/pollen assemblages are transported and laid down in marginal marine palaeoenvironments.

2.4 (d) Association and palaeoenvironmental trends between binary cluster groups

The binary dendrogram (text-fig. 2.1) which produced the original ten cluster groups also showed the hierarchy of association of 'super-clusters' at coefficients above 0.711, showing those cluster groups that are most closely related and those most dissimilar. This is reproduced in simplified form as text-fig. 2.6 i. The two most similar cluster groups are D and E, followed by G and H. At the next level up, A and B are grouped followed by J to G/H/I. At the next level D, E, F, G, H, I and J are all united as one huge super-group. Above this still, control group C is grouped with A/B, until finally at the next level all ten groups are unified. This hierarchy of cluster group associations is very closely mimicked by the kerogen types. Groups D and E have very similar proportions of fusinite (≃ 30%). Next most similar to these two is group F with ≃ 50% fusinite, ≃ 20% palynomorphs and ≃ 30% algal cysts. Groups G and H show similarly abundant palynomorphs, and are moderately well associated with group I which shows a lot of variation in kerogen type, though including several samples with abundant palynomorphs. Groups D, E, F, G, H and I are related to group J in all showing generally dominant fusinite, though J shows generally less algal cysts than D, E or F. Groups A, B and C are closely related in showing much lower proportions of amorphous liptinite and fine amorphous organic matter respectively. A copy of the binary dendrogram indicating kerogen associations between cluster groups (text-fig.

Binary (presence/absence) dendrogram showing the hierarchy of association of the ten cluster groups



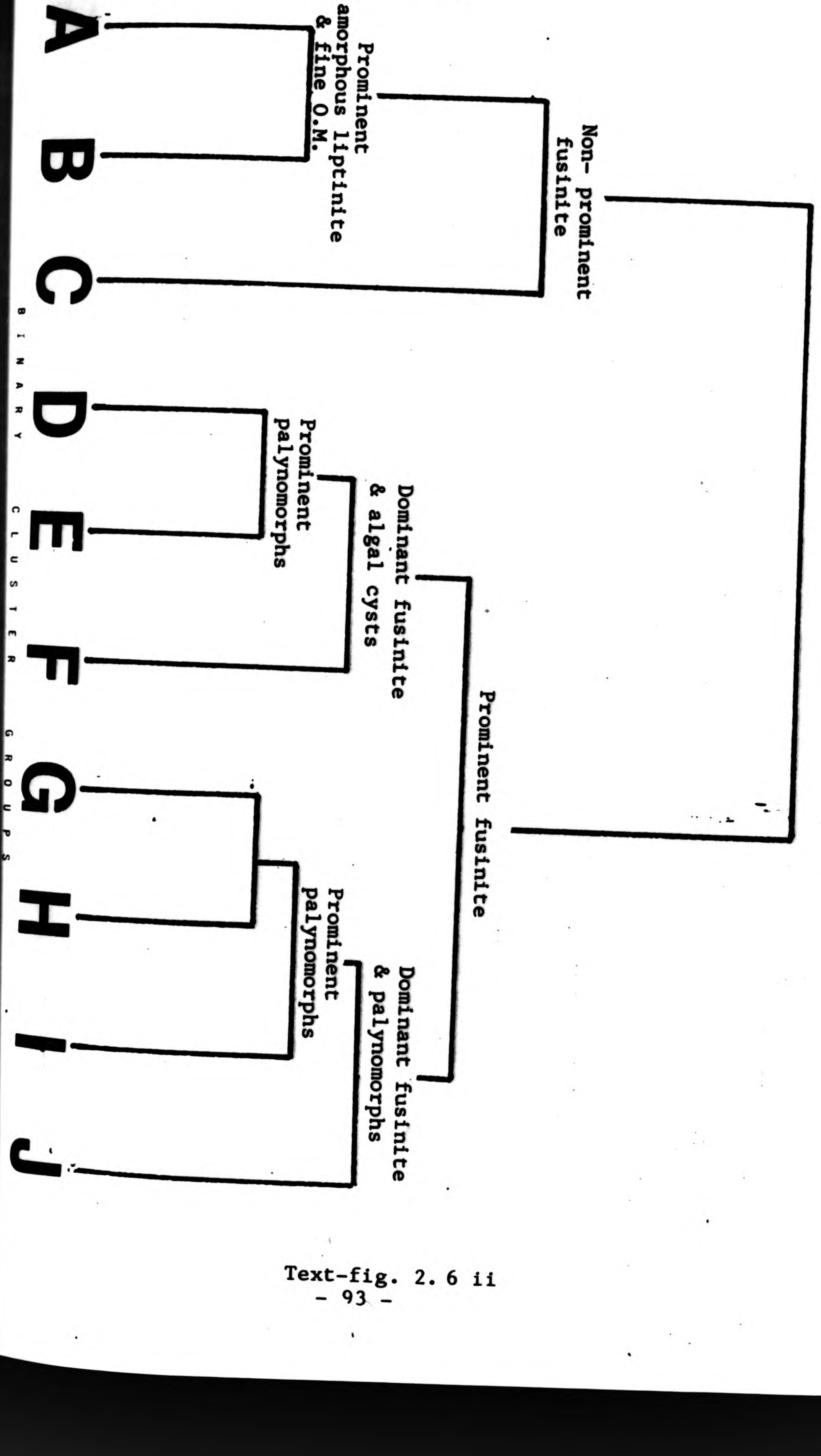
Text-fig. 2.6 i

2.6 ii) shows how similarly the cluster groups are associated on this criteria to the CLUSTAN grouping on spore/pollen assemblages. Fluorescent algal assemblages are not as clear cut in their distinctiveness between cluster groups but several basic associations can be recognised that are similar to associations formed by the spore/pollen assemblages (text-fig. 2.6 iii). Groups A and B are associated by the common occurrence of Segmented Alga type 1 and prominent Laevigate Algal Cysts. Groups D and E are associated by common occurrence of Incertae Sedis type 1 dinocysts. Groups D, E and F are associated by generally prominent Baltisphaeridium. Groups G and H are then united by prominent Pediastrum and Scenedesmus. Groups B, C, D, E, F, G, H, I and J are then all united by generally prominent Veryhachium, and the whole group is united by Colonial Spiny Masses common to all the groups. Two basic categories within the binary dendrogram can be recognised on lithology that show the same general broad separation of groups A and B from D - J. The former are characterised by prominent limestone with fish osteocytes and the latter by prominent mudstones (text-fig. 2.6 iv).

In summary the cluster groups do not only show distinct characteristic kerogen type lithology and fluorescent algae, but similar association to those seen by spore/pollen taxa between cluster groups are reflected by these parameters also.

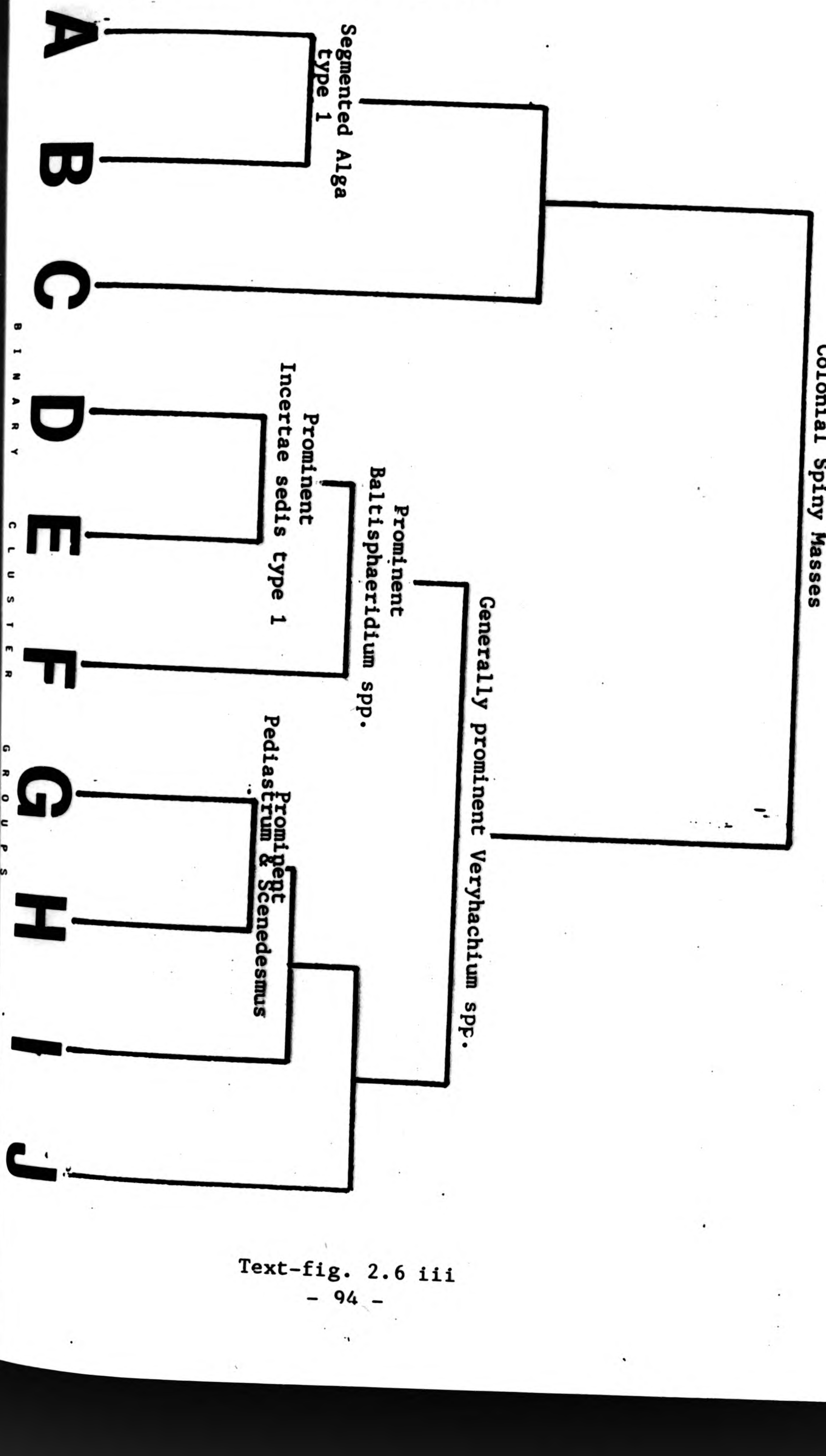
The binary dendrogram, which shows the cluster groups associations is based on 87 spore/pollen taxa. This provides too much data to be assessed by eye, but taxonomic associations between cluster groups can be displayed in the following way. The level of association between the various cluster

The association of kerogen types with binary spore/pollen cluster groups.



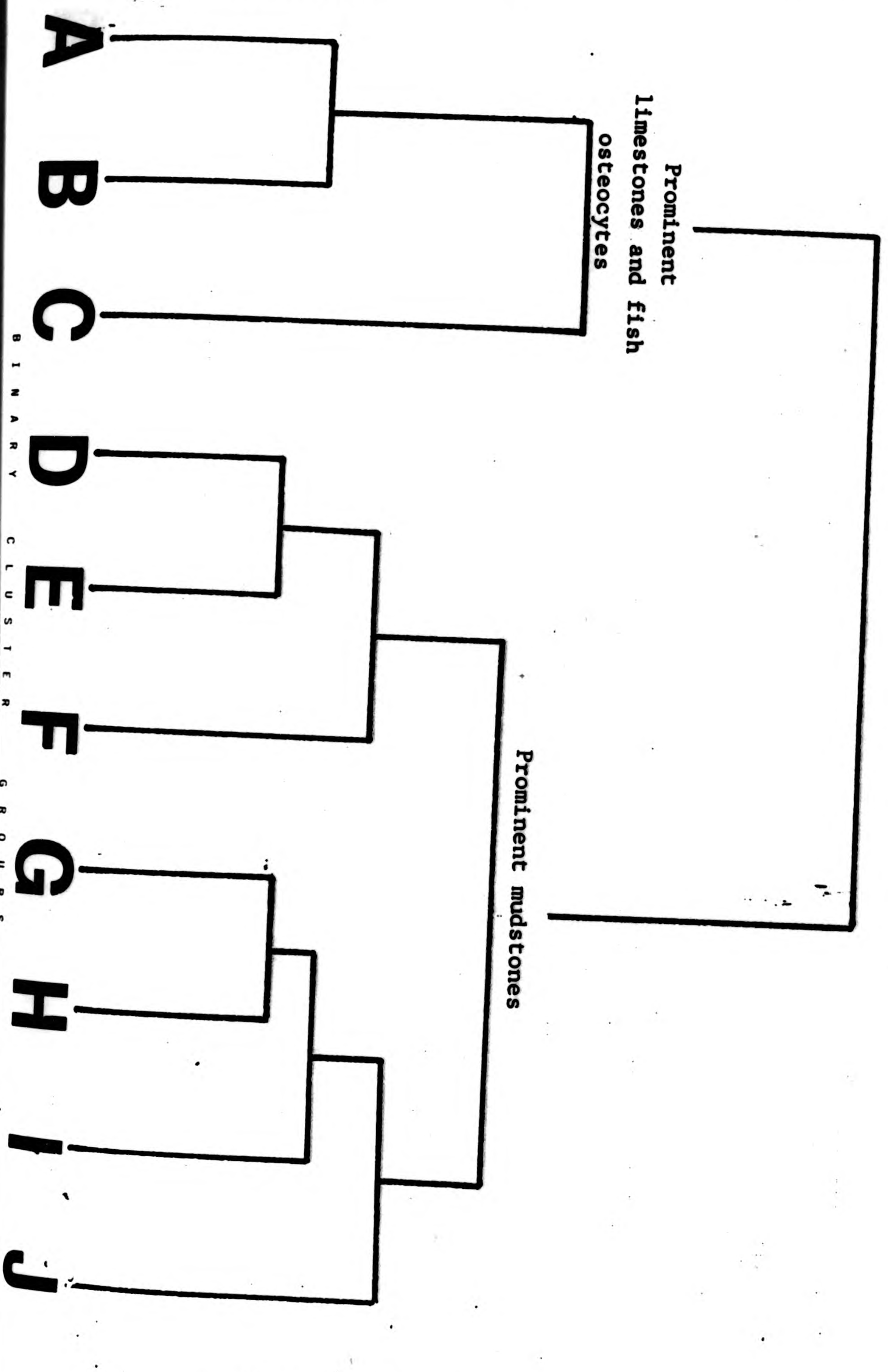
Text-fig. 2. 6 ii

The association of fluorescent algae with binary spore/pollen cluster groups.



Text-fig. 2.6 iii

The association of lithology with binary spore/pollen cluster groups.



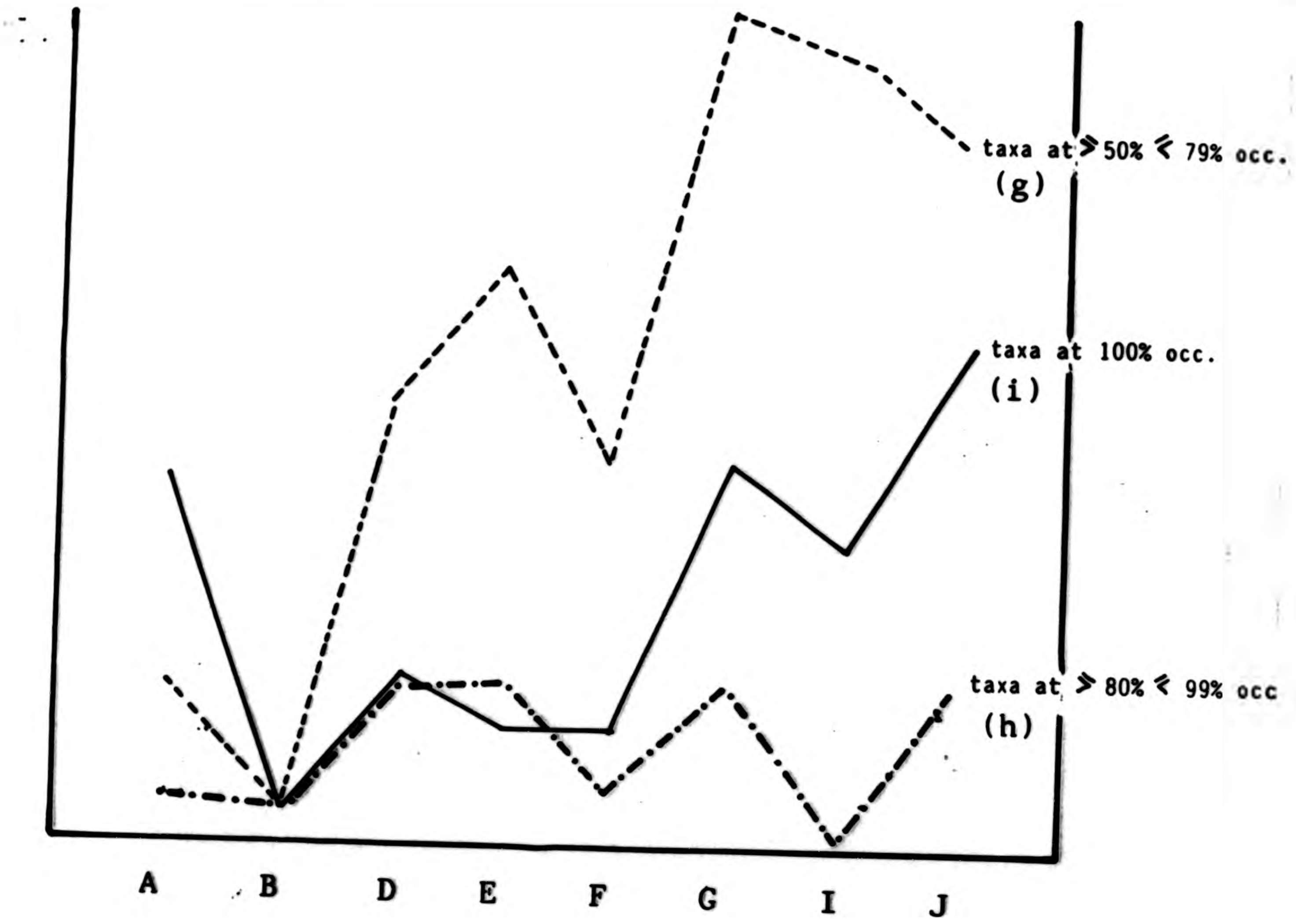
Text-fig. 2.6 iv

groups is given a specific coefficient of association by CLUSTAN. These values can be used to show a spatial association where cluster groups are positioned at distances from each other in proportion to the level of association between them. This diagram (Enclosure 5) gives the appearance of a map in plan view. Because of the restriction of a two dimensional sheet of paper the distances between groups cannot be made exactly proportional to the level of association. Associations between cluster groups are based on similarity in the spore/pollen assemblages. This includes similar occurrences of common, moderate and rare taxa as well as negative association of absent taxa. Groups can be joined together by lines representing spore/pollen taxa that are distinctly of joint high occurrence. The greater the number of such linkages between cluster groups will generally be proportional to the degree of association between them. Distortions to this rule will be caused by differences in the number of species showing high occurrence in a particular cluster group, which is partly related to the number of samples in that given group. For instance, groups G and J are not as closely related as D and E but show a greater number of species in common that are of joint high occurrence. The 'map' of cluster groups could be arranged so that distances between cluster groups is proportional to the number of joint high occurrences but this would ignore association at average or less than average values. It is difficult to compare cluster groups on taxa other than those that show peaks in their percentage occurrence traces (text-figs.2.5 i-xxx). It is also a subjective judgement as to what peaks exist on these graphs in many cases. Each trace must be judged in relation to the full range of percentage occurrences that it shows. Comparatively low values may be quite significant for one particular cluster group if the other groups contain very low percentage occurrence values. Much higher values may be unimportant where the average percentage occurrence is high across the board. Taxa that show little variation in percentage occurrence between cluster groups are of no value at all in comparing individual cluster groups as they tend to unite the whole group as one.

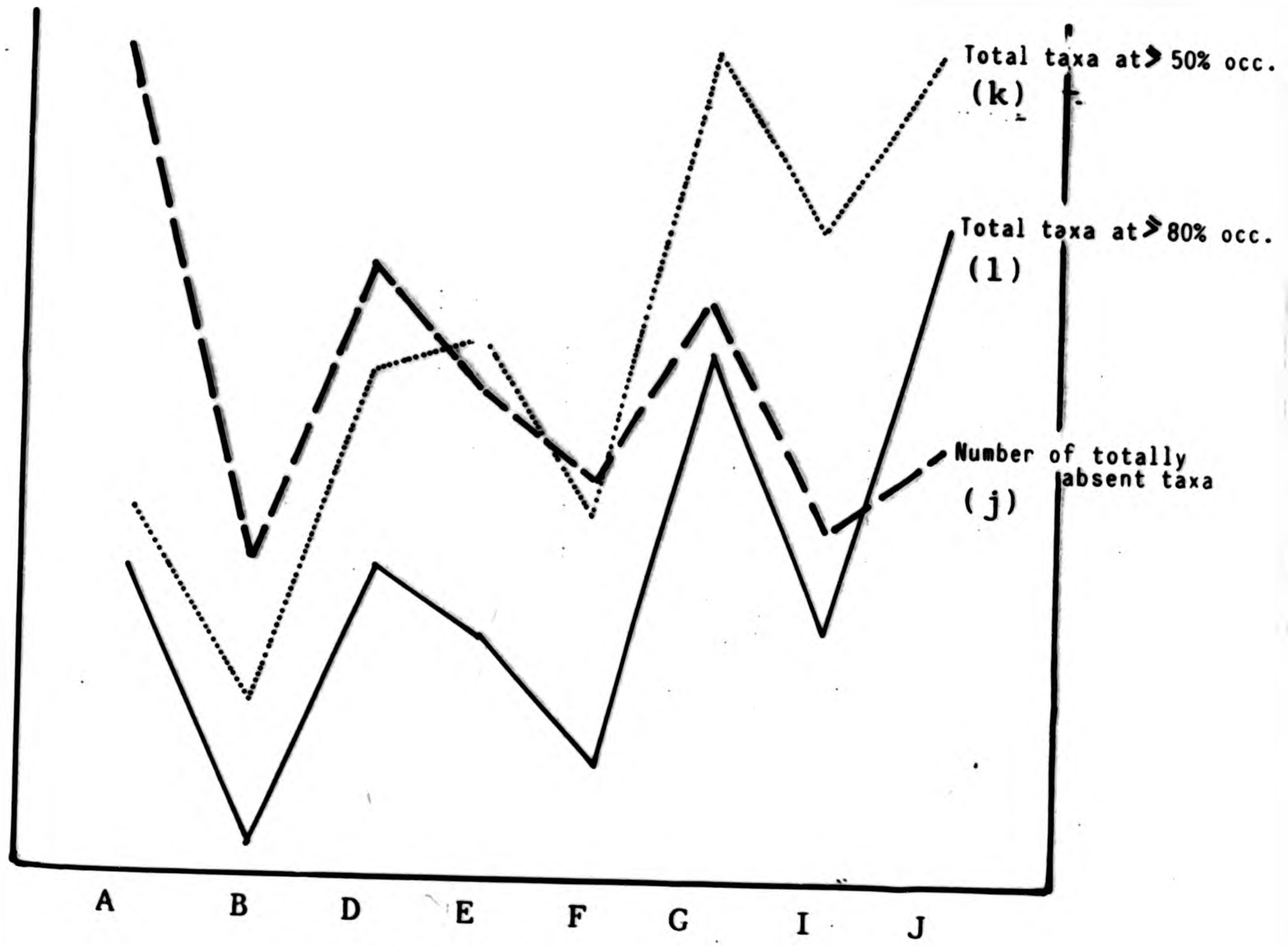
On the diagram (enclosure 5) circles of different sizes can be used in proportion to the number of 'peak' occurrences of spore/pollen taxa in a cluster group.

In describing the palynological assemblage of a given cluster group it is necessary to look at each sample within the group individually in order that inaccuracies produced by averaging and variation in the number of values (ie. samples) can be eliminated. This is the main reason why the palynofacies diagrams (enclosures 3 & 4) are necessary in addition to the summary diagrams. In many cases low average percentaage occurrence values of a particular taxon that might appear unimportant have been shown to form a subcluster within a cluster group that is highly significant (eg. Foraminiferal linings in subcluster F-1-b) as revealed by the palynofacies diagram. However in conjunction with this diagram a summary diagram (enclosure 6) is of great value in highlighting taxa that are obviously important in a particular cluster group, and doing this in a way that allows comparison with all the other groups at the same time. The occurrence characteristics of spore/pollen taxa in general can be compared between cluster groups by totalling the number of taxa in each group that fall into the 100%, >80% < 99%, and >50% <79% occurrence categories. These values can be plotted on a graph (text-fig. 2.7 i). Cluster groups showing the highest number of taxa present at >50% <79% in their samples, are E, G, I and J. At >80% <99% occurrence of taxa, cluster groups A, D, E, G and J show the highest number, while at 100% occurrence cluster groups A, G, I and J show most taxa. The total of all taxa at >50% and >80% occurrence can also be plotted (text-fig. 2.7 ii). These both show very similar trends, with cluster groups A, D, G and I showing the greatest number of taxa in these categories. A line showing the number of taxa that are completely absent in each of the cluster groups can be plotted, (text-fig. 2.7 ii). This reveals a very similar trend to that shown by cluster groups with prominently occurring taxa. It seems to be a rule that cluster groups showing many taxa that are consistently present in all or most of their samples, also contain high numbers of taxa that are absent. It must be stressed that high numbers of taxa at high percentage occurrence and high numbers of totally absent taxa are not necessarily mutually exclusive characteristics. Of course if all the palynological assemblages were intermixed then samples taken from this would tend to show all taxa present more or less every time. This does not appear to be the case, clusters of significantly associated taxa show just as many taxa that are completely absent. In my opinion this indicates that the cluster groups must represent palynological assemblages that do generally represent parent plants that were associated in the palaeo-

Total taxonomic occurrences within the binary cluster groups of taxa at various percentage occurrence categories.
(see Table 1)



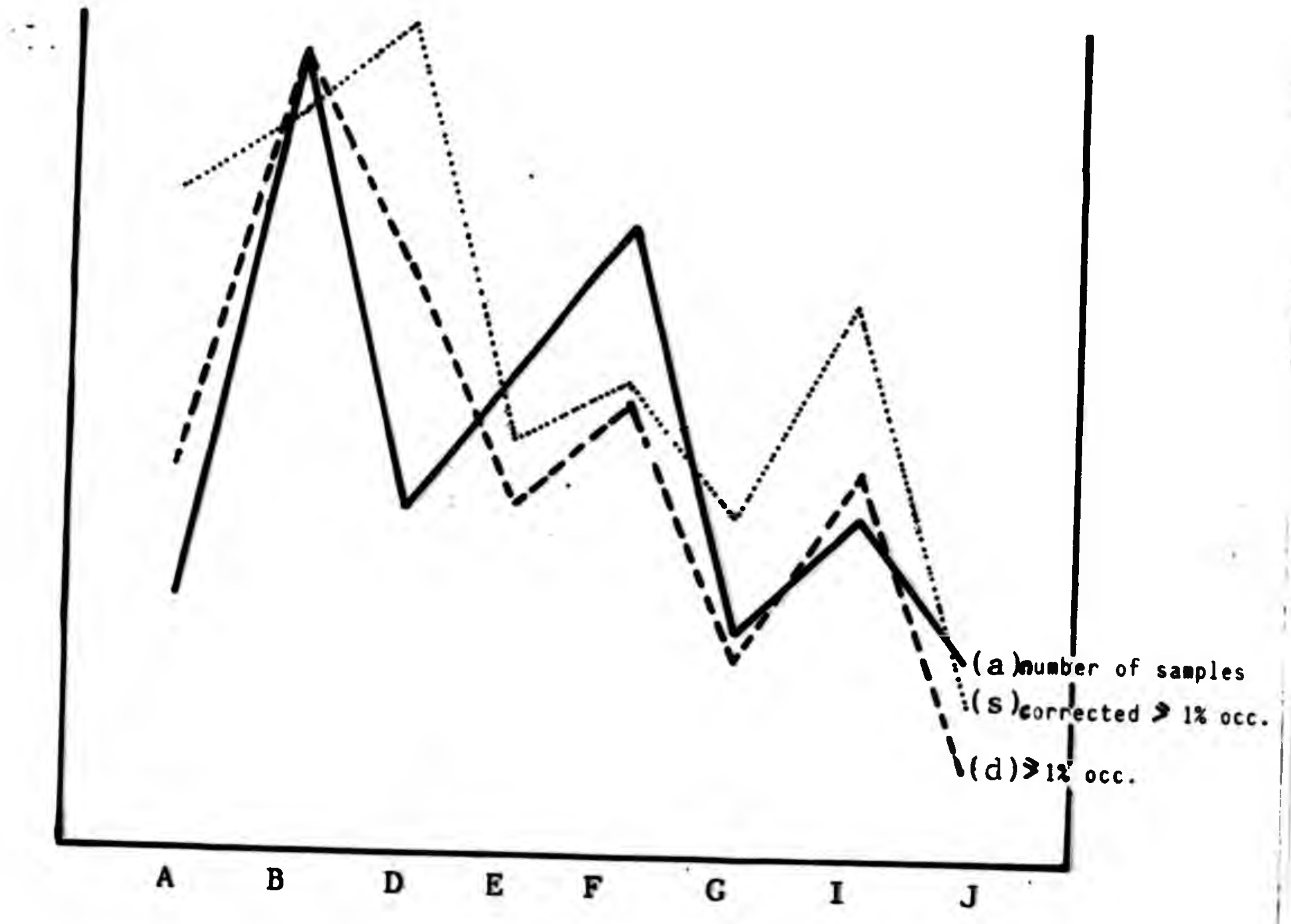
Text-fig. 2.7 i



Text-fig. 2.7 ii

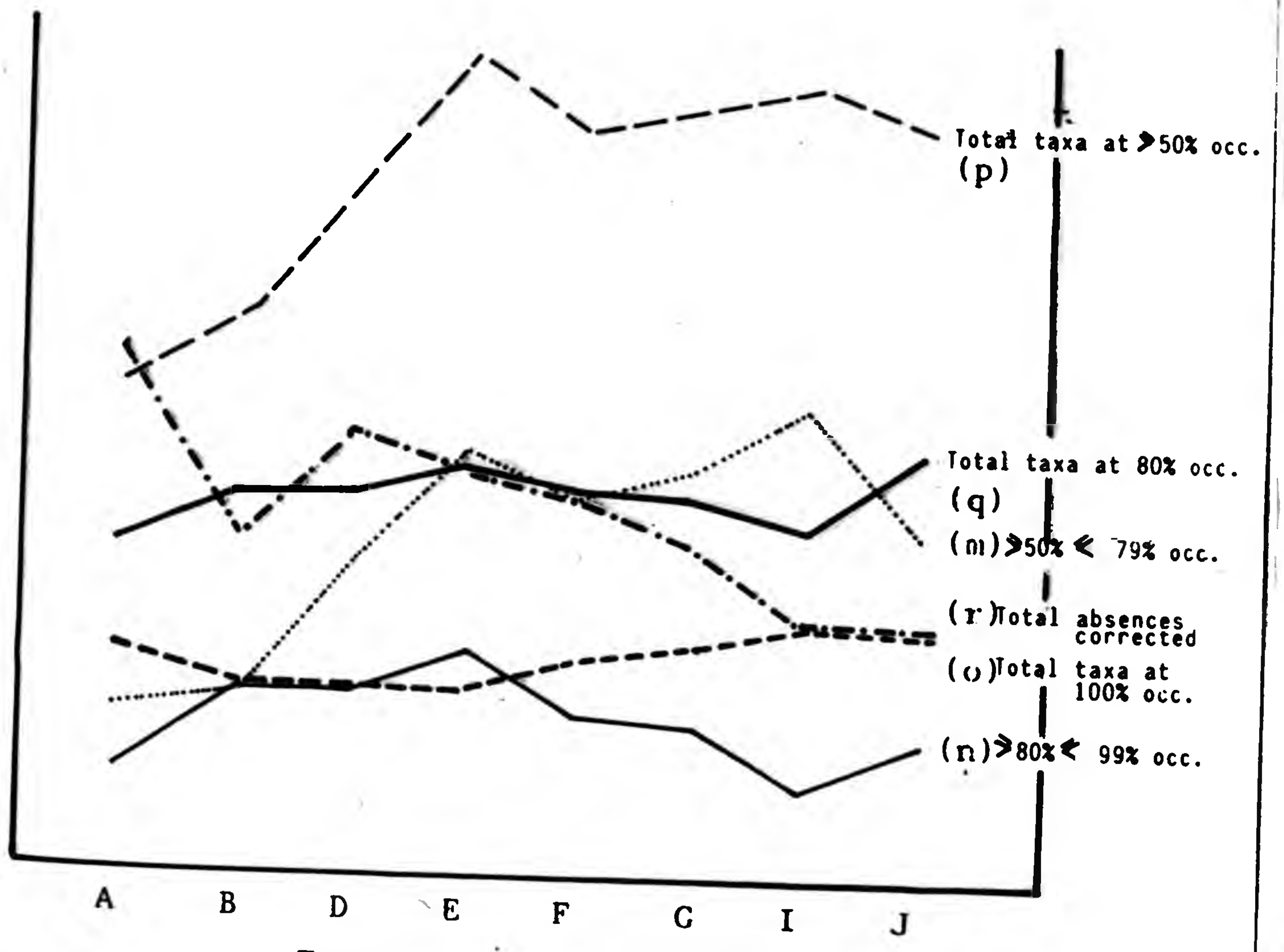
environment. Assemblages from different sources are not generally intermixed in a way that would suggest profound distortion by local reworking. A very different trend is revealed when taxa occurring at >1%, <9% levels (d) are plotted together with the number of samples in the various cluster groups (a). These two parameters show similar trends (text-fig. 2.7 iii), with cluster group B showing the highest number of both parameters. This relationship is not difficult to understand, for the larger is the number of samples in a cluster group the greater is the scope for introduction of unusual taxa at low occurrence, while taxa at higher occurrence levels will be 'diluted' to lower occurrence levels by samples that do not contain that taxon. For example if only two samples are present in a cluster group, then occurrence of a taxon in one will constitute a 50% occurrence, while if ten samples are present in the cluster group, occurrence of a taxon in one sample will only constitute 10% occurrence. The number of species present at >1% <9% occurrence is thus proportional to the number of samples in the cluster, though one has to bear in mind that individual cluster groups are defined by particular taxonomic assemblage characteristics, which has a bearing on the number of samples allocated to a particular cluster group. These two parameters can be plotted against each other (text-fig. 2.8 i). Cluster groups fall on a general line, where groups J and G are nearest the origin containing low numbers of taxa in the category and low numbers of samples. Groups A, I, F, D and E form a scattered intermediate grouping where these parameters are both 'medium'. Group B shows high occurrence of taxa in

Taxonomic occurrences at the > 1%, < 9% occurrence level.



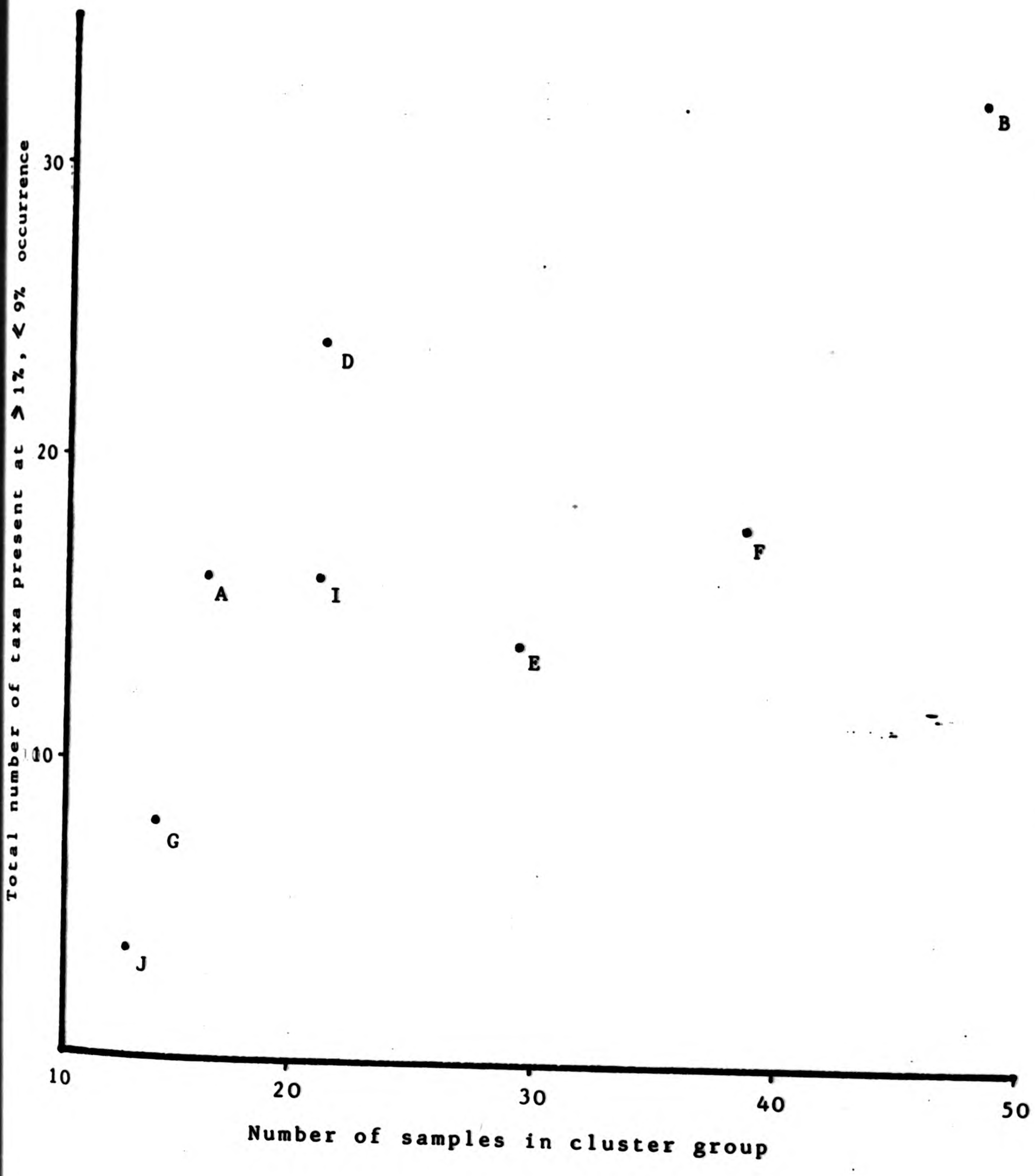
Text-fig. 2.7 iii

Taxonomic occurrences in the high occurrence categories, incorporating the correction factor of sample total.



Text-fig. 2.7 iv

The relationship of cluster group sample total and number of taxa present at > 1%, < 9% occurrence.



Text-fig. 2.8 i

this category and high sample number and lies furthest from the origin. It follows from this that multiplication of the number of taxa present at >1% <9% by the reciprocal of number of samples in the cluster should remove the effect of differences in sample number in comparing cluster groups for taxa in this occurrence category. The relationship between these two parameters is indirect and non-linear, and in practice it has been found that the square root of the reciprocal of the number of samples gives better results with a lower standard deviation between cluster groups.

$$\begin{array}{l}\text{Number of taxa present}\\ \text{at} > 1\% < 9\%\\ \text{occurrence}\end{array} \quad \times \quad \sqrt{\frac{1}{\begin{array}{l}\text{no. of samples}\\ \text{in cluster group}\end{array}}}$$

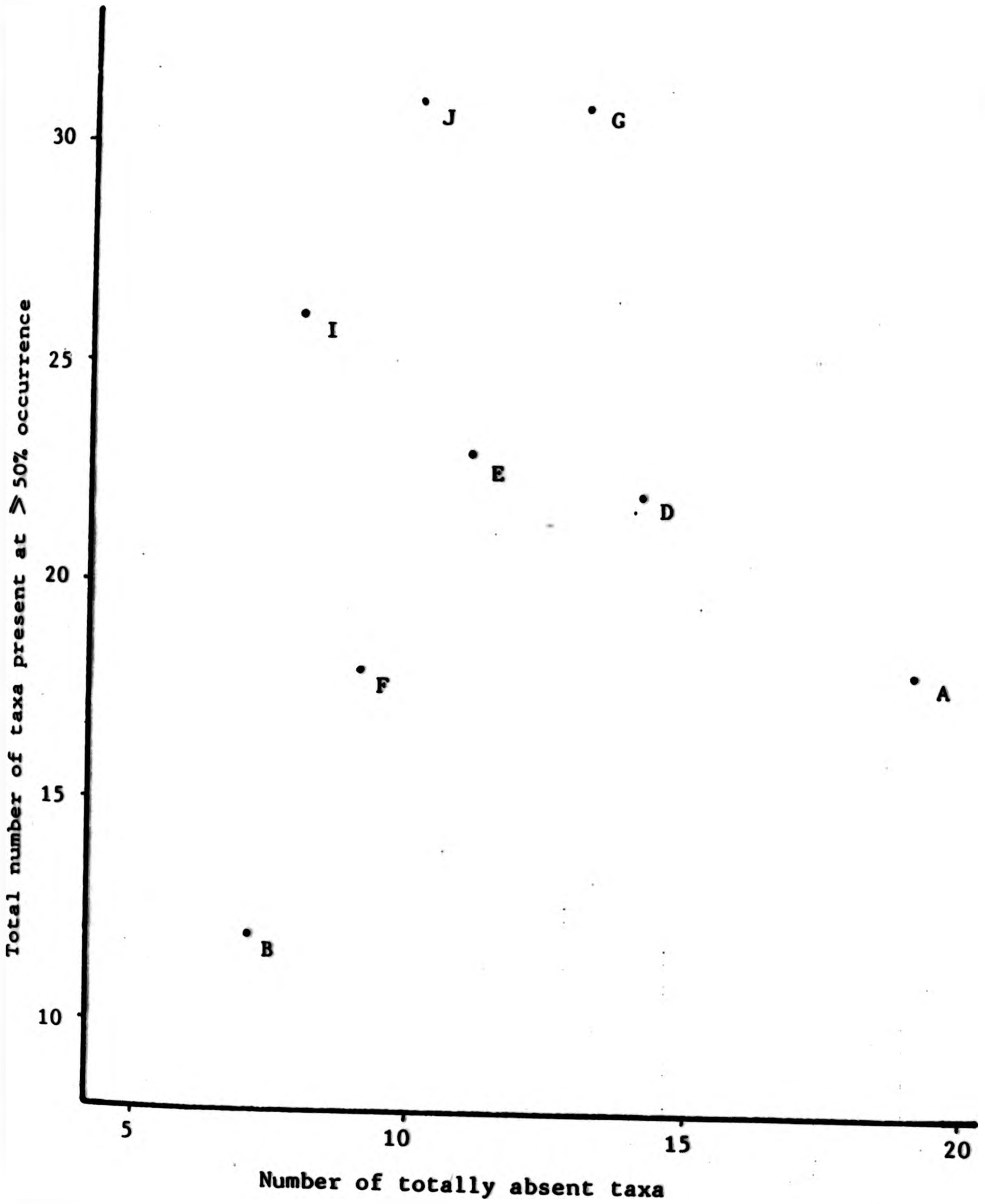
Results produced in this way have been replotted on text-fig. 2.7 iii. Cluster group D is revealed as now having the highest number of taxa in this occurrence category followed closely by B, A and I. A general trend of decreasing numbers of taxa in this low occurrence category from A to J probably reflects a decreasing effect of assemblage mixing by reworking as one moves from the strand line upstream to drier more uplifted habitats nearer to the hinterland, in my opinion. Exceptions to this trend such as high values in group I, have already been explained when the palynological assemblage of this cluster group was described in the previous section. Significant variation in the kerogen and fluorescent algal assemblages noted for cluster group I are probably due to a variety of sources of organic material hinting at reworking and mixing, similar to that postulated for group B.

The number of samples in a cluster group will also affect the number of taxa in the higher occurrence categories. A large number of samples will give greater scope for 'dilution' of taxa at high occurrence to lower levels by the addition of samples not containing that taxon. For example, if three samples are present in a cluster group, all containing a given taxon, that taxon's occurrence will be 100%. The addition of one more sample not containing that taxon will reduce its ocurrence to 75%. Once again it must be stressed that individual cluster groups have been erected on associations of spore/pollen assemblage characteristics which has no bearing upon the number of samples allocated to individual cluster groups. The association between higher occurrence levels (greater than 50%) with number of samples in a cluster, is inversely proportional as they will tend to decrease with increase in total sample number. The influence of sample number on the number of taxa in high occurrence levels can be removed by multiplication together of the two parameters. In practice it has been found (as before) that better results with lower standard deviation between cluster groups are obtained by using the square root of the number of samples:

$$\begin{array}{l}\text{Number of taxa present}\\ \text{in particular high}\\ \text{occurrence category}\end{array} \quad \times \quad \sqrt{\begin{array}{l}\text{Number of samples}\\ \text{in cluster group}\end{array}}$$

The number of taxa occurring in ≻50% ≪79%; ≫80% ≺99%; = 100%; ε ≻50 and ε ≻80% occurrence categories can be replotted following this treatment (text-fig. 2.7 iv). Trends so produced show greatly smoothed-out curves based on values with a much lower standard deviation (eg. values for total taxa at ≻80% give a standard deviation of 2.94, but after correction (as above) this is 0.4). These 'corrected' trends all show a general increase in number of taxa present in the high occurrence categories from cluster groups A to J. In my opinion this illustrates the general increase in variety and abundance of taxa within the palynofacies as one moves away from the more pioneer strand line communities, upstream to better developed plant communities nearer the hinterland. The close relationship between number of taxa in the high occurrence categories and the number of totally absent taxa has already been discussed. The number of totally absent taxa is also affected by the number of samples in the cluster group. A higher number of samples will tend to increase the chance occurrence of rare taxa, thus removing them from this category. Numbers of totally absent taxa can thus be corrected in the same way as for taxa in the high occurrence categories. The curve of this trend (r) has been plotted with the others on text-fig. 2.7 iv. This curve shows a general decrease from A to J, which also reflects the expected trend of increasing taxonomic diversity of plant communities towards the hinterland. The relationship between the number of totally absent taxa and taxa present at high occurrence (> 50%) can be shown on a graph (text-fig. 2.8 ii) where these two parameters have been plotted against each other. (Group B lies nearest the origin where both these parameters are low, reflecting the reworking and intermixing of palynomorphs from many sources with a lack of indigenous taxa). Group A contains low numbers of taxa in this commonly occurring category, reflecting the marginal pioneer palynofacies represented, but the distinctiveness of the palynofacies (ie.lack of influence of reworking

The relationship of cluster group sample total and total number of taxa present at ≯50% occurrence.



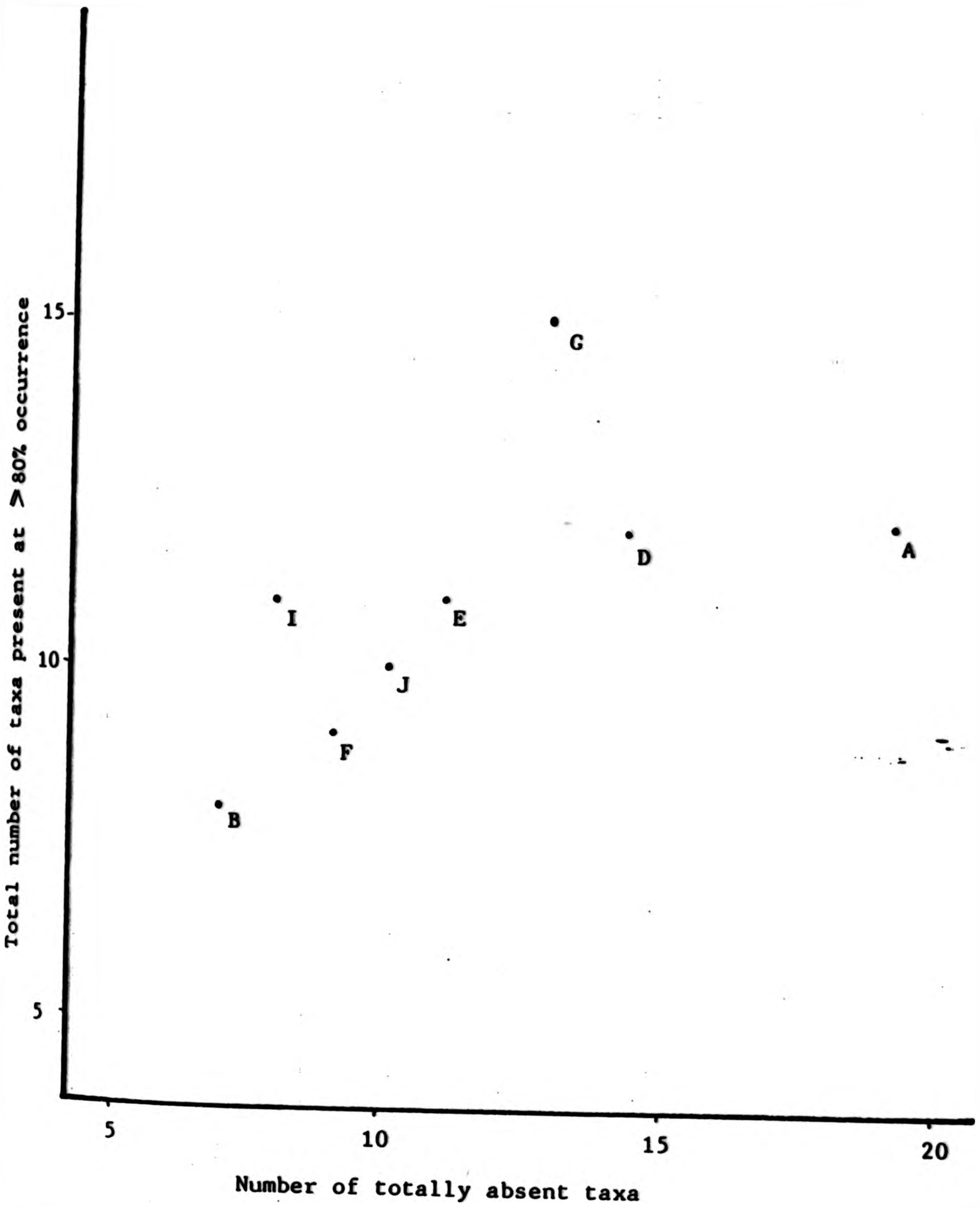
Text-fig. 2.8 ii

from elsewhere) is reflected by the high number of totally absent taxa. Groups G, I and J show high numbers of commonly occurring taxa and moderate numbers of totally absent taxa, reflecting the variety and richness of the palynofacies (reflecting their palaeoecological maturity). Groups F, E and D are intermediate between G, I and J, and the extremes of groups B and A. Taxonomic occurrences at the > 80% level have been plotted on text-fig. 2.8 iii. Generally the position of the various cluster groups shows little change. However groups I and J move relatively much closer to D, E and F. This is mainly due to the statistical limit of the method, in that 10 - 12 represent the maximum possible number of taxa that can be present at > 80% occurrence, in palynofacies that show high taxonomic variety. Group G remains high however, because its taxonomic variety is less (ie. number of totally absent taxa is greater). Group A is the next highest on this diagram for the same reason.

The conclusion from these two diagrams is that palaeoecological differences between binary cluster groups can be emphasized by this kind of diagram, and that plotting of number of taxa at > 50% occurrences reveals more valid results than plotting at > 80% occurrence.

A further manipulation of the spore/pollen occurrence data can be made that brings out the trend of rising taxonomic variety from cluster groups A - J in the clearest fashion. A cluster group that possesses low numbers of high occurrence taxa will generally contain high numbers of totally absent taxa. *Vice versa*, cluster groups with high numbers of high occurrence taxa will generally contain low numbers of

The relationship of cluster group sample total, and total number of taxa present at > 80% occurrence.

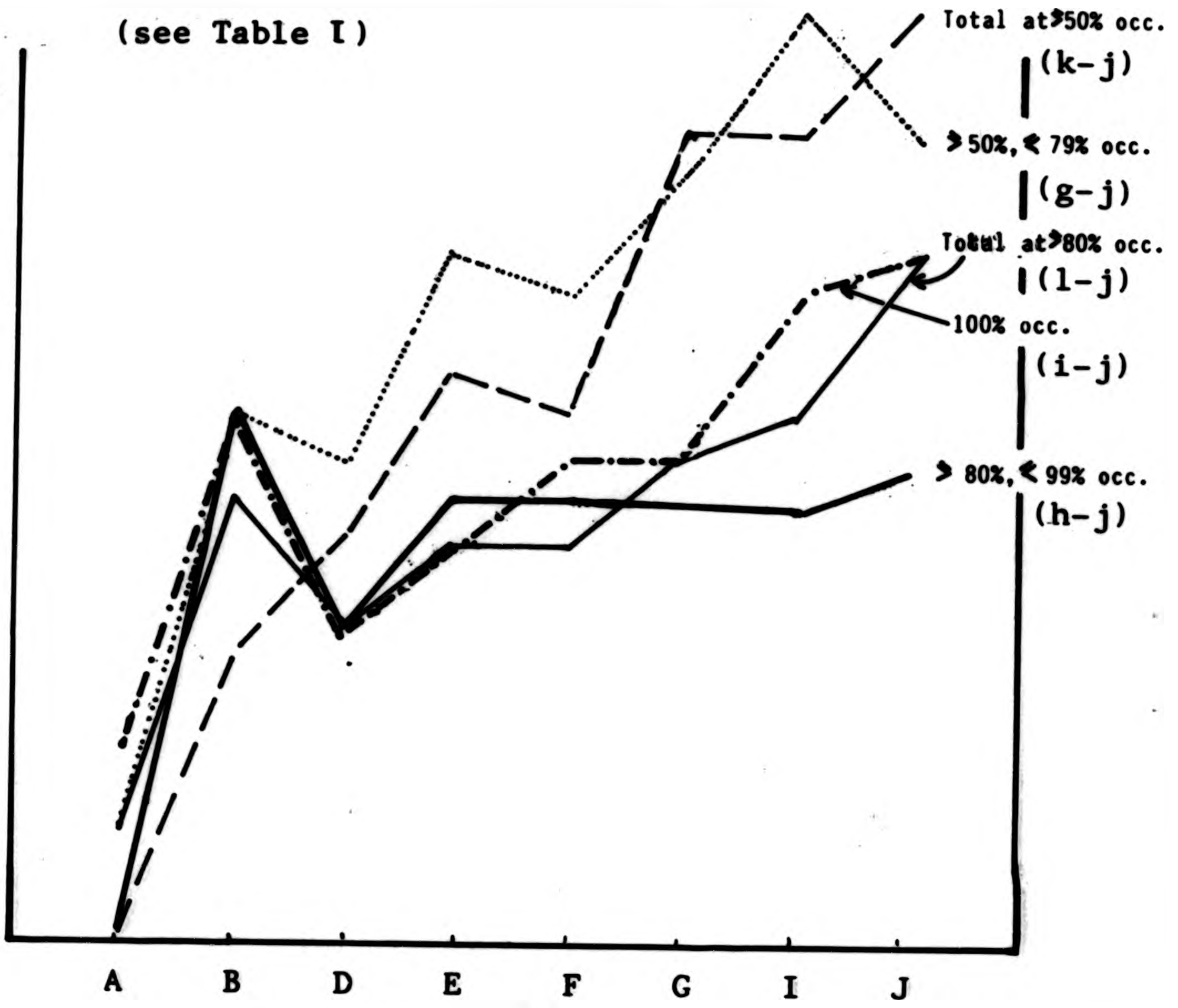


Text-fig. 2.8 iii

totally absent taxa. The number of absent taxa can be subtracted from the number of taxa present in the high occurrence categories and replotted. These high occurrence trends (see table II) have been plotted on text-fig. 2.9 i. As is expected the trend is now revealed as rising steeply from cluster groups A to J. This emphasizes the distinctly greater taxonomic variety across the Weald Clay basin from the impoverished pioneer strand line floras to the rich and diverse drier palaeoenvironments inland towards the source land massif. This rising trend is best brought out by the ⩾50 ⩽79% occurrence line. An interesting flexure that is displayed by some of the high occurrence trends shows a very steep rise from cluster groups A to B, falling back sharply again from B to D. The high values at group B reflect the low number of total absences rather than a high number of high occurrence taxa. This further shows the exceptional case of group B that in my opinion represents a lacustrine depositional environment that had no well developed indigenous flora of its own but acted as a trap for spores and pollen from a variety of other palaeoenvironments. These same data of high occurrence taxa minus totally absent taxa, have also been plotted incorporating the correction factor of multiplication by the square root of number of samples in the cluster group. This is given on text-fig. 2.9 ii. The rising trend from A to J is very similar to the uncorrected trends of text-fig. 2.9 i, but the 'flexure' at cluster group B is even more pronounced.

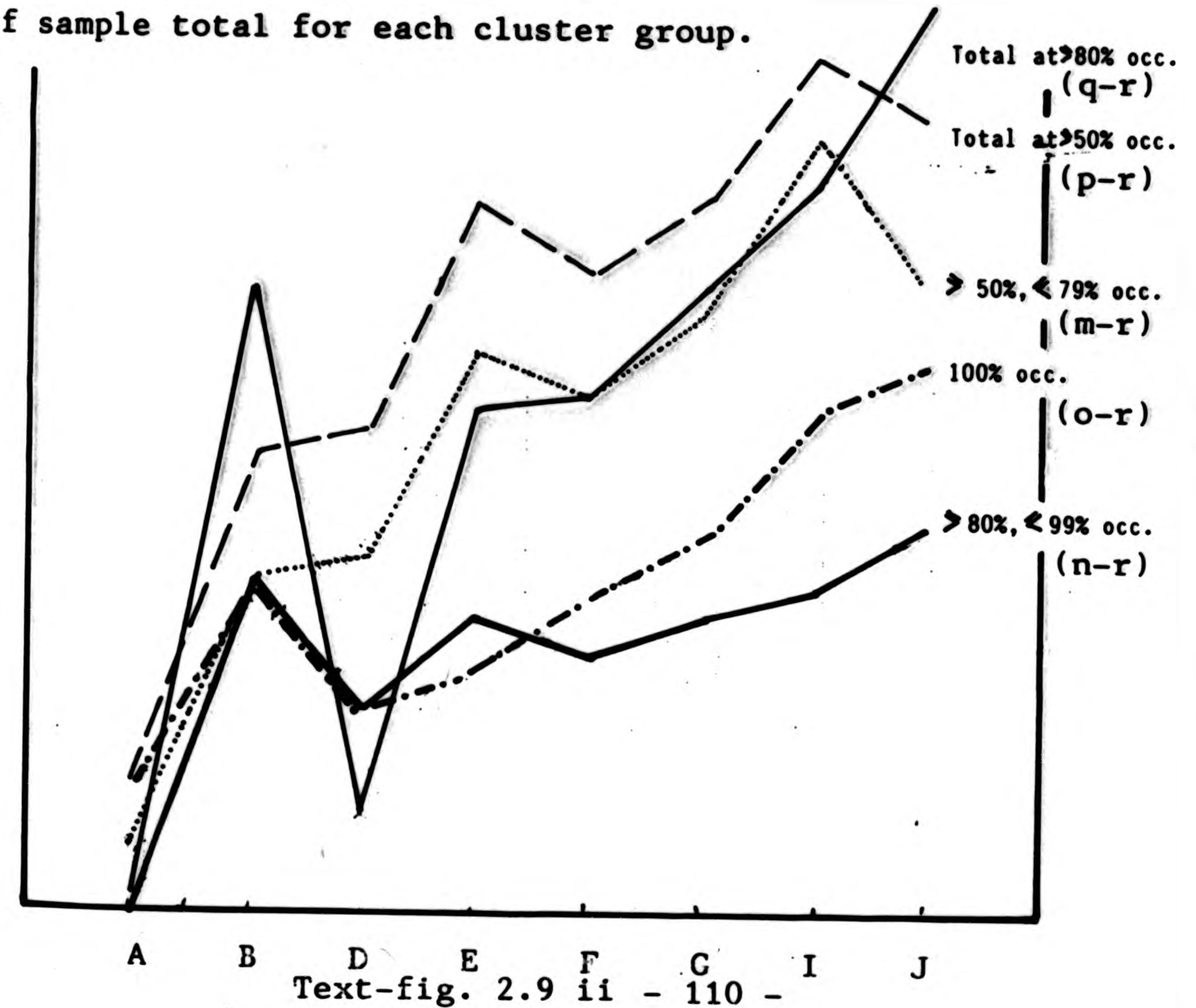
Both these diagrams show a much flatter line for the ⩾80% ⩽99% occurrence trend. It seems to indicate that at

Taxonomic occurrences at high occurrence categories minus the number of totally absent taxa.



Text-fig. 2.9 i

Taxonomic occurrences as above, incorporating the correction factor of sample total for each cluster group.



Text-fig. 2.9 ii

TABLE I

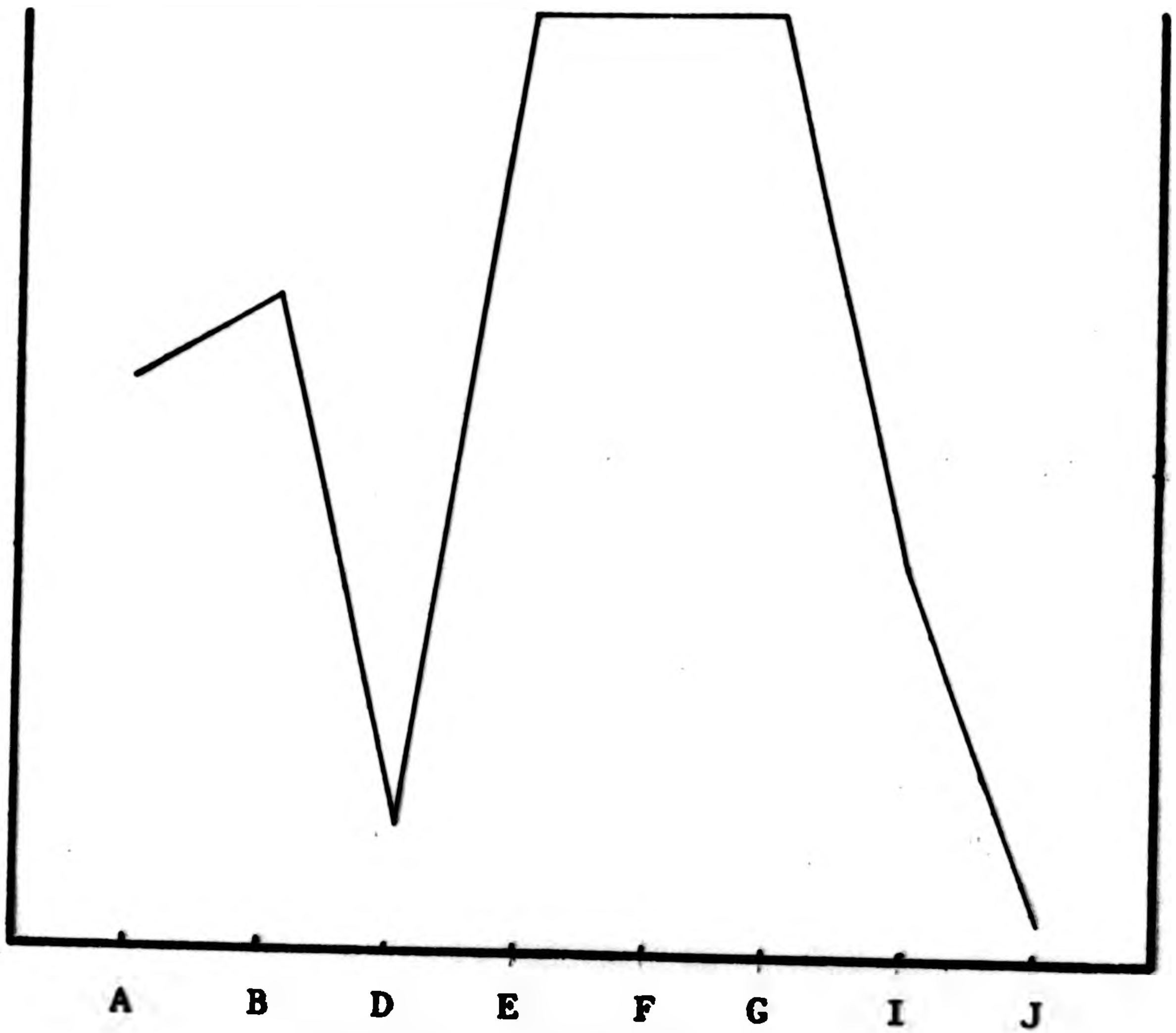
		A	B	D	E	F	G	I	J	SD
No of samples in cluster	(a)	16	48	21	29	38	14	21	13	12.5
$\sqrt{a}$	(b)	4.0	6.9	4.6	5.4	6.2	3.7	4.6	3.6	1.19
1/a	(c)	.0625	.0208	.0476	.0344	.0263	.0714	.0476	.0769	0.020
No of taxa at >1% occ	(d)	16	32	24	14	18	8	16	4	8.73
" >10% occ	(e)	22	23	17	26	26	26	20	16	4.035
" >30% occ	(f)	9	11	9	11	14	8	15	26	5.84
" >50% occ	(g)	6	4	10	12	9	16	15	14	4.3
" >80% occ	(h)	4	4	6	6	4	6	3	6	1.24
" 100% occ	(i)	8	4	6	5	5	9	8	11	2.39
No of totally absent taxa	(j)	19	7	14	11	9	13	8	10	3.8
taxa at >50% occ	(k)	18	12	22	23	18	31	26	31	6.63
" >80% occ	(l)	12	8	12	11	9	15	11	17	2.94
(b) x g/10	(m)	2.4	2.76	4.6	6.48	5.58	5.92	6.9	5.04	1.6
(b) x h/10	(n)	1.6	2.76	2.76	3.24	2.48	2.22	1.38	2.16	0.6
(b) x i/10	(o)	3.2	2.76	2.76	2.70	3.1	3.33	3.68	3.96	0.46
(b) x k/10	(p)	7.2	8.2	10.1	12.4	11.1	11.4	11.9	11.1	1.83
(b) x l/10	(q)	4.8	5.5	5.5	5.9	5.6	5.5	5.06	6.12	0.4
(b) x j/10	(r)	7.6	4.8	6.4	5.9	5.5	4.8	3.68	3.6	1.3
($d \times \sqrt{c}$ (	(s)	4	4.48	5.23	2.59	2.916	2.136	3.48	1.108)	1.3
((d x c) x 10	(t)	10	6.65	11.42	4.81	4.73	5.71	7.61	) 3.07)	2.81

the higher occurrence categories a 'saturation point' is reached where numbers of taxa are more or less similar amongst all the cluster groups, partly because the actual numbers of taxa in the very high occurrence categories are universally low. This shows again the feature noticed under discussion of text-figs 2.8 iii-iv that data on the >50% occurrence category brings out the best trends.

Finally some consideration can be made of data on intermediate occurrences in the >10% <29% and >30% <49% categories, that have not yet been mentioned. These categories are least likely to be affected by differences in sample number between cluster groups. These differences caused higher than expected high occurrence taxa due to low sample number or higher than expected low occurrence taxa due to high sample number. This effect has been previously described and eliminated by using a correction factor based on the square root and square root of the reciprocal of the sample total for each cluster group for the highest and lowest occurrence categories.

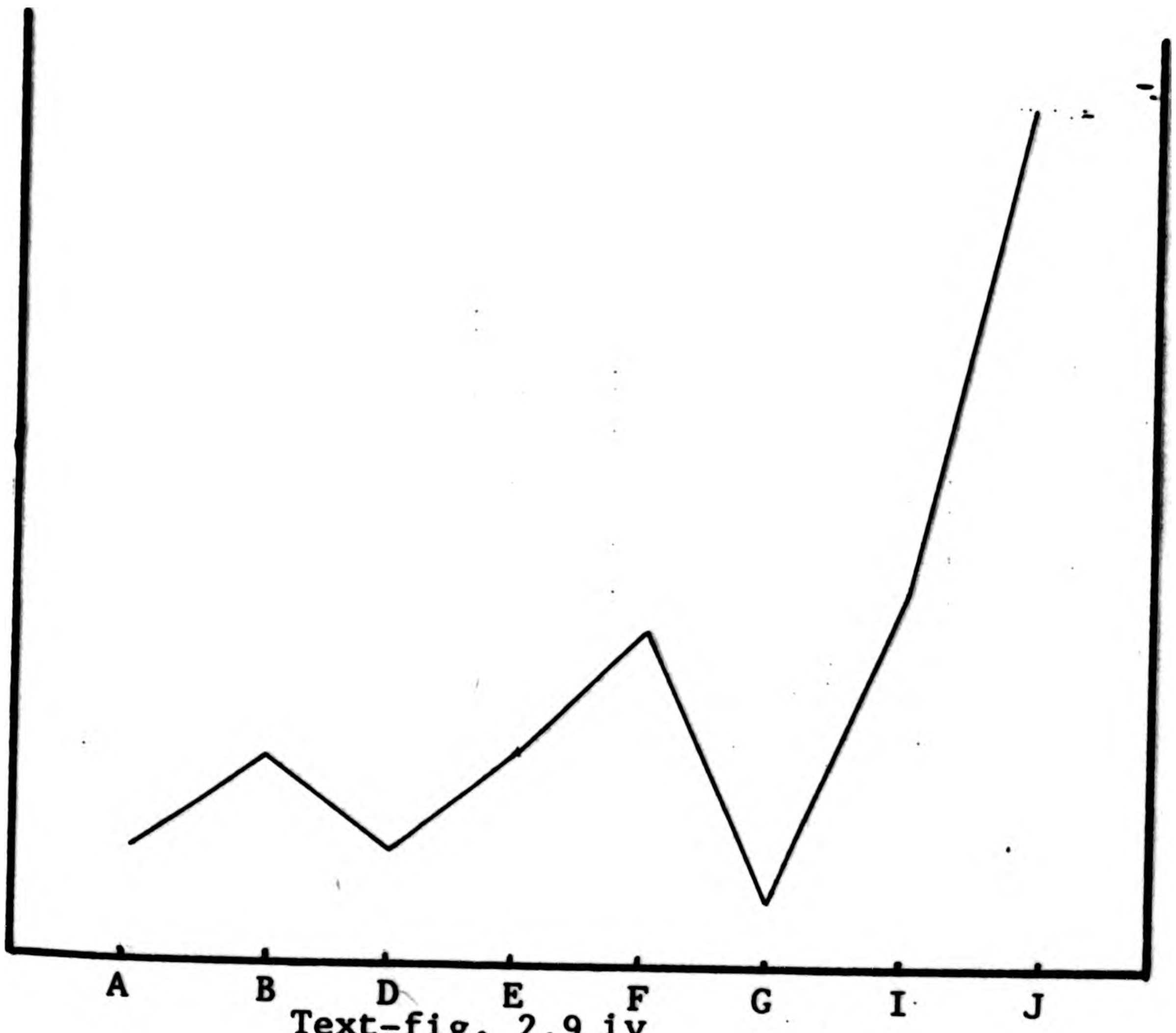
Data on taxonomic occurrences in the 'low intermediate' category >10% <29% is provided on text-fig 2.9 iii. Groups D1 and J show lowest values on this diagram which may be interpreted as indicating that they represent the driest part of the Weald Clay basin. It can be suggested that high taxonomic occurrences in this particular occurrence category correspond with greater likelihood that taxa are reworked into, rather than part of the indigenous flora. This is comparable with the high numbers of >1% <9% occurrence taxa that were washed into the lacustrine environment of group B. Here

Taxonomic occurrences at the > 10%, < 29% occurrence level.
(see Table I)



Text-fig. 2.9 iii

Taxonomic occurrences at the > 30%, < 49% occurrence level.
(see Table I)



Text-fig. 2.9 iv

however group B is not markedly higher than all the others as most taxa fall into this lower occurrence category. Also the reworking effect here is probably much more localised. The damper palaeoenvironments would provide the best areas for trapping spores and pollen. Evidence that groups D and J represent drier areas as they have such low numbers of taxa in this 'low intermediate' occurrence category is corroborated from another source. Examination of the palynofacies diagrams(enclosures 3 & 4) shows fluorescent algae to be lowest in these two groups, particularly so the lacustrine alga Botryococcus .

The trend of occurrences in the > 30% < 49% category is plotted on text-fig. 2.9 iv. This only shows a much higher number of taxa in group J than all the others. This only further emphasizes the much higher taxonomic diversity of this cluster group that must represent the most developed Weald Clay basin flora, in the most stable area near to the source lands.

TABLE II

	A	B	D	E	F	G	I	J
g - j	-13.0	-3.0	-4.0	1.0	0	3.0	7.0	4.0
h - j	-15.0	-3.0	-8.0	-5.0	-5.0	-5.0	-5.0	-4.0
i - j	-11.0	-3.0	-8.0	-6.0	-4.0	-4.0	0.0	1.0
k - j	-1.0	5,0	8.0	12.0	9.0	18.0	18.0	21.0
l - j	-7.0	1.0	-2.0	0.0	0.0	2.0	3.0	7.0
m - r	--5.2	-2.04	-1.8	0.58	0.08	1.12	3.22	1.44
n - r	-6.0	-2.04	-3.64	-2.66	-3.02	-2.58	-2.3	-1.44
o - r	-4.4	-2.04	-3.64	-3.2	-2.4	-1.47	0	0.36
p - r	-0.4	3.4	3.7	6.5	5.6	6.6	8.22	7.5
q - r	-2.8	0.7	-0.9	0	0.1	0.7	1.38	2.52

2.4 (e) Associations between spore/pollen taxa.

The percentage occurrence traces (P.O.T.) (text-figs. 2.5 i - xxx) have been used to compare spore/pollen assemblages between cluster groups and in the descriptions of individual cluster groups. They can also be used to compare the occurrence characteristics of individual palynomorph taxa. Taxa showing the most similar P.O.T.'s have been plotted together on the same axes for this purpose. In my opinion taxa that show these broad similarities in occurrence characteristics across most of the cluster groups must be palaeoecologically related. Of course where the percentage occurrence of two taxa falls below 50%, then occurrences of these two within the cluster group may not be within the same samples. However taxa that show well defined peaks overlapping up to 70% must be related palaeoenvironmentally. Some taxa are too rare to ever be present in any cluster group at greater than 50% occurrence. Such taxa can still be compared as they show similar occurrence between individual cluster groups, so they must be palaeoenvironmentally related in a general way. Other taxa are present in only very low percentages in all cluster groups. They are too rare to show any distinct occurrences in any particular cluster group. Occurrences of these taxa in individual cluster groups would probably be revealed if a much greater number of samples were examined. Some of these very rare taxa show subclusters within cluster groups, as revealed by the palynofacies diagram eg. Kuylisporites lunaris in subcluster B-1-b.

Cicatricosisporites potomacensis, Lycopodiacidites, Cook-

sonites sp. and *Kuylisporites lunaris* have been grouped together on text-fig. 2.5 xxviii. The only feature that they have in common is that they are very rare. *Lycopodiumsporites austroclavitides*, *Antulsporites* sp., *Stereisporites antiquasporites* and *Couperisporites* sp. (text-fig. 2.5 xxvii) are also generally rare taxa, with slightly higher occurrences in groups A, D, I and J. The rarity of these taxa is probably due to habitat restriction of the parent plants rather than their low spore production. Some taxa show a distinct rising trend in occurrence from cluster group A to J. A general palaeoenvironmental trend from groups A to J has been interpreted as being a trend traced inland from the strand line to drier, raised and species rich communities nearer the hinterland (section 2.4 (d)). These taxa may be interpreted as being most typical of the climax communities nearest the hinterland, and that spores are carried downstream from this palaeoenvironment, and are redeposited in palynofacies further away in successively diminishing numbers. This group of taxa has been divided into two. *Appendicisporites problematicus*, *Pilosisporites trichopapillosus*, *Todisporites* sp. and *Deltoidaspora* sp. (text-fig. 2.5 xxi) show this trend at slightly higher occurrence values than *Pilosisporites verus*, *Appendicisporites tricachanthus* and *Appendicisporites sellingii* (text-fig. 2.5 xxii). Other taxa show a similar trend to this with the exception of very low occurrences in cluster groups G and I. These probably represent taxa that favour the more proximal (with respect to the hinterland) palaeoenvironment but are not restricted to the most mature habitat, represented in the palynofacies by cluster group J, but can be important in other mudplain palynofacies (*Concavis-*

simisporites variverrucatus, *Matonisporites phleberopteroides*, and *Appendicisporites jansonii* (text-fig. 2.5 xv). Other taxa show a similar occurrence trend between groups J and F (*Calamospora* type, *Cicatricosisporites minor*, *Ischoysporites* sp. and *Trilobosporites bernissitartensis*, text-fig. 2.5 xvi). This is particularly well marked by *Concavissimisporites* spp., *Sestrosporites pseudoalveolatus*, *Pilosisporites* spp. and *Aequitriradites* spp. (text-fig. 2.5 xiii) and to a much lesser degree by the comparatively rare taxa *Trilobosporites apiverrucatus*, *Pilosisporites* cf. *notensis* *Schizosporis* spp. and *Sphaeripollenites psilatus* (Text-fig. 2.5 xiv). Taxa showing this same diminishing trend from J to A but with prominent occurrence in cluster group E are grouped on text-fig. 2.5 xi. These are *Contignisporites* sp., *Trilobosporites* sp., *Appendicisporites potomacensis* and *Foveosporites* sp.. The bisaccate pollen *Rugubivesiculites* sp. is particularly characteristic of groups E and F and is notably rare in groups D and G in common with *Microthyriaceae*, and *Pluricellaesporites* (text-fig. 2.5 xii). One group of taxa shows a generally diminishing occurrence trend from J to A, but with very marked low occurrence values in cluster groups F and I. These are *Polycingulatisporites* spp., *Appendicisporites tricornitatus*, *Trilobosporites canadensis* and *Densoisporites* spp. (text-fig. 2.5 xvii).

Other groups of taxa are independent of any palaeoenvironmental trend from J to A, but show distinct peak occurrences within one or a few cluster groups. These kind of trends have already been discussed (section 2.4 (b)) when cluster groups themselves were being compared. *Pilosisporites notensis*, *Cicatricosisporites pseudotripartites* and *Lycopodiumsporites* *marginatus* (text-fig. 2.5 x) show definitive association with prominent occurrences in groups D and I. *Coronatispora valdensis*, *Acanthotriletes varispinosus* and *Biretispora* sp are generally commonly occurring taxa (text-fig. 2.5 ix) but are less prominent in cluster groups B and G. *Cingulitriletes* sp., *Costatoperforosporites* sp. and *Distaltriangulispora* sp. (text-fig. 2.5 vii) are related in their occurrence characteristics, particularly so in group G. *Appendicisporites* spp., *Klukisporites* spp. and *Undulatisporites undulapolus* are commonly occurring taxa with generally lower occurrences in groups A, F and I (text-fig. 2.5 viii).

Some taxa appear to favour apparently quite different palaeoenvironments based on evidence so far discussed. Text-fig. 2.5 iii shows the associated P.O.T.'s of *Cicatricosisporites augustus*, *Leptolepidites* spp., *Reticulisporites* spp. and *Verrucosisporites* spp.. These taxa are of high occurrence in cluster groups A and G. Evidence so far presented suggests that group A shows the highest marine influence, while group G shows definite freshwater aquatic conditions. Both these environments would be expected to be particularly low-lying marshy areas of the alluvial braidplain. It is possible that the parent plants of these spores favoured this kind of terrain and could tolerate differences in salinity implied by these two palynofacies. Several very different P.O.T.'s have already been described for various species of *Cicatricosisporites*. This illustrates that this generic group, as well as showing great species diversity in the Early Cretaceous, also colonised a wide range of palaeoenvironments in the Wealden. Text-fig. 2.5 v shows *Cicatricosisporites australiensis* and *Cicatricosi*-

sporites annulatus that are of prominent occurrence in cluster groups D, E and J and are distinctly low in groups A and B. These palynofacies are thought to be generally uplifted and well drained with very low marine influence. Text-fig. 2.5 xxiii shows Cicatricosisporites hughesi and Cicatricosisporites hallei which have very similar P.O.T.'s with C. hughesi of generally higher occurrence. Both these taxa are of high occurrence in cluster groups A and J that are at opposite ends of the palaeoenvironmental 'range' already discussed. These are probably spores of fairly cosmopolitan plant species, though the reason for this trend is unknown. The close relationship of the P.O.T.'s of these two species raises the possibility that C. hallei is a rarer taxonomic variant of the same plant that produced C. hughesi type spores also. There is a certain amount of morphological similarity between these two species; both are characterised by fewer more robust striations than other species in this genus. Text-fig. 2.5 iv shows the similar P.O.T.'s of Lycopodiumsporites sp., Foveotriletes sp. and Tigrisporites scurrandus. These are all prominently reticulate spores, and are common in cluster groups G and E. Reticulisporites sp. in text-fig. 2.5 iii also shows this trend. In this instance, unlike Cicatricosisporites, morphological similarity is reflected in palaeoenvironmental uniformity. Text-fig. 2.5 v shows a very definite trend of Foraminisporis assymetricus in cluster group B. This is in contrast to the trend of Foraminisporis sp. (text-fig. 2.6 xx) which has a very low occurrence in group B. This suggests an antipathetic relationship between these two closely related taxa. (On the palynofacies diagram both forms have been plotted together under Foraminisporis spp.).

Text-fig. 2.5 i shows the close association between the occurrence of foraminiferal linings and the bisaccate pollen Vitreisporites pallidus. This pollen is a very long ranging Mesozoic taxon that is found in many different facies. In the Weald Clay samples it was never found in any great abundance but its occurrence does appear to be correlated with marine influence, along the strand line of the mudplain. If this was the habitat of its parent plant throughout the Mesozoic, this may be why it was incorporated into many different depositional facies. However it does not appear to have been a very prolific pollen producer. Text-fig. 2.5 ii shows the trend for Cerebropollenites mesozoicus. This taxon also shows a peak occurrence in cluster group A. Like V. pallidus this taxon appears to be a 'pioneer' species of the strand line. It shows other smaller peaks in groups D, E and I.

Other taxa show P.O.T.'s that do not overlap with others. Concavisporites jurienensis is one of these (text-fig. 2.5 vi). Celyphus rallus (text-fig. 2.5 xxiv) also shows an occurrence trend that is very different from any other. It shows particularly low occurrence in cluster groups A and J, suggesting that it does not favour marine conditions, nor the drier well developed habits nearer the hinterland, but rather the damper freshwater environments in between. This problematic palynomorph of probable algal origin will be discussed in greater detail elsewhere (section 3.3).

Other taxa that are of very high occurrence throughout the Weald Clay, including bisaccate pollen, Cicatricosisporites spp, Gleicheniidites spp. and Classopollis sp. are shown on text-figs. 2.5 xxix and xxx. These are all too cosmopolitan in their occurrence to show any variation that would allow palaeoenvironmental conclusions about them to be drawn. Binary presence/absence data is too simple a technique for handling these taxa, but they can be dealt with on the basis of multivariate data. This will be discussed in the next section.

2.4 (f) Summary

Section 2.4 commenced with a description of the palynofloral characteristics of the ten binary clusters. Evidence that these assemblages do actually show high fidelity (sensu Frederiksen, 1985) with genuine palaeoecological associations of plants growing in the Weald Clay braidplain has been discussed. This evidence is based on the non random clustering of lithology, kerogen type and fluorescent algal assemblages independantly with the ten binary clusters. Parameters that suggest marine influence affecting the palynofacies, such as occurrence of foraminiferal linings and marine dinocysts are most prominent in cluster group A. Cluster group B shows strong association with cluster group A in kerogen type and lithology, suggesting proximity of depositional environment, though marine parameters are distinctly less obvious. Groups D, E, F and G all show varying degrees of freshwater aquatic influence and very rare marine influence by their characteristic kerogen types and fluorescent algae. Groups I and J show generally rare freshwater aquatic influence and are assumed to represent palynofacies that were closest to the source land massif and most removed from direct marine influence.

Comparisons made between cluster groups to show the diversity of taxa represented by each, reveals a markedly rising trend from group A to group J. An assumption can be made that botanical diversity would be expected to increase across the Weald Clay braidplain from the marine influenced facies to the drier uplifted facies nearest to the hinterland. This assumption is based on the fact that plants living closest to the marine waters would inhabit an unstable environment, most prone to flooding by the sea and erosion by streams. At this 'downstream' location, flood water would be in greatest volume and undercutting of mudbanks and sandbars together with movement of the channels, most evident. Added to this, species would have to be salt water tolerant. In contrast, plants living nearer to the source land massif would inhabit less ephemeral environments that would be well watered, but drier with less standing water and less prone to erosion and much rarer marine influence. The mudbanks here would be slightly more uplifted providing comparitively stable environments, where a rich and diversified fern flora could develop, in contrast to the few 'pioneer' species nearer to the strandline.

The evidence on spore/pollen diversity, with a rising trend from groups A to J, provides good supporting evidence to the notion that 'fidelity' of the assemblages is high. In addition data is provided on the palaeogeography of the braidplain and the spore/pollen taxa that are most closely related by occurrence, and probably therefore, ecology.

2.5 MULTIVARIATE CLUSTER GROUPS

2.5 (a) Introduction

The treatment of palynomorph assemblages by multivariate methods involving counts made to determine the exact numerical proportions of individual taxa introduces a new dimension to the data, compared to binary presence/absence data. On the one hand there is a tendency to simplify as fewer numbers of taxa (ie. the most abundant ones) are involved. On the other hand, percentage occurrence data is infinitely more complex than mere binary presence/absence. To some extent the binary and multivariate methods are complimentary. The binary method, by giving equal importance to all taxa, allows the rarely occurring taxa their maximum influence within the palynofacies. Commonly occurring taxa are played down in importance, as being cosmopolitan, palynofacies cannot be differentiated on them. In essence then, the multivariate approach gives maximum control of the palynofacies to the most abundant taxa and very little sway to the rare ones.

The cluster analysis dendrogram produced by multivariate analysis is formed by linkages at a much higher coefficient than with binary data, indicating how much greater is the variation between samples by this method. The actual cluster analysis is in many ways much poorer than that produced by binary analysis as the cluster groups are extremely uneven, with a large number of cluster groups based on one or a few samples and a very few other groups containing a great number of samples (text-fig. 2.3 i - iv). Attempts at breaking the large cluster groups down by taking the cluster group 'cut-off' point at a lower coefficient only produces an even greater number of clusters containing very low numbers of samples. Taxa have been quantified by percentage frequency in individual cluster groups. An average percentage occurrence for each taxon has been used where there is more than one sample in a cluster group. This data has an advantage over binary data (see section 2.4 (d)) in that the number of samples in the cluster group will not greatly influence the values for each taxon. This assumes of course that the standard deviation of such averaged values is fairly low, as would be expected given that they have been clustered together. A disadvantage with this data is that being percentage frequencies, high values for one taxon brings a proportional decrease in the frequency of all the others. A good example of the effect of this is seen in cluster group VII which groups samples all containing very high frequencies of <u>Celyphus rallus</u>. In many of these samples <u>C. rallus</u> is present at over 80%. This leaves only 20% to be 'shared' between all the other taxa, making them all seem very low, obscuring comparison of these with cluster groups. <u>C. rallus</u> is thought to come from a different source than the spore/pollen taxa, so it can be regarded as incidental to the spore/pollen assemblage. In order that the spore/pollen percentage frequencies are not eclipsed by the presence of abundant <u>C. rallus</u>, these samples were counted a second time ignoring <u>C. rallus</u>, so that values for individual taxa can be compared with those in other cluster groups where <u>C. rallus</u> is low. These percentage frequencies that exclude <u>C. rallus</u> have been plotted as a bar extending beyond the linkage lines that join smaller bar lines for percentage frequencies that include C. rallus on the palynofacies diagram (enclosures 7 & 8).

The palynofacies of each cluster group can be described in the same way as for the binary clusters, using the same criteria. Most of these descriptions will be quite short as the number of samples that they constitute is so low. It is worth stressing again that the cluster groups are based solely on the spore/pollen assemblages. Palaeoenvironmental remarks will be drawn on individual palynofacies using trends in kerogen type, lithology and fluorescent algal assemblages together with palaeoenvironemntal markers such as foraminiferal linings. However the main discussion of palaeoenvironments is reserved for Chapter Three. A summary diagram showing the main percentage frequencies of individual palynomorph taxa in the samples within each multivariate cluster group at coefficient 4.0 (24 cluster groups), is given on enclosure 9.

2.5 (b) Cluster group characteristics

CLUSTER GROUP I

This cluster group comprising one sample, N.17, is distinct from all the others in containing very abundant Cicatricosisporites annulatus and Contignisporites sp.. The Apiculati, Muronati and Cingulati are generally well represented, though the Tricrassiti, Hilates and Disacciti are distinctly low in number. Classopollis spp.is distinctly low in abundance as well as Celyphus rallus.

The kerogen assemblage of this cluster group is distinctly lacking in any fine or amorphous material. It consists of fusinite and palynomorphs in approximately equal amounts. The lithology comprises iron-stained, non-laminated mudstone. Fluorescent algae are completely absent.

The palaeoenvironment suggested by this sample is strongly terrestrial. Aquatic indicators such as fluorescent algal cysts, C. rallus, or fine grained and amorphous kerogen are either very low or absent. The presence of iron-staining suggests pedogenesis. The extreme abundance of Cicatricosisporites annulatus and Contignisporites sp., and the rarity of normally cosmopolitan taxa such as Gleicheniidites spp. and bisaccates suggests that this is a highly localised in situ assemblage.

CLUSTER GROUP II

This cluster group also comprises a single sample, Pl.12. It is distinct in containing abundant Apiculati, particularly

Pilosisporites verus and *Concavissimisporites* sp. together with very abundant Auriculati, particularly *Matonisporites phleberopteroides* and *Trilobosporites* spp.. The Cingulati are comparatively well developed, as well as the Hilates and the Disacciti. In the latter case pollen assigned to *Alisporites* type are very low in number and *Celyphus rallus* is absent. *Schizosporis* spp. are important.

The kerogen assemblage of this cluster group is again distinctly lacking in fine or amorphous material. Fusinite and palynomorphs are present in approximately equal amounts. The lithology consists of a non-laminated silty mudstone. Fluorescent algae are completely absent.

The palaeoenvironment suggested by this sample (or cluster group) is strongly terrestrial and non-aquatic, in being barren of fluorescent algal cysts and *Celyphus rallus*, and containing prominent fusinite in the absence of fine or amorphous material. The palynomorph assemblage is comparatively specialised in containing abundant large trilete spores, and I think that it generally represents an *in situ* assemblage of the mudplain in a proximal position with respect to the hinterland.

CLUSTER GROUP III

This cluster group is comprised of sample Pl.11. It is distinct in containing comparatively abundant Apiculati, particularly *Concavissimisporites variverrucatus* and *Trilobosporites* spp within the Auriculati. *Gleicheniidites* spp., and *Classopollis* spp. are marginally more important than in groups I and II, but the Muronati, Cingulati and Hilates are distinctly very rare or absent. Schizosporis spp.are important.

The kerogen assemblage of this sample is dominated by fusinite, with palynomorphs and algal cysts forming a secondary element. The lithology comprises a non-laminated mudstone. Fluorescent algae are completely absent.

The palaeoenvironment suggested by this palynofacies is strongly terrestrial. The absence of fluorescent algae and Celyphus rallus suggests that the palaeoenvironment was non-aquatic. The prominence of fusinite with no fine or amorphous material supports this conclusion. The specialised spore/pollen assemblage that is barren of many cosmopolitan taxa suggests that this assemblage generally represents a local, in situ plant community of the drier, uplifted part of the alluvial plain, proximal to the hinterland.

CLUSTER GROUP IV

This group is comprised of three samples. It is characterised by prominent Cicatricosisporites minor and generally low records of bisaccates. The Muronati are generally prominent, though the Apiculati, Auriculati, Cingulati and Hilates are generally rare. Classopollis spp and Celyphus rallus are of moderate abundance.

The kerogen assemblage is dominated by fusinite, with comparatively prominent algal cysts and minor palynomorphs. The lithologies all comprise laminated mudstones, siltstones and fine sandstones. Fluorescent algae of Pediastrum, Scenedesmus,Botryococcus and Colonial Spiny Masses are present in moderate abundance.

The palaeoenvironment suggested by this cluster group is dominantly freshwater. An aquatic influence is suggested by the presence of freshwater algae and C. rallus.

CLUSTER GROUP V

This cluster group, comprising one sample CR.2, is characterised by prominent Leptolepidites spp, Stereisporites antiquasporites and Acanthotriletes varispinosus together with consistent Cingulati. The Muronati, Disacciti, Classopollis spp. and Celyphus rallus are conspicuously low in abundance or absent.

The kerogen assemblage of this sample is dominated by fusinite together with palynomorphs. The lithology comprises a non-laminated iron-stained mudstone. Fluorescent algae are absent.

The palaeoenvironment suggested by this sample is strongly terrestial non-aquatic, due to the absence of fluorescent algae and C. rallus and the dominance of fusinite with no fine or amorphous kerogen. The spore/pollen assemblage is comparatively specialised with an absence of many cosmopolitan taxa, indicating that this assemblage generally represents an in situ plant community in proximity to the hinterland.

CLUSTER GROUP VI

This cluster group comprises 32 samples. It is distinct in showing very prominent Cicatricosisporites spp. The Laevigati, Apiculati, Muronati, Auriculati, Tricrassiti and Cingulati are generally well represented. However bisaccate pollen, Classopollis spp. and Celyphus rallus are rather below average. A number of subclusters within this group are evident. Subcluster VI-1, comprising four samples, contains a generally rich assemblage of Laevigati, Apiculati and Muronati, with rare or absent Auriculati, Hilates and C. rallus. Subcluster VI-2, comprising one sample (W.12) contains prominent Concavissimisporites spp. and Acanthotriletes varispinosus. The Muronati are generally prominent though the Auriculati, Cingulati and Hilates are rare. Subcluster VI-3 comprises two samples only, and is distinguished from the rest of the cluster group by an association of rare bisaccates, moderate Classopollis spp. and moderate Celyphus rallus. Subcluster VI-4 comprising two samples, contains cosmopolitan Laevigati, Apiculati, Muronati and Auriculati though the Cingulati and Hilates are generally rare. Bisaccates are slightly more prominent with reduced Classopollis spp., and Sphaeripollenites psilatus is important. Subcluster VI-5 comprises 23 samples showing a good variety of taxa throughout. Bisaccates are generally reduced as well as Classopollis spp. but Celyphus rallus and Gleicheniidites spp. are slightly more prominent.

The kerogen assemblage of this cluster group is uniformly dominated by fusinite together with algal cysts and palynomorphs. Amorphous liptinite comprises a minor element. The lithologies are dominated by mudstones, generally laminated. A few siltstones are present but limestones are very rare. Fluorescent algae are generally few and far between in this cluster group. However Baltisphaeridium spp. are comparatively prominent. A few records of dinocysts are to be seen.

The palaeoenvironment represented by this cluster group is dominantly terrestrial in my opinion. The occurrence of prominent fusinite with few fluorescent algae and rare Celyphus rallus indicates that aquatic conditions are of minor importance, and that the palynofacies was comparatively proximal to the hinterland where conditions were drier and less susceptible to marine incursion. Standing water may have existed as small ponds where Baltisphaeridium spp. thrived.

CLUSTER GROUP VII

This cluster group is distinguished from all the others by the prominent occurrence of the anomolous palynomorph Celyphus rallus. The general variety of taxa is high throughout this cluster group apart from the general low percentage frequencies of spore/pollen taxa. Despite these diminished values caused by the prominence of C. rallus, Cicatricosisporites spp. are of particularly low percentage. Subclusters within this cluster group can be seen, but these are below the coefficient 4.0 level. Part of subcluster VII-c comprises the group of barren samples already described under the binary data as cluster group C. These samples cluster with this group as their diminished percentage frequencies most closely resemble barren samples. Subcluster VII-a contains the greatest variety of spore/pollen taxa across the board as well as most prominent C. rallus itself. (It is interesting to note that one sample included here, CH/M.16, contains no C. rallus). Subcluster VII-b shows generally reduced variety of taxa, though Cicatricosisporites spp. are more prominent and C. rallus is markedly lower. Subcluster VII-c shows generally much lower taxonomic variety but consistently high C. rallus.

The kerogen assemblage of this cluster group is distinct in showing prominent fine amorphous organic matter together with palynomorphs, and generally very low percentages of fusinite. Palynomorphs are particularly prominent in subcluster VII-a. The lithologies are distinct in being dominated by non-laminated mudstones, together with a high proportion of limestones. The fluorescent algal assemblage is particularly prominent and well developed, particularly so in the case of Veryhachium acritarchs. Other algae that in some instances are very abundant, such as Laevigate Algal Cysts and Colonial Spiny Masses, are consistently present in moderate numbers. Algae are generally richer in abundance within subcluster VII-a.

The palaeoenvironment represented by this cluster group is essentially that of Celyphus rallus, an aquatic alga, (Batten and van Geel, 1985). The abundance of other algae, particularly Veryhachium spp., suggests that an aquatic influence is particularly marked, while the low record of fusinite indicates a depositional environment distal with respect to the hinterland. However, marine indicators are not prominent in this cluster group, except for rare amorphous liptinite (as seen in cluster group A) and fish debris in one sample (W.98). Evidence presented under discussion of cluster group B, indicated that the presence of fine amorphous organic material may indicate lacustrine conditions. A variety of taxa with no specific spore/pollen abundances (similar to cluster group B), is also seen here. The abundance of palynomorphs in the kerogen fraction mostly reflects the abundance of C. rallus in the assemblages. When very abundant, this taxon is so numerous that it dominates the whole kerogen assemblage as well as the spore/pollen assemblage.

CLUSTER GROUP VIII

This cluster group contains only two samples, W.48 and W.75. It shows many similarities with cluster group VII, in that taxonomic variety is good. There are no distinctly high percentage frequencies, except for the occurrence of *Cooksonites* sp. in both samples, normally an extremely rare taxon. *Cicatricosisporites* spp. is generally low and *Celyphus rallus* is moderately abundant.

The kerogen assemblage of these two samples are very different. Sample W.48 contains prominent fine amorphous organic matter. Sample W.75 contains prominent fusinite. Both samples consist of mudstones, laminated in the latter sample. Fluorescent algae are of moderate occurrence in both samples.

Specific palaeoenvironmental conclusions cannot be drawn on this cluster group.

CLUSTER GROUP IX

This cluster group, comprising one sample, CH/M.11, is based on the high percentage frequency of *Cicatricosisporites pseudotripartites*. A comparatively specialised assemblage is to be found in occurrence with this abundant spore. These include *Concavisporites jurienensis*, *Pilosisporites verus*, *Leptolepidites* spp., *Reticulisporites* spp., *Klukisporites* spp., *Cicatricosisporites annulatus*, *Appendicisporites potomacencis* *Costatoperforsporites* spp. and *Vitreisporites pallidus*. (*Cicatricosisporites* spp. are generally not abundant, though on the diagram this appears to be so as this includes the totals for all species of *Cicatricosisporites*). *Gleicheniidites* spp. are generally low in occurrence, while bisaccates and Classopollis spp. are of moderate occurrence. Celyphus rallus is absent.

The kerogen assemblage of this sample is dominated by palynomorphs with fusinite as a minor element only. Amorphous liptinite is of comparatively moderate occurrence. The lithology of this sample comprises a non-laminated limey mudstone with iron staining. Very low records of a few fluorescent algae are to be seen, including Baltisphaeridium and Botryococcus.

The palaeoenvironment represented by this sample shows some marine influence in my opinion. This is indicated by the low percentage of fusinite indicating that the depositional environment is distal with respect to the hinterland, and the occurrence of amorphous liptinite, which by association with cluster group A, is thought to be marine derived.

CLUSTER GROUP X

This cluster group comprises seven samples. It is characterised by comparatively prominent Regresporites sp. A and Lycopodiacidites spp. that are normally very rare taxa. The Laevigati, Apiculati and Muronati are generally well represented, though the Auriculati, Cingulati and Hilates are generally poorly represented. Cicatricosisporites spp. and Celyphus rallus are generally diminished in importance, while Classopollis spp. and Gleicheniidites spp. are of slightly greater importance. Rather greater taxonomic variety is seen in subcluster X-2 than X-1.

The kerogen fractions are dominated by amorphous liptinite with low percentages of fine amorphous organic matter. Palynomorphs are of moderate importance, but fusinite shows very low values. The lithologies within this group are mainly mudstones with a comparatively high proportion of limestones. The fluorescent algal assemblage within this group shows consistent high numbers of Segmented Alga type 1, together with Colonial Spiny Masses and Laevigate Algal Cysts. Acritarchs of *Veryhachium* and *Baltisphaeridium* are present in very low numbers. *Scenedesmus* is important in one sample.

The palaeoenvironment in my opinion shows strong marine influence. Prominent amorphous liptinite and Segmented Alga type 1 were shown in cluster group A to be marine indicators. A depositional site distal with respect to the hinterland is indicated by the low percentages of fusinite. One sample (W.101) contains fish debris supporting a marine influence to this palynofacies.

CLUSTER GROUP XI

This cluster group is another that only comprises one sample, namely W.66. It is separated from the rest of the sample batch by very low records of Laevigati, but prominent *Pilosisporites* cf. *notensis*, *Appendicisporites problematicus* and *Cedripites* type. Other taxa represented are *Concavissimisporites variverrucatus*, *Leptolepidites* spp., *Acanthotriletes varispinosus*, *Cicatricosisporites hughesi*, *Appendicisporites jansonii* *Trilobosporites* spp., *Ischyosporites* sp., *Foraminisporis* sp., *Densoisporites* spp. and *Couperisporites* sp.. The Muronati and Cingulati are generally very poorly represented while *Gleicheniidites* spp. and *Celyphus rallus* are greatly reduced in percentage frequency. *Classopollis* sp. shows a generally reduced percentage.

The kerogen fraction of this sample comprises approximately equal amounts of fusinite, palynomorphs and algal cysts. The lithology is a siltstone with visible plant remains. The fluorescent algal assemblage is poor, including rare *Veryhachium* and Segmented Alga type 1.

This sample is thought to be a specialised assemblage representative of an *in situ* plant community as many cosmopolitan taxa are rare or absent. The palaeoenvironment is not clearly perceivable. However a possible marine influence may be indicated by the presence of Segmented Alga type 1.

CLUSTER GROUP XII

This cluster group is comprised of exactly half of the total set of samples. The group is separated from the other 50% of samples by a particular ratio of percentage frequencies of cosmopolitan taxa. There are no species that are numerically distinct to this group. The Apiculati are moderately well represented by *Leptolepidites* spp., *Verrucosisporites* spp. and *Acanthotriletes varispinosus* but large triletes within this group together with those comprising the Auriculati are distinctly very rare or absent. The Cingulati and Hilates are also of diminished importance. *Gleicheniidites* spp. and bisaccates are of general above average importance while *Cicatricosisporites* spp., *Classopollis* spp. and *Celyphus rallus* are of approximately average percentage frequency through this cluster group. Subclusters within this group can be distinguished. Subcluster XII-1 comprising 13 samples, contains a greater prominence of the following taxa than is seen in the rest of this cluster group:- *Leptolepidites* spp., *Verrucosisporites* spp., *Lycopodiumsporites austroclavitides*, *Foveotriletes* sp., *Coronatispora valdensis*, *Sestrosporites pseudoalveolatus*, *Cooksonites* sp., and *Cerebropollenites mesozoicus*. Subcluster XII-2 comprising 33 samples contains distinctly more prominent bisaccates while *Classopollis* spp.and *Celyphus rallus* are slightly reduced in importance. Subcluster XII-3 shows generally higher overall percentages of *Cyathidites* spp., *Cicatricosisporites* sp.and *Classopollis* spp.while bisaccates are of slightly lower percentage overall. Two distinct palynofacies within subcluster XII-3 can be distinguished. Subcluster XII-3-a contains prominent *Dictyophyllidites* spp.and *Calamospora* type. A particular subcluster comprising eight samples within subcluster XII-2-i that shows much reduced *Classopollis* spp., but a markedly greater representation of bisaccates can be recognised. Subcluster XII-3-c-ii contains prominent *Leptolepidites* spp., *Cicatricosisporites hughesi*, together with distinctly diminished *Gleicheniidites* spp. and *Classopollis* spp..

The kerogen fraction of this group, as would be expected with such a big batch of samples, shows great variation with no overall characteristic. However distinct subclusters that broadly correspond with the spore/pollen subclusters can be recognised. Subcluster XII-1 contains generally prominent palynomorphs with reduced fusinite. Subcluster XII-2 contains prominent fine amorphous grey organic matter, together with distinct amorphous liptinite and moderate fusinite and palynomorphs. Subcluster XII-3 contains a distinct association of algal cysts and amorphous liptinite,with distinctly higher percentages of fusinite. Subclusters XII-3-a and b contain no amorphous liptinite,while subcluster XII-3-d contains very prominent amorphous liptinite. The lithologies of this cluster group show a full spectrum of possibilities, as would be expected with so many samples. Subcluster XII-1 contains almost all non-laminated mudstones. Subcluster XII-2 contains a high proportion of laminated mudstones, particularly so within XII-2-ii. Subcluster XII-3 contains a high proportion of laminated mudstones,together with a high concentration of limestones in XII-3-c-ii. The fluorescent algal assemblages are moderately abundant throughout this cluster group. Laevigate Algal Cysts are particularly distinct throughout the whole group. Subcluster XII-1 contains distinct Colonial Spiny Masses and Scenedesmus, with only few Veryhachium and Baltisphaeridium acritarchs. Laevigate Algal Cysts are particularly prominent in subcluster XII-2. Acritarchs of Veryhachium (though not Baltisphaeridium), are particularly abundant within this subcluster. Subcluster XII-3 contains no distinct occurrences of fluorescent algae. While the proportion of these is comparatively low overall, individual isolated samples such as CH/P.64, P1.5 and LF.18, show very high percentages of different fluorescent algae.

The palaeoenvironment represented by this cluster group taken overall is very generalised. A distinctly aquatic aspect is evident throughout, indicated by the prominence of amorphous liptinite and/or fine amorphous grey organic matter, together with comparatively prominent fluorescent algae. That such a large number of samples are placed together in this one cluster group based on the common occurrence of approximately 'average' occurrences of cosmopolitan taxa indicates how common the parent plants of these taxa must have been in the Wealden Basin. The multivariate data does not allow more rarely occurring taxa (that may be more palaeoenvironmentally significant) to affect the cluster group allocations, in the way such taxa can affect the binary cluster groups.

CLUSTER GROUP XIII

This cluster group is comprised of 21 samples. Its principal characteristic is the high percentage frequency of Gleicheniidites spp. throughout. Taxonomic variation is generally good across the board particularly within the Apiculati and Muronati. Cicatricosisporites spp., bisaccates, Classopollis spp. and Celyphus rallus are all of roughly 'average' frequency. Sestrosporites pseudoalveolatus, Sphaeripollenites psilatus and Schizosporis spp. are comparatively important taxa. Several small subclusters within this cluster group are recognised. Subcluster XIII-1 comprising three samples, contains comparatively prominent foraminiferal linings, Foraminisporis spp. and Kuylisporites lunaris. Celyphus rallus is distinctly low in abundance. Subcluster XIII-2 comprises four samples showing particularly prominent Sphaeripollenites psilatus. Subcluster XIII-3 contains only one sample, Pl.4. This sample shows one of the most varied assemblages in the whole data set. Apiculati, Muronati, Auriculati and Tricrassiti are well represented together with Dictyophyllidites and Schizosporis spp.. Celyphus rallus is absent. Subcluster

XIII-4 (five samples) is distinguished from the rest of the group and the whole data set by the prominence of Reticulatisporites castellanus. The Muronati are generally very well represented. Subcluster XIII-5, with eight samples, contains particularly prominent Gleicheniidites spp.. The Muronati are generally well represented and taxonomic variety throughout is generally good. Celyphus rallus is generally reduced in importance.

The kerogen fraction of this cluster group is dominated by palynomorphs and fusinite. Subclusters XIII-1 and 2 are dominated by fusinite with palynomorphs and algal cysts as secondary elements. Subcluster XIII-3 (Pl.4) is dominated by palynomorphs with moderate fusinite. Subcluster XIII-4 contains significant fine amorphous grey material with very low proportions of fusinite, but high proportions of palynomorphs. Subcluster XIII-5 is dominated by fusinite with secondary palynomorphs and minor amorphous liptinite and fine amorphous grey material.Lithologies are mainly comprised of non-laminated mudstone, though lamination is more developed in subcluster XIII-5. Limestones are distinct in subcluster XIII-4. Sample Pl.4 (subcluster XIII-3) is a sandstone. The fluorescent algal assemblages are generally low within this cluster group, except for subcluster XIII-4 which contains a greater representation, particularly of Veryhachium spp..

The palaeoenvironment represented by this cluster group is non-specific, being based only on the prominence of Gleicheniidites spp.. Aquatic influences are most pronounced in subcluster XIII-4 where fluorescent algae are most prominent, together with fine amorphous grey O.M., and reduced fusinite, suggesting distance from the hinterland. The varied assemblage of sample P1.4 may be generally in situ and related to its sandstone lithology as a possible crevasse splay assemblage. Marine influence is evident in subcluster XIII-1 from the prominence of foraminiferal linings.

2.5 (c) Discussion

The previous section has indicated that the 13 multivariate cluster groups defined on percentage frequencies of spore/pollen taxa can also be independently characterised by lithology, kerogen type and fluorescent algae. The fidelity (sensu. Frederiksen, 1985) is less than that seen with the binary cluster groups.

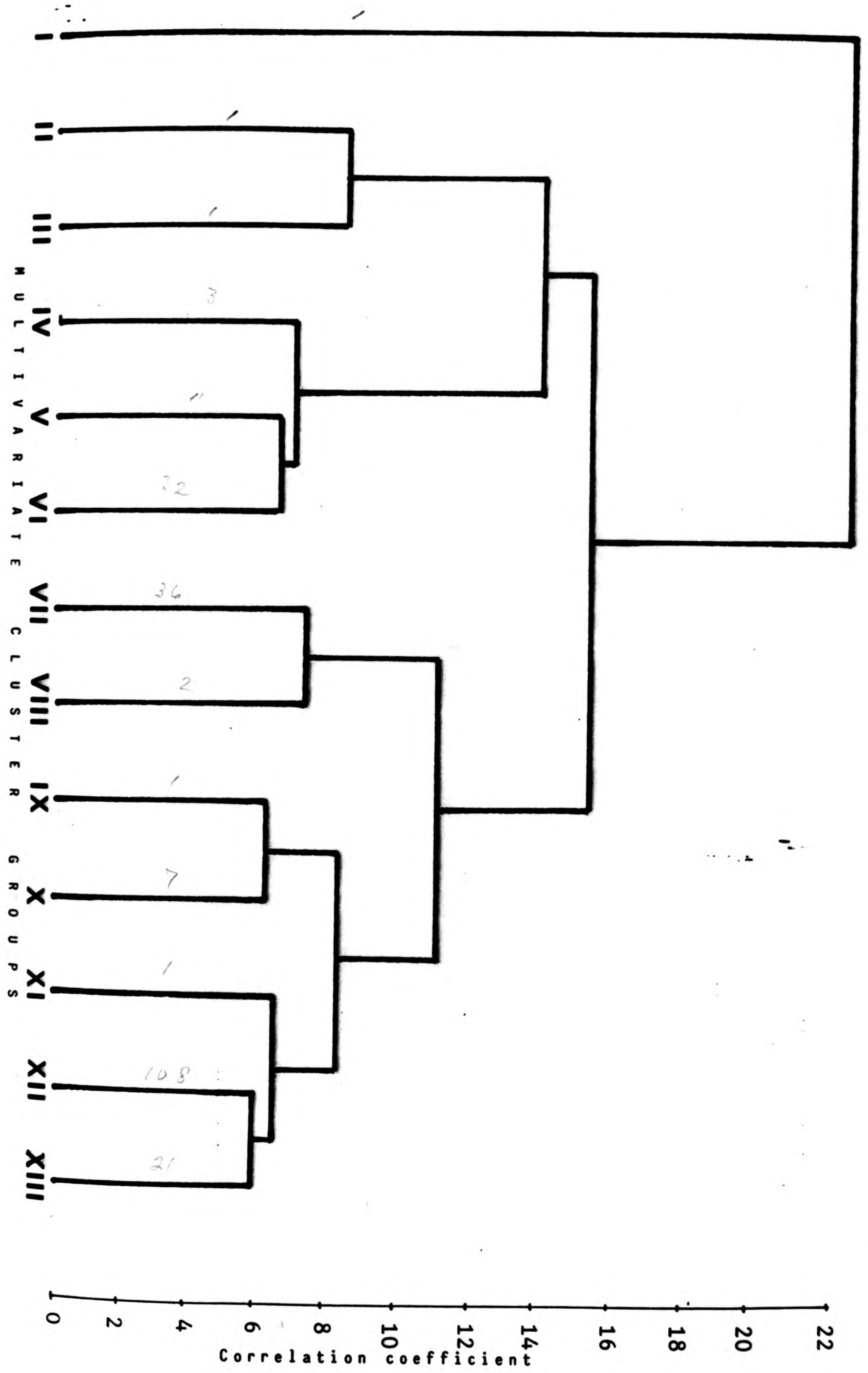
2.5 (d) Associations and palaeoenvironmental trends between multivariate cluster groups.

Text figure 2.10 i has been constructed to show the hierarchy of association of multivariate cluster groups above coefficient 6.0.

Groups XII & XIII are most closely related, followed by groups IX & X and groups V & VI. Above this, group XI is joined to XII/XIII, then group IV to V/VI. Above this, groups VII & VIII become linked, followed by IX/X to XI/XII/XIII. Above this, groups I & II are joined,followed by all of groups VII - XIII. Above this still, all of groups II - XIII. Finally at coefficient 22.3 the most dissimilar group, group I is linked to all the others, unifying the whole data set.

An attempt to find associations between the multivariate cluster groups based on kerogen type, fluorescent algae and lithology can be made. This is similar to the method used for the binary clusters, and is shown on text-fig. 2.10 ii. Kerogen types do conform with the basic separation of groups II - VI and groups VII - XIII. The former contain most prominent fusinite, while the latter contain most prominent amorphous liptinite. This same separation can be seen based on lithology. Groups II - VI contain only rare limestone, but limestones are quite common in groups VII - XIII. This latter 'super-group' shows most prominent fluorescent algae, particularly <u>Veryhachium</u> spp. in group VII and Segmented Algae type 1 in group X. Fluorescent algae are noticeably rare or absent in groups II - VI (and group I). Individually <u>Baltisphaeridium</u> is common in group VI, amorphous O.M. in groups VII & XII, palyno-

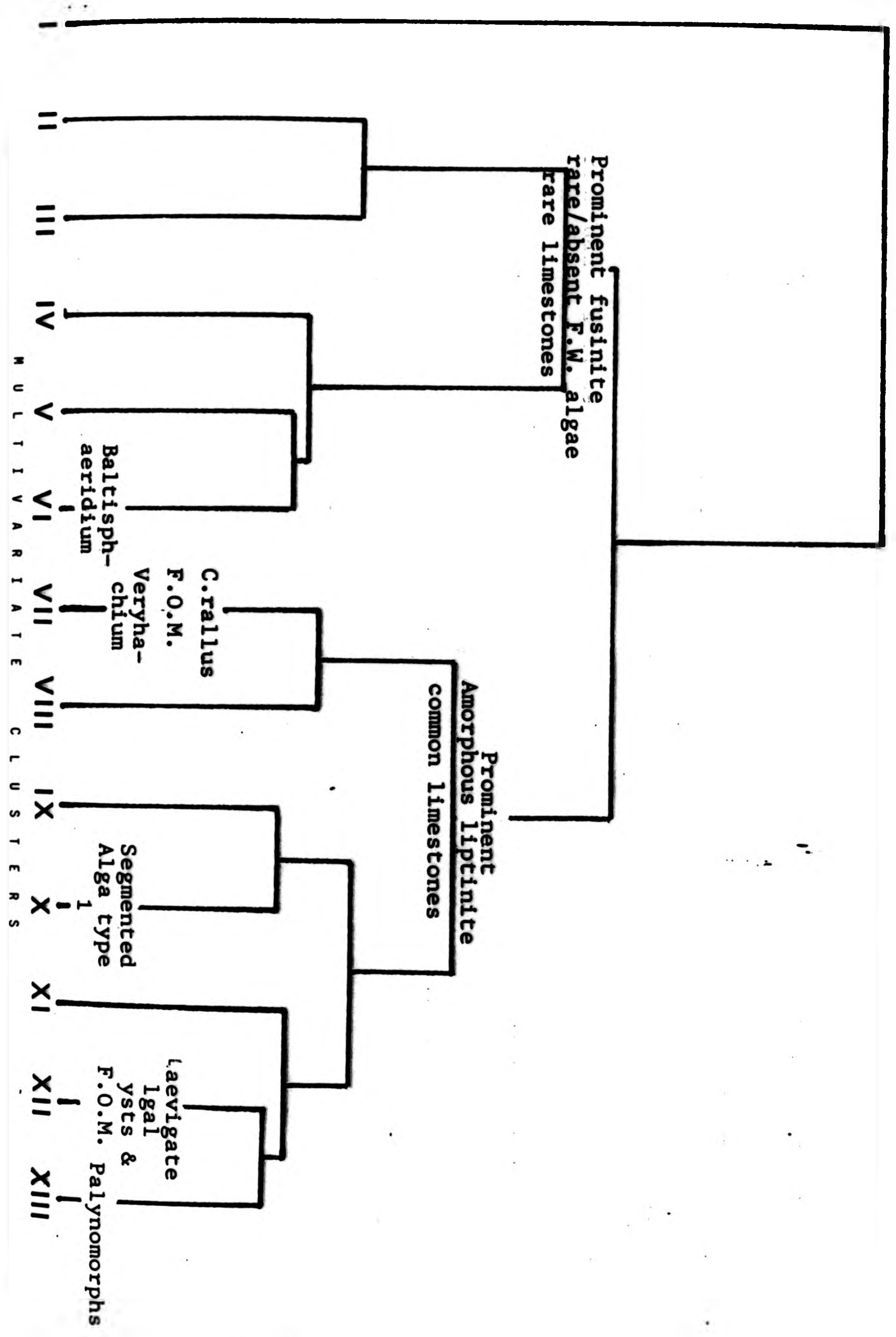
Multivariate (percentage frequency) dendrogram showing the hierarchy of association of the thirteen cluster groups



γ
TE

Text-fig. 2.10 i

The association of lithology, fluorescent algae and kerogen type with the multivariate spore/pollen cluster groups.

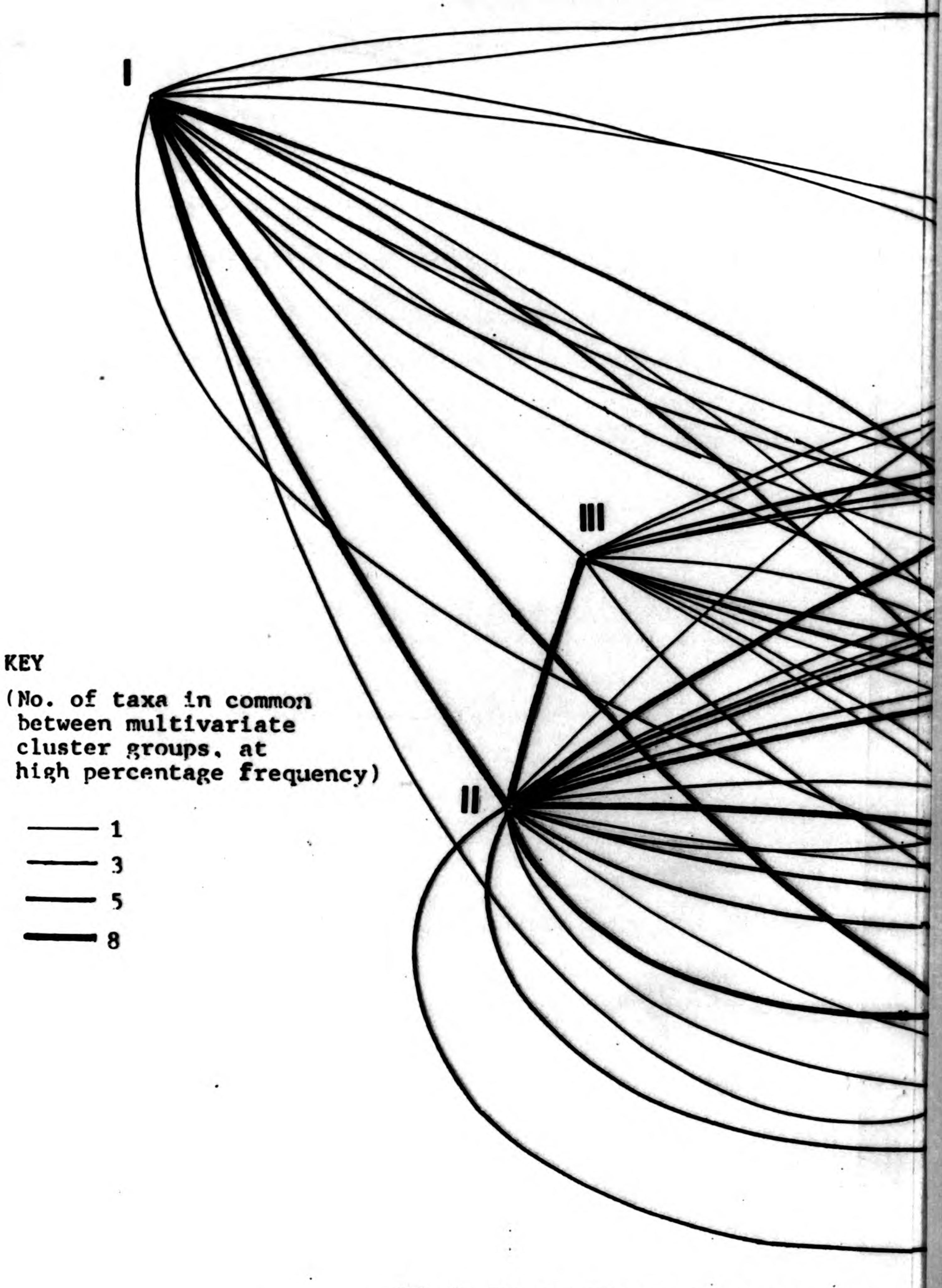


Text-fig. 2.10 ii

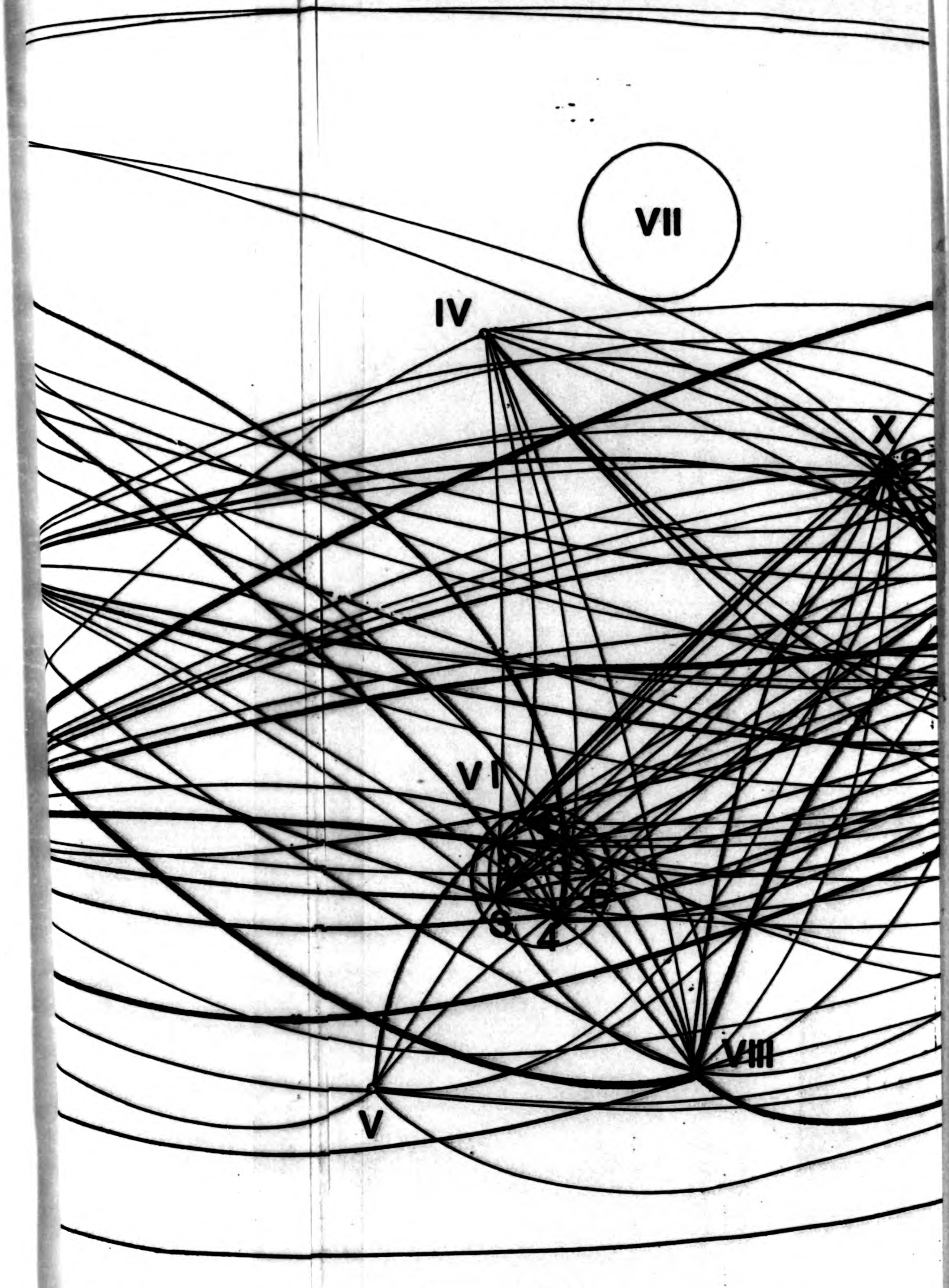
morphs in group XIII and Laevigate Algal Cysts in group XII.

The basic conclusion from this is that the parameters of kerogen type, fluorescent algae and lithology do broadly follow the pattern of multivariate clusters based on spore/pollen taxa. This indicates that the multivariate cluster groups are not random, and do reflect genuine palaeoecological groupings of spore/pollen taxa. However the groupings are much simpler than those seen by the binary data, showing that this data is much less sensitive for palaeoenvironmental determination. This conclusion was reached earlier on when it became evident that the multivariate groups tend to place large numbers of samples together in one or two large cluster groups, while most of the other groups are comprised of very few or even one sample. The evidence from the kerogen type, fluorescent algae and lithology is that groups I - VI represent drier uplifted palynofacies represented by more mature plant communities, while groups VII - XIII, the great bulk of samples, are the wetter, more ephemeral palynofacies of the Weald Clay braid-plain.

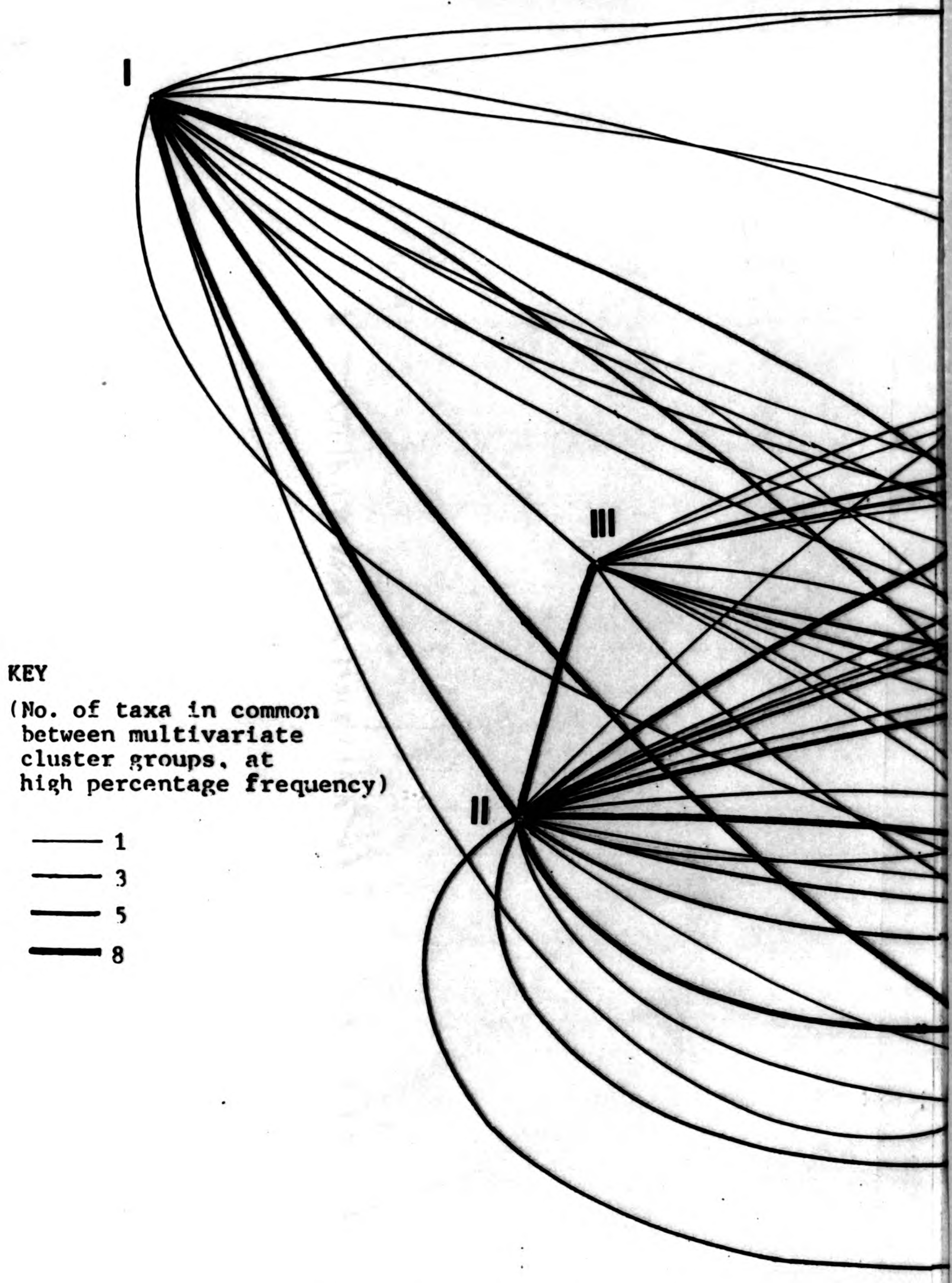
An attempt has been made to show a spatial association of multivariate cluster groups (text-fig. 2.11). Groups have been separated on the diagram using their coefficient of association to represent distance between groups. A circle for each group is drawn whose diameter is proportional to the number of samples in the cluster group. It is not possible to link the groups using characteristic taxa, as was done with the binary data (enclosure 5) as taxa are less distinctly characteristic of individual cluster groups here than with the binary data. Instead lines of different thickness representing the number of



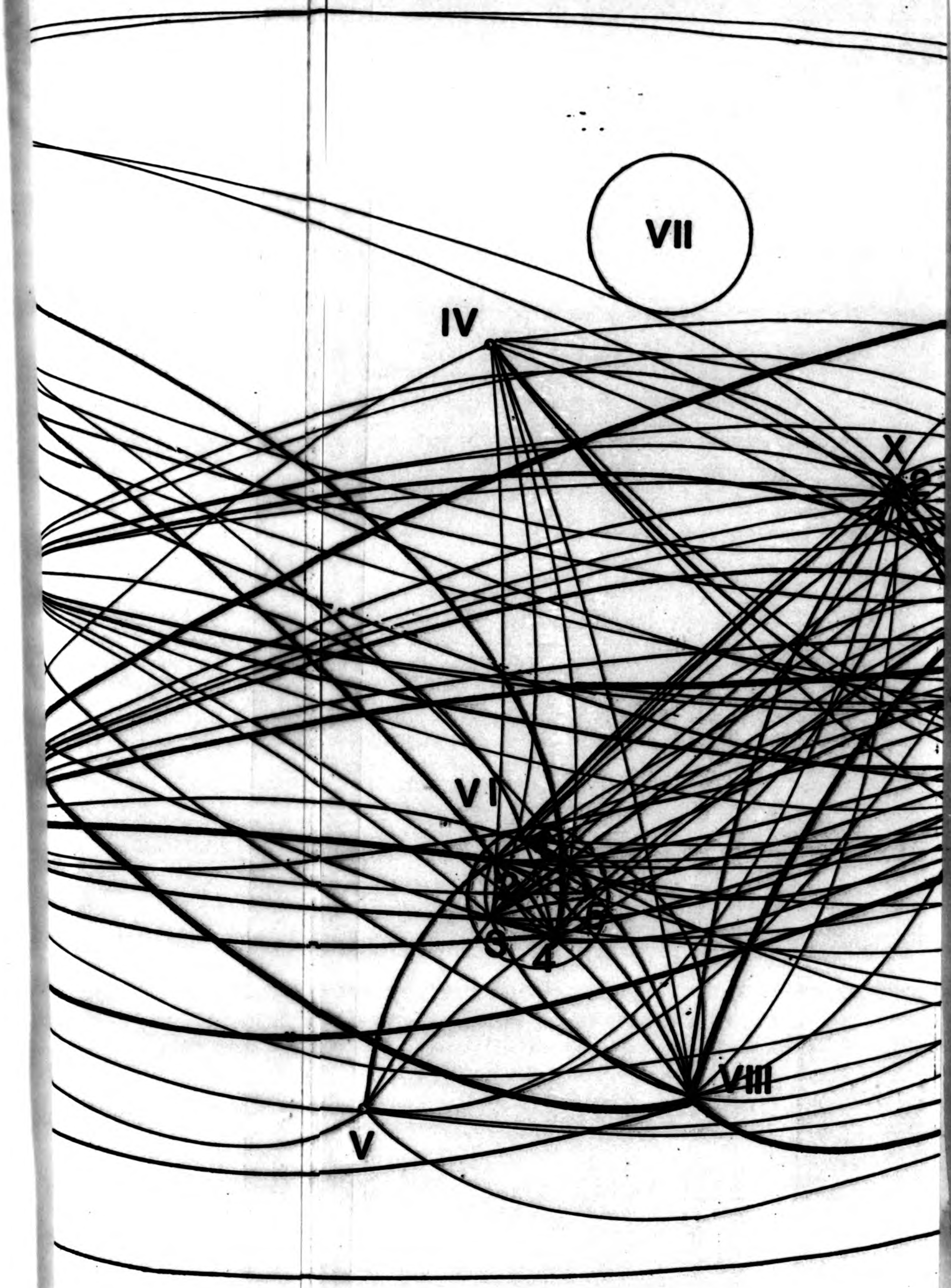
TAXONOMIC LI
MULTIVARIATE



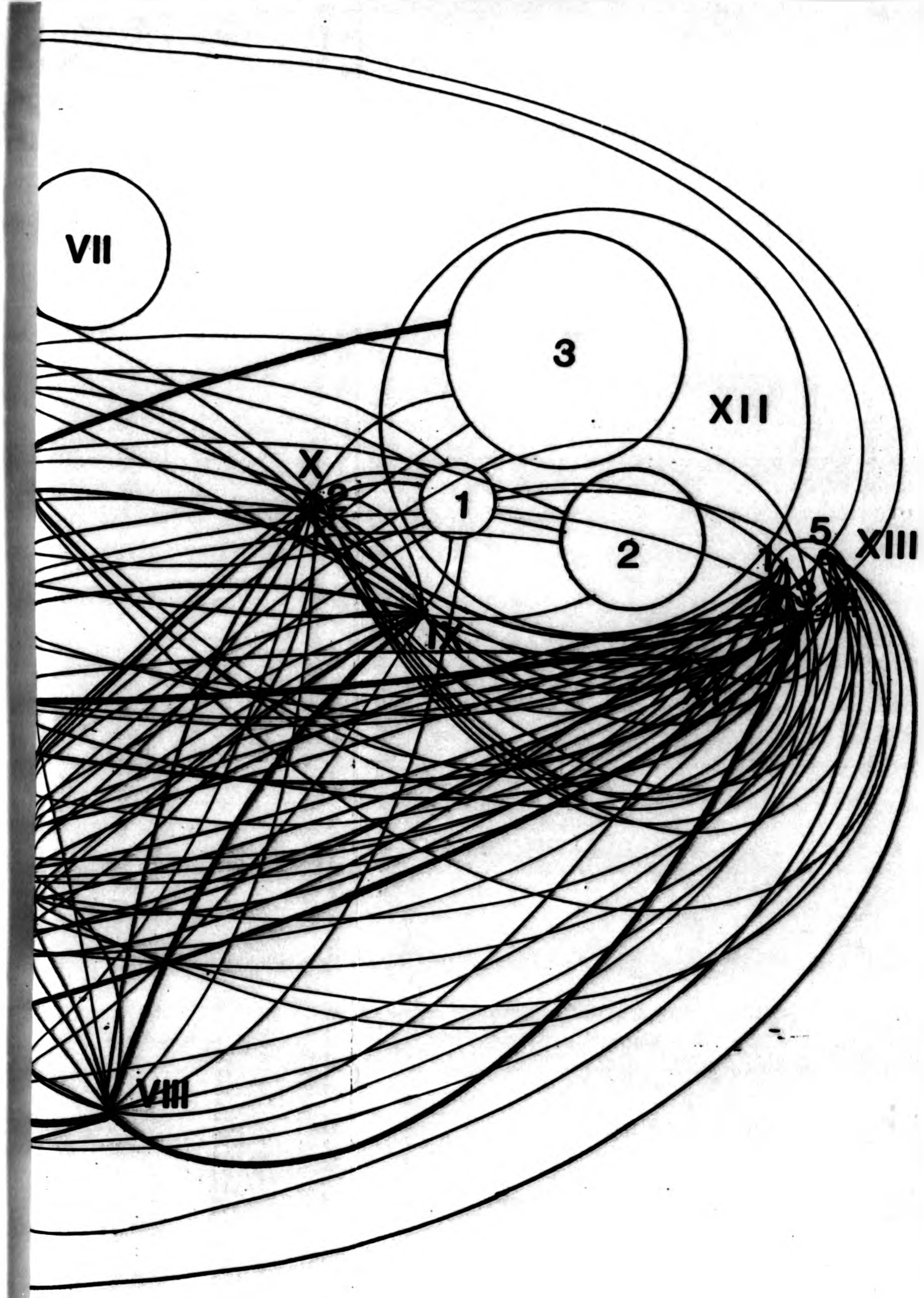
OMIC LINKS BETWEEN
ARIATE CLUSTER GROUP



TAXONOMIC LI
MULTIVARIATE



OMIC LINKS BETWEEN
ARIATE CLUSTER GROUP



WEEN
R GROUPS

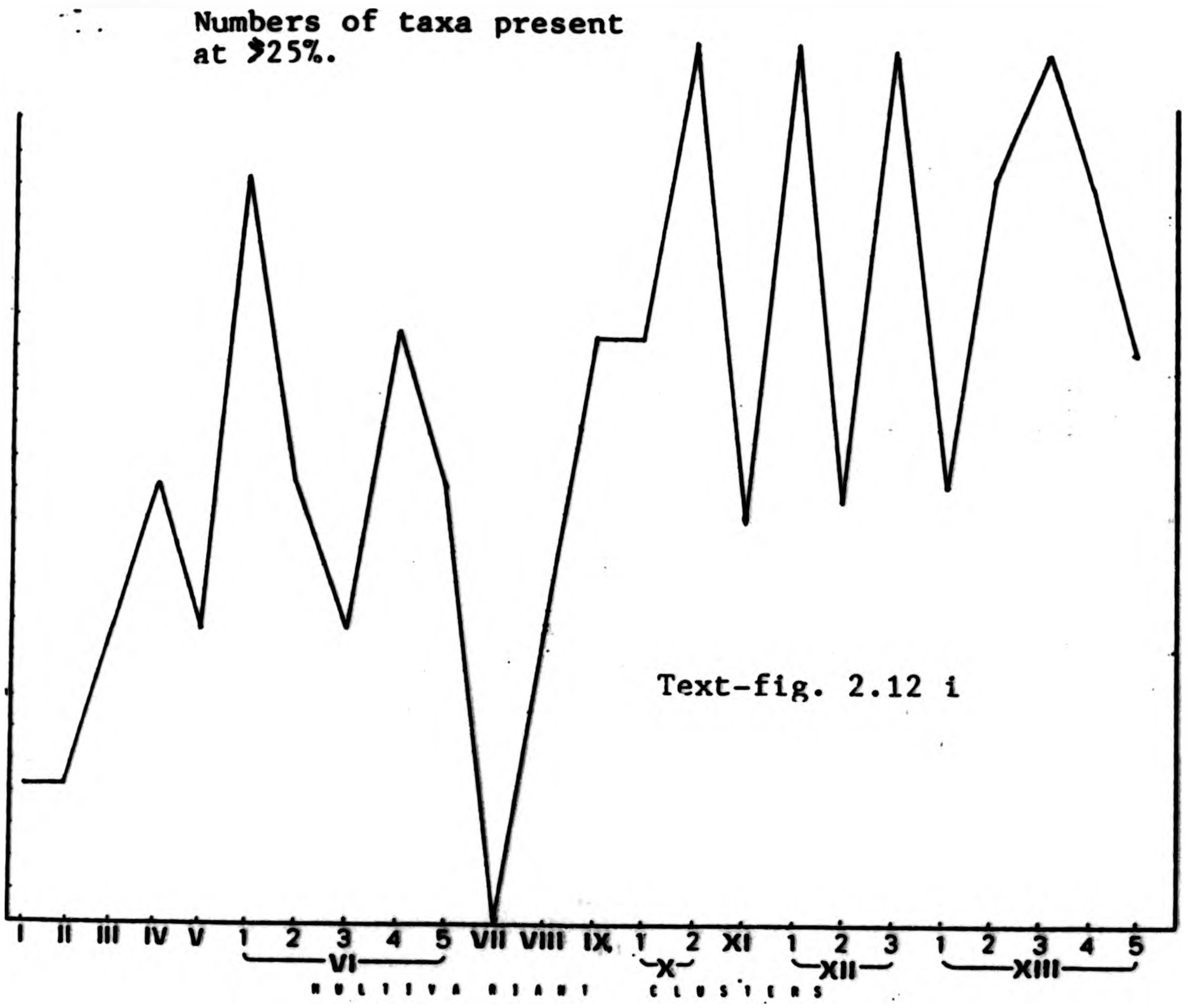
Text-fig. 2.11

taxa that show above average percentage frequency have been drawn linking the various groups. Taxa of mutual high percentage frequency between groups have been found by picking the three or four prominent peaks for each taxon on text-figs. 2.13 1 - 87 (see section 2.5 (e)). This diagram has limitations, for instance peaks are less common where a large number of samples in a group (eg. groups XII-1, XII-2 and XII-3), results in 'dilution' of high percentage frequencies individually in a given sample to lower values by averaging. However it does show that groups I - VI have generally much greater numbers and variety of taxa of above average percentage frequency than groups VII - XIII. This indicates the same broad separation of the former, as representing mature palynofacies with a large number of taxa, and the latter as more ephemeral pioneer species of the damper braidplain. An exception is group XIII, which shows great taxonomic variety, more similar to groups I - VI. In my opinion, this reflects significant transportation of palynomorphs of the drier uplifted areas into the damper braidplain by prominent channel influence in group XIII. Groups IX and X show higher numbers of taxa, probably by the effects of reworking. Groups III and IV show generally poorer variety than would be expected, as they represent particular mature palynofacies associations represented by large numbers of one or two taxa, rather than a great diversity. Cluster group VII shows no taxa of mutual above average occurrence with any other group, as this group is characterised by very abundant *Celyphus rallus*.

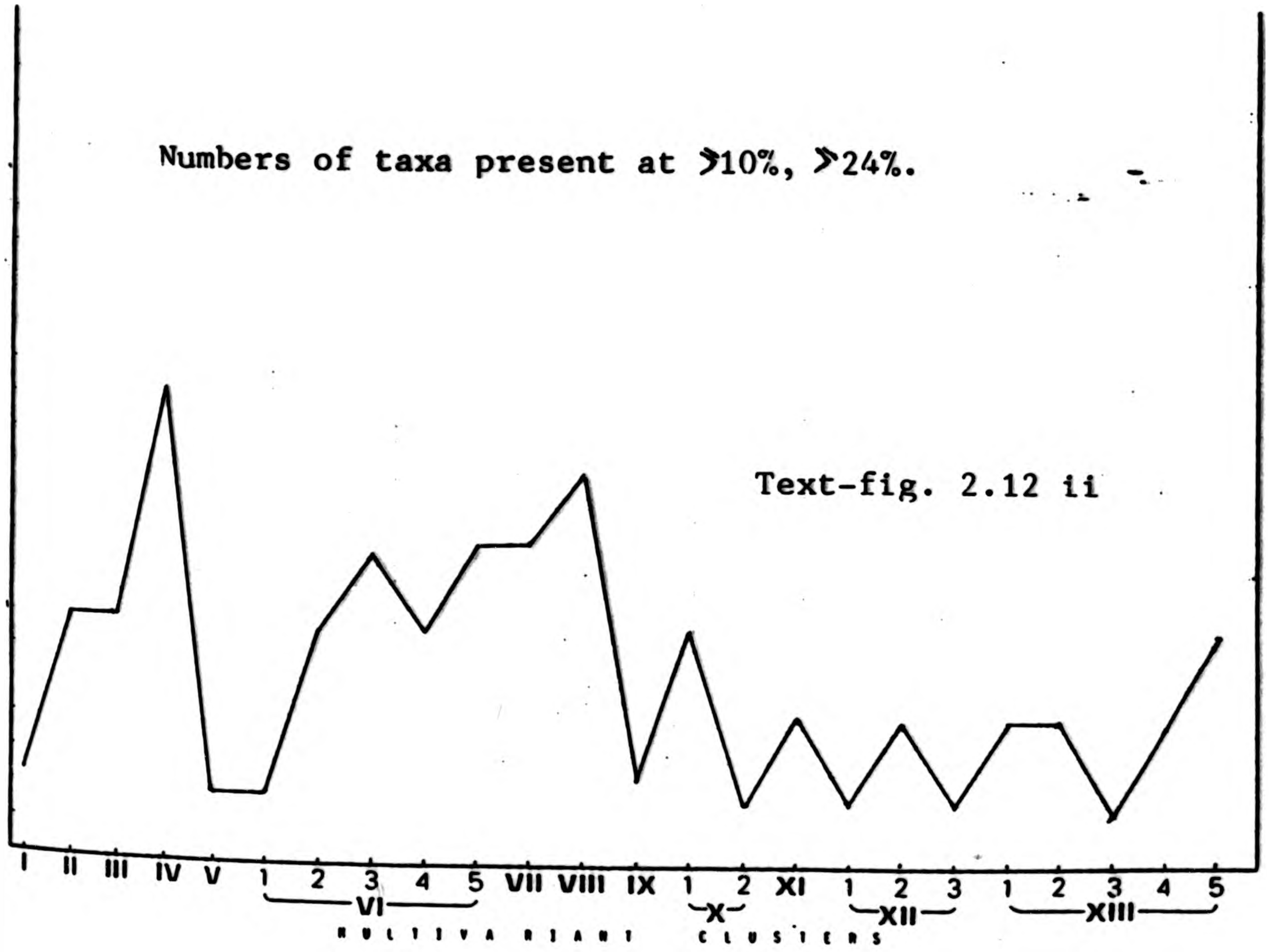
This data on text-fig. 2.11 is based on selected peaks of individual taxa that occur at a whole range of percentage frequencies. The 'maximum' is only relative for that particular species. Cluster groups can be compared based on comparatively low percentage frequencies of rare taxa, as well as on much higher percentage frequencies of more abundant taxa.

More direct data on the variety of taxa and taxonomic structure of the cluster groups can be found by comparing numbers of taxa present at various percentage frequency levels. This is similar to comparison of numbers of taxa present at particular occurrence categories as was attempted in section 2.4 (d) for the binary cluster groups. A series of graphs has been constructed (text-figs. 2.12 i-iv) for total number of taxa present at $>$ 25%; $>$10% $<$24%; $>$5% $<$ 9% and $>$2.5% $<$4%. Taxa cannot be compared below 1% occurrence as some cluster groups comprise only one sample and this would be below the smallest limit for these. Above 25%, comparisons cannot be made either as very few taxa occur above this percentage frequency level. Attempts at correcting for differences in sample number between cluster groups have not been successful as the differences are too great (unlike the binary groups). For instance introduction of a correction factor based on the square root, or even the cube root of the sample total per cluster group only produces a trend that shows peaks associated with high numbers of samples. It could be argued that this correction is unecessary anyway as samples only fall together in the same cluster group out of similarity in their constituent taxonomic percentage frequencies, which will not therefore be unduly influenced by averaging. However a certain amount of 'dilution' of occasional high percentage frequencies does occur within the large cluster groups by averaging, though once

Numbers of taxa present within the multivariate cluster groups at various percentage frequency categories.

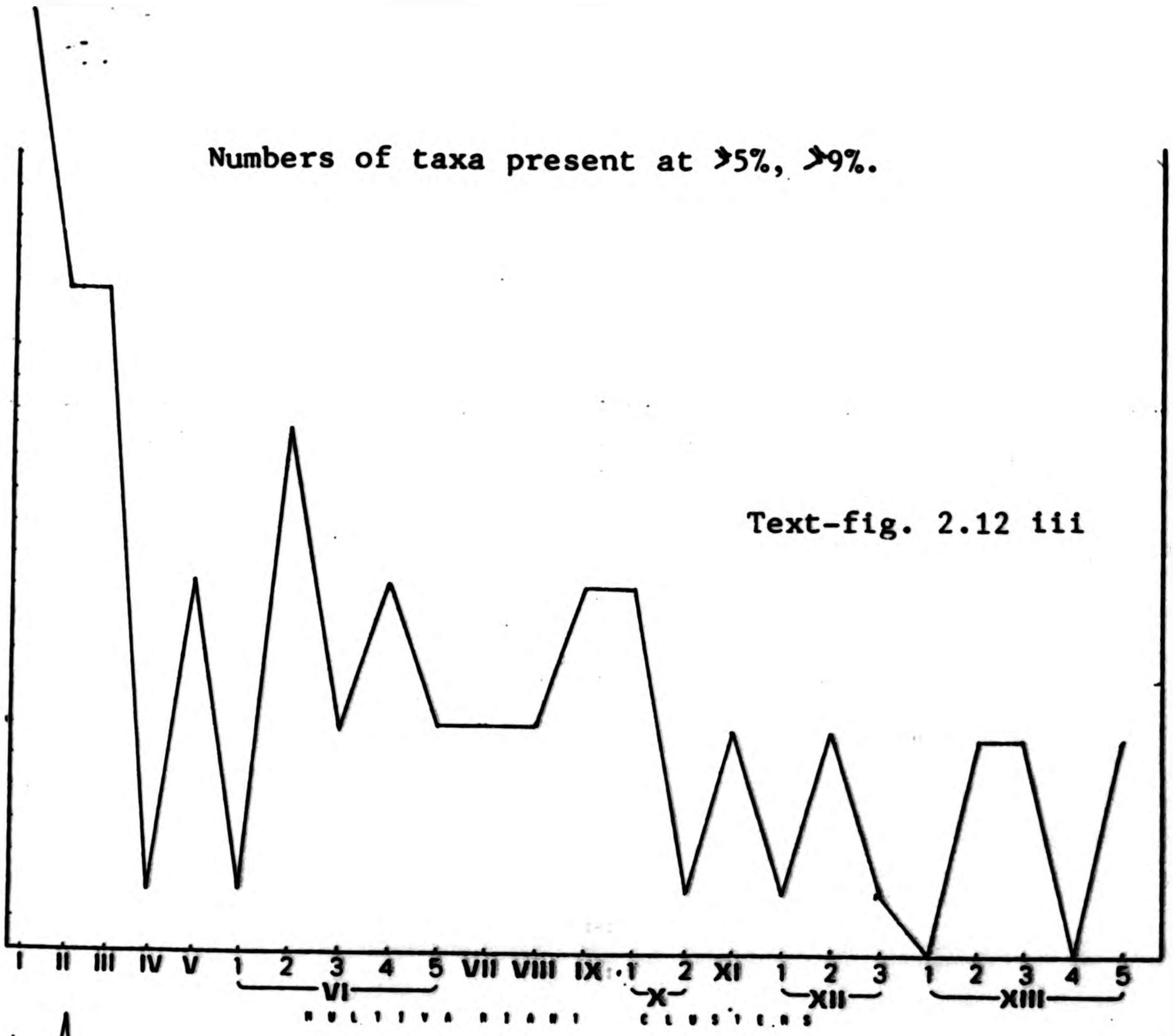

Numbers of taxa present at >25%.

Text-fig. 2.12 i

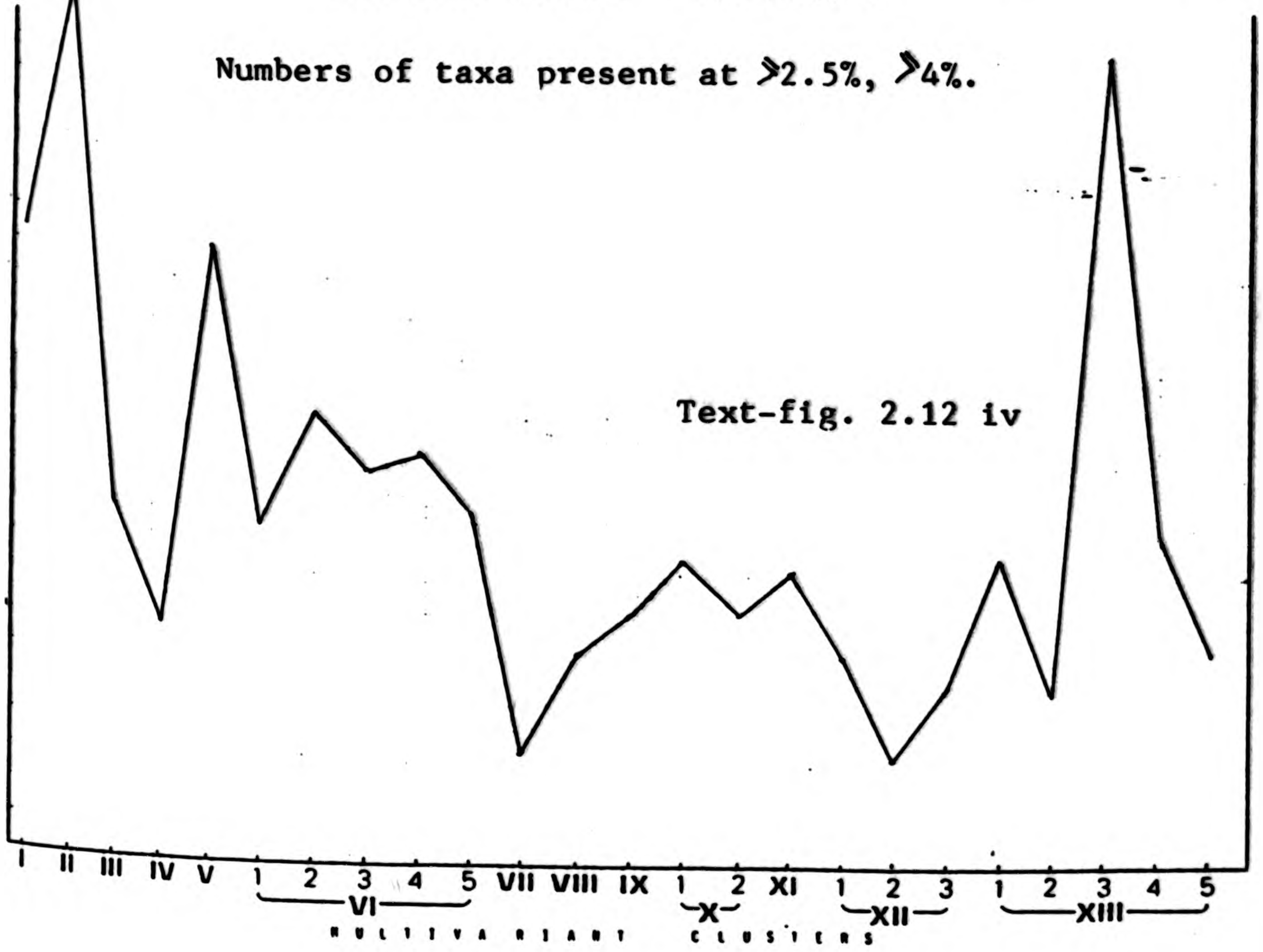

Numbers of taxa present at >10%, >24%.

Text-fig. 2.12 ii

Numbers of taxa present within the multivariate cluster groups at various percentage frequency categories.


Numbers of taxa present at ≥5%, ≥9%.

Text-fig. 2.12 iii


Numbers of taxa present at ≥2.5%, ≥4%.

Text-fig. 2.12 iv

again it must be stressed that such individual differences are presumably not sufficiently great for that sample to have clustered elsewhere or on its own.

Text-fig.2.12 i shows the numbers of spore/pollen taxa present above a frequency of 25%. A separation can be seen between groups I - VI and VII - XIII, the former showing generally lower values than the latter. (An exception is group VII that is an unusual group being based on the abundance of one taxon only.) This separation seems to indicate that taxonomic variety is less in groups VII - XIII allowing fewer taxa to occur at a greater percentage frequency. Text-figs. 2.13 ii-iv correspond to percentage frequency categories > 10% < 24%; > 5% < 9% and > 2.5% < 4% respectively. These lower percentage frequency categories all show the same trend of higher numbers of taxa within groups I - VI and lower numbers in groups VII - XIII. This is the opposite of text-fig. 2.12 i with number of taxa at > 25% frequency. This indicates that a greater number of taxa are present at the lower percentage frequency categories,as taxonomic variety is greater in these cluster groups. The greater variety means that few taxa can occur at high percentage frequency. Exceptions are seen with cluster group XIII-3 on text-fig. 2.12 iv (> 2.5% < 4%). As has been already mentioned this group may represent channel influence with considerable reworking from the more botanically prolific areas with considerable taxonomic enrichment. Generally greater numbers of taxa at low percentage frequencies within groups I - VI indicates the presence of richer, more varied plant communities where the Weald Clay braidplain is drier, less ephemeral and more uplifted.

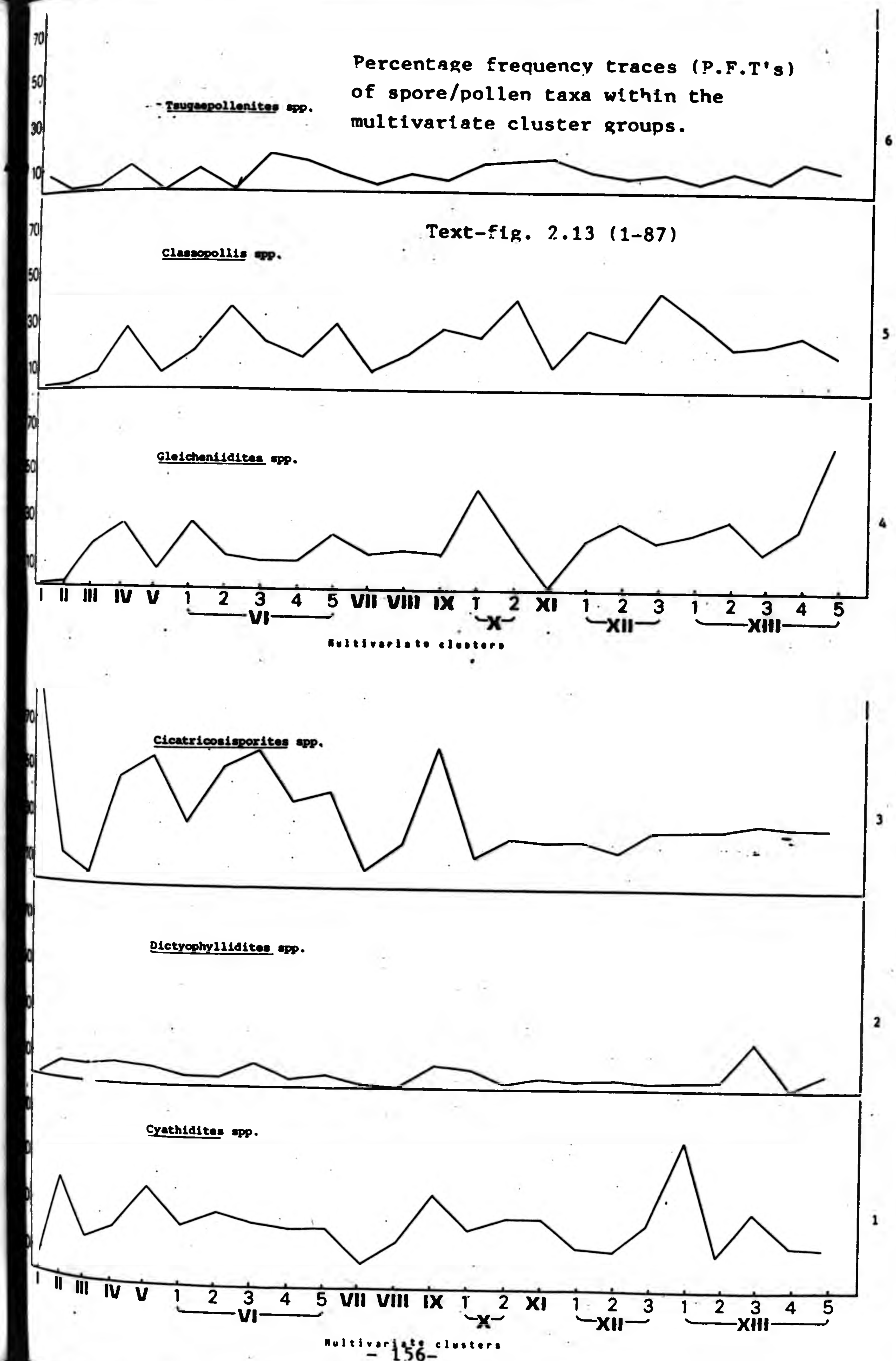
2.5 (e) Associations between spore/pollen taxa.

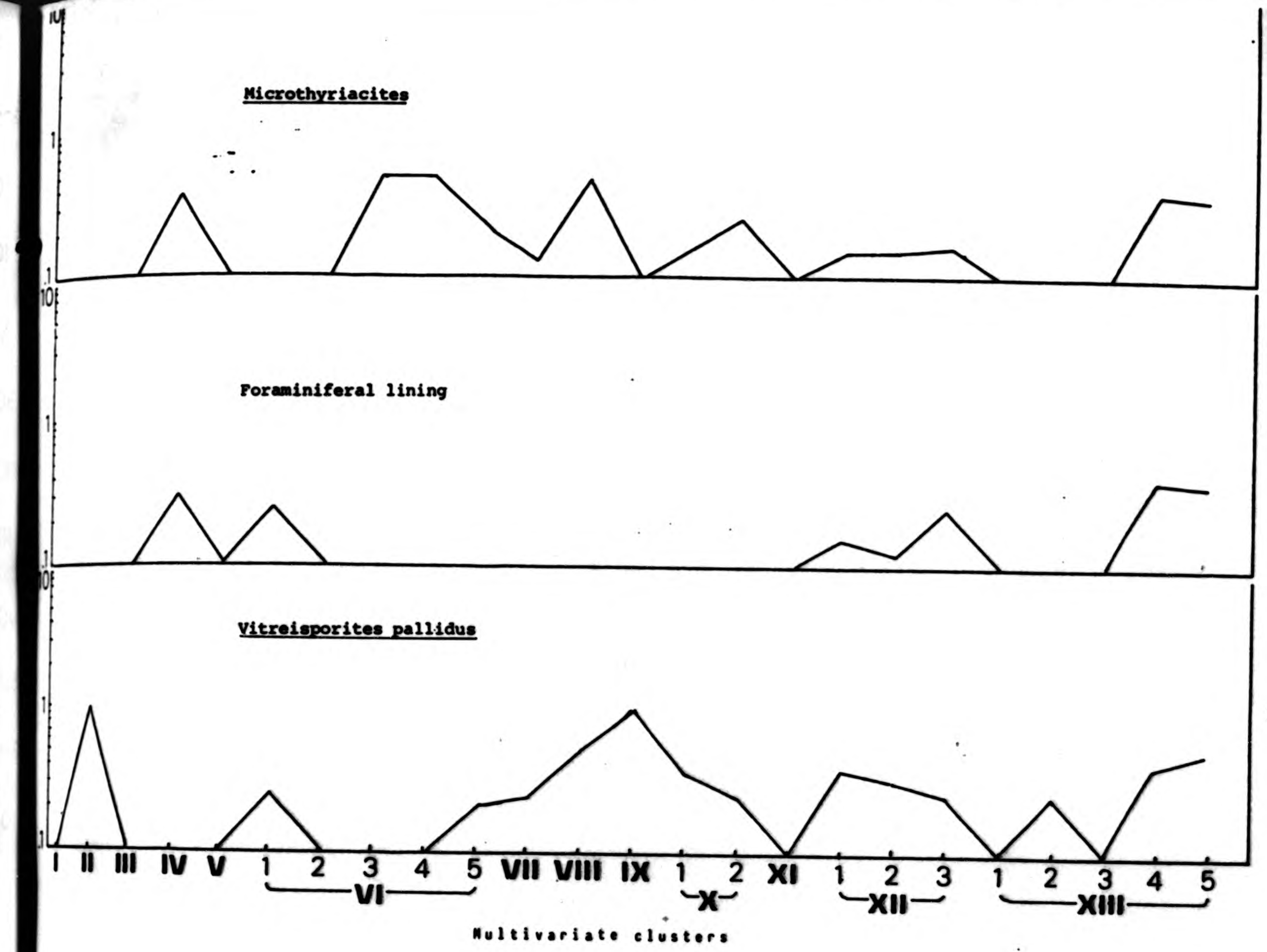
A series of diagrams has been produced to show the percentage frequency of each spore/pollen taxon through the thirteen multivariate cluster groups; see text-figs, 2.13 1-87. The numbers 1-87 correspond to the clustan coding series. Cluster groups at the 4.0 (24 clusters) level have been used in an attempt to break up the larger groups. These trends for each species can be called percentage frequency traces (P.F.T.'s), and are based on averaged percentage frequency count data for each of the 24 subclusters. A logarithmic scale has been used for taxa 11-87 in order to bring out very minor percentages and diminish very large ones, this being the nature of this data. Taxa 1-10 are all commonly occurring so a normal linear scale can be used.

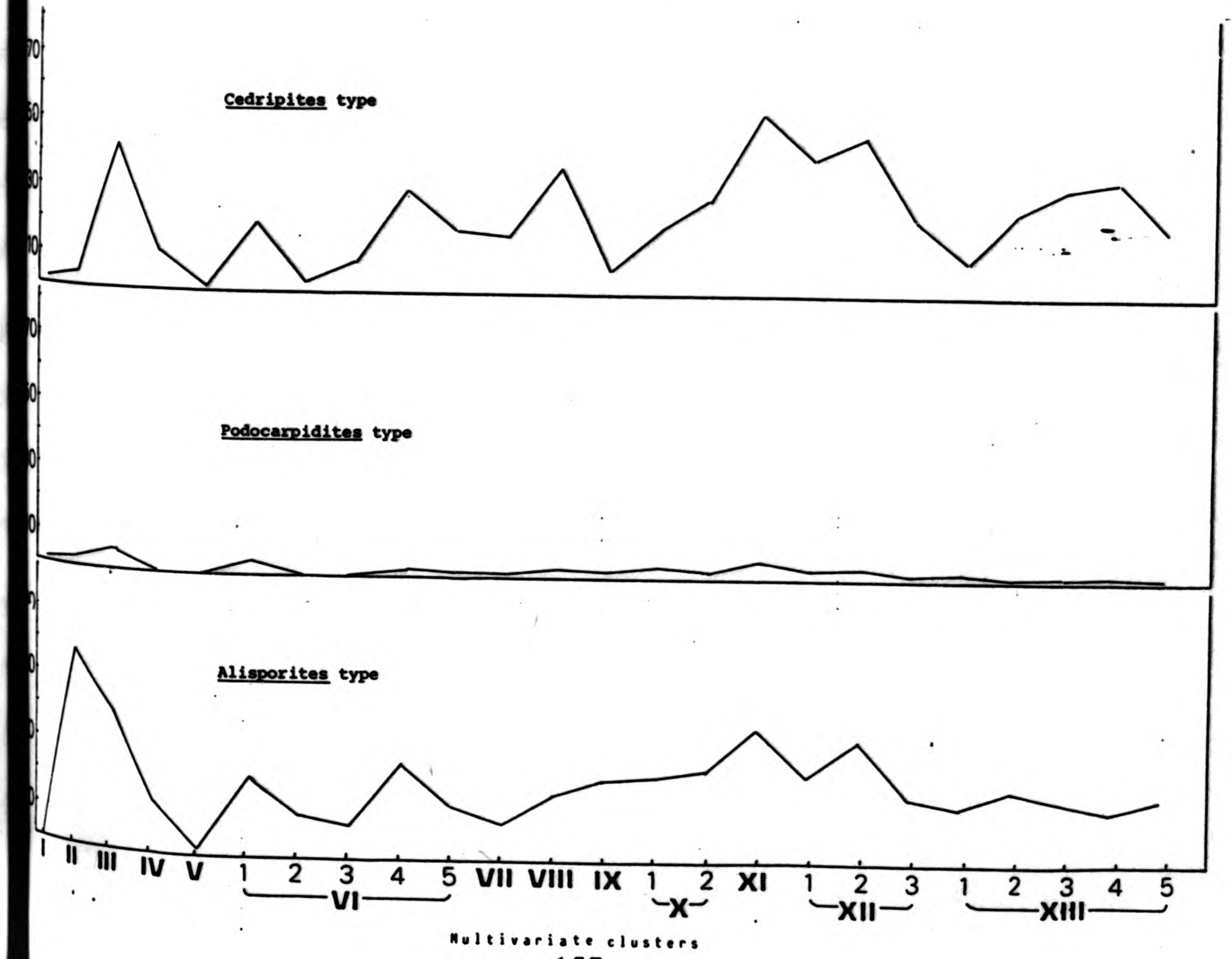
This percentage frequency data, being based on averaged count values for a particular <u>taxon</u> (R-mode analysis) in a particular cluster group is quite different from percentage occurrence (binary) data that is based on the percentage of <u>samples</u> (Q-mode analysis) that contain a given taxon in a given cluster group. It could be argued that P.F.T. data is less prone to distortion by sample total in a cluster group than P.O.T. data. However in practice the differences in sample totals within the multivariate cluster groups are so large that an inevitable distortion occurs. This is clearly the case in group XII that contains no prominent peaks, due to occasional high values in one sample being diluted to low values by averaging. High values are common in groups I & II that comprise only one sample. This may prevent the cluster groups from

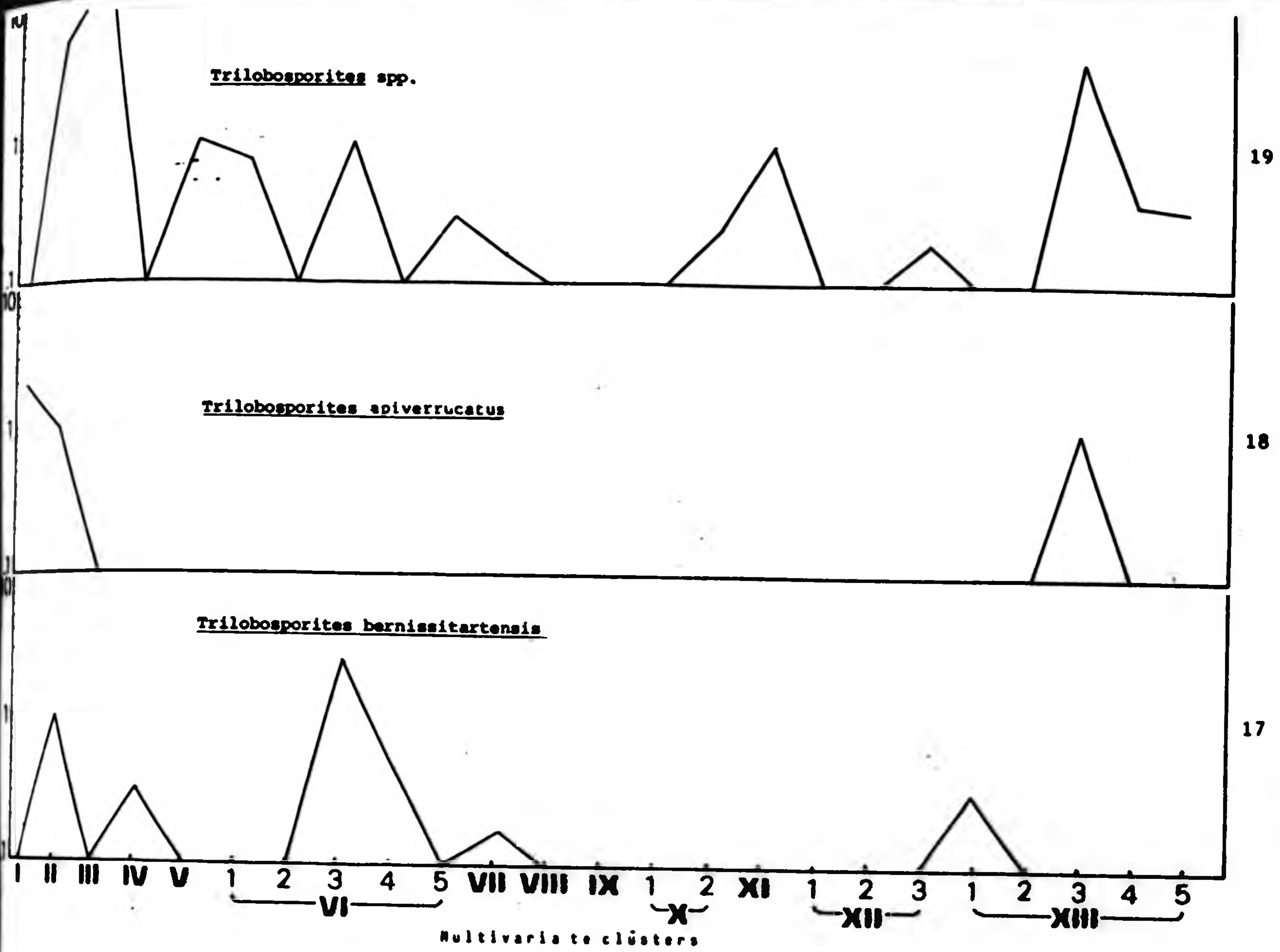
Percentage frequency traces (P.F.T's) of spore/pollen taxa within the multivariate cluster groups.

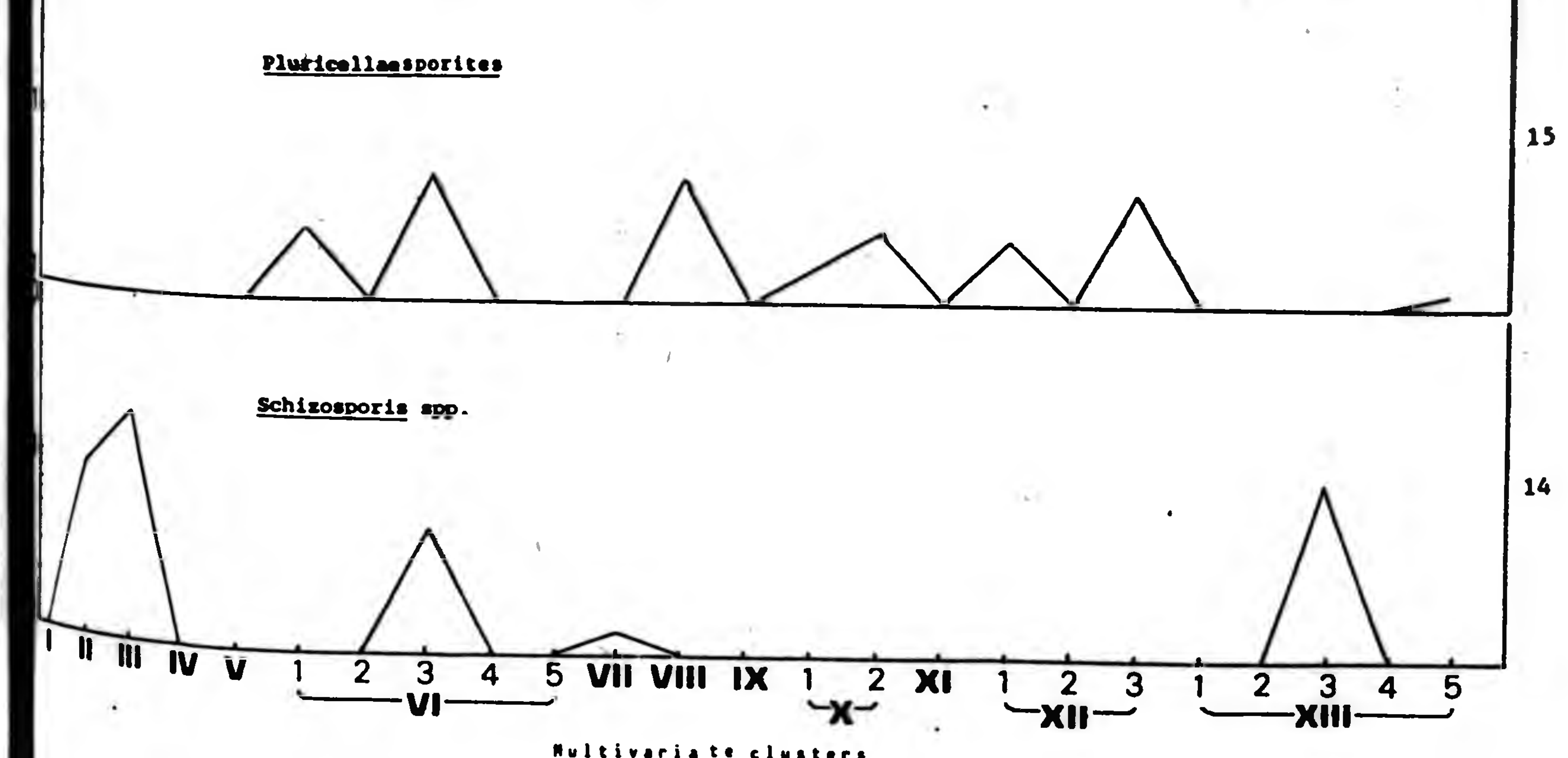
Text-fig. 2.13 (1-87)

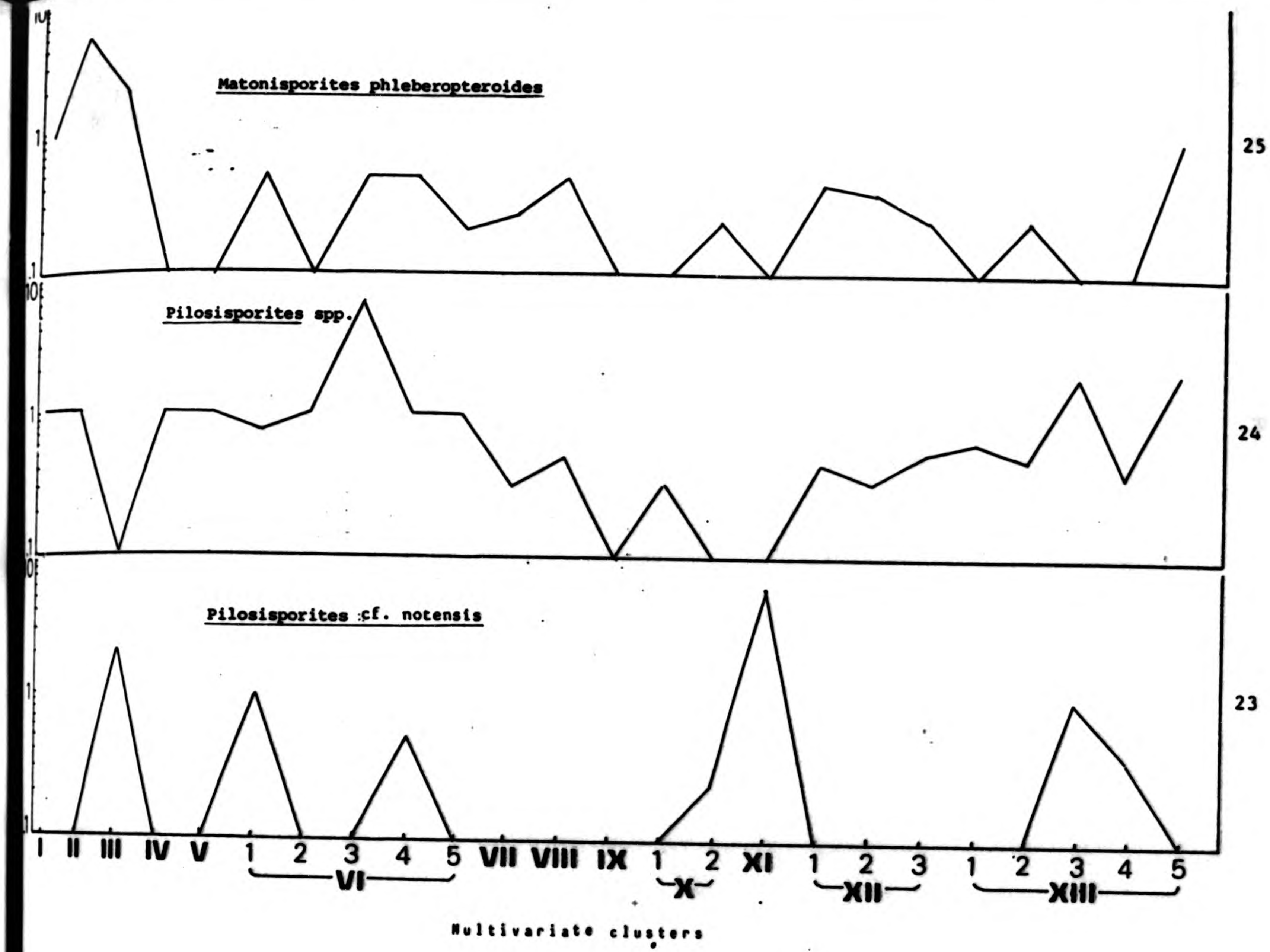


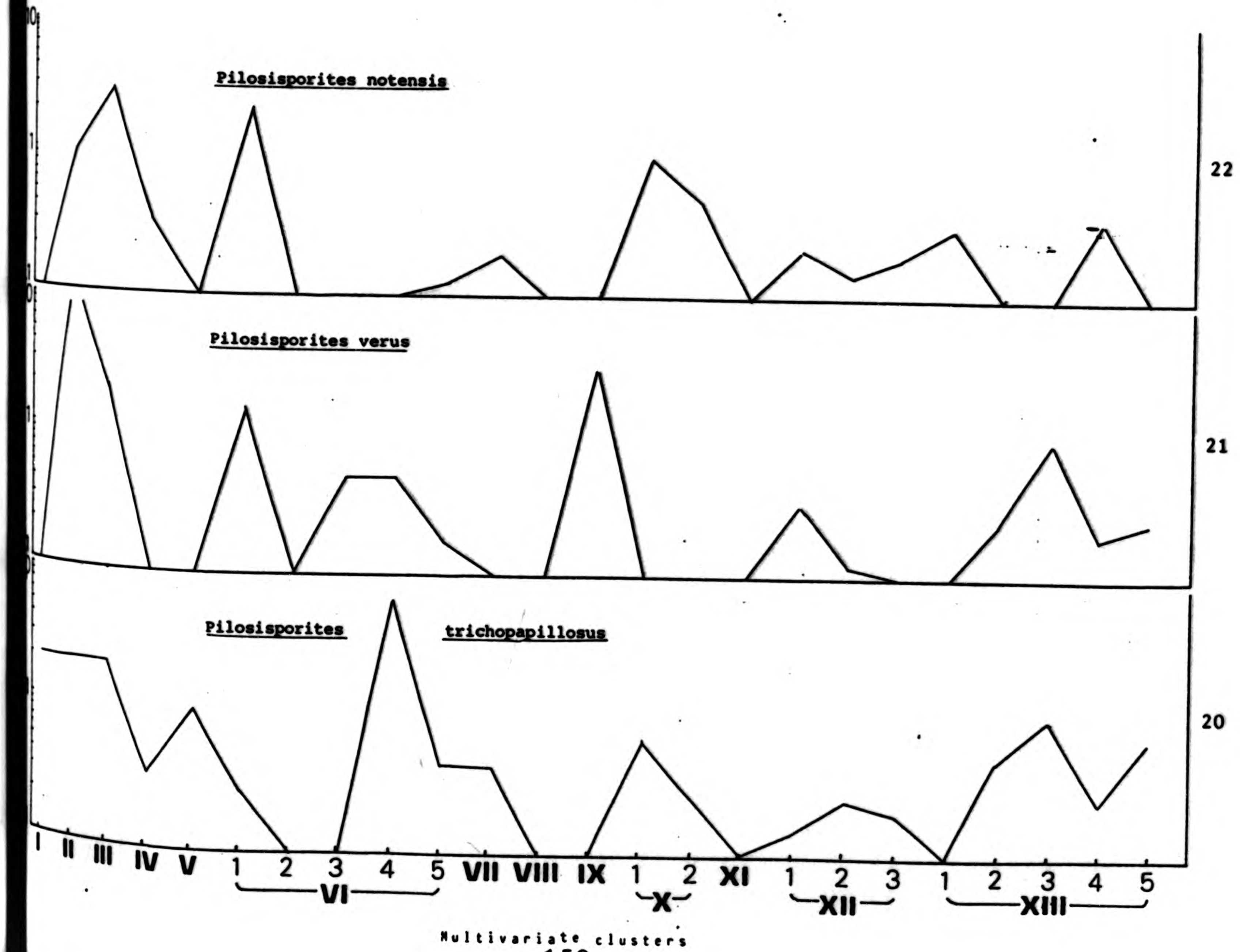

Microthyriacites
13
Foraminiferal lining
12
Vitreisporites pallidus
11
10
1
.1
I II III IV V 1 2 3 4 5 VII VIII IX 1 2 XI 1 2 3 1 2 3 4 5
VI
X
XII
XIII
Multivariate clusters

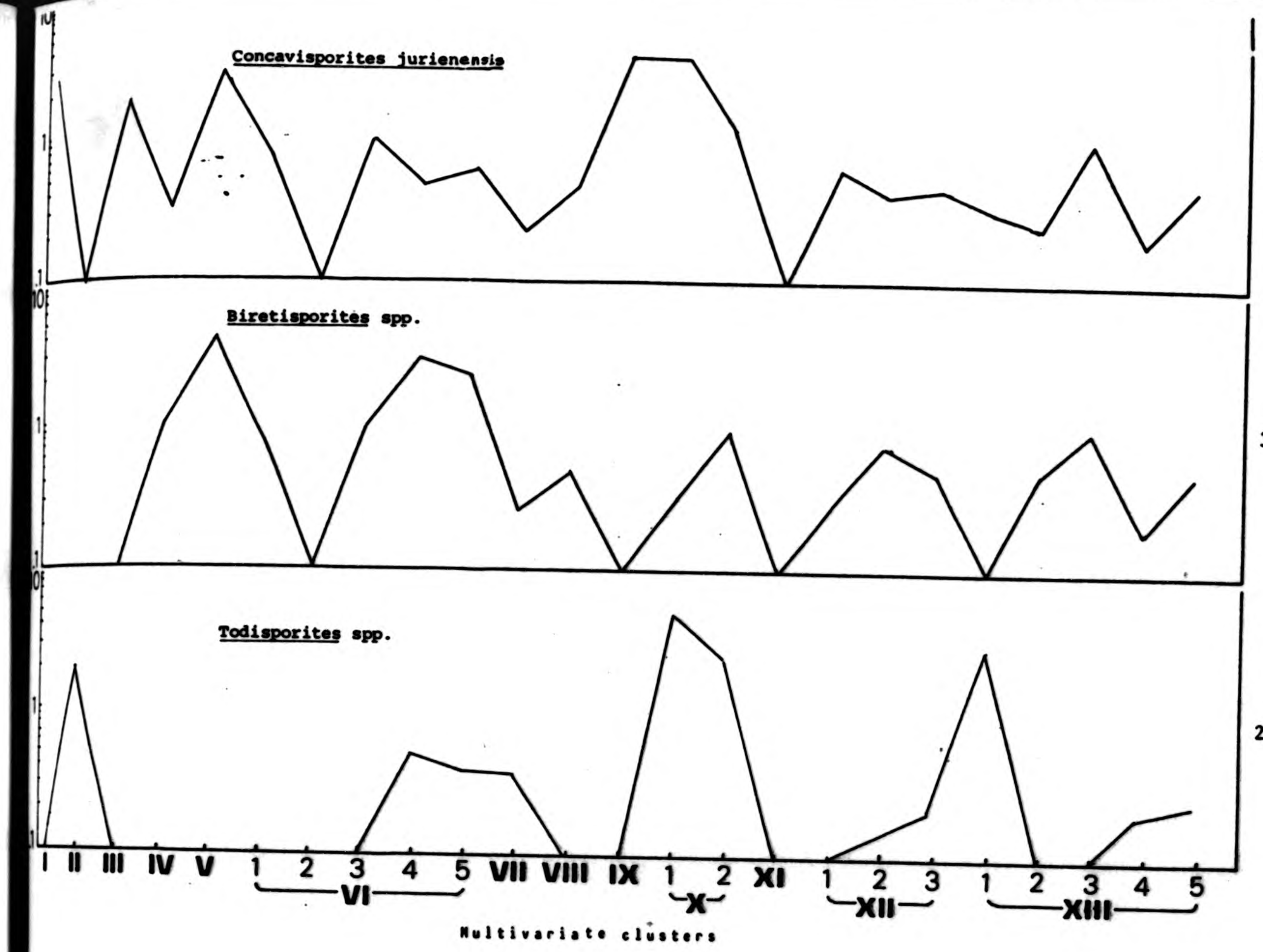

Cedripites type
9
Podocarpidites type
8
Alisporites type
7
70
60
50
40
30
20
10
I II III IV V 1 2 3 4 5 VII VIII IX 1 2 XI 1 2 3 1 2 3 4 5
VI
X
XII
XIII
Multivariate clusters

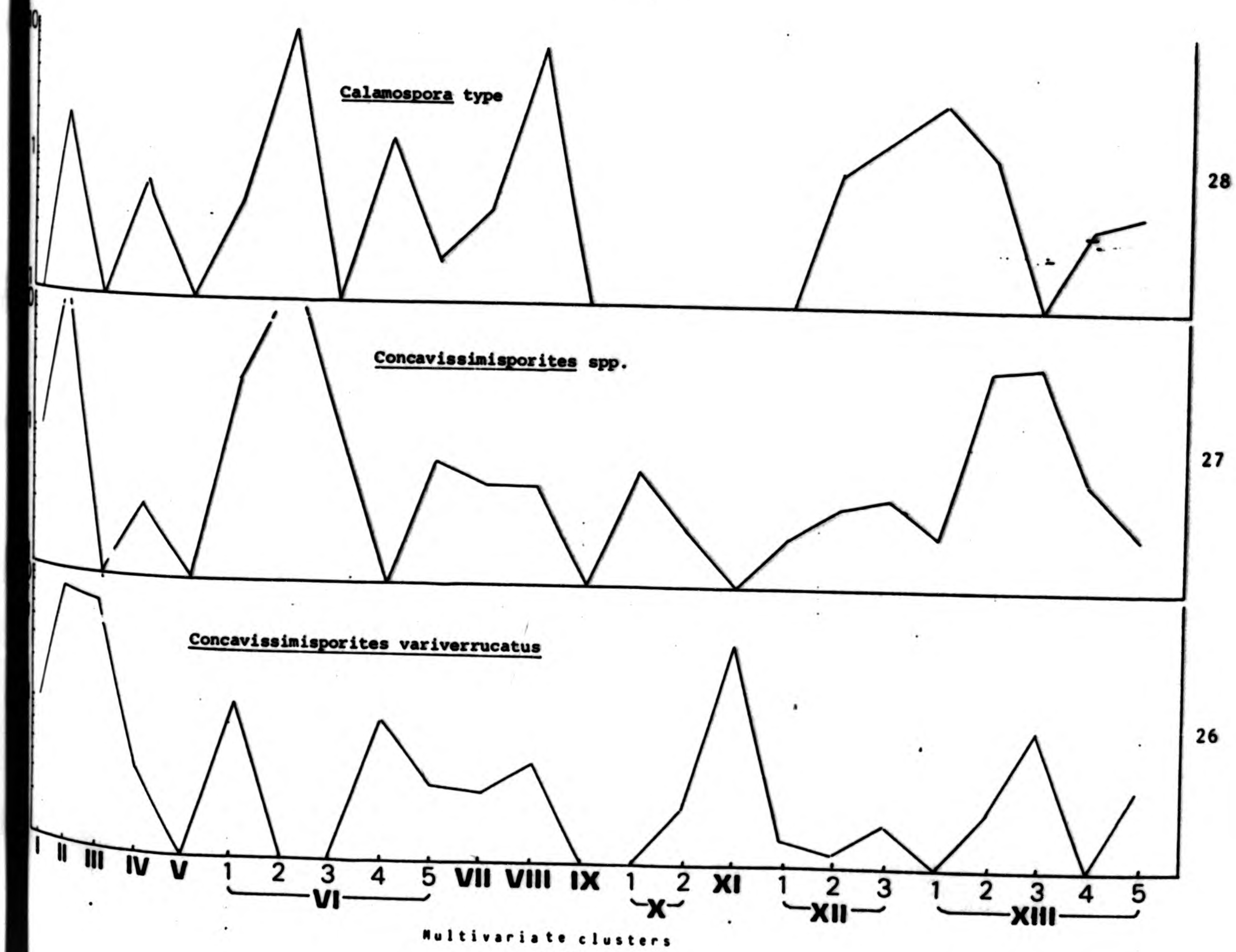

Trilobosporites spp.
19
Trilobosporites apiverrucatus
18
Trilobosporites bernissitartensis
17
10
1
.1
I II III IV V 1 2 3 4 5 VII VIII IX 1 2 XI 1 2 3 1 2 3 4 5
VI
X
XII
XIII
Multivariate clusters

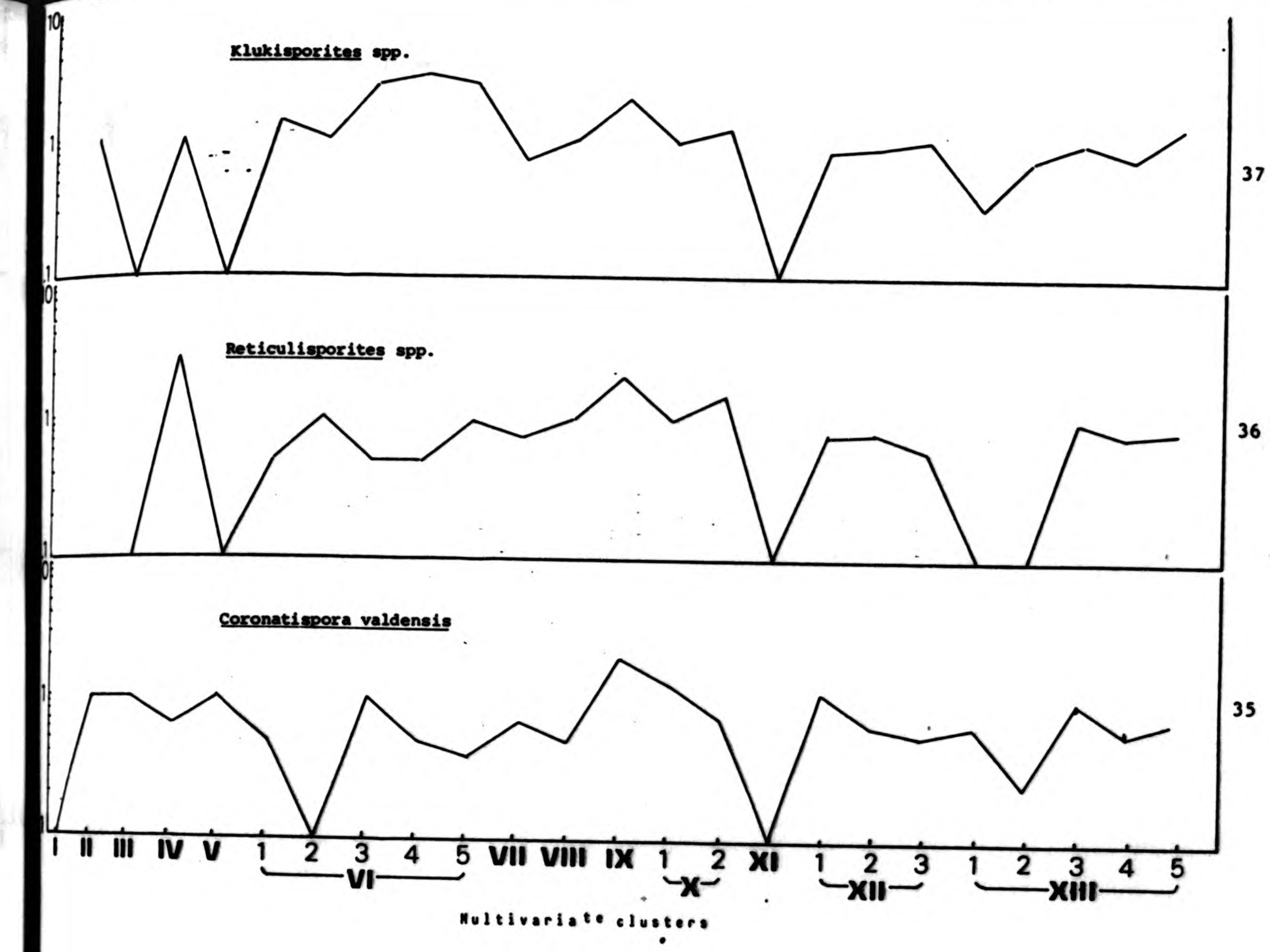

Trilobosporites canadensis
16
Pluricellaesporites
15
Schizosporis spp.
14
10
1
.1
I II III IV V 1 2 3 4 5 VII VIII IX 1 2 XI 1 2 3 1 2 3 4 5
VI
X
XII
XIII
Multivariate clusters


Matonisporites phleberopteroides
25
Pilosisporites spp.
24
Pilosisporites cf. notensis
23
10
1
.1
I II III IV V 1 2 3 4 5 VII VIII IX 1 2 XI 1 2 3 1 2 3 4 5
VI
X
XII
XIII
Multivariate clusters

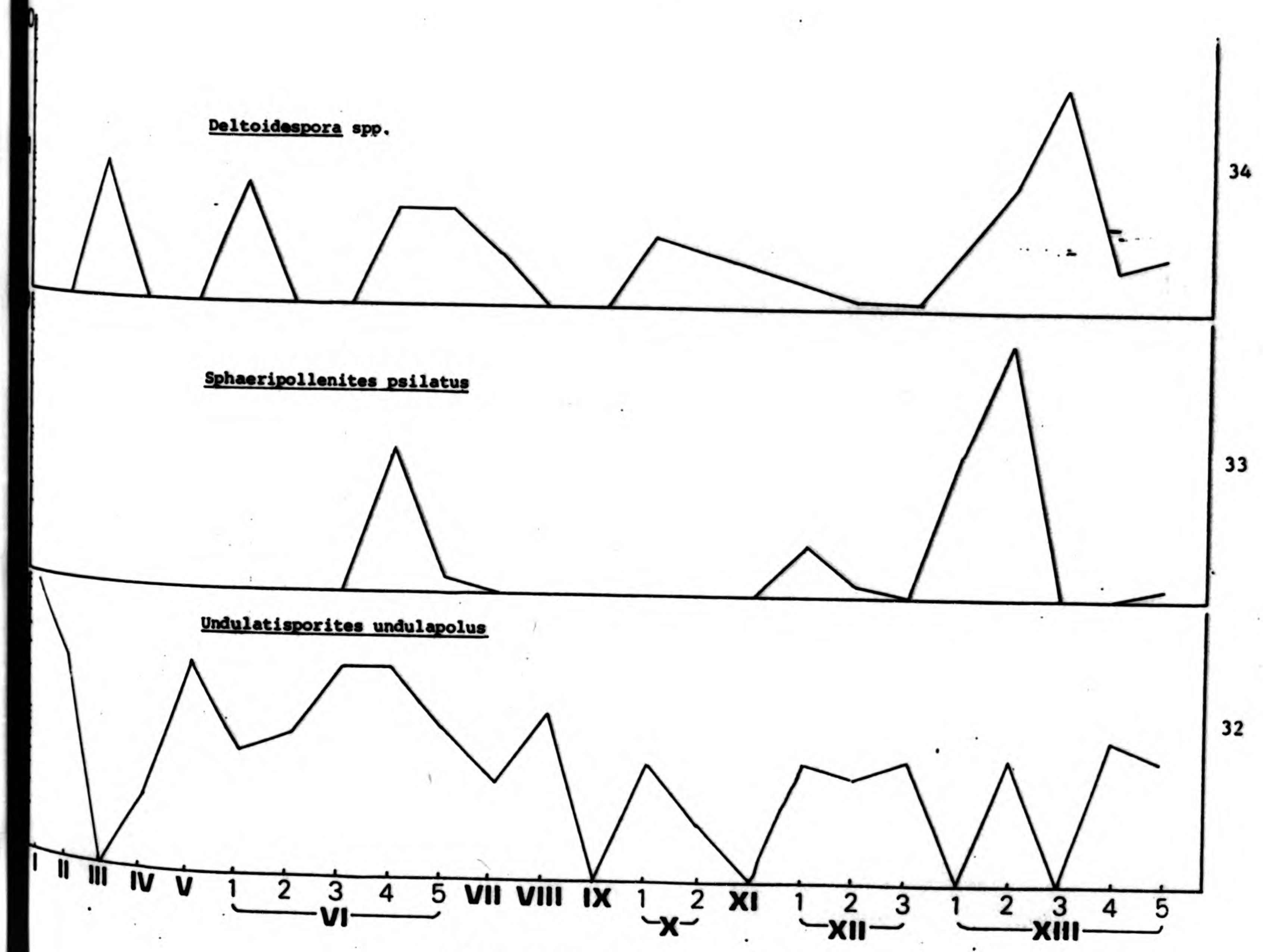

Pilosisporites notensis
22
Pilosisporites verus
21
Pilosisporites trichopapillosus
20
10
1
.1
I II III IV V 1 2 3 4 5 VII VIII IX 1 2 XI 1 2 3 1 2 3 4 5
VI
X
XII
XIII
Multivariate clusters


Concavisporites jurienensis
31
Biretisporites spp.
30
Todisporites spp.
29
10
1
.1
I II III IV V 1 2 3 4 5 VII VIII IX 1 2 XI 1 2 3 1 2 3 4 5
VI
X
XII
XIII
Multivariate clusters

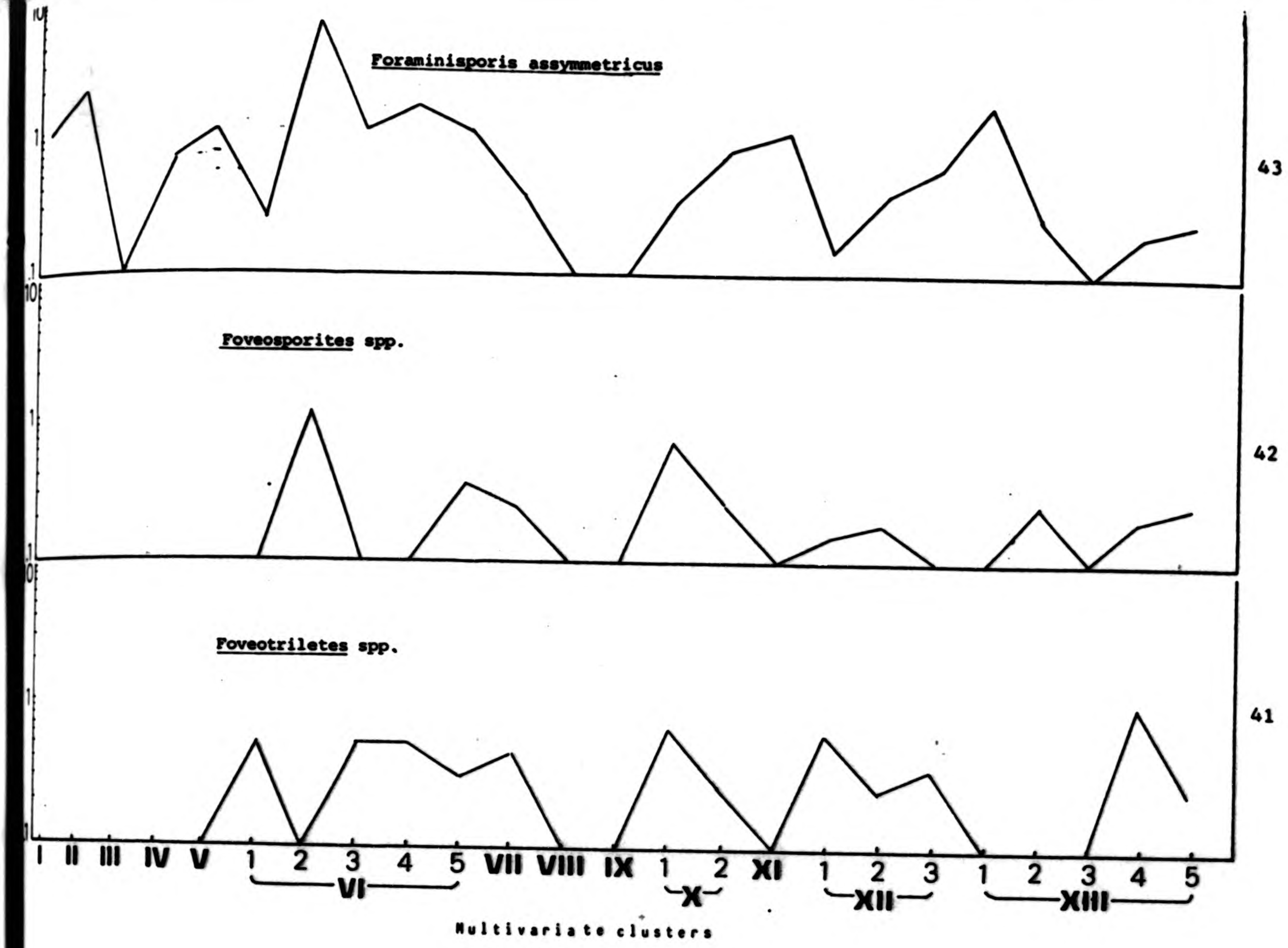

Calamospora type
28
Concavissimisporites spp.
27
Concavissimisporites variverrucatus
26
I II III IV V 1 2 3 4 5 VII VIII IX 1 2 XI 1 2 3 1 2 3 4 5
VI
X
XII
XIII
Multivariate clusters

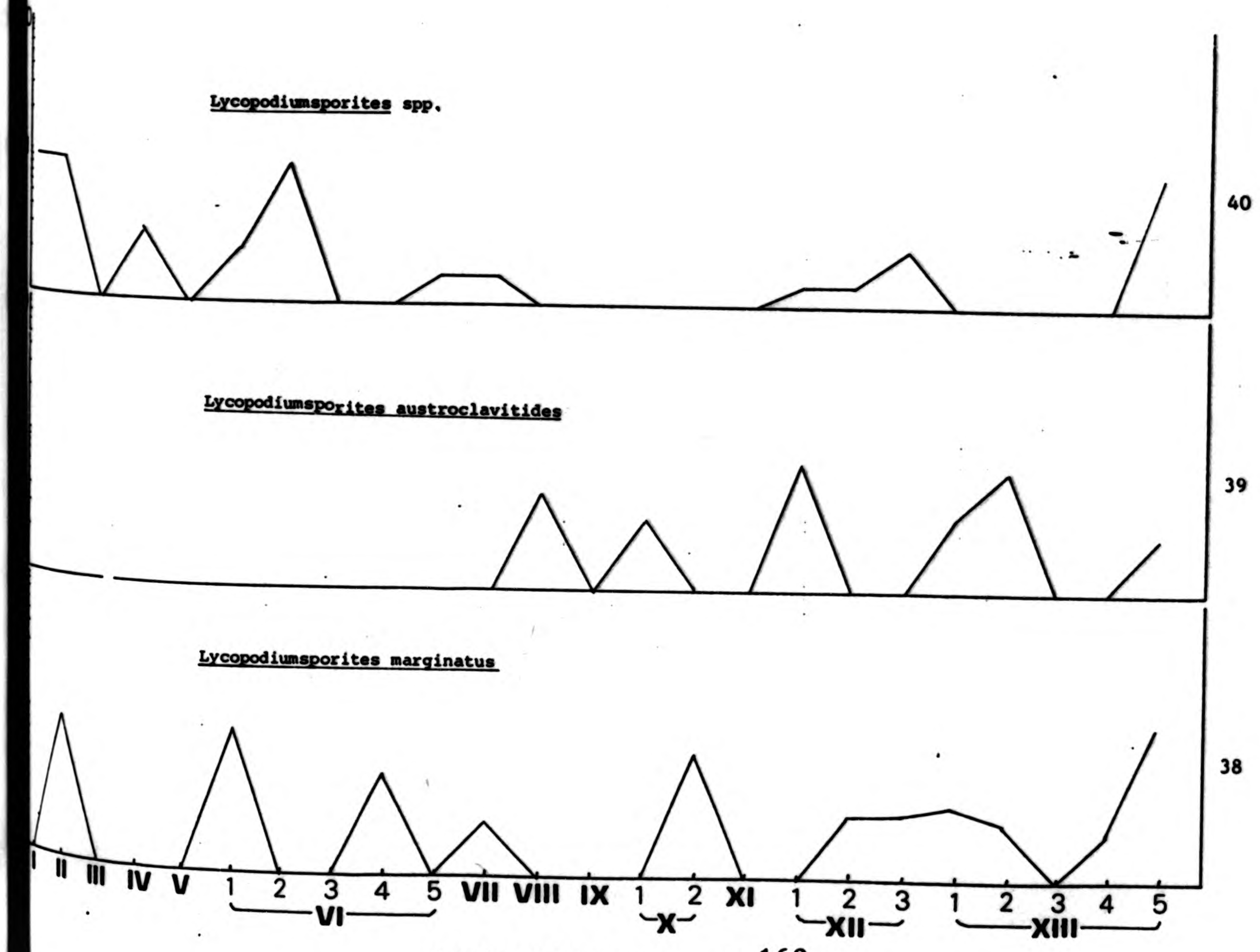


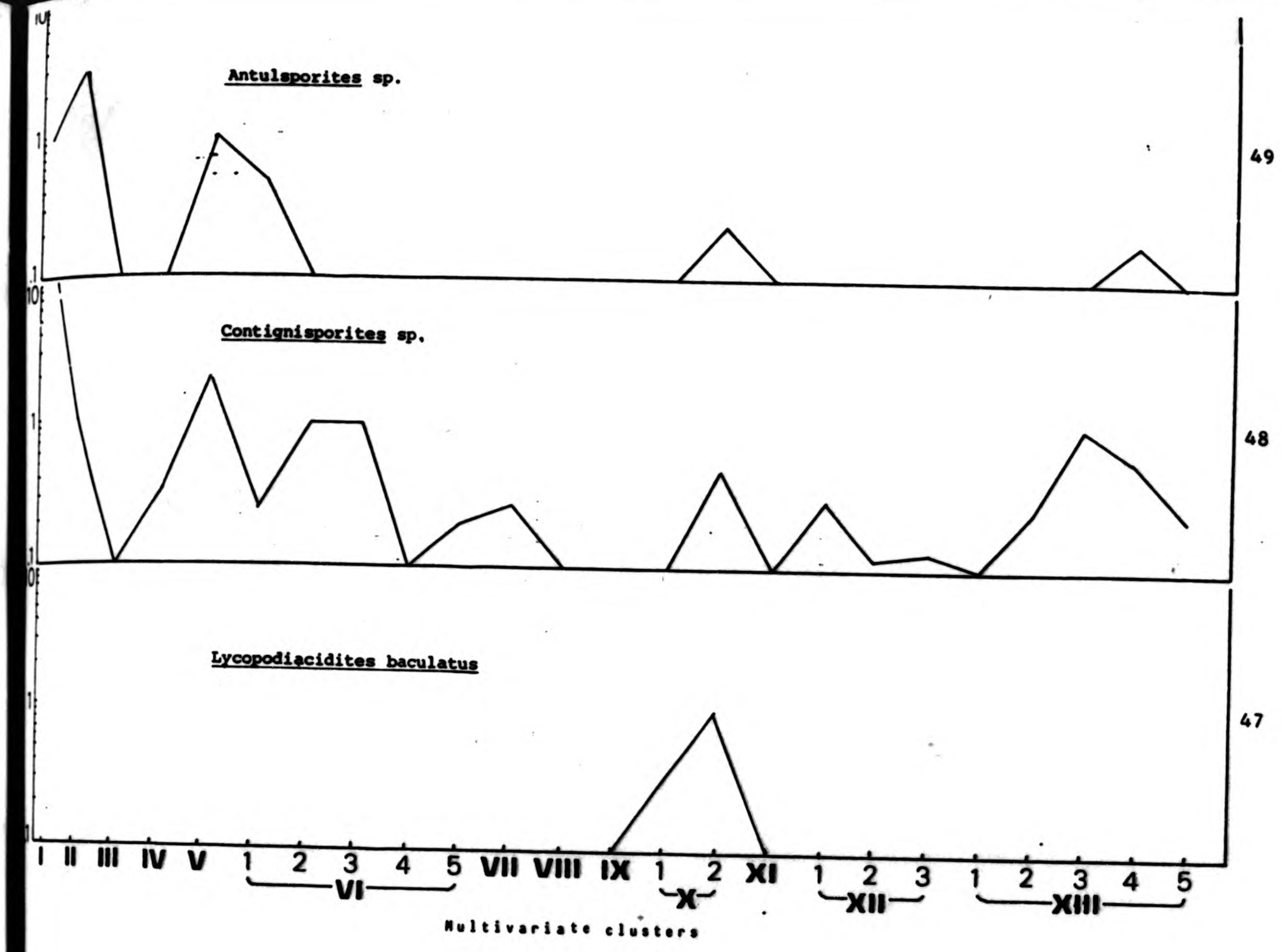
10
1
.1
Klukisporites spp.
37
Reticulisporites spp.
36
Coronatispora valdensis
35
I II III IV V 1 2 3 4 5 VII VIII IX 1 2 XI 1 2 3 1 2 3 4 5
VI
X
XII
XIII
Multivariate clusters

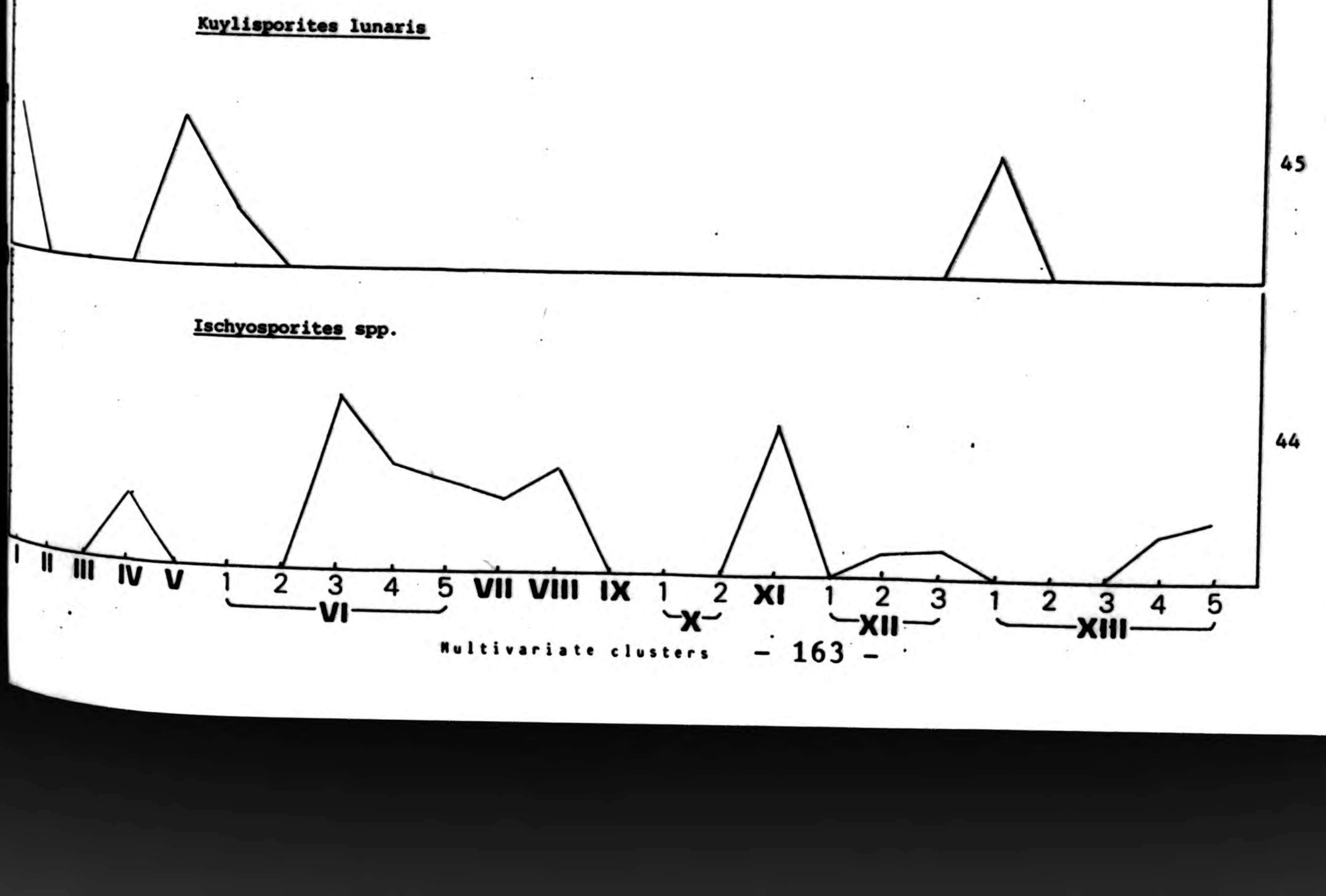


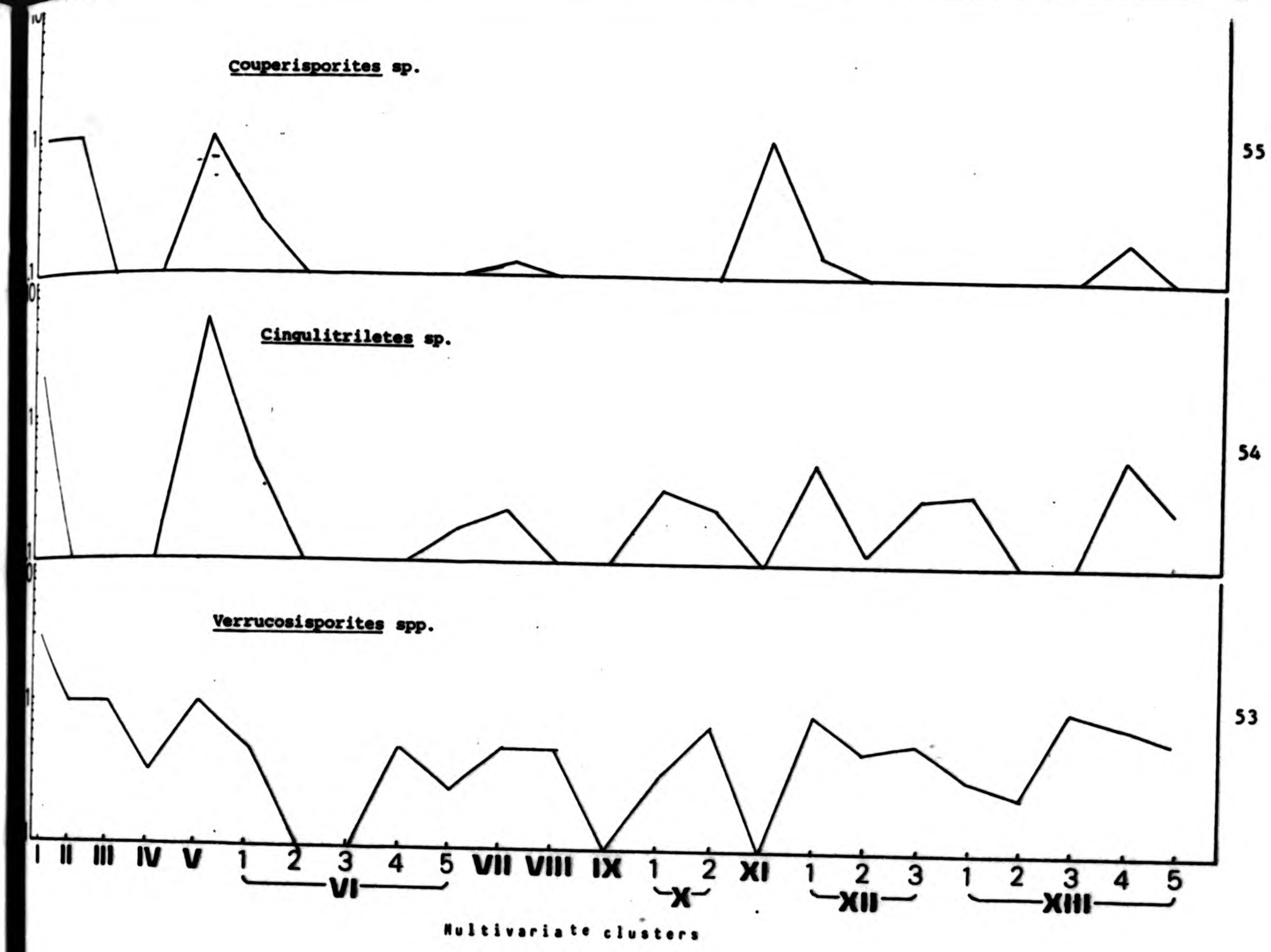
Deltoidespora spp.
34
Sphaeripollenites psilatus
33
Undulatisporites undulapolus
32
I II III IV V 1 2 3 4 5 VII VIII IX 1 2 XI 1 2 3 1 2 3 4 5
VI
X
XII
XIII
Multivariate clusters

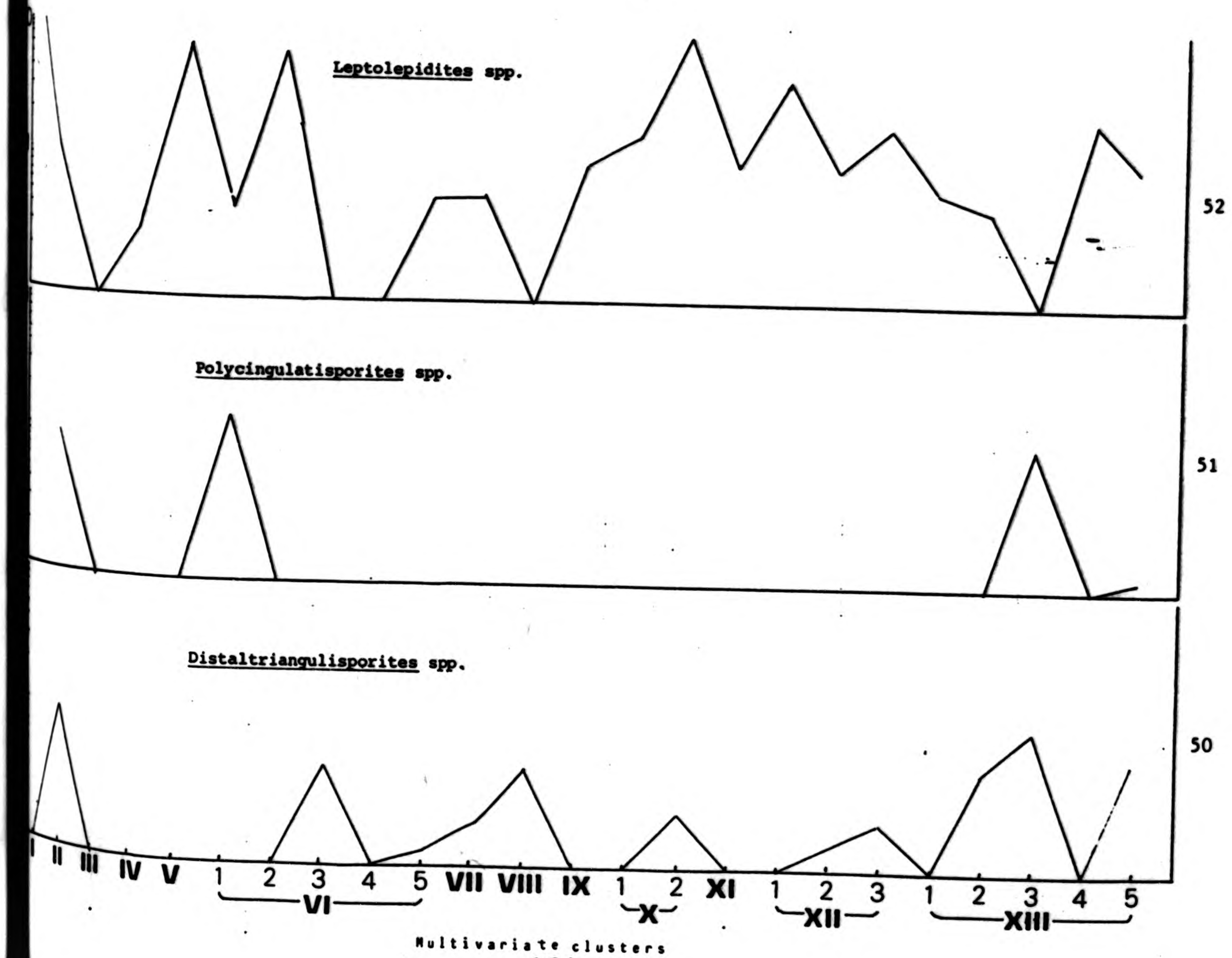

Foraminisporis assymmetricus
43
Foveosporites spp.
42
Foveotriletes spp.
41
10
1
.1
I II III IV V 1 2 3 4 5 VII VIII IX 1 2 XI 1 2 3 1 2 3 4 5
VI
X
XII
XIII
Multivariate clusters

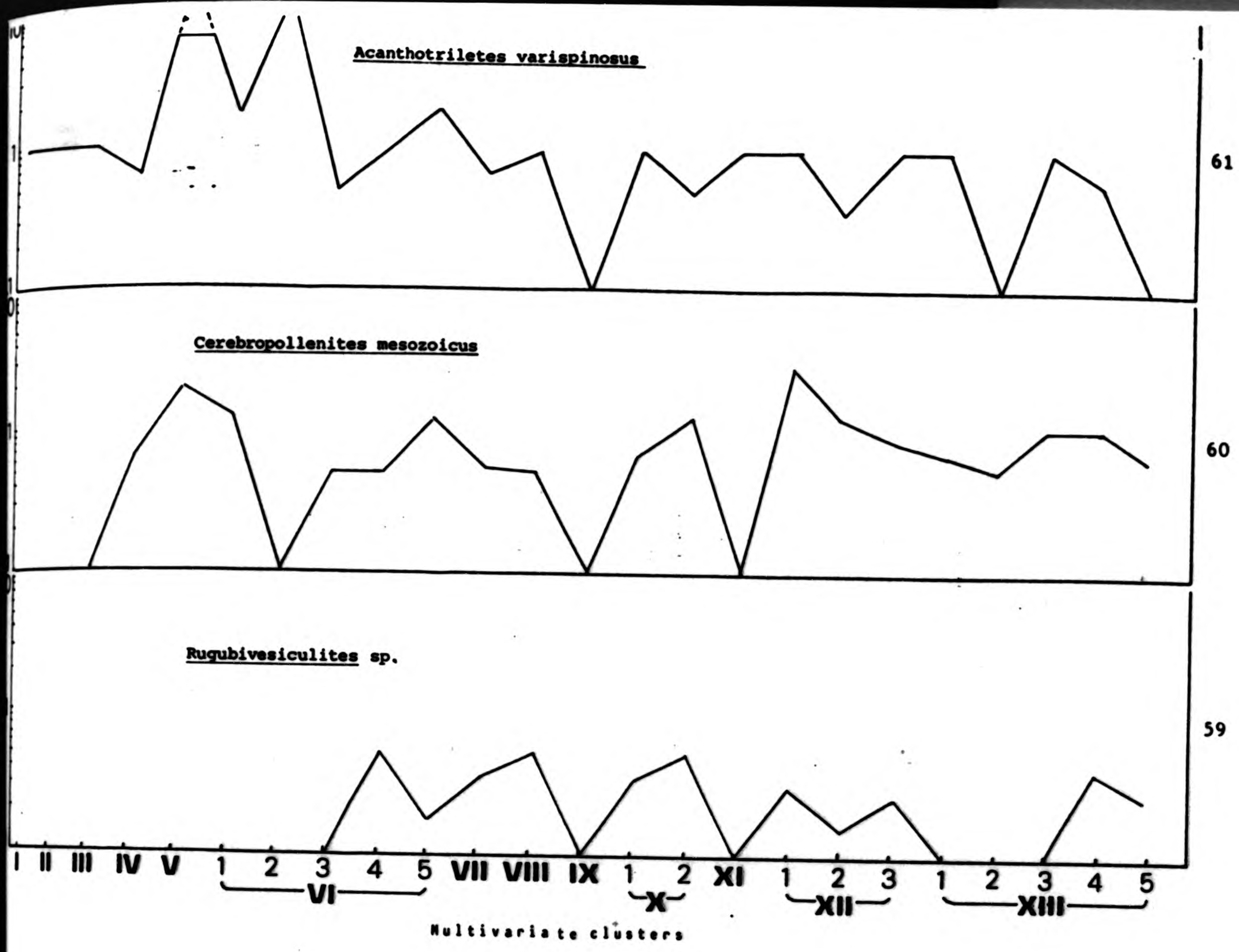

Lycopodiumsporites spp.
40
Lycopodiumsporites austroclavitides
39
Lycopodiumsporites marginatus
38
I II III IV V 1 2 3 4 5 VII VIII IX 1 2 XI 1 2 3 1 2 3 4 5
VI
X
XII
XIII
Multivariate clusters

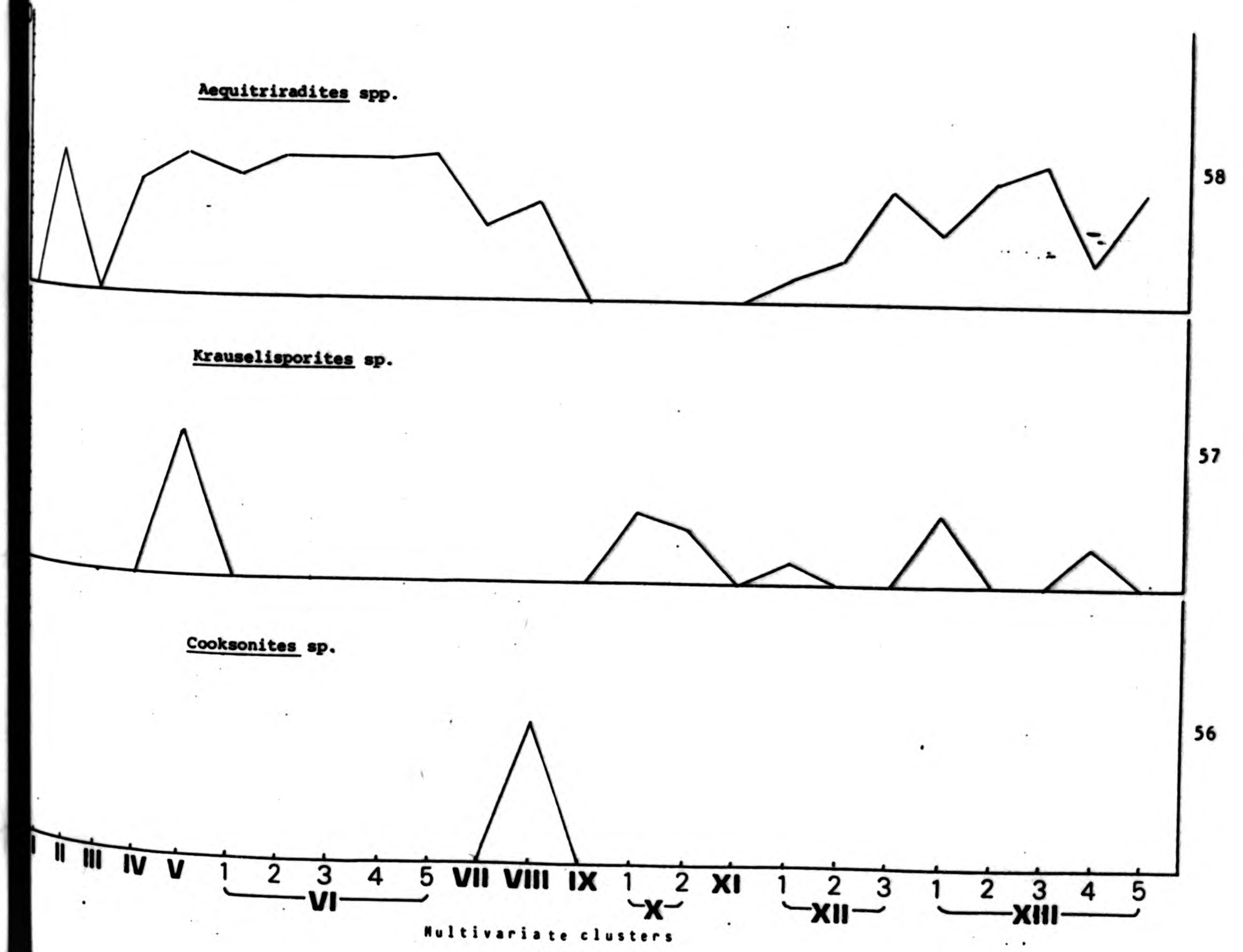

Antulsporites sp.
49
Contignisporites sp.
48
Lycopodiacidites baculatus
47
10
1
.1
I II III IV V 1 2 3 4 5 VII VIII IX 1 2 XI 1 2 3 1 2 3 4 5
VI
X
XII
XIII
Multivariate clusters

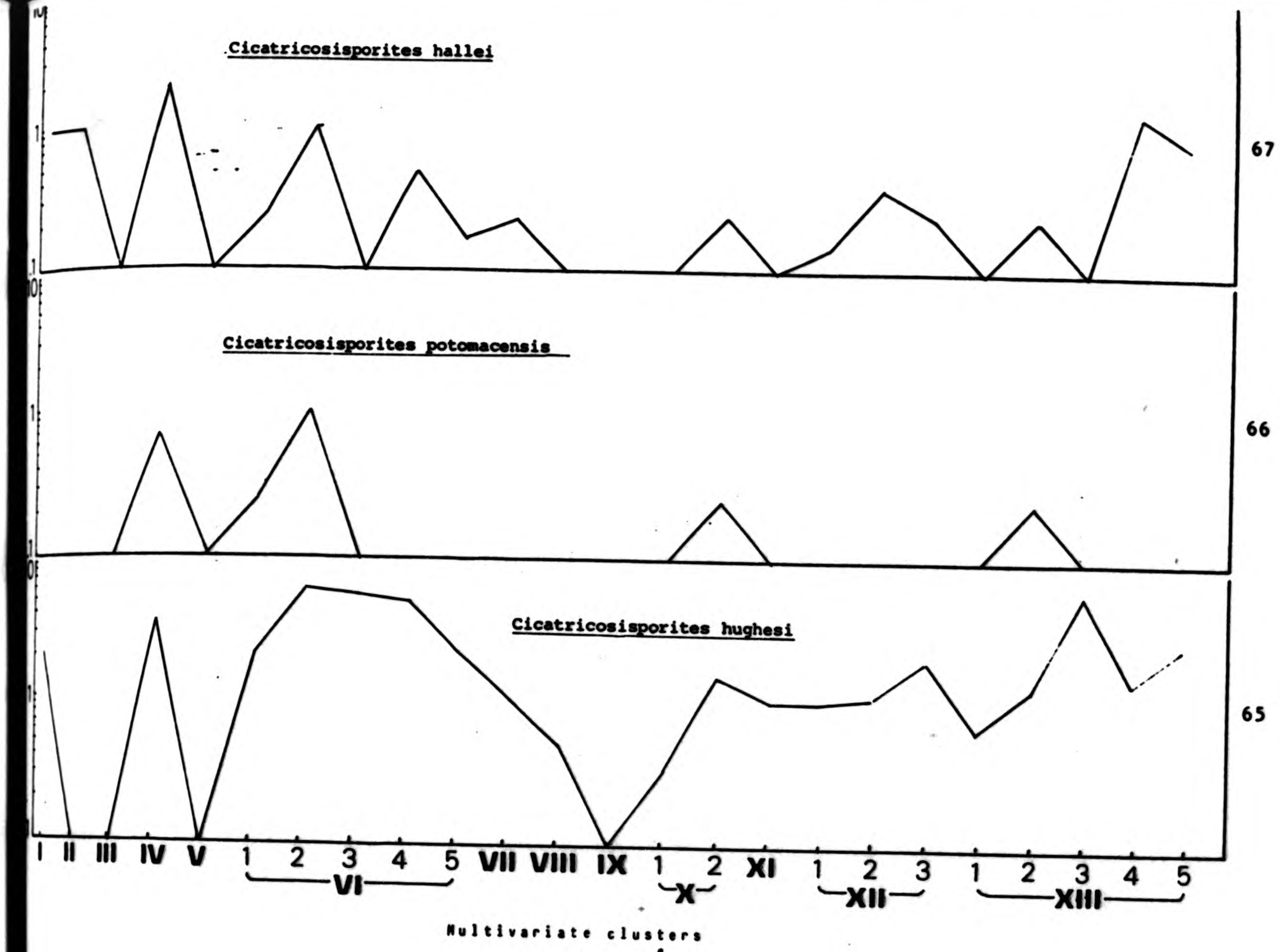

Sestrosporites pseudoalveolatus
46
Kuylisporites lunaris
45
Ischyosporites spp.
44
10
1
.1
I II III IV V 1 2 3 4 5 VII VIII IX 1 2 XI 1 2 3 1 2 3 4 5
VI
X
XII
XIII
Multivariate clusters

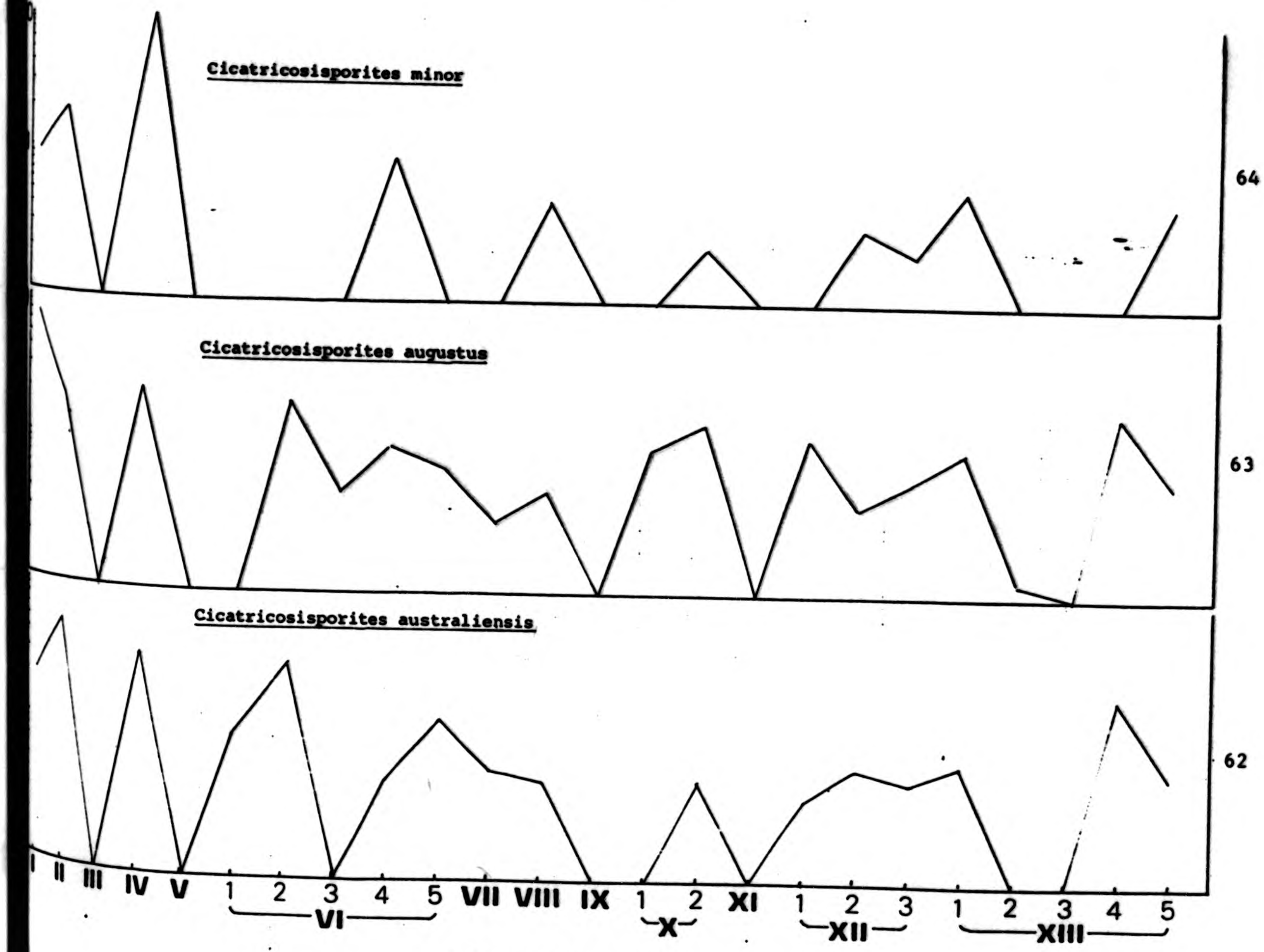

Couperisporites sp.
55
Cingulitriletes sp.
54
Verrucosisporites spp.
53
I II III IV V 1 2 3 4 5 VII VIII IX 1 2 XI 1 2 3 1 2 3 4 5
VI
X
XII
XIII
Multivariate clusters

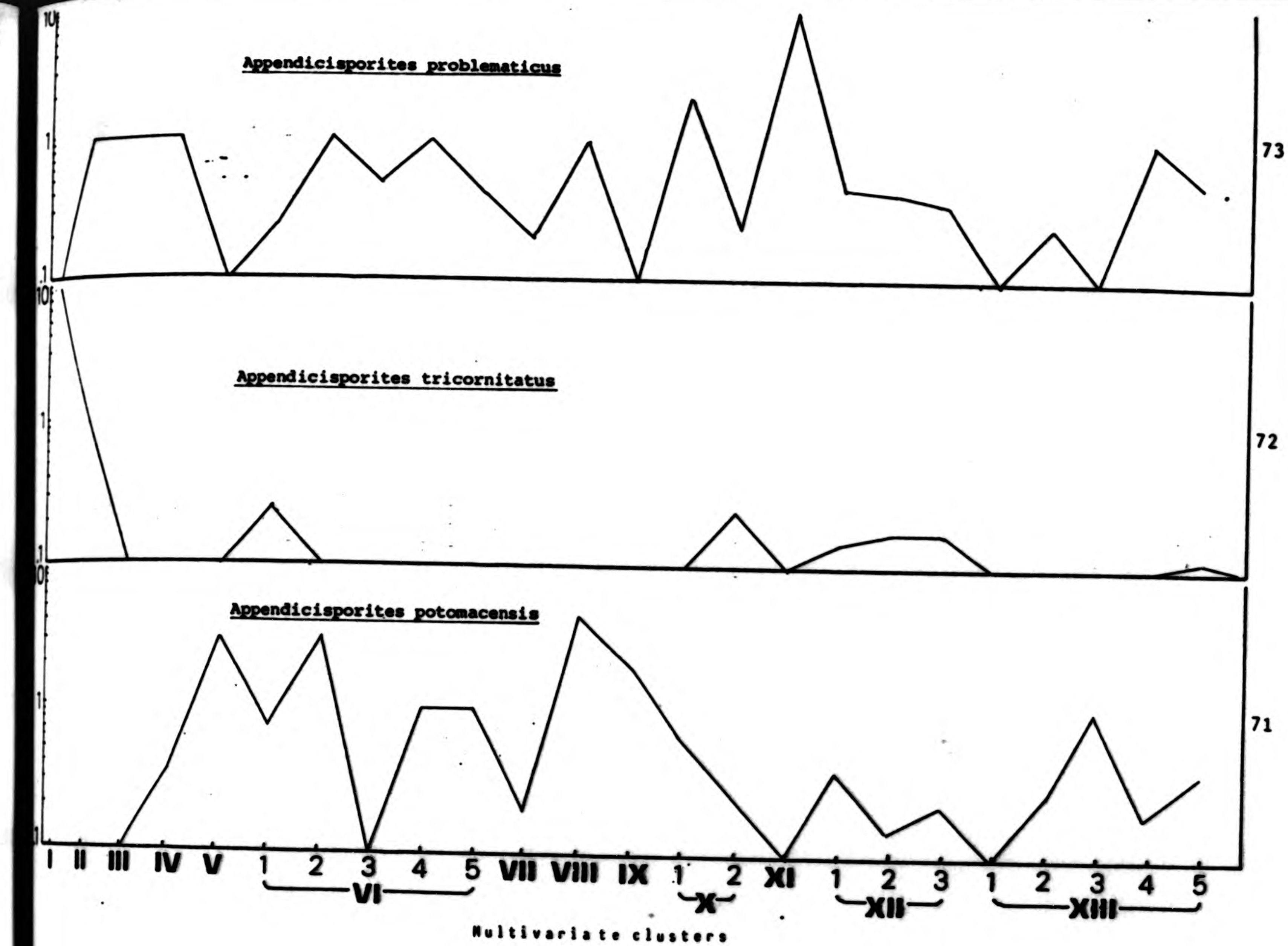

Leptolepidites spp.
52
Polycingulatisporites spp.
51
Distaltriangulisporites spp.
50
I II III IV V 1 2 3 4 5 VII VIII IX 1 2 XI 1 2 3 1 2 3 4 5
VI
X
XII
XIII
Multivariate clusters

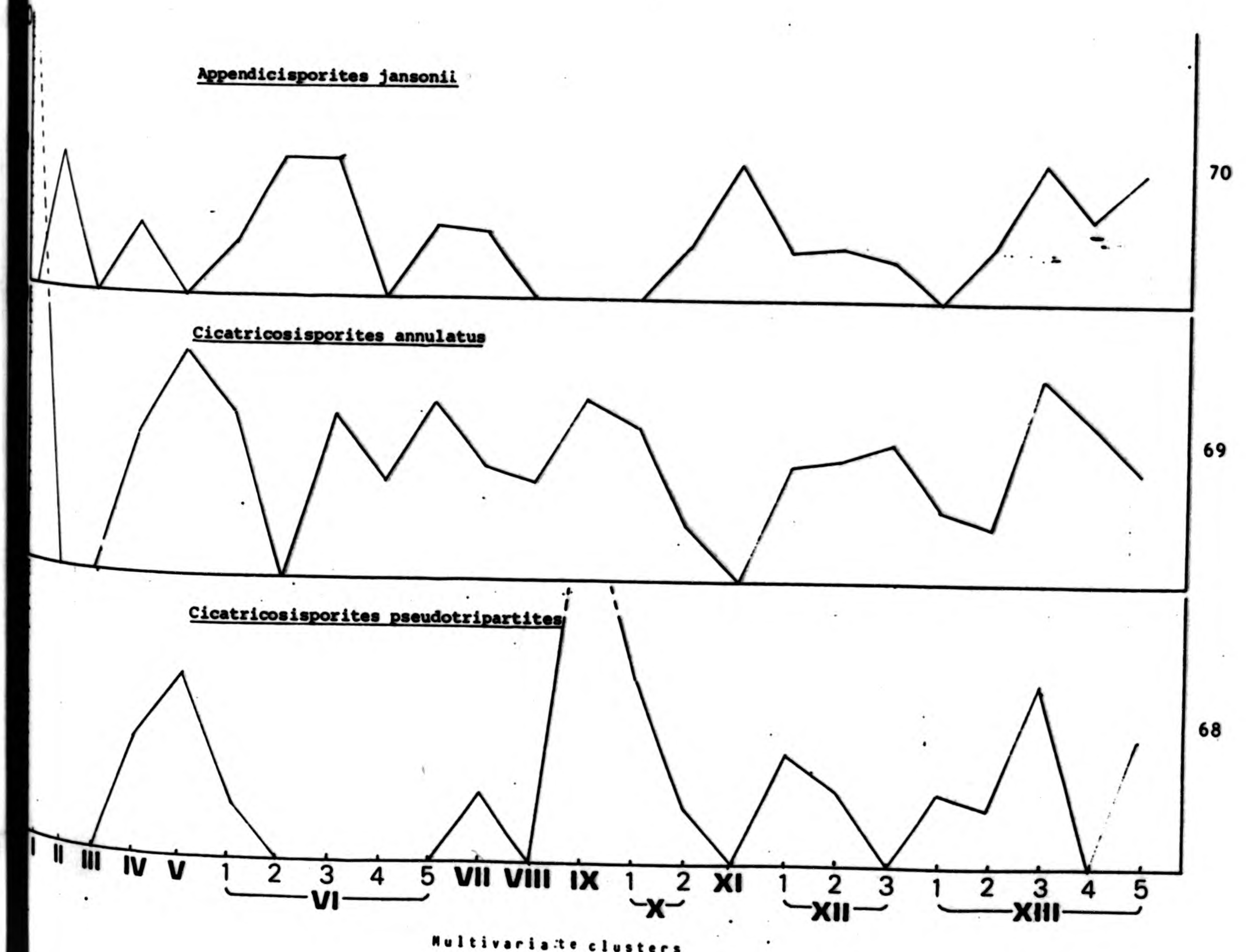

Acanthotriletes varispinosus
61
Cerebropollenites mesozoicus
60
Rugubivesiculites sp.
59
I II III IV V 1 2 3 4 5 VII VIII IX 1 2 XI 1 2 3 1 2 3 4 5
VI
X
XII
XIII
Multivariate clusters

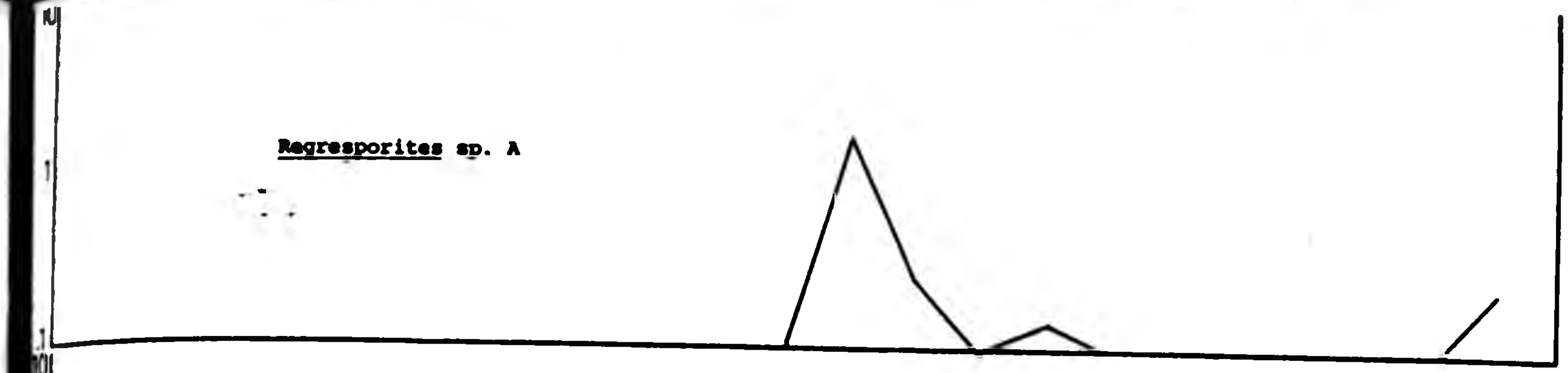

Aequitriradites spp.
58
Krauselisporites sp.
57
Cooksonites sp.
56
I II III IV V 1 2 3 4 5 VII VIII IX 1 2 XI 1 2 3 1 2 3 4 5
VI
X
XII
XIII
Multivariate clusters


Cicatricosisporites hallei
67
Cicatricosisporites potomacensis
66
Cicatricosisporites hughesi
65
I II III IV V 1 2 3 4 5 VII VIII IX 1 2 XI 1 2 3 1 2 3 4 5
VI X XII XIII
Multivariate clusters

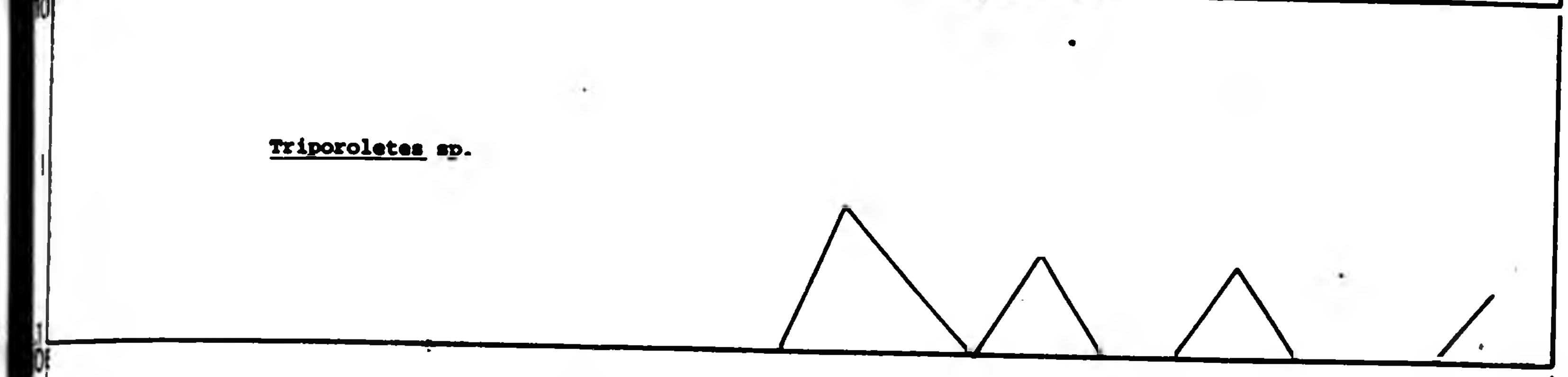

Cicatricosisporites minor
64
Cicatricosisporites augustus
63
Cicatricosisporites australiensis
62
I II III IV V 1 2 3 4 5 VII VIII IX 1 2 XI 1 2 3 1 2 3 4 5
VI X XII XIII
Multivariate clusters


Appendicisporites problematicus
73
Appendicisporites tricornitatus
72
Appendicisporites potomacensis
71
10
1
.1
I II III IV V 1 2 3 4 5 VII VIII IX 1 2 XI 1 2 3 1 2 3 4 5
VI
X
XII
XIII
Multivariate clusters


Appendicisporites jansonii
70
Cicatricosisporites annulatus
69
Cicatricosisporites pseudotripartites
68
I II III IV V 1 2 3 4 5 VII VIII IX 1 2 XI 1 2 3 1 2 3 4 5
VI
X
XII
XIII
Multivariate clusters



79



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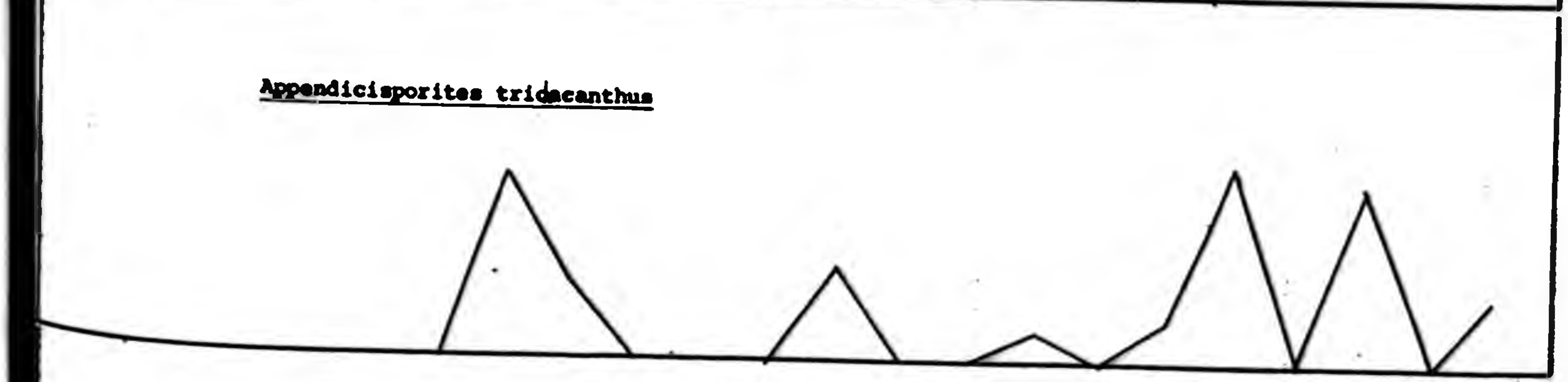
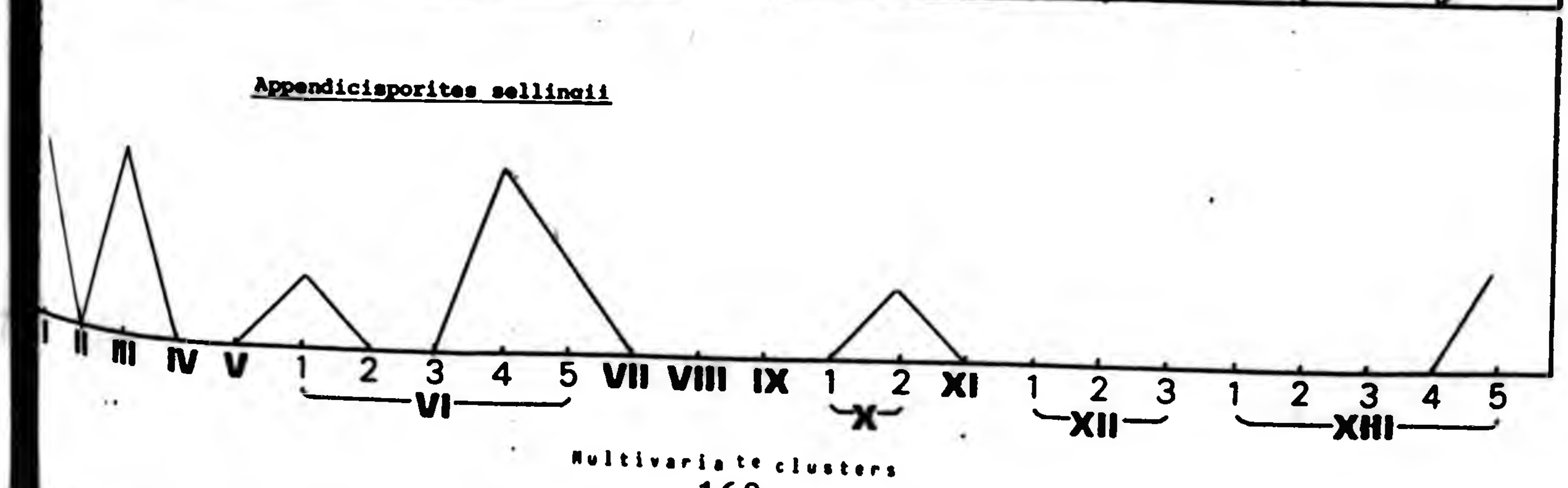
77

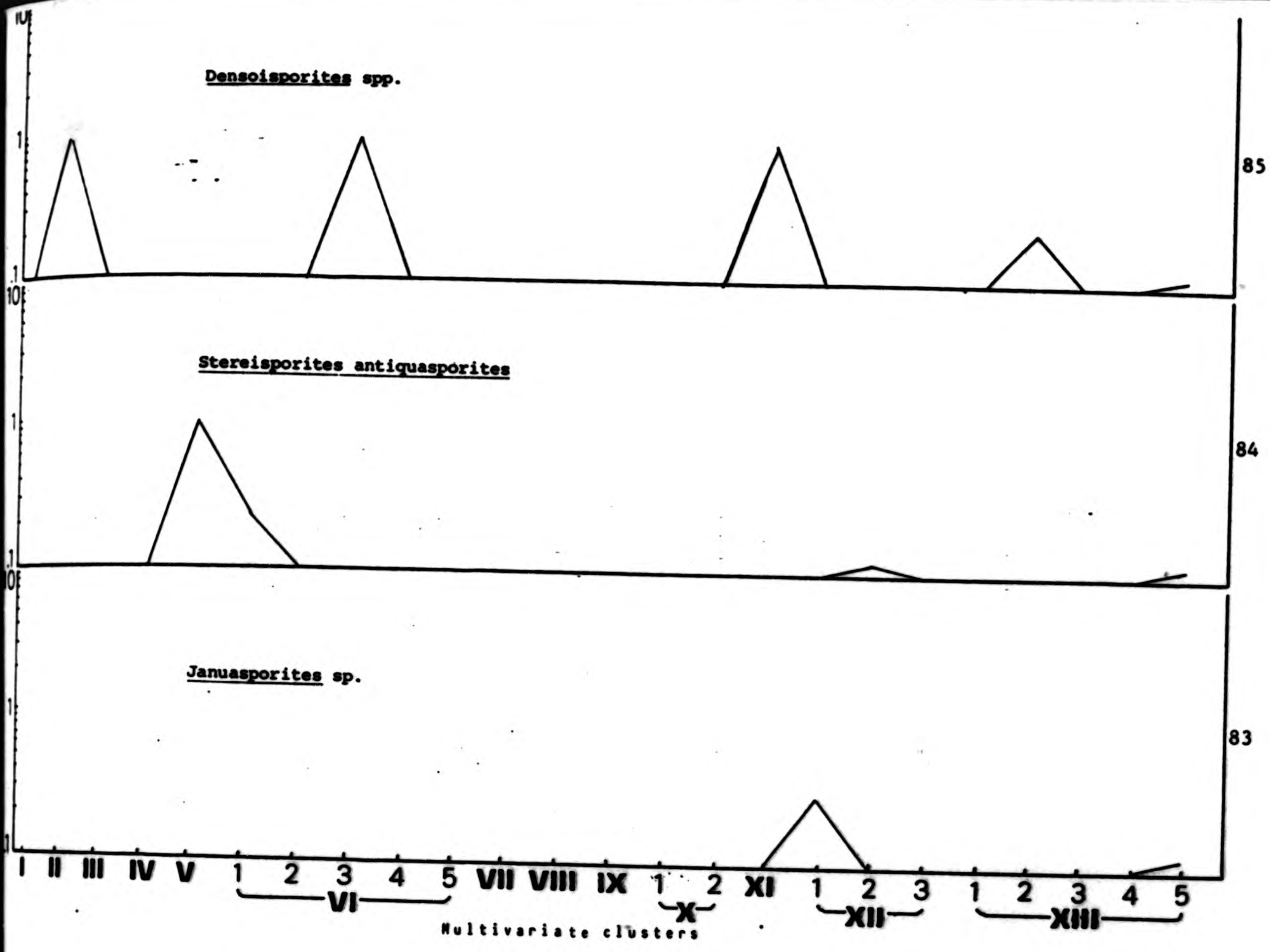
76

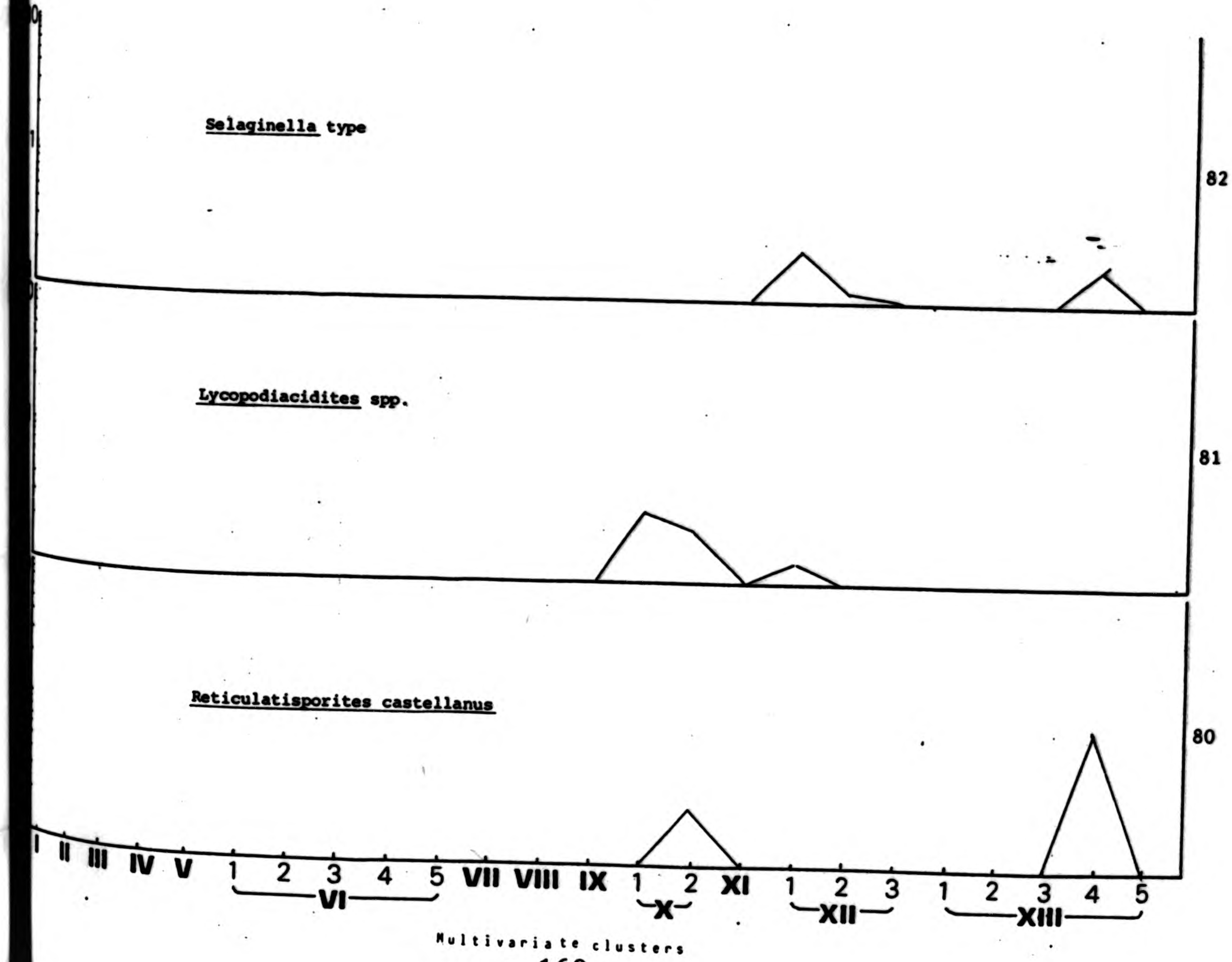


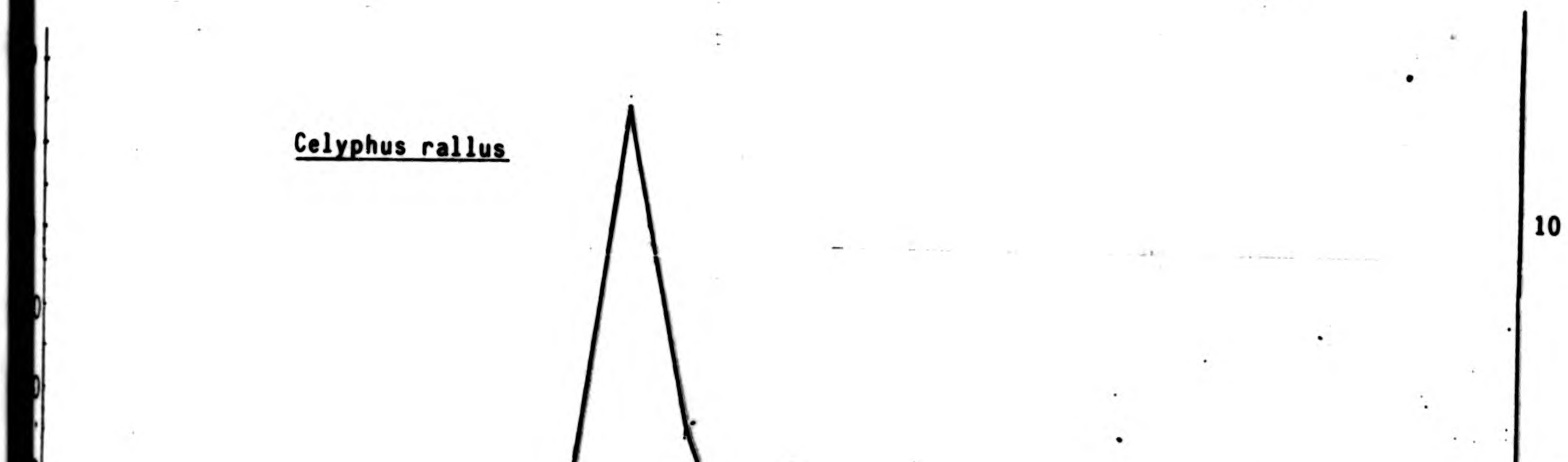
75



74


Densoisporites spp.
85
Stereisporites antiquasporites
84
Januasporites sp.
83
10
1
.1
I II III IV V 1 2 3 4 5 VII VIII IX 1 2 XI 1 2 3 1 2 3 4 5
VI
X
XII
XIII
Multivariate clusters


Selaginella type
82
Lycopodiacidites spp.
81
Reticulatisporites castellanus
80
10
1
I II III IV V 1 2 3 4 5 VII VIII IX 1 2 XI 1 2 3 1 2 3 4 5
VI
X
XII
XIII
Multivariate clusters


Celyphus rallus
10
Tigrisporites scurrandus
87
Foraminisporis assymetricus
86
I II III IV V 1 2 3 4 5 VII VIII IX 1 2 XI 1 2 3 1 2 3 4 5
VI
X
XII
XIII
Multivariate clusters

being compared directly but taxa themselves can still be compared as the criteria are the same for each taxon. Generally speaking some quite good comparisons of P.F.T's between taxa can be made that probably indicate palaeoecological associations with the binary P.O.T. data in section 2.4 (e). In fact many of these associations are similar to those seen with the binary data. However attempts at overlapping taxa showing similar traces on the same graph has been tried but has been found to be fraught with difficulties. The multivariate cluster groups are generally poorly defined, and when they are well defined it is usually on cluster groups with only a few, or one, sample. It is not worth making detailed and often tentative comparisons for the sake of the small amount of additional palaeoecological information that would be yielded. It is possible that this could be done using a small computer program, but this is outside the scope of the present study. Text-figs. 2.13 1-87 are included, in order that cursory comparisons between taxa can be made, and also to show the nature of this data. Not many particularly significant conclusions can be drawn from them on their own.

Further comments on the palaeoecology of particular spore/pollen taxa are reserved for section 3.4 in the next chapter, where the binary and multivariate data are combined in the light of inferred palaeoecology of the defined palynofacies.

2.5 (f) Summary

A poorer separation of rock samples into distinct cluster groups, with less obvious independant association of other parameters is seen with the multivariate cluster groups, compared with the binary ones. Large groups characterised by regularly occuring taxa eg. Cicatricosisporites spp. in group VI, Celyphus rallus in group VII and Gleicheniidites spp. in group XIII, are to be seen. However even within these large groups and subgroups, characteristics or recurrent associations of kerogen type, lithology and fluorescent algae are to be seen. Certain groups that contain only one or a few taxa, eg. groups I-VI stand out in the same way they did in group J of the binary analysis, as dry uplifted palynofacies close to the hinterland. Group VI is generally freshwater and group VII represents abundant Celyphus rallus. Groups VIII, IX and XI comprise only few samples that may represent specialised 'local' plant associations. Group X is marine influenced, while group XII isa highly cosmopolitan group comprising 50% of the data set. Group XIII is likewise cosmopolitan in its palaeoenvironmental inferences.

CHAPTER 3

PALYNOFACIES AND PALAEOENVIRONMENTS OF THE WEALD CLAY

3.1 GENERAL INTRODUCTION

In this chapter all of the data so far described, multivariate and binary cluster analysis of spore/pollen assemblages together with kerogen types, fluorescent algae and lithological information will be pooled to give an overall summary of depositional environments. A broad palaeoenvironmental reconstruction of a portion of the Weald Clay basin will be attempted based upon the available evidence placed within the latest sedimentological regime as depicted by Allen (1975, 1976, 1981). This reconstruction (Enclosure 17) will try to include all of the depositional sites that could account for the range of palynological assemblage types that have been so far seen in this study. No particular horizon within the Weald Clay or geographical position other than the northern limb of the present Wealden anticline is intended. The diagram will be distorted only in showing all of the inferred depositional sites together for comparison as an idealised view representing the whole basin. Remarks on specific geographical sample locations will be confined to a later section (3.4).

3.2 COMBINED ANALYSIS OF BINARY AND MULTIVARIATE DATA

One way of combining the multivariate and binary data is to place the sample sequences produced by both methods along the x and y axes of a graph and then to plot the coinciding positions of each sample. In this way it is possible to make a spatial separation of samples that is proportional to the associations between samples designated by both these methods simultaneously. There are two ways of doing this, firstly by spacing the samples equally along each axis as in enclosure 10. Samples in greatest proximity (but within individual boxes that define cluster group limits) are obviously those most closely related. In this way equal importance can be given to each sample whether it is part of a large cluster group or forms one on its own. Associations between samples at any coefficient of association can be viewed by drawing a circle to include as many samples as necessary for stressing any particular associations. The diagram also provides plenty of space for writing down assemblage characteristics however small the cluster groups are. A second way of drawing this diagram is to space the cluster groups (rather than the samples) equally along each axis. This has been done on enclosure 11. Binary clusters are equally spaced at the 0.711 level (10 clusters), multivariate clusters at the 4.0 (24 clusters) level. In this way samples are grouped on the same spot if they fall within the same cluster group limits by both binary and multivariate methods. On this diagram the number of samples coinciding at each point has been denoted by circles of diameter proportional to the number of samples at that point. A list of actual samples at these points is provided on enclosure 12. This diagram shows very well the fairly even spread of samples throughout groups A to J by binary analysis but the disproportionate grouping of samples into groups VII and XII by multivariate analysis. It is interesting to note that some cluster groupings coincide quite well between binary and multivariate analysis, eg. group A is largely grouped within group XII-3 but group J is spread throughout groups I to XIII.

Palaeoenvironmental parameters of the palynofacies grouped by this diagram can be defined when the spore/pollen, kerogen, fluorescent algal assemblages and lithological characteristics are analysed for each group. This is too much data to put on one diagram so a series of diagrams has been produced; enclosure 13 with spore/pollen data; enclosure 14 with kerogen data; enclosure 15 with fluorescent algal data and enclosure 16 with lithological data. Obviously it is not possible to display all of the data at one point so boxes in available spaces containing the data are labelled to their respective palynofacies group at their coincident points. Data for samples at each point has been listed in the order defined by the binary analysis as this provided a better correlation of spore/pollen assemblage to kerogen type, fluorescent algae and lithology than the multivariate analysis. By keeping samples in this order then subclusters at a lower coefficient (eg. at coefficient 3.0, 36 cluster level) can be recognised. Enclosure 10 will also be useful in this respect. In describing each of the palynofacies groups I have decided that the most straightforward systematic way is from the point of view of the binary presence/absence cluster groups as they provide a more even sample separation and appear to be more palaeoenvironmentally significant. Thus multivariate separations within group A will be described followed by those in group B etc.

Most groups are represented by a few or only one sample, making them less significant from a palaeoenvironmental point of view, even though they are quite clearly defined. Most of these may represent important palynofacies that are only limited in size (ie. number of samples) by the comparatively small number of samples in this study. Given a lot more samples they would become numerically more important. Some of the samples that form isolated palynofacies such as those in groups I - V contained notably very distinctive assemblages at the time of original examination on the microscope. A palynofacies that is repeated throughout a rock sequence (ie. represented by numerous samples from various horizons and localities) must be of palaeoenvironmental significance. In theory, every palynofacies assemblage can be explained in terms of a palaeoenvironment once enough is known about particular spore/pollen species and assemblages.

3.3 THE PALAEOENVIRONMENTS OF WEALD CLAY PALYNOFACIES GROUPS

3.3 (a) General palaeoenvironmental setting

Allen (1981) describes the argillaceous phases of the whole Wealden Series as broadly comparable, ie. those within the Hastings Beds (Durlston, Wadhurst and Grinstead Clays) were laid down in a similar 'mudplain' environment as the Weald Clay. The following quote is relevant (Allen, 1981 p.394): "On the massifs, the provincial model portrays lower relief, warm climates, lighter episodic rainfall and vegetation still liable to extensive fires. In the basin the scene is a watery mudplain with occasional sandy channels and numerous semi-permanent lakes, lagoons and bays. Leaks in the coastal defences were frequent from the first, and major breaches developed during the upper Wealden." The argillaceous formations are considered to have accumulated in brackish lagoons and bays of the 'pro-fan' facies distal to the meanderplains where arenaceous deposits, during dominant periods of deposition of the latter, were laid down. During periods when the source massif was of low relief and rainfall low (Allen, 1975, 1981; Batten & Sladen, 1984) such as during Weald Clay times, the reduction in bedload in the streams lead to transgression of the argillaceous deposits over the whole basin. Sedimentary facies included "mud-filled sloughs, muddy scour-hollows....sand-filled runnels....and high-sinuosity channels all traversing lacustrine and lagoonal clays." (Allen, 1981). Brackish marine phases within the Wealden are well known (Anderson, 1967 ; Kilenyi and Allen, 1968; Allen, 1981; Batten, 1981) and evidence from Allen(1975, 1981)indicates that this came by transgression of the boreal sea from the north and northwest and possible from the Tethys to the south, as well as locally raised salinites within the basin by evaporation (MacDougall & Prentice,1964). Evidence exists that some depositional channels within the Weald Clay carried freshwater, others brackish and that some were tidal (Allen, 1981 p.388). Red mottling and oxidation of ironstones Allen(1975, 1976, 1981) indicates that most of the facies except the black laminated ostracod shales, could be exposed and soils develop on them supporting herbaceous pteridophytes and lycopods (Batten, 1974; Lake & Thurrell,1974).

All of these factors are particularly important for consideration in drawing a 'base'. palaeogeography for the palynofacies distinguished in this study, and a wider summary of them and the regional picture has already been provided in the introduction (chapter 1). The palaeoenvironment diagram (enclosure 17) has been drawn with a high sinuosity stream extensively braided in places draining into a 'high salinity lake' that can be regarded as the most proximal part of the transgressive boreal sea. To the right of the main channel on the diagram some older braided areas now abandoned and left at successively higher levels (Willams & Rust, 1969) provide areas exposed long enough for soils and plant communities to develop. To the left of the channel the environments are shown as wetter and more marshy with many small ponds, lakes and minor channels as well as tidal channels. Along the strand-line of the high salinity lake a number of environments are shown that would have been frequently influenced by salt water. The diagram is foreshortened distance-wise from hinterland to strandline.

Additions to this 'base' and the palynofacies that I consider are palaeoenvironmentally significant will be described and added to this model in the next section. To avoid confusion and repetition this will be done from the viewpoint of the binary cluster groups ,working from A to J ,and for reasons already mentioned (Section 3.2). In following this next section,close reference is required to enclosures 13, 14, 15 and 16 to the 'base' palaeogeography (enclosure 17). The palynofacies have been numbered from 1 to 75 for rapid reference,and to avoid confusion with other numbers these will always be underscored when referred to, and for shorthand will usually be called 'facies' rather than palynofacies.

3.3 (b) Description of the 75 palynofacies and palaeoenvironmental conclusions

(i) Palynofacies and palaeoenvironments within group A.

Palynofacies *5*, coinciding with group XII-3 comprises the largest number of group A samples. Evidence presented in section 2.4 (b) suggested that group A is the most marine of all, particularly subcluster A-a which contains consistent formaniniferal linings. The strong correlation of amorphous liptinite, Segmented Algatype 1 and Laevigate Algal Cysts (particularly in A-a) must indicate the marine origin of these. The high incidence of limestones (mainly *Neomiodon* shells) together with low fusinite percentages here indicates that the environment was generally far removed from sources of clastic supply and influx of hinterland material. In my opinion this is all further evidence to invoke a high salinity lagoon or large lake that was probably directly connected to or part of the transgressive boreal sea of Allen (1975, 1976, 1981) This particular assocation of generally marine parameters is defined by the common occurrence of *Cerebropollenites mesozoicus* and *Vitreisporites pallidus* which may have been capable of growing partly submerged in brackish or even seawater. They cannot have been washed into this environment as they would be important in freshwater palynofacies where this is not the case, and such inwashing would be accompanied by other taxa as well as raised fusinite content. Small offshore islands may have provided additional habitats for these taxa. Other taxa that are notably common here are *Leptolepidites* spp., *Verrucosisporites* spp., *Concavisporites jurienensis*, *Pilosisporites notensis* and *Cicatricosisporites hughesi*. These taxa can be common in other palynofacies that are more freshwater so their palaeoecology may be more complex. However occurrences in other facies will be dealt with in the appropriate section. From their occurrence here it does seem that they may have been able to tolerate raised salinities if they have not been unduly affected by local reworking from upstream. Subcluster A-a, that contains the most consistent foraminiferal linings, also contains significant occurrences of *Klukisporites* sp., *Costatoperforosporites* spp. and *Matonisporites phleberopteroides*. These species are also common in other more freshwater palynofacies but may also have been associated with more saline conditions. Subcluster A-b that contains rare foraminiferal linings, indicative of less marine influence than A-a does include one sample (W.94) with indigeous marine dinocysts of *Muderongia simplex*. However it also contains more prominent *Contignisporites* sp.and *Celyphus rallus* that are thought to be distinctly more freshwater forms and will be further discussed later. Cluster group XII contains no outstanding abundances of any taxa, but subcluster XII-3 contains more prominent *Cyathidites* sp., *Cicatricosisporites* spp. and *Classopollis* spp. than the rest of cluster group XII. Much discussion about *Classopollis* (Hughes,1973; Batten,1974, 1976; Oldham,1976; Alvin,1982) has centred on the habitat of the parent plant of this gymnosperm pollen, whether upland or 'mangrove' in location. More recently however, (Francis, 1983; Chaloner, 1984) that *Classopollis* represents a variety of plants. The bottom has fallen out of this discussion with the realisation that this genus includes a large number of species that probably thrived in a wide range of habitats. However the generally increased proportion of *Classopollis* spp. and lower bisaccates within subcluster XII-3 where most of cluster group A are to be found (ie. facies 5) supports a marginal marine environment for at least some Classopollis plants (see Batten,1974).

Facies 3 and 4 within subcluster XII-1 and XII-2 contain generally more prominent bisaccates than Classopollis spp. in contrast to facies 5, possibly indicating a greater influence of transportation as if nearer to the outlet of a channel. Facies 3 as well as including Leptolepidites spp.,Cerebropollenites mesozoicus and Verrucosisporites spp. that are particularly characteristic of group A also shows prominent Lycopodiumsporites austroclavitides, Foveotriletes sp., Coronatispora valdensis, Sestrosporites pseudoalveolatus and Cooksonites sp., freshwater taxa that may be further evidence of transportation. Facies 2 as well as including the characteristic group A 'marine' taxa also includes a specialised assemblage of Regresporites sp. A and Lycopodiacidites spp. that will be further discussed under part (ix) in the context of saline influence. Facies 1 lies within group VII where Celyphus rallus is extremely abundant. It is interesting to note that facies 1 comprises only one sample, and that this one sample does not exhibit a 'normal' group A kerogen or fluorescent algal assemblage. This very likely indicates significant but localised transportation of a more freshwater assemblage into a marine influenced palaeoenvironment. It also contains a richer assemblage of Apiculati than elsewhere seen in group A, supporting this inference. Celyphus rallus will be further discussed in part (ii) and (iv) but this one sample (W.82) does provide evidence that this anomolous microfossil (Batten, 1973, 1982) is not associated with particularly raised salinities. Facies 7 is probably in the same category as facies 1 in being a minority transported assemblage of freshwater spore/pollen taxa and kerogen within a marine influenced environment. Facies 6 contains a transported spore/pollen assemblage including good taxonomic variety of Apiculati and Muronati with Gleicheniidites spp.though its kerogen and fluorescent algae are typical of group A.

(ii) Palynofacies and palaeoenvironments within group B.

A large number of samples are categorised here, mostly within three large facies groups, 10, 15 and 16. Evidence already presented in section 2.4 suggested a lagoonal and/or lacustrine palaeoenvironment for cluster group B. (This was partly based on the prominence of fine amorphous grey organic matter that would have been winnowed away by the slightest current associated with a channel). Such a depositional environment is located in proximity to the marine facies of group A as amorphous liptinite, Laevigate Algal Cysts and Segmented Alga type 1 are also common in group B. Both groups A and B also show low records of Auriculati, Cingulati, Hilates and Appendicisporites spp. and limestones are relatively common in both. These various parameters are partly independent of one another in group B. For instance limestones and amorphous liptinite similar to group A are more prominent in facies 16 than 15 while Laevigate Algal Cysts and Segmented Alga type 1 characteristic of group A are more common in facies 15 than 16. In both facies 15 and 16 the portion of each that comprises subcluster B-3 contains more prominent Laevigate Algal Cysts. The absence of distinctive species within group B together with the generally high number of taxa present in low occurrence categories (see section 2.4 (d)) suggests that a local flora is not represented as would be expected in an environment that is fully waterlogged, but that pollen and spores are trapped from a wide range of surrounding habitats in low numbers.

Facies 16 shows the greatest overall assemblage similarity to cluster group A. Both contain prominent amorphous liptinite, have generally rare fluorescent algae except for Laevigate Algal Cysts and contain prominent limestones. This similarity probably reflects raised salinities within facies 16, though there is no direct evidence for this such as the presence of foraminiferal linings or indigenous dinocysts. However two of the samples, W.104 and W.98 do contain fish osteocytes. Facies 16 is probably a lagoon or bay partially open to the sea, containing brackish but not fully marine water (see enclosure 17.). Though not as saline as group A facies, it represents the highest salinities within group B. Facies 16 falls within subcluster XII-3 (similar to facies 5) that contained more prominent Cyathidites spp, Cicatricosisporites spp. and Classopollis spp. but reduced bisaccates. This is further evidence of an association between facies 16 and cluster group A (remembering that facies 5 contains the lion's share of group A samples). If prominent Classopollis is equated with raised salinities then this further supports evidence that facies 16 is the most saline palaeoenvironment within group B. It is interesting to note that facies 16 includes a number of samples falling into subcluster c-ii within subcluster XII-3. These samples contain particularly prominent Leptolepidites spp, Cicatricosisporites hughesi but rarer Gleicheniidites spp. . Leptolepidites spp. and C. hughesi have already been mentioned in the higher saline context of group A and their association here with reduced Classopollis spp. may indicate a facies association of these taxa where normally common Classopollis spp. are palaeoecologically excluded.

One sample within facies 5 (W.99) falls within XII-3-c-ii and this sample contains a much higher fusinite percentage than any other group A sample, and does not contain particularly prominent laevigate algal cysts. In my opinion this sample represents a transported facies 16 kerogen and algal assemblage. The abundance of fusinite in facies 16 is a particular characteristic. The palaeoenvironment must have been in proximity to the outlet of a channel which conveyed this hinterland material. Rather raised current energy in this case might account for the distinct lack of fine amorphous grey organic matter that is normally a characteristic of group B. However in this situation one would expect greater clastic input tending to 'dilute' the limestones. Perhaps this can be partly seen in samples W.29 and CH/P.54 that are of sandstone and siltstone respectively and have particularly high fusinite percentages.

The group of subcluster B-3 samples in facies 16 (some of which include some XII-3-c-ii samples already mentioned) show particularly high Laevigate Algal Cysts. This distinct similarity with group A must indicate a marine association here that is different from other parts of facies 16. Subcluster B-3 is characterised by particularly prominent Cicatricosisporites hughesi, Cerebropollenites mesozoicus and Pilosisporites trichopapillosus. Cicatricosisporites hughesi and C. mesozoicus have already been mentioned under group A as being particularly representative, so these taxa must confirm the marine association. Appendicisporites spp.that are common in subclusters B-1 and B-2 are very rare or absent in group A and B-3, indicating a further link. Likewise the Auriculati (except Ischyosporites spp.) are very rare or absent in groups A and B-3, but of minor occurrence in B-2 and B-1. Pilosisporites notensis was found to be prominent in group A and the prominence of *P. trichopapillosus* here may indicate a saline association of this species also. Both these taxa are morphologically very similar and could represent the same parent plant.

Facies *15*, which shows particularly prominent fine amorphous grey organic matter contains distinctly less prominent amorphous liptinite and limestones than facies *16*. These two parameters, being distinct group A characteristics, probably indicate reduced salinity within facies *15* compared to facies *16*. The great prominence of *Veryhachium* acritarchs within facies *15* which are certainly aquatic in origin, must be a function of this reduced salinity. It can further be noted that facies *15* lies within subcluster XII-2 where bisaccates are more prominent and *Classopollis* spp. and *Celyphus rallus* less so than other parts of group XII. If *Classopollis* spp. does indicate raised salinities as has been suggested, then this would support a less saline conclusion for facies *15* than *16*. It can further be noted that facies *15* shows a large number of samples that fall into a particular subcluster group within XII-2-i (see enclosure 8). These samples (HF8, BG22, BG21, LF2, W35, W40, CH/P7, W55) show very distinctly reduced *Classopollis* spp. and high bisaccates. (The Muronati, especially *Cicatricosisporites* spp., as well as *Tsugaepollenites* spp. and *Celyphus rallus* are markedly reduced in percentage occurrence also). Altogether six out of these eight samples occur within facies *15*. In my opinion this is further evidence of a less saline palaeoenvironment for facies *15* than facies *16*, assuming that bisaccates are mainly derived from the hinterland massif and *Classopollis* spp. are associated with raised salinities (see also Batten, 1974). Raised percentage of bisaccates in this instance is not particularly significant. The bisaccates are particularly well equipped for wind dispersal and are produced in great numbers. They probably get into most depositional environments in approximately equal numbers, which is why they appear in increased percentage in marine deposits where water transported spores that may be produced much nearer the strand line, are less easily transported. In the particular context of the Weald Clay, an apparently increased percentage probably only reflects a diminished representation of Classopollis spp., which can also be a major component of the spore/pollen assemblage. Facies 15 also includes a definitive group of B-3 samples similar to facies 16, that show important percentages of Laevigate Algal Cysts. These samples also contain rather more prominent limestones than the rest of facies 15. This must indicate the same marine influence, accompanied by the same characteristic spore/pollen taxa as previously mentioned. The overall palaeoenvironment represented by facies 15 is therefore a slightly saline lake with indigenous Veryhachium spp. where the energy was much reduced as indicated by the prominence of fine amorphous grey material (probably formed by in situ decomposition of organic material in the waterlogged conditions). A general lack of disturbance and alluvial influx is reflected by the generally much reduced fusinite percentages within this facies. The large number of samples (15) falling within this facies indicates how widespread it must have been in the Weald Clay basin. Facies 13 and 14 both contain prominent fine grey amorphous material and are probably a part of facies 15.

Facies 17, 18 and 19 fall within cluster group XIII where Gleicheniidites spp. are abundant and the Apiculati and Muronati are variously abundant. They mainly comprise coarser grained lithologies such as sandstone and siltstone and this together with with the prominence of freshwater taxa and fusinite suggests that they may represent rare small channels entering the slightly brackish lagoons. Fluorescent algae are rare probably indicating the locally raised energy. Facies 10 comprises a large group of samples within cluster group B that fall within cluster group VII, where Celyphus rallus is very abundant. Facies 10 is almost identical to facies 15 in kerogen composition, fluorescent algal assemblage and lithology. (The apparently greater percentage of palynomorphs in facies 10 than 15 only reflects the great prominence of Celyphus rallus as a bulk kerogen component). It is interesting to note that facies 10 shows a great number of subcluster B-3 samples. These as previously described, contain prominent group A 'marine' spore/pollen taxa. However in the case of facies 10 these B-3 samples are not accompanied by notably raised percentages of Laevigate Algal Cysts as was seen with facies 15 and 16. However Spiny Tetrads are more prominent. This may indicate that a more marine connotation is not applicable in this case. Amorphous liptinite is less common in facies 10 than 15 (present in one third of the samples rather than one half) and facies 10 is almost devoid of Segmented Alga type 1. In my opinion all this evidence is enough to suggest that facies 10 is distinctly less saline than facies 15. Other than these differences facies 10 bears great resemblance in the proportion of Veryhachium spp. (only slightly less prominent than facies 15) and Colonial Spiny Masses, Spiny Tetrads and Minute Leiospheres, as well as prominent fine amorphous grey organic matter to facies 15. A lacustrine environment similar to facies 15 but with lower salinity is therefore invoked for facies 10. It can be noted that all of the samples in facies 10 fall into subcluster VII-c which contains the most prominent Celyphus rallus itself as well as the poorest variety of spore/pollen taxa within cluster group VII. This is in line with the known characteristics of cluster group B as already described. Celyphus rallus can be common in other facies groups, and its position there will be discussed under the appropriate section. However its prominence within facies 10 (lagoonal, slightly brackish) and other aquatic freshwater facies, and its absence from marine influenced facies, suggests that it is a freshwater taxon. The general absence of cluster VII samples within group A, the 'marine' group, has already been discussed in the previous section, when evidence presented for the single sample (W82) falling into this category suggested that it was a reworked assemblage. Celyphus rallus is sufficiently commonly occurring to be present in most samples, so definitive statements concerning its palaeoenvironment are mostly only applicable where it is very abundant. It is possible that some other palaeoenvironmental parameter than salinity plays a part in the presence of 'blooms' of Celyphus rallus, for instance pH. or availablity of trace elements or other nutrients. Batten & Van Geel, (1985) suggested that alkalinity in the palaeoenvironment may correlate with an abundance of this palynomorph. However, the present data indicates that Celyphus rallus is an aquatic freshwater taxon, but its abundant presence in some aquatic freshwater environments but not others cannot yet be explained (see also discussion under section 3.4). Facies 10 with its characteristic kerogen and algal assemblage has been placed on the facies diagram taking into account all of the palaeoenvironmental evidence discussed (enclosure 17).

Facies 8 and 9 show greater taxonomic variety of freshwater spores and pollen and probably represent transportation. Facies 11 is based on prominent Cooksonites sp. which may have been a rare form occasionally associated with the various lacustrine environments described. Facies 12 is based on the abundance of Cicatricosisporites psuedotripartites in one sample (CH/M11) which could therefore represent a restricted local stand of plants sometimes associated with the lakes. The lacustrine environments of group B represent a large part of the Wealden palaeoenvironment being 25% of all the samples in this study.

(iii) Palynofacies and palaeoenvironments within group C

This group contains one facies, facies 20. This coincides with cluster group VII, the 'prominent C. rallus' cluster group. However all of the samples in facies 20 are barren of palynomorphs, and are clustered here where they resemble assemblages dominated by one taxon, with low percentage frequency of all others. These samples all contain particularly prominent amorphous liptinite and limestones are moderately prominent. These parameters cannot really be equated with group A where they formed part of a marine assemblage,as there is no spore/pollen assemblage to compare. Several of these limestones contain the freshwater gastropod Viviparus. Alkaline conditions within the palaeoenvironment may have resulted in the destruction of spores and pollen.

(iv) Palynofacies and palaeoenvironments within group D

This group of samples is characterised by the overall prominence of Foraminisporis assymetricus together with various other taxa as aleady described. The general evidence already presented under cluster group D (section 2.4 (b)) indicated that the environment was distinctly freshwater. Aquatic indicators such as abundant Celyphus rallus and fluorescent algae are generally quite rare. This is well illustrated by facies 24 comprising only one sample (W13) in cluster group VII (the abundant Celyphus rallus group) and this contains abundant fine amorphous grey organic matter (very rare for group D) suggesting that it is a group D assemblage reworked to a 'facies 10' type environment or facies 10 kerogen reworked into a group D palaeoenvironment. Facies 26 contains the greatest number of group D samples (six). It bears some similarity to facies 15 in kerogen type but unlike facies 15 it contains Segmented Alga type 2 and Incertae Sedis type 1 instead of prominent Veryhachium spp., and it shows only very rare limestones. Despite the similarity in kerogen, the presence of amorphous grey organic matter is much less pronounced than in facies 15 and two samples (HF.9 and HF.4) that contain abundant Laevigate Algal Cysts and amorphous liptinite are from the upper Weald Clay. (This may indicate that some reworking occurred at this time, with previously deposited facies 10 assemblages reworked during the transgression, and redeposited with marine derived material). This similarity probably only reflects proximity of facies 15 rather than a similar lacustrine environment, as aquatic influences are so diminished in group D. Incertae Sedis type 1 and Segmented Alga type 2 are particularly characteristic of the Beare Green samples. They may have favoured some unknown environmental parameter and probably thrived in small isolated ponds where conditions did not favour Veryhachium spp.. Facies 26 contains more samples falling within subcluster D-2-b where Distaltriangulispora sp. was more prominent.

Facies 27 shows a general similarity in kerogen assemblage to facies 16, with abundant fusinite but rare fluorescent algae. This may also indicate proximity to this environment and the implied influence of a higher energy current bringing in this hinterland material and resulting in coarser grain size (siltstones in Pl.1 and CH/P.32) Facies 23 lies within subcluster VI-5 where taxonomic variety is good, Classopollis spp. and bisaccates are rare and Gleicheniidites spp. is moderate in percentage. Celyphus rallus and Veryhachium spp. are slightly more abundant here than in the rest of group D indicating greater aquatic influence, probably as isolated ponds favouring *Baltisphaeridium* spp, also. Most samples in facies 23 fall into subcluster VI-5-a where *Acanthotriletes varispinosus*, *Reticulisporites* spp., *Foraminisporis* sp. and *Cingulitriletes* sp. are particularly prominent. These taxa may therefore have favoured damper ground. Subcluster D-2-a is more prominent here indicative of greater abundance of large trilete spores. Facies 21 contains the single sample CR.2 already described under cluster group V as containing prominent *Leptolepidites* spp., *Stereisporites antiquasporites*, *Acanthotriletes varispinosus* and abundant Cingulati. This is thought to represent an *in situ* association of these taxa. It also falls within subcluster D-1 where *Cicatricosisporites minor*, *Appendicisporites trichacanthus*, *Krauselisporites* sp. and *Couperisporites* sp. are more important. Facies 28 lying within subcluster XIII-1 also contains the 'D-1' assemblage, but being a Hurlands Farm sample (HF.1) shows marine influence in the form of foraminiferal linings. (The special case of Hurlands Farm samples will be discussed in section 3.4) Facies 22 comprises one sample LF.8 showing the varied 'group VI-1' spore/pollen assemblage. Facies 25 is similar with the varied 'group XII-1' assemblage. Both are generally dry uplifted facies.

Drier uplifted areas of the mudplain that I regard as a likely palaeoenvironment of group D palynofacies may have been areas of braided channels (in proximity to group B palynofacies) now abandoned and rarely flooded, after the manner described by Williams and Rust (1969) (see enclosure 17).

(v) Palynofacies and palaeoenvironments within group E

Group E bears some resemblance to group D in having two main facies within subcluster VI-5 and cluster XII. Group E assemblages contain abundant fusinite, palynomorphs and algal cysts in the kerogen assemblage with very rare amorphous material, and in my opinion they are associated with the drier uplifted parts of the braidplain similar to group D facies. Groups D and E are the most closely related binary cluster groups of all, they are the first to be grouped together by the dendrogram.

Facies 34, containing nine samples, lies within subcluster XII-3. It shows very little evidence of marine influence and can be divided into two 'subfacies'. One of these 'subfacies' is defined by very low fluorescent algal occurrences and falls within subcluster E-3-b. This subcluster is devoid of Acanthotriletes varispinosus Microthyriacites sp. and Contignisporites sp. and contains only rare Undulatisporites undulapolus and Celyphus rallus. These taxa are all particularly common in the rest of facies 34 (ie. subcluster E-1) which contains much more abundant fluorescent algae. These algae are Micrhistridium, Pediastrum and Scenedesmus that by analogy with present day forms are distinctly aquatic freshwater taxa. The notable occurrence of Vitreisporites pallidus and Cicatricosisporites augustus in this subcluster indicates that they too favour damper ground here. These taxa have already been mentioned in the context of Groups A and B that represent markedly low lying and damp palaeoenvironments (though with raised salinities).

The greater taxonomic variety including an abundance of the above mentioned taxa suggests that these favour slightly damper soils where plant communities were richer and small ponds may have existed to support the freshwater algae. It is interesting to note that Acanthotriletes varispinosus was concluded as favouring damper ground in facies 23. Facies 30 is similar in kerogen type to facies 34 but it has a uniform fluorescent algal assemblage that is not divisible into subfacies for subcluster E-3-b and E-1|E-2|E-3-a.

This difference cannot yet be explained. This facies falls within subcluster VI-5 where *Cicatricosisporites* spp.are most abundant. Several samples within this facies fall within subcluster VI-5-a. The palaeoenvironment of this facies is probably, therefore, closely similar to facies 23, but it must occupy a part of the mudplain where group E taxa are dominant. These are *Microthyriaceae* sp, *Rugubivesiculites* sp, *Reticulisporites* spp, *Lycopodiumsporites* spp, *Cicatricosisporites australiensis*, *Cicatricosisporites annulatus* and *Undulatisporites undulapolus*. (In section 3.4 it is noted and discussed that groups D and E have quite different locality characteristics, ie. frequencies of occurrence of these groups in the various sampled sections of this study).

Facies 29 probably represents a local *in situ* assemblage particularly characterised by *Cicatricosisporites minor* (ie. characteristic of cluster group IV). It is interesting to note that *C. minor* was found to be characteristic of subcluster D-1 that included the isolated facies 21 (sample CR.2) that also had the characteristics of an *in situ* assemblage of the drier mudplain. Facies 31 comprises only two samples that fall into cluster group VII, the common *Celyphus rallus* group. As with group D, this must reflect the rarity of aquatic conditions here. However these two samples are slightly anomalous in being almost completely barren of fluorescent algae, except for moderate *Botryococcus* in LF.6, that are normally strongly associated with *C. rallus*. This was also seen to be the case with facies 24 in group D, and it may reflect the very restricted aquatic freshwater conditions. In these circumstances *Celyphus rallus* may deoxygenate the water rapidly, and be capable of surviving in comparatively anaerobic conditions that *Veryhachium* spp. cannot tolerate, as a possible explanation. This situation is probably quite rare as so few samples occur in these two facies. Both facies *24* and *31* fall within subcluster VII-c, that part of the group where taxonomic variety of spores and pollen is lowest, but *Celyphus rallus* is most abundant. Facies *32* and *33* represent a few samples falling into the generalised cluster group XII. Facies *35* includes two samples (both W.60 samples are grouped here, despite one of them being very rich in *Celyphus rallus*). This facies is within group XIII, the rich *Gleicheniidites* spp. multivariate cluster group, and subcluster 4 where *Reticulatisporites castellanus* and *Costatoperforosporites* spp. are prominent. This is accompanied by common *Veryhachium* spp., Laevigate Algal Cysts, Spiny Tetrads and Segmented Alga type 2 with Incertae Sedis type 1 in sample BG.33. Fusinite percentage is very low and fine grey amorphous material is common in W.60, that is also a prominent limestone. The palaeoenvironment was probably lacustrine and isolated from a channel. Facies *36* by contrast shows a much greater fusinite percentage and contains only rare fluorescent algae. It lies within subcluster XIII-5-v where *Cicatricosisporites* spp. are much more prominent. This is probably a channel facies.

(vi) Palynofacies and paleoenvironments within group F

Facies *45* within this group contains 17 samples, the largest number amongst the whole data set, coinciding with subcluster XII-3. This subcluster contains generally more prominent *Cyathidites* sp., *Cicatricosisporites* spp. and *Classopollis* spp. but lower bisaccates overall than the rest of cluster group XII. Its cluster group F characteristics include the presence of *Celyphus rallus* in all samples together with common *Pluricellaesporites*, *Concavissimisporites* spp., *Pilosisporites* spp., *Aequitriradites* spp., *Schizosporis* spp., *Appendicisporites jansonii* *Trilobosporites bernissitartensis*, Ischyosporites spp, Calamospora type and Foraminisporis spp..

Facies 45 is a distinctly homogeneous group as regards kerogen type, fluorescent algae and lithology with no obvious separation into subfacies. There is also no evidence of subclustering of spore/pollen assemblages within group XII-3, or group F. The fusinite percentage is uniformly high within this facies while fluorescent algae are distinctly low in number.

All of this evidence suggests that the depositional environment was well drained, freshwater and non-aquatic with a mature plant community fairly proximal to the hinterland represented by the above mentioned spore/pollen taxa. However, small but distinct marine influences occur in this facies, mainly as three samples falling into subcluster F-1-b that contains consistent foraminiferal linings and a few samples with amorphous liptinite and a few limestones. Subcluster F-1-b is also characterised by Leptolepidites spp. that has already been seen to correlate well with marine influenced facies of cluster group A. In my opinion the palaeoenvironment was dry and comparatively uplifted as most of the evidence suggests, but that marine influence from tidal channels and/or locally raised salinities by evaporation have affected this facies. Numerically 17 samples (the number in this facies) out of 211 (the total samples in this study) represents about 8% of the data set. This facies must have been fairly widespread if it covered 8% of the mudplain basin, where most of the facies so far described are about one quarter of this size.

Facies 41 defines a group of six samples falling into the common Celyphus rallus group VII category. This indicates a 're-vival' in aquatic conditions pertaining to this anomalous microfossil, that was notably rare in groups D and E, but common in group B. Fluorescent algae including Veryhachium spp., Granulate Algal

Cysts, Laevigate Algal Cysts, *Botryococcus* , Colonial Spiny Masses, Spiny Tetrads and Minute Leiospheres. This fluorescent algal assemblage is closely similar to facies 10. The kerogen assemblage is similar to this facies in a few respects also, in containing some fine amorphous grey material and rare amorphous liptinite but these are less than in facies 10. Facies 41 contains distinctly much greater fusinite percentage indicative of its more proximal position to the hinterland. It also contains most of its samples within subcluster VII-b that shows moderately good spore/pollen variety, with particularly prominent *Cicatricosisporites* spp., which supports this conclusion, as richer assemblages are to be expected on more stable drier ground where plant communites have had longer to mature. (All samples within facies 10 lie within subcluster VII-c where spore/pollen variety is very poor). A lacustrine palaeoenvironment within this 'proximal' zone is suggested. This is in keeping with evidence from facies 45 that suggested the palaeoenvironment was more low-lying and prone to tidal effects though facies 41 remained mostly freshwater (though evidence from facies 10 suggested that *Veryhachium* spp. and *Celyphus rallus* could tolerate very slight brackishness)compared to the uplifted less aquatic group D and E palaeoenvironments.

Facies 37 lies within cluster group IV similar to facies 29, containing prominent *Cicatricosisporites minor* and may be a generally *in situ* assemblage as already discussed. Facies 38 lies within subcluster VI-2 and contains prominent *Concavissimisporites* spp., *Acanthotriletes varispinosus* together with well represented Muronati. Evidence already presented suggested that cluster group F palynofacies were more low lying than group D and E, and it has also been suggested that *A. varispinosus* may have favoured damper ground. The spore/pollen assemblage in facies 38 may therefore represent a generally in situ plant association. Facies 39 lies within sub-cluster VI-3 and shows rare bisaccates, but moderate Classopollis spp. and Celyphus rallus. Fluorescent algae are very rare probably indicating that aquatic conditions were very restricted. Stagnant water, possibly depleted of oxygen by Celyphus rallus has been suggested as a possibility where the pool of standing water was very small. Facies 40 contains moderately abundant fluorescent algae together with fusinite and algal cysts as a bulk kerogen maceral. This indicates that the palaeoenvironment was generally damp and depositional influx from channels took place. However the local environment must have been comparatively low energy as indicated by the common occurrence of laminated mudstones. A freshwater lake, possibly prone to drying out is suggested as the depositional environment. Facies 42 (single sample W.75) is characterised by Cooksonites sp. that is normally very rare together with moderate Celyphus rallus and reduced Cicatricosisporites spp.(similar to facies 11 in group B). This sample contains limestone and fine amorphous grey material as well as prominent Veryhachium spp.. All of these links with group B suggest that this is a transported group F assemblage (ie. group B shows no distinctive species so the group F taxa remain the 'dominant' ones in the assemblage after transportation). Facies 43 (W.66) comprises one sample with a unique spore/pollen assemblage that is sufficiently distinct to encapsulate cluster group XI. It shows an assemblage of prominent Pilosisporites cf. notensis, Appendicisporites problematicus and Cedripites type. Amongst other taxa that are important are Leptolepidites spp. and Cicatricosisporites hughesi. Segmented Alga type 1 is present and this, in addition to these latter two taxa, may indicate some marine influence, as was deduced from facies 45. Facies 44 (two samples) is probably very close to facies 45 but contains much more prominent bisaccates. Facies 46 and 47 lie within cluster group XIII where *Gleicheniidites* spp.are prominent. Both show particularly high fusinite percentages suggesting a high energy channel, probably accounting for the lack of fluorescent algae. Both contain foraminiferal linings and are linked with facies 17 and 18 in subclusters XIII-1 and -2 respectively. Subcluster XIII-1 shows definitive foraminiferal linings and *Kuylisporites lunaris* (this subcluster also includes the marine sample HF.1 in cluster group D). Facies 46 and 47 may well represent tidal channels that are supplied with hinterland fusinite as well as marine indicators. *Sphaeripollenites psilatus* within subcluster XIII-2 may be associated with such channels.

Group F facies do seem to show consistent marine influence virtually throughout, despite other distinctly freshwater indicators all suggesting a tidal channel palaeoenvironmental influence, where evidence suggests the terrain was comparatively low lying but normally well drained.

(vii) Palynofacies and palaeoenvironments within group G

This group comprising only 13 samples is characterised by a particularly distinct spore/pollen assemblage. This consists of an association of *Costatoperforosporites* spp, *Distaltriangulispora* sp, *Foveotriletes* sp.and *Tigrisporites scurrandus*. The variety of spores and pollen in this group is very high, and 'palynomorphs' in general form a prominent total kerogen maceral. Facies 52 (five samples) shows prominent palynomorphs in the total kerogen assemblage, with two samples only, showing high percentages of fusinite. All of the samples (except W.20) fall within subcluster G-1 where *Concavisporites jurienensis* and *Acanthotriletes varispinosus* are notably more common. Fluorescent algae are present in small numbers, particularly Segmented Alga type 2 in the Beare Green samples. The freshwater algae Pediastrum and Scenedesmus are comparatively prominent with a few records of Veryhachium sp.. In my opinion this facies represents an ox-bow lake, overbank type assemblage. This was therefore normally away from influx of channel debris (ie. fusinite) except for the finest material carried in suspension that mainly comprised palynomorphs. Intermittently damp conditions may have favoured the particular in situ parent plants represented by the distinctive spore/pollen assemblage. Small ponds of standing water would have supported the distinctly freshwater algae. Facies 51 is similar to facies 52 but with more bisaccates. Facies 50 is also closely related with more prominent algal cysts (as part of the total kerogen) together with particularly distinct Scenedesmus and Botryococcus, probably indicating greater freshwater aquatic influence to the overbank deposit. Facies 49 comprises a single sample, W.30. This facies shows very distinct marine influence, with amorphous liptinite, Laevigate Algal Cysts and Segmented Alga type 1. This facies probably indicates marine influence via tidal channels that could very occasionally affect overbank deposits at particularly high stand. Facies 48 comprises two rich Celyphus rallus samples, here accompanied by prominent Veryhachium spp., and must represent more permanent aquatic conditions. Both fall into subcluster XII-a that has the greatest taxonomic variety, in keeping with the rest of group G. Facies 53 within subcluster XIII-5 with particularly prominent Gleicheniidites spp. together with fusinite may represent rather more channel influence to this general overbank, ox-bow depositional environment. Facies 54 may represent more stagnant overbank conditions with prominent fluorescent algae, amorphous and limestones developed, and is probably closely associated with facies 48.

(viii) Palynofacies and palaeoenvironments within group H

Next most closely related after groups D and E are groups G and H by the binary dendrogram. Group H only comprises two samples, W.36 and W.47 that were counted twice, so have counterparts,with Celyphus rallus and without,making a total of four samples. Both W.36 samples fall within group VII. This is unusual, and must indicate that prominent C. rallus is not the only criterion of group VII. These samples all fall within subcluster VII-a that have the greatest taxonomic variety, and it is probably this that is their associated characteristic. Group H can be regarded as part of group G, to which it is so closely related. Both samples contain Foveotriletes sp., Verrucosisporites sp. and Reticulisporites sp.. Facies 54 contains a very similar kerogen and fluorescent algal assemblage to facies 48 (which also falls within subcluster VII-a) ie, very low fusinite percentage and abundant Veryhachium spp. and Scenedesmus .. This facies must represent more permanent aquatic conditions within the overbank environment similar to facies 48. Facies 55 lies within sucluster XIII-4. It comprises the single sample W.47 ignoring its Celyphus rallus content. Subcluster XIII-4 is characterised by Reticulatisporites castellanus.

Group H samples could not be included in the statistical analysis of section 2.4(d) as being only two samples,taxa can only be at 0%, 50% or 100% occurrence.

(ix) Palynofacies and palaeoenvironments within group I

Cluster group I contains a large number of palynofacies that are very evenly spread throughout most of the multivariate cluster groups. There is no distinct grouping of samples around one or two palynofacies as with some other groups. This must immediately indicate that group I contains facies that span a very full range of Weald Clay palaeoenvironments or are influenced by these. This conclusion was broadly arrived at in section 2.4 (b) when it was apparent that no distinct theme of the kerogen and fluorescent algal assemblage could be discerned for group I as a whole. The number of totally absent taxa is particularly low in this group with only group B having a lower number (text-fig.2.7ii). When corrected for number of samples (text-fig. 2.7 iv) group I is shown to have one of the lowest number of total absences, in common with group J. In common with group B, group I has one of the highest numbers of rarely occurring taxa, (category $\geq$ 1%, $\leq$ 9% occurrence, see text-fig. 2.7 iii). However unlike group B, group I has one of the highest frequencies of taxa in the higher occurrence categories (text-figs.2.7 iv, 2.9 i & ii). This general high taxonomic variety in both the high and low occurrence categories is further evidence of the wide range of palaeoenvironments that are represented here. The characteristic spore/pollen taxa of this group are 'dominant' because of their variety and abundance. Even when reworked or transported from their source to environments nearer the strand line, they are still of sufficient prominence to 'override' the local spore/pollen input, that nearer the strand line is much sparser in variety. Thus an apparent spread of group I facies across a broad range of environments is probably more a function of group I spore/pollen transportation rather than marine influence to comparatively more proximal (with respect to hinterland) palaeoenvironments, though such influence cannot be discounted altogether. The sparser variety of taxonomic input from palaeoenvironments further downstream is probably not equalled by the actual spore/pollen production from the individual 'local' taxa, that are not diminished in quantity by transportation. Thus where numeric variables of individual taxa are taken into account (ie. the multivariate cluster groups) peak abundances have much greater influence on the palynofacies than spore/pollen variety. Thus the various 'local' palaeoenvironments are reflected by the large number of multivariate cluster groups that group I assemblages have been allocated to. In my opinion this must partly account for the particular 'across the board' clustering pattern of group I palynofacies.

Taxa that are important in cluster group I are as follows: Biretisporites spp., Concavisporites jurienensis, Pilosisporites notensis, Acanthotriletes varispinosus, Lycopodiumsporites marginatus, Cicatricosisporites pseudotripartites, Appendicisporites potomacensis, Matonisporites phleberopteroides and Sestrosporites pseudoalveolatus. Most of these taxa have not been of significance in the preceding cluster groups so they must represent some localisation of flora here. Facies 56 (sample Pl.11) comprises cluster group III with common Apiculati, Concavissimisporites variverrucatus, Trilobosporites spp. together with Gleicheniidites spp., Classopollis spp., Schizosporis spp. and generally rare Muronati, Cingulati, hilates and Celyphus rallus. It lies within subcluster I-3 where the Auriculati are particulalry important. This facies is characterised by prominent fusinite and palynomorphs and is totally barren of fluorescent algal cysts. The palaeoenvironment is distinctly non-aquatic in aspect, however the taxon Schizosporis reticulatus (Cookson & Dettman ,1959) is an aquatic alga. It may characterise some very specialised aquatic environment. By analogy with modern environments the pitcher plant (Nepenthes) has specialised leaves that form a cup retaining water to trap insects. This environment can support a large number of aquatic forms such as algae and mosquito larvae, and is clearly very specialised in comparison to a pond or lake. Schizosporis reticulatus may have favoured some equally specialised aquatic palaeoenvironment in the Lower Cretaceous, in an otherwise dry well drained environment. Such a specialised environment could have been damp vegetation, living or dead, or for instance temporary pools of water within dense foliage. No true aquatic environment such as a pond or lake could have existed as *Celyphus rallus* and all fluorescent algae are absent. Many of the large trilete taxa of facies 56 must represent the local flora. It is interesting to note that *Classopollis* spp. is fairly common in this facies. This must be indigenous, and in my opinion it must indicate a drier, uplifted habitat for the taxon encountered here. Detailed high power microscope work would undoubtedly reveal a separate species from that prevalent in groups A and B. This supports evidence that *Classopollis* plants may have been a diverse group adapted to a variety of Mesozoic habitats (Alvin 1982). Facies 57 (sample CH/P.44) is also a specialised assemblage (lying in group IV in common with facies 29 and 37) where *Cicatricosisporites minor* as well as Muronati and Auriculati are prominent. Fluorescent algae are fairly common in facies 57, particularly *Baltisphaeridium* spp., *Pediastrum* and *Botryococcus* though *Veryhachium* spp. are distinctly absent. This supports evidence presented earlier (under facies 10 and 15) suggesting that *Veryhachium* spp. may have thrived in slightly brackish conditions. It is possible that *Veryhachium* spp. favoured large open water masses or perhaps different water pH, trace elements or nutrients, but there does appear to be a clear habit difference between this taxon and *Baltisphaeridium* spp., and this difference is related to distance from strand line. Facies 57 falls within subcluster I-2 where *Tigrisporites scurrandus* is more prominent over the Auriculati. The Auriculati do seem to correlate well with evidence of non-aquatic conditions and this may be a further indicator of this. Facies 58 lying within subcluster VI-5 (similar to facies 23, 30 and 40) contains prominent *Baltisphaeridium* spp. (and Colonial Spiny Masses) with very rare *Veryhachium* spp. similar to the situation just seen with facies *57*. Bisaccates are rare in this facies though taxonomic variety is good in this predominantly dry uplifted facies with a well developed, mainly indigenous palynoflora. Bisaccates have been a 'standard' component of all facies, and they do not seem to be any more prominent in the drier uplifted facies here. They must originate from outside the basin as has been suggested (Batten, 1974). They probably formed the dominant vegetation of the source massif of Londinia (Allen,1981), an environment that was actively eroded and left no remnant *in situ* palynofacies. Being wind pollinated and produced in large numbers they were able to get into most mudplain facies in approximately equal numbers. Facies *59* comprises three samples in the common *Celyphus rallus* (group VII) category. These all show 'typical' other aquatic characteristics such as prominent *Veryhachium* spp. Two of the samples (CH/P.16 and CH/M.16) fall within subcluster VII-a (rich taxonomic variety) and may represent transportation of group I taxa into the group G realm (facies *48*). Sample W.52 lies within subcluster VII-c where taxonomic variety is poorest, but it contains the subcluster I-3, prominent Auriculati assemblage. These taxa have been equated with particularly dry conditions. This must indicate transportation and deposition in an aquatic palaeoenvironment and that transportation was much further than samples CH/M.16 and CH/P.16, to the group B realm of facies *10*, where all samples fall within subcluster VII-c and amorphous liptinite, fine amorphous grey organic matter and limestones occur, as is seen in sample W.52. Facies *60*, within subcluster X-2, shows distinct marine influence by its prominent amorphous liptinite and generally rare fluorescent algae. *Regresporites* sp. A and *Lycopodiacidites* spp. are comparatively prominent in this facies similar to facies *2*, also within group X. This facies probably indicates transportation of group I taxa to a marine (group A type) palaeoenvironment but it could be the result of tidal action into, or into the viscinity of, the group I realm. Facies 61 (sample CH/M.36) shows particularly prominent marine influence in the form of the greatest number of Segmented Alga type 1 of any sample in this study. Facies 62 contains comparatively prominent *Baltisphaeridium* with very rare *Veryhachium* spp., a situation encountered with facies 58. It shows the typical varied subcluster XII-1 assemblage and is probably a generally *in situ* facies within group I, but with greater aquatic influence. Facies 63 contains a much more typically group B type kerogen and fluorescent algal assemblage and is linked within subcluster XII-2 with facies 15, of which it is probably a part. Facies 64 does not show any similarity with its 'counterpart' (ie. facies 16 also within subcluster XII-3) in cluster group B but does show some association with the Large facies 45 (cluster group F), where fusinite and algal cysts with subsidiary algal cysts are main constituents of the bulk kerogen, and *Veryhachium* spp. together with Laevigate Algal Cysts are common in the fluorescent algal assemblage. Facies 64 is thus a further example of group I assemblage transportation downstream, in my opinion. Facies 65, within subcluster XIII-5 comprises a single sample, CH/M.25 with very rare fluorescent algae and prominent palynomorphs as a bulk kerogen maceral. Subcluster XIII-5 is the very prominent *Gleicheniidites* spp. group and this sample showed prominent rootlets (ie. as part of the lithology prior to maceration). All the indications are that it is a generally in situ deposit of the dry uplifted group I palaeoenvironment. *Gleicheniidites* spp. were noted as an important element of facies 56 so the facies realm of group I may be in part, the zone of '*Gleicheniidites*' plants.

Group I palynofacies have shown generally good evidence of being derived from floras of a generally dry uplifted palaeoenvironment comparatively close to the hinterland but that they are easily capable of transportation, presumably by rivers. Braided river channels, here with more fixed courses produced by scouring through the slightly greater relief of this realm may have been the spore/pollen vectors.

(x) Palynofacies and palaeoenvironments within group J

Group J shows the greatest variety of taxa in the highest occurrence categories (text-fig.2.7 i & ii, 2.9 i & ii). In keeping with this its number of total absences is amongst the lowest, similar to group I, but unlike group I it has very low numbers of taxa in the low occurrence category ($>1\%$, $<9\%$, text-fig. 2.7 iii). This suggests that there has been little introduction of taxa from external sources. Transported taxa would be expected to be of much lower percentage occurrence than indigenous ones. Group J facies are not spread throughout the wide range of multivariate cluster groups as was found with group I. There is a 'gap' where they are absent from groups VIII to XII-2. However group J samples are split into a large number of facies comprised of mostly one (and never more than two) samples each. This is because most of the assemblages do represent <u>in situ</u> facies that are still unique and undisturbed by even local reworking. The 'gap' mentioned above is significant as it includes cluster group X. This group was prominent in group I, involving the marine influenced facies. This influence is absent here, and aquatic influences as a whole (that are primarily responsible for transporting spores and pollen) are very much played down within cluster group J. Many of the taxa of this group are held in common with group I (see text-figs. 2.5 xxi & xxii) and enclosure 5) and these are typical of dry uplifted well developed plant communities similar to group I. The great variety of abundant taxa here are as follows: the Apiculati and Auriculati (in general) Klukisporites spp., Cicatricosisporites minor, Cicatricosisporites hughesi, Cicatricosisporites hallei, Appendicisporites jansonii Appendicisporites problematicus, Contignisporites sp., the Cingulati, Bisaccates, Sphaeripollenites psilatus and Aequitriradites spp..

Cicatricosisporites minor has already been seen as a characteristic of facies 29, 37 and 57 (cluster group IV) that were considered as in situ freshwater facies. Cicatricosisporites hughesi however was a particular characteristic of cluster A, the most marine group. Its prominence here (together with C. hallei) in group J that shows the least marine influence is anomalous and not yet fully explicable.

Facies 66 (sample N.17) shows prominent Cicatricosisporites annulatus and Contignisporites sp. together with prominent Apiculati, Muronati and Cingulati and is an in situ assemblage, showing no aquatic influence, of the driest part of the mudplain, closest to the hinterland. Facies 67 (sample P.12) contains prominent Apiculat Pilosisporites verus, Concavissimisporites sp., Auriculati, Matonisporites phleberopteroides and Trilobosporites spp.. The Cingulati Hilates, bisaccates and Schizosporis spp. are also common here. This is sufficiently unique and undisturbed an assemblage to form its own facies similar to 66 and again no aquatic influences are to be seen. Remarks made concerning facies 56 (group I) concerning Schizosporis spp. are also applicable here. This alga must have been specially adapted to find a habitat here. The taxon M. phleberopteroides, like C. hughesi is anomalous here, in also being common in cluster group A.

Bisaccates are prominent in this facies, which may indicate that they occur in association with the fern flora of this facies. However this may only be a function of the proximity to the hinterland where their gymnospermous parent plants were the main vegetation. Soil development (Sladen and Batten,1984) on the source massif was likely to have been quite different from the mudplain, such that their respective floras remained quite distinct.

Both facies 66 and 67 fall within subcluster J-1 where the Muronati are particularly abundant. Facies 68 contains two samples (Pl. 6 and BG.23) both falling within subcluster J-2 where Costatoperforosporites spp. are particularly conspicuous. This taxon was prominent in group A-a as well. This facies contains prominent Laevigati, Apiculati and Muronati with rare or absent Auriculati, Hilates and Celyphus rallus, and is distinctly non aquatic with only very rare fluorescent algae. The Auriculati are replaced here by more prominent Laevigati and Apiculati than seen in facies 66 and 67. This must illustrate the variety of vegetation within this dry uplifted zone where distinct plant communities are able to become more developed than elsewhere.

Facies 69 (samples W.68 and W.72) comprises subcluster VI-4 where the Laevigati, Apiculati, Muronati, Auriculati, Sphaeripollenites psilatus and bisaccates are all moderate in abundance, and Cicatricosisporites spp. are generally more common, (ie.the group VI characteristic). Both these samples fall within subcluster J-3 where Rugubivesiculites sp. and Sphaeripollenites psilatus are particularly abundant. Sample W.68 is probably transported as it contains amorphous liptinite and fine amorphous grey organic matter as well as limestone and fluorescent algae. However the facies is probably a general in situ group J one. Facies 70 (sample W.71) lies within subcluster VI-5 where taxonomic variety is good, and bisaccates and Classopollis spp. rare. It is also completely barren of fluorescent algae and shows a particularly high fusinite percentage (probably related to its sandstone lithology). It is typically non-aquatic. Facies 71 (sample W.23) lies within cluster group VII, the prominent Celyphus rallus group and in keeping with this it shows prominent fluorescent algae, particularly Veryhachium spp.. The palynomorph assemblage is quite varied (subcluster VII-a) and aquatic indications are obvious. This is probably an example of transportation of group J spores and pollen to facies 48 (also subcluster VII-a) within the realm of group G. Facies 72 (sample W.64) within subcluster XII shows clear aquatic influence with prominent Veryhachium spp. and like facies 64 is an example of spore/pollen transportation to facies 45 (group F), also in subcluster XII-3, that its kerogen, lithological and fluorescent algal assemblage is so close to. Facies 73 lies within subcluster XIII-2 where Sphaeripollenites psilatus is particularly common. It contains prominent Veryhachium spp. indicative of aquatic influence. Facies 74 (sample P1.4) comprises subcluster XIII-3 and it shows great spore/pollen variety, but only low records of fluorescent algae, and Celyphus rallus is absent. Facies 75 within subcluster XIII-5 really only comprises one sample (W.70) though W.23 is included here (when Celyphus rallus is ignored). Sample W.70 is barren of fluorescent algae, and lying within subcluster XIII-5 it shows very abundant Gleicheniidites spp. and taxonomic variety is good. Facies 73, 74, and 75 are all within cluster group XIII, the prominent Gleicheniidites group. This taxon shows no clear association with any one facies or cluster group and cluster group XIII is particularly well spread throughout groups A to J. In my opinion this must indicate that, like the bisaccates it does not originate from the mudplain, but is derived from the source massif. Its parent pteridophyte may thrive as undergrowth beneath the gymnosperm forest. Many of the group XIII facies show unusually high fusinite percentage that has been interpreted as indicative of channel influence. Higher energy conditions in such a situation might have caused winnowing of fluorescent algae that are generally low in this cluster group. The slightly greater prominence of group XIII facies within group J is probably only a function of greater proximity of group J to the source massif. Facies 65 in group I may also be an *in situ* locality of *Gleicheniidites* spp..

3.3 (c) Summary and discussion

1. Palynofacies 1 - 75 represent associations of spore/pollen taxa that are derived from plants that grew in a range of palaeoenvironments on the Wealden braidplain. The binary cluster groups A to J generally record plant associations in conditions of decreasing salinity followed by a general decrease in freshwater aquatic influence to drier uplifted environments of greater taxonomic abundance and diversity. Additional more generalised separation of palaeoenvironments is possible using multivariate cluster groups I - XIII.

2. Palynofacies 1 - 7 (in group A) show the greatest marine influence in the form of foraminiferal linings and marine dinocysts. Amorphous liptinite, Segmented Alga type 1 and Laevigate Algal Cysts are associated in abundance with these facies indicating that they are marine derived elements. There is evidence of local reworking of fusinitic kerogen and Celyphus rallus into this palaeoenvironment.

3. Palynofacies 8 - 19 (in group B) provide evidence of lacustrine depositional environment. This is based on the high diversity of spores and pollen, but lack of any *in situ* taxa that are numerically dominant. Fine amorphous grey organic matter is common in these palynofacies as would be expected in low energy lacustine conditions. Subgroups within the group B palynofacies show different degrees of overlap in character with group A palynofacies, suggesting that a range of lacustrine environments existed from

strongly to weakly brackish. Some palynofacies in this group show greater amounts of channel influence.

4. Palynofacies 21 - 36 (groups D & E) show evidence of being laid down in drier uplifted areas of the braidplain, possibly areas left at slightly higher elevation by channel movement and slight downcutting. Aquatic influences are few, probably as isolated small ponds, and marine influence is very low.

5. Palynofacies 37 - 46 (group F) represents a comparatively large part of the braidplain where conditions were generally dry and uplifted as in groups D and E, but with greater tidal marine influence.

6. Palynofacies 48 - 55 (groups G & H) may represent overbank, ox-bow depositional conditions, where palynomorphs (as a total kerogen maceral type) are high in percentage. A particular distinct spore/pollen assemblage may represent plants that favoured the intermittently damp conditions.

7. Palynofacies 56 - 65 (group I) probably represent a wide range of braidplain depositional environments that diverse (near hinterland) spore/pollen taxa were reworked to, or influenced by.

8. Palynofacies 66 - 75 (group J) represent diverse floras of the dry uplifted areas of the braidplain. These floras may have spread to the alluvial fans on steeper gradients associated with the slopes of the source land massif. Their *in situ* preservation potential in such areas would be fairly

low, indicated by the low number of samples falling into this group.

The general trend in palynofloras across the Weald Clay braidplain, from areas adjacent to the sea to those near to the hinterland source area was broadly as follows:

Along the strandline adjacent to the sea, possibly partly submerged at high tide similar to modern mangroves, the parent plants of the gymnosperms *Cerebropollenites mesozoicus* and *Vitreisporites pallidus* existed. Various other pteridophytes such as *Leptolepidites* spp. and *Verrucosisporites* spp. spore producers may have been directly or indirectly associated with these plants. Behind the strandline extensive lagoons and lakes existed, where the ground was too permanently waterlogged to support an indigenous flora. Further inland from this, slightly drier uplifted areas characterised by the Bryophyte *Foraminisporis assymetricus* and plant fungi *Microthyriacites* existed in areas that probably supported fairly rich associations of pteridophytes such as *Cicatricosisporites* spp., *Klukisporites* spp., *Acanthotriletes varispinosus* and *Coronatispora valdensis*. Through this raised area and the lagoons and lakes, slow moving braided streams moved seawards. Probably in close proximity to such stream channels but nearer to the hinterland was an area of fairly dry uplifted terrain inhabited by pteridophytes including some that produced large trilete spores of *Trilobosporites bernissitartensis*. However more low lying areas associated with this, supported semi-permanent ponds that could possibly be tidally marine influenced or subject to raised salinity by evaporation. The channels further inland from here may have formed extensive overbank or ox-bow lake facies characterised by pteridophytes producing the spores Costatoperforosporites spp, Distaltriangulispora sp., Foveotriletes sp., and Tigrisporites scurrandus, as well as various other pteridophytes. Further inland towards the source area, extensive dry uplifted areas existed between the braided channels and overlapping on to steeper gradient alluvial fans running directly off the London/Brabant massif. These environments supported rich assemblages of schizeaceous pteridophytes and others producing large trilete spores such as Matonisporites phleberopteroides and Trilobosporites spp.. The source lands themselves were largely covered by gymnospermous trees producing bisaccate pollen, but an extensive undergrowth of pteridophyte ferns may have existed with them, particularly characterised by Gleicheniidites spp. spore producers.

This broad picture can be compared to published work on Early Cretaceous spore/pollen assemblages, palynofacies and palaeoecology. Norris (1968) recognised three suites of palynomorphs from the marine Upper Kimmeridgian and Portlandian into the freshwater Berriasian from England. This was a period of general marine regression. The lowest most marine influenced suite (suite A) is characterised by an assemblage of spores and pollen that includes Cerebropollenites mesozoicus and Vitreisporites pallidus. This is in agreement with the marine connotation of these taxa in the present study. Other taxa mentioned by Norris such as Classopollis spp. and Inaperturopollenites spp. in this suite, were found too universally in the present study to show distinct positive association with marine influence. However Laevigate Algal Cysts that were recorded in strong association with the marine facies may be equivalent to

Inaperturopollenites spp. *sensu* Norris. Other taxa from suite A such as *Gleicheniidites senonicus* and *Cicatricosisporites australiensis* may be reworked source land taxa, from the present data. Suite B of Norris includes such taxa as *Acanthotriletes varispinosus*, *Leptolepidites* spp. and *Cicatricosisporites* sp.. These taxa are comparable with those characteristic of the 'intermediate' freshwater braidplain of the present study. Suite C of Norris includes large trilete spores such as *Trilobosporites* spp, *Appendicisporites* spp., *Cicatricosisporites* spp. and *Contignisporites* sp.. This is broadly comparable with the diversified mature, near hinterland flora observed in the present study. Generally speaking Norris' three suites all include long ranging taxa that are environmentally controlled by the changing overall paleaoenvironment of marine regression from the Jurassic to Early Cretaceous. A major environmental factor during such regression would have been the gradual diminishing of marine influenced terrains and increased development of drier uplifted freshwater basinal habitats. In my opinion this same range of strandline to near hinterland palaeoenvironments can be recognised in 'microcosm' in the present data that partially mimics and complements the regional changes from the Jurassic to the Cretaceous, recognised by Norris. Another gradual change noted by Norris(1968) (also Norris, 1969) is the increase in spore/pollen diversity through the Late Jurassic to Early Cretaceous. This also mimics the increase in spore/pollen diversity from the distal to proximal areas (with respect to the hinterland) within the present study where mature, species rich assemblages (ie. group J) were observed near the hinterland and less diversified pioneer communities (ie. group A) near the strandline.

Other palynofacies studies on Wealden sediments have been carried out by Batten (1968, 1973, 1974.) Batten (1973) detailed a number of recurrent groupings of spore/pollen taxa. Most of these groups included parameters not considered in the present study, such as spore/pollen preservation and use different taxa or broad generic groups. Despite these differences of approach, comparable data has been observed in the present study. Assemblage types (AT's) 3, 13, 14 and 15 are characterised by Pilosisporites, Trilobosporites and Concavissimisporites respectively, and show high diversity similar to Groups I and J of the present study. Brown wood is an important character in these AT's similar to abundant vitrinite observed in groups I and J. 'Secondary character' S2, with Celyphus rallus is similar to group VII while S4 with Microforaminifera is similar to groups A, F and I of the present study.

Batten (1968) equated spores of Pilasporites allenii from the Hastings Beds in association with Equisetites lyellii plants an inferred pioneer species. However P.allenii was not recorded in the present study. Batten (1973) recorded assemblages of local (well preserved) and 'hinterland' (poorly preserved) spore taxa in association with Equisetites lyellii soil beds and fragment partings in the Wadhurst Clay. However no comparable pattern of spore occurrences can be observed with the present study. For instance Cerebropollenites mesozoicus and Vitreisporites pallidus occurred more commonly in the 'hinterland' assemblages of Batten (1973). Evidence from Batten (1974) that conifers (producing Bisaccate pollen) were the main flora of the hinterland is supported by the present data. However no additional light can be shed on the palaeoecology of Classopollis plants, as

Classopollis occurred almost uniformally throughout the assemblage groups of the present study. However it is likely that Classopollis in group J is a different species from that in group A.

3.4 THE PALYNOFACIES AND PALAEOENVIRONMENTAL SEQUENCE AT SAMPLED WEALD CLAY LOCALITIES

3.4 (a) Introduction

Following the discussion of Weald Clay palynofacies and the palaeoenvironments that they represent, samples can now be taken out of their cluster groups and put back in stratigraphic order for each locality. Each sample has been taken to be a representative of its assigned palynofacies. It is a fairly straightforward procedure to list the facies number and the inferred palaeoenvironment against each sample (see palynofacies sequence diagrams, enclosures 1 & 2). Horizontal lines have been drawn through the 'saw-tooth' part of the diagram when both the multivariate and binary cluster groups change between adjacent samples. From this information it is possible to zone the sequence at each locality by palaeoenvironment, and compare any conclusions with already published data, where this exists. The next step would be to number or name these zones in some way, but this has not been done here as a correlation is not being attempted at this time. This study is more concerned with primary recognition of palynofacies and their individual palaeoenvironments. However zones will be informally labelled for description. The ultimate value of distinguishing the large number (75) of palynofacies assemblages and their palaeoenvironments, is that placed in stratigraphic order, the zones so recognised would provide correlative tie-points of use in a detailed basin analysis. In theory, given a much larger number of samples than is possible to handle in a single Ph.D thesis it would be possible to produce a very complete picture geographically and stratigraphically of a rock sequence such as the Weald Clay.

Enclosures 1 & 2 contain too much information, and the diagrams themselves are too large, to be easily assimilated at a glance. In the discussion to follow an A4 size diagram that summarises details of stratigraphic value will be used, based on the large diagrams. However it is necessary to refer to the large diagrams for the complete picture. This small diagram (eg. text-fig.3.1 i) is constructed with a 'palynofacies log' on the left side. This is an attempt to combine the multivariate and binary cluster facies sequence (see enclosures 1 & 2) as a single line. One way of doing this would be to list the palynofacies in a hierarchy based on some parameter such as salinity. This hierarchy could then form the scale of the log. However while such a hierarchy of facies could be made within groups A & B it would be very difficult for groups C to J. In section 2.4 (d) it was argued that the spore/pollen taxa do show a general trend from A to J that is probably related to distance from strand line, where such a direct trend could not be recognised from groups I to XIII. Thus the 'palynofacies log' scale has been based primarily on the trend from A to J by simply listing the facies from 1 to 75, as if it were a numeric scale. Vertical lines have been drawn for the 14 most common facies. The multivariate cluster groups are thus only allowed to influence the scale within the confines of the binary cluster group allocation of each facies. Zones have been drawn where a distinct change occurs in the facies trend, that also correlates well with a break in the trend of lithology, kerogen type and fluorescent algal assemblage. Some spore/pollen taxa show distinct occurrence or frequency changes coincident with these breaks. The right hand side of the diagram (eg.text-fig.3.1 i) shows the trend of these various other parameters. This has the appearance of a biostratigraphic range chart (where a vertical line represents the evolutionary appearance and extinction of a given taxon) though of course here the ranges are all totally palaeoenvironmentally controlled. A solid black vertical line through the palynofacies log shows the 'average' facies for each zone, though of course as the scale is not a true numeric one this line only represents the modal or median facies of each zone, as a summary for greater visual clarity. Likewise the standard deviations (in brackets for each zone) are only intended to give an impression of the degree of facies change within each zone.

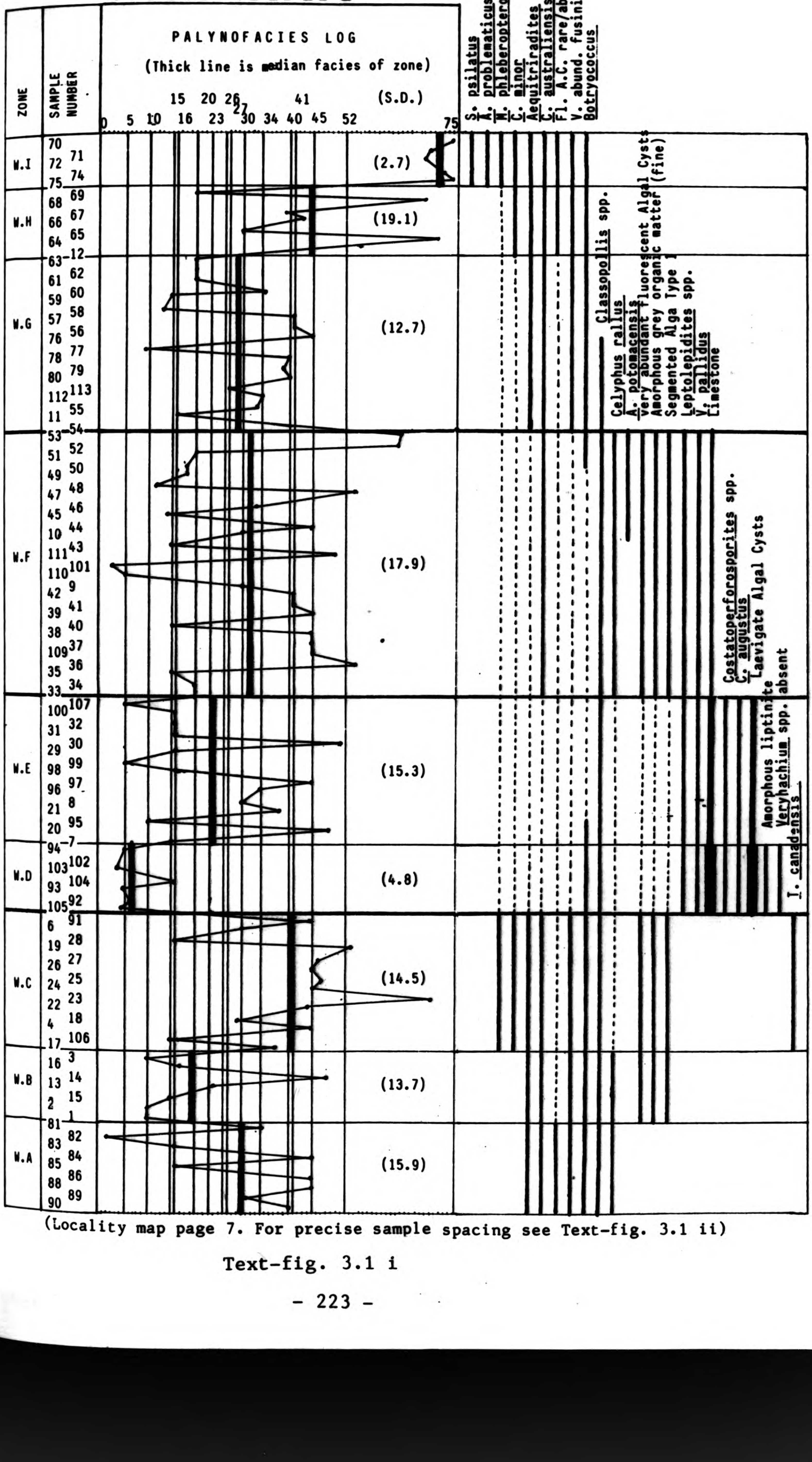
In the ensuing discussion of each locality further palaeoenvironmental details not previously discerned will emerge from the general facies trends, and the obvious association that must exist between adjacent facies within the same zone.

A second small diagram (eg.text-fig. 3.1 ii) will show the actual correct vertical spacing of samples, and where applicable, the overlapping nature of some of the sampling from the same horizon further along the outcrop. The broad palaeoenvironments and zones are added to this diagram as an overall conclusion for each locality.

3.4 (b) Warnham Pit

The section collected at Warnham pit has been divided up into nine distinct zones, labelled W.A, W.B, W.C, W.D, W.E, W.F, W.G, W.H, and W.I (see text-fig.3.1i-ii). Zones W.A to W.C record a generally increasing facies (according to the facies sequence). Zone W.A contains three samples within the large facies 45 where conditions are thought to be generally dry and uplifted with some tidal influence. Other samples fall into facies 30, 31, 34 and 40, recording freshwater lacustrine, through restricted aquatic conditions to a drier freshwater palaeoenvironment. Facies 16 brackish lagoonal conditions are recorded for two samples. One sample (W.82) comprises facies 1 within cluster group A that has already been remarked as showing a typically 'non-group A' kerogen assemblage that probably represents transportation from facies 10. The overall palaeoenvironment of this zone appears to be generally freshwater with limited marine influence. Zone W.B appears to show greater brackish and aquatic influence throughout, with several samples falling within facies 10, and one (W.13) comprising facies 24 that has already been remarked as showing a typically facies 10 kerogen and fluorescent algal assemblage. Channel influence (facies 17) and lacustrine ?ox-bow conditions (facies 40) are also recorded in this zone. Zone W.C shows a general return to the drier uplifted conditions of W.A with several facies 45 samples. Samples 17 and 18 (facies 37 and 29 respectively) records uplifted *Cicatricosisporites minor* 'stands'. One sample (W.23) falls within group J as facies 71, that has already been discussed as possibly transported to the facies 48 lacustrine palaeoenvironment. Only two samples show definitive brackish influence (samples W.106 and W.28, facies 15 and 16 respectively), while one sample (W.27)

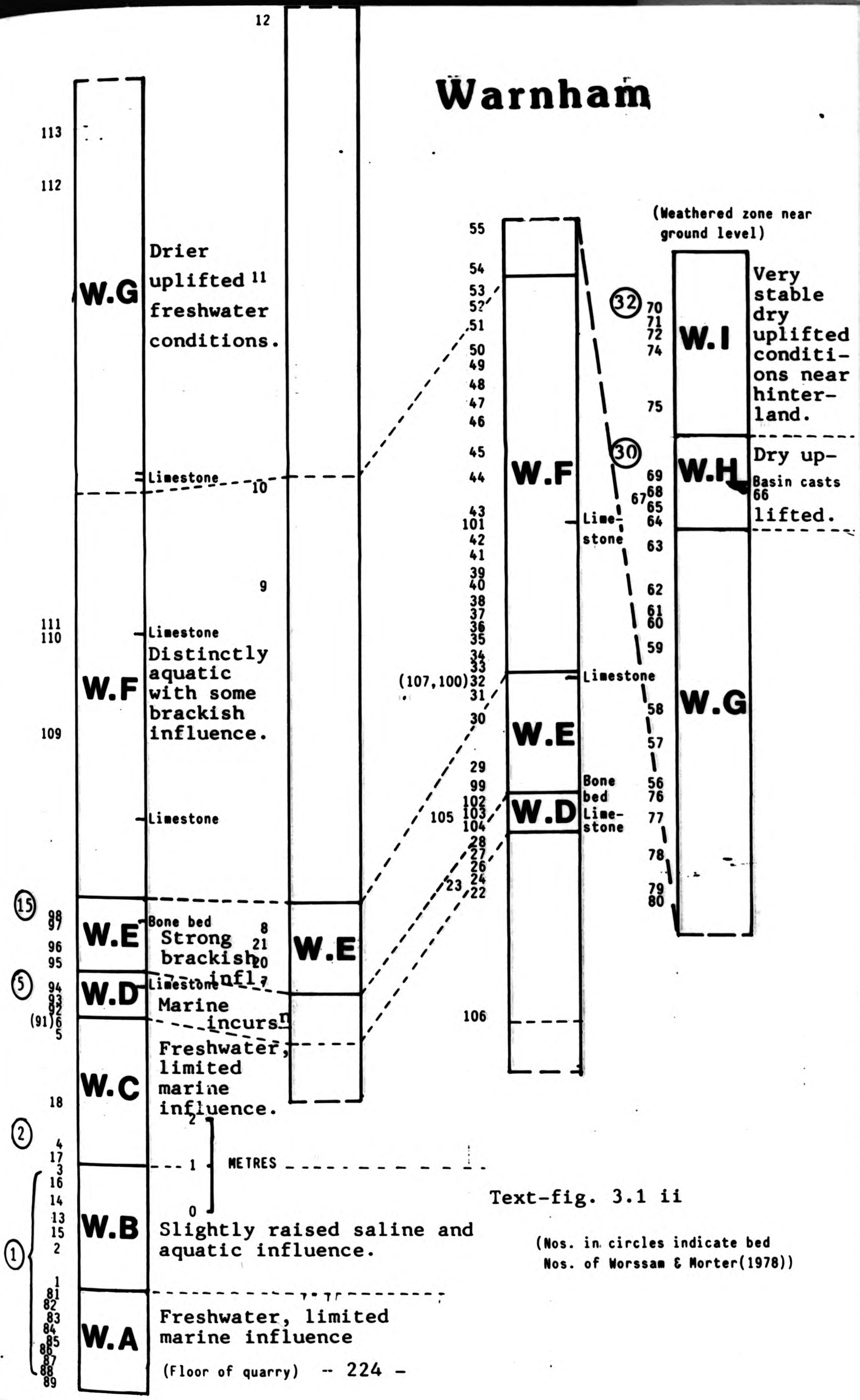
WARNHAM



(Locality map page 7. For precise sample spacing see Text-fig. 3.1 ii)

Text-fig. 3.1 i

Warnham



Text-fig. 3.1 ii

(Nos. in circles indicate bed Nos. of Worssam & Morter(1978)) comprises facies 46 that represents a tidal channel. Zones W.A to W.C show several taxa that are characteristic of generally drier uplifted palaeoenvironments including *Matonisporites phleberopteroides*, *Cicatricosisporites minor*, *Aequitriradites* spp. and *Cicatricosisporites australiensis*. These three zones also show abundant fusinite indicating proximity to the hinterland as well as other general freshwater aquatic indicators such as prominent fluorescent algal cysts, *Celyphus rallus* and fine amorphous grey organic matter.

Between samples W.91 and W.105 a very distinct change in palynofacies occurs. Zone W.D is characterised by almost all samples within group A, though one sample (W.104) lies within the brackish lagoonal facies 16 of cluster group B. This narrow zone sees a termination of almost all the characters seen in zones W.A to W.C (see text-fig. 3.1 i). *Filosina* limestones become prominent together with very abundant Laevigate Algal Cysts and amorphous liptinite and the taxa *Costatoperforosporites* spp., *Cicatricosisporites augustus*, *Leptolepidites* spp. and *Vitreisporites pallidus* become important. There is no doubt that the boundary of W.C and W.D represents a marine incursion.What is particularly significant in my opinion is that it is not a short lived event, extending only through zone W.D but its diminishing effects appear to persist through zones W.E and W.F. Only the presence of persistent *Botryococcus* here seems enigmatic. Zone W.E is characterised by several facies 16 (brackish lagoonal) samples. A facies 10 (slightly brackish, lacustrine) and a facies 15 (brackish lacustrine) sample are present as well as two facies 5 strongly marine samples. Other facies represented all show distinct aquatic influence though they are more freshwater in character, with tidal channel conditions represented. (facies 48, 38, 30, 34, 45 and 49). Most of the characteristic zone W.D parameters of kerogen type, fluorescent algae and spore/pollen taxa persist through zone W.E slightly less prominently. Zone W.F shows a further 'rise' in facies with many samples falling into facies 45 where conditions were drier and uplifted but with tidal influence. Marine influence appears around a band of *Viviparus* limestone (samples W.110 and W.101) and several samples fall within facies 15 (brackish lacustrine conditions). Freshwater lacustrine influence is represented by facies 54, 41, 30 and 33. Samples W.52 and W.53 show very 'high' palynofacies, but they do lie within multivariate clusters VII-c and XII-3, that include facies 15 and 45 respectively. These samples may represent reworking from upstream sites. Channel influence is seen with samples W.49 and W.50. Clear brackish / marine influence persists through zone W.F (Segmented type 1, *Leptolepidites* spp, *V. pallidus* and limestone) though less so than previously, with a termination in prominent Laevigate Algal Cysts, *Costatoperforosporites* spp.and *Cictricosisporites augustus*. *Cicatricosisporites australiensis*,prominent previously in zones W.A to W.C,reappears. Also reappearing in this zone are prominent *Celyphus rallus*, very abundant fluorescent algal cysts and fine amorphous grey organic matter. These parameters are all equated with distinctly aquatic conditions where conditions were only slightly saline. The boundary with the overlying zone W.G, falling between samples W.54 and W.11, sees a termination in all these characters, with a return to very abundant fusinite as seen in zones W.A to W.C. *Aequitriradites* spp become re-established. Aquatic influences of zone W.F are all very reduced here, indicating a change to drier uplifter freshwater conditions. Palynofacies 40, 33, 34, 39, 41 and 35 are represented. Rare brackish influence is seen with two facies 16 samples (W.11 and W.113) and one facies 15 sample (W.59). Facies 45 is represented by one sample (W.76). The boundary with zone W.H sees a rapid 'jump' in facies number with no facies present below cluster group E (ie.no group A, B or D facies). This change heralds further drying and greater proximity to the hinterland. Cicatricosisporites minor becomes re-established and fluorescent algal cysts are now quite rare. In situ assemblages such as facies 43 and 69 are represented together with palynofacies 41, 72, 30 and 39 that are all restricted aquatic freshwater facies. This zone contains the prominent Warnham sandstone described by Prentice (1962). Prentice concludes that the sandstone represents a crevasse splay tongue sand suddenly and violently spread over a comparatively limited area where there was abundant vegetable and animal life. Groove casts of drifted vegetation are described. A sample of this sandstone (W.69) yielded a barren palynomorph assemblage (facies 20). Sandstones are often unsuitable lithologies for palynomorph preservation, but the comparatively mature vegetation of the clay surrounding this sandstone seen in this study fits very well with Prentice's description. The top zone of the Warnham section (W.I) is heralded by a very marked jump in facies number; facies are almost all within cluster group J. Facies represented are 69, 70, 73 and 75 that are almost all distinctly rich in in situ palynofloral assemblages. Fluorescent algal cysts are very rare, algal cysts as a bulk kerogen fraction are also particularly reduced. Sphaeripollenites psilatus Appendicisporites problematicus and Matonisporites phleberopteroides are all prominent throughout this zone. The depositional environment must have been stable, dry and comparatively uplifted when these palynofacies where laid down.

The sequence of palynofacies at Warnham shows some interesting features that deserve further comment. Most important in my opinion is that a very distinct change occurs at the zone W.C/W.D boundary,with a marine incursion. The effects of this incursion appear to diminish gradually through the Warnham section presumably by increased sedimentary influx, until the zone W.F/W.G boundary when brackish/marine influences are as rare as within zones W.A - W.C This seems to indicate a cyclic process that starts with marine incursion. This is at variance with the opinion of Worssam (1963) and Worssam and Morter(1978), (based on the Maidstone area) that the cycle starts with a sand or red clay overlying '<u>Paludina</u>'limestone. In my opinion such a sand or red clay is near the top of a sedimentary cycle and that while the influx of sand represents an abrupt change in lithology,the palynofacies sequence across this unit at Warnham shows no profound change as does occur at the base of the <u>Filosina</u> limestone, or as occurs in the zone above the sandstone unit at the W.H/W.I boundary. However, the palynofacies cycle sequence will only be verified if it can be traced vertically more than once in a more complete section than visible at Warnham.

The marine incursion at the W.C/W.D boundary is fairly abrupt but it is possible that slight intimations of this change are discernible within zone W.C. Segmented Alga type 1 occurs with amorphous grey organic matter and abundant fluorescent algae (ie. indicative of low lying lacustrine conditions) and a lower incidence of <u>Celyphus rallus</u> (ie.due to slightly raised salinity) are to be seen.

The standard deviation of the palynofacies for each zone is particularly low within W.D and W.I indicating that conditions were much more stable than at other times when it could alternate rapidly between various kinds of freshwater sedimentary deposition.

Brackish/marine indications within the Weald Clay have been known for a long time. (Arkell, 1947; Anderson and Casey, 1957; Worssam 1963, 1965; Allen & Keith, 1965; Taylor, 1963; Macdougall & Prentice, 1964 ; Allen <u>et al</u>. 1973 ; Lake & Thurrell, 1974;

Allen ,1975, 1976, 1981). A brackish/marine microfauna from Warnham, dominated by ostracods was described by Kilenyi & Allen(1968). Evidence presented in this study provides futher details of this brackish/marine event at Warnham based on palynology. Zones W.D and W.E of this study are a clear representation of 'Bed 2a' of Worssam & Morter (1978). It is interesting to note that Filosina, the more marine gastropod than Viviparus occurs in zone W.D that is also concluded as the most marine interval based on palynology.

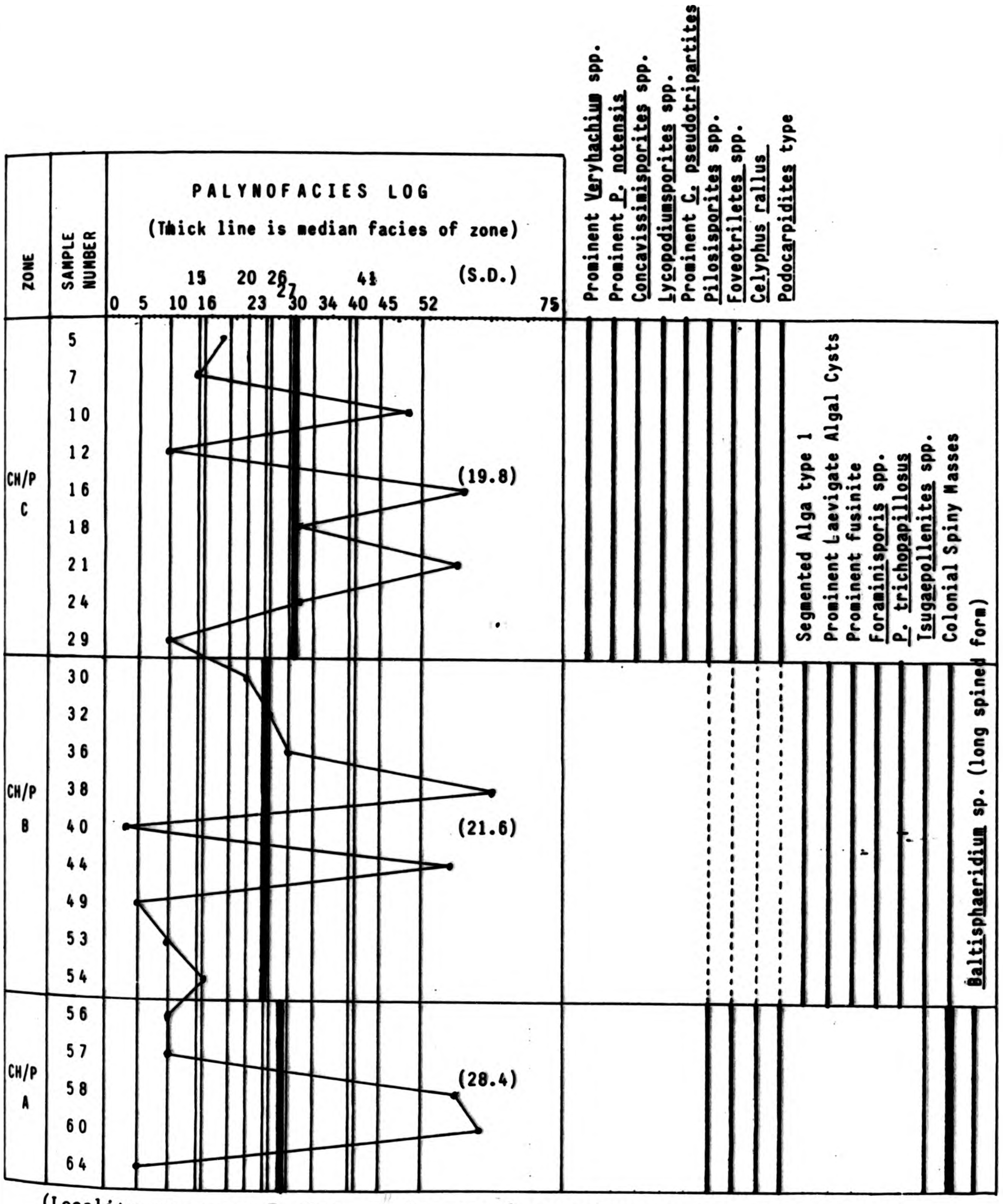
Since the writing of this section, Anderson (1985) has provided a very complete description of ostracod 'faunicycles' throughout all of the Wealden Beds. Faunicycles are based on particular associations of comparatively freshwater ostracoda (Cypridea spp. - C - phase forms) and comparatively saline ostracoda (S - phase forms). The Warnham Pit section falls into the middle of the Lower Weald Clay (Henfield phase) of Anderson(1985). This is characterised by Assemblage 12, encompassing faunicycles 75 - 81. S - phase species are particularly prominent in faunicycle 75, gradually decreasing through to faunicycle 79, depicting high salinities changing upwards to lower salinities. This trend is exactly the same as that picked out by the rising palynofacies number seen throughout the Warnham Pit section from zones W.D to W.I of this study based on spore/pollen palynofloras, with independent support from fluorescent algal assemblages and kerogen types.

3.4 (c) Chailey Cores

Samples examined from two cores, CH/M and CH/P supplied by Redlands Brick Company showed some distinctive palynofacies features. Both cores, though separated by only a few hundred yards show enough distinctions for each to be discussed separately following initial comments on their common characteristics. Lithologies generally comprise mudstones, mainly non-laminated, and limestones are rare. Kerogen assemblages are dominated by palynomorphs with common fine amorphous grey organic matter and moderately common amorphous liptinite. Comparatively speaking fusinite is much less abundant than in the majority of samples from other localities. This evidence, and the evidence from the palynofacies sequence, all indicates that depositional conditions were comparatively brackish, though only intermittently so due to the proximity of the strandline, rather than definitive evidence of a marine incursion event as occurred at Warnham. Most Chailey samples fall within cluster group I that showed generally good taxonomic variety and the facies sequence shows the predominance of aquatic freshwater influence or brackish influence. Fluorescent algae and Celyphus rallus are consistently well developed throughout, indicative of the generally low lying waterlogged conditions that could be influenced by marine waters at any time. Leptolepidites spp., Cicatricosisporites pseudotripartites and Tsugaepollenites spp. are particularly characteristic of the Chailey cores.

The CH/P core shows distinctly prominent algal cysts as a bulk kerogen maceral in comparison to CH/M, and also shows more prominent Celyphus rallus, Costatoperforosporites spp., Todisporites spp. and fluorescent algal cysts. Core CH/P has been divided up into three zones, CH/P.A, CH/P.B and CH/P.C (text-figs. 3.2 i & ii)

CHAILEY P



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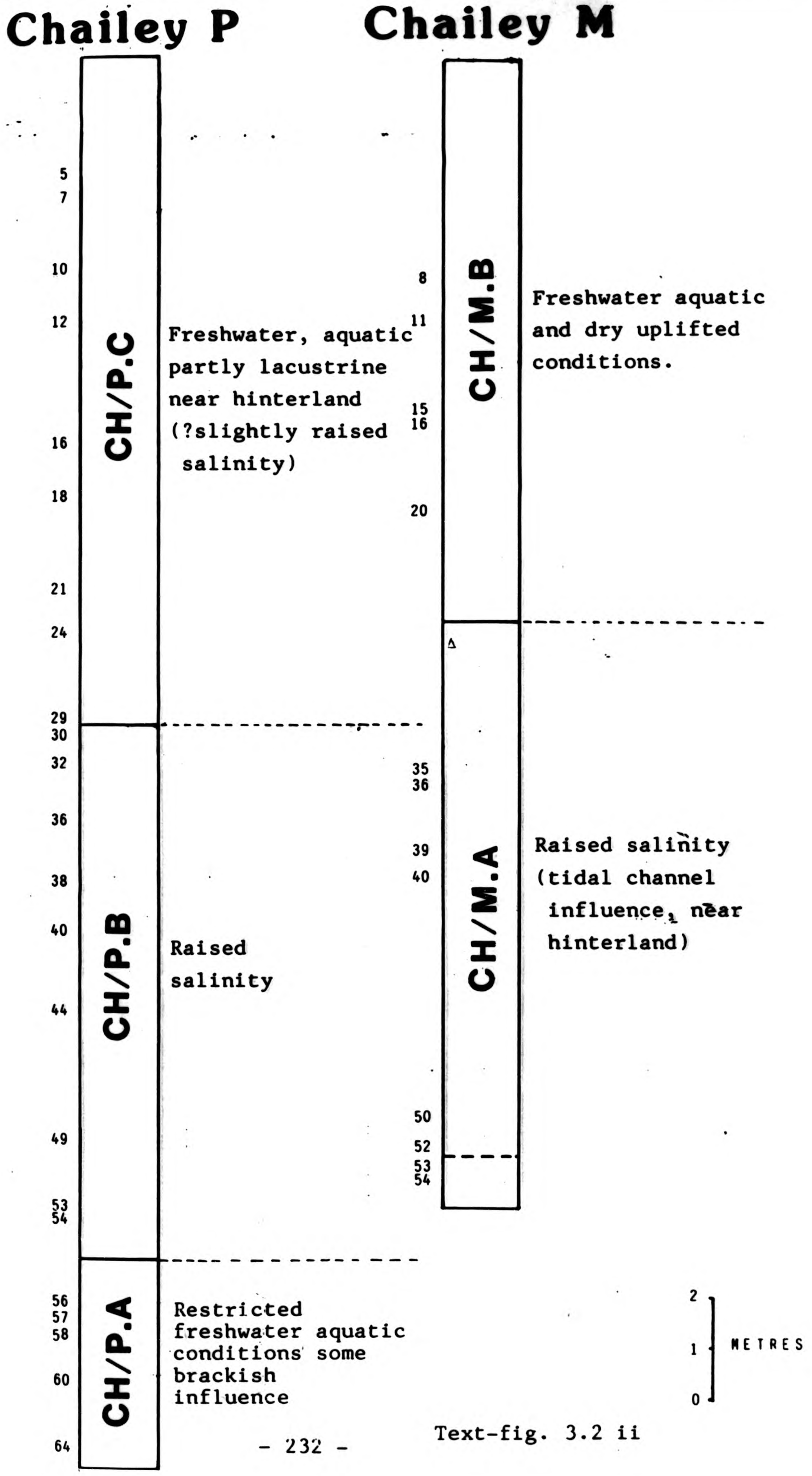
Text-fig. 3.2 i



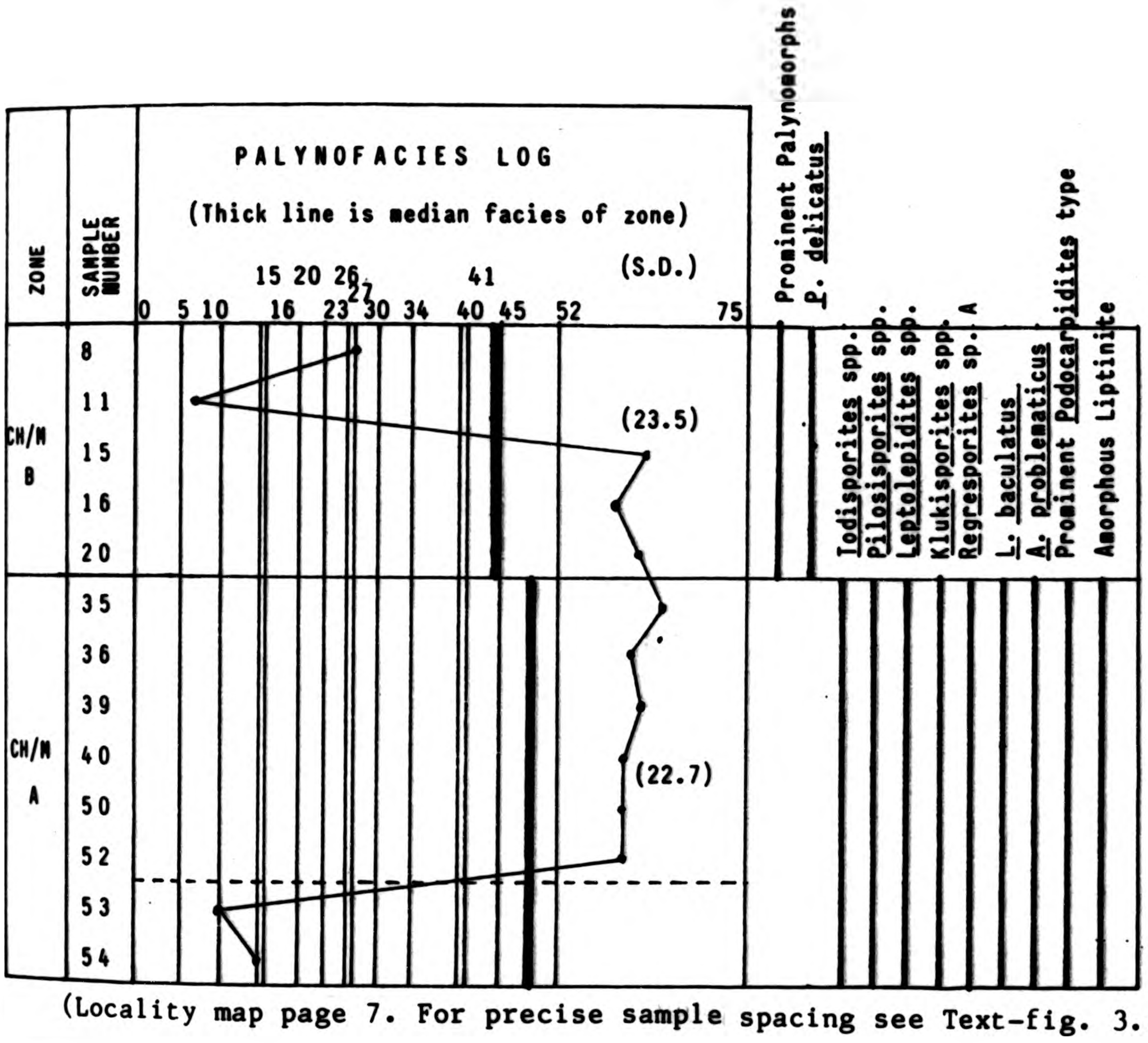
Text-fig. 3.2 ii

Zone CH/P.A is most characterised by the prominence of long spined *Baltisphaeridium* sp. and Colonial Spiny Masses. *Veryhachium* spp. and Laevigate Algal Cysts are decidedly rare. This indicates the predominance of generally restricted freshwater aquatic conditions probably as small ponds, in my opinion, though as the facies sequence indicates, brackish influence still occurs throughout. Zone CH/P.B contains the most prominent marine influence in this core with particularly prominent Laevigate Algal Cysts and Segmented Alga type 1 together with rare *Celyphus rallus*. The spore taxa *Foraminisporis* spp. and *Pilosisporites trichopapillosus* are more prominent in this zone than above or below. Both these taxa have already been mentioned in the text of raised salinities, the former within cluster group F and the latter within subcluster group B-3. The median palynofacies is also slightly lower, indicative of raised salinities. However other parameters that have been associated with raised salinity such as prominent limestone and low fusinite percentages do not apply here, quite the opposite. In my opinion this, together with the frequently rich and diversified spore/pollen assemblage indicates that marine influence is localised via tidal channels inland, some way from normal strand line, rather than an actual 'event' of marine incursion as would be induced by regional downfaulting or rise in sea level. Zone CH/P.C shows a number of similarities with zone CH/P.A including a rise in palynofacies (which shows less variance of the standard deviation). *Veryhachium* spp. are particularly prominent within this zone together with the spore taxa *Pilosisporites notensis*, *Concavissimisporites* spp., *Lycopodiumsporites* spp. and *Cicatricosisporites pseudotripartites*. In my opinion this zone represents a return to mainly freshwater aquatic deposition, but here more open lacustrine conditions (? perhaps with very slightly raised salinity) existed where *Veryhachium* spp.

and *Celyphus rallus* thrived (as opposed to the restricted aquatic conditions of *Baltisphaeridium* sp.,in CH/P.A) The depositional environment may have been comparatively close to the hinterland as spore/pollen assemblages are fairly rich and diverse, and palynomorphs form a prominent bulk kerogen maceral component.

The CH/M (text-fig.3.2 iii) core shows prominent amorphous liptinite and reduced fusinite throughout, with generally much lower incidence of fluorescent algal cysts than the CH/P core,as well as lower algal cysts as a bulk kerogen maceral. The sequence can be divided up into two zones that are only moderately well defined. The palynofacies sequence is remarkably constant, being dominated by cluster group I samples. This is similar to the CH/P core, but does not show the facies fluctuation of the latter. Zone CH/M.A contains prominent *Todisporites* spp., *Pilosisporites* spp., *Leptolepidites* spp., *Klukisporites sp*., *Regresporites* sp. A, *Lycopodiacidites baculatus*, *Appendicisporites problematicus* and *Podocarpidites* type. Two samples at the base of this core contain prominent *Celyphus rallus* & fusinite and do not contain these taxa. Generally however the kerogen fraction is dominated by liptinite with low fusinite percentage. All this evidence including the characteristic spore/pollen taxa, is indicative of particularly raised salinity associated with tidal channel influence to a depositional environment comparatively close to the hinterland. Laevigate Algal Cysts are totally absent from this zone, where they could be expected to be quite prominent. This apparent anomaly cannot be explained at present. Zone CH/M.B shows very prominent palynomorphs with low fusinite in the kerogen assemblage and it contains comparatively prominent *Pilosisporites cf. notensis* This zone represents greatly reduced salinity in my opinion,as 'saline' CH/M.A taxa are missing together with amorphous liptinite. The facies sequence also shows no brackish influence, with fresh-

CHAILEY M



(Locality map page 7. For precise sample spacing see Text-fig. 3.2 ii)

Text-fig. 3.2 iii

water aquatic or generally dry uplifted facies represented. The broad palaeoenvironmental conclusions for both cores CH/P & CH/M suggest a general correlation of zone CH/P.C to CH/M.B and CH/P.B to CH/M.A .

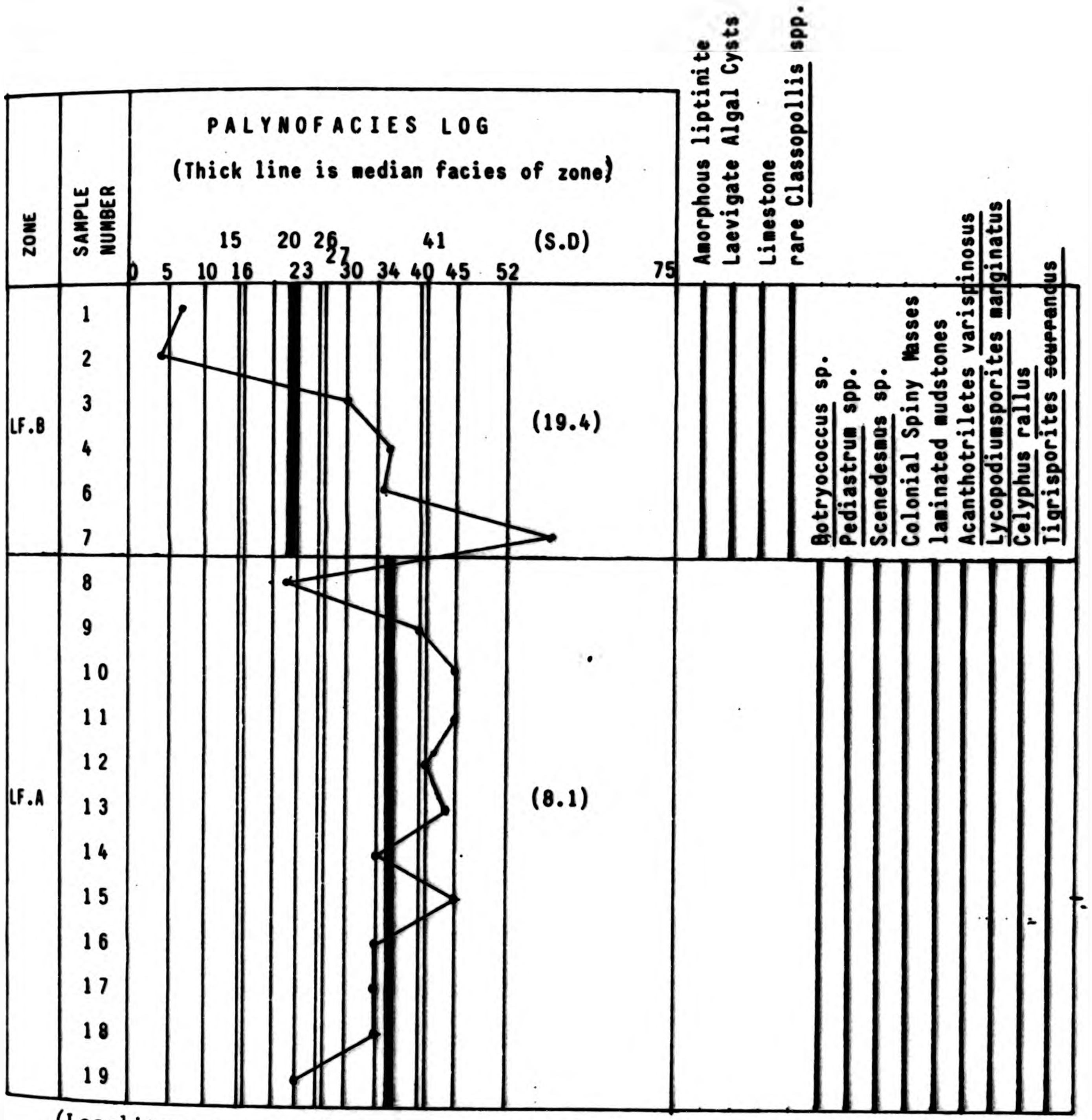
3.4 (d) Lingfield Pit

The most obvious characteristic of the palynofacies sequence at Lingfield is its general uniformity throughout (cluster groups XII with E and F). This uniformity is also reflected in the section at outcrop which shows little variation in lithology, type of bedding or colour. The section as a whole shows fairly abundant (approximately 50%) fusinite in the kerogen assemblage. Fluorescent algal cysts are generally rare, though as a bulk kerogen maceral algal cysts are generally common. Other characteristics of the sequence are general uniform representation of the taxa Vitreisporites pallidus and Aequitriradites spp.,but Costatoperforosporites spp. are completely absent.

Despite the general uniformity of the Lingfield section, two reasonably well defined zones can be recognised, labelled LF.A and LF.B (text-figs. 3.3 i & ii). Palaeoenvironments of the Lingfield section will be discussed during description of these two zones. Zone LF.A is characterised by distinctly more prominent fluoresent algal cysts than zone LF.B, particularly of the freshwater algae Botryococcus Pediastrum Scenedesmus and colonial spiny masses. This evidence, together with the actual palynofacies sequence, indicates that this zone is entirely nonmarine but shows good aquatic freshwater influence. Aquatic conditions are not evident throughout the whole sequence, for example samples 16, 17, and 8 are well drained, dry palynofacies. Other samples such as 18 and 12 show much better developed fluorescent algal assemblages together with fine grey amorphous material and amorphous liptinite and must represent more permanent larger lakes. Generally however the aquatic environments were probably small temporary ponds, the general palaeoenvironmental setting being some distance from the strand line and uplifted, near the hinterland. Taxa characteristic of this zone include Acanthotriletes varispinosus (already discussed as favouring damp ground), Lycopodiumsporites marginatus and Tigrisporites scurrandus. Well laminated mudstones within this zone must be associated with the generally undisturbed lacustrine environments.

Zone LF.B is distinguished from LF.A by brackish/marine influence. This is indicated by the greater representation of amorphous liptinite, limestones and Laevigate Algal Cysts. Celyphus rallus is less prominent here, and spore/pollen taxonomic variety is less. The palynofacies sequence reveals that this zone still lies within the freshwater realm, near to the hinterland, similar to zone LF.A, but channel influence is marked. Samples LF.1 and LF.2 show the typically marine cluster group A spore/pollen assemblage, but the kerogen type and fluorescent algal assemblage is less typical of this group, and may indicate transportation. In my opinion the marine influence is via tidal channels and not as a regional marine incursion as seen at Warnham.

LINGFIELD



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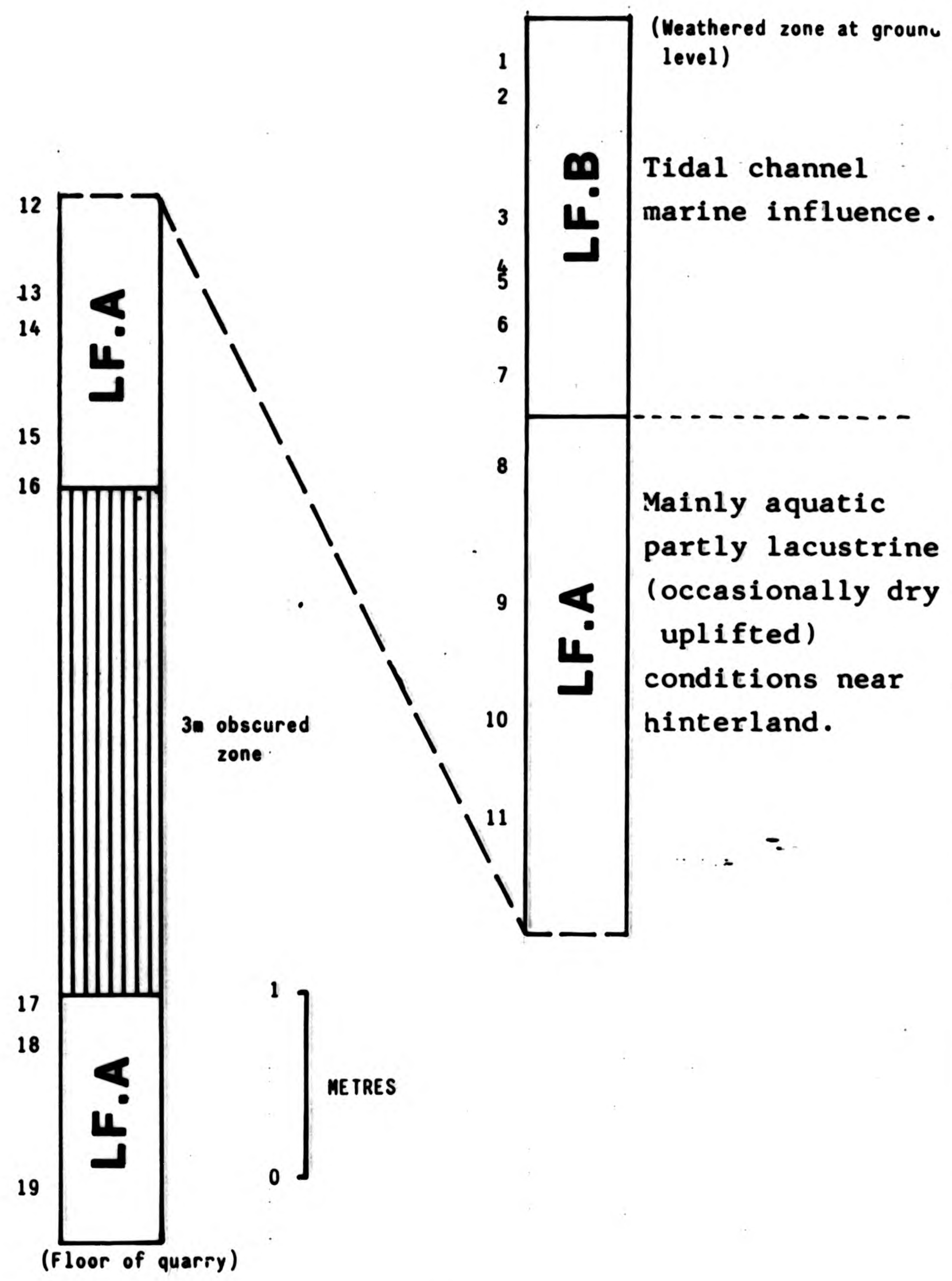
Text-fig. 3.3 i

Lingfield



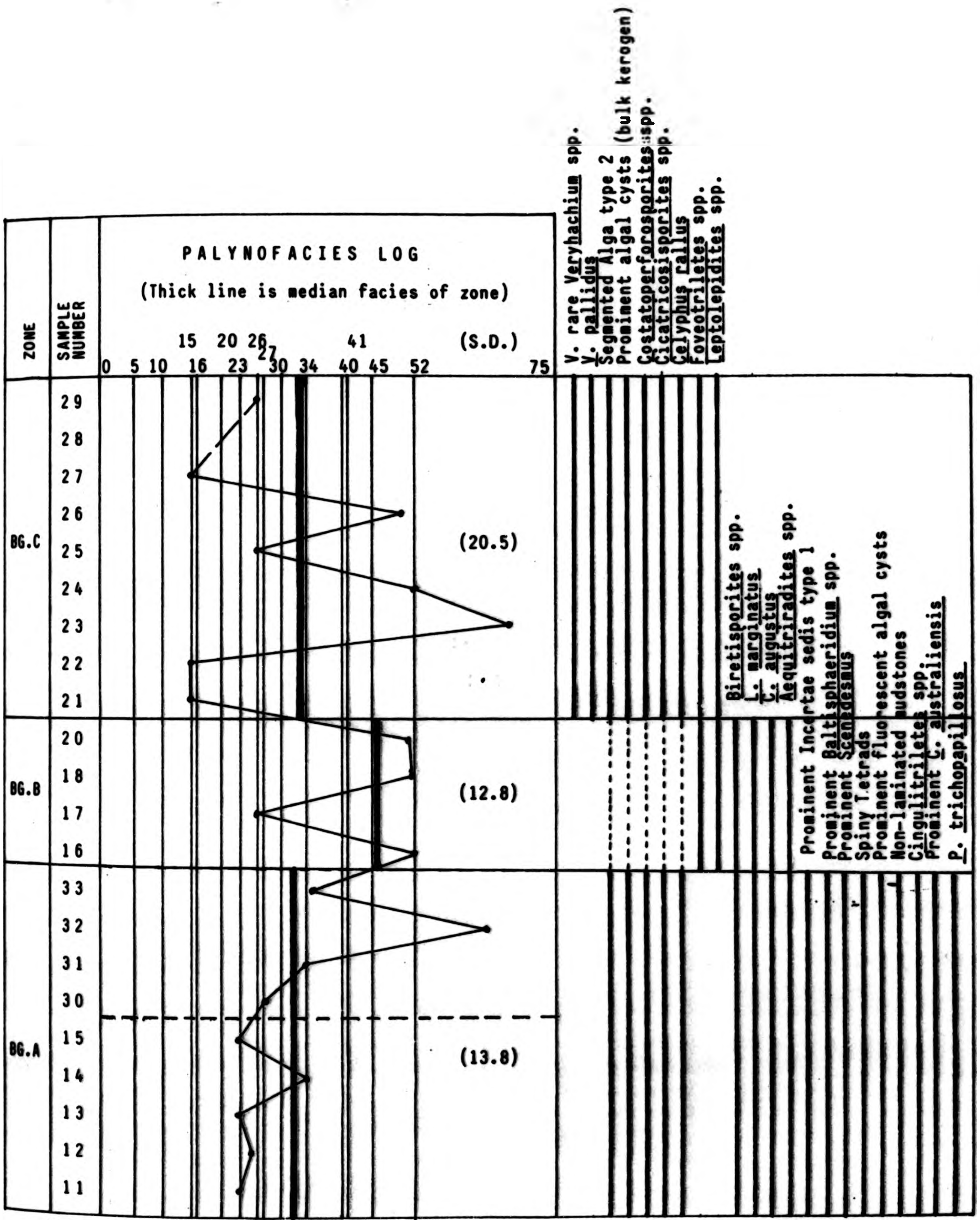
Text-fig. 3.3 ii

3.4 (e) Beare Green Pit

The Beare Green section lies near to bed 9b of Worssam & Morter (1978). The samples collected in this study are all characterised by particularly high percentages of semifusinite and fusinite. Palynomorphs as a bulk kerogen component are well represented, though algal cysts are slightly less important. Amorphous liptinite and fine amorphous grey organic matter (that have been associated with marine influence) are almost completely absent. The fluorescent algal assemblage is characterised by two very distinctive taxa that are unique to Beare Green. One of these has not yet been formally named. Descriptions are provided herein (chapter 4) They are Segmented Alga type 2, and the dinocyst Incertae Sedis type 1. The latter taxon has recently been described as CINCTURO-JUDITH Hughes & Harding (1985). Botryococcus and Colonial Spiny Masses are totally absent. Bisaccates are generally abundant in this section, but the taxon Cerebropollenites mesozoicus (that is characteristic of more marine facies, within cluster groups A and B-3) is very noticeably rare or absent. The facies sequence reveals that brackish influence is particularly unusual in this sequence. In my opinion the Beare Green sequence is distinctly freshwater, and lacking in marine influence. The generally rich and varied spore/pollen assemblages here indicate that the palaeoenvironment was fairly well uplifted and at some distance from the strand line with fairly mature fern communities developed. Raised bisaccate and inertinite percentages may hint at the proximity of the hinterland.

The sampled Beare Green section has been divided into three moderately well defined zones. Zone BG.A is particularly characterised by comparatively abundant fluorescent algal cysts, including Veryhachium spp., Baltisphaeridium sp. (Short Spined Form), Scenedesmus

BEARE GREEN



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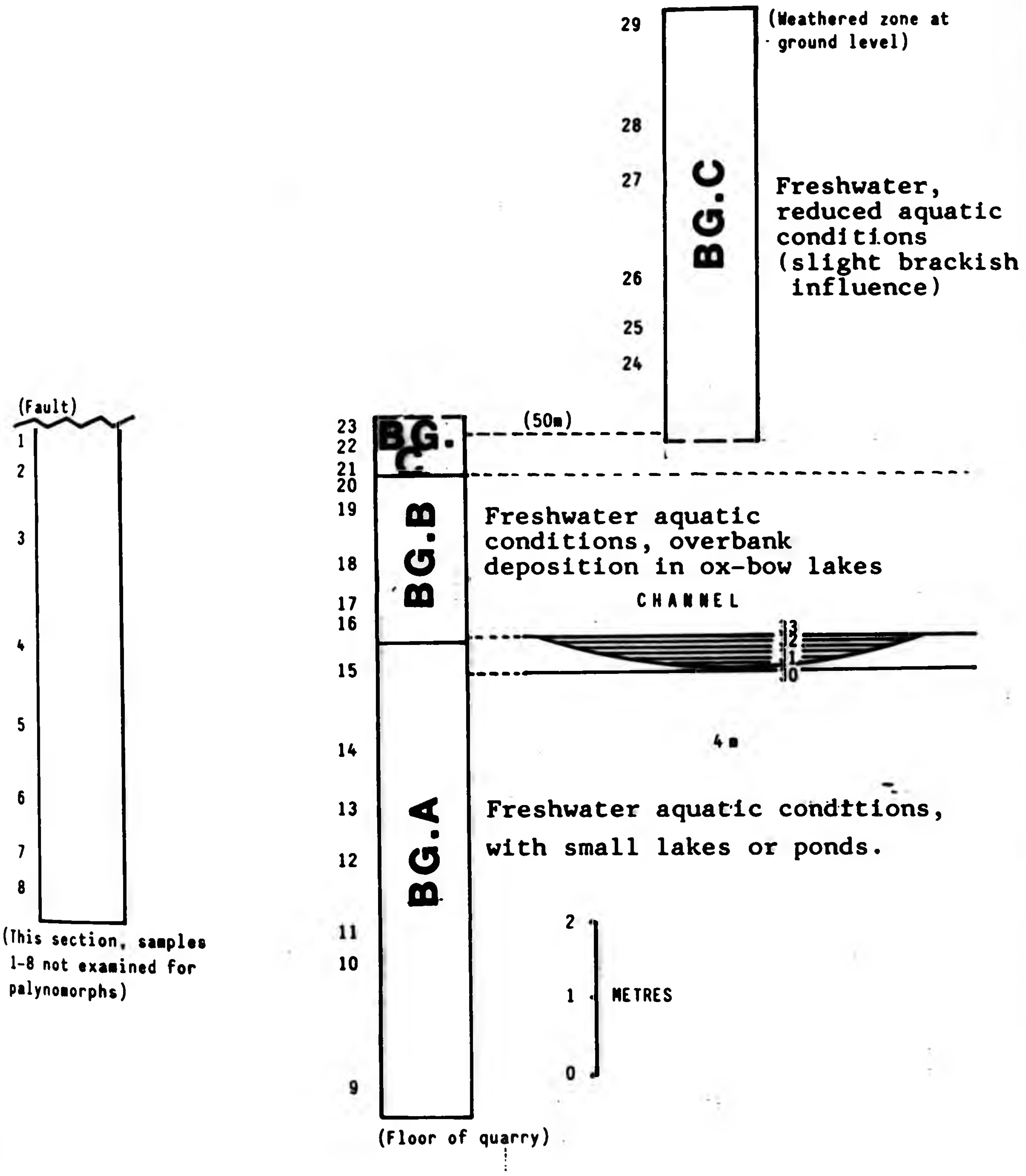
Text-fig. 3.4 i

Beare Green



Text-fig. 3.4 ii

and Spiny Tetrads. These fluorescent algae are only abundant in comparison to the zones BG.B and BG.C but not particularly so compared to the whole batch of samples. Incertae Sedis type 1 dinocysts are particularly common in this zone. The spore taxa *Cingulitriletes* sp., *Pilosisporites trichopapillosus* and *Cicatricosisporites australiensis* are characteristic of this zone, but they are rare or absent in the zones above. *Pilosisporites trichopapillosus* was abundant in subcluster B-3. In common with zone BG.C, *Celyphus rallus*, *Costatoperforosporites* spp. and *Cicatricosisporites* spp.are prominent taxa. Non- laminated mudstones are a particular feature of this zone. The facies sequence is dominated by aquatic freshwater facies such as 23, 34, 35 and 64. There is no clear brackish indication. Aquatic conditions probably existed as isolated ponds or small lakes. This must have been the habitat of Incertae Sedis type 1 dinocysts.

Samples taken from immediately beneath, within and just above a channel have been separated (BG.30, BG.31, BG.32 and BG.33). This is a different channel from the one described by Harris (1981), as the present one occurs solely in mudstones, visible as a darker colour. These four samples show an interesting trend of rising facies through the channel (27 - 34 - 64) reverting to facies 35 above. This is accompanied by generally rising frequency of segmented alga type 2. The facies sequence suggests that the channel developed through already damp terrain with sample BG.31 (facies 34) in damper freshwater conditions. Sample BG.32 (facies 64) records probable transportation to facies 45 before conditions became lacustrine above it (sample BG.33).

Zone BG.B shows certain taxa in common with BG.A. These are *Biretisporites* spp., *Lycopodiumsporites marginatus*, *Cicatricosisporites augustus* and *Aequitriradites* spp.. Laminated mudstones are quite prominent together with cluster group G facies that are mainly overbank deposits,probably in small ox-bow type lakes, unsuitable for Celyphus rallus. Zone BG.C shows several features in common with BG.A as already mentioned. Its principal characteristic is the rarity of fluorescent algal cysts, particularly Veryhachium spp.. The facies sequence reveals facies 26 to occur in three samples, suggesting generally dry freshwater conditions with some ponds. Brackish influence with facies 15 is also indicated (supported by the consistent Vitreisporites pallidus here) while the remainder of samples are all in the freshwater overbank category. Despite these influences the general rarity of fluorescent algal cysts and lower Celyphus rallus indicates comparatively reduced aquatic influence. Segmented Alga type 2 is most common in this zone, possibly slightly more so than in zone BG.A. It appears to occur independently of the presence of other fluorescent algae, possibly indicating that it actually has a non-aquatic source, associated instead with the particular Beare Green fern flora.

Harris (1981) concluded that fusinized fern remains from Beare Green "were buried in a floodplain where the land surface stood distinctly above sea or lake level, some way from both hills and seas.....I plant my ferns on low banks near the flood plain and perhaps on the higher parts of the plain itself, but I reserve the lower parts for other vegetation.....I suppose that the three fern species were tall herbs and the equivalent vegetation today would be grassy savannah or bracken covered heath."

The plant remains are comparatively unfragmented indicating that they grew more or less in situ and Gymnosperm remains are noticeably absent,indicating that they were not part of the local flora, though they probably were abundant as forests, on the hinterland massif.

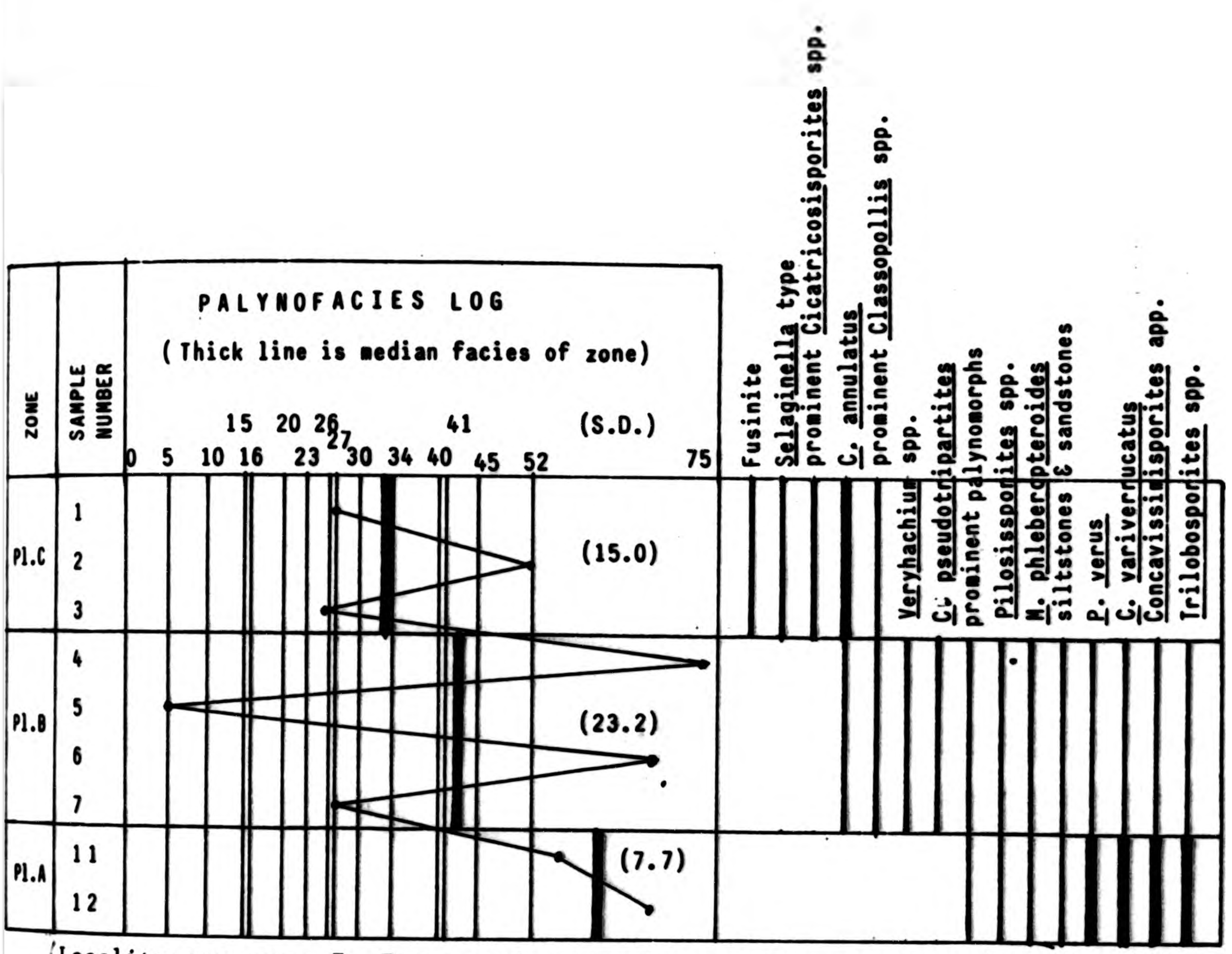
This general depositional setting is supported by the present results, where saline influences are very low and plant communities are apparently well developed. The abundance of gynmosperm pollen and fusinite supports the general proximity of the source massif.

3.4 (f) Pluckley Pit

The sequence from Pluckley is typically characterised by rich well developed spore/pollen assemblages. Podocarpidites type is distinctly prominent throughout the sequence. Palynomorphs comprise an important part of the bulk kerogen. A rich variety of spore/ pollen taxa must indicate mature well developed plant communities well away from the strand line. The prominence of fusinite indicates that the hinterland was near at hand. Fluorescent algal cysts are generally rare and Celyphus rallus is totally absent suggesting that aquatic influences are rare. The sequence can be divided into three zones, Pl.A, Pl.B and Pl.C. This does not include two barren intervals, one at the base of the section, and one between zones Pl.A and Pl.B (see text-figs. 3.5 i - ii)

Zone Pl.A comprises only two samples, Pl.11 and Pl.12, but they come from a very distinctive purple siltstone or fine sandstone that contains abundant fragmented fusinite, visible in hand specimen. This bed lies above and below barren intervals and is characterised by prominent Pilosisporites verus, Concavissimisporites variverrucatus, Concavissimisporites spp.and Trilobosporites spp.. The palynofacies (67 and 56) both indicate that in situ assemblages are represented. Schizosporis reticulatus is present in both samples, an aquatic colonial green alga that is normally extremely rare. Classopollis spp.are particularly low in this zone indicating that this taxon is not an important part of the in situ plant community. This bed may represent a landslip or outwash,following a forest fire on the hinterland, into the most proximal part of the mudplain where mature fern communities existed. Zone Pl.B is characterised by prominent Pilosisporites spp., Concavissimisporites spp., Appendicisporites spp.and Trilobosporites spp. similar to zone Pl.A. The spore Cicatricosisporites pseudotripartites is particularly characterstic together with Veryhachium spp..

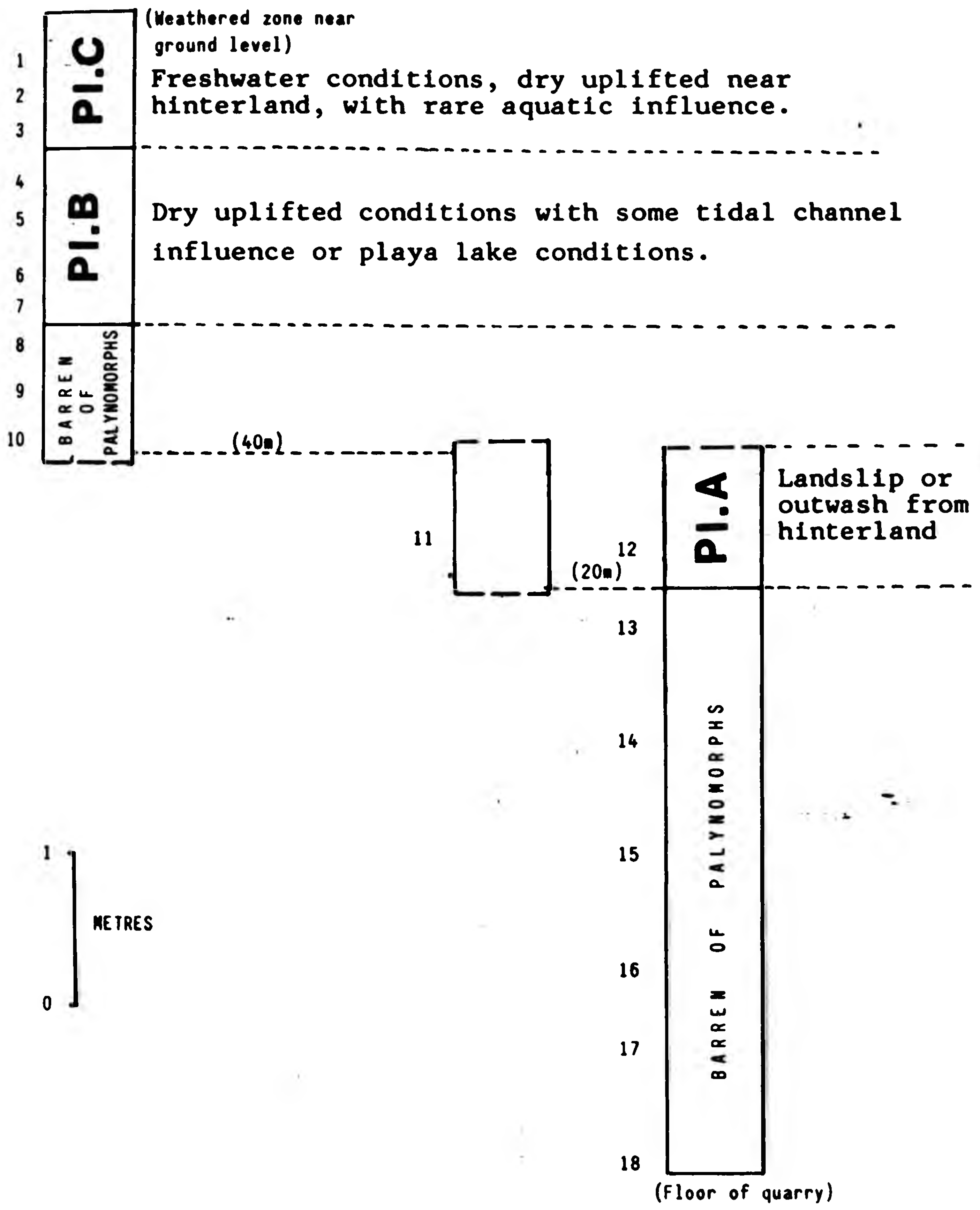
PLUCKLEY



(Locality map page 7. For precise sample spacing see Text-fig. 3.5 ii)

Text-fig. 3.5 i

Pluckley



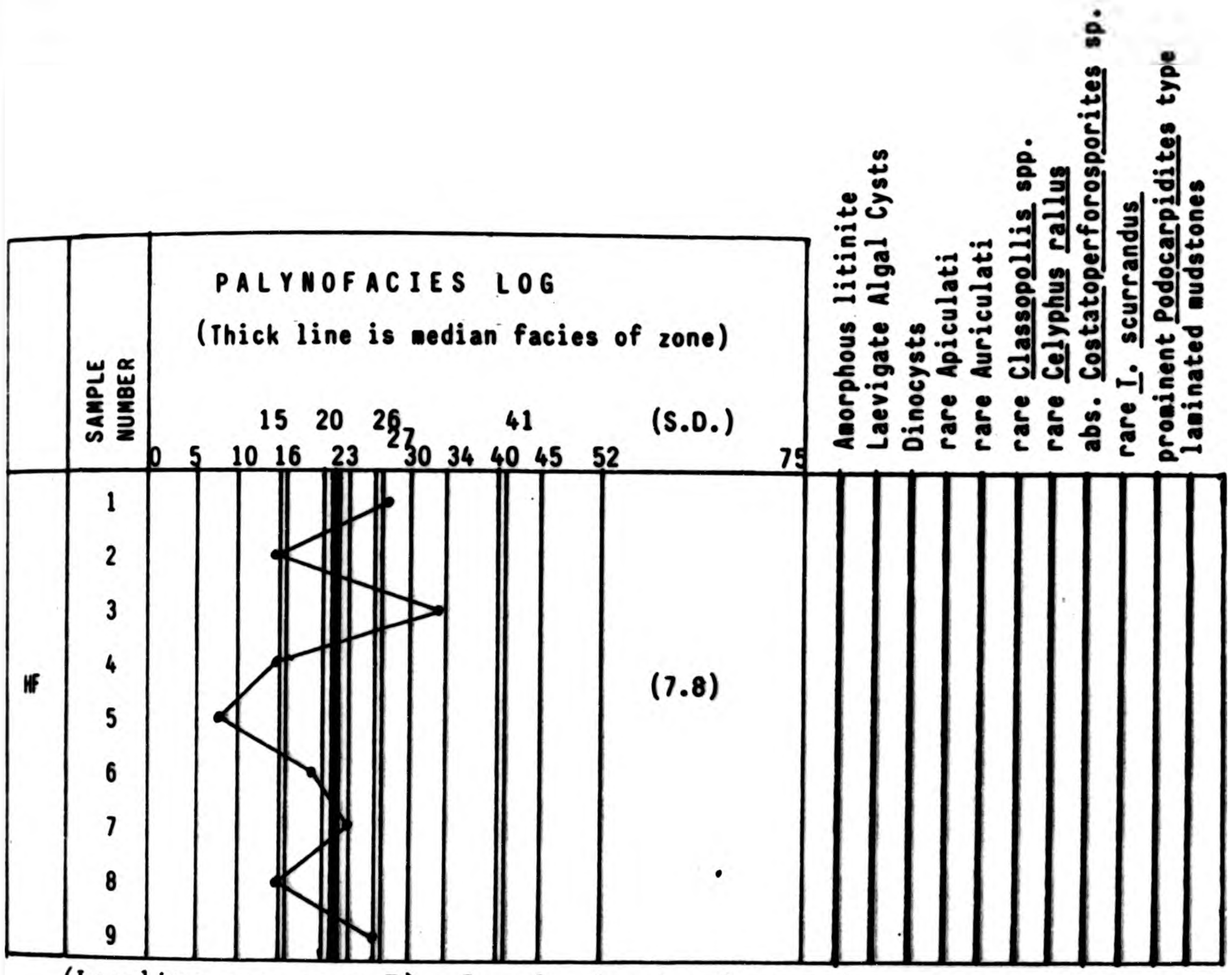
Text-fig. 3.5 ii

The latter must indicate some slight aquatic influence, though this taxon is very low in abundance in comparison to the whole set of samples in this study. One sample (Pl.5) lies within facies 5 where marine influence is at its strongest. The palynofacies sequence indicates generally dry uplifted environments, so this sample must indicate only tidal channel influence. This sample is different from others in the strongly marine facies 5 in containing abundant Veryhachium spp. but only rare Laevigate Algal Cysts. It could represent some specialised saline environment such as that associated with evaporation of a pond or lake, well away from the strand line. Zone Pl.C shows a few characteristics of zone Pl.B such as comparatively prominent Cicatricosisporites annulatus and Classopollis spp., but taxonomic variety is generally reduced in comparison, particularly so of the Apiculati. Fusinite is particularly prominent here, together with Cicatricosisporites spp.. The palynofacies sequence indicates a freshwater regime with little aquatic influence. This is in agreement with Allen (1975 p.422) who states under discussion of north-eastern Weald Clay cycles that "salinities probably varied less farther east because many of the near-marine and brackish horizons appear to fade out....The environment seems to have been a stable sweetwater flood-plain, seldom polluted by the sea."

3.4 (g) Hurlands Farm borehole

This sequence of nine core samples from near the top of the Weald Clay do not show any differentiation into zones (see text-fig. 3.6), so palynofacies and palaeoenvironments can be discussed in the context of the whole sequence at once. Spore/pollen taxonomic variety is generally low, particularly of the Apiculati and Auriculati. *Costatoperforosporites* spp. are completely absent (similar to Lingfield). *Classopollis* sp. and *Celyphus rallus* are both much reduced in percentage in comparison to most Weald Clay localities. Reduced spore/pollen variety is partly caused by evident poor preservation, which also accounts for the absence of vitrinite and semifusinite. Marine indications are strong throughout this sequence as would be expected at the top of the Weald Clay, when regional marine transgression occurred. Dinocysts are common together with Laevigate Algal Cysts and amorphous liptinite. Fluorescent algae and *Celyphus rallus* are generally rare. However it is interesting to note that the palynofacies sequence reveals hardly any marine influence, palaeoenvironments are almost all freshwater and several are non-aquatic. In my opinion this apparent contradiction sheds light on the manner of the marine transgression to the overlying Atherfield Clay. Sediments laid down at this time must have been totally reworked, together with their spore/pollen assemblages that were laid down in previously freshwater conditions. This accounts for the poor palynomorph preservation and shows that sources of new sediment supply had completely vanished by this time following erosion and transgression of the source lands (Allen, 1975, 1981). Marine type plant communities (ie. those represented by spore/pollen taxa in cluster group A) could not develop as marine conditions were too rapidly transgressive, but marine derived kerogen and palynomorphs were mixed with the

HURLANDS FARM



(Locality map page 7). Sample depths (metres):

HF.1 - 97.00 HF.6 - 102.50
HF.2 - 98.00 HF.7 - 103.50
HF.3 - 99.50 HF.8 - 104.50
HF.4 - 100.50 HF.9 - 104.68
HF.5 - 101.50

Text-fig. 3.6

reworked muds. Currents must have been very sluggish as indicated by the prominence of well laminated sediments.

3.4 (h) Nutfield and Cranleigh samples

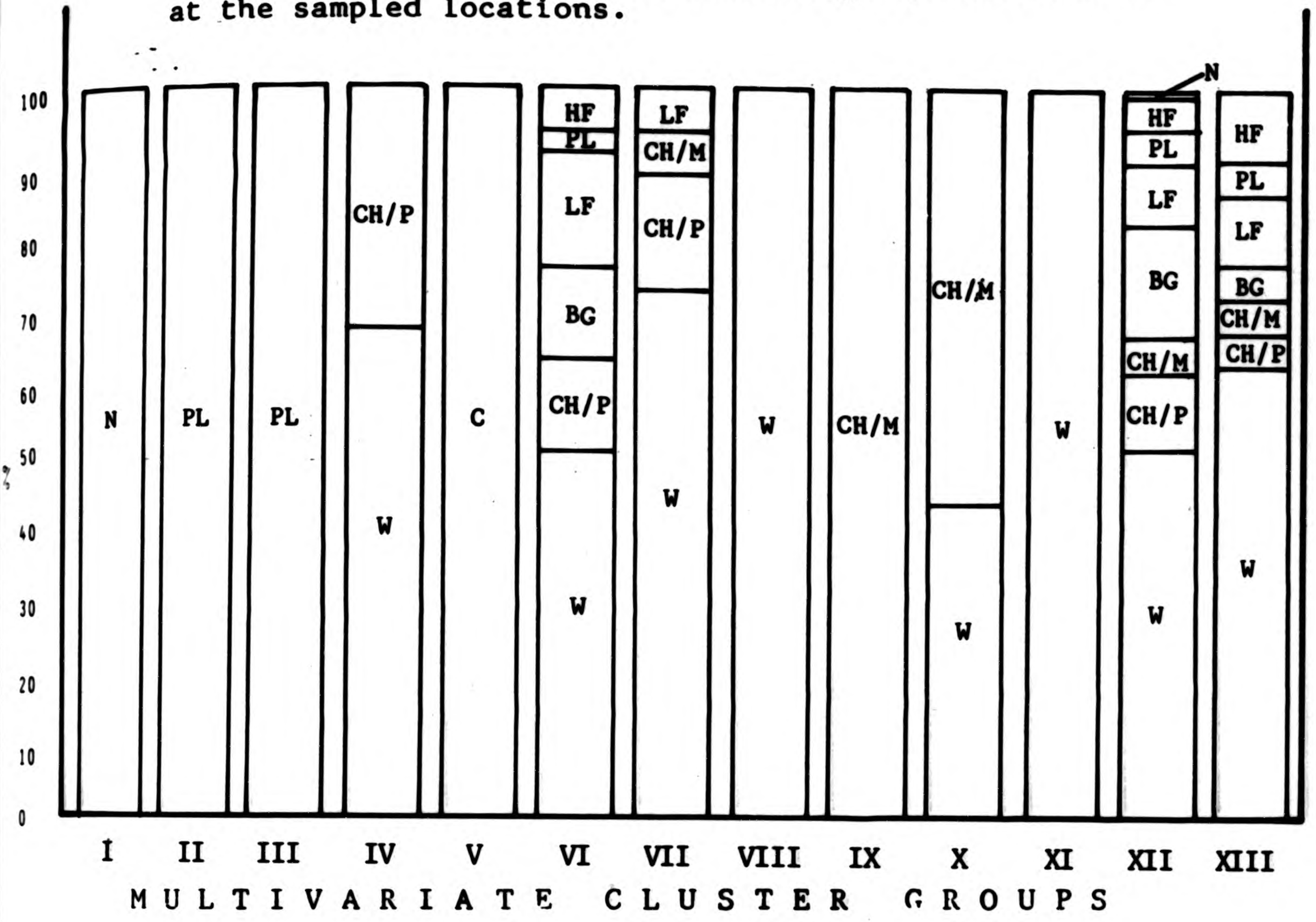
These samples are isolated from any stratigraphic sequence as they were collected from ditches or road cuttings together with other samples that yielded totally barren assemblages due to extensive weathering. However they have provided unique spore/pollen assemblages that in the case of N.17 and CR.2 have formed their own multivariate cluster groups which have already been discussed (groups I and V respectively). Sample N.15 yielded a more usual assemblage, falling within the large facies 15 characterised by brackish lacustrine conditions.

3.4 (i) Summary and Discussion

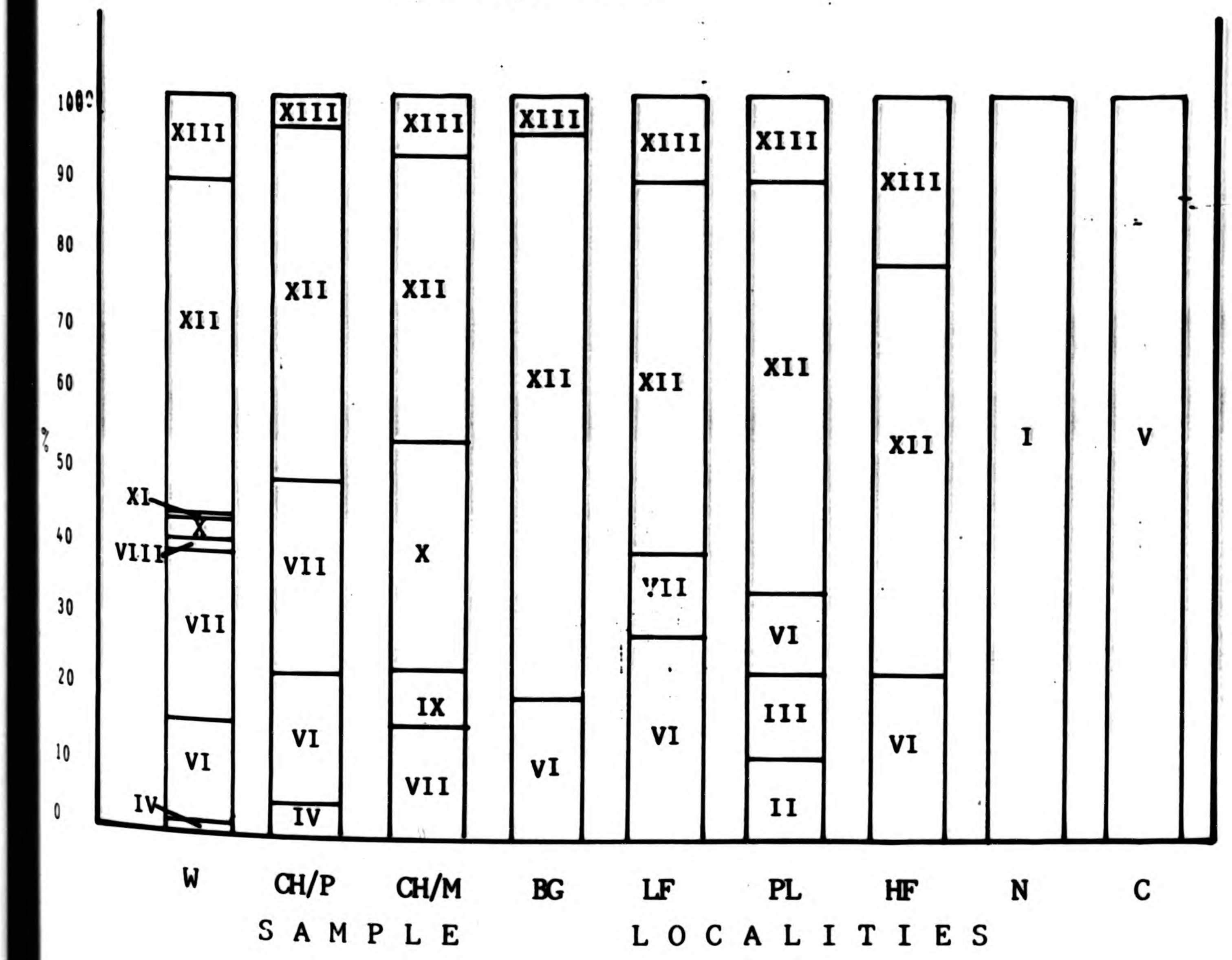
By way of summary and to allow a general comparison of all the Weald Clay localities in this study a number of histograms have been drawn (text-figs. 3.7 i - v). Geographical and stratigraphical changes throughout the Weald Clay (within the confines of the localities sampled in this study) will be discussed. The histograms have been drawn in two separate ways for the multivariate and binary data. The upper diagram shows the percentage composition of samples from localities, within respective cluster groups. This tends to show a percentage bias in favour of localities with a great number of samples, so the lower diagram shows percentage occurence of cluster groups within respective localities. This is independent of differences in sample number betweeen localities, but localities with only a small number of samples appear to be dominated by one cluster group. Reference to both of these diagrams together should obviate the inherent disadvantage of each.

Warnham is dominated by samples falling with groups F and B where aquatic influence and brackishness are most pronounced. The drier uplifted groups D, E, and J are of comparatively minor importance. The uplifted <u>in situ</u> cluster groups I, II, III and V are not represented. Groups VIII and XI (facies <u>11</u> and <u>43</u>) are included in group B and F respectively and they represent <u>in situ</u> assemblages of the lower wetter mudplain. Group VII (<u>Celyphus rallus</u>) is of comparative importance at Warnham and Chailey, indicative of aquatic conditions. Brackish/marine influences are pronouned at Chailey, particularly in core CH/P which contains the greatest representation of cluster group A. Group B is important in both Chailey cores together with group I where particular aquatic conditions, with possibly tidal marine influences are very pronounced.

Summary of the multivariate cluster group occurrences at the sampled locations.

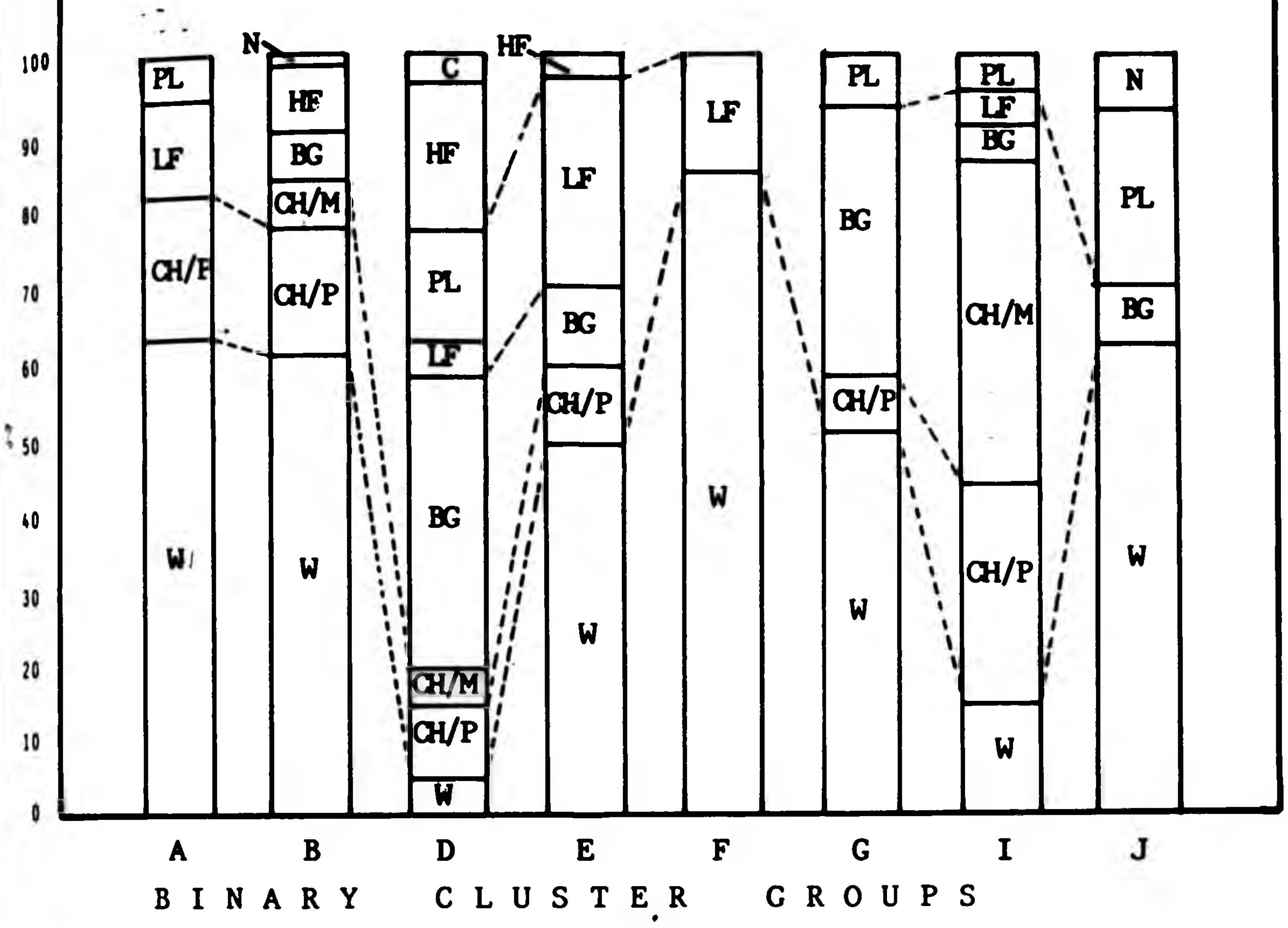


Text-fig. 3.7 i

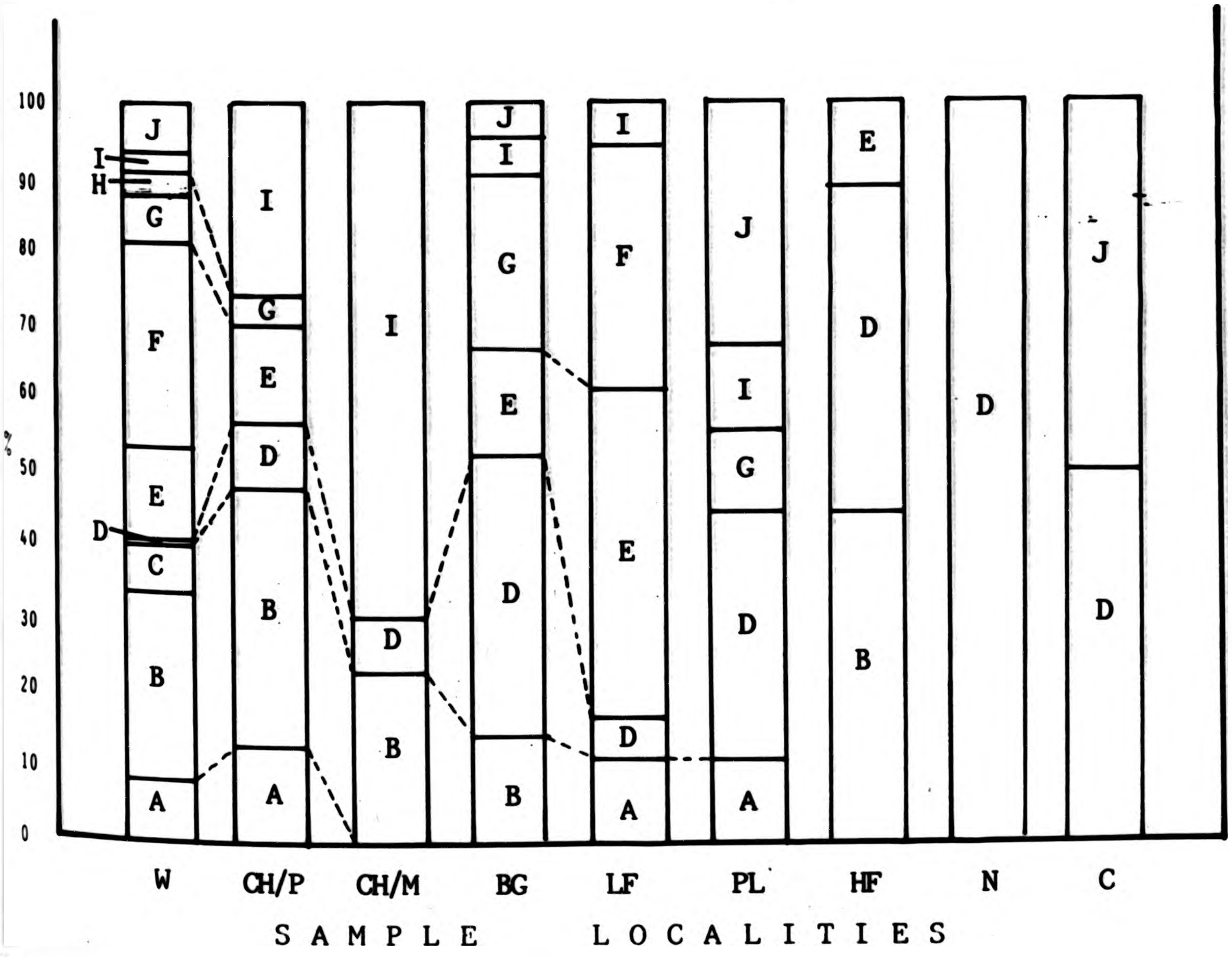


Text-fig. 3.7 ii

Summary of the binary cluster group occurrences at the sampled locations.

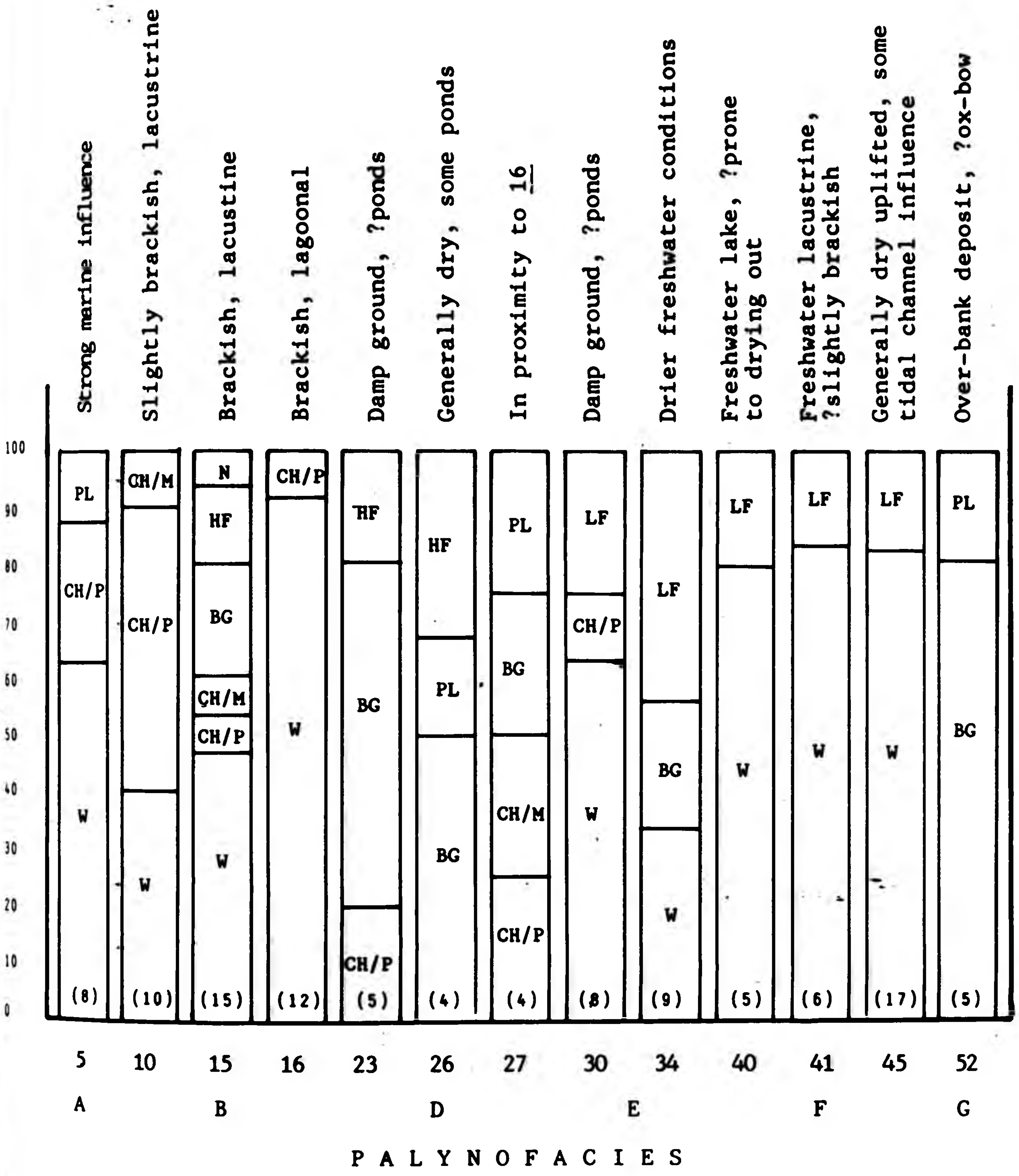


Text-fig. 3.7 iii



Text-fig. 3.7 iv

Summary of the 13 principle palynofacies at the sampled locations.



Text-fig. 3.7 v

These low lying aquatic environments are also represented in group X which is totally dominated by Warnham and Chailey samples. As at Warnham the drier uplifted palaeoenvironments are not important at Chailey, taking the section as a whole. Text-fig. 3.7 v provides a summary of the percentage composition by localities of the 13 principal palynofacies (facies 20, the barren one is excluded here). These palynofacies are all those that contain four or more samples. The Warnham and Chailey samples dominate facies 5, 10 and 16 and are important in facies 15. These are all facies where brackish/marine influence of varying degrees is to be seen. The Warnham and Chailey samples are important in facies 30 that has aquatic freshwater influence, while facies 40, 41, 45 that tend towards generally drier conditions with less brackish influence, are important at Warnham, probably due to its greater stratigraphic range than that at Chailey. The Beare Green section shows much less brackish influence with no samples falling into the marine influenced cluster group A. It has a few samples within group B but none of these fall within facies 16 of this group where marine influences are greatest. Most of the Beare Green samples lie within cluster group D that contains only one Warnham sample. This group contains generally uplifted dry palaeoenvironments with little aquatic influence (facies 23, 26 and 27). Groups G and E, also mainly uplifted and freshwater are also important at Beare Green, while the taxonomically mature facies within groups I and J are comparatively important. Beare Green samples fall only within multivariate cluster groups VI, XII and XIII. These are all large groups of samples so no individually outstanding *in situ* type assemblages are to be seen at Beare Green. At Lingfield the most prominent binary cluster group, is group E (facies 30 and 34), that comprises generally dry uplifted facies with very little brackish influence. Cluster group F (facies 40, 41 and 45) is also important, where conditions are also dominantly freshwater. Several Lingfield samples fall within cluster group A where marine influence is greatest, but more of these occur in facies 5. They all appear to be the result of transportation or channel influence. Definitive marine influence appears to be comparatively unimportant at Lingfield. As at Beare Green no individually distinctive assemblages are to be seen and Lingfield is also only represented by multivariate cluster groups VI, XII and XIII. Pluckley is characterised by the greatest number of group J samples. This cluster group contains facies that comprise too few samples to register on text-fig. 3.7 v but they are well exemplified in multivariate cluster groups II and III (facies 67 and 56). Group J samples represent the most 'mature' ie. taxonomically varied, assemblages characteristic of the dry uplifted mudplain near the hinterland. Group D samples are also important at Pluckley, that includes mainly dry uplifted palaeoenviromments, though with slightly more aquatic influence than group J. Despite the uplifted distal nature (with respect to the strand line) of Pluckley, one sample falls into facies 5. This indicates how low lying the Weald Clay mudplain must have been for marine influence to extend this far, though as has been mentioned, it is possible that this sample represents raised salinity within the basin by evaporation, as facies 5 marine parameters such as abundant Laevigate Algal Cysts do not occur. The Hurlands Farm samples, all undoubtedly marine influenced by the occurrence of abundant dinocysts as well as characteristic marine type kerogen, only contain samples falling within cluster groups B, D and E. No group A samples are represented. It can only be reiterated that this must provide good evidence that previously laid down sediments and their characteristic freshwater palynofacies were being reworked at this time, as the source lands had been completely eroded away or transgressed. The Nutfield and Cranleigh samples provide well developed *in situ* assemblages (multivariate cluster groups I and V, facies *66* and *21* of the dry uplifted mudplain).

It is interesting to note from text-fig. 3.7 ii that (except for the Nutfield and Cranleigh samples) multivariate cluster group XII is present in about 50% of all samples from all localities. Likewise group VI and XII show very constant percentage occurrences at all localities. These latter two groups are characterised by prominent percentages of *Cicatricosisporites* spp. and *Gleicheniidites* spp. respectively, the commonest Weald Clay spore genera. Cluster group XII comprises a particular association of percentage frequencies of commonly occurring taxa. When all is said and done it is surprising how similar spore/pollen assemblages are from all Weald Clay samples. Yet despite this, differences do exist that are sufficiently well marked to define palynofacies groups of palaeoenvironmental significance.

CHAPTER 4

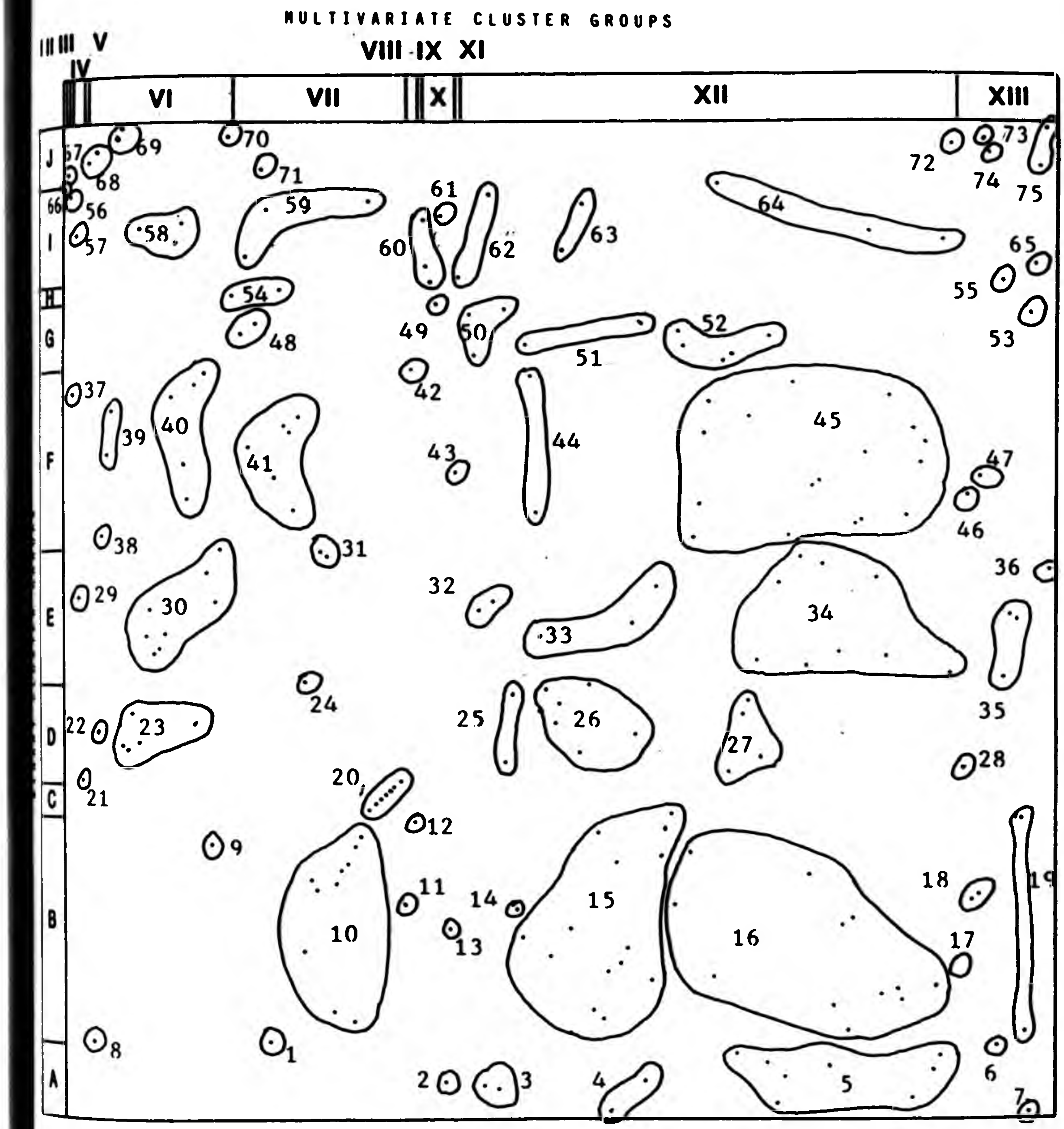
TAXONOMY

Introduction

This chapter provides brief taxonomic descriptions of all the palynomorph types encountered in this study, together with plates of all types and variants from the most commonly to rarely occurring forms. This study is not taxonomic, so the descriptions are not exhaustive. However greater importance has been attached to fitting individual taxa into the palynofacies scheme that is the main theme of this study. The 87 spore/pollen taxa that formed the basis of the cluster analysis study are dealt with in most detail. Each of these is provided with a summary of its occurrence within every sample in the study using a reduced, A4 size version of the multivariate and binary sample matrix from which palynofacies and palaeoenvironments were defined (enclosure 10). As this reduced version is too small for the environments to be included, reference must be made to text-figs. 4.0 i and 4.0 ii for this information. Spore/pollen taxa not included in the cluster analysis due to their rarity, are given a general palaeoenvironmental comment, according to their pattern of occurrence in the palynofacies scheme, or no comment is made. The fluorescent algae were not used in performing the cluster analysis but their occurrence within the palynofacies scheme is summarized on enclosure 15. The semiquantitative symbols used for displaying abundances of specimens in the 75 palynofacies are as follows:

× 1; ○ 2-4; ⊙ 5-8; ⊛ 9-15; ◑ 16-20; ● 21-25; ■ 25-100; ⌘ >100.

Combined multivariate & binary cluster groups for palynofacies and palaeoenvironments

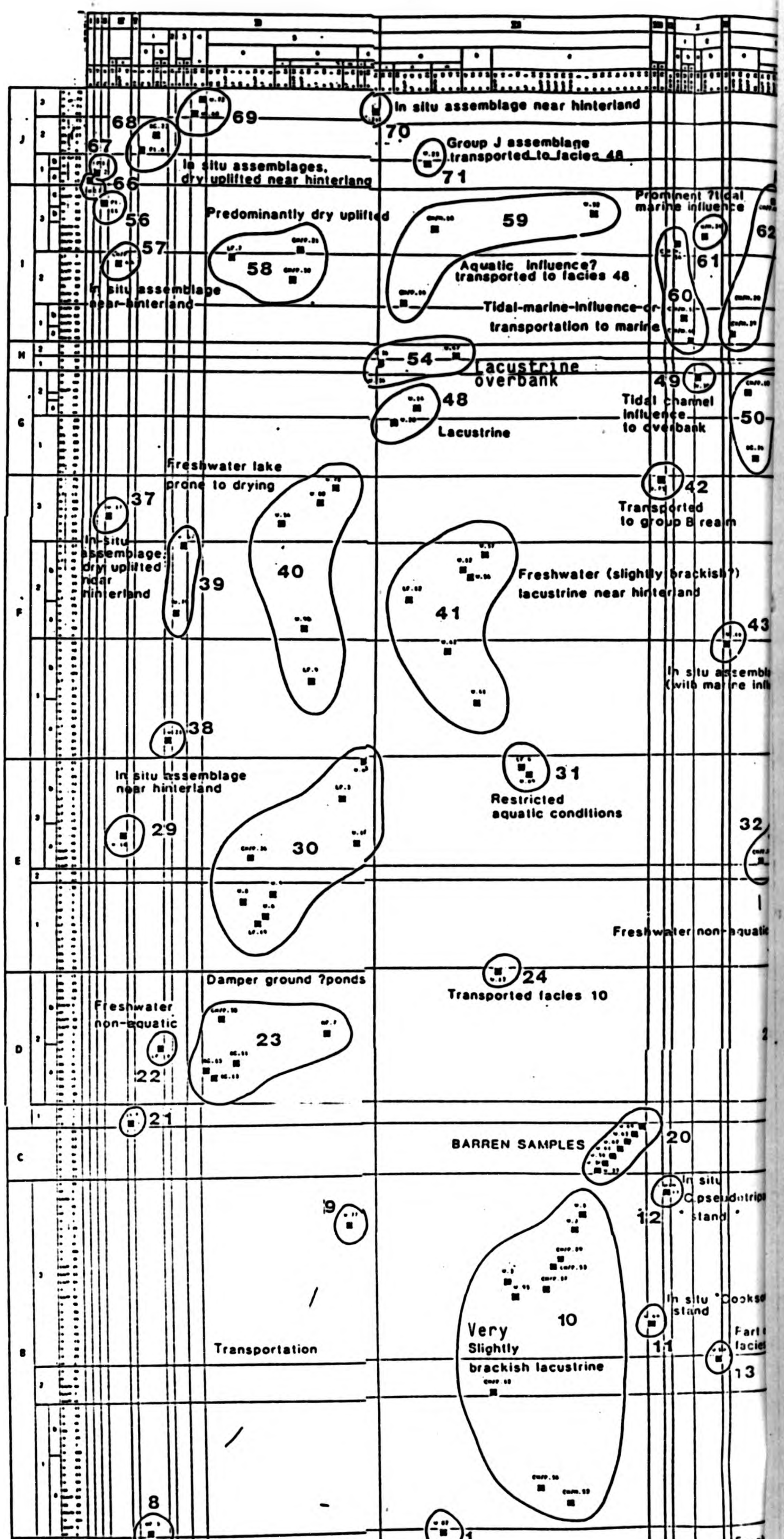


A - Strongly marine influenced palynofacies (1-7)
B - Brackish lagoonal or lacustrine palynofacies (8-19)
C - Control group (20)
D - Dry freshwater palynofacies (21-28)
E - Dominantly aquatic freshwater palynofacies (29-36)
F - Minor marine influence within freshwater palynofacies (37-47)
G/H - Overbank ponds and standing water palynofacies (48-55)
I - Mixed marine influenced and drier, freshwater palynofacies (56-65)
J - Dry uplifted, near hinterland palynofacies (66-75)

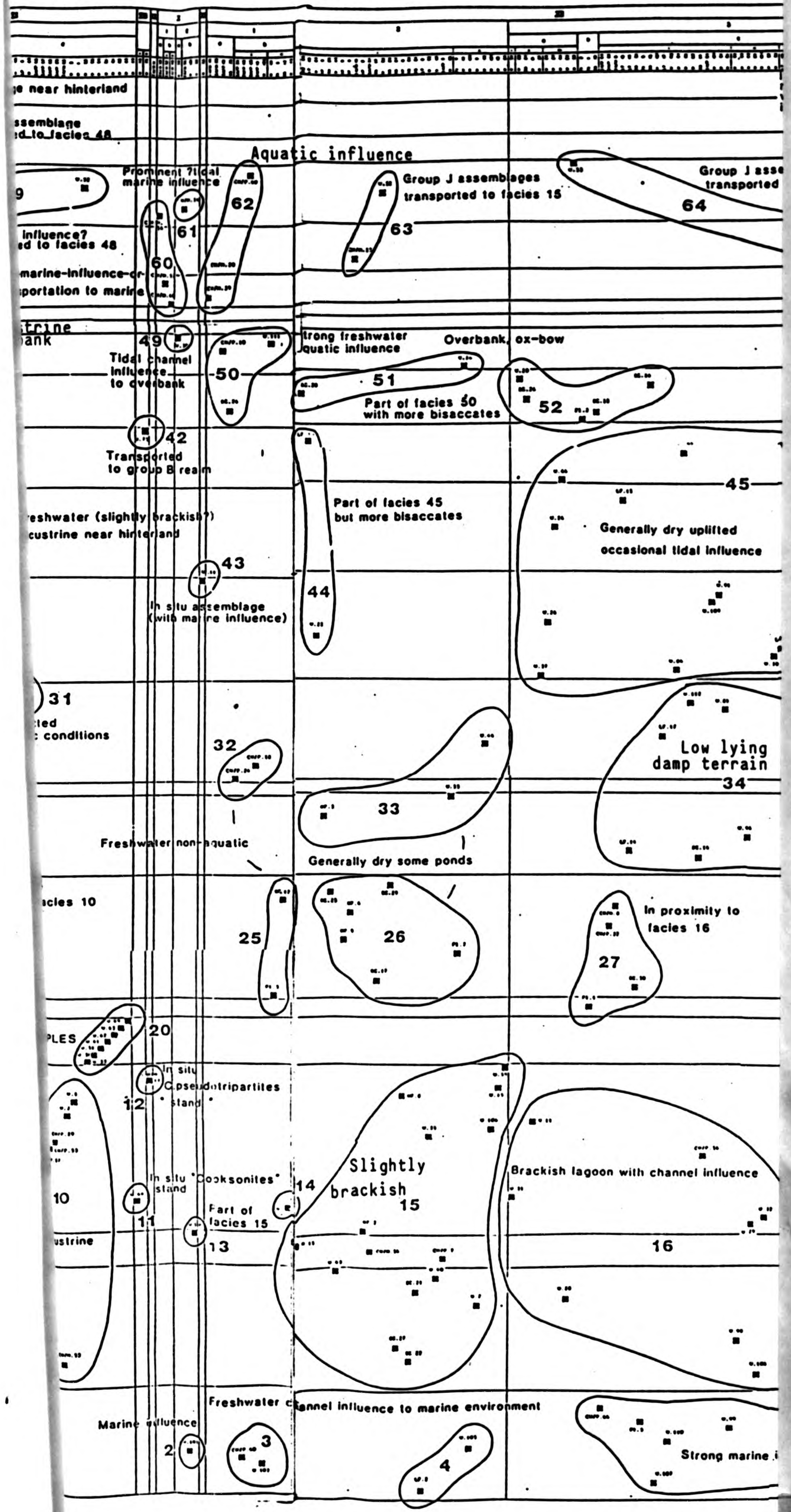
I/II/III/V - Strongly dry uplifted terrestrial palynofacies
IV - Dominantly freshwater palynofaci
VI - Prominent Cicatricosisporites
VII - Prominent Celyphus rallus
VII/IX/X/XI - Mixed marine influencec and freshwater palynofacies
XII - General mudplain palynofacies
XIII - Prominent Gleicheniidites

Text-fig. 4.0 i

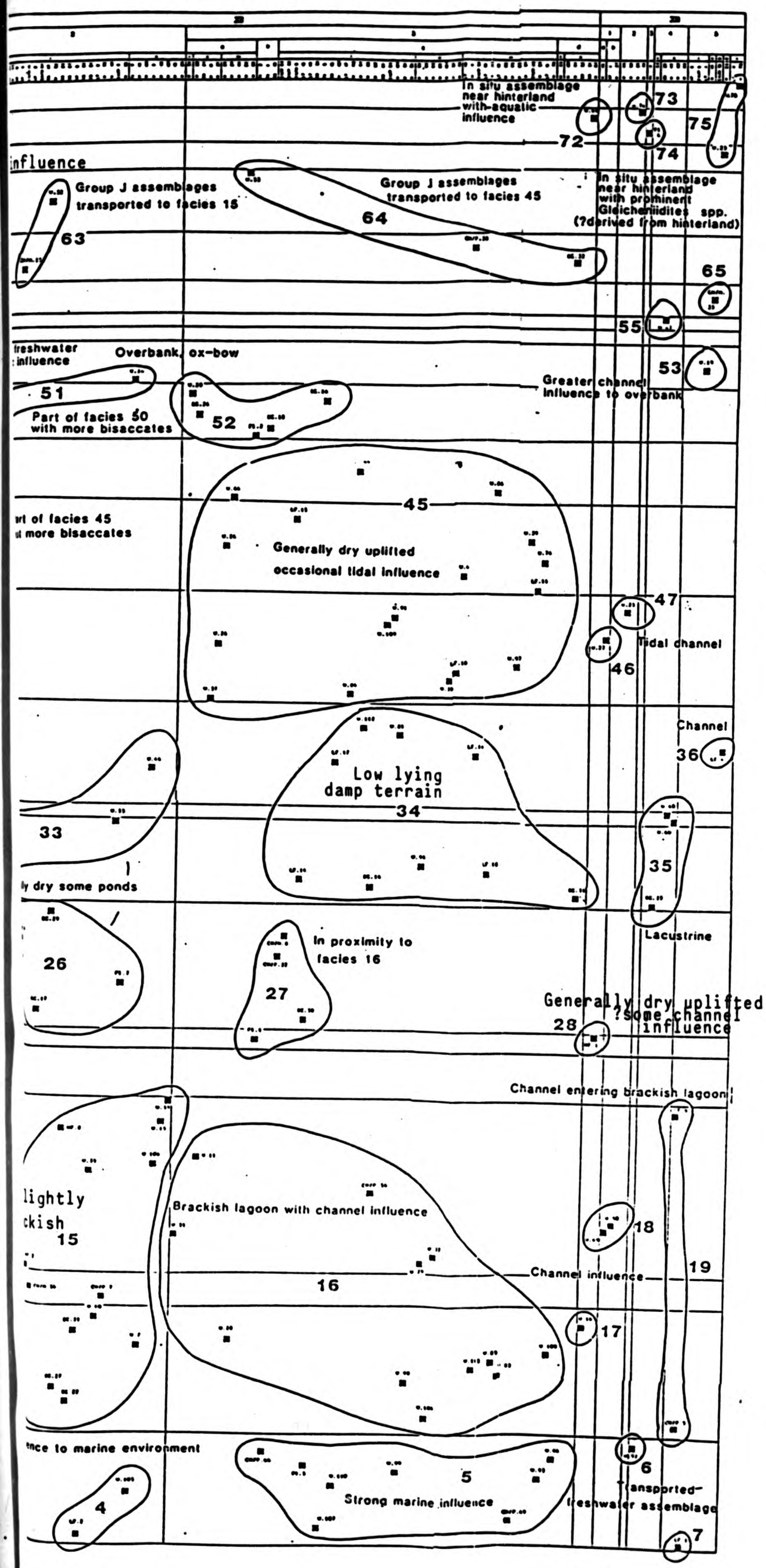
COMBINED MULTIVARIANT &BINARY CLUS



ARIANT &BINARY CLUSTER GROUPS FOR PALYNOFACIES & PALAEOENV



ROUPS FOR PALYNOFACIES & PALAEOENVIRONMENTS



Text-fig. 4.0 ii

Anteturma SPORITES
Turma TRILETES
Subturma AZONOTRILETES
Infraturma LAEVIGATI

1. Genus Cyathidites (Couper, 1953; Dettmann, 1963)

Type species: C. australis

Remarks: This genus includes laevigate or psilate spores of triangular to concave triangular outline. Such spores can be very common as the dominant component of the palynomorph assemblage. A variety of types can be distinguished based on size, shape and wall thickness, so this group probably represents a diversity of unrelated plants. However the grains observed in this study fall into the diagnosis of C. punctatus (Delcourt et al., 1963).

Plate 1, figs. 1 - 17

Palaeoenvironment: See Text-fig. 4.1. In this study specimens of Cyathidites spp. seem to be more common in facies that are generally damp, eg. facies 16, 45, 30, 40 & 41.

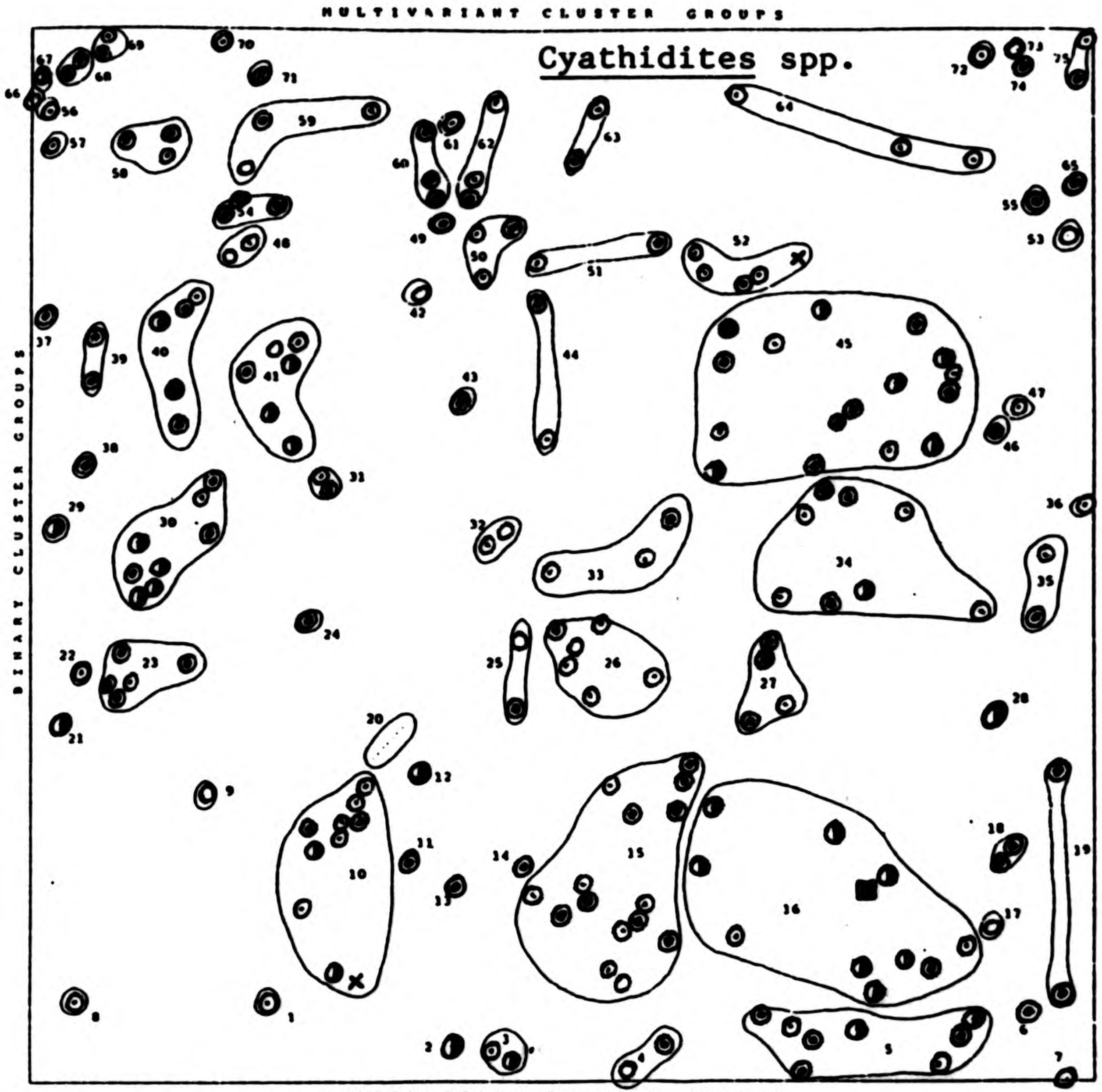
2. Genus Dictyophyllidites (Couper, 1958)

Type species: D. harrissii

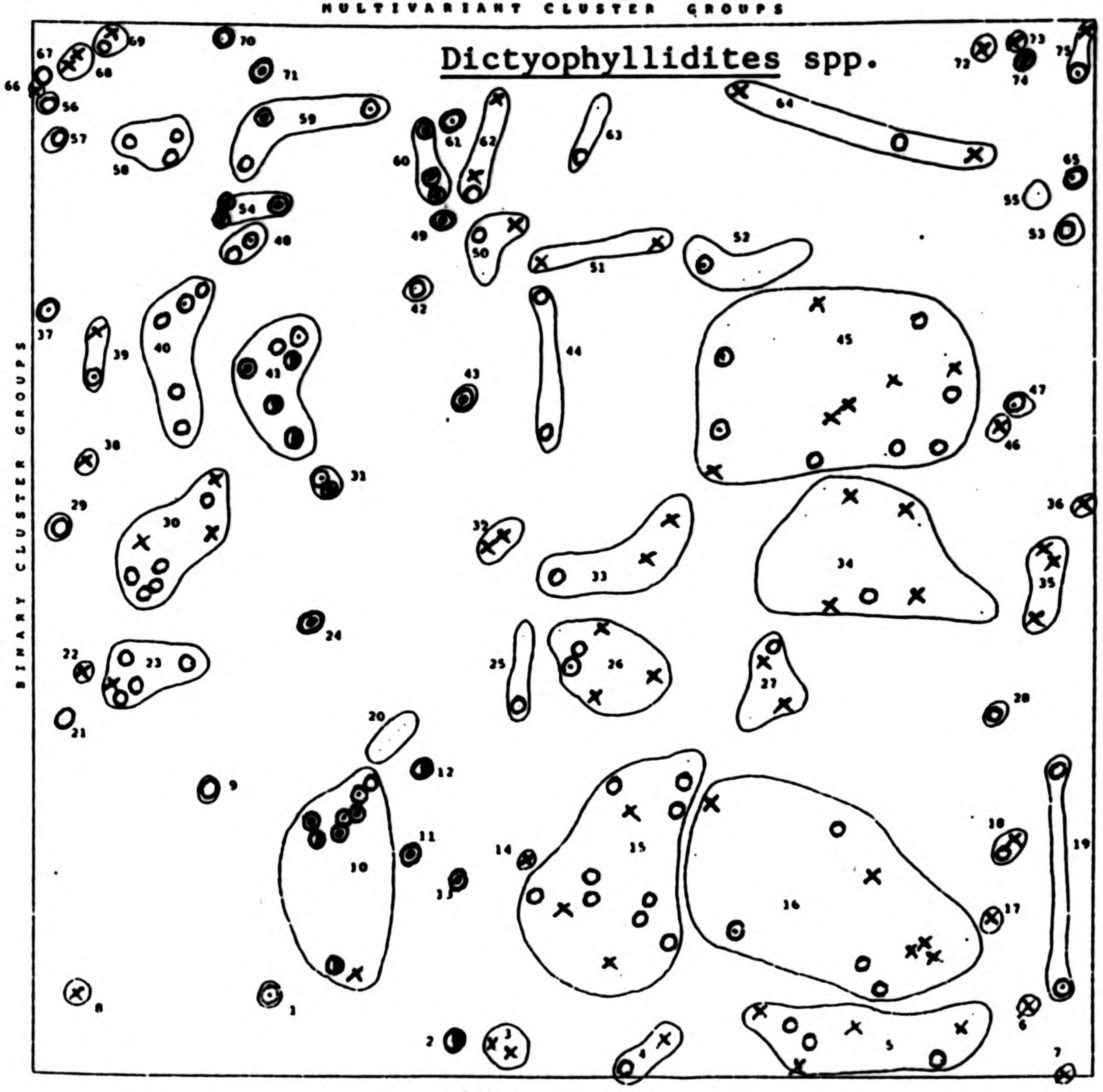
Remarks: This genus includes concave triangular grains similar to Cyathidites spp., but with thickened laesurate margins. Like Cyathidites spp. the group probably represents a diversity of plants.

Plate 1, figs. 32 - 49; Plate 2, figs. 1 - 21

Palaeoenvironment: Text-fig. 4.2 shows that Dictyophyllidites correlate well with Celyphus rallus in binary cluster group VII, as well as the small groups VIII, IX & X. The facies within these groups encompass the whole range from strandline to hinterland so this association cannot



Text-fig.
4.1



Text-fig.
4.2

be fully explained at the moment.

3. Calamospora type

This informal group probably includes a variety of taxonomic groups from poorly preserved spores to algal cysts.

Plate 6, figs. 1 - 16

Palaeoenvironment: They are associated with the dry uplifted near hinterland facies 66 - 69 as well as those with lacustrine influence such as 15, 16, 41 & 52 (see text-fig. 4.3).

4. Genus Todisporites (Couper, 1958)

Type species: T. major

Remarks: This genus includes smooth thick walled spores of circular outline with simple laesurae. Forms recorded here agree with the diagnosis of T. major.

Plate 2, figs. 65 - 69

Palaeoenvironment: These spores show a tendency (text-fig. 4.4) to cluster around the drier inland facies and are quite negatively associated with marine influenced facies except by probable reworking.

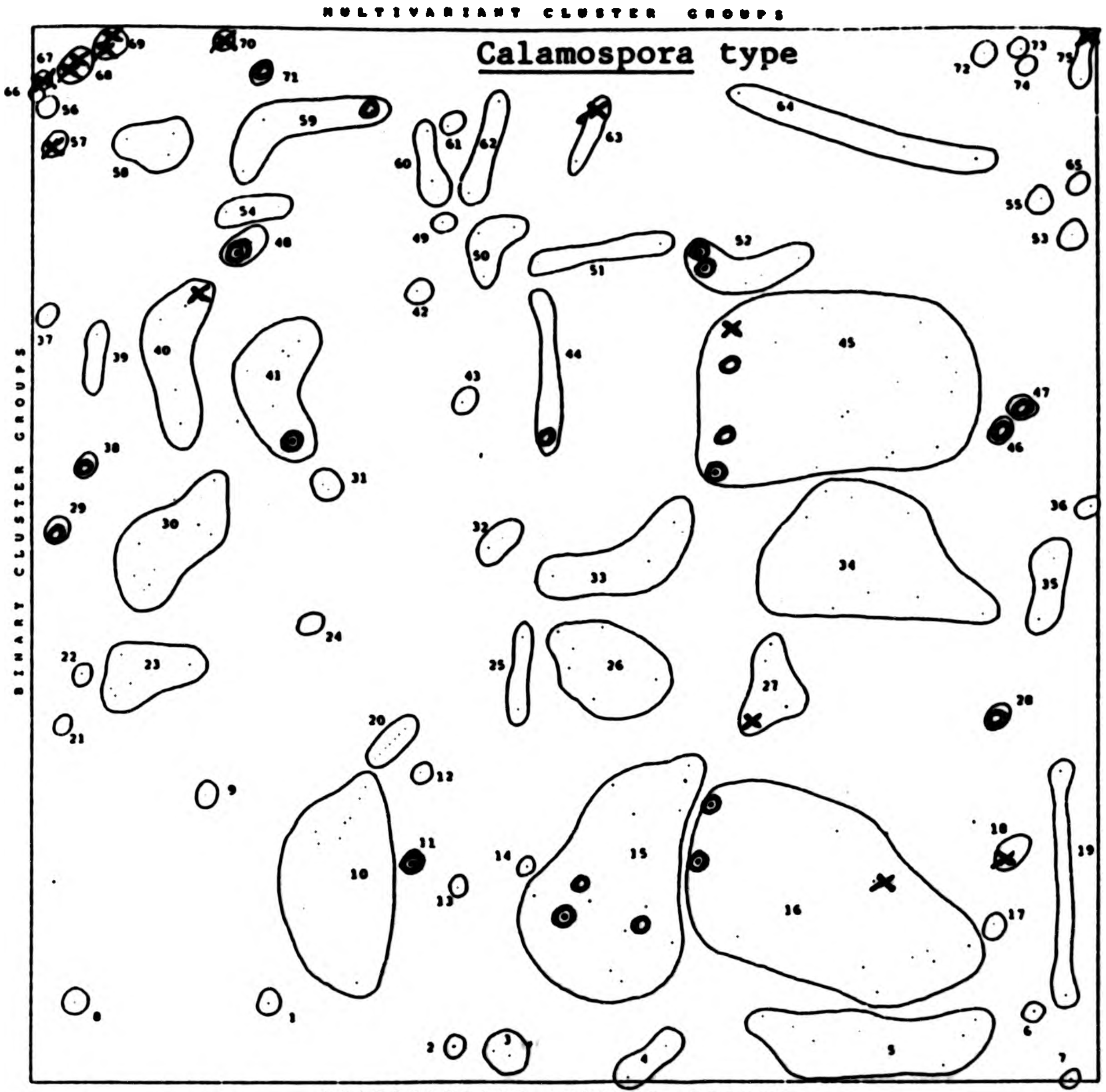
5. Genus Biretisporites (Delcourt & Sprumont emend. Delcourt Dettmann & Hughes, 1963)

Type species: B. potoniaei

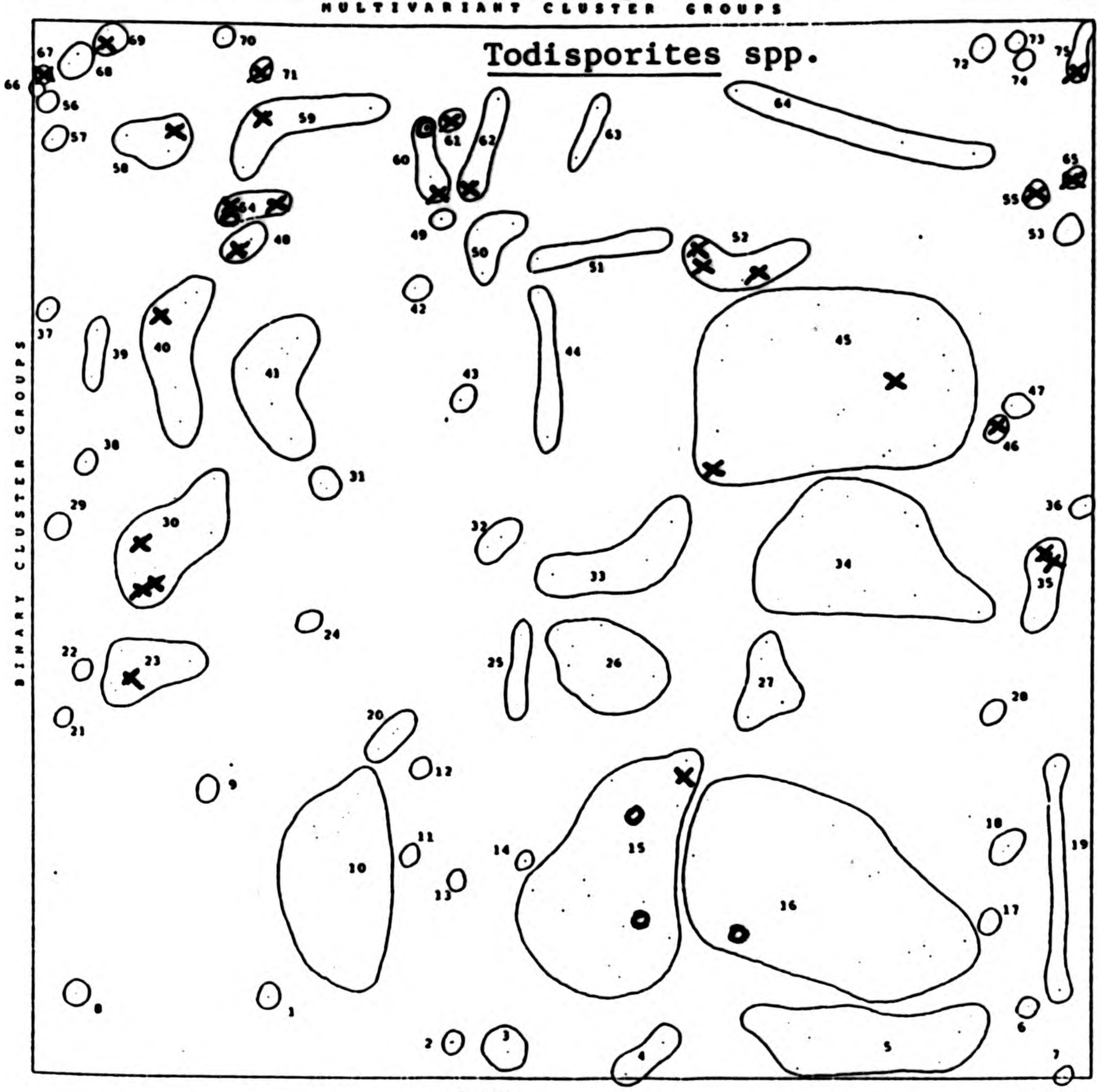
Remarks: This genus includes smooth thick walled triangular to concave triangular grains with well developed labra. No attempt has been made here to separate species.

Plate 2, figs. 31 - 44

Palaeoenvironment: These spores show a fairly even dis-



Text-fig. 4.3



Text-fig. 4.4

tribution throughout most of the Weald Clay palynofacies except those associated with the strand line. They show slightly above average occurrence in facies 23 & 30 that show evidence of dampness but are distinctly freshwater (see text-fig. 4.5).

6. Genus Concavisporites (Pflug, 1953 emend. Delcourt & Sprumont, 1955)

Type species: C. rugulatus

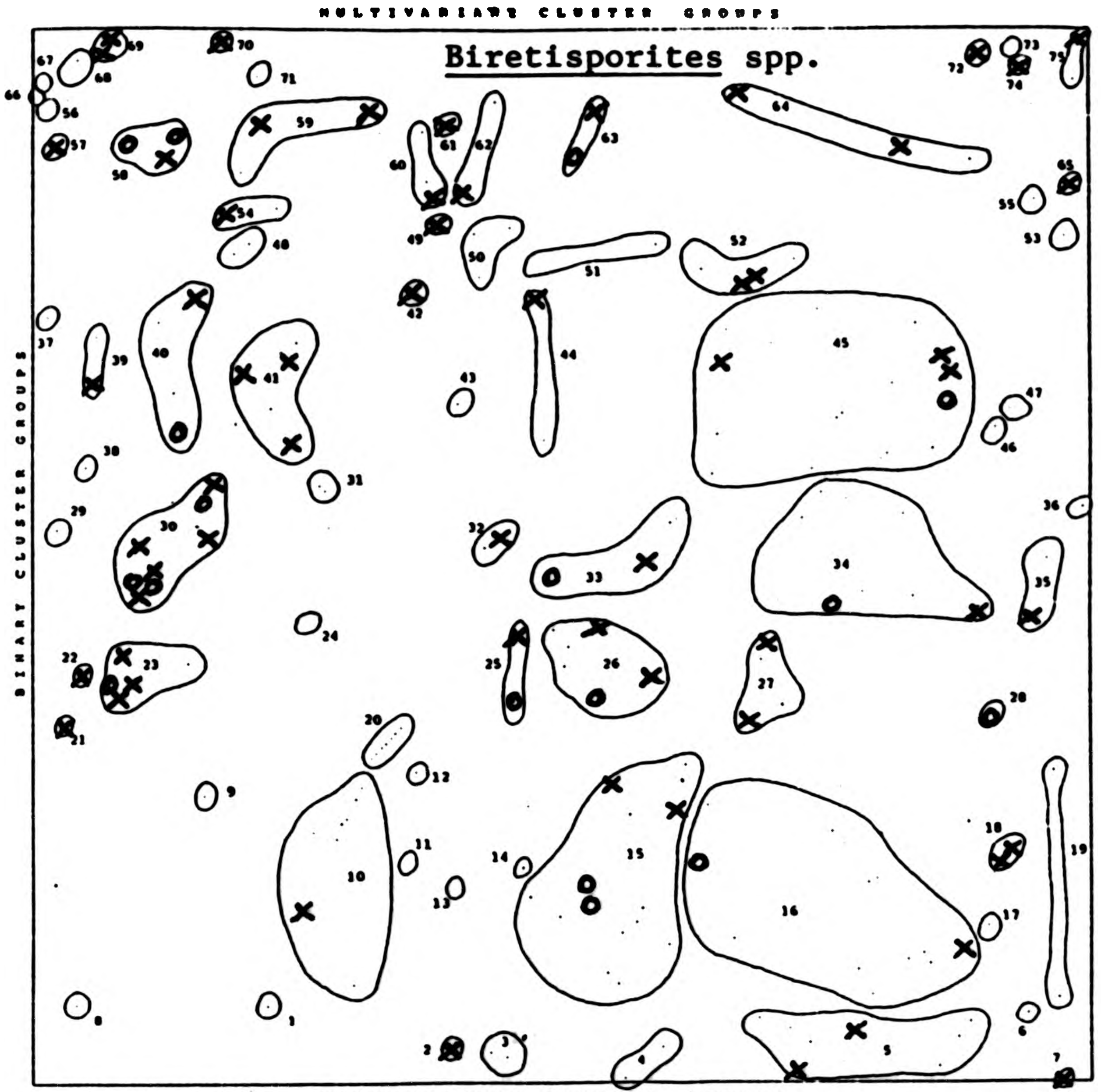
Remarks: The original description of Pflug stipulated strongly concave sides, though Balme (1957) noted that many specimens do not show this feature. One species C. jurienensis Balme (1957) was recognised in this study Laesurae always extend to the equator and are bordered by thickenings that narrow towards the radii (figs. 20, 21 & 22) or are of uniform thickness (figs. 18, 19 & 23 - 28). Balme describes arcuate thickenings sometimes extending as sharply angular auriculae at the apices. This is clearly visible on figs. 19, 22 & 23. In others (figs. 18, 20, 21 & 24 - 28) the auriculae are well back from the ends of the laesurae.

Plate 1, figs. 18 - 27

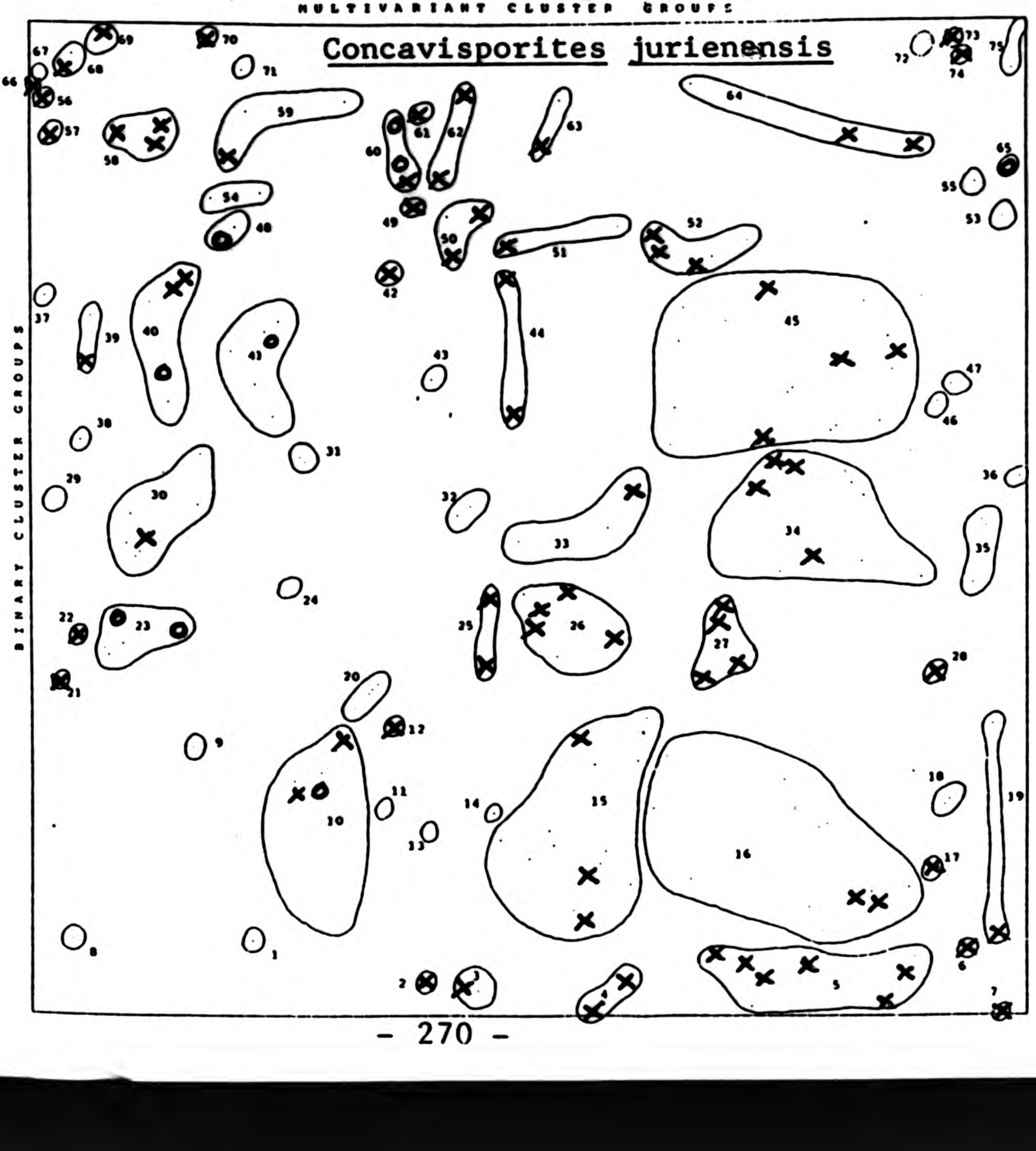
Palaeoenvironment: As visible on text-fig. 4.6 these spores are widely distributed throughout all Weald Clay palynofacies. However they show an above average association with marine influenced facies 2 - 7 and 60 - 62. The parent plant may thus have tolerated raised salinities.

7. Genus Undulatisporites (Pflug, 1953)

Type species: U. microcutis



Text-fig. 4.5



Text-fig. 4.6

Remarks: This genus accommodates trilete spores with undulate raised commisures, straight to convex sides and a smooth to slightly sculptured exine. The specimens encountered in this study have been placed in U. undulapolus (Brenner,1963). These have a strongly undulate laesurae in the proximal polar area.

Plate 2, figs.41 - 56

Palaeoenvironment: Text-fig.4.7 shows that these grains are distinctly negatively associated with marine influence but are otherwise quite cosmopolitan particularly in the dry uplifted facies.

8. Genus Deltoidospora (Miner,1935, emend. Potonié, 1956)

Type species: D. hallii

Remarks: These are deltoid or subdeltoid spores with very thick exines, which distinguishes them from Cyathidites.

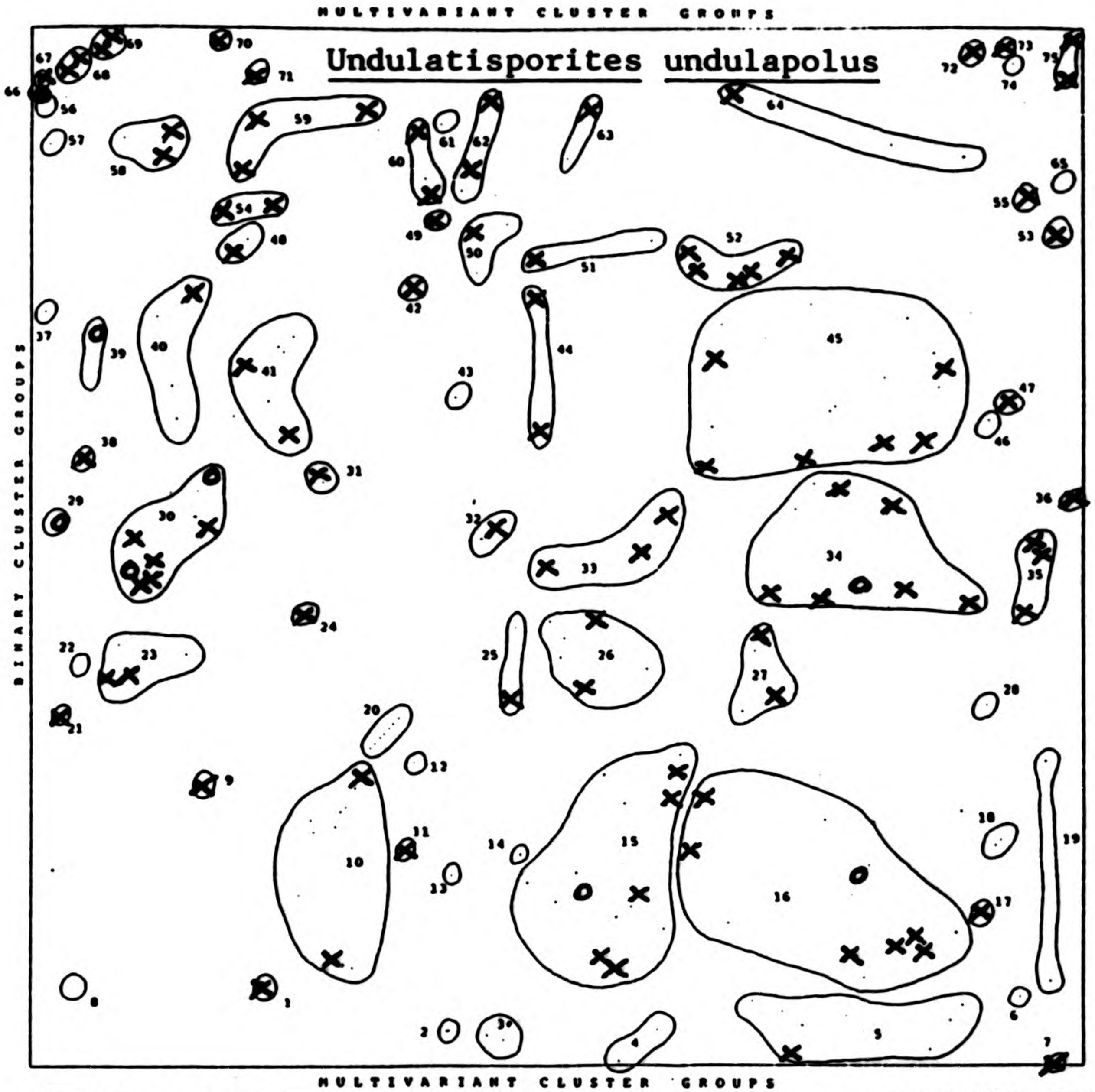
Plate 1, figs. 28 - 31

Palaeoenvironment: These grains were only rarely recorded and do not show any particular facies restriction, except for a possible slight grouping in cluster XIII (see text-fig. 4.8)

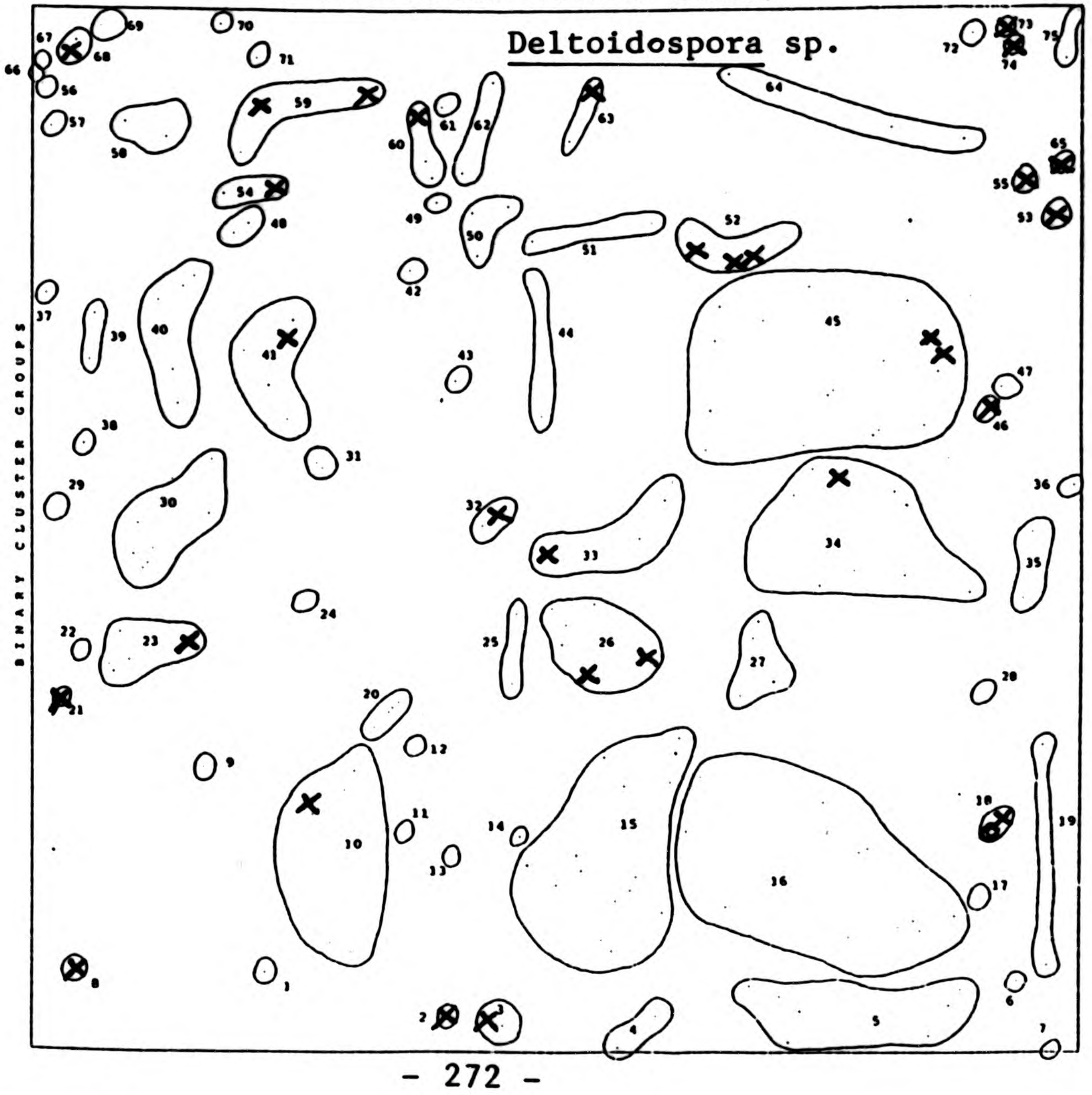
9. Genus Stereisporites (Pflug, 1953)

Type species: S. stereoides (Potonié & Venitz) Pflug(1953)

Remarks: These spores ~~are~~ convex triangular with simple laesurae. The exine is smooth and grains are of small size. Only the species S. antiquasporites (Wilson & Webster) Dettman(1963)was recognised in this study. It is distinguished from others in the genus by the presence of



Text-fig. 4.7



Text-fig. 4.8

a distal polar thickening.

Plate 2, figs.25 - 30

Palaeoenvironment: These grains were only rarely encountered, so no facies association can be inferred (see text-fig.4.9). Pocock (1962) notes the use of this taxon as an environmental marker associated with coals. Likewise Dettman (1963) notes its abundance in highly carbonaceous samples. Coals are unknown in the Weald Clay, probably accounting for the rarity of this taxon here.

10. Genus Auritulinasporites Nilson (1958)

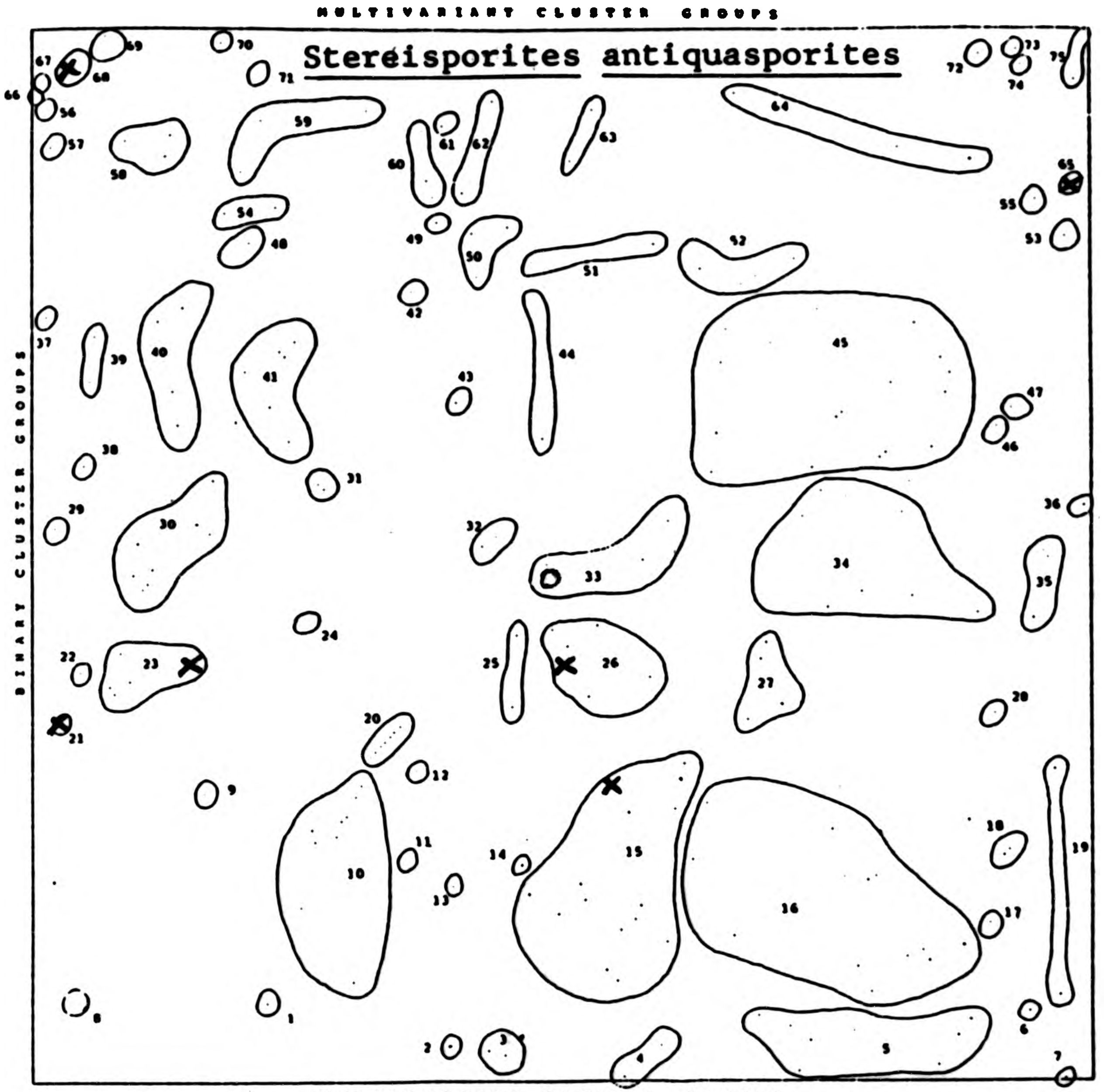
Type species: (See Nilson, 1958)

Remarks: This genus is similar to Dictyophyllidites but bears very much thicker laesurate margins.

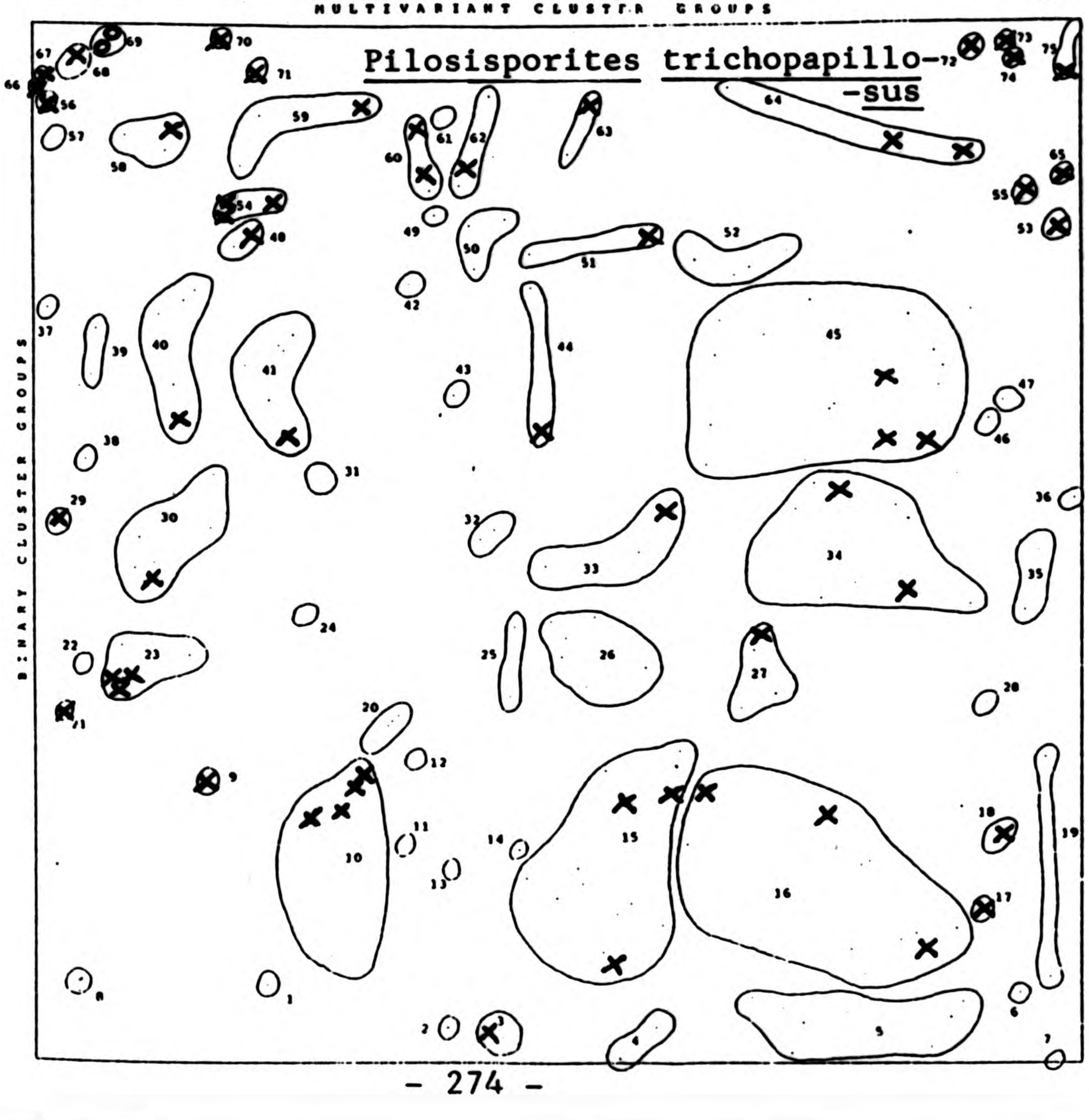
A. deltaformis (Burger, 1966) Plate 2, figs. 57-64 & 72

This species has particularly thickened laesurate margins (4-6u thick) that curve around the radii without interruption. The thickened laesurate margins resemble Dictyophyllidites pectinataeformis (Bolkhovitina) Dettmann (1963).

Palaeoenvironment: This species was too rarely occurring to assess its distribution within the palynofacies scheme.



Text-fig. 4.9



Text-fig. 4.10

Infraturma APICULATI

1. Genus Pilosisporites (Delcourt & Sprumont, 1955)

Type species: P. trichopapillosus (Thiergart)

Remarks: This genus accommodates large concave or straight sided trilete spores with a distinct ornament of pilae or spines and subsidiary grana. This genus was found in abundance in the Weald Clay, and a number of species were recognised.

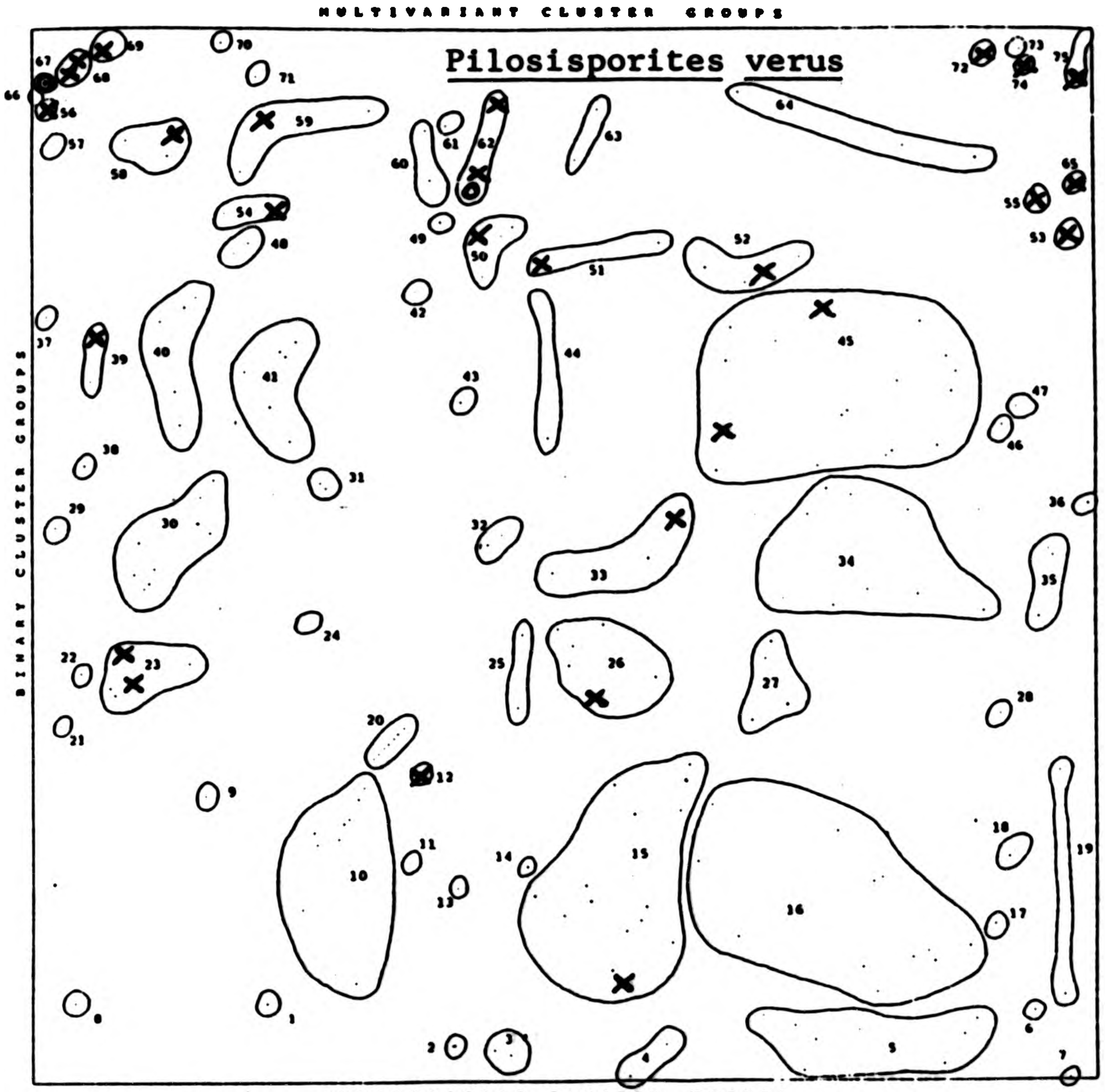
(a) P. trichopapillosus Plate 5, figs. 6 - 25. These grains have a dense ornament of short spines, that tend to be more crowded at the radii and along the laesurae.

Palaeoenvironment: These grains are particularly recorded in the dry uplifted facies with cluster group J (facies 56, 66 - 75). Occurrences within facies 53, 54, 55 & 65 may be a direct result of transportation from these comparatively uplifted areas. Moderate abundances within other facies such as 23, 45 and 34 may be local concentrations within the drier parts of these facies. Its presence in facies 10, 15 & 16 is probably by reworking. This species is definitely negatively associated with the most marine facies of group A (see text-fig. 4.10).

(b) P. verus (Delcourt & Sprumont, 1955) Plate 5, figs. 34 - 41. These grains have a denser ornament of longer spines than P. trichopapillosus.

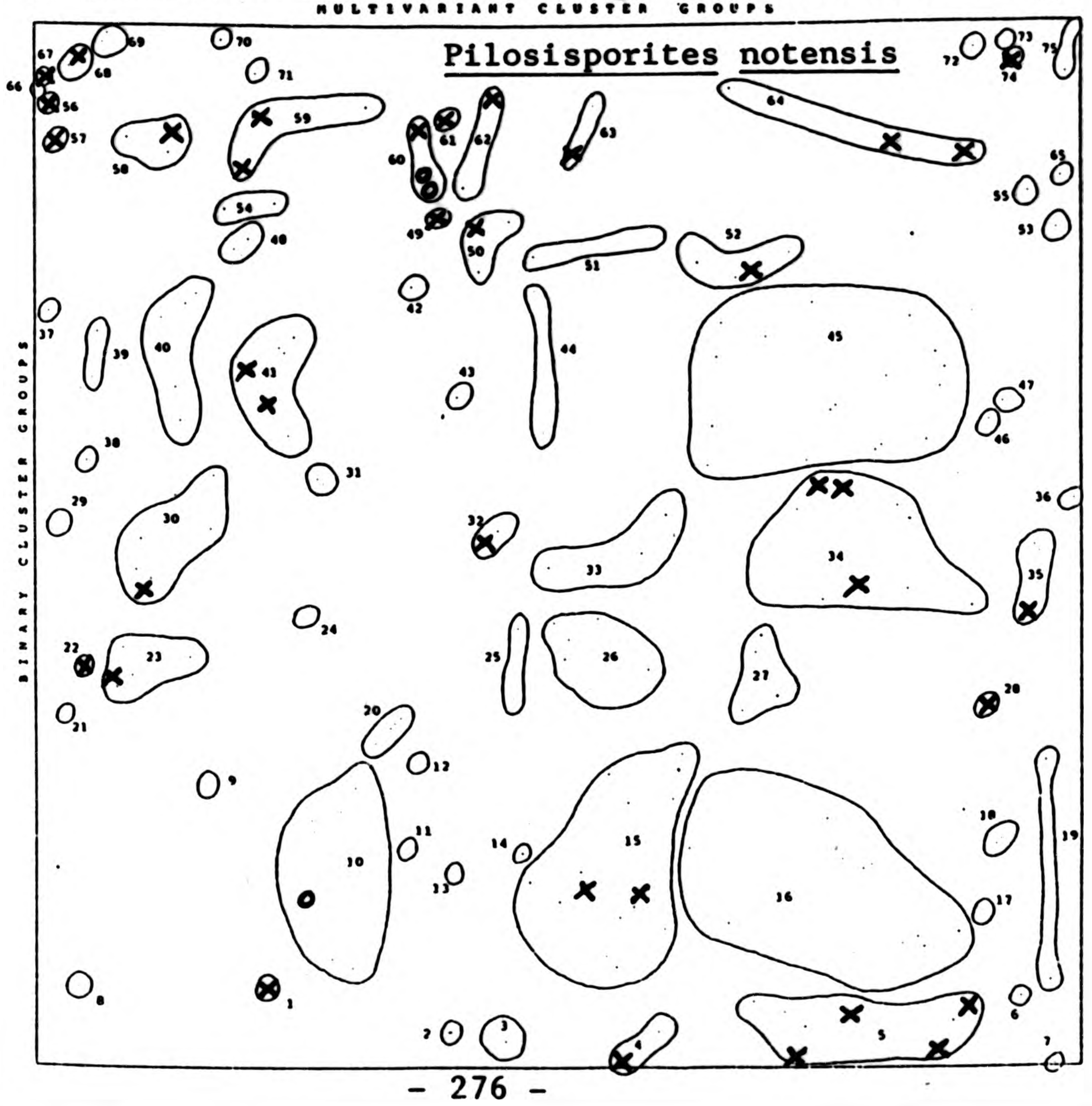
Palaeoenvironment: This species shows particularly strong association with the dry uplifted facies of group J (see text-fig. 4.11).

(c) P. notensis (Cookson & Dettmann, 1958), Plate 5, figs. 1 - 5.



Pilosisporites verus

Text-fig. 4.11



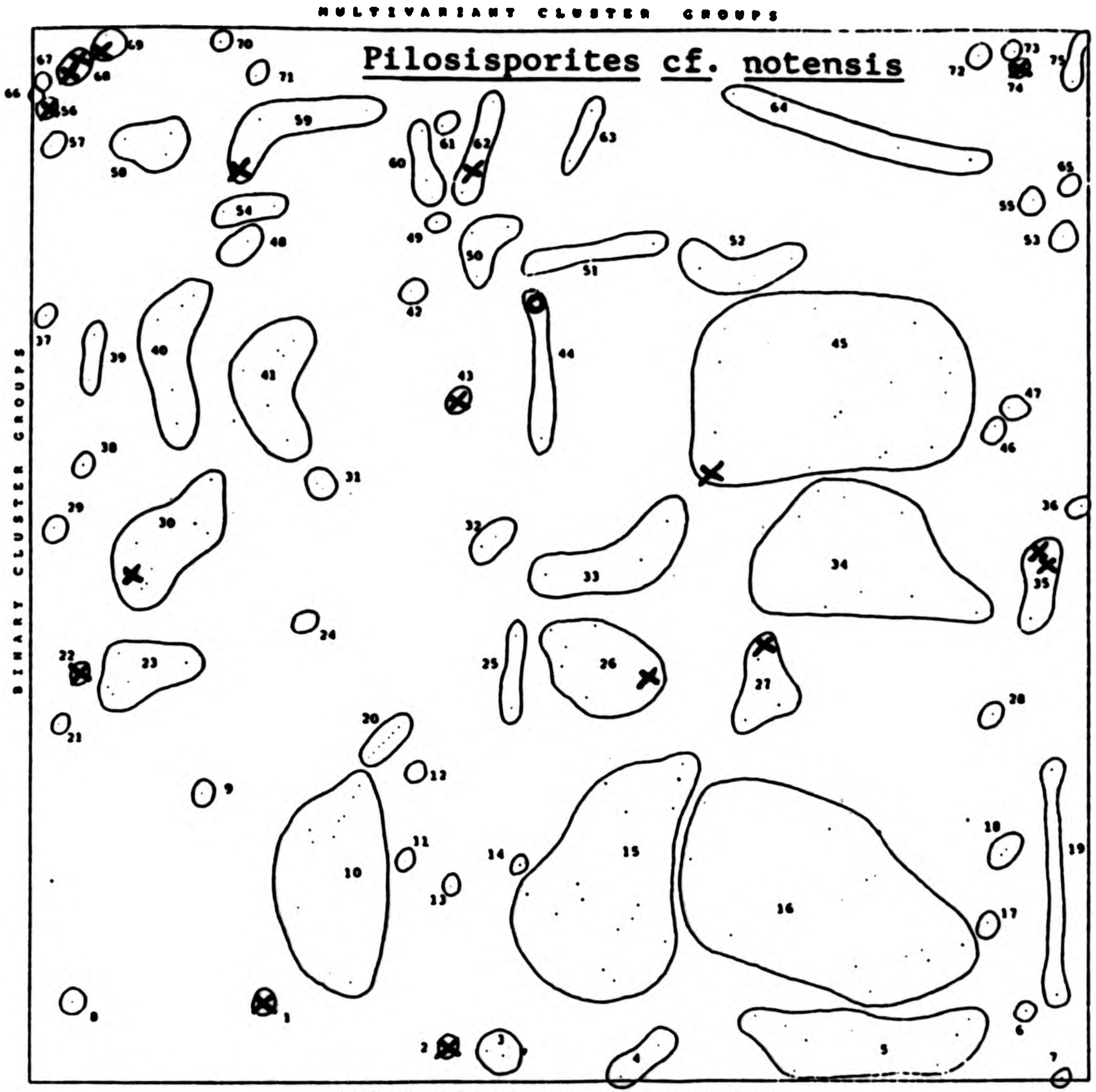
Pilosisporites notensis

Text-fig. 4.12

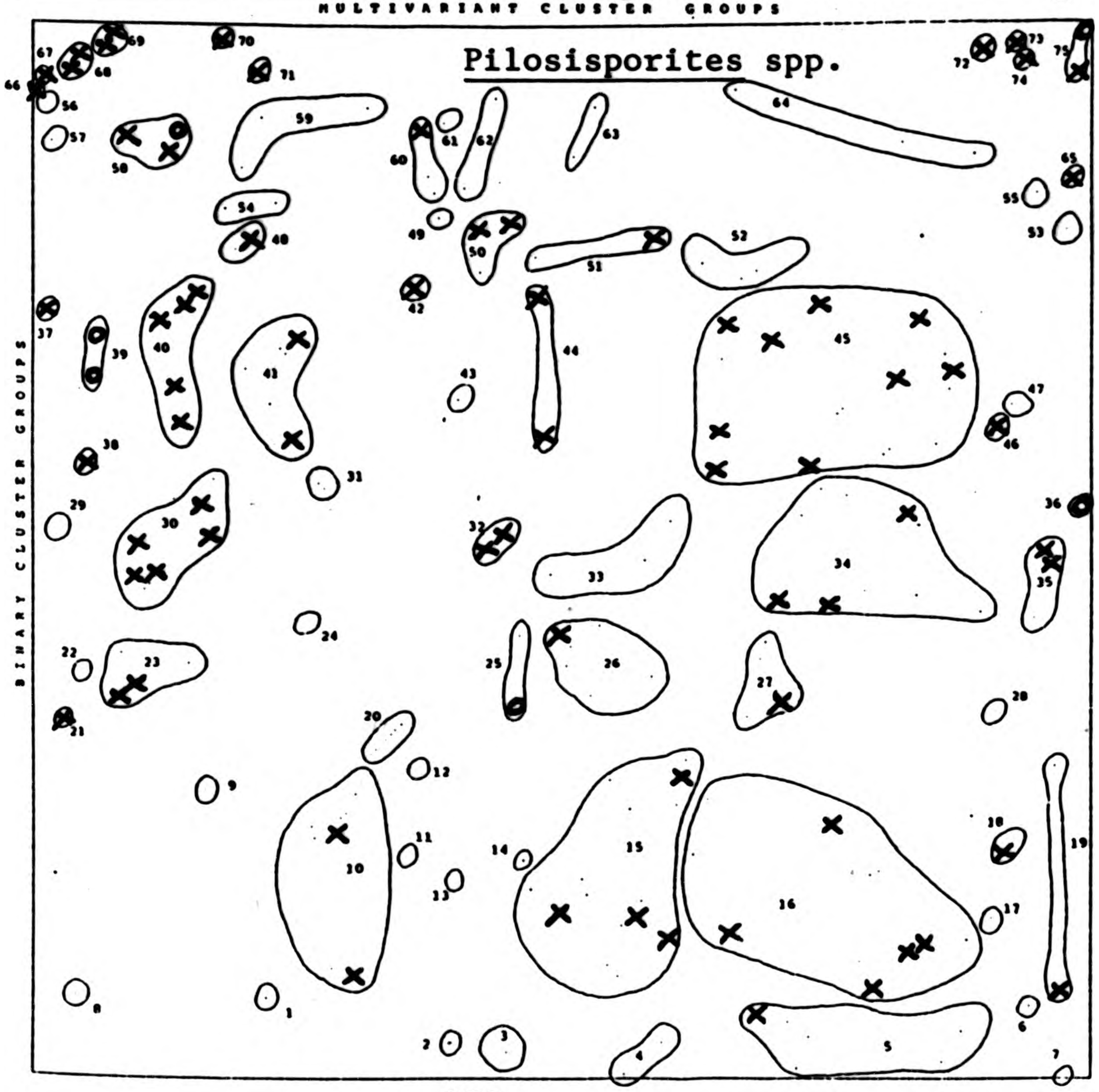
This species has an ornament of larger spines with wider bases than P. verus, that are less dense in arrangement.
Palaeoenvironment: These grains show a similar grouping within cluster group J, however this is restricted to facies 66 - 68 (see text-fig. 4.12). This species shows a definite association with marine influenced facies 60 - 62 and facies 4 & 5. It is possible that this association is caused by local reworking, however this has not affected the other species of Pilosisporites, so may well be a genuine marine association.

(d) P. cf. notensis Plate 5, figs. 26 - 33. This species is distinguished by having a thinner exine, that can be folded, and an ornament of very small spines.
Palaeoenvironment: This species was generally rare compared to the others, but shows a similar association with the dry uplifted group J facies, 68, 69 & 74 (text-fig. 4.13)

(e) P. spp. This taxonomic group was used for all Pilosisporites specimens that were too poorly preserved to be allocated to any of the above four species.
Palaeoenvironment: Once again they show a strong association with cluster group J (see text-fig. 4.14). In addition there is also a good spread of these grains amongst other facies within groups D - I. This is probably due to reworking, as would be expected with poorly preserved grains. However they remain negatively associated with 'marine' facies within groups A & B.



Text-fig. 4.13



Text-fig. 4.14

2. Genus Concavissimisporites (Delcourt & Sprumont,1955
emend. Delcourt, Dettmann &
Hughes,1963)

Type species: C. verrucosus

Remarks: The genus is for triangular concave to almost straight sided spores with a more or less evenly developed ornament of verrucae over the entire exine.

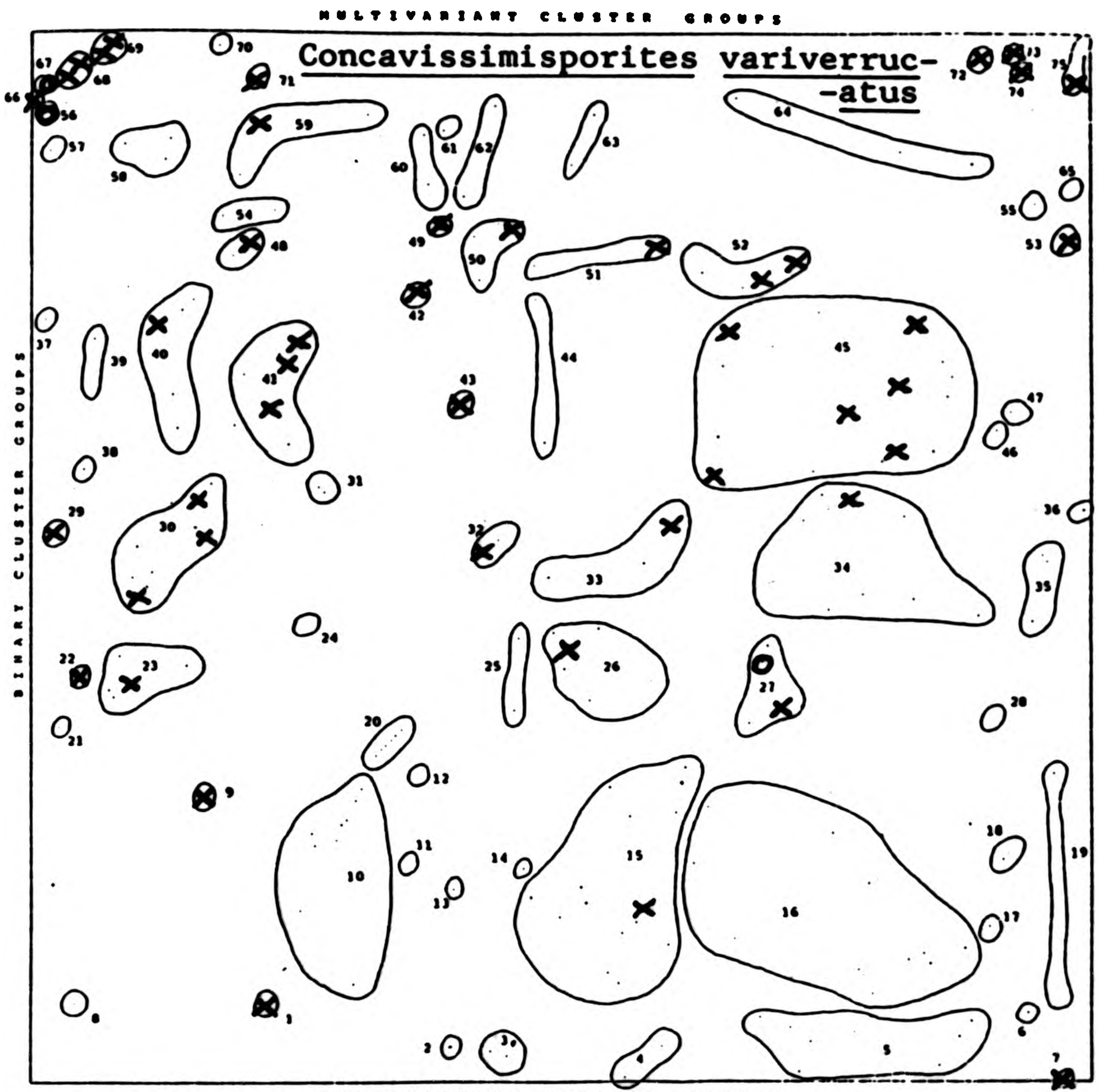
(a) C. variverrucatus (Couper,1958; Brenner,1963). Plate 3, figs. 1 - 9 & 11 - 16. This species accommodates most of the taxa assigned to this genus encountered in this study. However specimens on plate 3, figs 1 & 2 may be included within Tuberositriletes grossotuberculatus (Bolchovitina) Döring((1966).

Palaeoenvironment: Text-fig.4.15 reveals that this species is strongly grouped within the dry uplifted facies J. However it is less restricted to this habitat than several species of Pilosisporites, and shows a general moderate occurrence through cluster groups D - I. It is quite negatively associated with the lacustrine and marine influenced facies of groups A & B.

(b) C. crassatus (Delcourt & Sprumont,1955) Plate 3,figs. 10 & 17 - 35. This species accommodates grains with generally smaller verrucate elements than C. variverrucatus. This species was not treated separately from C. spp in the CLUSTAN analysis, so individual palaeoenvironmental data is not available. However see note below.

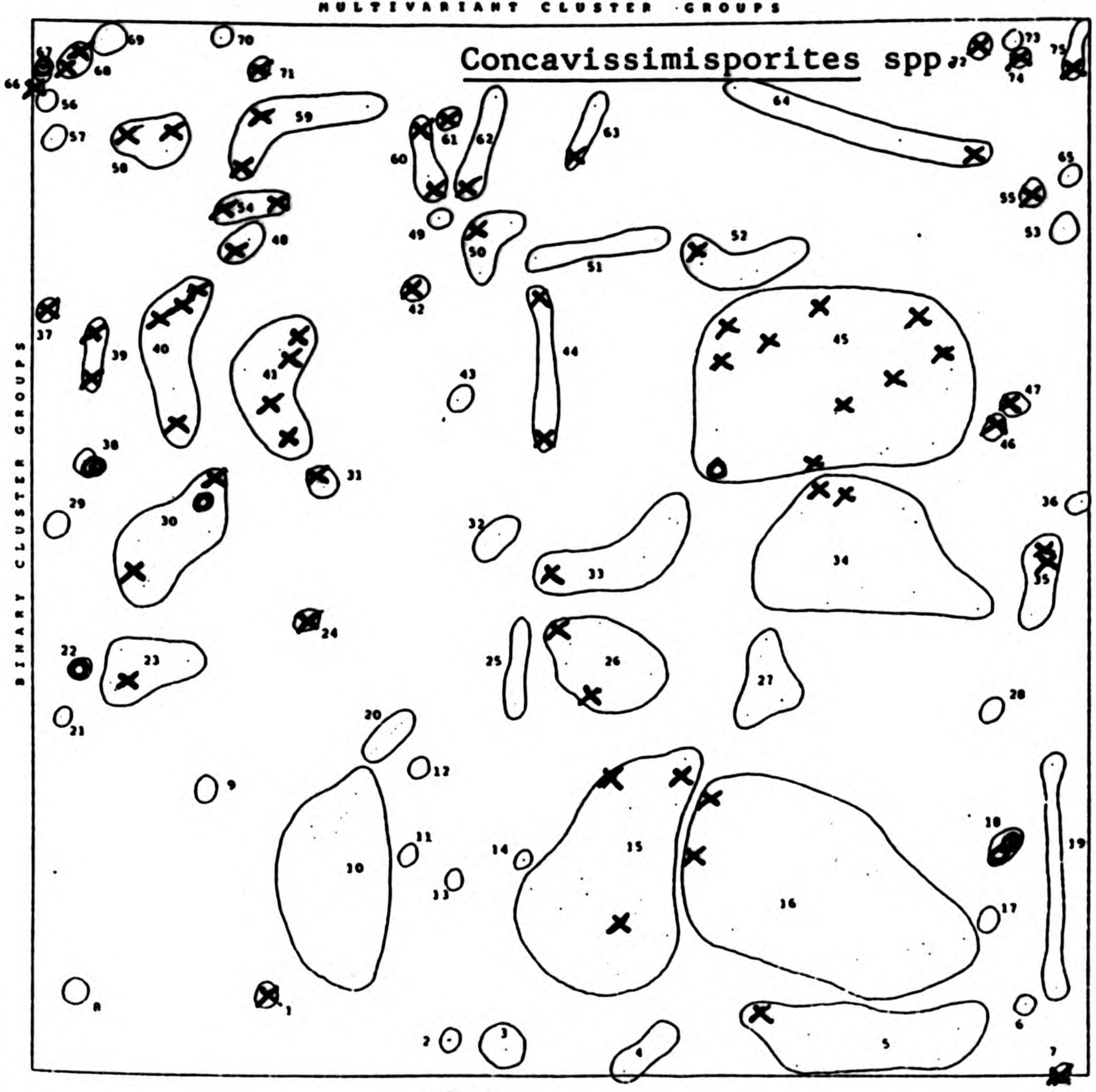
(c) C. sp. A Plate 3, figs.36 - 41. These grains show the very distinct concave radial areas of this genus, but the verrucate elements are very reduced in size.

Palaeoenvironment: Poorly preserved species of Concavissimisporites together with C. crassatus and C. sp.A were



Concavissimisporites variverrucatus

Text-fig. 4.15



Concavissimisporites spp.

Text-fig. 4.16

all included for palaeoenvironmental purposes as C. spp. (see text-fig.4.16). This group shows a general even spread through the freshwater facies D - J, but is rare in brackish/marine facies A - B.

3. Genus Leptolepidites (Couper,1953)

Type species: L. verrucatus

Remarks: This genus incorporates subtriangular spores with very large verrucate projections developed equally on the distal and proximal surfaces.

Five different morphotypes have been recognised that cannot easily be assigned to recognised species. However for the purposes of the CLUSTAN analysis the genus Leptolepidites was taken as one group.

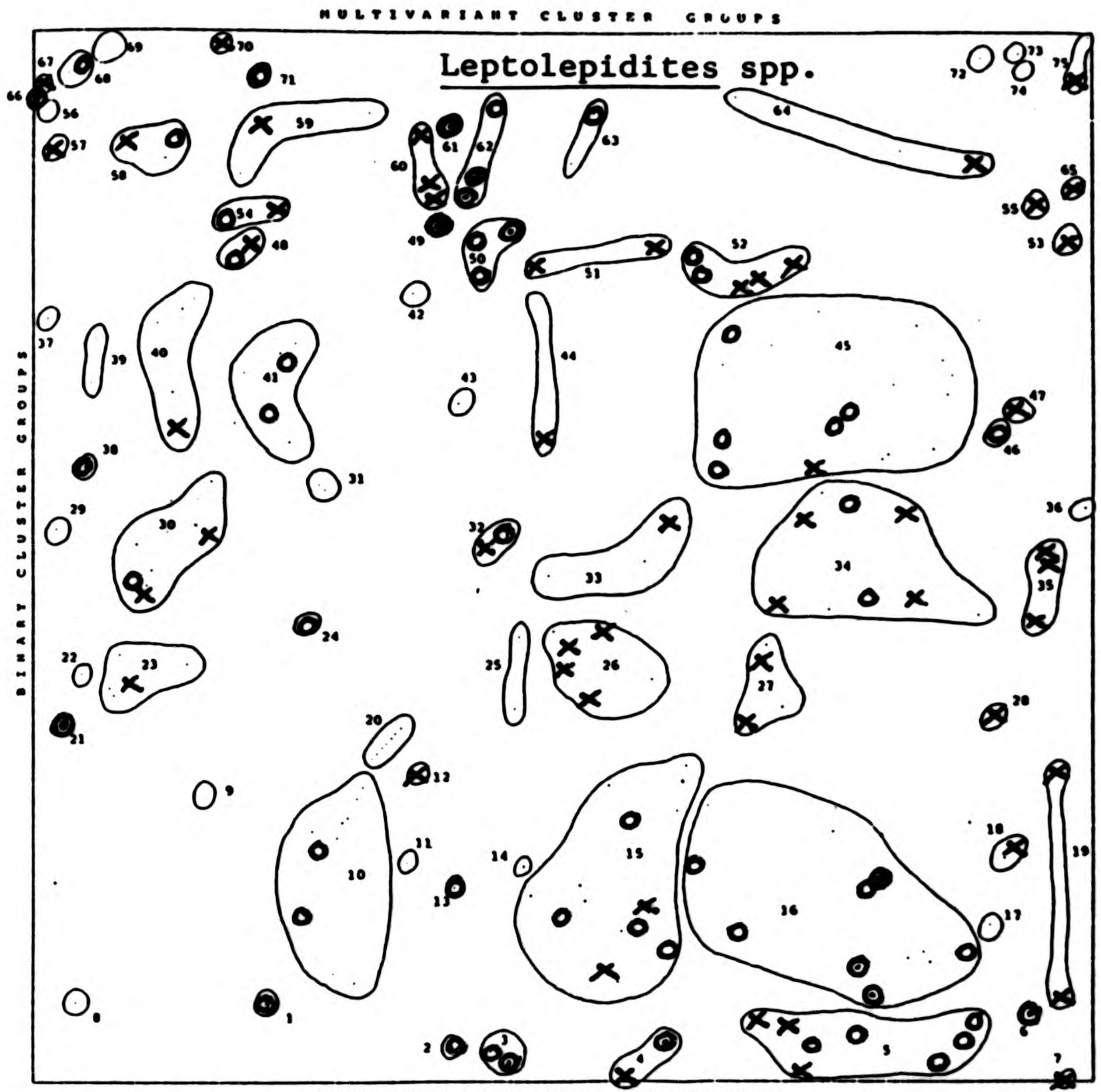
(a) L. sp. A Plate 4, figs.37 - 40 & 43. These grains may fall within the species L. plurituberosus (Döring,1964) Dorhoffer & Norris(1977). They have a fairly even distribution of verrucae.

(b) L. sp B Plate 4, figs. 41, 42, 44 - 50, 52, 54, 57 & 59. These grains may fall within the species L. proxigranulatus (Brenner, 1963; Dörhöfer, 1979). The verrucae around the equator show a tendency to fuse.

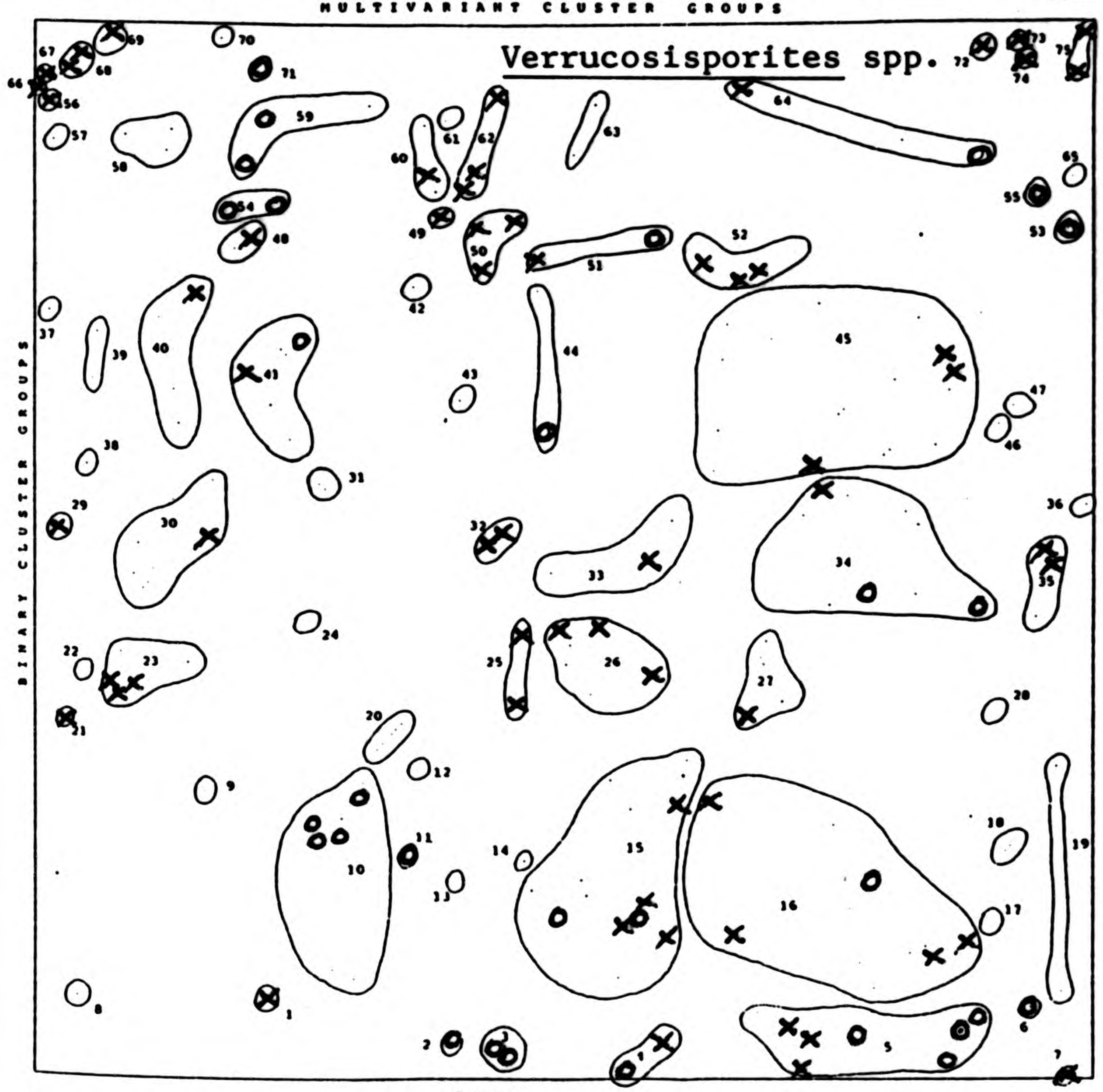
(c) L. sp. C Plate 4, fig. 53. One specimen allocated to this group shows swollen verrucae at the radii.

(d) L. sp. D Plate 4, figs. 55, 56 & 58. With this morphotype fusion of the verrucae is much more marked forming a partial cingulum around one portion of the equator.

(e) L. sp. E Plate 4, fig. 51. One specimen assigned to this morphotype shows a small number of extremely swollen verrucae.



Text-fig. 4.17



Text-fig. 4.18

Palaeoenvironment: Text-fig.4.17 shows Leptolepidites spp to be fairly well distributed throughout all Weald Clay palynofacies. However group A facies 1 - 7 show these grains particularly well, as well as many group B facies. This must indicate that they could tolerate slightly brackish conditions. They are also particularly prominent in facies 49 & 60 - 62 within cluster group I where there is evidence of tidal marine influence.

4. Genus Verrucosisporites (Ibrahim,1933, emend. Potonié & Kremp,1954)

Type species: V. verrucosus

Remarks: This genus comprises circular to subcircular grains with an exine thickly crowded with broad based warts (verrucae) more or less irregularly rounded or in some cases arcuate.

For the purposes of the CLUSTAN analysis this genus was taken as one group, Verrucosisporites spp. However, several morphotypes and one established species have been recognised in this study.

(a) V. obscurilaesuratus (Pocock,1962) Plate 4, figs.1 - 15 & 23. These are verrucate spores with indistinct laesurae, and have irregular subcircular outline. The verrucae are flat topped and irregularly shaped, sometimes fusing to form short ridges.

(b) V. sp. A Plate 4, figs.16 - 18. This morphotype is distinguished by the possession of prominent laesurae.

(c) V. sp. B Plate 4, figs.19 - 22. These grains are distinguished by their large size.

(d) V. sp. C Plate 4, fig.36. Only rarely occurring, this morphotype is of very small size.

Palaeoenvironment: Verrucosisporites spp. show a generally even spread across all Weald Clay palynofacies (see text-fig. 4.18). They are particularly pronounced within cluster group A and part of B, the brackish/marine influenced facies. This must indicate their tolerance to raised salinities, similar to Leptolepidites spp. This palaeoecological association may indicate phyletic overlap between these genera that are morphologically similar. However Verrucosisporites spp. are more prominent with the drier uplifted group J facies than are Leptolepidites spp. indicating that this overlap is not complete. Within the broad generic group of Verrucosisporites spp. there must be salinity tolerant as well as dry upland taxa represented.

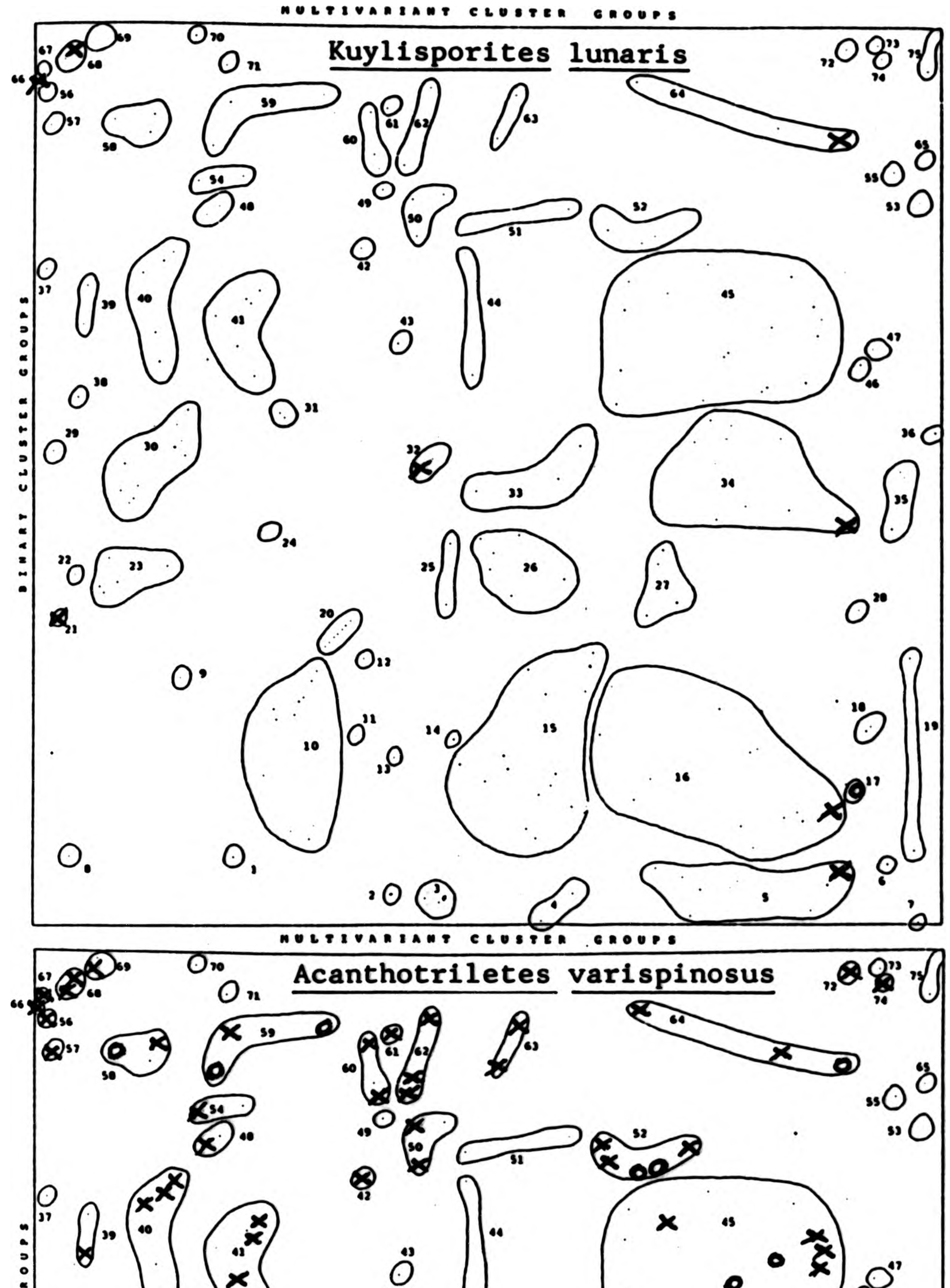
5. Genus Kuylisporites (Potonié,1956)

Type species: K. waterbolki

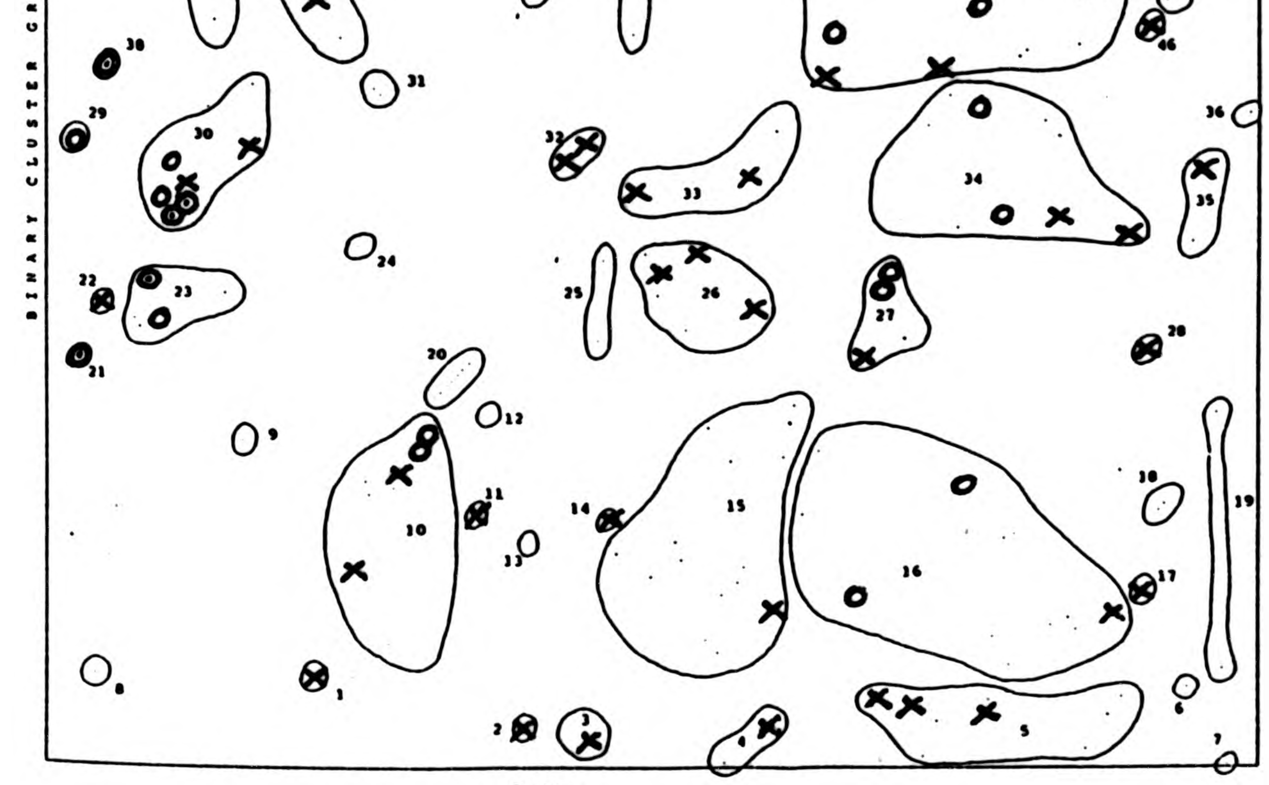
Remarks: This genus is characterised by the presence of scutulae. These are conspicuous crescentic-shaped elevations. Forms identified in this study fall within K. lunaris (Cookson & Dettmann,1958).

Plate 6, figs.64 - 67

Paleoenvironment: A few rare occurrences of this taxon were observed in this study (see text-fig.4.19). Three of these occurrences are seen in the dry uplifted facies 21, 66 & 68 while others occur in channel facies 17. It is therefore probably derived from plants that favour mature species rich communities near the hinterland. Its low abundance may be due to low spore production.



Text-fig. 4.19



Text-fig. 4.20

6. Genus Acanthotriletes (Naumova 1937?, 1939 ex Potonié & Kremp,1954)

Type species: A. ciliatus ((Knox) Potonié & Kremp,1954)

Remarks: This genus accommodates trilete spores with attenuated closely crowded spines of a length greater than twice their diameter. Species encountered in this study fall within A. varispinosus Pocock (1962).

Plate 6, figs. 17 - 47

Palaeoenvironment: Text-fig.4.20 shows that this taxon is strongly associated with facies 23 & 30 that probably represent low-lying damp freshwater environments. They are markedly low in occurrence in cluster groups A & B while they tend to cluster with the 'inland' palynofacies.

7. Genus Neoraistrickia (Potonié,1956)

Type species: N. truncata (Cookson) Potonié (1956)

Plate 6, figs. 48 & 49

Remarks: This genus is for baculate spores with a rounded triangular amb. It was only rarely encountered in this study and assigned only to N. spp. It was not analysed through CLUSTAN for palaeoenvironmental data.

8. Genus Osmundacidites (Couper, 1953)

Type species: O. wellmanii

Remarks: This genus is distinguished by a predominantly granulate exine. It was generally only of rare occurrence, and was not encoded for CLUSTAN.

Plate 7, figs.29-33 & 35-46

9. Genus Lophotriletes Naumova(1937)ex Potonié & Kremp (1954)

Type species: L. gibbosus (Ibrahim) Potonié & Kremp (1954)

Remarks: This genus accommodates subtriangular trilete spores covered by tapered cones whose basal diameter is equal to, or less than their height. A few poorly preserved specimens, generally conforming to this description, have been assigned to L.spp in the present study.

Plate 7, figs. 1-7 ; Plate 6, figs. 68-74

Palaeoenvironment : These spores were too rarely occurring to be assessed as to their palynofacies association by cluster analysis.

10. Genus Converrucosisporites Potonié & Kremp (1954)

Type species: C. triquetrus (Ibrahim)

Remarks: This genus accommodates spores with a strong verrucate ornament, similar to Verrucosisporites. They differ from this genus in being triangular rather than circular in ambital outline. The genus closely resembles, and may be synonymous with, Tuberositriletes

C. exquisitus (Singh, 1971) Plate 4, figs. 24-35.

This species is distinguished by particular large closely spaced verrucae.

Palaeoenvironment: This taxon, though not run separately through CLUSTAN, shows a distinct association with dry, uplifted, near hinterland palynofacies (Sample PL.12).

11. Genus Microreticulatisporites Knox (1950) emend. Bharadwaj (1955)

Type species: M. lacunosus (Ibrahim) Knox (1950)

Remarks: This genus includes triangular spores with a reticulate ornament of luminia not exceeding 3u in diameter.

M. uniformis Singh (1964) Plate 9, figs. 73-79.

This species conforms to this description of Singh (1964) (p.97).

Palaeoenvironment: This taxon was too rarely occurring to enable its palaeoenvironment to be assessed by cluster analysis.

12. Selaginella type

Remarks: Comparatively rarely occurring specimens of spore tetrads bearing an ornament of well spaced long thin capitate spines, have been placed in this informal taxonomic group.

Plate 7, figs. 47-53

Palaeoenvironment: The rare occurrences of this taxon fall within generally freshwater aquatic palaeoenvironments (text-fig 4.81).

Infraturma MURONATI

1. Genus Lycopodiumsporites Thiergart(1938) ex Delcourt & Sprumont,(1955)

Type species: L. agathoecus (Potonié) Thiergart,(1938)

Remarks: This genus accommodates spores bearing a regular reticulum of muri on the distal surface. Three species were recognised in this study, with very rare occurrences of two other form genera.

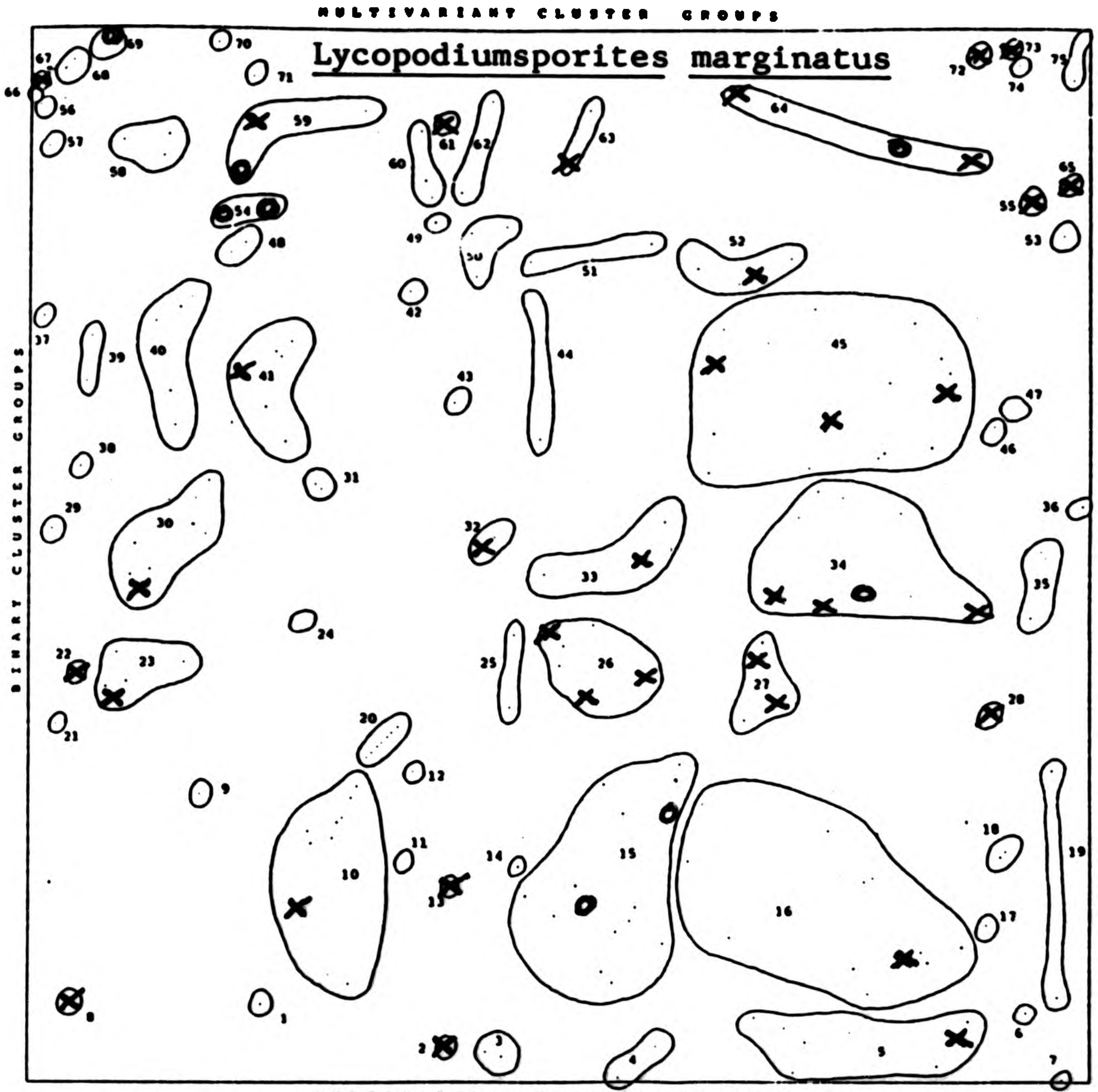
(a) L. marginatus (Singh,1964) Plate 8, figs.1 - 14. This species has a broad reticulum of muri raised into a membraneous network.

Palaeoenvironment: This taxon occurs uncommonly but fairly widely throughout all Weald Clay samples. It generally avoids any marine influence (cluster groups A & B) and favours damp 'intermediate' regions that are not too dry and uplifted (eg.facies 26, 27, 34 & 54). See text-fig.4.21.

(b) L. austroclavitidites (Cookson) Pocock,(1962). Plate 8, figs.18 - 41 & 47. Generally small sized grains with long muri.

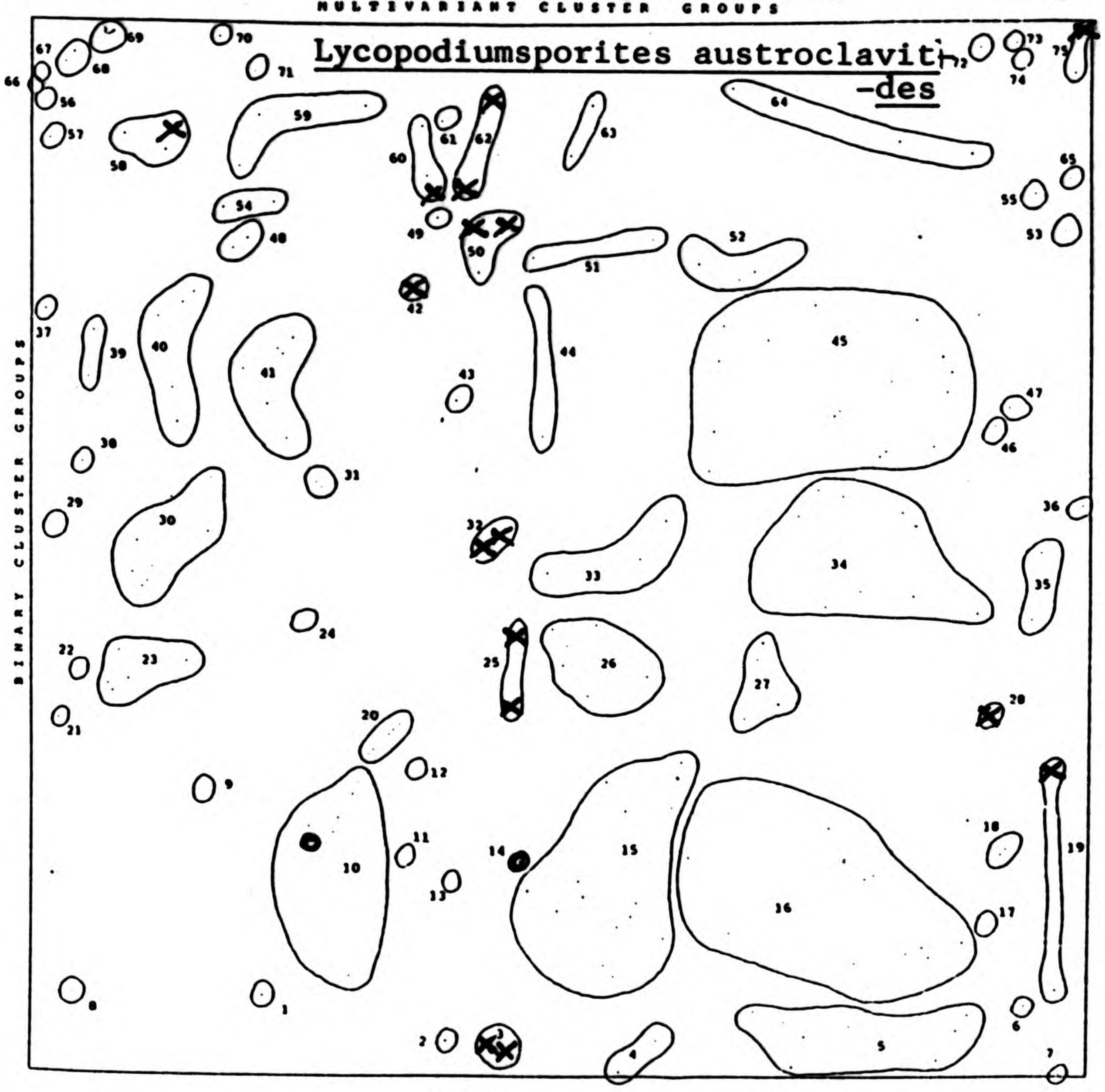
Palaeoenvironment: This taxon shows a very strong grouping within cluster group XII-1. This cannot be fully explained at the moment as this group represents a range of palaeoenvironments. However it could be a channel association.

(c) L. expansus (Singh,1971) Plate 8, figs.15 - 17. This taxon is characterised by very wide luminae together with high membraneous muri forming a network around the spore body.



Lycopodiumsporites marginatus

Text-fig. 4.21



Lycopodiumsporites austroclavitides

Text-fig. 4.22

(d) L. crassimacerius Hedlund (1966) Plate 8, fig. 45 This taxon is characterised by a coarse reticulum of low muri. It was only very rarely encountered in this study, and was not run separately through CLUSTAN.

(e) L. sp. A Plate 8, fig.42. This is a single occurrence of a large concave trilete spore with low thin reticulate muri and wide luminae.

(f) L. sp. B Plate 8, fig.44. A single occurrence of a large convex trilete spore with low thin muri that are undulate in outline.

Palaeoenvironment: Text-fig.4.23 shows the occurrence of Lycopodiumsporites spp. that were too poorly preserved to be assigned to recognisable species. These show a distribution within the 'intermediate' facies (cluster groups D - G) where conditions were not generally affected by raised salinities nor unduly dry and uplifted, but generally low-lying and damp.

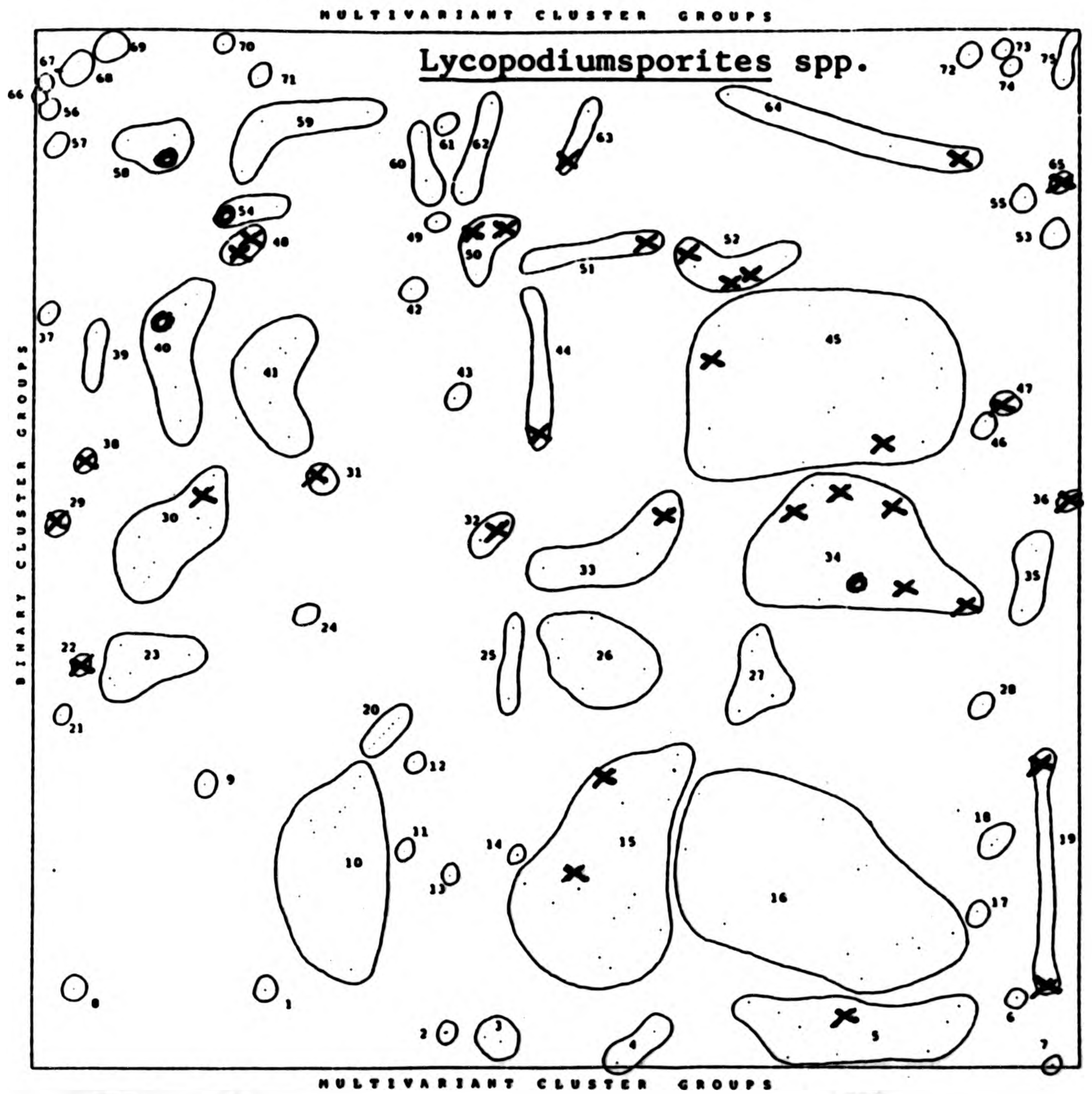
2. Genus Reticulisporites Potonié & Kremp (1953)

Type species: R. parrogranulatus Weyland & Krieger (1953)

Remarks: This genus includes spores with low reticulate muri and generally concave sides and rounded apices. Two species were recognised in this study.

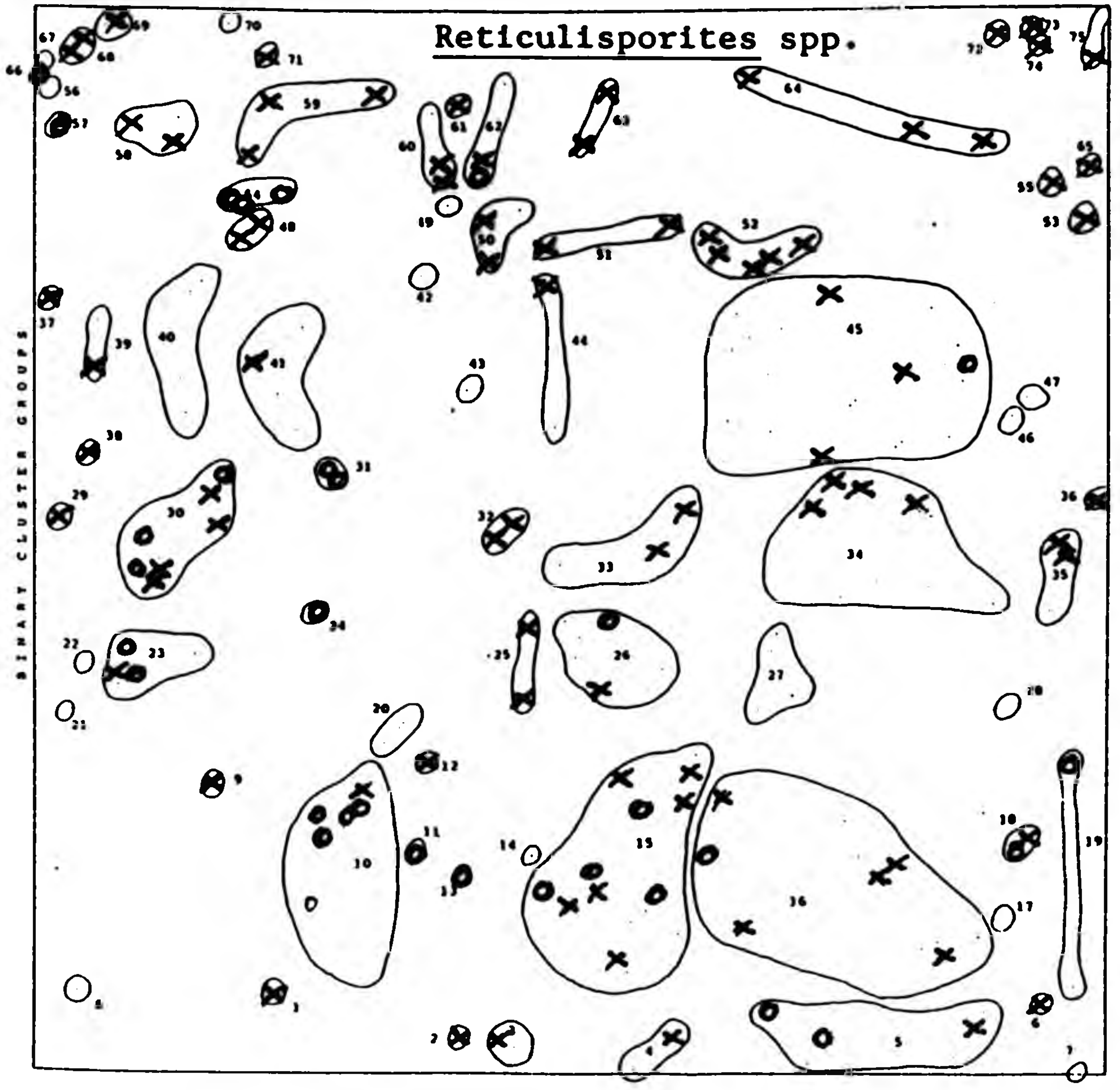
(a) R. elongatus (Singh,1971) Plate 8, figs.64 - 77. This taxon has a distal imperfect reticulate sculpture with angular elongate luminae and low narrow muri.

(b) R. cf. elongatus Plate 8, figs. 64-77 .
These grains are similar to R. elongatus except that the muri are disjointed and broken in places.



Lycopodiumsporites spp.

Text-fig. 4.23



Reticulisporites spp.

Text-fig. 4.24

Palaeoenvironment: For palaeoenvironmental analysis in CLUSTAN these taxa were grouped together as Reticulisporites spp. (see text-fig.4.24). These grains were quite commonly occurring, thoughout most Weald Clay palynofacies. A distinct association of them with facies 10, 15, 30 & 60 - 62 is to be seen. These represent low-lying damp palaeoenvironments that can be affected by raised salinities, though this genus remains generally cosmopolitan.

3. Genus Tigrisporites Klaus(1960)emend. Singh(1971)

Type species: T. halleinis

Remarks: This genus is distinct in possessing a distal polar disk-like thickening that is surrounded by a rugulate reticulate or verrucate sculpture. Only the species T. scurrandus (Norris ,1967) was recognised in this study in low to moderate abundance. This taxon has widely spaced random distal rugulae.

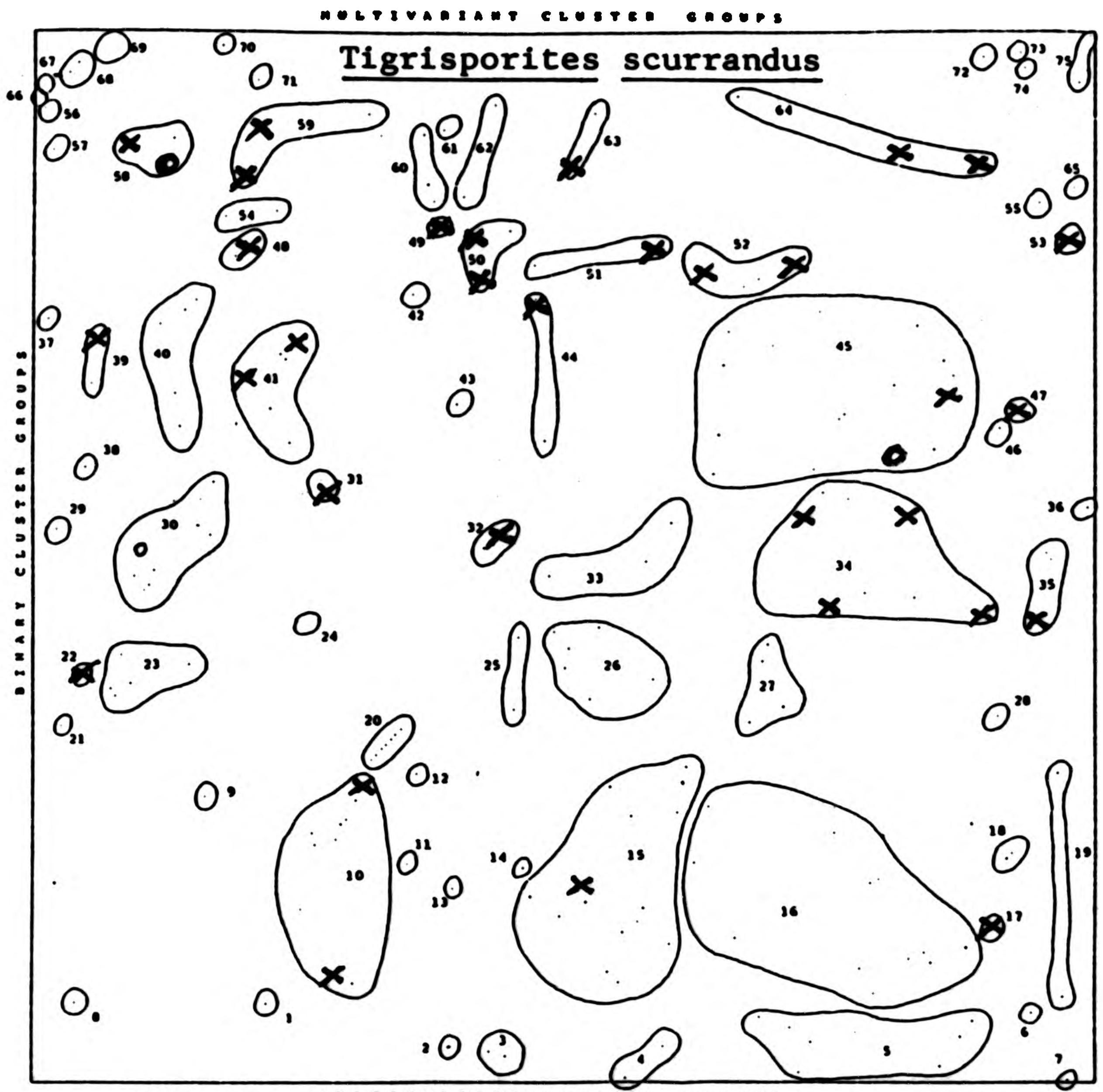
Plate 8, figs. 59 - 63

Palaeoenvironment: The palaeoenvironmental association of this taxon is distinctly low-lying freshwater, within cluster groups D - I. They are quite negatively associated with strandline facies as well as the most proximal to hinterland, dry uplifted facies.

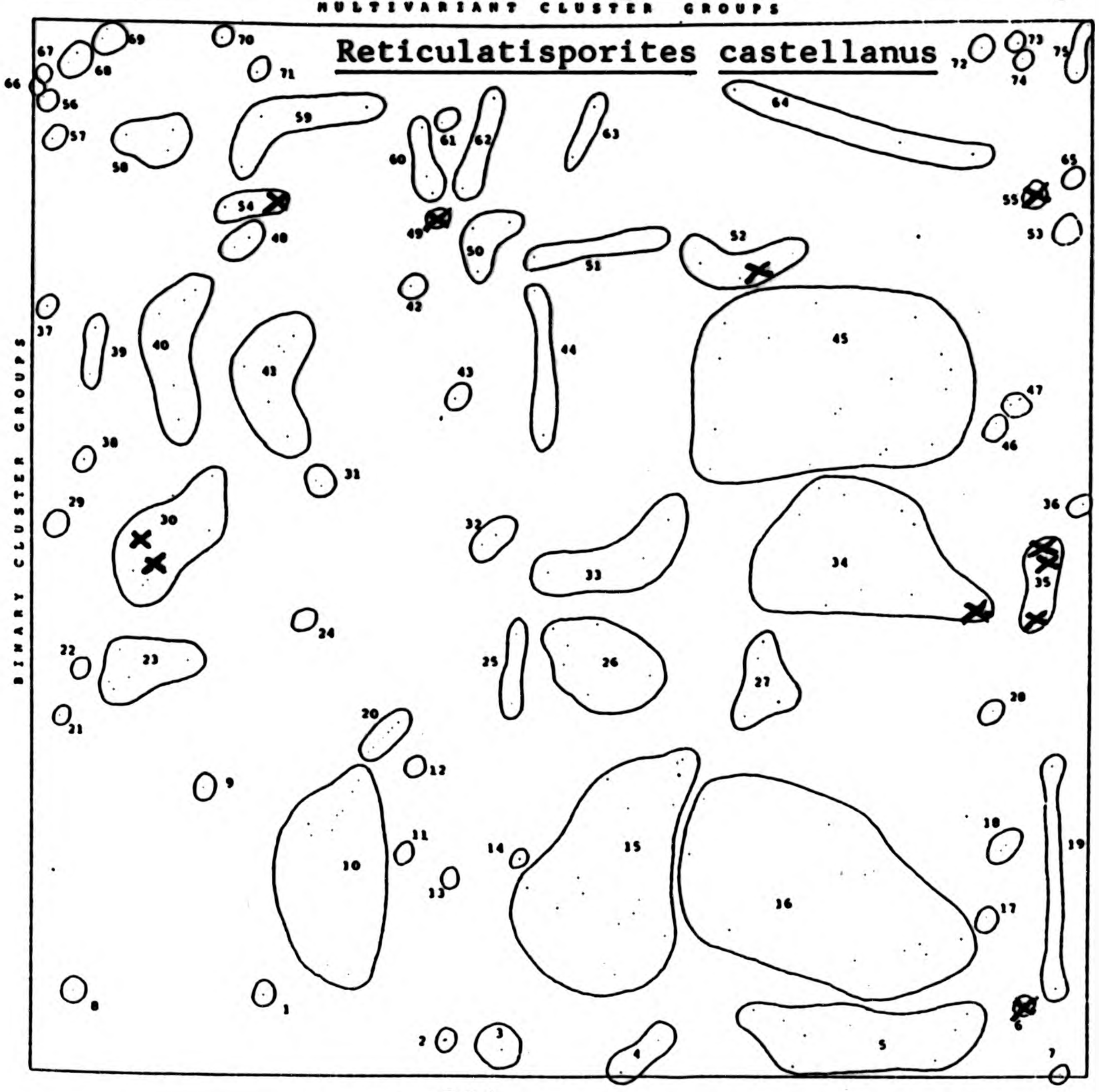
4. Genus Reticulatisporites (Ibrahim) Schopf, Wilson & Bentall(1944

Type species: R. reticulatus

Remarks: This genus includes spores of subcircular to circular outline with a coarsely and often irregularly reticulate exine. One species has been recorded rarely



Text-fig. 4.25



Text-fig. 4.26

in this study, R. castellanus (Pocock,1962). This species is strongly reticulate with high translucent muri. Pocock,(1962) draws a comparison of it with certain Bryophyte spores.

Plate 10, figs. 1 - 13

Palaeoenvironment: This taxon shows a positive correlation with the channel facies 6, 35 & 55 of cluster group XIII. Its parent plant may thus favour moving water, as an aquatic or riparian plant. Alternatively it may be ecologically allied with Gleicheniidites spp. that are most abundant in group XIII, and which may be primarily part of the sourcelands flora (see text-fig. 4.26).

5. Genus **Foveotriletes** Van der Hammen(1954) ex. Potonié(1956)

Type species: F. scrobiculatus

Remarks: This genus is characterised by spores with very even small rounded luminae, unlike the irregular luminae of Foveosporites spp. Most specimens can be assigned to F. subtriangulatus Brenner(1963), while two other morphotypes, F. sp. A & F. sp. B have also been recognised.

(a) F. subtriangulatus Brenner(1963). Plate 10, figs 14 - 28. This species has fovea more closely spaced on the distal than the proximal surface.

(b) ? F. sp. A Plate 10, figs. 29 - 32 & 37. These specimens are distinguished by their similar size and ornament to F. subtriangulatus but have an apparent monolete aperture. They could be assigned to "Foveomonoletes".

(c) F. sp. B Plate 10, figs. 33, 34 & 36. These grains have a rather more robust exine with larger foveolae.

Palaeoenvironment: Text-fig.4.27 shows that Foveotriletes spp are most prominent in cluster groups G - I. These are generally taxonomically diverse "mature" facies of the Weald Clay braidplain. Occurrences in cluster group B are probably due to reworking. Foveotriletes spp. are again negatively associated with brackish/marine influence and the dry uplifted group J facies.

6. Genus Foveosporites Balme(1957)

Type species: F. canalis

Remarks: This genus accommodates spores of circular to rounded triangular amb with a proximal and distal ornament of sparse irregular foveolae that often coalesce to form short channels. None of the specimens identified in this study could be assigned to a recognised species. They have been designated F. sp. A.

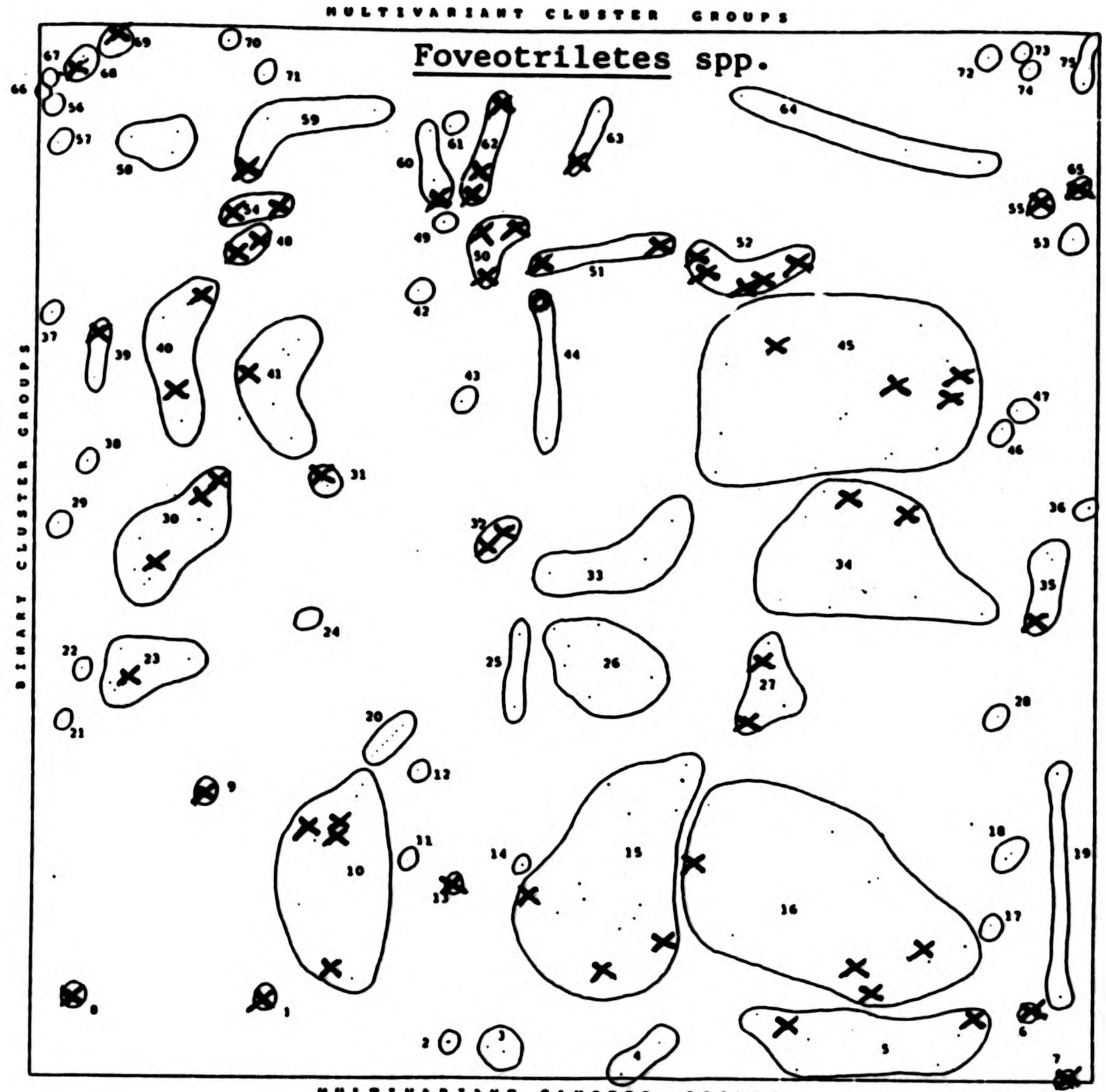
Plate 10, figs.35 & 38 - 44

Palaeoenvironment: Foveosporites spp. as a general group are plotted on text-fig. 4.28. They show a general spread between cluster groups E - I, and distinctly negative association with dry uplifted group J palynofacies and marine influenced groups A & B palynofacies.

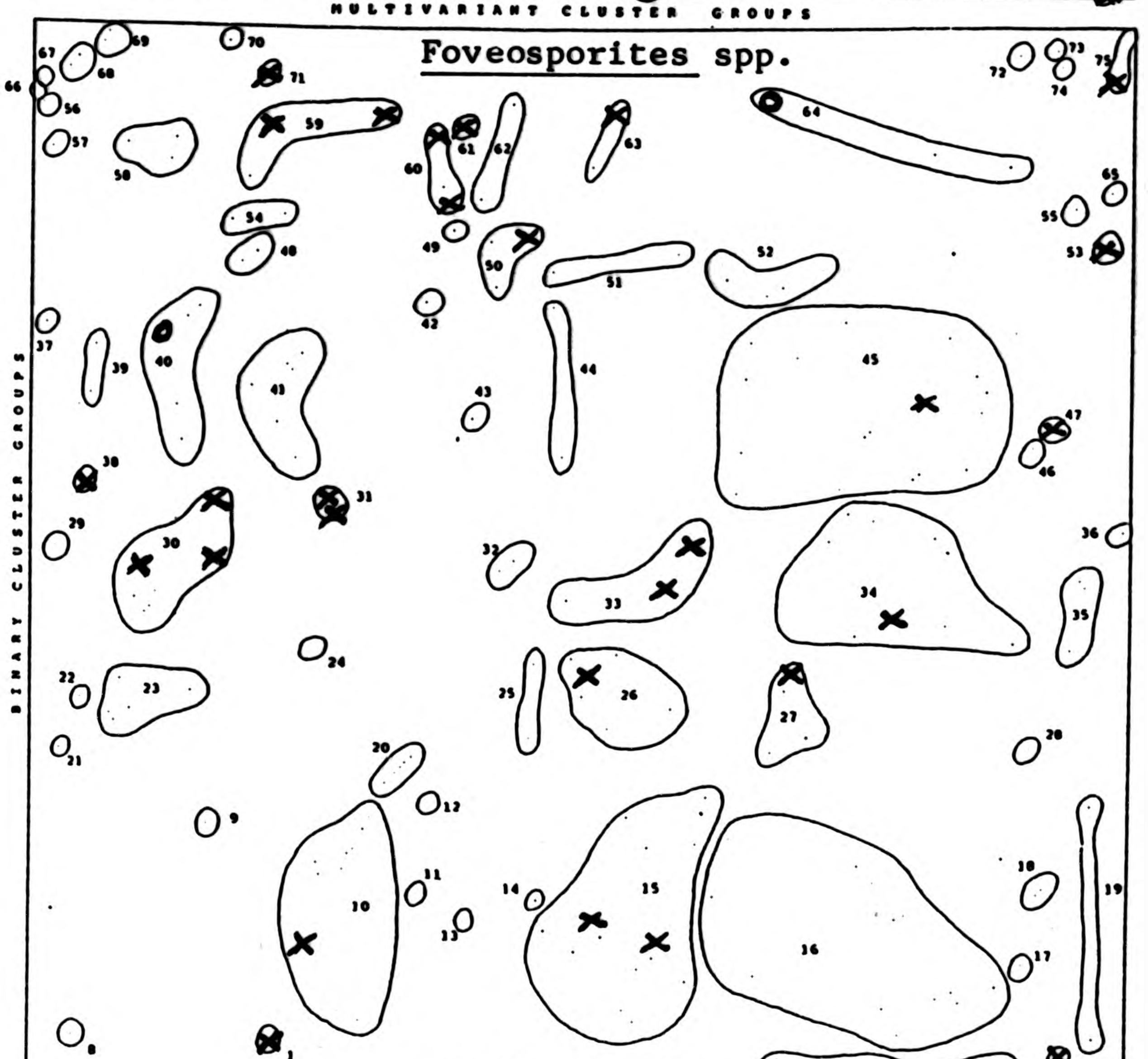
7. Genus Klukisporites Couper(1958)

Type species: K. variegatus

Remarks: The genus incorporates spores with foveolate to foveo-reticulate ornament on the distal surface. The luminae are irregularly shaped. These spores are generally of more robust appearance than Lycopodiumsporites, Foveotri-



Text-fig. 4.27



Text-fig. 4.28

letes & Foveosporites. Two recognised species and one morphotype have been observed in this study.

(a) K. pseudoreticulatus Couper(1958). Plate 9, figs.1 - 33 & 46. These spores have unequal, angular luminae and straight to concave sides.

(b) K. foveolatus Pocock(1964). Plate 9, figs.34 - 45, 47 - 51 & 55 - 64. This species has circular luminae of uniform size.

(c) K. sp. A Plate 9, figs.52 - 54. This species shows generally larger irregular luminae and much thinner muri than K. pseudoreticulatus & K. foveolatus.

Palaeoenvironment: This genus is generally cosmopolitan within the freshwater environments of the Weald Clay, particularly facies 30, 23, 40 & 45. The parent plants of Klukisporites spp.must have been a prominent element of the braidplain flora, particularly on damp soils.

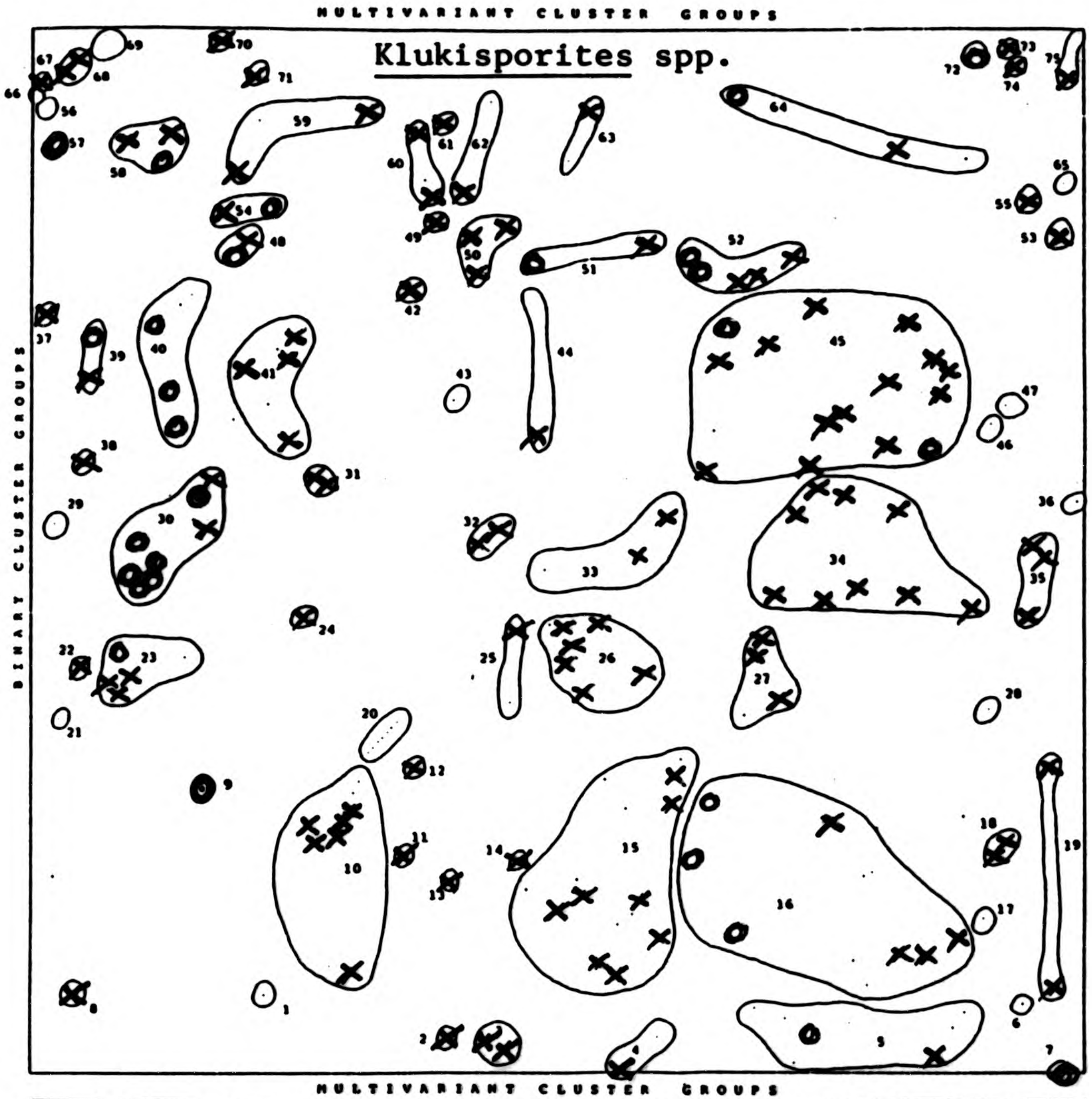
8. Genus Regresporites (Batten,1973)

Type species: R. lophus

Remarks: This genus was erected for robust spores with a distal sculpture of rugulae with grana, verrucae clavae or baculae sometimes present. One morphotype encountered within this study falls within this genus but it differs from R. lophus in showing a distal ornament of discreet small isolated verrucae and no rugulae. This taxon has been designated R. sp. A for the time being.

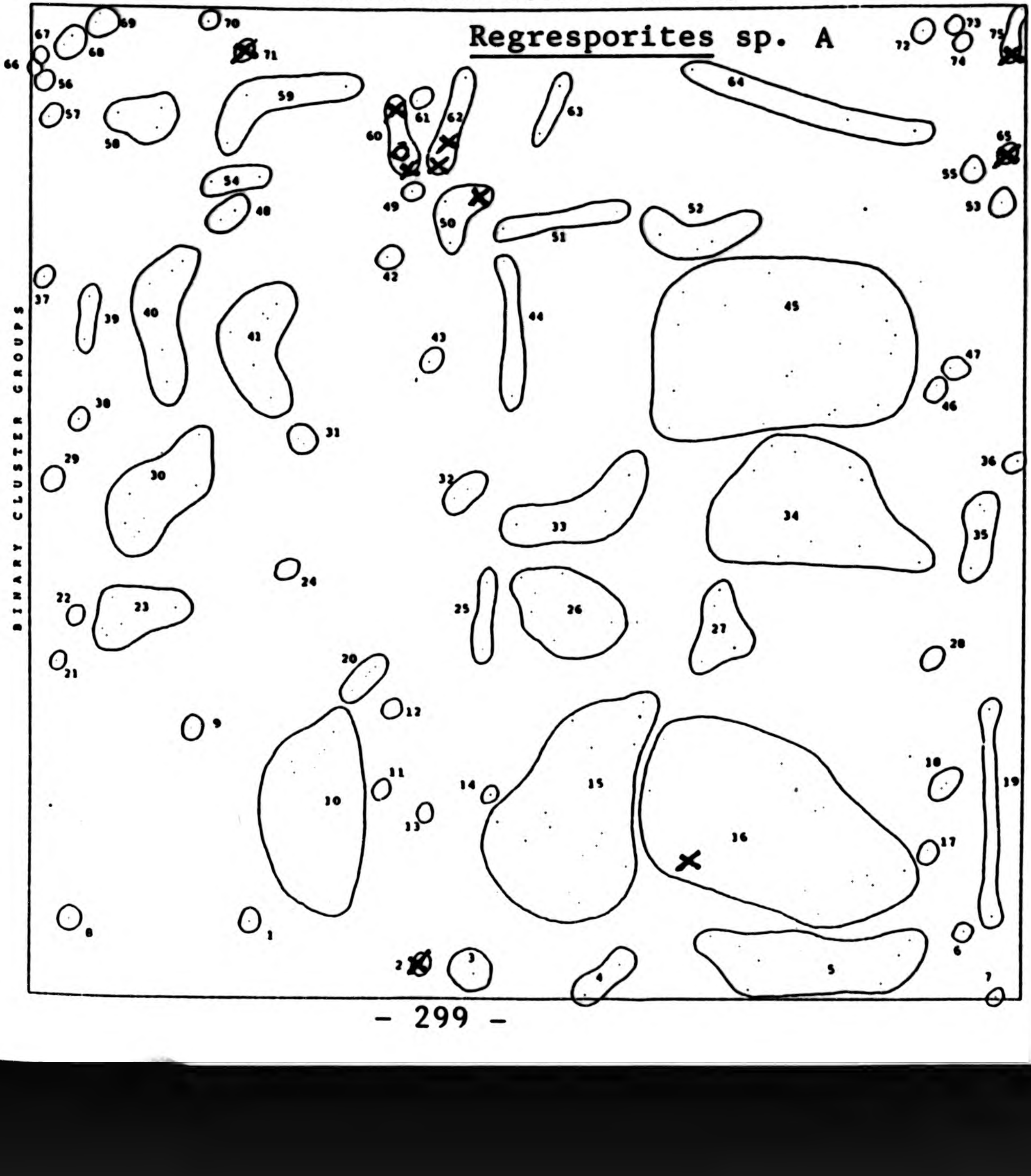
Plate 7, figs.7 - 25

Palaeoenvironment: Specimens of Regresporites sp. A show a marked concentration within facies 60, 62 & 50. These are distal facies with respect to the strandline (within



Klukisporites spp.

Text-fig. 4.29



Regresporites sp. A

Text-fig. 4.30

cluster group I) that show marine influence, possibly by tidal influences or locally raised salinity due to evaporation (see text-fig. 4.30).

9. Genus Lycopodiacidites Couper(1953)emend.Potonié(1956)

Type species: L. bullerensis Couper(1953)

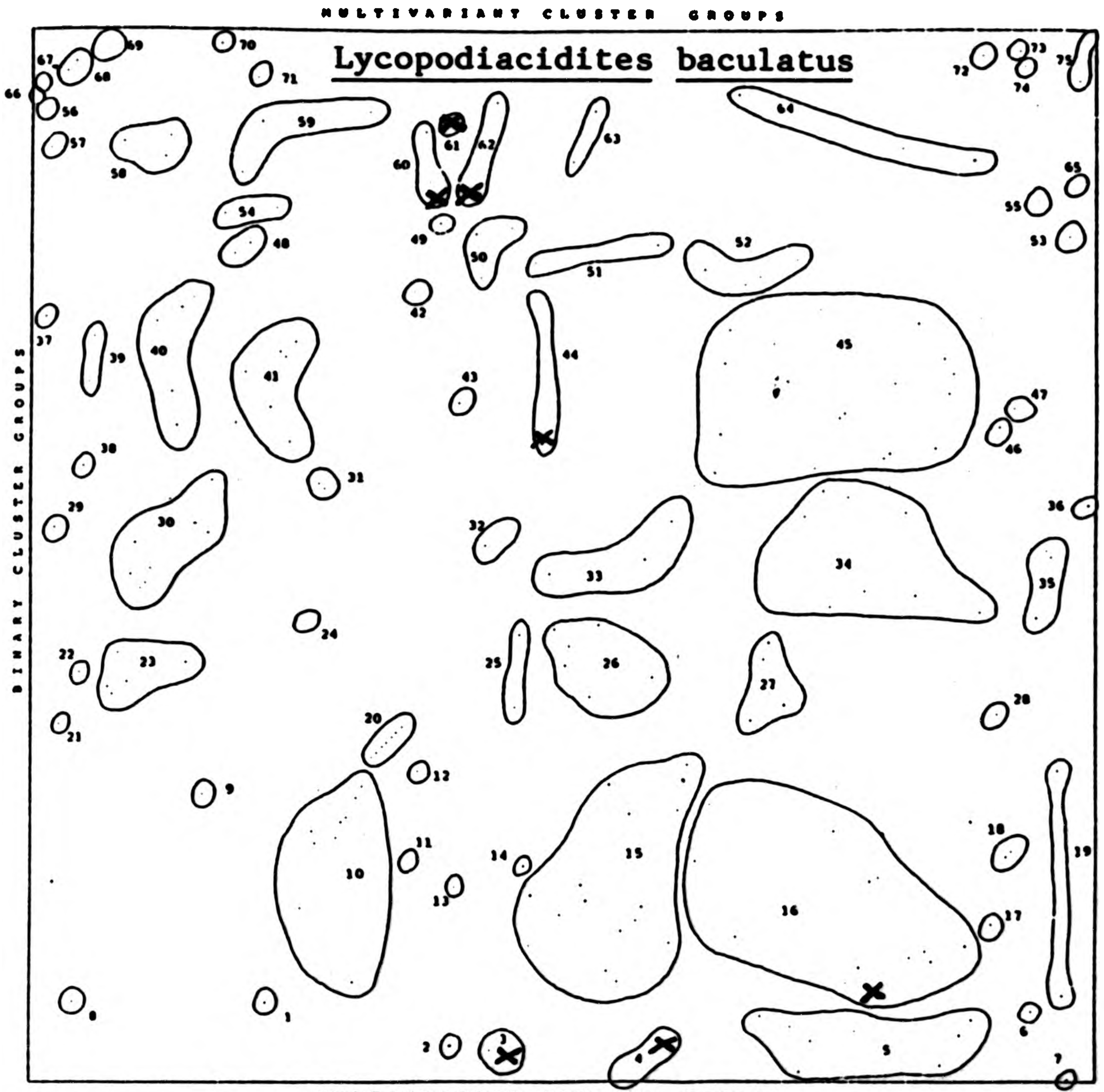
Remarks: This genus accommodates spores with a smooth proximal surface and a distal rugulose verrocose or baculate exine. Two species have been recognised in this study.

(a) L. baculatus (Pocock,1962) Plate 6, figs. 50 - 63. According to Pocock this spore ranges from the Oxfordian to Purbeckian. If the present identification is upheld as correct, this would require extension of its upper range. This taxon is described as bearing baculae 3 - 9u in length that are wide at their base, and blunt. The proximal face is flattened with reduced ornament. The exine is reticulate.

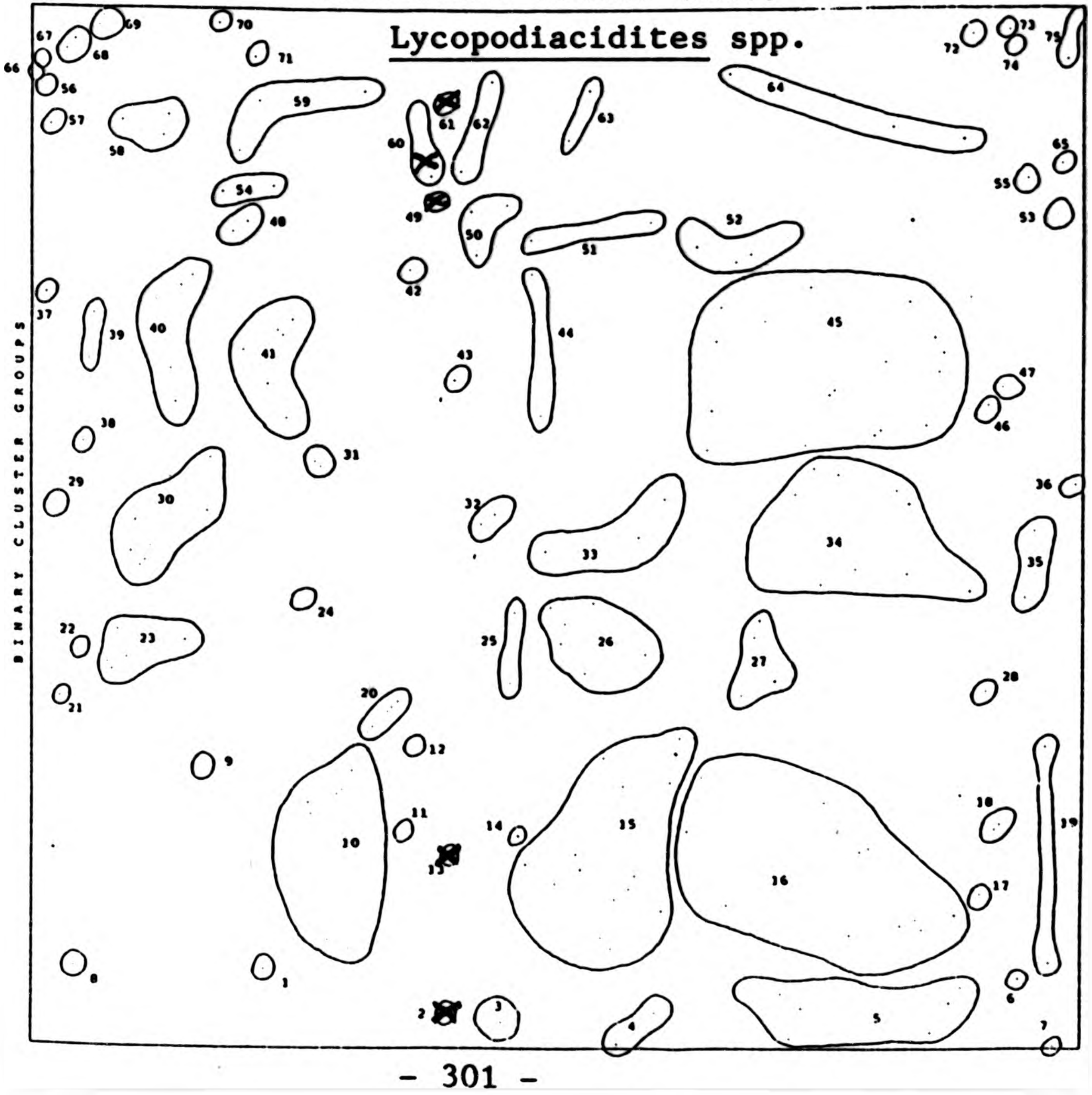
Palaeoenvironment: Text-fig.4.31 reveals a trend that gives this taxon a distinct marine association, in the tidally influenced facies 60, 61 & 62 and strandline facies 3 & 4.

(b) L. cf. caperatus Plate 9, figs.65 - 72. Lycopodiacidites caperatus (Singh,1971) shows crenullated grooves. These spores are similar except they show rugulae sometimes forming a disjointed reticulate pattern.

Palaeoenvironment: These taxon were included within Lycopodiacidites spp. for the CLUSTAN palaeoenvironmental analysis, together with poorly preserved grains. They show the



Text-fig. 4.31



Text-fig. 4.32

same association with tidally marine influenced facies 49 60 & 61 as well as brackish marine facies 13 & 2, as seen with L. baculatus (see text-fig. 4.32).

10. Genus **Cicatricosisporites** Potonié & Gelletich (1933)

Type species: C. dorogensis

Remarks: This genus was erected for schizaecean spores with a distal and equatorial sculpture of more or less parallel muri. Several species have been recognised in this study.

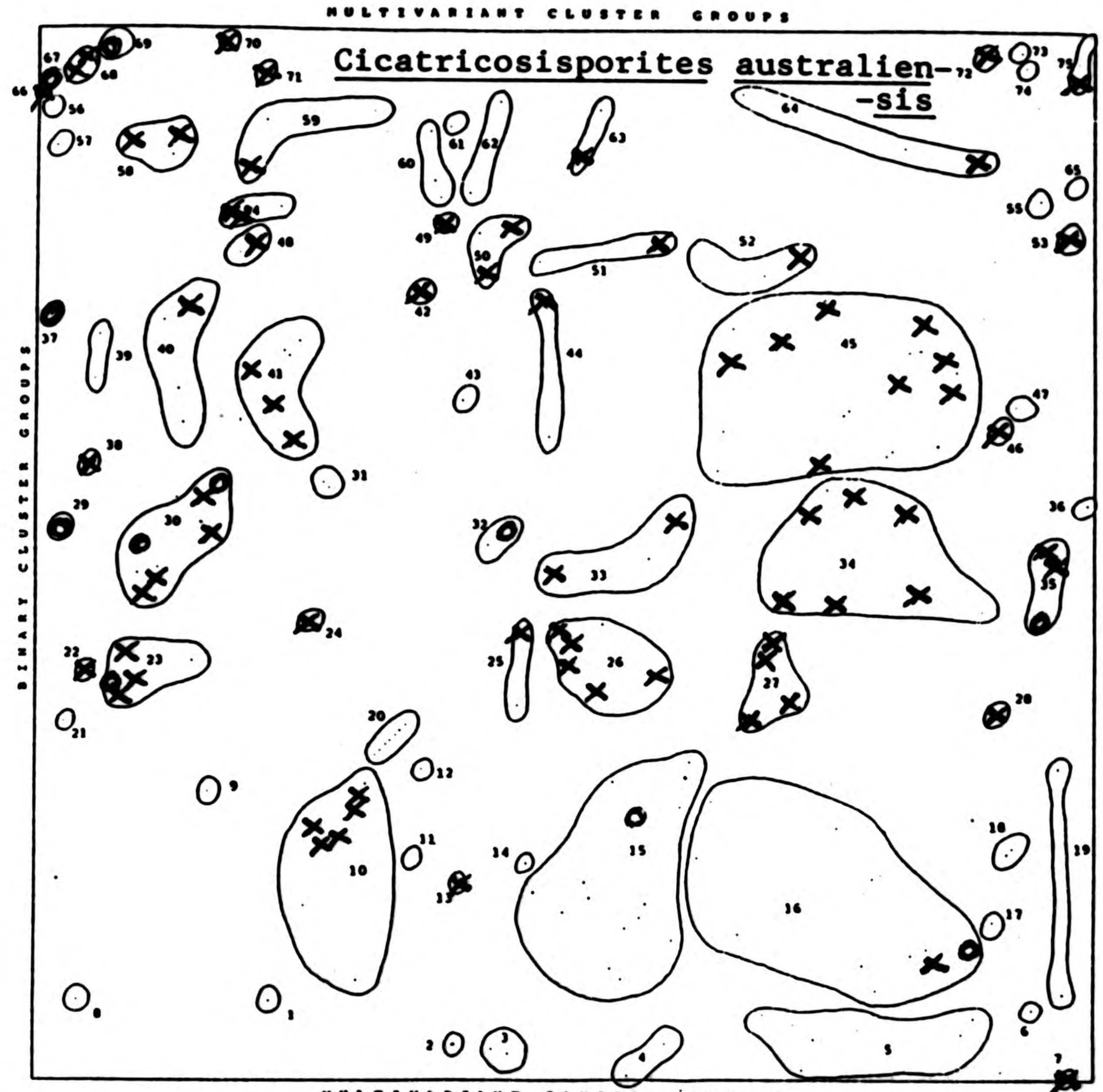
(a) C. australiensis (Cookson) Potonié (1956). Plate 12, figs. 7 - 13. this species is characterised by narrow ribs that run parallel to the inter-radii and coalesce at the radii. The muri therefore show a triangular pattern that parallels the spore amb.

Palaeoenvironment: This species is distinctly negatively asssociated with any marine influence (marine facies in cluster groups A & B and tidally influenced facies 60 - 62). Otherwise they show a cosmopolitan distribution throughout cluster groups D - J. They are slightly more common in damp low-lying facies 23 & 30 (see text-fig. 4.33).

(b) C. augustus Singh (1971). Plate 12, figs. 20 - 27. This species is characterised by very fine muri that run generally parallel to the radii.

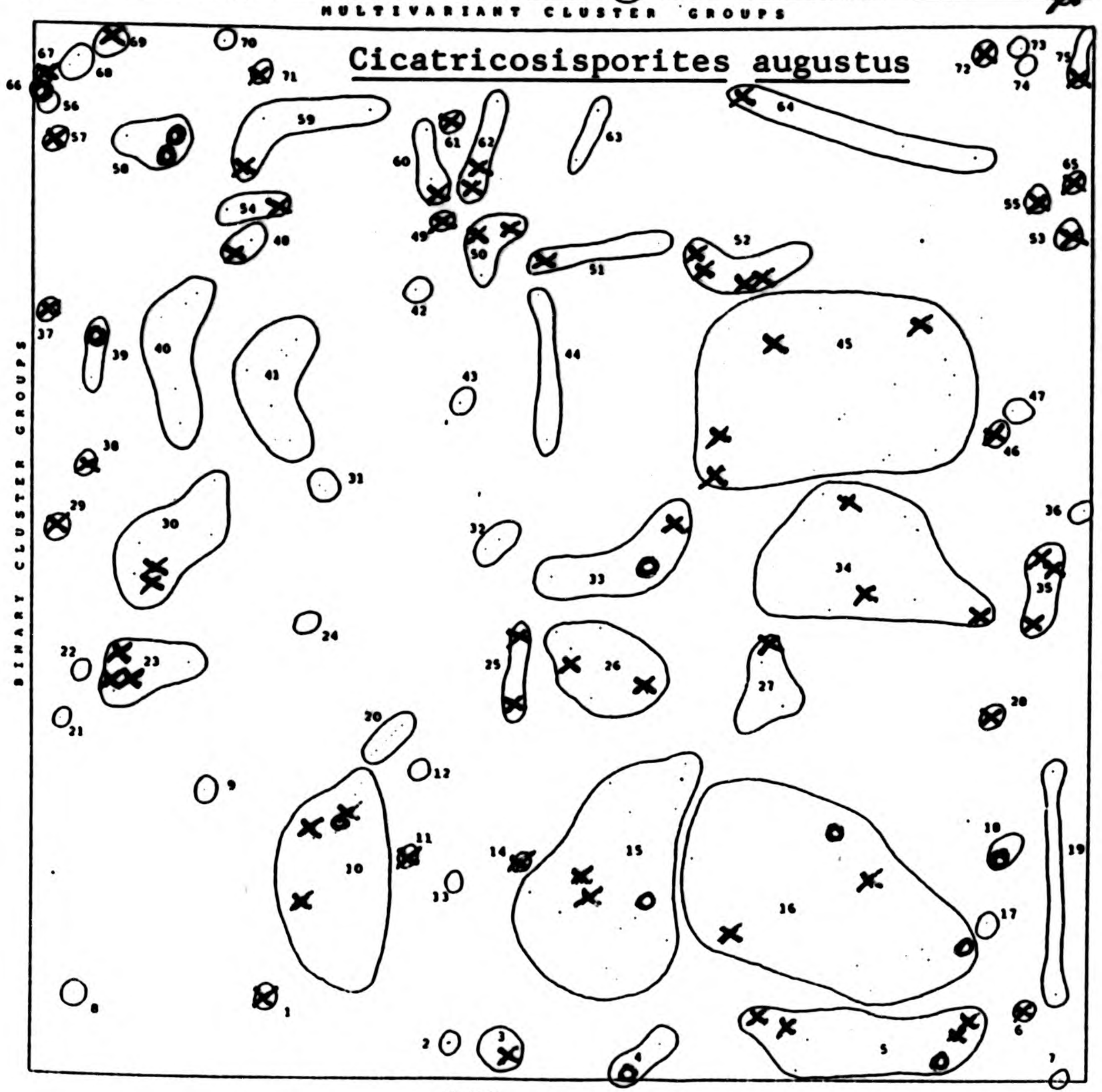
Palaeoenvironment: This species is generally cosmopolitan throughout the Weald Clay. It is distinctly associated with marine facies within cluster groups A & B and tidally influenced facies 60 - 62 (see text-fig. 4.34)

(c) C. minor (Bolkhovitina) Pocock (1964). Plate 11, figs. 56 -



Cicatricosisporites australiensis

Text-fig. 4.33



Cicatricosisporites augustus

Text-fig. 4.34

64, 67 & 71 - 72. This species is distinguished by its small size.

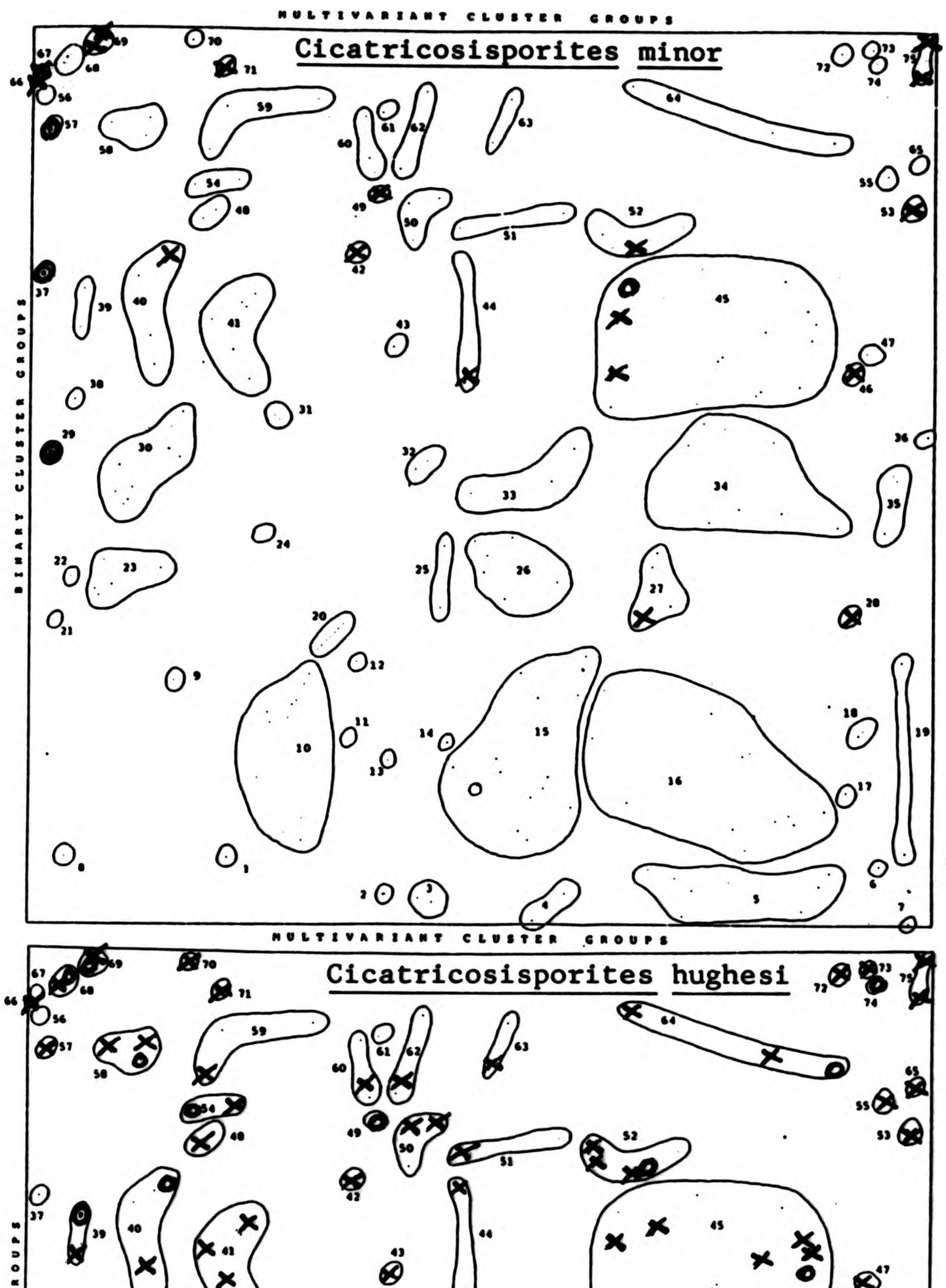
Palaeoenvironment: Text-fig.4.35 shows this species to be generally rare in occurrence, but it is markedly associated with the dry upland flora of cluster group J and is negatively associated with 'intermediate' low-lying, waterlogged palaeoenvironments or any showing brackish/marine influence.

(d) C. hughesi Dettmann (1963). Plate 11, figs.37-55. This species is characterised by three to five well-spaced distal ribs that are arranged broadly parallel to the inter-radial areas, and coalesce at the radii. The proximal surface is smooth.

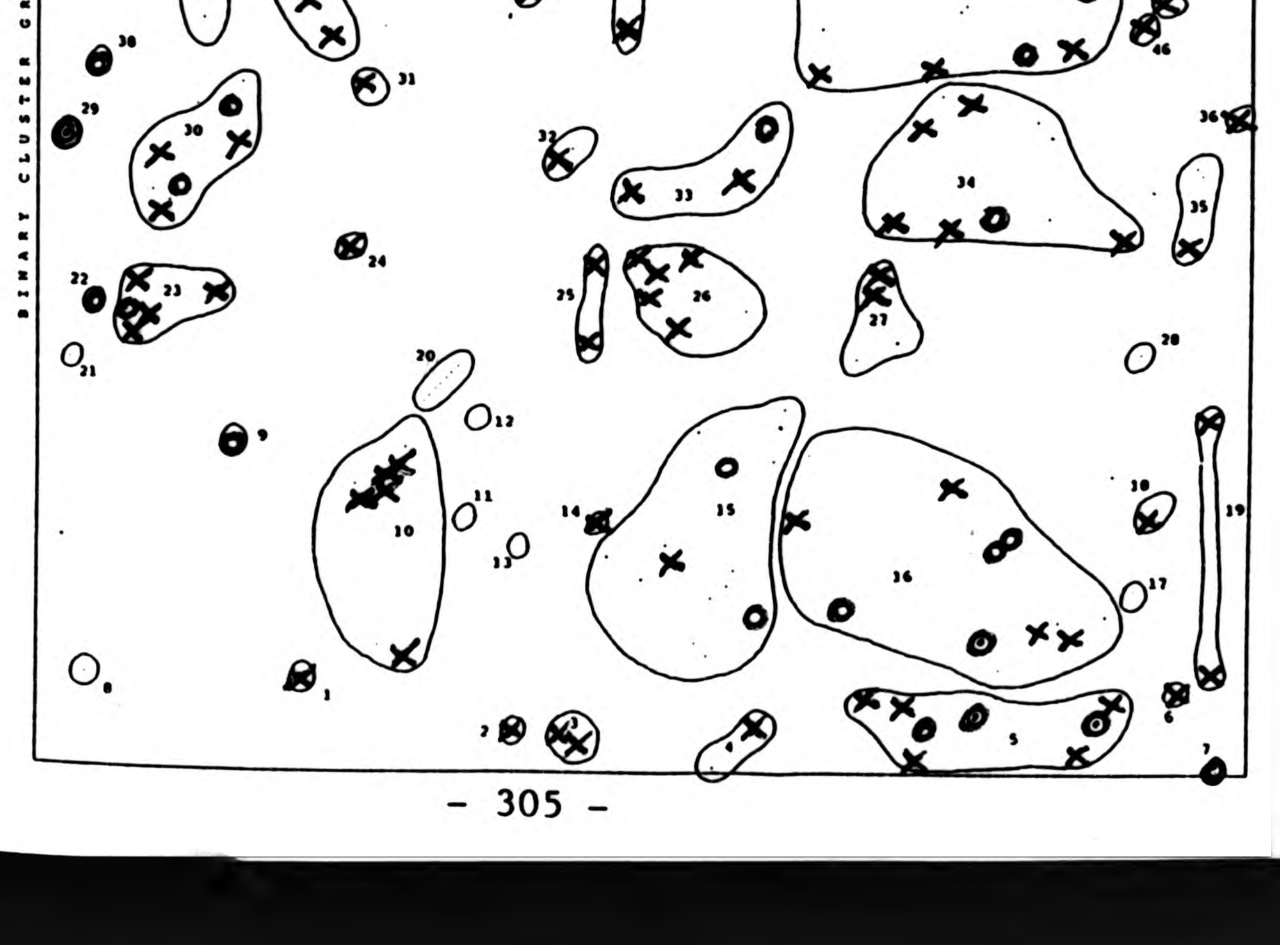
Palaeoenvironment: Text-fig.4.36 shows that this taxon must come from plants that were widely distributed over the Weald Clay braidplain. They show a distinct association with the marine influenced facies in group A & B. This could be partly overemphasised by the low diversity in these facies that make this taxon appear more common here.

(e) C. potomacensis Brenner (1963). Plate 12, figs.1 - 6. This species has distal ribs that cross the exine in one direction from one radial area to the opposite two. Ribs on the proximal surface run parallel to the inter radial areas.

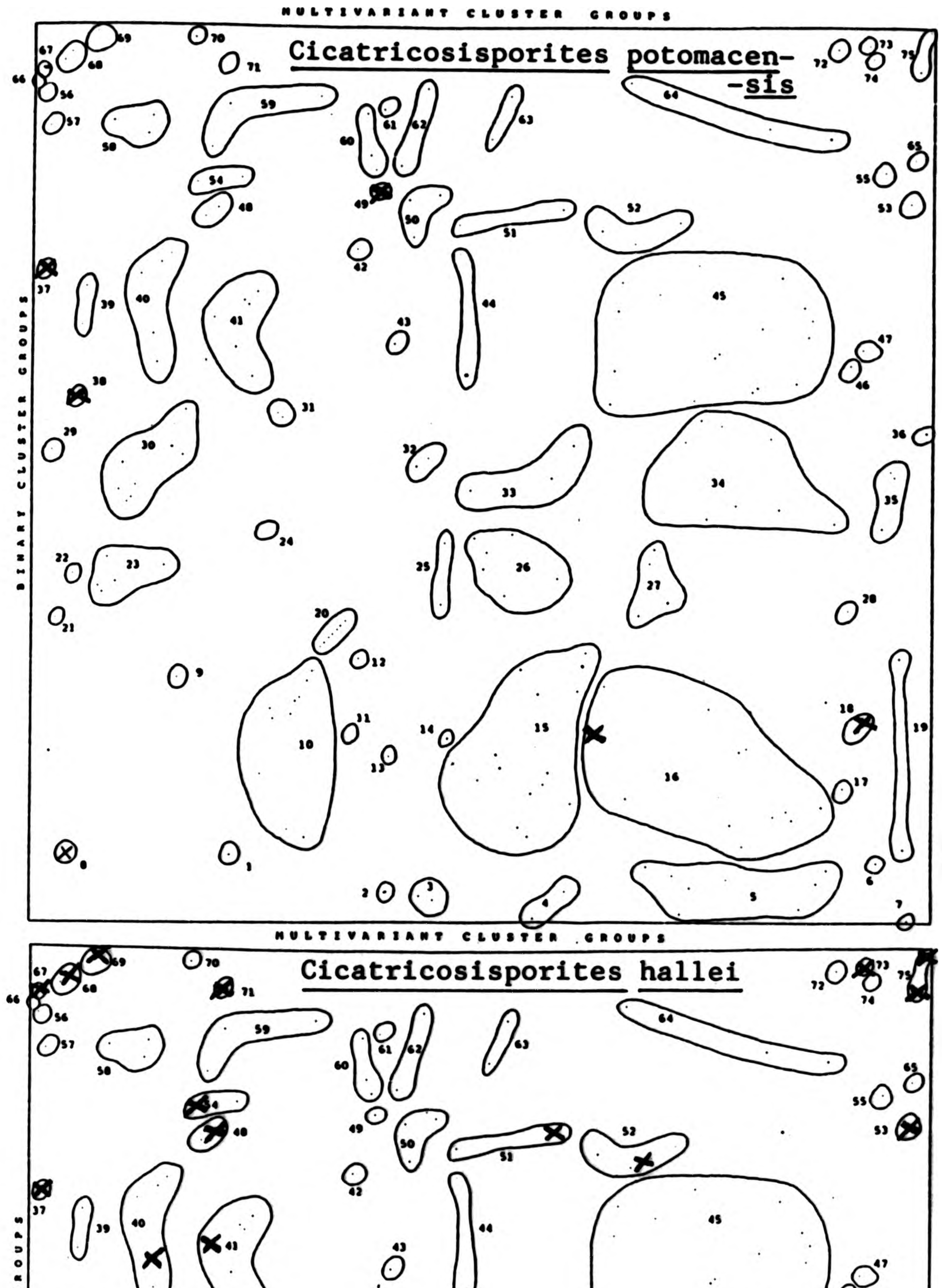
Palaeoenvironment: This taxon was too rarely recovered for its distribution to reveal palaeoecological information, though it probably favours non-brackish/marine influence (see text-fig.4.37).



Text-fig. 4.35

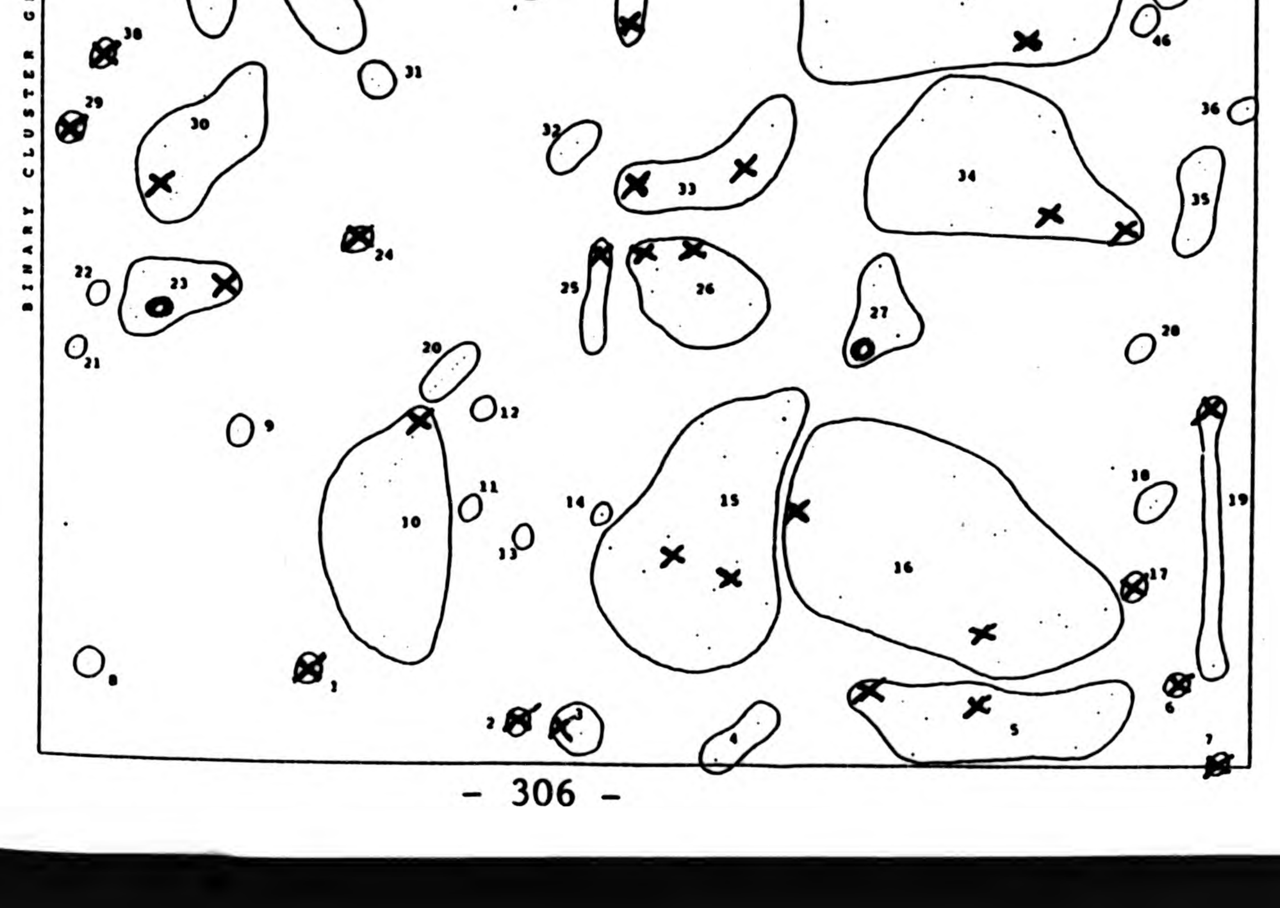


Text-fig. 4.36



Cicatricosisporites potomacensis

Text-fig. 4.37



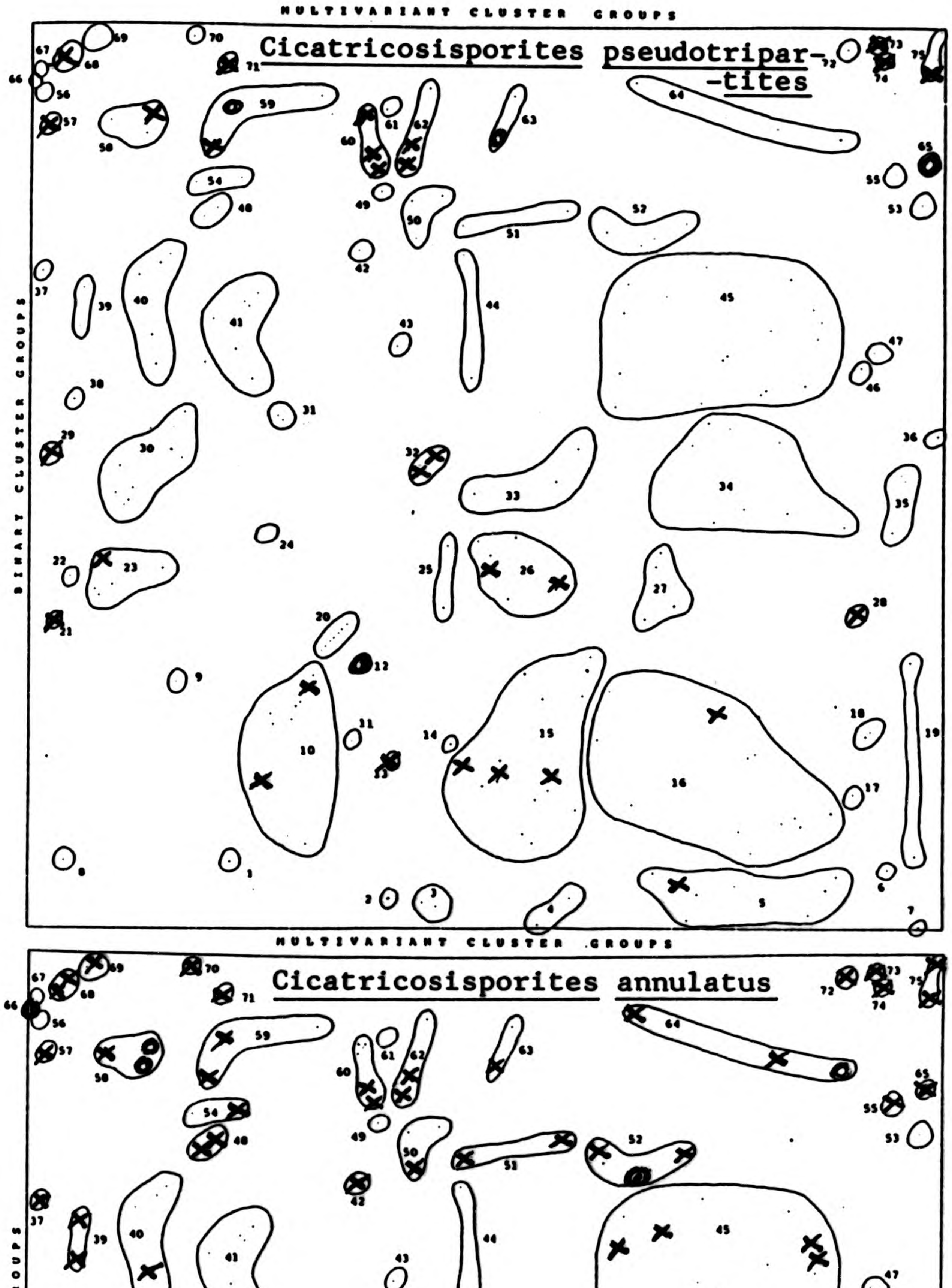
Cicatricosisporites hallei

Text-fig. 4.38

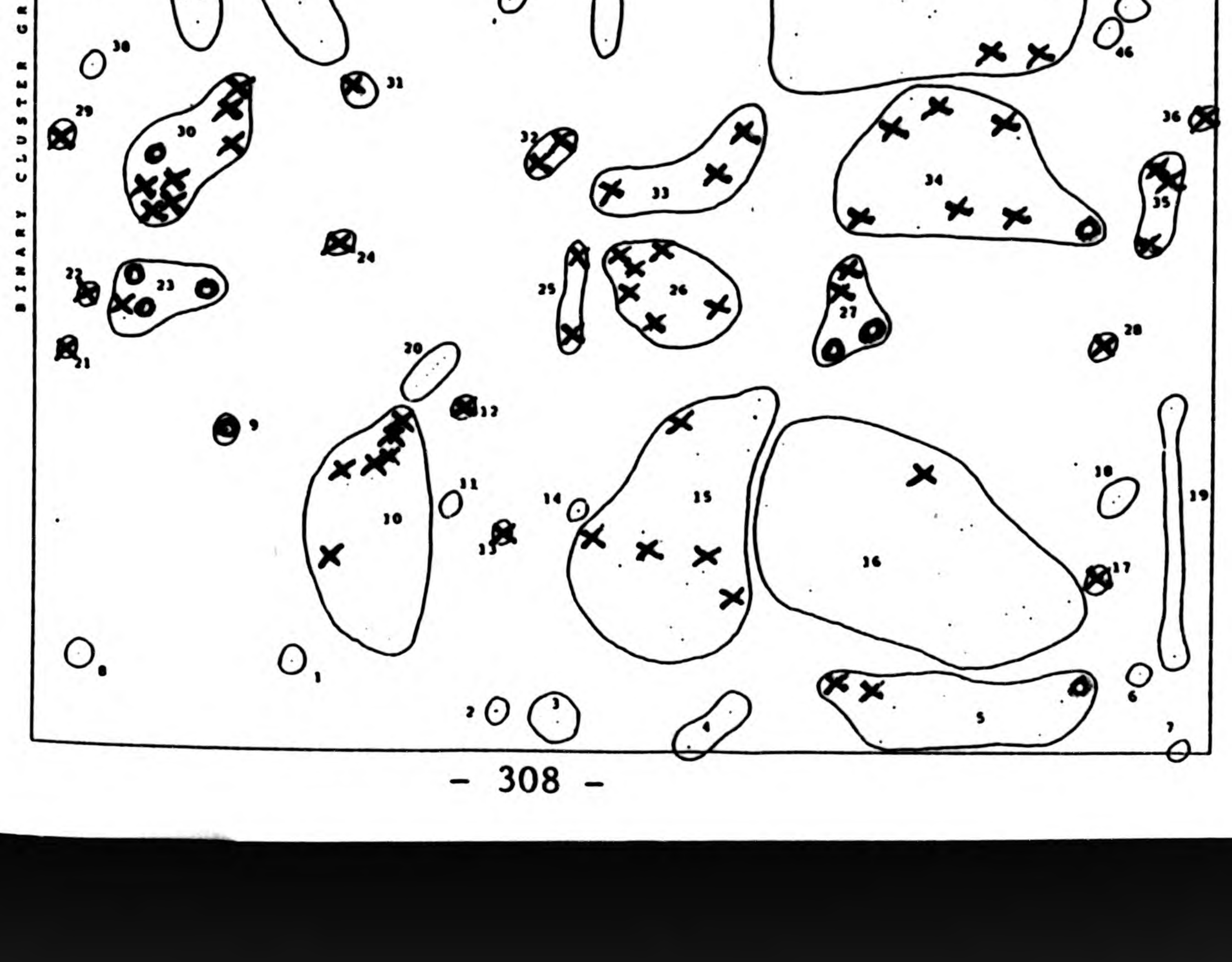
(f) C. hallei Delcourt & Sprumont (1955). Plate 11, figs. 24 - 36. This species has two sets of parallel distal ribs that meet obliquely along a line, and proximal ribs that run obliquely to the inter-radial areas.
Palaeoenvironment: This species appears to be fairly cosmopolitan but generally favours the freshwater palaeoenvironments behind the strandline (see text-fig. 4.38)

(g) C. pseudotripartitus (Bolkhovitina) Dettmann (1963). Plate 11, figs. 1 - 6 & Plate 12, figs. 14 - 19. This species is characterised by a few (two to three) ribs in each interradial region that run parallel to the inter-radial areas. There may be synonymy between this species and C. hughesi.
Palaeoenvironment: Text-fig. 4.39 shows the distribution of C. pseudotripartitus. It is very abundant in facies 12 (represented by sample CH/M.11) as well as occurring in several other group B facies. It shows a definite concentration within groups I & J, particularly facies 60 & 62. This taxon may therefore tolerate or favour some brackish/marine influence. This trend of abundance within the dry uplifted facies as well as those showing marine influence is similar to the trend seen with C. hughesi. This may be further evidence of synonymy between these two taxa.
N.B. the abundant C. pseudotripartitus in facies 12 is of a morphotype that tends to lie in equatorial compression. This could be the spore of a 'stand' of dominant fern species in this palynofacies.

(h) C. annulatus Archangelsky & Gamerro (1966). Plate 11, figs. 8 - 23. This species has a proximal pattern of ribs running parallel to the inter radial areas, and a distal pat-



Text-fig. 4.39



Text-fig. 4.40

tern that run in a U-shape.

Palaeoenvironment: This species was fairly common in most Weald Clay environments except those affected by brackish marine influence. Its parent plant must have been a ubiquitous member of the freshwater braidplain flora (see text-fig. 4.40)

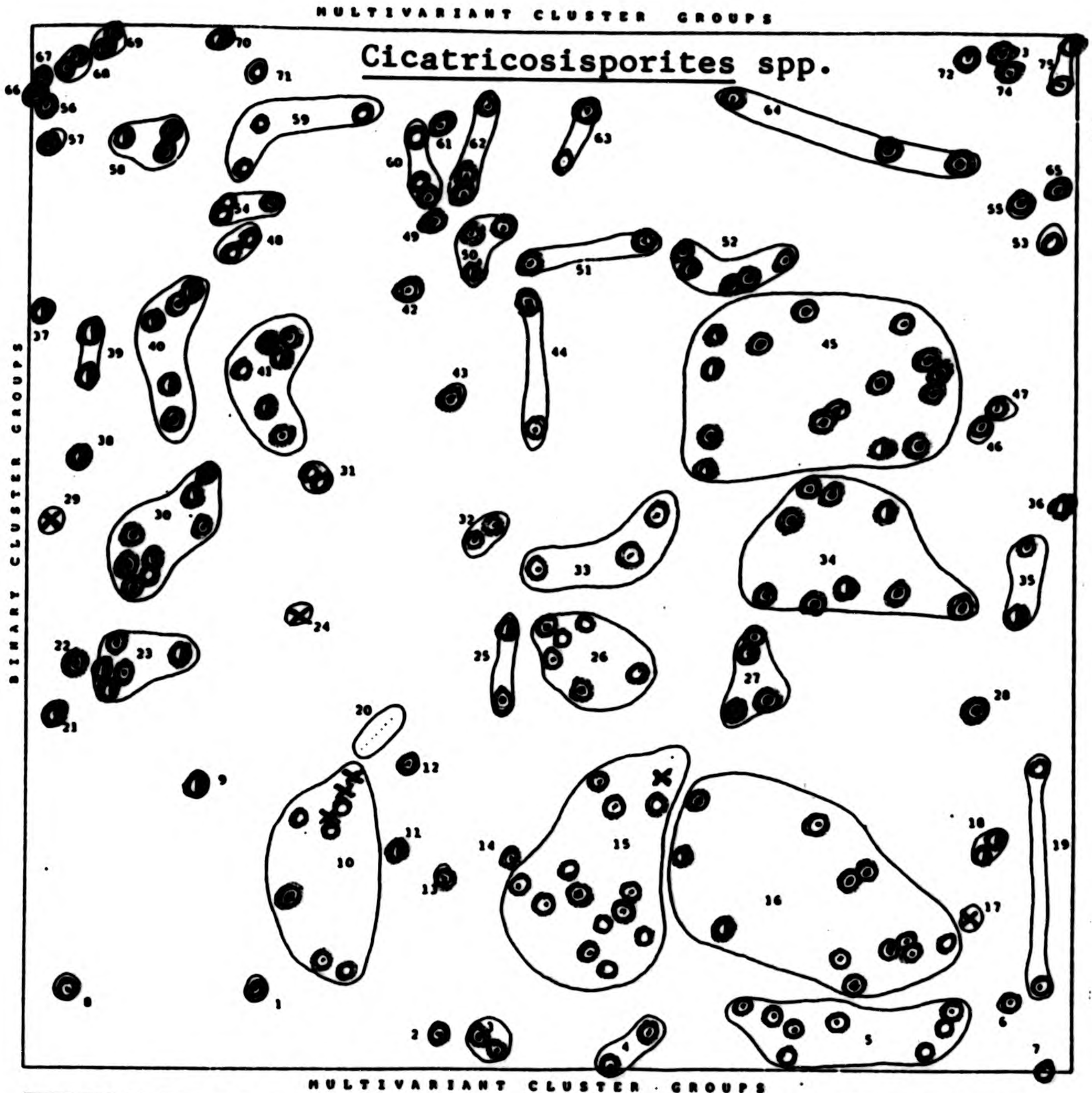
(i) C. sp. A. Plate 12, figs. 28-30 & 33, 34. These specimens of Cicatricosisporites are distinguished by their large size with labrate trilete margins. The dorsal surface is strongly convex so that the grains tend to lie in oblique or equatorial compression.

(j) C. sp. B. Plate 12, figs. 31, 32, 35-37 & 43. These specimens of Cicatricosisporites are of large size range with muri that are very narrow and finely juxtaposed.

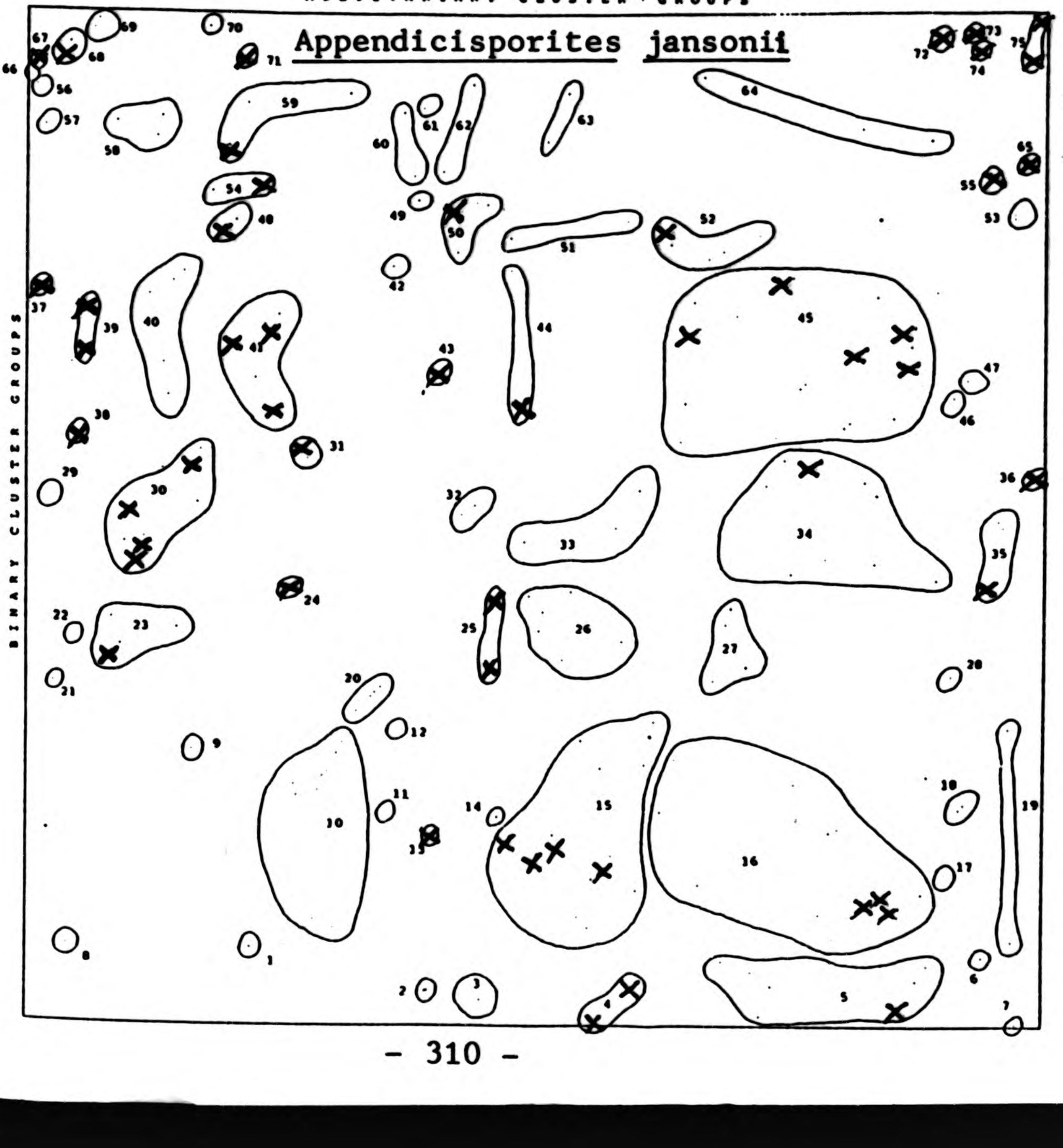
(k) Monolete 'Cicatricososporites' spp. Plate 12, figs. 39-41 & 44-46. Monolete or bilaterally symmetrical costate spores were vary rarely encountered in this study. Some of them such as figs. 39, 40, 41 & 44 may be aberrant specimens, though figs. 45 & 46 may be true monolete spores.

(l) Polyads of Cicatricosisporites sp. Plate 12, figs. 38, 42, 47 & 48. Rare occurrences of attached costate spores were observed. Those illustrated on fig. 38 & 42 may fall within C. minor, fig. 47 may represent C. pseudotripartites, and fig. 48, C. hallei.

Text-fig. 4.41 shows the distribution of Cicatricosisporites spp. throughout all the palynofacies of this study. This includes all poorly preserved or poorly defined specimens that could not be assigned to definite species (Plate 11, figs. 65, 66 & 68-70). Cicatricosisporites plants must have been one of the most typical Wealden



Text-fig. 4.41



Text-fig. 4.42

fern groups. They are most common in cluster groups D-J where habitants were more 'mature' and species-rich. This is very much the pattern of species diversity that is revealed throughout this study.

11. Genus Appendicisporites Weyland & Krieger (1953)

Type species: A. tricuspidatus

Remarks: This genus accommodates spores with a cicatricose ornament of parallel muri together with the development of radial appendices (auriculae). Several species were recognised in this study.

(a) A. jansonii Pocock (1962) Plate 19, figs. 1-9. This species has ribs running parallel to the equator and coalescing at the apices, not projecting beyond the general ambital outline. These spores are of comparatively large size.

Palaeoenvironment: This taxon shows an association with facies 72-75 and facies 55 & 65, 34 & 36 where Gleicheniidites spp. are prominent (cluster group XIII). Apart from this it shows a moderate spread throughout most other facies including the marine influenced facies 4, 15 & 16 (but not facies 60-62). Its association with Gleicheniidites spp. may indicate that it is part of the source lands flora that can find its way into most braidplain facies (see text-fig. 4.42)

(b) A. potomacensis Brenner (1963) Plate 18, figs. 27 , & 32-46. This species has slightly projecting appendices at each radial region.

Palaeoenvironment: This taxon shows no particular association with any facies (except possibly with damper facies

23, 30 & 40) but seems to be negatively associated with any marine influence (see text-fig. 4.43).

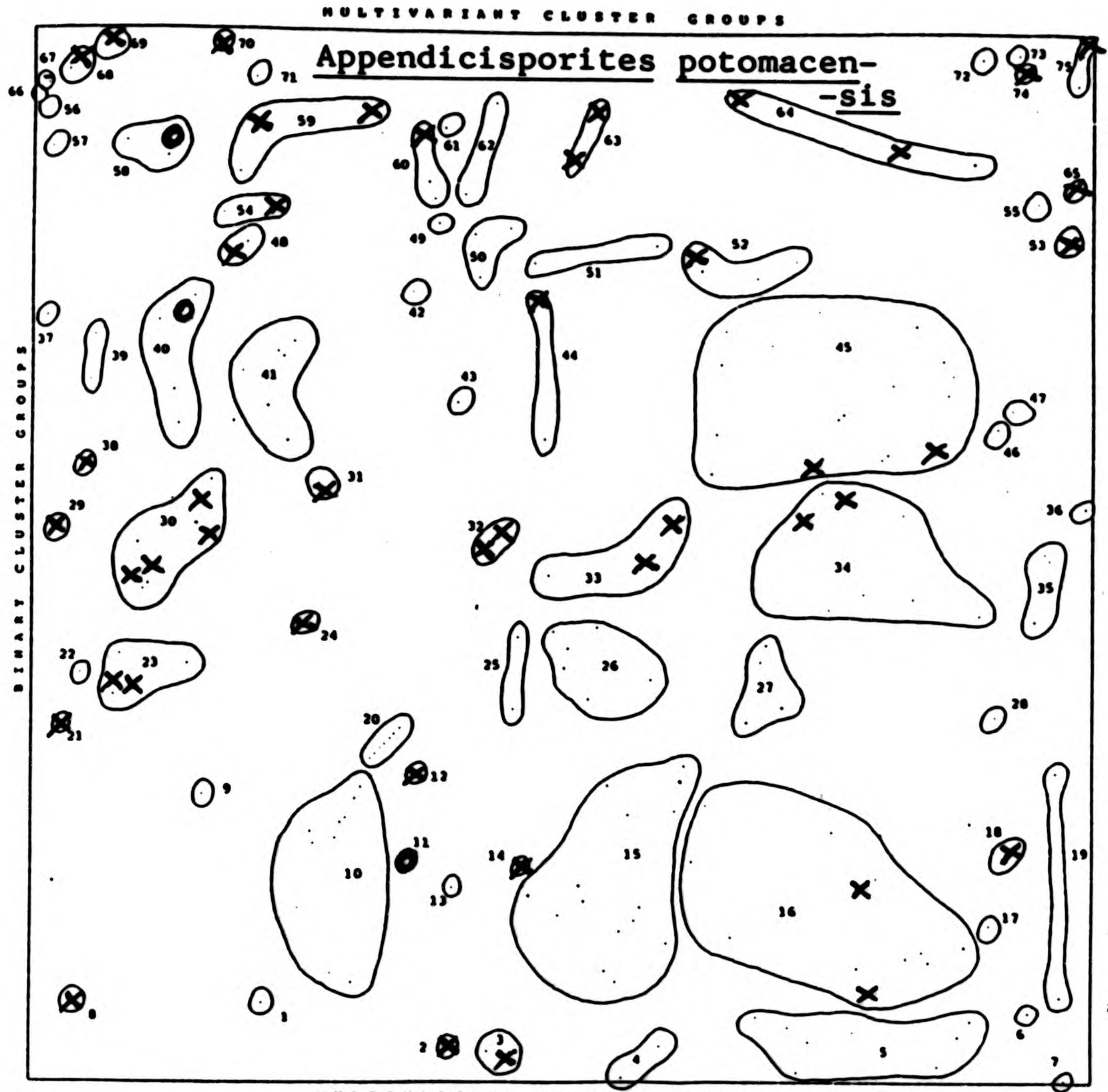
(c) A. tricornitatus Weyland & Greifeld (1953) Plate 19, figs. 11 & 15. This species was described by Weyland & Greifeld as having 'thimble like' processes. It may be synonymous with A. potomacensis.

Palaeoenvironment: Text-fig. 4.44 shows this spore to be distributed within the drier uplifted facies, and to be negatively associated with damp conditions or marine influence. On the other hand this distribution (that appears mutually different from A. potomacensis) may be evidence that these taxa are synonymous, ie. two separate species names could have been used at separate facies during this study for the same taxon.

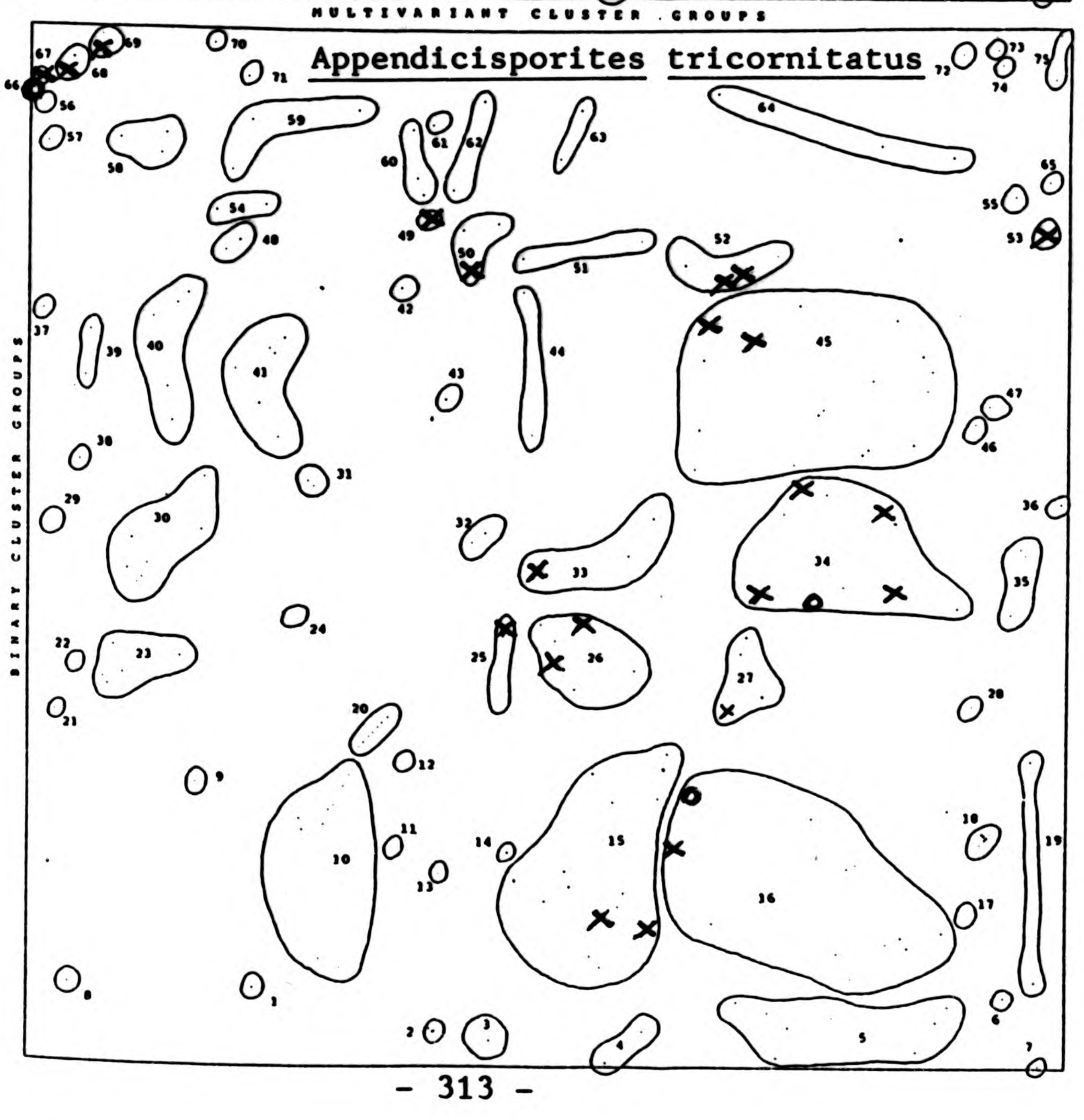
(d) A. problematicus (Burger) Singh (1971) Plate 18, figs. 47-53 & 60. This species has 3-5 distal ribs that are parallel to the equator and a smooth contact area. The ribs are quite well separated and can show crests. Equatorial ribs can form a flange.

Palaeoenvironment: This taxon shows no particular facies association except that it is probably negatively associated with brackish/marine influence (see text-fig. 4.45). This is a contrast to its morphological relative, Cicatricosisporites hughesi that shows brackish/marine association.

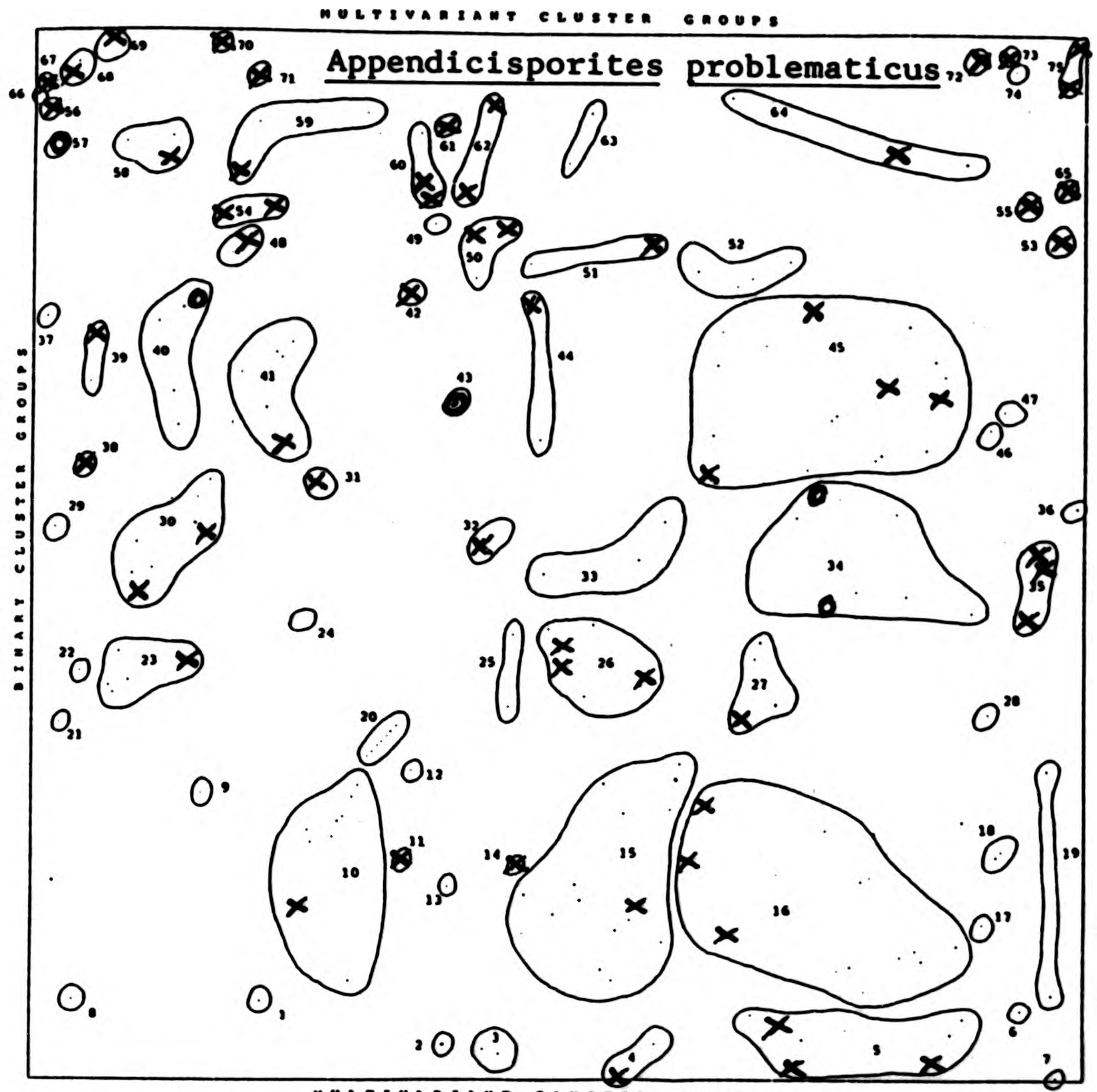
(e) A. trichacanthus (Maljavkina) Singh (1964) Plate 18, figs. 1-19 & 54-59 and Plate 19, figs. 33 & 34. This species is characterised by tightly packed ribs on the dorsal and ventral surfaces, rounded appendices and a tendancy for



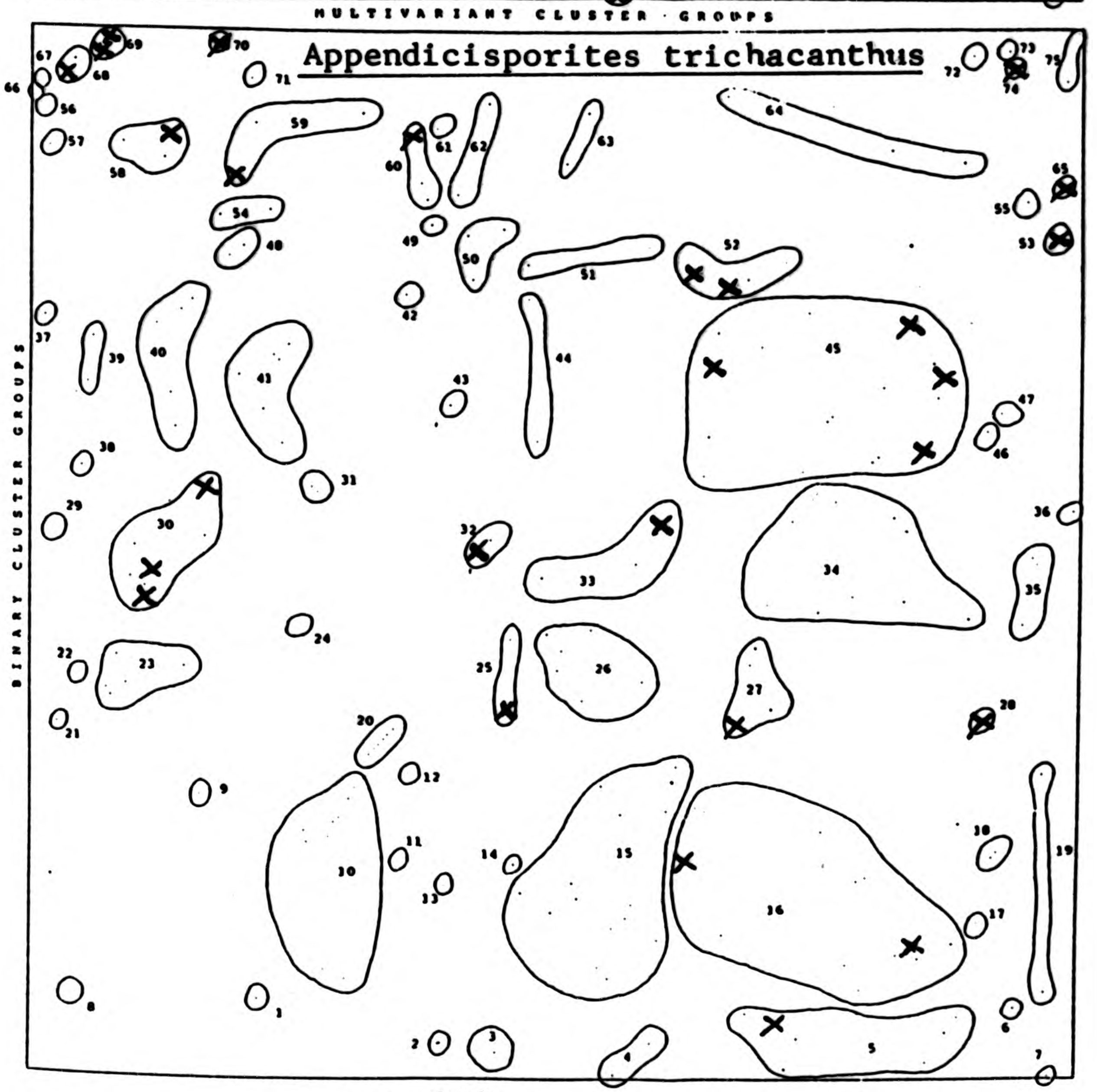
Text-fig.
4.43



Text-fig.
4.44



Text-fig. 4.45



Text-fig. 4.46

the distal ribs to fuse forming a ridge from the central areas to the appendices.

Palaeoenvironment: Text-fig. 4.46 shows that this taxon has no particular facies association except that it is negatively associated with brackish/marine influence.

(f) A. sellingii Pocock (1964) Plate 18, figs. 20-26 & 28-31. These are quite large robust grains with rounded non-projecting apices.

Palaeoenvironment: This species shows a facies association within the dry uplifted cluster group J (see text-fig. 4.47).

(g) A. spinosus Pocock (1964) Plate 19, figs. 16-22. This species is distinct in having spines or baculose elements.

Palaeoenvironment: This taxon was too rarely occurring to run separately in CLUSTAN, but the rare occurrences of it lie generally within freshwater uplifted or waterlogged facies well away from the strandline.

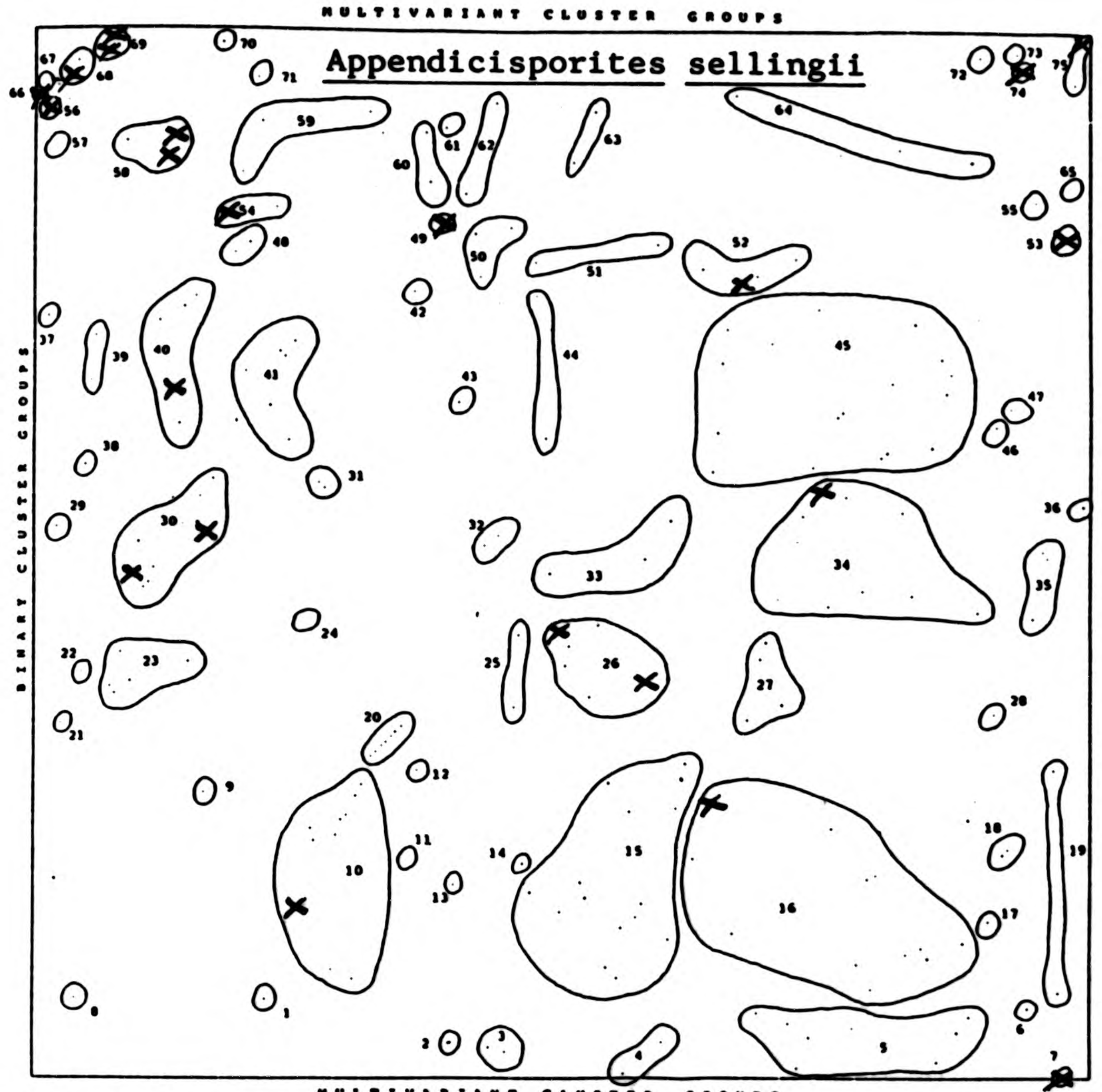
(h) A. unicus (Markova) Singh (1964) Plate 19, fig. 10. This species has particularly long pendulous apical thickenings. Only a single specimen was observed within the present study.

(i) A. sp. A Plate 19, figs. 23-27. These specimens are of generally large size range with finely juxtaposed muri but poorly developed auriculae.

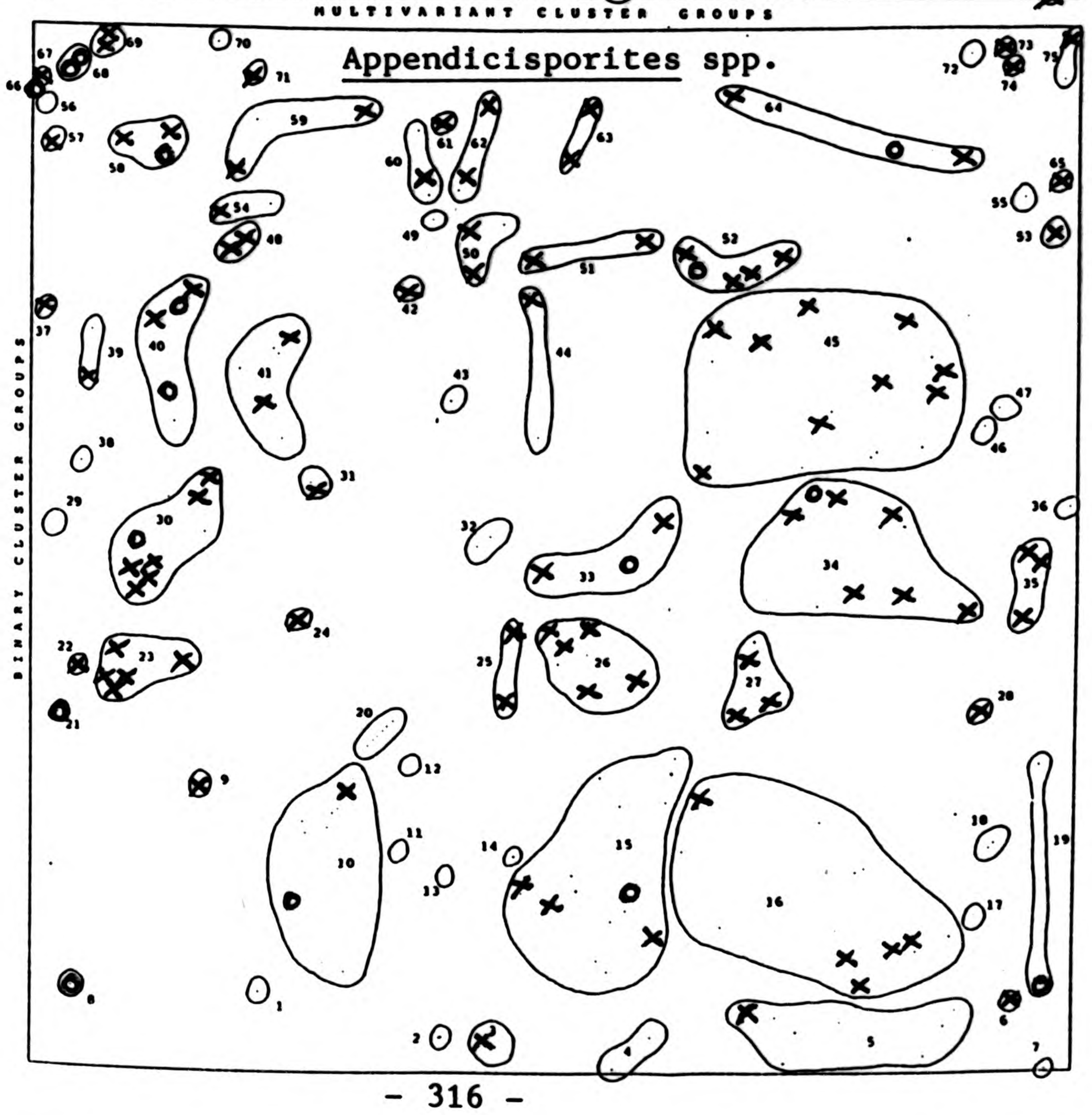
(j) A. sp. B Plate 19, figs. 28-32 & 35-38. These specimens of Appendicisporites have poorly defined auriculae.

(k) A. sp. C Plate 19, fig. 39. This specimen has massively developed auriculae in proportion to the main body of the spore.

(l) A. sp. D Plate 19, figs. 40-45. These specimens generally



Text-fig. 4.47



Text-fig. 4.48

display very robust muri and the auriculae do not protrude prominently beyond the ambital outline.

A. spp. Text-fig. 4.48 shows the distribution of general Appendicisporites specimens that could not be, or were too poorly preserved to be assigned to species. This distribution is fairly uniform throughout all the freshwater braidplain facies, with slightly increased representation in the dry uplifted near hinterland facies 67-69.

12. Genus Costatoperforosporites Deak (1962)

Type species: C. fistulosus

Remarks: This genus accommodates spores with a 'cicatricose' ornament of parallel ribs that are perforated by rows of small holes. For the purposes of CLUSTAN analysis the group was treated as a whole generic group. However a few species of several morphotypes were recognised in this study.

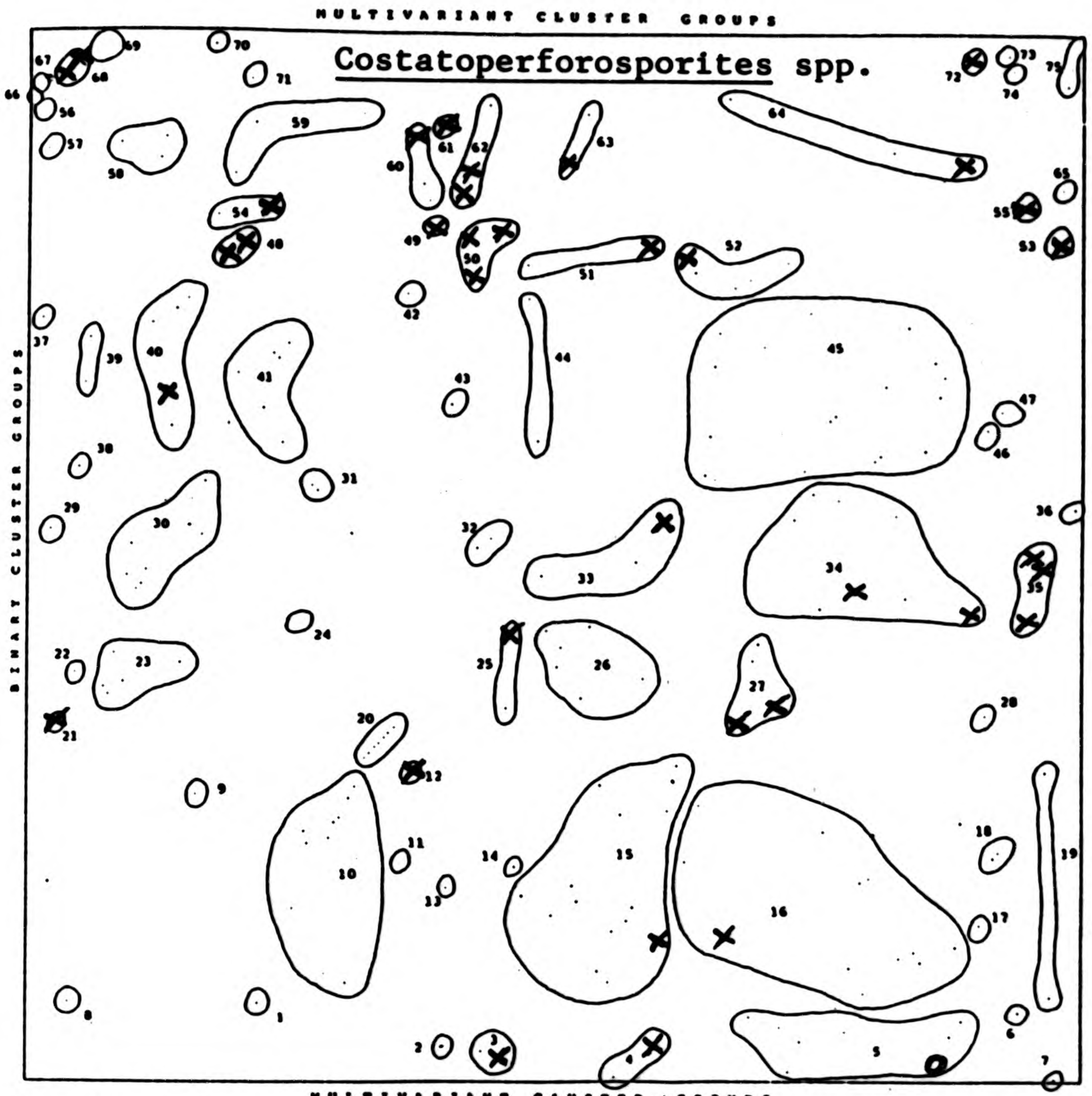
(a) C. fistulosus Deak (1962), Plate 13, figs. 1-10. This species has a proximal ornament of ribs parallel to the equator and distal ribs all running in one direction.

(b) C. foveolatus Deak (1962), Plate 13, fig. 11 & 14. This species is characterised by distal and proximal ribs that run parallel to the equator.

(c) Costatoperforsporites spp. Plate 13, figs. 15-35. A variety of types of Costatoperforosporites were encountered as mostly single specimens not readily assignable to recognised taxa. They range from forms with wide, well spaced muri and small auriculae (fig. 28), to forms with very well developed auriculae (fig. 35) to forms with very finely juxtaposed narrow costae (fig. 22).

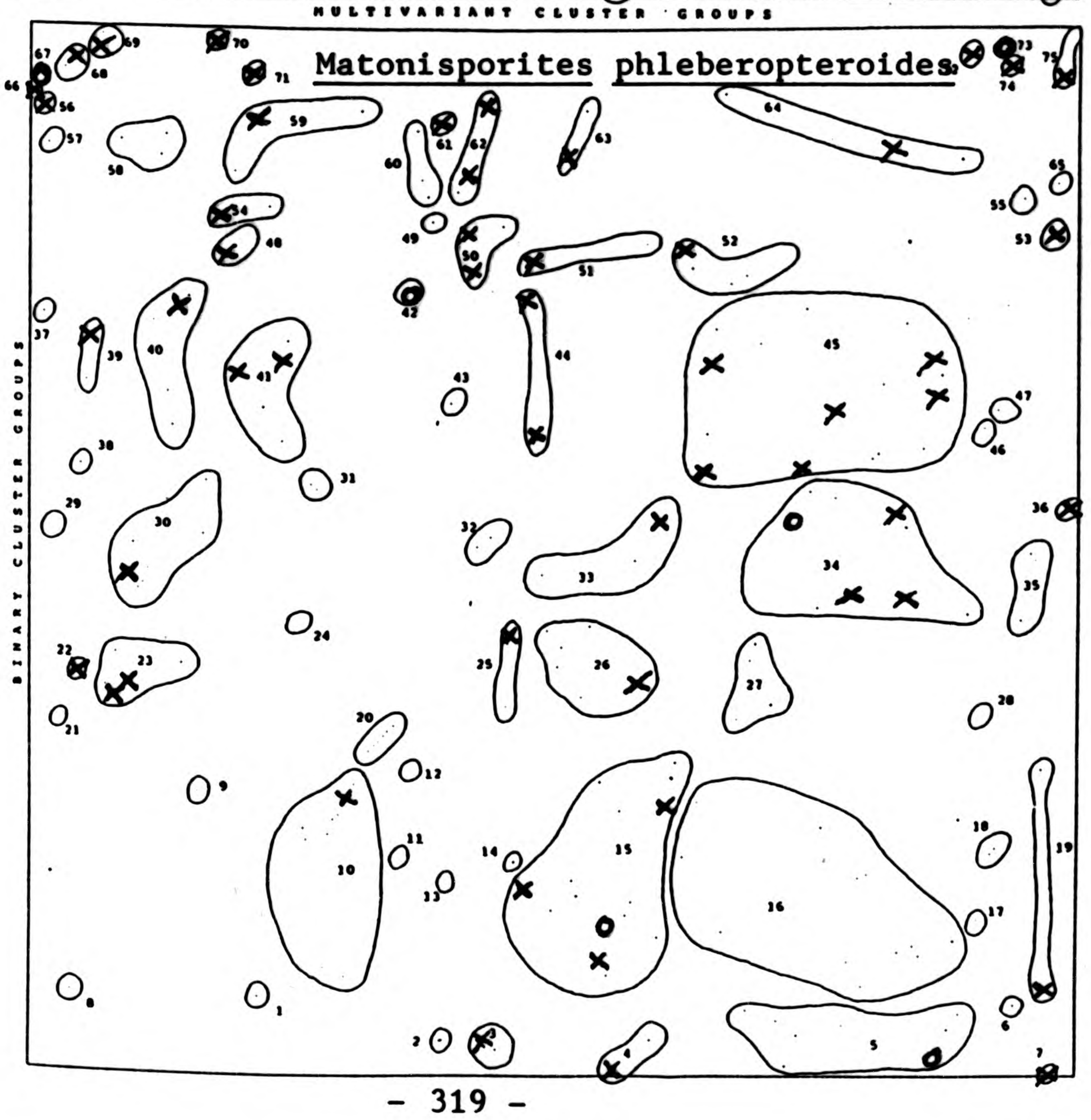
C.spp.:

Palaeoenvironment: Text-fig. 4.49 shows a distinct association of Costatoperforosporites spp. with facies 48 & 54 as well as 49, 50-53, 62 & 35. These are all overbank or channel influenced facies. The wide range of morphotypes that are non-repetitive in occurrence, and resemble several types of Appendicisporites spp., is possible evidence that the holes in the ribs are not phyletic but some may be preservational.



Costatoperforosporites spp.

Text-fig. 4.49



Matonisporites phleberopteroides

Text-fig. 4.50

Subturma ZONOTRILETES
Infraturma AURICULATI

1. Genus **Matonisporites** Couper (1958)

Type Species: M. phleberopteroides

Remarks: This genus was erected for large unsculptured spores with a thick to very thick exine. Only one species was recognised in ~~this~~ study, namely M. phleberopteroides itself. Though no mention was made of the well developed auriculum in the type description, this was emphasised by Potonié (1960) who transferred the genus to the Auriculati, stressing the presence of valvae at the radial regions.

Plate 14, figs. 1 - 19

Palaeoenvironment: Text-fig. 4.50 shows a fairly uniform distribution of M. phleberopteroides within most facies. However there is a distinct concentration of occurrence within the drier uplifted cluster group I - J. These spores are probably negatively associated with brackish/ marine influence. Their occurrence in facies A - H is probably due to local reworking.

2. Genus **Trilobosporites** (Pant, 1954) ex Potonié (1956)

Type species: T. hannonicus Delcourt & Sprumont (1955)

Remarks: This genus is characterised by the possession of both valvae at the radial regions and a verrucate ornament. Several species have been recognised in this study.

(a) T. hannonicus (Delcourt & Sprumont) Plate 15, figs. 1 - 30.
This taxon is characterised by well developed valvae together with an ornament of small verrucae that can fuse to small rugulae over the rest of the exine.

Palaeoenvironment: Almost all occurrences of this taxon were from one sample (Pl.12) that lies within the dry uplifted near hinterland facies. Being so limited in extent it was not treated separately within CLUSTAN.

(b) T. cf. hannonicus Plate 15, figs. 31 - 38. This taxon resembles T. hannonicus in every respect except that this type bears a collar like thickening that is separated from the valvae by a narrow furrow.

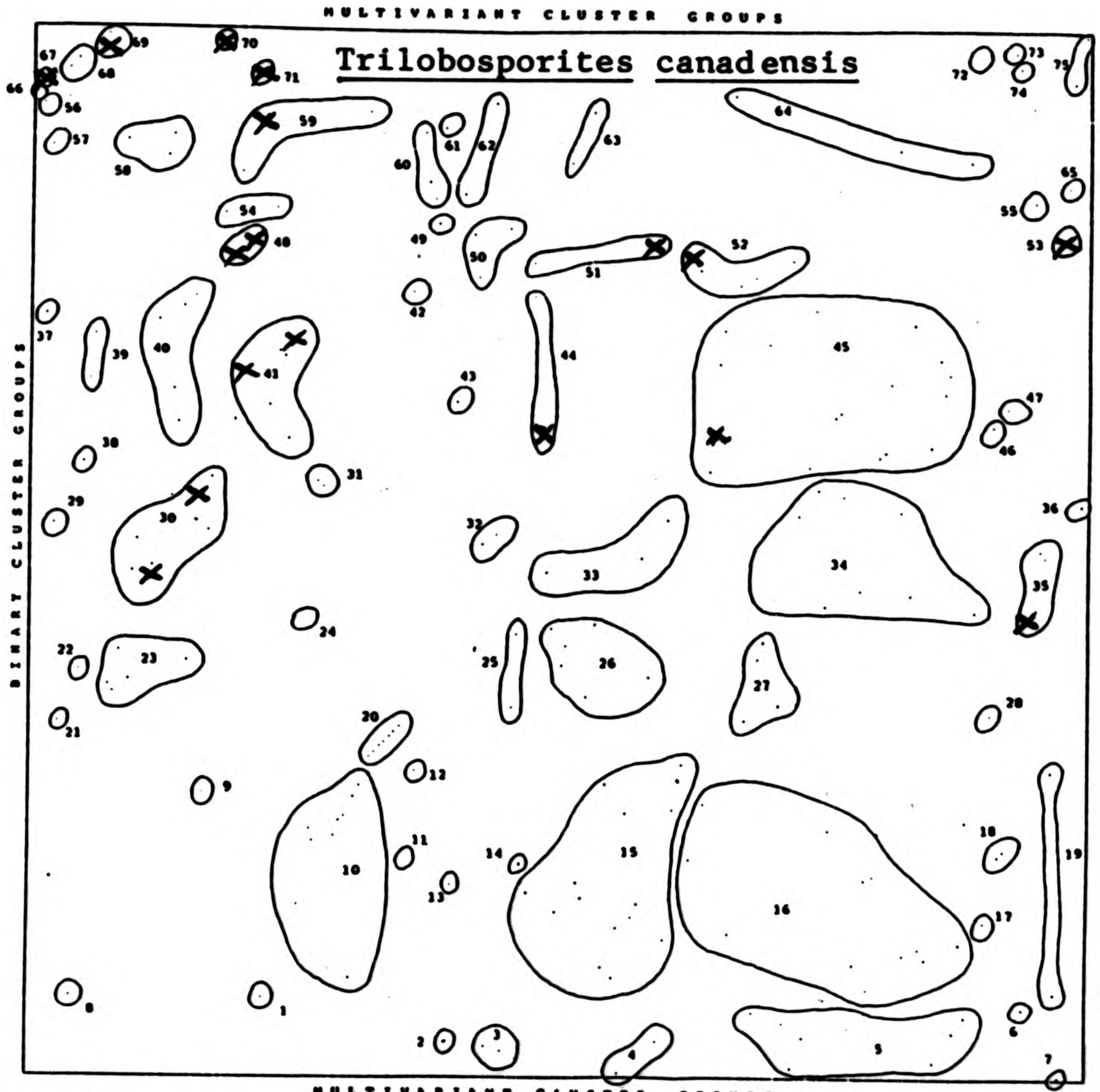
Palaeoenvironment: This taxon is also confined to one sample, Pl.12, within the dry uplifted near hinterland facies.

(c) T. canadensis Pocock(1962) Plate 17, fig. 15. Pocock(1962) considers that this species may be synonymous with T. bernissitartensis. It is characterised by a similar ornament, though the valvae are formed as a cluster of several large verrucae.

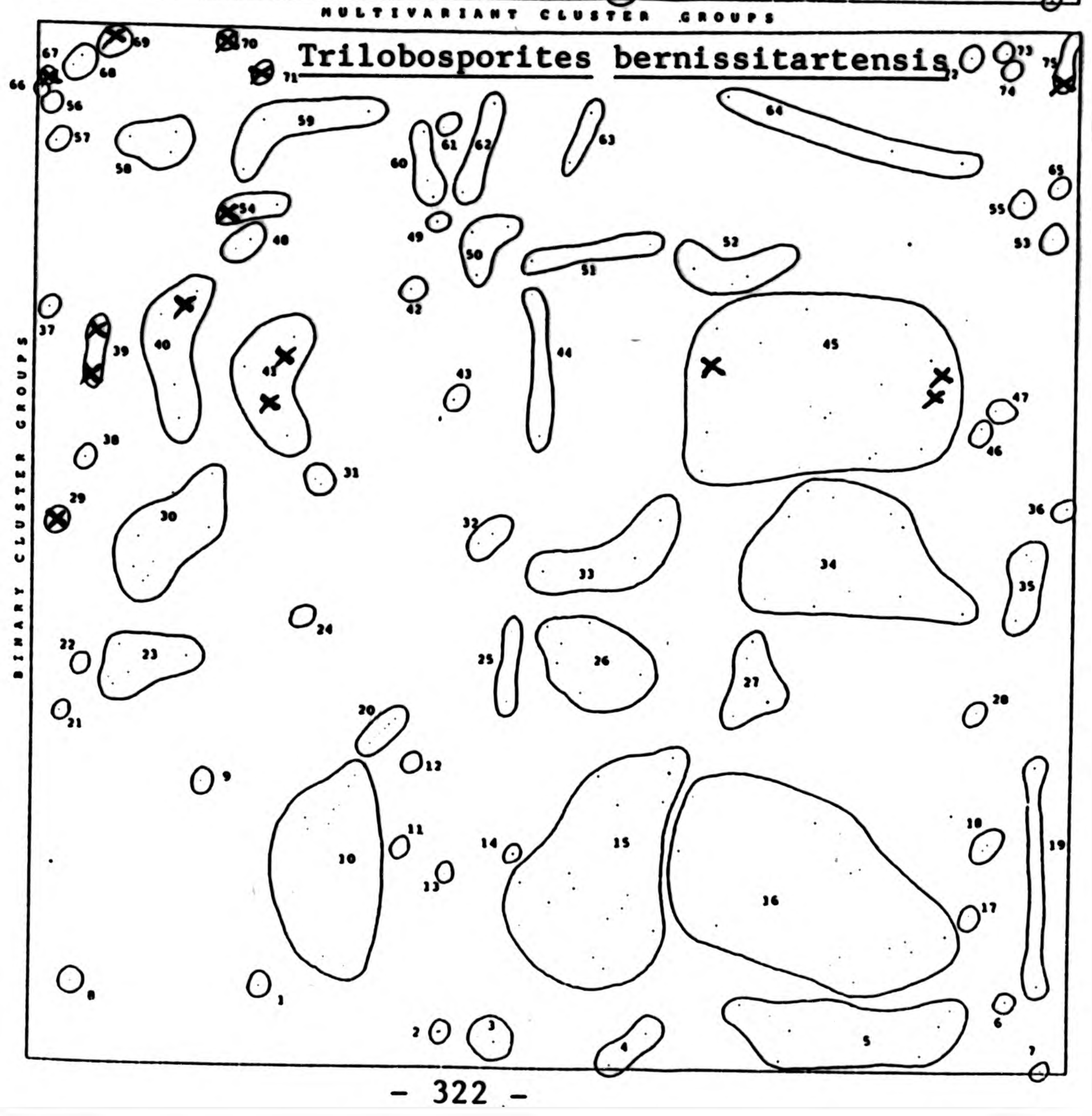
Palaeoenvironment: Text-fig. 4.51 shows that T. canadensis has a very similar distribution to T. bernissitartensis, that may be evidence of conspecificity. It is typical of the dry uplifted near hinterland facies and is very far removed from any brackish/marine influence.

(d) T. bernissitartensis (Delcourt & Sprumont) Potonié((1956). Plate 16, figs. 38 - 45. This taxon shows a generally triangular outline with valva that do not bulge laterally. Labiae are quite well developed along the laesurae and the varrucae, though individually large, are poorly developed, with frequently unclear outline.

Palaeoenvironment: Text-fig. 4.52 shows that this taxon is very much restricted to the dry uplifted facies. There



Text-fig. 4.51



Text-fig. 4.52

are no occurrences 'seaward' of facies 29 (cluster group E) or within marine influenced facies (cluster group X).

(e) T. apiverrucatus (Couper 1958). Plate 17, figs. 16 - 26. This species resembles Concavissimisporites variverrucatus in being distinctly concave trilete with abundant well developed verrucae. However it is included in Trilobosporites as the radial ornament is much better developed than on the inter radial, proximal and distal surfaces. This taxon could be included in Impardecispora as the radial ornament does not form valvae sensu stricto.

Palaeoenvironment: Almost all occurrences of this taxon are within sample Pl.12 within the dry uplifted near hinterland facies (see text-fig.4.53).

(f) T. cf. apiverrucatus Plate 17, figs.7 - 13. These spores all show various degrees of development of prominent verrucae at the valvae. This taxon is similar to Impardecispora apiverrucata Couper(1958).

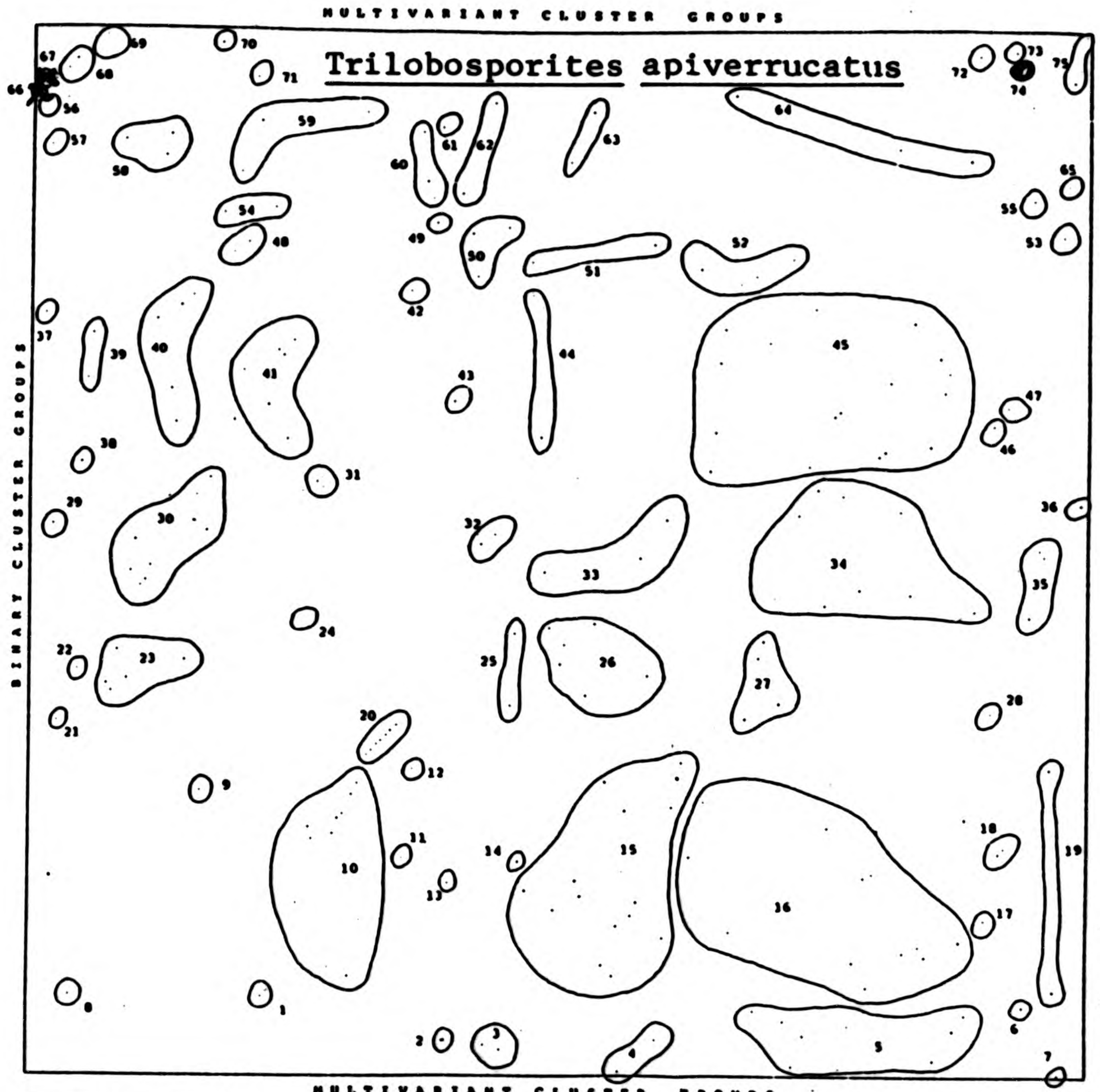
(g) T. trioreticulosus Cookson & Dettmann(1958). Plate 16, figs.13 - 15. This taxon is characterised by wide lumina giving an open reticulate pattern with wide muri, on its valvae. Srivastava(1981) refers to this taxon as Impardecispora trioreticulosa.

(h) T. cf. trioreticulosus Plate 16, figs. 27 - 28. Rare occurrences of this taxon, bearing a reticulate ornament on the valvae, but of smaller size range than T. trioreticulosus were noted

(i) T. sp. I

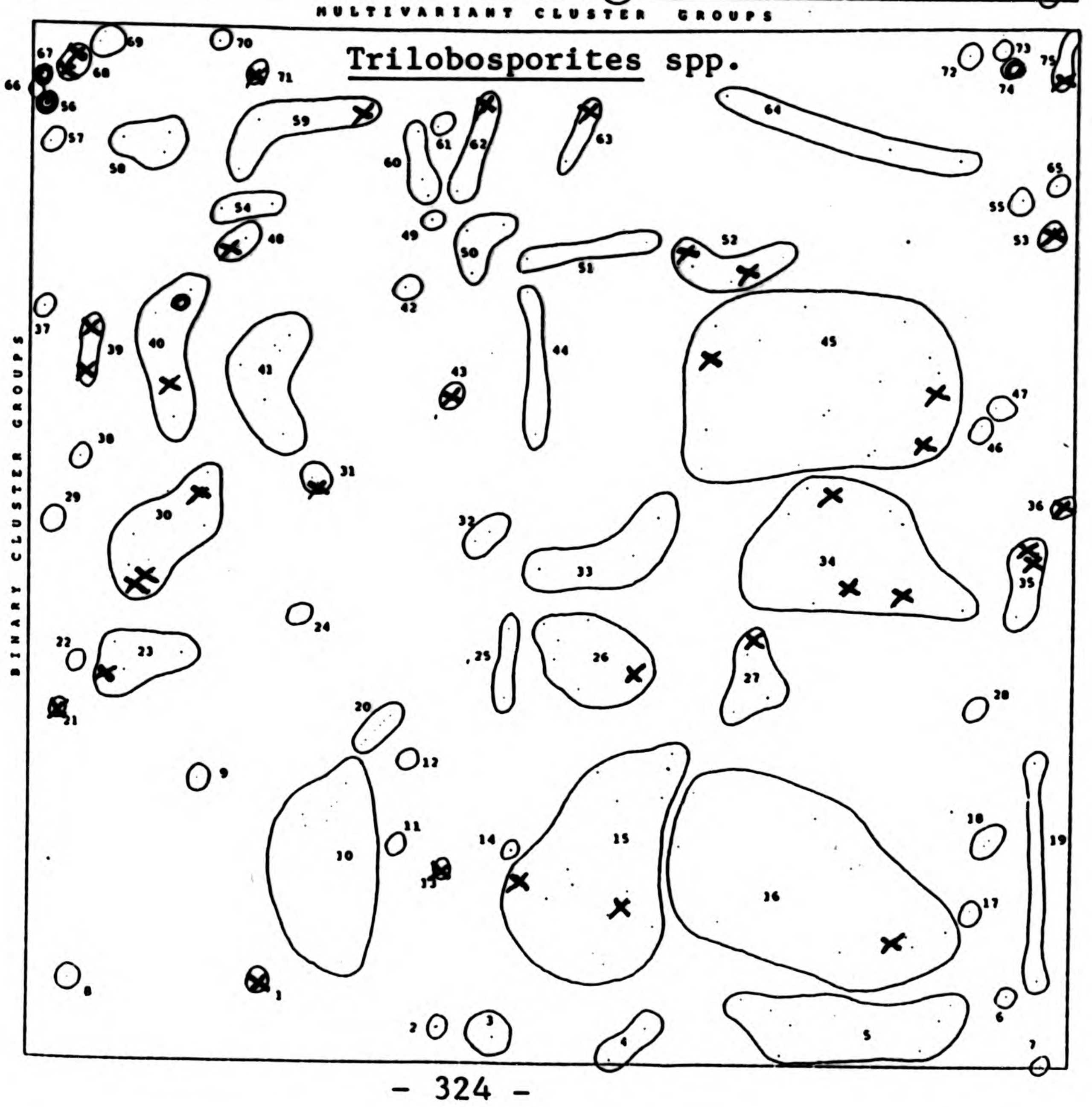
Plate 16, figs.19,20 & 29 - 31.

Description: Thick walled concave trilete spores with markedly square shaped valvae and very thick well developed



Trilobosporites apiverrucatus

Text-fig. 4.53



Trilobosporites spp.

Text-fig. 4.54

labra along the laesurae. An ornament of small separated verrucae is seen on the proximal surface.

Size range: 28 (43.2) 52 u ; 5 specimens measured.

Locality: Sample Pl.12 Redlands Pluckley brick pit, Sussex .

Palaeoenvironment: Sample Pl.12 where this taxon is most common is within the dry uplifted near hinterland braid-plain facies.

(j) T. sp. J

Plate 16, figs.16, 17 & 21 - 25.

Description: Markedly concave thick-walled trilete spores with equator almost parallel to the laesurae. A thickened margo at the ends of the trilete rays is separated from the oval shaped valvae by a narrow furrow.

Size range: 30 (37.1) 40 u ; 7 specimens measured.

Locality: Sample Pl.12 Redlands Pluckley brick pit Sussex.

Palaeoenvironment: Sample Pl.12 is within the most dry uplifted hinterland facies.

(k) T. sp. A Plate 16, figs. 1 - 10. This taxon resembles T. hannonicus but the valvae are much reduced, likewise the size of the verrucae/rugulae that form the distal and proximal ornament.

Palaeoenvironment: Also most common in sample Pl.12 this taxon is associated with dry uplifted near hinterland habitats.

(l) T. sp. B Plate 16, figs. 11 & 12. This rare taxon shows a verrucate sculpture with slightly increased ornament size on the valvae.

(m) T. sp. C Plate 16, fig. 32. Single occurrence of a markedly concave trilete grain with verrucate sculpture.

(n) T. sp. D Plate 16, fig. 26; Plate 17, figs. 5 & 6. This taxon shows verrucae aligned along the laesura as well as a dispersed ornament over the proximal and distal surfaces. The valvae are poorly developed.

(o) T. sp. E Plate 16, fig. 33. Rare specimen with three to four rare verrucae forming the valvae.

(p) T. sp. F Plate 16, fig. 34. Rare spore with poorly developed valvae and verrucate ornament.

(q) T. sp. G Plate 16, figs. 35 - 37. Rare specimen with very large unevenly developed valvae together wih very thick labrae along the laesurae.

(r) T. sp. H Plate 17, figs. 1 & 2. Rare specimens with narnow rounded valvae and few verrucae that are concentrated in the proximal polar region.

(s) T. spp. Many specimens of Trilobosporites were too poorly preserved for assignment to recognised taxa, so were placed in this general group.

Palaeoenvironment: Text-fig. 4.54 shows that Trilobosporites spp. are generally confined to the dry uplifted near hinterland facies of group J, but by local reworking (during which time they probably became degraded, hence their inclusion in here) they can be spread downstream as far as group B palynofacies.

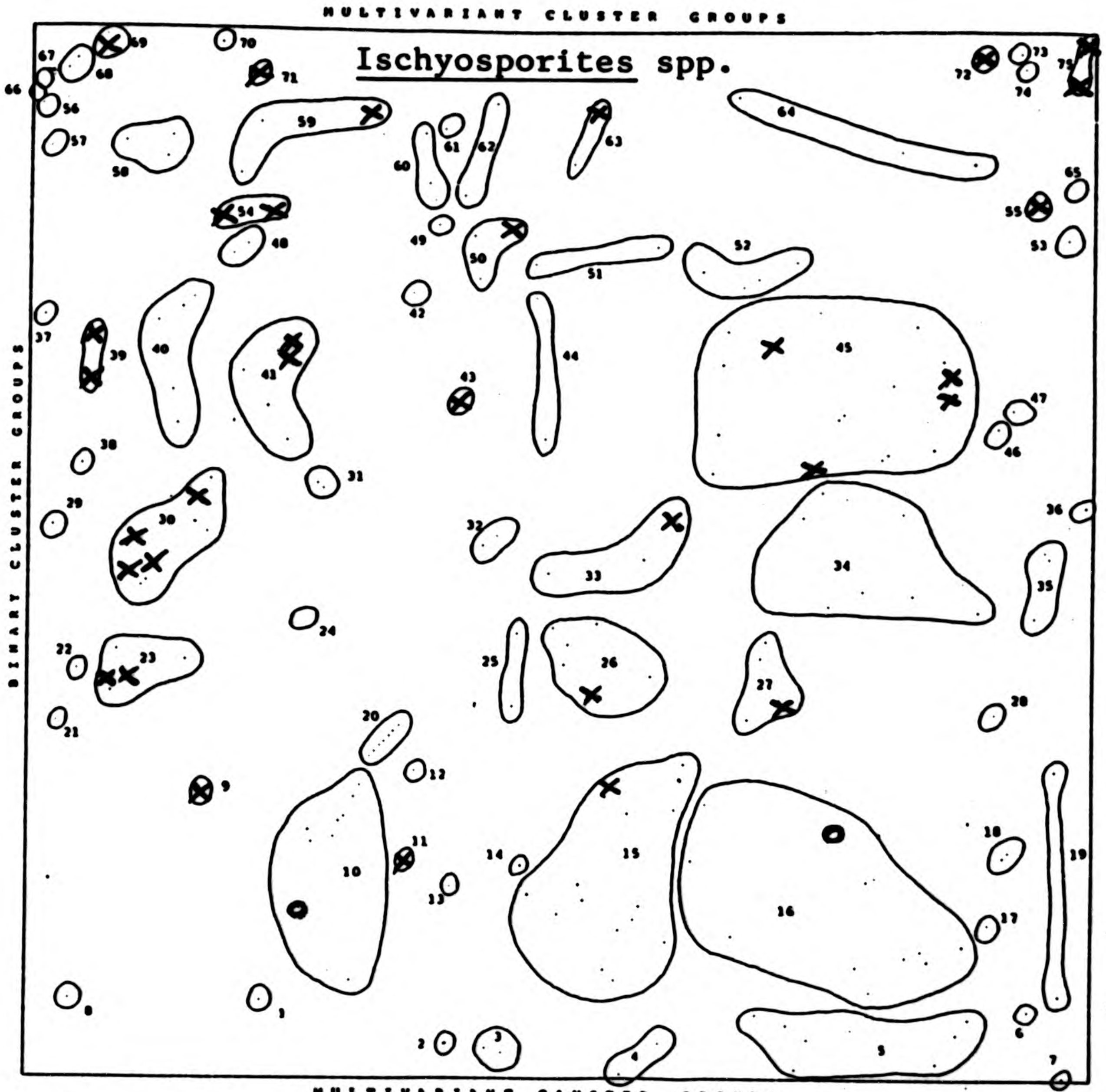
3. Genus Ischyosporites Balme (1957)

Type species: I. crateris

Remarks: These spores are ornamented by heavy ridges that to form an irregular reticulum. The distal side is arched and thickened particularly at the apices, forming valvae that distinguish it from Klukisporites. One species was recognised in this study, I. punctatus Cookson & Dettmann(1958).

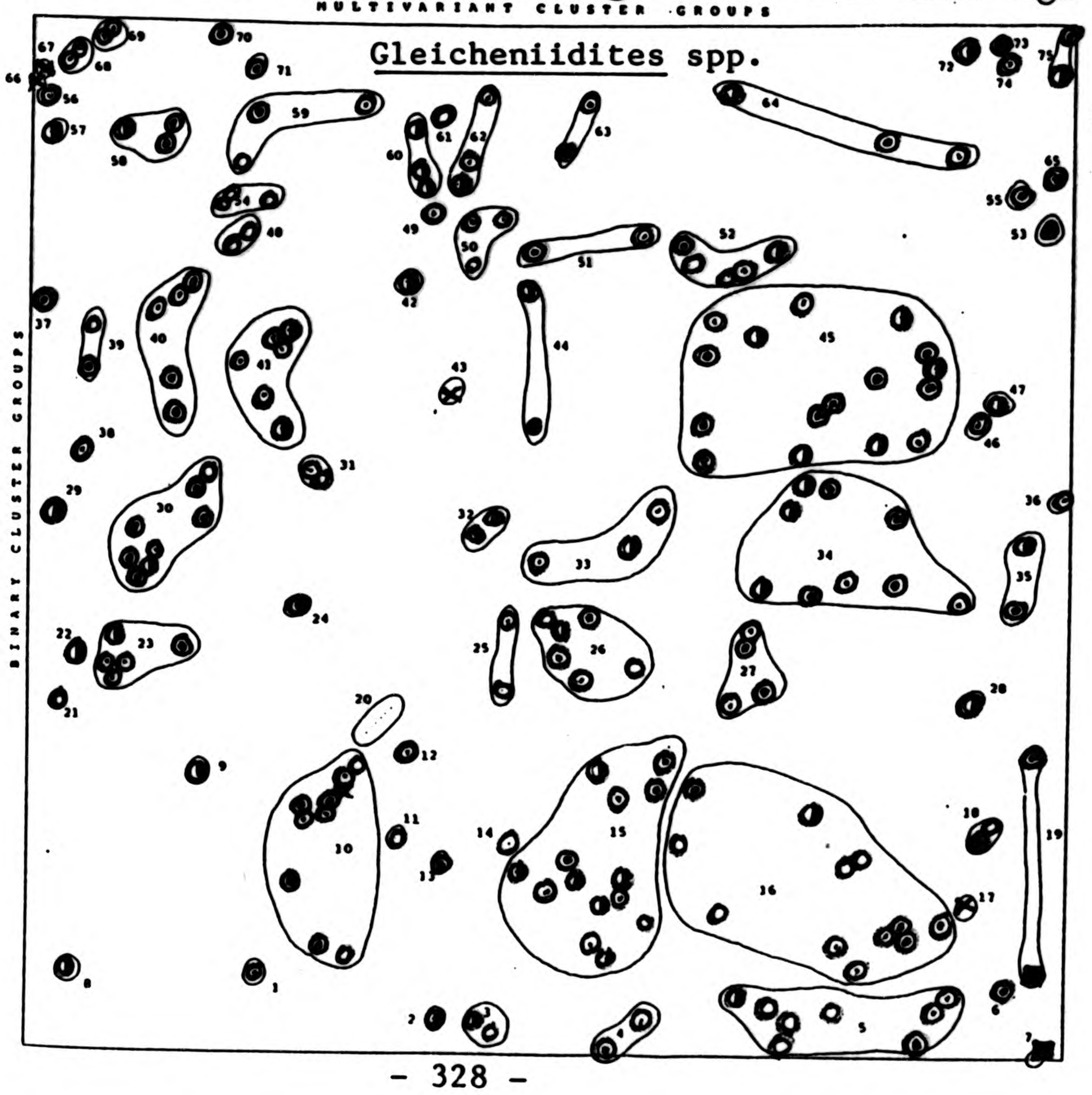
Plate 14, figs. 20 - 38

Palaeoenvironment: Ischyosporites spp. appear from text-fig. 4.55 to be a taxon of the freshwater braidplain, no occurrences are seen in facies 1 - 7 (group A) and only rare ones in group B. They are most common in facies 30 where freshwater aquatic influence is noted, likewise facies 54, 72 & 75. They are rare or absent in the driest uplifted facies of group J. These taxa are therefore more characteristic of the 'intermediate' palaeoenvironments of the damp but freshwater braidplain, neither too dry and uplifted nor brackish influenced.



Ischyosporites spp.

Text-fig. 4.55



Gleicheniidites spp.

Text-fig. 4.56

Infraturma TRICRASSITI

1. Genus Gleicheniidites Ross (1949) ex Delcourt & Sprumont (1955) emend. Dettmann (1963)

Type species: G. senonicus

Remarks: This genus consists of smooth trilete spores with crassitudes in each equatorial region. Three species were recognised in this study.

(a) G. senonicus (Ross, 1949) Plate 20, figs. 1 - 32, 36 - 37 & 48. Proximo-distal flattening causes three distinct folds on the distal surface to develop in some specimens. Others have much more thickly developed crassitudes that do not extend as far as the apices, leaving a slight depression in the ambital outline either side of each apex.

(b) G. circinidites (Cookson) Dettmann, 1963 Plate 20, figs. 38 - 41, 42 - 44 & 47. This species is reserved for forms with crassitudes that extend around the apices, and show quite well developed laesurate margins.

Palaeoenvironment: For the purposes of CLUSTAN analysis the genus was treated as a single group (text-fig. 4.56). This diagram illustrates how widespread and numerically dominant this genus is within the Weald Clay. However it is reduced in number in facies 3, 4, 5, 16 & 43. These are all marine influenced facies. Occurrences here are probably due to local reworking. Thus Gleicheniidites plants were probably strictly freshwater. Facies with cluster group XIII show Gleicheniidites in very great abundance. Many of these facies are associated with channels, which could indicate that large numbers of these spores are being transported from the hinterland where it may form an important fern undergrowth. It may thrive in the poorer soils here where it cannot compete so well in the richer soils of the braidplain.

2. Genus **Coronatispora** Dettmann(1963)

Type species: C. perforata

Remarks: This genus includes foveolate to reticulate spores with an inter radial thickening and a circumpolar ridge on the distal side that surrounds a polar thickening. Only one species, C. valdensis, (Couper) Dettmann(1963) was recognised in this study.

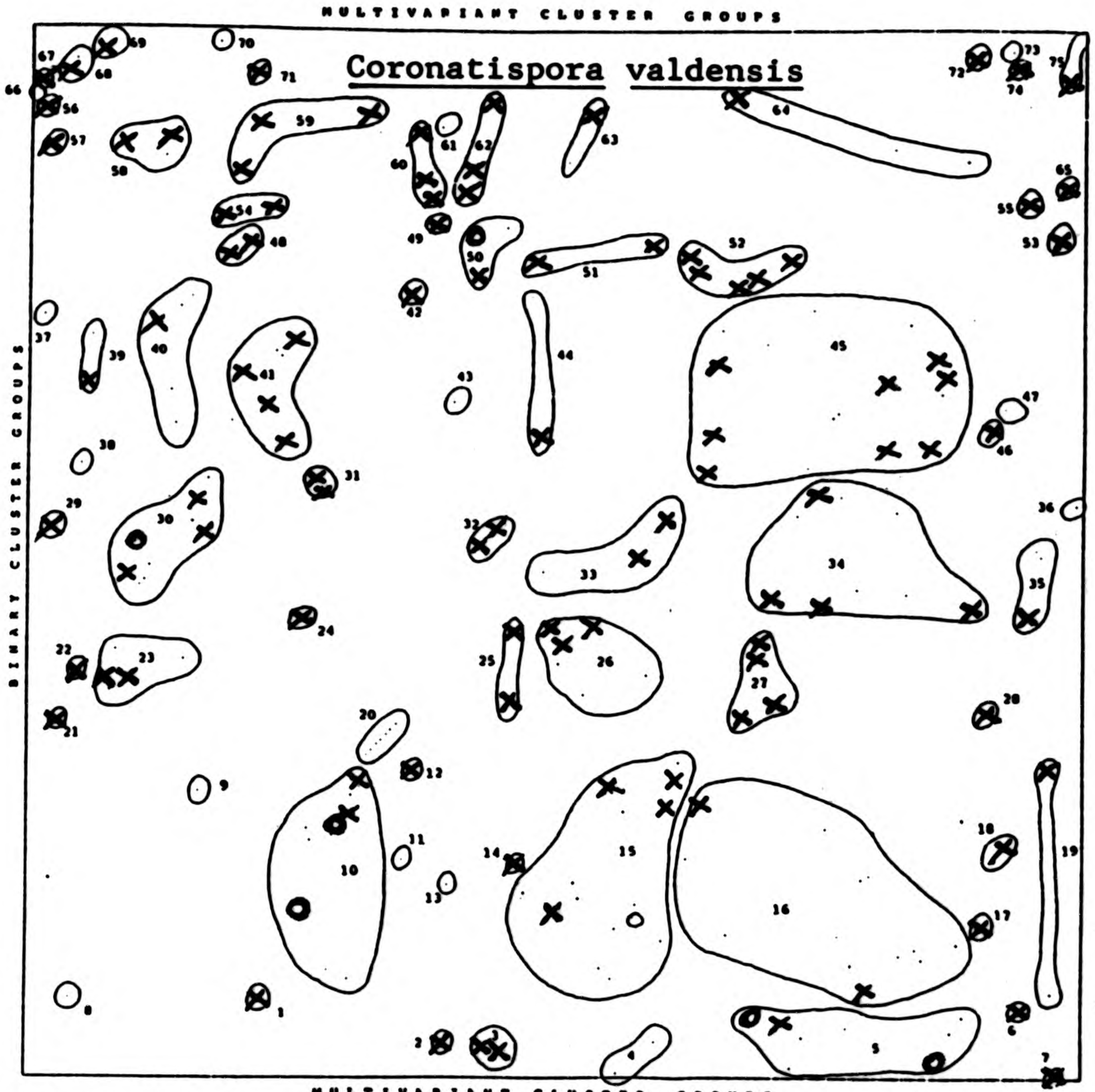
Plate 20, figs. 61 - 76

Palaeoenvironment: Text-fig. 4.57 shows C. valdensis to have a very even distribution throughout all of the palynofacies. Its distribution is generally greater in groups D - J, while it is absent from most group B samples. Occurrences in Group A are probably reworked. The parent plant of this spore is probably a low spore producer that inhabits most freshwater Weald Clay braidplain palaeoenvironments.

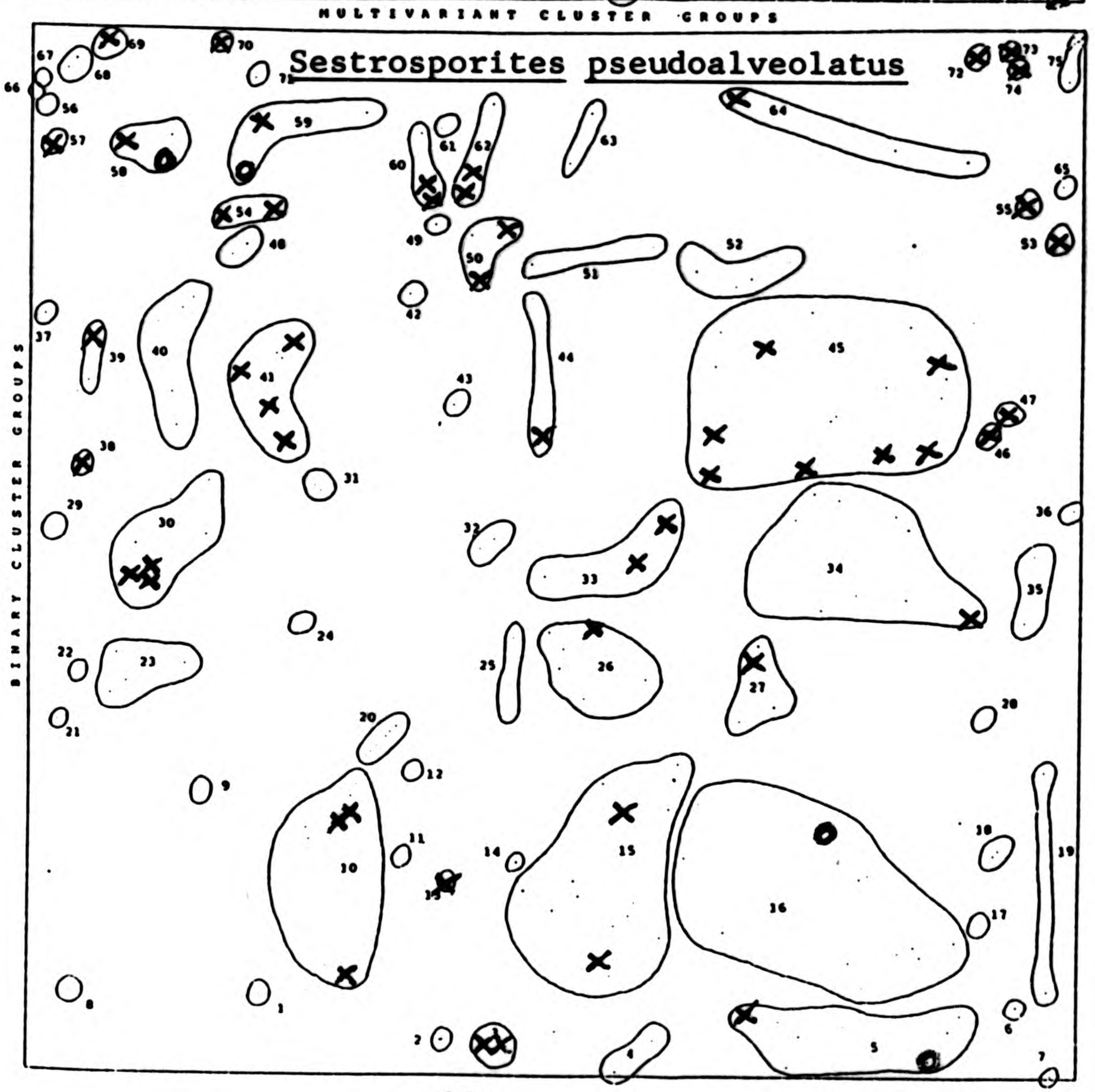
3. Genus **Sestrosporites** Dettmann(1963)

Type species: S. irregulatus (Couper) Dettmann(1963)

Remarks: This genus accommodates spores with inter radial crassitudes and foveolate to foveo-reticulate sculpture.



Text-fig. 4.57



Text-fig. 4.58

One species S. pseudoalveolatus has been recognised in this study, that conforms with the diagnosis of Dettmann 1963.

Plate 20, figs. 49 - 58 & 60

Palaeoenvironment: Text-fig. 4.58 shows that S. pseudoalveolatus is less common than C. valdensis but shows a similar distribution in most freshwater braidplain palaeoenvironments. Occurrences in groups A & B (brackish/marine influenced) are rarer and probably reworked.

4. Genus Clavifera Boklhovitina (1966)

Type species: C. triplex

This genus was separated from other gleicheniaceous spores in possessing bulbous projections at the equatorial radii. Only one species, C. triplex, was recovered in this study.

Plate 20, figs. 33-35 & 45-46

Palaeoenvironment: This spore was only rarely recovered in the present study, and included in Gleicheniidites spp. for the purposes of CLUSTAN.

Infraturma CINGULATI

1. Genus Cingulitriletes Pierce(1961)emend. Dettman(1963)

Type species: C. congruens

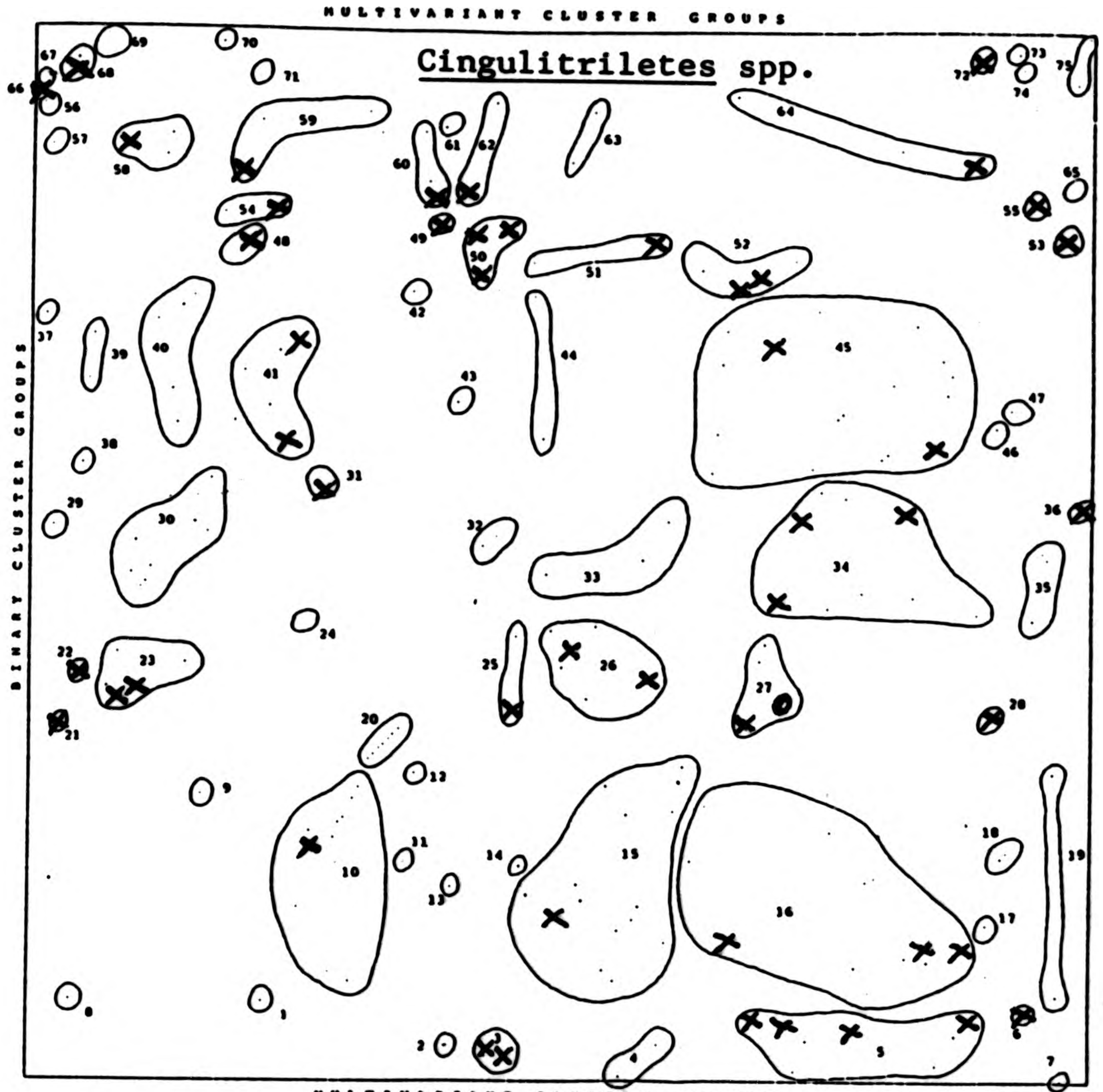
Remarks: This genus accommodates convex trilete cingulate spores. Three species have been recognised in the present study.

(a) C. clavus (Balme) Dettmann(1963) Plate 21, figs. 1 - 15. The radially striate cingulum of C. clavus bears some similarity to Cingulatisporites distaverrucosus Brenner (1963) that has a partially verrucate cingulum.

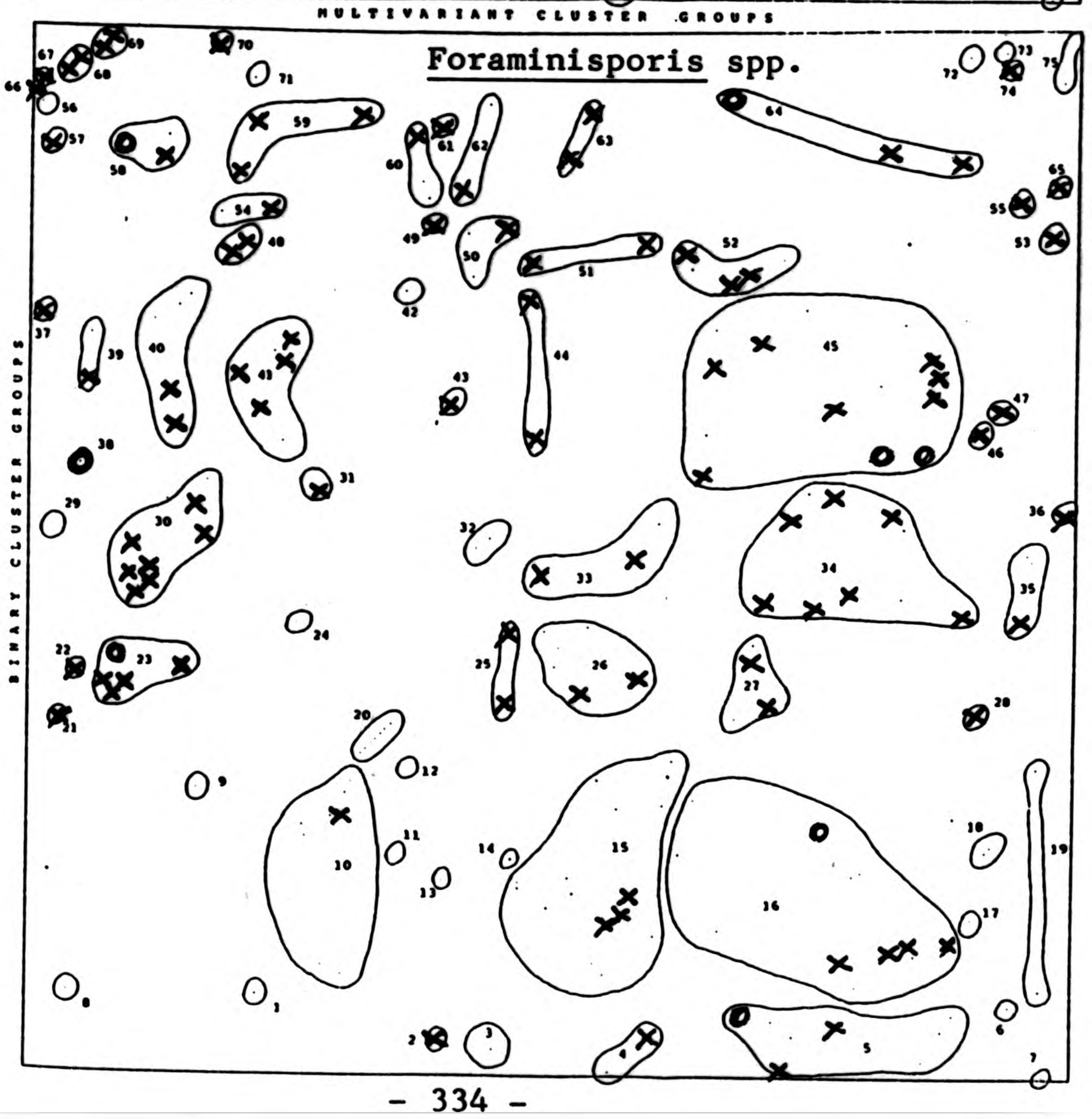
(b) C. sp. A Plate 21, figs. 16 - 29. This taxon shows a well defined verrucate to foveolate sculpture that bears some resemblance to Foveosporites sp. cf. F. canalis Balme. However, it differs in having a well defined cingulum and unornamented proximal contact areas.

(c) C. sp. B Plate 21, figs. 30 - 41. This morphotype shows a well defined cingulum together with large projecting baculae, that could be a degradation feature.

Palaeoenvironment: Cingulitriletes spp. are generally rare and show no easily definable preference amonst the defined palynofacies except for a possible grouping within facies 49, 50, 60 & 61. These are marine influenced, likewise several occurrences are noted in group A. It may tolerate brackish influence therefore. However given the three separate species dealt with it is likely that different plants of varied ecological requirements are included here (see text-fig. 4.59).



Text-fig. 4.59



Text-fig. 4.60

2. Genus Foraminisporis Krutzsch(1959)

Type species: F. foraminis

Remarks: These spores possess a narrow sculptured cingulum that allows their inclusion within the Cingulati. Specimens in this study have been assigned to F. assymetricus (Cookson & Dettmann) Dettmann(1963). However some species have a reduced cingulum and approach F. wonthagiensis (Cookson & Dettmann) Dettman (1963) in appearance. Dettman (1963) mentions the close association of F. wonthagiensis with Osmundacidites that is characterised by a very reduced cingulum (if at all present) and small isolated spinulae, see Plate 21, fig. 68 of this study. However F. assymetricus is generally characterised by low closely packed polygonal shaped verrucae that are never fused but always distinctly isolated.

Palaeoenvironment: These spores are distinctly freshwater amongst the Weald Clay palynofacies of the present study. They are present in most samples within cluster groups D - J but are distinctly low in number in brackish/marine influenced groups A & B (see text-fig. 4.60).

3. Genus Polycingulatisporites (Simoncsics & Kedves, 1961
Playford & Dettmann, 1965)

Type species: P. circulus

Remarks: This genus incorporates spores with a circumpolar ridge that concentrically encircles a polar thickening. Only one species was recognised in this study, P. segmentatus (Stover, 1962 - originally Taurocusporites segmentatus). It is distinguished by the possession of small closely packed verrucae on the proximal surface.

Plate 22, figs.24 - 32

Palaeoenvironment: This taxon was only rarely occurring, and generally restricted to cluster group J (facies 67, 68 and 74). These are all facies that represent dry uplifted near hinterland palaeoenvironments. Occurrences in facies 48, 54 & 50 are probably rare indigenous occurrences while others in facies 15, 26 & 45 are probably reworked (see fig.4.61).

4. Genus Antulsporites (Archangelsky & Gamerro 1966)

Type species: A. baculatus

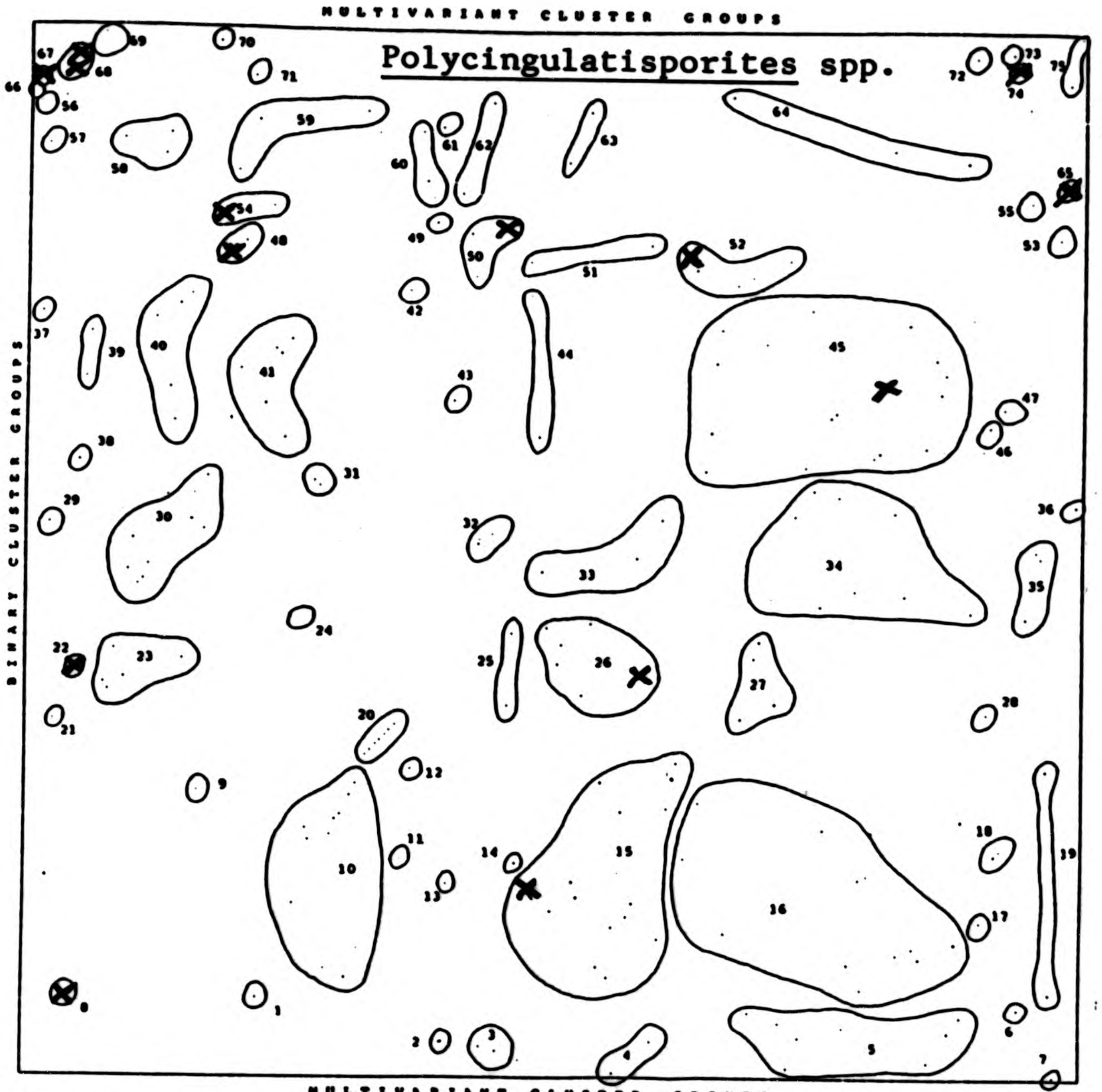
Remarks: This genus accommodates cingulate spores with a cingulum that is slightly segmented, together with a strong distal ornament of verrucae spines or baculae. Several form genera were recognised in this study that could not easily be assigned to recognised species. Some of these (particularly A. sp. A) may fall within Polycingulatisporites as the distal ornament does form a weakly defined circumpolar ridge.

(a) A. sp. A plate 22, figs.1 - 12. This taxon is characterised by well defined distal rugulae or verrucae.

(b) A. sp. B Plate 22, figs.13 - 18. This taxon shows the development of abundant closely packed small distal verrucae.

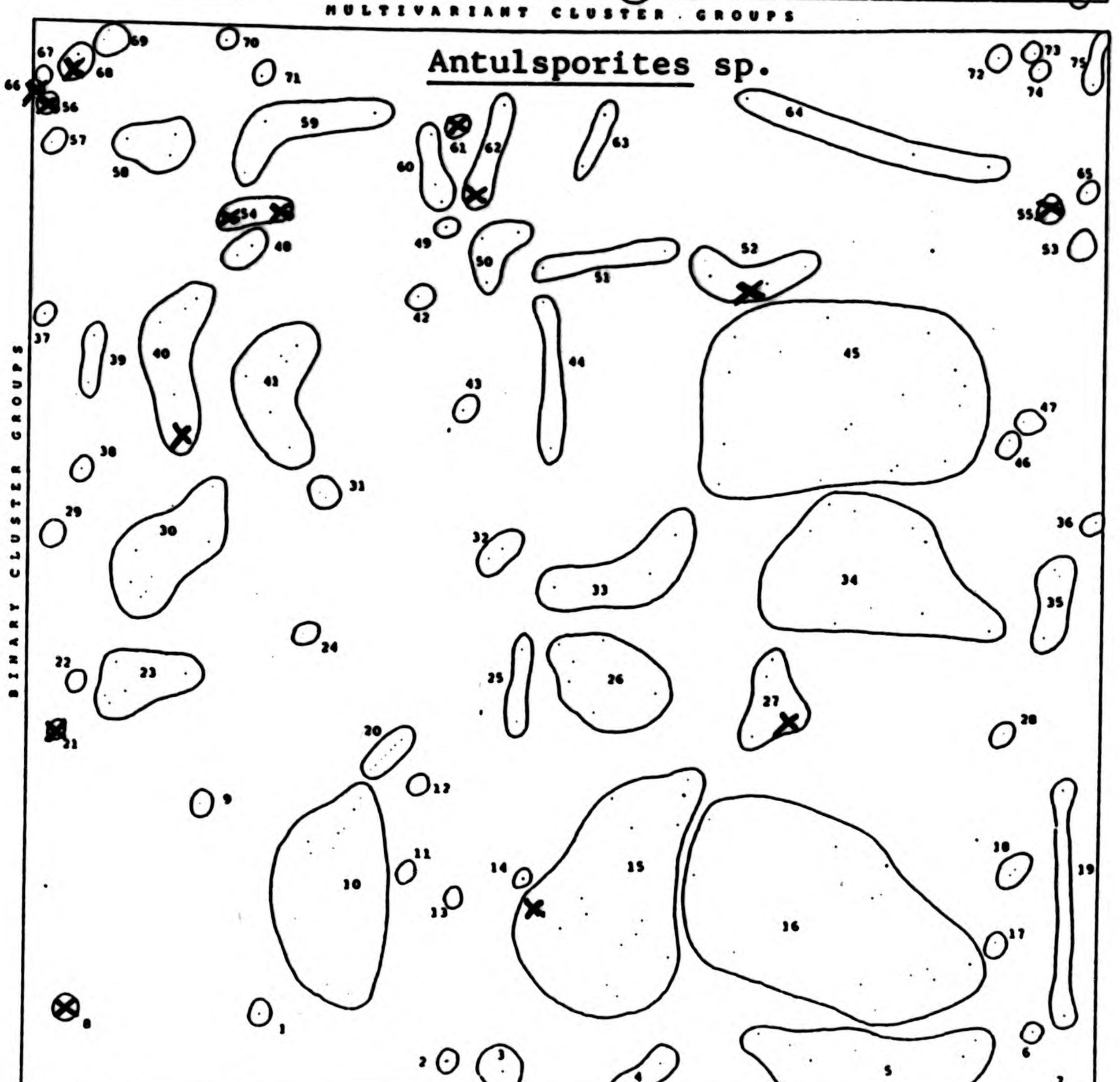
(c) A. sp. C Plate 22, figs.19 - 20. This taxon is distinguished by its small size range and closely packed small distal verrucae.

(d) A. sp. D Plate 22, figs.21 - 22. This taxon is of small size range with a comparatively thick cingulum especially



Polycingulatisporites spp.

Text-fig. 4.61



Antulsporites sp.

Text-fig. 4.62

in the inter radial area.

Palaeoenvironment: These spores show a closely similar facies association to Polycingulatisporites, in being generally restricted to the dry uplifted near hinterland facies. This association with Polycingulatisporites may indicate a phyletic association between these morphologically similar taxa (see fig. 4.62).

5\. Genus **Distaltriangulispora** (Singh,1964, 1971)

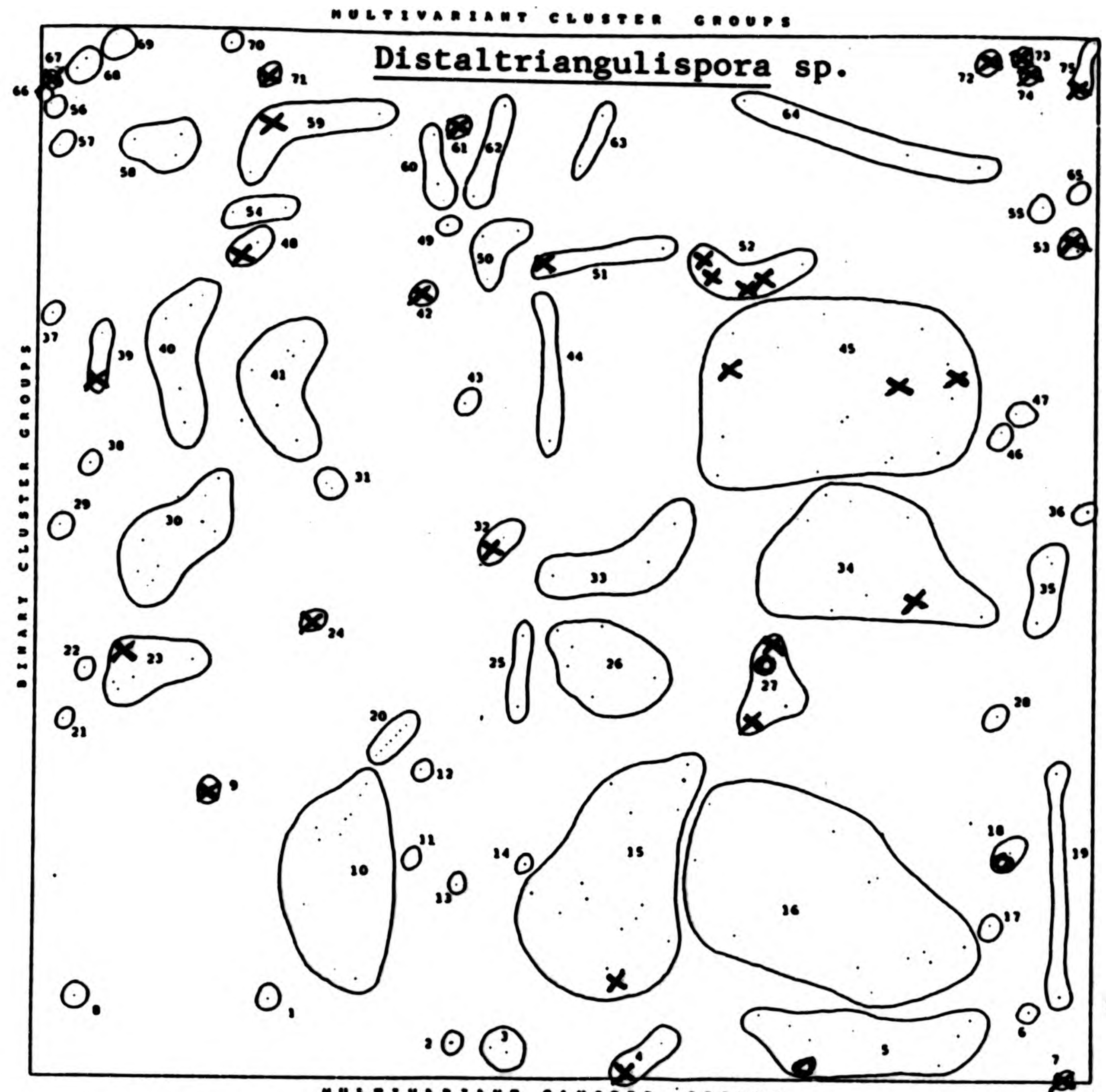
Type species: D. perplexus

Remarks: This genus accommodates spores with a thickened triangular shield on the distal surface and a verrucate to rugulate sculpture and generally thickened apices. Two taxa within this genus have been recognised within the present study.

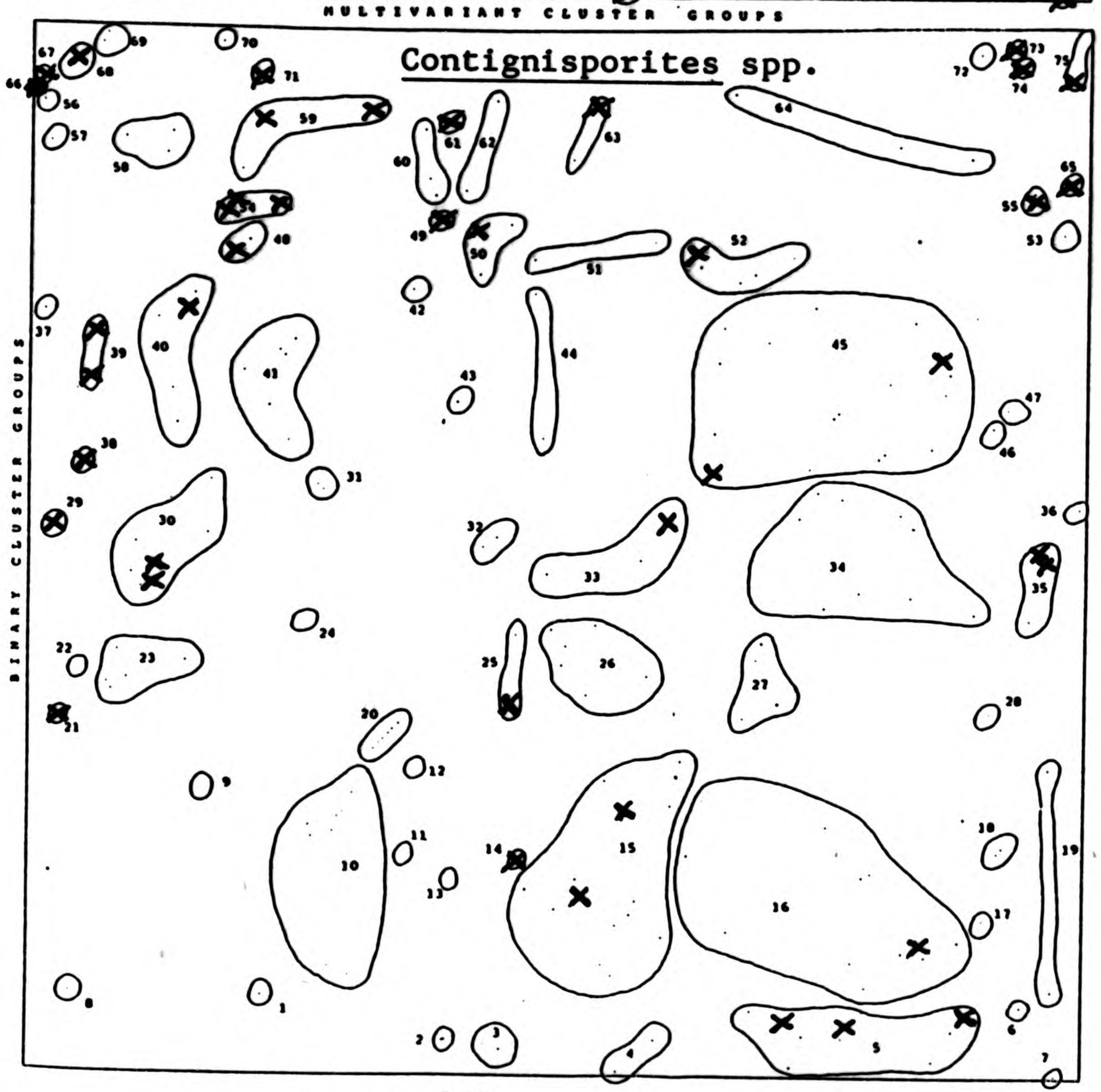
(a) D. perplexus (Singh,1964) Plate 22, figs.42, 43, & 45. This species was only rarely encountered, but conforms to the description of Singh(1964 p.55).

(b) D. sp. A Plate 22, figs 33 - 41. This species bears a resemblance to D. irregulari (Singh,1971),but differs in showing well developed verrucae and a cingulum that is much wider in the inter radial area.

Palaeoenvironment: Text-fig.4.63 shows this taxon to be present in facies 72 - 75 that represent uplifted near hinterland environments. It is quite rare in the dry uplifted facies 66 - 69, unlike Polycingulatisporites sp. Further evidence that it may favour damper soil is seen by its general cosmopolitan appearance in most Weald Clay facies. It is quite rare and probably reworked into brackish/marine influenced group A & B facies.



Text-fig. 4.63



Text-fig. 4.64

6. Genus Contignisporites Dettmann(1963)

Type species: C. glebulentus

Remarks: This genus accommodates spores with parallel distal muri that coalesce with the cingulum. Four species within Contignisporites were recognised in the present study.

(a) C. cooksonii (Balme) Dettmann (1963) Plate 22, figs. 46 - 55. This taxon is distinguished from others in the genus by its possession of a proximal sculpture in the form of a circumpolar ridge.

(b) C. cf fornicatus (Dettmann 1963) Plate 22, figs. 58 - 64. This taxon shows distal muri and cingulum that are closely similar to C. fornicatus though unlike this species, no proximal sculpture can be observed here.

(c) C. sp. A Plate 22, fig. 56. This taxon is distinguished by its triangular outline.

(d) ? C. sp. B Plate 22, fig. 57. This taxon shows a very thick cingulum and unevenly spread, very thick distal muri.

Palaeoenvironment: Text-fig. 4.64 shows Contignisporites spp to be generally associated with drier uplifted facies within groups I & J. It is generally rare in most other 'intermediate' and brackish/marine influenced facies.

7. Genus Densoisporites Weyland & Krieger (1953) emend. Dettmann (1963)

Type species: D. velatus

Remarks: Spores with a loose structured sculpture layer are included in this genus. The sculpture is proximally attached and equatorially thickened. Rare records of taxa that resemble D. velatus were recorded in this study as

D. cf. velatus.

Plate 28, figs. 6 - 13

Palaeoenvironment: This taxon, though rare, is distinctly freshwater with all records within cluster groups E - J (see text-fig. 4.65).

8. Genus **Krauselisporites** Leschik(1955), emend. Jansonius(1962)

Type species: K. dentatus

Remarks: Originally described as alete, these are trilete zone spores with a distal spinose ornament. One species K. linearis (Cookson & Dettmann) Dettmann(1963) was recognised in this study.

Plate 22, figs. 65 - 75

Palaeoenvironment: Text-fig. 4.66 shows these spores to be quite rarely occurring but generally grouped around facies 49, 50, 60 & 62. These facies may be tidally influenced associated with channels near the hinterland. Its occurrence in facies 28 & 6 may also be tidal channel influenced.

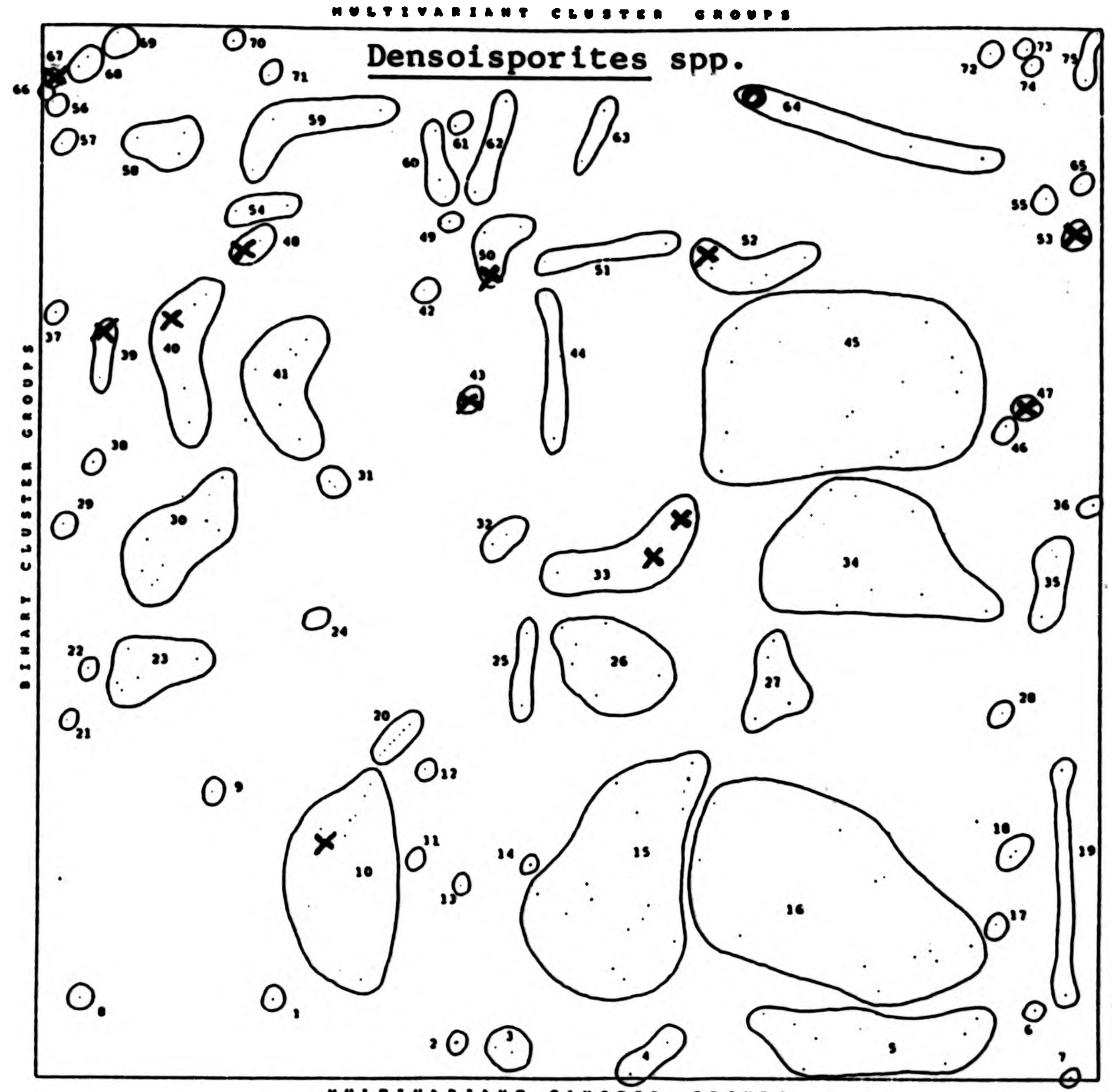
9. Genus **Rogalskaisporites** Danzé-Corzin & Laveine (1963)

Type species: Not designated

Remarks: A single specimen was recovered, assignable to R. cicatricosus (Rogalska) Danzé-Corzin & Laveine (1963). This species is distinguished by radially disposed ridges and canals with a polar thickening.

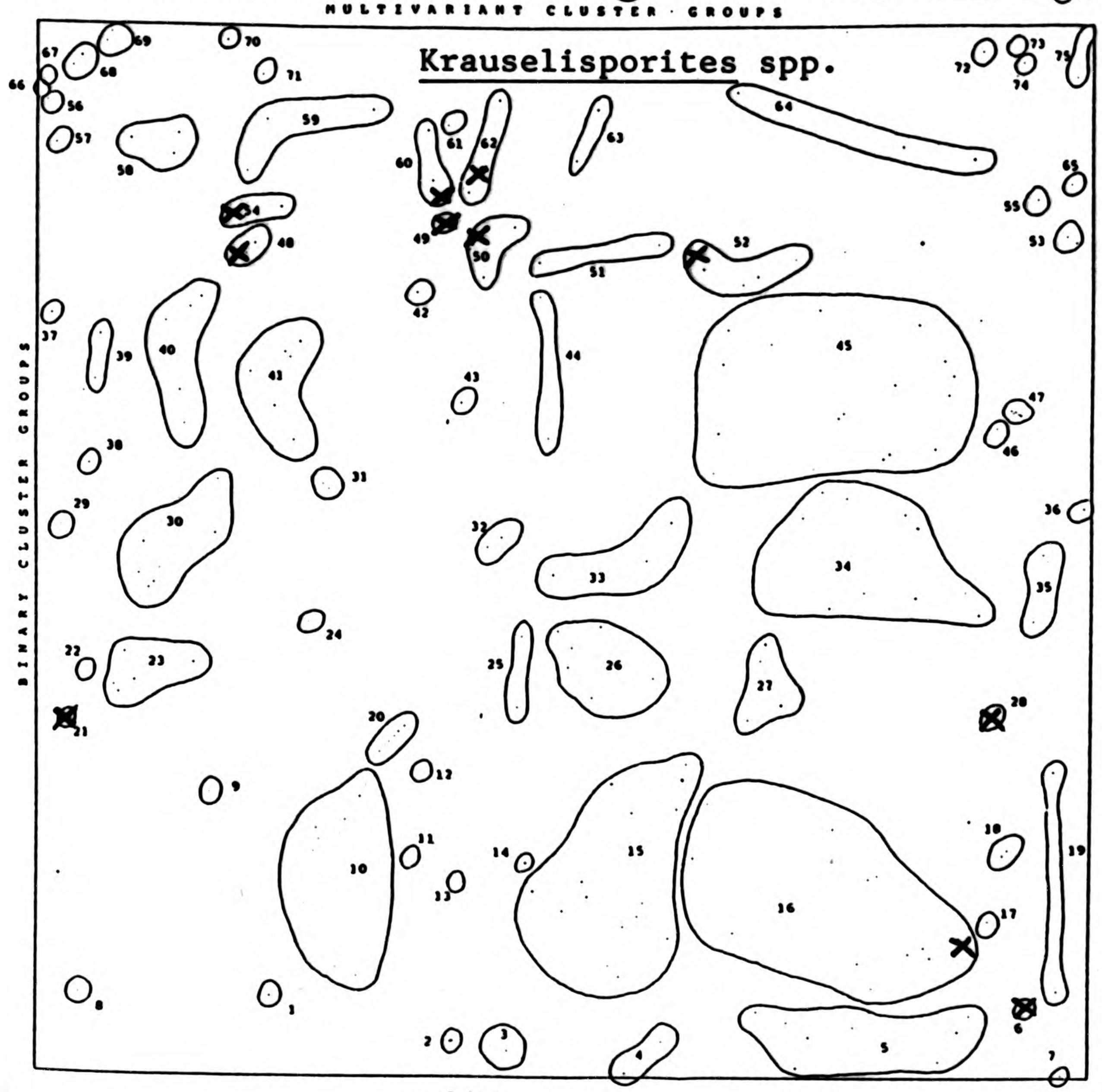
Plate 20, fig. 59.

Palaeoenvironment: Palaeoenvironmental conclusions cannot be drawn based on a single occurrence.



Densoisporites spp.

Text-fig. 4.65



Krauselisporites spp.

Text-fig. 4.66

Turma HILATES

1. Genus Aequitriradites Delcourt & Sprumont emend. Cookson & Dettmann(1961)

Type species: A. dubius

Remarks: This genus incorporates proximally inaperturate spores with a membraneous zona. A hilum opening is developed on the distal surface. Three species have been recognised in the present study.

(a) A. spinulosus (Cookson & Dettmann,1961) Plate 23, fig. 2. This species as described is broadly defined, incorporating three separate varieties. The distal pole is composed of small discrete spines.

(b) A. verrucosus (Cookson & Dettmann,1961) Plate 23, figs. 1, 3 - 34 & 36 - 38. This taxon has low hexagonal based verrucae that compose the distal polar area.

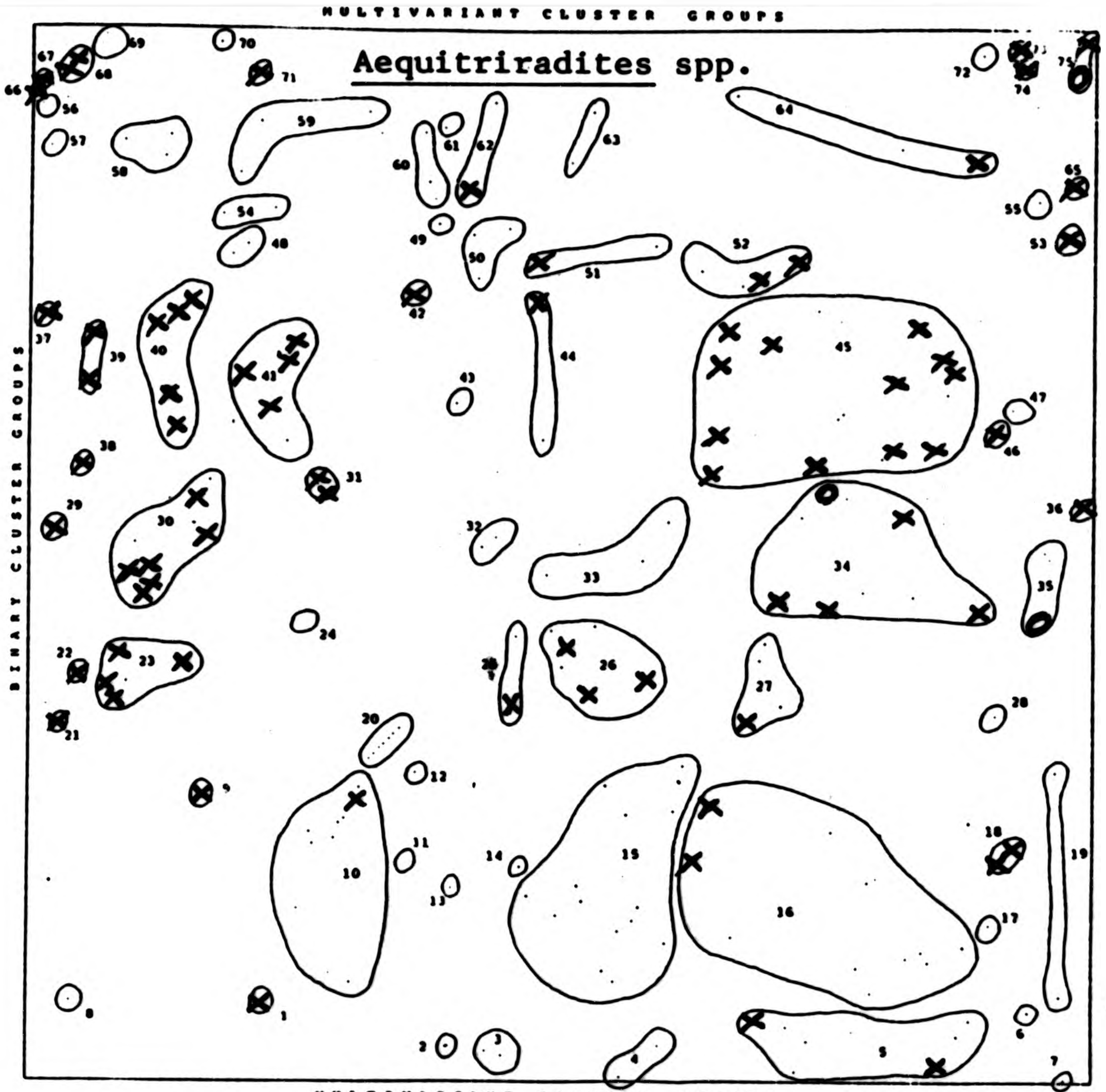
(c) A. sp. A Plate 23, fig. 35. This taxon is distinguished by its foveolate sculpture.

Palaeoenvironment: For CLUSTAN analysis the generic group as a whole was treated as one - see Text-fig. 4.67. This taxon was moderately common as a minor element in most Weald Clay samples. It shows a strong grouping within the 'intermediate' facies of groups D & E. These represent generally waterlogged freshwater palaeoenvironments. Aequitriradites spp. are quite negatively associated with any brackish/marine influence.

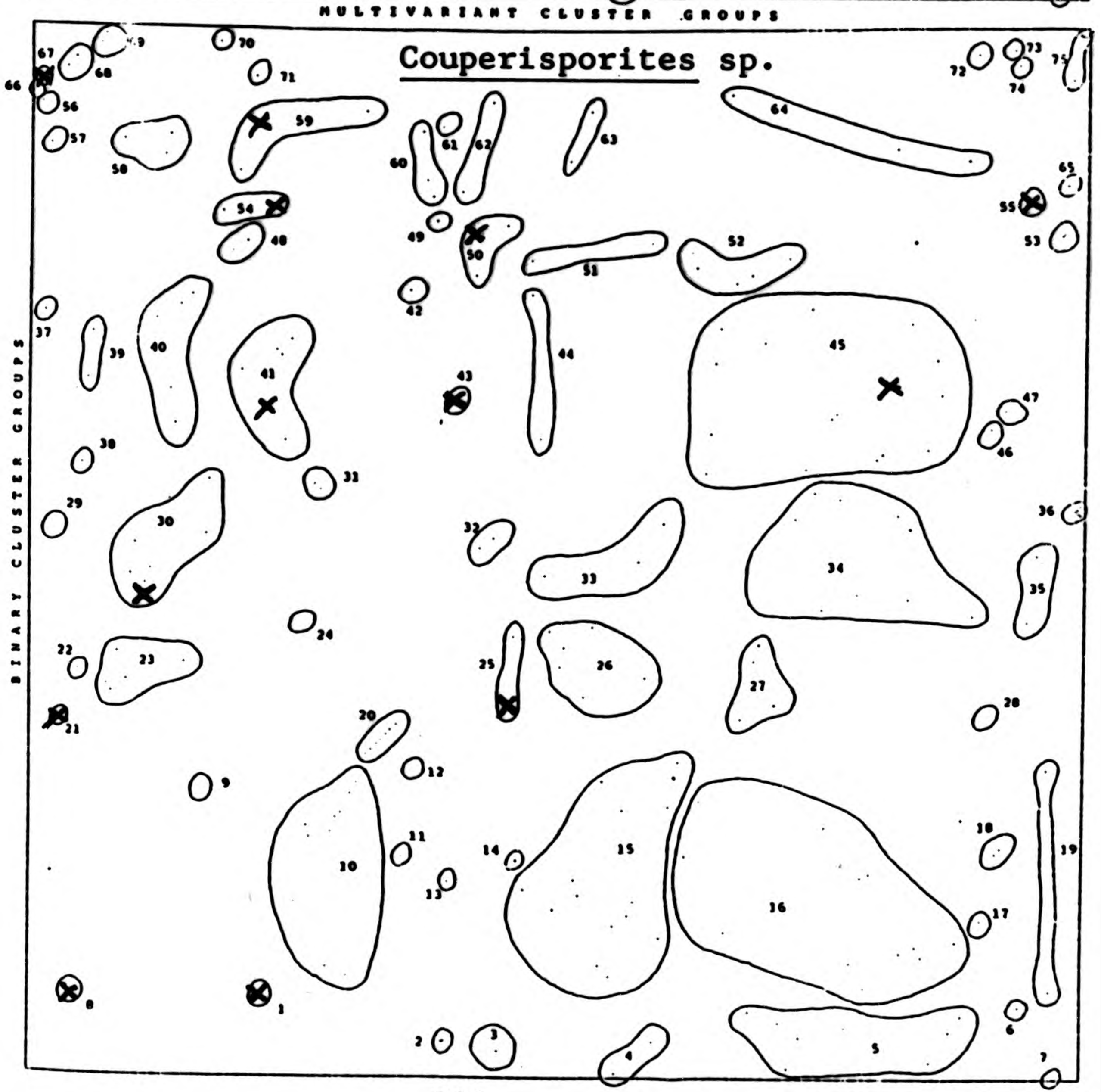
2. Genus Couperisporites Pocock(1962)

Type species: C. complexus

Remarks: These hilate spores have a two layered sclerine



Text-fig. 4.67



Text-fig. 4.68

and an enveloping zona. One species *C. complexus* (Couper) Pocock(1962)was recognised in this study.

Plate 24, figs.1 - 20

Palaeoenvironment: Though much more rarely occurring than *Aequitriradites spp*, *Couperisporites* share a similar habitat, restricted to the damp freshwater facies (see text-fig. 4.68).

3. Genus *Cooksonites* (Pocock) Dettmann(1963)

Type species: *C. variabilis* Pocock(1962)

Remarks: These are distally hilate grains with various sculptural elements. The hilum may form by natural exinous breakdown. Only one species was recognised in this study, *C. variabilis* Pocock(1962). The exine in this taxon is composed of one structured cingulate layer.

Plate 28, fig.1

Palaeoenvironment: This spore was only very rarely occurring (see text-fig.4.69) but almost restricted within facies *62* where there may be tidal marine influence.

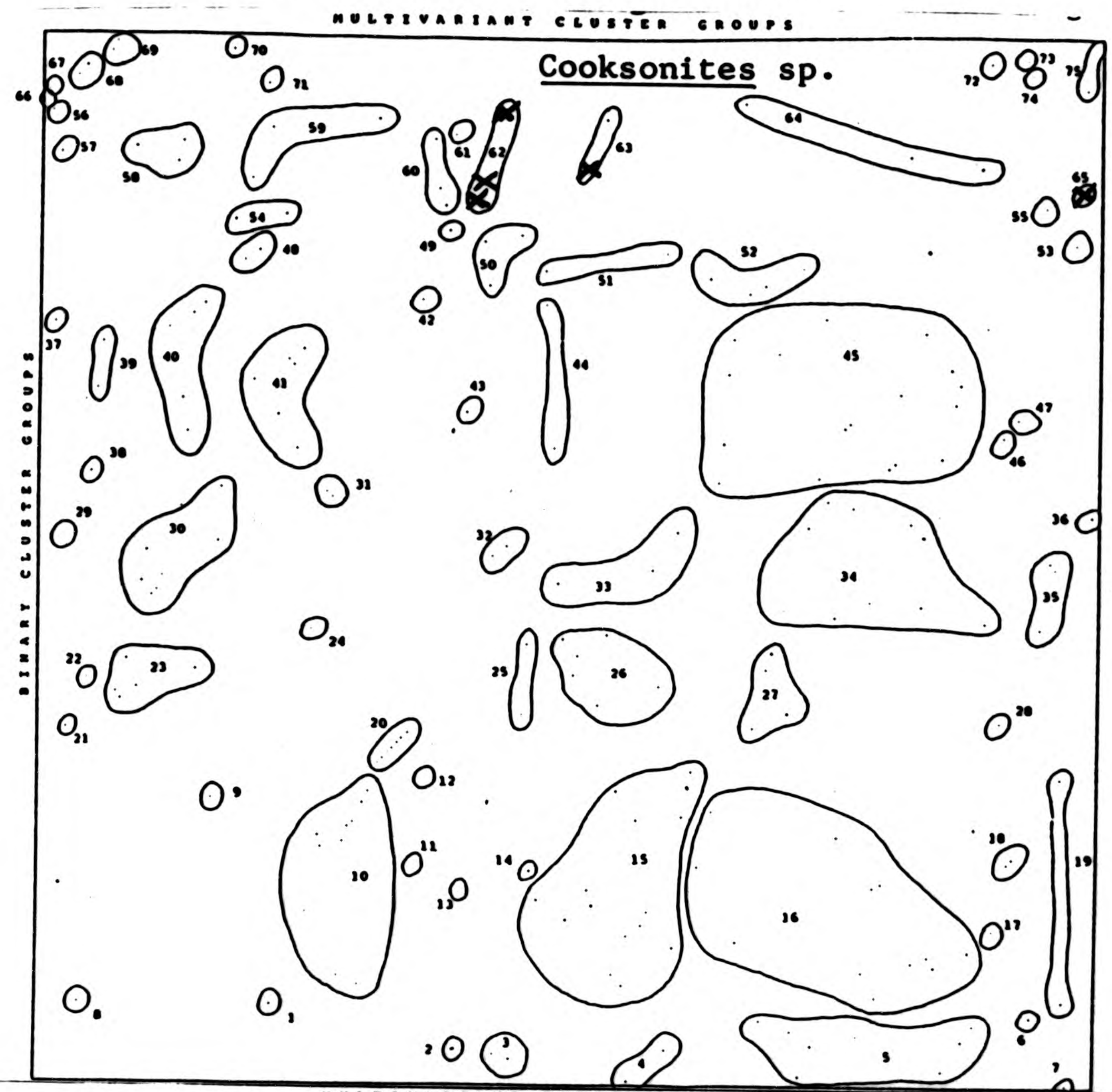
4. Genus *Januasporá* Pocock(1962)emend. Singh(1964)

Type species: *J. reticularis*

Remarks: These spores have a two layered exine, the ektexine being loose and hyaline. One species was recognised here designated *J. sp. A* as it could not be compared with any described species, in having a reticulate ektexine.

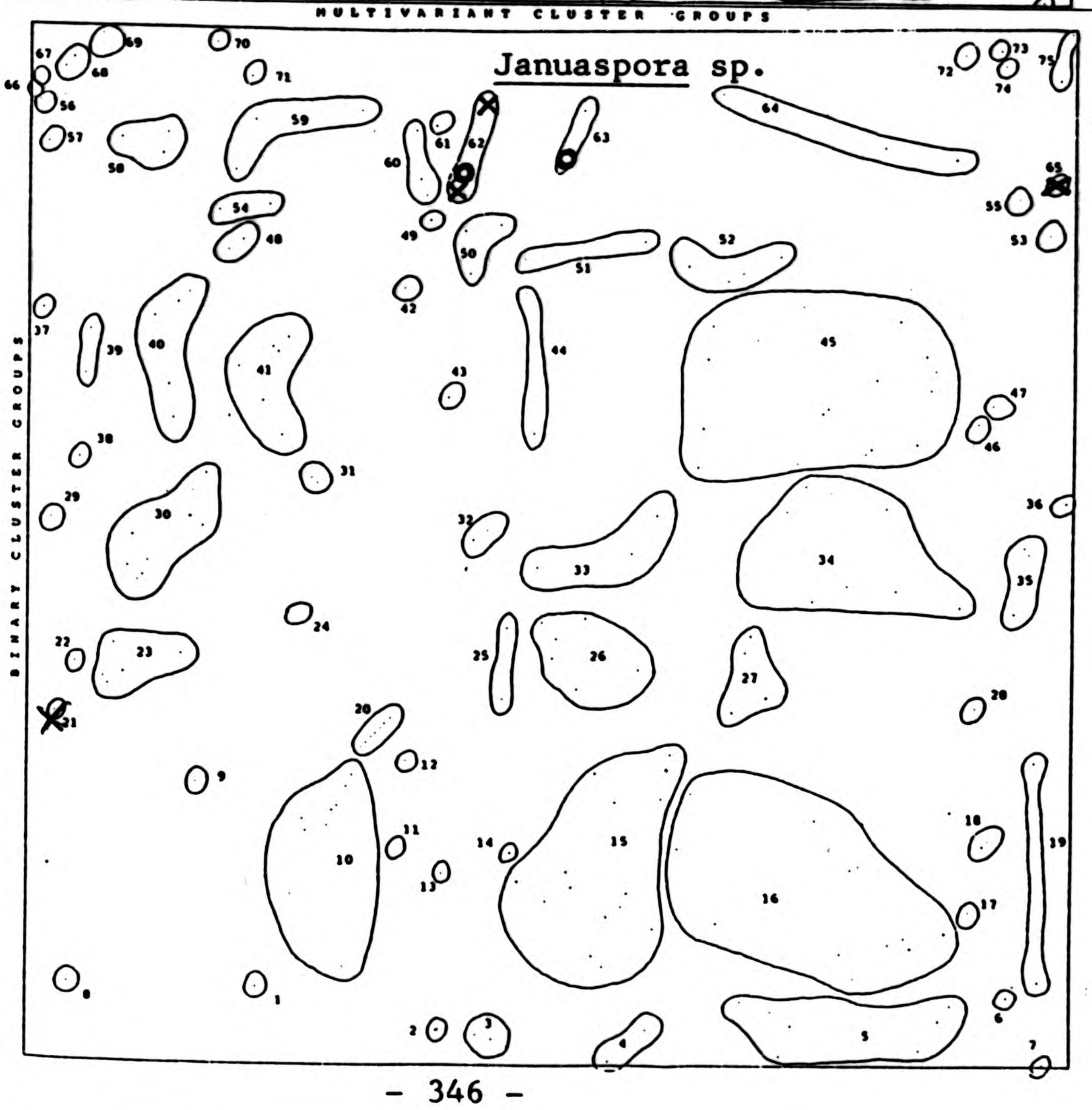
Plate 26, figs.33 - 45

Palaeoenvironment: This taxon shows a similar association to *Cooksonites* within facies *62* that may imply tidal marine



Cooksonites sp.

Text-fig. 4.69



Januaspora sp.

Text-fig. 4.70

influence.

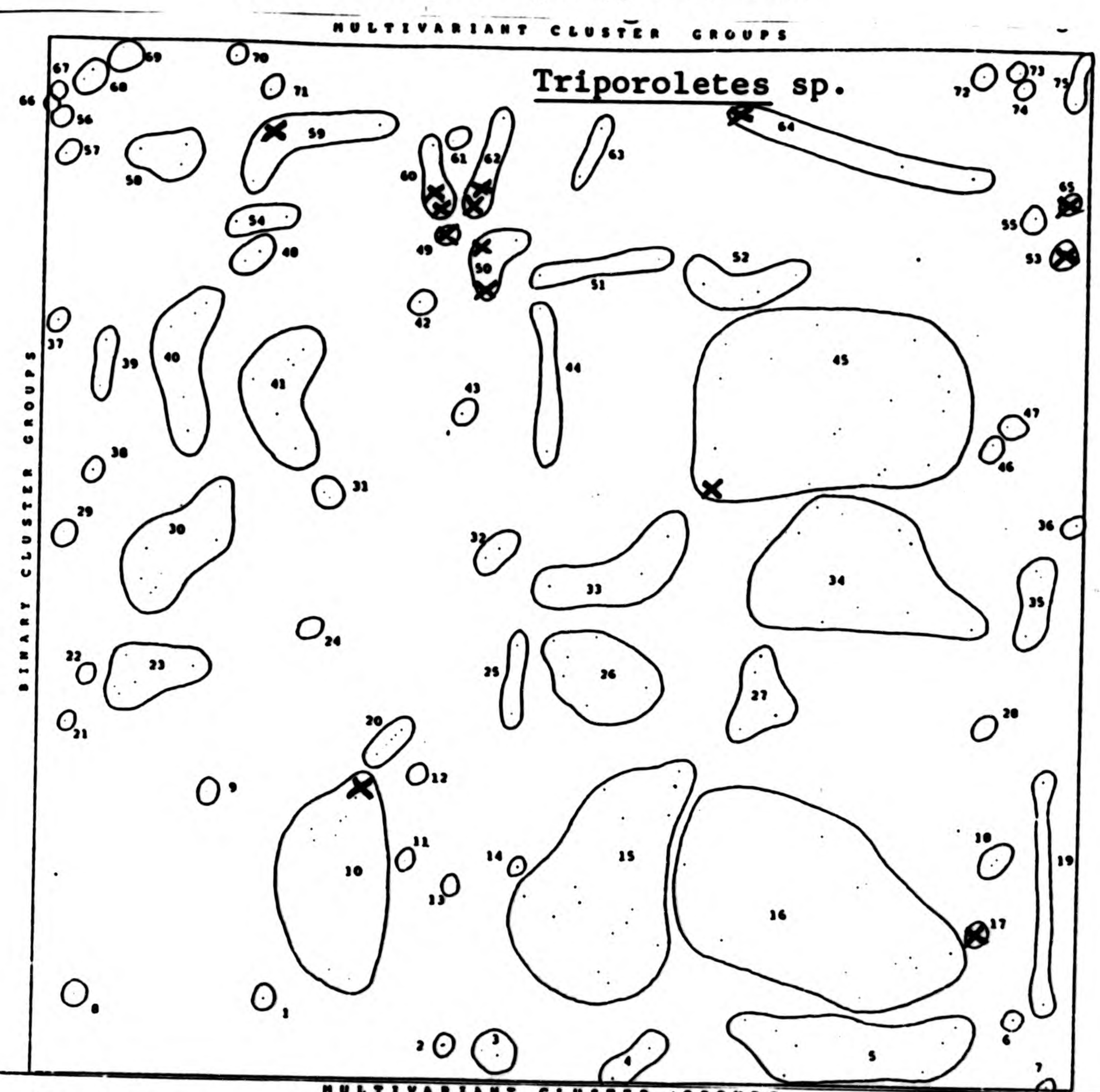
5. Genus Triporoletes Mtchedlishvili(1960)emend. Playford(1971)

Type species: T. singularis

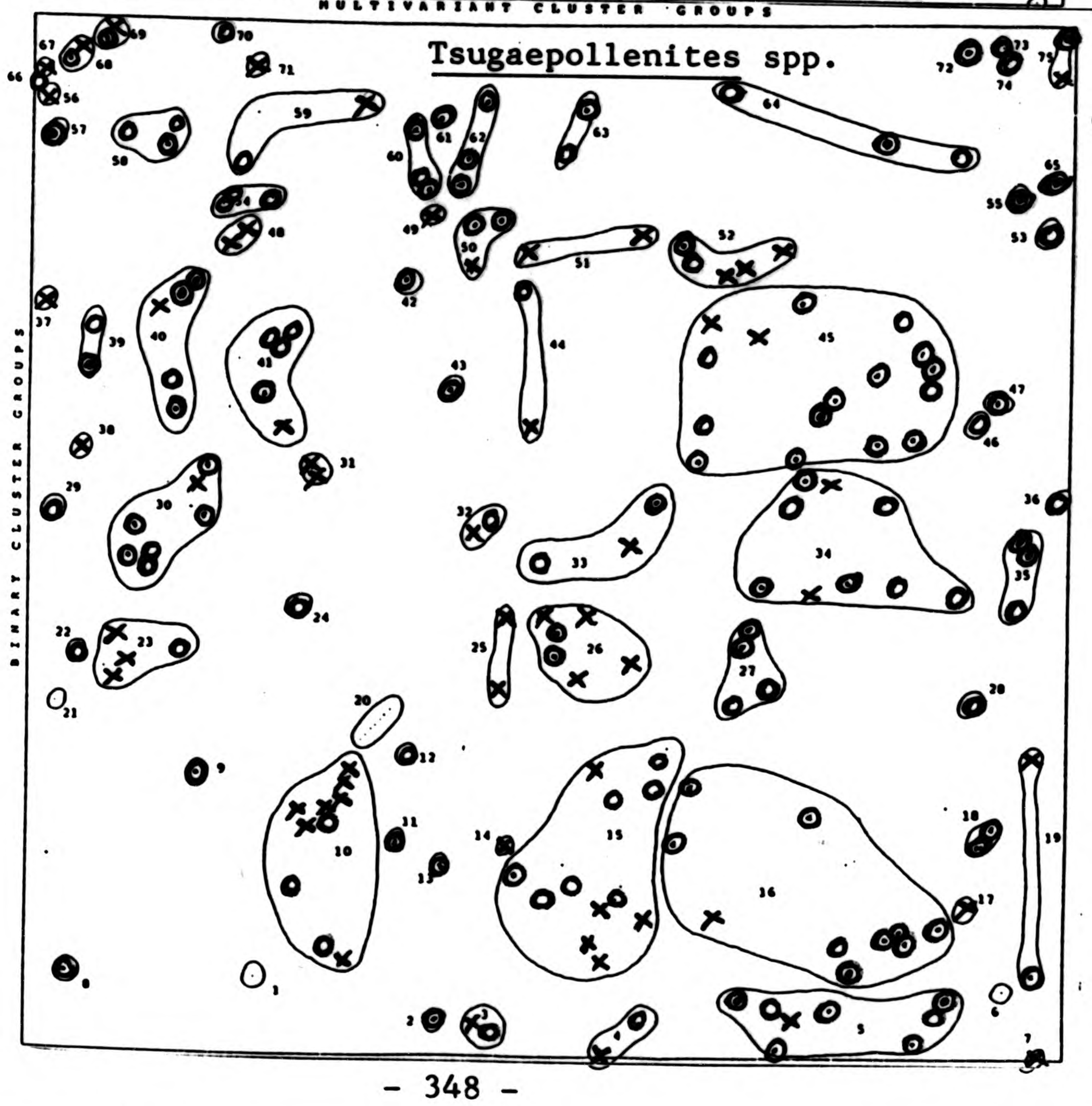
Remarks: Playford(1971)showed Triporoletes to be a junior synonym of Rouseisporites (Pocock,1962). This genus is characterised by spores bearing muroid ridges that usually form a reticulum on the distal surface. The proximal surface is smooth. A faint tetrad mark is occasionally developed. One species has been recognised in this study, T. reticulatus Pocock(1962). This taxon has a membraneous zona forming a proximal and distal reticulum with luminae 15 - 30 wide. Invaginations at the equator occur at each radial region.

Plate 8, figs.48 - 54

Palaeoenvironment: Text-fig.4.71 shows this Triporoletes spp. to be quite rarely occuring, generally confined to facies 49, 50, 60 & 62 in association with other Hilates. These facies, as previously mentioned, may be tidally marine influenced, though located quite close to the hinterland.



Text-fig. 4.71



Text-fig. 4.72

Anteturma POLLENITES
Turma SACCITES
Subturma MONOSACCITI

1. Genus Tsugaepollenites Potonié & Venitz emend. Potonié(1958)

Type species: T. igniculus

Remarks: This genus is characterised by a two-layered exine that is monosaccate equatorially enclosing small vesiculae near the poles. Two species were recognised in this study.

(a) T. trilobatus (Balme) Dettmann(1963) Plate 26, figs.1 - 19. This species is distinguished by its trilobate radially folded saccus as seen in equatorial view.

(b) T. dampieri (Balme) Dettmann(1963): Plate 26, figs.20 - 27. This species is of uniform rounded outline, that can be undulate and slightly constricted at the radii.

Palaeoenvironment: This genus was too commonly occurring to allow distinctions between the various facies to be based on it (see text-fig.4.72). In future work valuable palaeoecological data might be yielded if species and variants are carefully separated for individual analysis.

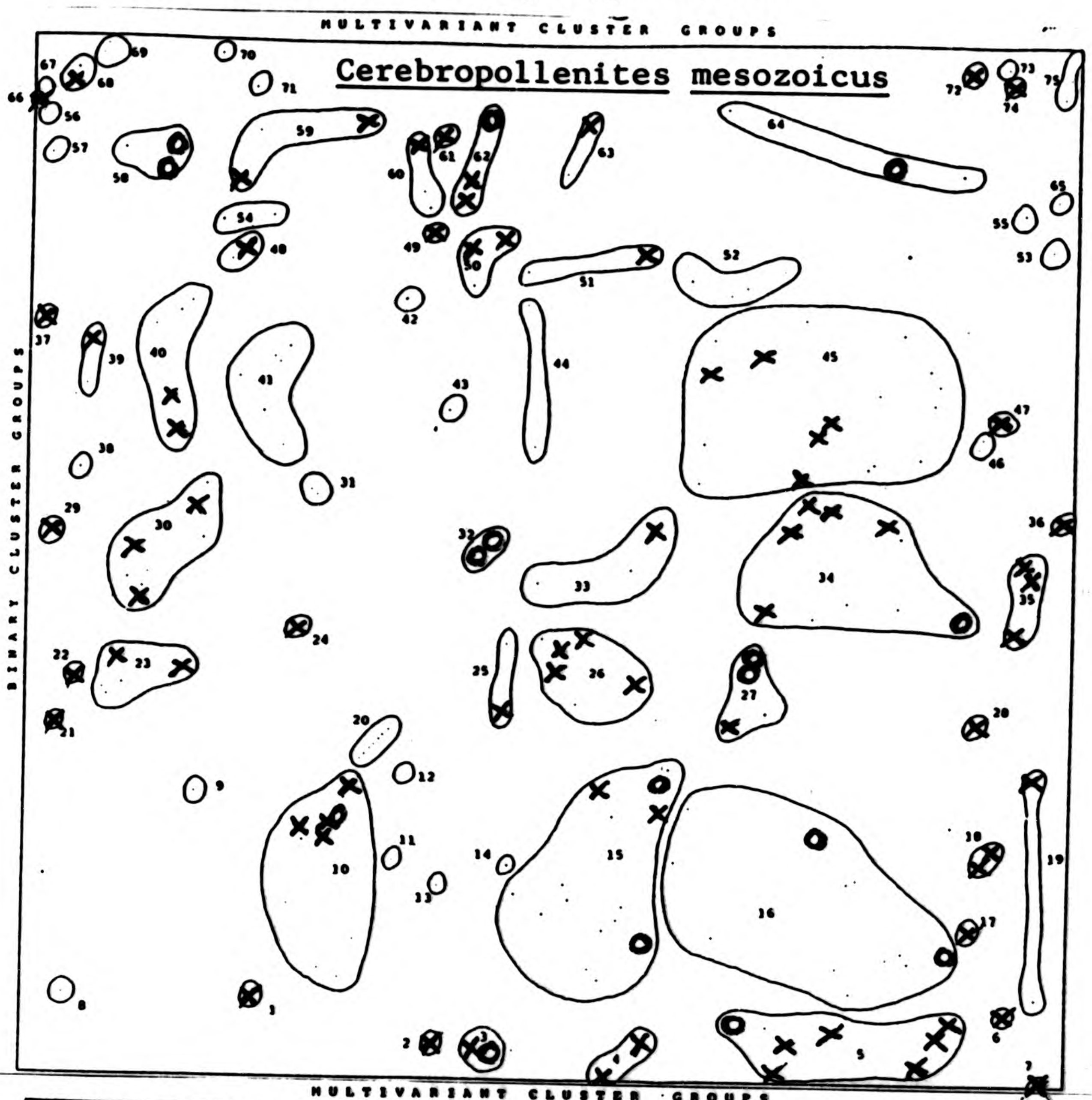
2. Genus Cerebropollenites Nilsson (1958)

Type species: C. mesozoicus (Couper)

Remarks: This genus incorporates inaperturate zonate spores with numerous small protruding corrugated sacci over the body, and a smooth thin circular area on the distal surface. Only one species (the type) was recognised in this study.

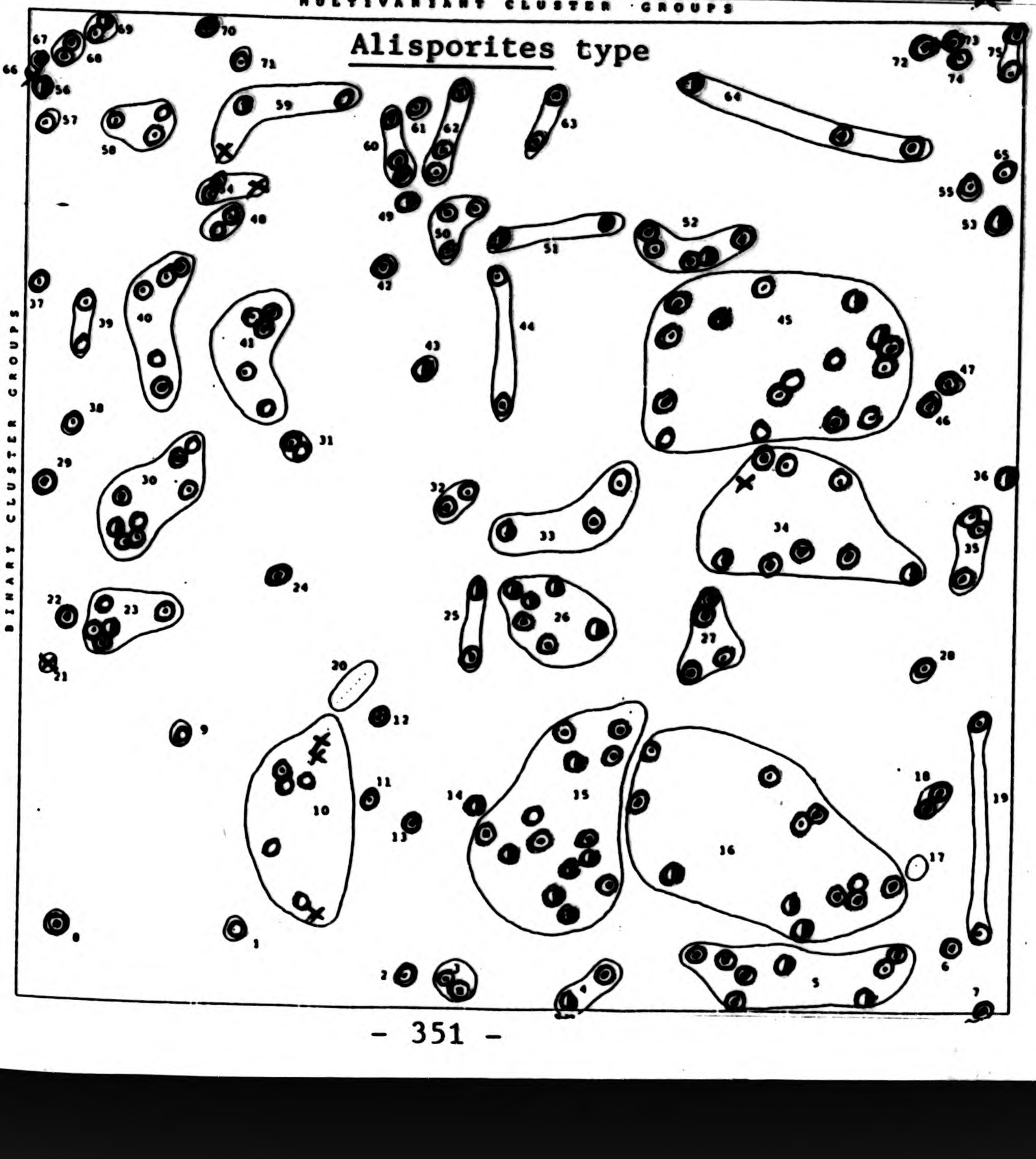
Plate 26, figs.46 - 52

Palaeoenvironment: Text-fig.4.74 shows this taxon to be of moderate occurrence in most Weald Clay facies. However it is particularly common in facies 1 - 7 (group A, see also text-fig. 2.5 ii) that are strongly brackish/marine influenced, along the strandline. Several occurrences are also seen in facies 60 - 62 that are probably also marine influenced facies. It is generally very rare or absent within the drier uplifted non-marine group J facies. The parent plant of C. mesozoicus was probably capable of growing in a "mangrove" type habitat that was tidally inundated by brackish or fully saline water. Additional evidence for such an association is seen by the co-occurrence of C. mesozoicus with dinoflagellate cysts of a shallow shelf sea in the Bathonian of South-West England (Riding, Penn & Woollam, 1985).



Cerebropollenites mesozoicus

Text-fig. 4.73



Alisporites type

Text-fig. 4.74

Subturma DISACCITES

1. Alisporites type

Type species: A. opii Daugherty (1941)

Remarks: Alisporites type has been used in this study to group together all bisaccates that have vesicles which are less wide or the same width as (in equatorial view) the central body. Aberrant specimens are shown on Plate 25, figs. 50, 51 & 53.

Plate 25, figs. 24 - 40 & 49

Palaeoenvironment: No discernible pattern in the distribution of this highly ubiquitous group can be seen in the Weald Clay facies of this study (see text-fig 4.74). This is in keeping with their origin on the sourceland massif and their airborne dispersal uniformily over the mudplain.

2. Cedripites type

Type species: C. eocenicus Wodehouse (1933)

Remarks: Cedripites type has been used in this study to group all bisaccates which have a curved central body or proximally extending vesicles that tends to cause the grains to lie in lateral compression.

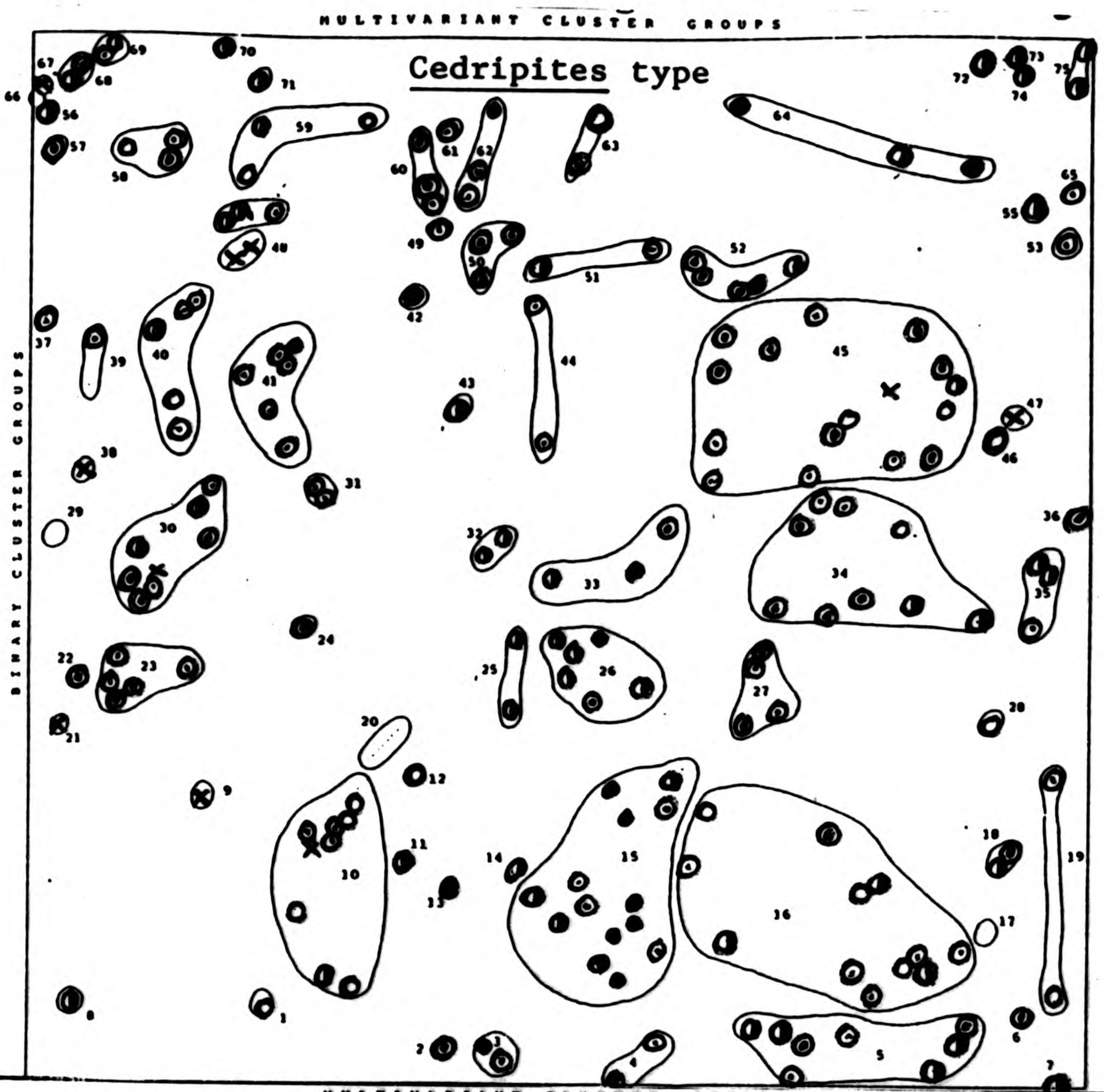
Plate 25, figs. 41 - 46 & 48

Palaeoenvironment: See text-fig. 4.75. Comments made with Alisporites type are equally applicable with Cedripites type.

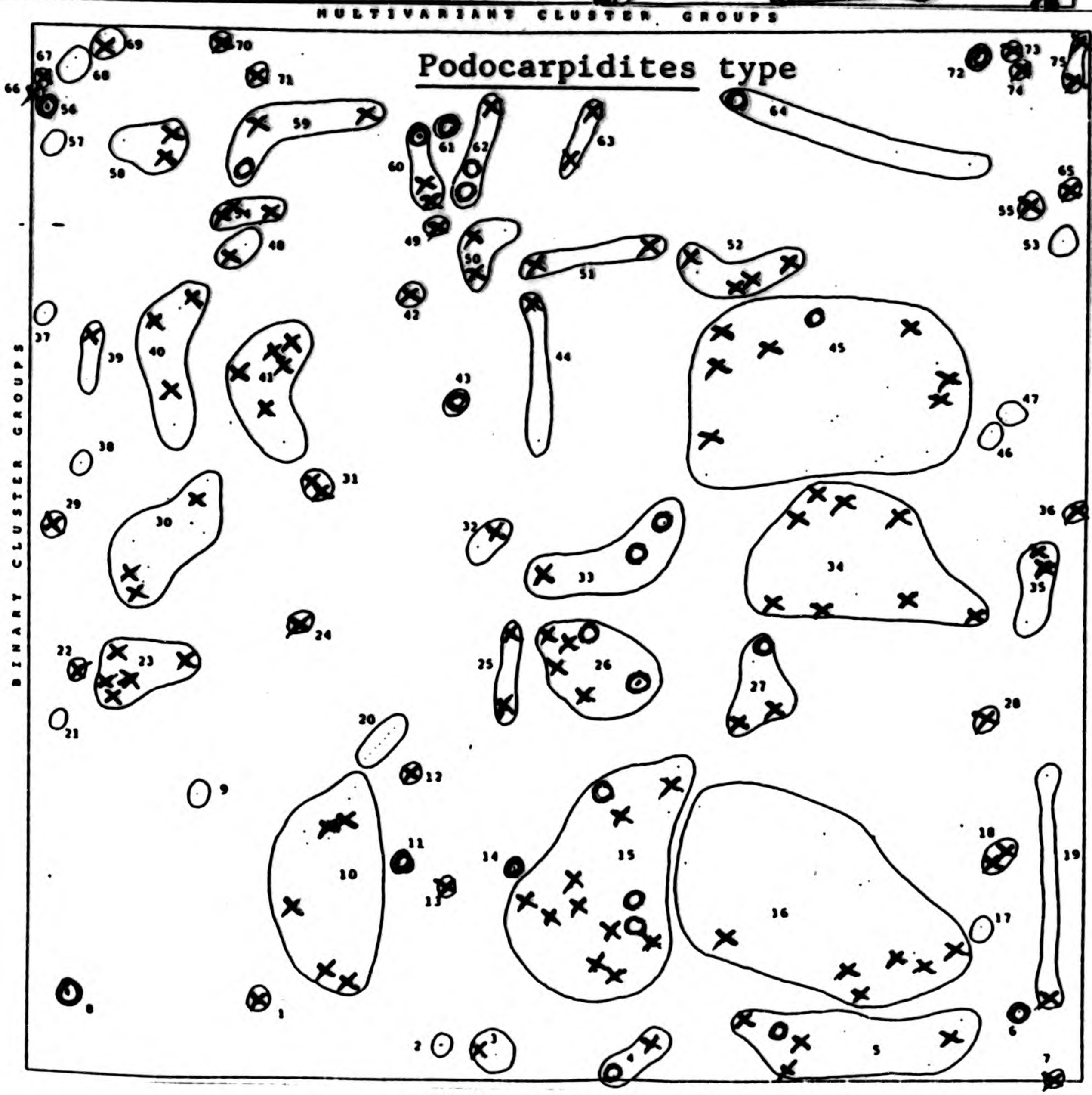
3. Podocarpidites type

Type species: P. ellipticus Cookson (1947)

Remarks: Podocarpidites type has been reserved for bisac-



Text-fig. 4.75



Text-fig. 4.76

cates with vesicles that are wider than the central body, which itself can be very reduced in size.

Plate 25, figs. 1 - 7

Palaeoenvironment: Podocarpidites type are generally less commonly occurring than Alisporites type or Cedripites type, however environment comments made for Alisporites type are equally applicable here.

4. Phyllocladidites type

Type species: P. mawsonii Cookson (1947)

Remarks: This genus is reserved for bisaccates with very reduced vesicles.

Plate 25, fig. 47

Palaeoenvironment: Only rarely occurring Phyllocladidites type was not treated separately in CLUSTAN. However general comments on the palaeoecology of the bisaccates made under Alisporites type are probably applicable here.

5. Dacrycarpites type

Type species: D. australiensis Cookson & Pike (1953)

Remarks: These grains are distinguished by their trisaccate condition. They differ from Microcachyridites Cookson (1947) ex Couper (1953), in that the latter possess much smaller vesicles.

Plate 25, fig. 52

Palaeoenvironment: This taxon was only very rarely encountered, so it was not run in CLUSTAN and palaeoecological comments cannot be made.

6. Genus Vitreisporites Leschik (1955) emend. Jansonius (1962)

Type species: V. signatus

Remarks: This genus accommodates very small bisaccate grains with vesicles that are of the same width as the central body giving the whole grain an oval or lozenge shaped outline. One species, V. pallidus (Reissinger) Nilsson (1958), was identified in this study.

Plate 25, figs. 20 - 23

Palaeoenvironment: Text-fig 4.77 shows this taxon to have a marked association with 1 - 19. This falls within groups A & B (see also text-fig. 2.5 i) where brackish/marine influence is greatest. The parent plant of V. pallidus may therefore have been "mangrove" in habit, either favouring or tolerating brackish or fully saline waters.

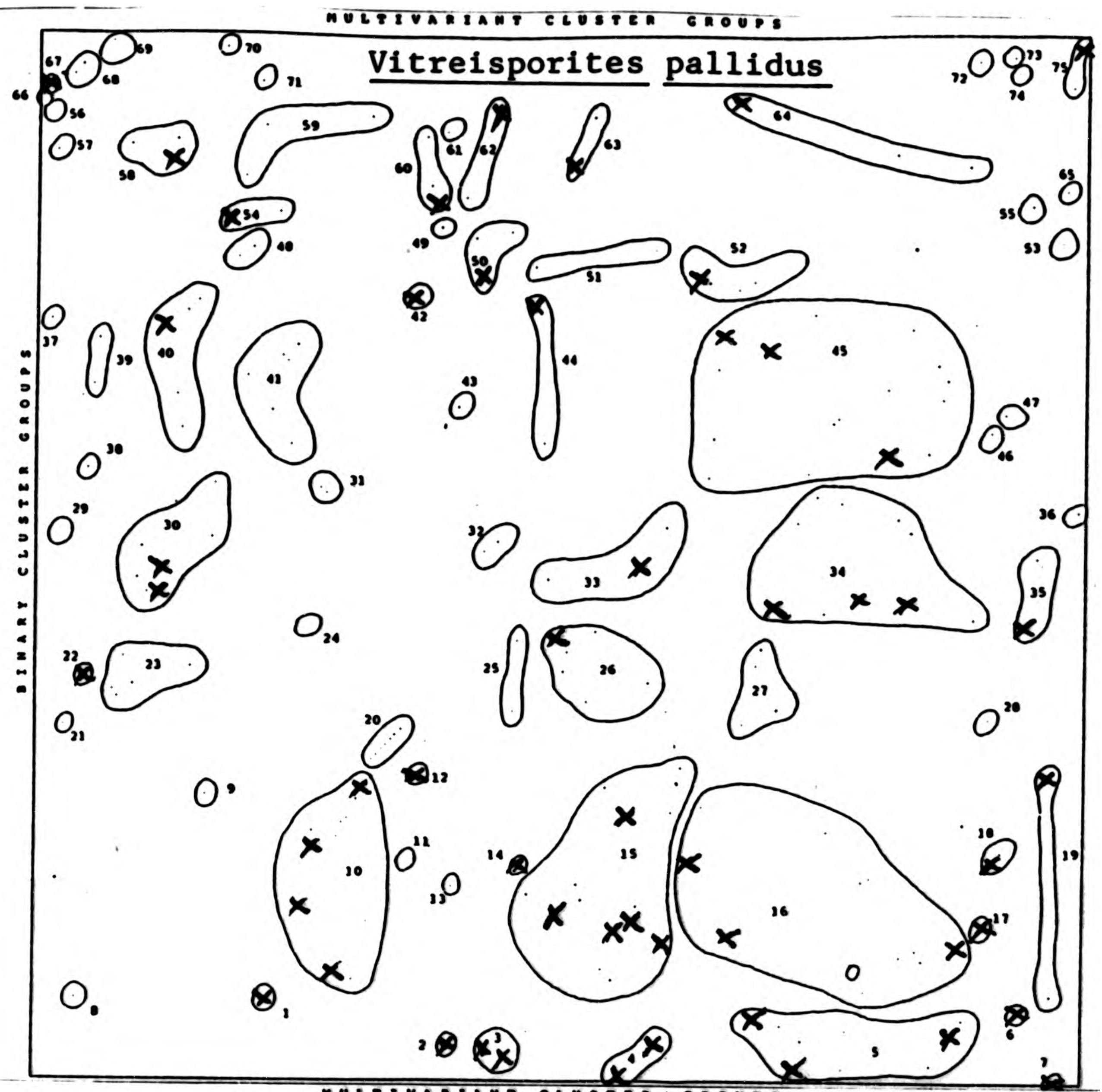
7. Genus Rugubivesiculites

Type species: R. convolutus Pierce (1961)

Remarks: This genus was proposed to accommodate bisaccate pollen with a prominent rugulate ornament on the proximal surface of the central body. One species was recognised, R. reductus Pierce (1961).

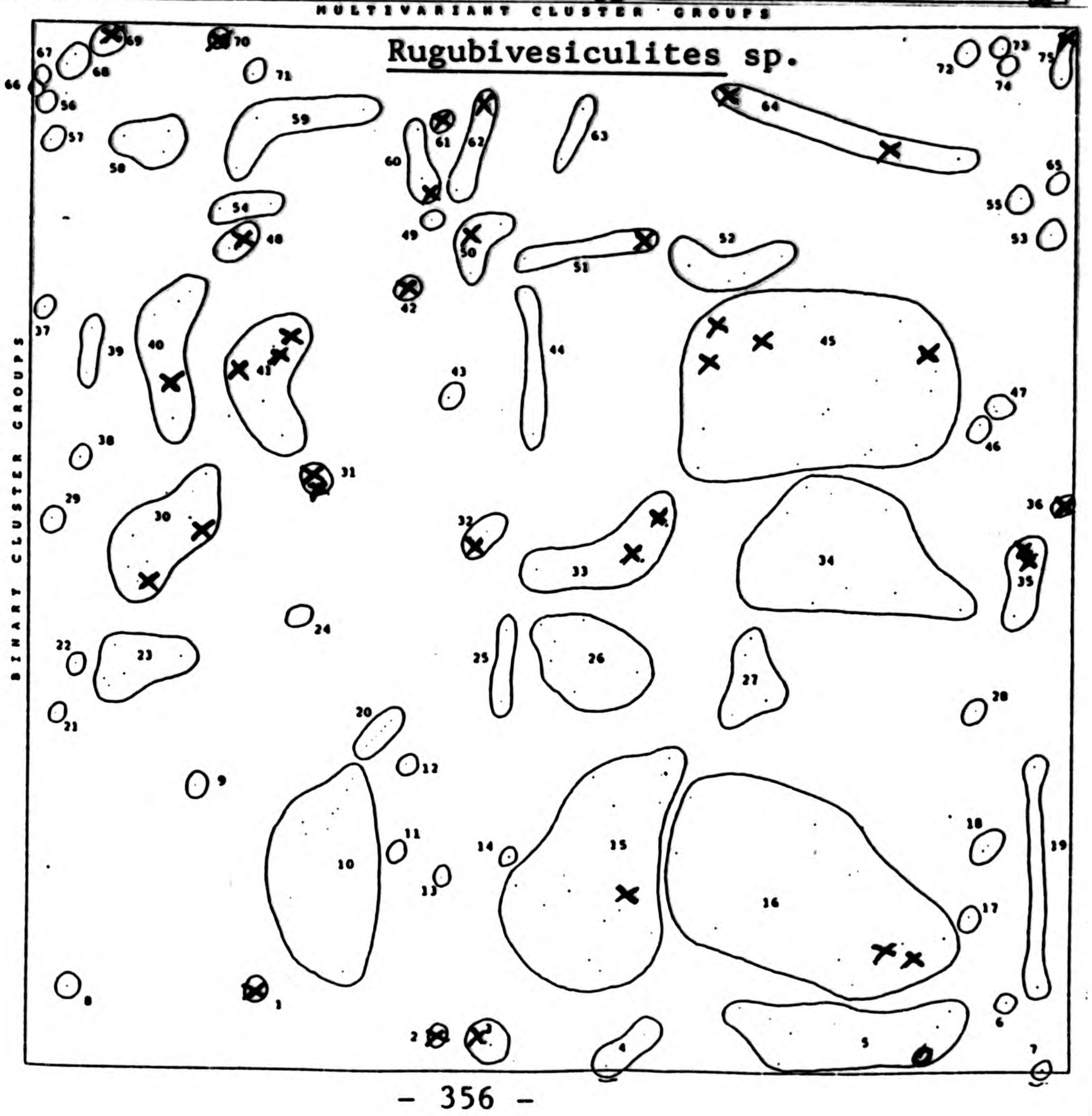
Plate 25, figs. 8 - 19

Palaeoenvironment: Text-fig. 4.78 shows that this taxon is generally more abundant in cluster groups D - J, rather than A & B indicating that its parent plant could not tolerate brackish water. This distribution pattern probably indicates that these plants were part of the braidplain flora rather than being associated with the source-lands gymnosperm flora, that found their way into all of the braidplain facies.



Vitreisporites pallidus

Text-fig. 4.77



Rugubivesiculites sp.

Text-fig. 4.78

Turma ALETES

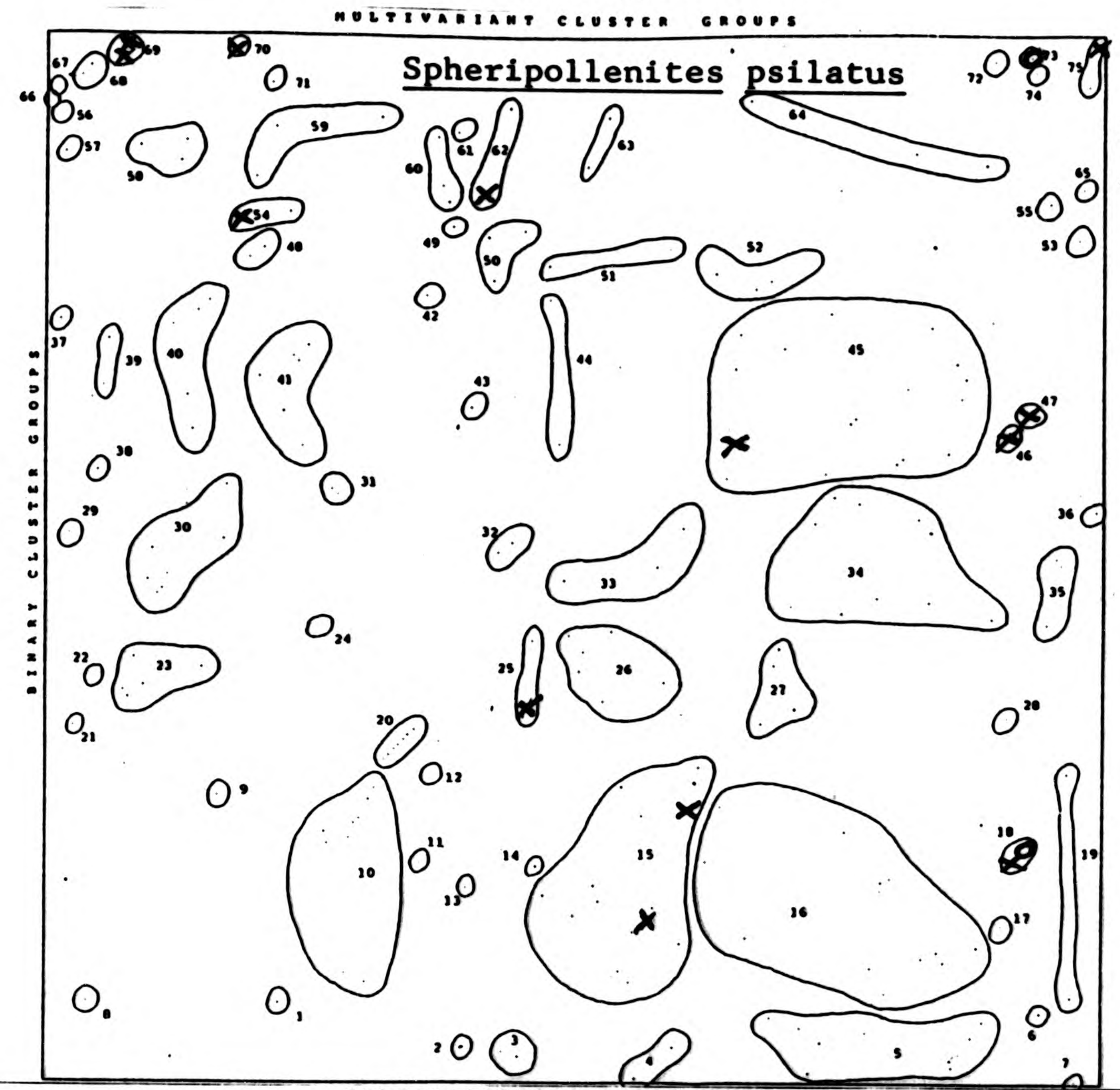
1. Genus Spheripollenites Couper(1958)

Type species: S. scabratus

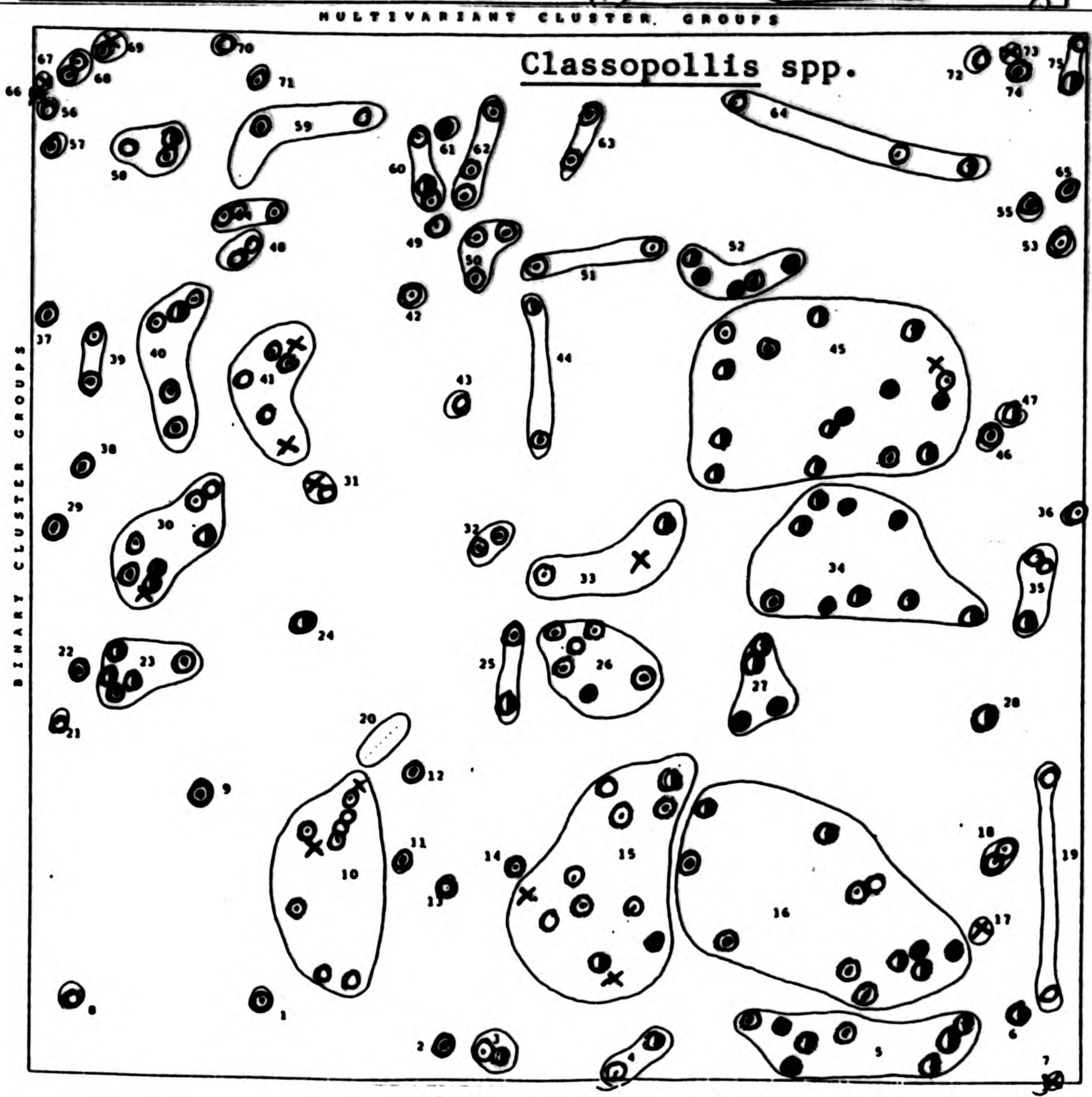
Remarks: This genus accommodates small spherical pollen grains with a poorly developed pore. These grains were only rarely encountered in the present study and separate species were not identified.

Plate 2, figs.22 - 24

Palaeoenvironment: Text-fig.4.79 shows that Sphaeripollenites are most common in the dry uplifted group J facies (69, 70, 73 & 75). Occurrences in facies 46, 47 & 18 can be explained by strong channel influence of these group XIII facies, while rare occurrences in facies 15, 25 & 45 are probably also transported.



Text-fig. 4.79



Text-fig. 4.80

Turma POROSES

subturma MONOPORINES

1. Genus Classopollis (Pflug emend. Pocock & Jansonius 1961)

Type species: C. classoides

Remarks: This genus accommodates probable gymnosperm pollen that are distally monoporate, with a very faint trilete mark sometimes observable on the proximal surface that is non-functional. A striated band (rimulus) on a thickened equatorial band is to be seen, that is separated from the spore body by an equatorial groove. The grains are spherical but often occur in tetrads. No attempt has been made in this study to separate species of Classopollis.

Plate 28, figs. 32 - 39

Palaeoenvironment: Palaeoenvironmental considerations of Classopollis sp. have already been extensively discussed in section 3.3 (b). Text-fig.4.80 shows that Classopollis spp. were quite commonly occurring in almost all Weald Clay samples encountered in the present study. Classopollis spp. are particularly abundant in group XII-3 that includes facies 5 where most of the marine influenced samples of group A occur. Marine influence is also seen within facies 16, 34 and 45, also within group XIII-3 (see text-fig.4.86 for the distribution of foraminiferal linings). This corroborates the association of marine influence with Classopollis spp. mentioned by many workers (Batten 1974, 1976, Oldham 1976, Alvin 1982). However it does not account for distinct occurrences of Classopollis spp. in other non-marine facies, eg. within group J. These occurrences probably represent separate species within this genus that had quite different palaeoecological requirements. These differences would probably be revealed in the pollen if a detailed examination was made. Chaloner (1984) mentioned that Classopollis plants probably thrived in a wide range of habitats. However, evidence on the overall distribution (text-fig 4.80) still indicates that most Classopollis occurs in marine influenced facies. If different facies can be recognised by their respective spore/pollen floras then a previously recognised range of such facies might provide a starting ground in a taxonomic search of diversity in a group such as Classopollis that had many different species individually adapted to a variety of palaeoenvironments.

Turma PLICATES

Subturma PRAECOLPATES

Genus Eucommiidites (Erdtmann) Hughes (1961)

Type species: E. troedssonii

Remarks: A few rare specimens of this taxon were recorded in the present study. According to Hughes (1961) this pollen grain bears a single furrow with rounded ends, the margins of which close over it in the middle. The opposite convex face bears a ring furrow near the margin.

Plate 28, figs. 45 & 46

Palaeoenvironment: With only rare specimens, palaeoenvironment conclusions remain tentative. However the two facies (26 & 52) where this taxon occurs are distinctly freshwater, with no brackish influence.

Subturma MONOCOLPATES

Genus Ginkgocycadophytus Samoilovitch (1953)

Type species: G. caperatus

Remarks: This genus is characterised by an elliptical shape with a furrow or 'tenuitas' extending the full length of the grain.

(a) G. nitidus (Balme) de Jersey (1962) Plate 27, figs. 2 & 4 These grains are of small size range with the tenuitas slightly wider at the equator than at either end.

(b) G.spp. Plate 27, figs. 1,3 & 5-14. A number of monocolpate pollen types were recovered, distinguished mainly on size variation. Some show rounded ends, others pointed.

Palaeoenvironment: *Gingkocycadophytus* species are generally confined to freshwater palynofacies, without brackish/ marine influence.

? Modern Pollen Contaminants.

Very rare pollen probably representing modern contamination was encountered. *Retitricolporites* sp., Plate 28,fig.47; *Triorites* sp., Plate 28,fig. 47, and *Bombacidites* sp., Plate 28,figs. 53 & 54.

MISCELLANEOUS SPORES

1. Trilete Spores Undifferentiated

Plate 28, figs. 11-31

A number of trilete spores were observed in the Weald Clay that could not be assigned to recognised taxa. These are generally of simple morphology with trilete rays extending to the radii. Figures 14 & 15 show a distinctly two-layered wall structure.

2. Spore Type X

Plate 28, figs. 40-43

Rare occurrences of this spore type were observed of unknown affinity. This spore is of small size range (30u) with a distinctly triangular outline. Well developed radial thickenings are developed that are linked to smaller interradial thickenings, sometimes forming a cingulum. The distal surface is ornamented by an irregularly shaped thickening.

3. Spore Type A.

Plate 62, fig. 1

A single specimen of a rounded triangular non-trilete spore was recovered, 60u in size, with a finely reticulate distal surface, and a granulate proximal surface. Regularly spaced small branching tubercles project from the equator up to 5u in length.

4. Spore Type B

Plate 62, fig.2

A single specimen of a differentiated spore tetrad was encountered, each grain about 30u in size.

5. Spore Type C

Plate 62, fig.3

This spore is trilete with an extremely thick wall and well developed auriculae, and is 60u in size.

6. Spore Type D

Plate 62, fig. 4

A single specimen of an unknown spore type, 80u in size, non-trilete, of rounded triangular shape, was encountered. The exine was observed to bear membraneous ridges ornamented by rows of pendulous processes up to 10u in length.

7. Spore Type E

Plate 62, fig.5 ; Plate 26, figs. 30 & 31

A few rare specimens of a large two layered non-trilete spore up to 100u in size was observed. The exine is ornamented by a fine reticulum. This spore is of unknown affinity.

8. Spore Type F

Plate 62, fig. 6; Plate 26, figs. 28 & 29

A few rare specimens of a large two layered non-trilete spore was encountered. This spore is up to 100u in size, and of unknown affinity.

9. Spore Type G

Plate 62, fig. 7 a-b.

A single specimen of a very large spore 120u in size was encountered, non-trilete, with a thickened inner body, of unknown affinity was encountered.

10. Spore Type H

Plate 62,fig. 8

A single specimen of a very large two layered non-trilete spore 100u in size was observed.

11. Spore Type I

Plate 66, fig. 6

A single large ?spore was encountered, bearing long pendulous processes. A single laevigate trilete spore was observed inside this large ?spore.

12. Spore Type J

Plate 7,figs. 26-28

Rare occurrences of a trilete spore were encountered bearing an ornament of short cristae.

13. Verrucate tetrads.

Plate 4, figs. 60-65; Plate 10, figs. 45-47, 49 & 50

Rare specimens of verrucate spores were encountered forming tetrads. They may fall within the genera Verrucosisporites or Leptolepidites

FLUORESCENT ALGAE (See Enclosure 15)

1. Genus Veryhachium (Deunff) Deunff (1955)

Type species: V. trisulcum

Remarks: This genus of acritarchs includes three to four (rarely five) horned triangular, rectangular or tetrahedral structures. A number of different morphotypes have been designated to accommodate the various types based on shape and horn number. A three-pronged triangular form (Plate 43, figs. 1-10) could be accommodated in V. reductum (Deunff), Jekhowsky (1961); a four-pronged rectangular form (Plate 43, figs. 11-17) could be included within V. lairdi (Deflandre) Deunff (1954) and a four or five-pronged tetrahedral form (Plate 43, figs. 18-31) may fall within V. rhomboidium Downie (1959).

Size range:			
	3-pronged triangular:	25(27)30u	10 specimens
	4-pronged rectangular:	25(28)32u	8 specimens
	4-pronged tetrahedral:	22(26)31u	14 specimens

Plate 43, figs. 1-31; Plate 79, figs. 1-4; Plate 82; Plate 86, figs. 1a & b.

Palaeoenvironment: The three morphotypes of Veryhachium have been plotted individually on enclosure 15. However they do not show any clear differentiation in occurrence, so can be discussed as one palaeoecological group. They are most common in facies 15 that is considered to represent a slightly brackish water lake near the strandline. They are absent or present in low numbers in the most marine influenced facies 1-7 of group A and facies 16. Very rare abundances within these facies can be attributed to local reworking. Veryhachium spp. are common in other facies that show strong aquatic influence such as the presence of limestone and fine grey amorphous material, such as facies 41.

2. Genus Baltisphaeridium (Eisenack) Eisenack (1958)

Type species: B. longispinosum

Remarks: Fairly large numbers of spiny acritarchs were encountered in the Weald Clay. They all have a general size range above 20u for the central body, allowing inclusion in Baltisphaeridium. Two types were distinguished, simply referred to as 'Long Spined Form' and 'Short Spined Form'.

(a) Long spined form: Plate 45, figs. 35-46; Plate 46, figs. 1-23; Plate 83, figs. 1-3 & Plate 84, figs. 1-5.

This acritarch is characterised by an extremely thin delicate body and long, very thin, solid processes that are slightly thickened at the base. The body appears quite brittle and is prone to breakage. The processes tend to remain straight even in crushed specimens. This taxa may fall within B. multispinum Singh (1964).

Size range: 23(37)55u (including processes) 26 specimens measured. Processes are on average 10u in length, occasionally up to 15u.

(b) Short spined form: Plate 45, figs. 1-34; Plate 83, figs. 4-9; Plate 84, fig. 6. This acritarch shows very simple morphology, with an ornament of very dense short spines covering the central body. This taxon may fall within B. fimbriatum (White) Sarjeant (1959) or B. sp. B of Singh (1971).

Size range: 16(22)34u 34 specimens measured. Spines are 1-2u in length.

Palaeoenvironment: Both these taxa show similar occurrence characteristics. They are most common within generally freshwater aquatic palynofacies, such as 23 and 30. They are quite negatively associated with marine influence. (See enclosure 15). The aquatic environment may have been small temporary ponds within the braidplain rather than larger more permanent bodies of water nearer the strandline.

3. Genus Micrhystridium (Deflandre) Deflandre (1937)

Type species: M. inconspicuum

Remarks: Small spiny acritarchs were occasionally encountered in this study with oval to rounded central bodies of less than 20u in diameter (Plate 48, figs. 1-62). Most could probably be accommodated in the species M. fragile (Deflandre,1947) or M. stellatum (Deflandre,1945). Very rarely they showed some polarity of spine development (fig. 48) or wide spine bases (figs. 46, 49, 52 & 58). The specimen shown on fig. 62 has four branching processes arising from the corners of a rectangular/polygonal central body. This is probably within generic limits of Multiplicisphaeridium.

Size range: 14(22)35u 63 specimens measured (including spines)

Plate 48, figs.1-62; Plate 87, figs.1 & 3.

Palaeoenvironment: *Micrhystridium* spp. generally occurred in freshwater aquatic palynofacies. They were too rarely encountered to be more specifically correlated to any particular facies.

4. Genus *Pediastrum*

Type species: *P. paleogeneites*

Remarks: Rare occurrences of specimens assignable to *Pediastrum* were encountered in this study. They show the typical colonial disc shaped coenobium with short processes projecting from the perimeter.

Plate 47, figs.1-14; Plate 85, figs.3 & 4.

Size range: 25(36)50u 14 specimens measured.

Palaeoenvironment: *Pediastrum* was only rarely occurring in the Weald Clay, and seems to be confined to aquatic freshwater palynofacies.

5. Genus *Botryococcus*

Type species: *B. braunii*

Remarks: Small colonial masses of cells very typical of *Botryococcus* were encountered occasionally in abundance, in the Weald Clay material.

Plate 51, figs.14, 17-20 & 23; Plate 93, figs.1-4

Palaeoenvironment: *Botryococcus* is a freshwater lacustrine alga known from the Precambrian to Recent. It occurs in abundance as the dominant alga in oligotrophic lake waters (Hutchinson, 1957; Chu, 1942). In the present study it does occur throughout all palynofacies but never as a dominant. However it is occasionally abundant within marine influenced palynofacies such as 16 that represent permanent standing water bodies. Such water bodies may have developed stratification. Oligotrophic surface waters are often associated with such conditions where organic material is accumulated and not recycled into the lake, within an anoxic lower water layer.

6. Genus *Scenedesmus*

Scenedesmus sp. A.

Remarks: Large numbers of structures resembling modern *Scenedesmus* spp. illustrated by Petersen (1912) were encountered in the Weald Clay. Fossil occurrences of *Scenedesmus* have not been recorded in the literature as yet (Tappan, 1980). These structures are of simple morphology consisting of oval or boat-shaped cells joined side by side to form a small colony. The indi-vidiual cells tend to curve in the middle, particularly those at either side, in the shape of butterfly wings. Two possible types were recognised, those with sharp ended cells and those with slightly flat terminations.

Size range: 25(31)45u 34 specimens measured.

Plate 44, figs. 1-34; Plate 80, figs. 1-6.

Palaeoenvironment: *Scenedesmus* occurred in most aquatic freshwater palynofacies particularly facies 34. According to Hutchinson (1957) and Chu (1942) Scenedesmus is associated with eutrophic water bodies. Sediments of the Weald Clay were probably laid down in nutrient rich braidplain environments associated with shallow ponds and lakes with an abundant in situ fern flora.

7. MISCELLANEOUS INDETERMINATE FLUORESCENT ALGAE

(a) 'Colonial Spiny Masses' Generally rare occurrences of this undescribed taxa were encountered in the Weald Clay. They consist of eight small spherical cells linked in two rows of four. Individual cells show an ornament of very fine hairs. These hairs are similar to those described on some modern freshwater algae by Petersen (1912). The surface of each cell shows a granulate ornament.

Size range: 15(23)30u 12 specimens measured. Individual cells of each colony ar abount 5u in diameter. Plate 43, figs. 32-45; Plate 79, fig. 15; Plate 81, figs. 3 & 5-8.

Palaeoenvironment: This taxon shows a definite association with freshwater and slightly brackish lacustrine environments such as facies 10 & 15. Facies 10 contains abundant C. rallus that may indicate alkaline influences (Batten & Van Geel, 1985).

(b) 'Spiny Tetrads' Generally rare occurrences of this undescribed taxon were encountered. These structures comprise four cells closely joined in a square packing arrangement. Occasionally diametrically opposite cells are joined in the centre, and the tetrad is slightly elongate and diamond-shaped. They show a finely granulate surface ornament and characteristically have a small central body that is brightly autofluorescent, within each cell. Groups of fine hairs similar to those described by Petersen (1912) are to be seen projecting from the four corners of each tetrad. Similar structures have been observed in the Wealden Group by Harding (pers. comm. 1986).

Size range: 14(17)24u 10 specimens measured.

Hairs are approximately 10u in length.

Plate 47, figs. 20, 25-34; Plate 81, figs. 1-4.

Palaeoenvironment: The taxon is not common enough in occurrence to show a good facies association beyond a general aquatic freshwater and possibly brackish preference.

(c) 'Minute Leiospheres'. Rare occurrences of these small palynomorphs were observed. They are probably more common but are lost during 10u mesh-sieving in palynological processing. They appear comparatively thick walled with compression folds and are brightly autofluorescent. Occasional small 'colonies' of them are to be seen though some form tetrads of square packing arrangement. Some may show fine hairs (Petersen,1912).

Size range: 6(8)9u 5 specimens measured

Plate 46, figs. 24-32 & 36; Plate 79, figs. 12-14.

Palaeoenvironment: A general association with aquatic freshwater (possibly brackish) palynofacies was noted.

(d) 'Segmented Alga type 1.' This taxon is an elongated segmented structure, usually comprising about 10 (up to 15) disc-shaped segments that are stacked to form a slightly curved oblong structure. The wall is very thin and commonly wrinkled, sometimes showing a faint microgranulation. A thickened brightly autofluorescent structure occurs on either side of each segment.

Size range: 25(44)60u 9 specimens measured. The width of the structure is 10-15u.

Plate 47, figs. 15-19 & 21-24; Plate 80, figs. 8 & 10; Plate 82, figs. 1 & 2; Plate 86, fig. 2.

Palaeoenvironment: This taxon appears to be quite strongly associated with marine influenced facies 3, 5 and 15.

(e) 'Segmented Alga type 2'. This taxon forms a ladder shaped structure of two broadly parallel sides joined by cross links. They were only found in the Beare Green material where they could be extremely abundant.

Size range: 23(38)50u 26 specimens measured.

Plate 80, figs. 7 & 9

Palaeoenvironment: This taxon is closely associated with the Beare Green material, so must depend on particularly local conditions. They are distinctly aquatic freshwater in palynofacies association.

(f) 'Laevigate Algal Cysts': Extremely large numbers of these simple structures could be found in some Weald

Clay samples.

Size range: 10(15)21u 30 specimens measured.

Plate 85, fig. 1; Plate 88, figs. 2 & 3 and Plate 89.

Palaeoenvironment: These structures could occur in all aquatic Weald Clay palynofacies but they were found to be present in particularly large numbers with marine influenced facies 5 and subcluster B-3 of facies 15 and 16.

(g) 'Granulate Algal Cysts': Rare occurrences of simple thin walled structures showing a granulate ornament were encountered.

Size range: 10(26)50u 10 specimens measured

Plate 79, figs. 6 & 7.

Palaeoenvironment: Generally aquatic palynofacies.

(h) 'Large Thick Walled Cysts': Rare occurrences of some thick walled strongly autofluorescent algal cysts were observed.

Size range: 20(23)30u 5 specimens measured.

Plate 46, figs. 33-35; Plate 79, figs. 8, 9 & 11.

Palaeoenvironment: Generally aquatic.

(i) 'Very Small Spiny Acritarchs': Very rare occurrences of spiny acritarchs of very small size range were encountered.

Size range: 8(9)12u 4 specimens measured

Plate 47, figs. 35-38; Plate 79, fig. 10

Palaeoenvironment: Generally aquatic.

IN SITU DINOCYSTS

1. **Cannosphaeropsis** sp.

Type species of genus: C. utinensis (O.Wetzel,1933)

Remarks: A single specimen of this genus was recovered from sample W.82. Cannosphaeropsis is distinguished by the presence of trabeculae linking the distal terminations of the processes.

Plate 29, fig.11

2. **Callaiosphaeridium** (Davey & Williams in Davey et al. 1986)/ Florentina sp. (Davey & Verdier, 1973)

Remarks: A single specimen of a taxon assignable to this broad taxonomic group due to poor preservation was obtained from sample HF.1. It shows distinctive open ended large hollow processes, some reduced in size with one antapical process of larger size than the rest.

Plate 38, fig. 12

3. **Canningia** sp. A

Type species of genus: C. reticulata Cookson & Eisenack (1960)

Remarks: A few dinocysts with an apical archeopyle and uniform ornament of small capitate processes have been assigned to this group.

Plate 36 figs. 1-15

4 (a) Cribroperidinium sp.A

Type species of genus: C. sepimentum (Neale & Sarjeant, 1962)

Remarks: Specimens of this taxa turned up occasionally in a few samples. This form is of generally small size range with a prominent cingulum and a rounded or conical shaped apex with a small apical process.

Plate 33, figs. 4-13

(b) Cribroperidinium sp.B

Remarks: This morphotype is distinguished by its larger size range and closer resemblance to C.edwardsi. Specimens recovered in the present study are fairly thin walled and non-robust, unlike C.edwardsi. One specimen (Plate 42, fig.10) shows prominent spines arranged along paraplate boundaries.

Plate 41, figs. 1-5 & 7-8; Plate 42, figs. 9-12

5 (a) Hystrichodinium sp.

Remarks: Rare specimens of poorly preserved dinocysts, well ornamented with solid non-tabular processes were observed

Plate 38, figs. 10 & 13

(b) Hystrichodinium pulchrum (Deflandre, 1935)

Type species of genus: H.pulchrum (Deflandre, 1935)

Remarks: Rare specimens of this distinctive taxon with well developed cingulum and long pointed pendulous processes were observed.

Plate 39, figs. 2 & 3

6. *Hystrichosphaerina* sp.

Type species: *H. schindewolfii* (Alberti, 1961)

Remarks: Occasional specimens of this genus were recovered, showing distal linkage between process groups. Preservation was generally poor.

Plate 29, figs. 1-10 & 12

7. *Kiokansium*/*Hystrichodinium* sp.

Type species of Kiokansium: *K. unituberculatum* (Tasch, in Tasch, McClure & Oftedahl, 1964)

Remarks: Several specimens, poorly preserved but possibly assignable to *Kiokansium* were recovered from the Hurlands Farm material.

Plate 39, figs. 4-13

8. *Muderongia simplex* subsp. *microperforata* (Davey, 1982)

Type species of genus: *M. mcwhaei* (Cookson & Eisenack, 1958)

Age range: Valanginian - Barremian (Evitt 1975); Early Valanginian - Late Ryazanian (Davey, 1982); Late Hauterivian (Harding, pers.comm.)

Remarks: A few very poorly preserved specimens of this species were recovered from two samples in the Warnham section. These specimens show typical small lateral horns and two short antapical horns.

Plate 42, figs. 1-8

9. Odontochitina operculata (Deflandre & Cookson, 1955)

Type species of genus: O. operculata (O. Wetzel, 1933; Deflandre & Cookson, 1955)

Age range: Middle Barremian - Maastrichtian

Remarks: One specimen of this species, showing well developed apical, antapical and single lateral horns and well developed endocyst was observed in sample HF.1

Plate 37, fig.4

10. Oligosphaeridium sp.

Type species: O. complex (White, 1842) Davey & Williams in Davey et al. (1966)

Remarks: Rare specimens displaying hollow trumpet shaped plate centred processes typical of this genus were recovered form sample HF.1

Plate 38, figs. 2 & 3

11. Pseudoceratium cf. pelliferum

Type species of genus: P. pelliferum (Gocht, 1957)

Age range: Berriasian - Aptian (Bujak & Williams, 1985)

Remarks: Several specimens of this taxon were recovered from sample HF.1. These specimens have slightly longer horns than the type species.

12. *Sirmiodinium* (Alberti,1961)/*Scriniodinium* (Klement,1957)
Remarks: A single specimen of a poorly preserved dinocyst was assigned to this broad group.
Plate 41,fig. 6

13. *Stiphrosphaeridium* (Davey, 1982)/*Surculosphaeridium* (Davey & Williams in Davey *et al.* 1966)/ *Cymosphaeridium* 'complex' (Davey,1982)
Remarks: Rare occurrences of poorly preserved chorate dinocysts that have been assigned to this general complex, are grouped here. All have solid generally plate centred processes that can be fenestrate or distally branched arising from a spherical or oval shaped autophragm.
Plate 30,figs. 1-15; Plate 31,figs. 1-6

14. *Spiniferites* sp. (Mantell,1850 emended Sarjeant,1970)
Type species of genus: *S. ramosus* (Ehrenberg,1838; Loeblich & Loeblich,1966)
Remarks: This long ranging genus is represented by a few specimens in the Hurlands Farm sample HF.1.
Plate 38,figs. 1,4, 7-9, 11 & 15.

15. *Subtilisphaera terrula* (Davey,1974; Lentin & Williams,1976
Type species of genus: *S. senegalensis* (Jain & Millepied, 1973)
Age range: Mid. Barremain (Davey,1974; Lentin & Williams, 1976); Late Hauterivian (Harding pers.comm.)

Remarks: This genus accommodates non-tabulate cavate dinocysts with a well developed cingulum.

Plate 40, figs. 17-22

16. Systematophora sp.

Type species of genus: S. areolata (Klement, 1960)

Remarks: Rare specimens bearing plate centred processes that tend to show ring complexes were observed.

Plate 38, figs. 5 & 6

17. Tanyosphaeridium variecalamum (Davey & Williams in Davey *et al.* 1966)

Type species of genus: T. variecalamum

Age range: Hauterivian - Santonian (Williams & Lentin in Evitt, 1975)

Remarks: This taxon is easily distinguished by its markedly elipsoid shape and short tubiform capitate non-tabular processes.

Plate 38, fig. 14

18. Proximochorate cysts undiff.

Remarks: A number of specimens that could only be assigned to this broad Form Taxonomic group were encountered. This group includes a wide variety of size, shape and wall thickness.

Plate 31, figs. 10-20

19. **Incertae sedis type 1**

Remarks: Specimens closely comparable with those encountered abundantly within a few samples of the study have recently been described by Hughes & Harding (1985). They have been treated using the biorecords nomenclatural method of the Cambridge School. "Incertae sedis type 1" of the present study fall within "cf B. CINCTURO-JUDITH" of the Hughes & Harding (1985). They are distinguished by a well pronounced cingulum and no definite archeopyle other than rupture in the apical region. The cingulum is defined either by a lighter equatorial band or zonate parallel lines, in the present material. It is noteworthy that this taxon may fall within the present generic limits of *Dapcodinium*, though this monotypic genus is presently restricted to the Early Mesozoic.

Palaeoenvironment: This dinocyst is particularly characteristic of the Beare Green samples examined in this study, falling into facies 34, 52 & 64 (see Appendix 1, Text-fig. B). These are distinctly freshwater palynofacies (see section 3.3(b)), leading to the conclusion that this dinocyst may be freshwater in origin.

Plate 40, figs. 1-15

MISCELLANEOUS PALYNOMORPHS

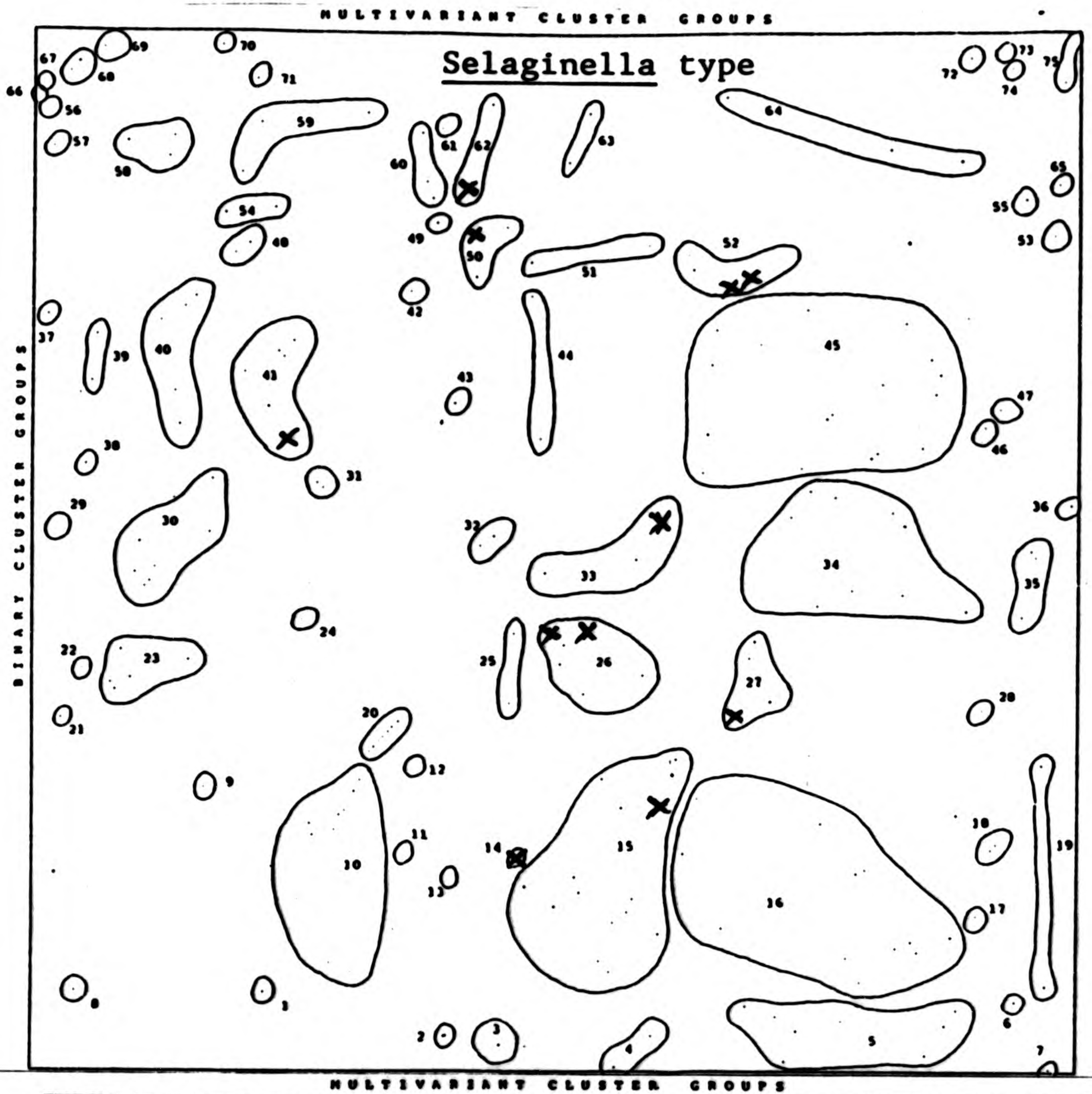
1. Celyphus rallus Batten (1973)

(Monospecific)

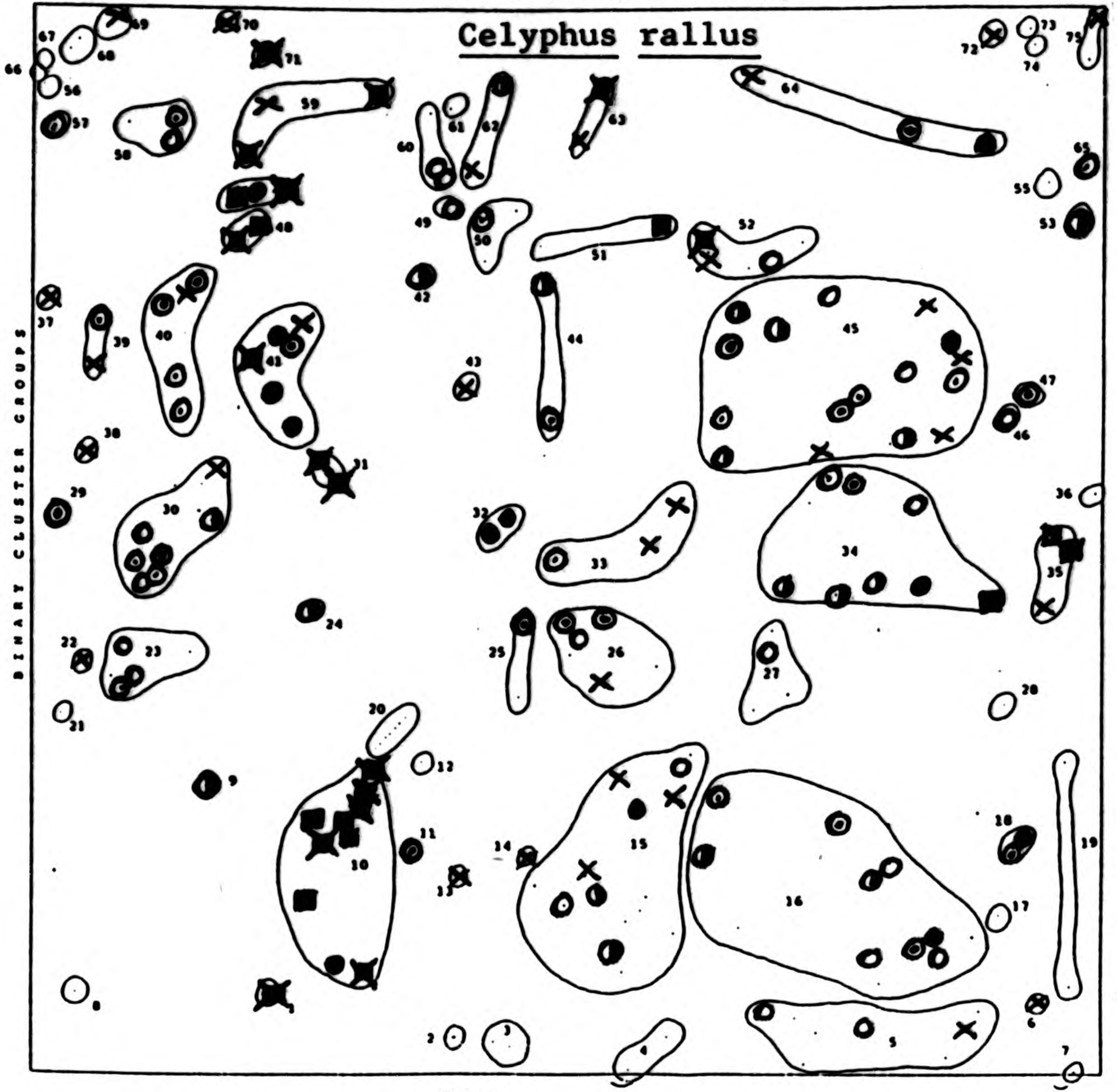
Remarks: This anomalous palynomorph was present in most samples examined in this study and was overwhelmingly abundant in some. Specimens observed conform closely to those described by Batten (1973). Individual specimens are in the form of a cylinder closed at one end, but bearing a pore and open at the other which becomes thin and fragmented. Dark bands normal with the long axis, ornament the body, that are random in position and thickness. Occasional spherical masses of these structures occur, where individuals are arranged with the pore closed and pointing towards the centre of the sphere. In this case the ornament is uniform between adjacent cells, giving the appearance of bands concentric with the spherical ball.

Plate 64, figs. 2-8

Palaeoenvironment: The abundance of this taxon within the Weald Clay material (see text-fig. 4.82) of the present study indicates that it must have played an important part in the overall ecology. It was sufficiently common for samples containing it in overwhelming abundance to form their own group, group VII. This group cuts across most of the binary cluster groups from B to G, that contain the majority of braidplain facies. However it is distinctly low in number within group A, that is the most marine influenced, and group J that represents generally dry uplifted facies. It is thus mainly confined to the 'intermedi-



Text-fig. 4.81



Text-fig. 4.82

ate' facies of the damp freshwater braidplain, so is almost certainly an aquatic organism. This is also highly likely given the spherical shape of Celyphus rallus masses. They may have tolerated slightly raised slainities given their abundance in facies 10. However, some factor other than salinity controls their ecology as they can be both very abundant or absent in both raised or lowered salinity palynofacies. Batten & Van Geel (1985) suggest the possible importance of raised pH in causing 'blooms' of it. They indicate an affinity of C. rallus with Rivulariacean blue-green algae.

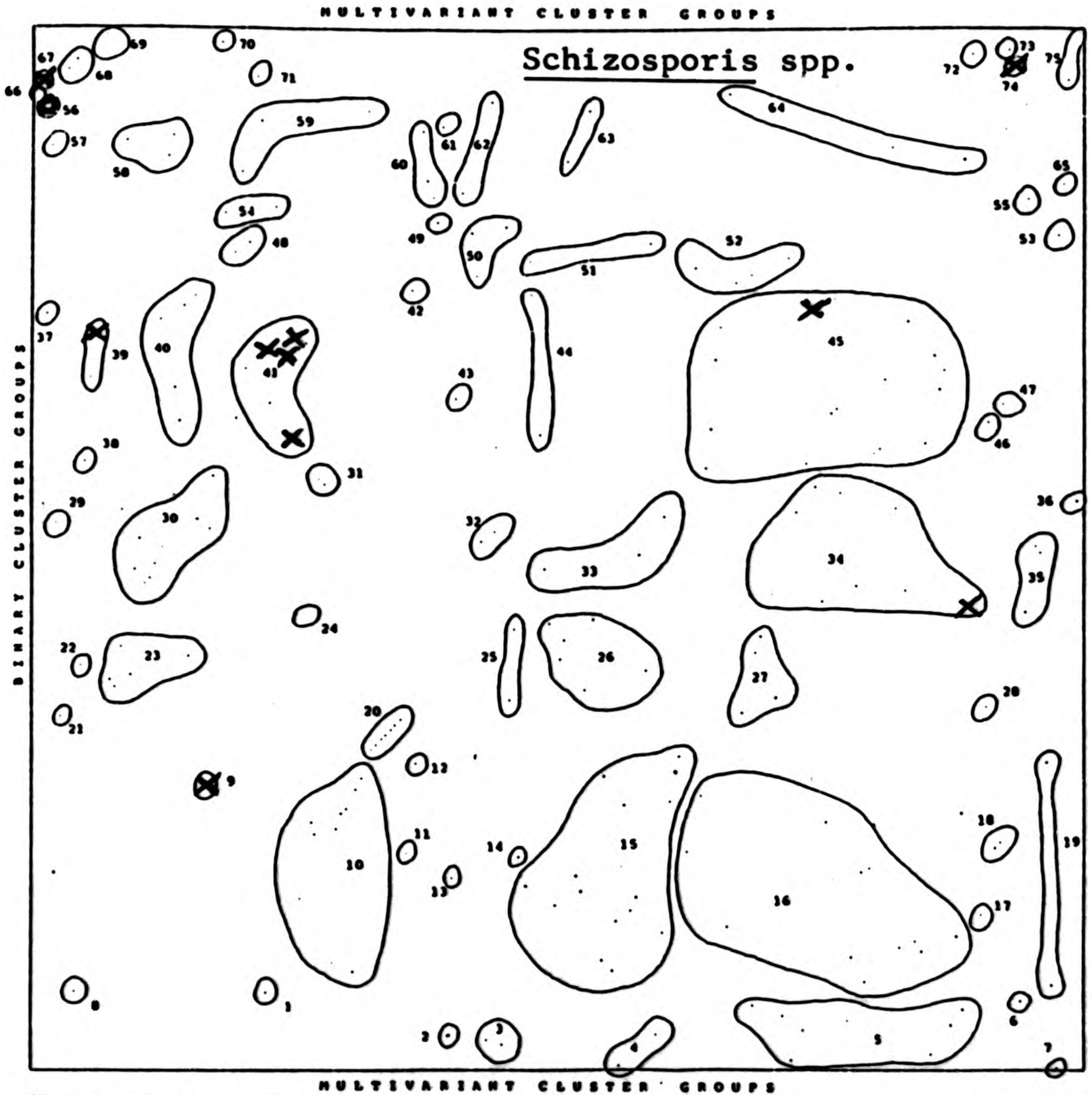
2. Genus Schizosporis Cookson & Dettman (1959)

Type species: S. reticulatus

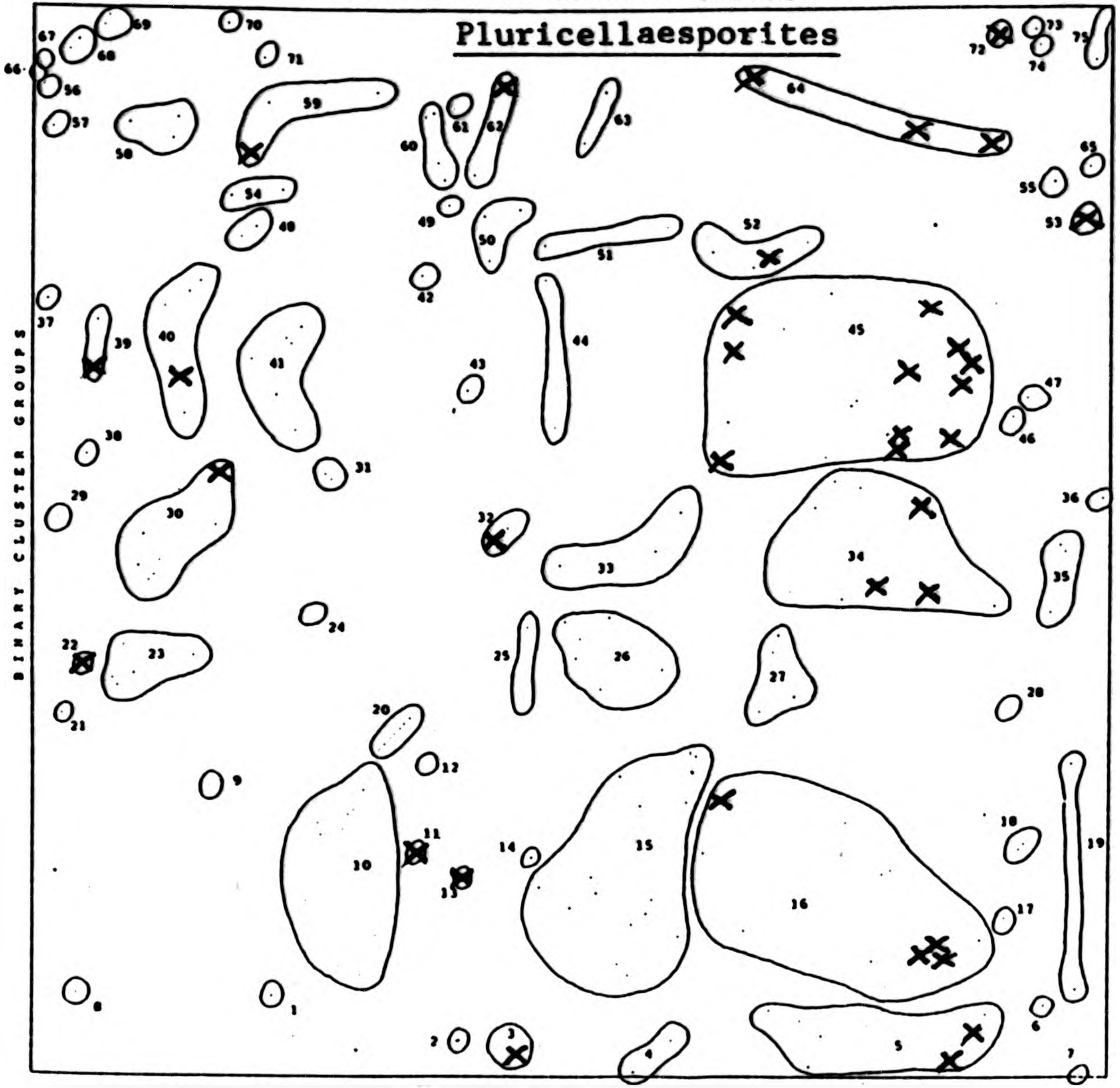
Remarks: These are biconvex spores that split into two parts and possess a thick well developed reticulum. Specimens encountered in this study are closely similar to S.reticulatus.

Plate 64, figs. 9-14

Palaeoenvironment: These spores are probably aquatic by analogy with modern day examples from a pond described by Pierce (1977). However in the present study the best and most well preserved examples were recovered in the dry uplifted near hinterland facies of group J (see text-fig. 4.83). If they were aquatic within this palaeoenvironment it may have been highly specialised such as temporary pools of water within damp vegetation as suggested in section 3.3 (b). They are quite negatively associated with the majority of damp freshwater or brackish braidplain facies



Text-fig. 4.83



Text-fig. 4.84

of the present study.

3. Class BASIDIOMYCETES

Genus **Pluricellaesporites** Van der Hammen(1954b)

Type species: P. typicus

Remarks: This genus accommodates fungal spores that are uniseriate with cells separated by septa. A slit opening in the septa links adjacent cells. No attempt has been made in this study to separate species.

Plate 65, figs. 19 - 30

Palaeoenvironment: Text-fig. 4.84 shows these fungal spores to be quite rare but generally occurring in the damper braidplain facies of groups B - I. It is to be expected that fungae would favour such damp conditions.

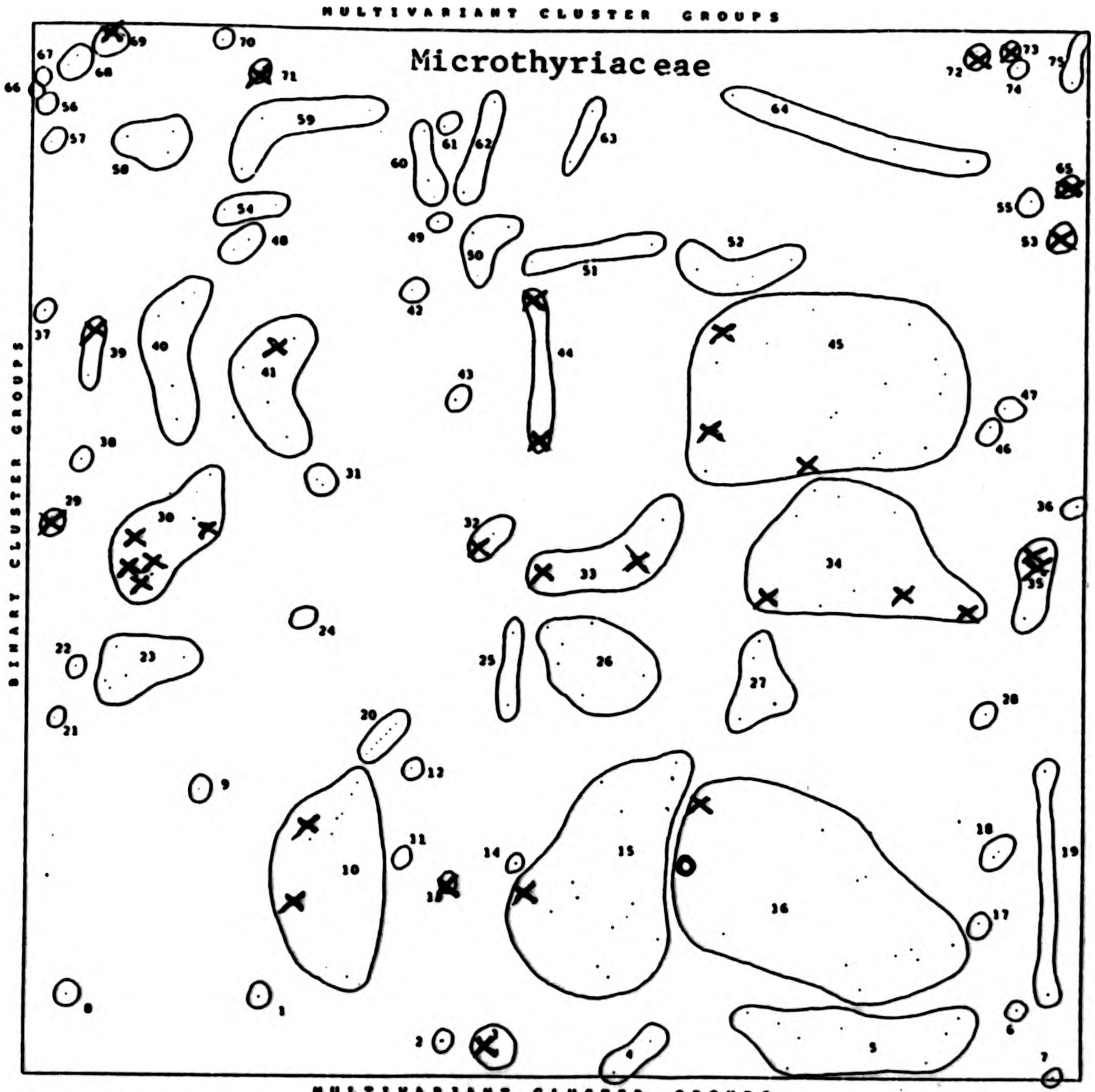
4. Class ASCOMYCETES

Family MICROTHYRIACEAE Dilcher (1965)

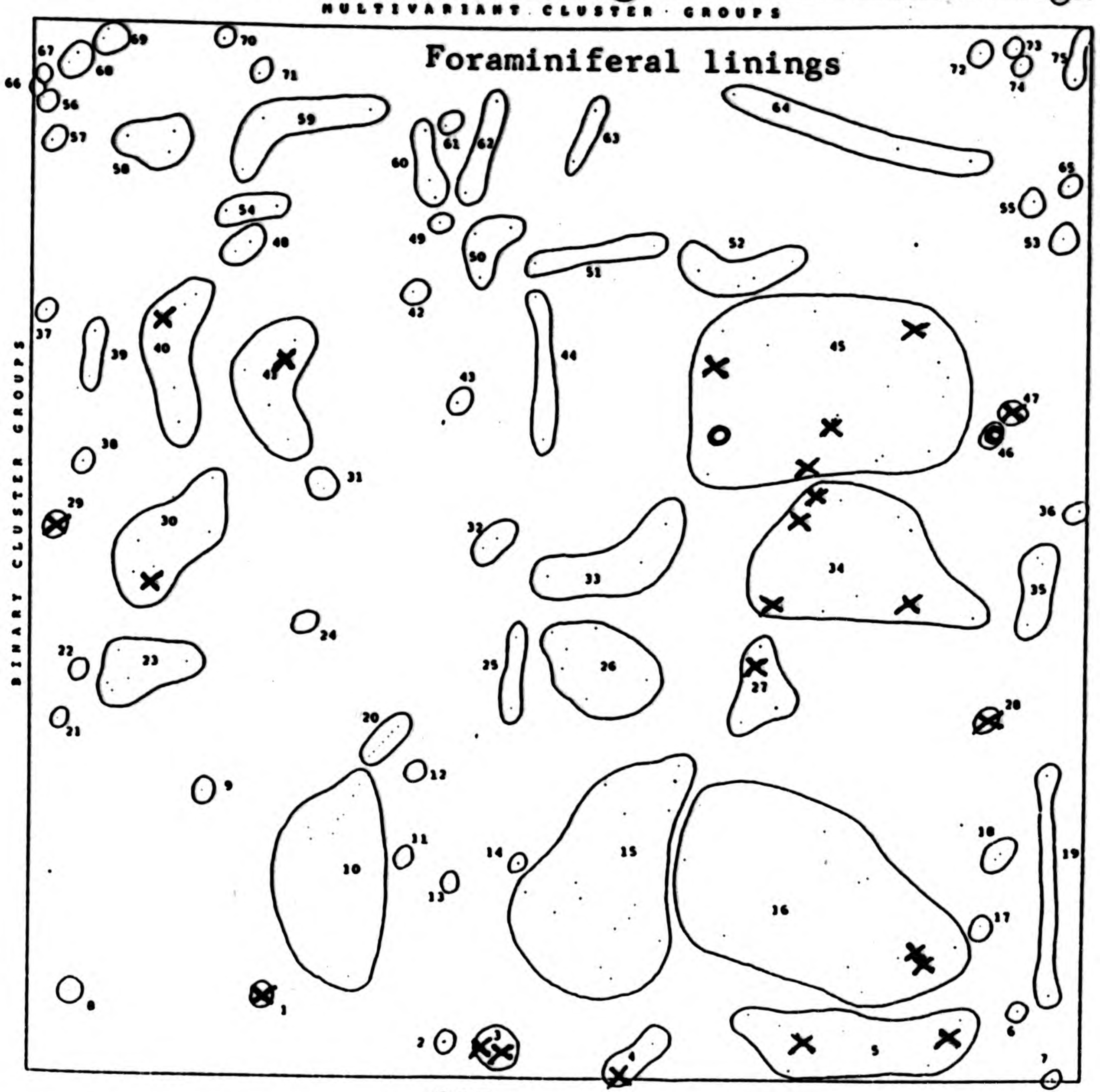
Remarks: These fungal fruiting bodies are characterised by a circular disc of radiating cells, that probably had an ecology similar to their infestation of higher plant leaves in the present day.

Plate 65, figs. 31 - 39

Palaeoenvironment: Text-fig. 4.85 shows these fungal bodies to be fairly evenly distributed within the damp freshwater facies of groups B - F, with a few occurrences in group J where there is some aquatic influence (facies 72 & 73.



Text-fig. 4.85



Text-fig. 4.86

5. Fungal material, type 1

<u>Remarks</u>: Rare occurrences of groups of small brown sheets of cells, of probably fungal origin were encountered.

<u>Plate 67, figs. 11-13</u>

6. Fungal material, type 2

<u>Remarks</u>: Rare occurrences of dichotomously branching structures of probable fungal origin were encountered.

<u>Plate 67, figs. 14-17</u>

7. ?Bacterial cells

<u>Remarks</u>: Small oval shaped cells of very simple morphology were observed in one sample, possibly representing bacterial cells.

<u>Plate 65, fig. 40</u>

8. Class CHLOROPHYCEAE

Family TASMANACEAE

Genus <u>Crassosphaera</u> Cookson & Manum (1960)

<u>Remarks</u>: Rare occurrences of these highly autofluorescent algal cells were encountered in the Weald Clay. They consist of hollow spherical cells with small surface projections, usually in a very regular pattern, each perforated by a radial tubule. Two species were recognised: <u>C. bella</u> Singh (1971) - Plate 65, figs. 9-15 & 18, and <u>C. ornata</u> Singh (1971) - Plate 65, figs. 16 & 17.

<u>Plate 65, figs. 9-18</u>

9. **Foraminifera**

Remarks: A few occurrences of chitinous foraminiferal linings were encountered in the present study, usually as single occurrences in isolated samples.

Plate 65, figs. 1 - 8 & 12 - 13

Palaeoenvironment: The marine association of the foraminifera is undoubted. As such the few occurrences form a lynch pin in the present study in allowing a definite marine connotation to be made for cluster group A (see text-fig. 4.86). Additional occurrences of them in facies 43 & 34 indicate marine influence of areas of the braidplain well away from the normal strandline. Foraminifera are quite absent within cluster groups G - J, supporting the evidence that these represent palaeoenvironments near the hinterland, well away from marine influence, and were generally freshwater and dry uplifted depositional sites.

REWORKED JURASSIC DINOCYSTS

1. Ctenidodinium cf. gochtii (Sarjeant, 1976)

Type species of genus: C. ornatum (Eisenack, 1935) Deflandre (1938)

Age range: Bajocian - Callovian (Bujak & Williams, 1985)

Plate 32, fig. 11

2. Glossodinium dimorphum (Ioannides, Stavrinos & Downie, 1977)

Type species of genus: G. dimorphum

Age range: Oxfordian - Portlandian

Plate 32, fig. 8

3(a) Gonyaulacysta jurassica (Deflandre, 1938; Norris & Sarjeant, 1985)

Type species of genus: G. jurassica

Age range: Callovian - Kimmeridgian

Plate 34, figs. 1-5; Plate, 35 figs. 1 & 2

(b) Gonyaulacysta cf. helicoidea (Eisenack & Cookson, 1960; Sarjeant in Davey *et al.* 1969)

Plate 34. fig. 16 a & b

(c) Gonyaulacysta sp.

Plate 34, fig. 7

4. Kleithriasphaeridium sp.

Type species of genus: K. corrugutam (Davey, 1974)

Plate 33, fig. 1

5. Leptodinium sp.

Type species of genus: L. subtile (Klement, 1960)

Plate 34, fig. 19

6(a) Scriniodinium crystallinum (Deflandre, 1938; Klement, 1960)

Type species of genus: S. crystallinum

Age range: Callovian - Oxfordian

Plate 35, figs. 7 & 8

(b) Scriniodinium sp.

Plate 34, fig. 9; Plate 35, fig. 6

7. Sirmiodinium grossii (Alberti, 1960)

Type species of genus: S. grossii

Age range: Bathonian - Oxfordian

Plate 32, fig. 20

8. Systematophora sp.

Type species of genus: S. areolata (Klement, 1960)

Plate 35, figs. 4 & 5

9. Tubotuberella cf. eisenackii (Deflandre, 1938)

Type species of genus: T. rhombiformis (Vozzhenikova, 1967)

Age range: Bajocian - Oxfordian (Williams & Bujak, 1985)

Plate 34, fig. 17

10(a) Wanea fimbriata (Sarjeant,1961)

Type species of genus: W. spectabilis (Deflandre & Cookson, 1955; Cookson & Eisenack,1958)

Age range: Oxfordian (Woollam & Riding,1983)

Plate 32,fig. 15

(b) Wanea sp.

Plate 31, fig. 9

REWORKED CARBONIFEROUS SPORES

1. Genus Densosporites (Berry) Butterworth, Jansonius, Smith & Staplin (1964)

   Type species: D.covensis Berry (1937)

   Plate 27, figs. 16-23 & 34

   Remarks: These spores are clearly reworked, showing a much higher 'Thermal alteration index' colour than the *in situ* material. They show the typical thickened cingulum of this genus.

2. Genus Lycospora (Schopf, Wilson & Bentall) Potonié & Kremp (1954)

   Type species: L. micropapillata (Wilson & Coe) Schopf, Wilson & Bentall (1944)

   Plate 27, figs. 24-30

   Remarks: This genus accommodates cingulate trilete spores with a granulate or infragranulate body. It is an extremely ubiquitous genus within the Carboniferous. Two species can be recognised, L. pellucida (Wicher) Schopf, Wilson & Bentall (1944) (Plate 27, fig.24) and L. pusilla (Ibrahim) Schopf, Wilson & Bentall (1944) (Plate 27, figs. 25-30)

3. Genus Dictyotriletes (Naumova) Smith & Butterworth (1967)

   Type species: C. bireticulatus (Ibrahim) Potonié & Kremp (1954)

   Plate 27, figs. 31-39

Remarks: Spores tentatively assigned to Dictyotriletes sp. were recovered in this study, all showing very high thermal alteration index. They show a typical reticulate ornament.

These spores are typically Carboniferous, representing reworking from Carboniferous rocks of the source lands. They are generally long ranging Viséan-Westphalian. However, Dictyotriletes is a typically Westphalian genus.

REWORKED PALAEOZOIC ACRITARCHS

Very rare occurrences of Palaeozoic acritarchs were observed in the Weald Clay. These are illustrated on Plate 27, figs. 40-46. A variety of species can be distinguished but these have not been assigned to recognised taxa. They all show very high thermal alteration index typical of the Palaeozoic.

MISCELLANEOUS ORGANIC MATERIAL

1. CENOSPHERES

A number of spherical structures of doubtful affinity were observed in the Weald Clay. (Plate 28, figs. 2-5 & 55-57; Plate 66, fig. 1). The structure illustrated on Plate 66, fig. 1 is closely similar to Linotolypae of Eisenack (1978). According to Jansonius (1984), this material is a modern contaminant produced by diesel engines, typically taxis, and is a common constituent of dust in London.

2. LEAF HAIRS

One structure observed from the Weald Clay (Plate 66, fig. 2) bears strong resemblance to a group of leaf hairs.

3. UNKNOWN PLANT/ANIMAL STRUCTURE

Plate 66, figs. 3 & 4, illustrates a fragment of a membraneous structure bearing a row of closely set spines along one edge. This is probably of arthropodal or possible botanical origin. One segmented oval shaped object (Plate 66, fig.5) is of unknown affinity.

4. FISH OSTEOCYTES

Abundant specimens of possible bone cells from fish were observed in some Weald Clay samples, typically those containaing visible bone fragments in hand specimen. These structures show a central plate with randomly branching appendages (Plate 71,figs. 1-12). Figure 17 shows one with 'bone' material supported between the branching appendages. They form a useful brackish/ marine indicator. Other material of possible fish bone origin occurs as a plate with a random pattern of concentric circles (Plate 71, figs.13, 15 & 16). Larger fragments (Plate 71, figs. 14 & 18) may also be of fish (Teleost) origin.

5. AMOEBIC CYST

Rare occurrences of small egg shaped structures displaying a thick wall composed of a regular mesh pattern of elongated hexagons. A large pore is visible at one end (Plate 71,figs. 19-27). These structures may be remains of Rhizopods (Thecamoeboids). (Tappan 1980)

6. FUNGAL MATERIAL

Rare occurrences of probable fungal material, forming hyphal masses of tissue,were observed (Plate 76, figs. 15, 17 & 18 ; Plate 64, fig. 1).

7. AMORPHOUS MASS

Sometimes of quite common occurrence these structures are of various size and shape (Plate 78,figs. 1-9). They show typical compression folds of a spherical structure. The origin of these 'amorphous masses' is unknown, but they may be produced during chemical maceration during preparation. Bubbles of gas produced during HF treatment may collect organic material on their surface which partly solidifies.

8. ANNULUS CELLS & SPORE MASSES

Occasionally observed in the Weald Clay were remains of the thickened annulus cells from the dehiscence mechanism of the sporangium from pteridophytes together with spore masses (Plate 63, figs. 1-12).

9. MISCELLANEOUS SPORINITE

Various structures resembling spores in size and shape were encountered during routine logging, but of uncertain affinity (Plate 62, figs. 9-15 & 19). Some are probably undifferentiated algal cysts (Plate 28, figs. 49-52).

10. PLANT STRUCTURE (TYPE A)

A few records were made of short tubular structures with a flared, frilled margin at one end, sometimes forming small colonies (Plate 62, figs. 16-18).

11. MICROFOSSIL (TYPE A)

A single specimen of a small oval structure bearing a herringbone pattern of diagonally branching fine hairs was encountered. This structure is of unknown affinity (Plate 62, fig. 20 a-b).

12. STOMATA

A rare occurrence of cuticular material bearing stomatal apertures was observed (Plate 70,fig.8)

13. CUTICULAR MATERIAL

A few large fragments of ?plant cuticle showing epidermal cells with a 'sutured' or 'jig-saw' margin were encountered (Plate 70,figs. 1-4).

14. VITRINITE

A few large fragments of organic material showing oblong shaped cells were encountered, possibly representing vitrinite (Plate 68, figs. 1-7; Plate 69, figs. 1,3, 6 & 7). Other fragments showing distinct cross connecting elements that may be schlerenchymatous tissues were observed (Plate 67, figs. 5,7, & 8). Some well preserved tissues were observed bearing rows of ring-like thickenings, possibly also of schlenchymatous origin (Plate 67, figs. 1-4 & 6).

15. INERTINITE (SEMIFUSINITE, FUSINITE)

Some large opaque fragments of organic material showing good cellular structure were occasionally observed. These are almost certainly fusinite fragments produced by incomplete burning of woody material (Plate 70, figs. 5-7 & 8-10; Plate 76,figs. 1-14 & 16; Plate 77,figs. 1-11, Plate 89, fig.1.

16. LIPTINITE

Liptinitic kerogen (amorphous liptinite) that is strongly autofluorescent is illustrated on Plate 86; Plate 88, fig.1; Plate 90, figs. 1-3 & Plate 91. Liptinitic resin is illustrated on Plate 87, fig. 7.

Chapter 5

CONCLUSIONS

5.1 GENERAL SUMMARY

The Wealden Basin was formed in the Early Cretaceous at a time of worldwide marine regression. It was one of several small provincial basins that were formed, of dominantly terrestrial character, in which the universal stratigraphic control provided, in the Jurassic, by open marine ammonites and dinocysts was lost. The sediments of the Wealden Basin show a fine balance between terrestrial and marine influence, particularly so in the Weald Clay times. Clastic input into the basin was comparatively reduced at this time following erosion of the London-Brabant source-lands. This fine balance between terrestrial and marine influence resulted in comparatively rapid vertical and lateral facies changes within the Weald Clay. Allen (1981) has shown that the sediments are best interpreted at present, as braidplain/mudplain deposits laid down by meandering rivers, that were liable to intermittent flooding by brackish/marine waters. This unstable, marginal environment could not support trees, but only a shrub flora of ferns.

The Weald Clay yields rich and well preserved palynological assemblages from almost all samples processessed. This assemblage includes spores, pollen, freshwater algae, dinocysts and other palynomorphs, together with kerogen material. In the present study spores assignable to 61 genera comprising 97 assigned species and 46 unassigned species have been observed. In addition 3 in situ pollen taxa have been recognised and 12 spore types of unknown affinity. A number of autofluorescent algal types have been recognised, assigned to 6 recognised genera. One of these, Scenedesmus, has not previously been described in the fossil record. Another 9 taxa of fluorescent algae, here given informal names, have been observed that have not previously been described. Records of in situ dinocysts are generally rare, however 21 taxa have been recognised, mostly from upper Weald Clay samples that are transitional to the transgressive Atherfield Clay. Some of these dinocysts are poorly preserved, and thus assigned to generalised groups. Nine miscellaneous palynomorph types have been observed. Reworked palynomorphs in the form of 14 Jurassic dinocyst taxa, 4 Carboniferous spore taxa and some very rare Palaeozoic acritarchs were encountered. Finally 15 different miscellaneous organic structures have been described.

These palynomorphs have not been exhaustively described, but only provide a catalogue, together with photographs of all the types encountered. This study is primarily a palynofacies analysis carried out in an attempt to refine palaeoenvironmental information on the Weald Clay mudplain and to examine recurrent groups of palynomorphs, in an attempt to glean palaeoecological information on the taxa, and in the case of the spores, their respective parent plants.

The palynofacies study was carried out using a cluster analysis package (CLUSTAN) on 87 of the most commonly occurring spore/pollen taxa, both generic groups and where possible individual species. Of these, 10 were particulaly abundant taxa. A total of 211 Weald Clay samples was used in this analysis. This included 6 samples that were analysed twice as separate samples, once including Celyphus rallus and once ignoring this taxon, that could be overwhelmingly abundant in the palynomorph assemblage. The cluster analysis package was run twice, using binary data (presence/absence) and multivariate data (percentage frequency) on the same samples. In both cases, the cluster groups produced were analysed in detail for the criteria of spore/pollen occurrence or abundance that characterised each one. The cluster analysis results were produced in the form of a dendrogram. This format allows any number of cluster groups to be allocated, depending on the desired coefficient of association, from a maximum corresponding to the full set of 211 samples, to a minimum of one when the entire set is united. The binary data fell easily into 10 cluster groups, all of approximately the same size. Thirteen multivariate cluster groups were created. However the multivariate data showed profound imbalance of cluster group size. Approximately half of all the samples were included in one cluster group, while most of the others contained only a few or even one sample. Using a higher coefficient of association did allow the single large cluster group to be dissociated, but result in an even greater number of very minor groups. A compromise was sought using several different coefficients of association (or 'cut-off points') with clusters and subclusters, to allow the small and large groups to be emphasised as necessary. Subclusters were also allocated to the binary cluster groups. The spore/pollen occurrence levels for each taxon across the 10 binary cluster groups were plotted on a series of graphs called 'percentage occurrence traces' (P.O.T.'s). Taxa showing similar trends were plotted on the same axes. It is postulated that such taxa must be palaeoecologically related. Percentage frequency traces (P.F.T.'s) were plotted for the 13 multivariate cluster groups, however it was not possible to show similarity between P.F.T.'s by plotting them together on the same axes due to the imbalanced nature of the cluster groups.

The 10 binary, and to a lesser extent the 13 multivariate cluster groups showed particular characteristic associations with kerogen type, fluorescent algae, lithology and marine indicators. This suggests that they do to some extent, represent true palaeoecological associations controlled by the palaeoenvironment. In the case of the binary data, one of the cluster groups showed distinct marine influence (comparatively common foraminiferal linings and dinocysts). This marine influence was diminished in the next most closely related group, and generally showed a decline throughout the other groups. This indicates that the palaeoecological associations represented by the binary cluster groups are in part controlled by salinity. Detailed analysis of the spore/pollen diversity within the binary cluster groups was done. (The effect of different cluster group size was compensated for using statistical techniques). This showed a general trend of markedly increasing diversity coincident with decreasing marine influence. This suggested that the cluster groups represent a trend of parent plant communities from 'mature', species-rich communities of the proximal (with respect to the sourcelands) drier uplifted mudplain, to poor diversity 'pioneer' plant communities of the distal mudplain, where the terrain was more low-lying, water-logged and liable to brackish/marine inundation. One cluster group was found not to conform to this general trend, in showing a high diversity of taxa but generally greater marine influence. However this same cluster group contained no dominant taxa at high occurrence and was markedly characterised by fine grey amorphous organic matter. It is postulated that this cluster group represents lagoonal/lacustrine deposition close to the strandline where fine organic material could settle, away from alluvial currents. Such an environment would not support a local pteridophyte flora but would act as an efficient palynomorph trap for transported taxa, explaining its anomalously high spore/pollen diversity but low dominant spore/pollen count. A by-product of this environmental trend was that spore taxa, representing parent plants possibly tolerant of brackish/marine influence, could be recognised. Such taxa include Vitreisporites pallidus and Cerebropollenites mesozoicus. In addition certain kerogen types (notably amorphous liptinite), fluorescent algae (notably Segmented Alga type 1) and lithologies (notably limestone) could be recognised as associated with marine influence.

The multivariate data did not reveal a trend that could be related to salinity or spore/pollen diversity. Groups were defined on the abundance of particular cosmopolitan taxa such as Cicatricosisporites spp., Celyphus rallus and Gleicheniidites spp.. The single large group seemed merely to show a particular association of cosmopolitan taxa that were very common. The small cluster groups however showed particularly unusual taxonomic associations and abundances, some of which may represent freak preservation of an extremely localised community. In fact many of these small groups coincide with the 'proximal' binary cluster groups, suggesting that their preservation is due to their being laid down well away from brackish/marine and alluvial channel influence of the distal mudplain. The multivariate cluster group containing abundant Gleicheniidites contained high records of bisaccate pollen (the latter thought to be derived from the tree flora of the source-lands) and inertinite (probably derived from comminuted woody charcoal from forest fires on the source-lands). Gleicheniidites' parent plant may therefore have been a common understorey fern of the forested source-lands. The multivariate cluster group containing abundant Cicatricosisporites spp. also showed high diversity of other pteridophyte spores, indicating that it probably represents 'typical' high diversity, generally distal mudplain environments.

The multivariate and binary cluster groups were placed as two axes of a matrix, and the samples plotted within the matrix. Groups of samples falling close together were enclosed and designated as palynofacies. A total of 75 such facies were erected, of which 15 formed 'principal' facies comprising four or more samples. The derived palynofacies were each given a palaeoenvironmental 'descripter' based on known information concerning marine influence, lagoonal/lacustrine influence, channel influence, aquatic freshwater influence and spore/pollen diversity associated with the 'distal' versus 'proximal' binary cluster groups. These derived facies were used in drawing a sedimentary model for the Weald Clay mudplain (enclosure 17).

Samples within the cluster analysis were placed back in stratigraphic order for each locality and the palaeoenvironmental 'descripter' for each sample was used to plot a depositional environmental sequence for each locality. The palynofacies of each sample was plotted to produce a 'palynofacies log' supported by direct palynomorph trends revealed by the 'pollen diagram' for each locality. The Warnham samples yielded an interesting trend that suggested comparatively sudden brackish/marine transgression associated with the Viviparus and Filosina limestones, followed by gradually increasing freshwater influence upsection, suggesting gradual regression by mudplain/braidplain progradation. This offers a different interpretation of the Wealden cyclothem from that presently recognised (Worssam & Morter, 1978). This interpretation invokes renewed course clastic supply by rejuvenation of the source-lands as the initial deposits of the cycle, followed by gradual marine transgression as alluvial supply lapsed, with erosion of the source-lands. The Warnham section shows the transgressive marine influence as a fairly sudden event, with hardly any change in palynofacies above and below an alluvial sand unit near the top of the section. If the Warnham section is representative of a typical Wealden cyclothem, this would also imply reinterpretation of the accepted tectonic control of the basin and source hinterland of the London Brabant Massif in the Early Cretaceous.

The two cores examined from Chailey (CH/M & CH/P) are located in comparatively close proximity and partly cover the same stratigraphic interval. However rapid lateral variations in lithofacies prevent a direct correlation. Palynofacies information presented in this study indicates a correlation based on a salinity change that could not be recognised without the use of cluster analysis to produce palaeoenvironmental 'descripters', (see page 232).

The Beare Green, Lingfield and Pluckley samples seem to show, on the whole, more monotonous mudplain sequences, generally freshwater in aspect. Probably, the sections are too small to reveal any good regressive or transgressive trends. The Hurlands Farm section, representing upper Weald Clay/transitional Atherfield Clay samples, reveals a generally monotonous sequence of freshwater spore/pollen palynofacies, but with marine elements not normally seen within the Weald Clay proper, such as abundant dinocysts. This apparent contradiction of palynofacies features probably indicates that the muds are largely reworked locally from the Weald Clay proper, the London Brabant Massif at this time having virtually ceased to be a positive feature contributing sediments into the basin. Mixing of palynofacies by reworking may account for the monotonous character of the spore/pollen palynofacies with 'introduced' marine elements. In addition the spore/pollen taxa show very poor preservation not seen in the Weald Clay proper, consistent with reworking.

The 211 Weald Clay samples from several localities within the Weald Clay, separated vertically and laterally, can perhaps be regarded as a representative sample of the formation. The percentage of samples falling into particular palynofacies may therefore be comparable with the percentage by area within the mudplain represented by particular derived palaeoenvironments.

For instance 47 of the 211 samples (22%) fall into the lagoonal/ lacsutrine category suggesting that within the mudplain 22% of the terrain may have been occupied by this palaeoenvironment. This information is of use in reconstructing the palaeoenvironmental setting of the mudplain. The percentage of palynofacies for the various samples localities have been plotted in this way in order to compare and contrast the general depostional regimes represented at all the localities.

Published palynomorph data by Norris (1968, 1969) on palynomorph assemblages across the Jurassic/Cretaceous boundary shows changes related to an overall decrease in salinity associated with marine regression at this time. These salinity controlled palynomorph assemblages generally agree with those seen 'in microcosm ' within the brackish to freshwater gradient of the Weald Clay braidplain. Recently published data by Anderson (1985) shows salinity related changes in ostracod assemblages that agree with those indicated in the present study on palynology for the same Weald Clay interval.

Chapter 4 provides brief descriptions of all the palynomorphs encountered in this study. The derived palynofacies model is used in discussing the palaeoecology of each taxon wherever possible.

Finally four appendices describe and discuss the in situ dinocysts (biostratigraphy), particular corrosion patterns of spore/pollen taxa encountered, the autofluorescent phenomoena of Weald Clay palnymorphs and the fragments of insect debris (including possible Lepidopteran cuticular scales)encountered during routine logging. The derived palynofacies are used in these appendices where possible in making palaeoenvironmental conclusions and supporting arguments, in the case of the insect fragments, favouring their interpretation as in situ rather than modern contaminants.

In a separate volume is provided a catalogue of 93 plates and captions of all the palynomorph types together with folded palynofacies and palaeoenvironmental charts (enclosures 1-17).

5.2 EVALUATION OF STATISTICAL METHODS

1. Cluster analysis using the program CLUSTAN has been carried out on spore/pollen count data from 211 Early Cretaceous Weald Clay samples from Southeast England. The purpose of this analysis has been to examine recurrent associations of spore/pollen taxa. Batten (1973a) used cluster analysis to analyse Wealden palynological assemblages, but this was based on the older Hastings Beds that underlie the Weald Clay. CLUSTAN has not previously been used in studies of Early Cretaceous palynological assemblages.

2. The CLUSTAN program was run twice, firstly on the spore/pollen count data encoded into the program as either present or absent (binary format), and secondly on the full percentage frequency count data for each taxon (multivariate or quantitative format). The cluster groups in each case were generated in the form of dendrograms that separated the 211 samples into a number of cluster groups. The binary dendrogram was found to produce ten fairly clear cut cluster groups with (very approximately) similar numbers of samples in each group. However, the multivariate dendrogram was found not to produce clear cut evenly balanced cluster groups. Using a convenient "cut-off point" the dendrogram could be separated into 13 cluster groups that contained widely varying numbers of samples. Approximately half of the samples were found to fall into one large cluster group, while the remainder were separated into cluster groups comprising only one or a few samples. This difference in 'quality' of the clusters produced by each

dendrogram immediately suggests that the presence/absence binary method is superior to the quantitative or multivariate method in palynological analysis of the Weald Clay. This has been confirmed during analysis of the palynofacies of both types of cluster groups.

3. In addition to the dendrogram print-out by CLUSTAN the binary analysis also produced for each taxon, a list of the percentage of samples in each cluster group containing that taxon. This information was used to plot what have here been termed "percentage occurrence traces" (POT's) for each taxon across the ten cluster groups. In a like manner the multivariate data has been plotted for the 13 designated cluster groups, producing "percentage frequency traces" (PFT's) for each taxon. However these are rather cruder than the POT's, as they comprise only the mean percentage frequency of each taxon within all the samples of each cluster group. They are less meaningful due to the great difference in size of the multivariate cluster groups.

4. The POT's allow a way of grouping together taxa using the CLUSTAN cluster groups that are based on groups of samples. This is done by plotting on the same axes, POT's that show similar trends between the ten binary cluster groups. It has not proved possible to group the PFT's in the same way.

5.3 SIGNIFICANT CONTRIBUTIONS OF THE WORK

1. Cluster groups have been designated on spore/pollen count data from 211 Weald Clay samples, using the computer program CLUSTAN (Wishart 1978). It has been shown in this study that the cluster groups obtained are to some extent natural groups that represent particular associations of Weald Clay braidplain palaeoenvironments. The evidence for this has come from distinctive kerogen assemblages, lithologies and freshwater algal assemblages that characterise each cluster group. These parameters were not used in the clustering procedure that was based solely on the spore/pollen taxa.

2. Evidence of particular kerogen, lithological and freshwater algal assemblages characterising each cluster group suggests that the spore/pollen taxa of each group must to some extent represent parent plants that were palaeoecologically/taphonomically related. Use of POT's (as described above) to plot together taxa showing similar ocurrence trends across all the binary cluster groups provides evidence that such taxa represent parent plants that probably were palaeoecologically related. Such palaeoecological associations between spore/pollen taxa have not been shown in this way before. Batten (1973a) demonstrated a number of recurrent associations of spore genera in the Hastings Beds underlying the Weald Clay using cluster analysis. Some of these associations broadly agree with those seen here though the present study concentrates on individual species rather than genera.

3. A series of parent plant associations has been demonstrated from distal to proximal parts of the Weald Clay braidplain. This has not previously been shown in any palynofacies study.

Rare marine dinocysts in one binary cluster group (A) and high inertinitic kerogen percentages in another binary cluster group (J) (suggesting proximity to the London/ Brabant massif sourcelands) has been recorded. This suggests that parent plant associations represented by the distinctive spore/pollen taxa of each cluster group may be related to the position of these plant associations on the Weald Clay braidplain. Other binary cluster groups show varying degrees of intermediate characteristics between these two extremes, such as the presence and abundance of various aquatic algal indicators and aquatic derived kerogen, that suggests low-lying damper terrains nearer to the strandline. Some corroborating evidence that a series of plant associations from proximal to distal parts of the braidplain may be represented by the binary cluster groups, has come from consideration of palynomorph diversity of each binary cluster group. The cluster groups that appear to represent the most low lying locations, proximal with respect to the strandline have distinctly lower diversity than those that are more proximal with respect to the sourcelands. This trend would be expected, with species poor communities in 'pioneer' habitats influenced by brackish water along the strandline, and mature species rich communities in stable, dry, uplifted locations nearer to the sourcelands (Frederiksen,1985).

4. The multivariate spore/pollen cluster groups show characteristic kerogen types, lithologies and freshwater algal assemblages to some degree. They are therefore only very generally representative of actual parent plant communities and have not been demonstrated to show any definite palaeoecological trends. However they have been used as the second axis of a grid that plots on the first axis the upper to lower braidplain binary cluster groups. It is appreciated that the order of the binary cluster groups (A - J) produced by the dendrogram is partly flexible. However the palynofacies information has shown that the order as provided by the dendrogram broadly agrees with the trend from more strandline associated clusters at one end to more source hinterland associated clusters at the other. Thus, it has not necessitated changing the cluster group sequence, though arguably some minor changes could be made.
This method of combination of multivariate and binary spore/pollen cluster groups has not previously been attempted in any palynological study. The grid so produced, being based on a proven palaeoecological trend, places all of the 211 samples individually within a position that broadly reflects the palaeoecology of plant communities across the Weald Clay braidplain. Samples falling close together within this grid have been enclosed by a circle and numbered sequentially. A total of 75 palynofacies assemblages has been so designated.

5. This palaeoenvironmental grid has been used to plot the occurrence and abundance of all 87 spore/pollen taxa in all 211 samples used in the cluster analysis in an attempt to attach palaeoenvironmental parameters to the parent plant of each taxon. Some corroborating evidence of spore/pollen palaeoecological interpretations of the present study has come from the work of Norris (1968, 1970) who noted particular changes in the assemblages of spores across the Jurassic/Cretaceous boundary. These changes are associated with environmental change from marine to non-marine at this time. The most marine influenced suite of Norris is similar to the strandline palynoflora of the present study, while the more non-marine suites are similar to the dry uplifted near hinterland palynoflora of the present study.

6. The numbering sequence of the 75 palynofacies has been arranged so that the lowest numbers are within the marine influenced, strandline binary cluster group, and the highest numbers those furthest away from the strandline, near to the sourcelands. By plotting these numbers against the sampled sections in stratigraphic order, it has been possible to plot a 'palynofacies log' for each section. This log has been used in a detailed analysis of the palaeoenvironmental trend for each sampled location. This method of palynofacies analysis of a sequence has not previously been attempted. At one location (Warnham), a marine transgression has been demonstrated, initiated

with Viviparus and Filosina limestones that grade up through mudstones to regressive freshwater sandstones. This is possibly a cyclic sequence initiated by basin subsidence followed by gradual sediment infill back to base level. This differs from the presently recognised Wealden cyclothem (Worssam & Morter 1978) that is thought to be initiated by uplift of the sourcelands leading to deposition of regressive sands in the basin, followed by gradual marine transgression as the sediment supply became exhausted by erosion. Some corroborating evidence for the present palynofacies interpretation at Warnham has been provided by the ostracod faunicycles of Anderson (1985).

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APPENDIX 1

DINOPHYCEAE

Introduction

Persistent marine conditions are unusual in the Weald Clay, so *in situ* marine dinocysts are a rare component of the palynological assemblage. Where dinocysts do occur they are still overwhelmingly dominated by land derived spores, pollen and freshwater algal cysts. However a small diversity of dinocysts were observed in the present study, some of important biostratigraphic value. Occasional 'flood' occurrences of reworked Jurassic dinocysts were observed.

Biostratigraphy

In situ dinocysts are recorded on Plates 29-31, 33 & 36-42. Five of the *in situ* dinocyst taxa have been drawn up on a range chart (text-fig. A). *Pseudoceratium pelliferum* a general range within the Ryazanian - Aptian (Bujak & Williams, 1985). *Tanyosphaeridium variecalamum* ranges from the Hauterivian to Santonian. (Williams & Lentin in Evitt, 1975). *Muderongia simplex* is given a range of Valanginian to Barremian by Evitt (1975). However Davey (1982) considers the *M. simplex* subspecies *microperforata* to be restricted to the Early Valanginian - Late Ryazanian, though recently (Harding, 1986 pers.comm.) considers it to be restricted to the Late Hauterivian. *Subtilisphaera terrula* is considered to be restricted to the mid Barremian by Davey (1974), though Harding (pers.comm.) suggests a Late Hauterivian age. An occurrence of Odontochitina operculata, considered to range from mid Barremain to Maastrichtian, was recorded in one upper Weald Clay sample from the Hurlands Farm borehole.

A general age range of Hautervian - Barremian is therefore recorded for the Weald Clay, in keeping with its recognised age (Rawson et al.1978).

Palaeoenvironment

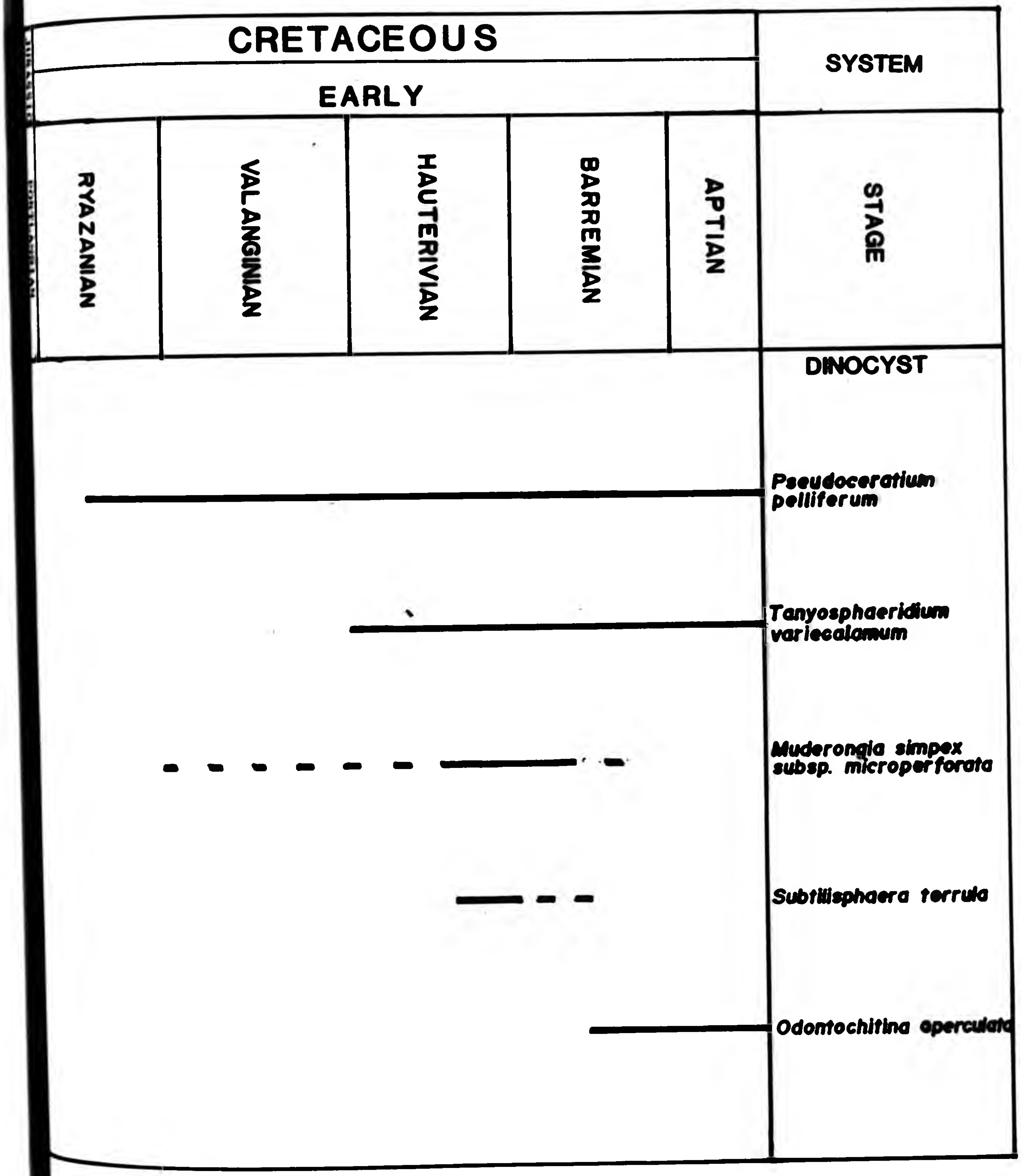
Occurrences of in situ dinocysts are given on text-fig B. Generally speaking, as expected the dinocysts are most prominent in facies 1 - 16 that are most open to marine influence. Occasional unexpected occurrences, such as in facies 58 are probably due to downstream transportation of an essentially dry, uplifted spore/pollen assemblage.

Reworked Dinocysts

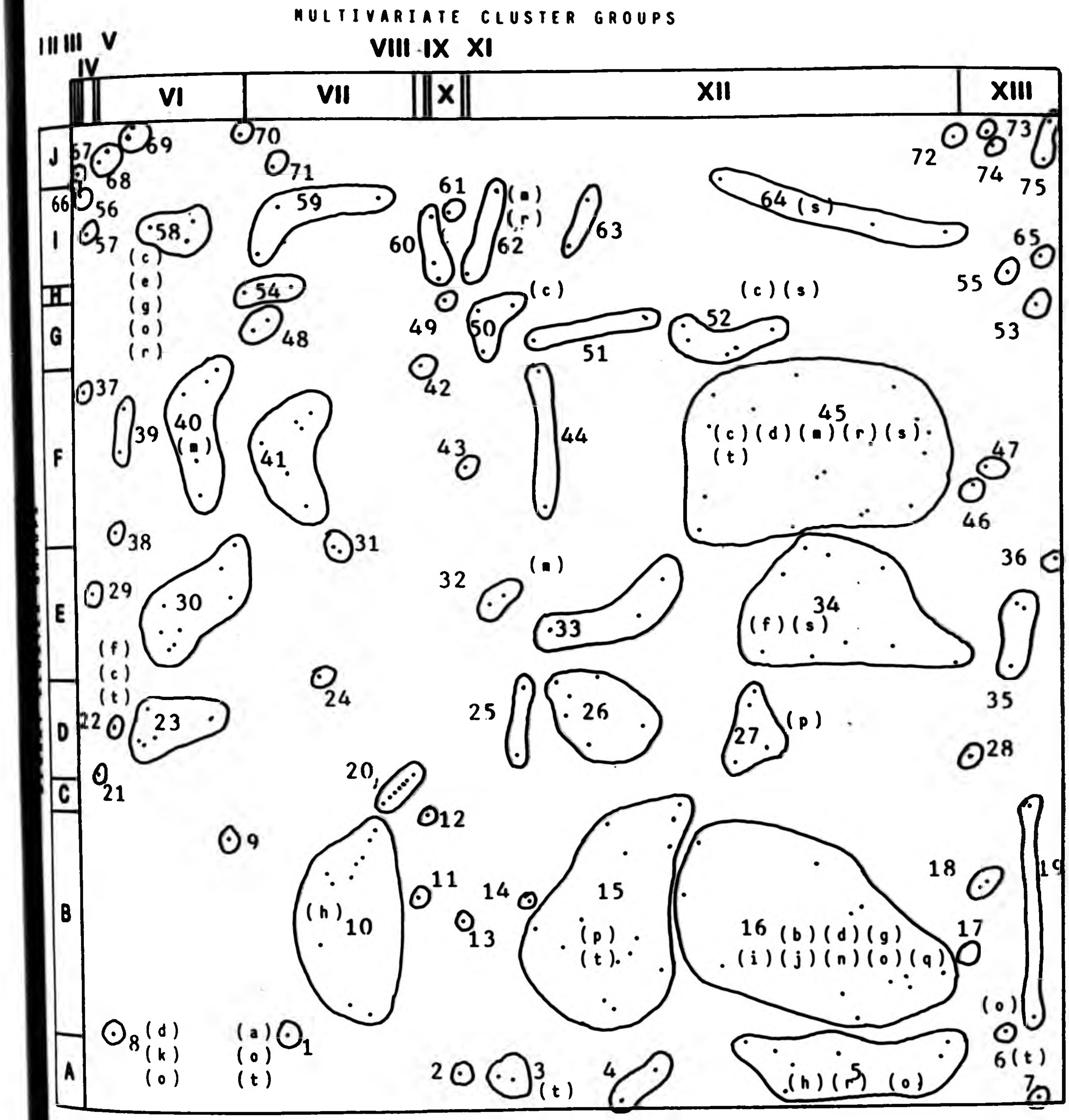
A few Weald Clay samples contained abundances of diverse reworked Middle-Late Jurassic dinocysts (Plates 31, 32, 34 & 35). Six of the taxa have been drawn up on a range chart (Text-fig. C). These are Ctenidodinium gochtii (Bajocian-Callorian); Tubotuberella cf. eisenackii (Bajocian-Oxfordian); Scriniodinium grossii (Bathonian-Oxfordian); Scriniodinium crystallinum (Callovian-Oxfordian); Wanea fimbriata (Oxfordian) and Glossodinium dimorphum (Oxfordian-Portlandian). These ranges are taken from Bujak & Williams (1985) and Woollam & Riding (1983).

These dinocysts are confirmed as reworked, as they show no association with the marine influenced facies 1 - 16 (see text-fig. D).

Stratigraphic ranges of important dinocyst taxa



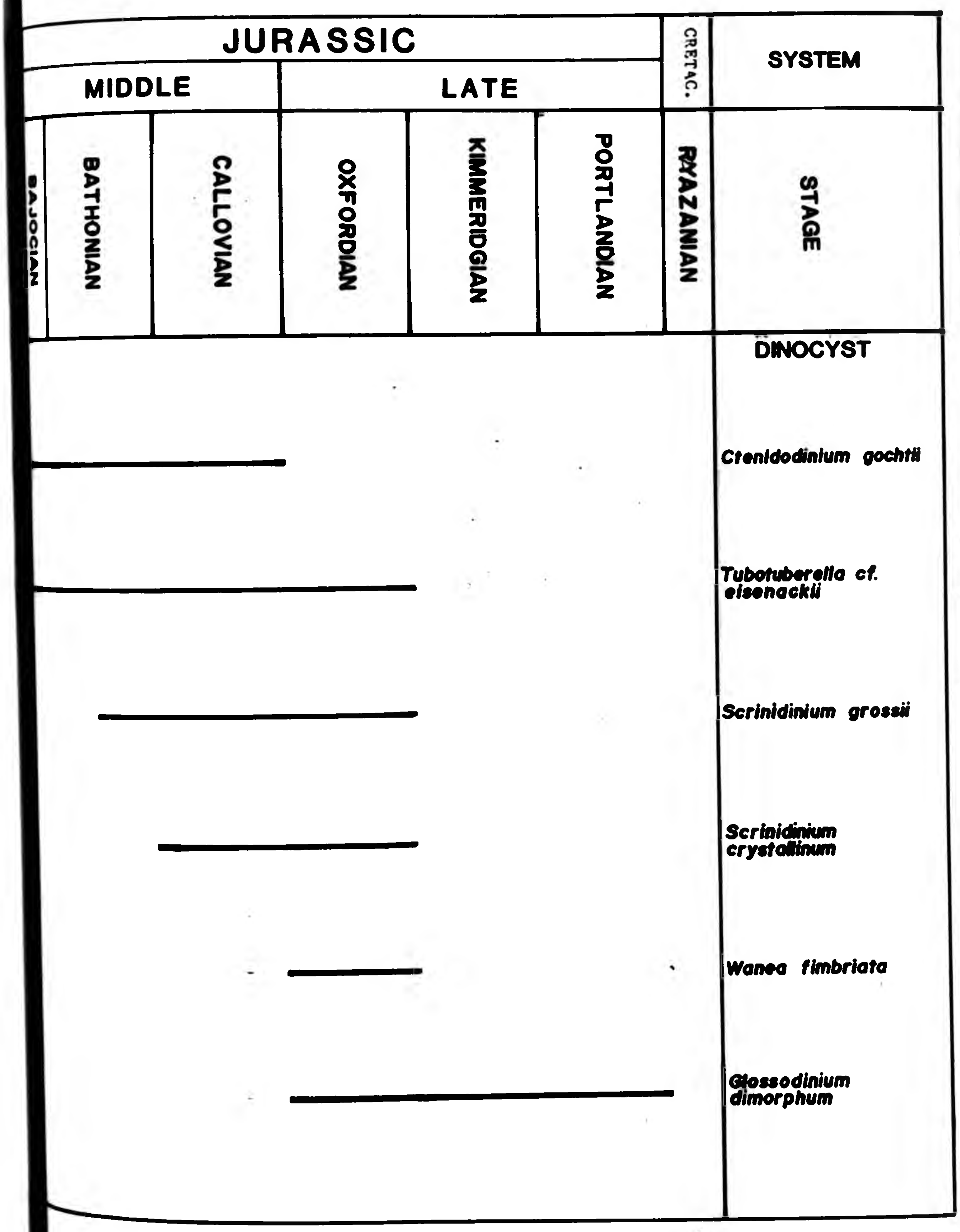
Text-fig. A



(a) Cannosphaeopsis sp.
(b) Callaiosphaeridium sp.
(c) Cribroperidinium sp.A
(d) Cribroperidinium sp.B
(e) Hystrichodinium sp.
(f) Hystrichosphaerina sp.
(g) Kiokansium sp.
(h) Muderongia simplex
(i) Oligosphaeridium sp.
(j) Odontochitina operculata
(k) Pseudoceratium pelliferum
(l) Sirmiodinium/Scriniodinium
(m) Stiphrosph./Cymososph./Surcul.
(n) Spiniferites sp.
(o) Subtilisphaera terrula
(p) Systematophora sp.
(q) Tanyosphaeridium variecalamum
(r) Proximochorate undiff.
(s) Incertae sedis type 1
(t) Cyclonephelium sp.A

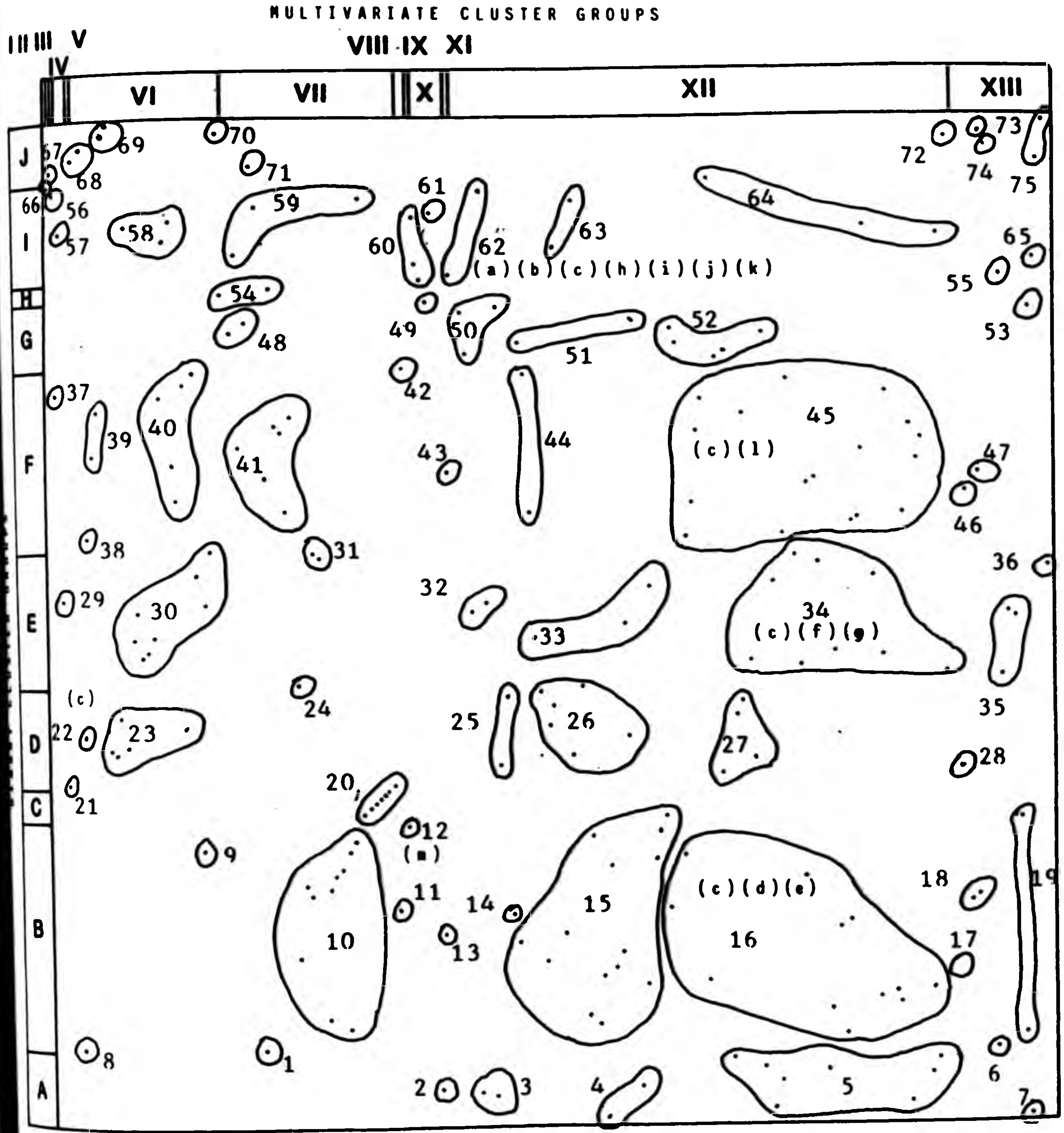
Text-fig. B

Stratigraphic ranges of reworked dinocysts



Text-fig. C

Reworked Dinocysts



(a) Ctenidodinium gochtii
(b) Glossodinium dimorphum
(c) Gonyaulacysta jurassica
(d) Gonyaulacysta helicoidea
(e) Gonyaulacysta sp.
(f) Kleithriaspaeridium sp.
(g) Leptodinium sp.
(h) Scriniodinium crystallinum
(i) Scriiodinium sp.
(j) Sirmiodinium grossii
(k) Systematophora sp.
(l) Tubotuberella cf. eisenackii
(■) Wanea fimbriata

Text-fig. D

APPENDIX 2

SPORE DEGRADATION

A number of different types of degradation of spore/ pollen exines were recorded in the Weald Clay material. Most of these effects are probably caused by bacterial and/ or fungal effects during and shortly after deposition of grains, though some is caused by oxidation destruction.

These various types of degradation are described as follows (see text-fig. E) :

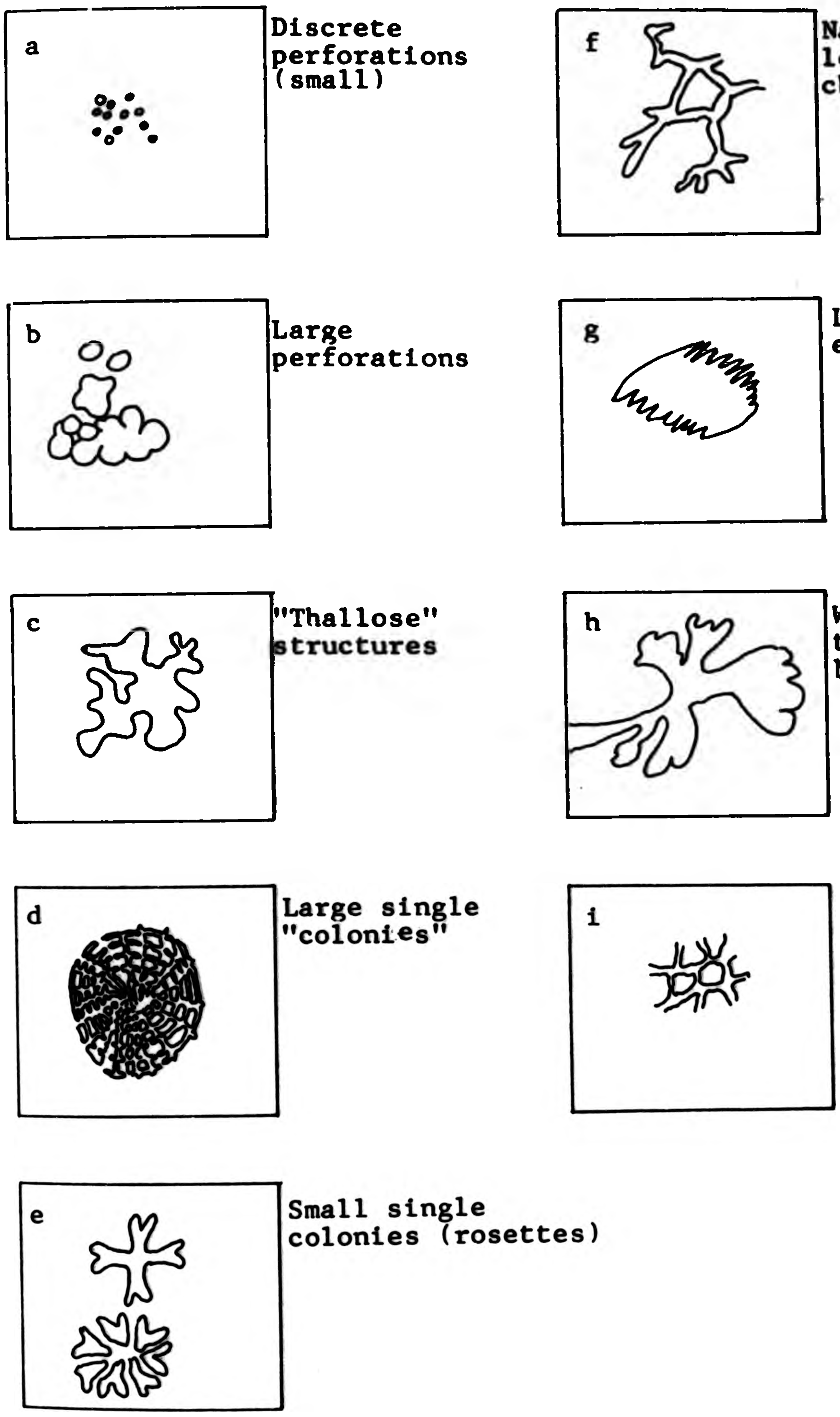
(a) Discrete perforations (small)

This kind of corrosion appears as clusters of minute circular perforations 0.8u to 1.0u in size that are individual but tend to coalesce under severe attack and cause complete fragmentaiton of the exine. Small perforations of this kind have been described by Havinga (1964, 1967) and Elsik (1970).

This kind of degradation has been seen affecting a number of Wealden genera. See Plate 53, fig. 7 Cicatricosisporites sp. Various large trilete genera such as Trilobosporites sp. Concavissimisporites sp. and Pilosisporites sp. Plate 57, figs. 1-15 and Plate 56, figs 3-11. A more extreme form of this corrosion may be seen on Plate 57, figs. 11 & 12. Also Klukisporites sp. Plate 59, figs. 1, 7 & 8. Bisaccates illustrated on Plate 61, figs 7-12 show this type of corrosion including Vitreisporites pallidus (see Plate

Spore degradation patterns in the Weald Clay

(Not to scale)



a Discrete perforations (small)

b Large perforations

c "Thallose" structures

d Large single "colonies"

e Small single colonies (rosettes)

f Narrow lobate channels

g Large serrated edge perforation

h Wide channels terminated by branched lobes

i Reticulate channels

Text-fig. E

59, fig. 13) See also Plate 53, figs 1 & 5-11, 18, 19, 22 & 23; Plate 54, fig. 1; Plate 55, fig. 13 and Plate 59, figs. 17 & 20.

(b) Large perforations

Less commonly seen, this kind of action tends to produce large circular or oval holes in the exine (see Todisporites Plate 55, fig.12). They can also coalesce over larger areas or along muri, as in Plate 54, fig.3 or around the ambital margin, Plate 59, fig.21.

Spores exhibiting this kind of degradation are often too badly degraded to be assigned to any recognised genera. (See Plate 55, figs.1-3; Plate 59, fig.6)

(c) "Thallose" structures

Not commonly seen, this kind of infestation affects a localised but random area of exine that spreads in two directions. A spore of unknown affinity exhibiting this kind of degradation is seen on Plate 55, figs. 7-9.

(d) Large single "colonies"

These large spectacular microbial "colonies" show a high degree of organisation. Arranged around a central point, perforating channels radiate out like spokes, and are cross-linked by concentric channels. The whole "colony" is up to 21u in size and is circular in shape. An analogy can be drawn between this kind of action and that displayed by some deposit feeding trace fossil producing organisms which by ordered grazing, very completely exploit the sediment leaving a very small area unexplored. See Plate 55, fig. 6 & 10, and Plate 54, fig.6.

(e) Small single "colonies" (Rosettes)

Commonly occurring on many genera these small perforation structures have been well documented by Elsik (1970). They have also been produced artificially in controlled environmental conditions by Havinga (1964). The structures appear as an arrangement of bilobed petaloid perforations or rosettes, four to seven in number, radiating from a centre. They are of limited size, not spreading out indefinitely as in type (d). They tend to impinge on one another causing the "petals" of one colony to overlap part of the exine that would be occupied by another "colony".

A number of laevigate trilete spores are shown on Plate 52, figs. 1-15. These poorly preserved grains probably include the genera Cyathidites, Dictyophyllidites and Biretisporites. See also Plate 54, figs.7, 14, 17 & 18; Plate 60, figs. 13, 14 & 16-22.

(f) Narrow lobate channels

Possibly occurring by lateral development of one or more "petals" of type (e) these narrrow channels branch dichotomously at about the same angle producing a radiating network of narrow channels with lobate terminations. This pattern of degradation is visible on a variety of strongly ornamented Wealden genera; Cicatricosisporites sp. Plate 53 figs 2-4; Appendicisporites sp. Plate 54, fig.2; Coronatisporites valdensis Plate 59, figs.9-12; Sestrosporites pseudoalveolatus Plate 59, fig.5, Leptolepidites sp. Plate 59, fig. 3; Undulatisporites sp. Plate 59, figs. 23 & 24. See also examples on Plate 54, figs.9-13; Plate 55, fig. 11.

(g) Large serrated edged perforation

Degradation of this form is visible on a few grains and could be partly enhanced by oxidation. A number of large trilete spores such as Matonisporites sp. (Plate 58, figs. 5, 6, 8 & 9) and Concavissimisporites sp. (Plate 58, fig.7) show the effects of this degradation.

(h) Wide channels terminated by branched lobes.

This kind of degradation could be a later stage in the kind of action that produces narrow channels. See Plate 55 figs. 4 & 5, which displays a grain of Biretisporites sp. with this degradation.

(i) Reticulate channels

Occasionally seen are channels that tend to explore the exine leaving hexagonal networks, of very small size. A poorly preserved grain of Cycadopites sp. (Plate 59,fig.22) exhibits this form of degradation.

(j) Microbial action between ornament

Spores that have significantly thickened regions on the exine occasionally display areas of microbial degradation aligned at the edge of these thickenings. A specimen of Clavifera triplex (Plate 59,fig.16) shows exine degradation on the proximal edge of the arcuate thickenings. A tetrad of Classopollis sp. (Plate 59,fig. 19) shows microbial action between the striation of the rimulus. See also Verrucosisporites sp. Plate 59,fig.25.

(k) Large bulbous projections

Some spores show large bulbous projections that superficially resemble part of the ornament. See Plate 61 figs.

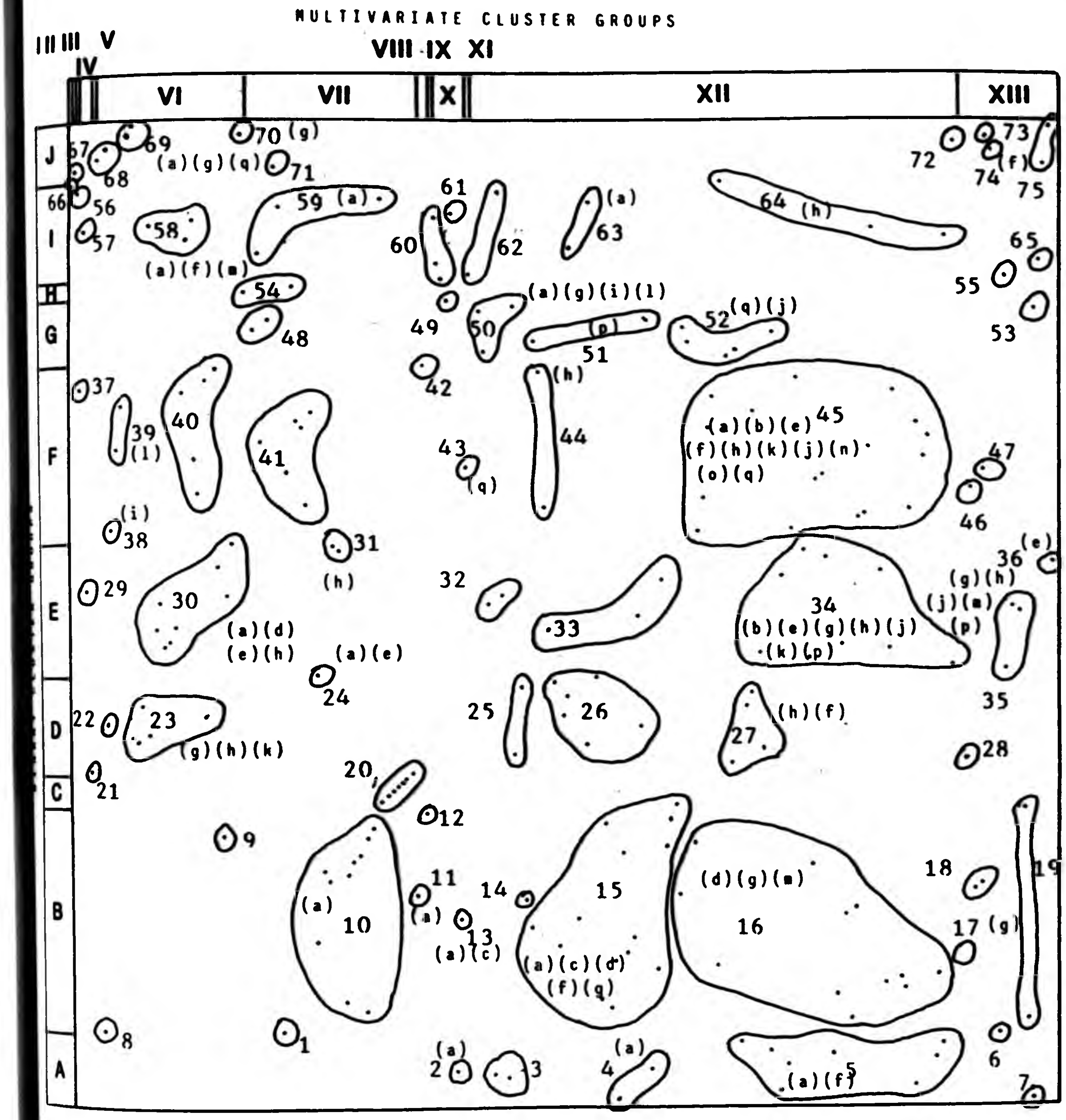
1-6 and Plate 60,fig. 15).

(1) General oxidation

Many spores show a general thinning of the wall and consequent fragmentation that is associated with general oxidation destruction. See Plate 53,figs. 5, 12-17, 20 & 21; Plate 54,fig. 15; Plate 55,figs. 14-16; Plate 56,figs. 1 & 2; Plate 58 figs. 1-4; Plate 59 figs. 2-4, 14 & 18 and Plate 60 figs. 2-9. Some spores show this oxidation in a very selective form (see Plate 54,figs. 4, 5 & 8) with severe oxidation of one portion of the exine, while the remainder is well preserved. Plate 53,fig. 13 shows two similar grains side by side that show very different preservational states.

Palaeoenvironment

Occurrences of "rosette" structures and corroded grains of various spore taxa are recorded on text-fig. F. Individual types of destruction as described above have not been plotted as individually they are too rarely occurring. Degraded spores and pollen are most common in facies 23, 30, 34, 45 and 50. These are all palynofacies showing strong freshwater aquatic and marine influences. Degradation effects by bacteria and fungae can be expected to occur in waterlogged terrains. Remains of actual fungal hyphae similar to those described by Moore (1963) may occur on Plate 59,fig.18. Degraded grains are less prominent in facies A & B (that are lagoonal/lacustrine and marine influenced) probably due to development of anoxia within the more permanent standing water. Under anoxic conditions only slow anaerobic degrada-



(a) Rosettes
(b) Aequitriradites spp.
(c) Cyathidites spp.
(d) Pilosisporites spp.
(e) Trilobosporites spp.
(f) Concavissimisporites spp.
(g) Cicatricosisporites spp.
(h) Appendicisporites spp.
(i) Leptolepidites spp.
(j) Klukisporites spp.
(k) Lycopodiumsporites spp.
(l) Acanthotriletes spp.
(m) Gleicheniidites spp.
(n) Vitreisporites pallidus
(o) Ischyosporites spp.
(p) Coronatisporites valdensis
(q) Celyphus rallus

Text-fig. F

tion will occur (Demaison & Moore 1980). In addition drier uplifted palaeoenvironments would not have favoured fungal and bacterial degradation of grains, and do not show degraded spores. Examples of partially degraded spores (Plate 54, figs. 4, 5 & 8) may be caused by anoxia within the sediment itself in which the spore is partially buried, while the degraded part was exposed to aerobic degradation just above the sediment/water interface. Exine degradation by pyrite growth within the exine is common in the Weald Clay (Plate 60, figs. 1 & 11).

APPENDIX 3

FLUORESCENCE OF PALYNOMORPHS

The term autofluorescence is used to describe the property of objects that emit long wavelenth light when exposed to the excitation effect of visible or UV-light. Spore and pollen exines and other palynomorphs are normally autofluorescent and the application of this phenomenon has been used extensively in maturation studies, van Gijzel (1966, 1967, 1981a,b)

In the present study, autofluorescence of palynomorphs has been very useful in making some very small thin algal cyst types clearly visible. Some of these types are almost impossible to see in normal or phase-contrast illumination . See Plate 82; Plate 84 ,fig.1 and Plate,86 fig.1 for comparative views. These cysts can form by far the most numerically dominant part of the palynological assemblage in the Weald Clay, so their recognition is obviously very important in a palynofacies study.

In addition to the use of fluorescence as part of the normal microscope logging procedure, some peculiar effects on palynomorphs of exposure to UV-light,noticed in passing, are commented on.

Fluorescence of Weald Clay Palynomorphs

The most clearly autofluorescent palynomorphs encountered in the Weald Clay were algal cysts. These structures are all very thin walled and generally showed bright yellow/ white autofluorescence(see Plates 43-51). Most of these cysts are in situ and showed fairly good preservation. However some poorly preserved, possibly reworked dinocysts could also show bright fluorescent colours (Plates 49 & 50). Spores in the assemblages normally showed duller yellow autofluorescent colours, particularly heavily ornamented forms (Concavissimisporites spp. Plate 3,figs. 2 & 9). Specimens of Pilosisporites spp. showed quite bright fluorescence of the small spines of the surface ornament (Plate 5,figs. 27, 38 & 39). Dull fluorescence of the muri of a specimen of Appendicisporites was observed (Plate 19, fig. 31), likewise Contignisporites (Plate 22,fig. 46) and Cicatricosisporites sp. (Plate 88,fig.1). Quite bright fluorescence was observed from the thin muronate elements of Lycopodiumsporites (Plate 8,fig.11). As a general rule it seems that brighter autofluorescence is obtained from thinner walled palynomorphs. However an exception to this occurs with Gleicheniidites spp. that often shows particularly bright autofluorescence of the thickened exine (Plate 20,figs. 14, 19, 20, 33 & 48; Plate 86,fig.2). Poorly preserved specimens also show bright yellow autofluorescence (Plate 87,fig.8). An exception to the rule of algae being autofluorescent is provided by the Rivulariacean alga Celyphus rallus (Batten & Van Geel 1985). This taxon does not show any autofluorescence beyond a dull brown (Plate 85,fig.2).

Autofluroescent Phenomena

Upon first exposure of an area of a microscope slide, autofluorescence is not immediately apparent, but takes time to develop. This time varies between samples and between localities. For instance the Warnham samples begin to autofluoresce in a matter of a few seconds, while the Beare Green and Chailey samples take up to twenty minutes. This 'development' time is therefore independent of sample type (field sample or core sample) and is probably related to local diagenetic factors. The Canada Balsam mounting medium used is normally fairly strongly fluorescent light blue when first exposed to UV-light. However after a few seconds' exposure it begins to lose its autofluorescence (fading effect or 'photochemical effect' of Van Gijzel,1981a). Thus,as the palynomorph is beginning to show increased autofluorescence it is thrown into sharper relief by a gradually darkening background. A series of photographs taken at low magnification, interspaced by a few minutes each, is shown on Plate 89. Plate 88,fig.2 shows an area of a slide at low magnification following exposure at high magnification. A ring outline of darker mounting medium marks the area of slide covered by the higher power lens. Subsequent re-examination of a palynomorph shows the Canada Balsam mounting medium to remain dark and the palynomorphs almost immediately autofluorescent. Development of autofluorescence must therefore be a one-way process involving chemical alteration.

Very prolonged exposure to UV-illumination causes palynomorphs to swell in size. This is accompanied by a blurring of the outline and partial destruction of the grain. (See Plate 49 and Plate 50). The reasons for these changes are not fully understood, but it could be simply local heating and melting with convection movement within the Canada Balsam during prolonged exposure to the incident UV-light.

APPENDIX 4

CUTICULAR SCALES AND OTHER INSECT REMAINS FROM THE WEALD CLAY (EARLY CRETACEOUS) OF SOUTHERN ENGLAND

I. INTRODUCTION

Binfield and Binfield (1854) recorded elytra, traces of wings and abdominal plates of Coleoptera, Neuroptera, and Diptera from various Wealden exposures near Hastings (Sussex). Brodie (1854) mentioned the occurrence of insect remains in the slatey blue/grey Pecten Beds of the Lower Purbeck of Durleston Bay Dorset, provisionally assigned to the genus Nothosomus. Also mentioned is the occurrence of Archaeoniscus and other elytra. The Middle Purbeck Formation is described as yielding well preserved wings and elytra of Gryllus, Acheta, Blatta and Libellula as well as some whole beetles mostly grouped in unorientated masses. Blair (1943) described burrows of Scolitidae beetles in wood from near Crowborough, Sussex. Fennah (1961) presented a detailed description of the apical portion of a wing and tegument that could be referred to the modern Family Cixiidae (Homoptera : Fulgoroidea) from the Weald Clay. Evans (1969) described in detail three Cretaceous aculeate wasps (Hymenoptera). They were well diversified indicating that their origin (as well as the other two main superfamilies of aculeates, the Bethyloids and ants), must lie at least in the Jurassic. Schluter (1975) recorded six Orders of insects in amber from the Middle Cretaceous of N.W. France; Isoptera, Neuroptera, Coleoptera, Hymenoptera, Lepidoptera and Diptera. Smart and Hughes (1973) looked at the inter-relationships of Coleoptera, Diptera and Hymenoptera with plants. More recently, Jarzembowski (1976) reviewed and added to the known Wealden insect fauna. Eight Orders are recognised, comprising: Odonata, Orthoptera (Ensifera), Blattoidea, Hemiptera (Homenoptera and Heteroptera), Neuroptera (Planipennia), Diptera (Bradycera), Hymenoptera (Apocrita) and Coleoptera. Most of these are fairly scarce except for blattoids (cockroaches) and Coleoptera (beetles). Jarzembowski (1981) has since added an isopteran termite to the Early Cretaceous insect fauna. All of these insects could have inhabited the Weald Clay basin during Early Cretaceous time.

II. DESCRIPTION OF MATERIAL (Present study)

The material described in the present study falls into the following categories:

1. Cuticular scales
2. ?Blattoid antennae
3. Wing fragments
4. Cuticle fragments
5. Limb fragments
6. Compound eyes

These are described and discussed as follows:

1. Cuticular scales (lamelliform scales)

Plate 75, figs. 10-22 and Plate 74, figs. 6 & 7 illustrate structures that show a strong similarity to lepidopteran cuticular scales. They are of the same size and general morphology to cuticular scales form recent Lepidoptera.

Description

The structures illustrated all fall into the size range 20-40u. They are wedge shaped, oval or barrel shaped membrane-like or lamelliform structures with longitudinal, regularly-spaced thickenings.

Comparison

Plate 75, fig. 11 shows clear crossribs between the longitudinal thickenings similar to cuticular scales described by Kristensen (1978) and Kristensen & Nielsen (1979). An attachment follicle is clearly visible in some of the material illustrated here (see Plate 75, fig. 18). Kristensen and Nielsen (1979, pp.93 & 95) illustrate lamelliform scales in which the longitudinal ridges extend distally beyond the scale margin. This feature is shown by the present material (Plate 75, fig.18). Kristensen (1978 p.279) illustrates "normal type" forewing cuticular scales whose distal margin is denticulate resembling that shown by the material on Plate 75, fig.16. (See also tafel 6 of Schluter, 1978).

2. ?Blattoid (Cockroach) antennae

Broken segments of a large tubular structure 60u in dameter, ornamented with regularly spaced whorls of orientated long, thin spines up to 50u in length have been recorded (Plate 74, figs.3-5). Some of the spines are probably missing in fig.4, where their basal attachment is visible as a circular hole with marginal thickening. The surface of tubular segments between spine bases show a clear arrangement of overlapping crescent shaped scale-like structures. These tubular segments must be parts of a complete structure of much greater length. The arrangement of spines and overlapping crescent shaped scales is closely comparable with that I have observed on the antennae of modern cockroaches.

Blattoid tegmina do occur in the Weald Clay (Jarzembowski 1976). This group exhibits particulalry well developed antennae in the present day. Fragments of a very elongated tubular structure of very large diameter, up to 110u, ornamented with regularly spaced tiny spines arranged in cross-cutting diagonal rows giving a diamond shaped pattern are illustrated on Plate 74, fig.1. Transverse ribs are also clearly well developed. Fig.2 shows a similarly ornamented segment with tiny spines as well as more widely spaced orientated long thin spines, and is also probably part of an insect antenna, but quite different form the ?blattoid type described above. A much longer structure, with clearly evident overlapping surface scales without spines is depicted on Plate 74, fig.9.

3. Wing fragments

Some large membraneous, sheet-like structures ornamented with regularly spaced curving spines 10u in length are displayed on Plate 73, figs.4-6. These are probably parts of a much larger structure. It is not absolutely clear that spines are present on both sides of the membrane, but if spines are present on both surfaces, then the membrane must be double sided, and this precludes it from being a fragment of cuticle. Elongated darker areas running vertically across the membrane (Plate 73, fig.5), about 25u in width, with spines more closely set on these parts could be portions of wing venation. Whalley (1978, Plate 11, fig.3) illustrates part of an insect wing at high magnification that shows spines of a type that closely resemble those recovered from the Weald Clay.

4. Cuticle fragments

Plate 73, figs.1-3 illustrate a membraneous structure which is strongly characterized by regularly interlocking crescent shaped plates, with a thickened rib along one edge, which resemble fragments of insect cuticle. Fig.2 of Plate 73 shows a double row of circular holes very similar to those also present on antennae, and probably represent bases of tubular spines rather than spiracle holes.

Plate 75, fig.9 shows a membraneous fragment decorated with regularly spaced short curving spines on one surface, which is probably part of the hairy cuticle of an insect.

Plate 72, figs.1-7 exhibit a variety of membraneous structures that may have affinities amongst the Insecta. Figs.1-3 show a membrane that is covered by closely-set holes; in fig.3 a distinct hexagonal pattern surrounds each hole. Longitudinal closely-set thickenings with occasional holes are visible on fig.5 of Plate 72. Figure 6 of the same plate shows a membrane that is covered by regularly spaced spot thickenings and small widely spaced marginally thickened holes that could be spine bases. Plate 67, figs.9 & 10 may also represent insect cuticle.

5. Limb fragments

Some fragments of elongated organic material are grouped as figs.1-8 on Plate 75. They are all strongly characterised by well developed orientated closely-set long pendulous spines that may be fragments of insect legs. Figures 1-2 show a constriction at one point which may indicate segmentation into a tarsus and a tibia, although fig.1 could be the segmented flagellar portion of an antenna. Figure 8 of Plate 74 illustrates a structure that could be part of a limb which has trapped spore grains and other fragments of organic material.

6. Compound eyes

A few structures recovered from the Weald Clay are thought to be parts of insect compound eyes, and are illustrated on Plate 69, figs.2, 4 & 5. Figure 5 shows a structure that is dome shaped, about 100 x 180u in size, and ornamented with closely-set ommatidial openings 8-10u in size, that are 2-4u apart. This structure bears very close resemblance in size and morphology, to compound eyes illustrated by Van Geel (1978) from a palynological preparation of material from a Holocene peat bog. Fragments of membraneous structures exhibiting very large openings 12-26u in diameter, but no more than 2u apart are shown on figs.2 & 4 of Plate 69. These are of a quite different character and may come from a much larger arthropod.

III. DISCUSSION

Insect structures are very rare in comparison to organic material of botanical origin in the Weald Clay. Of the insect remains recovered from Weald Clay samples, cuticular scales are the most common, particularly in sample BG.31 from Beare Green pit. Approximately one in every three Weald Clay samples contains an example of a cuticular scale. This includes samples taken from pit sections at Pluckley, Beare Green, Warnham and Lingfield.

Criticism could be levelled that the structures described are, all or in part, modern contaminants. However the material described does show features that indicate that this is unlikely. Great precaution was taken during sample collection and preparation to avoid external contamination.

Cuticular scales are produced in vast numbers by individual Lepidoptera. They completely cover the wings and body of the insect, and can become easly detached in large numbers from living or dead specimens. The aerodynamic properties of these small membraneous structures are such that they could easily be maintained suspended in the atmosphere in the slightest current of air. For this reason modern cuticular scales could cause contamination of rock samples. However all of the cuticular scales recovered from the Weald Clay show severe degradation in comparison to modern material.

This degradation could have been caused during transport and deposition of cuticular scales as sedimentary particles from the London massif into the Wealden basin, during Weald Clay times. Corrosion and degradation by oxidation and mechanical action is well known during transport and deposition of spores and pollen in many formations, including the Weald Clay. Some of the degradation could be caused by mineral growth of calcite or pyrite during diagenesis of the sediments. However, it could be argued that acids used in the chemical digestion of rock matrix during preparation of a palynological assemblage, are having a degradatory effect upon modern cuticular scales that are contaminants to the Weald Clay, giving them an artificially corroded and degraded appearance.

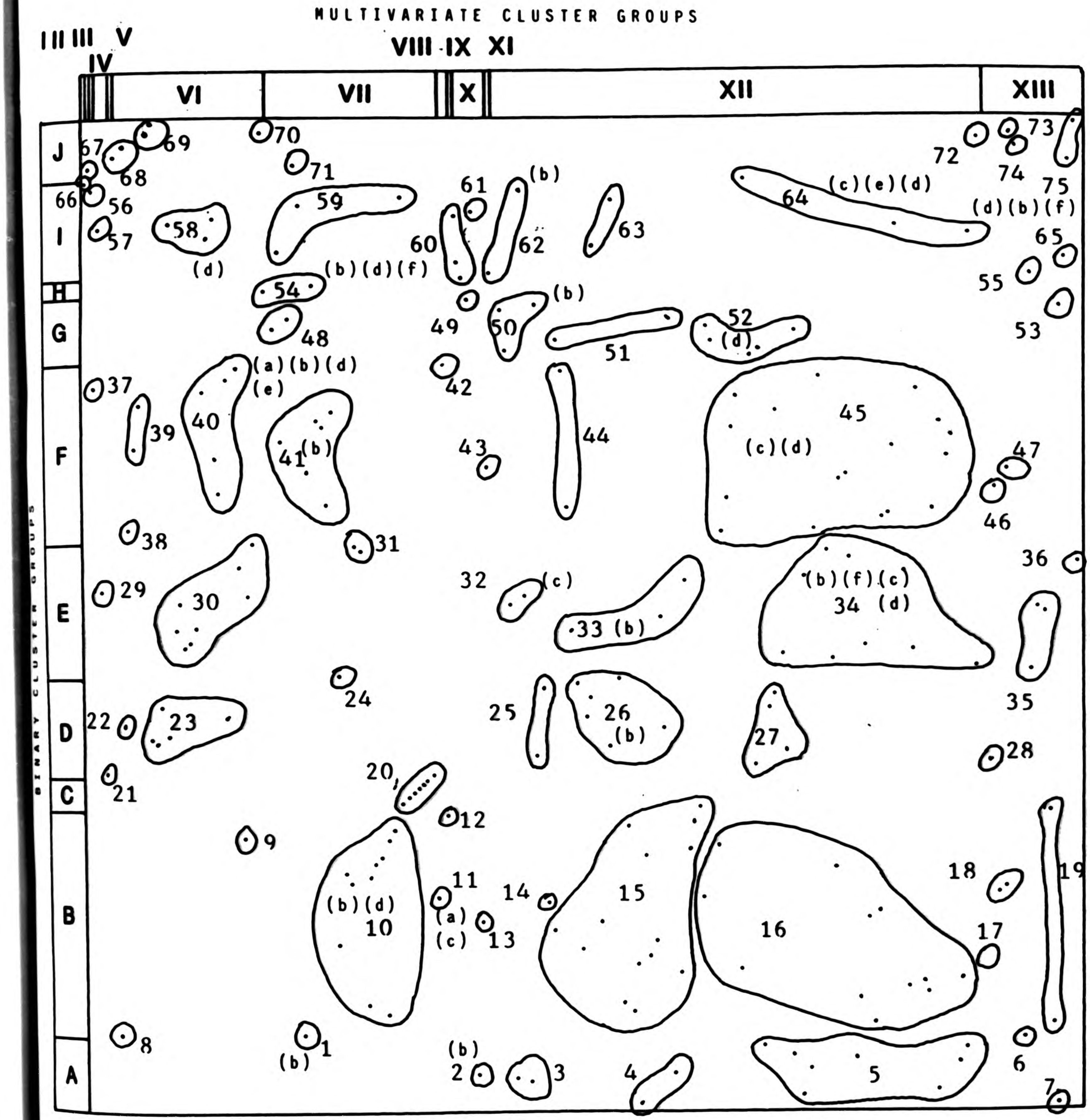
To test this, a specimen of the modern moth Micropterix was subjected to concentrated HCl and HF under the same conditions employed for preparation of a palynological assemblage. This involved 5 - 10 minutes submergence of Micropterix in concentrated HCl, followed by 48 hours in 40% HF. In no instance did these scales show any visible degradation of the kind displayed by the Wealden material. Micropterix was also subjected to the action of fuming HNO_3 (a powerful oxidizing agent). One scale showed a small crack across some of the longitudinal thickenings, but none of the effects listed for the Wealden material. It is stressed that HNO_3 was not used in preparation of the Weald Clay material. However it is still possible that the cuticular scales are a contaminant of HF and HCl, and are degraded due to very prolonged contact with these acids. On balance, the evidence favours these structures as *in situ*.

Of all the insect material recovered from the Weald Clay, cuticular scales are the most interesting as they are characteristic of the *Lepidoptera*. Their recovery from the Weald Clay may indicate the presence of this group of advanced adult insects at this time. Whalley (1978), in reviewing the Cretaceous record of *Lepidoptera*, mentioned that the earliest definitive record of this group is from the Aptian of the Lebanon. *Lepidoptera* are intimately bound up with the evolution of the angiosperms (Smart & Hughes ,1973). According to Whalley (1978) the development of flowering plants may have been the stimulus for the development of caterpillar and adult stages of *Lepidoptera*. Hughes (1984) recorded very early angiosperm pollen from the Wealden Series . The presence of possible *Lepidoptera* in the Wealden may be corroborating evidence of the presence of angiosperms at this time.

IV. PALAEOENVIRONMENT

The occurrence of insect remains in palynological preparations from the Weald Clay have been plotted on the palynofacies scheme of the study (text-fig. G). The material does show a distinct preferred association with facies *34* & *40*. This non-random grouping is additional evidence that the material is *in situ* rather than a modern contaminant. Facies *34* & *40* are both typically fairly

Insect Fragments



(a) Compound eyes
(b) Cuticles
(c) Antennae
(d) Cuticular scales
(e) wing fregments
(f) Limbs

Text-fig. G

dry uplifted palynofacies within the braidplian, well away from marine influence. Other insect occurrences in facies 26, 32, 33, 41, 52, 54, 58, 64 & 75 are also typically dry uplifted facies within the freshwater zone. Rare occurrences in facies 10, 1 & 2 (that are brackish/marine) are probably due to local reworking. The evidence seems to indicate that insects living in association with the pteridophyte flora of the braidplain favoured dry habitats within the freshwater zone.

TITLE The Palynology, Palynofacies and Palaeoenvironment of the early Cretaceous Weald clay of Southeast England.

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