Pollen and Spore Assemblages from the Oligocene Lough Neagh Group and Dunaghy Formation, Northern Ireland

Volume 2

John Andrew Fitzgerald

September 1999

8. PLANT FAMILIES AND THEIR DISPERSED POLLEN AND SPORE AFFINITIES

The following list is presented in order to depict the present global distribution and climatic type/region of the families to which form-genera and form-species have been assigned. The taxon is followed by the reference within which the familial assignation was made. Information on the number of extant genera and species within each family is stated, where this was available, to provide a guide to the diversity within each family. The information presented is primarily derived from Hyam and Pankhurst (1995). Further information may be obtained from Hyam and Pankhurst (1995), Willis (1985) and Heywood (1978).

Unless otherwise stated all the families are contained within the Division Spermatophyta, Sub-division Angiosperms. A clear and concise explanation of the classification and characteristics of the members of each Division and Class may be found in Holmes (1987).

Anacardiaceae

The Cashew family: 68 genera and approximately 800 species of trees, shrubs and lianas.

Distribution: Widespread, most species are tropical, some occur in temperate North America.

Class: Dicotyledon.

Dispersed pollen assigned: *Tricolporopollenites pseudocingulum*, Thomson and Pflug (1953).

Aquifoliaceae

The Holly family: 2 genera and approximately 400 species of shrubs and trees with leathery, often evergreen leaves.

Distribution: Widespread, tropical and temperate regions.

Class: Dicotyledon.

Dispersed pollen assigned: *Ilexpollenites iliacus*, Thomson and Pflug (1953), Graus-Cavagnetto (1968); *Ilexpollenites margaritatus*, Thomson and Pflug (1953), Graus-Cavagnetto (1968).

Azollaceae

A family of 1 genus, Azolla, Mosquito fern, water fern, fairy moss. A genus of 6-8 species of free-floating aquatic ferns, a basal cavity in leaves frequently contains blue-green nitrogen converting algae.

Distribution: Tropical and Warm regions.

Division: Pteridophyta.

Class: Filicopsida.

Dispersed pollen assigned: *Hydrosporis azollaensis*, Krutzsch (1962c); *Hydrosporis levis*, Krutzsch (1962c), see Salvinaceae.

Betulaceae

The Birch family: 2 genera and approximately 100 species of deciduous trees and shrubs.

Distribution: Northern temperate regions and mountains in tropical South America.

Class: Dicotyledon.

Dispersed pollen assigned: *Triporopollenites robustus*, Thomson and Pflug (1953), Graus-Cavagnetto (1968) see Myricaceae. *Trivestibulopollenites betuloides*, Thomson and Pflug (1953); *Alnipollenites verus*, Thomson and Pflug (1953).

Caprifoliaceae

The Honeysuckle family: 13 genera and 450 species of herbs, shrubs, small trees and lianas.

Distribution: Mainly northern temperate, occasionally tropical regions.

Class: Dicotyledon.

Dispersed pollen assigned: *Euretitricolporites microreticulatus*, Thomson and Pflug (1953); ?*Tricolporopollenites* sp. A (see Euphorbiaceae).

Cornaceae

The Dogwood family: 8 genera and 70 species of trees, shrubs and a few herbs.

Distribution: Northern temperate regions to tropical Asia, Africa and South America.

Class: Dicotyledon.

Dispersed pollen assigned: Also see Nyssaceae. *Nyssapollenites kruschi analepticus*, Thomson and Pflug (1953); *Nyssapollenties kruschi accessorius*, Thomson and Pflug (1953); *Nyssapollenites satzveyensis*, Thomson and Pflug (1953); *Nyssapollenites incognitus*.

Contains the genus *Nyssa*: a genus of 5 species of deciduous trees.

Distribution: North America, China, Indomalaysia.

Corylaceae

The Hazel family: 4 genera and 57 species of shrubs and trees, typically deciduous.

Distribution: Northern temperate regions.

Class: Dicotyledon.

Dispersed pollen assigned: *Polyatriopollenites carpinoides*, Thomson and Pflug (1953); *Polyatriopollenties stellatus*, Thomson and Pflug (1953).

Cryillaceae

Deciduous or evergreen shrubs and trees.

Distribution: North and Central America.

Class: Dicotyledon.

Dispersed pollen assigned: *Cryillaceaepollenites megaexactus*, Potonié (1931b), Graus-Cavagnetto (1968).

Cupressaceae

The Cypress family: 18 genera 133 species of coniferous shrubs and trees.

Distribution: Widespread.

Subdivision: Gymnnosperms.

Class: Coniferopsida.

Dispersed pollen assigned: *Inaperturopollenites cuspidataeformis*, Krutzsch (1971). *Inaperturopollenites* *dubius*, Thomson and Pflug (1953), Collinson (1983) Taxodiaceae or Cupressaceae see Taxodiaceae; *Inaperturopollenites insulipapillatus*, Krutzsch (1971).

Cyatheaecceae

A family of 1 genus and 600 species of tree ferns.

Distribution: Tropical to warm temperate regions.

Division: Pteridophyta.

Class: Filicopsida.

Dispersed pollen assigned: *Matonisporites*, Wilkinson (1979).

Cycadaceae

A family of 1 genus, *Cycas*, a genera of 20 species of palm like coniferous plants.

Distribution: Tropical regions of Africa, Asia and Australasia.

Subdivision: Gymnosperms.

Class: Cycadopsida.

Dispersed pollen assigned: *Cycadopites* Krutzsch (1970).

Cyperaceae

The Sedge family: 102 genera and approximately 3500 species of mainly perennial grass-like herbs.

Distribution: Widespread, especially in damp temperate sub-arctic regions.

Class: Monocotyledon.

Dispersed pollen assigned: *Cyperaceaepollis* Krutzsch (1970).

Elaeagnaceae The Elaeagnaceae family: 3 genera and 45 species of often thorny shrubs, simple leathery leaves.

Distribution: Northern temperate regions to tropical Asia and Australia.

Class: Dicotyledon.

Dispersed pollen assigned: *Boehlensipollis* Stuchlik (1964) in Krutzsch (1969).

Euphorbiaceae The Spurge family: 331 genera, and approximately 8000 species of herbs, shrubs and trees.

Distribution: Widespread.

Class: Dicotyledon.

Dispersed pollen assigned: ? *Tricolporopollenites* sp. A (see Caprifoliaceae).

Fagaceae The Beech family: 8 genera, approximately 1000 species of deciduous or evergreen trees and a few shrubs.

Distribution: Widespread except tropical Africa.

Class: Dicotyledon.

Dispersed pollen assigned: *Cupuliferoidaepollenites liblarensis liblarensis*, Graus-Cavagnetto (1968); *Cupuliferoidaepollenites liblarensis fallax*, Graus-Cavagnetto (1968); *Cupuliferoidaepollenites parmularis*, Thomson and Pflug (1953); *Quercoidites microhenrici*, Thomson and Pflug (1953); *Cupuliferoipollenites cingulum pusillus*, Potonié

(1960), Graus-Cavagnetto (1968); *Cupuliferoipollenites cingulum oviformis,* Potonié (1960), Graus-Cavagnetto (1968).

An important constituent of extant broad-leaved forests comprising a majority of the biomass with the exception of conifers, Heywood (1978). The family includes:

Castanea, Chestnut: 12 species of deciduous shrubs and trees.

Distribution: Northern Hemisphere temperate regions; *Cupuliferoipollenites cingulum pusillus,* Potonié (1960); *Cupuliferoipollenites cingulum oviformis,* Potonié (1960).

Fagus, Beech: 10 species of deciduous trees.

Distribution: Northern temperate regions.

Quercus, Oak: Approximately 600 species of deciduous and evergreen trees and shrubs.

Distribution: Temperate and warm regions of the Northern Hemisphere and mountainous region of the tropics.

Quercoidites microhenrici, Thomson and Pflug (1953).

Gentianaceae

The Gentian family: 76 genera, 1200 species of perennial herbs and occasionally shrubs.

Distribution: Widespread.

Class: Dicotyledon.

Dispersed pollen assigned: *Retitricolporites gentianoides.*

Gleicheniaceae

4 genera 140 species of terrestrial ferns, small to very large with partially creeping stems.

Distribution: Widespread in tropical regions.

Division: Pteridophyta.

Class: Filicopsida.

Dispersed pollen assigned: *Gleicheniidites senonicus*; *Toroisporis*.

Gramineae (now Poaceae)

The Grass family: 657 genera and approximately 7000 species of annual and perennial herbs.

Distribution: Cosmopolitan.

Class: Monocotyledon.

Dispersed pollen assigned: *Graminidites laevigatus*, Krutzsch (1970).

Juglandaceae

The Walnut family: 8 genera and approximately 60 species of deciduous trees.

Distribution: Mediterranean to tropical and East Asia, North and South America.

Class: Dicotyledon.

Dispersed pollen assigned: *Caryapollenites veripites*, Nichols and Ott (1978); *Momipites coryloides*, Wodehouse (1933), Nichols (1973); *Momipites quietus*, Nichols (1973), *Plicatopollis*, Krutzsch (1962a).

Lycopodiaceae 4 genera and approximately 500 species of terrestrial and epiphytic fern-like herbs or climbers.

Distribution: Widespread.

Division: Pteridophyta.

Class: Lycopsida.

Dispersed pollen assigned: *Camarozonosporites (Camarozonosporites) decorus*, Krutzsch (1963a); *Camarozonosporites (Camarozonosporites) heskemensis*, Krutzsch (1963a); *Lycopodiumsporites*. Krutzsch (1963a).

Magnoliaceae A family of 7 genera and 200 species of shrubs and trees.

Distribution: Widespread, tropical and warm temperate regions, not in Africa.

Class: Dicotyledon.

Dispersed pollen assigned: *Magnolipollis*, Krutzsch (1970).

Myricaceae A family of 3 genera and 50 species of aromatic shrubs and trees.

Distribution: Widespread.

Class: Dicotyledon.

Dispersed pollen assigned: *Triporopollenites robustus*, Fredericksen and Christopher (1978) suggested an association to *Casuarina*, Casuarinaceae, an extant Southern Hemisphere genus. Pollen of the Myricaceae is almost identical to

Casuarina so attribution to Myricaceae is possible as it has a Northern Hemisphere occurrence.

Nyssaceae

See Cornaceae, pollen of the genus *Nyssa* is contained within the family Cornaceae according to Hyam and Pankhurst (1995).

Dispersed pollen assigned: *Nyssapollenites kruschi analepticus*, Thomson and Pflug (1953); *Nyssapollenties kruschi accessorius*, Thomson and Pflug (1953); *Nyssapollenites satzveyensis*, Thomson and Pflug (1953); *Nyssapollenites incognitus.*

Onagraceae

The Evening primrose family, 17 genera and approximately 500 species of aquatic and terrestrial herbs and a few shrubs.

Distribution: Widespread, especially in SW North America.

Class: Dicotyledon.

Dispersed pollen assigned: *Corsinipollenites oculusnoctis*, Jansonius and Hills (1976).

Osmundaceae

A family of 3 genera and 18 species of terrestrial ferns with erect sometimes trunk-like stems covered in leaf bases.

Distribution: Widespread.

Division: Pteridophyta.

Class: Filicopsida.

Dispersed pollen assigned: *Baculatisporites nanus*, Krutzsch (1967a); *Baculatisporites primarius*, Thomson and Pflug (1953); *Baculatisporites quintus*, Thomson and Pflug (1953).

Palmae

The Palm family, 202 genera and approximately 2500 species of plants with unbranched trunks and a crown of feather-shaped or fan-shaped leaves.

Distribution: Widespread in tropical and subtropical regions, rarely temperate.

Class: Monocotyledon.

Dispersed pollen assigned: *Arecipites*, Krutzsch (1970); *Monocolpopollis tranquilloides*, Nichols, Ames and Traverse (1973); *Monocolpopollis tranquillus*, Thomson and Pflug (1953). *Dicolpopollis*, Thanikaimoni *et. al.* (1984).

Pinaceae

The Pine family, 12 genera and approximately 200 species of typically evergreen, resinous, coniferous trees and shrubs.

Distribution: Northern Hemisphere regions south to Malaysia and Central America.

Subdivision: Gymnnosperms.

Class: Coniferopsida.

Dispersed pollen assigned: *Pityosporites microalatus*, Thomson and Pflug (1953); *Pityosporites labdacus*, Thomson and Pflug (1953).

Platanaceae

A family of 1 genus, *Platanus*, Plane, Butterwood tree. A genus of 6-7 species of deciduous trees with palmately lobed leaves.

Distribution: Northern Hemisphere.

Class: Dicotyledon.

Dispersed pollen assigned: *Platanuspollenites ipelensis*, Pacltová (1978); (*Euretitricolpites* Group A Wilkinson and Boulter, 1980 as comparable to *Retitricolpites retiformis*, Salicaceae-Platanaceae, Graus-Cavagnetto (1968).

Podocarpaceae

A family of 17 genera and 200 species of evergreen coniferous shrubs and trees.

Distribution: Southern Hemisphere, north to Japan and Central America.

Subdivision: Gymnosperms.

Class: Coniferopsida.

Dispersed pollen assigned: *Podocarpaceae*, Krutzsch (1971).

Polypodiaceae

A family of 47 genera and approximately 500 species of terrestrial or epiphytic ferns.

Distribution: Widespread.

Division: Pteridophyta.

Class: Filicopsida.

Dispersed pollen assigned: *Laevigatosporites discordatus*, Thomson and Pflug (1953); *Laevigatosporites haardti*, Thomson and Pflug (1953); *Laevigatosporites haardti crassicus*; *Verrucatosporites alienus*, Thomson and Pflug (1953); *Verrucatosporites balticus balticus*, Krutzsch (1967a); *Verrucatosporites fuvus favus*, Krutzsch (1967a); *Verrucatosporites fuvus pseudosecundus*, Thomson and Pflug (1953); *Verrucatosporites histiopteroides minor*, Krutzsch (1962a); *Verrucatosporites poriacus poriacus*, Thomson and Pflug (1953); *Verrucatosporites poriacus microporiacus*; *Polypodiaceoisporites gracillimus*, Nagy (1963b); *Polypodiaceoisporites gracillimus semiverricatus*, Krutzsch (1967a); *Verrucingulatisporites undulatus undulatus*.

Pteridaceae

A family of 6 genera and approximately 290 species of terrestrial, lithophytic or aquatic ferns.

Distribution: Widespread.

Division: Pteridophyta.

Class: Filicopsida.

Dispersed pollen assigned: *Polypodiaceoisporites saxonicus*, Krutzsch (1967a).

Salicaceae

The Willow family, 2 genera and 355 species of shrubs and trees typically with deciduous leaves, often occur in wet environments.

Distribution: Widespread except Australia.

Class: Dicotyledon.

Dispersed pollen assigned: (*Euretitricolpites* Group A Wilkinson and Boulter, 1980 as comparable to *Retitricolpites retiformis*, Salicaceae-Platanaceae, Graus-Cavagnetto (1968).

Salviniaceae

A family of 1 genus and 10-12 species of free floating aquatic ferns.

Distribution: Tropical and warm temperate regions.

Division: Pteridophyta.

Class: Filicopsida.

Dispersed pollen assigned: *Hydrosporis azollaensis*, Krutzsch (1962c); *Hydrosporis levis*, Krutzsch (1962c), see Azollaceae.

Sapotaceae

A family of 53 genera and approximately 100 species of trees. The trees are bat pollinated.

Distribution: Widespread in tropical regions.

Class: Dicotyledon.

Dispersed pollen assigned: Pollen of the morphology of *Mediocolpopollis compactus* has been likened to the pollen of Sapotaceae, but differs in the germinal structure.

Schizaceae

A family of 4 genera and 150 species of terrestrial ferns.

Distribution: Tropical and southern warm temperate regions.

Division: Pteridophyta.

Class: Filicopsida.

Dispersed pollen assigned: *Cicatricosisporites dorogensis*, Thomson and Pflug (1953); *Cicatricosisporites paradorogensis*, Graus-Cavagnetto (1978); *Cicatricosisporites chattensis chattensis*, Krutzsch (1967a); *Cicatricosisporites chattensis minor*, Krutzsch (1967a); *Deltoidospora maxoides*, Chandler (1955); *Triplanosporites microsinuosus*; *Trilites multivallatus*, Krutzsch (1967a); *Varirugosisporites megaverrucatus*, Krutzsch (1967a).

Selaginellaceae A family of 1 genus, *Selaginella*, Little Club Moss, Spike Moss, a genus of 600-700 species of terrestrial or occasionally epiphytic, moss-like plants with creeping to erect stems.

Distribution: Cosmopolitan, mostly wet tropical regions.

Division: Pteridophyta.

Class: Lycopsida.

Dispersed pollen assigned: *Echinatisporis echinoides grausteinensis*, Krutzsch (1963b); *Echinatisporis embryonalis*, Krutzsch (1963b); *Muerrigerisporis*, Krutzsch (1963b).

Sparganiaceae Aquatic herbs. See Typhaceae.

Sphagnaceae Mosses.

Distribution: Cosmopolitan.

Division: Bryophyta.

Class: Sphagnopsida.

Dispersed pollen assigned: *Stereisporites (Distigranisporis) granistereoides*, Thomson and Pflug (1953); *Stereisporites (Distigranisporis) ancoris*, Thomson and Pflug (1953).

Symplocaceae

A family of 1 genus, *Symplocos*, a genus of 250 species of evergreen and deciduous shrubs and trees.

Distribution: Tropical and warm Asia, America and New Caledonia.

Class: Dicotyledon.

Dispersed pollen assigned: *Porocolpopollenties calauensis*, Thomson and Pflug (1953); *Porocolpopollenties vestibulum*, Thomson and Pflug (1953).

Taxodiaceae

A family of 10 genera and 13 species of resinous, coniferous trees, evergreen or deciduous.

Distribution: East Asia, Tasmania and North America.

Subdivision: Gymnosperms.

Class: Coniferopsida.

Dispersed pollen assigned: *Inaperturopollenites hiatus* Thomson and Pflug (1953); *Inaperturopollenites dubius*, Collinson (1983) Taxodiaceae or Cupressaceae; *Sequoiapollenties polyformosus*, Thomson and Pflug (1953); *Sciadopityspollenites quintus*, Krutzsch (1971); *Sciadopityspollenites verticillatiformis*, Krutzsch (1971).

Contains the genus *Sciadopitys*, a genus of 1 species of evergreen coniferous tree.

Distribution: Japan (Central Honshu).

Contains the genus *Sequoia*, a genus of 1 species of evergreen coniferous tree.

Distribution: Throughout North America.

Tiliaceae

The Lime family, 53 genera and approximately 1000 species of deciduous trees and shrubs.

Distribution: Widespread.

Class: Dicotyledon.

Dispersed pollen assigned: *Tiliaepollenties* sp. A; *Tiliaepollenites* sp. B; *Tiliaepollenites cecialensis*, Krutzsch (1961d); *Tiliaepollenites instructus*, Thomson and Pflug (1953).

Typhaceae

The Reedmace family, 2 genera and 24 species of tall aquatic herbs with simple erect stems usually submerged at the base.

Distribution: Widespread in freshwater habitats.

Class: Monocotyledon.

Dispersed pollen assigned: *Sparganiaceaepollenites polygonalis*, Thiergart (1937); *Sparganiaceaepollenites*, Sparganiaceae or Typhaceae, Collinson (1983), Mc Andrews *et al.* (1973), Machin (1971), Krutzsch (1970).

Contains the genus *Sparganium*, Bur reed: a genus of 2 species of aquatic herbs.

Distribution: Northern temperate regions, Malaysia to Australia and New Zealand.

Division Bryophyta

The following moss spores have not been assigned to a level below Division.

Corrusporis chattensis, Krutzsch (1967a);

Corrusporis globoverrucatus, Krutzsch (1967a);

Corrusporis tuberculatus, Krutzsch (1967a);

Corrusporis sp. A.

9. POLLEN AS A STRATIGRAPHIC TOOL IN THE TERTIARY

As a stratigraphic tool, pollen and miospores have the advantage of being able to be transported to all sedimentary environments. Owing to their size and resistance to degradation they are usually found in large numbers in all non-marine sediments of suitable particle size and thermal/geochemical history. Their occurrence in marine settings may allow for the correlation of marine and non-marine sediments.

The disadvantages of pollen and spores as stratigraphic indicators are that they are often facies controlled and restricted by provincialism. Since the evolution of land plants their distribution has not been global and the extension of a pollen and spore based stratigraphy to a continental or global scale is usually impossible except if used in a very basic, broadly ranging sense.

The provincialism of pollen and spores is affected by the rates of evolution of the parent flora. This is an issue of importance in the Tertiary as angiosperm evolution is widely regarded to have had a rapid progression. Sporne (1974) reported that there were over 250 000 species of extant angiosperms. Over the course of the Tertiary period many more must have existed. Given this diversity, attempts to classify pollen that does not exhibit a large number of characteristics, as is the case for many commonly occurring Tertiary tricolpate and tricolporate forms, has made classification a difficult task (Boulter and Wilkinson, 1977). In a study on the Oligocene of the Isle of Wight, Machin (1971) noted that "A large number of tricolporate types of unknown relationship are found in these deposits, not obviously of stratigraphical importance and mostly only distinguishable under oil immersion objective." (p.853) Problems such as these highlight the fact that the difficulties of classification and nomenclature of Tertiary pollen (mentioned in Chapter 6) impinge upon its perceived usefulness as a stratigraphic tool. As a result of this the stratigraphic usefulness of much Tertiary pollen has been disregarded or overlooked.

The stability of the flora over the period under stratigraphical question is an issue of importance. If a stable flora persists, as is thought to be the case throughout the Tertiary of Europe (Kräusel, 1961), the possibility of constructing a stratigraphic zonation upon a relatively unchanging data set will be at a minimum. Here the issue of ecological control of the floral type manifests itself. If a generally stable flora persisted and any changes that did occur were controlled by local ecological factors, then the palynofloral assemblages may not provide a very meaningful contribution to interbasinal or interregional correlations. The specificity of the floral type may be such as to preclude even intrabasinal correlations.

The facies, as previously mentioned, has an important control on the stratigraphic usefulness of the palynoflora. An autochthanous deposit such as a coal or lignite will contain a palynoflora of very localised specificity. Correlations of such lithologies are therefore not strictly of the deposits but of a similar floral assemblages originating from a similar set of local conditions. Palynostratigraphic zonations constructed upon a large amount of data gathered from such deposits should be applied with caution outside the area of origin.

Krutzsch (1967f) compiled pollen based zonations of the Tertiary of north-west Europe. The zonation contains the assumption that the taxa of the German Palaeogene pollen assemblages could be assigned to a palaeotropical floral group, 'eozän-paläotropische' element; an Arcto-Tertiary floral group, 'prä-arktotertiäre' element or an 'oberkretazische', Normapolles element. Boulter and Craig (1979) stated that this division was constructed based upon the assumed migration of plants in the Tertiary according to the Arcto-Tertiary Geoflora concept. Acceptance of this theory by many

Tertiary palaeobotanists led to the supposition that fossil taxa could be assigned to either a northerly centred temperate geoflora that occupied Arctic regions during the Tertiary, or to a warmer, more southerly centred geoflora containing presumed close relatives of modern plants of SE Asia as well as extinct taxa (Boulter, 1984).

The Arcto-Tertiary Geoflora theory of Tertiary plant migration has become accepted as fact by many authors and text books concerning plant geography (Cain, 1944; Chaney, 1947; Good, 1953) despite being originally put forward as a concept only a century ago. The concept proposes that a broad-leaved deciduous forest evolved in the Arctic during the Cretaceous. This migrated south during the Middle Tertiary in response to a gradually cooling climate to reside in middle latitudes, where it is found surviving today in SE North America and east central Asia. During the migration this Arcto-Tertiary Geoflora was thought to have undergone minimal change in its floristic composition.

Engler (1882) first used the term 'arcto-tertiäre Element' stating that this element was "... distinguished by numerous conifers and the numerous genera of trees and shrubs that now dominate in North America or in extratropical east Asia or in Europe." (free translation by Wolfe, 1977 p.39) In a detailed presentation of the history of the Arcto-Tertiary Geoflora concept, Wolfe stated that the concept is not supported by more recent knowledge of the Alaskan Tertiary vegetational and floristic history (Wolfe, 1972, 1977).

Wolfe (1977) noted that the concept of homotaxis is fundamental to the concept upon which the Arcto-Tertiary Geofloral concept is simply an application. Huxley (1870), in stating his theory of homotaxis reported that "It is possible that similar, or even identical faunae and florae in two different localities may be of extremely different ages..." (in Wolfe, 1977 p. 38). The adoption of this theory by palaeobotanists and neobotanists had a distinct effect upon the botanical thinking over the next century.

Wolfe (1977) reported that Huxley's 'possible' was interpreted as good evidence without any additional data. To further illustrate the acceptance of the Arcto-Tertiary homotaxis concept, Wolfe noted that the concept had gone almost unchallenged and had become accepted as a fact by almost all palaeobotanists. He further reported that Chaney's concept of the Arcto-Tertiary Geoflora (Chaney, 1936, 1938, 1940) was rooted in Clementsian ecology, "The differentiation of Tertiary vegetation into a series of climaxes, or a clisere, in response to differences in latitude and altitude was suggested by Clements almost twenty years ago." (Chaney 1936 in Wolfe, 1977 p. 40). The coupling of Clementsian ecology with Huxley's homotaxis produced statements from Chaney such as "It might even be said that if a flora from Oregon was closely similar in composition to one from Alaska, the age of the two must be different" (in Wolfe, 1977 p. 40).

As the fundamental theory of the Arcto-Tertiary Geoflora concept has been shown to be totally lacking in theory (Boulter and Craig, 1979), the basis of a stratigraphic zonation relying upon such a floristic element division has been questioned by them. They further note that the recognition of the floral elements of Krutzsch (1967f) depends on the ability of the pollen taxa to demonstrate a botanical affinity to a level of precision, enabling ecological and climatic deductions to be made.

The botanical attribution of dispersed fossil pollen to extant species is a point of moot amongst many palynologists and palaeobotanists. It is widely accepted that in the Neogene there is little doubt about the familial and even the generic attribution of most of the common and important fossil pollen to extant forms (Traverse, 1988). This is not the case for the greater part of the Tertiary. The effects of this disagreement upon the classification and nomenclature of fossil pollen (which subsequently affects the validity of a zonation that has some basis in these botanical attributions) have been outlined in chapter 6.

The ability of comparative morphology combined with the concept of uniformitarianism, tempered with an appreciation of the important effects of evolution to produce a realistic floral assemblage based solely upon the evidence of dispersed pollen, is the key to determining palaeoecological and palaeoclimatological environments for many areas. The utilisation of such ecologies and climatic phases in stratigraphic comparisons and correlations is consequently affected by the validity of the initial comparison and botanical attribution.

Boulter (1979) stated that Tertiary palynologists had consistently failed to produce workable biostratigraphic correlations for the continental deposits of lowland northern Europe. He suggested that this was because the pollen and spore records of evolutionary and climatic change occurring throughout the Tertiary in this area were not the result of regional fluctuations in climate or evolutionary processes, but due to local ecological factors.

The use of pollen and spores for biostratigraphic correlation has, by the greater majority of authors, been based upon the utilisation of an assemblage of form-species as a unit of comparison and correlation. Boulter (1980) suggested that reliance on form-species was not sound as these are difficult to compare scientifically due to the widely differing values of author judgement for the description of the small number of specimens upon which stratigraphically important form-species are based. The lack of distinctive features in many forms, as a result of factors such as the effects of parallel evolution, compounds the problem. This results in the view that species descriptions alone do not provide an adequate basis for comparison between sources. As a result of these beliefs, Boulter based interpretations for his broad Tertiary zonation upon form genera, only utilising very few form-species in the Oligocene where they were perceived to be of biostratigraphical importance.

In applying his method of form genus comparison Boulter (1980) defined six components or association of form genera, see fig. 9.1. The Taxodiaceous Swamp/Woodland Component and the Tricolpate and Tricolporate Pollen Types are the most broadly ranging in terms of stratigraphic extent as they occur throughout the Tertiary. The more stratigraphically restricted components; the Palm, Eocene, Oligocene and Neogene, comprise pollen that occurs in very small numbers as a total of the range of taxa that comprise each assemblage. Boulter further noted that pollen that has any stratigraphical value in the European Tertiary is nearly always very rare, some often only found as single specimens.

Meyer (1988) outlined the interregional pollen and spore zonation of the European Palaeogene produced by the International Geological Correlation Programme, Project No. 124. A preliminary chart was produced providing a summary of the synthesis of the pollen and miospore biostratigraphy of the Paleogene throughout the Northwest European Tertiary Basin. It was based on regional range charts from sections throughout Belgium, Germany, France, Great Britain and the Netherlands. Eight spore and pollen zones were constructed, SP1-SP8. The Palaeocene is covered by zones SP1-SP3, the Eocene by SP4-SP5 and the Oligocene by SP6-SP8. The Early Neogene is contained within SP8.

In the construction of the zonation a total of 38 species or genus groups were selected. These taxa were recognised to be widely distributed with well-established stratigraphic ranges. They occurred within most of the studied regions. In most cases pollen species were utilised as stratigraphic value was found attributable, where this

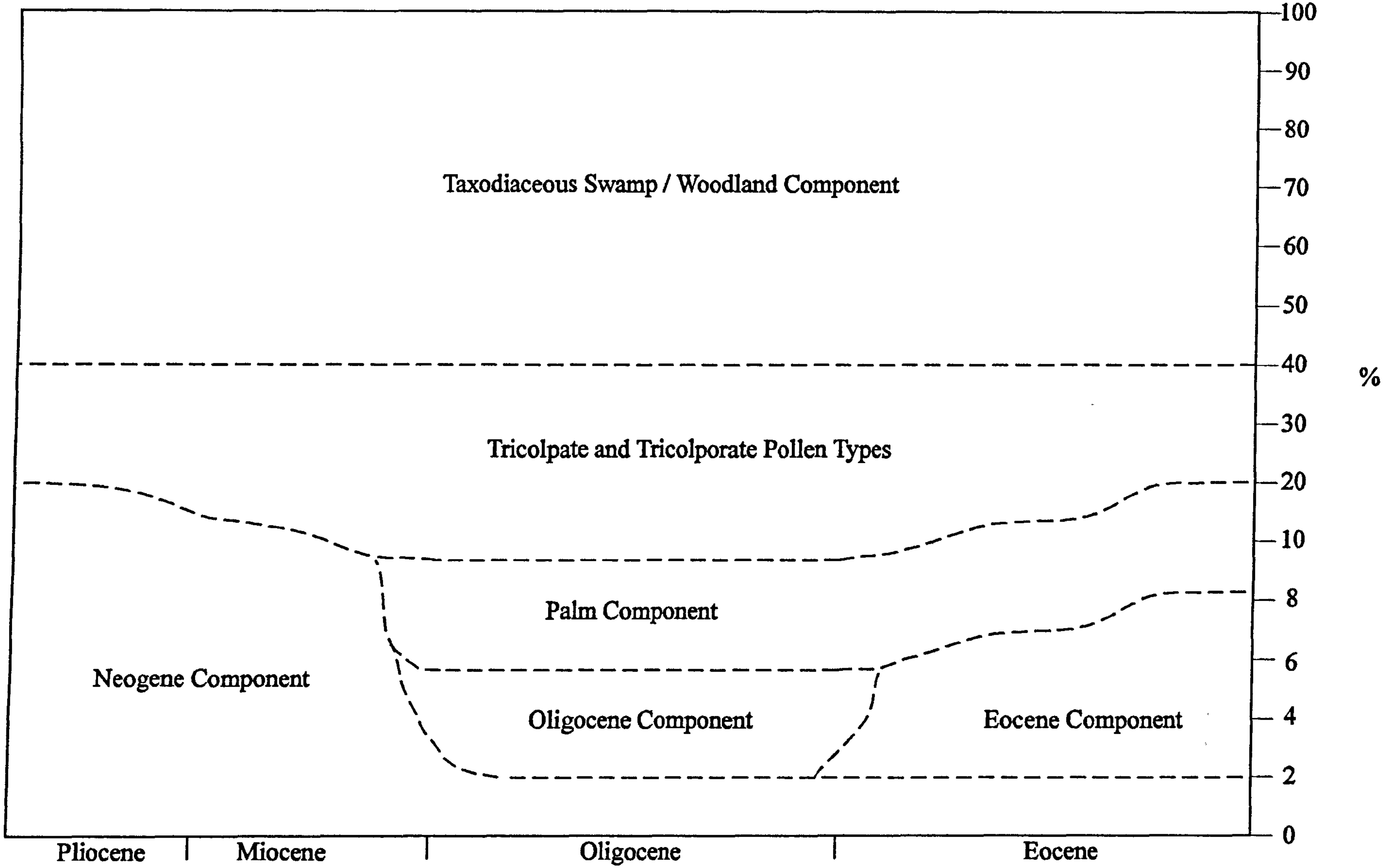


Fig. 9.1 Simplified summary of the major palynological features of the north west European Tertiary after Boulter (1980).

was not the case they were recognised at genus level. Meyer noted that some of the stratigraphic assignations needed to be treated with reservation due to the nature of the synthesis of the data set. It should be noted that taxa with a particular regional significance were not included. Ranges of taxa from the Polish Palaeogene were not included as it has been shown that the typical Palaeocene and Early Eocene species range up into the Middle or Late Oligocene and that species characteristic of the Middle and Late Palaeogene range down into the Palaeocene.

The stratigraphic zones SP6-SP8 were defined as follows:

Zone SP6 Early Oligocene (Early Tongrian, 'Ludian', Latdorfian s.s.)

Base: The first occurrence of *Dicolpopollis kockeli.*

Top: The species that mark the base of Zone SP7.

Zone SP7 Early and Middle Oligocene (Late Tongrian, Rupelian, Stampian)

Base: The first occurrence of *Boehlensipollis hohli*
Slowakipollis hippophaeoides
Caryapollenites simplex
Chenopodipollis multiplex.

Top: The last occurrences of *Pentapollenites Group*
Aglaoreidia cyclops
Beohlensipollis hohli.

SP7/SP8 boundary corresponds with the Rupelian/Chattian boundary.

This '*Boehlensipollis* Zone' is based upon the limited occurrence of this species within the Zone.

Zone SP8 Late Oligocene (Chattian)

Base: The taxa that mark the top of Zone SP7.

Top: Last occurrences of *Inaperturopollenites emmaensis*

Dicolpopollis kockeli.

The Zone continues into the Miocene.

The last occurrence of *Cicatricosisporites dorogensis* occurs in the Chattian (Palaeogene part of SP8). A further increase in summer-green 'Arcto-Tertiary' taxa is observed in this Zone.

9.1 The dating of Oligocene deposits within the British Isles

Watts (1962) presented brief results of the study of pollen assemblages of three sites from Tertiary deposits in Ireland:

1. Lignitic Clay at Ballymacadam, County Tipperary,
2. Lough Neagh Clays from the Washing Bay and Mire House boreholes,
3. Interbasaltic lignites from the Antrim, especially Craigahullier quarry near Portrush.

Pollen from these sites was described as comprising three main elements:

1. Taxa ranging through most of the Tertiary, some of which disappear at the onset of the Pliocene e.g.

Engelhardtia, Saptoaceae, *Ilex, Symplocos,* Palmae, *Sciadopitys Tricolporites megaexactus bruhlensis, Tricolpites liblarensis* and *Tricolpites microhehrici,*

2. Species not previously described,
3. Species whose occurrence was indicative of an early Tertiary age including:

the 'plicatoid' 'rhizophorid' and 'pseudocingulum' types of Krutzsch's (1957) 118 group, *Anacolosa* type *Oligopollis* and spores of 'cingulate' 'paradorogensis' and 'pseudoparadorogensis' groups. This assemblage was taken as suggestive of the end of the Eocene or early Oligocene.

The Balymacadam deposits were reported to have the richest representation of early Tertiary types and were referred to the early Eocene. Assemblages within the Lough Neagh Clays were noted to resemble those from Balymacadam, especially at their base, however, early Tertiary types were not so well represented and pollen assigned to Taxodiaceaae and *Nyssa* was noted as abundant. This flora was thought to indicate a younger age and an early or middle Oligocene age was presented for the Lough Neagh Clays. Watts reported that many of the species present do not occur in the Miocene or later Oligocene deposits from Germany.

Assemblages from the interbasaltic beds were noted as resembling those from the Lough Neagh Clays in the content of pollen of *Sequoia* type but much of the other pollen was noted as sparse and poorly preserved. The only conclusion drawn was that the interbasaltic assemblages had more in common with the Lough Neagh Clays than with the Ballymacadam deposit.

Wilkinson *et al.* (1980) noted that since the publication of Thomson and Pflug (1953), twelve important papers describing the Oligocene pollen and spore assemblages in Europe have been published. The assemblage lists within these papers show a strong similarity, depicting little floristic variation throughout the greater part of the Oligocene. As a consequence, the use of pollen and spores as a stratigraphic tool to determine a precise age is somewhat difficult. The approach adopted by Wilkinson *et al.* (1980) to date the Lough Neagh Clays was to undertake comparison with other

Oligocene assemblages throughout Europe. The following is a summary of the evidence they consulted and used.

1. *Boehlensipollis* was identified as restricted to the Oligocene (Gorin, 1975; Sittler and Schuler, 1975; Graus-Cavagnetto, 1976; Roche and Schuler, 1976; Krutzsch, 1976c, 1969).

2. The recognition of the regular occurrence together of *Dicolpopollis, Monocolpopollenites* and *Arecipites* was identified as a characteristic of the Oligocene in NW Europe.

3. Taxa that are described within the literature as restricted to the Chattian:

Verrucingulatisporites treplinensis	Krutzsch, 1961d
Cicatricosisporites chattensis	Krutzsch, 1961d
Corrusporis granotuberculatus	Krutzsch, 1967a
Corrusporis megabaculus	Krutzsch, 1967a

or well dispersed throughout, and considered to be characteristic of the Middle and Upper Oligocene of Europe (Krutzsch, 1967c):

Mediocolpopollis compactus ellenhausensis	Krutzsch, 1959c
Polypodiisporonites alienus	Potonié, 1931d
Tiliaepollenites insculptus	Mai, 1961
Tiliaepollenites instructus	Potonié, 1931a
Tricolporopollenites spinus	Krutzsch, 1962a
Porocolpopollenites calauensis	Krutzsch, 1961d
Polyatriopollenites stellatus	Potonié, 1931 ex Pflug, 1953

Tricolporopollenites ipelensis Pacltová, 1966, also recorded from the Palaeogene (Pacltová, 1966, 1978) and the Neogene of Europe (Boulter, 1971); but thought to be particularly significant as a low temperature indicator in the Upper Oligocene where it is especially abundant.

4. The absence of any forms characteristic of the Eocene or Miocene.

5. The recognition of assemblages that are comparable to those recorded by the following authors:

Pacltová (1960)	Chattian of Bohemia
Pacltová (1966)	Chattian of Slovakia
Gorin (1975)	Oligocene of the Grand Limage
Roche and Schuller (1976)	Tongrian of Belgium
Grabowska (1965)	Chattian of Poland
Doktorowicz-Hrebnicka (1957)	Chattian of Poland
Ziembinská-Tworzydlo (1974)	Chattian of Poland
Chateauneuf (1972)	Bouches-du-Rhône of France
Krutzsch (1967c)	Oligocene of East Germany

In describing pollen and spore assemblages from the Western British Isles: Lough Neagh Clays, Bovey Basin and Tremadoc Bay Basin, Wilkinson and Boulter (1980) listed taxa that they thought to be similar to other palynomorphs described from northern Europe as being more or less restricted to the Oligocene. These are listed below with their comparison to the published taxa.

Arecipites Group A	*Arecipites gossmarensis, A. lusticus, A. butomoides, A. longicolpatus* Krutzsch, 1970, Oligocene to Pliocene most common in Oligocene.

A. butomoides butomoides Krutzsch, 1970 as recorded by Ziembinská-Tworzydlo (1974), Upper Oligocene to Lower Miocene of Poland; cf. *Monocolpopollenites aerolatus* Potonié, 1934 as recorded by Pacltová (1960), Upper Oligocene to Lower Miocene of southern Bohemia; *Sabalpollenites aerolatus* (Potonié, 1934) Potonié, 1958, as recorded by Konzalova (1970).

Dicolpopollis Group A	*Dicolpopollis kockeli* Pflanzl, 1956, as recorded by Roche and Schuler (1976), Tongrian of Belgium; *D. kockeli parvigranulatus* Konzalova, 1970, Miocene northern Bohemia.
Mediocolpopollis	*Mediocolpopollis compactus* Krutzsch, 1959c *ellenhausensis* Krutzsch, 1967c, Upper Oligocene.
Nyssapollenites Group C	*Tricolporopollenites kruschi* subsp. *pseudolaesus* (Potonié, 1931d) Thomson and Pflug, 1953, recorded by Pacltová (1960), Upper Oligocene to Lower Miocene S Bohemia; *Psilatricolporites kruschi*

	(Thomson and Pflug, 1953) Roche and Schuler 1976, Tongrian of Belgium.
Porocolpopollenites Group B	*Porocolpopollenites calauensis* Krutzsch 1961d, Middle Oligocene of East Germany, Ziembinska-Tworzydlo (1974) Middle Oligocene of Poland. Krutzsch (1967c) notes the Stratigraphic range to be Uppper Eocene to Oligocene/Miocene boundary.
Tiliaepollenites Group B	*Intratriporopollenites instructus* Potonié, 1931, Thomson and Pflug, 1953, recorded by: Thomson and Pflug (1953), Pacltová (1960, 1966), Mai (1961), Ziembinska-Tworzydlo (1974) and Roche and Schuler (1976).

Intratriporopollenites instructus is believed to be rare in the Middle Oligocene, regularly present in the Upper Oligocene becoming more common with warmer conditions in the Miocene (Mai, 1961: Krutzsch, 1967c).

Tiliaepollenites Group C	*Intratriporopollenites insculptus* Mai, 1961, first appearing in Lower Oligocene occurring regularly in the Middle Oligocene and becoming common in the Chattian to

	Miocene; recorded by Pacltová (1966) and Ziembinska-Tworzydlo (1974).
Tricolporopollenites Group H	*Tricolporopollenites spinus* Krutzsch, 1962a, recorded by Grabowska (1965) and Ziembinska-Tworzydlo (1974) from the Middle Oligocene of Poland. Krutzsch (1967c) notes the range to be confined in central Europe to the Middle Oligocene.
Boehlensipollis Group A	*Boehlensipollis* sp. sensu. Sittler and Schuler (1975) *Sapindaceidites concavus* Wang, 1975, recorded by the Nanking Institute (1978) from the Oligocene of Bohai, China.
Boehlensipollis Group B	Recorded in the sections at Bovey and in the Bellbrook section (east of Lough Neagh), Wilkinson and Boulter (1980).
Polyatriopollenites	*Polyatriopollenties stellatus* in Pflug (1953). Krutzsch (1967c) does not regard the form-genus to become significant before the Chattian. Recorded by: Thomson and Pflug (1953), Pacltová (1960, 1966), Kedvas (1974), Ziembinska-Tworzydlo (1974).

Corrusporis Group A	*Corrusporis granotuberculatus* Krutzsch, 1967a, Upper Oligocene.
Corrusporis Group C	*Corrusporis megabaculus* Krutzsch, 1967a, Upper Oligocene.
Echinosporis	*Echinosporis echinatus* Krutzsch, 1967a, Lower Miocene *Echinosporis microechinatus* Krutzsch, 1967a, Chattain to Lower Miocene.
Cicatricosisporites Group E	*Cicatricosisporites chattensis* subsp. *minor* Krutzsch, 1967a, Upper Oligocene.
Cicatricosisporites Group F	*Cicatricosisporites chattensis* subsp. *chattensis* Krutzsch (1961d, 1967a), Upper Ologocene.
Camarozonosporites Group A	*Camarozonosporites semilevis* Krutzsch 1963a, Upper Oligocene.

Wilkinson and Boulter (1980) noted that as originally described there is but a fine distinction between *Camarozonosporites semilevis*, common in the Upper Oligocene of East Germany and *Camarozonosporites heskemensis* Krutzsch, 1963a, described by Krutzsch as characteristic of the Lower to Middle Oligocene.

Muerrigerisporis Group B	*Muerrigerisporis monstrans* Krutzsch, 1963a, Upper Oligocene.
Trilites Group D	*Trilites multivallatus* (Pflug, 1953) Krutzsch, 1959b; common Middle Oligocene and Miocene of East Germany Krutzsch (1967a), Middle Oligocene of Poland, Ziembinska-Tworzydlo (1974); Middle to Upper Oligocene of Rheinisches Bild, Germany, Thomson (1949), Thomson and Pflug (1953).
Verrucingulatisporites Group D	*Verrucingulatisporites treplinensis* Krutzsch, 1961d, Upper Oligocene of Germany, rare to regularly dispersed.

Jenkins *et al.* (1995) dated a section of the lacustrine deposited Flimston Clay in Pembrokshire as of probable late Oligocene Age. The pollen and spore assemblages were sparse, only 30 specimens were identified but were well preserved, showing no signs of reworking. The genera identified were *Ericipites, Cicatricosisporites, Tricolporopollenites, Polypodiaceaesporites, Monocolpopollenites and Pityosporites.* Despite admitting that the assemblages did not comprise reliable index fossils for age determination, a Chattian age was deduced on the basis of comparison to the Oligocene deposits in the same region outlined in Wilkinson and Boulter (1980). In their paper Jenkins *et al.* noted that the presence of *Cicatricosisporites chattensis* in the Lough Neagh Clays was one of the major reasons why a Late Oligocene rather than an Early Oligocene age was assigned to them by Wilkinson *et al.* (1980).

9.2 Stratigraphic age of the studied sections

The following taxa are thought to be of primary stratigraphic importance for assigning an Oligocene age to the sections studied:

Boehlensipollis Group B, Wilkinson and Boulter, 1980

Cicatricosisporites chattensis subsp. *chattensis*

Cicatricosisporites chattensis subsp. *minor*

Corrusporis species

Dicolpopollis kockeli

Mediocolpopollis compactus

Polyatriopollenites stellatus

Porocolpopollenties calauensis

Tiliapollenites instructus

Trocolporopollenties spinus

Triletes multivallatus

Their occurrences are listed for each section in tables 9.1-9.4, stars denote their presence at a particular depth. Within each section there are other taxa that are considered to provide supporting evidence for the age assignment. These are as follows:

Table. 9.1 Distribution of stratigraphically significant Oligocene taxa in 13/611.

13/611 Landagivey No. 1

Dunaghy Formation																	Lough Neagh Group													
264.00	262.00	261.00	260.00	259.58	250.00	230.00	218.00	209.00	208.00	206.00	190.00	174.00	170.00	166.00	164.80	160.00	157.41	155.19	154.00	149.12	131.00	121.00	110.00	100.00	89.00	82.00	69.95	60.00	47.00	**Depth (metres)**
						✸																✸			✸					*Arecipites* Group A, W & B, 1980
																														Boehlensipollis Group B, W & B,1980
									✸						✸								✸	✸						*Cicatricosisporites chattensis chattensis*
															✸									✸						*Cicatricosisporites chattensis minor*
																								✸						*Corrusporis* species
																														Dicolpopollis kockeli
	✸							✸														✸			✸					*Mediocolpopollenites compactus*
																												✸		*Polyatriopollenites stellatus*
						✸																								*Porocolpopollenites calauensis*
																														Tiliapollenites instructus
	✸							✸												✸		✸				✸				*Tricolporopollenites spinus*
										✸					✸									✸						*Triletes multivallatus*

13/603 Ballymoney No. 1

	Depth (metres)	*Arecipites* Group A, W & B, 1980	*Boehlensipollis* Group B, W & B,1980	*Cicatricosisporites chattensis chattensis*	*Cicatricosisporites chattensis minor*	*Corrusporis* species	*Dicolpopollis kockeli*	*Mediocolpopollenites compactus*	*Polyatriopollenites stellatus*	*Porocolpopollenites calauensis*	*Tiliapollenites instructus*	*Tricolporopollenites spinus*	*Triletes multivallatus*
Lough Neagh Group	48.00	*		*			*	*					
	60.00	*		*			*	*				*	
	80.10	*	*									*	
	100.00		*	*		*		*				*	
	120.00	*					*	*		*		*	
	130.00	*					*	*				*	
	150.00							*				*	
	161.19	*	*					*					
	180.00	*					*						
	200.07	*							*				
	218.60	*					*		*			*	
Dunaghy Formation	222.74	*										*	
	240.00	*										*	
	260.00	*									*	*	
	280.00							*				*	
	290.00	*										*	

Table. 9.2 Distribution of stratigraphically significant Oligocene taxa in 13/603.

27/415 Upper Mullan No. 1

	Depth (metres)	*Arecipites* Group A, W & B, 1980	*Boehlensipollis* Group B, W & B,1980	*Cicatricosisporites chattensis chattensis*	*Cicatricosisporites chattensis minor*	*Corrusporis spp.*	*Dicolpopollis kockeli*	*Mediocolpopollenites compactus*	*Polyatriopollenites stellatus*	*Porocolpopollenites calauensis*	*Tiliapollenites instructus*	*Tricolporopollenites spinus*	*Triletes multivallatus*
Lough Neagh Group	37.30	*					*		*				
	41.00								*			*	*
	51.00									*			
	61.00							*					
	71.00						*	*					
	75.95												
	85.00												
	102.00						*					*	
	115.00						*	*	*			*	*
	125.00		*										
	131.00												
	137.00											*	
	145.00					*							*
	151.80												
	153.00												
	165.00												
	173.00												
	175.00												
	181.00						*	*				*	
Antrm Lava Group	183.34							*					
	185.00												
	195.00												

Table. 9.3 Distribution of stratigraphically significant Oligocene taxa in 27/415.

36/4680Deerpark No. 2

	Depth (metres)	*Arecipites* Group A, W & B, 1980	*Boehlensipollis* Group B, W & B,1980	*Cicatricosisporites chattensis chattensis*	*Cicatricosisporites chattensis minor*	*Corrusporis* species	*Dicolpopollis kockeli*	*Mediocolpopollenites compactus*	*Polyatriopollenites stellatus*	*Porocolpopollenites calauensis*	*Tiliapollenites instructus*	*Tricolporopollenites spinus*	*Triletes multivallatus*
Lough Neagh Group	72.05			*		*						*	*
	80.00												
	90.00												
	103.62							*				*	
	110.00												
	131.71					*						*	
	140.67					*		*				*	
	150.56												
	169.05												*
	179.20												
	190.00												
	200.33	*	*				*			*		*	
	223.18	*										*	
	237.75			*									*
	242.25												
	245.30							*				*	
	250.00			*		*						*	*
	259.77					*							
	265.13							*	*		*		

Table. 9.4 Distribution of stratigraphically significant Oligocene taxa in 36/4680.

Camarozonospotites (Camaroxonosporites) decorus: Oligocene to Pliocene of Germany, Krutzsch (1963a).

13/611: 69.95m.

36/4680: 200.33m, 265.13m.

Camarozonospotites (Camaroxonosporites) heskemensis: Wilkinson and Boulter (1980) noted that there is only a fine distinction between this species and *Camarozonospotites (Camaroxonosporites) semilevis,* which is reported as common in the Upper Oligocene of Germany, Krutzsch (1963a).

13/611: 69.95m, 121.00m, 164.80m.

13/603: 48.00m.

36/4680: 72.05m, 110.00m, 250.00m, 265.13m.

Magnolipollenites neogenicus subsp. *minor*; recorded from the Upper Oligocene, Chattian of Germany, Krutzsch (1970); a questionable occurrence of this taxa in 13/611 at 60.00m provides very tentative support to the age.

Retitricolporopollenites gentianoides sp. nov. strongly resembles an unpublished taxon reported as having a rare occurrence in deposits of the Western British Isles and from the North Sea and restricted to Upper Oligocene, Jolley (pers. comm.).

13/603: 290.00m.

36/4680: 200.33m, 265.13m.

27/415: 183.34m.

Verrucatosporites alienus: Upper Oligocene, Chattian to Miocene of Germany, Krutzsch (1967a).

13/611: 100.00m, 110.00m.

13/603: 48.00m.

36/4680: 200.33m.

Verrucatosporites balticus subsp. *balticus*: Middle Oligocene to Pliocene of Germany, Krutzsch (1967a), as *V. balticus* not occurring below Zone 20 Calauer Bild, Middle Oligocene, Krutzsch (1970b).

13/611: 82.00m, 100.00m, 110.00m, 121.00m, 164.80m, 206.00m.

13/603: 48.00m.

36/4680: 72.00m, 250.00m.

27/415: 71.00m, 145.00m.

Verrucatosporites favus subsp. *favus*: Middle Oligocene to Miocene of Germany, Krutzsch (1967a).

13/611: 69.95m, 121.00m, 206.00m, 262.00m.

13/603: 80.10m, 161.19m, 240.00m.

36/4680: 72.05m.

Verrucatosporites favus subsp. *pseudosecundus*: Not occurring below Zone 20 Calauer Bild, Middle Oligocene, Krutzsch (1970b) as *V. pseudosecundus*.

13/611: 100.00m, 110.00m, 262.00m.

13/603: 80.10m, 100.00m, 161.19m, 218.60m, 240.00m, 280.00m.

36/4680: 72.05m, 140.67m, 200.33m, 237.75m, 265.13m.

27/415: 41.00m.

Verrucatosporites histiopteroides: Middle Oligocene to Miocene of Germany, Krutzsch (1967a), not occurring below Zone 20 Calauer Bild, Middle Oligocene, Krutzsch (1970b) a more consistent occurrence in the Post-Calauer Bilder Zone, Upper Oligocene, Krutzsch (1970b). Mainly distributed in the Upper Oligocene-Lower Miocene, Hochuli (1978). Recorded as *V. histiopteroides* subsp. *minor*.

13/611: 164.80m.

Platanuspollenties ipelensis: recorded by Pacltová (1978) as common in Middle Oligocene deposits and being characteristic of; and of particular abundance in certain phases of the Upper Oligocene. This species is recorded more or less continuously throughout all the sections.

Trocolporopollenties pseudocingulum is recorded in abundance throughout all the studied sections. This species forms the largest percentage of the tricolporate taxa. Durand (1964) recorded an increase in this taxon from the Middle Oligocene.

The pollen and spore zonation of the International Geological Correlation programme, Project No. 124, Meyer (1988) is only of limited use to delimit an age for the Lough Neagh Group and the Dunaghy Formation. The only taxon noted in the zonationan as stratigraphically indicative of the Oligocene that occurs in the studied sections is *Dicolpopollis kockeli*. This species is of limited occurrence throughout the studied sections as can be seen from tables 9.1-9.4 and enclosures 1-4. The occurrence of *Dicolpopollis kockeli* denotes an age not younger than Zone SP 8 Late Oligocene, Chattian, for the top sample analysed in 13/603 and 27/415. The non-occurrence of this species in 13/611 and the single occurrence at 200.33m in 36/4680 demands the utilisation of other taxa to delimit the age of the whole sections and specifically the Dunaghy Formation in both 13/611 and 13/603.

As may be noted from tables 9.1-9.4 the combination of taxa identified as stratigraphically diagnostic of the Oligocene have a distribution throughout the sections to effectively delimit the top and bottom samples as of Oligocene age.

Due to the general character of the assemblages Wilkinson and Boulter (1980) attributed an Upper Oligocene, Chattian age to their sections of the Lough Neagh Group. Jenkins *et al.* (1995) noted that the presence of *Cicatricosisporites chattensis* was one of the main reasons why Wilkinson and Boulter (1980) attributed an Upper Oligocene, rather than a Lower Oligocene age to their sections.

Within 13/611 *Cicatricosisporites chattensis* subsp. *chattensis* and *Cicatricosisporites chattensis* subsp. *minor* are recorded just below the top of the Dunaghy Formation at 164.80m and *Cicatricosisporites chattensis* subsp. *chattensis* is again recorded at 208.00m. Below this depth the occurrence of *Medicolpopollis compactus* may be taken as evidence of an Oligocene age, however, Krutzsch (1970b) recorded this taxon as present within the upper part of his Zone 18, Zeitzer Bild, Upper Eocene. The occurrence of *Tricolporopollenties spinus* at 209.00m and again near the bottom of the Dunaghy Formation at 262.00m may be taken as a more reliable indicator of an Oligocene age for this formation. This species was recorded by Krutzsch (1970b) as not occurring below his Zone 20, Calauer Bild, Middle Oligocene and into the Post-Calauer Bild, Upper Oligocene.

Similar lines of evidence seem to conform an Oligocene age for the Dunaghy Formation in 13/603. *Cicatricosisporites chattensis* is not recorded within the

Dunaghy Formation in this well. An occurrence of *Mediocolpopollis compactus* near the bottom of the section, at 280.00m may, as previously stated, be taken as indicative of Oligocene strata, however, as in 13/611, the occurrence of *Tricolporopollenties spinus* may be a more reliable indicator. This species is recorded consistently throughout the Dunaghy Formation in this well.

The taxa identified above and the distribution of the taxa in tables 9.1-9.4 combined with the supporting taxa previously specified seem to indicate that both the Lough Neagh Group and the Dunaghy formation as recorded in 13/611 and 13/603 may be assigned an Oligocene age. In view of the evidence presented it would seem that an Upper Oligocene age would be most applicable. However, a younger Oligocene age cannot be completely ruled out as the stratigraphic ranges of taxa used to delimit the age are principally derived from central European, particularly German sections, and differences in the range of these taxa may exist. The absence of any definite or significant Eocene or Miocene taxa further confirms the Oligocene age assignment for the sections.

Due to its distinctive morphology the pollen type described in this study as *Retitricolporopollenites gentianoides* may be of potential future use if its stratigraphic extent can be more reliably determined. It is worthy of note that it was only recorded within the lower parts of each section, within the last sample analysed in the Dunaghy Formation, 290.00m in 13/603 and within the lower parts of the Lough Neagh Group, 200.33m and 265.00m. Within 27/415 it was recorded at 183.34m within strata assigned to the Antrim Lava Group. Here it is interpreted as reworked into this highly weathered deposit.

9.3 Reworked Taxa

A single degraded specimen of *Anacolosidites* in 13/611 at 261.00m that resembled *Anacolosidites efflatus*; recorded by Krutzsch (1957) as ranging from the Lower to Upper Eocene, is thought to be possibly attributable to reworking. The pollen and spore zonation of International Geological Correlation programme, Project No. 124 (Meyer, 1988) noted that the first occurrence of the *Anacolosidites* Group marks the base of the SP3 Zone, Late Palaeocene. The last occurrence of this group marks the top of the SP4 Zone, Early -Middle Eocene. The lithology below 262.55m is recorded as clay, questionable tuff with weathered igneous material, and clay and conglomerate below 264.42m. Lithologies below 266.33 are assigned to the Antrim Lava Group. Whilst the specimen of *Anacolosidites* is recorded in a clay containing lignite fragments, the sample one metre below it at 262.00m represents a sediment with a clayey matrix containing orange pink clasts and some lignite traces. The proximity of this lithology that contains pollen characteristic of the Oligocene, the general character of the lithologies in the succeeding few metres and the poor preservation of the pollen specimen is thought to provide reasonable evidence that the specimen has been reworked into the assemblage of otherwise general Oligocene character.

The single occurrence of a specimen of *Plicatopollis* in 27/415 at 183.34m may represent reworking from sediments of an older age. The form genus was recorded as mainly of Eocene age by Krutzsch (1967c) but it is known to extend to the Middle Oligocene.

9.4 Application of form-generic groupings to stratigraphic resolution

Boulter (1979) presented a review of the pollen and spore assemblages from three Tertiary deposits from Ireland and compared the assemblages obtained with data from more than fifty Tertiary sections throughout NW Europe. The results of this review and comparison of data produced six groups of form-genera/components that were noted to be applicable to broadly defining the stratigraphic age of a Tertiary deposit. The utilisation of form-genera was intended to provide a sounder base for the comparison of data as the definition of form-species is regarded by Boulter to be based upon widely differing authors' judgements and consequently assemblages from a variety of sections difficult to compare.

Within the Oligocene a small number of form-species were identified to be of stratigraphical importance and were included in the Oligocene component.

The groups identified by Boulter are as follows:

1. Taxodiaceous Swamp/Woodland Component,
2. Lower Tertiary Component,
3. Oligocene Component,
4. Palm Component,
5. Neogene component,

Tricolpate and tricolporate pollen types were grouped to form the sixth component and plotted on a chart with the five components mentioned above to broadly illustrate the major features of Tertiary pollen and spore assemblages from NW Europe. This chart is reproduced as fig. 9.1.

In order to test the broadly defined stratigraphic zonation of Boulter (1980), the taxa recorded in the studied sections were assigned to Boulter's components. The pollen and spore data for each component was summed to compare the resulting distributions to those one would expect from the percentage distribution illustrated in fig. 9.1. The results for the complete sections in the four studied wells and for the Dunaghy Formation in 13/611 and 13/603 are presented in table 9.5.

The taxa that comprise each component specified by Boulter (1980) are presented in table 9.6. The taxa in the studied sections that form the Unassigned taxa in table 9.6 are listed in table 9.7.

The species that comprise the form-generic taxa identified as the Oligocene Component were not specified in Boulter (1980). The following taxa have been identified as stratigraphically significant in the Oligocene from Wilkinson and Boulter (1980) and were used to form the members of the Oligocene Component if they occurred in the studied sections:

Cicatricosisporites chattensis subsp. *chattensis*

Cicatricosisporites chattensis subsp. *minor*

Gothanipollis Group A, Wilkinson and Boulter, 1980

Gothanipollenties Group B, Wilkinson and Boulter, 1980

Mediocolpopollis compactus

Polyatriopollenties stellatus

Polypodiisporonites favus

Porocolpopollenties calauensis

Tiliapollenties insculptus

Tiliapollenties instructus

Tricolporopollenties spinus

Verrucingulatisporites treplinensis

Component of Boulter (1980)	13/611 Complete section %	13/611 Dunaghy Formation only %	13/603 Complete Section %	13/603 Dunaghy Formation only %	36/4680 Complete Section %	27/415 Complete Section %
Taxodiaceous Swamp/Woodland Component	57	59	43	49	77	59
Tricolpate and Tricolporate pollen types	35	37	47	46	18	38
Oligocene Component	2	3	3	2	3	1
Palm Component	2	<1	6	3	<1	<1
Lower Tertiary Component	<1	<1	<1	0	0	<1
Neogene Component	0	0	0	0	0	0
Unassigned taxa	4	1	<1	<1	2	<1

Table 9.5 Percentage of the Tertiary Component Groups of Boulter (1980) comprising each section.

Taxodiaceous Swamp/Woodland Component

Abiespollenites
Baculatisporites
Camarozonosporites
Carpinipites
Cedripites
Cicatricosisporites
Cicatricososporites
Compositoipollenites
Corsinipollenites
Deltoidospora
Echinatisporis
Echinosporis
Engelhardtiodites
Ericipites
Gleicheniidites
Graminidites
Ilexpollenites
Inaperturopollenites
Lycopodiumsporites
Microfoveolatosporis
Momipites
Monolites
Muerrigerisporis
Multiporopollenites
Myricipites
Myrtaceidites
Nyssapollenites
Osmundacidites
Periporopollenites
Piceaepollenites
Pityosporites
Podocarpidites
Polypodiaceaesporites
Polypodiaceoisporites
Polypodiidites
Polypodiisporonites
Polyvestibulopollenites
Porocolpopollenites
Salixipollenties
Sciadopityspollenites
Sequoiapollenites
Stereisporites
Subtriporopollenites
Tetracolporopollenties
Tiliaepollenites
Toroisporis
Tricolpopollenties
Tricolporopollenites
Trilites
Triplanosporites
Triporopollenites
Trivestibulopollenites
Tsugaepollenites
Ulmipollenites
Verrucingulatisporites

Lower Tertiary Component

Aglaoreidia
Anacolosidites
Basopollis
Brosipollis
Diporites
Duplopollis
Gallopollis
Interpollis
Labrapollis
Lymingtonia
Milfordia
Minorpollis
Nudopollis
Parsondites
Pentapollenites
Pistillipollenites
Plicapollis
Plicatopollis
Pompeckjoidaepollenites
Retiovoipollis
Sparganiaceaepollenites
Spinozonocolpites
Stephanoporopollenties
Trudopollis

Oligocene Component	**Palm Component**
Boehlensipollis	*Arecipites*
Cicatricsisporites taxa	*Dicolpopollis*
Corrusporis	*Monocolpopollenites*
Gothanipollis taxa	
Mediocolpopollis taxa	**Neogene Component**
Polyatriopollenties taxa	
Polypodiisporonites taxa	*Nupharpollenites*
Porocolpopollenites taxa	*Sciadopityspollenites*
Tiliaepollenites taxa	*Symplocospollenites*
Tricolporopollenites taxa	*Tricolporopollenites taxa*
Verrucingulatisporites taxa	*Tsugaepollenites*

Table 9.6 Taxa assigned to the Components of the European Tertiary, Boulter (1980).

Unassigned Taxa

13/611	**36/4680**
? *Cycadopites* spp.	*Cycadopites* sp. A
Cycadopites sp. A	Echinate spore sp. A
Echinate spore sp. A	Echinate spore sp. B
Echinate spore sp. B	Echinate spore sp. C
Echinate spore sp. C	? *Holkopollis* spp.
Hydrosporis azollaensis	*Hydrosporis levis*
Hydrosporis levis	*Saxosporis gracillus*
? *Magnolipollis neogenicus minor*	Trilete spore (undifferentiated)
Saxosporis gracillus	*Varrirugosporites megaverrucatus*
Trilete spores (undifferentiated)	
Varrirugosporites megaverrucatus	
13/603	**27/415**
Cycadopites sp. A	*Cycadopites* sp. A
Cyperaceaepollis spp.	*Foveotriletes* spp.
Saxosporis gracillus	*Hydrosporis levis*
	Saxosporis gracillus
	Trilete spore (undifferentiated)

Table 9.7 Taxa in studied sections unassigned to the Components of the European Tertiary, after Boulter (1980).

Sciadopityspollenites is listed as a member of the Taxodiaceous Swamp/ Woodland Component and of the Neogene component. As the species recorded, *Sciadopityspollenites quintus* and *Sciadopityspollenites verticillatiformis*, do not have a stratigraphic range restricted to the Neogene, all occurrences of this form genus were attributed to the Taxodiaceous Swamp/ Woodland Component.

The percentage totals of the components are seen to broadly agree with those presented in fig. 9.1. The Taxodiaceous Swamp/Woodland Component and the Tricolporate and Tricolpate Pollen Types display the highest percentages broadly agreeing with the general values for these groups of 60% and 30% respectively as shown in fig. 9.1. The absence of any pollen assigned to the Neogene Component and any significant amount of pollen of the Lower Tertiary Component (see table 9.5) leaves the small Oligocene Component as age diagnostic. Fig. 9.1. depicts a maximum value of approximately 4% for the Oligocene and Palm Components, decreasing later in the Oligocene. The percentages recorded for these components in table 9.5. again appear to broadly agree with those of fig. 9.1 and with the view of Boulter (1980) that any pollen of stratigraphical significance in the Tertiary is rare.

10 LATE PALAEOGENE PALAEOCLIMATE

10.1 Palaeogene palaeoclimate and the Eocene-Oligocene transition

During the Palaeogene the global climate underwent a great transition. In its most extreme representation the climate can be said to have passed from globally warm in the Cretaceous to glaciated in the Pleistocene. Between these two extremes a general cooling occurred (Savin, 1977, 1982). The Eocene to Oligocene has been identified as a key time of change by numerous lines of evidence from the marine realm (Kegwin and Corliss, 1986; Keller, 1983; Savin, 1977; Shackleton, 1986). Large changes in continental climate have been identified (Chaney, 1940; Kemp, 1978; Leopold and MacGinte, 1972; Retallack, 1986; Wolfe and Pore, 1982; Wolfe, 1980, 1985).

The early Eocene was the warmest time within the Cenozoic. During the early and middle Eocene the occurrence of forests at high latitudes indicates a warm continental climate in both the Northern and Southern hemispheres (Axelrod, 1984; Frakes and Kemp, 1973; Wolfe, 1980, 1985). Oxygen isotope ratios from planktonic and benthic foraminifera indicate warm marine conditions (Boersma *et al.*, 1987; Savin *et al.*, 1975 and Shackleton, 1986). The common theme running through most of these palaeoclimatic interpretations is the existence of a low thermal gradient throughout this time (Sloan and Barron, 1992).

Two of the most noticeable changes in the large-scale physical elements of the Earth within the Paleogene were:

1. The increasing tectonic uplift of the continents
2. The changes in sea surface temperature distributions.

These factors were identified as being largely responsible for the Palaeogene climatic change (Sloan and Barron, 1992). These changing factors had a distinct effect upon continental climate and upon its existing and evolving biota. Major mountain building episodes e.g. the Andes, Rockies, Himalayas and Alps, resulted in increasing the effects of rain shadow. The movement of continents facilitated the dispersal and isolation of animal and plant taxa. Movement of land-masses into higher latitudes contributed to the onset and growth of polar ice. The effects of these factors combined to produce a more complex climate than had previously existed, with increased latitudinal temperature gradients, more localised continentality and oceanicity and new barriers to migration (Crane, 1989).

Collinson and Hooker (1987) recorded changes in the vegetational and mammal communities of Britain from the late Palaeocene to early Oligocene. They noted that mammal habitats from early Eocene to early Oligocene changed from complex forests to a more open environment with forest patches. By the latest Eocene there was a marked wet-dry seasonality in southern Britain (Daley, 1989). Temperatures had fallen from their late early Eocene maximum although it was not until the early Oligocene that a marked temperature fall occurred. This was linked to Antarctic glaciation (Shackleton, 1986).

The idea of the 'terminal Eocene event' was first introduced by Wolfe (1978) and linked to a distinct and rapid temperature decline at the close of the Eocene. The climatic deterioration around the Eocene/Oligocene boundary has been described as the most important global climatic event occurring between Cretaceous/Tertiary boundary events and the late Pliocene glaciations (Wolfe, 1992). Its effects are noted in the marine record but are displayed to their maximum in terrestrial environments.

The suggestion of an abrupt climatic deterioration in the Oligocene was first put forward by Mac Ginte (1953). The cooling proposed by Mac Ginte was confirmed by Wolfe and Hopkins (1967) and established to have occurred rapidly, within a period of no longer than 2 million years. Oxygen isotope data from New Zealand (Devereux, 1967) and from the D.S.D.P. (Shackleton and Kennett, 1975; Keigwin, 1980) indicates a marked temperature decline around the Eocene/Oligocene boundary. The rapidity and size of the Oligocene deterioration has been disputed by Axelrod and Bailey (1969). Their assignation of an older age for the pre-deterioration floras and lower temperatures to these assemblages resulted in the recognition of a gradual temperature decline over several million years. Collinson *et al.* (1981) questioned the intensity of the early Oligocene deterioration. Changes noted within the Eocene of the London and Hampshire Basins indicate two major periods of floristic change that were interpreted as depicting a gradual cooling commencing in the latest early Eocene and occurring over a period of 15 million years. This evidence is in conflict with palaeotemperature curves from the North Sea which suggest a sudden and rapid cooling at the end of the Eocene (Buchardt, 1978a). See fig. 10.1.

The age and hence the name assigned to the climatic deterioration around the Eocene Oligocene boundary has varied with differing authors over time. Using a then accepted molluscan chronology, Mac Ginte (1953) considered the deterioration to have occurred between the middle and late Oligocene. Wolfe and Hopkins (1967) used a revised molluscan chronology and thought the event to have been of middle Oligocene age. Wolfe (1978) considered the deterioration to have occurred at the Eocene/Oligocene boundary based upon planktonic biochronology. As a consequence of this he termed the climatic deterioration the 'terminal Eocene event'. The deterioration has been dated radiometrically at 33 Ma and considered to occur within

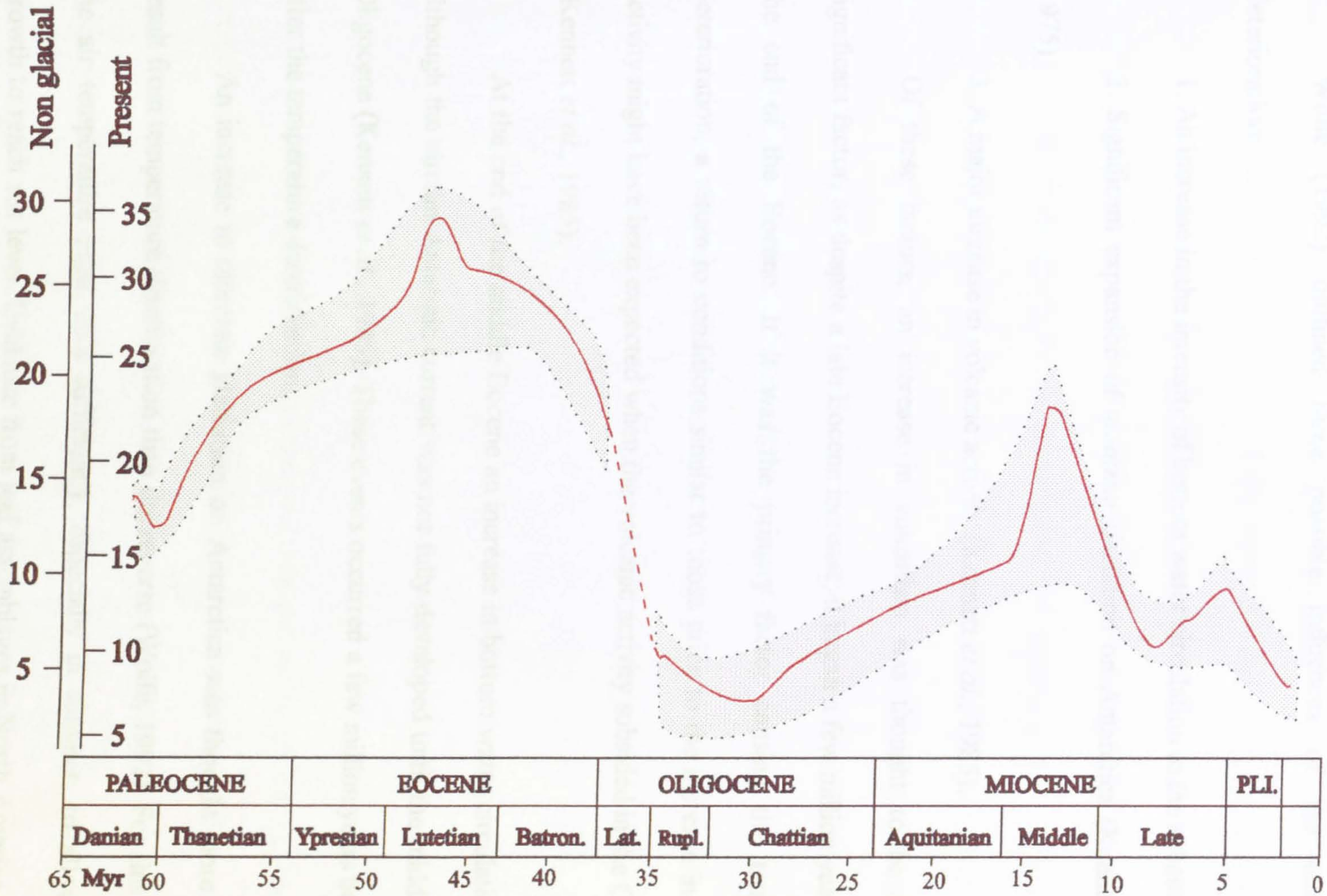


Fig. 10.1 Oxygen isotope palaeotemperature curves from the North Sea, after Buchardt (1978).

NP21 (Wolfe, 1992). The Eocene/Oligocene boundary has been dated at 34 Ma (Swisher and Prothero, 1990) therefore the event is considered to have occurred approximately 1 million years after the Eocene/Oligocene boundary (Wolfe, 1992).

Wolfe (1992) outlined three possible influences of the temperature deterioration:

1. An increase in the intensity of bottom water circulation in the subantarctic
2. Significant expansion of montane glaciation on Antarctica (Kennett *et al.*, 1975)
3. A major increase in volcanic activity (Kennett *et al.*, 1985).

Of these factors, an increase in vulcanism was thought to be the least significant factor, as despite a late Eocene increase, it began a few million years before the end of the Eocene. If it was the primary factor causing the temperature deterioration, a return to conditions similar to those prior to the increase in volcanic activity might have been expected when the volcanic activity subsided in the Oligocene (Kennett *et al.*, 1985).

At the end of the middle Eocene an increase in bottom water circulation began although the circum-Antarctic current was not fully developed until the middle or late Oligocene (Kennett *et al.*, 1985). These events occurred a few million years before and after the temperature deterioration.

An increase in montane glaciation on Antarctica was thought more likely to result from temperature deterioration than the reverse (Wolfe, 1992). For this to occur the air temperature must cool sufficiently, especially in summer, to allow glacier growth to reach sea level. Evidence from leaf assemblages in North America indicates a warming of the air temperatures during the latest Eocene/earliest Oligocene. Further evidence from leaf assemblages in western North America (Wolfe, 1978) indicates a warming of 3-4° C during the latter part of the Oligocene. If the continuing growth of ice on Antarctica were a primary factor in the cause of the temperature deterioration, a continued decline in temperatures throughout the Oligocene would have been expected.

Kennett *et al.* (1985) compared the Oligocene deterioration to events at the Cretaceous /Tertiary boundary and noted that no catastrophic extinction occurred at the Oligocene event. Wolfe (1992) noted that regional extinctions of the high latitude land flora, that could be classed as catastrophic, did occur e.g. the disappearance of 80-90 % of the genera from high latitudes in North America. He also noted that like the K/T event, the Oligocene deterioration was abrupt, and stated that this was hard to explain in relation to plate tectonic factors or changes in ocean circulation.

Due to these factors Wolfe (1992) suggested that explanations proposed to account for the Oligocene deterioration were unsatisfactory and the search for other explanations should continue.

10.2 Vegetational and palaeoclimate changes in Britain and other areas of western Europe during the Eocene-Oligocene transition

During late Eocene times Europe was only connected to North America by a land bridge between Greenland and northern Scandinavia (Tiffney, 1985). After this time North America was closed to the direct movement of elements to and from Europe which resulted in the development of an increasingly recognisable European floristic element.

A change from a dominantly evergreen, subtropical vegetation of the late Eocene, to a mixed evergreen and deciduous vegetation, with a warm but seasonal climate in the Oligocene, is evidenced from sections throughout Europe e.g. macrofloral evidence from the Weisselster Basin of Germany and from north west Bohemia (Czechoslovakia). Palynological evidence of transition records the loss of tropical and sub-tropical elements, an incoming of temperate elements and an increase in conifer pollen (Collinson, 1992). These changes across the Eocene/Oligocene boundary are generally perceived as a culmination of floristic changes resulting from a cooling climate which started in the early late Eocene. Around Britain this cooling event is supported by oxygen isotope data from North Sea sediments (Buchardt, 1978a).

Collinson (1992) (and the references therein) provide a summary of vegetational change around the Eocene/Oligocene boundary for many areas of western and central Europe. The common factor in most of these appears to be the decrease of taxa with a tropical and subtropical affinity and an increase in conifer pollen (Cavelier *et al.*, 1980; Chateauneuf, 1980; Iljinskaya, 1988; Kvacek *et al.*, 1989; Mai and Walther, 1978, 1985; Olliverier-Pierre *et al.*, 1987, 1988; Pulatova, 1990; Teslenko, 1990; Walther, 1990).

In southern England many authors have recorded the floristic changes between the latest Eocene and earliest Oligocene using a variety of macrofossil and palynological evidence (Boulter, 1984; Boulter and Hubbard, 1982; Collinson, 1983, 1990; Collinson *et al.*, 1981; Collinson and Hooker, 1987; Hubbard and Boulter, 1983; Machin, 1971).

Using macrofossil and palynological evidence Collinson *et al.* (1981) recorded a gradual decline in taxa with a tropical or subtropical affinity. Machin (1971), working on the micro fossil flora of the Isle of Wight, reported a decrease in the tropical families characteristic of the London clay flora in Headon times and a shift to a more northern flora containing elements characteristic of sub tropical SE Asia and SE North American vegetation. She reported a similar vegetational shift, evidenced from the macroflora in post Lower Headon times (Late Eocene), from an Indomalayan flora to a subtropical evergreen vegetation dominated by conifers from Middle Oligocene times.

Boulter and Hubbard (1982) and Hubbard and Boulter (1983) outlined a method for estimating palaeotemperatures for the Eocene and Oligocene of NW Europe. See fig. 10.2. Using multivariate statistical analysis (principal components analysis and cluster analysis) of pollen and spore spectra four major groupings of taxa were identified. Three of these had ecological significance and a fourth formed a 'rubbish-bin' of plant taxa reflecting the influences of transportation and catchment processes. By comparison with megafossil evidence, principally the leaf physiognomic classes of vegetation and associated climatic parameters of Wolfe (1979), they produced estimates of summer maximum and winter minimum temperatures.

The results of the study (Hubbard and Boulter, 1983) depicted a cool period with an unstable but equable climate prior to a thermal maximum/warming episode at the top of the London Clay and bottom of the Bracklesham Beds. This was followed by a decrease in climate equability producing another cool period before a very brief phase of warming in the lower Oligocene recorded at Bovey Tracey, Mochras and Lundy.

The Eocene is thought to have had generally mild winters and mean annual summer temperatures that changed considerably. The Oligocene climate is noted as being uniformly cooler with a climate characterised by relatively constant maximum summer and mean annual temperatures, but marked by strong fluctuations in the severity of the winters, reported to have often been of pronounced frigidity.

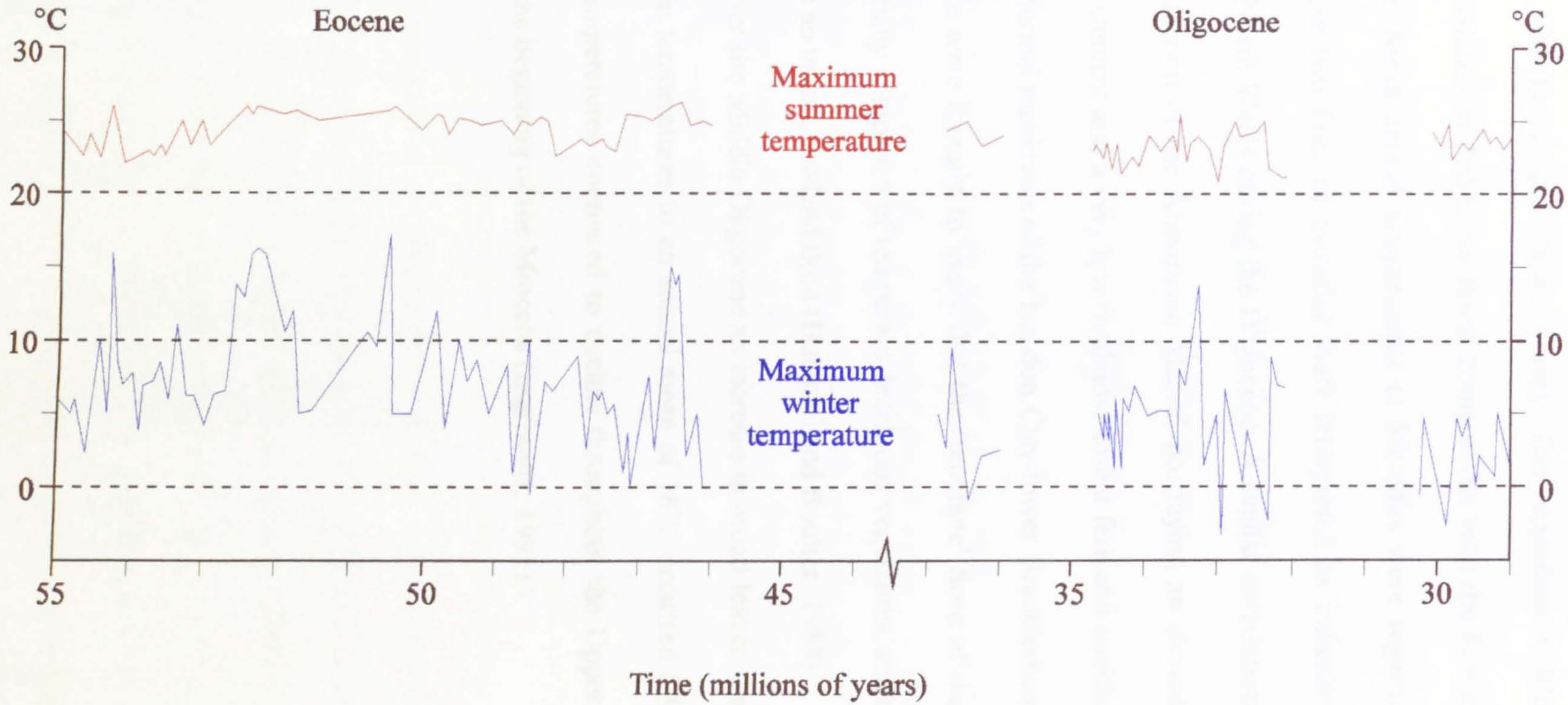


Fig. 10.2 Summer and winter maximum temperatures predicted from pollen spectra after Hubbard and Boulter (1983).

A brief warm phase noted from the pollen assemblages in the Oligocene of the Mochras borehole is considered to be of stratigraphical importance as it allowed correlation with Lundy and Bovey Tracey. The vegetation at Mochras portrayed a greater abundance of deciduous forest components with the fern and conifer element being rarer. Mean annual temperatures at Mochras were regarded as being 2-3°C lower. These two lines of evidence were interpreted as indicating that higher land existed in North Wales during the Oligocene. A similar correlation of the Calcaire de Campbon section of the Armoricain Massif, portraying an increased proportion of a deciduous element and a very low to almost absent fern and conifer element was made with the thermal maximum of the London Clay-lower Bracklesham floras. These lines of evidence were thought to imply that the 'montane' flora of the European Tertiary was essentially comprised of temperate deciduous vegetation, and that fern and conifer forest was an inland, lowland flora (Hubbard and Boulter, 1983).

After the Middle Oligocene an increase in broad leaved deciduous forest and a decrease in temperatures to an annual mean of 18°C occurred (Hubbard and Boulter, 1983). Temperatures continued to decline throughout the Upper Oligocene but rose again by the beginning of the Miocene (Ingrouille, 1995).

11. PALAEOECOLOGICAL INTERPRETATION

11.1 Application of form generic groupings to palaeoecological interpretation

Following from the view of Boulter and Craig (1979) and Boulter (1980) that the use of a taxonomic level below that of the form-genus is unnecessary for stratigraphic division in the Tertiary, Boulter and Hubbard (1982) and Hubbard and Boulter (1983) utilised form-genera as the taxonomic basis for multivariate statistical analysis of palynological data to produce groupings of taxa that could be related to forest types.

The usefulness of form-species in palaeoecological interpretation has been questioned by Farley (1989). He is of the view that many form-species do not have much biological or ecological value in Tertiary palynology and states that even most Quaternary palynologists only identify pollen to generic level despite the pollen being derived from extant plant taxa. The use of form-genera may blurr stratigraphic differences in deposits but not palaeoecological ones (Farley, 1989).

Pollen abundance data within this study has been recorded at the taxonomic level of form-species; because of this any potential stratigraphic and ecologic usefulness attributable to this level of division will have been retained. For the purposes of palaeoecological interpretation, the form-species and form-genera have been assigned to family level based upon previously published data. This enables a clearer picture of the vegetation to be determined.

Mosbrugger and Utescher (1997) describe a coexistence approach for quantitative terrestrial palaeoclimatic reconstruction. The procedure is based on the assumption that Tertiary plant taxa have a similar climatic requirement to the nearest living relative. Utilising a data set of Tertiary plant taxa, nearest living relatives, climatic requirements and an algorithm for analysis, they successfully obtained a series of temperature and rainfall parameters for Neogene fruit/seed floras and palynofloras.

The idea of assigning fossil pollen to an extant plant taxon and utilising the climatic parameters with which the extant plant exists to deduce palaeoclimate is not new and is a frequently used technique. The procedure suffers from possible erroneous assumptions. The identification of extant taxa with the fossil taxa of similar morphology may not be biologically correct and the climatic tolerance of the fossil taxa may have been different to that of the extant taxa. Such assumptions are needed to enable any progression in palaeoclimatic and palaeoecological reconstruction. The thesis that past situations and processes may be inferred from studying those of the present has been the cornerstone to geological and palaeontological thinking since the nineteenth century.

The assignation of fossil plant taxa, including pollen and spores, to extant equivalents is widely regarded to be more applicable to the later Tertiary than to earlier periods of time as plant evolution led to floras attaining greater similarity to those of the present.

Due to the composition of the palynofloras in the studied sections, the assignation to extant families produces groupings of essentially similar form-species composition to those that would occur if the data was grouped into form-genera. The familial groupings used do not result in any significantly greater assimilation of form-species than would occur if the all encompassing form-generic groups

Tricolpopollenites and *Tricolporopollenites* were utilised, indeed greater distinction of form-species is attained in the case of some Tricolporate pollen.

A degree of assimilation of form-generic taxa occurs in the case of pteridophyte spore families e.g. Polypodiaceae, this however does not detract from the palaeocological significance of the grouping as the taxa assigned are universally recognised as having a parental affinity to ferns. No greater ecological significance is noted to have been attributed to any of the form-species.

The pollen and spore abundance data recorded at the resolution of form-species is displayed as percentage frequency data in a histogram format as enclosures 1-4. A + symbol denotes an occurrence of the taxon outside the numerical count. The data grouped at family level is displayed in the form of a saw tooth diagram as enclosures 9-12.

It should be noted that for the purposes of clarity of illustration, reticulate tricolpate pollen assigned to *Euretitricolpites* Group A Wilkinson and Boulter, 1980; *Euretitricolpites* Group C Wilkinson and Boulter, 1980; *Supraretitricolpites* Group B Wilkinson and Boulter, 1980; and *Supraretitricolpites* Group D Wilkinson and Boulter, 1980 have been included in the family Salicaceae. The afore mentioned taxa are grouped into this family to prevent them from otherwise becoming consumed within the Unassigned Tricolpate pollen group. The author's opinion that pollen displaying their particular reticulate morphology might not be attributable to *Salix* is tentative and not proven, see discussion in chapter 7.3.1.

Taxa that comprise the Unassigned Tricolpate pollen group, the Tricolporate pollen group and the Unassigned Trilete spore group within the studied sections are as follows:

13/611

Unassigned Tricolpate pollen: *Tricolpopollenites hastus, Tricolpopollenites verrucatus, Tricolpopollenties* spp., *Retitricolpites* sp. A.

Unassigned Tricolporate pollen: *Retioperculotricolporites* spp., *Tricolporopollenties baculoferus, Tricolporopollenties spinoreticulatus, Tricolporopollenites spinus, Tricolporopollenties verrucatus, Tricolporopollenties* sp. B, *Tricolporopollenties* spp.

Unassigned Trilete spores: *Deltoidospora wolfii, Deltoidospora* spp., *Saxosporis gracilis,* Trilete spores (undifferentiated).

13/603

Unassigned Tricolpate pollen: *Tricolpopollenites hastus, Tricolpopollenites verrucatus, Retitricolpites* sp. A.

Unassigned Tricolporate pollen: *Tricolporopollenties baculoferus, Tricolporopollenties spinoreticulatus, Tricolporopollenites spinus, Tricolporopollenties verrucatus, Tricolporopollenties* sp. B, *Tricolporopollenties* spp.

Unassigned Trilete spores: *Deltoidospora wolfii, Deltoidospora* spp., *Saxosporis gracilis,*.

36/4680

Unassigned Tricolpate pollen: *Tricolpopollenites hastus, Tricolpopollenites verrucatus, Tricolpopollenties* spp.

Unassigned Tricolporate pollen: *Retioperculotricolporites* spp., *Tricolporopollenties baculoferus, Tricolporopollenties spinoreticulatus, Tricolporopollenites spinus, Tricolporopollenites* cf. *spinus, Tricolporopollenties verrucatus, Tricolporopollenties* sp. B, *Tricolporopollenties* spp.

Unassigned Trilete spores: *Deltoidospora wolfii, Deltoidospora* spp., *Saxosporis gracilis,* Trilete spores (undifferentiated).

27/415

Unassigned Tricolpate pollen: *Tricolpopollenites hastus, Tricolpopollenites verrucatus, Tricolpopollenties* spp., *Retitricolpites* sp. A, Retitricolpate pollen.

Unassigned Tricolporate pollen: *Retioperculotricolporites* spp., *Tricolporopollenties baculoferus, Tricolporopollenties spinoreticulatus, Tricolporopollenites spinus, Tricolporopollenties verrucatus, Tricolporopollenties* spp.

Unassigned Trilete spores: *Deltoidospora wolfii, Deltoidospora* spp., *Foveotriletes* spp., *Saxosporis gracilis,* Trilete spores (undifferentiated).

Taxa recorded as present outside the count are denoted by a + on enclosures 1-4. These taxa were incorporated within the % Abundance Family Affinity charts by the following calculation. Percentage values were taken as numerical occurrence values using an occurrence (+) as a numerical value of 1. These values were summed and divided by the number of taxa recorded in a sample to produce recalculated percentage values for all taxa recorded.

11.2 Lithofacies control on palynomorph assemblages

The control of lithofacies upon palynomorph assemblages, principally the presence and abundance of taxa, can affect the interpretation of palaeoecology and the precision of biostratigraphy applied to a terrestrial palynoflora. Even when using genera as a taxonomic base the facies is noted to exert a control on the precision of biostratigraphy (Farley, 1989).

When interpreting the palaeoecology of a sequence, an understanding of the depositional environment and possible effects of lithofacies control on the palynomorph assemblage is essential to avoid misinterpretations of abundance and distribution data. Different environments/lithofacies preserve pollen and spores in varying concentrations and abundances. Autochthonous pollen and spore assemblages, such as those from the lignitic facies of the Lough Neagh Group, will provide the best evidence for palaeocological interpretation as they will be more likely to contain an accurate representation of pollen and spore production from the parent flora.

11.3 Peat formation and wetland ecology

In order to interpret the palaeoecology and palaeoflora from the pollen and spore assemblages of the Lough Neagh Group an understanding of conditions under which the lignite formed is needed. Parnell *et al.* (1989) regarded the lignites and organic rich mudrocks as representing a swampy environment at the margin of a lake: thick lignites with a low ash content imply isolation from clastic input. The peat was considered to have originated from floating or raised swamps above the water level that never received transported mineral matter.

The peat forming environments of the Tertiary are far more clearly understood than those of the Palaeozoic or Mesozoic. Tertiary coals are dominated by Taxodiaceaeous conifers and a diverse range of arborescent shrub and herbaceous forms of angiosperms. No equivalents to the Northern Hemisphere temperate peats formed by *Sphagnum* have yet been identified before the Quaternary period (Collinson and Scott, 1987).

Peat formation and the peat forming environment is strongly influenced and, in some cases, controlled by the vegetation contributing to its formation (Collinson and Scott, 1987). The formation and accumulation of peat relies upon an imbalance in the ecosystem so that total energy fixation by photosynthesis exceeds the total respiration of the flora and fauna (Moore, 1987). Mc Cabe (1984) notes that the water table must be at, or above, the sediment surface and that the equation of Bellamy (1972) must balance.

Inflow + Precipitation = Outflow + Evapotranspiration + Retention

The imbalance in the energetic relations of the ecosystem originated by water logging of the environment impeding the detritivore and microbial activity (Moore, 1987).

Habitats within which peat accumulates may be given the general term 'mire' (Moore, 1987). A comprehension of the hydrological relationships in the different types of mire is necessary to enable an understanding of the nature and rate of peat formation.

Two distinct hydrological divisions of mires exist and exert pronounced effects upon the amount of inorganic input (ash content) to the peat.

1. Ombrotrophic system: This depends entirely upon rainfall for water input and consequently has a limited supply of inorganic material.

2. Rheotrophic system: Water input comes from rainfall, groundwater movement and overland drainage. This system has a higher input of inorganic material.

The surface of an ombrotrophic mire is raised above the level of groundwater through the formation of a mat of peat. Separation of ombrotrophic and rheotrophic mires may be difficult as they can occur in close association. On a small scale of metres as opposed to a more regional one of kilometres, hummocks of bog moss within a mire may be regarded as small ombrotrophic areas shedding water into drainage channels which may be thought of as minor rheotrophic systems (Moore, 1987).

The interplay of the hydrological regime and the climatic parameters to produce different types of mire ecosystem is illustrated in fig. 11.1 (after Etherington, 1983; Moore, 1987).

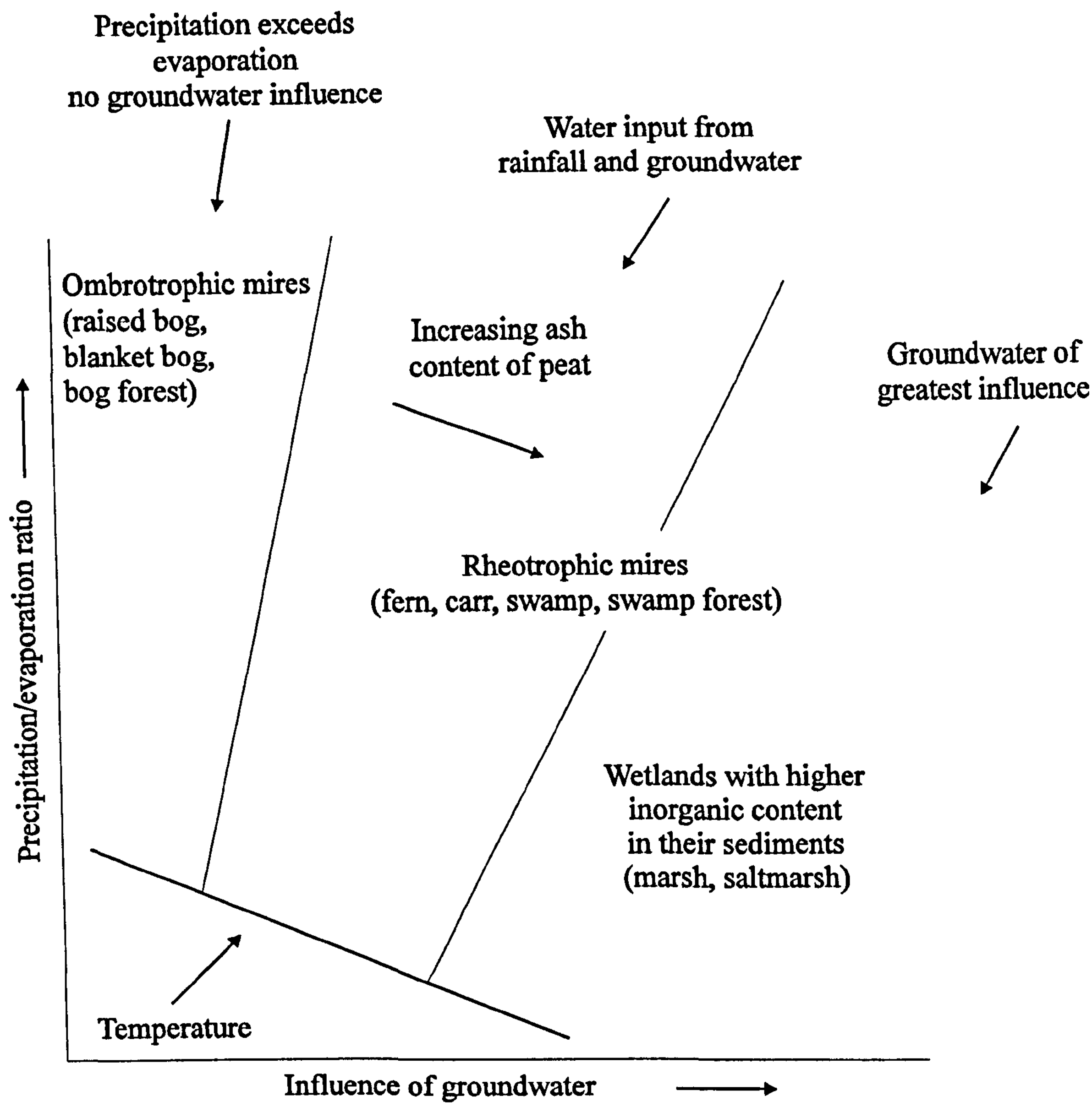


Fig. 11.1 Relationship between mires and their hydrological input in the terms of the relative influence of precipitation and groundwater (modified from Mc Cabe, 1984 after Etherington, 1983).

11.3.1 Terminology applied to mire ecosystems

Environments of peat, lignite and coal formation are often referred to in the literature as swamps. Wilkinson and Boulter (1980) and Wilkinson *et al.* (1980) proposed a warm, swampy environment similar to that described as a *Nyssa/Taxodium* swamp forest (Teichmüller and Teichmüller, 1968). Moore (1987) noted that this term has caused much confusion. He defined a terminology used in peatland ecology in relation to the two hydrological categories of mire (previously outlined). This terminology is outlined below.

Mire

This may be defined as a freshwater ecosystem in which there is a nett accumulation of organic matter in the soil. In its strictest sense the term mire could now not be attributed to a wetland ecosystem such as a marsh since peat does not develop.

Swamps

Swamps are defined as wetland ecosystems in which the water table is almost always above the sediment surface in the dry season. They are therefore essentially aquatic ecosystems.

Floating swamps

These are formed as a platform of roots, rhizomes or stolons of an emergent vegetation extending over open water. They often develop around lake margins in temperate and tropical climates.

Swamp forest

Essentially a rheotrophic swamp in which trees form an important constituent of the vegetation. Usually tropical or sub-tropical in occurrence they are typified by wooded mangrove swamps. The term 'carr' has been applied to rheotrophic temperate wooded mires.

Fen

A rheotrophic ecosystem in which the water table during the dry season may be below the surface of the peat.

Marsh

The term has been used in many different senses so as to have almost lost any specific connotation. Within the European literature it describes an ecosystem dominated by herbaceous vegetation on seasonally waterlogged mineral soils in which the water table is close to the soil surface. Periodic areation is sufficient to ensure very little, if any, peat development. The term may be applied to fresh and saline environments.

Bog

A term confined to ombrotrophic peat forming ecosystems.

Bog forest

The term refers to ombrotrophic forrested vegetation. In Eastern Europe and temperate North America raised mires are often of this type. Their vegetation consists of an upper story of coniferous trees, a dwarf shrub layer rich in ericaceous species and a ground covering of *Sphagnum* moss. In tropical regions bog forests are dominated by angiosperm species.

11.3.2 Autochthonous peat formation

Mc Cabe (1984) outlined three types of autochthonous peat formation and termed them Floating swamps, Low lying swamps and Raised swamps.

Floating swamps

Sometimes termed 'quaking bogs,' floating swamps may form in relatively shallow lakes. Dry periods may induce gas bubble formation (from organic decomposition) in semiaquatic peats. When hydration resumes the peat may have attained sufficient buoyancy to bulge upwards and tear away from the peat mat. In an open lacustrine environment free-floating peat mats may congregate around lake margins along with other plant material. The accretion of organic material results in the building of a platform reaching out over the lake. Peats formed will have a low ash content as the buoyancy of the peat mat will keep them above the influence of sediment loaded flood waters. Thick accumulations of peat will not be generated due to the upper and lower surfaces of the mat being exposed to degredation and because the shallow water will limit the thickness of mat able to be formed (Mc Cabe, 1984).

Low lying swamps

In low-lying swamps peat accumulates over an underlying topography and builds up to attain a nearly horizontal surface. Swamps of this type are slightly acidic, rich in plant nutrients and support a high density of vegetation. Their surfaces are often very wet with a telmatic flora of reeds and water lilies. In areas removed from clastic deposition they may accumulate thick high quality peats (Mc Cabe, 1984).

Raised Swamps

Raised swamps are the common type in cool temperate and tropical peat-forming areas. They characteristically have a raised convex form and steep convex sides with a flat central area that may contain small lakes in a mature swamp (Romanov in Mc Cabe, 1984). They only form when annual precipitation exceeds annual evaporation (Teichmüller and Teichmüller, 1982).

In temperate regions a low herbaceous flora with *Sphagnum* moss is the common vegetation. In tropical regions such raised swamps are densely forested, concentric zonation of floral communities is displayed and reflected in the peat profile.

A decrease in the number of tree species and a predominance of stunted forms is recorded towards the centre of tropical swamps (Anderson and Muller, 1975) as a consequence of the ground water becoming more oligotrophic, acidic and containing few plant nutrients.

Raised swamps produce low ash peats. Fitch (1954) records an ash content of 6.5% and a sulphur content of 0.2% from the alluvial plains of Borneo.

The high acidity of the water in such an ombrotrophic mire ecosystem is the cause of mineral leaching, this combined with the elevation of the mire ensures the formation of low ash peats. Thick peat accumulation may develop within this ecosystem impacting upon sedimentary processes and decreasing erosion rates, therefore having a stabilising influence upon an environment (Mc Cabe, 1984).

The term raised swamp for the type of ombrotrophic mire outlined by Mc Cabe (1984) is incorrect if one follows the previously outlined terminology of Moore (1987). The term bog forest would seem to be a more specific and applicable term.

The formation of the lignite from a precursor of peat accumulation in raised and floating bog ecosystems as proposed by Parnell *et al.* (1989) is accepted.

Mc Cabe (1984) notes that low ash coals originate from low ash peats. Parnell *et al.* (1989) report that thick lignites within the Lough Neagh Group have a low ash content of less than 10%, inplying isolation from clastic imput. Griffith *et al.* (1987) record an average ash content for lignite (dried prior to analysis) from the Ballymoney area as ranging between 11.4-76.4% with a mean of 47%, and from the Coagh district as between 4.4-69.4% with a mean of 39.23%. A lower lignite seam from the Crumlin area recorded an ash content (as mined) of 6.9%. Average sulphur content of the lignites in these areas was recorded in Ballymoney 0.5%, Coagh 0.17% and Crumlin 0.2%. Low ash and sulphur content of the lignites compares with data from raised bog swamps recorded by Fitch (1954).

The formation of peat in floating or raised bogs would be consistent with the low ash content of some of the lignites. Higher ash content of some lignites would imply a greater input of inorganic material. Some thin lignite seams are noted to be interbedded with poorly sorted sandstones indicating a greater fluvial influence and consequently a greater inorganic input.

The palaeoenvironment of peat formation for the Lough Neagh Group is thought to be more accurately regarded as an ombrotrophhic peat forming ecosystem and termed a raised bog forest.

11.4 Palaeoenvironment related to lithological characteristics

Analyses of the clay mineralogy of the Lough Neagh Group clay show kaolinite as the dominant clay mineral occurring with subordinate quantities of the micas and illite. No montmorillonite was recorded. A mineralogy comparable to the Oligocene clay at Bovey Tracy and Petrockstow, Devon (Stuart and Gallagher in Parnell *et al.*, 1989).

Kaolinite is widely regarded as a product of tropical weathering. Retallack (1992) notes that the nature of clay minerals in palaeosols may be a potential indicator of mean annual rainfall, equating kaolinite with a wet climate. Parnell *et al.* (1989) refer to a sequence from the Tertiary of Kalimanton, Borneo (Sieffermann, 1988) where crusts of siderite occur with lignite within kaolinitic sediments as an analogue for the Lough Neagh Group. The sequence from Kalimanton represents a water logged peat supporting an arborescent vegetation passing laterallly into soils which display lateritic weathering. The mineralogy of these deposits is dominated by quartz, kaolinite, geothite and giddsite, all of which are recorded within Lough Neagh Group sediments.

It has been shown that the basalt beneath the Lough Neagh Group in the Crumlin area has been extensively weathered to kaolinite (Lowman in Parnell and Meighan, 1989). The source of clays within the Lough Neagh Group is regarded to have been the weathered basalts, weathering probably having taken place under a tropical climate at some time after their Palaeocene extrusion, 30 million years before the deposition of the Lough Neagh Group (Parnell *et al.*, 1989).

The permineralisation of lignite by silica and siderite in the Lough Neagh Group is recorded by (Parnell and Shukla in Parnell *et al.*, 1989). A high Fe input is necessary for replacement by siderite, this was available by leaching from basalt. The presence of siderite is not indicative of tropical conditions. It requires specific conditions for deposition: high Fe and dissolved carbonate, low sulphide and a reducing environment (Garrels and Christ in Parnell *et al.* 1989). The presence of siderite and vivianite within Lough Neagh Group sediments indicates precipitation from non-marine low sulphur waters.

12. PALYNOFLORAL INTERPRETATION

12.1. Lignite

The lignitic facies generally record a palynoflora dominated by angiosperm pollen and to a lesser extent gymnosperm Taxodiaceous pollen. Pollen assigned to the Anacardiaceae and Fagaceae dominate with lesser quantities of Cornaceae/Nyssaceae and Salicaceae. Pollen of the Juglandaceae and Platanaceae occurs fairly consistently at a lesser abundance with occasional increases being recorded. Gymnosperm pollen of the Pinaceae is consistently recorded.

A precursor vegetation to the stable raised bog ecosystem supporting an arborescent vegetation would most likely have been aquatic or marginally aquatic. Collinson and Scott (1987) note that aquatic or marginal aquatic plants are important in the early stages of wetland succession producing organic debris and providing a means of trapping sediment. Pollen thought to originate from aquatic plants is infrequently recorded and low in abundance throughout the studied sections and comprises the Pteridophytes, Azollaceae/Salviniaceae (*Hydrosporis*) and the Angiosperms, Typhaceae/Sparganiaceae (*Sparganiaceaepollenites*). Collinson (1983) records a number of aquatic families represented in the macroflora of the Lower Oligocene Bembridge Marls but remarks upon the lack of correspondence between these and the microflora. She notes that a number of the aquatic families recorded in the macroflora produce pollen with a thin exine that might not have been preserved. Citing Sculthorpe (1967) she further notes that pollination is not usually hydrophilous so pollen is not directly introduced into water. Pollen of the Selaginellaceae and

Sphagnaceae may also have played an important role in the formation of the early bog vegetation.

Zonation of floral communities within raised swamps has been noted by (Moore, 1987 and references cited therein). A herbaceous or shrub layer, possibly forming an understory or a marginal vegetation to the Angiosperm/Taxodiaceae bog forest may have been represented by a flora comprising Salicaceae (often noted to occur in wet environments), Tiliaceae (*Tiliaepollenites*), Aquifoliaceae (*Ilexpollenites*) and Betulaceae (*Alnipollenites*). Andersen (1970) notes that pollen from shrubs and herbs may be poorly dispersed into lake or bog deposits.

Ingrouille (1995) notes that a North American version of *Taxodium* growing in swamps is often festooned with *Tillandsia* (Spanish moss), a genus of terrestrial and epiphytic herbs. Such an ecological niche in the Tertiary raised bog forest might have been filled by the epiphytic fern-like herbs or climbers of the Lycopodiaceae.

The climax flora may be regarded as a mixed deciduous broadleaved forest with a Nyssaceae/Taxodiaceae content. The dominant vegetation of the Oligocene of the Western British Isles including the Lough Neagh Group has been likened to the *Nyssa/Taxodium* swamp forest of Teichmüller and Teichmüller (1968) by Wilkinson and Boulter (1980) and Wilkinson *et al.* (1980).

Wilkinson *et al.* (1980) report that their largest pollen counts are of *Inaperturopollenites*. Whilst *Inaperturopollenties* is undoubtly an important element of the palynofloras recorded in this study, it only attains dominance at two horizons, one within 13/611 at 82.00m, the other within 27/415 at 71.00m. In general the most abundant pollen recorded is *Tricolporopollenties pseudocingulum* attributed to the Anacardiaceae. *Cupuliferoidaepollenties, Cupuliferoipollenites* and *Quercoidites* form the abundant Fagaceae component. Pollen attributed to Anacardiaceae and Fagaceae form the greatest proportion of the palynoflora. From this abundance and accessory taxa a mixed broadleaved vegetation is deduced.

Nyssapollenties forms an important constituent of the palynoflora. The occurrence of this pollen type with the important Taxodiaceaeous element (*Inaperturopollenites*) agrees with previously recorded ideas of a *Nyssa/Taxodium* vegetation, however, a greater influence of broadleaved vegetation may be indicated from the pollen assemblages obtained.

The occurrence of bisaccate pollen, here represented by Pinaceae (*Pityosporites*), within a swamp or bog ecosystem is traditionally thought to represent an upland coniferous flora.

Bisacate pollen was often noted to be poorly preserved or fragmented e.g. the acme of *Pinaceae* within a clay at 82.00m in 13/611. The fragmentary nature and poor preservation of some bisaccate pollen may be interpreted as an indication of transport from a location more distal to that of the dominant angiosperm flora. Wilkinson and Boulter (1980) interpret the origin of *Pityosporites* pollen they record as possibly from hummocks within the bog ecosystem.

It is certainly true that attribution of Pinaceae pollen to an upland montane flora is probably a gross generalisation given the variety of conditions that trees of this family occupy at present. Ingrouille (1995) notes the extant presence of *Pinus sylvestris* (Scots Pine) in drier and therefore more areated areas of floating bogs within Britain.

12.2 Relative pollen abundance

As outlined in a previous chapter, the relationship of pollen abundance to the parent flora is not a unitary ratio. The influence of disproportionate pollen productivity and dispersal capacity, particularly regarding the tree vegetation may be of importance (Von Post, 1916, 1918).

Assessment of the importance of these processes, particularly pollen productivity, is difficult for a palaeoflora. The pollen productivity of fossil taxa might not be able to be equated with that of modern taxa especially if they lived under differing climatic conditions and environmental stresses.

While no correction factor for possible greater pollen production from certain taxa has been attempted within this study, attention is drawn to the data presented from modern studies on pollen productivity (Andersen, 1970) as outlined previously.

12.3 Pollen preservation

An assessment of the effects of pollen preservation upon the recorded palynoflora and its effect upon the assumed palaeovegetation is largely untestable within this study as no palynofloral/macrofloral comparisons have been made. Such a comparison, if it were possible, might identify inconsistencies between the two data sets to highlight possible non/low occurrences of taxa in a palynofloral assemblage such as was highlighted in the aquatic component of the Bembridge Marls vegetation (Collinson, 1983).

12.4 Lough Neagh Group Clays

From the approximate pollen per gram data presented in Appendix 1 it may be noted that lignite and clayey lignite generally yield the greatest concentration of pollen. The clays and sandier facies of the Lough Neagh Group often have a lower pollen yield.

The dominant pollen types recorded from the lignitic samples are generally noted to occur in the lignitic clays but often with a higher Pteridophyte component. Sandy clays sometimes have a very low pollen yield per gram but this is by no means always the case. Pteridophytes are often commonly represented but some samples contain a well-developed angiospern palynoflora.

Such generalisations are somewhat broad as differing depositional environments will account for specific differences in preserved palynofloras. The sandier facies probably represent deposits of a fluvial system feeding a lacustrine environment. Sand and conglomerate, interspersed with clay and lignite facies, may be attributed to deltaic deposition at lake margins. The generally greater representation of Pteridophytes within these facies might be attributed to the occurrence of a fern flora in a setting marginal to the bog forest or situated along a riverside/water course. Collinson (1983) reports that Colinvaux (1976) and Schofield (1976) have demonstrated that where extensive non-aquatic vegetation is developed around a lake, fern spores comprise a large component of the palynoflora.

12.5 Dunaghy Formation

Within the type section of the Dunaghy Formation in 13/611 pollen recovery is very poor through the series of yellow-brown, khaki and red-brown clays to

208.00m. The palynofloral assemblage at this depth is dominated by Pteridophytes, Polypodiaceae principally *Laevigatosporites* with lesser amounts of angiosperms, *Quercoidites* (Fagaceae). Pollen recovery increases through a series of blue-grey clays to a depth of 230.00m when red-brown clays resume.

Clays with a lignitic or organic content were identified at 209.00m, 230.00m and 260.00m. These yielded pollen assemblages of similar general composition to those from the lignite further up the section in the Lough Neagh Group.

The Dunaghy Formation within 13/603 produced better pollen recovery. The succession does not contain the unproductive red-brown facies of 13/611. It comprises more brown, olive-green and blue-grey clays, with lignitic clays and thin lignite bands occurring with greater frequency. The assemblages recovered display an increased Pteridophyte content comprising *Laeviatosporites* (Polypodiaceae) compared to the successions within the Lough Neagh Group. The angiosperm content was essentially in the same proportion to that recorded within the Lough Neagh Group.

The predominance of Pteridophyte spores within some of the clay facies of the Dunaghy Formation, particularly the less productive redder lithiologies within 13/611, may be representative of an early colonising flora before the final establishment of an arborescent vegetation.

13. PALAEOCLIMATE DETERMINATION

Pollen and spore abundance data may be utilised to estimate palaeotemperatures. The approach of Boulter and Hubbard (1982) and Hubbard and Boulter (1983) was to relate the forest types they identified to the modern forest types and associated climatic parameters identified by (Wolfe, 1979). This enabled them to infer the mean annual temperatures (MAT) and mean annual temperature range (MATR) for their forest types. A similar procedure was followed by Jolley (1998) who compared Early Eocene palynofloras to an unpublished database generated from using detrended correspondence analysis on assemblages from the Palaeocene and Eocene of Europe. He used the frequency and composition of pollen and spore assemblages to create anologies to modern forest types and from these infer mean annual temperatures.

Boulter and Hubbard (1982) applied principal components analysis and cluster analysis to palynological data from Eocene sections in Southern Britain to produce three natural groupings of pollen and spores that were thought to be Palaeogene versions of:

1. Deciduous forest.
2. Fern and conifer forest.
3. Paratropical rain forest.

A fourth group was defined as a "rubbish bin" of taxa that reflected the effects of transport and catchment area.

The groupings are reported to be applicable to areas far removed geographically and chronologically e.g. an analysis of palynological data from

Nigeria (Salami, 1981) portrayed three major groups of plant community that are comparable to the European groupings. Hubbard and Boulter (1983) applied the principle to the Oligocene sections from the Western British Isles (Wilkinson and Boulter, 1980) and to Tertiary sections in the Paris Basin, (Chateauneuf, 1980) and the Armoricain Massif, (Olliver-Pierce, 1980).

If the groups identified depict a natural association of taxa forming a vegetational type, as deduced from the botanical affinity of the taxa that comprise the group, and as the groups of taxa have been proved to be valid in their application to Tertiary floras of the Southern Hemisphere and, in particular, to those sections of the Irish Oligocene, the Mirehouse and Bellbrook assemblages (Wilkinson and Boulter 1980) then the validity of applying the four defined groups to pollen and spore assemblages recognised within this study to delimit vegetational associations should not be called into question. As a result of this, the pollen and spore assemblages recorded in this study have been referred to these four groupings to delimit the probable palaeovegetation and associated climatic parameters that they represent. The form-genera assigned to each of the four natural ecological groups are listed in table 13.1. Taxa that could not be attributed to any of the four groups are listed within a fifth unassigned category. The relative percentages of these five groups have been plotted for each sample (see figs 13.1-13.4). To ensure a clearer depiction of the results barren samples have not been plotted.

The effectiveness of using the vegetational character to predict a forest type, and from this obtain estimates of palaeotemperature by comparison to climatological parameters of extant forests, may to some degree be verified by testing whether the present day climatological data may be used to identify vegetation distribution.

Deciduous Forest

Aglaoreida
Boehlensipollis
Corsinipollenites
Engelhardtioidites
Ericipites
Gothanipollis
Lycopodiumsporites
Mediocolpopollenties
Momipites
Monocolpopollenties
Myricipites
Nymphaeacidites
Periporopollenites
Podocarpidites
Polypodiidites
Porocolpopollenties
Reevesiapollis
Salixipollenites
Sequoiapollenites
Tricolpopollenties
Tricolporopollenites
Trilites
Ulmipollenites

Fern and Conifer Forest

Abiespollenites
Baculatisporis
Camarozonosporites
Carpinipites
Cedripites
Cicatricosisporites
Cycadopites
Deltoidospora
Echinatisporis
Echinosporis
Gleicheniidites
Graminidites
Piceapollenites
Polyatriopollenites
Polypodiaceaesporites
Polypodiaceoisporis
Polyvestibulopollenties
Reticulosporis
Sciadopityspollenites
Stereisporites
Subtriporopollenites
Toroisporis
Trivestibulopollenites
Tsugaepollenites

Paratropical Rain Forest

Anacolosidites
Arecipites
Bombacacidites
Brosipollis
Caryapollenites
Compositoipollenites
Dicolpopollis
Diporites
Ilexpollenites
Interpollis
Interporopollenties
Labrapollis
Microfoveolatisporis
Microfoveolatosporis
Milfordia
Multiporopollenties
Nudopollis
Nyssapollenites
other triporates
Pentapollenites
Pistillipollenites
Platycaryapollenites
Plicapollis
Plicatopollis
Popmpeckjoidaepollenites
Pseudospinaepollis
Reticulataepollis
Retiovoipollis

Paratropical Rain Forest continued

Retitriporites	*Tetracolporopollenties*
Sparganiaceaepollenites	*Tiliaepollenites*
Spinozonocolpites	*Triplanosporis*
Synplocospollenites	*Triporopollenites*

"Rubbish-bin"/Catchment

Inaperturopollenties	*Pityosporites*

Unassigned taxa

Baculatisporites	*Hydrosporis levis*
Corrusporis	*?Magnolipollis neogenicus minor*
Cyperaceaepollis	*Matonisporites*
Echinate spore sp. A	*Muerrigerisporis*
Echinate spore sp. B	*Saxosporis gracilis*
Echinate spore sp. C	Trilete spore (undifferentiated)
Foveotriletes	*Triplanosporites*
? Holkopollis	*Varrirugosporites megaverrucatus*
Hydrosporis azollaensis	*Verrucingulatisporites*

Table 13.1 Taxa comprising the Natural Groups reflecting Palaeovegetation after Boulter and Hubbard (1982) and Hubbard and Boulter (1983).

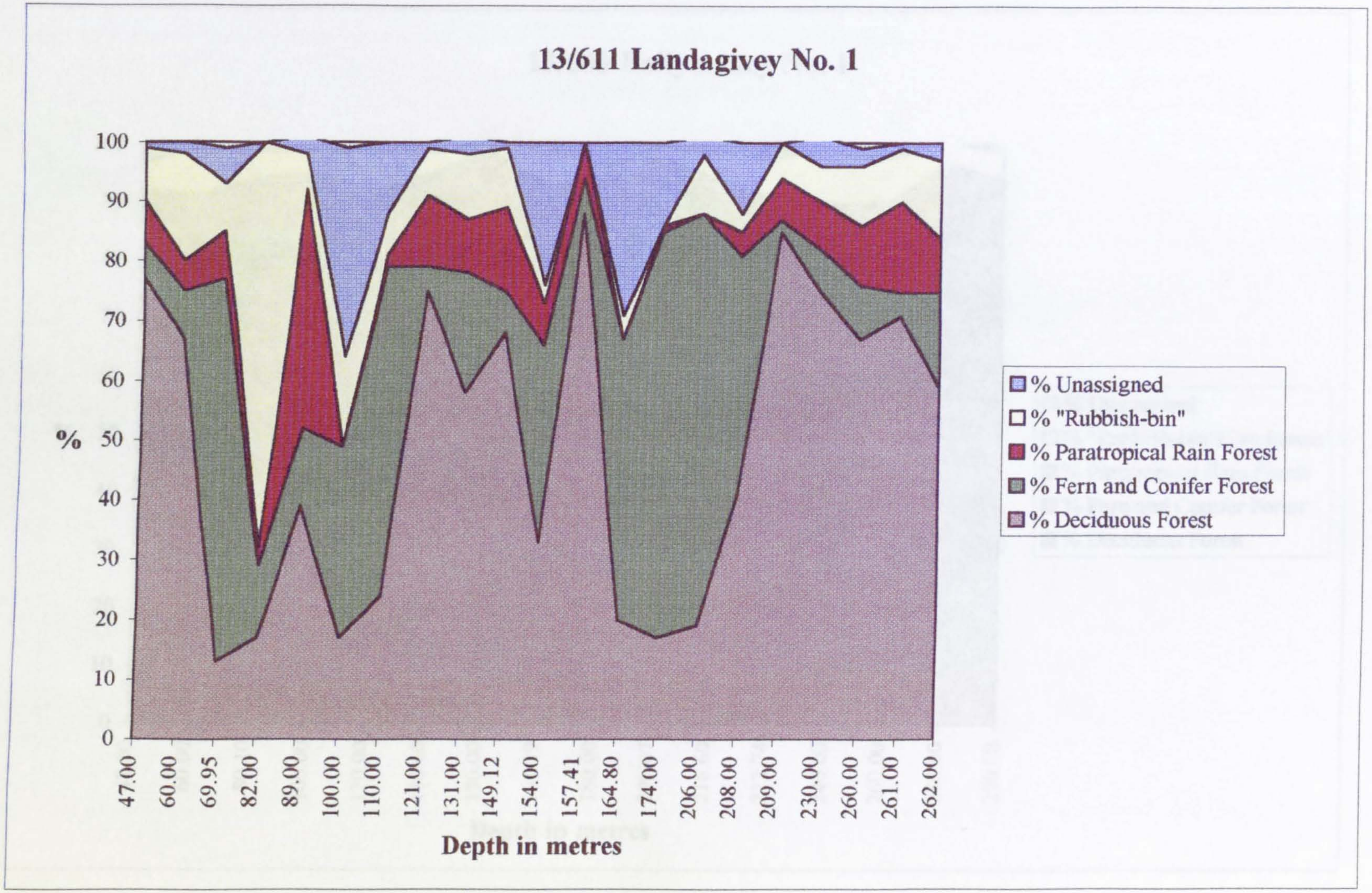


Fig. 13.1 Percentage composition utilising plant communities after Boulter and Hubbard (1983)

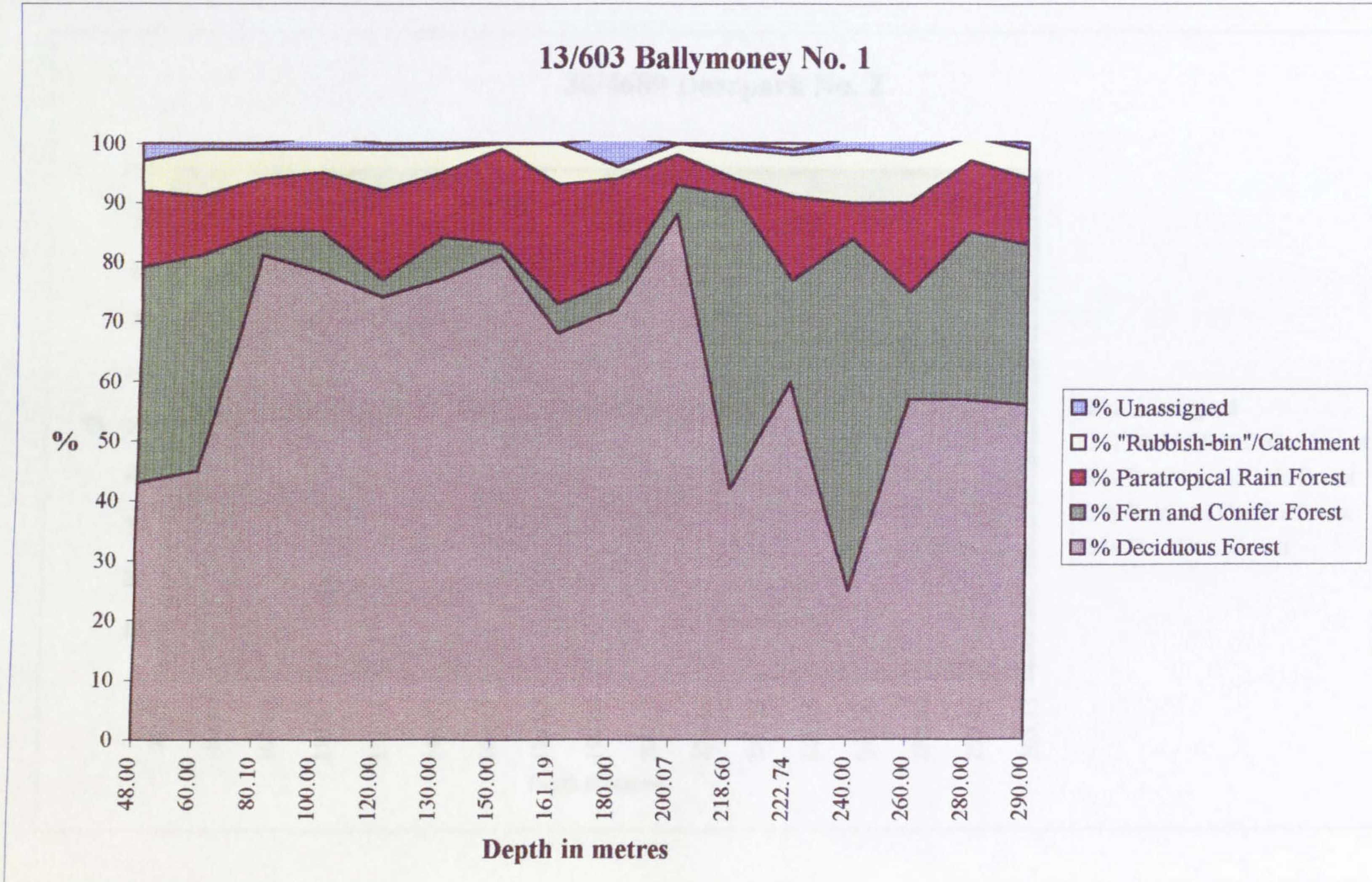


Fig. 13.2 Percentage composition utilising plant communities after Boulter and Hubbard (1983)

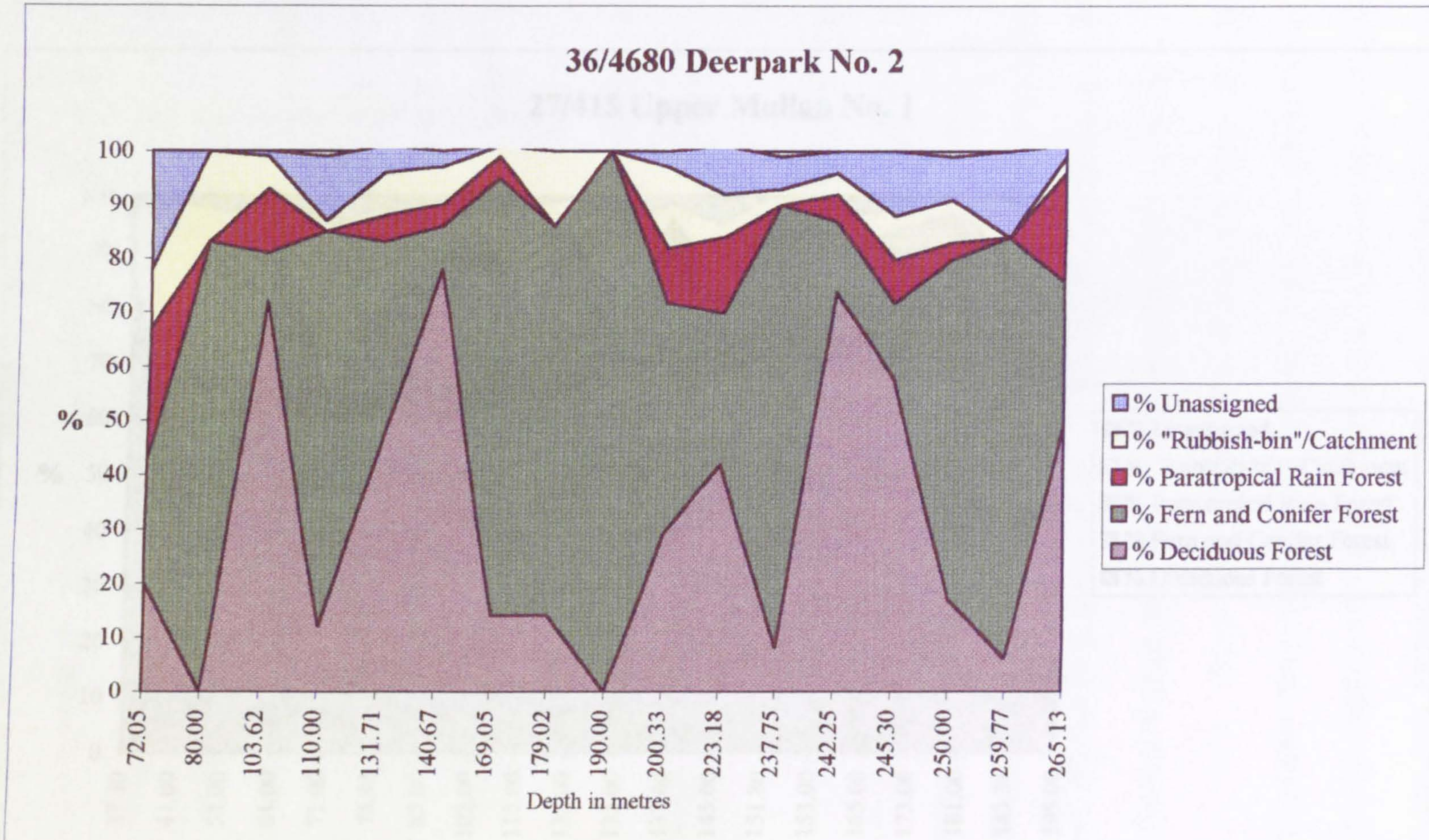


Fig. 13.3 Percentage composition utilising plant communities after Boulter and Hubbard (1983)

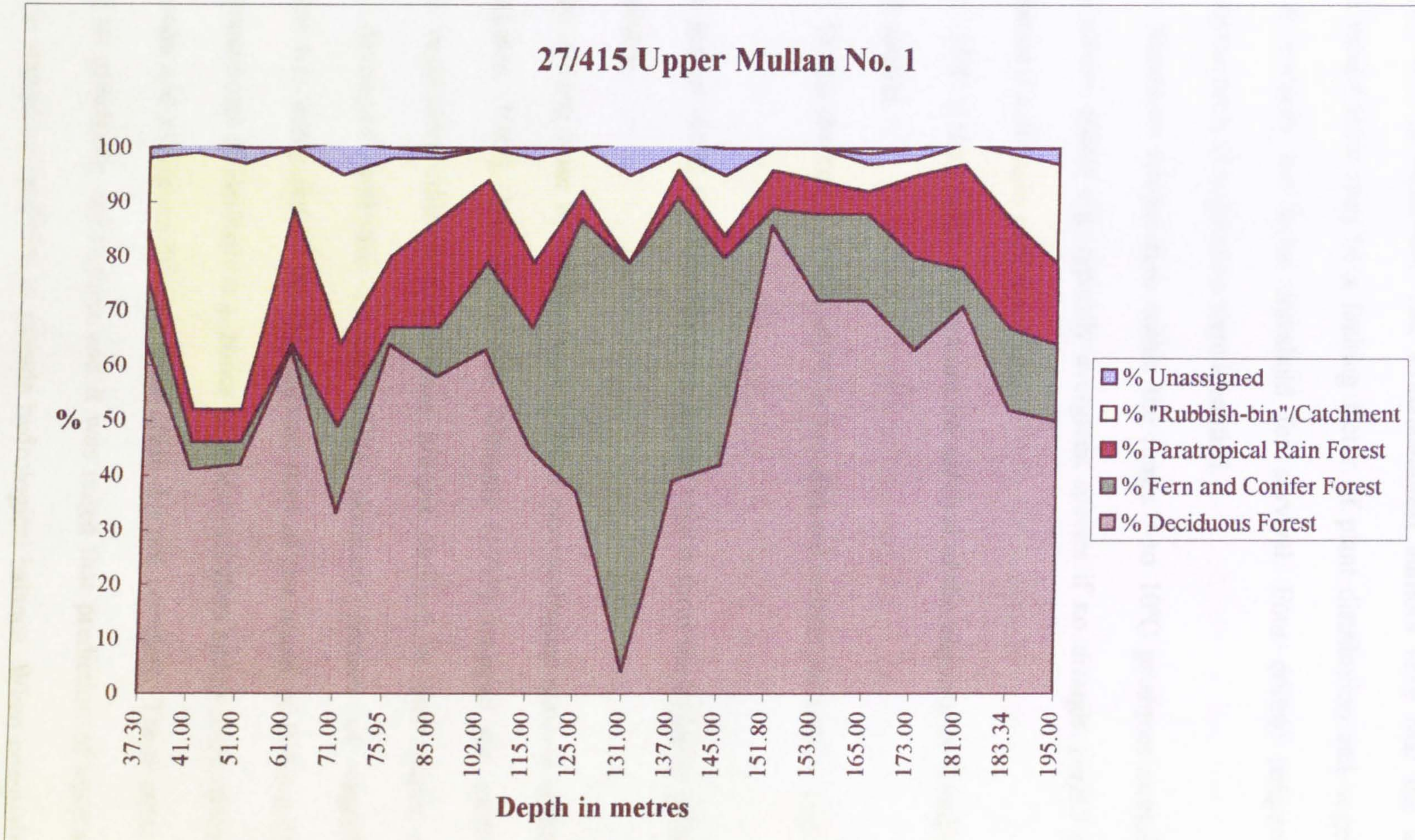


Fig. 13.4 Percentage composition utilising plant communities after Boulter and Hubbard (1983)

Woodward and Williams (1987) note that strong and universal correlations exist between vegetational distribution and the two major features of climate: namely temperature and precipitation. The aforementioned authors note that the annual minimum temperature may be a limiting factor of plant distribution and vegetation type if it exceeds the lethal threshold for survival. Four critical temperatures controlling the form of vegetation were identified.

1. Minimum temperature within the range 0 to 10°C produces mortality in chilling sensitive plants e.g. typically evergreen species if no drought period exists, but deciduous if a drought period persists.

2. -15°C is the lowest temperature for survival of the majority of broadleaved, evergreen species.

3. Within the range -15 to -40°C a broadleaved, winter deciduous vegetation occurs.

4. Below -40°C Conifers from the boreal region form the majority of species able to survive.

By utilising a set of climate records from meteorological stations around the world (Muller, 1982), Woodward and Williams (1987) mapped the pattern of predicted vegetation utilising temperature criteria outlined in their paper and a specially developed software package. The resultant pattern of vegetational distribution was compared to the vegetational map of the world of Polunin (1960). Despite some areas of similarity e.g. zones of tundra, conifers and in some cases areas of deciduous and evergreen forests, large areas did not correlate. These areas were identified as principally dry regions and it was noted that prediction of vegetational distribution should be modified to include hydrological balance. When comparing the vegetation distribution map based upon predictions incorporating temperature, precipitation and the water balance to that of (Polunin, 1960), a considerable degree of correlation was noted.

It would appear that if the prediction of present vegetational distribution using just temperature parameters leads to some erroneous predictions, particularly for dryer climates, then caution should be exercised when inferring temperature from a palaeovegetation without regard for the hydrological balance, as it may have a distinct effect upon the type of vegetation developed within a particular area.

The situation is further complicated as climatic control of vegetation type may be mediated through population processes such as gap creation and fill. Species with slight differences in their lethal threshold will be affected to differing extents as for example by a cooling of the climate. If the climate exceeds the lethal threshold of a species then a gap will be left in the vegetation to be filled by a species more resistant to the climatic change. The effect of this infilling of the vegetation will be either the retention of the existing vegetation but with a change in the composition of species with the same life form, or a change to a different type of vegetation and associated range of species (Woodward and Williams, 1987).

Woodward and Williams (1987) note that it is important to study the impact of climate on all stages of the life cycle. If only the seedling stage of a plant is affected by a climatic change preventing regeneration but the mature plant is unaffected, then the resultant change in vegetation would be slow and dependent upon the plant's life span.

The distribution of forest types (after Hubbard and Boulter, 1983) throughout the sections show that Deciduous forest and Fern and conifer forest are the dominant vegetation types. Paratropical rain forest is almost always subordinate to the aforementioned groups in all but a few horizons. Two noticeably sharp increases in the percentage of Paratropical rain forest are observed within 13/611 at 89.00m and within 27/415 at 61.00m. These increases may be related to a temperature increase based upon the type of flora developed. The increase in 13/611 can be accounted for by a sharp increase in the abundance of the megatherm taxa *Arecipites* (Palmae). A similar increase in Palmae has been noted in 13/603 at 80.10m and interpreted as an indication of a temperature increase akin to that in 13/611. The increase in Palmae in 13/603 is related to an increase in *Monocolpopollenites*. This genus lies within the Deciduous forest group of Boulter and Hubbard (1983).

Fern and conifer forest taxa are noted to increase before the boundary with the Dunaghy Formation in 13/611 and 13/603. This increased percentage is also recorded within the top section of the Dunaghy Formation.

It should be noted that increases in the Fern and conifer forest component accompanied by a corresponding decrease in the Deciduous forest component often occur in samples with a low pollen per gram abundance. The lithology may be noted as having an influence upon the distribution of vegetation type recorded, as illustrated by occurrences within 36/4680.

Samples with a high pollen per gram yield are generally lignites and clays with a lignitic content. These are all denoted by a sharp increase in the percentage of Deciduous forest and decrease in the Fern and conifer forest components.

Table 13.2 presents the temperature parameters associated with the forest groups of Hubbard and Boulter (1983). Fig. 13.5 illustrates the temperature

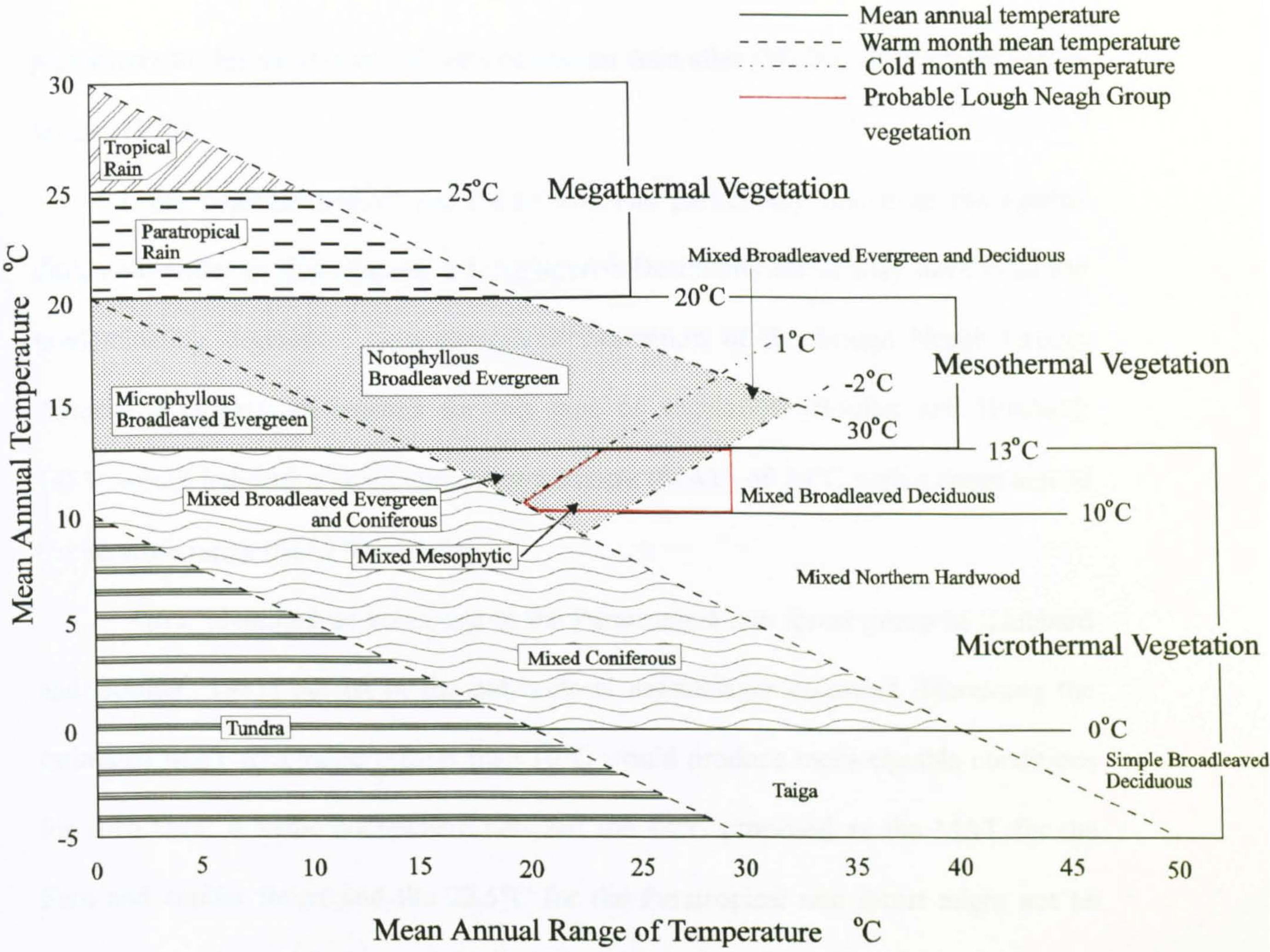


Fig. 13.5 Temperature parameters for forest types of eastern Asia (after Wolfe, 1985)

	Mean annual temperature °C	Mean annual temperature range °C
Deciduous forest	10	30
Fern and conifer forest	14	14
Paratropical rain forest	22.5	8

Table.13.2 Temperature parameters for the forest group of Boulter and Hubbard (1983)

parameters for humid to mesic forests of eastern Asia after (Wolfe, 1985 adapted from Wolfe, 1979).

From consideration of the above data and particularly that from the lignites discussed earlier in this chapter, a Broadleaved Deciduous forest may have been the predominating vegetation type throughout deposition of the Lough Neagh Group. Associated climatic parameters for this type of vegetation (Boulter and Hubbard, 1983) would indicate a mean annual temperature (MAT) of 10°C with a mean annual temperature range (MATR) of 30°C.

Taxa identified as belonging to the Paratropical rain forest group of (Hubbard and Boulter, 1983) persist in the palynofloral assemblages recorded. Increasing the estimated MAT to a value greater than 10°C would produce more equable conditions for such taxa. A value somewhere between the 14°C proposed as the MAT for the Fern and conifer forest and the 22.5°C for the Paratropical rain forest might not be unrealistic. The critical vegetational controlling temperatures (Woodward and Williams, 1987) outlined earlier, indicate that chilling sensitive plants may survive temperatures of 0°C and that broadleaved evergreen species can survive -15°C.

Ingrouille (1995) notes that from the Middle Oligocene there was a decrease in humidity and a rise in broadleaved deciduous forest vegetation. 71% of British fossil genera at this time have their relatives in China and Japan and 49% in the U.S.A.

A comparable vegetation to the suggested broadleaved deciduous forest of the Lough Neagh Group may have been similar to the Mixed Mesophytic forest described from the Yangtse province, China (Wang, 1961).

Most trees characteristic of the Mixed Mesophytic forest are plants of warm and moist parts of temperate regions. This forest type mainly comprises deciduous broadleaved trees, however a number of evergreen broadleaved trees and conifers are scattered throughout the forest.

Mean monthly minimum temperatures do not drop below 0°C, however, extreme minimum temperatures of -14°C have been recorded. The average frost free season ranges from 230-280 days. Mean monthly temperatures greater than 22°C are recorded for 4 months of the year and above 10°C for 8-9 months.

Mean monthly temperatures for the Temperate Deciduous Broadleaved forest (primarily comprising oaks) (Wang, 1961) are very similar to thoses of the Mixed Mesophytic forest, 3 months > 22°C and 7 months > 10°C. Mean annual precipitation of 1000-1500mm is recorded for the Mixed Mesophytic forest, twice the value of that for the Deciduous Broadleaved forest.

The overall picture developing for the climate during deposition of the Lough Neagh Group is one distinctly cooler than that of the Eocene but sufficiently warm to support the megatherm taxa of the Palmae, *Arecipites* and *Monocolpopollenites* and *Dicolpopollis*. The association of these taxa is thought to indicate a generally frost free environment.

A cooling and drying climatic phase is thought to have persisted towards the top of the Lough Neagh Group. Within 13/611 at 82.00m a decrease in *Nyssapollenites* is recorded occurring with a decrease in the Palmae from an acme at 89.00m. A similar decrease in *Nyssapollenites* is recorded within 27/415 at 51.00m. Within 13/603 this event occurs at 80.10m but coincides with the acme of the megatherm taxa *Monocolpopollenties*.

The first stratigraphic occurrence of *Sequoiapollenites* within 13/611 is recorded at 82.00m. *Sequoiapollenites* was recorded (Shukla in Parnell *et al.*, 1989) as occurring within the topmost assemblage in zone 4 (see fig. 3. p. 70 Parnell *et al.*, 1989) of sections of the Lough Neagh Group from the Coagh region to the west of Lough Neagh. *Sequoiapollenites* was not recorded from the 27/415 (Coagh region) in this study, however, it was recorded within the other Ballymoney section 13/603 at 80.10m. Mossbrugger and Utescher (1996) identified *Sequoiapollenites* as a 'cold outlier' from analysis of Tertiary floras using their coexistence approach, noting that the extant monotypic genus is restricted to relatively cold conditions. They suggest that during the Tertiary that taxa related to *Sequoia* probably lived in warmer habitats.

The first stratigraphic occurrence of *Polyatriopollenites carpinoides* (Corlyaceae) at 60.00m within 13/611 and an increase of *Momipites* (Juglandaceae) from 69.95m are thought to represent a drier, scrubby type flora (Jolley pers. comm.). The *P. carpinoides* event is recorded in 13/603 at 60.00m and manifests itself as a reappearance of the taxa at 51.00m in 27/415 after an absence since 181.00m. The increase in *Momipites* is recorded at 48.00m in 13/603 and at 37.30 in 27/415.

Graminoid pollen is noted to increase at 82.00m in 13/611, a similar increase is noted in the upper sections of 27/415 and a distinct peak is recorded at 60.00m in 13/603. The presence of Graminaceae is thought to be indicative of a drying climate.

Platanuspollenites ipelensis has been identified as a probable microtherm taxa (Pacltová 1978). An increase/acme within 13/611 at 60.00m may be interpreted as indicative of a cooling climate. The event is noted within 13/603 at 80.10m and within 27/415 at 51.00m.

38/4680 does not appear to record the cooling and drying of the climate noted within the other sections. This is thought to be because the event occurs above the top sample analysed. Within 13/611 and 27/415 the pronounced acme of *Nyssapollenites* occurs immediately before the clear decrease in abundance of this taxon, coinciding with the identified horizon at which the climatic change is first thought to become apparent. The acme of *Nyssapollenites* within 36/4680 occurs at 72.05m, the top sample analysed.

The level of precipitation and the hydrological balance have important effects upon the development and distribution of vegetation (Woodward and Williams, 1987). Dry periods may lower the temperature tolerance of a vegetation type. Mean monthly precipitation of the growing season has been thought to be a more limiting factor upon vegetation than mean annual precipitation or mean maximum and minimum precipitation (Mosbrugger and Utescher, 1997; Wolfe, 1993). Precipitation is a difficult climatic parameter to reconstruct using numerical climate models (Mosbrugger and Utescher, 1997).

The development of a vegetation is a complex interplay of a variety of factors e.g. temperature, precipitation/evapotranspiration (water balance), substrate, nutrient flow, altitude, and length of growing season. This should be borne in mind when accounting for observed changes in palaeofloras and explaining them in terms of climatic change. Whilst MAT and MATR are, without doubt, important controlling factors in vegetational development, it would be unrealistic to hope to fully explain vegetational succession and change solely upon such criteria.

14. BOREHOLE CORRELATION

14.1 Correlation of sections using pollen and spore assemblages

Traverse (1988) noted that coal beds are difficult to correlate using pollen and spores as the palynoflora of such deposits are notoriously local in derivation. They represent persistent biofacies that recur mostly in response to the environment. As a result of this, correlating beds may not be possible by correlating facies. Very similar palynofloras may occur in significantly separate stratigraphic horizons. Wilkinson and Boulter (1980) are of the opinion that the erratic occurrence of any potentially useful taxa for stratigraphic correlation within Tertiary deposits, due to rapidly changing ecological conditions, invalidates the use of most pollen and spores for detailed stratigraphic correlation. The stable flora and nature of the deposits of the Lough Neagh Group are regarded as unsuitable for stratigraphic work (Wilkinson and Boulter, 1980).

A basic correlation of four sections from the Coagh region is illustrated by (Parnell *et al.*, 1989). The correlations are based upon 4 zones defined by the relative amounts of the pollen and spore morphological groups Triporate, Alete, Bisaccate, Tricolporate and Trilete. The sections correlated all have very similar lithological successions and the greatest separation between the sections is 1.5km. Parnell *et al.*, (1989) noted that due to the structural setting of the basins containing the Lough Neagh Group one would not expect to correlate individual lignite seams from one district to another.

Wilkinson and Boulter (1980) reported some success in correlating the lower part of the Mire House borehole with the Middle shales of the Washing Bay borehole and relating these to sections at Mochras and Bovey Tracey.

The sampling resolution, and recovery in certain parts of the sections within this study is not regarded as sufficient to facilitate comprehensive correlations. Despite this, correlation of the four sections has been attempted and the results are presented as enclosure 13.

13/611 and 13/603 lie a little under 7km apart and display similar lithological successions. The palynofloras from the upper sections of both boreholes appear to record similar events, notably those that have been interpreted as indicating a cooling and drying climatic phase. Correlations for the lower parts of the sections are less certain.

Following the reported usefulness of *Mediocolpopollis* for correlating between Oligocene sections in the western part of the British Isles (Wilkinson and Boulter, 1980; Wilkinson *et al.*, 1980), correlation lines were drawn based upon its occurrence within the sections. Within 13/603 *Mediocolpopollis* occurs fairly consistently down hole to a depth of 161.19m. It is not recorded again until a single occurrence at 280.00m. Although recorded less consistently, the base of the upper occurrence in 13/611 is noted at 121.00m, the top of the lower occurrence is at 209.00m. Similar patterns of distribution of *Mediocolpopollis* into two possible phases were identified within 36/4680 and 27/415. It should be noted that these correlations are tentative as distribution of the species is not continuous.

Other possible lines of correlation are presented in enclosure 13.

15. CONCLUSIONS

15.1 Stratigraphy

The pollen and spore assemblages recovered from the four studied sections indicate that the sediments of the Lough Neagh Group and Dunaghy formation are of Oligocene age. This information was conveyed to the Geological Survey of Northern Ireland for inclusion in the 1997 revised edition, 1:250 000 Geological Map of Northern Ireland.

The absence of a dominant evergreen subtropical vegetation and any pollen diagnostic of the Eocene or earlier period precludes an older age assignment.

Whilst an Upper Oligocene age may be deduced based upon the reported stratigraphic significance of certain taxa identified, an earlier Oligocene age cannot be disproved for the Lough Neagh Group nor for the Dunaghy Formation.

15.2 Palaeoenvironment

From the pollen and spore assemblages recorded within lignitic facies it is deduced that a mixed (deciduous?) broad-leaved forest with a significant Nyssaceae/Taxodiaceae element formed the climax vegetation. This probably grew within a raised bog ecosystem within a fluvial-lacustrine environment.

A colonising flora dominated by pteridophytes formed the vegetation during deposition of the Dunaghy Formation prior to the establishment of a more stable angiosperm dominated vegetation.

An 'upland' flora represented by Pinaceae pollen grew in drier more areated areas that were probably removed from the raised bog forest.

15.3 Palaeoenvironment

The vegetation deduced from the pollen and spore assemblages is indicative of a vegetation growing within a climate cooler than that of the Eocene, thus supporting the concept of the Oligocene deterioration.

The presence of a warm temperate flora and some megatherm, frost sensitive taxa within the recorded assemblages suggests that the decrease of temperatures within the Oligocene had only a superficial effect upon the flora as recorded from the pollen and spore assemblages.

15.4 Pollen classification and nomenclature

It has become clear that classification and nomenclature of pollen within the Tertiary is complex and in some cases in a confused state. Whilst no one solution has been proposed, if indeed one is possible, it is thought that the solutions to problems of classification and nomenclature encountered within this study have not added to the pre-existing problems. The compromising solutions offered to the problems that have been highlighted may be easily accepted or rejected.

16. REFERENCES

ANDERSEN, S.T. 1970. The Relative Pollen Productivity and Pollen Representation of North European Trees, and Correction Factors for Tree Pollen Spectra. *Geological Survey of Denmark, II Series*, **96**, 1-99.

ANDERSON, J.A.R. and MULLER, J. 1975. Palynological study of a Holocene peat and a Miocene coal deposit from NW Borneo. *Rev. Palaeobotan. Palynol.* **19**, 291-351.

ANDERSON, R.Y. 1960. Cretaceous-Tertiary palynology, eastern side of the San Juan Basin, New Mexico. *State Bur. Mines and Min. Res. New Mex. Inst. Mining and Technology*, **6**, 1-58.

AXELROD, D.I. 1984. An interpretation of Cretaceous and Tertiary biota in polar regions. *Palaeogeog. Palaeoclim. Palaeoecol.* **45**, 105-147.

AXELROD, D.I. and BAILEY, H.P. 1969. Paleotemperature analysis of Tertiary floras. *Palaeogeog. Palaeoclim. Palaeoecol.*, **6**, 163-195.

BARTON, R. 1751. Lectures in natural philosophy designed to be a foundation for reasoning pertinently upon the petrifactions, gems crystals and sanative quality of the Lough Neagh in Ireland. Dublin.

BASSINGER, J.F. and DILCHER, D.L. 1984. Ancient bisexual flowers. *Science*, **224**, 511-513.

BAZLEY, R.A.B. 1978. Interglacial and interstadial deposits in Northern Ireland. *Rep. Inst. geol. Sci. London,* 77/16.

BELLAMY, D.J. 1972. Templates of peat formation. *Proc. 4th init. Peat Congress,* Helsinki, 4, 7-18.

BERRY, E.W. 1930. The past climate of the north polar region. *Smithsonian Misc. Coll.*, **82**, no. 6, 29pp.

BOERSMA, A., PREMOLI-SILVA, I. and SHACKLETON, N.J. 1987. Atlantic Eocene planktonic foraminiferal paleohydrographic indicators and stable isotope paleoceanography. *Paleoceanography*, **2**, 287-331.

BOLKHOVITINA, N.A. 1956. Atlas of spores and pollen from the Jurassic and Lower Cretaceous deposits of the Vilyui Depression. *Akad. Nauk SSSR, Trudy Geol. Inst., vyp.* **2**, 1-186.

BOLKHOVITINA. N.A. 1960. The naming of fossil pollen and spores in accordance with international regulations of botanical nomenclature. *Paleontl. Zhurn.*, 1960, no. **1**, 118-127.

BONNY, A.P. 1976. Recruitment of pollen to the seston and sediment of some English Lake District lakes. *J. Ecol.*, **64**, 859-887.

BONNY, A.P. 1978. The effect of pollen recruitment processes on pollen distribution over the sediment surface of a small lake in Cumbria, *J. Ecol.*, **66**, 385-416.

BOULTER, M.C. 1971. A survey of the Neogene Flora from two Derbyshire Pocket Deposits. *The Mercian Geologist*, **4**, 45-62.

BOULTER, M.C. 1979. Taxonomy and nomenclature of fossil pollen from the Tertiary. *Taxon*, **28**, (4), 337-344.

BOULTER, M.C. 1980. Irish Tertiary plant fossils in a European context. *J. Earth Sci. R. Dubl. Soc.* **3**, 1-11.

BOULTER, M.C. 1984. Palaeobotanical evidence for land-surface temperature in the European Palaeogene. *In* BRENCHLEY, P. (ed.) *Fossils and Climate*, John Wiley and Sons, Chichester, 35-47.

BOULTER, M.C. and CRAIG, D.L. 1979. A Middle Oligocene pollen and spore assemblage from the Bristol Channel. *Rev. Palaeobotan. Palynol.*, **28**, 259-272.

BOULTER, M.C. and HUBBARD, R.N.L.B. 1982. Objective and biostratigraphic interpretation of Tertiary palynological data by multivariate statistical analysis. *Palynology*, **6**, 55-68.

BOULTER, M.C. and WILKINSON, G.C. 1977. A System of Group Names for some Tertiary Pollen. *Palaeontology*, **20**, 559-579.

BROOKS, D. and THOMAS, K.W. 1967. The distribution of pollen grains on microscope slides. Part 1. The non-randomness of the distribution. *Pollen et Spores*, **9**, 621-629.

BUCHARDT, B. 1978a. Oxygen palaeotemperatures from the Tertiary period in the North Sea. *Nature*, **275**, 121-123.

BUZEK, C., HOLY. , F. and KVACEK, Z. 1967. Eine bemerkenswerte Art der Familie Platanaceae Lindl. (1936) im nordböhmischen Tertiä. *Monatsber. Dt. Akad. Wiss.*, **9**, 203-215.

CAIN, S.A. 1944. *Foundations of Plant Geography*. Harper and Brothers, New York, 556pp.

CAVELIER, C. 1979. La limite Eocène-Oligocène en Europe Occidentale. *Sci. Gèol. Strasb. Mém.*, **54**, 1-280.

CHANDLER, M.E.J. 1955. The Schizaeceae of the south of England in early Tertiary times. *Bull. Br. Mus. nat. Hist. (Geol.)*, **2**, (7), P. 291-314.

CHANDLER, M.E.J. 1957. The Oligocene flora of the Bovey Tracey lake basin Devonshire. *Bull. Br. Mus. nat. Hist. (Geol.)*, **3**, 73-124.

CHANEY, R.W. 1936. The succession and distribution of Cenozoic floras around the northern Pacific basin. *In* GOODSPEED, T.H. (ed.) *Essays in Geobotany in honour of William Albert Setchell.* University of California Press, Berkeley, California, 55-85.

CHANEY, R.W. 1938. Paleoecological interpretations of Cenozoic plants in western North America. *Botan. Rev.*, **9**, 371-396.

CHANEY, R.W. 1940. Tertiary forests and continental history. *Geol. Soc. Am. Bull.*, **51**, 469-488.

CHANEY, R.W. 1974. Tertiary centres and migration routes. *Ecol. Mongr.*, **17**, 139-148.

CHATEAUNEUF, J.J. 1972. Étude palynologique de l'Aquitanien. *Bull. Bur. Rech. min.*, **4**, 59-65.

CHATEAUNEUF, J.J. 1980. Palynostratigraphie et paléoclimatolgie de l'Eocène superior et de l'Oligocène du Bassin de Paris (France). *Mém. B.R.G.M.* **116**, 1-357.

COLE, G.A.J., WILKINSON, S.B., M'HENRY, A., KILROE, J.R., SEYMOUR, H.J., MOSS, C.E. and HAIGH, W.D. 1912. The Interbasaltic Rocks of North-East Ireland. *Memoirs of the Geological Survey of Northern Ireland.* 129pp.

COLE, G.A.J. and HALLISSY, 1924. Geology of Ireland. *Scientific proceedings of the Royal Dublin Society.*

COLINVAUX, P.A. 1976. Historical ecology in the Galapagos Islands, (i) A Holocene pollen record, from El Junco Lake, Isla San Cristobal. *J. Ecol.*, **64**, 989-1012.

COLLINSON, M.E. 1983. Palaeofloristic assemblages and palaeoecology of the Lower Oligocene Bembridge Marles, Hampstead Ledge, Isle of Wight. *Bot. J. Linn. Soc.*, **86**, 177-225.

COLLINSON, M.E. 1992. Vegetational and floristic changes around the Eocene/Oligocene boundary in western and central Europe. *In*: BERGGREN, W.A. and PROTHERO, D.R. (eds.) *Eocene - Oligocene climatic and biotic evolution.* Princeton University Press, Princeton 437-450.

COLLINSON, M.E., FOWLER, K. and BOULTER, M.C. 1981. Floristic changes indicate a cooling climate in the Eocene of southern England. *Nature*, **291**, 315-317.

COLLINSON, M.E. and HOOKER, J.J. 1987. Vegetational and mammalian faunal changes in the early Tertiary of southern England. *In*: FRISS, E.M., CHALONER, W.G. and CRANE, P.R., (eds.) *The origins of Angiosperms and their Biological Consequences*, Cambridge University Press, Cambridge, 259-304.

COLLINSON, M.E. and SCOTT, A.C. 1987. Implications of vegetational change through the geological record on models for coal-forming environments. *In*: SCOTT. A.C. (ed.) *Coal and Coal-bearing Strata: Recent Advances,* Geological Society Special Publication, No. 32. pp. 67-85. Blackwell Scientific Publications, Oxford.

COOKSON, I.C. 1947. Plant microfossils from the Lignites of the Kerguelen Archipeligo. *Reports B.A.N.Z. Antarct. Res. Exped.*, **2**, part 8, 129-142.

COOKSON, J.C. and PIKE, K.M. 1954. Some Dicotyledonous Pollen types from Cainozoic deposits in the Australian region. *Austr. J. Bot.*, **2**, 197-219.

COUPER, R.A. 1953. Upper Mesozoic and Cainozoic spores and pollen grains from New Zealand. *N.Z. Palaeontol. Bull.*, **22**, 77pp.

COUPER, R.A. 1958. British Mesozoic microspores and pollen grains: a systematic and stratigraphic study. *Palaeontographica Abt. B,* **103**, 75-179.

CRANE, P.R. 1989. Patterns of evolution and extinction in vascular plants. In ALLEN, K.C. and BRIGGS, D.E.G., (eds.) *Evolution and the fossil record.* Belhaven Press, London, 265pp.

CREPT, W.L. 1979. Some aspects of pollination biology of middle Eocene angiosperms. *Rev. Palaeobotan. Palynol.*, **27**, 213-238.

CUSHING, E.J. 1967. Evidence for differential pollen preservation in late Quaternary sediments in Minnesota. *Rev. Palaeobotan. Palynol.*, **4**, 87-101.

DALEY, B. 1989. Silica pseudomorphs from the Bembridge Limestone (Upper Eocene) of the Isle of Wight, southern England and their palaeoclimatic significance. *Palaeogeog. Palaeoclim. Palaeoecol.*, **69**, 233-240.

DANZÉ-CORSIN, J. and LAVAINE, J.P. 1963. Etude palynologique d'une argile provenant de la limite Lias-Dogger, dans un sondage á Bologne-sur-Mer. *Soc. géol. Nord.* **83**, 79-90.

DAVIS, M.B. 1965. A method for determination of absolute pollen frequency. *In* KRUMMEL, B. and RAUP, D.M. (eds.) *Handbook of palaeontological techniques.* W.H. Freeman, San Francisco, 674-685.

DAVIS, M.B. 1967. Pollen accumulation rates at Rogers Lake, Connecticut during late- and postglacial times, *Rev. Palaeobotan. Palynol.*, **2**, 219-230.

DELCOURT, A.F. and SPRUMONT, G. 1955. Les spores et grains de pollen du Wealdien du Hainaut. *Societe Belge de Geologie, de Paleontologie et Hydrologie, Memoirs nouvelle serie*, **4**, *(5)*, 73pp.

DETTMAN, M.E. 1963. Upper Mesozoic microfloras from southeastern Australia. *Proc. R. Soc. Vict.*,**77**, 148pp.

DEVEREUX, I. 1967. Oxygen isotope paleotemperature measurement on New Zealand Tertiary fossils. *N.Z. J. Science*, **10**, 988-1011.

DODSWORTH, P. 1995. A note of caution concerning the application of quantitative data from oxidised preparations. *J. Micropal.*, **14**, 6.

DOKTOROWICZ-HREBNICKA, J. 1957. Microfloristic investigations of brown-coal at Miroslawice Gorne in Lower Silesia. *Pr. Inst. geol.*, **15**, 167-186.

DÖRING, H. 1965. Die sporenpaläontologische Gliederung des Wealden in Westmecklenburg (Struktur Werle). *Beih. Geologie*, **47**, 1-118.

DURAND, S. 1964. L'analyse Pollinique des fromations du Paléogène Français. *Mem. Bur. Rech. Geol. Min.*, **28**, 1002-1008.

ELLIN, S. and Mc LEAN. D. 1994. The use of microwave heating in hydrofluoric acid digestions for palynological preparations. *Palynology*, **18**, 23-31.

ELSIK, W.C. 1966. Biologic degradation of fossil pollen grains and spores. *Micropalaeontology*, **12**, 515-518.

ELSIK, W.C. 1968. Palynology of a Palaeocene Rockdale lignite Milam County, Texas. *Pollen et Spores* **10**, 599-664.

ENGLER, A. 1882. Versuch einer Entwicklungsgeschichte der extratropischen Florengebeite der nordlichen Hemisphare und der tropischen gebiete. *Wilhelm Engelmann, Leipzig,* 202pp.

ERDTMAN, G. 1943. An introduction to pollen analysis. *Chronica Botanica*, 239pp.

ERDTMAN, G. 1947. Suggestions for the classification of fossil and recent pollen grains and spores. *Svensk Botan. Tidskr.*, **41**, 104-114.

ERDTMAN, G, 1954. *An introduction to pollen analysis.* Chronica Botanica. Waltham, Mass.

ETHERINGTON, J.R. 1983. *Wetland Ecology*. Studies in Biology No. 154. Arnold, London.

FAEGRI, K. 1956. Recent trends in palynology. *Botan. Rev.*, **22**, 639-644.

FAEGRI, K, and IVERSEN, J. 1950. *Textbook of Modern Pollen Analysis.* Munksgaard, Copenhagen, 168 pp.

FARLEY, M.B. 1989. Palynological facies fossils in nonmarine environments in the Paleogene of the Bighorn Basin. *Palaios*, 4, 565-573.

FARLEY, M.B. 1990. Vegetation distribution across the early Eocene depositional landscape from palynological analysis. *Palaeogeog. Palaeoclim. Palaeoecol.*, **79**, 11-27.

FAWCETT, A.H. and GRIMSHAW, J. 1989. Carbon 13 NMR characterization of Northern Ireland lignites. Abstract from workshop on The Lough Neagh Basin and its Lignites, Queens University, Belfast 1988 accompanying PARNELL, J., SHUKLA, B. and MEIGHAN, G.I., 1989. The Lignite and Associated Sediments of the Tertiary Lough Neagh Basin. *Irish J. Earth Sci.*, **10**, 67-88.

FITCH, F.H. 1954. North Borneo, mineral resources. *In*: ROE, F.W. (ed.) *Annual Report of the Geological Survey Department for 1953: British Territories in Borneo*, Government Printing Office, Kuching, Sarawak.

FOWLER, A. and ROBBIE, J.A. 1961. Geology of the Country around Dungannon. *Memoirs of the Geological Survey U.K.*, 274pp.

FRAKES, L.A.and KEMP, E.M. 1973. Palaeogene continental positions and evolution of climate. *In*: TARLING, D.H. and RUNCORN, S.K. (eds.) *Implications of continental drift to the Earth Sciences.* Academic Press, New York, **1**, 541-559.

FREDERIKSEN, N.O. 1979. Paleogene sporonorph biostratigraphy, Northeastern Virginia. *Palynology*, **3**, 129-169.

FREDERIKSEN, N.O. and CHRISTOPHER R.A. 1978. Taxonomy and biostratigraphy of the Late Cretaceous and Palaeogene triatriate pollen from South Carolina. *Palynology*, **2**, 113-145.

GABROWSKA, I. 1965. The Middle Oligocene age of the Tourn clays, based on spore and pollen analysis. *Kwartalnik Geologiczny*, **9**, 815-836.

GARDNER. J.S. 1885. On the Lower Eocene Plant-beds of the Basaltic Formation of Ulster. *Q. J. geol. Soc. London*, **41**, 82-92.

GARDNER. J.S. 1886. A Monograph on British Eocene Flora, vol.ii. London.

GERMERAAD, J.H., HOPPING, C.A. and MULLER, J. 1968. Palynology of Tertiary sediments from tropical areas. *Rev. Palaeobotan. Palynol.*, **6**, 189-348.

GOOD, R. 1953. *The Geography of the Flowering Plants.* Longmans, London, 518pp.

GORIN, G. 1975. Étude palynostratigraphique des sédiments paléogènes de la Grande Limagne (Massif central). *Bull. B.R.G.M.*, **3**, 147-181.

GRAUS-CAVAGNETTO, C. 1968. Étude Palynologie des divers Giesments du Sparnacien du Bassin de Paris. *Memoirs de la Societe geologique de France*, **47**, (110), 1-144.

GRAUS-CAVAGNETTO, C. 1976. Étude Palynologie du Paléogène du sud de l'Angleterre. *Cah. Micropaléont.*, **1**, 1-49.

GRAUS-CAVAGNETTO, C. 1978. Étude Palynologique de L' Éocéne du basin Anglo-Parisien. *Mém. Soc. Geol. France,* **131**, 1-64.

GRIFFITH, A.E., LEGG, I.C. and MITCHELL, W.I., (1987). Mineral Resources. *In*: BUCHANAN, R.H. and WALKER, B.M. (eds.) *Province City and People: Belfast and its Region.*Greystone Books, Belfast, 43-58.

GRIFFITH, R. 1837-1838. *Second report of the commissioners appointed to consider and recommend a general system of railways for Ireland,* H.C. 35, 34.

GUZMÁN, A.E.G. 1967. A palynological study on the upper Los Cuervos and Mirador Formations. (Lower and middle Eocene; Tibu area, Colombia.), E.J. Brill, Leiden, 68pp.

HANINGA, A.J. 1964. Investigation into the differential corrosion susceptibility of pollen and spores. *Pollen et Spores,* **6**, 621-637.

HANINGA, A.J. 1967. Palynology and pollen preservation. *Rev. Palaeobotan. Palynol.,* **2**, 81-98.

HANSEN, J.M. and GUDMUNDSSON, L. 1979. A method for separating acid-insoluble microfossils from organic debris. *Micropalaeontology,* **25**, 113/117.

HARDMANN, E.T. 1875. On the Age and Mode of formation of Lough Neagh (Ireland), with Notes on the Physical Geography and Geology of the Surrounding Country. *J. R. Geol. Soc. Ireland,* **4**, 170-199.

HARDMANN, E.T. 1876. Fossiliferous Pliocene clays overlying basalt near the shore of Lough Neagh. *Geol. Mag.,* (2) **3**, 556-558.

HARTLEY, J.J. 1948. The Post Mesozoid Succession south of Lough Neagh. *Ir. Nat. J.,* **9**, 115-121.

HARTLEY, J.J. 1951. Note on the Age of the Lough Neagh Clays. *Ir. Nat. J.,* **10**, 151-152.

HEER, O. 1862. The Fossil Flora of Bovey Tracey. *Phil. Trans. Roy. Soc. London,* **152**,

HESMER, H. 1933. Die natürliche Bestockung und die Waldentwicklung auf verschiedenartigen märkischen Standorten. *Zs. Forst-u. Jagdwesen,* **65**, 515-651.

HEYWOOD, V.H. (ed.) 1978. Flowering Plants of the World. Oxford University Press, Oxford, 335pp.

HICKEY, L.J. and WING, S.L. 1983. *Report to 5th Northeastern Paleobotanical Conference*. Harvard Forest, Petersham Massachusetts.

HOCHULI, P.A. 1978. Palynologische untersuchungen im Oligozän der Zentralen und Westlidhen Paratethys. *Beirtäge zur Paläontologie von Österreich,* **4**, 1-132.

HOLMES. S. 1987. *Handbook of Plant Types.* Hodder and Stoughton, Sevenoaks, 176pp.

HUBBARD, R.N.L.B. and BOULTER, M.C., 1983 Reconstruction of Palaeogene climate from palynological evidence. *Nature,* **30**, 147-150.

HUGHES, N.F. 1958. Palaeontological evidence for the age of the English Wealden. *Geol. Mag.,* **95**, 41-49.

HUGHES, N.F. 1963. The assignment of fossils to genera. *Taxon,* **12**, 336-337.

HUGHES, N.F. 1969. Suggestions for better handling of the genus in palaeo-palynology. *Grana palynol.,* **9**, 137-146.

HUGHES, N.F. 1970. The need for agreed standards of recording in palaeopalynology and palaeobotany. *Paläontographica. Abt. B,* **3**, 357-364.

HUGHES, N.F. 1971, Remedy for the general data handling failure in palaeontology. In, *Data Processing in Biology and Geology,* CURTBILL J.L. (ed.) *Systematics Association Spec.* **3**, 321-330.

HUGHES, N.F. 1973. Towards effective handling in palaeo-palynology. *In Morphology and systematics of Fossil Pollen and Spores, 3d Internat. Palyn. Congre. Novosibirsk (July 1971), Proc.* 9-14.

HUGHES, N.F. 1975. The challenge of abundance in palynomorphs. *Geoscience and Man,* **11**, 141-144.

HUGHES, N.F. and CROXTON, C.A. 1973. Palynologic correlation of the Dorset 'Wealden'. *Palaeontology,* **16**, 567-601.

HUGHES, N.F. and MOODY-STUART, J.C. 1966. Descriptions of schizaeaceous spores taken from early Cretaceous macrofossils.*Palaeontology,* **9**, 274-289.

HUGHES, N.F. and MOODY-STUART, J.C. 1969. A method of stratigraphic correlation using early Cretaceous spores. *Palaeontology,* **12**, 84-111.

HULL, 1878. *Physical Geography and Geology, Ireland.*

HUXLEY, T.H. 1870. The anniversary address of the President. *Geol. Soc. London Quart. Jour.,* **42**, 215-302.

HYAM, R, and PANKHURST, R. 1995. *Plants and their Names, A Concise Dictionary*. Royal Botanic Garden Edinburgh, Oxford University Press, Oxford, 537pp.

IBRAHIM, A.C. 1933. Spore forms of the Agir Horizon of the Rhur Basin. *Triltsch (Wuezburg)*, 1-46.

ILJINSKAJA, I.A. 1988. Contributions to the characterisation and origin of the Turgai flora of the U.S.S.R. *Tertiary Research*, **9**, 169-180.

INGROUILLE, M. 1995. *Historical Ecology of the British Flora*. Chapman and Hall, London, 347pp.

ISHCHENKO, M. 1952. Atlas of microspores and pollen of the Middle Carboniferous of the western part of the Donets Basin. *Akad. Nauk S.S.S.R. Inst. Geol. Nauk, Atlas*, 1-83.

JANSONIUS, J. and HILLS, L.V. 1976. *Genera File of Fossil Spores and Pollen*. Special publication, University of Calgary, Canada.

JENKINS, D., BOULTER, M.C. and RAMSAY, A.T.S. 1995. The Flinston Clay, Pembrokeshire, Wales: a probable late Oligocene lacustrine deposit. *Micropalaeontology*, **14**, 66.

JOHNSON, T. and GILMORE, JANE. G., 1921a. The Occurrence of *Dewalquea* in the Coal-Bore at Washing Bay. *Sci. Proc. R. Dublin Soc.*,**16**, 323-333.

JOHNSON, T. and GILMORE, JANE. G., 1921b. The Occurrence of *Sequoia* at Washing Bay. *Sci. Proc. R. Dublin Soc.*,**16**, 345-351.

JOHNSON, T. and GILMORE, JANE. G., 1922. The Lignite of Washing Bay, Co. Tyrone. *Sci. Proc. R. Dublin Soc.*,**17**, 59-65.

JOLLEY, D.W. 1991. Palynofloral Studies of Selected Late Palaeocene to Early Eocene Localities of Northwest Europe. *Unpublished Ph.D. thesis, University of Sheffield.*

JOLLEY, D.W. 1998. Early Eocene palynofloras from holes 915A, 916A, 917A, and 918D, East Greenland. *Proc. Ocean Drill. Prog. Sci. Res.*, **52**, 221-231.

JONES, R.A. and ELLIN, S.J. 1998. Improved palynological sample preparation using an automated focused microwave digestion system. *In*: BRYANT, V.M. and WRENN, J.H. (eds.) *New Developments in palynomorph Sampling, Extraction and Analysis;* American Association of Stratigraphic Palynologists Foundation, Contributions Series Number **33**, 23-28.

KEDVAS, M. 1961. Études Palynologiques dans le basin de Dorag, 2. *Pollen et Spores*, **3**, 101-153.

KEDVAS, M. 1974. Paleogene Fossil Sporomorphs of the Bakony Mountains, Part 2. *Akadémiai Kiadó*, 124pp.

KEDVAS, M. 1982. *in* KEDVAS, M. and RUSSEL, D.E. Palynology of the Thanetian layers of Menat and the geology of the Menat Basin, France. *Palaeontographica Abt. B*, **182**, 87-150.

KEIGWIN, L.D. 1980. Palaeoceanographic change in the Pacific at the Eocene-Oligocene boundary. *Nature*, **287**, 722-725.

KEIGWIN, L.D. and CORLISS. B.H. 1986. Stable isotopes in late middle Eocene to Oligocene foraminifera. *Geol. Soc. Amer. Bull.*, **97**, 335-345.

KELLER, G. 1983. Paleoclimatic analysis of middle Eocene through Oligocene planktic foraminiferal faunas. *Palaeogeog. Palaeoclim. Palaeoecol.*, **43**, 73-94.

KEMP, E.M. 1978. Tertiary climatic evolution and vegetation history in the southeast Indian Ocean region. *Palaeogeog. Palaeoclim. Palaeoecol.*, **24**, 169-208.

KEMP, E.M. and HARRIS, W.K. 1977. The palynology of Early Tertiary sediments Ninetyeast Ridge Indian Ocean. *Special papers in Palaeontology*, **19**, 70pp.

KENNETT, J.P., HOUTZ, R.E., ANDREWS, P.B., EDWARDS. A.R., GOSTIN, V.A., HAHOS, M., HAMPTON. M.A., JENKINS. D.G., MARGOLIS. S.V., OVENSHINE, A.T. and PERCH-NIELSEN, K. 1975. Cenozoic paleoceanography in the southwest Pacific Ocean, Antarctic glaciation and the development of the circum-Antarctic current. *In* KENNETT, J.P. and HOUTZ, R.E. *et al.*, *Init. Rept. Deep Sea Drilling Project, Wasjington D.C., U.S. Government Printing Office*, **29**, 1155-1169.

KENNETT, J.P. *et al.* 1985. Palaeotectonic impliations of increased late Eocene-early Oligocene volcanism from South Pacific D.S.D.P. sites. *Nature*, **316**, 507-511.

KINAHAN, G.H. 1878. *Geology of Ireland.*

KLAUS, W. 1960. Sporen der karnischen Stufe der ostalpinen Trias. *Jahrbuch der Geologischen Bundersanstalt (Austria)*, **5**, 107-183.

KONZALOVA, M. 1971. Arecales (Palmae) in the North-Bohemian Tertiary. *Sb. geol. ved. Paleontol.*, **13**, 143-158.

KRÄUSEL, R. (1961) Botanical evidence of climate, 3. The Tertiary. 235-246. In *Descriptive Palaeoclimatology*. NAIRN, A.E.M. (ed.) Interscience Publishers, New York, 380pp.

KREMP, G.O.W. 1949. Pollenanalytische Untersuchung des miozänen Braunkohlenlagers von Konin an der Warthe. *Palaeontographica*, **90**, 53-92.

KRUTZSCH, W. 1957. Sporen und Pollengruppen aus der Oberkreide und dem Tertiär Mitteleuropas und ihre stratigraphische Verteilung. *Z. Geologie*, **11**, 509-546.

KRUTZSCH, W. 1959b. Mikropaläontologische (sporenpaläontologische) Untersuchungen in der Braunkohle des Geiseltales. *Z. Geologie,* **21-22**, 1-425.

KRUTZSCH, W. 1959c. Einige nue Formgattungen und arten von Sporen und Pollen aus der mitteleuropäischen Oberkreide und dem Tertiär. *Palaeontographica B,* **105**, 125-157.

KRUTZSCH, W. 1961d. Beitrag zur Sporenpaläontologie der präoberoligozänen kontinentalen und marinen Tertiärablagerungen Brandenburgs. *Berichte Geologischen Gesellschaft DDR,* **5**, 290-343.

KRUTZSCH, W. 1962a. Stratigraphisch bzw. botanisch wichtige neue Sporen- und Pollenformen aus dem deutschen Tertiär. *Geologie,* **11**, p. 265-308.

KRUTZSCH, W. 1962c. Atlas der mittel- und jungtertiären dispersen Sporen- und Pollen- sowie der Mikroplanktonformen des nördlichen Mitteleuropas. Lieferung I Laevigate und toriate trilete Sporenformen. *Veb Deutscher Verlag der Wissenschaften,* Berlin. 108pp.

KRUTZSCH, W. 1963a. Atlas der mittel- und jungtertiären dispersen Sporen- und Pollen- sowie der Mikroplanktonformen des nördlichen Mitteleuropas. Lieferung II Die sporen der Anthocerotaceae und der Lycopodiaceae. *Veb Deutscher Verlag der Wissenschaften,* Berlin. 138pp.

KRUTZSCH, W. 1963b. Atlas der mittel- und jungtertiären dispersen Sporen- und Pollen- sowie der Mikroplanktonformen des nördlichen Mitteleuropas. Lieferung III Sphagnaceoide und selaginellaceoide Sporenformen. *Veb Deutscher Verlag der Wissenschaften,* Berlin. 128pp.

KRUTZSCH, W. 1966c. Die sporenstratigraphische gliederung des älteren Tertiärs im nördlichen Mitteleuropa (Paläozän-Mitteloligozän). Methodische Grundlagen und rerenwärtiger Stand der Untersuchungen. *Abh. zentr. geol. Inst.*, **8**, 112-149.

KRUTZSCH, W. 1967a. Atlas der mittel- und jungtertiären dispersen Sporen- und Pollen- sowie der Mikroplanktonformen des nördlichen Mitteleuropas. Lieferung IV und V Weitere azonotrilete (apiculate, murornate), zonotrilete, monolete und alete Sporenformen. *Veb Gustav Fischer Verlag Jena,* Berlin. 232pp.

KRUTZSCH, W. 1967c. Die stratigraphisch verwertbaren Sporen- und Pollenformen des mitteleuropäischen Alttertiärs. *Geol. Jahrb.*, **3**, 309-379.

KRUTZSCH, W. 1967f. Die Florenwechsel im Alttertiär Mitteleuropas auf Grund von sporenpaläontologischen Untersuchungen. *Abh. zrntr. geol. Inst.,* **10**, 765-788.

KRUTZSCH, W. 1968d. Zur Kenntnis des dispersen Oenotheraceen-(Onagraceen-) Pollens insbesondere aus dem mitteleuropäischen Tertiär. *Palaeontographica, Abt. B.*, 4, 765-788.

KRUTZSCH, W. 1969. Taxonomie Syncolp(or)ater und morphologisch Benachbarter Pollengattungen und-arten (sporae dispersae) aus der Oberkreide und dem Tertiaer. Teil I: Syncolp(or)ate und syncolp(or)atoide pollenformen. *Pollen et Spores,* **11**, 397-424.

KRUTZSCH, W. 1970. Atlas der mittel- und jungtertiären dispersen Sporen- und Pollen- sowie der Mikroplanktonformen des nördlichen Mitteleuropas. Lieferung VII Monoporate, monocolpate, longicolpate, dicolpate und ephedroide (polyplicate) Pollenformen. *Veb Gustav Fischer Verlag Jena.* 175pp.

KRUTZSCH, W. 1970b. Die stratigraphische verwertbaren Sporen- und Pollenformen des mitteleuropäischen Alttertiärs. *Jb. Geol.*, **3**, 309-379.

KRUTZSCH, W. 1971. Atlas der mittel- und jungtertiären dispersen Sporen- und Pollen- sowie der Mikroplanktonformen des nördlichen Mitteleuropas. Lieferung VI Coniferenpollen (saccates und "Inaperturates"). *Veb Gustav Fischer Verlag Jena.* 234pp.

KRYSTOFOVICH, A.N. 1929. Evolution of the Tertiary flora in Asia. *New Phytologist,* **29**, 303-312.

KVACEK, Z., WALTHER, H. and BUZEK, C. 1989. Palaeogene floras of W. Bohemia (C.S.S.R.) and the Weisselster Basin (G.D.R.) and their correlation. *Casopis pro miner a geol.*, **34**, 385-401.

LEFFINGWELL, H.A. 1971. Palynology of the Lance (Late Cretaceous) and Fort Union (Palaeocene) Formations of the type Lance area, Wyoming. *Geol. Soc. Amer. Spec. Paper*, **127**, 1-64.

LEIDELMEYER, P. 1966. The Paleocene and Lower Eocene pollen flora of Guyana. *Leidse Geol. Meded.* **38**, 49-70.

LEOPOLD, E.B. and MAC GINITIE, H.D. 1972. Development and affinities of Tertiary floras in the Rocky Mountains. In GRAHAM, A. (ed.) *Floristics and paleofloras of Asia and Eastern North America*. Elsevier, Amsterdam, 147-200.

MacGINITIE, H.D. 1953. Fossil Plants of the Florissant Beds, Colorado. *Carnegie Inst. Washington Pub.*, **599**, 189pp.

MACHIN, J. 1971. Plant microfossils from the Tertiary Deposits of the Isle of Wight. *New Phytol.*, **70**, 851-872.

MAI, D.H. 1961. Über eine fossile Tiliaceen-Blüte und tilioiden Pollen aus dem deutschen Tertiär. *Geologie*, **32**, 54-93.

MAI, D.H. and WALTHER, H. 1978. Die Floren der Haselbacher Serie im Weisselster-Becken (Bezirk leipzig, D.D.R.). *Abh. St. Mus. Miner. Geol. Dresd.*, **28**, 1-200.

MAI, D.H. and WALTHER, H. 1985. Die obereozänen Floren des Weiselster-Beckens und seiner Randgebiete. *Abh. St. Mus. Miner. Geol. Dresd.*, **33**, 1-260.

MANCHESTER, S.R. and CRANE, P.R. 1983. Attached leaves, inflorescences and fruits of Fagopsis, an extinct genus of fagaceous affinity from the Oligocene Florissant flora of Colorado, U.S.A. *Am. J. Bot.*,**70**, 1147-1164.

McANDREWS, J.H., BERTI, A.A. and NORRIS, G., 1973. *Key to the Quaternary pollen and spores of the Great Lakes region.* Life Sciences Miscellaneous Publications, Royal Ontario Museum.

McCABE. P.J. 1984. Depositional environments of coal and coal-bearing strata. *In*: RAHMANI, R.A. and FLORES, R.M. (eds.) *Sedimentology of Coal and Coal-bearing Sequences*, pp. 13-42. Special Publication of the International Association of Sedimentologists 7. Blackwell Scientific Publications, Oxford.

MEYER, K.J. 1988. *In* VINKEN, R. (compiler), 1988. The Northwest European Tertiary Basin. Results of the International Geological Correlation Programme Project No. 124. *Geol. Jahrb. (A)*, **100**, 288-294.

MINER, E.L. 1935. Paleobotanical examinations of Cretaceous and Tertiary coals: 1. Cretaceous coals from Greenland. 2. Cretaceous and Tertiary coals from Montana. *American Midland Naturalist*, **16**, 585-625.

MOORE. P.D. 1987. Ecological and hydrological aspects of peat formation. *In*: SCOTT. A.C. (ed.) *Coal and Coal-bearing Strata: Recent Advances*, Geological Society Special Publication, No. 32. Blackwell Scientific Publications, Oxford, 7-15.

MOORE, P.D., WEBB, J.A. and COLLINSON, M.E. 1991. *Pollen analysis.* Blackwell Scientific Publications, Oxford, 216 pp.

MOSBRUGGER, V. and UTESCHER, T. 1997. The coexistence appraoch-a method for quantitative reconstructions of Tertiary terrestrial palaeoclimate data using plant fossils. *Palaeogeog. Palaeoclim. Palaeoecol.*, **134**, 61-86.

MULLER, J. 1959. Palynology of recent Orinoco delta and shelf sediments. *Micropalaeontology*, **5**, 1-32.

MÜLLER, M.J. 1982. *Selected climatic data for a global set of standard stations for vegetation science*. Junk, The Hague.

MÜRRIGER, F. and PFLANZL, G., 1955. Pollenanalytische Datierung einiger hessischer Bruankhole. *Notizbl. hass L. Amt Bodenforsch*, **83**, 71-89.

MÜRRIGER, F. and PFLUG, H. 1951. Uber die Alterstellung der braunkohl von Burghasungen, Bezirk Kassel, auf Grund pollenanalytischer Untersuchungen und Vergleiche mit anderen Braunkohlen vorkommen. *Notizbl. hass L. Amt Bodenforsch*, **6**, 87-97.

NAGY, E. 1963b. Spores et pollen nouvaux d'une coupe de la briqueterie d' Eger (Hongrié). *Pollen et Spores,* **5**, 342-395.

NAKOMAN, E. 1965. Description d'un nouveau genre de forme: *Corsinipollenites. Annal. de la Soc. Geol. du Nord.*, **85**, 155-158.

NAUMOVA, S.N. 1939. The spores and pollen of the coals of the U.S.S.R. *Int. Geol. Congr. 17th Rep.(1937)*, 353-364.

NICHOLS, D.J. 1973. North American and European species of *Momipites* ("*Engelhardia*") and related genera. *Geoscience and Man,* **7**, 103-117.

NICHOLS, D.J., AMES, H.T. and TRAVERSE, A. 1973. On *Arecipites* Wodehouse, *Monocolpopollenites* Thompson and Pflug, and the species "*Monocolpopollenites tranquillus*". *Taxon,* **22**, 241-256.

NICHOLS, D.J. and OTT, H.L. 1978. Biostratigraphy and evolution of the *Momipites-Caryapollenites* lineage in the Wind River Basin, Wyoming. *Palynology,* 93-112.

OLLIVIER-PIERRE, M.F. 1980. Etude palynologique (spores et pollen) de gisements paléogènes du Masif Armoricain. Stratigraphie et paleogeographie. *Mem. Soc. geol. miner. Bretagne,* **25**, 1-239.

OLLIVER-PIERRE, M.F., GRAUS-CAVAGNETTO, C., ROCHE, E. and SCHULER, M. 1987. Eléments de flore de type tropical et variations climatiques au Paléogene dans quelques basins d'Europe nord-occidentale. *Mém. Trav. E.P.H.E. Inst Montpellier,* **17**, 173-205.

OLLIVER-PIERRE, M.F., RIVELINE, J., LAUTRIDOU, J.P. and CAVELIER, C. 1988. Le fosse de Céaucé (Orne) et les bassins ludiens (Eocene supérier) de la partie orientale du Massif armoricain: Sedimentologie, paléontoligie Intéret stratigraphique et tectonique. *Géologie de la France,* **1**, 51-60.

PACLTOVÁ, B. 1960. Plant microfossils (mainly Sporomorphite) from the lignite deposits near Mydlovery in the Ceské Budjovice Bsain (South Bohemia). *Sb. ustred, Ust. geol.,* **25**, 109-176.

PACLTOVÁ, B. 1966. The results of micropalaeobotanical studies of the Chattian-Aquitanian complex in Slovakia. *Rada matem. Pri. Ved.*, **76**, 1-68.

PACLTOVÁ, B. 1978. Evolutionary trends of platanaceoid pollen in Europe during the Cenophytic. *Cour. Forsch.-Inst. Senckenberg,* **30**, 70-76.

PANT, D.D. 1954. Suggestions for the classification and nomenclature of fossil spores and pollen grains. *Botan. Rev.*, **20**, 33-60.

PARNELL, J. and MEIGHAN, I.G. 1989. Lignite and associated deposits of the Tertiary Lough Neagh Basin, Northern Ireland. *J. Geol. Soc. London,* **146**, 351-352.

PARNELL, J., SHUKLA, B. and MEIGHAN, G.I. 1989. The Lignite and Associated Sediments of the Tertiary Lough Neagh Basin. *Irish J. Earth Sci.*, **10**, 67-88.

PECK, R. 1973. Pollen budget studies in a small Yorkshire catchment. In BIRKS, H.J. and WEST. R.G. (eds.), *Quaternary plant ecology*, Blackwell, Oxford, 43-60.

PFLANZL, G. 1956. Der Alter der Braunkohlen des Meißners, der Flöze 2 und 3 des Hirschberges und eines benachbarten Koklenlagers bei Laudenbach. *Notizblatt Hessischen Landesamt. Bodenf. Wiesbaden, Bd.*, **84**, 232-244.

PFLUG, H. 1953b. Zur Enstehung und Entwicklung des Angiospermiden-Pollens in der Ergeschichte. *Palaeontographica Abt. B*, **95**, 60-171.

PIERCE, R.L. 1961. Lower Upper Cretaceous plant microfossilsfrom Minnesota. *Bull. Minn. geol. Surv.*, **42**, 1-68.

POLUNIN, N. 1960. *Introduction to plant geography and some related sciences.* Longmans, London.

POTONIÉ, R. 1931a. Zur Microskopie dur Braunkohlen Tertiare Sporen und Blutenstaubformen (1, mitteilung). *Zeitschrift für Gewinnung und Verwertung der Braunkohle* H 16, **30**, p. 325-333.

POTONIÉ, R. 1931b. Pollenformen der miocänen Braunkohlen, (2. mitteilung). *Sitz. Ber. Ges. Naturf. Fr.*, **1-3**, 24-28.

POTONIÉ, R. 1931c. Pollenformen aus tertiären Braunkohlen, (3. mitteilung). *Jahrb. Preuss. Geol. Landesanst*, **52**, 24-28.

POTONIÉ, R. 1931d. Zur microskopie dur braunkohlen. Tertiäre sporen und Blütenstaubformen. (4, mitteilung). *Zieschrift fur gewinnung and verwetung der Braunkohlen*, **30**, (27), 554-556.

POTONIÉ, R. 1934. Zur mikrobotanik des eozanen humodils des geiseltals. *Arb. Inst. Palaobot.*, **4**, p. 25-125.

POTONIÉ, R. 1951. Revision stratigraphisch wichtiger Sporomorphen der mitteleuropäischen Tertiärs. *Palaeontographica B*, **91**, 131-151.

POTONIÉ, R. 1952. Zur Systematik isolierter Sporen fossiler Pflanzen. *Svensk. bot. Tidskr.*, **42**,128-173.

POTONIÉ, R. 1956a. Die stratigraphische Inkongruität der Organe des Pflanzenkörpers. *Paläont. Z.*, **30**, 88-94.

POTONIÉ, R. 1956b. Synopsis der Gattungen der Sporae dispersae, Teil 1, Sporites. *Beih. geol. Jb.*, **23**, 103pp. Hannover.

POTONIÉ, R. 1958a. Views on spore nomenclature. *Geol. Mag.*, **95**, 491-496.

POTONIÉ, R. 1958b. Synopsis der Gattungen der Sporae dispersae, Teil 2, Sporites (Nachträge) Saccites, Aletes, Praecolpates, Polyplicates, Monocolpates. *Beih. geol. Jb.*, **31**, 114pp. Hannover.

POTONIÉ, R. 1960. Synopsis der Gattungen der Sporae dispersae, Teil 3, Nachträge Sporites, Fortsenzung Pollenites. Mit generalregister zu Teil 1-3. *Beih. geol. Jb.*, **39**, 189pp. Hannover

POTONIÉ, R. 1966. Synopsis der Gattungen der Sporae dispersae, Teil 4, Nachträge zu allen Gruppen (Turmae). *Beih. geol. Jb.*, **72**, 244pp. Hannover.

POTONIÉ, R. 1975. Artbegriff und Palaeobotanik. *Rev. Palaeobotan. Palynol.*, **19**, 161-172.

POTONIÉ, R. and GELLETICH, J. 1933. Uber Pteridophyten sporen einer Eozanen braunkohle aue Dorog in Ungarn. *Sitzungsberichte der Gasellschaft Naturforschender Freunde*, **33**, 517-528.

POTONIÉ, R., THOMSON, P.W. and THIERGART, F. 1951. Zur Nomenclature und Klassifikation der Noegen Sporomorphae (Pollen und Sporen). *Geol. Jb.* **65**, 35-70.

POTONIÉ, R. and VENITZ, H. 1934. Zur mikrobotanik des miozanen Humodils der niederrheinischen Bucht. *Abh. Inst. Palaobot. Petrog. Brennsteine* **5**, 54pp.

PULATOVA, M.S. 1990. The main stages in development of the Eocene and Oligocene floras of south-eastern middle Asia. *In* KNOBLOCH, E. and KVACEK, Z. (eds.) *Proceedings of the Symposium Paleofloristic and paleoclimatic changes in the Cretaceous and Tertiary*. Geological Survey Publisher, Prague, 147-148.

RAATZ, G.V. 1938. Mikrobotanisch-stratigraphische Untersuchung der braunkohle des Muskaver Bogens. *Abhandlung Preussiche Geologische Landesanstalt* (1937), **183**, p. 48.

REMPE, H. 1937. Unterschungen über die Verbreitung des Blütenstaubes die Luftströmungen. *Planta*, **27**, 93-147.

RETALLACK, G.J. 1986. Fossil soils as ground for interpreting long-term controls on ancient rivers. *Journal of Sedimentary Petrology*, **56**, 1-18.

RETALLACK, G.J. 1992. Palaeosols and changes in climate and vegetation across the Eocene/Oligocene boundary. *In*: Berggren, W.A. and PROTHERO, D.R. (eds.) *Eocene - Oligocene climatic and biotic evolution*. Princeton University Press, Princeton, 382-398.

ROCHE, E. and SCHULER, M. 1976. Analyse palynologique (Pollen et Spores) de divers gisements du Tongrien de Belgique. *Service Geologique de Belgique, Professional Paper 1976*, **11**, 1-57.

Rock Color Chart, (1995). *The Geological Society of America,* Boulder Colorado, Munsell Color, U.S.A.

ROMANOWICZ, I. 1961. Analiza sporowo-pylkowa osadów trzeciorzedowych z okolic Boleslawca i Zebrzydowej. *Biul. Inst. Geol.,* **158**, 325-409.

ROSS, N.E. 1949. On a Cretaceous pollen and spore bearing clay deposit of Scania. *Bull. geol. Instn. Uppsala,* **34**, 25-43.

SAH, S.C.D. 1967. Palynology of an upper Neogene profile from Rusizi Valley (Brundi) *Mus. Roy. Afrique Centr. Tervuren. Ann. Ser. 8me serie Sci. geol.* 57.

SALAMI, M.B. 1981. Late Cretaceous and Early Tertiary palynofloras from the southern Nigeria sedimentary basin. *Unpublished Ph.D. Thesis,* University of Cambridge, England, 290pp.

SAVIN, S.M. 1977. The history of the Earth's surface temperature during the past 100 million years. *Ann. Rev. Earth Planet. Sci.,* **5**, 319-355.

SAVIN, S.M. 1982. Stable isotopes in climatic reconstructions. In *Climate in Earth history, National Reaseach council Studies in Geophysics.* National Academy press, Washington, D.C., 167-171.

SAVIN, S.M., DOUGLAS, R.G. and STEHLI, F.G. 1975. Tertiary marine paleotemperatures. *Geol. Soc. Am. Bull.,* **86**, 1499-1510.

SCHOFIELD, E.K. 1976. Historical ecology in the Galapagos Islands, ii) A Holocene pollen record, from El Junco Lake, Isla San Cristobal. *J. Ecol.,* **64**, 1013-1028.

SCHULTZ, E. 1966. Erläuterungen zu den sporenstratigraphischen Tabellen vom Zechstein bis zum Oligozän. *Abh. Zentr. Geol. Inst.,* **8**, 1-149.

SCULTHORPE. D.C. 1967. *The Biology of Aquatic Vascular Plants,* Edward Arnold, London.

SEWARD, A.C. 1914. Antarctic fossil plants. *Nat. Hist. Rep. Brit. Antarct. Exped. 1910, Geol.,* **1**, 1-49.

SHACKLETON, N.J. 1986. Paleogene stable isotope events. *Palaeogeog. Palaeoclim. Palaeoecol.* **57**, 91-102.

SHACKLETON, N.J. and KENNETT, J.P. 1975. Paleotemperature history of the Cenozoic and the initiation of Antarctic glaciations: oxygen and carbon isotopic analyses in D.S.D.P. sites 227, 279 and 281. *In* KENNETT, J.P. *et al.* (eds.) *Initial Rep. Deep Sea Drill. Proj.,* Washington, D.C., U.S. Government Printing Office, **29**, 743-755.

SIEFFERMANN, R.G. 1988. Origin of iron-carbonate layers in Tertiary sediments of central Kalimantan (Borneo), Indonesia. *Abstract Volume, IAS International Symposium on Sedimentology related to Mineral Deposits.* Beijing, China.

SITTLER, M. and SCHULER, M. 1975. Extension stratigraphique, répartition géographique et écologie de deux genres polliniques paléogènes observés en Europe occidentale: *Aglaoreidia* et *Boehlensipollis. Soc. bot. Fr., Coll. Palynologie*, **123**, 231-245.

SLOAN, L.C. AND BARRON, E.J. 1992. Paleogene climatic evolution: A climate model investigation of the influence of continental elevation and sea-surface temperature upon continental climate. *In* BERGGREN, W.A. and PROTHERO, D.R. (eds.) *Eocene - Oligocene climatic and biotic evolution.* Princeton University Press, Princeton, 202-217.

SMITH, D.G. 1989. Stratigraphic time-correlation in the Late Triassic of Svalbard: A discussion of N.F. Hughes's working methods. *Studies in Palaeobotany and Palynology, Special Papers in palaeontology*, **35**, 149-161.

SPORNE, K. R. 1974. *The morphology of angiosperms.* Hutchinson, London. 207pp.

SRIVASTAVA, S.K. 1967. Upper Cretaceous Microflora (Maestrichtian) from Scollard, Alberta, Canada. *Pollen et Spores*, **8**, 497-552.

SRIVASTAVA, S.K. 1972. Some spores and pollen from the palaeocene Oak Hill Member of the Naheola Formation, Alabama, U.S.A. *Rev. Palaeobotan. Palynol.*, **14**, 217-285.

STEWART, D.S. 1800. Report to the Dublin Society. *Trans. Dubl. Soc.* **1**, 142.

STOVER, L.E., ELSIK, W.C. and FAIRCHILD, W.W. 1966. New genera and species of Early Tertiary palynomorphs from the Gulf Coast. *University of Kansas Paleontological Contributations*, Paper **5**, 1-11.Paper **6**, 7.

SWANSTON, W. 1879. On the supposed fossiliferous Pliocene clays overlying basalt near the shore of Lough Neagh. *Geol. Mag.*, **6**, 62-65.

SWISHER, C.C. and PROTHERO, D.R. 1990. Single-crystal $^{40}Ar/^{39}Ar$ dating of the Eocene/Oligocene trnsition in North America. *Science*, **249**, 760-762.

TAKAHASHI, K. and JUX, U. 1982. Sporomorphen aus dem Palaogen des Bergischen Landes (West Deutschland). *Bull. Faculty of Liberal Arts, Nagasaki Univ. (Natural Science)*, **23**, 23-134.

TAUBER, H. 1965. Differential pollen dispersion and the interpretation of pollen diagrams. *Dan. Geol. Unders. Ser.*, 2, **89**, 1-69.

TAUBER, H. 1967. Investigations of the mode of pollen transfer in forested areas. *Rev. Palaeobotan. Palynol.*, **3**, 277-286.

TEICHMÜLLER, M. and TEICHMÜLLER, R. 1968. Cainozoic and Mesozoic Coal Deposits of Germany. *In*: MURCHISON, D. and WESTOLL, T.S. (eds.). *Coal and Coal-bearing Strata*, Oliver and Boyd, Edinburgh. 347-379.

TESLENKO, Ju.V. 1990. Floristic and palaeoclimatic changes in Palaeogene and Neogene times over the territory of the Ukraine. *In* KNOBLOCH, E. and KVACEK, Z. (eds.) *Proceedings of the Symposium Paleofloristic and paleoclimatic changes in the Cretaceous and Tertiary*, Geological Survey Publisher, Prague, 115-118.

THANIKAIMONI, CARATINI, C., VENKATACHALA, B., RAMANUJAM, C. and KAR, R. 1984. Selected Tertiary pollens from India and their relationship with African Tertiaty pollens. (eds.) *Inst. Franc. Podichéry, Trav. Sect. Scientif. Techn.*, **19**, 1-94.

THIERGART, F. 1938. Die Pollenflora der Niederlausitzer Braunkohle, besonders im Profil der Grube Marga bei Senftenberg. *Jahrb. Preuss. Geol. Landesanst,* 1937, **58**, p. 81-106.

THIERGART, F. 1940. Die Mikropäontologie als Pollenanalyse im Dienst der Braunkohlenforschung; *Schriften aus dem Gebiet der Brennstoff-Geologie*, **13**, 1-82, 14 plates., 3 tables., Enke-Verlag, Stugggart.

THOMPSON, P. 1986. Dating the British Tertiary Igneous Province in Ireland by the ^{40}Ar-^{39}Ar stepwise degassing method. *Unpublished Ph.D. thesis, University of Liverpool.*

THOMSON, P.W. 1949. Alttertiäre Elemente in der Pollenflora der niederrheinischen Braunkohle und einige stratigraphisch wichtige Formen derselben. *Palaeontographica Abt. B*, **90**, 94-98.

THOMSON, P.W. and PFLUG, H. 1953. Pollen und sporen des mitteleuropäischen Tertiärs. *Palaeontographica Abt. B,* **94**, p. 1-138.

TIFFNEY, B.H. (1985). The Eocene North Atlantic Land Bridge: its importance in Tertiary and modern phytogeography of the Northern Hemisphere. *Journal of the Arnold Arboretum*, **66**, 243-273.

TRAVERSE, A. 1955. Pollen analysis of the Brandon lignite of Vermont. *U.S. Dept. Int. Bur. of Mines Report.*, 5151, 1-107.

TRAVERSE, A. 1975. The challenge of abundance in palynomorphs: A critique. *Geoscience and Man,* **11**, 145-147.

TRAVERSE, A. 1988. *Palaeopalynology*. Unwin Hyman, London. 600pp.

TREVISAN, L. 1967. Pollini fossili del Miocenesuperiore nei tripoli del Gabbro (Toscana). *Palaeontographica Italica*, **62**, 1-73.

TSCHUNDY, R.H. 1973. Stratigraphic distribution of significant Eocene palynomorphs from the Mississippi embayment. *U.S. Geological Survey Professional Paper*, **743B**, 156pp.

VAN DER HAMMEN, T. 1956. A palynological systematic nomenclature. *Boln. geol.*, **4**, 63-101.

VAN DER HAMMEN, T and WIJMSTRA, T.A. 1964. Palynological study on the Tertiary and Upper Cretaceous of British Guiana. *Leidse Geologische Mededelingen*, **30**, 183-241.

VINKEN, R. (compiler), 1988. The Northwest European Tertiary Basin. Results of the International Geological Correlation Programme Project No. 124. *Geol. Jahrb.,(A)* **100**, 508pp.

VON POST, L. 1916. Skogstädpollen i sydsvenska totmosselagerföljder. *Geol. Förhandl.*, **38**, 384-394.

VON POST, L. 1918. Skogstädpollen i sydsvenska totmosselagerföljder. *Forh. 16. skand. naturforskermöte 1916*, Kristiania, 433-465.

WALTHER, H. 1990. The Weisselster Basin (G.D.R.)- an example of the development and history of Paleogene forest vegetation in central Europe. *In* KNOBLOCH, E. and KVACEK, Z. (eds.) *Proceedings of the Symposium Paleofloristic and paleoclimatic changes in the Cretaceous and Tertiary*. Geological Survey Publisher, Prague, 149-158.

WALTON, J. 1940. *An introduction to the study of fossil plants*. Adam and Charles Black, London, 188 pp.

WANG, C.W. 1961. The forests of China. *Maria Moors Cabot Foundation Publication Series No. 5*. Harvard University, Cambridge, Massachusetts, 313pp.

WANG, C.W. 1975. *In*, Nanking Institute of Geology and Palaeobotany, Academia Sinica (1978), Early Tertiary spores and pollen grains from the coastal region of Bohai, 177pp.

WATTS, W.A., 1962. Early Tertiary Deposits in Ireland. *Nature*, **193**, 600.

WATTS, W.A., 1963. Fossil seeds from the Lough Neagh Clay. *Irish Naturalists'. Journal*, **14**, 117-118

WEYLAND, H. and KRIEGER, W. 1953. Die Sporen and pollen der Aacher Kreide und ihre bedeutung für die Charakterisierung des mitteleren senons. *Palaeontographica, Abt. B.*, **95**, 6-29.

WILKINSON, G.C. 1979. A palynological survey of some Tertiary sediments in the western part of the British Isles. C.N.A.A. *Unpublished Ph.D. thesis, N.E.London Polytechnic*, 210pp.

WILKINSON, G.C., BAZLEY, R.A.B. and BOULTER, M.C. 1980. The geology and palynology of the Oligocene Lough Neagh Clays, Northern Ireland. *J. Geol. Soc. London,* **137**, 65-75.

WILKINSON, G.C. and BOULTER, M.C. 1980. Oligocene pollen and spores from the Western part of the British Isles. *Palaeontographica, Abt. B.*, **175**, 27-83.

WILLIS, J.C. 1985. A dictionary of the flowering plants and ferns. 8th edition, revised Airy-Shaw, H.K. Cambridge University Press, Cambridge, 1244pp.

WILSON, L.R. and WEBSTER, R.M. 1946. Plant microfossils from a Fort Union coal of Montana. *Am. J. Bot.*, **33**, 271-278.

WING, S.L. 1981. A study of paleocology and paleobotany in the Willwood Formation (early Eocene, Wyoming). *Unpublished Ph.D.thesis, Yale University.*

WODEHOUSE, R.P. 1932. Tertiary Pollen I. Pollen of the living representatives of the Green River Flora. *Torrey Bot. Club Bull.*, **39**, 313-340.

WODEHOUSE, R.P. 1933. Tertiary pollen-II. The oil shales of the Eocene Green River formation. *Torrey Bot. Club Bull.*, **7**, 749-524

WOLFE, J.A. 1972. An interpretation of Alaskan Tertiary floras. In Graham, Alan, ed. *Floristics and paleofloristics of Asia and Eastern North America, Publ. Co., Amsterdam,* 201-233.

WOLFE, J.A. 1977. Paleogene floras from the Gulf of Alaska Region. *U.S.G.S. Prof. Paper*, 997, 108pp.

WOLFE, J.A. 1978. A paleobotanical interpretation of the Tertiary climates in the Northern Hemisphere. *Amer. Scientist*, **66**, 694-703.

WOLFE, J.A. 1979. Temperature parameters of humid to mesic forests of Eastern Asia. *U.S.G.S. Prof.* Paper, 1106, 1-37.

WOLFE, J.A. 1980. Tertiary climates and floristic relationships at high latitudes in the Northern Hemisphere. *Palaeogeog. Palaeoclim. Palaeoecol.*, **30**, 313-323.

WOLFE, J.A. 1985. Distribution of major vegetational types during the Tertiary. *In*: SUNDQUIST, E.D. and BROECKER, W.S. (eds.) *The carbon cycle and atmospheric CO_2. Natural variations Archean to present.* Amer. Geophys. Union. Geophys. Monog., 32, 357-376.

WOLFE, J.A. 1992. Climatic, floristic and vegetational changes near the Eocene/Oligocene boundary in North America. In Berggren, W.A. and Prothero, D.R. eds., *Eocene - Oligocene climatic and biotic evolution.* Princeton University Press, 421-436.

WOLFE, J.A. 1993. A method of obtaining climatic parameters from leaf assemblages. *U.S. Geol. Surv. Bull.* 2040, 1-71.

WOLFE, J.A. and HOPKINS, D.M. 1967. Climatic changes recorded by Tertiary land floras in northwestern North America. *In* HATAI, KOTORA, (eds.) *Tertiary Correlation and climatic change in the Pacific: Pacific Sci. Cong. 11th Tokyo (1966) Symposium*, **25**, 67-76.

WOLFF, H. 1934. Mikrofossilien des Pliozanen Humodils der Grube Freigericht bei Dettingen a.M. und Vergleich mit aelteren Schichten des Tertiaers so wie posttertiaeren Ablagerungen. *Arb. Inst. Paläobot.*,**5**, 55-86.

WOLFF, J.A. and POORE, R.Z. 1982. Tertiary marine and non-marine climatic trends. In *Climate in Earth history. National Research Council Studies in Geophysics.* National Academy Press, Washington, D.C., 154-158.

WOODWARD, F.I. and WILLIAMS, B.G. 1987. Climate and plant distribution at global and local scales. *Vegetatio*, **69**, 189-197.

WRIGHT, W.B., 1924. Age and origin of the Lough Neagh Clays. *Quaterly J. Geol. Soc. London*, **80**, 468-488.

ZAKLINSKAJA, E.D. 1957. Stratigraphische Bedeuting der Nacktsamer-Pollen in den kainozoischen Ablagerungen des Pavlodar-Irtisch und nördlichen Aral-Gebietes. *Trudy A.N. S.S.S.R, Geol. Inst.*, **6**, 184pp.

ZAUER, V.V. 1960. in POKROVSKAJA, I.M. and STELMAK, N.K., 1960. Atlasoberkretazischer, paläozäner und eozäner und eozäner Sporen und Pollenkomplexe verschiedener Gebiete der U.d.S.S.R. Trudy VSEGEI, N.S., **30**, 574pp.

ZIEMBINSKA-TWORZYDLO, M. 1974. Palynological characteristics of the Neogene of western Poland. *Acta palaeont. pol.*, **19**, 309-432.

17. PLATES

Plates 1-44 illustrate the characteristics of the taxa described in chapter 7. All photographs were taken using Kodak Gold 200 ASA film using a Wild Photoautomat MPS 45 camera.and a Leitz Labrolux K microscope. Unless otherwise stated all photographs were taken utilising phase contrast microscopy under x1000 magnification.

Plate 1

Figure 1 *Arecipites* Group A Wilkinson and Boulter, 1980
27/415, 37.30m, slide 1, G39/1.

Figure 2 *Arecipites* Group A Wilkinson and Boulter, 1980
13/603, 180.00m, slide 1, Q43.

Figure 3 *Arecipites* Group A Wilkinson and Boulter, 1980
13/603, 180.00m, slide 1, Q43.

Figure 4 *Arecipites* Group C Wilkinson and Boulter, 1980
13/611, 89.00m, slide 1, M39/2.

Figure 5 *Arecipites* Group C Wilkinson and Boulter, 1980
13/611, 89.00m, slide 1, M39/2.

Figure 6 *Arecipites* Group C Wilkinson and Boulter, 1980
13/611, 89.00m, slide 1, N34/3.

Plate 1

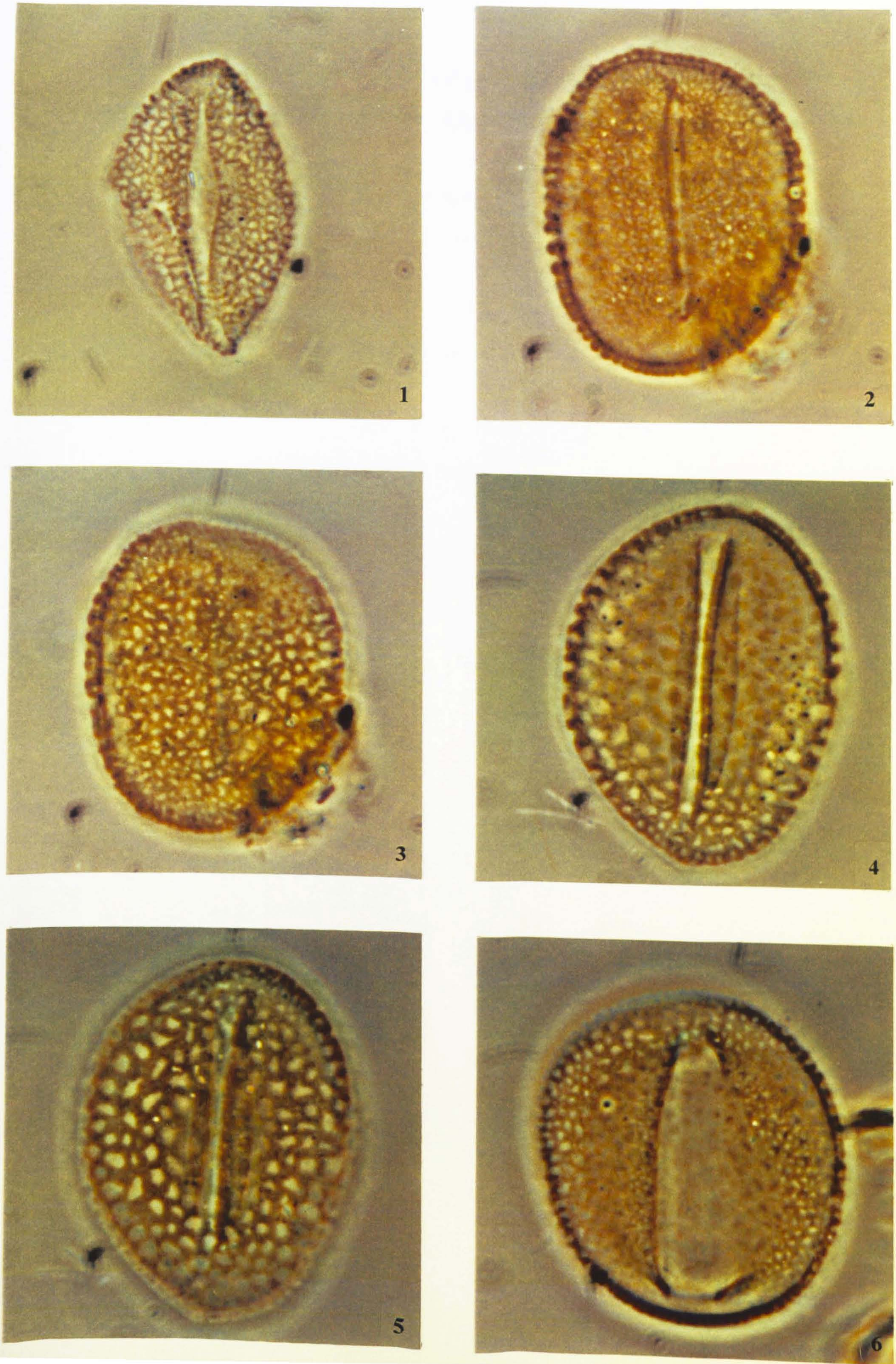


Plate 2

Figure 1 *Arecipites symmetricus*

13/603, 48.00m, slide 4, D39/4.

Figure 2 *Arecipites symmetricus*

13/603, 48.00m, slide 4, D39/4.

Figure 3 *Arecipites* cf. *papillosus*

13/611, 89.00m, slide 1, T51.

Figure 4 *Arecipites* cf. *papillosus*

13/611, 89.00m, slide 1, T51.

Plate 2

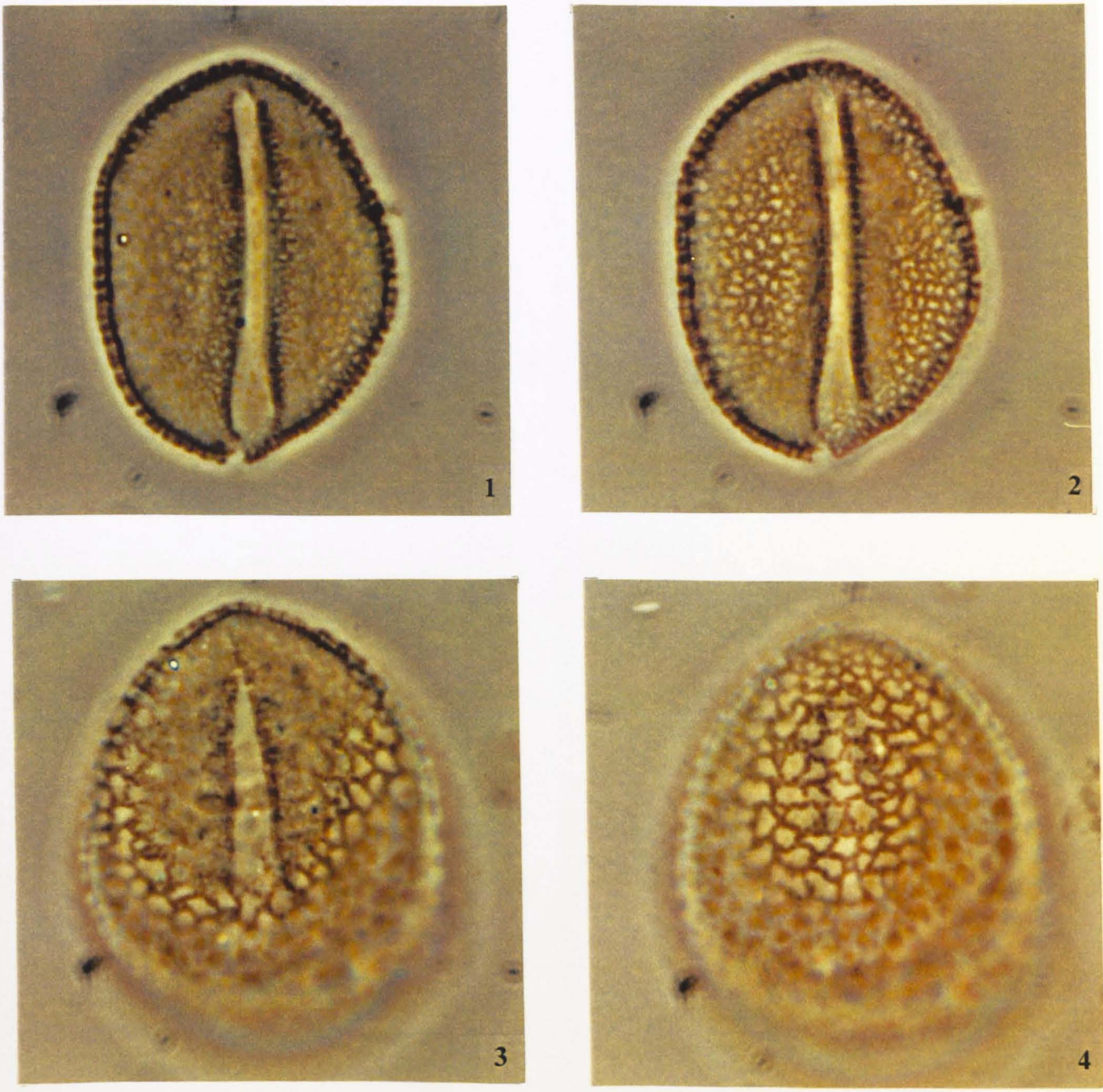


Plate 3

Figure 1	*Cycadopites* sp. A 13/611, 261.00m, slide 1, M55/3.
Figure 2	*Cycadopites* sp. A 13/611, 69.95m, slide 1, M42/1.
Figure 3	*?Magnolipollis neogenicus* subsp. *minor* 13/611, 60.00m, slide 2, M49.
Figure 4	*Monocolpopollenites tranquilloides* 13/611, 261.00m, slide 2, O42/1, x400.

Plate 3

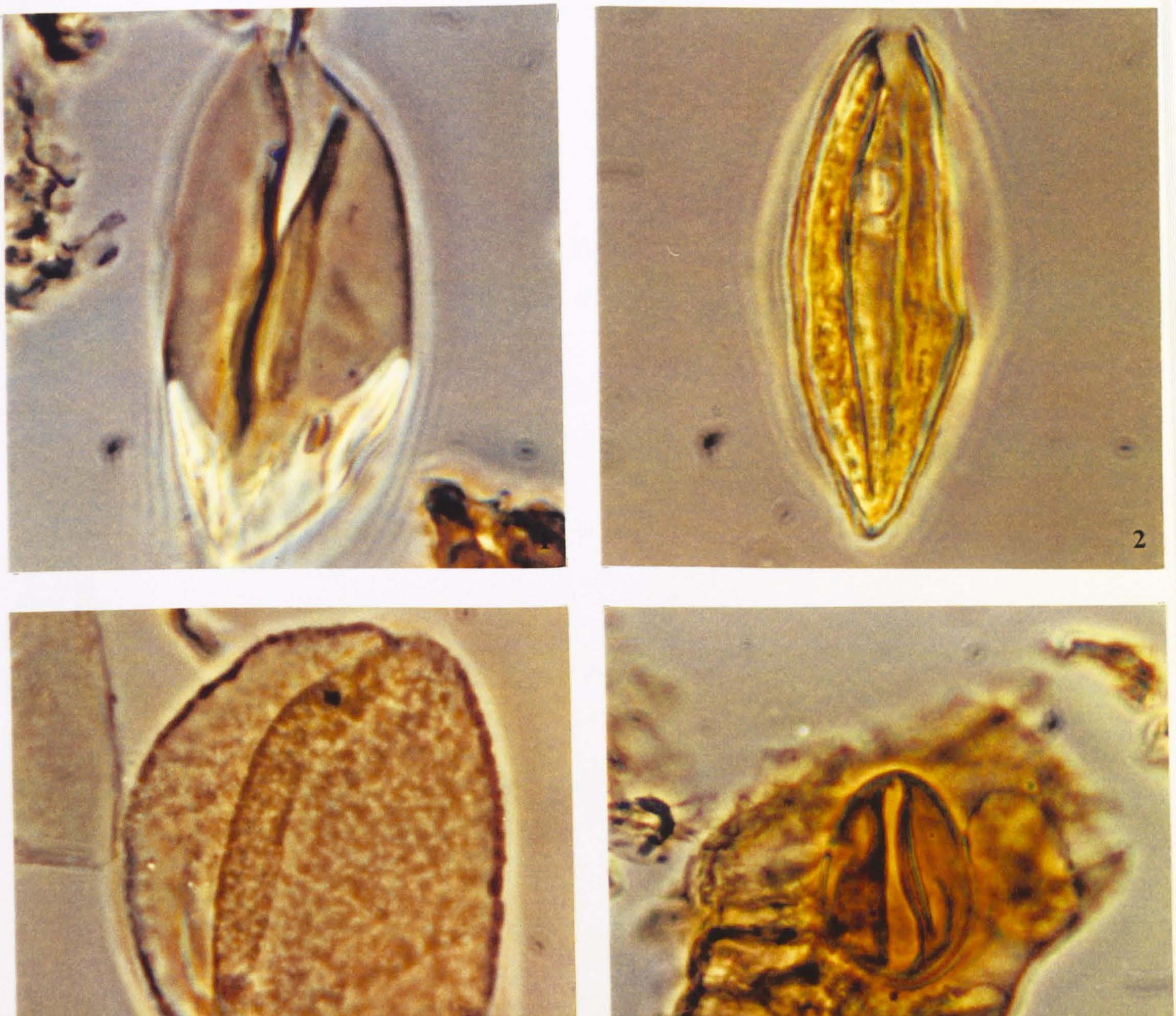


Plate 4

Figure 1	*Monocolpopollenites tranquillus* 13/611, 89.00m, slide 2, M45/3.
Figure 2	*Monocolpopollenites tranquillus* 13/603, 48.00m, slide 2, O45.
Figure 3	*Dicolpopollis kockelii* 13/611, 89.00m, slide 1, N48/4.
Figure 4	*Dicolpopollis kockelii* 13/603, 48.00m, slide 3, N44.
Figure 5	*Dicolpopollis kockelii* 13/603, 48.00m, slide 1, N40/3.
Figure 6	*?Dicolpopollis* Group D Wilkinson and Boulter, 1980 36/4680, 200.33m, slide 1, P49.

Plate 4

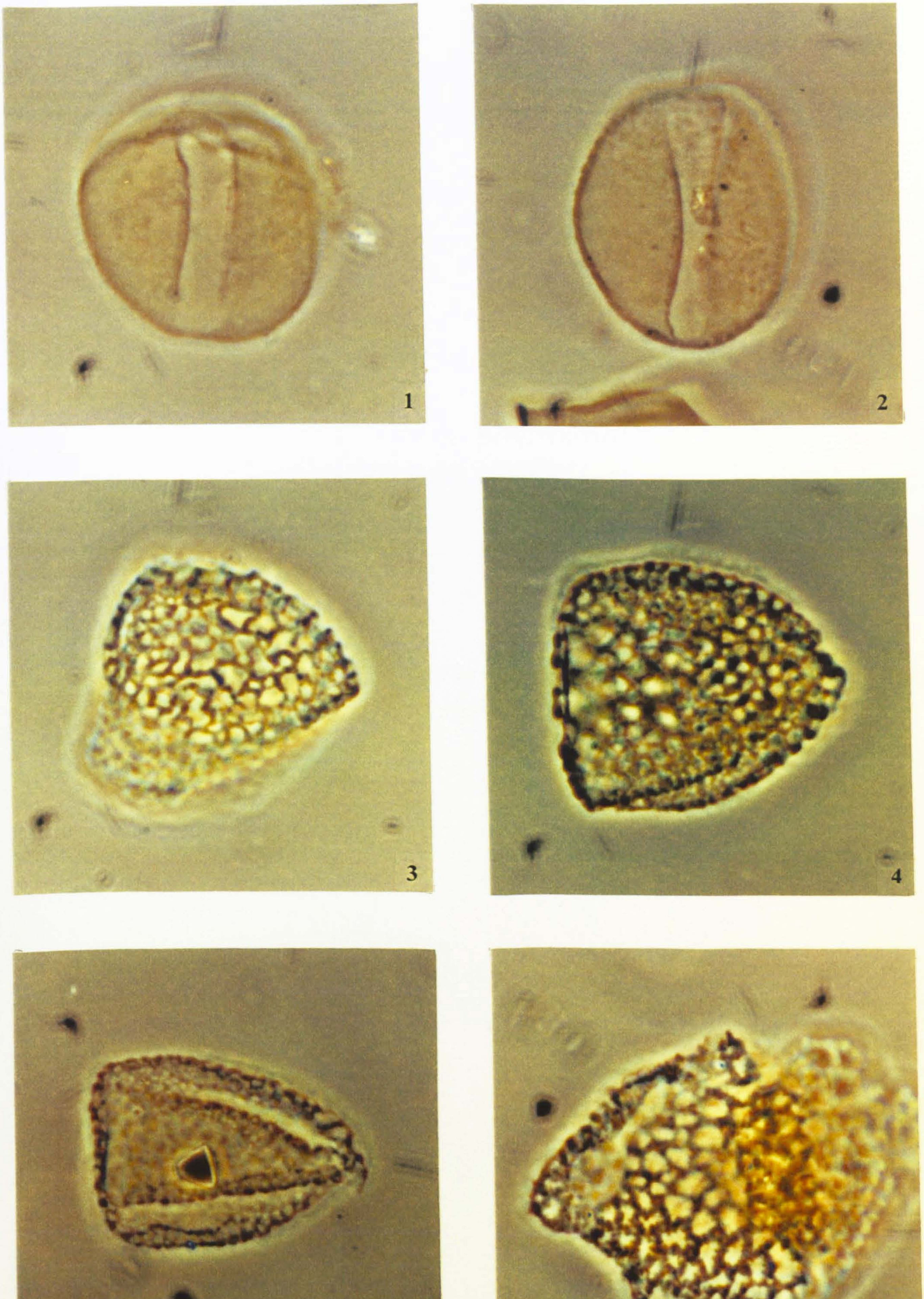


Plate 5

Figure 1	*Cupuliferoidaepollenites liblarensis*
	13/611, 261.00m, slide 1, M46/4.
Figure 2	*Platanuspollenites ipelensis*
	13/611, 209.00m, slide 4, M55/1.
Figure 3	*Platanuspollenites ipelensis*
	13/611, 230.00m, slide 2, M40.
Figure 4	*Platanuspollenites ipelensis*
	13/611, 230.00m, slide 2, M40.
Figure 5	*Platanuspollenites ipelensis*
	13/603, 80.10m, slide 2, M35/3, oblate compression.
Figure 6	*Platanuspollenites ipelensis*
	13/611, 60.00m, slide 2, M49/4, oblate compression.

Plate 5

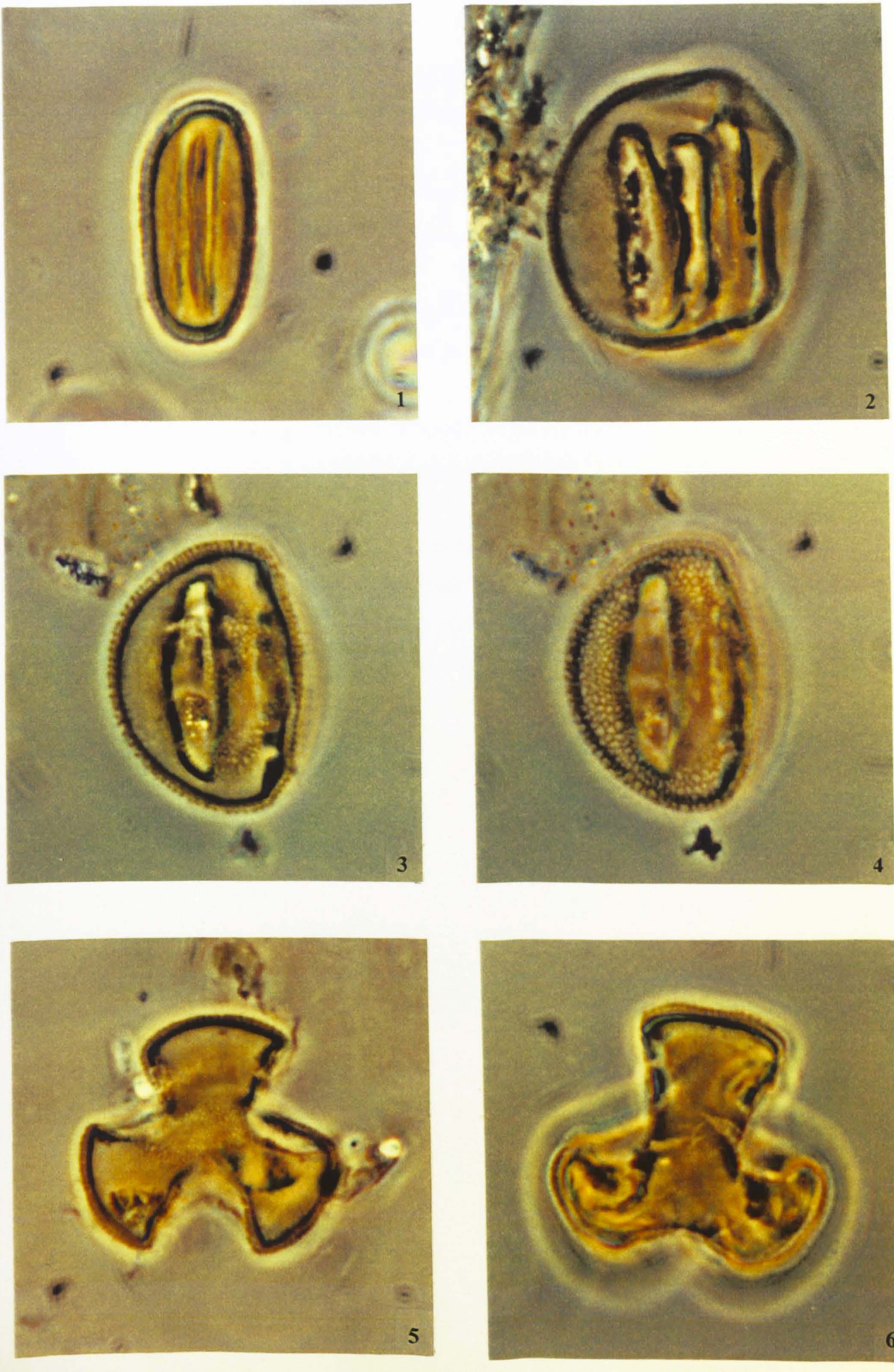


Plate 6

Figure 1 *Quercoidites microhenrici*

13/611, 208.00m, slide 1, H43/2, oblate compression.

Figure 2 *Quercoidites microhenrici*

13/611, 230.00m, slide 1, L32/4.

Figure 3 *Euretitricolpites* Group A Wilkinson and Boulter, 1980

13/611, 121.00m, slide 2, L37/4.

Figure 4 *Euretitricolpites* Group A Wilkinson and Boulter, 1980

13/611, 121.00m, slide 2, L37/4.

Figure 5 *Euretitricolpites* Group A Wilkinson and Boulter, 1980

13/603, 260.00m, slide 1, P50.

Figure 6 *Euretitricolpites* Group C Wilkinson and Boulter, 1980

13/603, 60.00m, slide 1, N49.

Plate 6

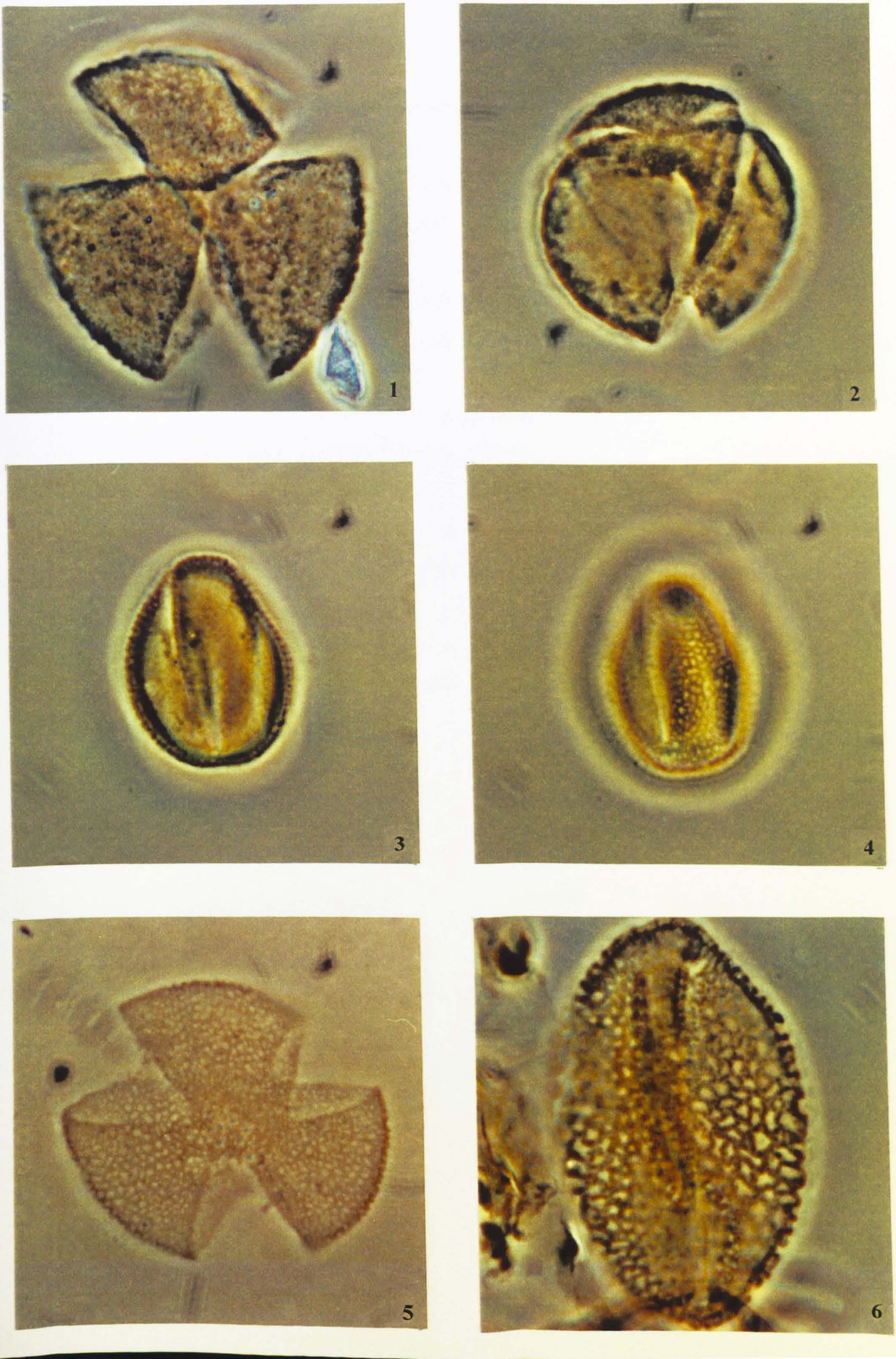


Plate 7

Figure 1	*Retitricolpites* sp. A Holotype 13/603, 280.00m, slide 1, K36/1.
Figure 2	*Retitricolpites* sp. A Holotype 13/603, 280.00m, slide 1, K36/1.
Figure 3	*Retitricolpites* sp. A 13/611, 261.00m, slide 2, L45/1.
Figure 4	*Retitricolpites* sp. A 13/611, 261.00m, slide 1, N43/2.
Figure 5	*Retitricolpites* sp. A 13/611, 261.00m, slide 1, N43/2.
Figure 6	*Retitricolpites* sp. A 13/611, 121.00m, slide 4, C45/3.

Plate 7

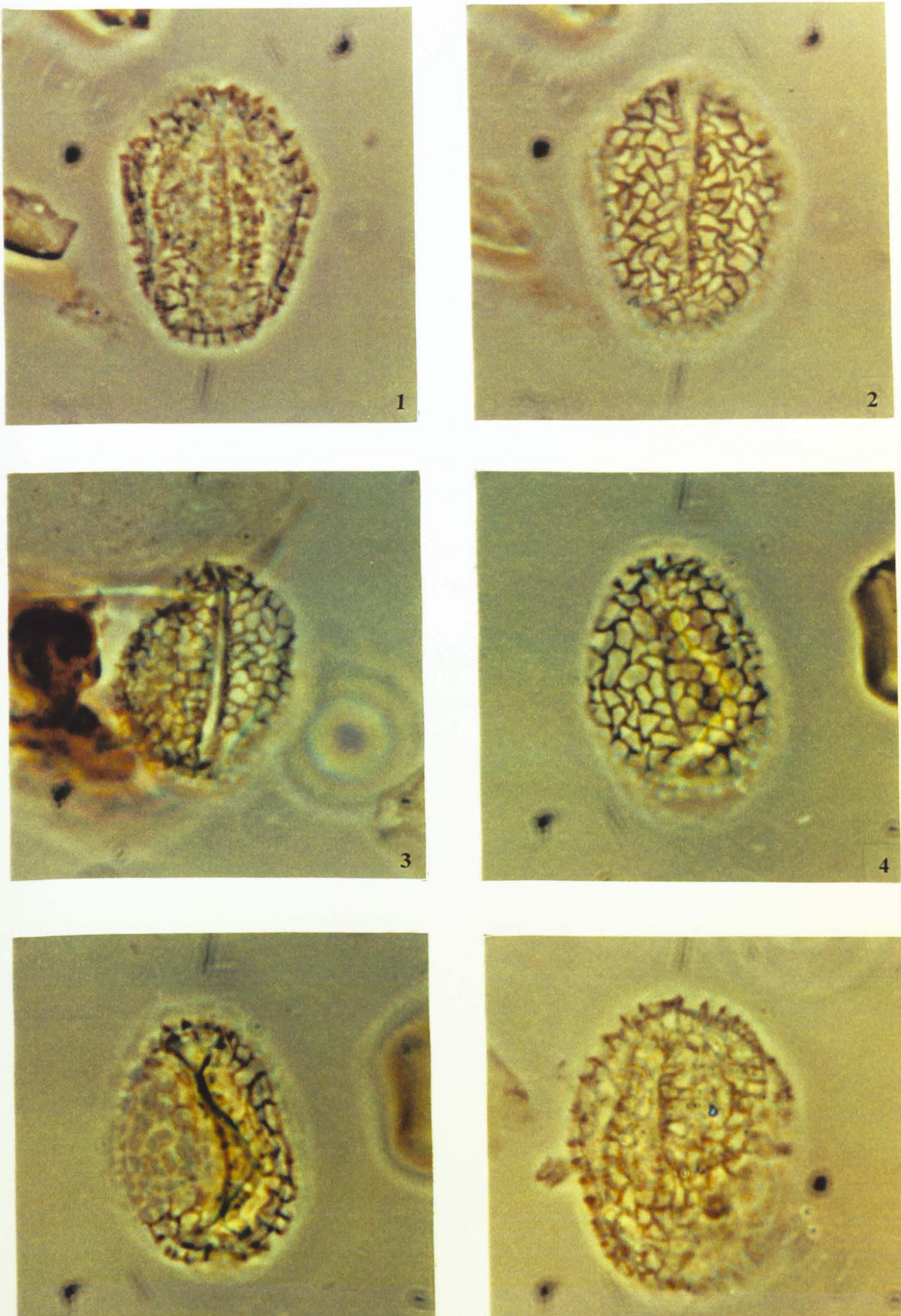


Plate 8

Figure 1	*Supraretitricolpites* Group B Wilkinson and Boulter, 1980 27/415, 37.30m, slide 1, D50/3.
Figure 2	*Supraretitricolpites* Group B Wilkinson and Boulter, 1980 13/603, 222.74m, slide 1, P39.
Figure 3	*Supraretitricolpites* Group B Wilkinson and Boulter, 1980 13/611, 47.00m, slide 3, M47.
Figure 4	*Supraretitricolpites* Group B Wilkinson and Boulter, 1980 13/603, 260.00m, slide 1, M35/3.
Figure 5	*Supraretitricolpites* Group B Wilkinson and Boulter, 1980 13/611, 82.00m, slide 3, P36.
Figure 6	*Supraretitricolpites* Group D Wilkinson and Boulter, 1980 36/4680, 140.67m, slide 1, N39/4.

Plate 8

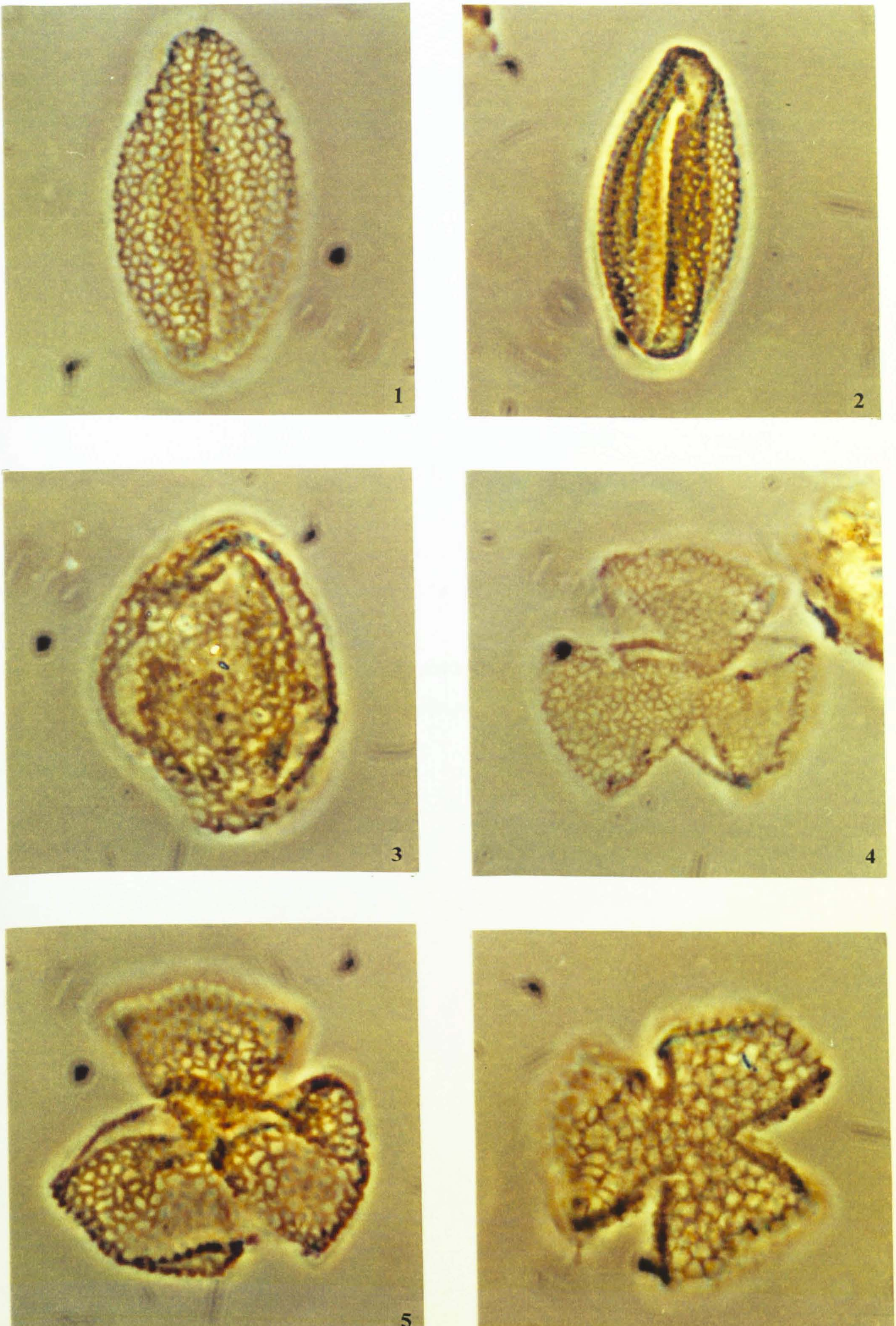


Plate 9

Figure 1 *Tricolpopollenites hastus*

Holotype, 13/603, 218.60m, slide 2, N41.

Figure 2 *Tricolpopollenites hastus*

36/4680, 200.33m, slide 1, O41/3.

Figure 3 *Tricolpopollenites hastus*

36/4680, 200.33m, slide 1, O41/3.

Figure 4 *Tricolpopollenites hastus*

36/4680, 200.33m, slide 1, P49/2.

Figure 5 *Tricolpopollenites verrucatus*

Holotype, 13/611, 47.00m, slide 1, H50/3.

Figure 6 *Tricolpopollenites verrucatus*

36/4680, 200.33m, slide 4, F45, oblate compression.

Plate 9

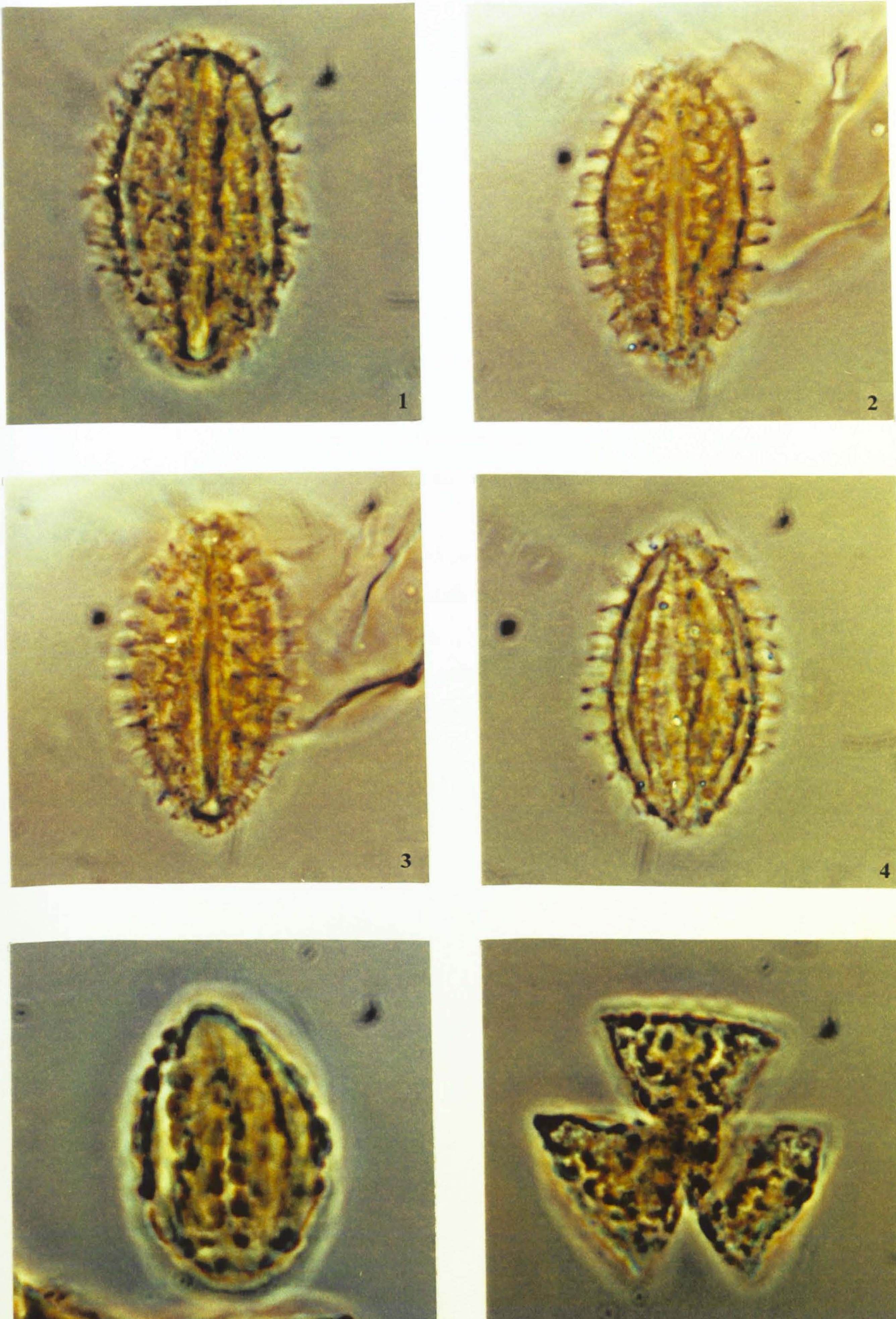


Plate 10

Figure 1	*Cryillaceaepollenites megaexactus* 36/4680, 265.13m, slide 2, M44/4.
Figure 2	*Cryillaceaepollenites megaexactus* 13/603, 60.00m, slide 1, N45/4.
Figure 3	*Cupuliferoipollenites cingulum* subsp. *pusillus* 27/415, 85.00m, slide 1, D43/1.
Figure 4	*Cupuliferoipollenites cingulum* subsp. *pusillus* 27/415, 85.00m, slide 1, G52.
Figure 5	*Cupuliferoipollenites cingulum* subsp. *pusillus* 13/603, 161.19m, slide 1, O39.
Figure 6	*Cupuliferoipollenites cingulum* subsp. *oviformis* 27/415, 41.00m, slide 1, D45/1.

Plate 10

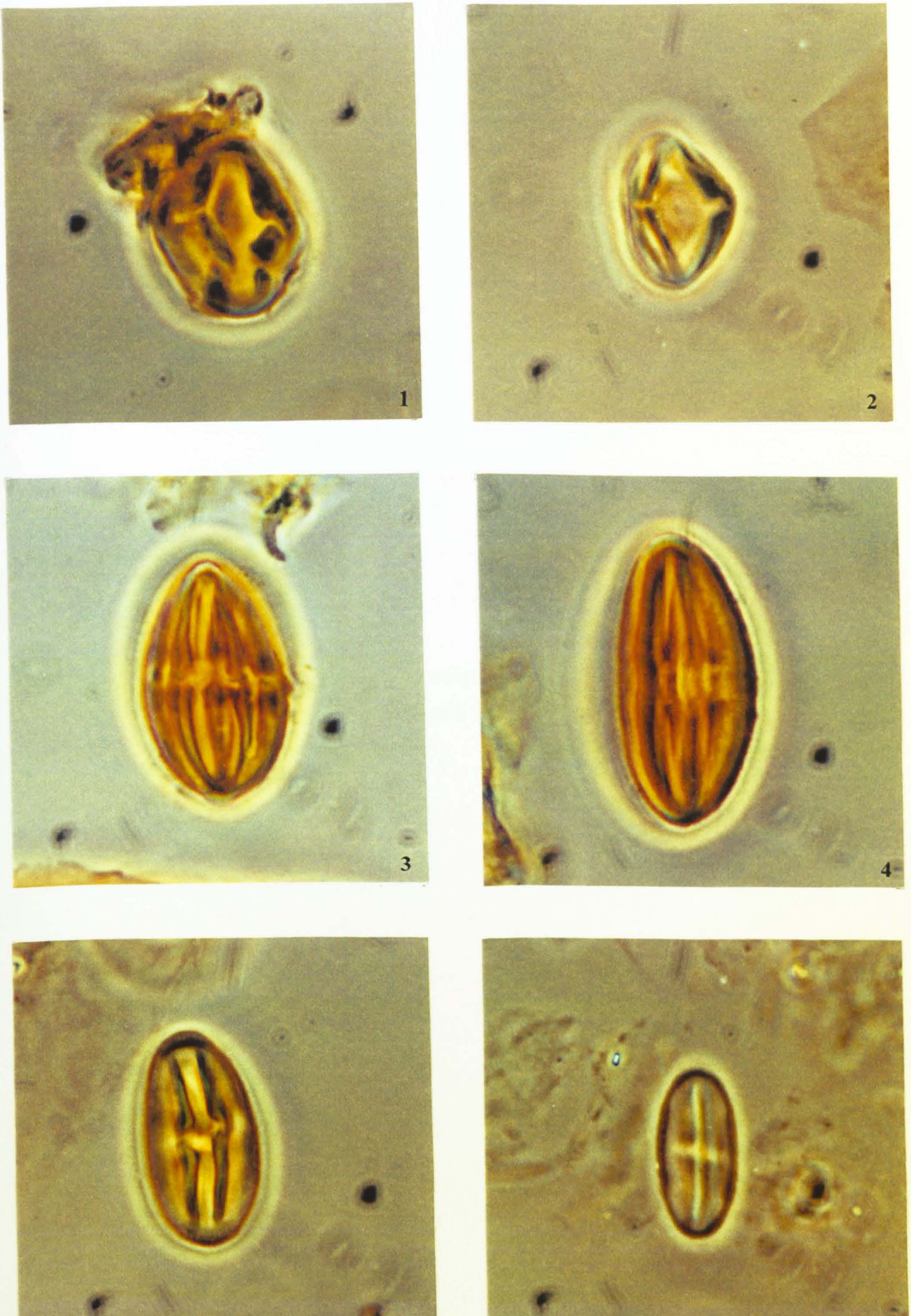


Plate 11

Figure 1	*?Holkopollenites* spp. 36/4680, 140.67m, slide 4, P50/4.
Figure 2	*?Holkopollenites* spp. 36/4680, 140.67m, slide 3, F38/1.
Figure 3	*Ilexpollenites iliacus* 13/611, 47.00m, slide 1, H38/1.
Figure 4	*Ilexpollenites iliacus* 13/611, 47.00m, slide 1, M40, oblate compression.
Figure 5	*Ilexpollenites margaritatus* 13/611, 230.00m, slide 1, L43/3.
Figure 6	*Ilexpollenites margaritatus* 13/611, 230.00m, slide 2, Q44/2.

Plate 11

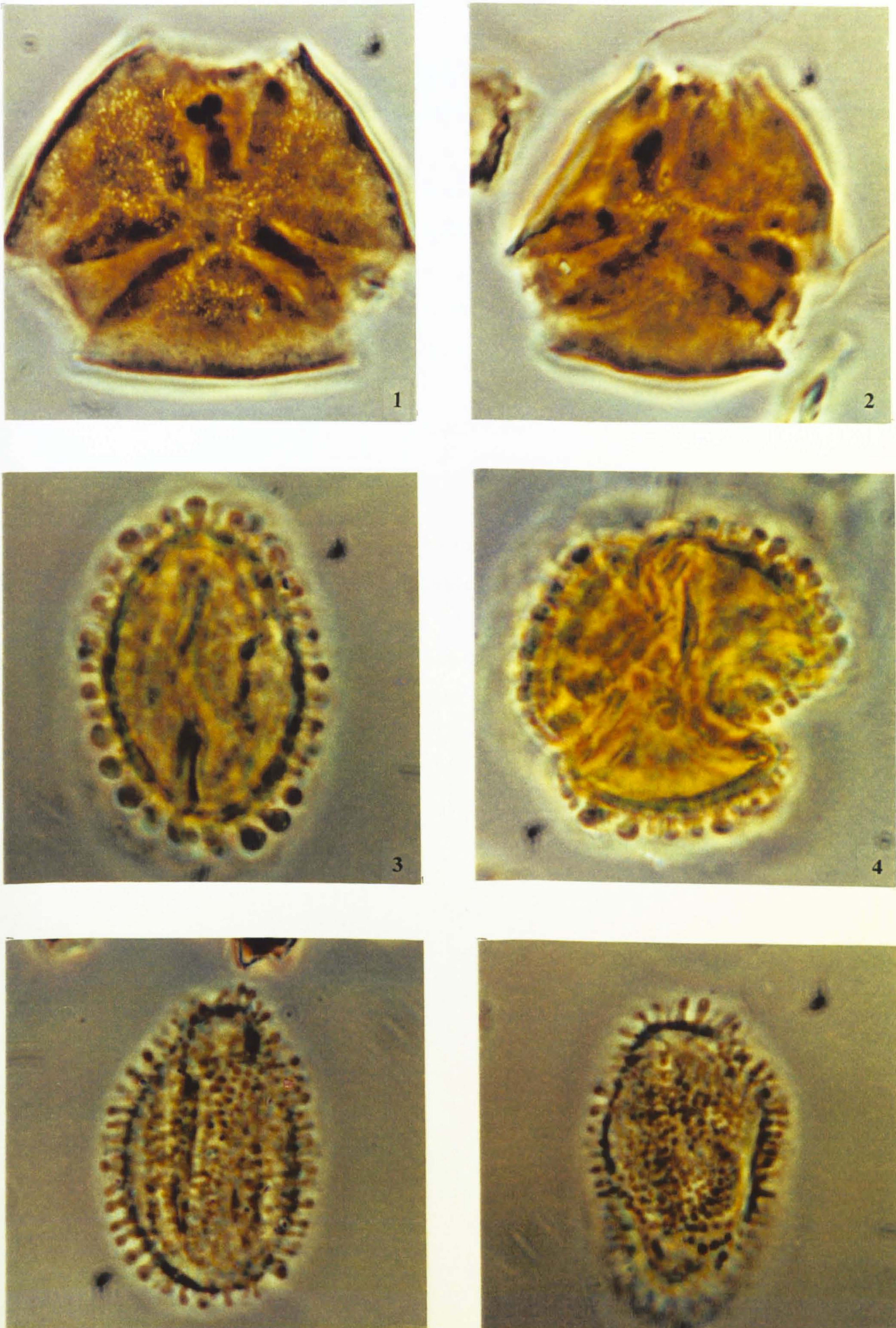


Plate 12

Figure 1 *Mediocolpopollis compactus*
13/603, 48.00m, slide 1, N37/1.

Figure 2 *Mediocolpopollis compactus*
13/603, 48.00m, slide 3, N44.

Figure 3 *Nyssapollenites kruschi* subsp. *analepticus*
27/415, 51.00m, slide 1, N35/3.

Figure 4 *Nyssapollenites kruschi* subsp. *analepticus*
27/415, 173.00m, slide 1, Q46/4.

Figure 5 *Nyssapollenites kruschi* subsp. *analepticus*
13/603, 80.10m, slide 2, M35, oblate compression.

Figure 6 *Nyssapollenites kruschi* subsp. *analepticus*
13/611, 209.00m, slide 3, N54/1, oblate compression.

Plate 12

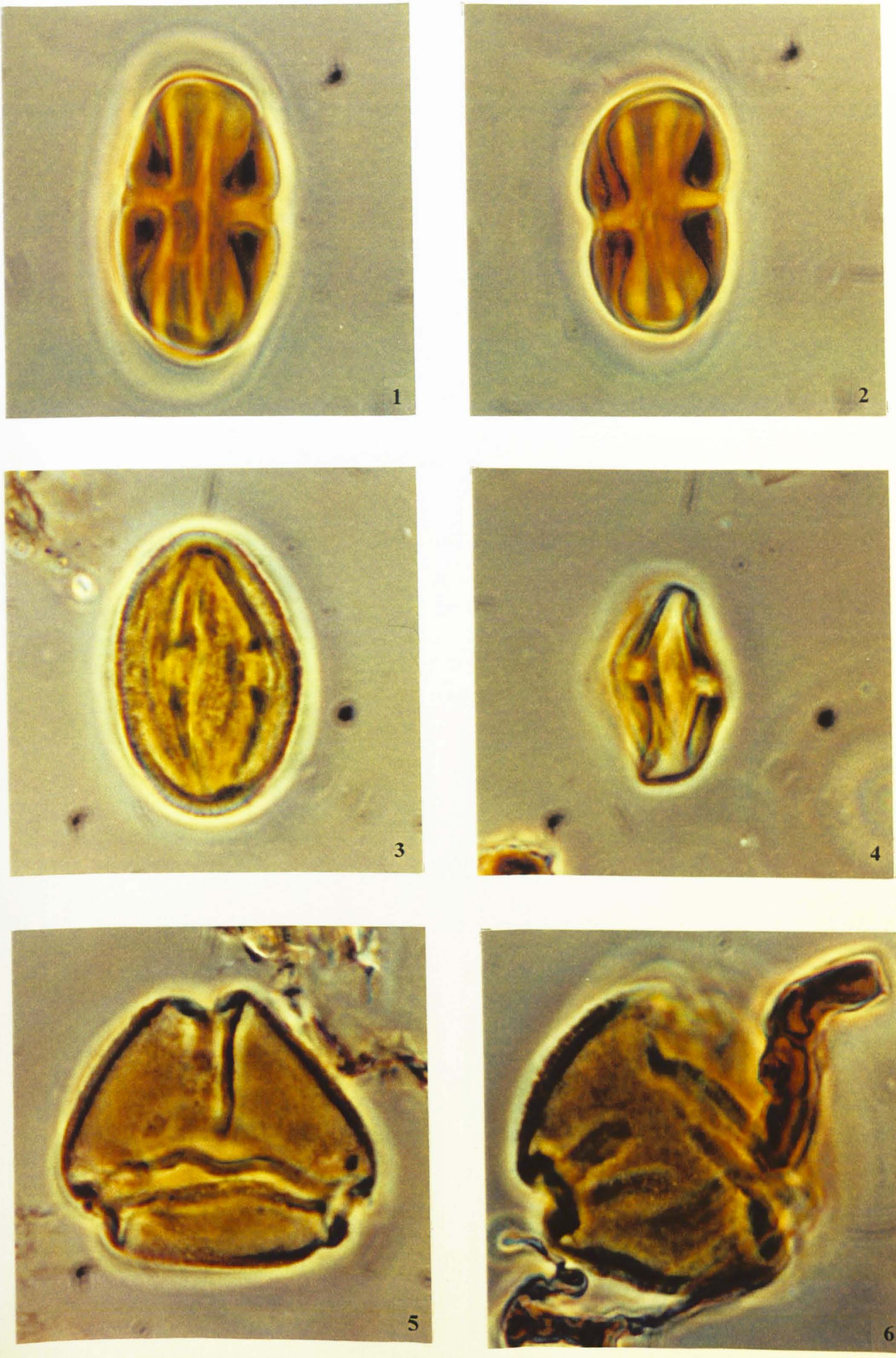


Plate 13

Figure 1	*Nyssapollenites kruschi* subsp. *accessorius* 13/611, 89.00m, slide 1, L36/3, x400.
Figure 2	*Nyssapollenites satzveyensis* 13/611, 121.00m, slide 2, L35, x 400.
Figure 3	*Nyssapollenites incognitus* Holotype, 36/4680, 265.13m, slide 1, Q45.
Figure 4	*Nyssapollenites incognitus* Holotype, 36/4680, 265.13m, slide 1, Q45.
Figure 5	*Porocolpopollenties calauensis* 13/611, 230.00m, slide 1, V52/2.
Figure 6	*Porocolpopollenties calauensis* 13/611, 230.00m, slide 1, V52/2.

Plate 13

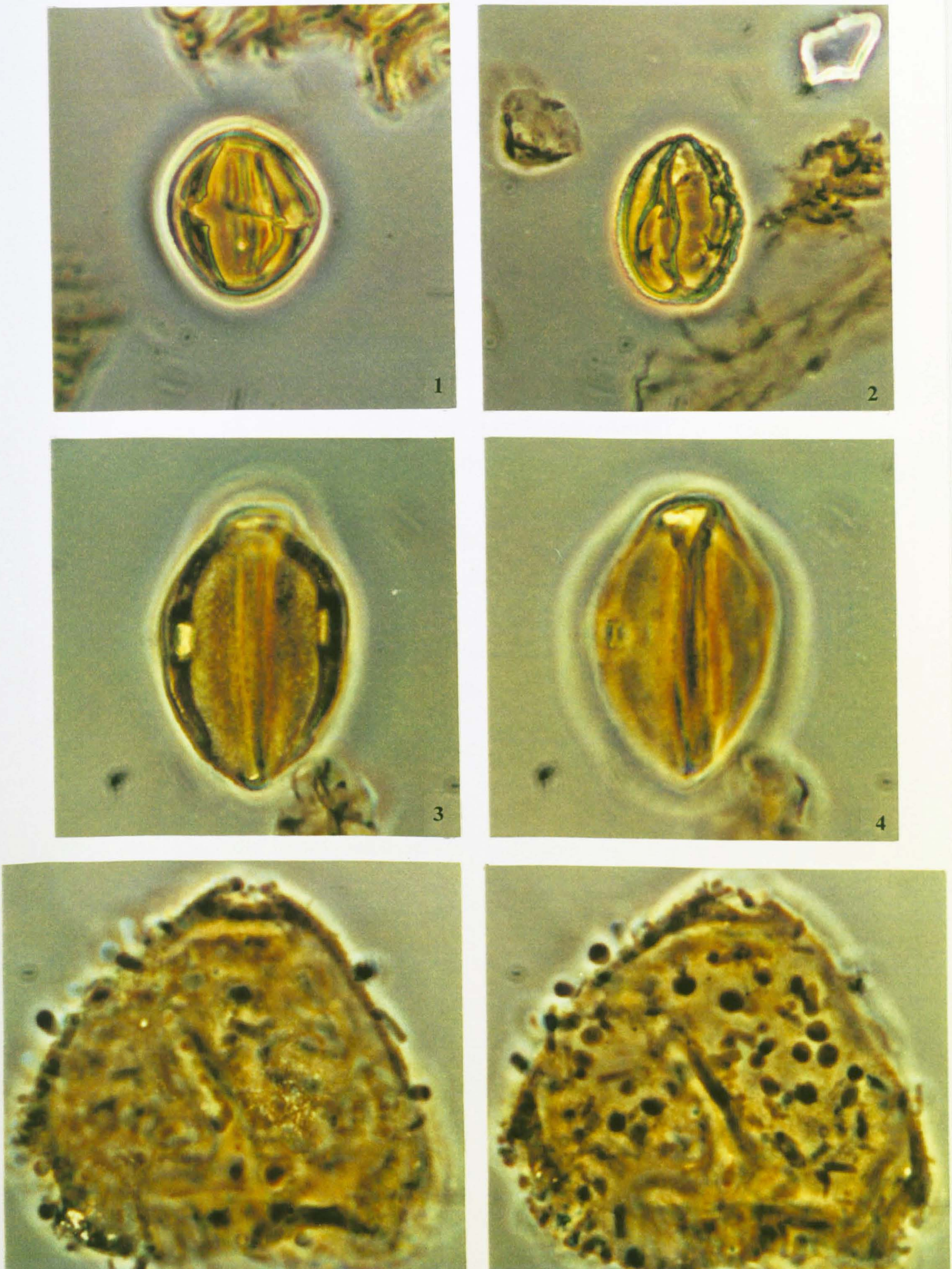


Plate 14

Figure 1 *Porocolpopollenites vestibulum*
13/611, 230.00m, slide 2, M43/1.

Figure 2 *Porocolpopollenites vestibulum*
36/4680, 137.71m, slide 1, O30.

Figure 3 *Porocolpopollenites vestibulum*
36/4680, 265.13m, slide 2, Y43/2.

Figure 4 *Porocolpopolleniies vestibulum*
36/4680, 265.13m, slide 2, L50/4.

Figure 5 *Euretitricolporites microreticulatus*
13/611, 82.00m, slide 1, M42.

Figure 6 *Euretitricolporites* cf. *microreticulatus*
36/4680, 103.00m, slide 3, Q35/3.

Plate 14

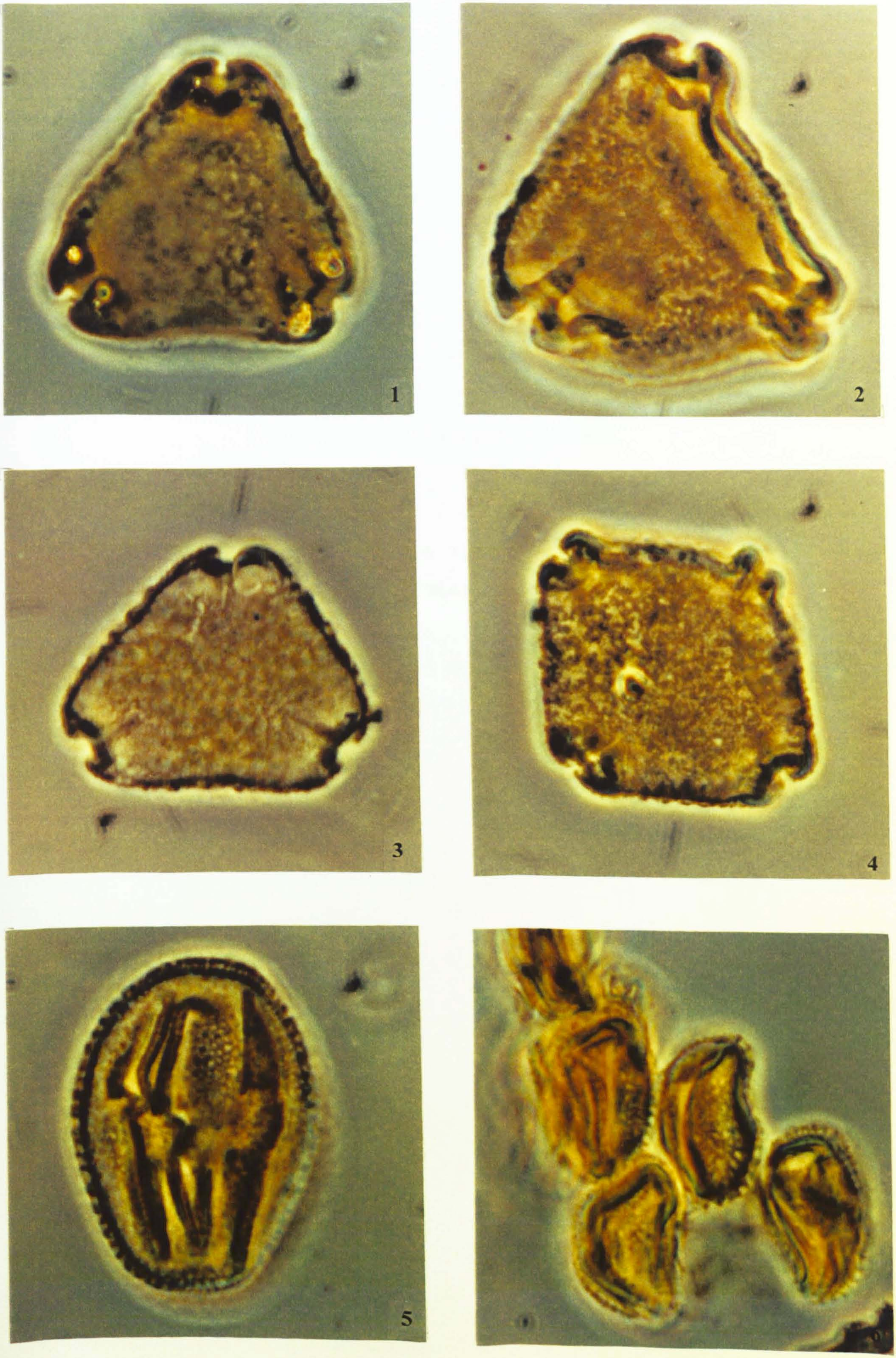


Plate 15

Figure 1	*Euretitricolporites* cf. *microreticulatus*
	13/611, 209.00m, slide 1, W50, oblate compression.
Figure 2	*Euretitricolporites* cf. *microreticulatus*
	13/611, 209.00m, slide 1, X51/1, oblate compression.
Figure 3	*Retioperculotricolporites* spp.
	Holotype, 36/4680, 140.67m, slide 4, S48/3, oblate compression.
Figure 4	*Retitricolporites* sp. A
	13/603, 60.00m, slide 4, K44/1, oblate compression.
Figure 5	*Retitricolporites* sp. A
	13/603, 60.00m, slide 4, T42/4, oblate compression.
Figure 6	*Retitricolporites* sp. A
	Holotype, 13/603, 60.00m, slide 4, L45, oblate compression.

Plate 15

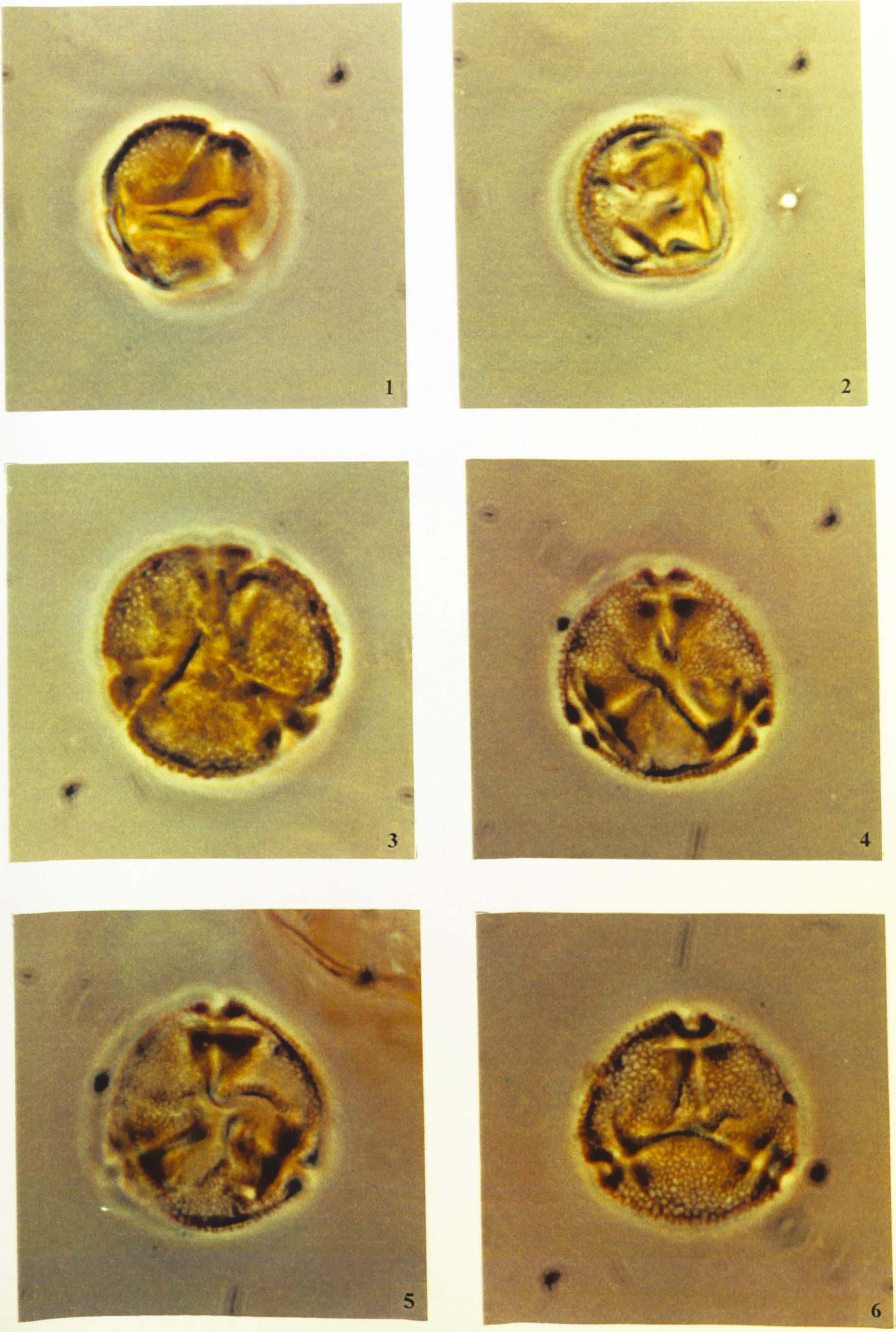


Plate 16

Figure 1	*Retitricolporites gentianoides* 36/4680, 200.33m, slide 4, P53/3.
Figure 2	*Retitricolporites gentianoides* Holotype, 36/4680, 265.13m, slide 3, W45/3.
Figure 3	*Retitricolporites gentianoides* 36/4680, 200.33m, slide 4, P53/3.
Figure 4	*Retitricolporites gentianoides* Holotype, 36/4680, 265.13m, slide 3, W45/3.

Plate 16

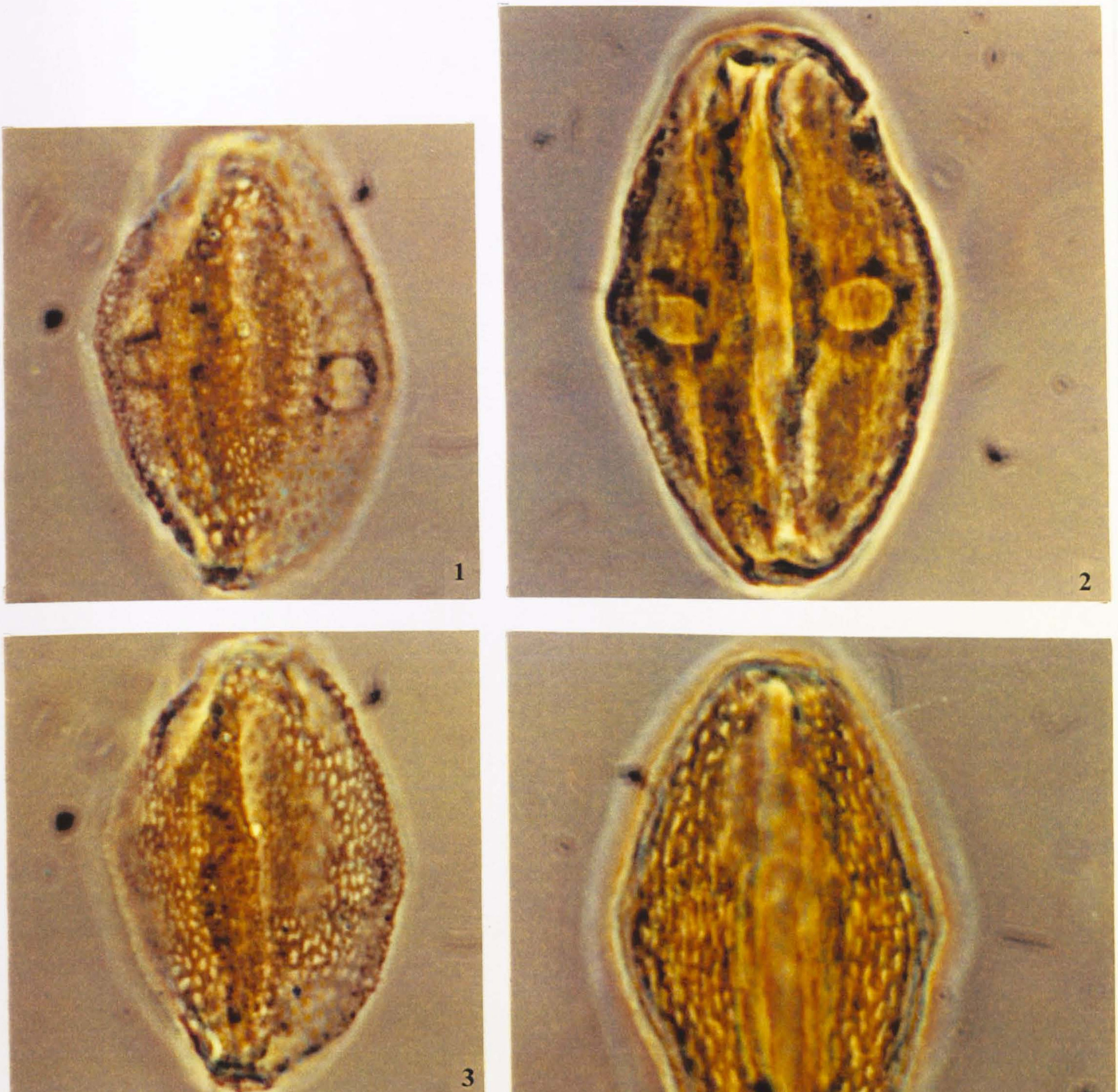


Plate 17

Figure 1 *Tiliaepollenties* sp. A

Holotype, 36/4680, 130.62m, slide 1, F49/1.

Figure 2 *Tiliaepollenties* sp. A

Holotype, 36/4680, 130.62m, slide 1, F49/1.

Figure 3 *Tiliaepollenties* sp. B

Holotype, 13/611, 60.00m, slide 2, L50/3.

Figure 4 *Tiliaepollenties ceciliensis*

27/415, 125.00m, slide 1, G46.

Figure 5 *Tiliaepollenties instructus*

36/4680, 265.13m, slide 3, W49/3.

Figure 6 *Tiliaepollenties instructus*

36/4680, 265.13m, slide 4, T34/3.

Plate 17

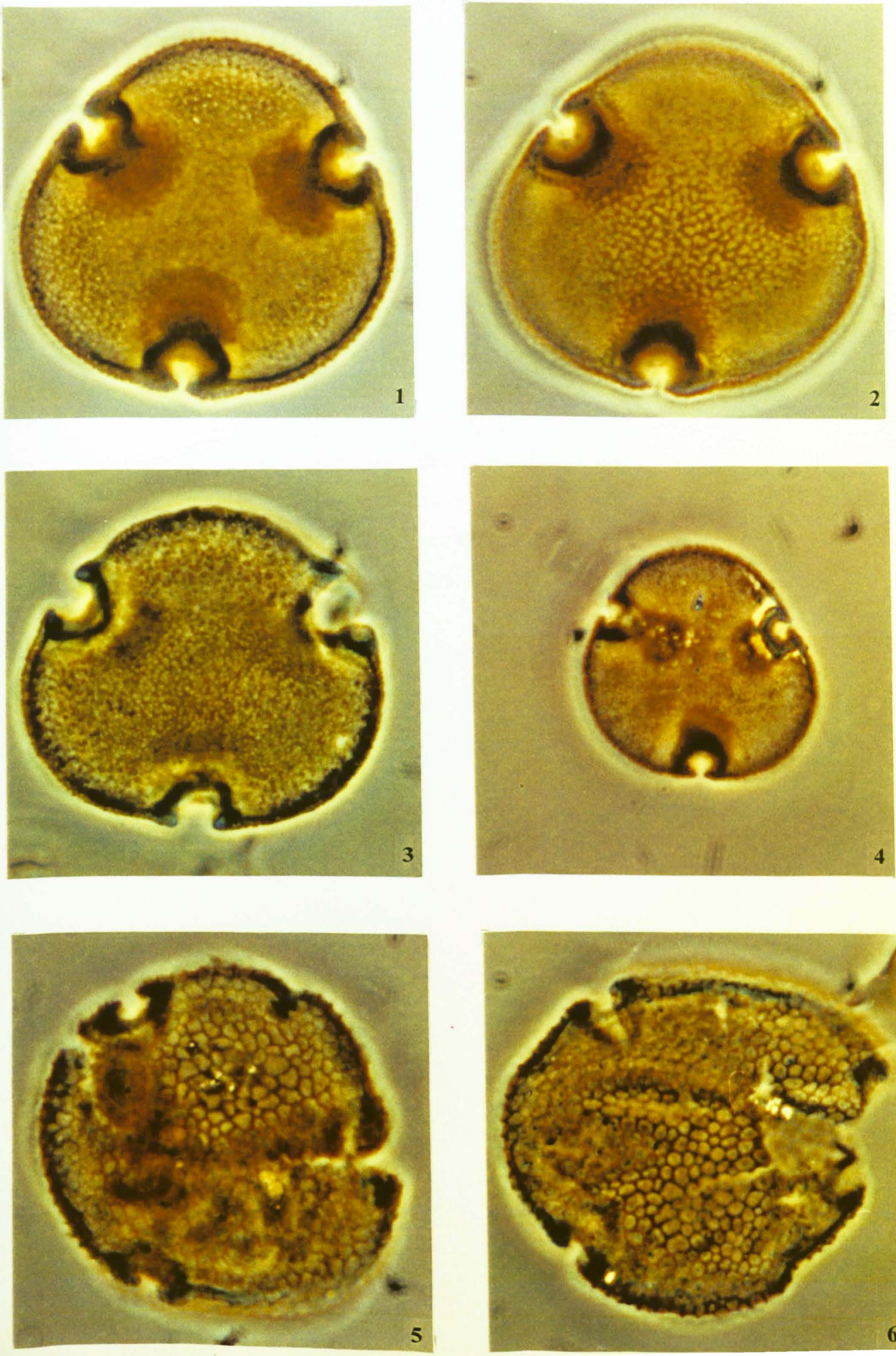


Plate 18

Figure 1	*Tricolporopollenites* sp. A Holotype, 13/603, 80.10m, slide 3, W36/4.
Figure 2	*Tricolporopollenites* sp. A Holotype, 13/603, 80.10m, slide 3, W36/4.
Figure 3	*Tricolporopollenites* sp. A Holotype, 13/603, 80.10m, slide 3, W36/4.
Figure 4	*Tricolporopollenites* sp. A 13/603, 100.00m, slide 4, B45/3.
Figure 5	*Tricolporopollenites* sp. A 13/603, 120.00m, slide 2, L41.
Figure 6	*Tricolporopollenites* sp. B Holotype, 13/611, 261.00m, slide 1, O53/1, oblate compression.

Plate 18

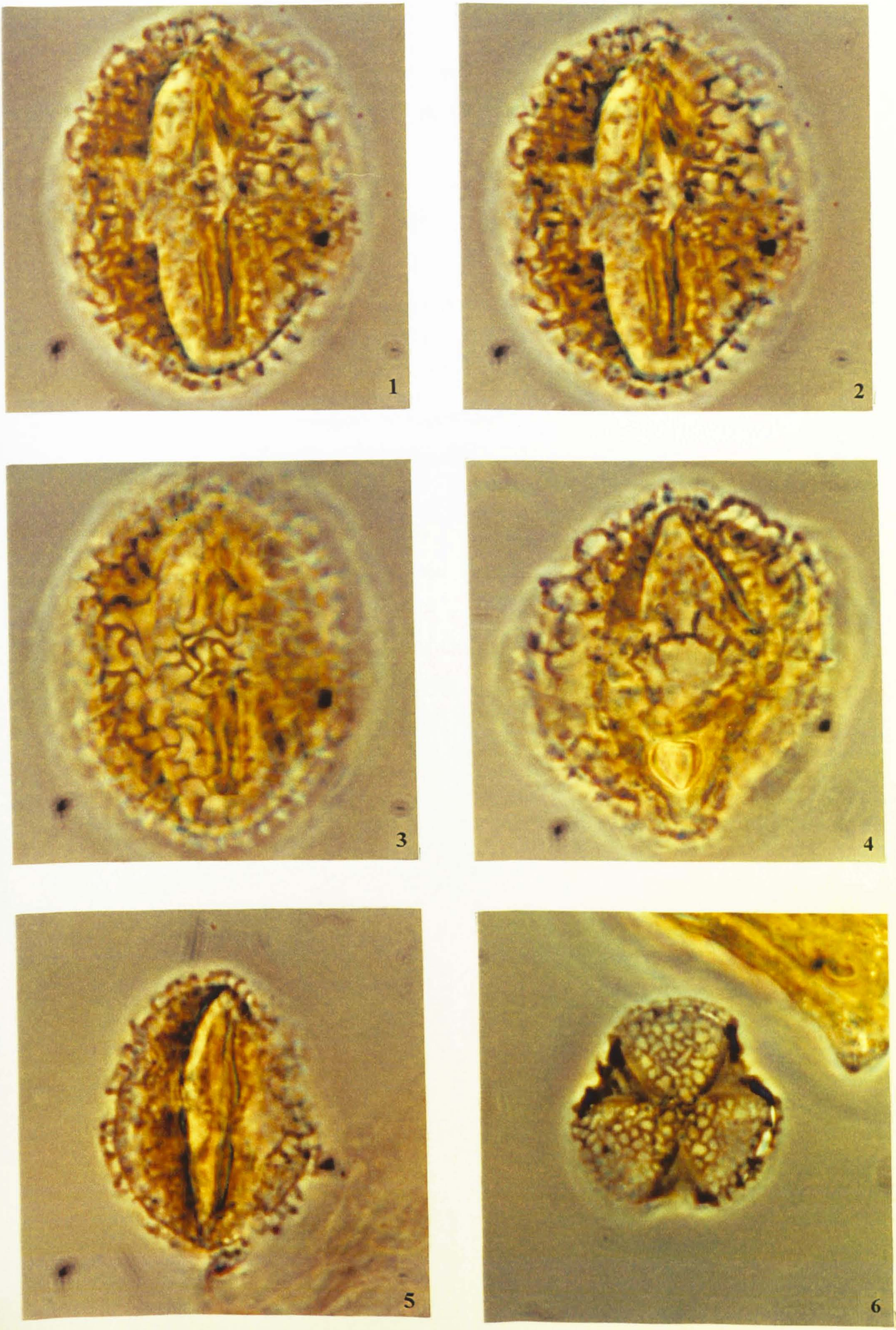


Plate 19

Figure 1	*Tricolporopollenites baculoferus* 36/4680, 131.71m, slide 1, P43/4.
Figure 2	*Tricolporopollenites baculoferus* 36/4680, 250.00m, slide 2, R49/3.
Figure 3	*Tricolporopollenites baculoferus* 13/611, 209.00m, slide 2, T47/2.
Figure 4	*Tricolporopollenites pseudocingulum* 13/611, 60.00m, slide 1, M46.
Figure 5	*Tricolporopollenites spinus* 13/603, 218.60m, slide 2, F45/1.
Figure 6	*Tricolporopollenites spinus* 13/603, 218.60m, slide 2, J36.

Plate 19

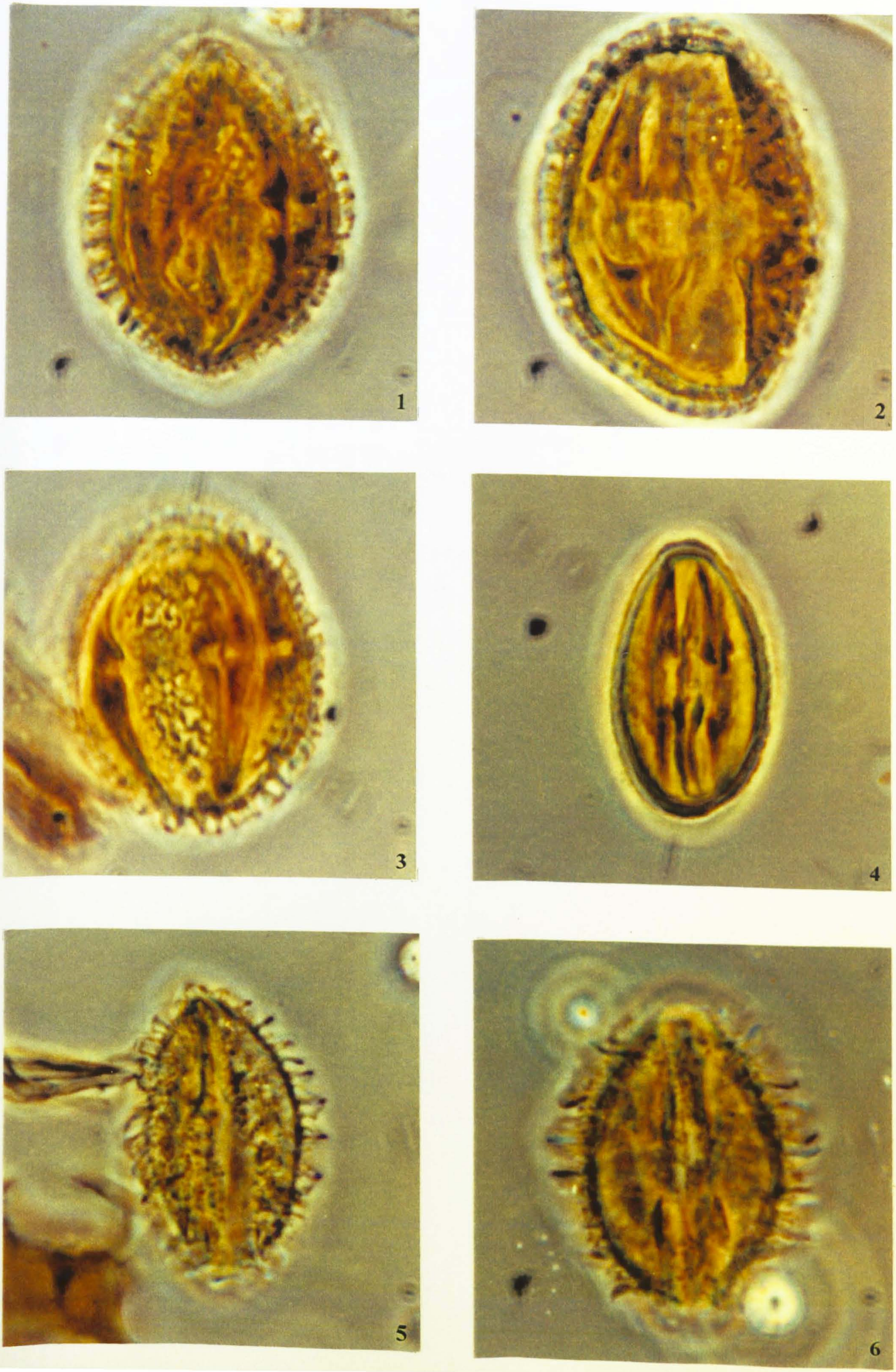


Plate 20

Figure 1	*Tricolporopollenites spinus* 13/603, 218.60m, slide 1, W50/4.
Figure 2	*Tricolporopollenites spinoreticulatus* Holotype, 27/415, 115.00m, slide 2, N44/4.
Figure 3	*Tricolporopollenites spinoreticulatus* Holotype, 27/415, 115.00m, slide 2, N44/4.
Figure 4	*Tricolporopollenites spinoreticulatus* 36/4680, 265.13m, slide 3, W43.
Figure 5	*Tricolporopollenites spinoreticulatus* 36/4680, 265.13m, slide 3, W43.
Figure 6	*Tricolporopollenites verrucatus* Holotype, 24/415, 85.00m, slide 1, F44.

Plate 20

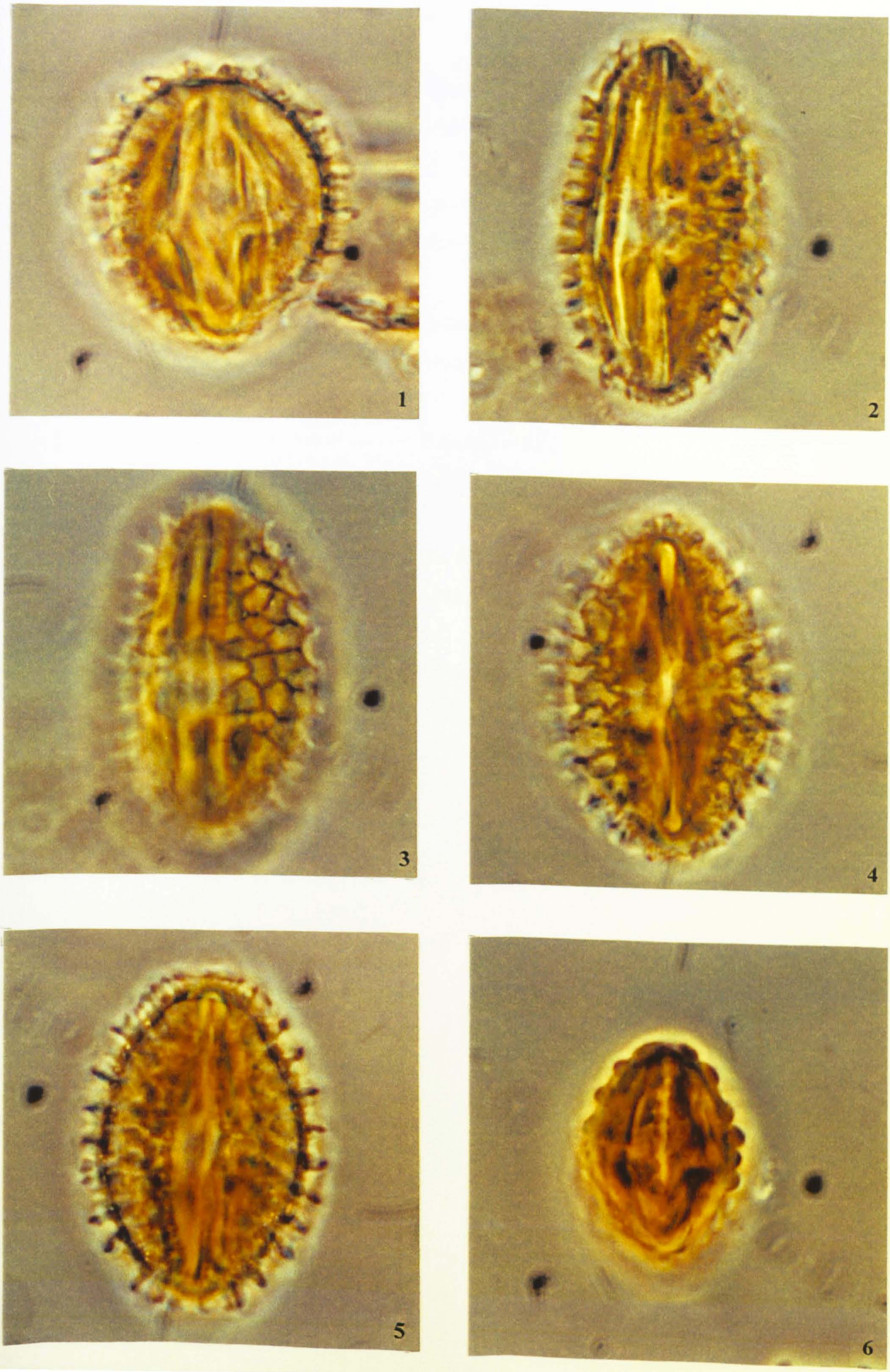


Plate 21

Figure 1	*Boehlensipollis* Group B Wilkinson and Boulter, 1980 27/415, 173.00m, slide 1, Q41/3.
Figure 2	*Boehlensipollis* Group B Wilkinson and Boulter, 1980 27/415, 173.00m, slide 1, Q41/3, ordinary transmitted light.
Figure 3	*Boehlensipollis* Group B Wilkinson and Boulter, 1980 27/415, 173.00m, slide 2, G39/4.
Figure 4	*Gothanipollis* Group B Wilkinson and Boulter, 1980 13/603, 161.19m, slide 4, D39.
Figure 5	*Gothanipollis* Group B Wilkinson and Boulter, 1980 13/603, 161.19m, slide 4, S44/1.
Figure 6	*Gothanipollis* Group B Wilkinson and Boulter, 1980 13/603, 130.00m, slide 2, N38/2.

Plate 21

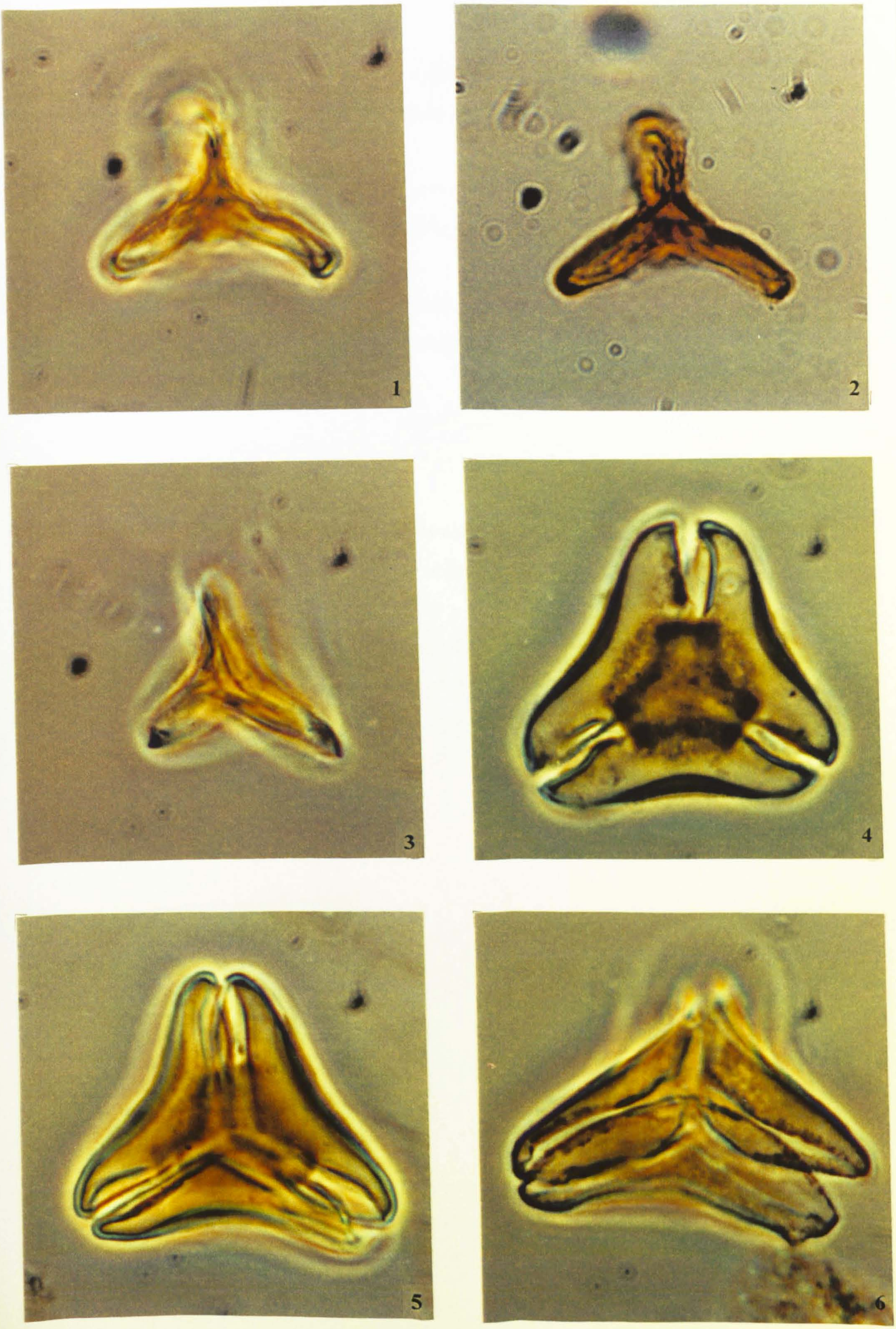


Plate 22

Figure 1	*Cyperaceaepollis* spp. 13/603, 260.00m, slide 1, A39/3.
Figure 2	*Cyperaceaepollis* spp. 13/603, 260.00m, slide 1, A39/3.
Figure 3	*Graminidites laevigatus* 13/603, 60.00m, slide 1, O48/2.
Figure 4	*Graminidites laevigatus* 13/603, 60.00m, slide 1, M44/3.
Figure 5	*Sparganiaceaepollenites polygonalis* 13/611, 69.95m, slide 1, E45.
Figure 6	*Sparganiaceaepollenites polygonalis* 13/611, 69.95m, slide 1, E45.

Plate 22

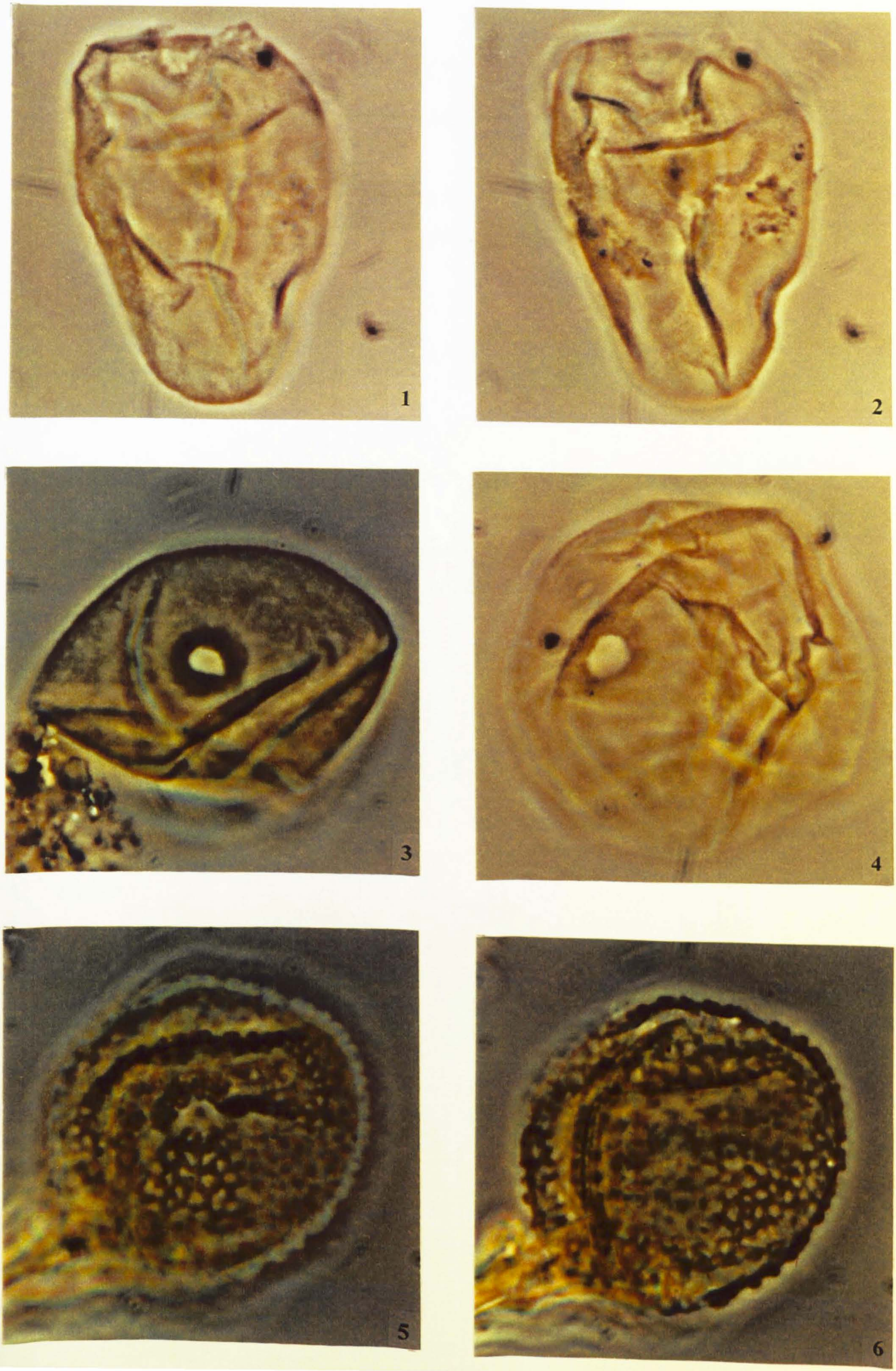


Plate 23

Figure 1	*Caryapollenites veripites* 13/611, 262.00m, slide 1, B41.
Figure 2	*Momipites coryloides* 13/611, 121.00m, slide 1, M41/2.
Figure 3	*Momipites quietus* 13/611, 121.00m, slide 1, L50/4.
Figure 4	*Momipites quietus* 13/611, 121.00m, slide 1, L42/3.
Figure 5	*Corsinipollenites oculusnoctis* 13/603, 218.60m, slide 4, D38.

Plate 23

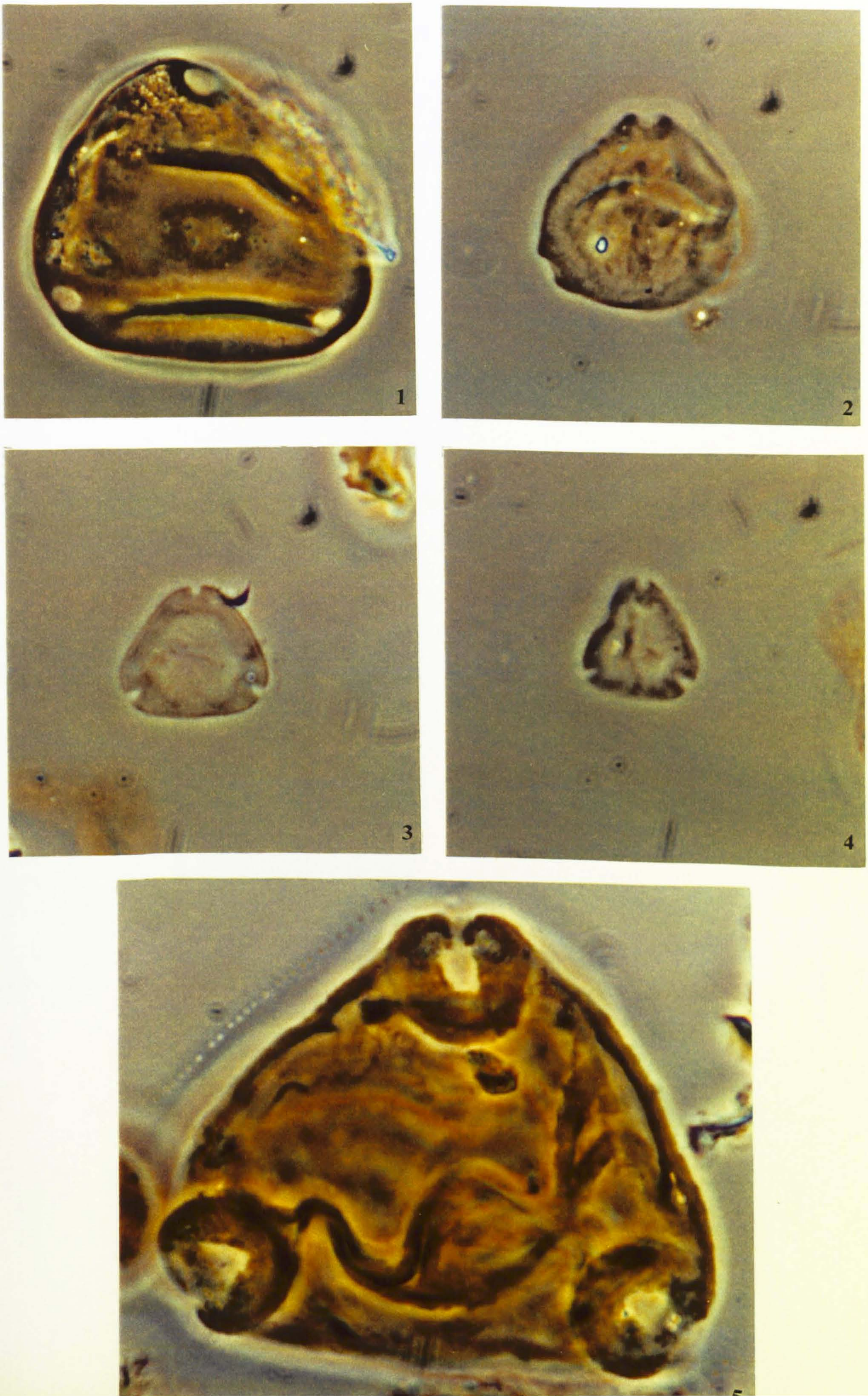


Plate 24

Figure 1 *Plicatopollis* spp.

27/415, 183.34m, slide 1, M33/3.

Figure 2 *Triporopollenites robustus*

27/415, 85.00m, slide 1, F45/1.

Figure 3 *Trivestibulopollenites betuloides*

13/611, 262.00m, slide 1, K36.

Figure 4 *Trivestibulopollenites betuloides*

13/603, 222.74m, slide 1, O31.

Plate 24

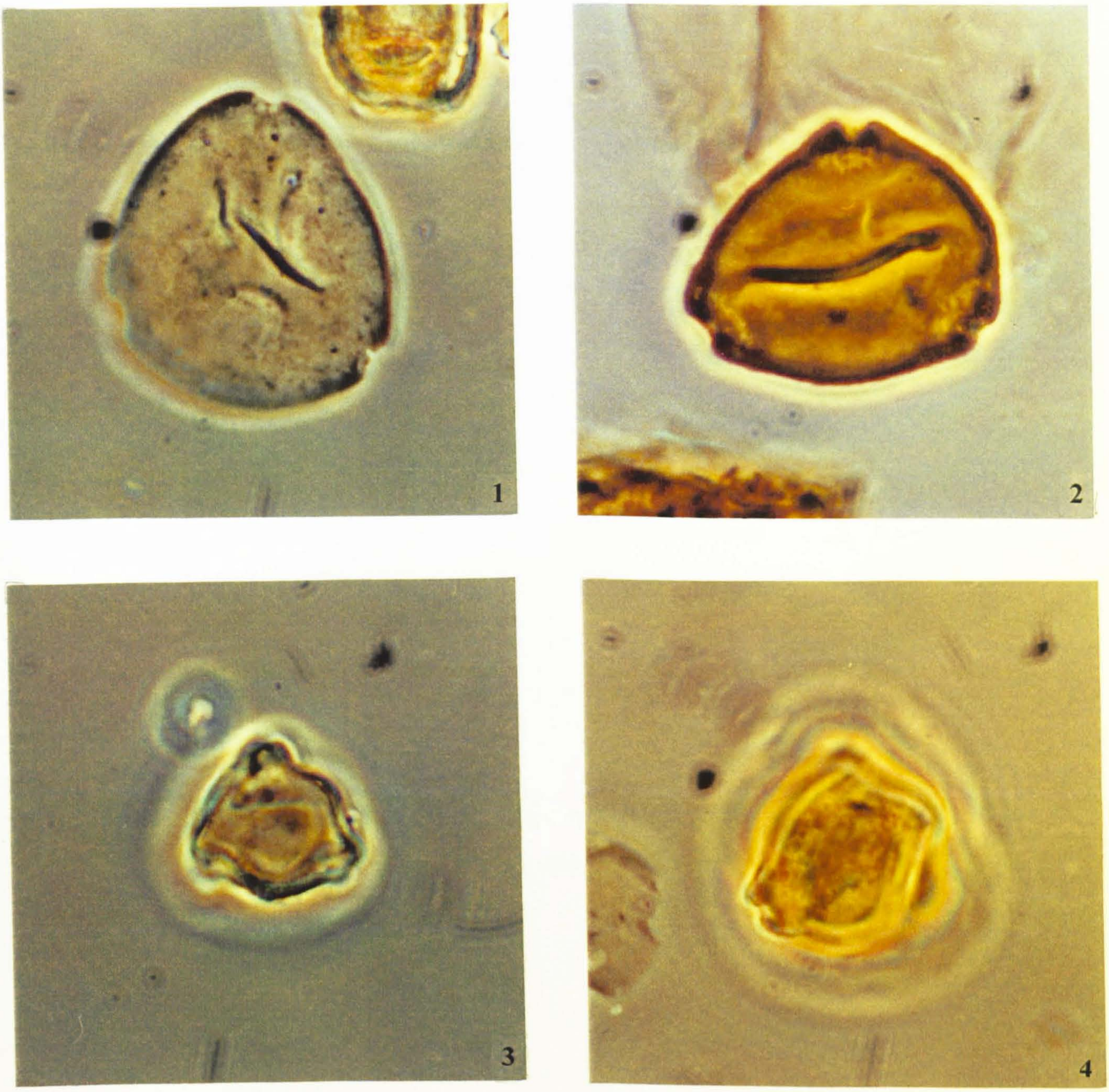


Plate 25

Figure 1	*Alnipollenites verus* 27/415, 125.00m, slide 1, J35.
Figure 2	*Alnipollenites verus* 13/611, 69.95m, slide 2, L42/3.
Figure 3	*Alnipollenites verus* 36/4680, 131.71m, slide 1, O41.
Figure 4	*Anacolosidites* spp. 13/611, 261.00m, slide 4, K43/2.
Figure 5	*Polyatriopollenites carpinoides* 13/611, 47.00m, slide 1, H36/1.
Figure 6	*Polyatriopollenites stellatus* 13/611, 60.00m, slide 3, M46/2.

Plate 25

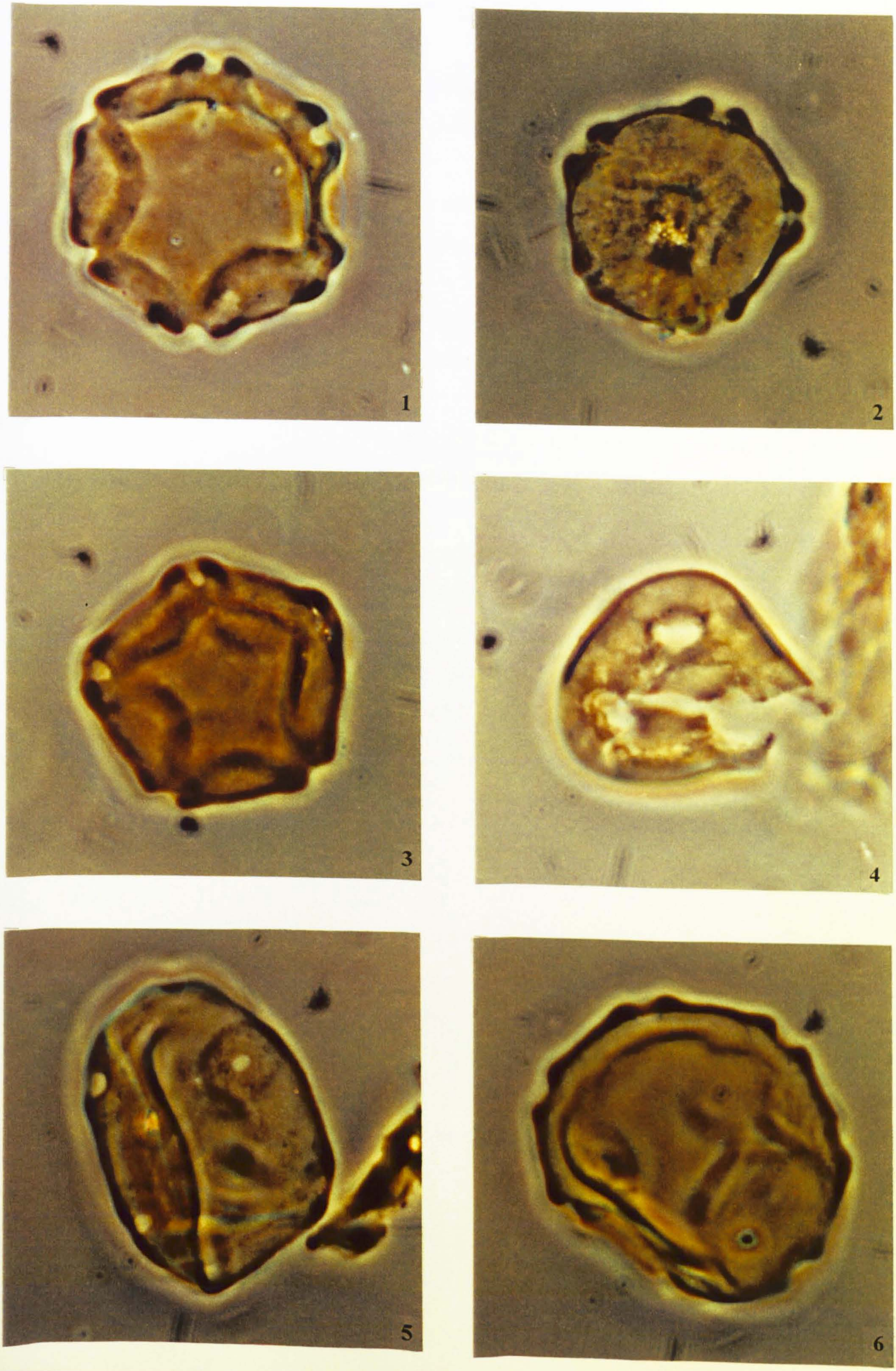


Plate 26

Figure 1	*Inaperturopollenites cuspidateformis* 13/611, 47.00m, slide 1, S43.
Figure 2	*Inaperturopollenites cuspidateformis* 13/611, 131.00m, slide 1, P36.
Figure 3	*Inaperturopollenites cuspidateformis* 13/603, 222.74m, slide 1, M33.
Figure 4	*Inaperturopollenites dubius* 13/611, 100.00m, slide 1, P38/1.
Figure 5	*Inaperturopollenites dubius* 13/611, 82.00m, slide 1, N52.
Figure 6	*Inaperturopollenites hiatus* 27/415, 41.00m, slide 1, J37/2.

Plate 26

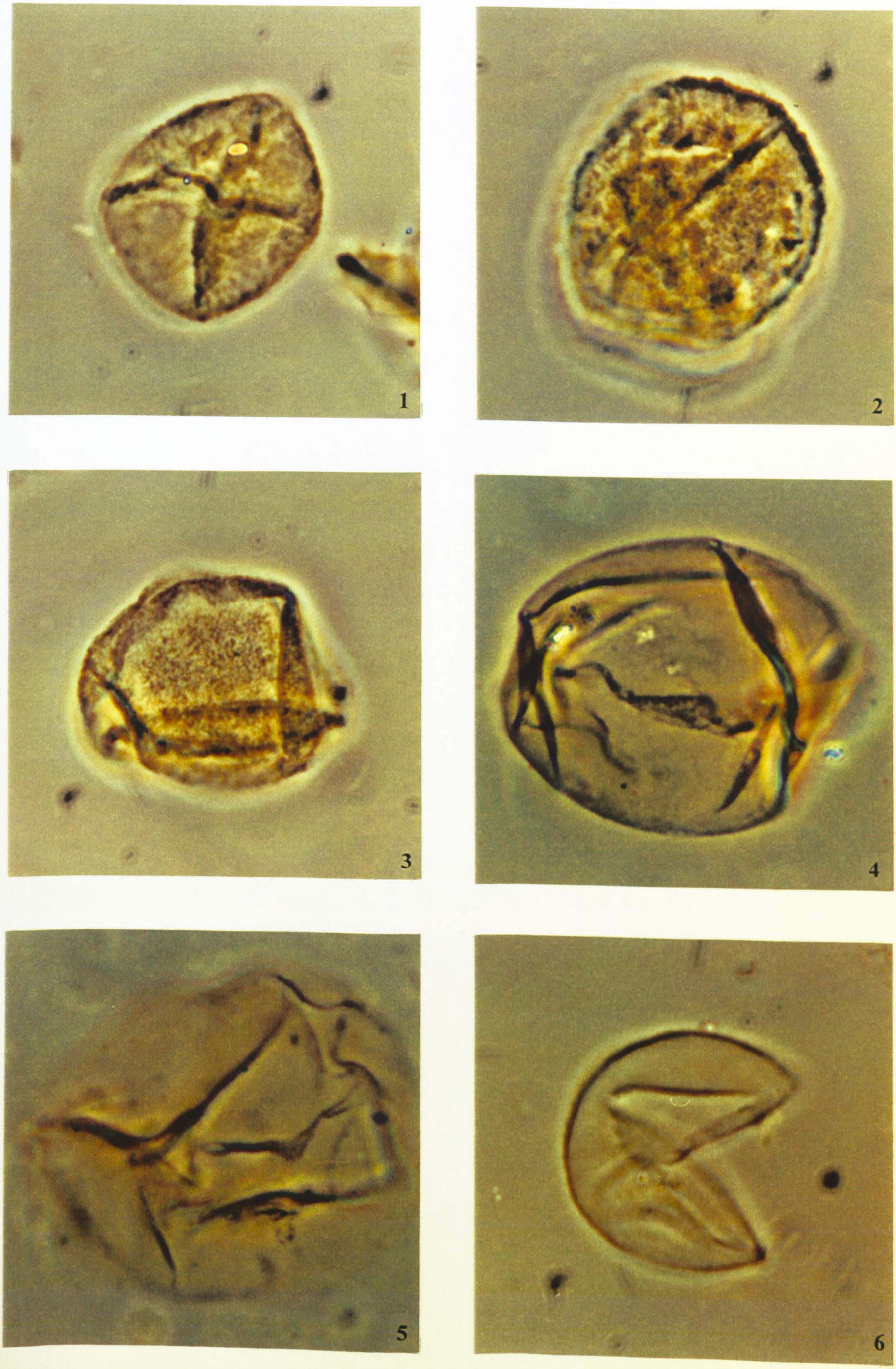


Plate 27

Figure 1	*Inaperturopollenites* cf. *hiatus* 13/611, 69.95m, slide 1, N52/2.
Figure 2	*Inaperturopollenites* cf. *hiatus* 13/611, 60.00m, slide 2, M49/4.
Figure 3	*Inaperturopollenites insulipapillatus* 13/611, 100.00m, slide 1, M51/4.
Figure 4	*Inaperturopollenites radiatus* subsp. *megaradiatus* 13/611, 60.00, slide 1, M54/4.
Figure 5	*Sequoiapollenites polyformosus* 13/611, 60.00m, slide 1, M36.

Plate 27

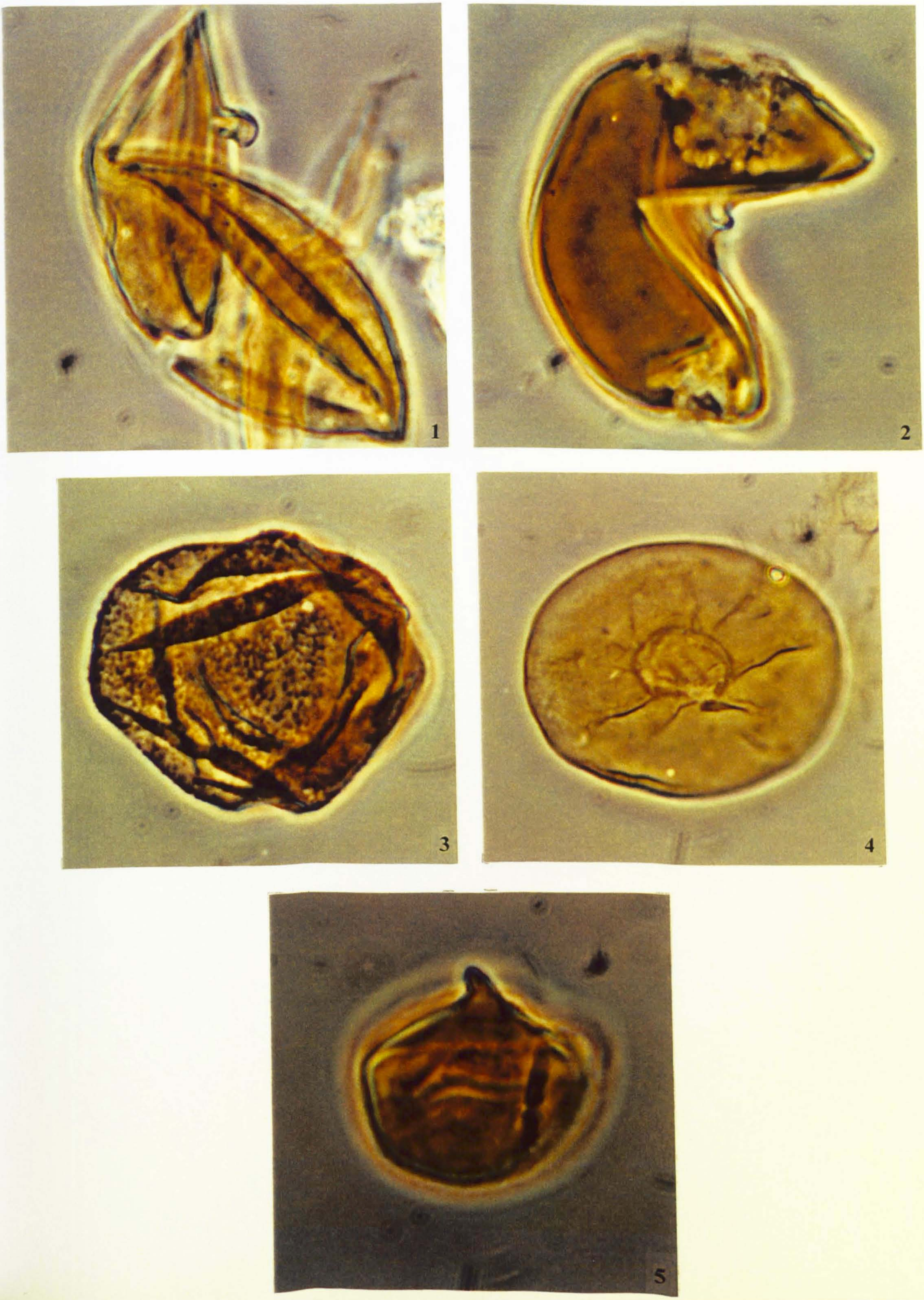


Plate 28

Figure 1 *Sciadopityspollenites quintus*

27/415, 71.00m, slide 1, H34.

Figure 2 *Sciadopityspollenites verticillatiformis*

27/415, 85.00m, slide 1, F36/1.

Figure 3 *Sciadopityspollenites verticillatiformis*

27/415, 85.00m, slide 1, F36/1, ordinary transmitted light.

Figure 4 Monosaccate conifer pollen sp. A

36/4680, 223.18m, slide 3, M51/1, x 400.

Plate 28

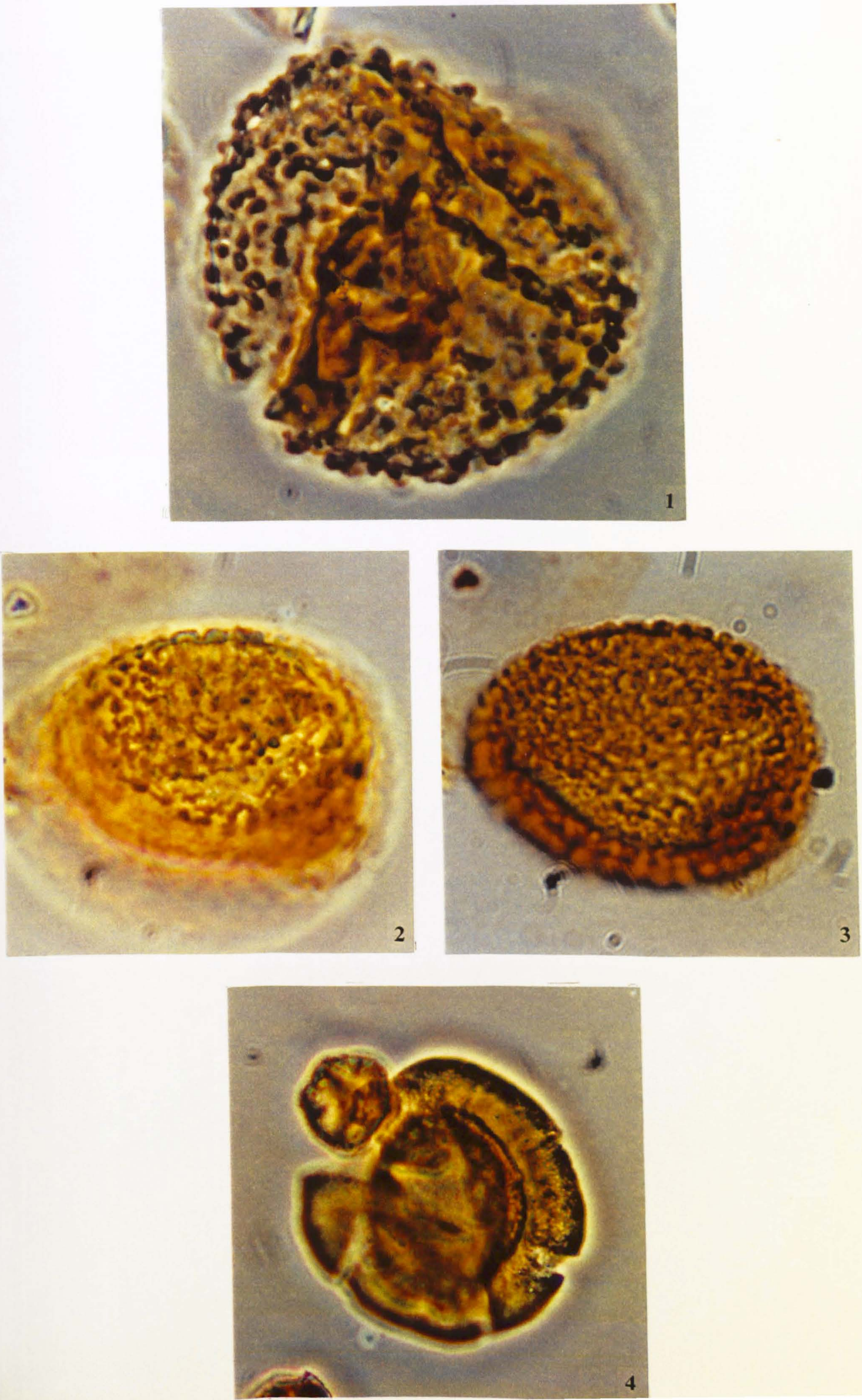


Plate 29

Figure 1	*Pityosporites microalatus* 13/611, 69.95m, slide 1, T38/3, x 400.
Figure 2	*Pityosporites labdacus* 36/4680, 265.13m, slide 3, S34/4, x 400.
Figure 3	*Pityosporites labdacus* 13/611, 262.00m, slide 4, R39, x 400.
Figure 4	*Pityosporites labdacus* 27/415, 51.00m, slide 1, N35, x 400.
Figure 5	*Podocarpidites libellus* 13/603, 120.00m, slide 1, F40/2, x 400.
Figure 6	*Podocarpidites libellus* 27/415, 41.00m, slide 1, D52/1, x 400.

Plate 29

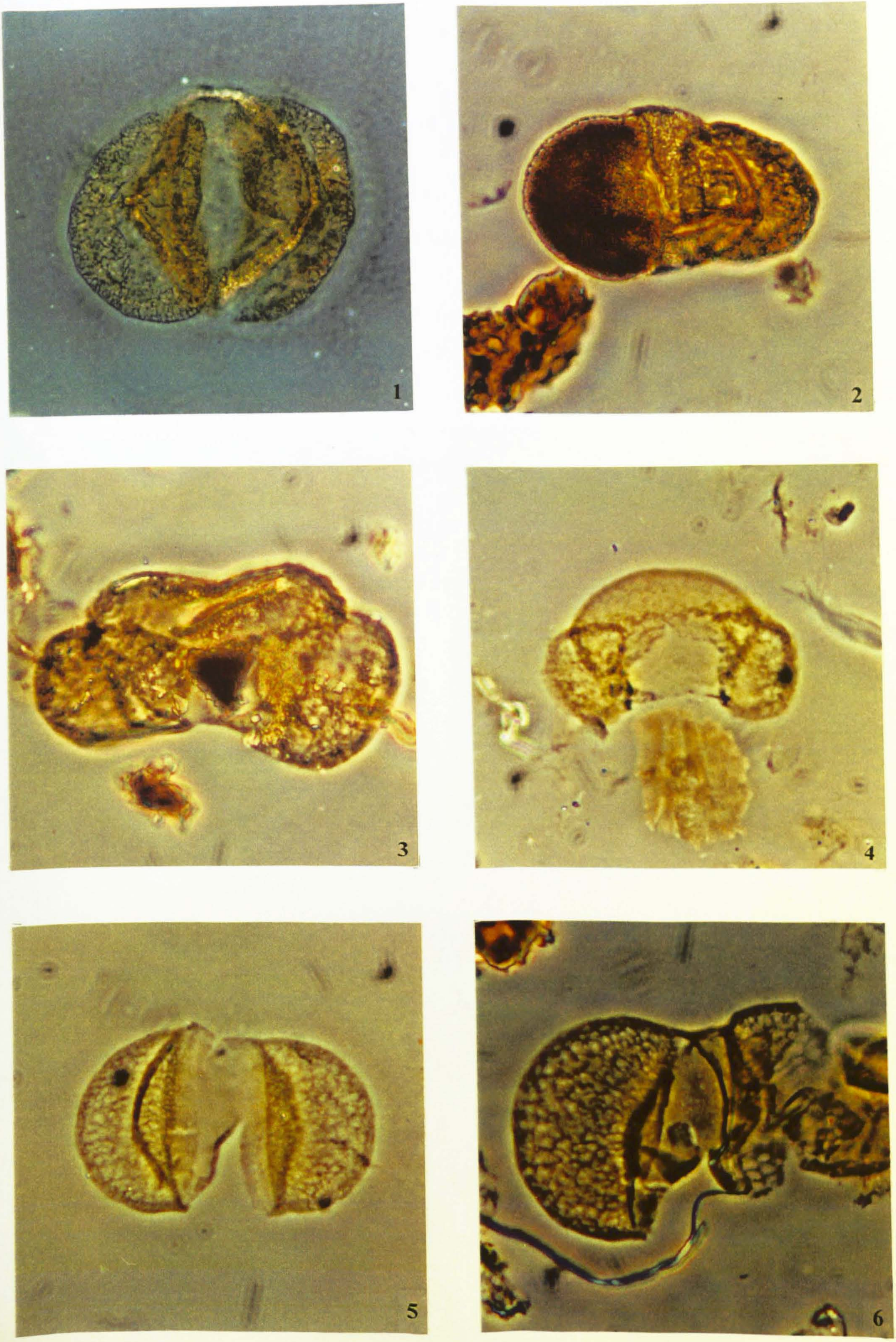
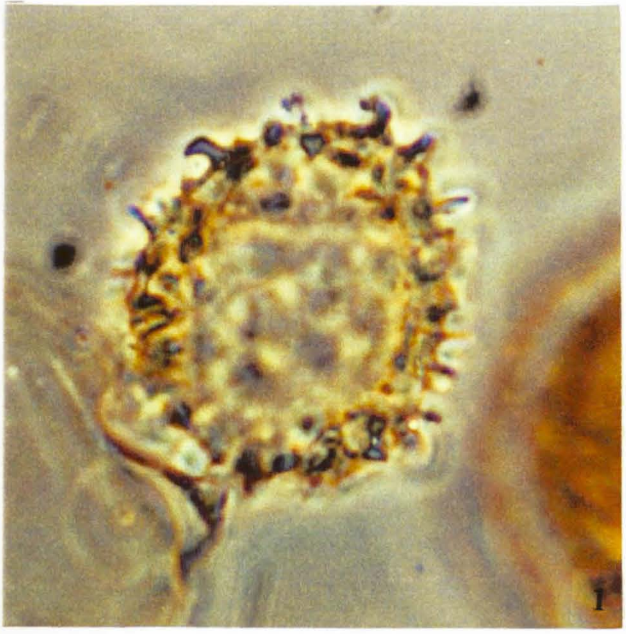
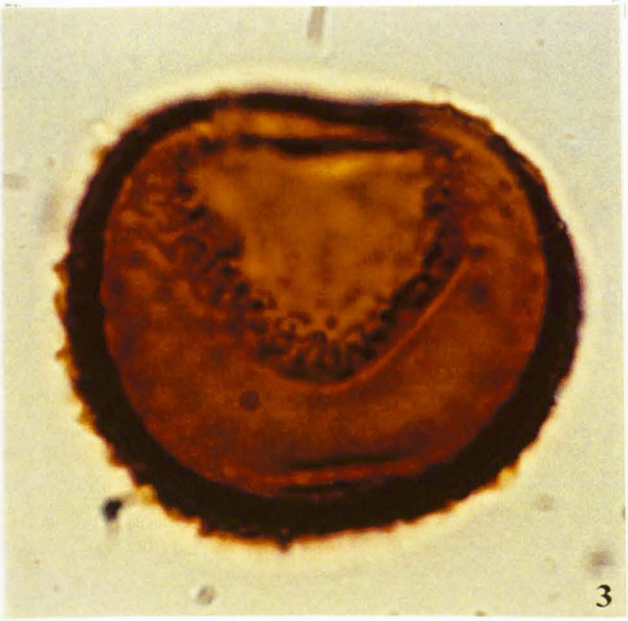


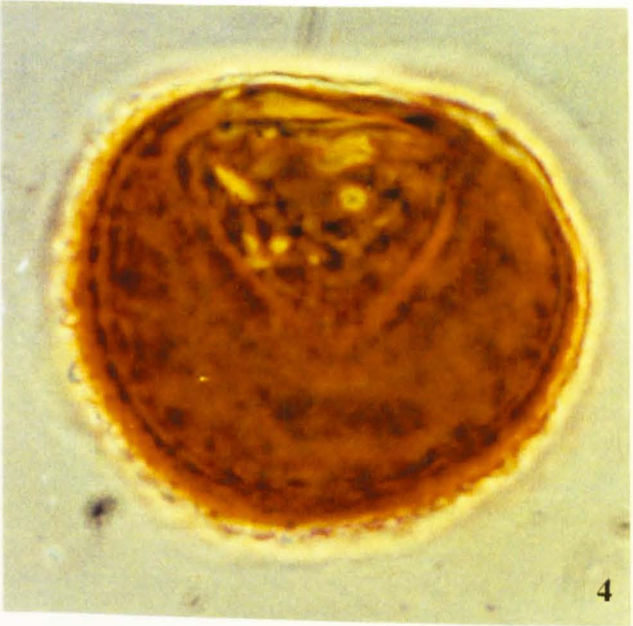
Plate 30

Figure 1	*Corrusporis chattensis* 36/4680, 72.05m, slide 1, N34/2, x 400.
Figure 2	*Corrusporis globoverrucatus* 13/611, 164.80m, slide 1, G53, ordinary transmitted light.
Figure 3	*Corrusporis globoverrucatus* 13/611, 164.80m, slide 1, G53, ordinary transmitted light.
Figure 4	*Corrusporis globoverrucatus* 13/611, 164.80m, slide 1, G53.
Figure 5	*Corrusporis tuberculatus* subsp. *tuberculatus* 36/4680, 72.05m, slide 4, W29/2.

Plate 30







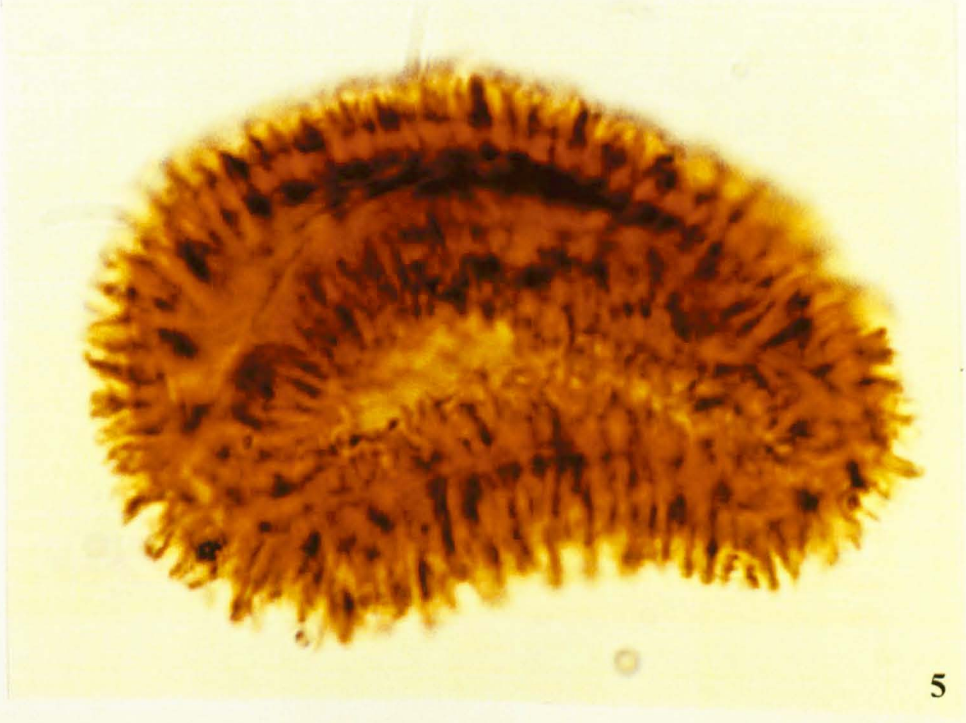


Plate 31

Figure 1	*Corrusporis tuberculatus* subsp. *minutus* Holotype 13/611, 100.00m, slide 3, S41/4.
Figure 2	*Corrusporis tuberculatus* subsp. *minutus* Holotype 13/611, 100.00m, slide 3, S41/4, ordinary transmitted light.
Figure 3	*Corrusporis tuberculatus* subsp. *minutus* Holotype 13/611, 100.00m, slide 3, S41/4, ordinary transmitted light.
Figure 4	*Corrusporis tuberculatus* subsp. *minutus* 36/4680, 72.05m, slide 1, N35/1, x 400.
Figure 5	*Corrusporis* sp.A Holotype, 36/4680, 72.05m, slide 1, M42/1, x 400.

Plate 31

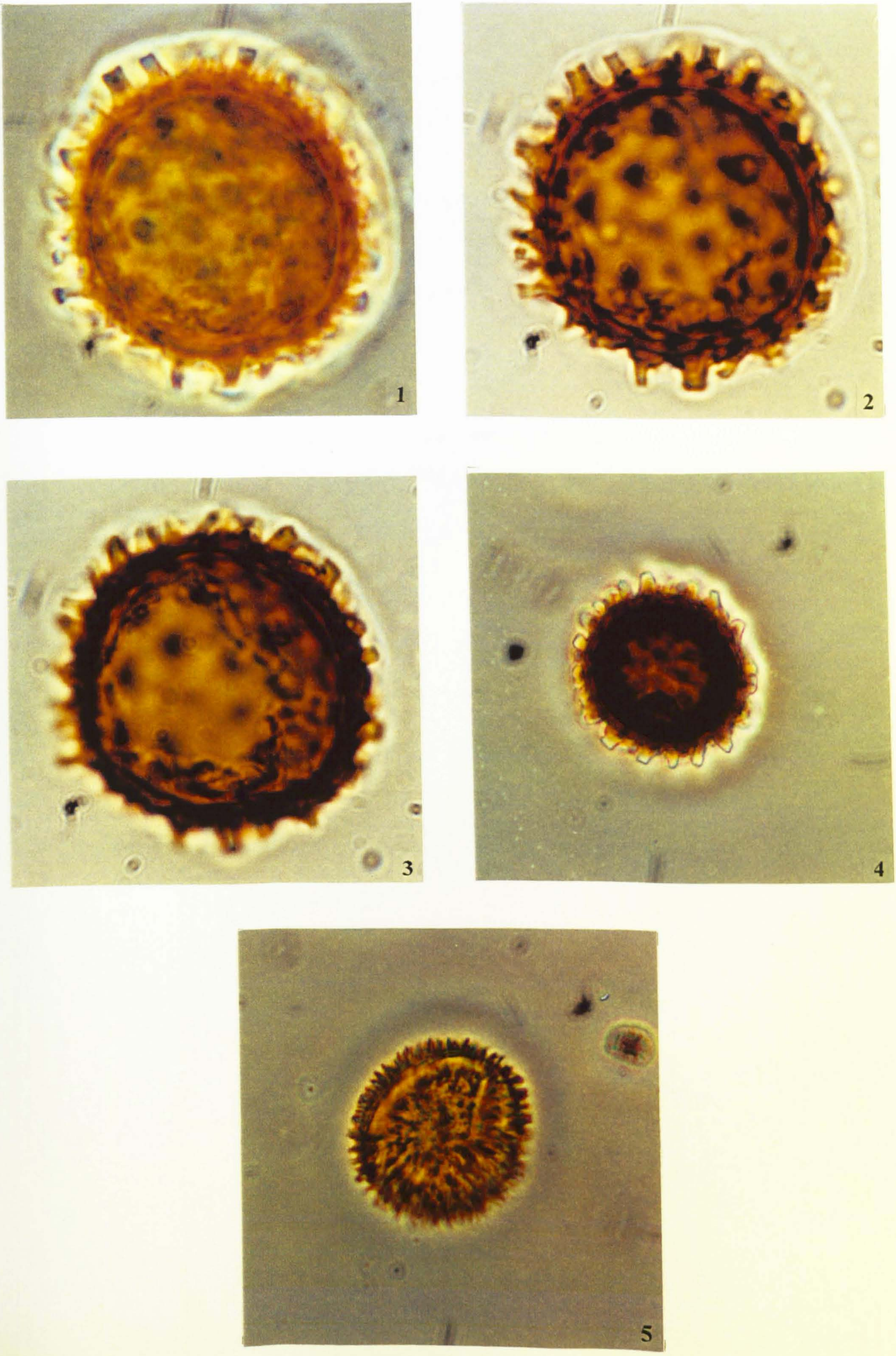


Plate 32

Figure 1 *Laevigatosporites discordatus*

13/603, 48.00m, slide 1, N46/3.

Figure 2 *Laevigatosporites haardti*

13/603, 48.00m, slide 1, D34.

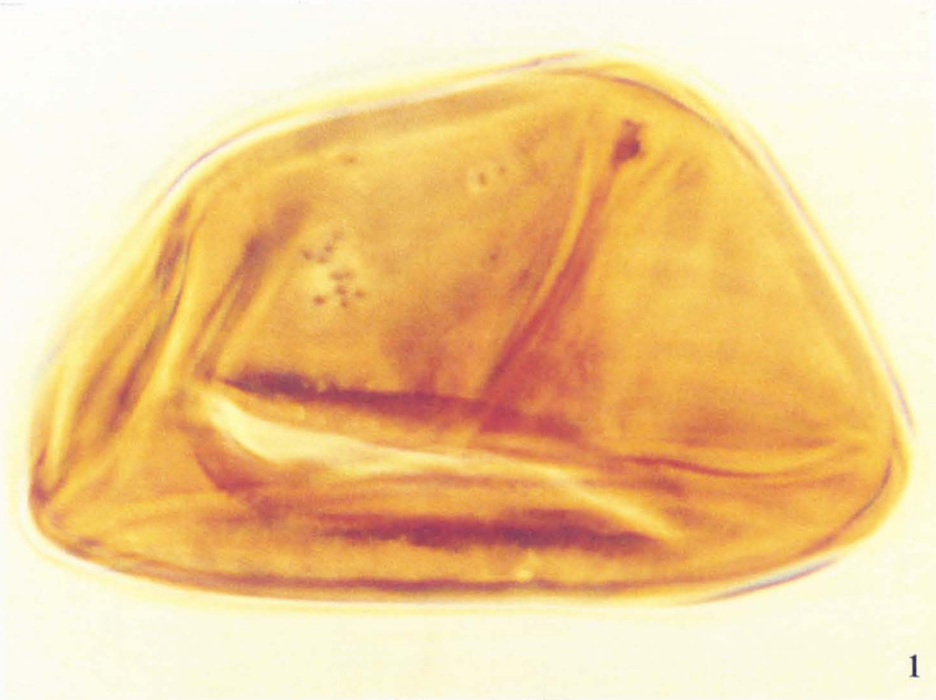
Figure 3 *Laevigatosporites haardti*

27/415, 125.00m, slide 1, D46.

Figure 4 *Laevigatosporites haardti* subsp. *crassicus*

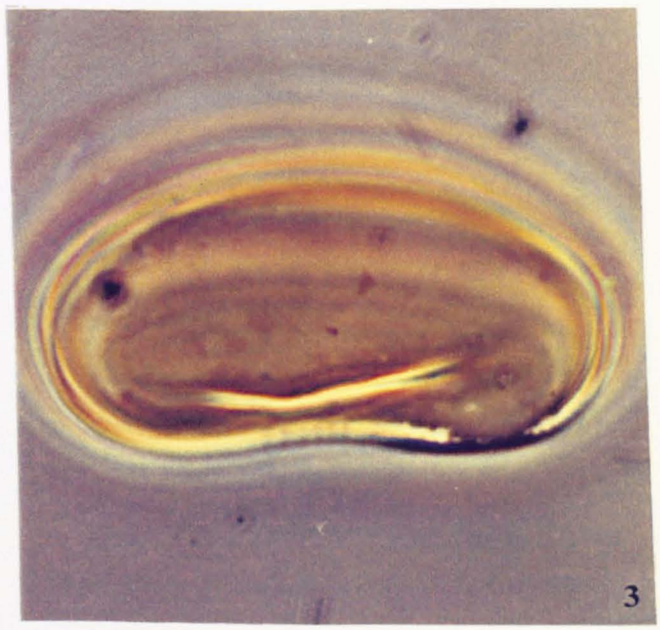
36/4680, 200.33m, slide 4, E32, x 400.

Plate 32



1

2



3

4

Plate 33

Figure 1 *Verrucatosporites alienus*

13/611, 110.00m, slide 1, V47/2, x 400, ordinary transmitted light.

Figure 2 *Verrucatosporites alienus*

13/611, 110.00m, slide 1, V47/2 x 400.

Figure 3 *Verrucatosporites balticus* subsp. *balticus*

13/611, 206.00m, slide 1, O45/2, ordinary transmitted light.

Figure 4 *Verrucatosporites balticus* subsp. *balticus*

13/611, 206.00m, slide 1, O45/2.

Figure 5 *Verrucatosporites favus* subsp. *favus*

13/603, 161.19m, slide 2, M31, x 400.

Figure 6 *Verrucatosporites favus* subsp. *pseudosecundus*

13/611, 110.00m, slide 1, W46/4.

Plate 33

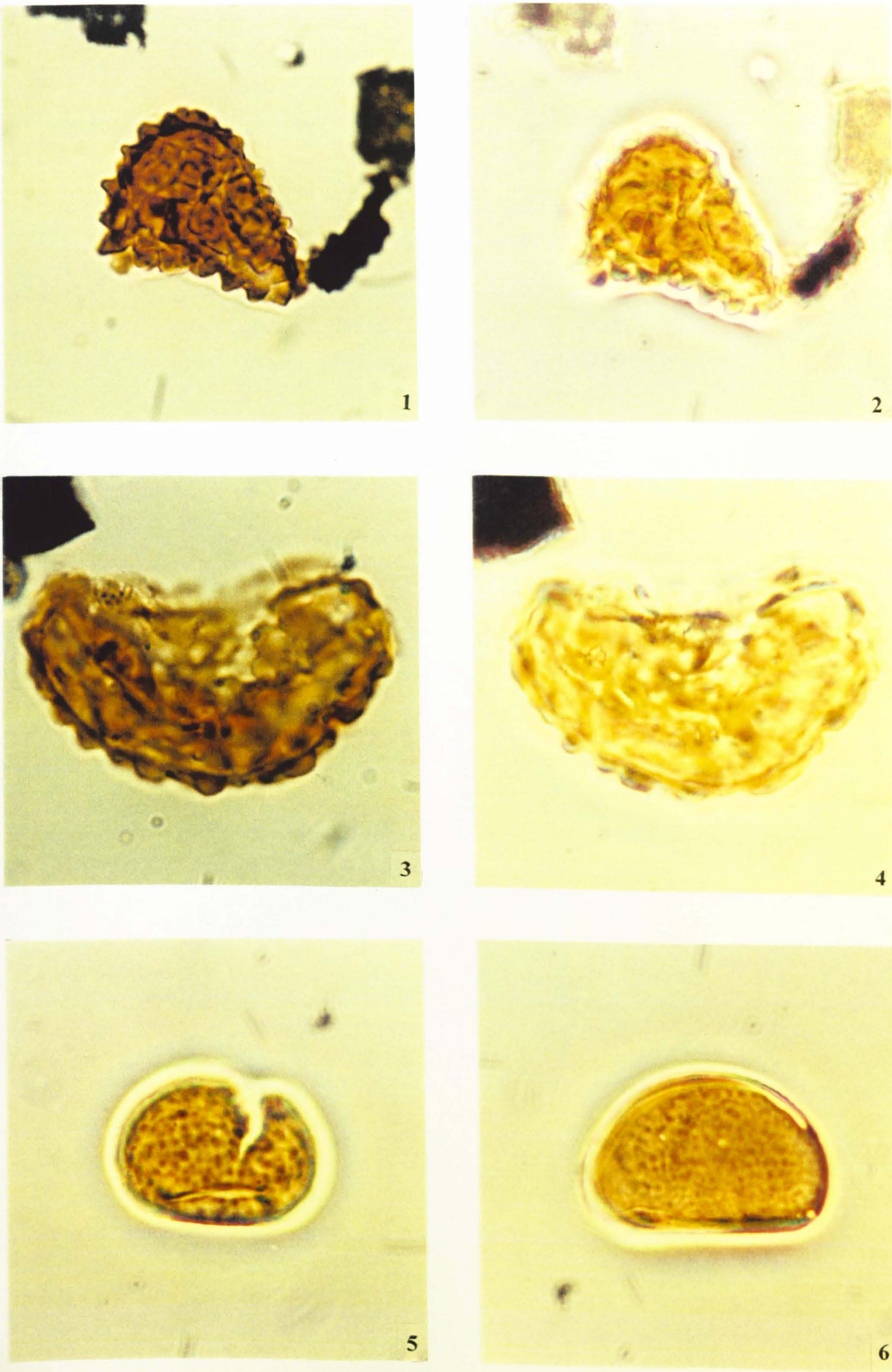


Plate 34

Figure 1 *Verrucatosporites histiopteroides* subsp. *minor*

13/611, 164.80m, slide 1, H37/4 x 400, ordinary transmitted light.

Figure 2 *Verrucatosporites poriacus* subsp. *poriacus*

13/611, 110.00m, slide 1, R41/4, x 400.

Figure 3 *Verrucatosporites poriacus* subsp. *microporiacus*

13/611, 110.00m, slide 1, U43/2, x 400.

Figure 4 *Verrucatosporites poriacus* subsp. *microporiacus*

13/611, 110.00m, slide 1, U43/2.

Plate 34

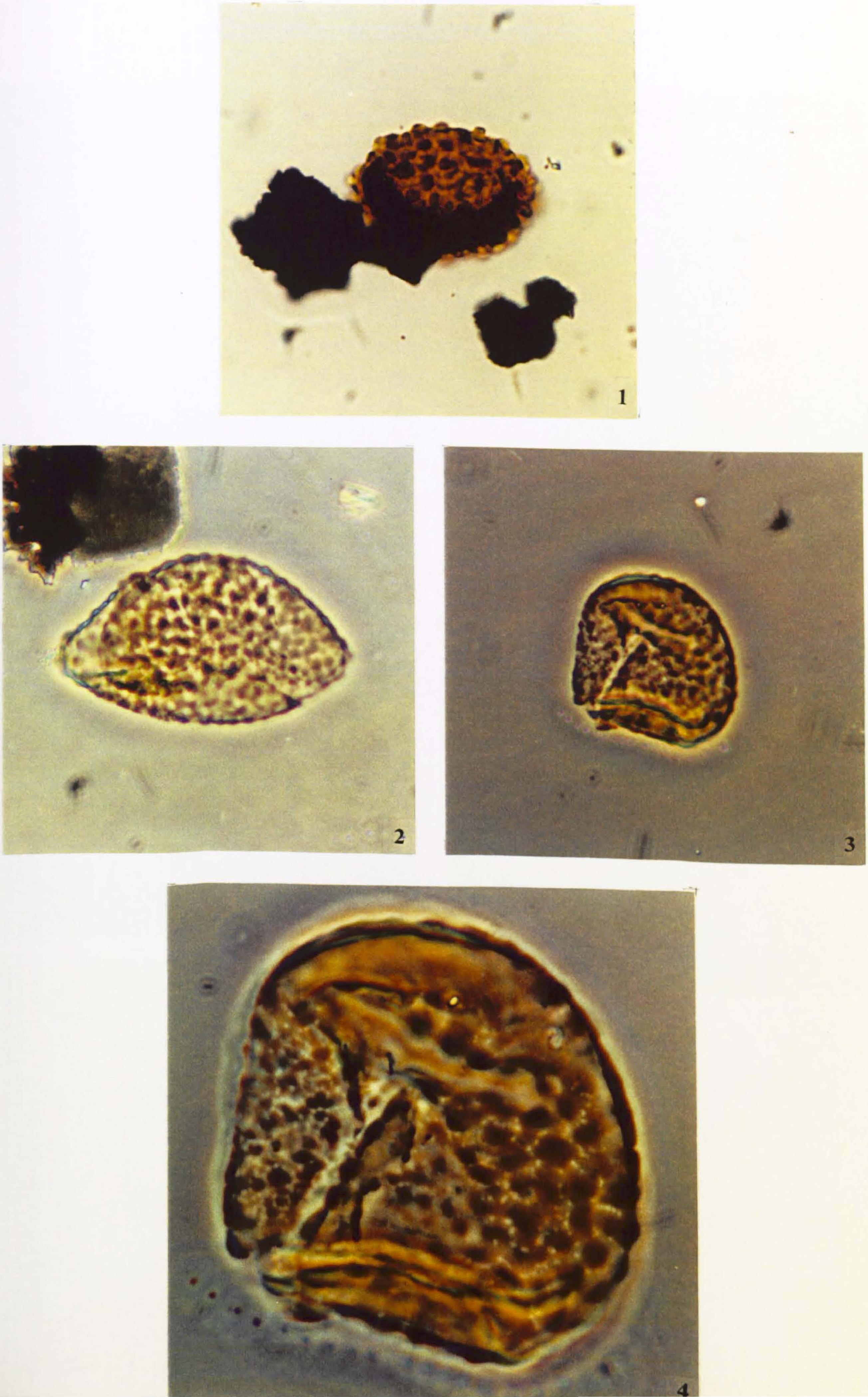


Plate 35

Figure 1	*Baculatisporites nanus*
	36/4680, 223.18m, slide 3, T47/2, x 400.
Figure 2	*Baculatisporites nanus*
	27/415, 71.00m, slide 2, P36/4, x 400.
Figure 3	*Baculatisporites primarius*
	13/611, 262.00m, slide 1, L55, x 400.
Figure 4	*Baculatisporites quintus*
	36/4680, 131.71m, slide 1, N36/4.
Figure 5	*Baculatisporites* sp. A
	27/415, 173.00m, slide 2, J46/2, x 400.

Plate 35

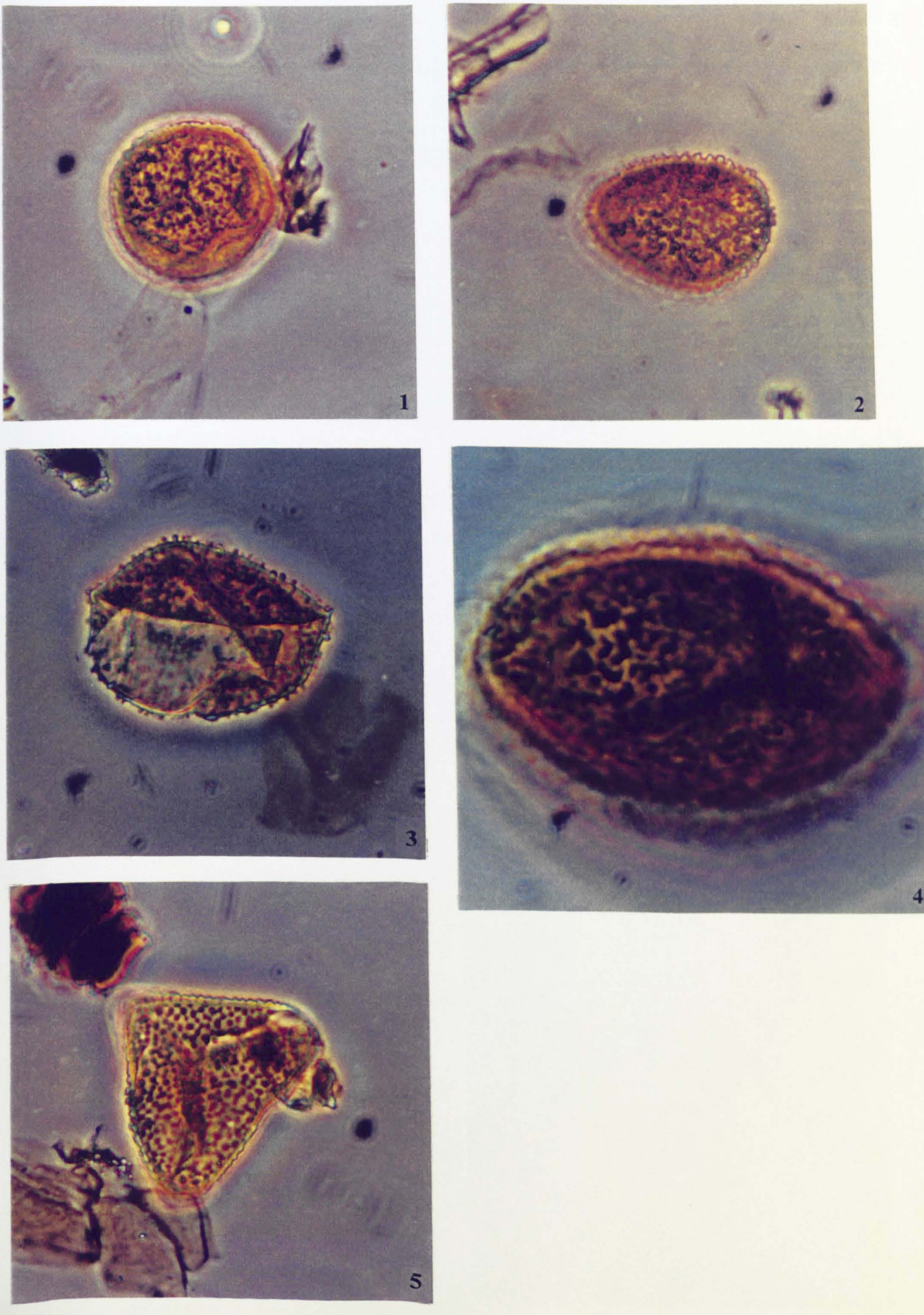


Plate 36

Figure 1 *Camarozonosporites (Camarozonosporites) decorus*

36/4680, 200.33m, slide 1, P49.

Figure 2 *Camarozonosporites (Camarozonosporites) heskemensis*

13/611, 164.80m, slide 1, G42/1.

Figure 3 *Camarozonosporites (Camarozonosporites) heskemensis*

13/611, 164.80m, slide 1, G42/1.

Figure 4 *Cicatricosisporites dorogensis*

36/4680, 265.13m, slide 2, D36, x 400.

Figure 5 *Cicatricosisporites dorogensis*

36/4680, 265.13m, slide 2, D36, x 400, ordinary transmitted light.

Plate 36

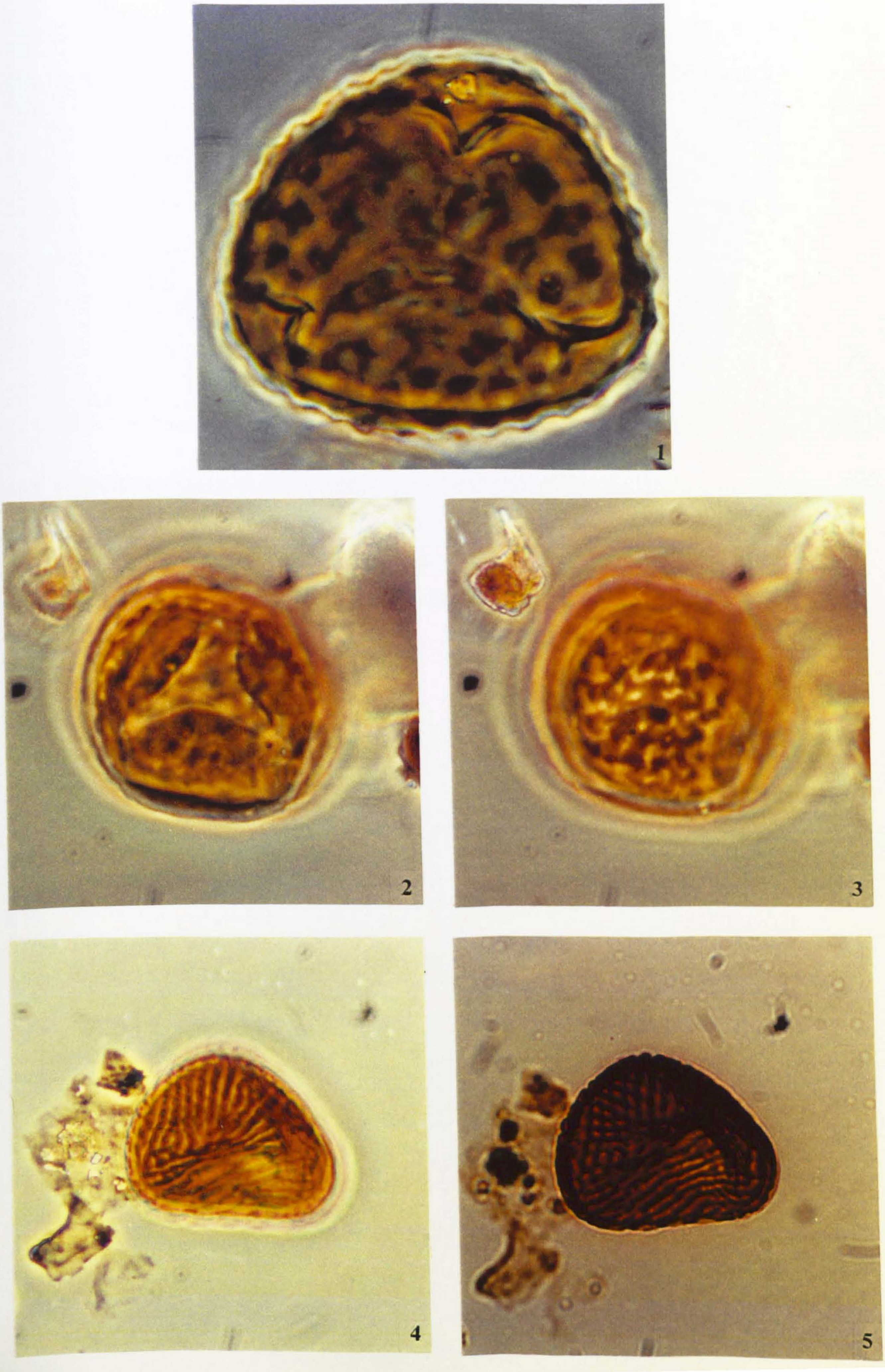


Plate 37

Figure 1	*Cicatricosisporites dorogensis* 36/4680, 265.13m, slide 2, G38, x 400.
Figure 2	*Cicatricosisporites dorogensis* 36/4680, 265.13m, slide 2, G38, x 400, ordinary transmitted light.
Figure 3	*Cicatricosisporites paradorogensis* 36/4680, 265.13m, slide 2, G349/4, x 400.
Figure 4	*Cicatricosisporites paradorogensis* 36/4680, 265.13m, slide 2, G49/4, x 400, ordinary transmitted light.
Figure 5	*Cicatricosisporites paradorogensis* 36/4680, 265.13m, slide 2, F42, x 400, ordinary transmitted light.

Plate 37

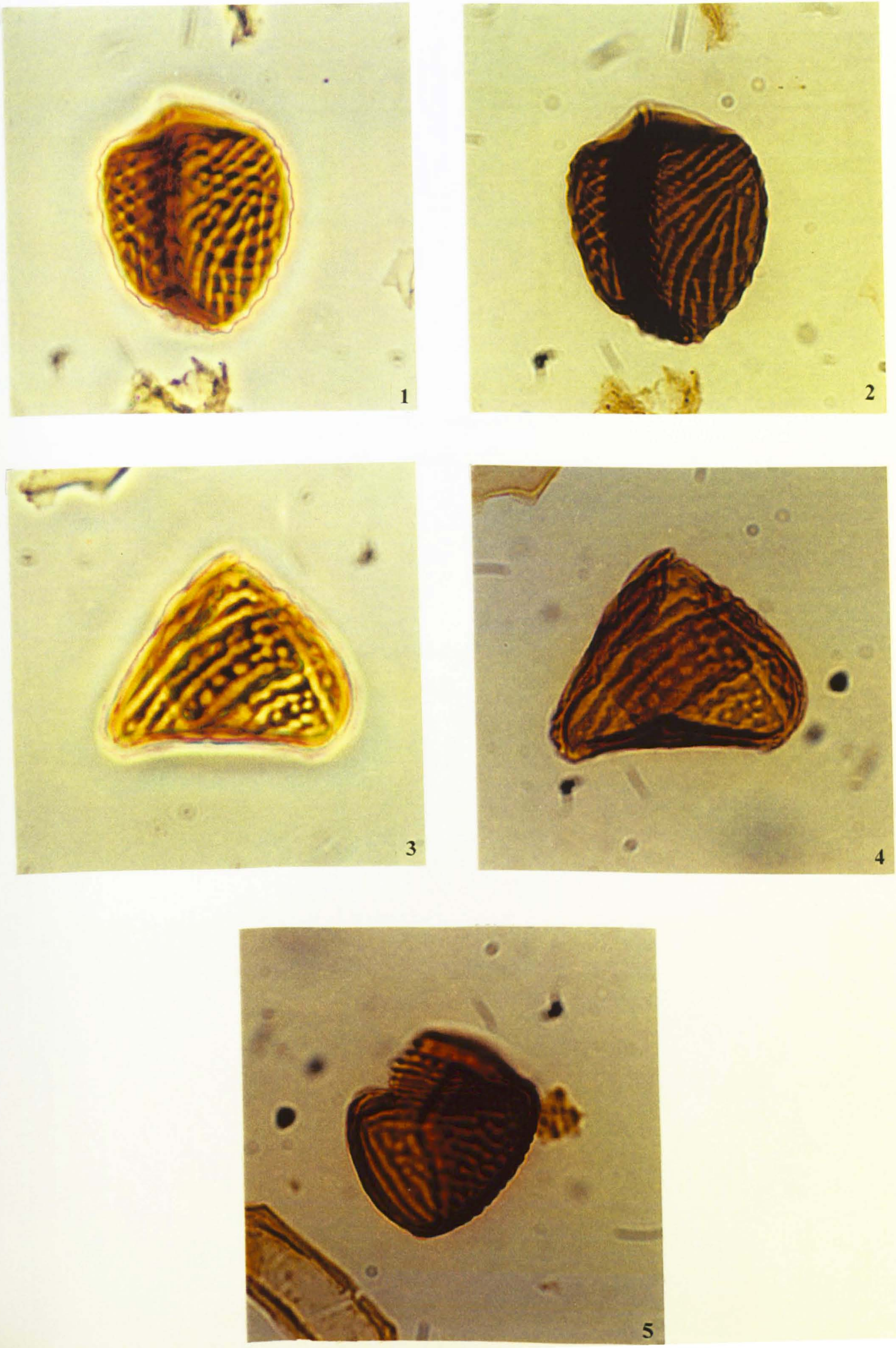


Plate 38

Figure 1	*Cicatricosisporites chattensis* subsp. *chattensis* 13/611, 110.00m, slide 1, K37/4, x 400.
Figure 2	*Cicatricosisporites chattensis* subsp. *chattensis* 13/611, 110.00m, slide 1, K37/4, x 400, ordinary transmitted light.
Figure 3	*Cicatricosisporites chattensis* subsp. *chattensis* 13/611, 100.00m, slide 2, L41, x 400.
Figure 4	*Cicatricosisporites chattensis* subsp. *chattensis* 13/611, 110.00m, slide 2, L41, x 400, ordinary transmitted light.
Figure 5	*Cicatricosisporites chattensis* subsp. *chattensis* 13/611, 110.00m, slide 1, S34/3, x 400.
Figure 6	*Cicatricosisporites chattensis* subsp. *chattensis* 13/611, 110.00m, slide 1, S34/3, x 400, ordinary transmitted light.

Plate 38

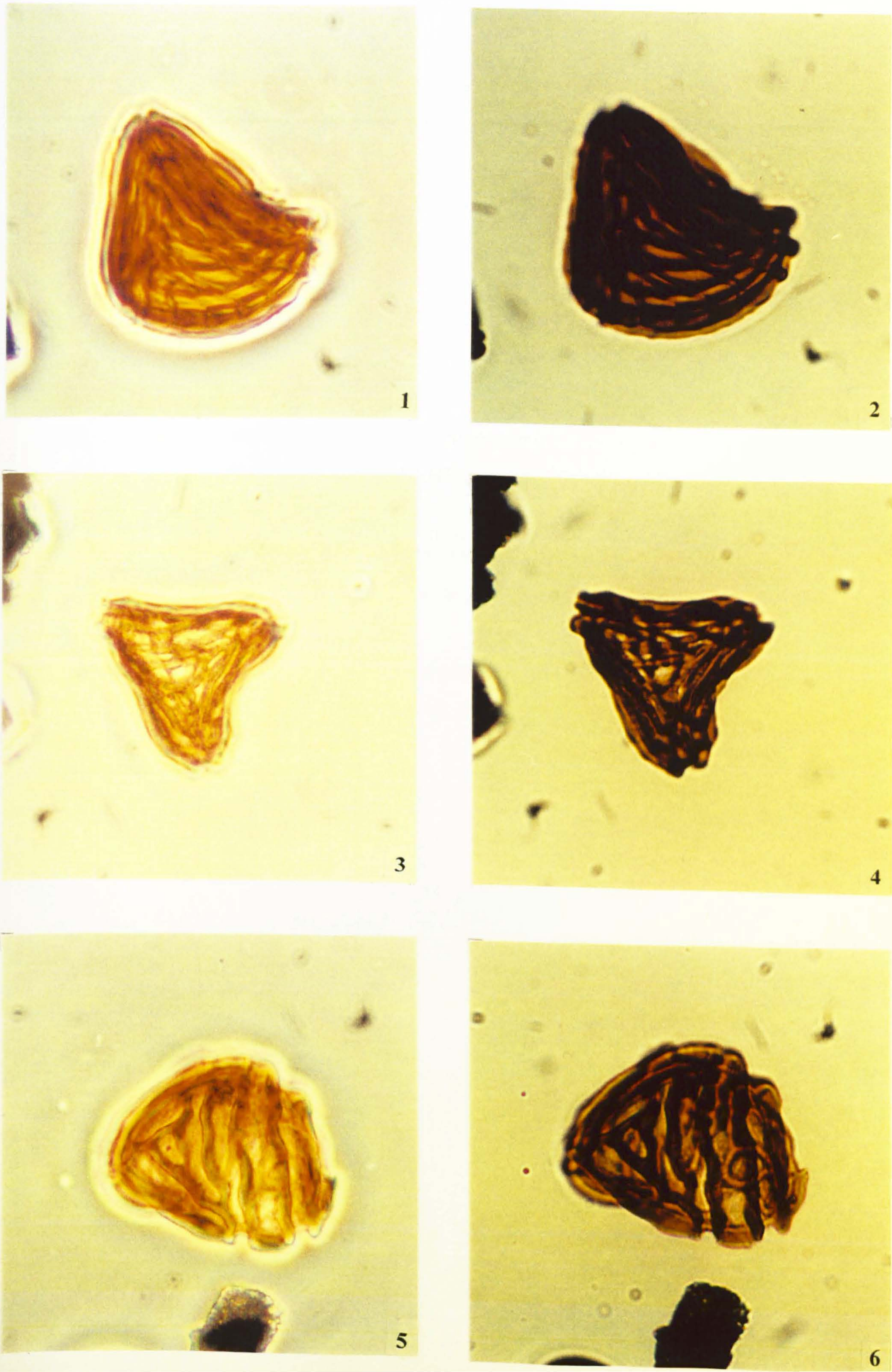


Plate 39

Figure 1	*Cicatricosisporites chattensis* subsp. *minor* 13/611, 100.00m, slide 1, Q37, x 400, ordinary transmitted light.
Figure 2	*Deltoidospora maxoides* 36/4680, 265.13m, slide 4, P37/1, x 400.
Figure 3	*Deltoidospora wolffi* 13/611, 154.00m, slide 1, R34/4.
Figure 4	*Echinatisporis echinoides* subsp. *grausteinensis* 13/611, 100.00m, slide 3, B35, x 400.
Figure 5	*Echinatisporis echinoides* subsp. *grausteinensis* 13/611, 100.00m, slide 3, B35, x 400, ordinary transmitted light.
Figure 6	*Echinatisporis embryonalis* 36/4680, 237.75m, slide 1, R38/4.

Plate 39

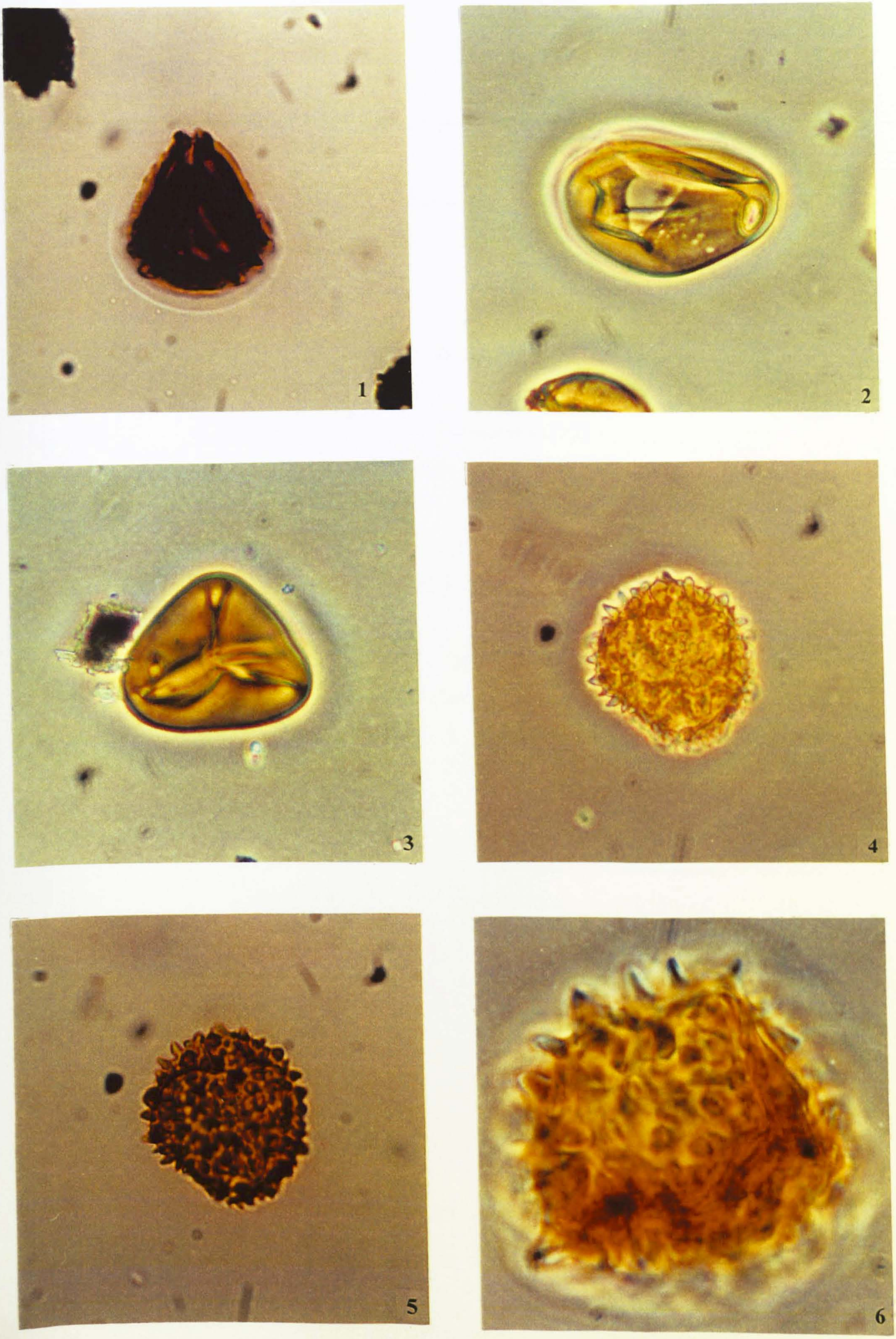


Plate 40

Figure 1	*Gleicheniidites senonicus*	13/611, 69.95m, slide 1, D43, x 400.
Figure 2	*Hydrosporis azollaensis*	13/611, 110.00m, slide 1, E50/4.
Figure 3	*Hydrosporis levis*	13/611, 100.00m, slide 2, O52/3.
Figure 4	*Lycopodiumsporites*	13/611, 100.00m, slide 2, U43.
Figure 5	*Lycopodiumsporites*	13/611, 100.00m, slide 2, U43.
Figure 6	*Matonisporites* spp.	13/603, 48.00m, slide 2, V35/1.

Plate 40

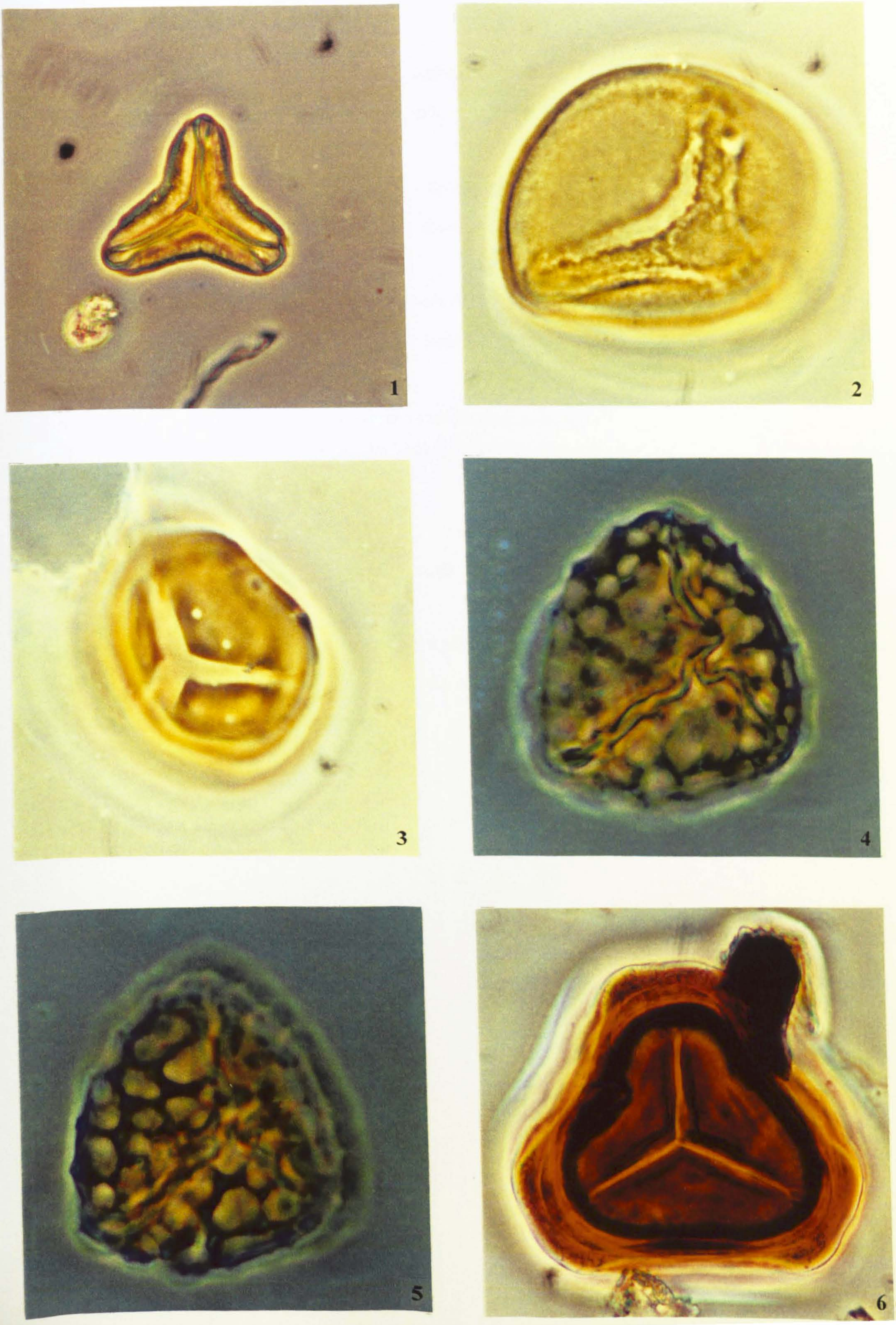


Plate 41

Figure 1	*Polypodiaceoisporites gracillimus* 13/611, 110.00m, slide 1, S43, x 400.
Figure 2	*Polypodiaceoisporites gracillimus* 13/603, 48.00m, slide 3, F47/3, x 400.
Figure 3	*Polypodiaceoisporites gracillimus* subsp. *semiverrucatus* 27/415, 71.00m, slide 1, M31/3, x 400, distal ornament in focus.
Figure 4	*Polypodiaceoisporites saxonicus* 13/611, 110.00m, slide 1, U46/1.
Figure 5	*Saxosporis gracilis* 36/4680, 72.05m, slide 1, M46/4.
Figure 6	*Stereisporites (Distigranisporis) granistereoides* 36/4680, 169.05m, slide 4, W44.

Plate 41

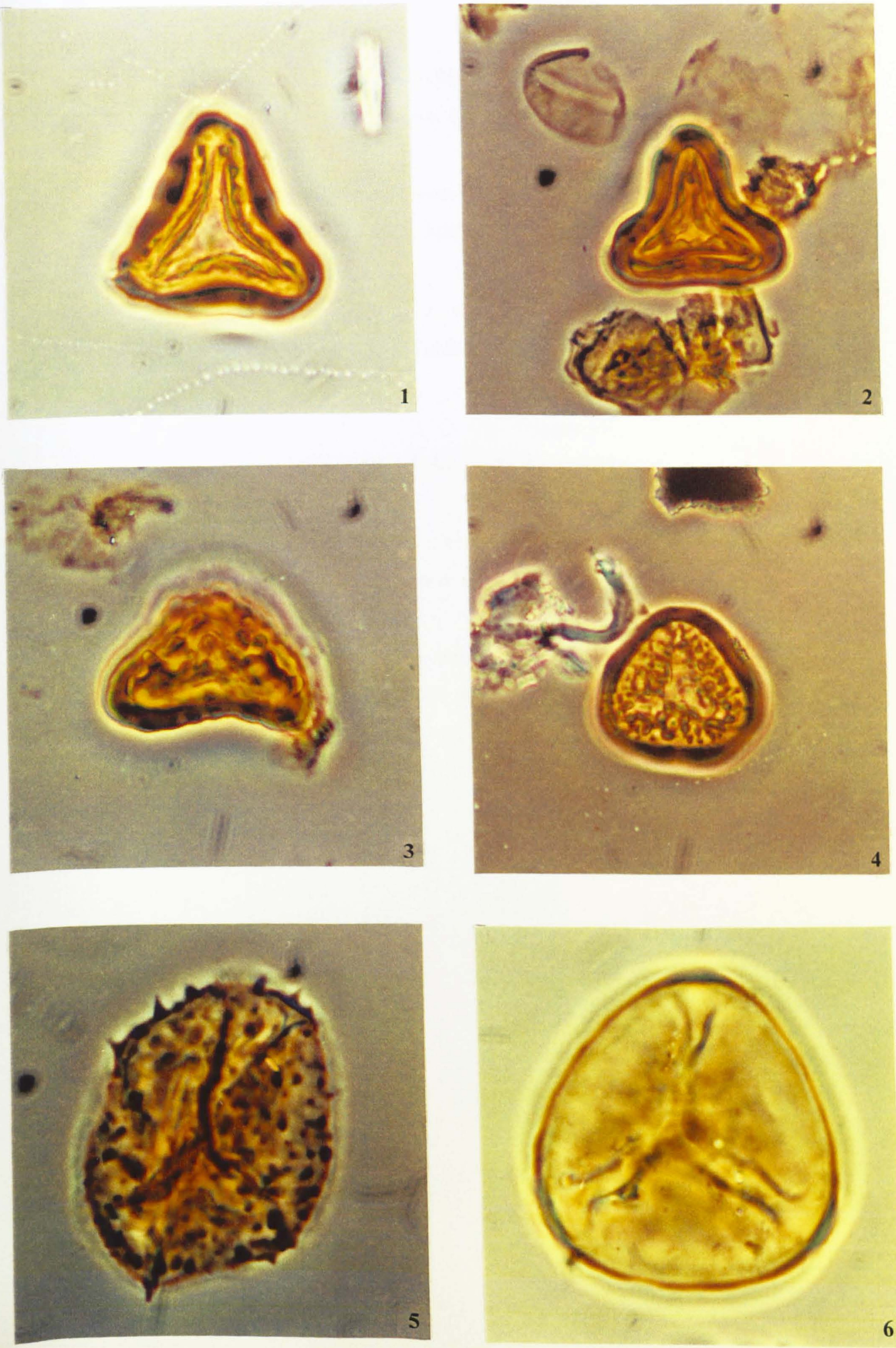


Plate 42

Figure 1	*Stereisporites (Distigranisporis) granistereoides* 36/4680, 169.05m, slide 4, W44.
Figure 2	*Stereisporites (Distancoraesporis) ancoris* 13/611, 47.00m, slide 2, N43.
Figure 3	*Toroisporis* spp. 13/611, 69.95m, slide 3, M33, x 400.
Figure 4	*Toroisporis* spp. 13/611, 69.95m, slide 1, L37, x 400.
Figure 5	*Trilites multivallatus* 13/611, 100.00m, slide 3, O52/2, x 400, ordinary transmitted light.
Figure 6	*Trilites multivallatus* 36/4680, 237.75m, slide 1, B46/2.

Plate 42

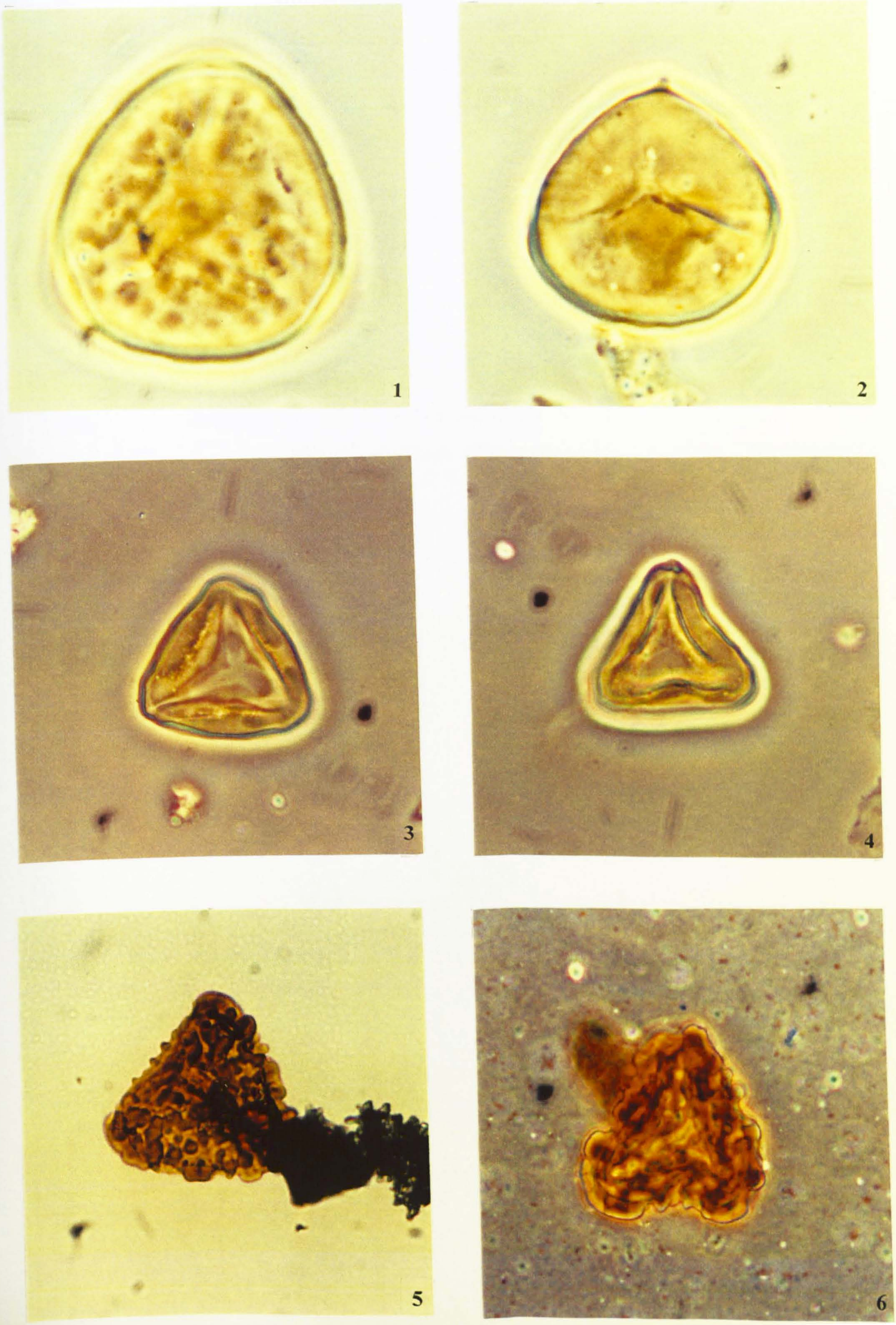


Plate 43

Figure 1 *Triplanosporites microsinuosus*

27/415, 41.00m, slide 1, E33/4, x 400.

Figure 2 *Triplanosporites microsinuosus*

27/415, 41.00m, slide 1, E33/4.

Figure 3 *Varirugosisporites megaverrucatus*

36/4680, 200.33m, slide 1, P32, x 400, ordinary transmitted light.

Figure 4 *Verrucingulatisporites undulatus* subsp. *undulatus*

13/611, 110.00m, slide 4, O45, x 400, ordinary transmitted light.

Plate 43

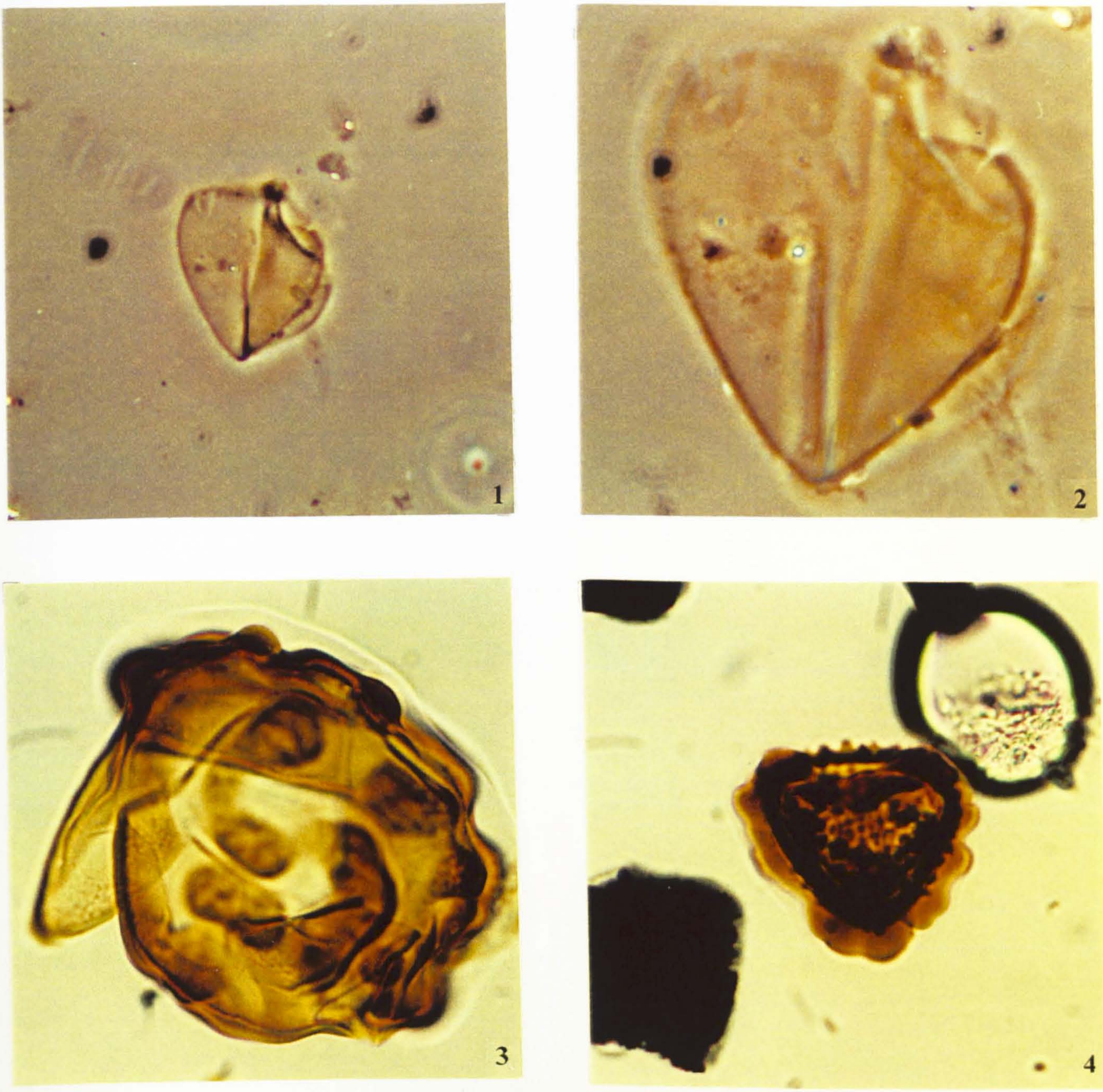
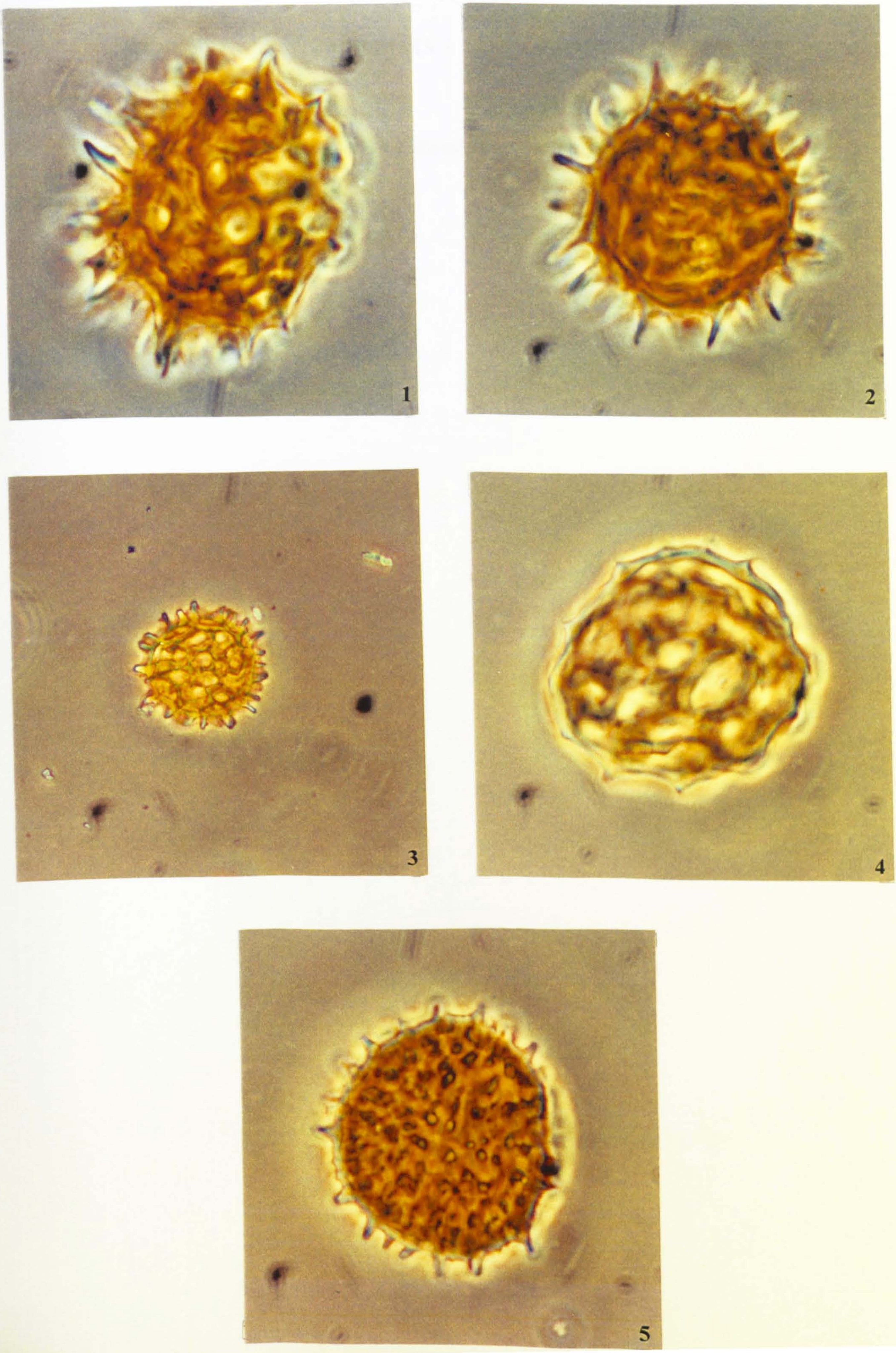


Plate 44

Figure 1	Echinate spore sp. A Holotype 13/611, 100.00m, slide 1, P36.
Figure 2	Echinate spore sp. A 13/611, 100.00m, slide 1, M48/1.
Figure 3	Echinate spore sp. A 13/611, 164.80m, slide 2, M49/4, x 400.
Figure 4	Echinate spore sp. B Holotype 13/611, 100.00m, slide 1, L35/3.
Figure 5	Echinate spore sp. C Holotype 36/4680, 72.05m, slide 1, O49.

Plate 44



APPENDIX 1

Appendix 1 contains tables A1-A4 illustrating the approximate pollen per gram data for the studied sections.

13/611 Landagivey No. 1

Depth (m)	Lithology	Pollen per gram
47.00	Lignite	919 400
60.00	Clayey sand	45 540
69.95	Lignite	393 300
82.00	Clay	25 080
89.00	Clayey lignite	141 900
100.00	Sandy clay	506
110.00	Clay	1 246
121.00	Clayey lignite	2 535 000
131.00	Clay	623
149.12	Lignite + clay	7 922
154.00	Clay	150
155.19	Lignite	Barren
157.41	Clay	78
160.00	Clay	Barren
164.80	Clay	125
166.00	Clay	Barren
170.00	Clay	Barren
174.00	Clay	450
190.00	Clay	Barren
206.00	Clay	65
208.00	Clay	285
209.00	Clay + lignite	22 440
218.00	Clay	Barren
230.00	Clay	25 960
250.00	Clay	Barren
259.58	?Tuff	Barren
260.00	Clay	25
261.00	Clay + lignite	4 400
262.00	Clay	8 800
264.00	?Tuff	Barren
265.65	Clay/?conglom.	Barren

Table A1. 13/611 Landagivey No. 1 approximate pollen per gram data.

13/603 Ballymoney No.1

Depth (m)	Lithology	Pollen per gram
48.00	Clay	97 680
60.00	Clay + lignite	154 880
80.10	Clay + lignite	864 747
100.00	Clay	50 160
120.00	Clay	48107
130.00	Clay + lignite	Not quantitative
150.00	Lignite	808 400
161.19	Lignite	559 200
180.00	Lignite	880 800
200.07	Lignitic clay	640 640
218.60	Clay	64 386
222.74	Lignitic clay	898 773
240.00	Clay	3 850
260.00	Clay	86 240
280.00	Lignitic clay	279 840
290.00	Clay	147

Table A2. 13/603 Ballymoney No. 1 approximate pollen per gram data.

36/4680 Deerpark No. 2

Depth (m)	Lithology	Pollen per gram
72.05	Clay	14 520
80.00	Sandy Clay	2
90.00	Sandy Clay	Barren
103.62	Sandy lignitic clay	11 000
110.00	Clayey sand	158
131.71	Lignitic clay	46 933
140.67	Sandy clay + lignit	14 080
150.56	Sandy clay	Barren
169.05	Sandy clay+ lignite	71
179.20	Sandy clay	4
190.00	Sandy clay	<1
200.33	Clay	5 427
223.18	Lignite	35 710
237.75	Sandy clay	660
242.25	Lignite	36 065
245.30	Lignite	11 000
250.00	Sandy clay	226
259.77	Clay	52
265.13	Clay	42 533

Table A3. 36/4680 Deerpark No. 2 approximate pollen per gram data.

27/415 Upper Mullan No. 1

Depth (m)	Lithology	Pollen per gram
37.30	Sand	7 773
41.00	Clay	374 000
51.00	Clay	219 413
61.00	Clay	308 587
71.00	Clay	132 880
75.95	Lignite	19 597
85.00	Lignite	530 279
102.00	Lignitic clay	138 711
115.00	Lignitic clay	258 720
125.00	Clay	211
131.00	Sandy clay	475
137.00	Clay + lignite	Not quantitative
145.00	Clay	411
151.80	Sandy clay	5 280
153.00	Sandy clay	45
165.00	Clay	9
173.00	Clay	15
175.00	Clay	Barren
181.00	Sand/mini conglom.	9 680
183.34	Clay/weathered basalt	10 368
185.00	Weathered basalt	Barren
195.00	Weathered basalt	2

Table A4. 27/415 Upper Mullan No. 1 approximate pollen per gram data.

APPENDIX 2

Appendix 2 contains descriptions of the cored sections from 13/611, 13/603, 36/4680 and 27/415 supplied by the Geological Survey of Northern Ireland.

13/611 LANDAGIVEY No. 1

Drilling near Agivey, Ballymoney and Stranocum 1984 Phase 1 extension.

Grid reference: Six inch quarter sheet 19 NW C 9100 2112

Location: 2.75 km at 217° from Bendooragh cross roads, Londonderry.

Exact site: Landagivey Townland, south east corner of disused airfield, 150 m east of Carlin's Farm, west bank of the River Bann.

Direction of bore: Down, cored from surface.

Bore made by: Drillsure Ltd.

Information from: Site geologists: F. Crozier and M. Lowther.

Date of sinking: 14.05.84 - 21.05 84.

Geological Classification	Description of strata	Thickness metres	Depth metres
Soil Sub soil	**Soil:** Brown, friable, underlain by light brown firm clay, no cores recovered from top 2.9m.	2.90	2.90
Post Glacial	**Pebbly Clay:** Grey-brown, very soft, top 0.93m slurry, basalt pebbles up to 2cm, very sticky.	0.93	3.83
	Sandy Clay: Grey-brown, soft, laminated.	0.73	4.56
	NCR	0.54	5.10
	Sandy Clay: Grey-brown, soft, sandy, laminated as above, firm.	1.00	6.10
	NCR	1.30	7.40
	Sandy Clay: Grey-brown, soft to firm, laminated	0.92	8.32
	NCR	2.08	10.40
	Clay/Sandy Clay: Alternating laminae of soft to firm brown clay and grey-brown sandy clay, poor recovery at top of core	1.30	11.70
	NCR	1.80	13.40
	Clay: Grey-brown, very soft to soft, slurry, laminated clay and sandy clay, poorly recovered	0.66	14.06
	Sandy Clay: Grey-brown soft sandy clay with thin brown clay bands	0.88	14.94
	EXCESS	0.16	14.78

Post Glacial	**Clay:** Brown, soft to firm, subordinate, grey sandy clay horizons	0.63	15.41
	NCR	0.09	15.50
	Clay: Brown, soft to firm with distinct thin grey sandy clay horizons (3-5mm) possibly a fining upwards cycle	0.55	16.05
	Clay: Brown and grey, laminated, firm to stiff	0.39	16.44
	EXCESS	0.04	16.40
	Clay/Sandy Clay: Brown, firm with grey sandy clay laminae	1.20	17.60
	EXCESS	0.03	17.57
	Clay/Sandy Clay: Interlaminated brown and grey-brown, firm to stiff, medium to coarse sandy laminae toward top, green-grey	0.70	18.27
	NCR	0.68	18.95
	Clay: Brown and grey-brown, laminated, stiff to firm	0.35	19.40
	Clay: Brown, soft, slurry with fragments of firm brown clay	0.25	19.65
	Clay: Brown and grey-brown, laminated, firm to stiff coarse sandy and pebbly laminae at end of run, green-grey with basalt pebbles up to 5mm also quartz, chalk and mudstone granules	0.52	20.17
	NCR	0.20	20.37
	Clay/Sandy Clay: Interlaminated brown clay and grey-brown sandy clay, firm to stiff	0.59	20.96
	NCR	0.29	21.25
	Clay: Brown, soft, slurry recovery with fragments of firm to stiff clay	0.15	21.40
	Clay/Sandy Clay: Brown, firm with thin grey sandy clay laminae	0.30	21.70
	EXCESS	0.15	21.55
	Clay: Poor recovery as slurry, brown, very soft with fragments of firm to stiff clay	0.75	22.30
	Clay/Sandy Clay: Brown firm to stiff clay with grey sandy laminae	0.57	22.87
	EXCESS	0.47	22.40
	Clay: Brown and grey laminated, firm to stiff, with thin grey sandy clay laminae, small (4-5mm) basalt pebbles	0.67	23.07
	Clay: Brown soft to firm, large fragment of basalt boulder, passes into firm brown sticky clay with dark brown-grey laminae	0.50	23.57
	NCR	1.83	25.40
	Clay/Sandy Clay: Interlaminated brown clay and grey sandy clay, very fine-grained, more sandy firm clay	0.70	26.10
	NCR	0.19	25.91

Post Glacial	**Clayey Sand:** Grey to dark grey clayey sand, firm becoming soft to very soft, brown clay band (1mm) at top	0.55	26.44
	NCR	0.08	26.52
	Sand: Fine-grained green-grey, some thin clayey horizons	0.50	27.02
	NCR	0.43	27.45
	Between 27.45 and 31.20 rock bit used, sand wouldn't core, chip samples taken clayey sand		
	NCR	3.75	31.20
Drift Glacial	**Boulder Clay:** Brown, stiff, slightly sand supporting well-rounded basalt clasts, up to 5cm, small quartz fragments, brown mudstone pebbles, small grey sandy clay patches	0.20	31.40
	Boulder Clay: Brown, stiff slightly sandy, pebbles of basalt, quartz, chalk and mudstone, some horizons of fine to medium-grained sand, large pale green quartz pebble (4cm)	0.83	32.23
	Boulder Clay: Large basalt boulders, up to 10cm in a stiff brown pebbly clay, pebbles of basalt, quartz, chalk and mudstone	0.57	32.80
	Boulder Clay: Clast supported, small rounded pebbles of basalt, also fragments pebbles of quartz, chalk and mudstone, clay contains much quartz sand material	1.20	34.00
	EXCESS	0.15	33.85
	Boulder Clay: Clast supported, basalt pebbles up to 3cm, sandy clay matrix, basalt boulders at base, small pebbles of basalt, chalk, quartz and mudstone	0.51	34.35
	NCR	0.05	34.40
	Boulder Clay: Clay supported clasts of basalt, quartz, chalk, mudstone and sandstone, and of ?granite, brown sandstone pebble, more sandy clay toward base	0.55	34.95
	EXCESS	0.10	34.85
	Boulder Clay: Small well-rounded clasts of basalt with minor chalk quartz and mudstone, clay matrix if firm to stiff and sandy	0.28	35.13
	Boulder Clay: Clast-supported, clasts of basalt quartz, chalk, flint, mudstone and red-brown sandstone, occasional large basalt boulder	0.50	35.63
	Boulder Clay: Clast-supported, clasts of basalt quartz, chalk, mudstone and sandstone	0.17	35.80
	Boulder Clay: Large basalt boulders in sandy clay, small quartz pebbles, also some calcite?	0.31	36.11
	Boulder Clay: Clast-supported, well rounded pebbles up to 5cm sandy clay, quartz and chalk fragments	0.45	36.56

Drift Glacial	NCR	0.09	36.65
	Boulder Clay: Clasts of basalt, chalk, quartz, mudstone and sandstone in sandy clay matrix	0.22	36.87
	Boulder Clay: Clast supported, basalt pebbles and boulders up to 9cm pebbles of quartz, chalk, mudstone and possibly granite, sandy clay matrix	1.08	37.95
	EXCESS	0.06	37.89
	Till: Matrix clayey with very high proportion of fine to coarse-grained quartz sand, clasts of basalt, quartz, flint, chalk and possibly granite. matrix supported	0.50	38.39
	NCR	0.16	38.55
	Till: Grey-brown, very sandy clay supporting well rounded small pebbles of basalt, quartz, flint and mudstone	0.44	38.99
	CORE WASHED AWAY NCR	1.00	39.99
	Boulder Clay: Several well rounded loose basalt pebbles up to 4cm passes into grey-brown pebbly sandy clay	0.41	40.40
	Boulder Clay: Grey, fine to medium-grained very stiff sandy clay supporting clasts of basalt, quartz, chalk and mudstone	1.82	42.22
	Sand: Brown, fine to medium-grained quartz sand firm, passes into stiff brown clay at base	0.12	42.34
	NCR	1.06	43.40
	Boulder Clay: Several boulder fragments, thin beds of grey sandy clay and black lignitic clay at base	0.15	43.55
	CORE LOST DUE TO SCRUBBING NCR	2.70	46.25
Lough Neagh Group	**Lignite:** Black, hard, woody, some patches of brown-black clayey lignite	1.25	47.50
	Lignitic Clay: Decreasing lignite content to base becoming grey-brown very stiff clay with wood fragments	0.43	47.93
	Clayey Lignite: Black-brown hard, very clayey, woody	0.44	48.37
	Lignitic Clay: Pale grey, very stiff, brown clay fragment and stringers	0.18	48.55
	Clay: Pale grey, very stiff, slight black mottling	0.30	48.85
	Lignitic Clay: Dark grey, firm	0.30	49.15
	Clay: Grey-dark grey, very stiff, woody fragments, many numerous woody fragments and stringers	0.35	49.50
	EXCESS	0.20	49.30
	Clay: 2-3cm clayey lignite horizon passes into pale grey clay with dark wood fragments and stringers	0.86	50.16
	Lignite: Black, hard woody, 5cm clay bed at base	0.85	51.01

Lough Neagh Group	**Clayey Sand:** Grey to black (black due to lignite straining), increasingly sandy to base, poorly consolidated fining upwards sequence	1.29	52.30
	NCR	0.10	52.40
	Sand: Grey, medium to coarse-grained, clay matrix, black lignitic patches	1.40	53.80
	Clayey Sand: Grey, fine-grained sand, stiff, black woody fragments, brown lignitic staining	0.80	54.60
	SAND WASHED AWAY NCR	0.80	55.40
	Clayey Sand: Grey, poorly consolidated fine-grained quartz sand, clay matrix, becoming brown-grey due to lignitic staining, black woody fragments	1.06	56.46
	SAND WASHED AWAY NCR	1.94	58.40
	Sandy Clay: Grey-brown stiff to very stiff, very sandy, fine-grained, brown lignitic staining occasional lignite fragment and laminae, white-buff flecks, increasingly lignitic to base	3.00	61.40
	Sand: Medium to coarse-grained quartz sand, poorly consolidated, clay matrix, more consolidated towards base, dark lignitic patches	0.40	61.80
	Clay: Sudden change to pale grey stiff to very stiff, slight dark grey-black mottling	0.25	62.05
	Ironstone/mudstone: Very hard, lithified mudstone	0.06	62.11
	NCR	0.34	62.45
	Sand: Medium to coarse-grained poorly consolidated quartz sand, loose clay matrix, grey-dark grey	0.62	63.07
	Ironstone: Fragments of hard lithified mudstone, grey	0.12	63.19
	LOOSE SAND WASHED AWAY NCR	1.21	64.40
	Clay: Pale grey, stiff to very stiff, slight black mottling, occasional black wood fragment, one slightly sandy horizon (5cm), clay mottled towards base	1.80	66.20
	EXCESS	0.20	66.00
	Lignitic Clay/Lignite: Pale grey becoming dark grey then dark brown-black lignitic clay, woody fragments, laminae, stringers, 12cm lignite band at 66.30	0.60	66.60
	Clay: Grey, stiff to very stiff, black wood fragments, more frequent towards base, lignite stringer	0.28	66.88
	Lignite: Black, hard, compact, woody, well preserved woody structure	0.53	67.41
	Lignite: Black, hard, compact, woody fragments	2.60	70.01
	Lignitic Clay: Grey to dark grey and brown, much woody material, hard black lignite stringer, clayey toward base	0.27	70.28

Lough Neagh Group	NCR	0.17	70.45
	Lignitic Clay/Clay: Dark brown to black lignitic clay passes into grey, very stiff clay, black mottling reworked lignite fragments, buff coarse sand grains within the clay at base	2.30	72.75
	Sandy Clay: Grey, packed with hard woody lignite fragments	0.65	73.40
	NCR	0.10	73.50
	Clay/Sandy Clay: Pale grey clay and slight sandy clay, packed with lignite fragments becoming more lignitic.	0.95	74.45
	Clay: Grey to pale grey, very stiff, slight black lignitic mottling, sandy clay patches, small patches of buff, fine-grained sand, occasional lignite fragment	2.16	76.61
	EXCESS	0.11	76.50
	Clay: Pale grey, very stiff, black mottling, sandy clay horizon at top, becoming sandy clay again toward base, gritty	0.49	76.99
	Ironstone: Very hard clay, grey possibly sideritic, less consolidated at top and base	0.38	77.37
	Clay/Sandy Clay: Interbedded, pale grey, stiff, fine to medium-grained sand material, slight black mottling, clay has a purple-grey tinge at base	1.59	78.96
	NCR	0.54	79.50
	Sandy Clay: Grey to blue-grey, fine grained, sandy clay, purple grey time at top, patches of very sandy clay, gritty	1.77	81.27
	Clay: Grey to pale grey stiff to very stiff, very slight black mottling, occasional lignite fragment, slightly clearer toward base. Bottom 15cm very fine grained sandy clay	1.40	82.67
	EXCESS	0.17	82.50
	Clay: Grey, very stiff, lignite fragments	0.15	82.65
	Ironstone: Broken fragments, hard, very fine-grained, possibly sideritic brown lignite fragments	0.08	82.73
	Lignitic Clay/Clayey Lignite: Dark grey-black clay with lignite fragments and laminae, poorly consolidated, passes into very clayey lignite horizon at base	0.45	83.18
	Lignite: Black, hard, woody, clayey patches	1.22	84.40
	Clay: Grey, very stiff, abundant black lignite debris and laminae, near horizontal attitude, buff-brown sandy patches. less lignitic toward base	0.44	84.84
	Ironstone: Hard, very fine-grained, sideritic, black and brown lithified woody fragments	0.30	85.14
	NCR	0.36	85.50

Lough Neagh Group	**Clay/Sandy Clay:** Grey clay with patches of slightly sandy clay, black lignite traces	0.28	85.78
	Liginitic Clay/Lignite: Black lignitic clay with hard lignite laminae	0.23	86.01
	Clay/Sandy Clay: Lignite content disappears in top 5cm, passes into grey clay with occasional black woody fragment, grey sandy clay with hard white ironstone nodules and grey clay at base	0.87	86.88
	Clay/Lignitic Clay: Rapid change to lignitic clay grey to dark grey with black woody laminae, thin clayey lignite horizon and grey clay horizon with abundant black lignitic debris	0.38	87.26
	Clay: Grey, very slightly sandy with sandy clay patches, black mottling, occasional wood fragment	0.70	87.96
	Lignitic Clay/Clayey Lignite: Dark grey firm lignitic clay and hard clayey lignite with lignite fragments and laminae	0.25	87.21
	Lignite: Hard, black compact woody fragments	0.38	87.59
	EXCESS	0.09	87.50
	Lignite: Black, hard, woody with thin clay horizons	0.40	87.90
	Clay/Ligintic Clay: Grey, very stiff, abundant black lignite debris, clayey lignite horizon	0.33	88.23
	Lignite: Black hard, compact occasional fragments of hard black wood, thin clay horizons	2.30	91.53
	EXCESS	0.03	91.50
	Lignitic Clay: Grey-dark grey and black lignitic clay/clayey lignite, very stiff	0.20	91.70
	Clay/Sandy Clay: Pale grey to grey, slight black mottling, black woody fragments, passes into sandy clay with gritty patches	1.13	92.83
	Ironstone: Yellow-grey, very hard, sideritic coarse grained	0.16	92.99
	Sandy Clay: Grey, slight black mottling, sideritic patches	0.27	93.26
	Lignitic Clay: Dark grey to black varies to dark brown to black clayey lignite with black to brown lignite horizon (8cm)	0.37	93.63
	Clay: Grey,very stiff,black mottling lignite fragments,18cm sandy clay horizon, passes into grey very stiff clay, black mottling, darkens and becomes lignitic in bottom 7 cm	0.70	93.33
	Clayey Lignite: Dark brown, clayey with hard, black lignite laminae, becomes very clayey at base	0.35	94.68

Lough Neagh Group	**Lignitic Clay/Clay:** Grey,very stiff mottled with black lignite fragments, several dark grey to black lignitic clay/clayey lignite laminae	0.98	95.66
	Clayey Lignite: Black, hard	0.35	96.01
	Sandy Clay: Grey to blue-grey, very stiff, faint black mottling	1.48	97.49
	Sandy Clay:Grey to blue-grey, as above with three hard thin ironstones beds	3.00	100.50
	Sandy Clay: Grey to blue-grey, small very sandy patches, gritty, 6 thin, hard, ironstone bands, scattered small ironstone nodules, sideritic, slight purple tinge toward base	3.00	103.50
	Sandy Clay: Grey to blue-grey, very stiff, slightly sandy, numerous white grains, occasional buff ironstone nodules and patches and thin ironstone bands	3.00	106.50
	Sandy Clay: Grey to blue-grey, very stiff to hard faint black mottling, hard buff to white ironstone patches and thin beds less sandy	3.00	109.50
	Clay/Sandy Clay: Grey, hard, black mottling,sandy clay horizons, hard ironstone bands and nodules, sideritic, more sandy in bottom 1cm	3.00	112.50
	Sandy Clay: Grey to pale grey, very stiff to hard, faint black mottled patches, fragments of sideritized wood in ironstone band in bottom 20 cm sand content decreases clay darkens and is mottled with black lignitic material	1.45	113.95
	Lignitic Clay/Clayey Lignite: Interbedded dark grey lignitic clay and black clayey lignite hard black woody laminae small buff ironstone nodules	0.68	114.63
	Lignite: Black, hard, compact thin clayey and woody laminae	0.90	115.53
	Lignite/Clayey Lignite: Black, hard with clayey lignite horizons, woody laminae fragments, thin beds of grey clay	2.37	117.90
	Clay/Lignitic Clay: Grey to dark grey, very stiff to hard abundant black woody fragments and laminae, more lignitic towards base	0.50	118.40
	Clayey Lignite: Black, hard, very clayey	0.12	118.52
	Lignite: Black, hard, very clayey lignite horizons, fragments of woody material	3.00	121.50
	Lignite: Black, hard, compact three grey clayey horizons containing black lignite fragments	2.58	124.08
	Clay/Sandy Clay: Grey, very stiff, black and brown woody fragments, clay slightly sandy, passes into grey sandy clay with numerous isolated white grains	0.50	124.58
	EXCESS	0.08	124.50

Lough Neagh Group	**Clay/Sandy Clay:** Grey to dark grey, hard, black mottling, darker lignitic horizons, numerous thin sandy clay horizons, gritty	1.90	126.40
	Lignite: Black-brown, hard, well compacted, several thin clayey horizons, bands of hard woody material	0.97	127.37
	Clay: Grey, very stiff to hard, packed with thin lignite fragments	0.20	
	EXCESS	0.07	127.50
	Clay/Clayey Lignite: Grey to dark grey, hard, abundant brown woody fragments and laminae	3.00	130.50
	Clay/Clayey Lignite: Grey to dark grey, hard, occasional black lignite lamine	0.40	130.90
	Sandy Clay: Blue-gray, faint black mottling, occasional black woody fragment	0.73	131.63
	Ironstone: Very hard, fine-grained sideritic	0.26	131.89
	Sandy Clay: Grey, very sandy, abundant white grains (? Clay)	0.24	132.13
	Clayey Lignite: Black, hard	0.08	132.21
	Clay: Grey, very stiff, friable, faint black-brown lignitic mottling, occasional hard black woody fragment	1.50	133.71
	EXCESS	0.21	133.50
	Clay: Blue-grey, very stiff, lignite traces, small nodules of buff ironstone	0.57	134.07
	Clay: Blue-grey, very stiff, lignite traces, ironstone fragments becoming more sandy towards base	0.39	134.46
	Ironstone: Hard, buff, sideritic	0.14	134.60
	Clay: Blue-grey, very stiff, lignite traces becoming very sandy to sandy, thin ironstone band at base	0.67	133.27
	hard woody lignite band at top, thin clayey lignite at base	0.20	135.47
	Clay: Blue-grey, very stiff, woody laminae and fragments, sandy to very sandy in the middle	0.54	136.01
	Lignitic Clay: Dark brown to brown-grey, very stiff, irregular banding, less lignitic toward base, brown-yellow, hard sideritic patch near top, sandy patches near base	0.49	136.50
	Clay: Blue-grey, very stiff, sandy near top, lignite traces increasing towards base, grey-brown	0.36	136.86
	Lignite: Dark brown to black, hard, clayey and woody lamine, clayey at base	0.15	137.01
	Clay: Blue-grey, very stiff, lignite traces, lignitic at top, brown-grey, sandy at base	0.34	137.35

Lough Neagh Group	**Clay:** Blue-gray, very stiff, grey-brown lignitic band at top, thin clayey lignite horizon and ironstone fragment, brown lignite laminae, sandy patches, ironstone patches in lower half	0.24	139.59
	EXCESS	0.09	139.50
	Clay: Blue-grey, very stiff, lignite traces, small patches of brown staining	0.19	139.69
	Lignitic Clay/Lignite: Black to brown-grey, very stiff to hard, irregular banding. Woody lignite band, less lignitic towards base	0.53	140.22
	Clay: Brown-grey to blue-grey, very stiff, lignite traces, yellow-brown bands sandy at base	0.45	140.67
	Clay: Blue- grey, very stiff to hard, pinky-brown patches, thin ironstone bands, sandy patches, lignite traces	1.85	142.52
	EXCESS	0.02	142.50
	Clay: Blue to grey-blue, very stiff, sandy patches lignite traces, 5cm ironstone band near top, 14cm band near base, both buff, hard	1.57	144.07
	Clay: Blue-grey to grey-blue, very stiff, some purple-brown patches near base, sandy to very sandy, thin ironstone bands (up to 9cm) lignite traces	1.44	145.51
	EXCESS	0.01	145.50
	Clay: Blue-grey, very stiff, purple-brown patches sandy to very sandy in places, lignite traces, ironstone bands (5cm, 12cm) brown grey clay with lignite traces towards base	1.87	147.37
	Clay: Blue-grey to brown-grey, very stiff, hard ironstone patches, lignite traces and laminae	1.28	148.65
	EXCESS	0.15	148.50
	Clay: Blue-grey, very stiff, sandy, hard, sideric patch near top, small ironstone nodules, some white (?clay) grains, woody fragments	0.45	148.95
	Lignite: Grey-brown to black, very stiff to hard, bands of clayey lignite and lignite clay, woody laminae, white (clay) grains	0.94	149.89
	Pebbly Clay: Blue-grey, very stiff, slightly conglomeratic, several lignite bands passes into granular conglomerate, rounded, white, brown, buff, and blue-grey clay pebbles, blue-grey clay matrix, vague fining upwards cycle, ironstone band at base	0.73	150.62
	Conglomerate: Very stiff, granular as above, lignite fragments and laminae, large wood fragments, hard ironstone band near base	0.94	151.56
	EXCESS	0.06	151.50

Lough Neagh Group	**Conglomerate:** Very stiff, as above, granular lignite fragments and band, ironstone fragmentat base	0.94	152.44
	lignite fragments, white (clay?) grains, hard ironstone patches	1.58	154.02
	Clay: Blue-grey, very stiff, brown-grey wuth whute clay grains	0.55	154.57
	EXCESS	0.07	154.50
	Lignitic Clay/Ironstone: Brown-grey to dark brown, laminated, very stiff to hard, 10cm buff, hard, ironstone band	0.48	154.98
	Conglomerate/Sandy Clay/Ironstone: Top is brown to blue-grey sandy clay with white clay grains, lignite traces, slightly conglomeratic below passes into 12cm ironstone band with pebly conglomerate at base containing multicoloured, rounded clay clasts	1.64	156.62
	Clay: Blue-grey with dark blue-grey patches, very stiff, some sandy patches	0.68	157.30
	NCR	0.11	157.41
Dunaghy Formation	**Clay:** Blue-grey, very stiff to hard, grey- black at top, 30cm very sandy sideritic band, brown some ironstone patches, purple-brown mottling	3.18	160.59
	EXCESS	0.09	160.50
	Clay: Blue-grey and brown-purple, mottled becoming brown and brown-purple, mottled at base	0.24	160.74
	Clay: Brown-purple to brown, mottled, very stiff to hard, crumbly becoming yellow-brown with blue-grey patches, sandy to verysandy, sideritic, hard buff ironstone patches, some patches of less sandy clay	2.92	163.66
	EXCESS	0.16	163.50
	Clay: Yellow-brown to khaki, very stiff, blue-grey patches, brown-orange mottling variably sandy, sideritic	17.42	180.92
	Clay: Khaki to brown and blue-grey, mottled, mainly orange-brown at base with orange-brown mottling slightly sandy near top, less sands toward base	0.63	181.55
	Clay: Orange-brown at top, very stiff, becoming khaki with blue-grey and orange-brown mottling occasional blue-grey patch and faint brown mottling, slightly sandy at top passing into very sandy clay then less sandy again toward base	2.72	184.27
	Clay: Khaki with blue-grey and dark khaki mottling very stiff, slightly sandy	0.33	184.60
	EXCESS	0.05	184.55

	Clay: Khaki with orange-brown patches, very stiff sheared, blue-grey mottled patches, other orange-brown and khaki patches, slight sandy to sandy, sideritic	3.05	187.60
	Clay: Orange-brown, very stiff	0.10	187.60
	EXCESS	0.15	187.55
	Clay: Orange-brown, very stiff, becoming khaki and orange-brown again at base with khaki mottling, blue-grey and khaki spots becoming sandy to base	2.98	190.53
	NCR	0.02	190.55
	Clay: Khaki and orange-brown with a few blue-grey patches, very stiff, slightly sandy to sandy	0.19	190.74
	Clay: Khaki, blue-grey, orange-brown and brick red mottled, very stiff, predominatly khaki, uniform orange-brown toward base, top 60cm are sandy, less sandy towards base	2.84	193.58
	EXCESS	0.03	193.55
	Clay: Orange-brown to khaki and blue-grey, very stiff, mottled, becoming brown-orange at base, few siderite grains	0.55	194.10
	Clay: Red and orange-brown, very stiff thin blue-grey bands khaki and brick-red mottling, lignitic traces ? Very sandy at top passing into slightly sandy clay	2.50	196.60
	EXCESS	0.05	196.55
	Clay: Red-brown with indistinct khaki and brick-red mottling, very stiff, lingnite trace slightly sandy at base	0.79	197.34
Dunaghy Formation	**Clay:** Red-brown, very stiff for to 1.20 m then becoming khaki with few blue-grey patches, lignite traces?	2,24	199.58
	EXCESS	0.03	199.55
	Clay: Khaki with blue-grey patches in top 70cm becoming red-brown with khaki mottling and blue-grey patches to base, very gritty near base	1.16	200.71
	Clay: Red-brown with khaki mottling becoming khaki with blue-grey patches, some red-brown patches, very stiff, very sandy, almost mini-conglomerate at base, clay grains,varying colours	4.88	205.59
	EXCESS	0.04	205.55
	Clay: Micro-conglomerate, clay grains of varying colours in blue-grey matrix, very stiff, passes into blue-grey and dark grey clay with khaki patches and mottling, lignite traces, non-sandy to very sandy	2.06	207.61
	Clay: Blue-grey with khaki-grey bands, very stiff grey-blue at base, sandy near top with sandy patches at base	0.93	208.54

	NCR	0.01	208.55
	Clay: Grey-blue, very stiff becoming grey and khaki-grey, sandy, sideritic	0.45	209.00
	Clayey Lignite: Dark brown to black, very stiff thin lignitic clay bands, sandy	0.28	209.28
	Clay: Grey-brown with blue-grey patches, very stiff, lignitic at top, dark brown, few lignite fragments	0.54	209.82
	Conglomerate: Brown clay matrix, very stiff with coloured clay granules, rounded, few blue-grey patches, sideritic in places, lignitic laminae, small pebbles bear base, too thin ironstone bands	0.90	210.72
	Clay: Blue-grey, very stiff, khaki laminae near base, lignite traces, sandy at base	0.34	211.06
	Clay: Blue-grey, very stiff, sheared, slightly sandy at top becoming very sandy towards base	0.56	211.62
	EXCESS	0.07	211.55
	Clay: Blue-grey, very stiff, very sandy, hard buff ironstone patches, dark brown to khaki patches becomes mottled with red-brown	2.79	214.34
	Clay: Brown-red with khaki and blue-grey mottling very stiff, slightly sandy	0.29	214.63
	EXCESS	0.08	214.55
Dunaghy Formation	**Clay:** Red-brown to brown-red, mottled very stiff becoming khaki at base some blue-grey patches and brick-red mottling, slightly sandy, ironstone nodules and bands	3.04	217.59
	EXCESS	0.04	217.55
	Clay: Khaki at top, very siff passes down into brick red with khaki mottling, slightly gritty	3.13	220.68
	EXCESS	0.13	220.55
	Clay: Brick-red, very stiff to hard, homogeneous	7.14	227.69
	Clay: Brick-red, very stiff to hard, homogeneous bottom 40cm is brick-red with khaki laminations then blue - grey with khaki patches, sandy blue-grey clay	1.95	229.64
	EXCESS	0.09	229.55
	Clay: Blue-grey, very stiff to hard at top, passes into grey lignitic clay for 70cm, grey to dark grey-black laminated clay blue-grey clay with dark blue-grey patches and thin khaki bands sandy coarse, rounded grains of grey, buff, off-white and brick red clay	1.46	231.01
	Clay: Grey, very stiff to hard, gritty, some lignitic clay, lignite laminations, faint brown-red mottling toward base	1.56	232.57
	EXCESS	0.02	232.55
	Clay: Grey becoming brick-red with grey mottling very stiff to hard, grey colour disappears toward base	1.87	234.42

Dunaghy Formation	**Clay:** Brick-red, very stiff to hard, sandy passing into slightly sandy, faint blue-grey mottling near the top	3.35	237.77
	Clay: Brick-red, very stiff to hard, homogeneous occasional brown and blue-grey patch	9.78	247.55
	Clay: Brick-red, very stiff to hard, homogeneous grades into brown, red and yellow, patchy mottled clay	3.30	250.58
	EXCESS	0.03	250.55
	Clay: Brick-red, very stiff to hard, brown and red-brown mottling variably sandy, red-brown toward base	8.29	258.84
	Clay (Tuff?): Brick-red and blue-grey, irregular banded, very stiff to hard, very sandy with angular yo sub-angular coarse-grained fragments mainly white, two hard ironstone patches	0.64	259.48
	NCR	0.07	259.55
	Tuff?: Blue-grey, very stiff to hard, packed with white angular coarse grains volcanic ash	1.33	260.88
	Clay/Lignitic Clay: Grey with black lignitic laminae, very stiff to hard, sandy, angular coarse grains near base	0.31	261.19
	Lignitic Clay/Clayey Lignite: Grey to black laminated, very stiff to hard, sandy	0.36	261.55
	Lignitic Clay: Grey at top becoming more lignitic to base, very stiff to hard, very sandy, angular coarse grains, woody laminae near base	1.16	262.71
	EXCESS	0.16	262.55
	Clay (Tuff): Blue-grey, very stiff to hard, numerous angular fragments of coarse grained material, woody lignite fragment at top, several pinky-red bands; two hard ironstone bands (10cm) at the top and near base, top band contains rounded clasts up to 5cm, lower band is red-brown with white and yellow-brown pyygmatic veins; possibly weathered igneous material, basal layer contains rounded clay pebbles	1.87	264.42
	Clay and conglomerate: Brown, blue-grey and red, laminated very stiff to hard, rounded and angular coarse grains, some granules passes into granular conglomerate in blue-grey matrix, yellow-brown staining	1.07	265.49
	NCR	0.06	265.55
	Conglomerate: Very stiff to hard, coarse grains to small pebble-sized clasts, rounded, mainly of clay, blue-green clay matrix with yellow-brown staining	0.78	266.33
Antrim Lava Group	**Weathered Basalt:** Turquoise-green, very stiff to hard with yellow-brown patches/bands toward base, highly altered	0.63	266.96
	Clay: Yellow-brown, hard, crumbly, weathered basalt sideritized?	0.14	267.10

Antrim Lava Group	**Weathered Basalt:** Green, red, brown, yellow, speckled/mottled clay, very stiff to hard highly weathered	0.69	267.79
	Weathered Basalt: Brick-red with some green mottling and yellow-brown laminations, very stiff to hard passes into green clayey material with white mottling, hard rubbly brown and scoriaceous near base, igneous texture at base	0.95	268.74
	Weathered Basalt: Green, faint igneous texture, very stiff to hard, brick-red patches, few thin hard rubbly laminae, yellow-brown,becomes brick-red with green patches, amygdaloidal at base	2.53	271.08
	Weathered Basalt: Bright red-purple, very stiff to hard with green and white amygdals, relict igneous texture	0.40	271.48
	NCR	0.07	271.55
	Weathered Basalt: Brick-red, very stiff to hard, crumbly becomes purple and amygdaloidal passes down into blue-purple net veined	3.20	274.75
	EXCESS	0.20	274.55
	Weathered Basalt: Dark grey to dark purple-grey and dark blue, less weathered than above, white and yellow-brown net veining	2.87	277.42
	Weathered Basaly: Dark green, hard, conchoidal fracture, bottle-green patches, glassy	0.26	277.68
	EXCESS	0.13	277.25
	Basalt: Dark green, hard, calcite? Veins, white soft soapy section dark brown and light green more weathered	3.12	280.67
	EXCESS	0.12	280.55
	End of Borehole		

13/603 BALLYMONEY No. 1

Drilling near Ballymoney 1983/1984.

Grid reference: Six inch quater sheet 17 NW C 9513 2554

Location: 200 m at 34° from Ballymoney Railway Station.

Exact site: Glebe townland; 400 m at 47° from Ballymoney town centre.

Direction of bore: Down, open hole drift, cored to base.

Bore made by: Drillsure Ltd.

Information from: Site geologists: F. Crozier and M. Lowther.

Date of sinking: 16.04.84 - 25.04 84.

Geological Classification	Description of strata	Thickness metres	Depth metres
Fill / Domestic Rubble	**Fill:** Grey, non-calcareous, fine-grained sandy clay with fragments of basalt, chalk quartz, flint, mudstone and cinder.	3.78	3.78
	Fill: As above but clay is calcareous.	6.10	9.88
	Fill: Grey-brown, calcareous sandy clay with fragments of basalt, chalk, quartz, cinder fragments and flecks of yellow and orange-brown material (domestic rubble)	3.05	12.93
	Fill: Grey-brown, calcareous sandy clay with fragments of basalt, chalk, quartz, mudstone and cinder	3.05	15.98
Drift	**Boulder Clay:** Pale brown sandy clay, calcareous with small basalt fragments and traces of chalk and quartz, some cinder fragments, probably contamination	12.20	28.18
	Boulder Clay: Pale brown-grey calcareous sandy clay with broken basalt fragments, traces of chalk and quartz	6.10	34.28
Lough Neagh Group	**Lignitic Clay:** Black to dark grey lignitic clay much black woody lignite, some calcareous sandy material	3.05	37.33
	Clay/Lignitic Clay: Soft, pale grey with some dark grey harder clay mixed in. Top 40cm probably fallen material as basalt and chalk clasts are mixed in	0.40	37.73

(Rafted Block?)	**Lignite:** Black to dark brown, very stiff, clayey, grey to pale grey interbedded horizons toward top, becomes clayey again toward base	0.60	38.33
	Clayey Lignite/Clay: Interbedded, clay horizons are pale grey, packed with lignitic material. Lignitic horizons are very stiff, black and clayey. Thin ironstone sand within a grey clay horizon at 38.59m	0.73	39.06
	Lignitic Clay: Dark grey to brown, very stiff, much lignitic material, some buff coloured clay mottling	0.18	39.24
	Clay: Pale grey, very stiff, slightly sandy, traces of lignite	0.15	39.39
	NCR	0.02	39.41
	Lignitic Clay: Pale grey, very stiff with dark grey lignitic mottling, passes into dark grey lignitic clay with several black to dark brown clayey lignite horizons, woody fragments throughout	2.59	42.00
	Ironstone: Buff, hard, sandy, sideritic. Black lignite material within the ironstone passes into partly lithified clay at base	0.35	42.35
	Lignitic Clay/Clayey Lignite: Interbedded lignitic clay and dark grey-black clayey lignite, woody fragments throughout, clay, stiff, occasional pale grey patches, several hard black lignite stringers	1.13	43.38
	Lignitic Clay: Grey-black firm to stiff, slightly sandy, black woody fragments	0.21	43.59
Drift	**Pebbly Clay:** Dark green-grey, stiff clay supporting small rounded pebbles of dark green basalt, quartz, chalk and much dark brown woody lignite. Looks like a boulder clay - non-lithified fine conglomerate. Basalt clasts up to 4cm diameter. Reworked lignite fragments. Siderite nodule	2.40	45.99
Lough Neagh Group	**NCR**	0.15	46.14
	Clay: Pale grey slightly sandy, black mottling with black lignitic material, passes into dark grey lignitic clay. Occasional fragments of buff, hard sandy material, probably sideritic. Passes down into pale grey clay with black woody fragments. Sandy at base with several large, hard, buff siderite nodules	0.93	47.07
	NCR	0.86	47.93
	Clay: Pale grey, soft to firm, slightly sandy, some black mottling and small black woody fragments. Top section (47cm) of core run poorly recovered. More sandy horizon at 48.65-48.90	1.15	49.08
	Ironstone: Pale blue-grey, hard, sandy, sideritic	0.20	49.28

Lough Neagh Group	**Sandy Clay:** Pale blue-grey, firm to stiff, slightly sandy, black-dark grey mottling some small buff coloured sandy patches	0.28	
	EXCESS	0.10	49.38
	Clay: Pale blue-grey slightly sandy, stiff black mottling, occasional more sandy horizon, black wood fragments	0.85	50.23
	Ironstone: Grey, hard, sandy, sideritic badly broken	0.20	50.43
	Sandy Clay: Grey, firm to stiff, slightly sandy, slightly dark grey-black mottling	0.20	50.63
	Lignitic Clay: Grey-dark grey, stiff, black wood fragments and laminae, thin beds of brown sand pass down into brown sandy lignitic clay	0.80	51.43
	Sandy Clay: Grey, firm to stiff slightly sandy, black mottling, becomes pale grey, traces of lignite, small siderite nodules within more sandy bands	0.72	52.15
	NCR	0.18	52.33
	Clay: Grey, stiff, black lignitic laminae and very thin lenses. Lignitic material throughout. Reworked lignite fragments. Hard black stringer 53.05-53.15 passes down into grey clay with lignite fragments	0.85	53.18
	Lignite: Marked change to black, hard slightly clayey lignite, crumbly	0.18	53.36
	Clay: Pale grey, stiff, some black mottling, thin lignite fragments and laminae, becoming sandy	0.68	
	EXCESS	0.04	54.00
	Lignitic Clay: Dark grey, stiff, black wood fragments	0.31	54.31
	Sandy Clay: Pale grey, stiff, harder more sandy horizon 54.47-54.52, partly lithified. Slight black mottling - becoming increasingly lignitic toward base	0.44	54.75
	Lignite: Sharp change to hard black lignite contact dips to 10o-20o, lignite is hard, woody with some clayey horizons stiff, crumbly	0.58	
	EXCESS	0.08	55.25
	Ironstone: Grey, soft clay above a thin hard lithified ironstone horizon. Casing reamed to 51m before this core was recovered - soft clay is probably fallen material	0.14	55.39
	Lignite: Black-brown, hard, woody lignite	0.11	55.50
	Clayey Lignite: Black-brown clayey lignite - lignite with thinly bedded clay bands becoming more clayey	0.31	55.81
	Clay/Lignitic Clay: Grey-dark grey, very stiff black lignitic material throughout. Black to dark grey mottling, occasional wood fragment	0.43	56.24
	Clayey Lignite: Black firm, very clayey, thin hard black band within clayey horizon	0.13	56.37

	Clay/Lignitic Clay: Grey-dark grey, stiff to very stiff, mottled, black lignite fragments and laminae. Thin very sandy clay horizon 57.66 - 57.70 - buff coloured very fine-grained	1.42	57.79
	Ironstone: Buff to black, very hard, sandy black lignite clasts	0.20	57.99
	NCR	0.51	58.50
	Lignitic Clay: Sandy packed with fragments of lignite, more sandy toward base, fine-grained	0.20	58.70
	Clay: Pale grey, stiff, slightly sandy, black mottling, which decreases toward base, clay becomes more sandy, very fine-grained	0.96	59.66
	Ironstone: Buff to grey, very hard, coarse-grained, sideritic	0.08	59.74
	Clay: Grey-dark grey, stiff, sandy patches, slight black mottling - leaf impression, patches and fragments of buff to brown sandy material	1.30	61.04
	Ironstone: Buff-grey, hard sideratic - only partly lithified at base	0.16	61.20
	NCR	0.21	61.41
Lough Neagh Group	**Sandy Clay:** Grey-dark grey, stiff, slightly lignitic at top. Buff coloured grains throughout; slight black mottling, clayey lignite horizon 62,08-62.14 with some sandy material	0.73	62.14
	Ironstone: Buff-grey, very hard, sideritic with some black lignite fragments	0.33	62.47
	Lignitic Clay: Thin horizon of non lithified ironstone passes into very clayey lignitic horizon	0.15	62.62
	Sandy Clay: Buff, very sandy, partly lithified becoming clayey with dark grey lignitic clay bands towards base	0.12	62.74
	Clay: Dark grey-grey, stiff, decreasing lignitic content to base, white-buff sandy patches, passes into pale grey clay with slight black mottling, several hard black stringers, passes down into broken grey clay with buff-brown sandy material in bottom 15cm	0.77	63.51
	NCR	0.02	63.53
	Clay/Lignitic Clay: Dark grey-black patchy clay and lignitic clay, some buff sandy material passes into pale grey stiff clay, slightly sandier and darker toward base	0.68	64.21
	Ironstone: Buff-grey, hard, coarse-grained, sideritic with black lignitic fragments	0.11	64.32
	Clay/Lignitic Clay: Grey-dark grey, stiff, much black lignitic material, several sandy horizons, thin ironstone band 65.38-65.40. More lignitic with fragments and laminae toward base	1.39	65.71

Lough Neagh Group	**Lignitic Ironstone:** Sideritized, completely lithified black-brown lignite, very hard	0.08	65.79
	Clay: Pale grey to grey, stiff, black lignitic mottling occasional woody fragment	0.30	66.09
	Lignite: Black, hard woody, partly lithified sideritic	0.13	66.22
	Clay/Sandy Clay: Pale grey to dark grey, stiff, more sandy horizons buff-grey coloured black wood fragments	1.32	67.54
	EXCESS	0.13	67.41
	Lignitic Clay: Grey-dark grey, stiff, black woody fragments, patches of dark grey lignitic clay and lignite laminae. Becoming increasingly lignitic with thin clayey lignite bands, slightly sandy toward base	1.08	68.49
	Clayey Lignite/Lignite: Thin black clayey lignite and lignite horizons within thicker lignitic clay bands, very clayey, firm to stiff	0.71	69.20
	Lignite: Black to brown, stiff to hard, slightly clayey with thin lignitic clay partings and lenses. Becoming very clayey	1.65	70.85
	EXCESS	0.19	70.66
	Lignitic Clay: Grey, stiff, packed with black woody fragments some larger reworked fragments thin laminae dipping approx. 20°	0.60	71.26
	Lignite: Marked change to hard, black woody lignite, partly sideritized, well-preserved wood structure. Sandy, sideritic buff-brown horizon at 73.81 - 73.93; some thin clay horizons separate thicker lignite bands ironstone horizon at 72.75 - 72.80.	1.53	72.79
	NCR	0.14	72.93
	Lignitic Clay/Clayey Lignite: Black-brown, firm to stiff clay and clayey lignite horizons with hard black lignite stringers and laminae	0.45	73.38
	Lignitic Clay: Dark grey, stiff, much hard black lignitic material mostly as laminae and stringers (up to 6cm) or reworked fragments	1.67	75.05
	Clay: Light grey, marked change from lignite above. Small lignite clasts occur in band at the top - pass down to grey-dark grey stiff mottled clay with occasional black woody fragments, some sandy patches	1.00	76.05
	Ironstone: Buff-grey, very hard, sideritic, coarse-grained, with black wood fragments	0.20	76.25
	Clay: Grey, very stiff, slightly sandy becoming increasingly sandy, slight black mottling	0.23	76.48

Lough Neagh Group	EXCESS	0.10	76.38
	Clay/Lignitic Clay: Grey sandy clay gradually passes into grey-dark grey clay with much lignitic material in the form of laminae and fragments, all nearly horizontal; ironstone band at 76.86-76.91	1.55	77.93
	Lignitic Clay: Towards base clay darkens with increased lignite content, several hard black stringers, laminae and thin fragments show sub-horizontal dip	1.07	79.00
	[DROPPED CORE] NCR	0.38	79.38
	Lignite: Thin hard black	0.12	79.50
	Lignitic Clay: Dark grey, stiff, horizontal laminae, thin fragments of lignite, some stringers and reworked fragments	0.46	79.96
	Lignite: Black, hard, partly sideritised	0.08	80.04
	Lignitic Clay: Passes down into grey-dark grey, stiff to hard, much lignitic material, laminae and reworked fragments - bottom 10cm comprise sandy clay which is less lignitic	1.20	81.24
	Ironstone: Pale yellow-grey, very hard, coarse-grained	0.13	81.37
	Clay/Sandy Clay: Grey, sandy clay passes down into stiff grey clay with black mottling and occasional wood fragment, several sandy clay horizons. Shallow to steeply angled shear planes (up to 45°)	1.12	82.49
	Excess due to dropped core being recovered		
	EXCESS	0.33	82.16
	Clay: Grey, firm becoming dark grey, lignitic	0.09	82.25
	Ironstone: Sharp contact with clay above, grey-buff, very hard, coarse-grained, sideritic	0.10	82.35
	Clayey Lignite: dark grey-black, stiff to very stiff, with hard black laminae fragments and stringers, some slightly sandy horizons. Steeply angled fracture plane	1.74	84.09
	Ironstone: Pale grey-buff, very hard, medium to coarse-grained, sideritic	0.09	84.18
	Lignitic Clay: Black-dark grey, much lignitic material, laminae and reworked fragments	0.31	84.49
	Ironstone: Lignitic clay band as above but replaced by very hard siderite	0.19	84.68
	Clay: Pale grey, stiff, black mottling, traces of lignite, some parts more sandy, sideritic, partly lithified	0.67	85.35
	EXCESS	0.18	85.17

Lough Neagh Group	decreasing sand content downwards becoming light grey very stiff clay with black mottling, several black woody lignite laminae reworked fragments, horizontal bedding	1.17	86.34
	Ironstone: Sharp contact with buff-grey, very hard, sideritic coarse-grained ironstone	0.11	86.45
	Clay: Grey, very stiff, black mottling, lignite laminae and fragments horizontal bedding	0.14	86.59
	Ironstone: Buff-grey, very coarse-grained hard, sideritic	0.10	86.69
	Clay: Grey, very stiff, black mottling, occasional woody fragment, two sandy clay horizons 87.12 - 87.14 and 87.25 - 87.30	0.83	87.52
	Ironstone: Thin buff-grey, very hard sideritic	0.05	87.57
	Sandy Clay: Grey, stiff, slight black mottling	0.13	87.70
	Clay: Grey, stiff to very stiff, black mottling, occasional black woody fragments, becoming sandy near base	0.50	88.20
	NCR	0.07	88.27
	Clay: Grey, very stiff, black mottling,	0.20	88.47
	Ironstone: Buff-grey very hard, lithified, coarse-grained, sideritic, some brown staining	0.10	88.57
	Clay: Grey, very stiff, slightly sandy, black mottling, horizontally bedded thin black woody fragments	0.70	89.27
	Ironstone: Buff-grey, very hard, granular, sideritic with some black lignite fragments	0.25	89.52
	Clay/Sandy Clay: Grey, stiff, slightly sandy black mottling some more sandy horizons	0.73	90.25
	Ironstone: Buff-grey, very hard, granular, traces of black lignite	0.18	90.43
	Sandy Clay: Grey, slightly sandy, stiff, slight black mottling, clayey horizons	1.00	91.43
	EXCESS	0.06	91.37
	Ironstone: Grey-buff, very hard, granular, sideritic	0.23	91.60
	Clay: Grey,very stiff, black mottling, occasional lignite fragment	0.23	91.83
	Ironstone: Grey, hard, very coarse grained, sideritic not completely lithified, thin 3cm clay band separating two ironstone bands	0.20	92.03
	Clay: Brown to grey, very stiff, sandy at top fragments and traces of lignite becoming more lignitic to base	0.20	92.23
	Clay: Brown to grey, very stiff, buff sandy patches (sideritic), traces and fragments of lignite	0.36	92.59
	Ironstone: Yellow-grey, hard, clayey at top and bottom where core browner sandy and very stiff	0.09	92.68

Lough Neagh Group	**Clay:** Brown to grey, very stiff lignitic speckling and mottling, some lignite fragments, clay is sheared. Patches of sideritic sand toward base	0.91	93.59
	Ironstone: Yellow-grey, hard, clayey at top and base, lignite fragments	0.10	93.69
	Clay: Brown-grey, very stiff, lognitic speckling, some stringers and fragments, very sandy horizon in the middle - sideritic	0.86	94.55
	NCR	0.19	94.74
	Clay: Brown-grey and grey-brown, very stiff, harder sandy patches near the top and bottom, lignitic mottling, rare lignite fragments and stringers darker more lignitic band near base	1.00	96.74
	Clay: Brown-grey to grey-brown, darker more lignitic patch toward top, very stiff, hard granular sideritic patches, lignitic mottling, some large woody fragments e.g. 96.70-96.80 and 97.32 - 97.41	1.67	97.41
	Ironstone: Yellow-grey, hard, clayey at top and base, lignite fragments	0.09	97.50
	Clay: Brown-grey, very stiff, harder sandy patches, lignitic mottling woody fragment	0.43	97.93
	EXCESS	0.36	97.57
	Clay: Brown-grey, very stiff, lignitic speckling, sandy patches	0.32	97.89
	Ironstone: Yellow-grey, hard, nodule	0.05	97.94
	Clay: Brown-grey, very stiff, sandy	0.04	97.98
	Lignite: Dark brown, hard, woody, lignite fragment with clay patches	0.08	98.06
	Lignitic Clay: Brown-grey to grey-brown, very stiff, becoming increasingly lignitic with traces and fragments of lignite, laminated lignitic clay, brown granular sideritic laminae to base, sheared	0.44	98.50
	Ironstone: Yellow-grey, hard, lignitic to base	0.10	98.60
	Clay; Brown-grey, very stiff, lignitic at top with woody chips, lignitic speckling and sandy patches	0.26	98.86
	Clay: Brown-grey, very stiff, lignitic speckling and one hard fragment, frequent sandy patches sideritic	0.76	99.62
	Ironstone: Yellow-grey, hard	0.19	99.81
	Clay: Brown-grey, very stiff, lignitic mottling occasional lignite band, slightly sandy with harder granular sideritic patches, sheared	0.95	100.76
	EXCESS	0.10	100.66
	Clay: Brown-grey, very stiff, sandy patches, sheared	0.14	100.80

Lough Neagh Group	**Ironstone:** Yellow-grey, hard, nodule	0.05	100.85
	Clay: Brown-grey, very stiff, lignitic mottling with some bands, sandy patches and several shear planes	0.91	101.76
	Ironstone: Yellow-grey, hard some lignitic clay clasts	0.09	101.85
	Clay: Brown-grey, very stiff, lignitic mottling, slightly sandy toward base	0.24	102.09
	Clay: Brown-grey, very stiff, lignitic mottling buff, sideritic patches	0.33	102.41
	Ironstone: Yellow-grey, hard	0.04	102.45
	Clay: Brown-grey, very stiff, sandy, lignitic mottling	0.71	103.16
	Ironstone: Yellow-grey, hard	0.04	103.20
	Clay: Brown-grey, very stiff, lignitic mottling some hard sideritic bands and sandy patches	0.63	103.83
	EXCESS	0.17	103.66
	Clay: brown-grey, very stiff, lignitic mottling and some lignitic bands, sideritic patches, very sandy near the top with shear planes	1.17	104.83
	Lignitic Clay: Brown to dark brown, very stiff sandy patches	0.13	104.96
	Ironstone: Grey-yellow and grey, hard some lignite clasts (sideritized)	0.04	105.00
	Lignitic Clay: Brown to dark brown, patchy, very stiff, buff sandy patches, some lignite fragments	0.27	105.27
	Lignitic Clay: Grey-brown to light brown, very stiff, sandy patches, 5mm lignite band near base, dark lignitic mottling	0.24	105.51
	Ironstone: Grey-yellow, hard, nodule, granular grey-brown lignitic clay in patches	0.10	105.61
	Lignitic Clay: Grey-brown and brown with dark brown lignitic mottling and some banding, very stiff, also mottled with buff sandy patches, some lignite fragments	0.87	106.48
	NCR	0.15	106.63
	Lignitic Clay: Grey-brown and brown-grey with dark brown lignitic mottling and banding, very stiff, abundant buff sideritic sandy patches, some woody lignite fragments, shear plane near base	1.66	108.29
	Ironstone: Hard, yellow-grey, unaltered brown lignitic clay in patches	0.04	108.33
	Lignitic Clay: Dark brown to brown, grey-brown and buff, laminated, some hard sideritic nodules at top below ironstone band, darker more lignitic bands	0.87	109.20
	Ironstone: Yellow-grey, hard nodule with unaltered lignitic clay in patches	0.06	109.26

Lough Neagh Group	**Lignitic Clay:** Interbedded clay and sandy clay, dark brown to grey brown and buff, some lignite stringers and fragments	1.26	110.22
	EXCESS	0.15	110.37
	Ironstone: Yellow-grey to buff, hard, includes very stiff bands of lignitic clay	0.21	110.58
	Lignitic Clay: Interbedded clay and sandy clay with lignitic clay laminae and fragments - becoming more mottled toward base with patches of granular siderite	1.62	112.20
	Lignitic Clay: Grey-brown, some lignitic mottling, very stiff, a few lignite fragments, buff sandy patches	0.26	112.46
	Ironstone: Yellow-grey to buff, hard with green-grey tinge, lignite clasts	0.12	112.58
	Lignitic Clay: Grey-brown, very stiff, some lignite fragments buff sandy patches	0.17	112.75
	EXCESS	0.12	112.63
	Lignitic Clay: Brown-grey, very stiff, lignite traces	0.09	112.72
	Ironstone: Green-grey, hard,woody fragments	0.10	112.82
	Lignitic Clay: Grey-brown, very stiff, lignitic mottling and some fragments, abundant buff sand patches	1.63	114.45
	Lignite: Dark brown, hard, buff sandy patches, sideritic	0.12	114.57
	Lignite: Dark brown, hard woody	0.04	114.61
	Lignitic Clay: Brown-grey to grey-brown and dark brown, patchy, very stiff, lignitic mottling and fragments, buff sand patches	0.81	115.42
	Ironstone: Buff to yellow-grey, haard, clasts of lignitic clay and lignite	0.07	115.49
	Lignitic Clay: Dark brown to brown and buff, very stiff, irregular, mostly dark brown and buff, sandy, sideritic toward base	0.41	115.90
	EXCESS	0.19	115.71
	Ironstone and Lignitic Clay: Dark brown and buff, stiff to hard, irregular banding	0.18	115.89
	Lignitic Clay: Buff to dark brown, very stiff, irregular banding	0.29	116.18
	Lignite: Dark brown, very stiff, black fragments, some sandy laminae and patches	0.10	116.28
	Lignitic Clay: Dark brown and black to grey-brown and buff, very stiff, varies from clayey lignitic to lignitic clay, sandy siderite patches, wood fragments, irregular banding, patches and mottling	2.42	118.70

Lough Neagh Group	**Lignitic Clay:** Brown to dark brown, very stiff, lignite fragments and sandy patches	0.03	118.73
	EXCESS	0.07	118.66
	Lignitic Clay: Dark brown to brown, very stiff with buff sand patches, several clayey lignite horizons, becoming sandy and crumbly	3.08	121.74
	EXCESS	0.11	121.63
	Lignitic Clay: Dark brown to buff, very stiff, irregular banding, patchy, lignite, stringers fragments and specks, rounded to sub-rounded coarse quartz sand grains, resmbling a fine conglomerate, sideritic	0.70	122.33
	Lignitic Clay and Ironstone: Ironstone is buff-off white, hard, clay is dark brown to brown, very stiff, partly sideritized	0.54	122.87
	Lignitic Clay: Dark brown to brown-grey, very stiff to hard with sideritic sandy patches, irregular banding, patchy lignitic mottling, several hard ironstone bands	1.83	124.70
	EXCESS	0.07	124.63
	Lignitic Clay: Grey-brown to dark brown, very stiff, mottled, buff sandy patches	0.44	125.07
	Ironstone: Buff, hard sideritic	0.08	125.15
	LigniticClay: Very stiff, green tinge near ironstone, irregular banding, grey-brown with dark brown and buff sand patches, some lignite fragments and laminae	1.21	126.36
	Ironstone: Buff, hard with lignitic clay	0.08	126.44
	Lignitic Clay: Brown-grey to dark brown-grey, very stiff, patchy and lignitic mottling, some lignite fragments, buff sandy patches	0.75	127.19
	Ironstone: Buff, hard	0.06	127.25
	Lignitic Clay: Dark grey-brown, very stiff, buff sandy patches	0.14	127.39
	NCR	0.24	127.63
	Lignitic Clay: Brown-grey to dark brown-grey, patchy, very stiff, lignitic mottling in places, lignite fragments and stringers, buff sandy patches some hard ironstone patches	1.43	129.06
	Lignitic Clay: Brown-grey to dark brown, very stiff, irregular banding, buff sandy patches, lignitic mottling	0.36	129.42
	Ironstone: Buff, hard, with interstitial lignitic clay	0.11	129.53
	Lignitic Clay: Brown-grey to dark brown, very stiff as above	0.46	129.99
	Ironstone: Buff, hard, interstitial lignitic clay	0.06	130.05

Lough Neagh Group	**Lignitic Clay:** Brown-grey to dark brown-grey, very stiff, traces of lignite, buff sandy patches	0.61	130.66
	Ironstone: Buff hard	0.04	130.70
	Lignitic Clay: dark brown, very stiff, lignite fragments, sandy patches	1.18	131.88
	EXCESS	0.27	131.61
	Ironstone: Buff, hard, interstadial, lignitic clay, sideritic	0.18	131.79
	Lignite Clay and Ironstone: irregularly banded dark brown lignitic clay, very stiff and buff hard, ironstone stringers and lenses	0.38	132.17
	Clayey Lignite: Dark brown, very stiff	0.05	132.22
	Ironstone: Buff, hard with clay inclusions	0.11	132.33
	Clayey Lignite and Ironstone: Dark brown, very stiff clayey lignite with buff, hard patches	0.09	132.42
	Clayey Lignite: Dark brown, very stiff, darker brown-black stringers, laminae and fragments. Occasional sideritic patch	0.81	133.23
	Lignitic Clay: Grey-brown, very stiff, lignitic traces and fragments, harder sandy layer	0.40	133.63
	EXCESS	0.08	133.55
	Ironstone: Buff, hard	0.05	133.60
	Lignitic Clay: Grey-brown, very stiff as above becoming less lignitic with sideritic parches	0.53	134.13
	Ironstone: buff, hard with lignite inclusions, laminae and stringers	0.29	134.42
	Clayey Lignite: dark brown with darker lignite traces, fragments and stringers, some paler less lignitic layers, very stiff	0.83	135.25
	Lignitic Clay: Grey-brown, very stiff, hard sandy (siderite) patches, lignite traces	0.53	135.78
	Lignitic Clay/Ironstone: Mixture of lignitic clay as above and very sandy (siderite) hard, buff	0.79	136.57
	Lignitic Clay: Grey-brown, very stiff, lignite traces	0.12	136.69
	NCR	0.10	136.79
	Clayey Lignite: Dark brown, very stiff	0.10	136.89
	Lignitic Clay: Grey-brown with lignite traces, fragments and stringers, siderite patches, more lignitic to base	1.09	137.98
	Clayey Lignite: Dark brown, very stiff to hard lignite traces, fragments, stringers, some grey-brown bands	1.04	139.02
	Ironstone/Clayey Lignite: Dark brown ironstone with clayey lignite bands	0.16	139.18

Lough Neagh Group	**Lignitic Clay:** Grey-brown, very stiff, lignite traces, very sandy in top half	0.49	139.67
	Clayey Lignite: Dark brown, very stiff to hard, woody at top becoming clayey	0.31	139.98
	EXCESS	0.15	139.83
	Lignite: Dark brown to black, very stiff to hard, sheared, hard wood fragments, sideritized patches	2.72	142.55
	Lignite: Dark brown to black, very stiff to hard woody	0.29	142.84
	ECR	0.14	142.70
	Lignite: Brown to dark brown-black, very stiff to hard, woody with subordinate clayey horizons, hard sideritized patches	3.12	145.82
	ECR	0.12	145.70
	Lignite: Brown to dark brown-black, very stiff to hard woody with occasional clay lenses/horizons	6.12	151.84
	ECR	0.04	151.78
	Lignite: Brown to black, woody, fibrous	0.96	152.74
	ECR	0.10	152.64
	Lignite: Brown to black, hard, subordinate clayey lenses/horizons, woody fragments	6.50	159.14
	ECR	0.05	159.09
	Lignite: Brown to black, hard, woody, fibrous patches	1.30	160.39
	Lignitic Clay: Grey-brown, stiff 160.3-160.6	0.22	160.61
	Lignite: Brown to black, hard, some thin lignitic clay horizons, occasional sideritic grain	6.47	167.08
	ECR	0.10	166.98
	Lignite: Dark brown to black, hard, very woody, few yellow-brown sideritic grains	3.14	170.12
	ECR	0.09	170.03
	Lignite: Dark brown to black, hard, woody, brown bands comprise fibrous woody material	1.79	171.82
	NCR	0.04	171.86
	Lignite: Dark brown to black, hard, woody, scattered yellow-brown siderite grains	1.29	173.15
	ECR	0.12	173.03

Lough Neagh Group	**Lignite:** Dark brown to black, hard, woody, several thin clayey horizons, occasional buff sideritic patch, sandy, powdery	3.03	176.06
	NCR	0.02	176.08
	Lignite: Dark brown to black, hard, woody with thin dark brown and brown-grey bands up to 12cm, grey-brown with lignite fragments and mottling, traces of cinder? 62cm from base	3.03	179.11
	ECR	0.03	179.08
	Lignite: Dark brown to black, hard, woody, several thin clay horizons dark brown to grey-brown, hard buff to grey ironstone band (3cm) approx. 1cm from base	3.10	182.18
	ECR	0.10	182.08
	Lignite: Dark brown to black, hard, woody, thin clay bands	2.98	185.06
	NCR	0.02	185.08
	Lignite: Dark brown to black, hard, woody, 9cm lignitic clay horizon, grey to brown, buff/yellow-brown siderite grains	2.89	187.97
	NCR	0.11	188.08
	Lignite: Dark brown to black, woody clay patches and bands mainly grey-brown, occasional yellow-brown grains	1.52	189.60
	Lignitic Clay: Brown-grey, very stiff with dark brown lignite fraagments and stringers, sandy in places (sideritic?), more lignitic to base, hard clay and woody bands, off-white clayey material in patches	1.54	191.14
	ECR	0.06	191.08
	Lignitic Clay: Brown-grey and grey-brown, very stiff with lignite traces, fragments and stringers, hard woody lignite bands and sandy patches	1.93	193.01
	Lignitic Clay/Lignite: Dark brown to black, hard woody lignite with much grey-brown to brown very stiff lignitic clay with lignite fragments	1.18	194.19
	ECR	0.06	194.13
	Lignite/Lignitic Clay: Interbedded dark brown, hard woody lignite and grey-brown lignitic clay, very stiff irregular banding	2.37	196.50
	Lignite: Dark brown to black, hard, woody with brown very stiff lignitic clay at top and base	0.45	196.95
	NCR	0.23	197.18

Lough Neagh Group	**Lignite:** dark brown to black, hard, top 40cm brown lignite clay with lignite fragments and stringers	3.01	200.19
	Lignitic Clay: Brown with black lignite fragments, very stiff	0.10	200.29
	ECR	0.11	200.18
	Lignite: dark brown to black, hard, woody with brown-grey clay bands up to 22cm, clay contains lignite stringers and fragments	2.65	202.83
	Lignite: Dark brown to black, hard, woody, some sideritized wood at top	0.33	203.16
	NCR	0.02	203.18
	Lignite: Dark brown tp black, hard, woody	0.15	203.33
	Lignitic Clay: Grey-brown grading into brown-grey with lignite fragments and stringers, very stiff, sandy patches near middle	1.12	204.45
	Lignite: Dark brown-black, hard, woody, clayey at ends	0.66	205.11
	Lignitic Clay: Grey-brown to brown-grey and dark brown, very stiff, irregular banded, with lignite fragments and stringers	0.63	205.74
	Lignite: Dark brown to black, hard, clayey, woody at base	0.53	206.27
	ECR	0.04	206.23
	Lignite: Dark brown to black, hard top half is woody, bottom half is clayey	0.72	206.95
	Lignite: Dark brown to black, hard, woody with irregular clay and lignitic clay bands and patches, some yellow-brown stringers	1.96	208.91
	Lignitic Clay: Grey-brown and brown-grey, very stiff, dark brown at top, lignite traces	0.46	209.37
	ECR	0.14	209.23
	Lignitic Clay: Grey-brown and brown-grey,very stiff with darker more lignitic bands, lignite stringers and fragments	0.70	209.93
	Lignite: Dark brown to black, hard, clayey with irregular woody bands, becoming more woody		
		1.13	210.96
	Ironstone: Buff, hard with hard sideritized woody lignite,siderite crystals within wood	0.46	211.42
	Lignite: Dark brown to black, hard, woody becoming clayey at base	0.85	212.27
	ECR	0.04	212.23

Lough Neagh Group	**Lignitic Clay:** Grey-brown, very stiff with lignite traces and fragments	0.12	212.35
	Lignite: dark brown to black, hard, woody with some clay horizons	2.89	215.23
	Lignite: dark brown to black, hard, woody becoming clayey toward base	0.53	215.76
	Lignitic Clay: Grey-brown becoming less lignitic and brown-grey, very stiff with lignite traces and fragments, sideritic patches	0.46	216.22
	Ironstone: Buff, very sandy, hard, sideritic, clayey at both ends, large lignite fragments	0.20	216.42
	Clay: Blue-grey, very stiff, lignite traces and fragments	0.32	216.74
	Ironstone: Brown and buff, hard, lignite traces/fragments, fine-grained	0.24	216.98
	Lignite: Dark brown to black, woody with irregular clay banding	1.35	218.33
	ECR	0.02	218.31
	Lignitic Clay: Varies from brown-grey to brown and dark brown with increasing lignite content, very stiff, irregular banding, hard, woody stringers and fragments	1.63	219.94
	Lignite: dark brown to black, hard, woody with irregular lignitic clay bands	0.59	220.53
Faulted	**Lignitic Clay:** Very lignitic becoming less lignitic very stiff to hard, brown-grey, becomes sandy, coarse-grained with lignite traces	0.44	220.97
contact	**Gritty Clay:** Small blue, white and orange-brown clay chips - very fine conglomerate	0.15	221.12
	Ironstone: Gradational contact above, grey to buff, hard siderite	0.24	221.36
	Clay: Grey to blue-grey, very stiff, conglomeratic as above with lignite traces, siderite fragments, near base is blue-grey clay becoming more lignitic	0.35	222.21
	Lignitic Clay: Dark brown to brown?grey, very stiff, irregular banding becoming less lignitic	1.05	223.26
Dunaghy Formation	**Clay:** Brown-grey, very stiff, lignite traces and fragments	0.50	223.76
	Lignitic Clay: Grey-brown, very stiff, with lignite fragments, 0.5cm lignite stringer at base	0.47	224.23
	Ironstone: Buff to grey, hard, lignite fragments	0.23	224.34
	ECR	0.06	224.40
	Lignitic Clay: Brown-grey and grey-brown, very stiff ironstone fragment near middle, lignite traces	0.47	224.87
	Lignite: Dark brown to black, hard, clayey with woody material, top 14cm are woody horizon	0.48	225.35

Dunaghy Formation	**Lignitic Clay:** Lignitic towards top, very stiff becoming grey-brown with lignite fragments and stringers, sandy patches - ironstone band 226.18-226.32	1.75	227.10
	Clay: Brown-grey, very stiff, lignite traces	0.30	227.40
	ECR	0.07	227.33
	Lignitic Clay: Grey-brown, very stiff, becoming more lignitic	0.10	227.43
	Lignite: Dark brown to black, hard, mainly clayey, woody toward base	0.23	227.66
	Clay: Grey-brown lignitic becoming blue-grey with traces of lignite, siderite nodules	1.21	228.87
	Ironstone: Buff, hard, sideritic	0.19	229.06
	Clay: Blue-grey, very stiff, sandy, lignite traces	0.54	229.60
	Ironstone: Buff, hard, sideritic	0.16	229.76
	Clay: Blue-grey, very stiff, sandy, lignite traces	0.65	230.41
	ECR	0.08	230.33
	Clay: Blue-grey with grey-brown patches, very stiff to hard, lignite traces, ironstone fragments, grades into ironstone below	0.75	231.08
	Ironstone: Buff, hard, sideritic	0.08	231.16
	Clay: Blue-grey with brown lignitic patches, very stiff to hard, lignite traces, sandy near top and base	1.14	232.30
	Ironstone: Buff, hard, sideritic	0.11	232.41
	Clay: Blue-grey, very stiff to hard, sandy, lignite traces	0.97	233.38
	Clay: Blue-grey, sandy, very stiff to hard, ironstone nodules, lignite fragments, conglomeratic with small clay grains; ironstone bands at 233.71-233.80, 234.49-234.60	1.69	235.07
	Ironstone: Buff to blue-grey, hard, sideritic	0.21	235.28
	CLAY: Blue-grey to grey-brown and lignitic toward base. Two thin conglomerate bands near the top and base with granules and small pebbles, fragments of buff, brown and white clay sandy patches	0.59	235.87
	Lignite: Dark brown to black, hard, clayey, woody band	0.95	236.77
	ECR	0.05	236.72
	Lignitic Clay: Hard, very sandy, sideritic, lignite stringer, sideritized at base	0.22	236.99
	Ironstone: Buff to brown, hard	0.12	237.11
	Clay: Brown passing into blue-grey with brown patches, very stiff to hard, slightly sandy patches, ironstone fragments and lignite traces	1.93	239.04

Dunaghy Formation	NCR	0.39	239.43
	Clay: Brown, very stiff to hard becoming lignitic	0.20	239.63
	Lignite: Dark brown to black, hard, woody horizon at base	0.08	239.71
	Clay: Brown to grey-brown, very stiff to hard with lignite traces	0.67	240.38
	Ironstone: Buff, hard	0.08	240.46
	Clay: Brown, very stiff to hard, sandy layers, lignite traces, ironstone band at 240.60-240.69, becomes conglomeratic to base, blue-grey and brown, patchy with small clay clasts and rounded pebbles	2.14	242.60
	ECR	0.37	242.23
	Clay: Brown-grey, very stiff to hard	0.07	242.30
	Ironstone: Buff, hard with 5cm grey-brown clay horizon 242.46-242.51	0.30	242.60
	Clay: Grey-brown to brown, very stiff to hard, lignite laminae toward base	0.20	242.80
	Conglomerate: Interbedded conglomerates and thin ironstones, clay clasts, rounded up to 39mm lignite traces, fragments and laminae	0.98	243.78
	Lignite: Dark brown, hard, ironstone nodule	0.04	243.82
	Clay: Brown-grey,very stiff to hard, lignite traces	0.45	244.27
	NCR	0.38	244.65
	Clay: Brown,blue-grey patches, very stiff to hard, sandy to base	0.34	244.99
	NCR	0.49	245.48
	Clay: Brown, blue-grey patches, very stiff to hard, then blue-grey with brown patches, sandy to very sandy, hard, ironstone nodules, lignite traces	2.82	248.30
	Lignite: Dark brown to black, hard, mostl clayey with some woody bands	0.28	248.58
	ECR	0.51	248.07
	Clay: Blue-grey to brown mottled, very stiff to hard, lignitic toward top becoming sandy, some hard ironstone nodules, lignite fragments	3.03	251.10
	NCR	0.07	251.17
	Clay: Brown with blue-grey patches, very stiff to hard, very sandy, lignite traces, hard ironstone nodules	3.04	254.21
	NCR	0.06	254.27
	Clay: Brown with blue-grey patches, very stiff to hard, some ironstone nodules and lignite fragments	0.90	256.17

Dunaghy Formation	**Clay:** Brown and purple-brown withblue-grey patches, very stiff to hard, sandy to very sandy, hard ironstone patches	2.17	257.34
	NCR	0.03	257.37
	Clay: Blue-grey with brown patches then brown to base, sandy patches, lignite traces, fragments and several stringers, ironstone nodules, becomes brown with blue-grey patches	3.26	260.63
	ECR	0.16	260.47
	Clay: Brown with blue-grey patches,very stiff to hard, becoming sandy, thin lignitic horizon, lignite traces	0.81	261.28
	Ironstone: Buff to brown-grey, hard	0.48	261.76
	Clay: Brown becoming blue-grey, with brown patches, very stiff to hard, lignite traces, becoming sandy	1.76	265.52
	NCR	0.05	263.57
	Clay: Blue-grey with brown patches and bands, very stiff to hard, sandy toward top, thin ironstone band toward top, lignite traces numerous thin ironstone bands near base	3.08	266.65
	NCR	0.03	266.68
	Clay: Blue-grey, very stiff to hard, ironstone bands, sandy becoming grey-brown to brown, lignitic	3.22	269.90
	ECR	0.15	269.75
	Clay: Blue-grey, very stiff to hard, several ironstone bands, fine conglomerate in lower half, lignite traces, clay becoming grey-brown, sandy, sheared	3.15	272.90
	ECR	0.07	272.83
	Clay: brown-grey to grey-brown, very stiff to hard, thin ironstone bands up to 15cm	2.66	275.49
	Clay: Grey-brown at top becoming brown to base with increasing lignite content, very stiff to hard	0.39	275.88
	Lignite/Lignitic Clay: Dark brown-black, hard, sandy at top, irregular banding	0.67	276.55
	Clay: Grey-brown in top 1.5m, blue-green and then brown at base, very stiff to hard, lignite fragments, ironstone nodules, badly sheared	2.24	278.79
	Ironstone: Buff, hard, sideritic	0.19	278.98
	Lignitic Clay: Brown, very stiff to hard, conglomeratic at base	0.13	279.11
	EXCESS	0.23	278.88
	Clay: Blue-grey, hard becoming brown-grey at base	0.61	279.49

Dunaghy Formation	**Lignitic Clay/Lignite:** Brown-dark brown to black, hard, mostly lignitic clay and clayey lignite with woody horizon, irregular banding	2.38	281.87
	NCR	0.06	281.93
	Lignitic Clay: dark brown to black, hard	0.47	282.40
	Lignite: dark brown ro black,hard, woody with irregular clay banding	2.21	284.61
	Lignitic Clay/Clay: Dark brown, very stiff to hard, becoming brown-grey at base	0.63	285.24
	ECR	0.08	285.16
	Clay/Lignitic Clay: Brown-grey to dark brown, very stiff to hard, clayey lignite bands, irregular, sheared	2.56	287.72
	NCR	0.10	287.82
	Lignitic Clay/Clay: Grey-brown to dark brown, very stiff to hard, thin clayey lignite horizon	0.78	288.60
	Clay: Grey-brown, very stiff to hard, becoming blue-grey, lignite traces, sandy toward base, several thin ironstone bands, sheared	2.51	291.11
	ECR	0.18	290.93
	Clay: Blue-grey, very stiff to hard, very sandy, becoming purple-brown with ironstone nodules towards base	0.92	291.85
	Clay: Blue-grey with brown mottling near top, several fine conglomeratic horizons, very sandy to sandy, very stiff to hard	1.82	293.67
	Clay: Blue-grey, very stiff to hard, very sandy in top 45cm conglomeratic, thin lignite fragments and stringers	0.72	294.39
	NCR	0.06	294.45
	Clay: Blue-grey,very stiff to hard, lignitic, becoming sandy with lignite traces, fragments and stringers, becoming brown with fine pebbles material	2.53	296.98
	NCR	0.15	297.13
	Clay: Brown, lignitic, very stiff to hard, becoming blue-grey, sandy with some hard ironstone nodules, grey-brown clay with blue-grey patches at base	1.71	298.84
	Clay: brown, very stiff to hard with small ironstone patches becoming blue-grey with sandy patches, lignitic band and laminae, brown at base	1.13	299.97
	NCR	0.21	300.18
	Clay: Grey-brown, sandy to very sandy, in places siderite veins,18cm clayey lignite horizon, traces of lignite throughout becoming more lignitic toward base	3.10	306.28

Dunaghy Formation	**ECR**	0.15	306.13
	Lignite: Brown to black, hard, woody, irregular clay bands	0.54	306.67
?Antrim Lava Group?	**Volcanic Breccio-Conglomerate:** Buff-grey, hard, well-rounded clasts up to 2cm red, yellow-buff, white or brown clay (?decomposed basalt) in splintery matrix, rare lignite clasts, sideritic, bauxitic	0.20	306.87
	Volcanic Breccio-Conglomerate: grey-buff, very stiff to hard, relict pebbles of decomposed basalt (now clay) in granular matrix representing former highly sheared, fractured and spheroidally weathered basalt	1.43	308.30
	Bauxitic Laterite: pale grey-white, very stiff to hard, porous, 'chalky' texture hygroscopic, small darker granules, banded, friable	0.60	308.90
	Lateritised Basalt: Blue-grey at top becoming red-brown stained towards base, gritty texture, very stiff, bauxitic at top	0.33	309.23
	Clay (Laterite): Blue-grey, very sandy (gritty) texture, patches of hard ?ironstone, very stiff	0.92	310.15
Antrim Lava Group	**Weathered Basalt:** Brown and blue-grey at top becoming white speckled and net veined below top 20cm, turning buff to blue-grey and green-grey at base	1.89	312.04
	Weathered Basalt: Light green, hard, veins of ?siderite	0.18	312.22
	NCR	0.06	312.28
	Basalt: Partly weathered, light green, hard, speckled with dark green	0.81	313.09
	ECR	0.13	312.96
	Basalt: dark green, veins of buff/off-white calcite? Occasional reddish speckling	2.27	315.23
	NCR	0.05	315.28
	Basalt: Light and dark green, hard, calcite? veining	2.21	317.49
	ECR	0.07	317.42
	Basalt: Partly weathered basalt passes into dark green crumbly more weathered basalt material, brick red horizon passess back into less weathered basalt, vesicular, veined, speckled	2.09	319.51
	NCR	0.12	319.63
	Basalt: Dark green, speckled, vesicular, calcite veins	1.81	321.44
	ECR	0.06	321.38

Antrim Lava Group	**Basalt:** Dark green, speckled, vesicular, calcite veins, becoming more weathered, crumbly	2.91	324.29
	ECR	0.06	324.23
	End of Borehole		

36/4680 DEERPARK No. 2

Phase 1 Drilling programme 1983-1984.

Grid reference: Six inch quater sheet 62 NE J 0878 6856

Location: 4.81 km at 315° from Aghalee.

Exact site: Deerpark townland, south end of Brankin's Island; 375 m at 177° from Deerpark House.

Direction of bore: Down, open hole drift, core remainder of hole.

Bore made by: Drillsure Ltd.

Information from: Site geologists: F. Crozier and S. Warnock.

Date of sinking: 7.01.84 - 18.01.84.

Geological Classification	Description of strata	Thickness metres	Depth metres
Drift	**Open Hole to 55.26m**		55.26
	Clay: Brown, stiff, fragments of basalt	0.40	55.66
Lough Neagh Group	**Sandy Clay:** Grey, stiff, very fine-grained sand, basalt fragments.	0.46	56.12
	Sandy Clay: Grey, hard, very sandy, very fine-grained	0.07	56.19
	Sandy Clay: Grey-brown, very stiff; rounded fragments of basalt	0.64	56.83
	NCR	0.18	57.01
	Sandy Clay: Grey to grey-brown	0.14	57.15
	Clay: Grey-brown, very stiff	0.26	57.41
	Clay: Blue-grey to grey-brown, very stiff	0.26	57.67
	Clay: Grey-brown, very stiff, quartz grains	0.07	57.74
	Clay: Blue-grey, mottled, very stiff, thin band of fine-grained sand	0.66	58.40
	NCR	0.22	58.62
	Clay: Grey-brown to blue, very stiff to hard, patches of fine-grained sand becoming more sandy	1.42	60.04
	EXCESS	0.21	59.83
	Clay: Brown, very stiff, becoming grey-brown, two bands of blue-grey, very stiff clay	0.73	
	EXCESS	0.18	60.34
	Clay: Grey-brown, mottled blue-grey, very stiff	0.28	60.62
	Clay: Pale grey-buff, mottled, very stiff	0.26	60.88

Lough Neagh Group	**Clay:** Blue-grey to grey-brown, mottled, very stiff, buff patches	0.49	61.37
	Sandy Clay: Purplish-brown and grey, fine-grained sand, very stiff; fragments of weathered basalt, quartz grains	0.49	61.86
	Clay: Dark brown, very stiff, abundant lignitic material, basalt fragments	0.80	62.66
	Sandy Clay: Blue-grey, very stiff, fragments of lignite	0.60	
	NCR	0.85	64.11
	Sandy Clay: Blue-grey, very stiff to hard, fragments of white sandstone	1.23	65.34
	Sandy Clay: As above	1.33	66.67
	Sandy Clay: Brown, very stiff, fine-grained, sandy, becoming lignitic	0.80	67.47
	Sandy Clay: Blue-grey, very stiff, fine-grained sand, white fragments of silicified sandstone	0.63	68.10
	Sandy Clay: Grey-brown, very stiff, becoming darker and less sandy	0.30	68.40
	Clay: Grey-brown, hard, slightly sandy, traces of lignite, silicified sand fragments	0.78	69.18
	Sandy Clay: Blue-grey, very stiff, fine-grained sand	1.19	70.37
	Sandy Clay: Blue-grey to brown, mottled	0.12	70.49
	Clay: Blue-grey to brown, mottled, hard silicified sand grain aggregates	0.39	70.88
	Clay: Grey-brown to brown, very stiff, sandy patches, traces of lignite	0.57	71.45
	Clay: As above	0.65	72.10
	Sandy Clay: Grey-brown to blue-grey, mottled slightly sandy	1.02	73.12
	Clay: Grey-brown, hard, hard ironstone nodule	0.42	73.54
	Sandy Clay: Blue-brown becoming blue-grey, hard becoming grey brown the blue, hard	0.96	74.50
	Clay: Blue-grey, hard becoming sandy	0.76	75.26
	Clayey Lignite: Black	0.09	75.35
	Lignitic Clay: Grey-brown, hard, abundant lignite material	0.29	75.64
	Lignite: Dark brown, hard	0.22	75.86
	Clay: Pale brown, hard, lignite fragments and three thin bands of lignite	0.59	76.45
	Clay: Grey to grey-brown, hard, lignite fragments and stringers	0.81	77.26
	Clay: Blue-grey, hard becoming sandy	0.29	77.55
	Sandy Clay: Blue-grey, hard, fine-grained, sandy, purple-grey patches, ironstone nodules	1.75	79.30

Lough Neagh Group	**Sandy Clay:** Grey-brown, hard, medium-grained sand becoming darker and less sandy	1.30	80.60
	Clay: Grey-brown, hard, blue-grey hard patches, mottles blue to purple-grey in bands	2.23	82.83
	Sandy Clay: Grey-brown, hard, fine-grained sand	0.82	83.65
	Sandy Clay: Grey-brown, hard, fine-grained sand, becoming coarser	0.63	84.28
	Sandy Clay: Blue-grey, stiff, medium-grained sand	0.20	84.48
	Sandy Clay: Stiff to very stiff, medium to coarse-grained sand becoming lignitic	0.77	85.25
	Clayey Sand: Brown, firm	0.20	85.45
	Sandy Clay: Blue-grey, very stiff	0.44	85.89
	Clay: Blue-grey to grey-brown, mottled, hard	0.24	86.13
	Clay: Grey-brown to brown, sandy patches	0.57	86.70
	Clay: Dark brown, hard, sandy patches, ironstone nodules	1.70	88.40
	Clay: Blue-grey, hard, buff mottling, becoming slightly sandy	1.35	89.75
	Clay: Blue-grey to buff, mottled as above	0.31	90.06
	Clay: Blue-grey to grey-brown, mottled, fine-grained sand in bands	2.73	92.79
	Clay: Blue-grey to grey, hard	1.01	93.80
	Clay: Grey, hard, traces of lignitic material	1.13	94.93
	Clay: Blue-grey to brown mottled, sandy patches, ironstone (siderite) nodules	0.91	95.84
	Clay: Brown to blue-grey, mottled, hard	0.96	96.80
	Clay: Brown, hard	0.90	97.70
	Clay: Blue-grey to brown, mottled, fine-grained sandy patches	0.40	98.10
	Clay: Grey, becoming slightly sandy	0.80	98.90
	Clay: Blue-grey, hard, slightly sandy	0.27	99.17
	Clay: Dark brown, very hard, blue grey patches, sideritic, becoming blue-grey to brown, mottled, traces of lignite	1.77	100.94
	Sandy Clay: Blue-grey, hard, becoming less sandy	1.00	101.94
	Clay: Grey, hard, sandy patches, becoming more sandy, traces of lignite	1.05	102.99
	Sandy Clay: Grey, hard, clayey sand bands, becoming lignitic	0.62	103.61
	Lignite: Dark brown, hard	0.07	103.68
	Clay: Grey, hard, slightly sandy, yellow-green patches	0.28	103.96
	Clay: Blue-grey, hard, mottled, yellow-green becoming sandy	1.03	104.99
	Clay: Blue-grey to yellow-green, mottled as above, ironstone nodules	1.15	106.14

Lough Neagh Group	**Sandy Clay:** Blue-grey to brown, hard	0.31	106.45
	Clay: Blue-grey, very sandy	1.60	108.05
	Sandy Clay: Blue-grey hard, very sandy as above	1.89	109.94
	Sandy Clay: Grey-brown, hard, very sandy becoming clayey sand, traces of lignite becoming more sandy and softer	0.68	
	NCR	0.48	111.10
	Sand: Fine to medium-grained quartz sand, grey-brown, patches with grey clay matrix	1.04	
	NCR	0.45	112.59
	Sand: Medium to coarse-grained sand becoming consolidated, partly sideritised, grey clay matrix.	0.41	113.00
	Clay: Brown-blue, mottled, very stiff, becoming slightly yellow	1.14	114.14
	Sandy Clay: Blue-brown, mottled, stiff, fine to medium-grained sand	0.36	114.50
	Clay: Brown-blue, mottled, very stiff, slightly sandy	1.84	116.34
	Sandy Clay: Blue, very stiff becoming less sandy, mottled blue-brown, stiff	0.60	
	NCR	0.24	117.20
	Clay: Brown-blue, mottled, very stiff, sandy bands, ironstone nodules	2.85	120.05
	Sandy Clay: Blue, firm, fine-grained sand	0.20	120.25
	Clayey Sand: Fine to medium-grained quartz sand, blue, stiff, clay matrix	1.17	121.42
	Clayey Sand: Blue-grey to purple-brown, as above	0.37	121.79
	Sandy Clay: Purple-brown, stiff, less sandy	0.20	121.99
	Sand: Brown, fine to medium-grained quartz sand in a brown-purple clay matrix. Sand content and grain size increases toward base	1.31	123.30
	Sand: As above, becoming clayey	0.58	
	NCR	0.28	124.16
	Sand: Poorly consolidated soft sand	0.20	
	NCR	2.00	126.35
	Clayey Sand: Brown, firm, fine-grained sand	0.17	126.52
	Sandy Clay: Blue-brown-grey, mottled, stiff to very stiff, ironstone nodules	1.00	127.52
	Sandy Clay: Brown-blue, mottled, stiff, ironstone bands	1.88	129.40
	Sandy Clay: As above	0.24	129.64
	Sandy Clay: Brown-grey, mottled, stiff to very stiff, slightly sandy	1.06	130.70
	Clayey Sand: Brown-grey, mottled, very stiff	0.49	131.19
	Sandy Clay: Brown-grey mottled, stiff becoming slightly lignitic	0.52	131.71
	Lignitic Clay: Brown-dark grey, very stiff	0.27	131.98

Lough Neagh Group	**Clay:** Grey, very stiff	0.24	
	NCR	0.23	132.45
	Clay: Blue-grey-brown, mottled, very stiff, ironstone nodules	0.53	132.98
	Sandy Clay: Brown-grey, mottled, stiff becoming less sandy	0.45	133.43
	Clay: Blue-grey, very stiff, brown-green mottling, partly sideritised	1.50	134.93
	Clayey Sand: Blue-grey, firm, becoming darker, fine to medium-grained sand	0.57	135.50
	Ironstone: Coarse-grained, hard, siderite	0.29	135.79
	Lignite: Black	0.01	135.80
	Sand: Very coarse-grained, hard, few small pebbles	0.20	136.00
	Sandy Clay: Blue-grey, stiff	0.23	136.23
	Sandy Clay: As above but with less sand	2.32	138.55
	Sandy Clay: Grey, stiff, patches of clayey sand	1.02	139.57
	Clayey Sand: Grey, hard with black to dark brown lignitic patches, fine to medium-grained sand	0.30	139.87
	Sand: Dark grey-grey, fine to medium-grained quartz sand, thin lignitic clay bands	0.57	140.44
	Sandy Clay: Grey-brown, mottled, stiff, fragments of dark brown lignitic material, white ironstone nodules	1.16	141.60
	Sandy Clay: Grey, stiff to very stiff, fragments of lignite and white sandstone	2.34	143.94
	Sand: Grey-brown, fine to medium-grained sand becoming lignitic	0.71	144.65
	Sandy Clay: Blue-grey, very stiff, brown mottling	1.37	146.02
	Sandy Clay: Dark grey-brown with blue-grey mottling becoming less sandy	1.32	
	NCR	0.36	147.70
	Sandy Clay: Grey-blue-brown, mottled, very stiff to hard	2.86	150.56
	Clayey Sand: Blue-grey stiff, becoming more sandy, fine-grained sand, clay clasts (weathered pebbles)	2.00	152.56
	Clayey Sand: Dark grey-brown, lignitic fragments, becoming less consolidated	1.05	153.64
	Sandy Clay: Blue-grey, very stiff, more sandy bands, lignite fragments, becoming mottled brown	1.75	155.39
	Clay: Blue-grey to brown, mottled, very stiff	0.60	
	NCR	0.86	156.85
	Sandy Clay: Grey to blue-brown, mottled, very stiff to stiff, partly sideritised. Clay clasts, rounded	3.05	159.90
	Sandy Clay: Grey-brown, very stiff, mottled becoming dark grey, clay clasts	2.70	162.60

	Sandy Clay: More sandy with gritty texture, grey-brown, mottled, very stiff	0.35	162.95
	Sandy Clay: As above	0.64	163.59
	Sandy Clay: Dark brown, less sandy	1.40	164.99
	Sandy Clay: Blue, more sandy	0.26	165.25
	Clay: Dark grey, hard to stiff	0.75	166.00
	Clay: Dark grey, very stiff	1.00	167.00
	Sandy Clay: Grey-brown, mottled, very stiff	2.05	169.05
	Sandy Clay: Grey-brown, mottled, very stiff	0.18	
	NCR	2.87	172.10
	Sandy Clay: Blue-grey, soft to firm, becoming dark grey, hard, less sandy	2.20	
	EXCESS	0.50	173.80
	Clay: Dark grey, stiff to very stiff, subrounded clay clasts	0.98	174.78
	Sandy Clay: Grey-brown, mottled, stiff	0.44	175.15
	Sandy Clay: Blue to grey-brown, stiff to very stiff, sideritic	2.70	177.85
	Clay: Dark grey, firm to stiff, becoming sandy	0.35	178.20
	Sandy Clay: Dark grey, stiff becoming blue-grey, very stiff, mottled brown patches, partly sideritised	1.20	179.40
	Clay: Dark grey, very stiff	0.50	179.90
	Sandy Clay: Dark grey, very sandy, fine to medium-grained sand, red grains (traces) in sand	0.33	180.23
Lough Neagh Group	**Sandy Clay:** Dark grey, stiff becoming grey-brown, mottled, stiff	1.02	181.25
	Sandy Clay: Grey becoming dark grey slightly lignitic, lignite stringer	0.33	181.58
	Sandy Clay: Grey to brown-green, stiff becoming greener and back to dark grey	1.13	182.71
	Sandy Clay: Blue-grey, stiff, very fine-grained sand	1.59	184.30
	Sandy Clay: As above	1.42	185.72
	Sandy Clay: Brown-dark grey more sandy, lignitic traces and stringers	1.65	187.37
	Sandy Clay: As above	0.46	187.83
	Sandy Clay: Blue-grey, stiff, very fine-grained sand, dark grey mottled patches	0.74	188.57
	Sandy Clay: Grey-brown, mottled, hard, partly sideritised	0.56	189.13
	Sandy Clay: Blue-grey, mottled, stiff, becoming more blue-grey and more sandy	1.18	
	NCR	0.11	190.40
	Sandy Clay: Dark grey-brown, mottled, very stiff to stiff, becoming blue-green. Passes back to dark grey and becomes more sandy, sideritic	3.05	193.45

Lough Neagh Group	**Sandy Clay:** Grey-blue to brown, mottled, very stiff becoming more sandy	1.08	194.53
	Sandy Clay: Dark grey	0.44	194.97
	Clay: Dark grey, crumbly	0.63	195.60
	Sandy Clay: Grey, stiff	0.90	196.50
	Sandy Clay: Blue-grey, very stiff becoming dark grey	1.09	197.59
	Sandy Clay: Dark grey-brown, lignite traces	0.64	198.23
	Sandy Clay: Dark grey-brown, medium to coarse-grained sand, partly sideritised	0.52	198.75
	Sandy Clay: Grey-brown, stiff, less sandy	0.80	199.55
	Sandy Clay: Blue-grey, very stiff to stiff	0.78	200.33
	Clay: Dark grey, very stiff	0.54	200.87
	Sandy Clay: Grey-blue, mottled, stiff to very stiff	1.73	203.60
	Clay: Grey-blue to brown, mottled, firm to stiff becoming crumbly	1.95	
	NCR	1.10	205.65
	Ironstone: Grey, hard, sideritic with patches of firm sand	1.65	207.30
	Sandy Clay: Dark grey-brown, mottled, stiff	0.64	207.94
	Sandy Clay: Dark grey-brown, mottled more sandy, partly sideritised	0.76	208.70
	Sandy Clay: Grey-blue, stiff, becoming slightly more sandy	3.05	211.75
	Sandy Clay: Grey-blue to grey-brown, mottled, stiff, partly sideritised, becoming slightly lignitic	1.43	
	EXCESS	0.42	213.18
	Clay: Grey-brown, very stiff, slightly sandy	0.06	213.24
	Clay: Grey-brown to blue-grey, firm	0.08	
	NCR	1.48	214.80
	Clay: Blue-grey to grey-brown, firm, slightly sandy	0.20	
	NCR	2.85	217.85
	Clay: Grey, stiff	0.12	
	NCR	1.63	219.60
	Clay: Blue-grey, hard, crumbly	0.10	
	NCR	1.20	220.90
	Clay: Grey-brown, stiff to crumbly becoming blue-grey	0.24	221.14
	Clay: Blue-grey, hard, slightly sandy	0.24	221.38
	Sandy Clay: Blue-grey, hard, white ironstone nodules, lignite fragments	1.43	222.81
	Lignitic Clay: Dark brown, hard	0.05	222.86
	Clay: Dark grey-brown, hard, lignite fragments	0.16	223.02
	Sandy Clay: Grey, very sandy, lignitic material, white ironstone nodules	0.50	223.52
	Lignitic Clay: Dark grey-brown, hard	0.14	
	NCR	0.29	223.95

Lough Neagh Group	**Clay:** Blue-grey, stiff, traces of lignite	0.95	224.90
	Clay: Blue-grey, hard, as above, band of pale grey clay	1.16	226.06
	Clay: Grey-brown, mottled, hard becoming grey	0.56	226.62
	Sandy Clay: Grey, hard	0.31	226.93
	Clay: Blue-grey, hard	0.07	227.00
	Clay: Grey, hard, crumbly	0.08	227.08
	Sandy Clay: Blue-grey, hard, slightly sandy	0.38	227.46
	Clay: Brown-blue, mottled, hard, sandy patches, white ironstone nodules	1.93	229.39
	Clay: Blue-grey, hard becoming grey slightly sandy	0.61	230.00
	Sandy Clay: Blue-grey, hard, very fine-grained sand, hard ironstone nodules	0.92	230.92
	Clay: Grey-brown, hard	0.21	231.13
	Clay: Grey, hard, lignitic material	0.67	231.80
	Sandy Clay: Blue-grey, mottled yellow-brown	0.54	232.34
	Clay: Grey-brown to brown, hard, lignite traces, two lignite stringers	0.58	232.92
	Clay: Grey, hard, crumbly, traces of lignite	0.13	233.05
	Clay: Grey, hard, as above, becoming slightly sandy	0.83	
	NCR	0.81	234.69
	Clay: Grey-brown to blue-grey, stiff	0.40	235.09
	Clay: Grey to blue-grey, stiff, lignite and hard ironstone nodules	0.15	
	NCR	0.89	236.15
	Clay: Hard, sandy patches, hard ironstone nodules	1.76	?
	EXCESS	0.16	237.75
	Clay: Grey, hard, as above	0.60	?
	Clay: Grey, stiff, slightly sandy	0.14	?
	Clay: Grey, hard becoming sandy	0.58	?
	EXCESS	0.37	238.70
	Sandy Clay: Blue-grey to grey, slightly sandy, hard, siderite nodules	2.40	?
	EXCESS	0.10	241.00
	Clay: Blue-grey to grey, stiff, crumbly	0.12	?
	Clay: Grey-brown, hard, slightly sandy, lignitic material	0.90	?
	Lignite: Dark brown, hard, clayey patches	0.31	?
	EXCESS	0.08	242.25
	Lignite: Dark brown, hard, as above	0.04	242.29
	Lignitic Clay: Dark grey-brown, hard	0.16	242.45
	Lignite: Dark brown-black, hard	0.31	242.76
	Clay: Grey-brown, hard, lignite traces and fragments	0.70	243.46
	Lignitic Clay: Dark grey-brown, hard	0.06	243.52
	Clay: Dark brown, hard, lignite fragments	0.25	243.78
	Lignite: Dark brown-black, hard	0.30	
	NCR	0.22	245.30

	Lignite: As above	0.10	245.40
	Lignitic Clay: Dark brown	0.23	245.63
	Clay: Grey-brown, hard, lignite traces and fragments, stringers	1.09	246.72
	Clayey Lignite: Dark brown	0.22	246.94
	Lignite: Black, hard	0.15	247.09
	Clay: Grey-brown, hard, lignite fragments becoming grey to blue-grey	0.83	
	NCR	0.43	248.35
	Clay: Blue-grey, hard, becoming pale grey, lignite fragments, becoming crumbly	0.87	249.27
	Clay: Grey, stiff to very stiff	0.22	249.49
	Sandy Clay: Grey, hard, coarse-grained sand	0.16	249.65
	Clay: Grey, hard, sandy bands	1.15	
	NCR	0.05	250.80
	Clay: Blue-grey, hard becoming dark grey-brown	0.60	251.40
	Lignite Clay: Dark brown, hard	0.42	251.82
	Clay: Pale grey-brown, hard, soft bands, fragments of lignite	0.30	252.12
Lough Neagh Group	**Clay:** Pale grey to blue-grey, hard sandy patches, lignite traces, ironstone nodules	2.28	254.40
	Sandy Clay: Blue-grey, hard, crumbly softer bands, lignite traces	1.50	255.90
	Clay: Grey, hard, crumbly	0.26	256.16
	Lignite Clay: Dark brown, very stiff	0.10	256.26
	Clay: Blue-grey, hard, lignite traces becoming darker and sandy	0.48	256.74
	Sandy Clay: Blue-grey, hard, fine-grained sand	0.25	
	NCR	0.15	256.99
	Sandy Clay: Blue-grey to grey, firm, fine to medium-grained sand	0.26	257.40
	Sandy Clay: Blue-grey, hard, slightly sandy, white ironstone nodules, becoming more sandy	2.00	259.40
	Clay: Blue-grey, hard, white ironstone nodules	0.50	259.90
	Sandy Clay: Blue-grey, hard, very sandy	2.65	262.55
	Clayey Sand: Dark grey, hard, becoming lignitic	1.07	263.62
	Conglomerate: Pebbles and fragments of weathered basalt, feldspar, quartz and lignite in a pale brown sand and grey clay matrix	0.49	264.11
	Clayey Lignite: Dark brown, very stiff	0.18	264.29
	Lignite: Black, hard, band of very stiff grey-brown clay	0.56	264.85
	Clayey Lignite: Dark brown, hard	0.08	264.93
Faulted	**Clay/Mudstone:** Pale grey, very hard, large dark brown, soft, lignite fragment, sheared	0.20	265.13

Contact

Antrim Lava Group	**Lithomarge:** Grey-brown, very stiff, crumbly patches of brown clay	0.27	265.40
	Weathered Basalt: Grey-green, very stiff clay matrix containing weathered basalt fragments	0.25	265.65
	Weathered Basalt: Dark grey-green, hard, brecciated serpentinised, chalcoprite? and pyrite in matrix	2.30	267.95
	Basalt: Dark grey, fresh	0.75	268.70
	Basalt: Fresh, hard, minor alteration along veins	4.05	272.75
	Basalt: As above but becoming oxidised, red colouration	1.05	273.80
	Basalt: Red, hard, thoroughly oxidised, spots of soft green and white mineralisation	1.95	275.75
	Basalt: As above becoming less oxidised, pale green with red patches	2.97	278.72
	Oxidised Basalt: Red-green, hard, red oxidised material and pale green-white mineralisation	0.98	279.70
	Basalt: Less oxidised becoming bright green	2.15	281.85
	END OF BOREHOLE		

27/415 UPPERMULLAN No. 1

Lough Neagh Drilling Programme Phase 3, borehole No. 14.

Grid reference: Six inch quarter sheet 31 SW H 9451 7915

Location: Upper Mullan near Derrycrin, County Tyrone.

Exact site: 1600m ESE of Derrycrin cross-roads, 750m NE of Eglish No. 1 borehole.

Direction of bore: Down, open hole through drift, core through remainder of hole.

Bore made by: Drillsure Ltd.

Information from: Site geologists: F. Crozier and M. Lowther.

Date of sinking: 27.06.84 - 03.07.84.

Geological Classification	Description of strata	Thickness metres	Depth metres
Drift	**Clay (subsoil):** light pinky brown; a few gritty fragments; calcareous.	3.45	3.45
	Clay: probably boulder clay; light brown, pink patches or tinge in places; gritty with basalt, quartz, calcareous and chert fragments; calcareous.	12.20	15.65
Lough Neagh Group	**Clay:** grey, browny-grey and light grey, with a few small brown patches; gritty, mostly with quartz fragments although also some basalt chert and mica fragments at top (15.65-18.70); also some woody lignite fragments;		
	non-calcareous, although occasional calcareous fragment; becomes very gritty from 30.90 to 37.00m.	21.35	37.00
	End of open hole		
	Clay: firm; pale grey, slight black mottling.	0.35	37.35
	Sand: partly lithified, medium to coarse quartz sand; black woody lignite fragment	0.02	37.37
	Clay: very stiff to hard; dark green homogenous	0.25	37.62
	NCR	0.88	38.50
	Sand: loose, medium grained quartz sand; (lost core possibly this).	0.01	38.51
	Clay: very stiff; dark green; homogeneous, hard buff-khaki ironstone band ar 39.02m; clay is very dark below this.	0.85	39.36
	NCR	0.44	39.80

Lough Neagh Group	**Clay:** stiff; green, passing down to dark to very dark green, homogeneous; blocky fracture.	1.37	41.17
	Ironstone: very hard, lithified; white-grey; ironstone fragments in clay above and below.	0.10	41.27
	ECR	0.02	41.25
	Clay: very stiff; dark green homogeneous; one lighter green, slightly sandy patch; some dark and very dark green laminations.	1.26	42.51
	NCR	0.29	42.80
	Clay: very stiff; dark green; homogeneous; sheared, some blocky fracture; some paler green banding, olive green towards base.	3.00	45.80
	Clay: very stiff to hard; sheared; some blocky fracture; dark green to olive green; almost homogeneous; two thin, pale green-brown, slightly sandy horizons.	3.00	48.80
	Clay: very stiff to hard; dark green to olive green, with some very dark green mottling; sheared blocky fracture; pale brown ironstone band (50.30-50.36m) hard, slightly sandy, very fine grained.	3.00	51.80
	Clay: very stiff to hard; dark green to lime green, slightly paler towards base; sheared.	0.80	52.60
	Clay: very stiff; grey to pale grey with black speckling.	0.31	52.91
	Ironstone: very hard lithified; buff.	0.05	52.96
	Clay: very stiff to hard; dark green to olive green, homogeneous; sheared.	1.84	54.80
	Clay: very stiff to hard; dark green to olive green, some slightly paler green bands; sheared, some blocky fracture; a few very small black organic fragments; resembles an unlithified mudstone.	3.00	57.80
	Clay: very stiff to hard; dark green to olive green; one pale brown slightly sandy patch; sheared, with steep and shallow angled shear planes in all places.	3.00	60.80
	Clay: very stiff to hard; dark green to olive green; sheared with some blocky fracture, especially near base; one hard, buff, lithified ironstone band (61.31-61.40m).	3.00	63.80
	Clay: very stiff to hard; sheared some blocky fracture; dark green to olive green, some slightly paler green horizons.	1.92	65.72
	Ironstone: very hard, lithified buff grey; sandy, very fine-grained.	0.09	65.81
	Clay: very stiff to hard; dark green to olive green	0.79	66.60
	Ironstone: very hard, lithified; buff grey; sandy, very fine-grained	0.15	66.75
	Clay: very stiff to hard; dark green to olive green.	0.10	66.85
	ECR	0.05	66.80

Lough Neagh Group	**Clay:** very stiff to hard; dark green to olive green and dark grey, patchy; sheared blocky fracture, different coloured clays brought side-by-side by shearing.	0.45	67.25
	Ironstone: very hard, lithified; buff pale grey; sandy, very fine-grained; some firm to stiff grey clay mixed in, including 1cm horizon around middle.	0.21	67.46
	Clay: very stiff to hard; grey to green with some black speckling; some buff, very fine-grained sand mived in; one buff, sandy, very fine-grained partly lithified ironstone band (68.96-69.05m)	1.96	69.42
	Ironstone: very hard, lithified fine-grained; buff white grey.	0.09	69.51
	Clay: very stiff to hard; dark green and dark grey; yellow-brown fine-grained sandy sandy patch; very fine laminations.	0.29	69.80
	Clay: very stiff to hard; dark grey and dark green, some black speckling; some plae grey-buff very fine-grained sandy horizons; a few thin black lignite fragments.	1.50	71.30
	Ironstone: very hard, lithified; buff-white; very fine-grained sandy.	0.12	71.42
	Clay: very dtiff to hard; dark grey to dark green; homogeneous, blocky fracture.	0.67	72.09
	Ironstone: very hard, lithified; buff-white; very fine-grained sandy.	0.06	72.15
	Clay: very stiff to hard; dark grey with black speckling; homogeneous, blocky fracture.	0.26	72.41
	Ironstone: very hard, lithified; buff-white to pale grey; very fine grained sandy.	0.12	72.53
	Clay: hard; dark green-grey; homogeneous; blocky fracture.	0.10	72.63
	NCR	0.17	72.80
	Sandy Clay: very stiff to hard; brown-grey with black speckling; very fine grained, slightly sandy, becoming sandier to base.	0.25	73.05
	Ironstone: very hard, lithified; buff-grey, very fine-grained, sandy.	0.05	73.10
	Clay: very stiff to hard; dark green-grey; homogeneous.	0.82	73.92
	Ironstone: very hard; lithified; buff-grey; fine-grained, sandy.	0.10	74.02
	Clay: very stiff to hard; dark green-grey, some black speckling, fairly homogeneous, with a few faint, small very fine-grained sandy patches; passes down to dark grey-brown and dark grey with a few thin yellow-brown very fine-grained sandy horizons; becomes very dark brown to base.	1.78	75.80

Lough Neagh Group	**Clay:** very stiff to hard; dark grey; sharp contact with darker grey clay horizon; homogeneous.	0.12	75.92
	Lignite: sharp horizontal contact with clay above; black to dark brown; hard, well compacted, good quality; some woody fragments with structure preserved within the lignite often as thin lenses.	2.88	78.80
	Lignite: hard, black good quality; woody patches within compacted lignite show well preserved structure, including knots.	3.00	81.80
	Lignite: hard black; good quality; well compacted; hard woody fragments enclosed.	1.85	83.65
	Clayey lignite: very stiff to hard; black to dark grey clay with much woody lignitic material, stringers and laminae; alternating bands of woody lignite and lignitic clay.	0.19	83.84
	Clay: very stiff to hard; pale white to grey.	0.01	83.85
	Lignitic clay: hard; grey to dark grey; thin woody fragments and laminae; more lignitic to base.	0.20	84.05
	Lignite: hard; black; well compacted; good quality.	0.75	84.80
	Lignite: hard; black; well compacted good quality; woody fragments enclosed have well preserved structure.	3.00	87.80
	Lignite: hard; black; well compacted; good quality.	2.10	89.90
	NCR	0.90	90.80
	Lignite: hard; black to dark brown; well compacted; some clayey lignitic material; one 10cm lignitic clay horizon with woody fragments.	1.85	92.65
	ECR	0.74	91.92
	Lignite: hard; black; well compacted; good quality; woody fragments, lenses and stringers, a little clay mixed in; pale grey clay horizon, (92.83-92.90m).	1.88	93.80
	Lignite: hard black; woody with much preserved structure; good quality; near top pale grey, hard, clayey horizons, packed with lignitic fragments and debris.	2.10	95.90
	Clay: very stiff to hard; pale grey, some slight black mottling; black woody lignite fragments.	0.32	96.22
	Lignite: hard; black well compacted; woody stringers and fragments; several thin pale grey clay horizons and patches around middle.	0.58	96.80
	Lignite: hard; black well compacted.	0.30	97.10
	Clayey Lignite: hard; dark brown; well compacted; woody material in much clay.	0.16	97.26
	Lignitic Clay: stiff to very stiff; plae grey; black, hard, woody debris and stringers; dark grey ar base.	0.26	97.52

Lough Neagh Group	**Lignite and Clayey lignite:** very stiff to hard; black to dark brown; lignite with clayey lignite horizons; also several pale lignitic clay horizons (max. 10cm) with woody fragments, lenses and stringers.	2.28	99.80
	black to dark brown hard clayey lignite and very stiff pale grey clay horizons with lignitic mottling; poor quality.	0.83	100.63
	Lignite: hard; black; woody; several thin, pale grey clay bands, increasing to base; becomes clayey lignite at base.	1.48	102.11
	Clay: stiff to very stiff; grey with brown to dark brown mottling; occasional black woody fragment; dark brown grey thin lignitic clay horizon.	0.44	102.55
	Sandy Clay: very stiff; grey with faint black mottling or speckling; slightly sandy or gritty; thin black woody lignite fragments.	0.25	102.80
	Sandy Clay: very stiff; grey with black mottling or speckling; occasional black woody lignite fragment; slightly sandy or gritty, increasing to very sandy or gritty at base (probably sideritic).	0.80	103.60
	Ironstone: very hard, lithified; plae yellow-grey; fine grained sandy; lithified and unlithified black woody fragments; grey sandy clay band, hard at 103.90-104.00m.	0.50	104.10
	Sandy Clay: very stiff; grey to pale grey; sideritic; several small, buff, hard sideritic nodules near top; occasional small lignite fragments.	1.70	105.80
	Ironstone: very hard, lithified; pale yellow-grey; fine grained sandy, sideritic; gritty at base.	0.21	106.01
	Sandy Clay: very stiff; grey with faint black mottling; slightly sandy (sideritic) less to base.	0.25	106.26
	Ironstone: very hard, lithified; pale yellow-grey; fine grained, sideritic; long thin cavities - possibly rootlet cavities.	0.23	106.49
	NCR	2.31	108.80
	Clay: very stiff; pale yellow-grey; minute lignite fragments give black mottling or speckling; dark brown 10cm lignitic clay horizon around middle; occasional small black woody fragment; more lignitic at base.	0.85	109.65
	Clayey lignite and Lignitic clay: alternating bands of black very stiff, clayey lignite and grey to dark grey clay horizons; clay full of black woody fragments, debris and stringers; many thin woody lignitic laminae throughout; about 50/50 lignitic clay/clayey lignite	2.15	111.80

Lough Neagh Group	**Clay:** very stiff to hard; pale grey: packed with hard thin, black woody lignite fragments.	0.19	111.99
	Clay and Lignitic clay: very stiff to hard; varies black to pale grey; thinly banded; thicker banding to base, with 12cm woody lignite horizon.	0.40	112.39
	Lignite: hard; black; woody; some irregular banding.	0.33	112.72
	Lignitic Clay and Lignite: very stiff to hard; thin, alternating, black lignite bands and grey to dark grey clay with lignite fragments; horizons about 5-10cm.	0.38	113.10
	of pale grey, very stiff clay with lignite fragments, and black, very stiff, clayey lignite (about 60cm) in total; hard woody stringers, lenses and fragments throughout clay.	1.70	114.80
	Lignitic Clay: very stiff to hard; grey to dark grey; lignitic fragments; several dark brown to black very lignitic horizons-clayey lignite-poor quality; occasional hard black fragments, stringers, lenses.	1.87	116.67
	Clay: very stiff to hard; grey; small traces of black woody lignite; several very small white patches of ?; clay becomes slightly sandy in bottom half; several 2-3cm diameter buff-white siderite nodules.	1.23	117.90
	ECR	0.10	117.80
	Clay: very stiff to hard; grey.	0.09	117.89
	Clay: very stiff to hard; pale grey with blue-black wavy mottling and speckling, marble-like appearance.	0.09	117.98
	Sandy clay: hard, grey; very sandy or gritty; poorly consolidated; partly lithified, cemented.	0.10	118.08
	Clay: hard; grey with blue black mottling.	0.16	118.24
	Sandy clay: hard; grey; very sandy or gritty; poorly consolidated; partly cemented.	0.12	118.36
	Clay: hard; pale grey with blue-black mottling.	0.09	118.45
	Ironstone: hard, gritty or sandy grey clay at top; passes into very hard, lithified kellow-grey, fine grained ironstone.	0.14	118.59
	Sandy Clay: hard; grey; slightly sandy (sideritic); some small harder, pale brown sandy patches; sandier in bottom 20cm.	0.66	119.25
	Ironstone: very hard, lithified; pale yellow-grey; fine grained.	0.12	119.37
	Sandy Clay: hard; pale grey; fine-grained sandy; very gritty adjacent to top and bottom ironstones.	0.35	119.72
	Ironstone: very hard, lithified; pale yellow-grey; fine-grained.	0.05	119.77

Lough Neagh Group	**Granular Clay:** hard; pale grey; slightly sandy; full of coarse grain (sand) size and granule size particles of pale grey-blue to brown soft clay.	0.29	120.06
	Ironstone: very hard, buff.	0.01	120.07
	Sandy Clay and Clay: hard; pale grey, fine to medium grained sandy or gritty (sideritic) clay; passes into hard, dark grey clay with faint black mottling increasing to base, becoming mottled with thin black woody lignite fragments.	0.48	120.55
	NCR	0.25	120.80
	Clay: hard; dark grey; speckled with black lignite material.	0.08	120.88
	Lignite: hard; brown to black; woody.	0.06	120.94
	Clay: hard; dark grey in to 10cm; becomes lighter pale blue-grey clay with hard, buff to yellow-grey ironstone nodules.	0.26	121.20
	Sandy Clay: hard; grey; medium to coarse-grained very sandy or gritty with rounded siderite grains; a couple of black to brown hard woody lignite fragments.	0.85	122.05
	Ironstone: very hard; pale yellow-grey; fine-grained.	0.10	122.15
	Granular Clay: hard; pale grey; coarse grain (sand) size and granule size, well rounded particles of pale grey-blue soft clay.	0.15	122.30
	Clay: hard; grey with black speckling and mottling; passes into 10cm of dark grey to black lignitic clay then to dark grey clay with scattered lignite traces.	0.75	123.05
	Clay: hard; grey; very fine grained white material throughout, sometimes concentrated in patches; some small black woody lignite fragments.	0.35	123.40
	NCR	0.40	123.80
	Clay: hard; grey with black wavey mottling or speckling throughout; dark lignitic band in middle.	0.90	124.70
	Sandy Clay: hard blue-grey with blue-black mottling gives marbled appearance; slightly gritty; near base mottling disappears and becomes hard, very sandy, grey clay.	0.80	125.50
	Ironstone: very hard, lithified; pale yellow-grey; very fine-grained.	0.09	125.59
	Granular Clay: very stiff to hard, grey coarse-grained sandy clay; passes into hard, pale green-grey clay, packed with rounded granules of pale green-grey, white, and some black clay giving a mini-conglomerate; several lignitic laminae; several less granular bands.	0.37	125.96

Lough Neagh Group	**Clay and Sandy Clay:** hard; dark grey; black woody laminae; passes into hard, grey clay with very fine grained buff sandy material, coarsening towards base.	0.20	126.16
	Ironstone: very hard; pale yellow-grey; very fine grained.	0.15	126.31
	Sandy Clay: hard; grey then becomes hard, blue grey, slightly sandy; sharp contact with ironstone above.	0.49	126.80
	Clay: hard; blue-grey with black mottling and large patch of purple-brown mottling; several small buff ironstone nodules.	0.40	127.20
	Clay: hard; purple-brown, green and grey mottled with small black (possibly organic) patches; becomes mainly grey, very slightly sandy; bottom 15cm is purple-grey with blue-green mottling.	0.70	127.90
	Clay: hard; grey to blue-grey with faint black mottling or speckling; large black woody fragments and several small fragments; becomes sandy with occasional siderite nodules.	0.88	128.78
	Ironstone: very hard; pale yellow-grey; sandy.	0.06	128.84
	Sandy Clay: hard; grey with purple mottling; slightly sandy; very sandy at base above ironstone.	0.62	129.46
	Ironstone: hard; pale yellow-grey; very fine-grained.	0.11	129.57
	Sandy Clay: hard; purple-grey, becoming blue-grey; sandy rounded siderite grains throughout.	0.28	129.85
	ECR	0.05	129.80
	Clay: hard; pale blue-grey.	0.05	129.85
	Ironstone: hard; grey to buff; partially cemented; very sandy.	0.16	130.01
	Sandy Clay: hard; pale blue-grey with a few purple-brown patches and thin black horizon with possibly organic laminae; slightly sandy.	0.39	130.40
	Ironstone-Sandy Clay: partially lithified, very sandy blue-grey clay; some lithified to form a very hard ironstone; several small purple-brown patches.	0.44	130.84
	Clay: hard; grey to blue-grey with some purple-brown mottling; some slightly sandy patches or horizons, becoming more sandy to base; one hard sandy ironstone band of 4cm.	1.07	131.91
	Sandy Clay: hard; medium to coarse sandy; grey to blue grey to purple-grey, with brown-purple patches; partially cemented; some sideritic patches.	0.77	132.68
	Clay: hard; purple-grey; mottled at base hard, green-grey with black spheroidal weathering, possibly around organic fragments	0.20	132.88
	ECR	0.08	132.80

Lough Neagh Group	**Clay:** hard; pale green-grey; black spheroidally weathered spots as above	0.14	132.94
	Clay: hard; purple-grey with green-brown mottling, and faint black speckling	0.09	133.03
	Ironstone: hard; green-grey; gritty; partially cemented; sideritic	0.15	133.18
	Clay: hard; grey to dark grey with purple-grey mottling; black to dark brown lignitic clay band	0.40	133.58
	Ironstone: very hard; buff to yellow-grey; sandy-gritty	0.15	133.73
	Sandy Clay: hard; blue-grey with some dark blue-black mottling; gritty, due to medium to coarse rounded sideritic grains throughout	1.09	134.82
	Ironstone: very hard; yellow-grey to buff; sandy-gritty	0.18	135.00
	Clay: hard; blue-grey with some purple-brown patches, some black mottling, and a yellow-brown patch near base; gritty, due to medium to coarse sideritic grains scattered throughout	0.80	135.80
	Clay: hard; sheared; blue-grey with faint black mottling purple-brown patches and brown-green organic fragments	0.21	136.01
	Sandy Clay: hard; blue-grey with faint black mottling, grey-brown at base; gritty with medium to coarse rounded sideritic grains throughout, very gritty at base	0.82	136.83
	Clay: hard; pale grey; 2-3cm dark grey lignitic clay band, below which grey clay is mottled with black; also some green mottling at base	0.75	137.58
	Sandy Clay: hard; grey and brown-grey, mottled; gritty-sandy, sideritic	0.37	137.95
	Clay: hard;pale grey; 2-3cm dark grey lignitic clay bands, below which grey clay is mottled with black	0.34	138.29
	Sandy Clay: hard; pale grey; gritty with medium to coarse sideritic grains; two 1cm black woody stringers and large reworked woody fragment at base	0.60	138.89
	ECR	0.09	138.80
	Sandy Clay: hard; purple-brown and grey, mottled; very gritty with medium to coarse rounded siderite grains thin, steeply dipping ironstone band	0.25	139.06
	Clay: hard; green-brown, mottled with possibly organic black fragment or patch; passes into grey with green-grey mottling	0.45	139.52

Lough Neagh Group	**Sandy Clay:** hard; grey with green and dark grey mottling, gritty with rounded medium to coarse siderite grains, one thin black woody fragment; becomes blue-grey with some purple-grey patches, grit, with one 2cm very hard ironstone band; becomes blue-grey with faint black mottling; becomes grey-green, very gritty	2.06	141.58
	Clay: hard; blue-grey; small, buff sideritic patches	0.18	141.75
	Ironstone: very hard; grey to blue-grey; very gritty; partially cemented sideritic clay band	0.06	141.82
	ECR	0.02	141.80
	Clay: hard; blue-grey, with faint dark blue-black mottling, becoming more evident; also becoming slightly sandy	0.50	142.30
	Sandy Clay: hard; purple-brown; very gritty with medium to coarse rounded siderite grains; becomes grey-brown; then yellow-brown, very gritty, some shearing	1.55	143.85
	Sandy Clay: hard; grey and purple-grey, patchy; becoming brown-grey, with grey patches and some green grey mottling and some faint black mottling in places; less gritty than above, though increasing to base	0.95	144.80
	Ironstone: very hard; yellow-grey to buff; fine to medium grained; gritty	0.13	144.93
	Clay: hard; purple-grey and grey, mottled; slightly sandy; one black reworked woody fragment	0.30	145.23
	Sandy Clay: hard; grey and green-grey; very gritty, sideritic; one buff siderite nodule	0.19	145.42
	Clay: hard; grey to blue-grey with purple-grey mottling; slightly sandy	0.27	145.69
	Clay: hard; grey with some green to olive-green	0.31	146.00
	Clay: hard; dark green-grey with many grains of coloured clay; becomes dark grey and more grainy; black lignite fragments, laminae and one stringer; bottom 5cm has white granular material	0.65	146.65
	Clay: hard; grey and blue-grey; some slightly sand patches	0.78	147.43
	Granular Clay: thin, buff, hard ironstone passes into coarse-grained sandy or granular clay with coloured, rounded clay granules	0.20	147.63
	Clay: hard; grey; gritty; sideritic	0.17	147.80
	Sandy Clay and Clay: top 10cm are purple-grey, gritty sideritic clay; sheared contact with grey, very sideritic in places, sometimes very sandy with some hard ironstone patches near top; speckled in otherp laces with mostly white, but some dark specks	3.08	156.88
	ECR	0.08	156.80

Lough Neagh Group	**Conglomerate:** hard; dark green matrix, mainly off-white and dark green clasts of clay with other colours; mostly rounded, some angular, possibly fining-upward cycle (not very well ordered), small pebbles to coarse grain size and specks	0.87	157.67
	Clay: hard; mostly blue-grey in top half, with some brown mottling and sandy, sideritic in places; bottom half is mostly brown to purple-brown, also sandy in places, some very sandy patches; broken up, crumbly near base; occasional clay clast and specks in places	2.21	159.88
	ECR	0.08	159.80
	Clay: hard; brown. purple-brown, light blue, mottled, sometimes in concentric pattern with light blue on inside (the original colour?); sandy, sideritic with some very sandy patches	0.41	160.21
	Clay: hard; varies in irregular bands from purple to purple-brown to brown and blue-grey mottled to brown; sandy, sideritic, except in bottom section, where becomes packed with clay specks	1.61	161.82
	Ironstone: very hard; buff mostly; appears to be a sideritized clay packed with clay specks	0.27	162.09
	Clay: hard; green-blue at top, packed with mostly white and green clay specks; becoming brown and then brown-blue-grey, still with many specks, white, green, red, orange; some small pyrite nodules around middle	0.74	162.83
	ECR	0.03	162.80
	Clay: hard; brown-blue-grey to brown, irregularly banded; packed with clay specks; some lignitic traces near base; pyrite nodules in various places, up to 1cm diameter with good cubic form	0.79	163.59
	Clay and conglomerate: hard; clay is brown in general, but packed with many colours of clay specks; band of 43cm near base contains clay clasts of coarse-grain to small pebble size, fairly unsorted; some pyrite nodules; some lignitic traces	0.97	164.56
	Clay: hard, light blue with brown and some dark blue mottling, some small pyrite nodules and crystally and specks near top	1.18	165.74
	NCR	0.06	165.80
	Clay: hard; top is light blue with brown mottling; rest is brown with some light blue mottling	1.27	167.07
	Clay: hard; crumbly in places and shears easily; mostly brown with blue-grey mottling; some brown-purple with brown mottling; some blue-grey with brown mottling; some clay specks near base	1.90	168.97

Lough Neagh Group	ECR	0.17	168.80
	Clay: hard; brown and blue-grey mottled; packed with clay specks; specks harder toward base - siderite; probably both clay and siderite grains with siderite increasing to base	1.42	170.22
	Clay: hard; irregularly banded brown and blue-grey; packed with clay specks and probably also some siderite grains in top about half; with well-rounded clay clasts of coarse-grain to small pebble size in bottom about half (mostly coarse to granule size); some hard ironstone fragments or patches about 1m from top	1.66	171.88
	ECR	0.08	171.80
	Mini-conglomerate and Clay: hard; top 60cm is brown clay packed with coarse-grain to granule size clay clasts and with many dark brown lignitic laminae and thin bands; this grades into fairly dark brown clay with some lignitic traces with 1.5cm mini- conglomeratic band, and conglomerate of mostly granule and small pebble size clay clasts at base	1.08	172.88
	Clay: hard; blue-grey to light blue with some brown grey mottling; blue-grey becomeas more blue-grey towards base; mostly sandty to very sandy, sideritic	0.54	173.42
	Clay: hard; blue-grey at top with some brown mottling; rest is green-blue, also with brown mottling; sandy, sideritic with some very sandy patches	1.32	174.74
	NCR	0.06	174.80
	Clay: hard; green-blue with some purple mottling and some brown patches near base; sandy., sideritic in top section; some white and dark clay (?) specks near and at base; one good shear near base	2.16	176.96
	Clay: hard; green-brown with some blue-grey or green-blue mottling; becoming blue-grey at base with some brown mottling; packed with clay specks	0.83	177.79
	NCR	0.01	177.80
	Clay: hard; brown-blue-grey with many clay specks of many colours; specks increase at base as clay becomes buff overall with darker organic laminae	1.19	178.99

Lough Neagh Group	**Conglomerates:** hard; top is mini-conglomeratic with lignitic laminae, fragments and stringers common; majority is a poorly sorted conglomerate of mainly rounded clay clasts, mostly granule-size to pebble-size (although smaller and larger occur) of many colours, including dark green, orange, buff, and off-white in a dark green clay matrix; some lignitic traces; at base, dark green small to large rounded pebbles, probably basalt in matrix of dark green clay and/or coarse-grain to granule size dark green grey clasts; some pea-sized pyrite nodules (spheroidally weathered in-situ basalt?)	1.50	180.94
	Conglomerate: hard; small to large rounded pebbles, probably basalt in matrix of dark green clay and/or coarse- grain to granule size dark green clay clasts; most clasts dark green, some various browns and other colours	0.45	180.94
	ECR	0.14	180.80
	Mini-conglomerate: hard; a few dark green pebbles at top; rest is packed with mostly buff grey specks and has frequent lignitic laminae and some fragments	0.34	181.14
	Conglomerate: hard; dark green small, medium and large pebbles in dark green clay matrix; band of clayey lignite near base; some mosly small pebble size pyrite nodules. Conglomerate or in-situ weathered basalt?	0.84	181.98
	Conglomerate: hard; dark green clay matrix with mostly coarse-grain size to granule size clay clasts, many colours; some up to medium pebble size near base (fining upward cycle); clasts mostly rounded; a few lignitic traces and fragments near top	1.00	182.98
Antrim Lava Group	**Highly Weathered Basalt (Clay):** hard; green-blue with some darker green mottling near base; inside some brown (iron-rich) spots in places; also in places - white clay specks, causing sandy clay	0.65	183.63
	Highly Weathered Basalt (Clay): hard; green-blue; some iron-rich spots	0.15	183.78
	NCR	0.02	183.80
	Highly Weathered Basalt (Clay): hard; top 1.10m is green-blue with some iron-rich spots and with some brown mottling towards base; rest is orange-red, brown-red, red-brown, green-blue brown and dark brown, yellow-brown and red, mottled	3.06	186.86
	ECR	0.06	186.80

Antrim Lava Group	**Highly Weathered Basalt (Clay):** hard; sheared and broken up in places; red-brown with some dark green areas and "clasts"; some good igneous texture near base; some very small specks of native copper; a few brown-yellow patches or "clasts"	3.01	189.81
	ECR	0.01	189.80
	Highly Weathered Basalt (Clay): hard; red-brown with brown-yellow spots and with dark green "clast" near top that shows possible igneous texture; becomes more red-purple to base, still with brown-yellow areas (some may be veins) and some lighter blue-purple areas	0.41	190.21
	Highly Weathered Basalt (Clay): hard; sheared and broken up in places; red-brown and brown-red overall, with some patches or "clasts" of mostly brown-yellow clay; some dark green "clasts" at base	2.57	192.78
	NCR	0.02	192.80
	Highly Weathered Basalt (Clay): hard; sheared and broken up in places; red-brown and brown-red overall, with some patches or "clasts" of mostly brown-yellow clay; some dark green "clasts" at base	0.80	193.60
	Highly Weathered Basalt (Clay): hard; some shears;mostly red-brown with some brown-yellow patches but also some dark green areas with good igneous texture; one of these, near base, is very hard and contains some white calcite veins and veinlets	2.37	195.97
	ECR	0.17	195.80
	Highly Weathered Basalt (Clay): hard; orange-brown at top becoming red-brown at base; results of spheroidal weathering shown well, especially in top half with some of the "clasts" (various browns, greens, reds and off-whites), exhibiting igneous texture	0.97	196.77
	Highly Weathered Basalt (Clay): hard;some shears; mostly red-brown but with dark green (less weathered?) band near base, showing igneous texture and with calcite veinlets; calcite veinletts also in other areas; spheroidal weathering again shown up with various colours of "clasts", igneous texture in some	2.10	198.87
	ECR	0.07	198.80
	Highly Weathered Basalt (Clay): hard; some shears; crumbly in places; mostly red-brown overall with other clours in "clasts"; some brown-yellow spots near base; less red-brown, more green-brown and in places dark green towards base	1.24	200.04

Antrim Lava Group	**Highly Weathered Basalt (Clay):** hard; crumbly in most places; dark green mostly with igneous texture in places; red-brown at top and in bottom section; some calcite veins in harder band around middle	1.87	201.91
	ECR	0.11	201.80
	Highly Weathered Basalt (Clay): hard; crumbly; red-brown at top, and brown-red and red-brown around middle, rest is dark green; some "clasts" at top	1.60	203.40
	Highly Weathered Basalt (Clay): hard; crumbly, some shears; dark green;some very light green and white weathering product in veins; some igneous texture	1.44	204.84
	ECR	0.04	204.80
	Highly Weathered Basalt (Clay): hard; some shears; crumbly; dark green becoming green-red-brown and then brown-red and green-red-brown to base; igneous texture in dark green area	1.97	206.77
	Highly Weathered Basalt (Clay): hard; crumbly; mostly red-brown with some dark green areas or patches mainly at base	1.02	207.79
	NCR	0.01	207.80
	Highly Weathered Basalt (Clay): hard; crumbly; dark green at top and bottom, but mostly red-brown; igneous texture in dark geen areas	2.37	210.17
	Highly Weathered Basalt (Clay): hard; crumbly; dark green with igneous texture in places; green-brown patch near base	0.72	210.89
	ECR	0.09	210.80
	Highly Weathered Basalt (Clay): hard; sheared; crumbly; purple-dark green; good igneous texture in places; purple tint to base	2.58	213.38
	Highly Weathered Basalt (Clay): hard, very hard at top; some shears; crumbly dark green overall with green-brown band just above middle, including some brown-yellow spots and patches; igneous texture in places; purple tint to base	0.57	213.95
	ECR	0.15	213.80
	Highly Weathered Basalt (Clay): hard; sheared; crumbly;purple-dark green; good igneous texture	1.21	215.01
	Weathered Basalt: very hard; dark green with many calcite veins and veinlets	1.75	216.76
	NCR	0.04	216.80
	Weathered Basalt: very hard; dark green	1.58	218.38
	ECR	0.18	218.20
	End of Borehole		

ENCLOSURE 1

Pollen and Spore Assemblages from the Oligocene Lough Neagh Group and Dunaghy Formation, Northern Ireland
John Andrew Fitzgerald
September 1999
Enclosure 1. 13/611 Landagivey No. 1 % Abundance Histogram

13/611 LANDAGIVEY No. 1

INTERVAL 0.00m - 280.55m
SCALE 1:1500

% Abundance Histogram

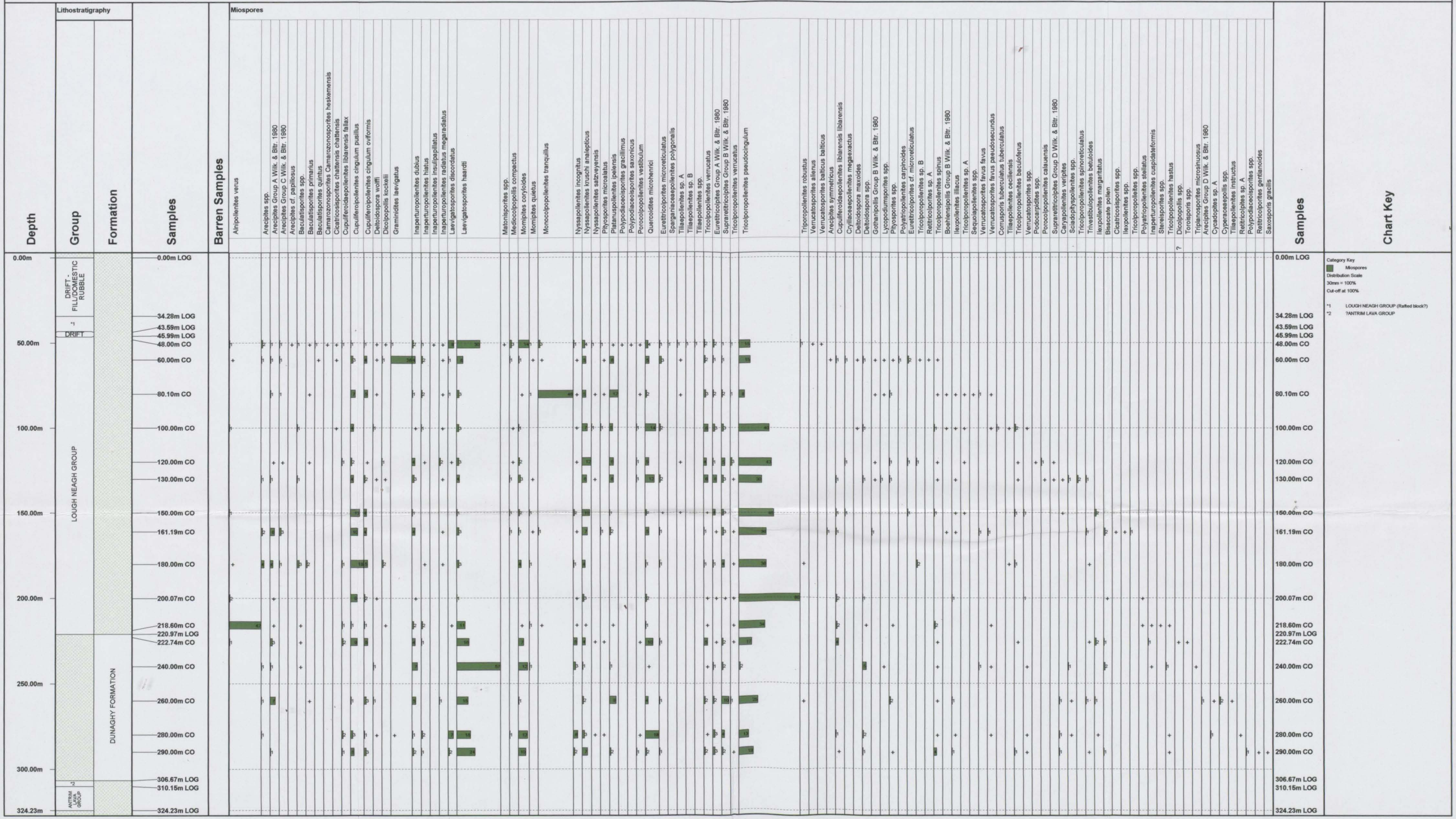
ENCLOSURE 2

Pollen and Spore Assemblages from the Oligocene Lough Neagh Group and Dunaghy Formation, Northern Ireland
John Andrew Fitzgerald
September 1999
Enclosure 2. 13/603 Ballymoney No. 1 % Abundance Histogram

13/603 BALLYMONEY No. 1

INTERVAL 0.00m - 324.23m
SCALE 1:1500

% Abundance Histogram



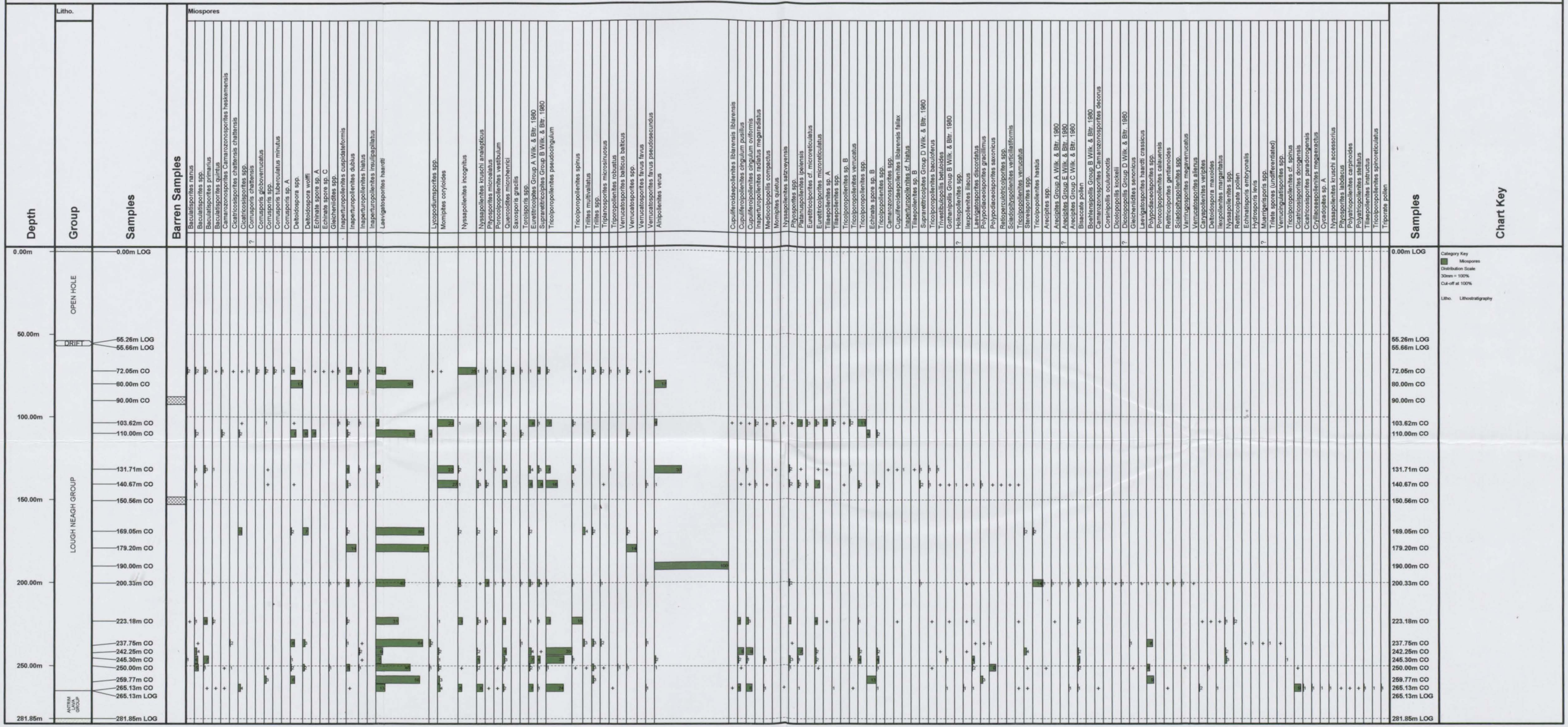
Pollen and Spore Assemblages from the Oligocene Lough Neagh Group and Dunaghy Formation, Northern Ireland
John Andrew Fitzgerald
September 1999
Enclosure 3. 27/415 Upper Mullan No. 1 % Abundance Histogram

ENCLOSURE 3

36/4680 DEERPARK No. 2

INTERVAL 0.00m - 281.85m
SCALE 1:1500

% Abundance Histogram



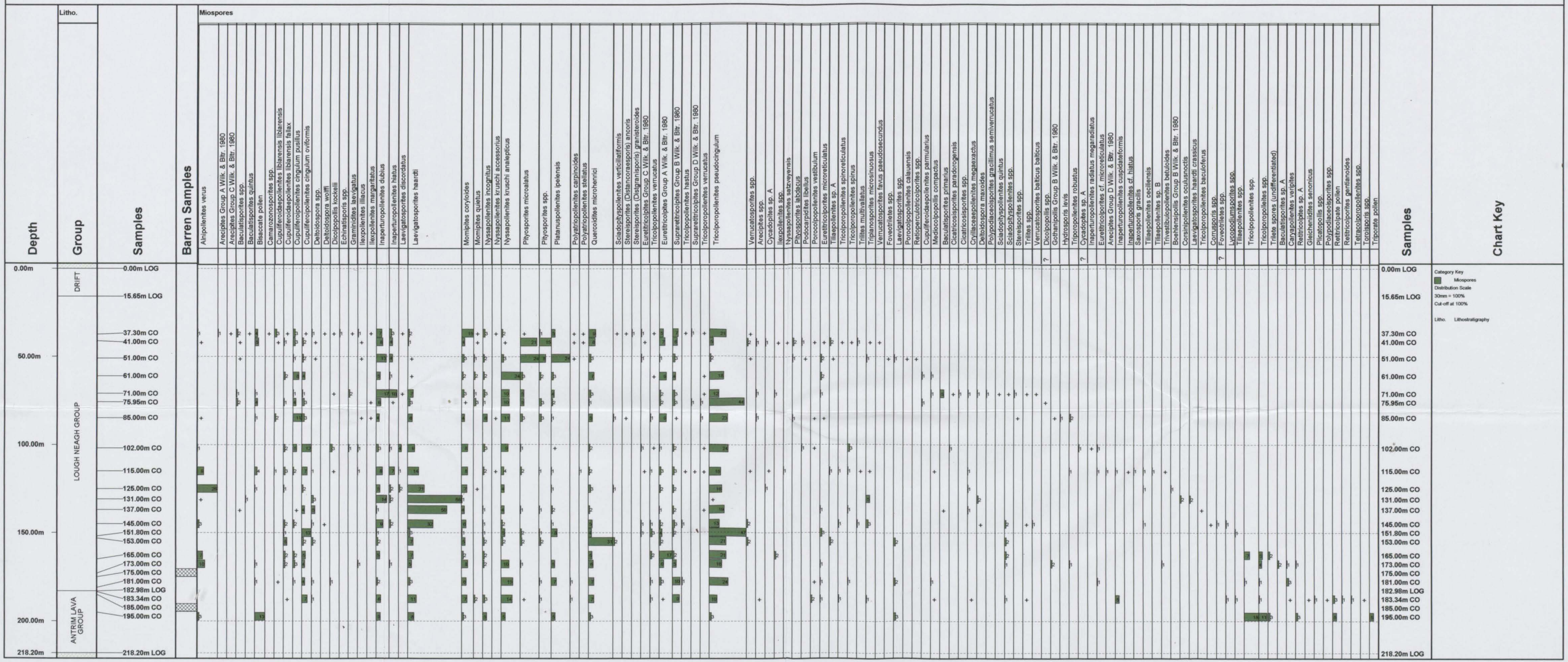
ENCLOSURE 4

Pollen and Spore Assemblages from the Oligocene Lough Neagh Group and Dunaghy Formation, Northern Ireland
John Andrew Fitzgerald
September 1999
Enclosure 4. 36/4680 Deerpark No. 2 % Abundance Histogram

27/415 UPPER MULLAN No. 1

INTERVAL 0.00m - 218.20m
SCALE 1:1500

% Abundance Histogram



ENCLOSURE 5

13/611 LANDAGIVEY No. 1

INTERVAL 0.00 - 280.55m

Stratigraphic Range Chart

Pollen and Spore Assemblages from the Oligocene Lough Neagh Group and Dunaghy Formation, Northern Ireland
John Andrew Fitzgerald
September 1999
Enclosure 5. 13/611 Landagivey No. 1 Stratigraphic Range Chart

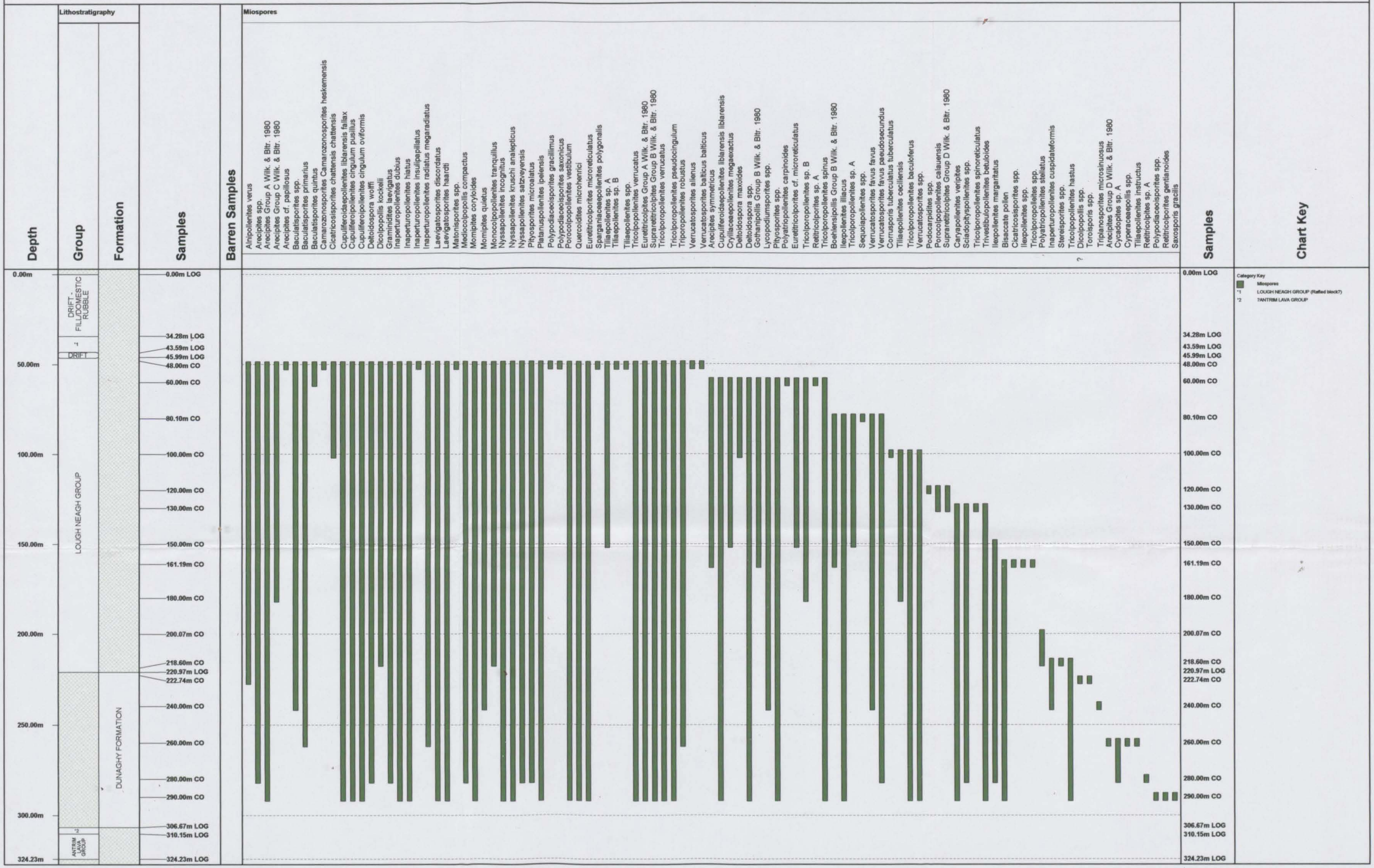
Pollen and Spore Assemblages from the Oligocene Lough Neagh Group and Dunaghy Formation, Northern Ireland
John Andrew Fitzgerald
September 1999
Enclosure 6. 13/603 Ballymoney No. 1 Stratigraphic Range Chart

ENCLOSURE 6

13/603 BALLYMONEY No. 1

INTERVAL 0.00 - 324.23m

Stratigraphic Range Chart



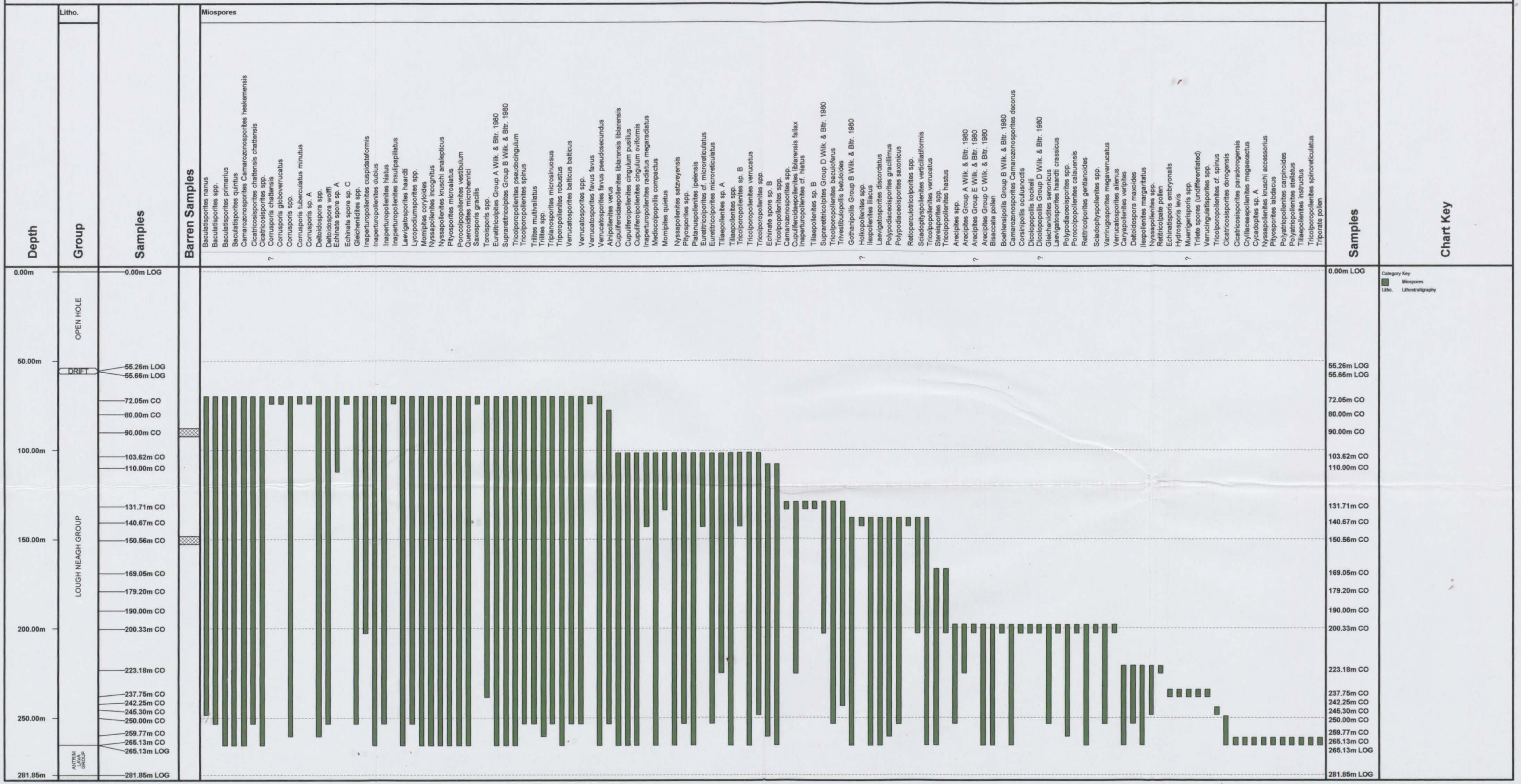
ENCLOSURE 7

Pollen and Spore Assemblages from the Oligocene Lough Neagh Group and Dunaghy Formation, Northern Ireland
John Andrew Fitzgerald
September 1999
Enclosure 7. 27/415 Upper Mullan No. 1 Stratigraphic Range Chart

36/4680 DEERPARK No. 2

INTERVAL 0.00 - 281.85m

Stratigraphic Range Chart



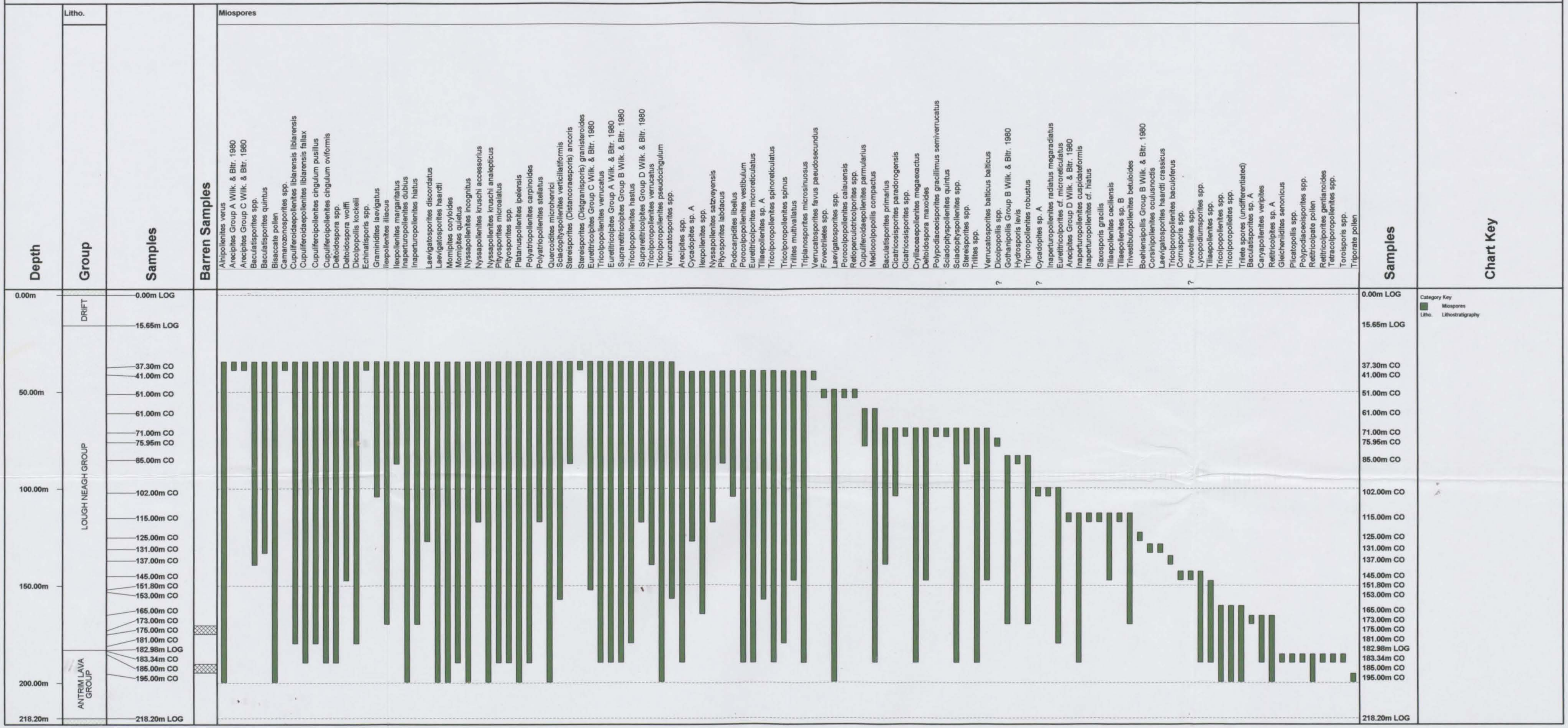
Pollen and Spore Assemblages from the Oligocene Lough Neagh Group and Dunaghy Formation, Northern Ireland
John Andrew Fitzgerald
September 1999
Enclosure 8. 36/4680 Deerpark No. 2 Stratigraphic Range Chart

ENCLOSURE 8

27/415 UPPER MULLAN No. 1

INTERVAL 0.00 - 218.20m

Stratigraphic Range Chart



Pollen and Spore Assemblages from the Oligocene Lough Neagh Group and Dunaghy Formation, Northern Ireland
John Andrew Fitzgerald
September 1999
Enclosure 9. 13/611 Landagivey No. 1 % Abundance Familial Affinity

Pollen and Spore Assemblages from the Oligocene Lough Neagh Group and Dunaghy Formation, Northern Ireland
John Andrew Fitzgerald
September 1999
Enclosure 10. 13/603 Ballymoney No. 1 % Abundance Familial Affinity

Pollen and Spore Assemblages from the Oligocene Lough Neagh Group and Dunaghy Formation, Northern Ireland
John Andrew Fitzgerald
September 1999
Enclosure 11. 27/415 Upper Mullan No. 1 % Abundance Familial Affinity

Pollen and Spore Assemblages from the Oligocene Lough Neagh Group and Dunaghy Formation, Northern Ireland
John Andrew Fitzgerald
September 1999
Enclosure 12. 36/4680 Deerpark No. 2 % Abundance Familial Affinity

ENCLOSURE 13

BOREHOLE CORRELATION

KEY

LOUGH NEAGH GROUP
- NON-LIGNITIC STRATA: Clay, sandy clay, sand, ironstone, thin lignite and clayey lignite and lignitic clay.
- LIGNITIC STRATA: Lignite and clayey lignite (>20 cm thick).
- GREEN CLAY: Dark green, hard, homogeneous clay, rare ironstone.
- CONGLOMERATE: Pebbly clay with clasts of clay, lignite, ironstone and basalt.

DUNAGHY FORMATION: 13/603: Clay, sandy clay rare ironstone, thin lignite and lignitic clay, conglomerate, lithomarge (of igneous origin).
13/611: Mottled brown, khaki, brick red clay with conglomerate, thin lignite and tuff.

ANTRIM LAVA GROUP: Basalt lavas, lithomarge

?ANTRIM LAVA GROUP: Lithomarge, laterite, palaeosol horizons, clay, weathered basalt.

Cooling drying climate.

Normal contact.

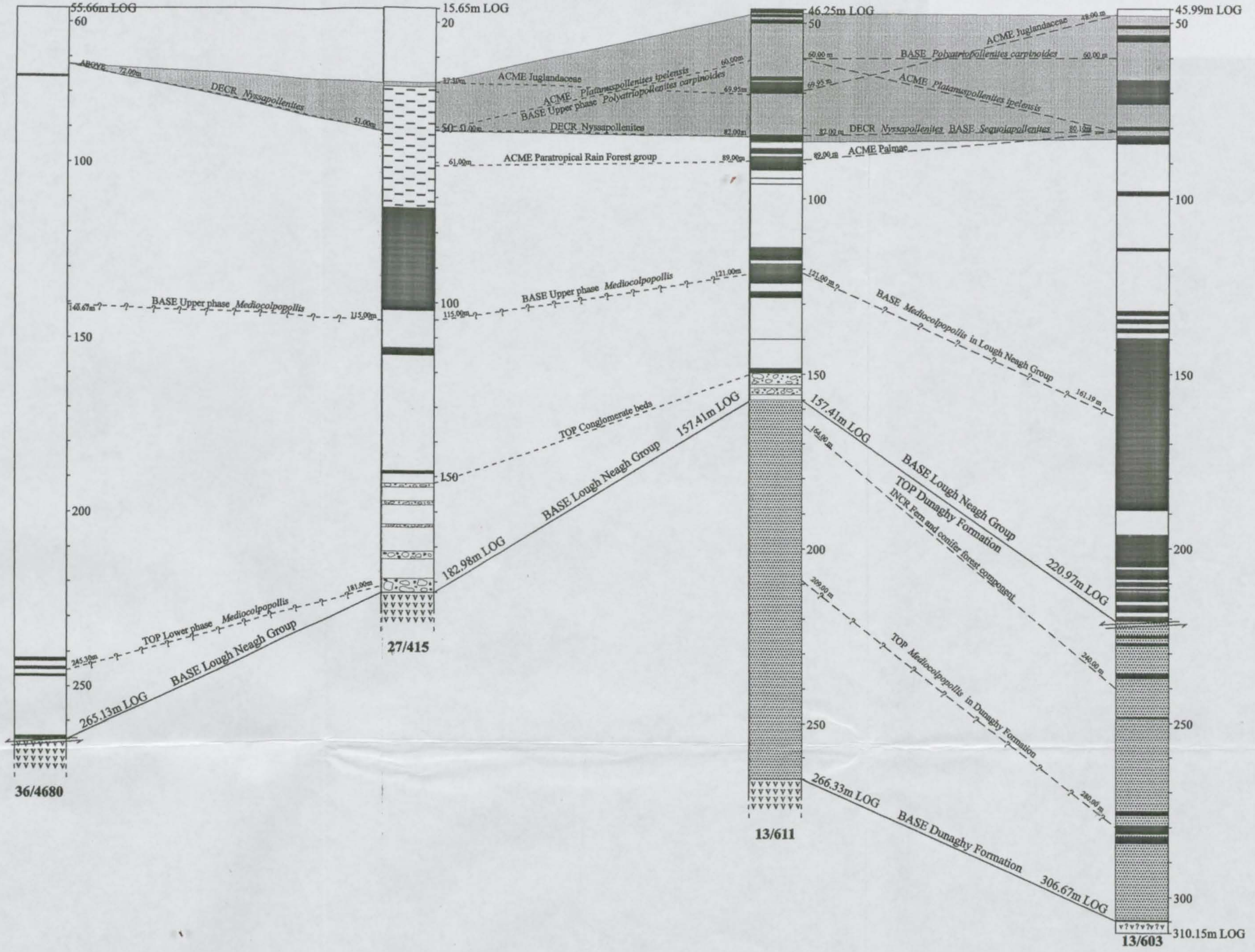
Faulted contact.

Line of correlation

Line of questionable correlation

DECR Decrease

INCR Increase



Pollen and Spore Assemblages from the Oligocene Lough Neagh Group and Dunaghy Formation, Northern Ireland
John Andrew Fitzgerald
September 1999
Enclosure 13. Correlation Panel