The palynology of selected Ordovician localities in Scotland

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This thesis is dedicated to Barbara and Bernard Whelan

with my love.

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Summary

Ordovician samples have been collected from various places from within three separate terranes in Scotland; the Highland Border Complex, the Southern Uplands and the Midland Valley. The samples have been palynologically processed and their assemblages studied with the aim of understanding some of the palaeoecological, biostratigraphical and thermal relationships of the three areas.

Seventy one samples have been processed from nine localities of the Highland Border Complex and these have yielded fifteen species of chitinozoans in four genera, as well as indeterminate species of those genera. There are also five species of acritarchs in four genera as well as other microfossils. Black shales from the Complex yield the most diverse palynomorph assemblages, and were probably deposited from Arenig through to Caradoc although not necessarily at the same time in different parts of the basin. The preservation of palynomorphs appears to be better in the west of Scotland than in the east.

From the Southern Uplands samples have been processed from Coldingham Bay and proved barren, from Barrhill the assemblages are poor, but from the Ordovician-Silurian boundary beds (*C. peltifer* to *P. acuminatus* Zones) at Dob's Linn they are quite diverse although abundance is very low, with forty three samples yielding thirty three species of acritarchs in eighteen genera, thirty one species of chitinozoans in thirteen genera and various other microfossils. The boundary cannot be delineated using the palynological assemblages, and although *Tylotopalla* sp. A and *Ancyrochitina ancyrea* Eisenack 1931 are common in most of the samples from the boundary the palynomorphs do not appear to mirror the changes that occur in the graptolite assemblages.

From the Midland Valley samples have been processed from eight miscellaneous localities in the region of Girvan , giving very little biostratigraphical data, although one sample from Doularg Hill is dated as upper Arenig to lower Llanvirn. A section of twelve samples processed from the Mill and Shalloch Formations (*D. complanatus* and *D. anceps* Zones) at Woodland Point, Girvan, has yielded thirty five species of chitinozoans in twelve genera including a new species *Angochitina woodlandensis* and five new combinations; *Belonechitina comma* (Eisenack 1959), *Belonechitina hirsuta* (Laufeld 1967), *Belonechitina micracantha* (Eisenack 1931), *Belonechitina schopfi* subsp. *americana* (Taugourdeau 1965), and *Belonechitina*

seriespinosa (Jenkins 1969). There are also forty seven species of acritarchs in twenty one genera, including two new species; *Actinotodissus woodlandense*, and *Goniosphaeridium girvanense*, and many scolecodonts. Spores are common and three species are recognised at Woodland Point. The samples are dated as Upper Ordovician and *Calpichitina lenticularis* (Bouché 1965) and *Acanthochitina barbata* appear to be important Upper Ordovician indicators, possibly being near-shore species as they are not found in rocks of the same age at Dob's Linn. *Calpichitina lenticularis* is very important in one sample and less so in all the others and it is suggested that it may be reworked. The palaeoecological picture at Woodland point shows an offshore situation in the Mill Formation, becoming more near-shore at the base of the Shalloch Formation and then more off-shore again.

The palaeoecology of both Dob's Linn and Woodland Point are discussed and chitinozoans found to be more common in black shales than grey mudstones, although the acritarchs do not appear to be preferentially found in grey mudstones or black shales. Netromorph acritarchs are less common at Dob's Linn than was expected, but are very common at Woodland Point which may suggest that the sediments at Woodland Point were deposited more offshore than those at Dob's Linn but were more greatly influenced by turbiditic material. Sphaeromorph acritarchs at Woodland Point are very common and due to the variable thickness of the walls it is suggested that there is a mixing of near-shore and off-shore species, possibly by the turbiditic action mentioned above. *Belonechitina* is markedly more important at Woodland Point than at Dob's Linn the reverse of which is true with *Cyathochitina*. The suggested reason for this is that *Belonechitina* is a near-shore species whilst *Cyathochitina* is an off-shore species. *Veryhachium* appears to become more important towards the end of the Ordovician, as a sample each from Woodland Point and Dob's Linn contain three species of this relatively rare genus, although the significance of this is not yet known.

The samples from Dob's Linn and Woodland Point are compared with published works using the Jacquard Coefficient and the results presented. The samples at Dob's Linn are compared with the Ordovician-Silurian boundary sediments elsewhere, and although different species are present at Dob's Linn and on Anticosti Island, and the abundance and diversity is lower at Dob's Linn, the boundary in Scotland has a much better palynomorph assemblage than was expected. The boundary assemblage presented here is quite similar to the one in Skåne, Sweden.

Finally the thermal history of the samples is discussed, and a general trend appears, with the samples from Girvan being the least altered, those from the Southern Uplands being moderately altered and finally the Highland Border Complex samples which have been subjected to temperatures probably between 200 and 300°C, and thus strongly altered.

Chapter 1 - Introduction

During the years 1980-1984 much work was undertaken by the research group at Glasgow University on the Highland Border Complex, studying it's petrography, structure, and palaeontology in great detail. During this time some preliminary work was undertaken on the palynology (Burton *et al.* 1984, Burton and Curry in Curry *et al.* 1984). This prompted the initiation of a more comprehensive research project into the palynology of the Highland Border Complex, with the aim of helping to understand its rôle within the Caledonian Orogenic belt.

The rocks of the Highland Border Complex have been subjected to complex deformation and consequently fossil yields are very low and the preservation very poor, but Curry (1986b) states '..it is the poorness and intractibility of the exposures which arguably makes the fossil discoveries all the better as a demonstration of the potential of palaeontology for tectonics..'. In the last twenty to thirty years palynology has become a standard and important biostratigraphical tool to use on well preserved sediments, particularly in the oil industry where samples are small and macrofossils would be broken, or on sediments that are sparse in macro- or other micro-fossils. Why then should it not be used on more poorly preserved sediments? Laufeld (1967) remarked that "...the chitinozoans' high degree of resistance against tectonic disturbances is remarkable and opens the possibility of using them as a stratigraphic tool in tectonically disturbed and slightly metamorphosed sediments in, e.g., the Caledonides, especially when our knowledge of full relief material has become greater".

Marine palynomorphs have many advantages not shown by other groups of fossils in that they do not appear to show the marked provincialism that conodonts and graptolites show (Bergström 1986), they are present in the main types of marine sediments, many species have short vertical ranges and their extraction is neither complicated nor particularly time consuming. However Paris (1981) states that much of the early work on chitinozoans was not done systematically and the material used was often poorly preserved. It is then the studies carried out on diverse and well preserved material (e.g. Jenkins 1967, 69,70, Loeblich and Tappan 1978, Turner 1984, Achab 1977a,b, 1978a, b) which allow work to be undertaken on much poorer material.

Throughout the processing of these highly deformed rocks it has become clear that chitinozoans are generally more resistant than most acritarchs. Jenkins (1967, p. 477) remarks on this fact and concludes that acritarchs are more readily destroyed by carbonisation and oxidation, though the relative preservation of acritarchs and chitinozoans may depend upon lithology (K.J. Dorning pers. comm.). However palynomorphs still provide the best hope of reasonable biostratigraphical evidence from marine sedimentary rocks. Downie (1973, p. 240) states "....In many apparently unfossiliferous Palaeozoic rocks they (acritarchs) provide the only biostratigraphical evidence and in most marine strata of Palaeozoic age they outnumber other common fossils". Foraminifera and ostracods are of little stratigraphical value in rocks of this age (Jenkins 1967).

Theoretically palynology is an extremely useful tool, applied to rocks of all kinds, as only a small sample of rock is needed, usually about a hundred grammes. Although palynological work is common on undeformed sediments, it is more rarely attempted on deformed rocks. Several workers though, have shown its importance, among them Downie and Ford (1966), Wadge, Owens and Downie (1967), Downie and Tremlett (1968), Lister, Burgess and Wadge (1967), Burmann (1968,70) Downie *et al.*, (1971), Gardiner and Vanguestaine (1972), Smith (1977), Colthurst and Smith (1977), Kalvacheva (1978), Molyneux (1979), Graham and Smith (1981), Molyneux and Rushton (1984) and Albani *et al.* (1985). Chitinozoans and acritarchs from the Highland Border Complex, although often bent, when well preserved can be identified, often to specific level.

The initial aim of this project has been to apply palynological techniques to the parts of the Highland Border Complex which are deficient in macrofossils, with the object of providing a coherent stratigraphy for it. This will lead, eventually, to the resolution of the origins, and resolve the conflict over the formation, stratigraphy and tectonic history of the Complex. Acritarchs and chitinozoans seem to be excellent groups on which to study the biostratigraphy of poorly preserved sediments.

Samples have been processed from all major transects across the Highland Border Complex and from as many different lithologies as possible from each transect. The fossils are difficult to extract, sometimes deformed and often recrystallised to graphite (Downie *et al.* 1971) which destroys fine structures.

It is important to note that palynomorphs are often the only fossil evidence that is available from large parts of this much deformed Complex, and therefore very valuable for biostratigraphical interpretation. Identifiable specimens of chitinozoan and acritarch species have been recovered, as well as scolecodonts, and other microfaunal remains, from rocks of high geothermal alteration, up to and including marble. Parts of the contiguous Dalradian rocks have also been investigated which have yielded a specimen of a small shelly fossil of Tommotian-Atdabanian age (late Proterozoic to Lower Cambrian).

The Midland Valley and the Southern Uplands form adjacent terrains to the Highland Boundary Complex, and Ordovician rocks are exposed within these two structural areas, particularly at Girvan in the southern Midland Valley and at several localities in the Southern Uplands, from which material was collected to use as comparative material to the Highland Border Complex material.

In 1985 the international stratotype of the Ordovician-Silurian boundary was designated at the base of the *Parakidograptus acuminatus* graptolite Biozone in the Linn Branch section at Dob's Linn in the Central Belt of the Southern Uplands of Scotland (Cocks 1985). As no formal palynological study had previously been undertaken at Dob's Linn, samples were collected from the Ordovician *Climacograptus peltifer, Climacograptus wilsoni, Dicranograptus clingani, Pleurograptus linearis, Dicellograptus complanatus, Dicellograptus anceps, Climacograptus extraordinarius, Glyptograptus persculptus* and Silurian *P. acuminatus* graptolite Biozones, at the Little Cliff, Main Cliff and Linn Branch sections. Samples were collected from all the graptolite zones, but particular attention was paid to collection from two areas

(a) the *D. anceps* Zone, in order to assess the effect of facies variations on the distribution of the palynomorphs

(b) the Ordovician-Silurian boundary. Samples were collected from five, ten, fifteen, twenty and thirty centimetres either side of the Ordovician-Silurian boundary, to test for a correlation with the graptolite zones.

Preservation of the Dob's Linn palynomorphs is much better than those of the Highland Border Complex, but is still not very good. Therefore a third locality was selected for sampling: Girvan. There are about three thousand metres of Upper Ordovician and Lower Silurian sediments at Girvan, all of which are low metamorphic grade. It seemed logical to collect samples of an approximately similar age to those from Dob's Linn, and so the Upper Ordovician (*D. complantus* to *D.anceps*Zones) Shalloch and Mill Formations were chosen. Turner (1979 m.s.), had collected one sample from the Shalloch Formation on the Girvan foreshore for comparative material to his main sample area of the type Caradoc in Shropshire. In this present study eleven samples were collected from the Shalloch Formation, and one from the underlying Mill Formation of the Upper Whitehouse Group at Woodland Point, in order to ascertain as to whether Turner's (1979 m.s.) conclusions were correct.

Other samples collected at Girvan include one from the Caradoc infra-

Kilranny mudstones at Dow Hill, two from the Caradoc Ardwell Flags (Ardmillan Braes and Ardwell Farm) and two from the Lower to Middle Ordovician Jubilation Member from Plantation Burn, Doularg Hill. Samples were also collected from Barrhill in the Northern Belt of the Southern Uplands, Coldingham Bay, on the Berwickshire coast, and at Ballantrae south of Girvan .

Both the samples from Girvan and Dob's Linn have yielded well preserved and identifiable acritarchs, chitinozoans and at Girvan spores. Organic-walled microfossils are subject to alteration related to the thermal effects that the sediments have suffered. At Girvan the acritarchs are almost colourless to yellow, at Dob's Linn they are dark brown to grey or black and the palynomorphs from the Highland Border Complex are invariably black.

The specimens that have been found in the Highland Border Complex although poorly preserved have yielded valuable biostratigraphical imformation that have led to a number of stratigraphical conclusions.

Precambrian and Lower Palaeozoic palynological research from Scotland.

The previous palynological research that has been carried out in Scotland is listed in Downie (1984), and that and other records are summarised below.

The oldest recorded acritarchs in Britain are from chert pebbles in the Applecross Formation of the Torridonian which are thought to be about 1650 to 1800 million years old (Muir and Sutton 1970). A poor assemblage of acritarchs was retrieved from the Stoer Group of the Torridonian which indicates a Riphean age (Cloud and Germs 1971). Acritarchs have also been retrieved from the Diabaig (Naumova and Pavlovsky 1961; Downie 1962) and Cailleach Head Formations (Gunn 1907) and are more varied than those from the Stoer Group, but also indicate a Riphean age. Downie records Lower Cambrian acanthomorph acritarchs from the Fucoid Beds of Scotland (unpublished, recorded in Downie 1966), and Downie (1975) reviewed the published records of the acritarchs of the Torridonian and Dalradian in Scotland.

Downie *et al.* (1971) published a record of palynomorphs from the Highland Border Complex and parts of the Dalradian. The yield consisted mostly of poorly biostratigraphically constrained and preserved material from the Dalradian although the records of well preserved chitinozoans from the Macduff Slates appear to contradict the structural synthesis of the Dalradian, suggesting that the youngest Dalradian rocks were Ordovician in age. Downie *et al.* (1971)

concluded that the Macduff Slates and the Highland Border Complex were both Arenig in age. Bliss (1977) comprehensively studied large parts of the Dalradian of Scotland in his Ph.D. thesis and obtained poorly preserved acritarchs from several localities. He was unable to verify an early Ordovician age for the Macduff Slates. In 1982 Downie described an acritarch assemblage which contained fifty-three species from the Lower Cambrian of Scotland, Norway, Greenland and Canada. The assemblage included a diverse selection of acanthomorph acritarchs.

Burton *et al.* (1984) retrieved chitinozoans from the Margie Limestone at North Esk, Edzell, concluding that they had a Caradoc age. Burton and Curry *in* Curry *et al.* (1984) recorded chitinozoans from various parts of the Highland Border Complex and Dorning (1985) reviewed the acritarch flora of the Highland Border Complex rocks from North Glen Sannox, Arran.

Lindström (1957) has found the Lower Hartfell black graptolite shale at Morroch Bay, near the Rhinns of Galloway, to contain chitinozoans and Jansonius (1964) recorded chitinozoans from the Laggan Burn Limestone, Balclatchie Beds, in the Stinchar valley near Girvan in the Midland Valley. Turner (1979) studied samples from the Llandeilo to Ashgill at Girvan for his Ph.D. thesis, but only as comparative material to type Caradoc area in the Welsh Borderlands .

In Cocks (1985) there is an unconfirmed report of chitinozoans being found at Dob's Linn. Molyneux (pers. comm.) has studied samples from the sediments at Dob's Linn, and other places in the Southern Uplands in his work for the Survey, concentrating particularly on the Llandovery sediments. Dorning (1982) discussed the early Wenlock age for the Knockgardner and Straiton Grit Formations of Ayrshire. Samples from the Llandovery Mulloch Hill Formation at Girvan are dominated by sphaeromorphs although there are some nice specimens of *Hogklintia.* Samples of Llandovery/Wenlock sediments from Bargamy Pond Burn contain a large number of *Veryhachium* specimens along with other acanthomorph acritarchs such as *Diexallophasis, Ammonidium* and *Tylotopalla.* For localities see Cocks and Toghill (1973). Molyneux (1987) describes an assemblage of acritarchs from the Linkim Beds in the Southern Uplands which are Wenlock in age.

Previous Research into Ordovician Palynology.

A great deal of work has been done on the palynology of the Palaeozoic in general and the Ordovician in particular, work which would take many pages to document. Thus only a brief review is presented consisting of the Ordovician taxonomic papers that have been most commonly used, and which deal with well preserved material.

The literature is separated into chitinozoan and acritarch publications, and then dealt with geographically within each of those two sections.

CHITINOZOANS

Jenkins and Legault (1979) and Taugourdeau *et al.* (1967) are useful general publications discussing the ranges of selected chitinozoans.

Europe and Russia

The first paper published dealing with palynomorphs (Eisenack 1931) recorded chitinozoans from the Baltic, and since then many papers have been written dealing with chitinozoans from that area and other parts of Europe. The most useful ones are listed here. Eisenack (1931, 1955a, b 1959a, 1962a, b, 1965, 1968b) deals mainly with erratic blocks from the Baltic, Rauscher (1970, 1974), Rauscher and Doubinger (1967) concern chitinozoans, mainly of Lower or Middle Ordovician age from Normandy, Schallreuter (1981, 1983) record Caradoc and Middle Ordovician taxa from Sweden and northern Germany respectively. Henry *et al.* (1974) and Paris (1979) deal with Portuguese Caradocian sediments, Paris and Mergl (1984) discuss the Arenig of Bohemia, and Tynni (1975) reports on the Caradoc of Finland. Laufeld (1971) discusses chitinozoans from the *P. linearis* Zone and Llandovery of Podolia, Russia, and Umnova (1969) records chitinozoans from the Russian Platform. Particularly useful papers include Taugourdeau (1961) who deals with the Caradoc/Ashgill of Aquitaine, France, Laufeld (1967) dealing with the Caradoc of Dalarna, Sweden, Nõlvak (1980) describing the upper Caradoc and Ashgill of Baltic, Grahn (1980, 1981a, b, 1982a, 1984a, b) records taxa from the Llanvirn to Ashgill of Sweden and Paris (1981) who in a monograph, deals with the Ordovician to Devonian of south-west Europe.

America

Wilson (1958a, b), Wilson and Hedlund (1964), and Wilson and Dolly (1964) produced a series of short papers dealing with chitinozoans from the Middle Ordovician Sylvan and Tulip Creek Formations in Oklahoma. Following on from this work Jenkins (1969, 1970) produced excellent papers dealing with the chitinozoans of the Viola and Fernvale Limestones (1969) and the Sylvan Shale of Oklahoma (1970) and Grahn and Miller (1986) detailed the chitinozoans from the Middle Ordovician Bromide Formation. Jansonius (1964) described several new genera and species from the Ordovician of Canada and Britain, while Neville (1974) discussed middle Ordovician taxa from Newfoundland. In the late seventies and the eighties many papers were published on the Middle and Upper Ordovician of Anticosti Island (Achab 1977a, b, 1978a, b, 1984), and mainland Canada (Martin 1975, 1980, 1983, and Achab 1986a, b). Grahn and Bergström (1984) dealt with chitinozoans from the southern Appalachians and Grahn (1975) with Llandovery and Wenlock chitinozoans from Ohio and Kentucky, while Wright and Meyers (1981) discussed Upper Ordovician chitinozoans and acritarchs from Kansas.

Britain

There is a sparse record of chitinozoan publications from the British Isles. Atkinson and Moy (1971) discussed upper Ordovician chitinozoans from North Wales, Jansonius (1964) recorded chitinozoans from the Caradoc of Scotland, Jenkins (1967) described Middle Ordovician chitinozoans from the Welsh Borderlands, and Lister, Cocks and Rushton (1969) recorded taxa from the Caradoc of Kent.

Other areas

Taugourdeau (1966b), Bouché (1965), Benoit and Taugourdeau (1961) describe faunas from the Ordovician of the Sahara. Elaouad-Debbaj (1984, 1986) and Molyneux and Paris (1985) are three particularly useful papers dealing as they do with the upper Caradoc and Ashgill of Morocco and Libya respectively. Combaz and Peniguel (1972) dealt with Ordovician chitinozoans from Australia.

ACRITARCHS

Diez and Cramer (1974, 77) provide lists of published ranges of selected acritarchs, and Turner (1979 m.s.) details many of the acritarch papers which are not mentioned in this review.

Europe

Eisenack (1931) detailed a few species of acritarchs from the Baltic, and he followed this early paper with many more dealing with acritarchs (Eisenack 1938 , 48, 55a, 58a, b, 62b, 65, 72a, 76). Other work carried out in this area includes Tynni (1975), Bockelie and Kjellström (1979) and particularly useful papers by Kjellström (1971a,b, 1972, 1976). In France work was being undertaken by Deflandre (1942, 1945 and 1946), Deunff (1955, 1959), Rauscher (1974) and Paris and Deunff (1970) dealing with the Llanvirn of France. In Belgium Martin (1966a, 1969) recorded Ordovician and Silurian acritarchs, and Elaouad-Debbaj (1978) produced a very comprehensive paper on the Upper Ordovician of Portugal. Gorka described well preserved acritarchs from the Lower Ordovician (1969) and Upper Ordovician (1980) of Poland. Cramer (1971) deals with Silurian acritarchs but is a very useful paper to consult.

America

Much very useful literature has been published dealing with the United States and Canada. Staplin, Jansonius and Pocock (1965) produced a paper which contained several new genera and species of acritarchs from the Trenton Formation of Anticosti Island, then described as Middle Ordovician, but now known to be Upper Ordovician (Jacobson 1987). This work in Canada has been followed up by Martin (1980, 1983), Duffield and Legault (1981), a particularly useful paper by Jacobson and Achab (1985) and by Loeblich and Tappan (1978) the latter of which reappraised much of the work done by Staplin *et al.* (1965). Tappan and Loeblich (1971), Loeblich (1970), Loeblich and MacAdam (1971), Loeblich and Tappan (1969) produced papers using the scanning electron microscope and dealing with the surface structure of many species of acritarchs. Colbath (1979) discussed the Caradoc acritarchs of Indiana, Jacobson (1978) recorded acritarchs from the upper Caradoc of Kentucky, and Wright and Meyers (1981) illustrated acritarchs from Kansas.

The following two papers although Silurian, have proved very useful - Miller and Eames (1982)from the Medina Group of New York, and Thusu (1973) from the Llandovery L'Ilion Shale.

Britain

Some references are already listed in the section on Scottish palynology, and under palynomorphs from poorly preserved sediments. Much of the acritarch work done in Britain has been on the Silurian, and very little comparable material from the Ordovician is available. Lister, Cocks and Rushton (1969) recorded Caradoc acritarch taxa from Kent, Lister (1970) produced a monograph on the Wenlock and Ludlow acritarchs of the Welsh Borderlands and, Dorning (1981) also described taxa from the Wenlock and Ludlow of Shropshire. Turner (1984, 1985) described acritarchs from the type Caradoc and type Llandeilo, respectively, whilst Hill and Dorning (1984) dealt with acritarchs from the type Llandovery.

Africa

Again very little work has been done on the palynomorphs of the African continent. Bär and Riegel (1980) worked on sediments of Ordovician age from Ghana, Jardiné *et al.* (1974) produced an acritarch zonation from sediments in Algeria, and Molyneux and Paris (1985) record Caradoc and Ashgill acritarchs from Libya.

Note : In the following text Lower Ordovician is taken as Tremadoc and Arenig, Middle Ordovician as Llanvirn and Llandeilo, and Upper Ordovician as Caradoc and Ashgill.

Chapter 2 - Stratigraphy

Introduction

As already stated in Chapter 1, at its initiation this project was intended only to concentrate on the Highland Border Complex, exposed along the Highland Boundary Fault. It was later extended to include Girvan in the Midland Valley, and Dob's Linn, Barrhill and Coldingham Bay, in the Southern Uplands (Figure 1). This project thus forms something of a Scottish Ordovician palynological reconnaissance survey, with varying results. It is therefore necessary to treat the stratigraphy of the areas separately, to discuss their palynological assemblages separately, and finally to compare the results.

The Highland Border Complex

The Highland Border Complex (Figure 2) is a structurally condensed sequence which crops out in a narrow north-east/south-west zone throughout Scotland, from Stonehaven (near Aberdeen) through Edzell, Callander, and Aberfoyle into Arran, with a possible extension into Ireland. The Complex includes a wide variety of rock types (including serpentinites, amphibolites, spilites, cherts, black shales, arenites, rudites and limestones), indicative of a marginal basin, with a stratigraphical history which includes several unconformities and a tectonic history which includes dismemberment of the entire Complex by strike-slip faulting. The field relationships within the Complex are both complicated and obscure, not only with respect to each other but also the neighbouring terranes. It is tectonically as well as lithologically highly complex, the rocks being in many places severely deformed and often extensively mineralised or recrystallised, with many of the original sedimentary features having been destroyed, obscured or overprinted by penetrative cleavages in the process (Curry *et al.* 1984). Such deformational and thermal problems are rarely encountered in routine palynological work. Henderson and Robertson (1982) suggested that the Complex had been deposited in a basin of Cambrian age, and then thrust over the Dalradian terrane. Recent work suggests that the Highland Border Complex originated as an Ordovician marginal basin adjacent to the Midland Valley Massif and was subsequently faulted against the Dalradian terrane, (Curry *et al.* 1984).

Previous Palaeontological Research

The sedimentary rocks of the Highland Border Complex have for a long time been the subject of palaeontological investigation. Campbell (1911,1913) discovered brachiopods, crustaceans, and worm tubes at Stonehaven, and Jehu (1912) and Jehu and Campbell (1917) found a similar but

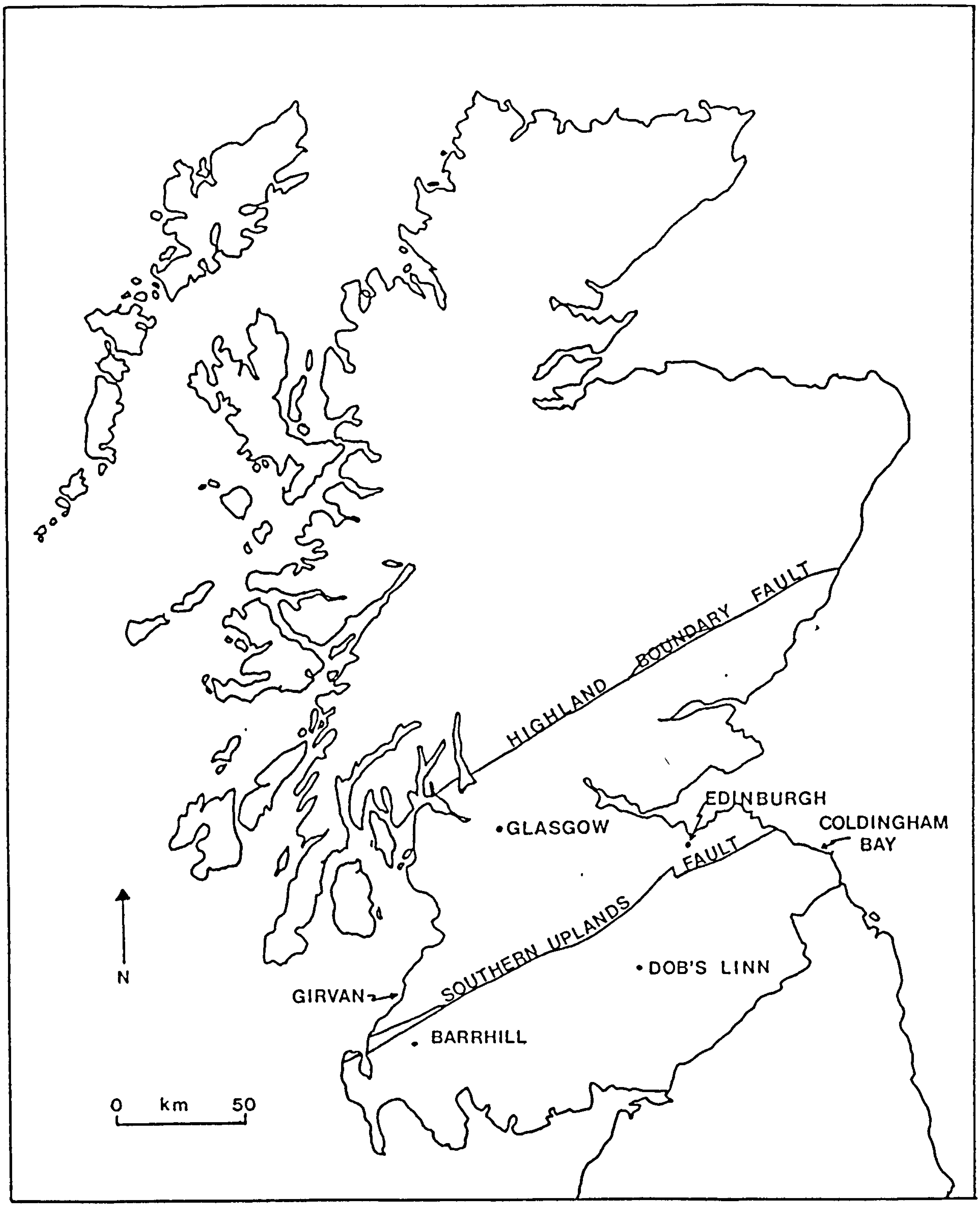


Figure 1. Map of Scotland showing the localities discussed in the text.

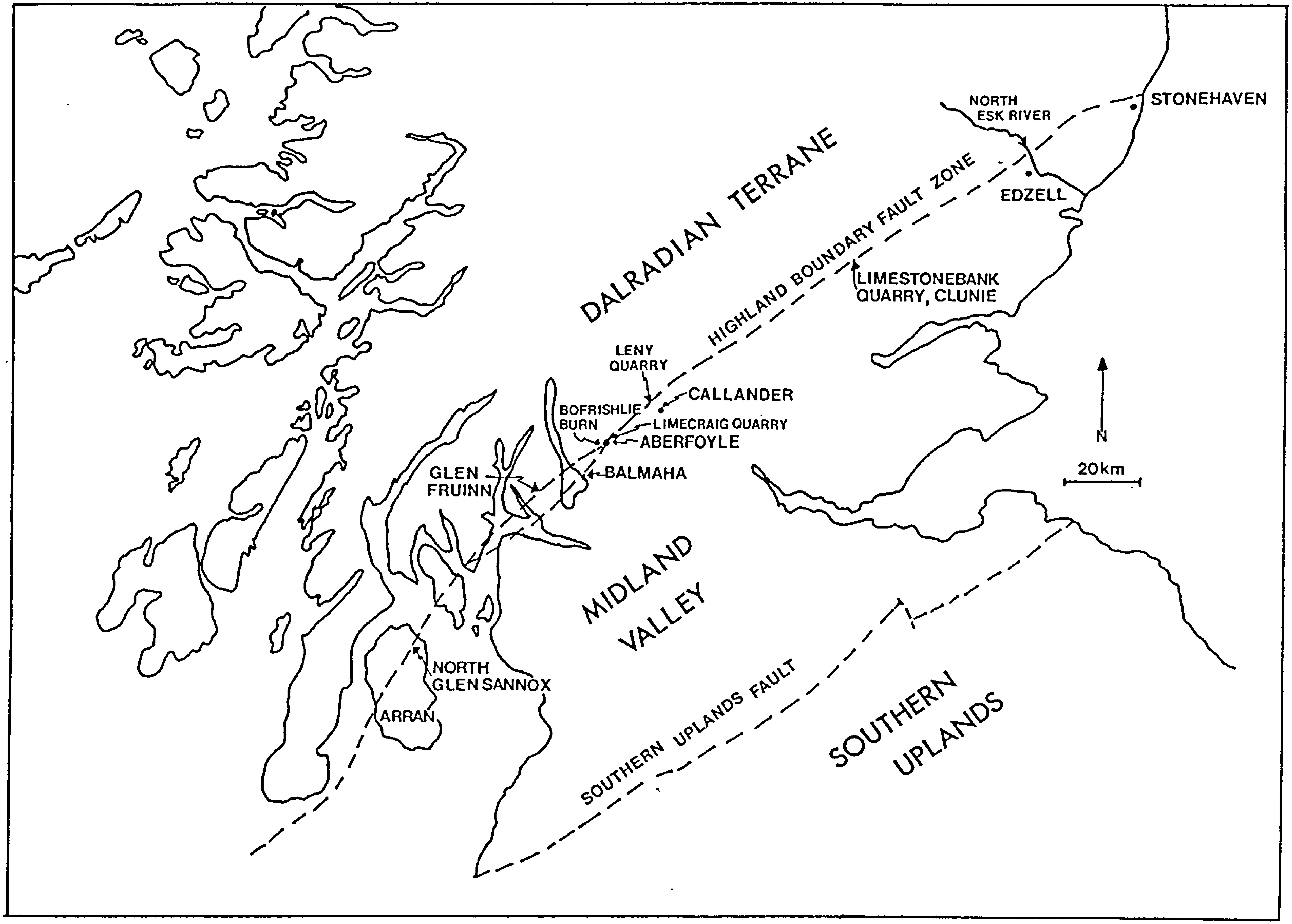


Figure 2 : map showing localities of the Highland Border Complex mentioned in the text

more diverse fauna from rocks in the Aberfoyle area, all suggesting a Lower Cambrian to Early Ordovician age. Pringle (1939) discovered brachiopods and the trilobite *Pagetides* at Leny Quarry, Callander, which suggest an upper Lower Cambrian age. Anderson and Pringle (1944) reported brachiopod fragments from North Glen Sannox on Arran, which they considered to be almost the same as the ones found at Aberfoyle.

On re-examination of Jehu and Campbell's (1917) material Bulman (1963) found the graptolites unacceptable, and Rowell (1963) expressed doubt as to the validity of the brachiopod species identifications, while confirming that they were definitely inarticulate brachiopods. Lister in Downie *et al.* (1971) examined the scolecodont found in the Jehu and Campbell (1917) fauna, also finding it unacceptable. Anderson (1947) reported a Caradoc age for the Dounans Limestone, but this has since been found to be based on a misconception by Pringle in unpublished work, (Curry *et al.* 1982). At this point the only reliable age for the Complex was that of Lower Cambrian for the Leny Limestone.

Cummins (1967) attempted to extract fossil microplankton from the Dalradian and Highland Border 'Series' but with no success. However Downie *et al.* (1971), looking at the Dalradian of Scotland reported a Tremadoc to Llanvirn age for acritarchs found in the the Jasper and Greenrock Formation, in the North Esk section at Edzell, and a possible Llanvirn age for a chert at Bofrishlie Burn, Aberfoyle. The investigations of Curry *et al.* (1982, 1984) revealed a diverse silicified fauna of brachiopods, trilobites, ostracods, gastropods and other groups from the Dounans Limestone at Aberfoyle which is well preserved and has an undoubted age of mid Arenig (Late Canadian) as reported by Curry *et al.* (1982) and Ingham *et al.* (1985) and confirmed on conodont evidence by M.P.Smith (pers. comm.). Other localities of the Complex have proved to be sparse in calcareous fauna. However palynomorphs are fairly abundant. Burton *et al.* (1984) reported an assemblage of chitinozoans from the Margie Limestone of the North Esk section, which suggested a mid to late Caradoc age. Burton and Curry (1984) in Curry *et al.* (1984) further described a wide range of chitinozoan occurrences with Ordovician ages from many key localities. It was these last two papers that initiated this present research.

Dorning (1985) recorded several specimens of fairly simple acritarchs referable to the genera *Leiosphaeridia*, *?Leiosphaeridia* and *?Navifusa* from North Glen Sannox, Arran and noted that they had been subjected to a minimum palaeotemperature of at least 200°C. The abundance of sphaeromorphs appears to suggest a deep water marine environment, though no particular stratigraphical interpretation can be made.

Previous Research into the Highland Border Complex

There has been a long but sporadic interest in the rocks of the Highland Border Complex. Early workers included MacCulloch (1824) who discussed the trap deposits, limestone, serpentine and conglomerate of Limestone Bank Quarry, Clunie, Perthshire, and Lyell (1825) who described the Highland Border serpentinites at Quharity Burn. In 1850 Nichol noted the similarity between the Highland Border Complex rocks and the cherts, shales and greywackes of the Southern Uplands suggesting that the Highland Border rocks formed the northern limb of a syncline dipping under the Midland Valley. Peach and Horne (1899) endorsed this, and a Lower Ordovician age for the Complex became accepted.

Barrow (1901) working at North Esk proposed a bipartite stratigraphy of a lower spilite, chert and shale association - termed the Jasper and Greenrock Series which he thought was Early Ordovician (Arenig) age on lithological criteria, unconformably overlain by an upper unit which consisted of sandstones, shales and limestones and which he termed the Margie Series. This was considered to be possibly Silurian in age. Later Barrow revised his ages downward, but still considered them to be younger than the Dalradian rocks to the north. He further thought that Dalradian rocks had been thrust over the Highland Border Complex rocks in a southerly direction along a major reverse fault, whereas the contact with the Devonian rock to the south he took to be a normal fault. It is now known that the northern boundary is a complex fault zone, although with a late southerly reverse fault component, and that the Devonian rocks are unconformable upon the Highland Border Complex (Curry *et al.* 1984). The fault is more difficult to recognise in the east, as is the division into two units, although Clough (1895) had noticed a differentiation between the black shales and cherts and the grits at Aberfoyle, and Jehu and Campbell (1917) were also able to divide the Aberfoyle rocks into the 'Lower Black Shales and Chert Series' unconformably overlain by the shallower water 'Margie Series', which they said contained detritus of the former, and included the Aberfoyle Limestone in the Margie Series. Pringle (1941) reversed the order of the Jasper and Greenrock Series and Margie Series advocated by Barrow (1901), stating that the Margie Series was the older.

Anderson (1947) did not include the Leny Limestone in the Highland Border Complex, and in fact correlated the Leny and Margie Limestones with the Ben Ledi grits, suggesting that they were both Dalradian, and of Cambrian age. Shackleton (1958) recognised downward facing structures in the Dalradian and a possible one in the Highland Border Complex at Aberfoyle, and so concluded that the two units had had a similar structural history and that the Margie 'Series' was older than the Jasper and Greenrock unit. Johnson and Harris (1965, 1967), considered the Jasper and Greenrock to be ?Arenig in age and the Margie rocks to belong to the Dalradian, which they felt was reinforced by downward facing structures of equivalent rocks on Arran. Johnson and Harris (1965,67) and Harris (1969) thus both favoured a Dalradian history for the Highland Border Complex.

Henderson and Robertson (1982) and Henderson and Fortey (1982) assert that the Highland Border Complex represents a dismembered tectonically emplaced ophiolite of Caledonian age, which originated in a narrow ocean basin and was subsequently thrust south, by crustal shortening during the Grampian Orogeny. Robertson and Henderson (1984) further postulate that the Highland Border Complex comprises terrigenously derived turbidites with a similar source to the Dalradian, a dismembered ophiolite and ophiolite derived sediments. The igneous rocks consist of two groups, those that display MORB characteristics and those show within plate chemistry. The sediments they say show tropical weathering below a ?mid-Devonian unconformity, and compare the Highland Border Complex rocks to a marginal basin model such as the Gulf of California. Curry *et al.* (1984) offered evidence to show that the Complex had been deposited in a marginal basin and subsequently faulted against the Dalradian.

In the following sections Tables 1-16 show the data for all samples collected in this study. The key to the Palaeontological Content is as follows :

a : barren
b : non specifically attributable palynomorphs
c : sphaeromorph acritarchs only
d : a few specifically attributable palynomorphs
e : many specifically attributable palynomorphs.

Stratigraphy

As already stated the stratigraphy and structure is highly complicated by folding, faulting, and lacunae. Nine main localities have been collected from during this study, and will be examined in detail below.

(1) North Glen Sannox, Arran (Figure 3, Table 1)

Gunn *et al.* (1903) suggested that the rocks of Arran were the same age as those of Ballantrae, due to their lithological similarity. Curry *et al.* (1984) failed to find any fossils from this locality but tentatively accepted an Arenig age as specified by Anderson and Pringle (1944) for *Acrotreta* from the black shales. The outcrop is in the North Sannox Burn, and a series of silicified limestones (HB/A/2,4,6) suggested by Curry *et al.* (1982) to be equivalent to the Dounans Limestone, and black shales (HB/A/1,3) and an arenite (HB/A/5), have been sampled from this locality. Volcanic rocks containing pillow lavas are also exposed at this locality. Anderson and Pringle (1944) stated that the 'Arenig' rocks and the Dalradian had undergone a similar deformational and metamorphic history. Downie *et al.* (1971) reported that they had yielded only organic matter of indeterminate age from this locality. Dorning (1985) illustrates specimens of the genera' *Leiosphaeridia* and *Navifusa* from a black mudstone collected from the south bank of the North Sannox River (Arran 771, NR9976 4683). The acritarchs are all fairly simple forms and record palaeotemperatures of a minimum of 200°C (TAI 4.0) and suggest a deep water environment but are biostratigraphically indeterminate, though they may be comparable with the Ordovician (Llandeilo to Caradoc) forms described by Turner (1979) from Girvan (Dorning 1985).

(2) Glen Fruin (Figure 4, Table 2)

Samples of black shales that Downie *et al.* (1971) studied from the banks of the River Fruin, yielded a few possible sphaeromorph acritarchs. One sample (HB/GF/1) has been studied here which was obtained from north of Helensburgh.

(3) Balmaha (Figure 5, Table 2)

Rocks of the Highland Border Complex were sampled from the bed of Loch Lomond north of Balmaha Pier. The exposure was revealed during the time of exceptionally low water conditions of 1984. The sequence consists of a serpentinite conglomerate with a carbonate matrix, a very indurated limestone, and a soft black shale. Samples were taken from the limestone (HB/BAL/1) and the black shale (HB/BAL/2), which are separated from each other by a disconformity. Pieces of the carbonate rock were found in the base of the black shale. The Loch Lomond Clastics (Henderson and Robertson 1982) which are a possible equivalent to the Achray Sandstone, although present at this locality were not sampled.

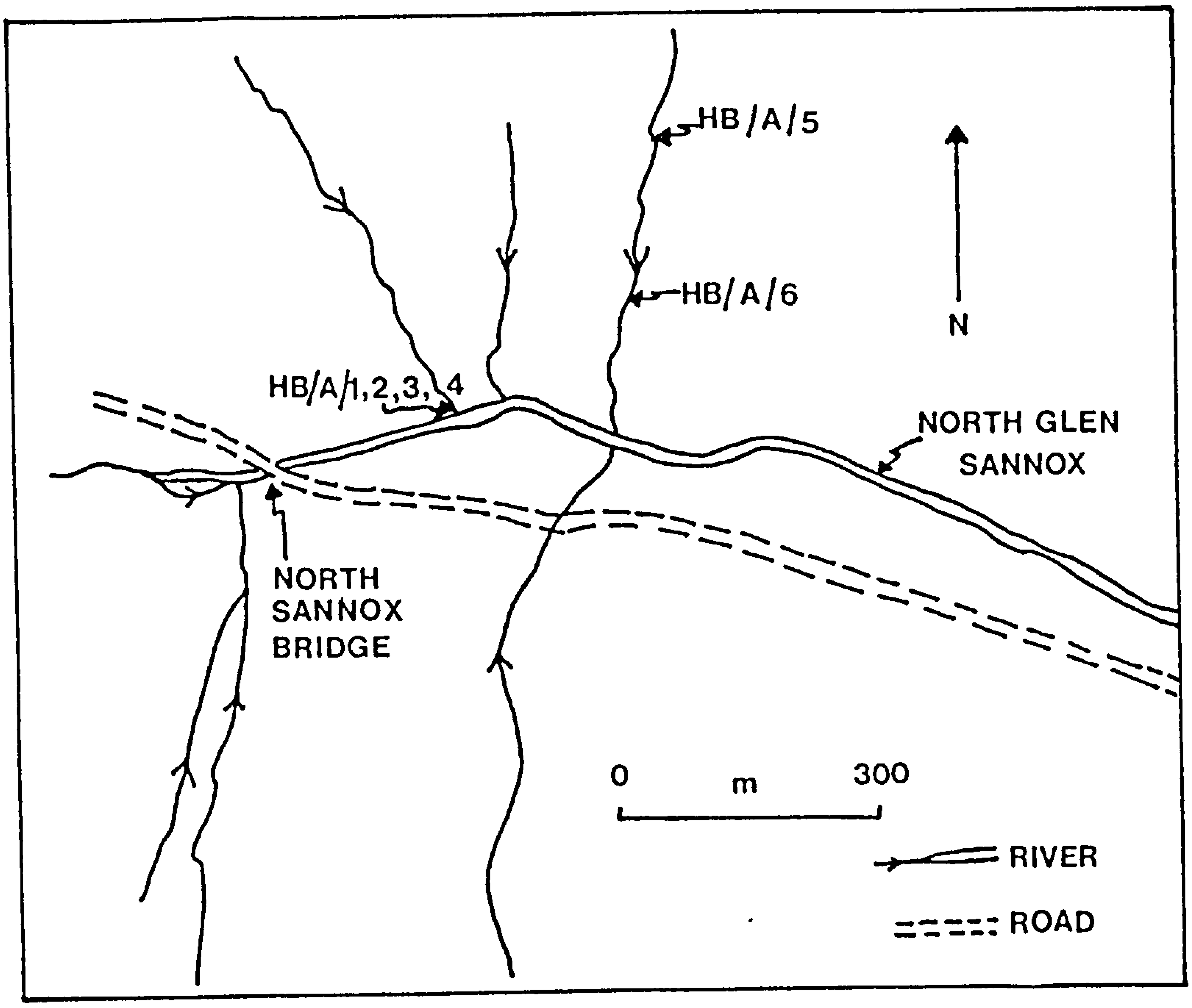


Figure 3 : map showing the approximate localities of samples collected at North Glen Sannox, Arran.

NORTH GLEN SANNOX, ARRAN. [NR 997469].

Sample Number	Lithology	Palaeontological Content
HB/A/1	Black shale	b
HB/A/2	Silicified limestone	a
HB/A/3	Black shale	d
HB/A/4	Silicified limestone	b
HB/A/5	Silicified limestone	b
HB/A/6	Black shale	a

Table 1 : sample number, lithology and palaeontological content for samples from North Glen Sannox, Arran.

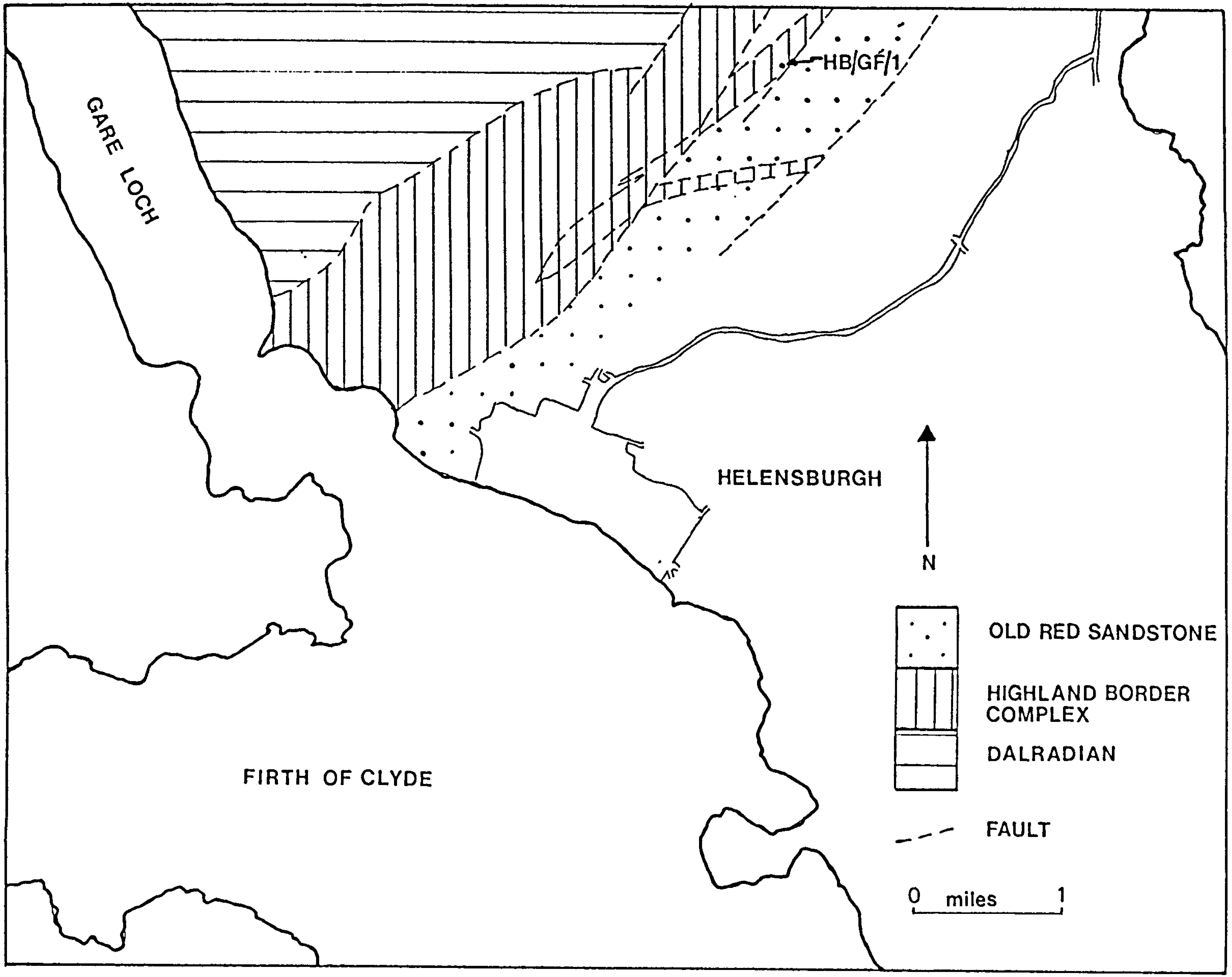


Figure 4 : geological map of the Glen Fruin area

GLEN FRUIN. [NS 318870]

Sample Number	Lithology	Palaeontological Content
HB/GF/1	Black Shale	d

BALMAHA [NS 24166912]

Sample Number	Lithology	Palaeontological content
HB/BAL/1	Very hard limestone containing serpenitinite fragments	b
HB/BAL/2	Black shale with silicified interbeds	d

Table 2 : sample number, lithology and palaeontological content for samples from Glen Fruin and Balmaha

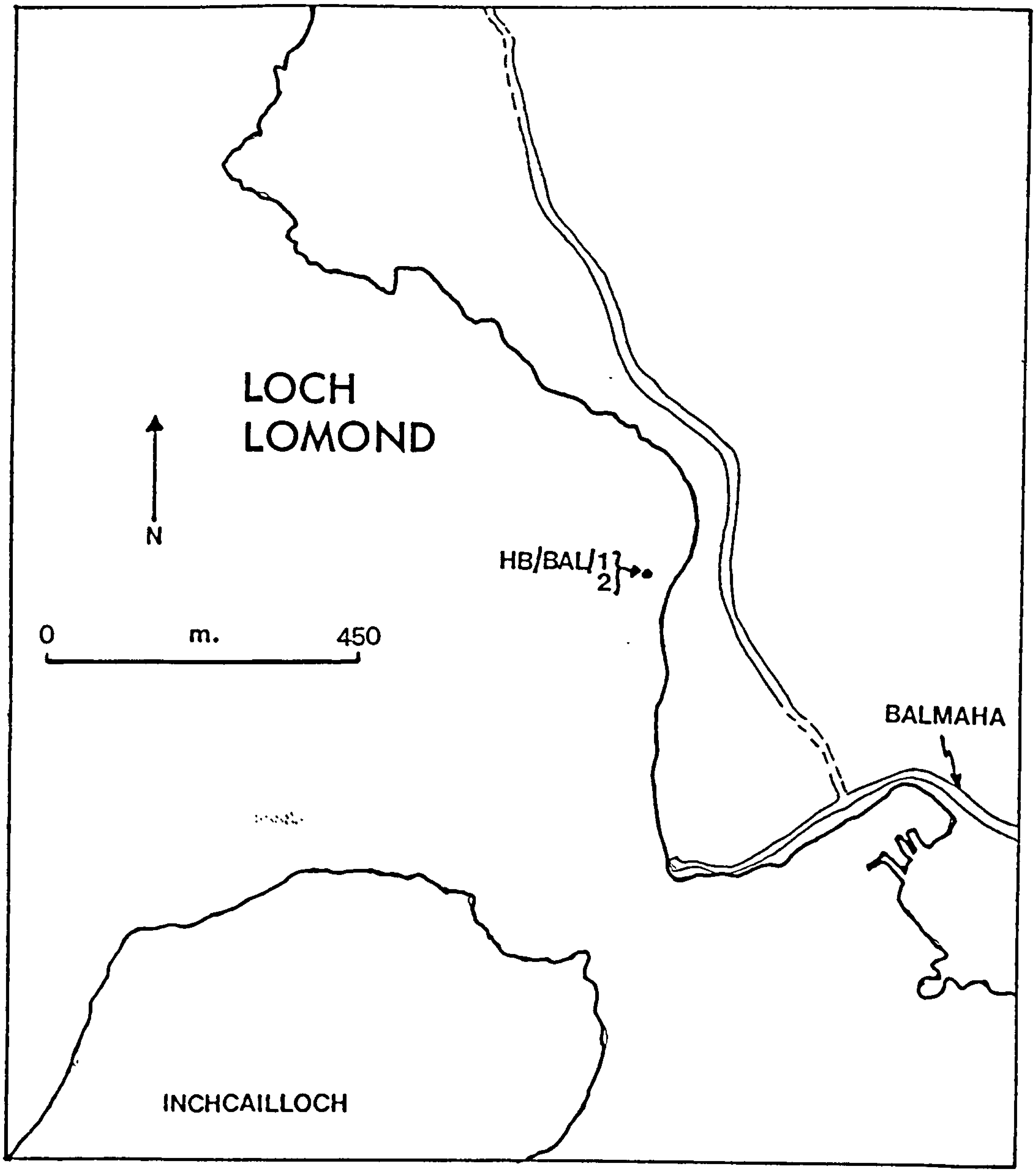


Figure 5 : locality map showing the position of samples collected from Loch Lomond during very low water levels.

(4) Bofrishlie Burn, Aberfoyle. (Figure 6, Table 3)

At this locality black shales (HB/BB/1,2,5), a siltstone (HB/BB/3) and a chert (HB/BB/4) have been collected. The field relationships here are further complicated by intense forestry work, though a small quarry cut into the forestry shows a relationship between a black shale and a paler mudstone suggesting that the paler mudstone is older than the black shales. Re-examination of material discovered by Jehu and Campbell (1917) confirms the presence of a Lower to Middle Ordovician age (Curry *et al.* 1982) for the cherts at this locality. Downie *et al.* (1971) recorded microfossils indicative of Llanvirn or younger age from dark shales in Bofrishlie Burn, which is substantiated by Burton and Curry (in Curry *et al.* 1984), who discovered *Lagenochitina cylindrica* Eisenack 1931 which suggests a Llanvirn to Llandeilo age for the black shales.

(5) Limecraig Quarry, Aberfoyle. (Figure 7, Table 4)

The geology of this quarry is well documented by Curry *et al.* (1984, 1986a), and has been excavated in order to study the Dounans Limestone which had been extensively quarried (Curry 1986a). There is a diverse suite of rocks exposed here, serpentinite, limestone-serpentinite admixture, the Dounans Limestone, Lime-craig Conglomerate containing quartzite clasts which have been dated as 1700 million years old by Rb/Sr isotope methods, (B. J. Bluck pers. comm.), ?black shale, Achray Sandstone and unconformably above them the Old Red Sandstone. The Dounans Limestone was probably deposited on a shallow marine shelf, probably forming part of an early Ordovician carbonate sequence extending beneath the Midland Valley. Ingham *et al.* (1985) have recorded a diverse silicified fauna from this locality, with a Lower Arenig age, and several samples were collected for palynological processing, The first was unconformably in contact with the Old Red Sandstone (HB/LC/2), the second faulted against the serpentinite (HB/LC/3), and the third from the spoil heap (HB/LC/5). The matrix of the Lime Craig Conglomerate (HB/LC/4) was also collected as were several samples from the Achray Sandstone (which contains subordinate shales), (HB/LC/1,7,8,9,11). Also a loose block of black shale (HB/LC/6) and a red sandstone (HB/LC/10) were collected. Downie *et al.* (1971) were unable to date a sample of a grey shale from this quarry. A subordinate shale in the Achray Sandstone yielded two faunas for Burton and Curry (in Curry *et al.* 1984). They recorded the older *Desmochitina minor grandicolla* Eisenack 1958, and the younger *Conochitina robusta* (Eisenack 1959), from the Achray Sandstone at Limecraig Quarry,which suggested

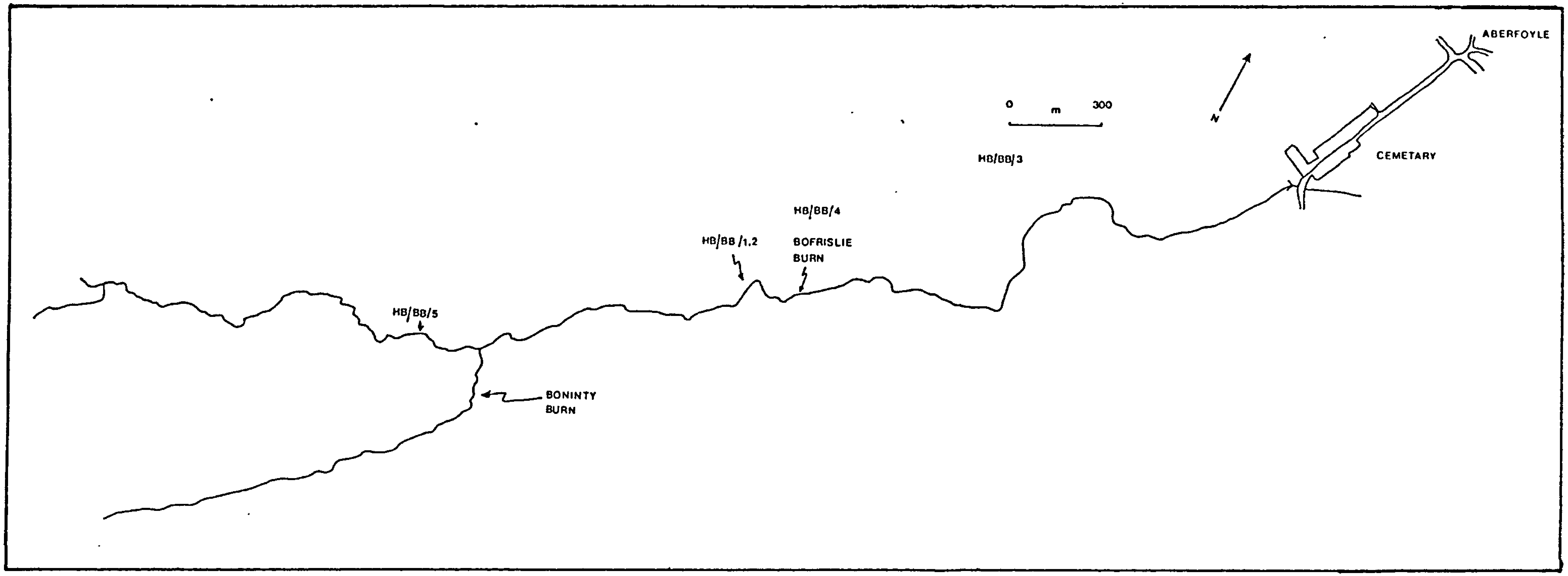


Figure 6 : locality map showing the approximate position of samples collected at Bofrishlie Burn, Aberfoyle

BOFRISHLIE BURN, ABERFOYLE [NS 511997]

Sample Number	Lithology	Palaeontological Content
HB/BB/1	Black shale	c
HB/BB/2	Black shale	d
HB/BB/3	Siltstone	d
HB/BB/4	Chert	a
HB/BB/5	Black shale	d

Table 3 : sample number, lithology and palaeontological content for samples from Bofrishlie Burn, Aberfoyle.

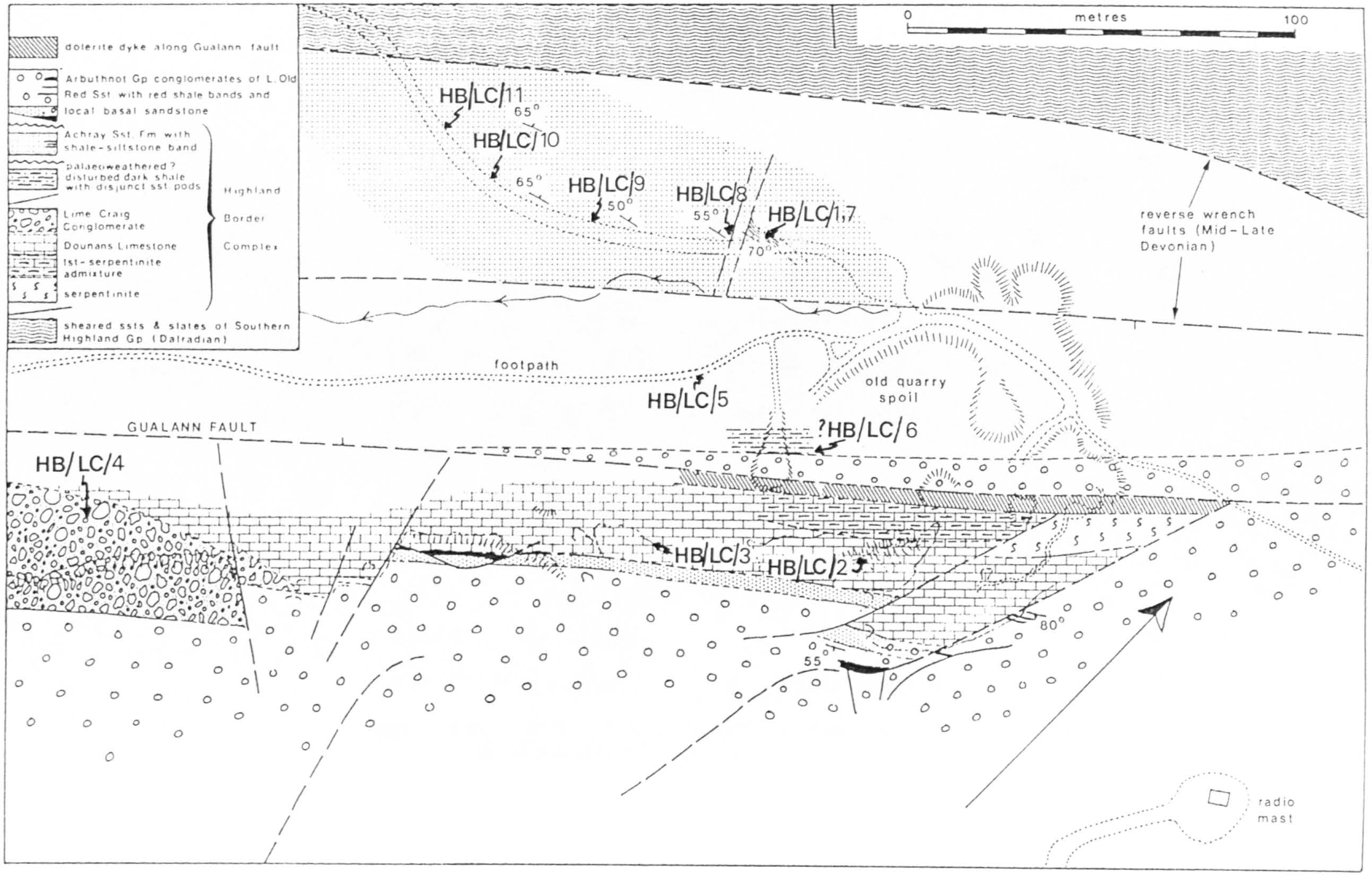


Figure 7 : geological map indicating the position of samples collected at Limecraig Quarry, Aberfoyle
(after Curry et al. 1984)

LIMECRAIG QUARRY, ABERFOYLE. [NN 533018].

Sample Number	Lithology	Stratigraphical unit	Palaeontological Content
HB/LC/1	Pale muddy shale	Achray Sandstone Formation	b
HB/LC/2	Limestone	Dounans Limestone	b
HB/LC/3	Limestone	Dounans Limestone	c
HB/LC/4	Conglomerate matrix	Limecraig Conglomerate	b
HB/LC/5	Limestone	Dounans Limestone	b
HB/LC/6	Black shale		b
HB/LC/7	Pale muddy shale	Achray Sandstone Formation	b
HB/LC/8	Pale muddy shale	Achray Sandstone Formation	a
HB/LC/9	Buff sandstone	Achray Sandstone Formation	b
HB/LC/10	Red sandstone		b
HB/LC/11	Buff sandstone	Achray Sandstone Formation	b

Table 4 : sample number, lithology, stratigraphical unit and palaeontological content for samples from Limecraig Quarry, Aberfoyle.

that an older (Llanvirn-Llandeilo) sequence had been reworked during deposition of the Achray Sandstone in Caradoc-Ashgill times. One specimen of a conodont *Parapanderodus striatus* (Graves and Ellison 1941) which suggests a late Canadian to Early Whiterockian (Latest Tremadoc to Latest Arenig) age has been found from the Dounans Limestone (M.P. Smith pers. comm.).

(6) Leny Quarry at Callander. (Figure 8, Table 5)

This probably forms the faulted remains of an early Highland Border basin (Ingham *et al.* 1985). Here, the Leny Limestone (HB/LQ/1,2,3,4,5, 6,7), grits (HB/LQ/9, 10,11,12,16,17,18), and porphyry rocks are exposed south of the Highland Boundary fault. North of the fault some samples of limestone and shale were collected (HB/LQ/13,14,15,19) which may be part of the Leny Limestone or more likely the Dalradian sequence. Downie *et al.* (1971) found only finely comminuted debris and rare sphaeromorphs from a sample of the Leny Limestone at this locality. Stubblefield (*in* Brown *et al.* 1965) states that the Leny Limestone is upper Lower Cambrian on the basis of the trilobites at this locality (Pringle 1939) and Harris (1969) taking the Leny sequence to belong to the local Dalradian on structural evidence, and using Stubblefield's date, considered the Dalradian to extend as far as the Lower Cambrian. Read (1961) did not consider the age of the Leny Limestone to be significant due to its position on a major fracture. Harris (1969) records repetition of the Leny Limestone on the north side of the quarry, which may be in the same position as that found by Bluck during the course of recollecting for this project. It is not apparent whether this is the Leny Limestone or in fact, and indeed more likely, a lens of limestone belonging to the Dalradian succession.

(7) Limestone Bank Quarry, Clunie. (Figure 9, Table 6)

This quarry was plane tabled in the summer of 1987 (B.J. Bluck pers. comm.), and a series of samples of limestones (HB/CQ/1,6,9,12) and peperites (HB/CQ/2,5) were mapped and collected. The apparently lower part of the Highland Border Complex sequence consists of a pure white limestone, and a peperite (that is a lava intruded into wet calcareous sediment). A sandstone possibly equivalent to the Achray Sandstone is separated from the limestone and peperite by a dolerite dyke, and nowhere are the limestone and sandstone outcropping next to each other. The sandstone is separated from the Old Red Sandstone by an unconformity. Undeformed *Euconochitina brevis* (Taugourdeau and Jekhowsky 1960) which has a range of Arenig to Llandovery. were recorded

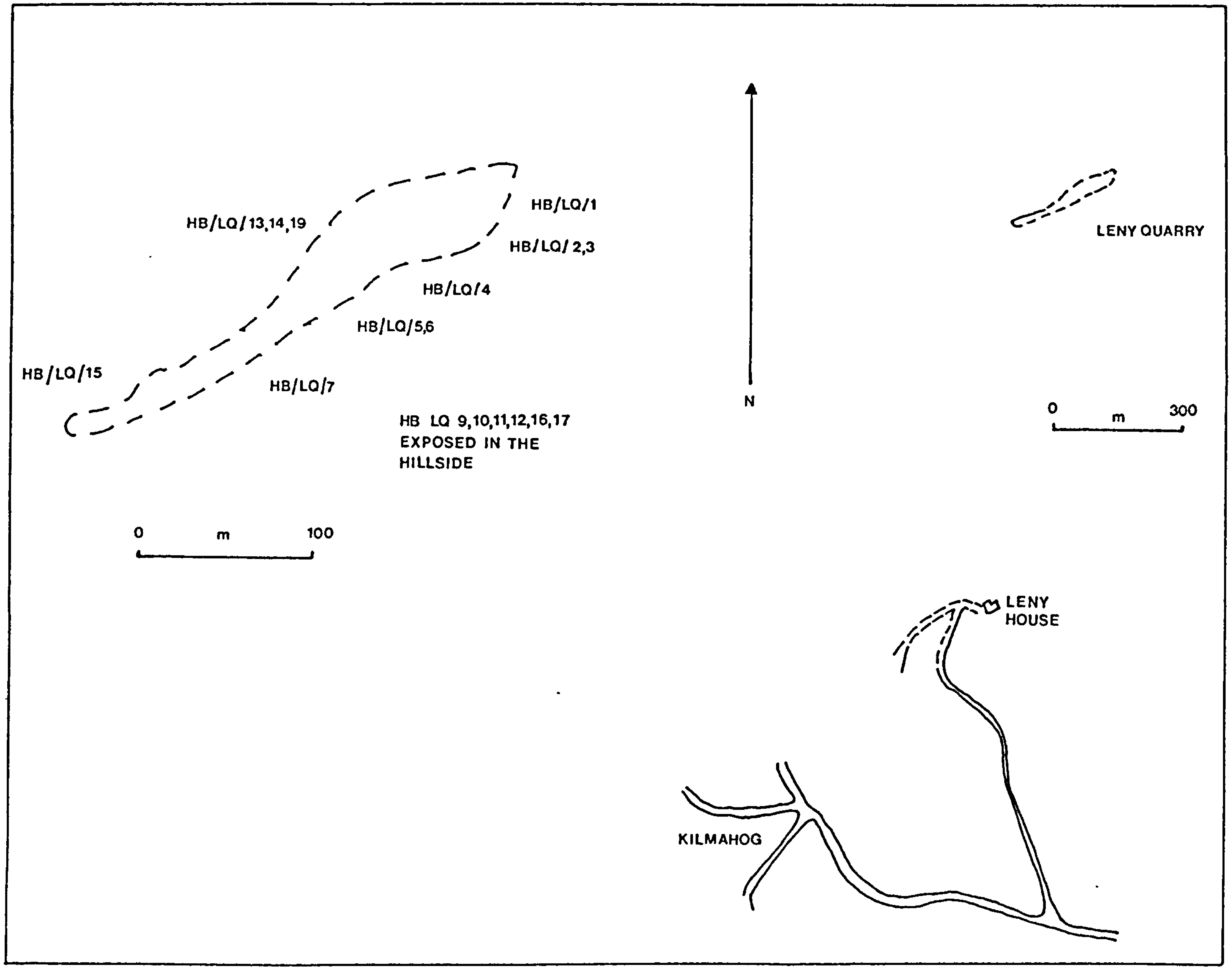


Figure 8 : locality map showing the approximate position of samples collected at Leny Quarry, Callander

LENY QUARRY, CALLANDER [NN 606089].

Sample Number	Lithology	Stratigraphical unit	Palaeontological Content
HB/LQ/1	Dark grey limestone	Leny Limestone	c
HB/LQ/2	Brown muddy limestone	Leny Limestone	c
HB/LQ/3	Dark grey limestone	Leny Limestone	c
HB/LQ/4	Dark grey limestone	Leny Limestone	c
HB/LQ/5	Weathered shale	Leny Limestone	c
HB/LQ/6	Dark grey limestone	Leny Limestone	c
HB/LQ/7	Light grey limestone	Leny Limestone	a
HB/LQ/9	Grit		d
HB/LQ/10	Grit		a
HB/LQ/11	Grit		a
HB/LQ/12	Grit		a
HB/LQ/13	Dark grey limestone		b
HB/LQ/14	Dark grey limestone		b
HB/LQ/15	Dark grey limestone		a
HB/LQ/16	White grit		a
HB/LQ/17	Grit		a
HB/LQ/19	Dark grey shale		b

Table 5 : sample number, lithology, stratigraphical unit and palaeontological content for samples from Leny Quarry, Callander

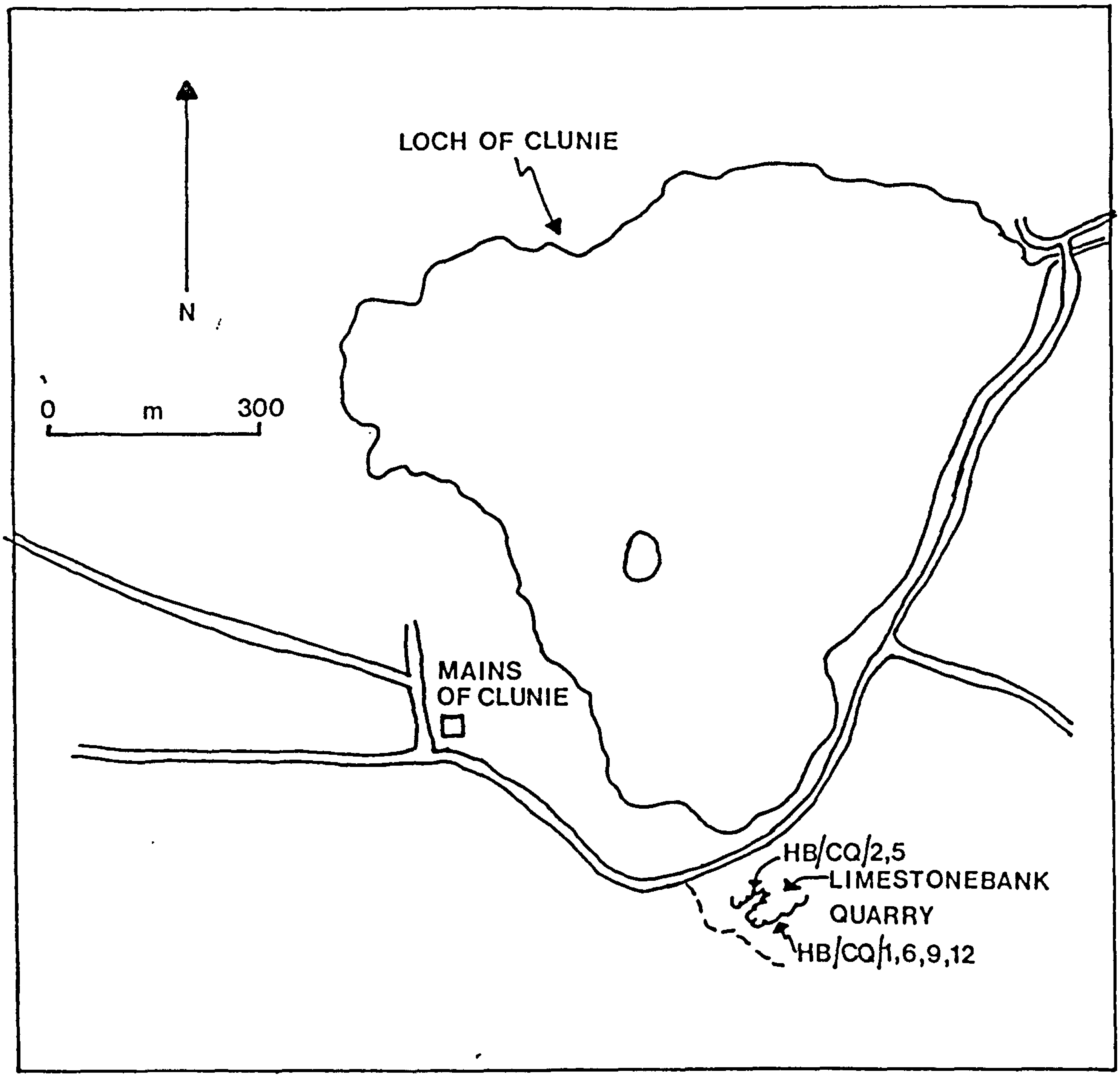


Figure 9 : locality map showing the position of samples collected from Limestonebank Quarry, Clunie, Perthshire.

LIMESTONEBANK QUARRY, CLUNIE. [NO 114436].

Sample Number	Lithology	Palaeontological Content
HB/CQ/1	White limestone	d
HB/CQ/2	Pepperite	a
HB/CQ/5	Pepperite	a
HB/CQ/6	White limestone	a
HB/CQ/9	White limestone	a
HB/CQ/12	White limestone	a

Table 6 : sample number, lithology and palaeontological content for samples from Limestonebank Quarry, Clunie.

from a limestone at this locality by Burton and Curry (in Curry *et al.* 1984).

(8) The North Esk section at Edzell (Figure 10, Table 7)

At Edzell the Highland Border Complex rocks are exposed in a section cut by the river North Esk. There are two structurally separate blocks are separated from each other by probable strike slip faulting.

The SE structural Block

The Lintrathen Porphyry separates the Old Red Sandstone conglomerates to the south from the Highland Border Complex. The first sediments encountered to the north of the Lintrathen Porphyry (which is Late Silurian to Devonian) are a series of pale grey/yellow greywackes and mudstones (HB/NE/7,10,11,17) which exhibit a spaced cleavage and may be equivalent to the Achray Sandstone although they do look very similar to the Dalradian seen at Stonehaven (but do not exhibit blue quartz). Further north the red and grey shales (HB/NE/6) followed by purple dolomites and purple and grey shales (HB/NE/13,14), the purple dolomites (HB/NE/1,2,9) are cut by two quartz dolerite dykes. This sequence is continously folded and thrown into broad open folds. A fault separates these rocks from the NW structural block and the Jasper and Greenrock.

The NW structural Block

The Jasper and Greenrock consists of well developed pillow lavas, subordinate jasper veins, black shales (HB/NE/15,16,18) and cherts (HB/NE/19). Downie *et al.* (1971) discovered about sixty acritarchs in the Jasper and Greenrock giving an age ranging from Arenig to ?Llanvirn. The next unit of this group is a conglomerate which possibly unconformably overlies the Jasper and Greenrock and which consists of well rounded pebbles of the Jasper and Greenrock lithologies and quartzite clasts. Above this are shales and carbonates (HB/NE/3) and sandstones and shales (HB/NE/8) which are separated from the Margie Limestone (HB/NE/4), with subordinate shales (HB/NE12) by a fault. North of the Highland Boundary Fault the Dalradian is emplaced. Burton *et al.* (1984) described *Pogonochitina* cf.*spinifera intermedia* Taugourdeau 1961, *Desmochitina (Desmochitina) juglandiformis* Laufeld 1967, *Lagenochitina* cf. *prussica* Eisenack 1931, *Velatochitina* sp., *Siphonochitina* sp., *Clathrochitina* sp. *and Conochitina* sp. from the Margie Limestone which gives a mid-to-late Caradoc age for the limestone. An ostracod has also been found at this locality (Curry *et al.* 1984). Earlier workers equated the Margie Limestone with the Leny Limestone (Anderson 1947) although this clearly cannot be the case now.

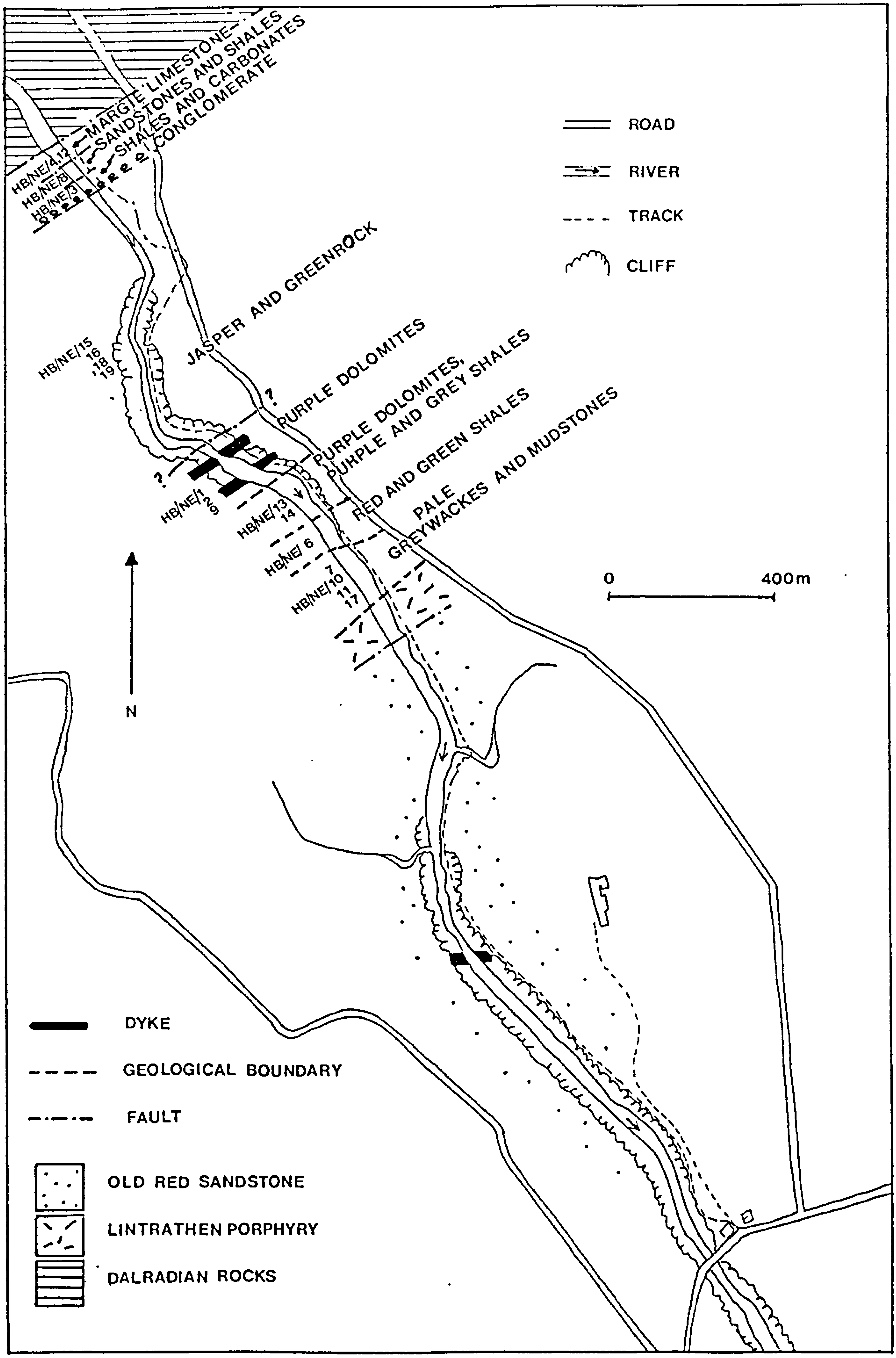


Figure 10 : geological map showing the position of samples collected from the banks of the River North Esk, Edzell.

RIVER NORTH ESK SECTION, EDZELL [NO 585734]

(South-east structural block)

Sample Number	Lithology	Stratigraphical unit	Palaeontological Content
HB/NE/1	Purple limestone		b
HB/NE/6	Pale mudstone		a
HB/NE/7	Sandstone		a
HB/NE/9	Purple shales		a
HB/NE/10	Pale mudstone		b
HB/NE/11	Pale shale		b
HB/NE/13	Purple shale		b
HB/NE/14	Purple shale		c
HB/NE/17	Purple shale		a

Table 7 : Sample number, lithology, stratigraphical unit and palaeontological content for samples from the River North Esk section at Edzell.

NORTH ESK RIVER SECTION : (Continued)

(North-west structural block)

HB/NE/2	Limestone	Jasper and Greenrock	a
HB/NE/3	Black shale		b
HB/NE/4	Black limestone	Margie Limestone	b
HB/NE/8	Black shale		c
HB/NE/12	Black shale	Margie Limestone	b
HB/NE/15	Black shale	Jasper and Greenrock	a
HB/NE/16	Black shale	Jasper and Greenrock	a
HB/NE/18	Black shale	Jasper and Greenrock	a
HB/NE/19	Chert	Jasper and Greenrock	a

(9) Craigeven Bay, Stonehaven. (Figure 11, Table 8).

At Stonehaven the Highland Boundary Fault crops out along a short stretch of coast between Slug Head and Garron Point, interrupted between the points by Craigeven Bay. At Slug Head, the southerly outcrop, the junction between the Old Red Sandstone and the Highland Border Complex is an unconformity, now nearly vertical. Below the unconformity the Highland Border Complex consists of pillow lavas and limestones containing jasper veins and small blebs of chert (HB/S/5). Across Craigeven Bay which is in Dalradian rocks, the Highland Boundary Fault appears again and to the seaward side of it are black shales (HB/S/3,4), followed by red mudstones and cherts all interbedded with pillow lavas and affected extensively by strike-slip faulting. At Garron Point there is a small outcrop of black mudstones that are called the *Polylopia* shales, from which two samples were collected (HB/S/1,2). Again the contact with the Dalradian is the Highland Boundary Fault.

Although the work by Campbell (1911, 1913) has since been discredited, reinvestigation of the cherts has yielded inarticulate brachiopods and possible coleolids which suggest an Ordovician age, which may be as refined as Llanvirn (Curry *et al.* 1984). Trinucleid trilobites and dendroid graptolites have been found in a silicified black shale, exposed at low tide, from the north end of Craigeven Bay, right next to the Highland Boundary Fault.

General stratigraphic framework of the Highland Border Complex

No undoubted Dalradian material has ever been found in the Highland Border Complex and so it is assumed that the two terranes were separate during the deposition of the Highland Border Complex sediments (Bluck 1984). It has already been stated that the relationships between lithologies in the Highland Border Complex are very complicated, and make it difficult to form a comprehensive stratigraphic framework. Bluck *et al.* (*in* Curry *et al.* ,1984), use four rock assemblages which have a stratigraphical significance and this practise will be continued here, although at present the stratigraphy is undergoing review (Whelan *et al.* 1988), and the tentative correlation based on the biostratigraphy is shown in Figure 12.

Rock Assemblage 1

This is composed of serpentinites and associated ophiolitic rocks such as amphibolites, and spilites, which may show a phase of early ocean-crust that was

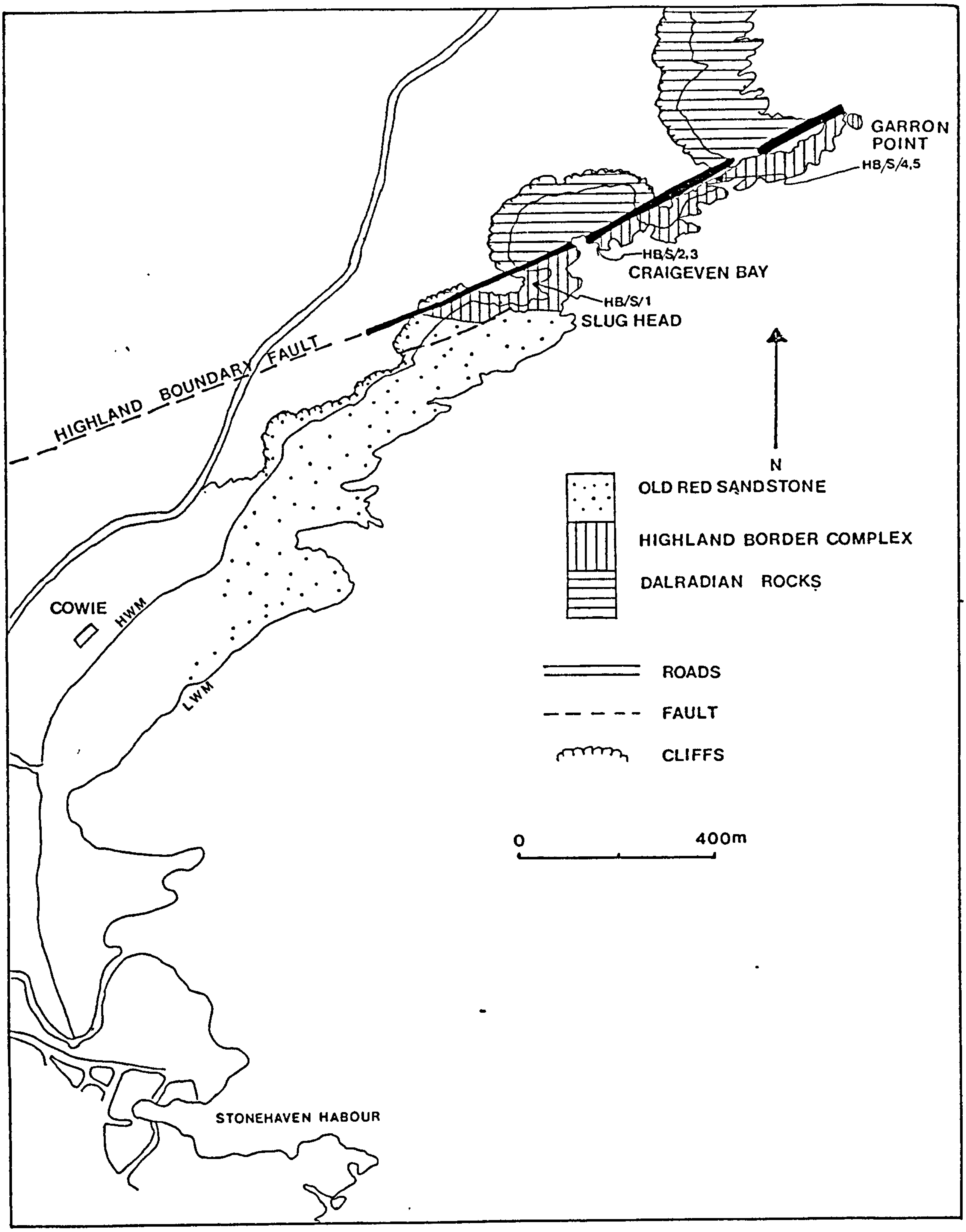


Figure 11 : geological map showing the position of samples collected at Stonehaven.

STONEHAVEN [NO 891875]

Sample number	Lithology	Locality	Stratigraphical unit	Palaeontological content
HB/S/1	Black shale	Garron Point	Polylopia Shales	a
HB/S/2	Black shale	Garron Point	Polylopia Shales	c
HB/S/3	Black shale (20m south of HBF)	North Craigeven Bay		a
HB/S/4	Black shale (10m south of HBF)	North Craigeven Bay		b
HB/S/5	Limestone with chert and jasper	Slug Head		a

Table 8 : sample number, lithology, locality, stratigraphical unit and palaeontological content for samples from Stonehaven.

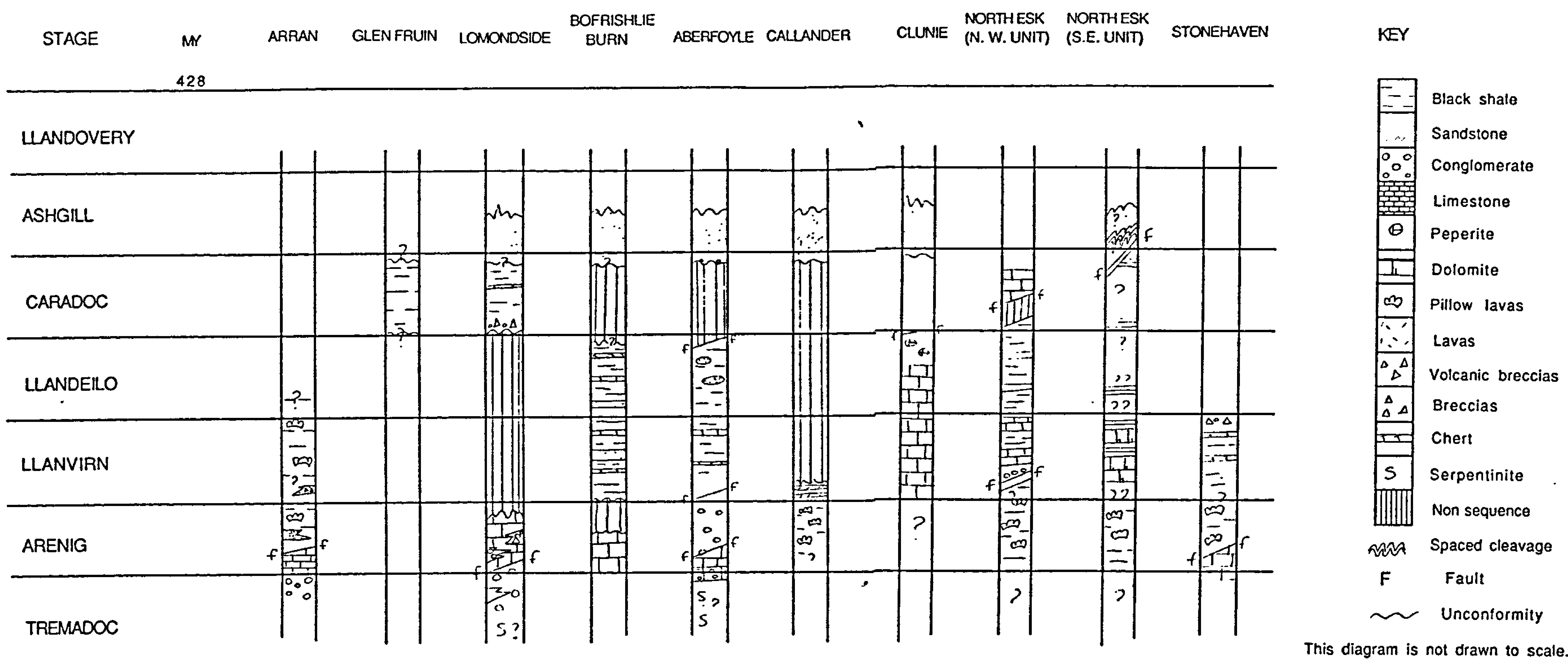


Figure 12 : diagram illustrating the stratigraphical position of various sections from the Highland Border Complex

formed and then obducted in Early Ordovician or pre-Ordovician times.

Rock Assemblage 2

This assemblage is separated from 1 by an unconformity and contains the Arenig Dounans Limestone and the associated Limecraig Conglomerate from Limecraig quarry, the serpentinite conglomerate from Balmaha, ?the basal silicified limestone from Arran, and the carbonate, with jasper veins and chert blebs, at Stonehaven.

Rock Assemblage 3

Black shales, cherts, tuffs, spilitic lavas, and greywacke turbidites are ubiquitous throughout the Complex, though the black shale recognised by Jehu and Campbell (1917) from Limecraig Quarry has not been found.

Rock Assemblage 4

A tectonic event caused this assemblage to unconformably overlie assemblage 3. It contains sandstones and conglomerates and often contain black shale debris, (e.g. in the "Loch Lomond Clastics" of Henderson and Robertson 1982). This assemblage includes the limestones, and shales at North Esk. The unconformity below this assemblage is probably present throughout the whole of the Complex (Bluck *et al.* 1984).

Geotectonic Setting

There are two viewpoints on the relationship of the Highland Border Complex to the Dalradian massif, one that suggests that their structural histories are related and another that postulates that the Highland Border Complex formed away from the Dalradian terrain and that the two areas were not related until much later.

Both the Highland Border Complex rocks and the Dalradian rocks are steeply dipping or vertical (Curry 1986b), and this has led to them being taken as a single structural unit. Shackleton (1958) found downbend structures that suggested that the Highland Border Complex was equivalent to the Dalradian. Henderson and Robertson (1982) interpreted the Highland Border Complex rocks as being formed to the north of or within the Dalradian basin and subsequently being thrust over the Dalradian as an envelope to the Tay nappe. Ikin and Harmon (1984) were in agreement with this and using stable isotopes they discarded the palaeontological and radiometric evidence for the Complex and argued that it had been formed either within or north of the Dalradian Supergroup and involved in the Grampian Orogeny.

The cleavage planes of Dalradian and Highland Border Complex rocks cannot be correlated across the Highland Boundary fault (Curry 1986b), indeed a considerable rotation is necessary to align the two terranes (Johnson and Harris 1967). Harte *et al.* (1984) do not regard the deformation in the Dalradian rocks and the Highland Border Complex as correlatable, and therefore the Highland Border rocks could not have been involved with those of the Dalradian during the formation of the Tay nappe.

Many kilometres of erosion took place from the Dalradian terrane during the Ordovician, but no material of this kind has ever been recognised in the Highland Border Complex sediments (Bluck and Leake 1986). The earliest known record of Dalradian debris is the Lower Old Red Sandstone. Thus the Highland Border Complex must have been deposited in a basin which at the time was not adjacent to the Dalradian massif, but which became juxtaposed with it at a date no earlier than the latest Silurian (Bluck and Leake 1986). The lack of Dalradian debris as well as the undoubted Ordovician age makes it impossible that the Dalradian and Highland Border Complex were adjacent during the Ordovician. This and the fact that much of the Highland Border Complex had not been deposited at the time of the main peak of Dalradian metamorphism (Dempster 1984), makes the theory that the Highland Border Complex was formed north of the Dalradian massif and thrust over it during the formation of the Tay nappe, postulated by Henderson and Robertson (1982) untenable.

The Highland Border Complex was probably deposited in a marginal basin flanked to the south-east by the Midland Valley volcanic or plutonic arc massif (Bluck *et al.* 1984), supplying sediment to the Highland Border basin. The basin which must have been larger than its present day extent, as the Dalradian was probably thrust over it and the Devonian deposited onto it (Bluck 1984), and was accreted onto the Dalradian by strike-slip and thrust faulting. The closure resulted in the Highland Border rocks having a structural grain similar to that of the Dalradian, thus giving the appearance of structural unity between the two (Longman *et al.* 1979).

While the isotopic, and structural evidence cannot be argued about within the scope of this work, the range of specimens found show that the Highland Border Complex could not have taken part in the Grampian Orogeny.

Southern Uplands

The Southern Uplands in Scotland will be dealt with using the three-fold division of

Peach and Horne (1899) that is as a Northern Belt, a Central Belt and a Southern Belt.

The Northern Belt

This area consists of Ordovician greywackes overlying mafic volcanics, bedded cherts graptolitic shales and conglomeratic beds. The latter contain some shelly fossils which are otherwise restricted to limestones which may possibly be olistostromic (Walton 1983). There is one area in the Northern Belt that is of interest to this study.

Barrhill (Figure 13, Table 9)

At Barrhill samples were collected from a section at Cross Water (NX 28 SW). There are two formations, the older Lochryan and younger Cairnerzean Formations. The Lochryan Formation consists of greywackes rich in quartz, with rare pyroxene and hornblende, and grey siltstones often bearing graptolite rich laminae (*pers. comm.* J.D.Floyd 1985). Several samples (SU/B/1,3,8, 10,12,13, 14, and 16) were collected from fine grained siltstones and graptolitic shales from this formation.

The Cairnerzean Formation (SU/B/4,6) consists of greywackes rich in pyroxene and/ or amphiboles, and siltstones. The two formations extend from the Llandeilo to the Caradoc in age.

Two samples were collected from the same locality by J.D.Floyd in 1985. SU/B/19 from the Caradoc, and SU/B/17 is Silurian. Both of these are siltstones.

The Central Belt

The Central Belt is separated from the Northern Belt by the Orlock Bridge Fault, and consists predominantly of greywackes, though there are inliers of Ordovician and Silurian sediments - the Moffat Shales. There are several exposed inliers though the only one that has been collected for this study is at Dob's Linn.

Dob's Linn (Figure 14)

Dob's Linn is ten miles north-east of Moffat at the Head of the Moffat Water. At this locality the Glenkiln, Hartfell and Birkhill Shales, composing the Moffat Shale Group (Caradoc to Llandovery), crop out in continuous sections, one of which contains the International stratotype of the Ordovician-Silurian boundary. This latter section and a number of others were sampled in detail. The structure of Moffat Shale Group was first postulated by Lapworth (1878), and Peach and Horne (1899) as exhibiting tight, isoclinal anticlines, although it is now held that the

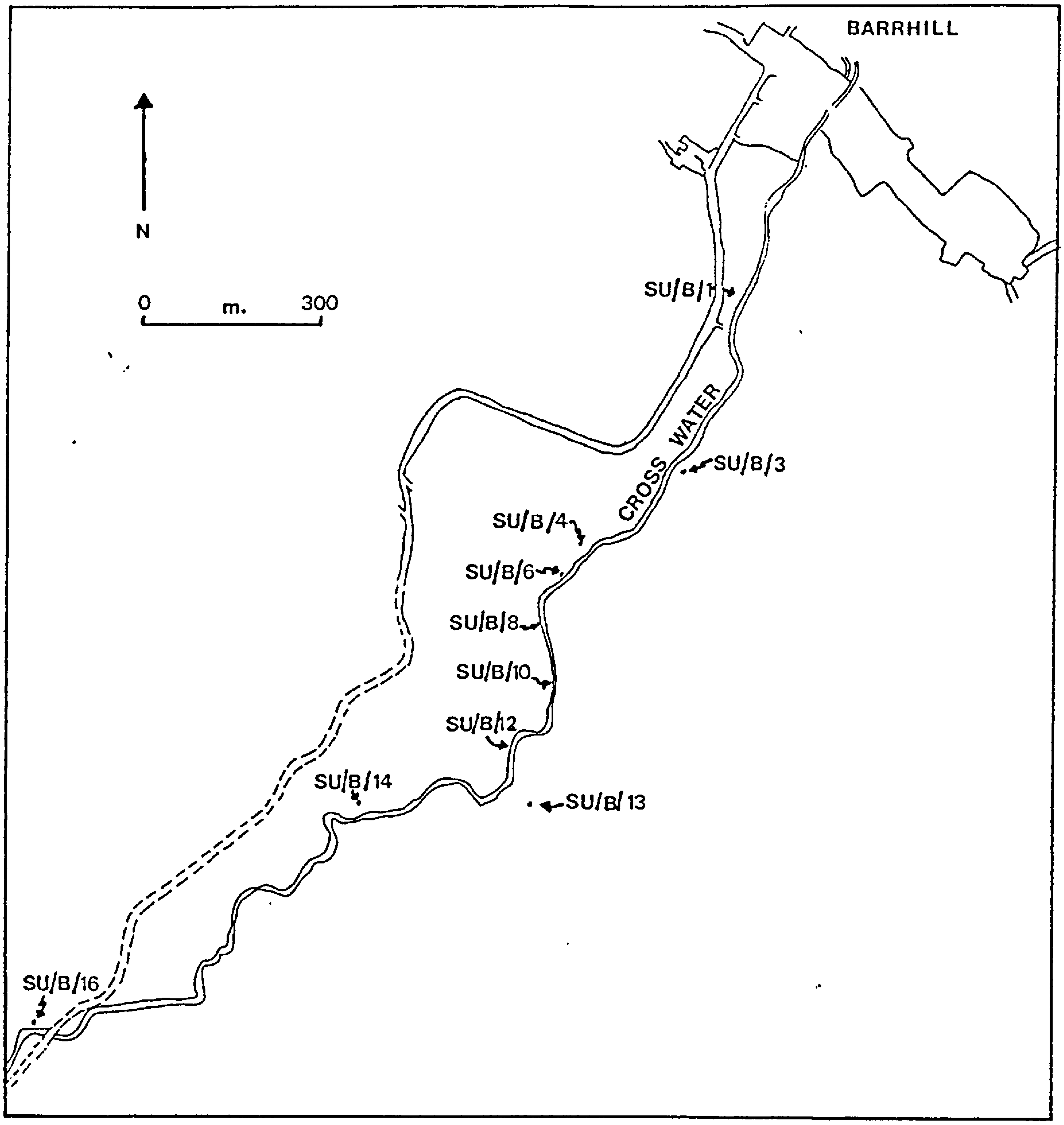


Figure 13 : locality map showing the position of the samples collected at Cross Water, Barrhill.

CROSS WATER< BARRHILL [NX 22325819-NX 22245807]

Sample number	Lithology	Stratigraphical unit	Palaeontological content
SU/B/1	Fine-grained siltstone	Lochryan Formation	c
SU/B/3	Fine-grained siltstone	Lochryan Formation	c
SU/B/4	Fine-grained siltstone	Cairnerzean Formation	c
SU/B/6	Fine-grained siltstone	Cairnerzean Formation	c
SU/B/8	Fine-grained siltstone	Lochryan Formation	c
SU/B/10	Fine-grained siltstone	Lochryan Formation	c
SU/B/12	Black shale/siltstone	Lochryan Formation	c
SU/B/13	Black shale/sitstone	Lochryan Formation	b
SU/B/14	Black shale/silttone	Lochryan Formation	c
SU/B/16	Black shale/siltstone	Lochryan Formation	d
SU/B/17	Fine-grained siltstone		b
SU/B/19	Fine-grained siltstone		b

Table 9 : sample number, lithology, stratigraphical unit and palaeontological content for samples from Cross Water, Barrhill.

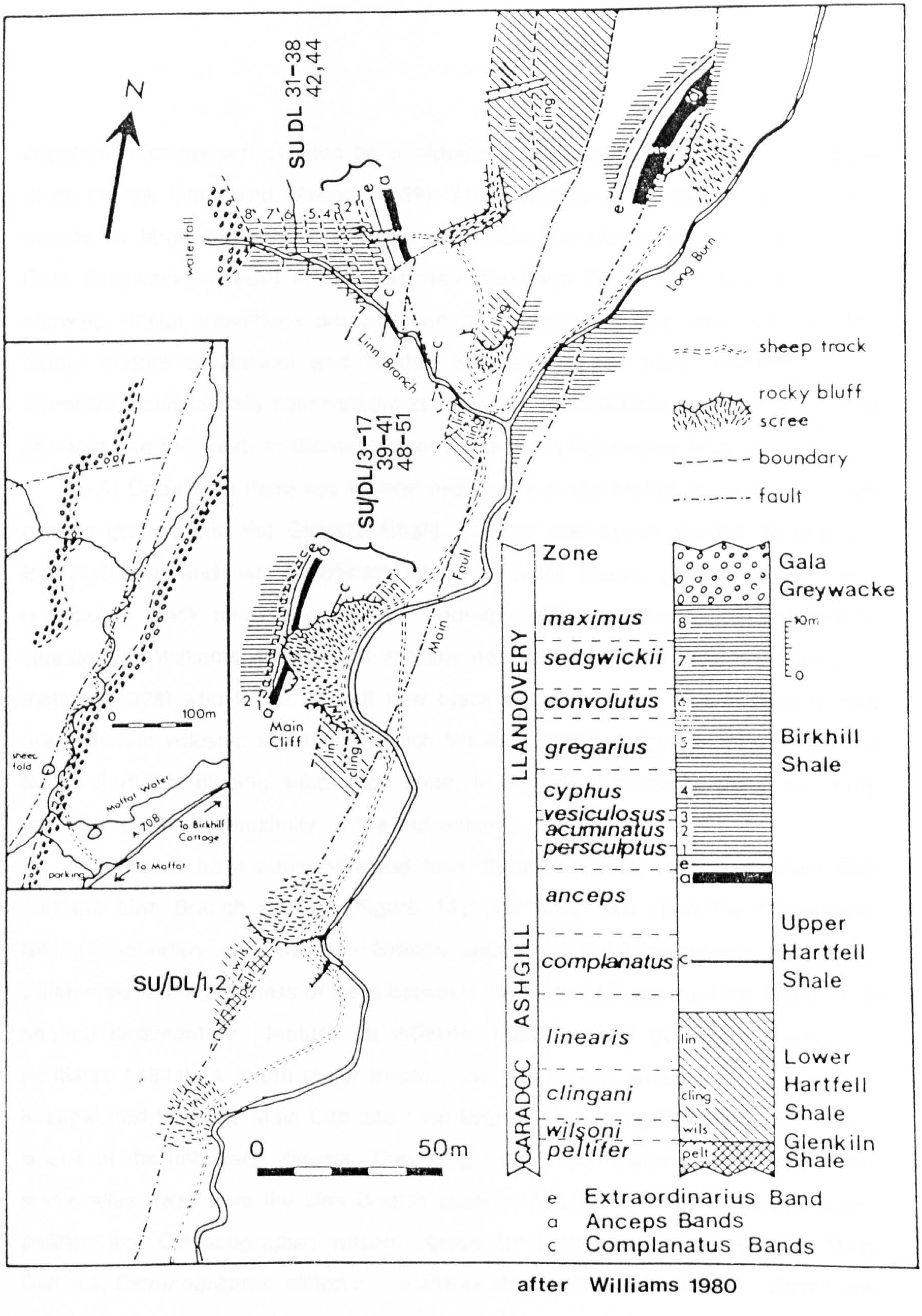


Figure 14 : geological map showing the position of the samples collected at Dob's Linn.

structure is composed of tilted beds dipping predominantly to the north, (Leggett *et al.* (1979), Craig and Walton (1959). These shales are replaced higher in the section by large amounts of sparsely graptolitic late Llandovery greywackes (the Gala Greywacke Group) in the *Rastrites maximus* Zone. Fault bounded tracts showing similar transitions are common all through the Southern Uplands. The ninety metres of Hartfell and Birkhill Shales exposed here (Williams 1981), represent a substantially condensed sequence, as an equivalent sequence a hundred kilometres to the west, at Girvan is over three thousand metres thick.

At Dob's Linn there are several exposures of the Moffat Shale Group which can be divided into the Glenkiln Shales, Upper and Lower Hartfell Shales and Birkhill Shales and which consists mainly of black shales, grey mudstones with occasional black shale bands, rare nodular basic igneous rocks and detrital limestones (Williams 1988), and metabentonites. The area was remapped by Ingham (1978) who found several new black shale horizons. The metabentonites are waterlain volcanic sediments, which Williams (1980) suggests may be related to the northerly dipping subduction zone, though their presence does not imply anything about the proximity of the vulcanicity.

Samples have been collected from three localities, Little Cliff, Main Cliff and the Linn Branch section (Figure 14); the latter two span the Ordovician-Silurian boundary and the Linn Branch section is the International stratotype. Differences in the thickness of beds between the Main Cliff and the Linn Branch is an original sedimentary feature as different beds thicken by different amounts (Williams 1982a). A fourth major locality, the Long Burn, which was not sampled is separated from the Main Cliff and Linn Branch section by the Main Fault which is one of the imbricate thrusts. The Long Burn section was probably deposited many miles away from the Linn Branch section. At Little Cliff the *Climacograptus peltifer* and *Climacograptus wilsoni* graptolite Biozones are exposed. At Main Cliff the *Dicranograptus clingani* to *Parakidograptus acuminatus* Zones are exposed, and although some strike slip faulting has caused repetition of the upper Anceps and Extraordinarius black shale Bands, and the beds dip at about 45°, they are consistently the right way up (Williams 1980). At the Linn Branch, the zones *Dicellograptus anceps* to *R. maximus* are present, and although the beds are overturned, the stratigraphy is not complicated by repetition (Williams 1980). Samples have been collected from all the represented Ordovician graptolite

Biozones and from the Silurian *P.acuminatus* Zone, but collecting has been more concentrated from the *D.anceps* to *P.acuminatus* Zones, and fixed space sampling has been undertaken either side of the Ordovician-Silurian boundary which coincides with the base of the *P. acuminatus* Zone.

More samples have been taken from the Main Cliff than the Linn Branch section as reconnaissance work showed that the Main Cliff samples are more abundant in palynomorphs than the Linn Branch ones. Toghill (1968b) noted that the Main Cliff is a better place for measuring up the basal beds of the Birkhill Shale, although the sediments have been subjected to large scale gravity rotation (Ingham 1974).

Previous palaeontological research at Dob's Linn

Graptolites were first recorded here in the 1850's, although the stratigraphical implications were not then realised. Lapworth first worked at Dob's Linn, and in a succession of papers, including his major publication in 1878 recorded the structure and the graptolite biostratigraphy, and in 1889 produced a paper comparing the strata at Dob's Linn and Girvan. Subsequent work has been done on the graptolites by Peach and Horne (1899), Elles and Wood (1901-1918), Davies (1929), Packham (1962), and Toghill (1968, 1968a, 1970). The sections at Dob's Linn were totally re-collected, and the material worked on by Williams (1982a, 1982b, 1983, 1986, 1987,1988), Williams and Ingham (in press), Williams and Lockley (1983), and Williams and Rickards (1984).

Williams and Lockley (1983) record an algal fibre, and describe epiplanktonic inarticulate brachiopods from the upper Complanatus Band at Dob's Linn indicating quiet bottom water conditions. Lamont and Lindström (1957) first reported the presence of conodonts at Dob's Linn and Barnes and Williams (1988) discussed more fully the implications of the conodont data. They have found about 100 specimens mainly from the *D. anceps* Zone, indicating a Conodont Alteration Index (CAI) of 5-7, which suggests a maximum temperature of 300°C (that the sediments have been taken to). The diversity is low, no fixed clusters were found, and the preservation was poor often only as moulds, and identification was mostly only to generic level. Conodonts are rare near the Ordovician-Silurian boundary, most are from black shales. The abundance is typically three to five species per graptolite zone, which is as expected for deep ocean environment. Chemical processing has yielded nothing, and all the specimens were on bedding plane sections. No conodonts were recovered from the *Climacograptus? extraordinarius* Zone. The *Glyptograptus persculptus* Zone yielded a conodont species diagnostic of the Ordovician, whilst the *P. acuminatus* zone yielded mostly coniforms that cross the boundary in other parts of the world, although one specimen of *Oulodus? kentuckyensis* was found that is known only from the Silurian.

A specialised (blind) dalmanitid trilobite was found 10cm below the *C.?extraordinarius* Band in a nodular limestone by Ingham. Williams (1986) records that it is congeneric but not conspecific with *Mucronaspis (s.l.) cellulana* described by Siveter *et al.* (1980) from an equivalent *C. ?extraordinarius* Zone in Ireland. The species appears to be restricted to Dob's Linn, and probably lived in deep water below the photic zone (Williams 1980).

Stratigraphical Framework

As already stated the Moffat Shale Group can be divided into four main units all of which are conformable.

The Glenkiln Shale(Figures 14, 15, Table 10)

This is the oldest stratigraphic unit exposed at Dob's Linn and consists of five metres of orange weathering black cherty shale with sparse graptolites comprising the *C. peltifer* Zone (SU/DL/1), exposed at Little Cliff.

The Lower Hartfell Shale (Figures 14, 15, Tables 10, 11)

The Lower Hartfell Shale consists of about twenty metres of black abundantly graptolitic shales comprising the *C. wilsoni* (SU/DL/2) Zone exposed at little Cliff, *D. clingani* (SU/DL/3) and some of the *P.linearis* (SU/DL/4) Zone, exposed at Main Cliff. This unit is quite siliceous at the base but this decreases upwards (Williams 1986).

The Upper Hartfell Shale (Figures 14, 15, Tables 11,12,14)

The younger Upper Hartfell Shale is often called the Barren Mudstones due to the scarcity of graptolites, and it is a sequence (twenty eight metres thick) of predominantly finely bioturbated massive grey-green mudstones and shales (Williams and Rickards, 1984), with subordinate thin black shale bands. There are two Complanatus Bands, although originally only one was known. A second thinner stratigraphically higher one was found by Ingham (*In* Ingham and Williams 1974) which is separated from the first by a locally bioturbated mudstone (Williams 1987). There are also five Anceps Bands which are strongly graptolitic and one Extraordinarius Band which is less graptolitic, and

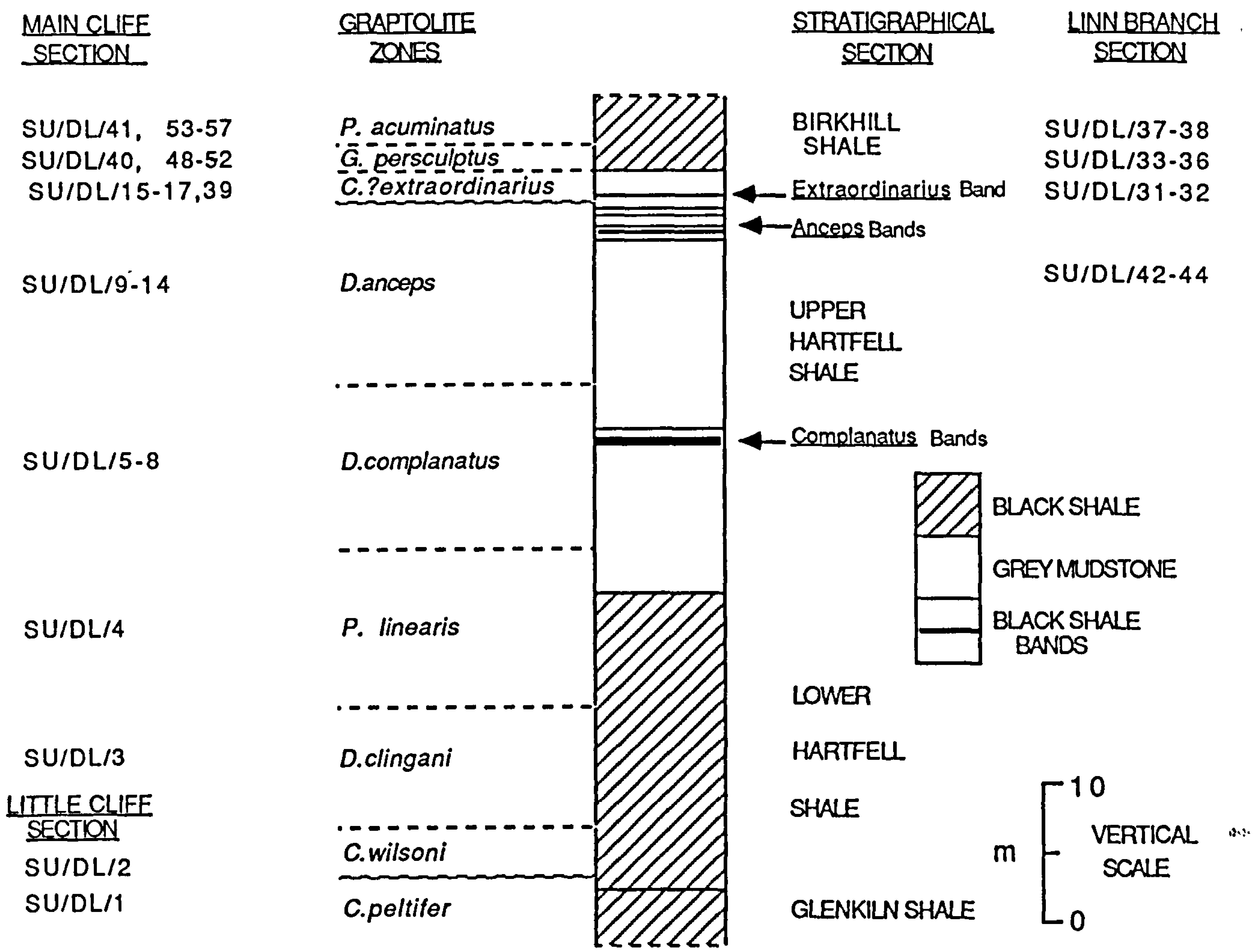


Figure 15 : stratigraphical section for the three localities at Dob's Linn

LITTLE CLIFF, DOB'S LINN [NT 31966157]

Sample number	Graptolite Zone	Lithology	Stratigraphical unit	Palaeontological content
SU/DL/1	C. peltifer	Black shale	Glenkiln Shale	d
SU/DL/2	C. wilsoni	Black shale	Lower Hartfell Shale	d

Table 10 : sample number, graptolite zone, lithology, stratigraphical unit and palaeontological content for samples from Little Cliff, Dob's Linn.

MAIN CLIFF SECTION, DOB'S LINN [NT 31966157]

Sample Number	Graptolite Zones	Lithology	Stratigraphical unit	Palaeonotological content
SU/DL/3	D. clingani	Black shale	Lower Hartfell Shale	d
SU/DL/4	P. linearis	Black shale	Lower Hartfell Shale	d
SU/DL/5	D. complanatus	Grey mudstone	Upper Hartfell Shale	c
SU/DL/6	D. complanatus	Black shale	Upper Hartfell Shale	d
SU/DL/7	D. complanatus	Grey mudstone	Upper Hartfell Shale	c
SU/DL/8	D. complanatus	Grey mudstone	Upper Hartfell Shale	d
SU/DL/9	D. anceps	Black shale	Upper Hartfell Shale	e
SU/DL/10	D. anceps	Black shale	Upper Hartfell Shale	e
SU/DL/11	D. anceps	Black shale	Upper Hartfell Shale	d
SU/DL/12	D. anceps	Grey mudstone	Upper Hartfell Shale	d
SU/DL/13	D. anceps	Black shale	Upper Hartfell Shale	c
SU/DL/14	D. anceps	Black shale	Upper Hartfell Shale	d
SU/DL/15	D. anceps	Grey mudstone	Upper Hartfell Shale	d

Table 11 : sample number, graptolite zone, lithology, stratigraphical unit and palaeontological content for samples from the Main Cliff section, Dob's Linn.

MAIN CLIFF SECTION

Sample number	Graptolite Zone	Lithology	Stratigraphical unit	Palaeontological content
SU/DL/16	D. anceps	Black shale	Upper Hartfell Shale	c
SU/DL/17	D. anceps	Grey mudstone	Upper Hartfell Shale	e
SU/DL/39	C? extraordinarius	Grey mudstone	Upper Hartfell Shale	e
SU/DL/40	G. persculptus	Black shale	Birkhill Shale	d
SU/DL/41	P. acuminatus	Black shale	Birkhill Shale	e
SU/DL/45	D. anceps	Grey mudstone	Upper Hartfell Shale	b
SU/DL/46	D. anceps	Grey mudstone	Upper Hartfell Shale	e
SU/DL/47	D. anceps	Grey mudstone	Upper Hartfell Shale	e
SU/DL/48	G. persculptus	Black shale	Birkhill Shale	d
SU/DL/49	G. persculptus	Black shale	Birkhill Shale	d
SU/DL/50	G. persculptus	Black shale	Birkhill Shale	e
SU/DL/51	G. persculptus	Black shale	Birkhill Shale	e

Table 12 : sample number, graptolite zone, lithology, stratigraphical unit and palaeontological content for samples from the Main Cliff section, Dob's Linn.

metabentonite horizons.

Four samples were collected from the *D.complantatus* Zone. One from the nine metres of grey mudstone below the lowest Complanatus Band (SU/DL/5), a black shale from the lowest Complanatus Band (SU/DL/6), and two grey mudstones from above it (SU/DL/7,8).

There are thirteen metres of grey mudstone between the Complanatus Bands and the Anceps Bands, and the the strata encompassing the latter show a thickness of one point six metres at the Main Cliff, and four point five metres at the Long Burn section to the north which Williams (1986) attributes to original sedimentary variation. There are five Anceps Bands and there is a sudden increase in diversity in Band C (Williams 1986) and there is a widely different fauna between Anceps Bands A to B and C to E. Thus Williams (1982b) subdivided up the *D. anceps* Zone into two subzones, although this practice will not be followed here.

Nine samples have been collected from the *D. anceps* Zone at Main Cliff, SU/DL/9, 10,11,13 and 14 from the Anceps black shale Bands A to E respectively and SU/DL/45,12,46, and 47 from the grey mudstones in between them, and two (SU/DL/42,45) from grey mudstones from the *D. anceps* Zone at the Linn Branch section. The boundary between the *D. anceps* and the *C.? extraordinarius* is somewhere above the Anceps Band E in the Hartfell Shale.

Above the *D. anceps* Zone is the *C ? extraordinarius* Zone added by Rickards (1979) based on the discovery by Ingham and Williams (1974) of a black shale band between the top of the Anceps Bands and the Birkhill Shale. Four samples have been collected from this Zone at Main Cliff (SU/DL/15,16,17 and 39) and two from the Linn Branch (SU/DL/31,32). The *C.? extraordinarius* Zone falls within the Hirnantian and the *G. persculptus* Zone is by definition Hirnantian. The boundary between the *C? extraordinarius* and *G. persculptus* Zones probably falls within the top of the Upper Hartfell Shale (Williams 1986).

The Birkhill Shale (Figures 14, 15, Tables 12, 13, 14)

The Birkhill Shale (forty-three metres) comprises a laminated, pyritic, black shale with abundant graptolites, and represents the *G. persculptus* to *R. maximus* Zones The *G. persculptus* Zone was first recognised by Toghill (1968b) though the species had been recorded by Davies (1929). The boundary between the *G. persculptus* and the *P. acuminatus* Zone is well marked at Dob's

MAIN CLIFF SECTION

Sample number	Graptolite Zone	Lithology	Stratigraphical unit	Palaeontological content
SU/DL/52	G. persculptus	Black shale	Birkhill Shale	e
SU/DL/53	G. persculptus	Black shale	Birkhill Shale	d
SU/DL/54	G. persculptus	Black shale	Birkhill Shale	e
SU/DL/55	G. persculptus	Black shale	Birkhill Shale	d
SU/DL/56	G. persculptus	Black shale	Birkhill Shale	e
SU/DL/57	G. persculptus	Black shale	Birkhill Shale	e

Table 13 : sample number, graptolite zone, lithology, stratigraphical unit and palaeontological content for samples from the Main Cliff section, Dob's Linn.

LINN BRANCH SECTION, DOB'S LINN [NT 31966158].

Sample Number	Graptolite Zone	Lithology	Stratigraphical unit	Palaeontological content
SU/DL/31	C? extraordinarius	Black shale	Upper Hartfell Shale	c
SU/DL/32	C? extraordinarius	Grey mudstone	Upper Hartfell Shale	d
SU/DL/33	G. persculptus	Black shale	Birkhill Shale	c
SU/DL/34	G. persculptus	Black shale	Birkhill Shale	d
SU/DL/35	G. persculptus	Black shale	Birkhill Shale	d
SU/DL/36	P. acuminatus	Black shale	Birkhill Shale	c
SU/DL/37	P. acuminatus	Black shale	Birkhill Shale	d
SU/DL/38	P. acuminatus	Black shale	Birkhill Shale	c
SU/DL/42	D anceps	Grey mudstone	Upper Hartfell Shale	a
SU/DL/44	D. anceps	Grey mudstone	Upper Hartfell Shale	d

Table 14 : sample number, graptolit zone, lithology, stratigraphical unit and palaeontological content for samples from the Linn Branch section, Dob's Linn.

Linn with the incoming of *Akidograptus ascensus* and *Parakidograptus acuminatus* (Williams 1986). The graptolite *Akidograptus* first appears at the base of the *P. acuminatus* Zone at Dob's Linn, though in China it appears lower than this (Berry 1987). Six samples have been collected from the *G. persculptus* Zone at Main Cliff (SU/DL/40,48-52) and three from the Linn Branch (SU/DL/33-35). Six samples have been collected from the *P. acuminatus* Zone at Main Cliff (SU/DL/41,53-57) and three at the Linn Branch (SU/DL/38-38). The Birkhill Shale is replaced vertically by the Gala Greywackes in the *R.maximus* Zone.

The Ordovician- Silurian Boundary at Dob's Linn

Cocks *et al.* (1970) first established the base of the Silurian at Dob's Linn at the base of the *G. persculptus* Zone, that is at the boundary between the Upper Hartfell and the Birkhill Shales. However the boundary was finally designated at the base of the *P. acuminatus* Zone, that is one point six metres above the base of the Birkhill Shale in the Linn Branch section. This allows the shelly *Hirnantia* fauna to remain in the Ordovician (Cocks 1985). The boundary is marked by the incoming of the graptolites *Akidograptus ascensus* (Davies 1929) and *Parakidograptus acuminatus s.l.* (Nicholson 1867) (Cocks 1985).

Berry (1987) argues that there is a major extinction of Late Ordovician taxa at the top of the *D. anceps* Zone, and a new radiation in the *G. persculptus* Zone. Therefore the base of the *G. persculptus* zone would be a better position for the boundary. He argues also that Dob's Linn is a poor place for a boundary due to the scarcity of fossils other than graptolites, and due also to structural complexity which may influence thicknesses and therefore the stratigraphical ranges of the fossils. The base of the *G. persculptus* Zone cannot be delineated as there are few graptolites in the Upper Hartfell Shale; the base is probably above Anceps Band E (Williams 1986). There is a graptolite extinction at the *D. anceps/ C. ? extraordinarius* Zone boundary (Williams 1988), five point five metres below the base of the *P. acuminatus* Zone (Berry 1987). In China this extinction occurs a quarter of a metre below the base of the *G. persculptus* Zone, whereas at Dob's Linn it occurs three point five metres below the base of the *G. persculptus* Zone. Therefore Berry (1987) regards the base of the *G. persculptus* Zone as a more suitable place for the boundary. This extinction could be said to be a biological event and could be used as the Ordovician-Silurian boundary (Berry 1987).

Berry *et al.* (1984) and Wilde *et al.* (1984, 86) show chemical changes in the grey shales near the Extraordinarius Band which may be related to the oxygen conditions in the waters. Between *G. persculptus* Zone and *C.? extraordinarius* Zone there is a calcium carbonate rich layer, which is in a similar place in the sections in China, and could possibly be used as an indication of the boundary.

Lespérance *et al.* (1987) rightly state that few of the guidelines needed for a boundary are found at Dob's Linn, as it is structurally complex, is a condensed sequence, is of limited lateral extent and most of the graptolite zones are not well constrained in the grey mudstones. Furthermore the two species that mark the boundary do not appear together in China, where the pre-*P. acuminatus* strata also bear a monograptid fauna. The CAI at Dob's Linn is 5-7, leading Lespérance *et al.* (1987) to state that "....the strata are thermally complex, limiting their value in studies of palynology.....". The latter clearly is not the case, as shown by the present study and Whelan and Burton (1988), the other objections notwithstanding. Lespérance (1985) has attempted to correlate the *P. acuminatus* Zone boundary with carbonate platform sequences on Anticosti Island and the appearance of the trilobite *Acernaspis* may coincide with the *P. acuminatus* Zone boundary but this has not yet been tested. The boundary at Dob's Linn is really only useful for deep water sequences, but other places that have been sited for the boundary also have many drawbacks. At Dob's Linn at least the boundary is continuous, if condensed, whereas in Anticosti Island reef sediments are present at about the boundary level containing few palynomorphs and graptolites, although conodonts are common, along with other groups of fossils. It is thus difficult to use the groups common at Dob's Linn for biostratigraphical purposes on Anticosti Island.

Williams (1986) suggests that the base of the *P.acuminatus* Zone is the most suitable place for the Ordovician-Silurian boundary as it is impossible to define the base of the *G. persculptus* Zone. Elsewhere there is often an unconformity at the base of the Silurian due to late Ordovician regressions and early Silurian transgressions related to contemporary glaciation.

At the present time the Ordovician-Silurian boundary is one point six metres above the base of the Birkhill Shale in the Linn Branch section at Dob's Linn (Cocks 1985). Toghill (1968a,b) defined the Ordovician-Silurian boundary at the Main Cliff as one point zero six metres above the base of the Birkhill Shale but Williams (1983) remarks that if the basal beds of the Birkhill Shale are included it is more like one point six four metres. Either Toghill did not include these basal beds in the Birkhill Shale or they have been faulted out where he measured them.

The Southern Belt

The rocks of this belt are predominantly Llandovery and Wenlock in age, but will not be covered in any great detail in this work. Only one locality has been sampled.

Coldingham Bay (Figure 16)

The unfossiliferous Coldingham Beds (Shiells and Dearman 1963) consist of pale grey and buff coloured shales (SU/CB/1-4) which form an inlier within the Lower Old Red Sandstone basin that lies within the greywacke terrane of the Southern Uplands prism. The rocks of the inlier are relatively flat-lying and lack a cleavage, are isoclinally folded and sheared and Oliver *et al.* 1984 suggest that they may be deformed by soft sediment deformation. Shiells and Dearman (1963) suggest that these beds may be the oldest in the area, and the complexity of their structure may be related to deep levels of orogenic zones, on these grounds they postulate that the Coldingham Beds are Cambrian or early Ordovician or possibly older, although Oliver *et al.* (1984) suggest that they may have a late Silurian age.

Depositional environment

The sediments of the Southern Uplands and Girvan were deposited in the northern sector of the Iapetus ocean (originally named by Harland and Gayer 1972), which separated the Lake District and the Southern Uplands during the Ordovician. At Dob's Linn shales and mudstones were deposited offshore and in deep water, during the Caradoc to Llandovery (Cocks 1985). In the *R. maximus* Zone the first indisputable greywackes (Williams 1988) were deposited (Williams 1988). Dewey (1971), Leggett (1980) and Leggett *et al.* (1979) considered the shales to be truly pelagic, and formed during periods of high eustatic sea levels and increased primary production, however the sediments of the upper Ordovician and Lower Silurian Moffat Group display sedimentary features (Williams and Rickards 1984, Williams 1988) which suggest that they were more likely to have been deposited by hemipelagic, distal turbidites in the abyssal depths of the Iapetus Ocean (Williams 1988). The source area must have contained carbonates to allow for the carbonate rich horizons in the sequence at Dob's Linn. Northerly directed subduction subsequently transported the sediments to the site of deposition by proximal turbidites and resulted in diachronous deposition of the Gala Greywacke

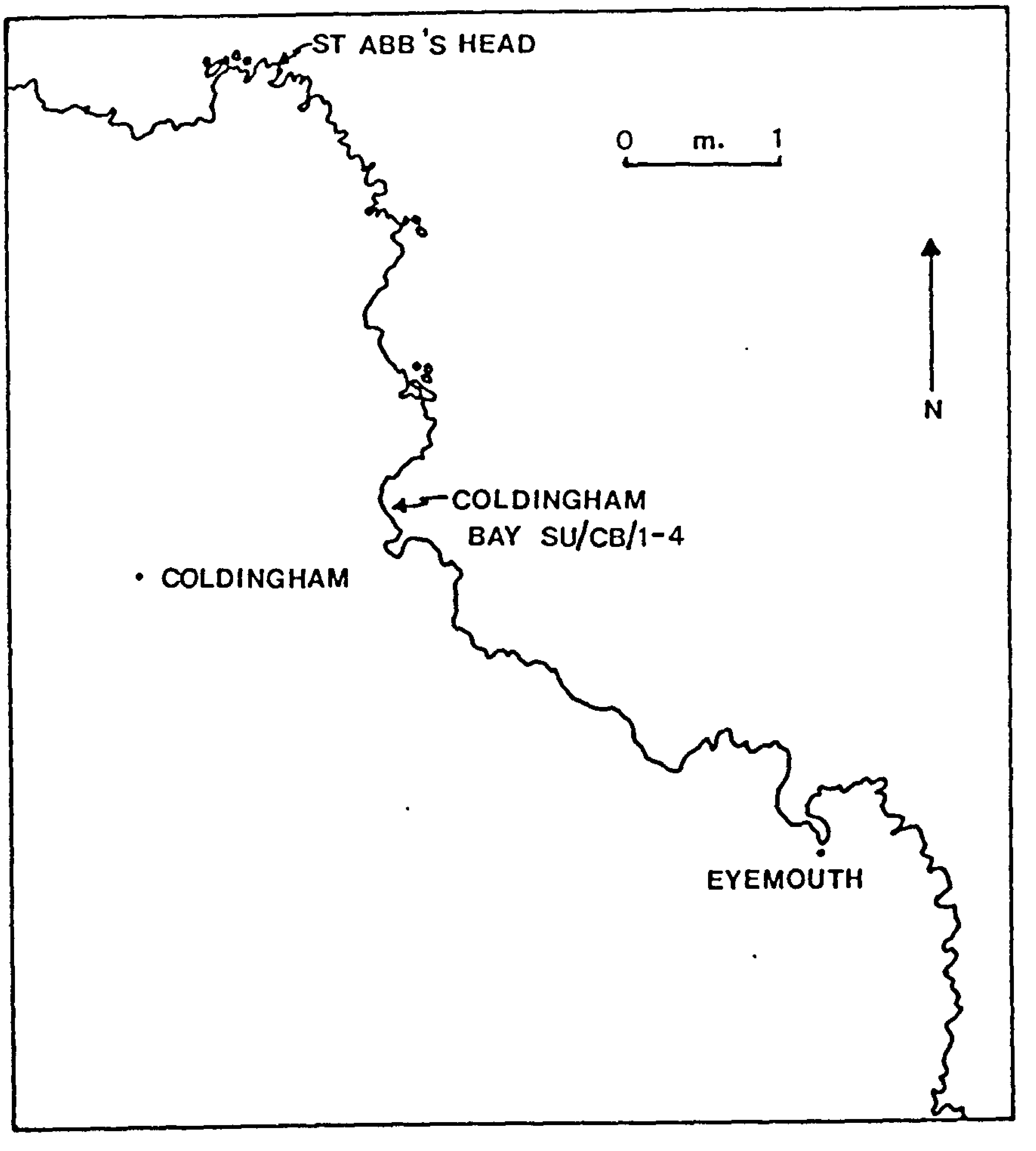


Figure 16 : locality map showing the position of Coldingham Bay.

Group. Deformation related to this subduction produced imbricate thrusting and metamorphism to prehnite-pumpellyite facies (Williams 1988).

Sea level during the Caradoc was high and not related to glaciation (Leggett 1980) but possibly to the formation of new oceanic crust (Leggett 1978). Low sea level in the Ashgill and high sea level in the Llandovery were probably related to Southern Hemisphere glaciation (Berry and Wilde 1978, Leggett 1980). Sea level changes were thus responsible for major changes in lithology, but small scale lithological variation may have been related to fluctuations in oxygen levels (Williams and Rickards 1984). Graptolite horizons have been subjected to winnowing by current activity which may have controlled the oxygen levels along with the density of organic matter (Williams and Rickards 1984). Williams (1986) further notes that "The worldwide graptolite mass extinction which occurred at the base of the *C? extraordinarius* Zone and resulted in the extinction of at least five genera and numerous species was almost certainly related to the late Ordovician southern-hemisphere glaciation which also accounted for the sudden change in shelly faunas at the base of the Hirnantian stage". Wilde *et al.*(1986) show that there is no extraterrestrial source for the extinctions at the Ordovician-Silurian boundary.

Structural History of the Southern Uplands

Leggett *et al.* (1979) divided the three belts first described by Peach and Horne (1889) into ten discrete tracts, bounded by major reverse strike faults, and originally deposited far apart (Leggett *et al.* 1979). Most sequences consist of cherts, lavas or graptolitic shales below thick sequences of greywackes which have a diachronous base and young progressively south. Systematic variations in the regional timing of the transition from shales to greywackes, along with the complex younging relationships between and within the tracts (first recognised by Craig and Walton 1959) are thought to reflect the progressive growth of an accretionary prism (McKerrow *et al.* 1977), over a northerly dipping subduction zone during closure of the Iapetus Ocean. This model was first suggested by Mitchell and McKerrow (1975) who record an analogy of the Southern Uplands with the Burma orogen. McKerrow *et al.* (1977), Leggett *et al.* (1979), and Leggett (1987) subsequently expanded and refined the model for deposition of the sediments of the Southern Uplands in a fore-arc trench followed by the sequential accretion of packets of strata to form an accretionary prism.

Moseley (1977,78) disputed this model due to the postulated closure of the Iapetus Ocean at the end of the Ordovician, which would have terminated subduction of the ocean floor before the last accretionary packets were supposed to have formed.

Murphy and Hutton (1986) and Hutton and Murphy (1987) while agreeing with the principle of an accretionary prism model in the Ordovician however dispute this model in the Silurian, as they think that subduction was completed at both margins of Iapetus by late Ordovician times and that Silurian turbidites were deposited in a successor basin. They hypothesised that the basin structure is a sinistral transcurrent imbricate stack, the result of oblique terminal collision of Cadomia with Laurasia at the end of the Silurian (Murphy and Hutton 1986). Morris (1987) suggests that the rocks of the Central and Southern Belts were deposited in a fore-arc setting but that the Northern Belt in a back arc basin which closed and was deformed at the end of the Ordovician, and then overthrust by the allochthonous thrust-stack of imbricated Central and Southern Belts fore-arc sequence at the end of the Silurian. Kelling *et al.* (1987) agree with the accretionary prism model for the Llandeilo to Llandovery sediments and reject the back arc model, but agree with Hutton and Murphy (1987) that the later sediments were deposited in a successor basin. Barnes *et al.* (1987) conclude that the Northern Belt was formed by accretionary prism but not the Central Belt.

Needham and Knipe (1986) believe that accretion occurred from Llanvirn to the Wenlock, and that its deformation had a south-easterly direction suggesting underthrusting of lower crustal material of Cadomian affinity. Later there was a reversal in transport direction with north-west thrusting, and this along with the fact that the northern part of the Southern Uplands is underlain by Midland Valley type crust (Hall *et al.* 1983) suggests to them that partial northward obduction has occurred. Thus the Southern Uplands are considered to be a large scale pop-up structure between a fore-thrust and a back thrust which partially obducted it toward the north-west (Needham and Knipe 1986).

The imbricate thrust stack with complex younging directions has been used to support both accretionary prism and piggybacked thrust duplex models in a marginal foreland or successor basin (McCurry 1986). Detailed mapping in the Rhinns of Galloway suggests that some tracts actually young south-east and support sequential simple shear and pure shear deformation in a steady state trench environment (McCurry 1986).

Stone *et al.* (1987) totally dispute the accretionary prism model and suggest that as well as a land mass supplying sediment from the north, southern material (i.e. oceanward in the fore-arc setting) also supplied mature quartzose and andesitic material. The sediments were thus deposited in a back arc basin, with the Iapetus Ocean closing in the Llandovery by arc-continent collision and producing a south east propagating thrust stack, which ramped over the eroded remains of the volcanic arc and provided detritus to a foreland basin, the sedimentary fill of which now forms the Hawick Group and younger sediments (Stone *et al.* 1986).

The mechanism by which the structure of the Southern Uplands was formed is obviously still uncertain, as there are as many theories as there are people working on it. Many workers still hold with the accretionary prism model for all or part of the Southern Uplands, and only exhaustive field work and tighter stratigraphical controls will resolve the controversy.

The basin is underlain by continental basement which suggests that the Southern Uplands is allochthonous (Bluck 1984).

Midland Valley

Girvan is situated in the south-western tip of the Midland Valley, and is a classic area of Lower Palaeozoic geology. The Lower Ordovician Ballantrae Complex is an ophiolitic complex formed in a marginal basin-arc type setting (Bluck 1982) which was obducted prior to the unconformable deposition of the Ordovician and Silurian cover in a proximal fore-arc environment (Longman *et al.* 1979). It is associated with olistostrome deposits which include black shales. Work by Rushton *et al.* (1986) suggests that the main Pinbain (Figure 17) olistostrome sequence is Lower Arenig in age. At Pinbain the olistostrome is bounded to the south by a fault and to the north by the metamorphic sole. The main ophiolitic rocks have been thrust over the olistostrome which may have been formed by the ophiolite or prior to obduction. The relationship of the olistostrome to the ophiolite is a very complicated one, and any age dates that could be determined would aid in the interpretation of the ophiolitic complex. The Ballantrae Complex forms part of the source for the Middle and Upper Ordovician sediments, of which there are about three thousand metres at Girvan. They are broadly equivalent in age to those at Dob's Linn, which thus represents a substantially condensed sequence. The sediments at Girvan were in all likelihood deposited in a series of fault bounded basins on an unstable slope or slopes probably paralleling an active subduction

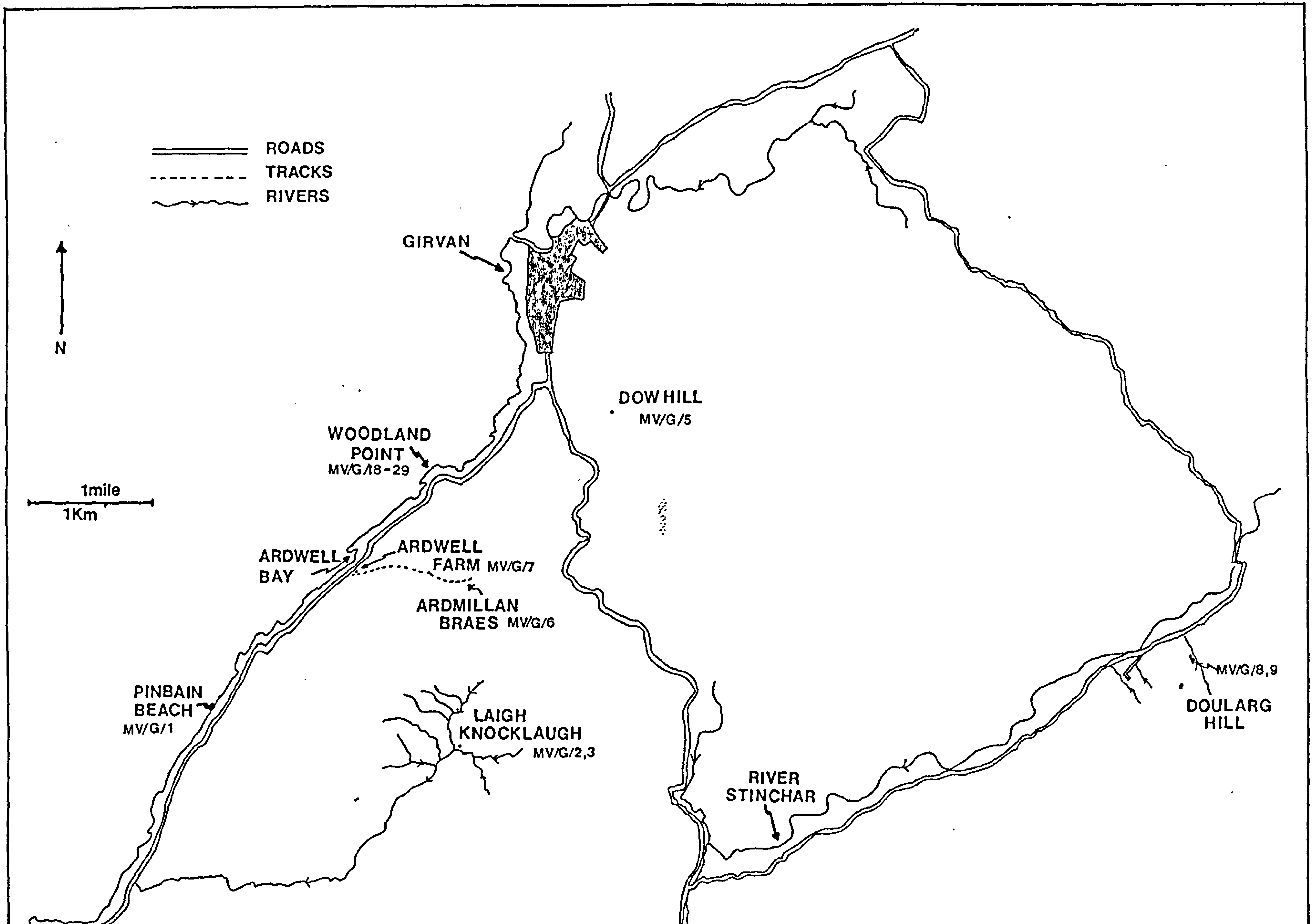


Figure 17 : map of the Girvan Area showing the position of samples collected

trench to the south-east (Ingham 1978). Macrofossils are represented mainly by graptolites but there are also shelly horizons, with presumably washed in material (Ingham 1978). The fore-arc represented by the Middle and Upper Ordovician sediments was terminated by the Southern Uplands being thrust over it (Bluck 1984).

Pinbain Beach and Hill,Ballantrae (Figure 17, Table 15)

One sample of limestone (MV/G/1) was collected from the olistostrome on Pinbain beach, and a sample of limestone (MV/G/2) and one of black shale (MV/G/3) were collected from the olistostrome exposed in a stream beneath the ophiolite sole about four hundred metres north-north-west at Laigh Knocklaugh.

The Girvan Foreshore

The oldest sediments collected at Girvan are the Infra-Kilranny mudstones (Figure 18) at Dow Hill (MV/G/5) (Figure 17, Table 15) which are dark grey mudstones containing a shelly fauna and are broadly equivalent in age to the inland Balclatchie Group, thus being early Caradoc (Walton 1983). The second group which is younger than the Infra-Kilranny mudstones and rests with discordance upon that group (Ingham 1978) is the Ardwell Group. Two samples (Figure 17, Table 15) of dark grey mudstones were collected from this group. The first, from the base of the Ardwell Group at Ardmillan Braes (MV/G/6) and the second higher up at the gate of Ardwell Farm (MV/G/7). There is general disagreement as to whether the sediments were deposited in a neritic environment (Hubert 1966) or in a downslope turbidite regime (Williams 1962). This group has been much affected by soft sediment deformation, and the graptolites indicate a late middle or late Caradoc age for the top of this unit (Ingham 1978).

The succeeding and conformable unit to the Ardwell Group is the Whitehouse Group (Figure 18), which is lithologically very diverse, but no samples were collected from the bulk of it, except for one from the Mill Formation (uppermost formation of the Upper Whitehouse Group) at Woodland Point (Figure 19, Table 16) . This formation consists of grey and green striped mudstones and shales overlain by shales which contain graptolites of the *D. complanatus* Zone. Above this are more grey-green shales from which one sample was collected (MV/G/29).

The Shalloch or Barren Flags Formation lies conformably above the Mill Formation (Figure 18,19, Table 16). It begins with a thin grey mudstone which is persistent over a large area (J.K.Ingham pers. comm.). Above this is about two hundred and thirty metres of sandstones and shales (total about three hundred and

MISCELLANEOUS GIRVAN SAMPLES

Sample number	Lithology	Locality	Stratigraphical unit	Grid reference	Palaeontological content
MV/G/1	Limestone	Pinbain Beach		NX 21375915	a
MV/G/2	Limestone	Laigh Knocklaugh		NX 21715921	c
MV/G/3	Black shale	Laigh Knocklaugh		NX 21715921	d
MV/G/5	Grey mudstone	Dow Hill	Infrakilranny mudstone	NX 21925961	d
MV/G/6	Grey mudstone	Ardmillan Braes	Ardwell Flags	NX 21695941	e
MV/G/7	Grey mudstone	Ardwell Farm	Ardwell Flags	NX 21595941	e
MV/G/8	Grey limestone	Doularg Hill	Jubilation Member	NX 22695929	e
MV/G/9	Grey limestone	Doularg Hill	Jubilation Member	NX 22695929	e

Table 15 : showing the sample data for samples collected at Girvan.

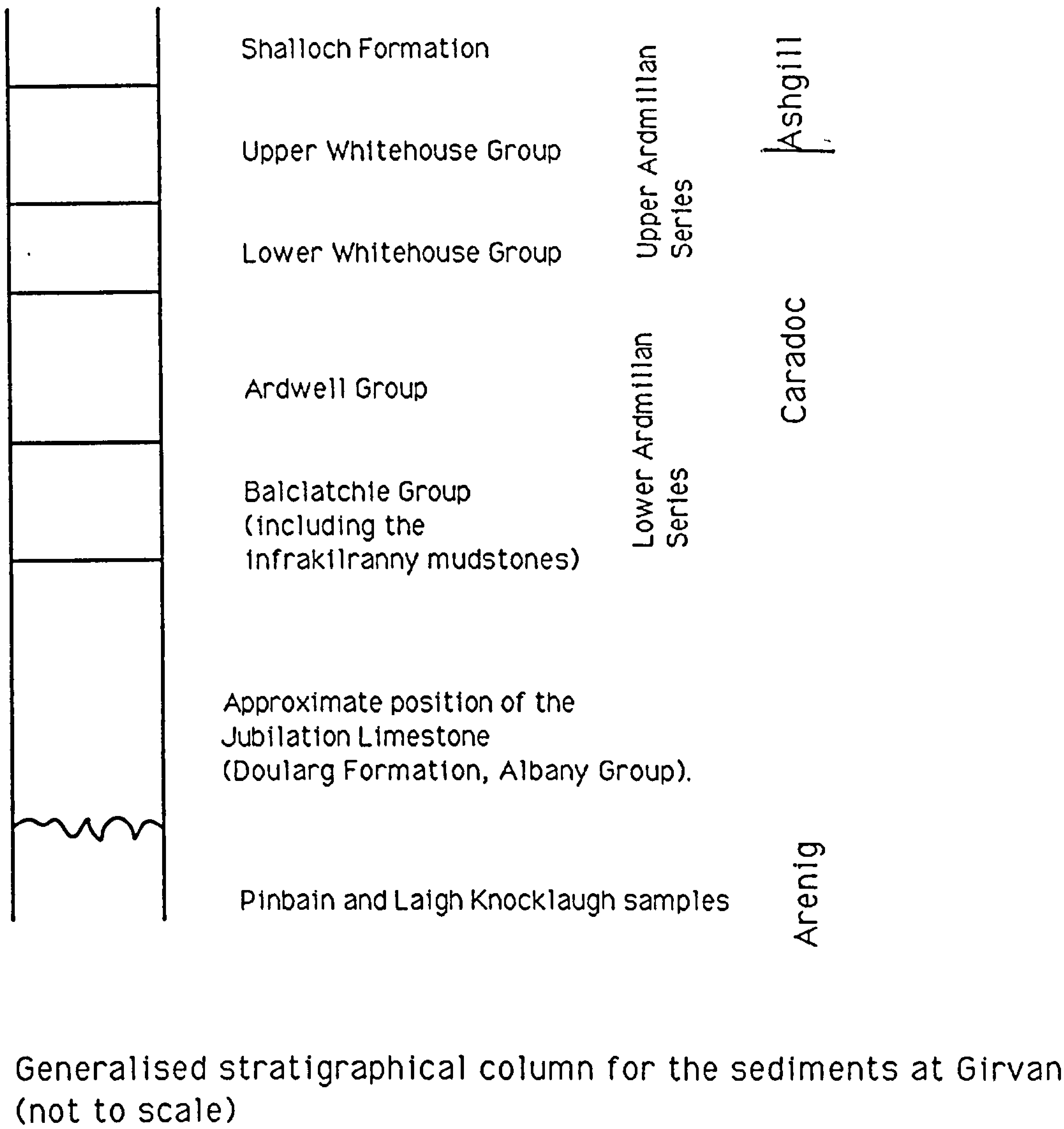


Figure 18 : generalised stratigraphical column for the sediments at Girvan.

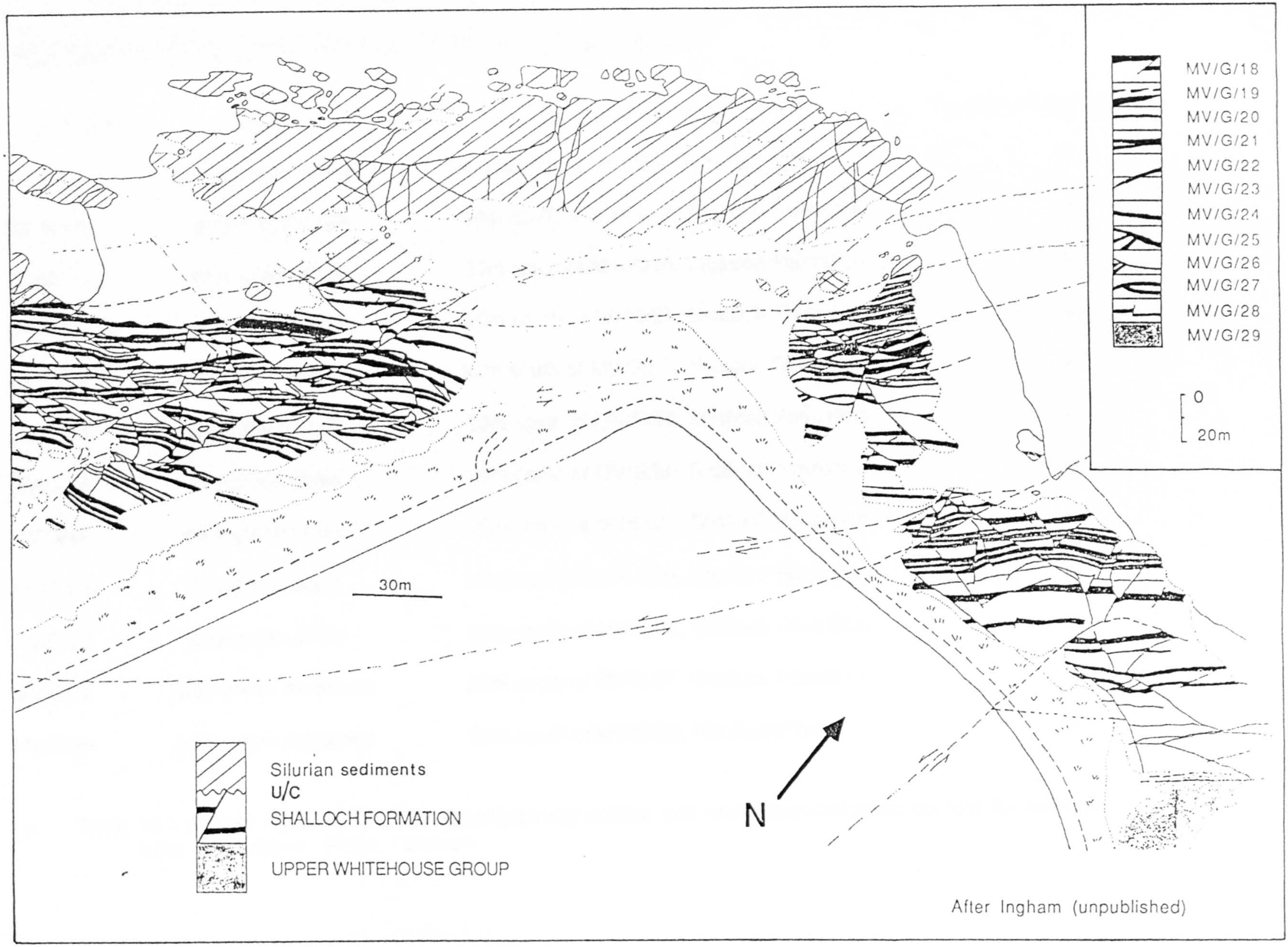


Figure 19 : geological map of the Woodland Point area

WOODLAND POINT (BLACK NEUK), GIRVAN [NX 21745954].

Sample Number	Lithology	Locality/Stratigraphical unit	Palaeontological content
MV/G/18	grey-green mudstone	Exposed top of Shalloch Formation	e
MV/G/19	grey-green shale	20m south of MV/G/18, Shalloch Formation	e
MV/G/20	grey-green shale	20m south of MV/G/19, Shalloch Formation	e
MV/G/21	grey-green shale	20m south of MV/G/20, Shalloch Formation.	e
MV/G/22	grey-green mudstone	20m south of MV/G/21, Shalloch Formation	e
MV/G/23	grey-green shale	20m south of MV/G/22, Shalloch Formation	e
MV/G/24	grey-green shale	20m south of MV/G/23, Shalloch Formation	e
MV/G/25	grey-green shale	20m south of MV/G/24, Shalloch Formation	e
MV/G/26	grey-green shale	20m south of MV/G/25, Shalloch Formation	e
MV/G/27	grey-green shale	20m south of MV/G/26, Shalloch Formation	e
MV/G/28	grey-green mudstone	20m south of MV/G/27, Shalloch Formation	e
MV/G/29	grey-green mudstone	20m south of MV/G/28, Mill Formation.	e

Table 16 : sample number, lithology, locality/stratigraphical unit and palaeontological content for samples from Woodland Point, Girvan.

thirty metres in the Myoch Bay/Haven area) which pass unconformably into the basal Silurian. The sandstones are greenish-grey, fine-grained, laminated, for the most part ungraded with ripple marks and convolute lamination (Walton 1983). They are interbedded with greenish-grey or grey mudstones and shales. There are three thin limestones that contain recognisable Lower Ashgill shelly debris (Ingham 1978). Graptolites are found at the base of the unit representing the *D. complanatus* Zone and one hundred and eighty metres from the base representing the *D. anceps* Zone, Therefore somewhere within this unit the *D. complanatus / D. anceps* Zone boundary is exposed. Hubert (1966) records a change from greenish to grey shales, brought about by a change of current from south-west to north-east. Samples were collected at approximately twenty metre intervals throughout the Shalloch Formation exposed at Woodland Point (Figure 19).

Hubert (1966) regarded the Upper Whitehouse beds as pro-deltaic shallow water deposits, and the Shalloch formation as flysch sediments deposited in the deeper neritic zone, but Ingham (1978) is in favour of the Upper Whitehouse beds as being deposited in reasonably deep water as the macrofauna preserved is regarded as an intermediate between a *Clorinda* type community and a graptolitic facies. He considers the sediments to have been deposited on a subsiding unstable slope of a submarine fan (Ingham 1978). Harper (1979) states that the Upper Whitehouse Group and the Shalloch Formation sediments were deposited in a predominantly unstable and often turbulent off-shore continental slope environment, at depths of three hundred to a thousand metres and is thus in full agreement with Ingham (1978).

<u>Stinchar Valley</u>

Two samples (MV/G/8,9) (Figure 17, Table 15) were collected from the Jubilation Member (Doularg Formation, Albany Group), which is a grey muddy limestone exposed in Plantation Burn east of Doularg Hill (NX 26912 92895). It is Whiterockian (?Arenig to Lower Llandeilo) in age (Ross and Ingham 1970). The terminology used here is informal (J.K.Ingham pers. comm.).

Chapter 3 - Sampling and Preparation

Introduction

Seventy one samples have been processed from the Highland Border Complex, forty three from Dob's Linn, twenty from the Girvan area, twelve from Barrhill, and four from Coldingham Bay. Their lithologies are listed in Chapter 2.

Sampling

Although Paris (1981) recommends layer by layer sampling this has not been feasible from the Highland Border Complex, due to the complexity of deformation. Jenkins (1967, p. 480) states ..." that within short sequences of either mixed or uniform lithology, the concentration of chitinozoans in the rock may vary greatly and capriciously, but the same species are present everywhere and the relative abundances of each species....... remains much the same" Therefore it is not necessary to sample every lithology, and indeed any lithology could in theory yield chitinozoans. At Girvan sampling has been carried out at approximately twenty metre intervals, and at Dob's Linn collecting has been carried out systematically (though not layer by layer) through the Hartfell Shale and Birkhill Shale, but also at five to ten centimetre intervals across the approximate position of the Ordovician/Silurian boundary. Paris (1981) also warns of the fact that some layers contain mixed assemblages (e.g. chloritised oolite with phosphoritised pebbles at the base of the formation of Louredo in Portugal). As the succession at Dob's Linn suggests that a small amount of sediment was deposited over a long time period, it is likely that samples will contain an assemblage from more than one time interval and it has not been possible to sample layer by layer. At Girvan the sediments represent a turbidite sequence and so are likely to contain material washed in, a factor which must be also taken into account with the Dob's Linn sediments.

The abundance of palynomorphs in a sample is dependent on several factors, among them

(a) the rate of sedimentation

(b) preservation at or near the sediment/water interface

(c) the facies preference of the living creatures for the environment.

By virtue of the rate of sedimentation mudstones normally contain relatively more palynomorphs. The relative scarcity of chitinozoans must be explained therefore by another method, probably due to preservation of the sediments and the long time over which such a short sequence was deposited.

In a deformed area it may be advantageous to collect calcareous rocks as while they are less likely to contain chitinozoans (? and acritarchs) they are also less susceptible to deformation (Paris 1981). Where there are deformed sequences of alternating mudstones and sandstones, the argillaceous layers are far more preferable for the reason given above. If folding is present then the sample is best taken from the area of the flank of the fold rather than the hinge (Paris 1981), although in the Highland Border Complex it is often difficult to ascertain the position of the hinge.

Palynomorphs appear to be preserved up to greenschist facies, albeit poorly (Smith and Saunders 1970) but once into biotite grade rocks, or near a thermal aureole, it is extremely unlikely that any fossils will remain. Pacltová (1986) illustrates material which she claims are organic microfossils from biotite grade gneisses in Czechoslovakia, although the figured material appears to be very poorly preserved.

Preparation

The two groups, acritarchs and chitinozoans, although widely different systematically, share the common features of acid insolubility, extreme durability and of being abundant or at least present in most marine lithologies. All the equipment used in preparation must be free of contamination, and was thus initially sterilised using chromic acid (concentrated sulphuric acid and potassium dichromate), and then scrubbed with detergent and water. The samples themselves are scrubbed with detergent and water to remove surface contaminants.

Physical Breakdown

The samples are broken down to 1 cm cubes using a hammer, or in the case of very indurated sediments, using a jaw crusher.

Chemical Breakdown

Since carbonate material can cause problems later in processing, it is tested for at this stage, using dilute hydrochloric acid. Those samples that proved positive have the carbonate removed by the following method. They are placed in litre beakers, damped down slightly, then 40% hydrochloric acid is added slowly, until the effervescence stops. The supernatant acid is decanted, and the process is repeated until all the carbonate is removed.

The next step is the digestion of silicate material. All samples are placed in polythene beakers, and 40% hydrofluoric acid is added until the beaker is about half full. The sample is then left for between a week and a month, stirred twice daily, after which the acid is decanted, and the sample neutralised. The samples are now ready to be washed through a 10 μm mesh with tap water, and studied under a microscope. Several mineral residues can be removed by further treatment.

(a) Calcium fluoride : If the calcium carbonate is not completely digested, then during the reaction with hydrofluoric acid, calcium fluoride will form. This is easily removed by boiling the sample in hydrochloric acid. In some samples (e.g. the Shalloch Formation ones) boiling twice in hydrochloric acid completely removed all the mineral that was present after the sample was decanted from hydrofluoric acid.

(b) Pyrite : This can be removed by heavy mineral separation using zinc bromide.

However many of the palynomorphs have been found to have some pyritisation of the test, and therefore the pyrite should be removed chemically using cold nitric acid. The sample is placed in a beaker and concentrated nitric acid is added and left for about five minutes. The residue is then checked and the process repeated if necessary. This technique is rarely used, as nitric acid is an oxidising agent and Highland Border Complex specimens could be destroyed using it. In many of the samples from Dob's Linn there is so much organic matter that it has little effect, and it is more effective to use just a small amount of residue on the coverslips.

(c) Quartz : Any quartz and other silicates that are left after reacting with hydrofluoric acid can be swirled away using a large clock glass.

(d) Clay : Large amounts of clay can be removed by centrifuging with zinc bromide (S.G. 2.0), though this may cause very brittle palynomorphs to break and therefore was used only with the Dob's Linn and Girvan samples. Paris (1981) points out that the techniques using zinc bromide are too harsh to use on carbonised material.

Oxidation

There are two common methods of oxidation, nitric acid and Schulze Solution (nitric acid and potassium chlorate). Nitric acid has been used occasionally to allow the removal of excess pyrite, but oxidation is generally unfavoured because it can bias the sample in favour of the heavier forms or destroy delicate membranes, and a thick dark specimen is better than a thin corroded one (Paris 1981). Schulze solution is a stronger oxidising agent which is commonly used to oxidise amorphous material but has not been used at all in this study.

Samples with only a little organic residue, are made into strew mounts, and then scanned using an ordinary biological microscope. To make a strew mount a small volume of the sample is mixed with a few drops of the dispersant 'Cellosize', the mixture pipetted onto coverslips and left to dry. The coverslips are inverted onto slides onto which 'Petropoxy' has been smeared to act as a mounting medium, and heated on a hot plate at 135°C for 10 minutes. Slides are logged at x200, and identifications made at x1000, using immersion oil. Interesting specimens are referenced using an England Finder Slide.

Samples that contain a lot of residue (organic and mineral), are separated into greater than and less than 60 µm fractions. The latter is made into strew mounts as described as above. The greater than 60µm fraction is dried and any interesting specimens are picked (using a very fine paint brush). These are then mounted onto SEM stubs, coated in gold, and studied using the scanning electron microscope.

Problems encountered mainly stem from the indurated nature of the rocks:

(a) Maceration can take up to a month

(b) The high proportion of clay clogs up the 10 µm mesh and makes sieving a difficult task. Because of this problem the chemical sodium pyrophosphate (Bates *et al.* 1978) was used to see if it would help suspend the clay. It is generally used with modern pollen samples and was not very useful in these samples. It is often difficult, when there is such a low yield of specimens, to tell if any method is successful at concentrating the palynomorphs, and while this technique may prove very useful with more abundant samples, it was not very successful here.

(c) It would be more advisable to sieve using a 7µm mesh (Cwynar *et al.* 1979) as Dorning (1986) states that up to 30% of acritarchs can be lost by using 10µm mesh, however this was attempted and found to take far too long.

Preparation of samples for small shelly fossils

Samples of limestone and calcareous shales from Leny Quarry were dissolved in fifteen percent acetic acid and then sieved through a 60μm mesh. The larger fraction was then picked and the specimens studied using the scanning electron microscope.

Thin Sections

Paris (1981) notes that there are many disadvantages in using thin sections to identify palynomorphs in that the material is difficult to observe and identify. However sections have been studied from some of the Highland Boundary localities with very little effect apart from one chitinozoan found in a grit at Leny Quarry.

Photography.

All transmitted light photographs were taken on either the Zeiss photomicroscope Pol. 2 at Glasgow University or the Reichert microscope at Sheffield University. The scanning electron microscope photographs were taken at Glasgow University or Britoil in Glasgow. All light microscope photographs were taken using Pan F film, and scanning electron microscopes were taken using FP4 film. Colour photographs were kindly taken by K.J. Dorning, Pallab Research, Sheffield. Films were developed using standard developing techniques.

Specimens are stored in the Hunterian Museum, Glasgow.

CHAPTER 4 - The major Palynomorph Groups

Acritarchs and chitinozoans although classified under different nomenclatural codes share the common features of having organic walls (and therefore acid insolubility), and small size. They can therefore be extracted from the rock using the same techniques. These features together with a wide geographical distribution, an independence of facies changes, and many short ranging species make them useful in Palaeozoic stratigraphy, (Jenkins 1967). Both forms darken as the sediments are heated due to their walls being composed of complex organic molecules.

Problems related to dealing with deformation and diagenetic effects

As already stated deformation of rock can lead to many problems among palynomorphs, the least of which is parallel splits on the surface of the fossil, particularly in chitinozoans, in a plane that represents the original cleavage of the rock (Jenkins 1967). Other common problems of intensely heated sediments are felting, destruction of the ornament and growth of new minerals making ornament difficult to discern. Downie *et al.* (1971, p. 3) deal comprehensively with all these features.

Most of the palynological problems relate to reasonably high grade deformation. However even the palynomorphs from rocks that have been affected only by diagenesis may have been subject to a slight change in colour. They may be pale yellow in colour (e.g. at Girvan), showing that they have been only gently heated, dark brown to grey when raised to a temperature of about 200°C e.g. at Dob's Linn (Whelan and Burton 1988), or completely black when heated above this (Highland Border Complex). The relative colour and transparency depends to some extent on wall thickness and composition, and chitinozoans are usually initially darker than the acritarchs due to their different chemistry. Eventually the specimens are recrystallised to graphite, containing as much as 98.6% carbon (Downie *et al.* 1971 p. 3). Organic-walled microfossils may suffer some shrinkage when heated and will eventually be destroyed above about 400°C. Specimens are often folded during compaction and dewatering of their host sediments, and the spines and processes may be broken if the fossil has been carbonised. Distortion of fossils does not appear to be a very important when it comes to identifying specimens, although it may make the general silhouette difficult to determine. Burmann (1969) shows that cracks begin with fine fractures usually related to the stress direction.The random growth of pyrite crystals may distort the shape of the palynomorph and often obscures fine detail.

Reworking and Contamination

During this study every effort has been made to prevent contamination, and additionally due to the sparsity of specimens in the present samples it is unlikely that contamination between samples will be important. Modern day contamination is far more likely, and fresh water diatoms, and modern pollen have been found in several of the samples. It is known that samples that have been collected near fresh water often contain amoebal cysts, and fragments of spiders' jaws (K.J.Dorning and C.Hunt pers. comm.).

Reworking has not been significantly observed in these samples although Turner (1982) catalogued thirty seven species of reworked acritarchs and it cannot be ruled out that reworking has occurred.

Chitinozoans

The hollow, flask-shaped chitinozoans were first found by Eisenack at the end of the nineteen-twenties (Eisenack1930,1931) and have a stratigraphical range from Ordovician (Tremadoc) to Devonian. They have an uncertain systematic position, although it seems most likely that they are the egg cases of annelid worms (Kozlowski 1963). They have a world-wide distribution, and occur in greatest numbers in shallow water sediments. Many species are short ranging, as they evolve rapidly (Jenkins 1968) and therefore this group is biostratigraphically useful. The test forms only a small part of the postulated life cycle (Jenkins 1968). They range in length from about 60μm to 2000μm. Chitinozoans can be grouped into about 50 genera containing approximately 450 species.

Morphology

The main morphological terms for the test are shown in Figure 20. Where the structure of the test wall is known it appears to be triple walled and composed of the variously developed periderm which forms the ornamentation (hairs, tubercles, spines etc. which may be randomly dispersed or aligned e.g. *Hercochitina*) of the test (Paris 1981), the inner ectoderm which forms the microstructure (similar to graptolites (Paris 1981), and the endoderm which

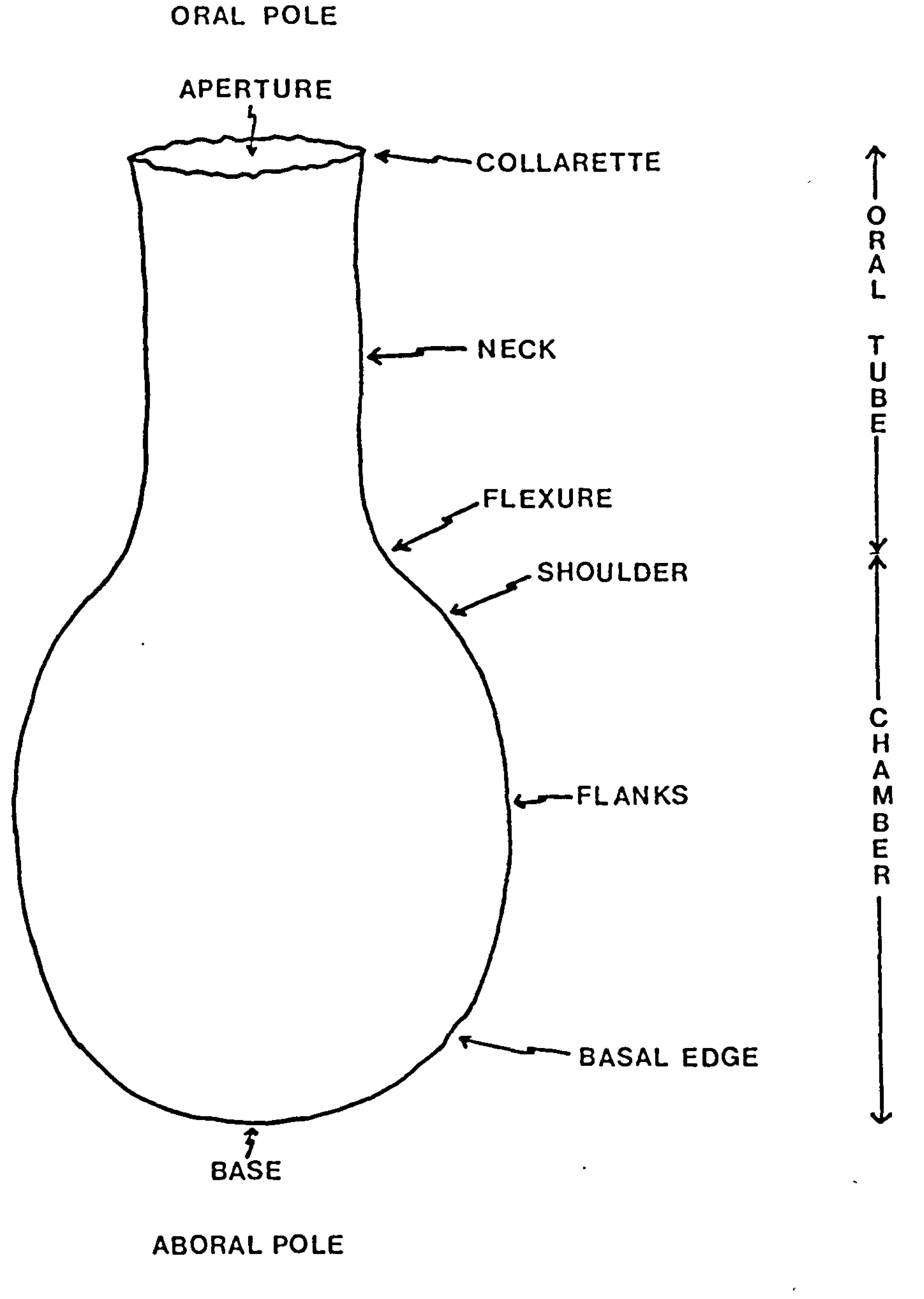


Figure 20 : external morphology of the chitinozoan

forms the internal structures such as the prosome, operculum (Figure 21). Most show radial symmetry about a central longitudinal axis (Jenkins 1968). The body communicates with the exterior by means of a 'mouth', which is closed with either an operculum (in the case of forms without a neck, e.g. *Desmochitina*) which may be smooth or micro-ornamented, or in species with a neck (or oral tube), a prosome (a long internally directed annular tube), which apparently played a protective rôle (Jansonius 1970), as both the operculum and the prosome appear to have been hermetically sealed (Paris 1981). In certain cases the neck is flared at the end to form a collarette. A concavity at the base of the neck is termed the flexure, and the body terminated orally by means of a shoulder (Paris 1981). The ornament may have been related to reproduction or to facilitate flotation (Jansonius 1970).

The base of the chitinozoan is very important in taxonomy, and variations in the shape and ornament are shown in Figure 22. Chitinozoans occur most often as as single entities, more rarely as chains, or very exceptionally in cocoons surrounded by an organic pellicle (Jenkins 1968). Most single chitinozoans appear to be at the same point of development and Jenkins (1968) suggests that it is possible that they were not released as single tests until they were mature. Taugourdeau and Magloire (1964) and Jansonius (1964) support the idea that chitinozoans budded orally or aborally whilst Paris (1981) thinks that a more accurate idea would be that each new cell is generated from a 'gonad' at the aboral end of the chain and then grows. Embryonic individuals presumably did not contain enough 'chitin' to allow for fossilisation, though small transparent forms with embryonic lids are found which may be early stages (Paris 1981). Paris (1981) divides chains into several different types, which cover the different modes of attachment : simple juxtaposition, simple adherance, double adherance, reinforced fixing, neck-body 'hugging', cocoons, and 'planarian' colonies. The ornament and the outline or silhouette of the chitinozoan are both very important in taxonomy, and the main silhouettes are shown in Figure 23.

Most tests will have been distorted to some extent, particularly the ones from the Highland Border Complex, and this compression, along with other diagenetic changes must be taken into account when studying chitinozoans (Jansonius and Jenkins 1978). Paris (1981) discusses the formation of pyrite on chitinozoan tests (which is common on both acritarchs and chitinozoans in this

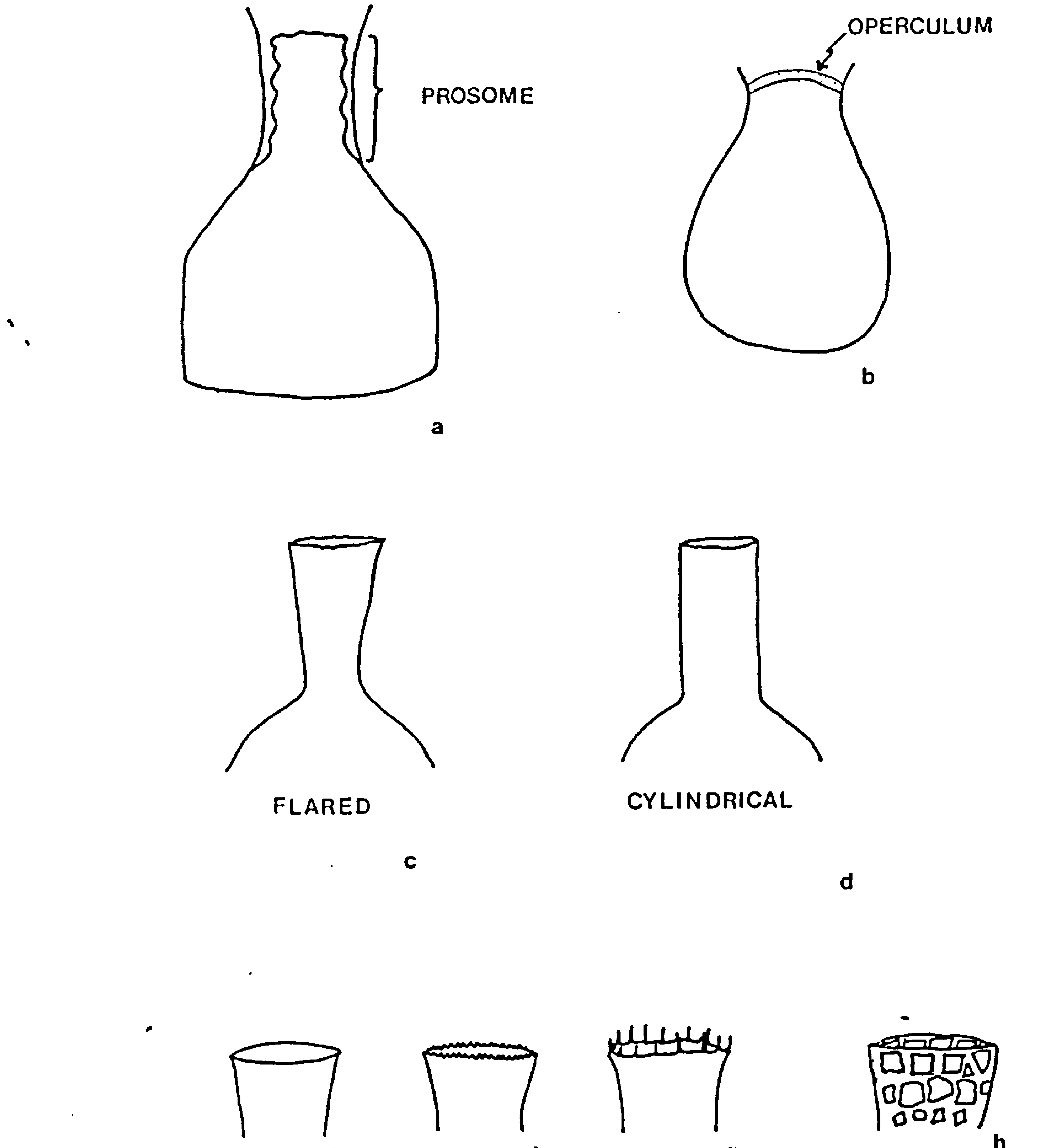


Figure 21 : (a) and (b) showing internal features of the oral tube (after Paris 1981); (c) and (d) showing types of oral tube (from Combaz et al. 1967); (e) to (h) shows the variation in the types of aperture.

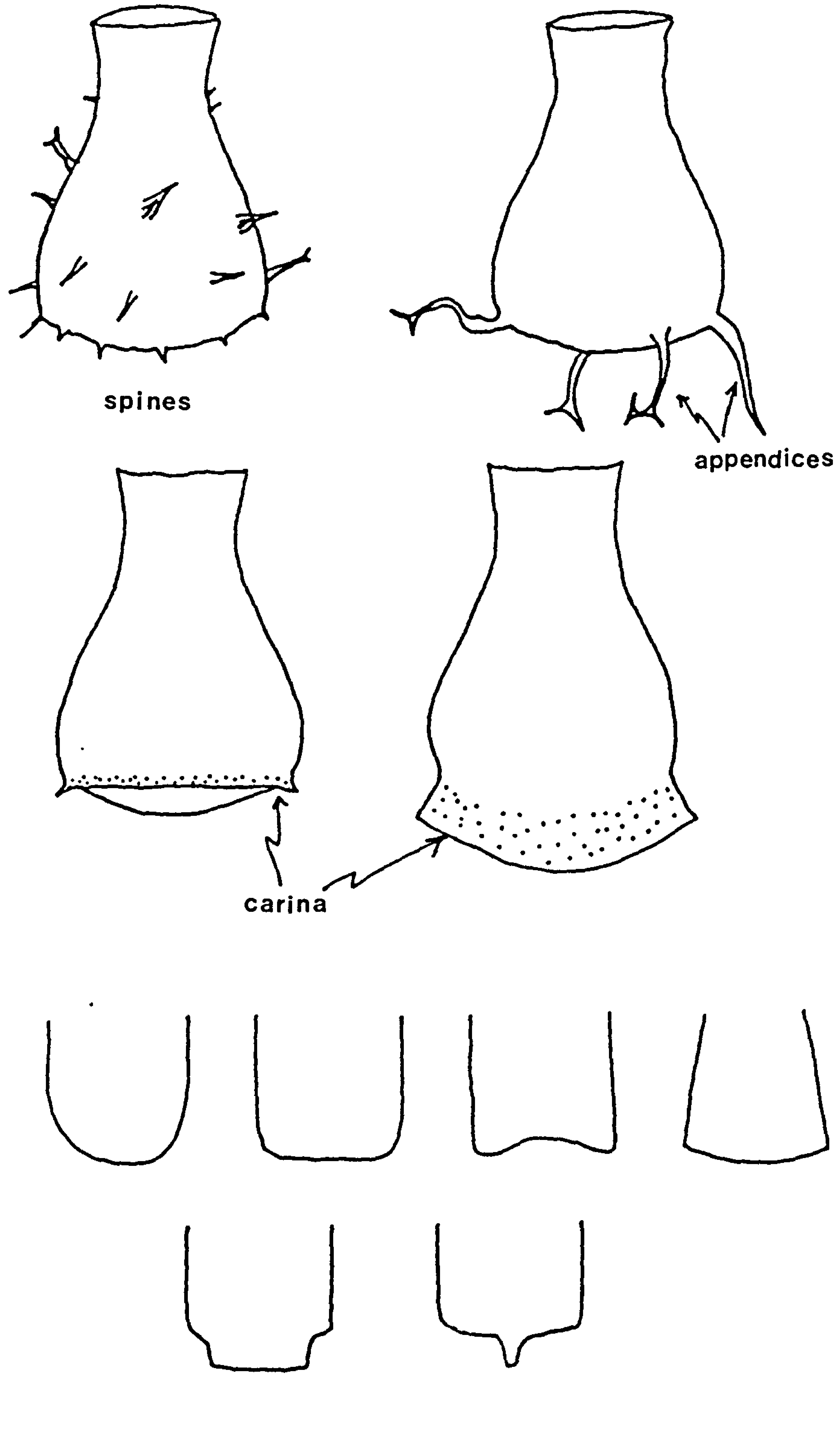


Figure 22 : types of ornament in chitinozoans (after Jenkins 1968)

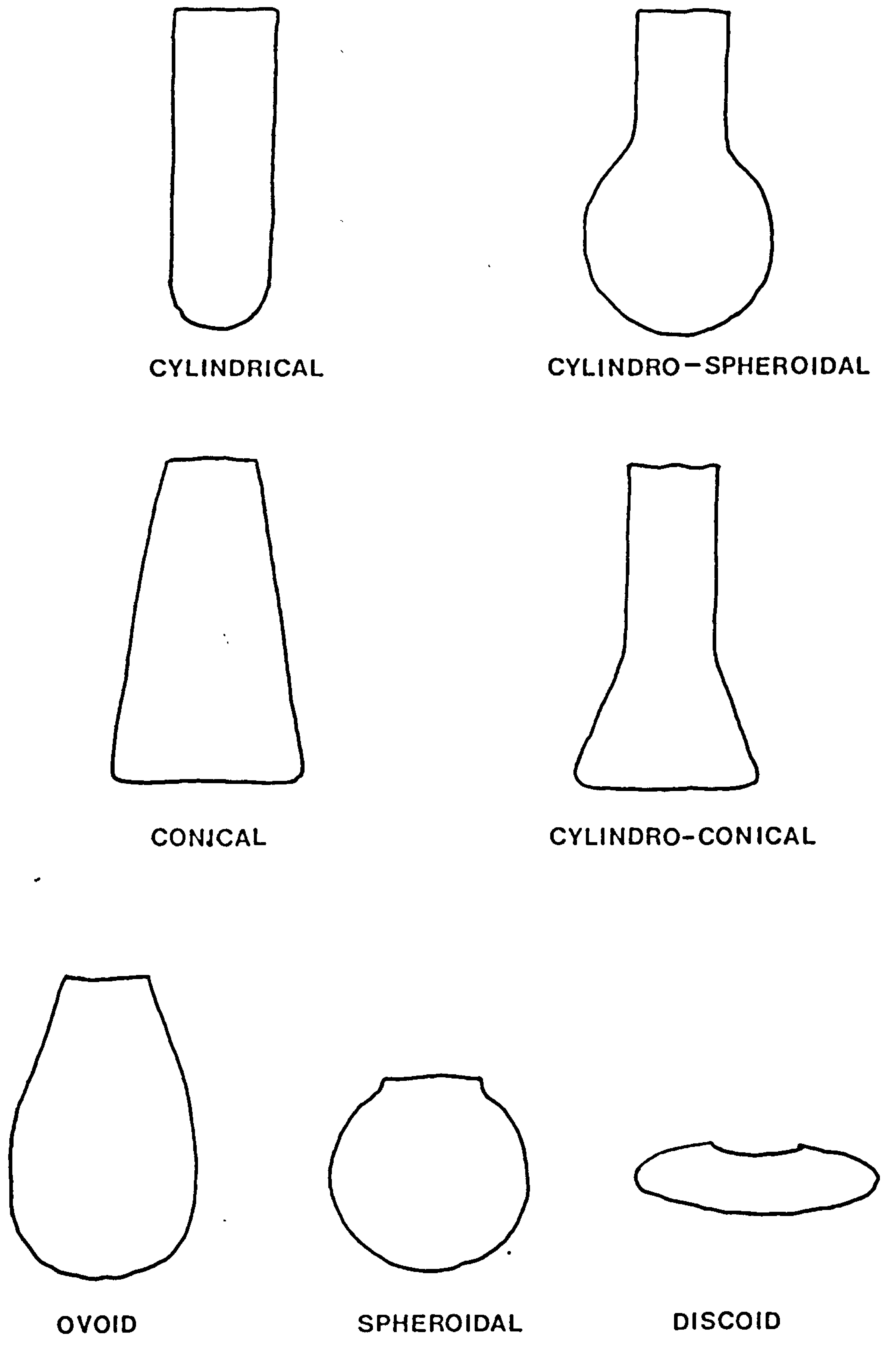


Figure 23 : variety of silhouettes of chitinozoans (after Combaz *et al.* 1967).

work), and infilling by bitumen but remarks that they have no importance in the diagnoses.

Nature of the test

The material of which the walls of the chitinozoans is composed has for a long time been a subject of speculation, but it is completely acid insoluble even when heated (Eisenack 1931), and therefore it is likely that it is some organic compound. Various theories to its nature have been advanced over the years which fall into two groups, chitin or pseudochitin. Modern chitin is affected by caustic soda if it has already been hydrolysed by heating with hydrochloric or sulphuric acids, and as these substances have no affect on chitinozoans they cannot be composed of chitin (Collinson and Swalb 1955) although Eisenack (1931) suggested that the test could be composed of chitin which is stabilised by an anhydrous structure that resists hydration. Collinson and Swalb (1955) concluded that the chitinozoan test is similar to the Recent Thecamoebaea testacean *Gromia oviformis* considered to be psedochitinous and suggests that the chitinozoan test is also pseudochitinous. Voss-Foucart and Jeuniaux (1972) chemically analysed 8000 specimens of *Cyatochitina campanulaeformis* (*sic*), from an Ordovician boulder in Warsaw, and they found that the chitinozoans do not contain chitin, although they state that this does not mean that the body wall of original chitinozoans did not contain chitin. Laufeld (1967) advises great caution and suggests that the test wall of chitinozoans be termed "chitin" for convenience sake, as psedochitin suggests a proteinaceous polymer. It is apparent that the composition of the chitinozoan test wall is still an unknown compound, but with more sophisticated analytical techniques this problem may one day be resolved.

Affinities of the chitinozoans

Chitinozoans are widely distributed in marine sediments and are found with many other groups, such as acritarchs, graptolites and scolecodonts. Their affinity has been much debated over the years, and many hypothoses have been proposed. Riding (1981) discusses the postulated affinities for the chitinozoans.

Among the Protozoans, the chitinozoans have been allied to various groups. One of the first affinities postulated was to the testaceans (Eisenack 1931, Collinson and Swalb 1955), however the two groups have a disparate chemistry and testaceans are commonly lacustrine. Collinson and Swalb (1955) compare chitinozoans to the testacean *Gromia oviformis* but Hedley (1963) disputes this comparison. Foraminiferans are comparable in size and Eisenack (1931) compares the chitinozoans to pseudochitinous tubular foraminiferans. Tintinnids (Deflandre 1945, Reid and John 1978) are ciliate protozoans with a similar morphology to the chitinozoans although they have a non-comparable chemistry. Flagellates/Rhizopods (Collinson and Swalb 1955) are both groups of marine flagellate protozoans which are superficially similar to chitinozoans, but not enough to suggest a definite affinity. Staplin (1961) hypothesised on a comparison between chrysomonads and chitinozoans, and in 1973 Obut suggested a close affinity of the chitinozoans and the dinoflagellates. Paris (1981) remarks on the similarity between acritarchs and chitinozoans, *e.g.* *Lusitania lusitanicum* Elaouad-Dabbaj 1978 and *Eisenackitina* Jansonius 1964. Wrona (1980) shows the similarity between *Aremoricanium* Deunff 1955 and certain chitinozoans. These similarities however appear to be merely coincidental and Paris (1981) states that there are two major differences between the two groups

(a) Communication between the appendages and the central cavity. Modern studies using the scanning electron microscope show the appendages of chitinozoans do not communicate with the centre of the vesicle (Paris (1981) although one case was reported by Combaz and Poumot (1962) (although this was using ordinary transmitted light), whereas those of acritarchs often do.

(b) Chitinozoans have never been found in brackish environments, whereas acritarchs have been (Paris 1981).

Acritarchs are also generally smaller in size, thinner walled and of more variable morphology. With the exception of the testaceans and the tintinnids which have a non-comparable chemistry, all the protozoan hypotheses are possible, however, Riding (1981) notes that the chitinozoans ability to form chains, and their absence of excretory pores suggests that they would not have been able to live in the free state, and thus biases the affinities of the chitinozoans towards the metazoans.

Suggested affinities to metazoan groups include the gonothecae of hydrozoans (coelenterates) (Glaessner 1948), although these are not found in chains, have a very limited morphological range, and are larger than most chitinozoans. Jenkins (1968) suggested that the chitinozoans occur commonly with graptolites and that they might be their early larval or pre-prosicular stage, however Paris (1981) discusses in detail this theory and along with Laufeld (1974) notes that the ranges of graptolites and chitinozoans are sufficiently different to prevent there being a relationship. Grahn and Afzelius (1980) suggested that the chitinozoans could have been fish eggs and Kozlowski (1963) noting that the cocoons of *Desmochitina* were hermetically sealed proposed that they were the eggs of annelid worms or gastropods. Eisenack (1968b), Jenkins (1970) and Laufeld (1974) believe that this is the most likely hypothesis for the affinities of the chitinozoans.

Locquin (1977) suggested that the chitinozoans are allied to the fungi, though general chemistry and morphology suggest that they are more related to animals than to plants. Paris (1981) notes that the forms of fungi that the chitinozoans are suggested to have affinities with, are usually forms that are parasitic on terrestrial plants, and would thus make it unlikely that they are related to the chitinozoans.

It is most likely that the chitinozoans are the eggs or egg-cases of some metazoan, although the animals which produced the eggs may never have been fossilised. This is generally taken as the consensus today, but is not as yet undeniably proven (Riding 1981). Paris (1981) discusses the convergent evolution of the eggs of various groups of metazoans to show the similarity between them and chitinozoans, but notes that the chitinozoans that are heavily ornamented seem to have no parallels. It is therefore possible that they are a polyphyletic group. The macrofossils that were living at the same time as the chitinozoans with the most similar ranges are the cornulitids, tentaculitids, certain orthoconic cephalopods, and possibly soft-bodied organisms that have left no trace in the fossil record. Paris (1981) suggests that the latter provide the best possiblity although it may never be possible to prove this.

Reasons for the disappearance of the chitinozoans in the fossil record include the possibility that the group of animals that produced them, instead of becoming extinct at the end of the Devonian, may have changed their mode of life, and thus had a different method of reproduction, although Paris (1981) suggests that it is more likely that they were the reproductive products of a group of vermiform organisms which became extinct in the Devonian. Laufeld (1974) stated that the appendices and spines of several taxa suggest that they were eggs of some sort of metazoan, and where the chains are coiled may have been laid by a spirally coiled animal, and thus assumes that the chitinozoans are polyphyletic, possible related to both polychaetes and gastropods.

Taxonomy of the chitinozoans

Generic and specific characteristics have normally been determined using the silhouette which facilitates work on poorly preserved material. However recent advances in scanning electron microscopes and infrared filter techniques has allowed more work on the surface ornamentation and oral characteristics to be carried out. It is preferable if both light and scanning electron microscope is used in the identification of specimens. Often this is not possible, for example at Dob's Linn there is too much organic residue to enable the chitinozoans to be picked, and the material from the Highland Border Complex is too sparse. However at Girvan, specimens of the same species are often encountered in strew mounts and in the larger fraction.

The general shape, the nature of the basal margin, the tendancy to occur in chains and internal features where they can be seen are the most important generic features (Jenkins 1968), and thus variously dependent on the preservation. Species are classified on distribution of ornament, the shape of the aperture and collarette, the size and shape of the basal margin and processes, minor differences in the test shape, and differences in size.

Various suprageneric classifications have been specified by Eisenack (1931), van Oyen and Calandra (1963), Jansonius (1964), Tappan (1966) and Taugourdeau (1966), although Bockelie (1978) expresses her doubt as to the validity of most of the classifications. Jenkins (1967) uses Eisenack's (1931) classification on the grounds that Jansonius' (1964) classification is hard to follow as it uses the structure of the test wall and the prosome which are generally hard to see. Jenkins (1968) remarks that it is not really necessary to impose a classification composed of families onto a group of animals whose affinities and relationships to each other are so poorly known, particularly when there is such a small number of genera. Specimens will be listed alphabetically here as the generally poor preservation of most of the specimens allows no addition to be made to any phylogenetic suprageneric classification.

Palaeoecology

Chitinozoans have been found in most types of marine sediments including siltstones and sandstones, although they are not present in reef limestones, pyroclastic rocks, and red beds (Grahn 1981). Opinion appears to be divided as to whether they were facies controlled or not, although it is generally agreed that a basin with a supply of fine terrigenous clastics provided the most favourable environment. Laufeld (1974) states that the chitinozoans distribution on bedding planes shows that they could not have been infaunal. We therefore know that the chitinozoans were epifaunal and they (and the animals that produced them) were marine, but it is difficult to make more specific palaeoecological statements without introducing a number of assumptions.

There appears to be little agreement on whether chitinozoans were planktonic or benthonic. Jenkins (1968) states that they were independent of minor facies changes, and occur in calcareous and non- calcareous lithologies and thus favours a planktonic mode of life. Laufeld (1967) supports this hypothosis due to the chitinozoans wide geographic range, facies independence, and the possible use of spines as floatation aids. *Clathrochitina* may have contained air sacs in its reticulate carina (Laufeld 1967). Kozlowski (1963) is in favour of a benthonic mode of life, and sites thickness of test and the possibility that the aboral pore may have been attached to the sea bed, though this need not be so. They may have fixed onto seaweed and thus made the chitinozoans epipelagic (Laufeld 1967). Dorning (1987) states that most chitinozoans were benthic. Jenkins (1967) is of the opinion that the chitinozoans were initially benthic and attached to the substrate and later planktonic. Laufeld (1974) suggests that some forms were planktonic, e.g. forms with spines or appendices, and other forms such as the large, thick walled *Conochitina* species were benthonic.

It would appear that either there are both benthonic (e.g. thick walled tests) and planktonic species (ornate thin forms with complex ornament (Chaiffetz 1972) or that some part of the life cycle was planktonic. Rapid dispersal across North America, Europe and North Africa would favour a planktonic environment for this part of the life-cycle (Riding 1981). Different species reach their maximum abundances in different types of rocks and this would suggest a preference for different types of sediments and that the chitinozoans were benthonic, though this would seem to contradict their worldwide distribution (Grahn 1981), and lack of provincialism (Paris 1981). Urban and Kline (1970) show a facies controlled assemblage in the Middle Devonian of the U.S.A., although Jenkins (1968) attempts to rationalise this by showing that most groups of fossils are facies dependent to some extent, and chitinozoans appear to be less affected by facies control than many of the other groups.

Paris (1981) discusses the different environments in which chitinozoans are found, and shows a low diversity in arenaceous sediments with the highest diversity and abundances in argillaceous beds. Abundances decrease in deeper ocean water, and where there are alternations of calcareous and argillaceous beds the latter are generally richer in chitinozoans, although Paris (1981) points out that this may either be due to compression of the less competent beds, or to the fact that carbonates generally accumulate more quickly. In the outer shelf environment there are fewer chitinozoans, as storm wave action prevents their deposition (Paris 1981). Taugourdeau and Jekhowsky (1960) and Laufeld (1974) have shown that the abundance of chitinozoans is inversely proportional to sediment size.

Both Jenkins (1970) and Wright (1978) consider the relationships between sedimentary environment and abundance. Laufeld (1967) invokes turbulence and oxygenation of waters to explain the absence of chitinozoans in some reefal samples. Laufeld (1974) shows an inverse relationship between the percentage of calcium carbonate and the abundance of chitinozoans. Chitinozoans are totally absent when the proportion of calcium carbonate is greater than 90%. There is also an increase in the abundance of chitinozoans away from the reef environment, (Laufeld 1974)which is verified among the acritarchs by the work of Staplin (1961). Jenkins (1970b) shows the absence in pyroclastic sediments, and Wright (1978) invokes low salinity as the main cause in the low abundance of chitinozoans. Paris (1981) examining a variety of sediments concludes that volcanism is unfavourable to chitinozoans as it makes the waters agitated and inhospitable, and in glacio-marine sediments he postulates that the absense of chitinozoans is due to the low salinity . Care must be taken because the absense of chitinozoans may be related to the fact that they lived there and were not preserved or that there were not enough nutrients in the water in the first place (Grahn 1981). *Cyathochitina campanulaeformis* and *Conochitina capitata* are mutually exclusive (Grahn 1981). *Ancyrochitina* and *Conochitina* are almost mutually exclusive in the Ordovician-Silurian boundary beds in Sweden, a factor apparently related to water depth, as *A. ancyrea* is more common where there is a higher proportion of quartz grains and therefore the water was probably shallower. The inverse is true of *C. robusta* which migrated in with transgressions (Grahn 1978). Grahn (1978) suggests therefore that *C. robusta* was benthic, while *A.*

ancyrea was planktonic. Dorning (1983) also reports a great variation in abundance of *Conochitina* and *Ancyrochitina* with great changes in abundance (dominance) from one bed to another in the Welsh Borderlands' wide shelf environment. This is explained by there being little or no mixing of assemblages (Dorning 1983).

Cyathochitina byensis and *Desmochitina complanata* have only ever been found in calcarenites (Grahn 1981). *Cyathochitina campanulaeformis* and *C. striata* prefer soft terrigenous muds and *Desmochitina* spp. reach their highest frequency on skeletal sand bottoms (Grahn 1981). Smaller forms, such as *Desmochitina*, are common in deeper water areas (Dorning 1987) whereas flask shaped forms without long spines are common in shallow-water areas (Laufeld 1974) e.g *Sphaerochitina*. *Cyathochitina* may have been attached to the substrate (Kozlowski 1963) or to seaweed (Laufeld 1967). Species with shorter, more numerous spines are more frequent in inshore shelf areas and species with long ornate spines appear to be associated with offshore shelf areas. (Dorning 1987). This may be analagous to the situation in Mesozoic oceans where dinoflagellate cysts with numerous processes appear to be more in common when waters were warmer, and so less dense (Davey 1970), although it must be noted that the chitinozoans are much larger and their spines may not have had the same function. Chains are more common in temperate areas marked by non-calcareous sediments than in areas of carbonate deposition (Dorning 1987).

Chitinozoan abundances are not as high as those shown by the acritarchs and it is rare to find concentrations greater than twenty per gram of rock and it is usually about zero point two per gram of rock, although Jenkins 1967 has recorded as many as one hundred and fifty seven to one hundred and seventy five per gram of rock. Taugourdeau and Jekhowsky (1960) submitted two hundred and ninety eight samples to statistical tests and the median abundance was found to be zero point two per gram of sediment, whereas thirty percent yielded nothing and twenty percent contained more than two specimens per gram of rock. Grahn (1978) shows that in a section spanning the Ordovician-Silurian boundary in southernmost Sweden, there are ten chitinozoans per gram in Silurian samples but only two per gram in the Ordovician samples. Chitinozoans are more common in the black shales than in the grey mudstones (Grahn 1978).

Stratigraphical Position of Chitinozoans

The oldest known chitinozoans are Tremadoc in age, although there have been reports of Cambrian forms, now doubted even though Laufeld (1967) states that such an occurrence is not improbable. They became well established by the Arenig (Jenkins 1967). In the Lower Ordovician they are large and smooth walled, and the trend is for a decrease in size throughout the Ordovician. Arenig chitinozoans often have large siphons, but after the lower Llanvirn these began to decrease. The carina also appeared in Lower Ordovician rocks, and this feature persisted into the upper part of the Ordovician. In the middle to upper Caradoc strongly developed ornamentation began to be produced. Appendices appeared in the lower Caradoc and discoidal tests were first seen in the latest Llandeilo (Jenkins 1968). These trends help us to give a broad age to poorly preserved assemblages even when the specimens cannot be identified to species level. Chitinozoans attained their acme in the Upper Ordovician where there are the most diverse forms shown by the group, and probably made up a larger part of the microbiota than it did before or after (Jenkins 1968). By the Silurian and Devonian although the tests were becoming smaller in size, they were developing more elaborate processes, (Laufeld 1967). By the Upper Devonian the chitinozoans had begun to decline, and there are only doubtful records of any Carboniferous or younger forms.

Biostratigraphy

Work done on well preserved material in many countries has enabled this present work on less well preserved material. Work undertaken by Jenkins (1967) on sections with short sampling interval (mixed or uniform lithologies) show that the concentration of the chitinozoans may vary greatly but the relative abundance of each species (nos/thousand chitinozoans) remains the same and the same species are present. Jenkins (1967) states that a common character of chitinozoan assemblages is the relatively small number of species that they contain. The average number of species in each of thirty one assemblages from Shropshire is seven species, the least varied containing only two, the most varied consisting of twelve to fourteen species. In the Viola and Fernvale Limestones the diversity ranged from four to nine species species, though most of the assemblages had five to seven species. Paris (1981) points out that depending on sampling space an interval of uncertainty ranging from a few centimetres to a few metres exists between the first observation, or disappearance of a taxon and its true appearance, or extinction. Only a great deal of research will allow this interval to be reduced. With microfossils, bed by bed searching cannot be considered as absolute proof of disappearance of a species. Processing more than one sample from a bed may show a taxon considered extinct in preceeding beds. And thus only comprehensive processing of well constrained sections can enable us to use chitinozoans (and acritarchs) to their full potential. In the Highland Border Complex material, samples that are found to contain chitinozoans may yield nothing when reprocessed. In areas where the palynomorphs are poorly preserved the 'palynomorph assemblages' obtained may thus provide biostratigraphical evidence that is valid may be unreproducible without disproportionate effort.

Acritarchs

Acritarchs are a polyphyletic group with a stratigraphical range from Precambrian to Recent, and a diameter range of 5-500μm with an average of approximately 15-100μm. Their general morphology suggests an affinity with dinoflagellate cysts, and prasinophycean algae, but they may also be ancestral to other groups (extant or extinct). There are about 3000 species in 330 genera. A fuller treatment of this group can be found in Tappan (1980).

Morphology

Evitt (1963) diagnosed the acritarchs as : "Small microfossils of unknown and probably varied biological affinities consisting of a central cavity enclosed by a wall of single or multiple layers and of chiefly organic composition; symmetry, shape, structure, and ornamentation varied; central cavity closed or communicating with the exterior by varied means, for example: pores, a slitlike or irregular rupture, a circular opening (the pylome)." Later this was extended by Downie *et al.* (1963) : "Unicellular or apparently unicellular microfossils consisting of a test composed of organic substances and enclosing a central cavity. Shape of the test spherical, ellipsoidal, discoidal, elongate or polygonal; test surface smooth, granular, punctate or perforate. Spines or other processes, raised ridges (crests), flanges, wings or other outgrowths present or absent; where present, distributed regularly or irregularly. Inner capsule present or absent; where present, connected to the test by varied means or lacking such connection. Shell opens by rupture, splitting or formation of a simple circular pylome. Rarely a loose number of tests associated in a chain".

The main body is termed the vesicle which can as already stated be spherical to elliptical, fusiform, flasklike, stellate, pear-shaped etc (Figure 24). There can be one or two original walls which may be separate or in contact, and sometimes

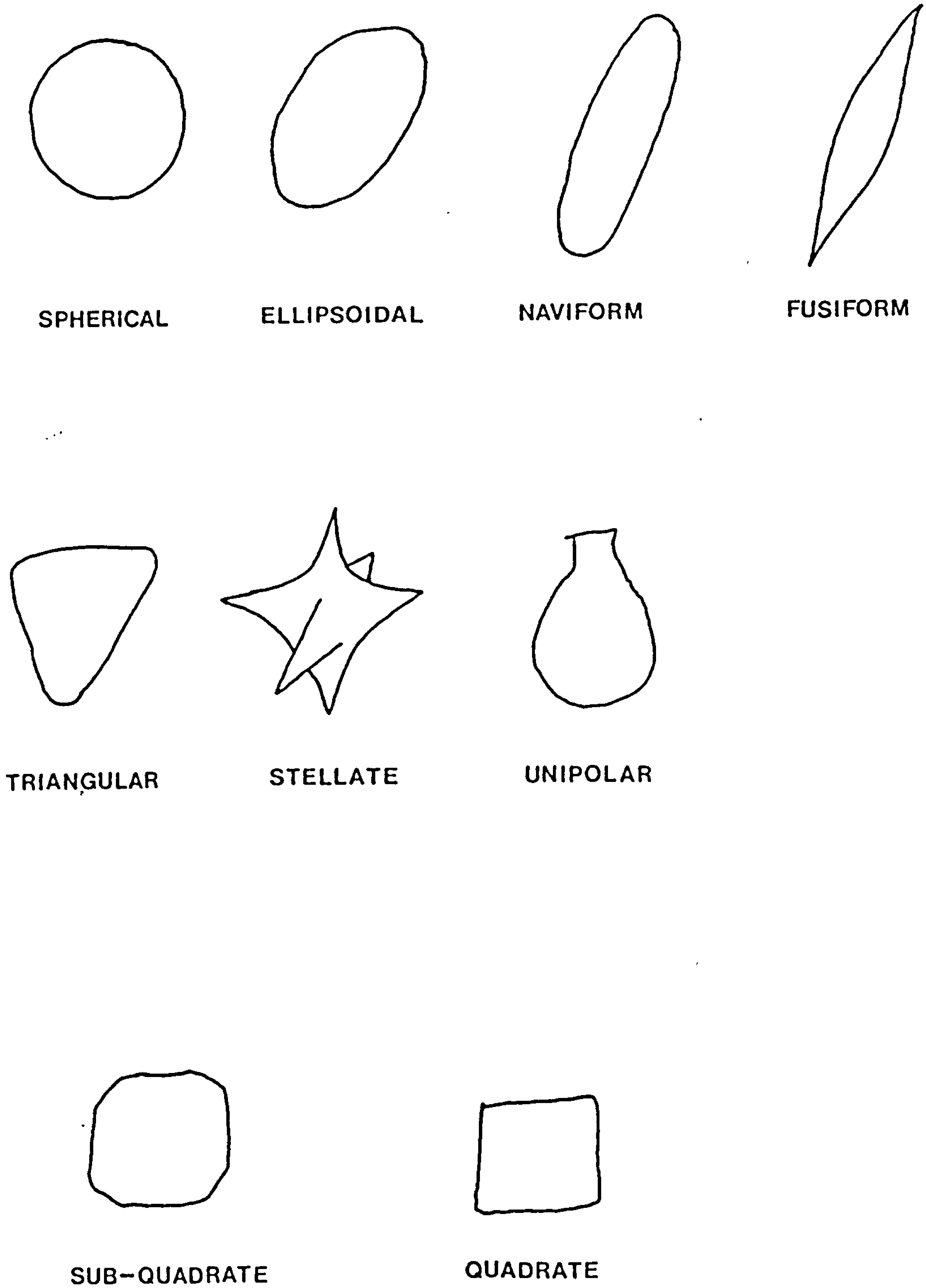


Figure 24 : Variation in the shape of the vesicle in acritarchs (redrawn from Downie 1979)

there is secondary development of the walls, e.g. where plugs form at the base of processes in general such as *Baltisphaeridium* (Figure 25) . The ornamentation may be in the form of sculpture (<2µm after Downie (1979) or <5µm after Williams (1978) or processes (>2µm after Downie (1979) or >5µm after Williams (1978). Tappan and Loeblich (1971) distinguish ornament (>1µm) from microornament (<1µm). Lister (1970) divided processes into heteromorphic (more than one type of process) or homomorphic (only one type of process), this feature is shown in Figure 25. Processes which can number from one to several hundred, can be hollow or solid or partially solid and be branched or unbranched, and may be spread randomly over the test or concentrated in some pattern. The majority of the acritarchs were probably cysts and as such show excystment features, some of which are illustrated in Figure 26.

Classification and affinity of the acritarchs

Acritarchs have been known since the late nineteenth century (White 1862), although much of the early research done on them is taxonomically confusing. Some of the acritarchs originally belonged to a group termed hystrichospheres (meaning 'spiny ball'), which also contained many species of dinoflagellate cysts. These latter were removed from the hystrichospheres and the residue became part of the group Acritarcha (Evitt 1963). Eisenack (1931) reviewed the affinities of the hystrichospheres and concluded that they were cysts due to their chemical nature, morphology and excystment features. Opinion is divided as to whether the acritarchs are a polyphyletic or monophyletic algal group.

Wetzel (1933) adopted a zoological classification for the dinoflagellates and some of the acritarchs, considering them to be of uncertain affinity but possibly being swayed by the opinion of Lohmann (1904) that they were the eggs of planktonic organisms. This classification was later reinforced by various workers (see Downie 1973 p. 245). Treating the acritarchs under a zoological nomenclature has not generally been accepted and although the acritarchs consist of a diverse assemblage of forms they were officially classified under the International Code of Botanical Nomenclature by Downie *et al.* (1961) and have generally been treated thus since. Deflandre (1936), Staplin *et al.* (1965), Downie (1967), Tappan (1968), Loeblich (1970) and Tappan and Loeblich (1971), consider the acritarchs to be a group containing widely different algal

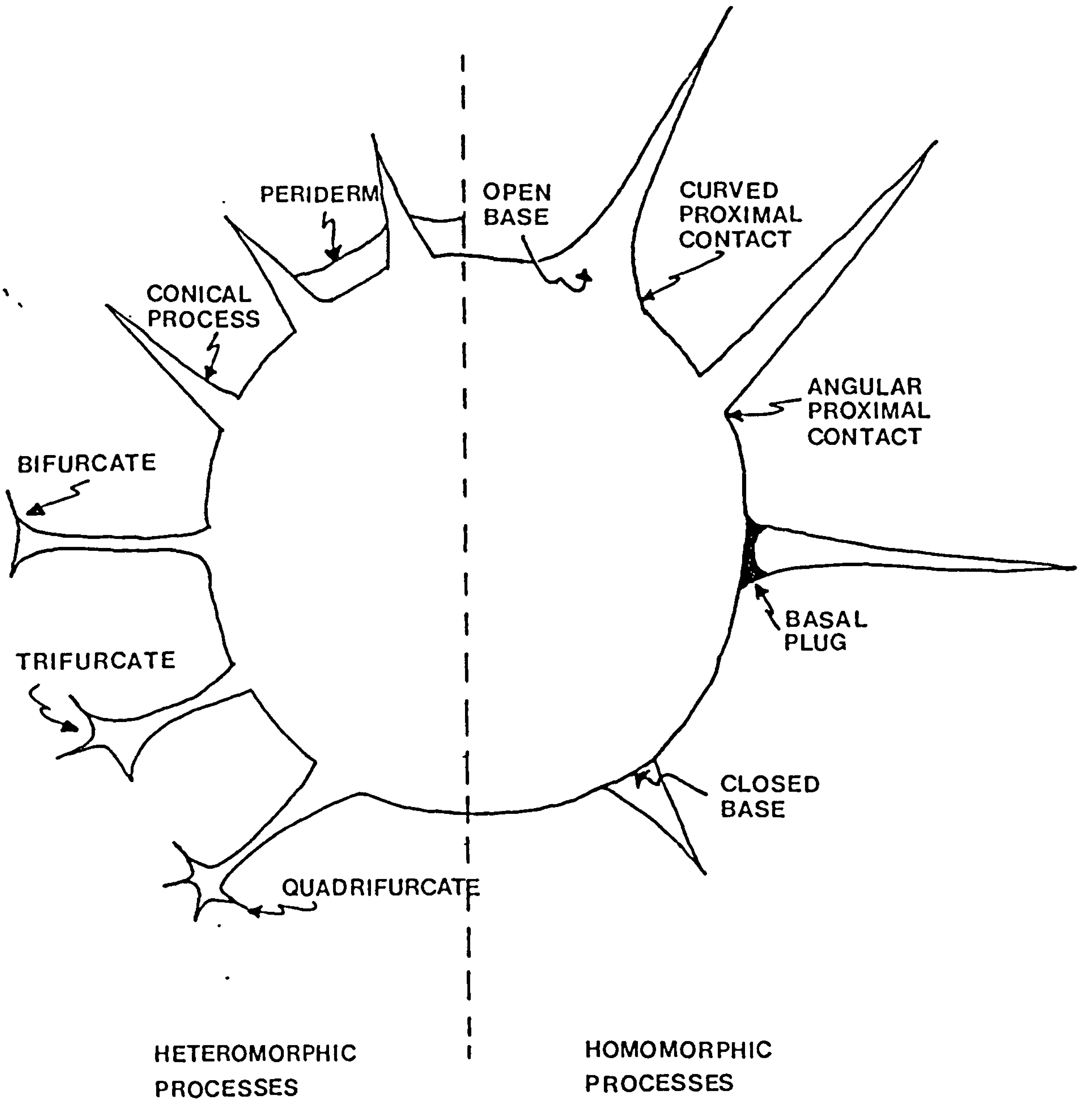


Figure 25 : terminology of acritarch processes (from various sources)

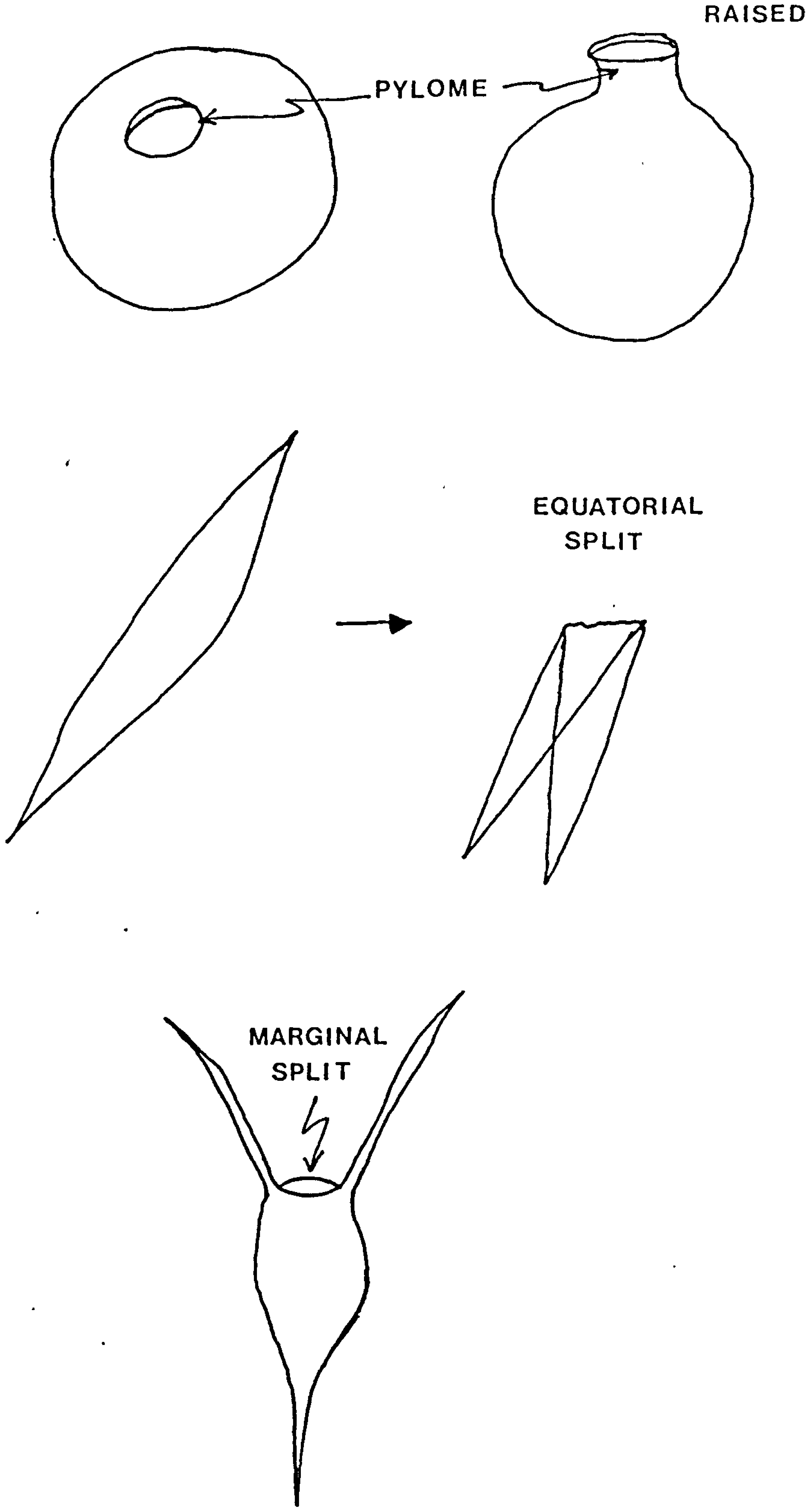


Figure 26 : excystment features in acritarchs.

classes, while Mädler (1963,1967) and Eisenack (1963a) were of the opinion that the hystrichospheres were a homogeneous group, going as far as to erect the class Hystrichophyta (Mädler 1963) containing both acritarchs and dinoflagellate cysts.

Downie *et al.* (1963) reviewed the the position within the acritarchs and considered them to be a heterogeneous mixture of cysts, eggs or tests of animals or plants but treated under the botanical code. They divided them into 13 non-Linnaean subgroups which are informal under the botanical codes of nomenclature, although the genera and species that they contain are legal. Timofeyev (1966) introduced a similar system. Many of the subgroups first proposed have been removed to other groups such as the dinoflagellate cysts and the prasinophycean algae, but other subgroups have been proposed. However this was inevitable and was the reason that an informal classification was erected in the first place. Eisenack (1969) stated the unimportance of whether acritarchs are vegetative individuals or resting cysts as this is irrelevant to their classification as they are self supporting organisms. Most workers simply now use an alphabetical system for listing species.

Of the original thirteen subgroups, five will be used here, purely as descriptive terms.

(a) Sphaeromorph acritarchs.

Acritarchs having a smooth to ellipsoidal shell lacking an inner body. Surface granular, smooth, punctate, or perforate, but not otherwise ornamented. Without observed opening, with simple circular pylome, or opening by splitting. (Downie *et al.* 1963).

(b) Acanthomorph acritarchs.

Acritarchs having a spherical or ellipsoidal test, without an inner body, and without crests. Processes isolate, simple or branching, solid or hollow, distributed arbitrarily or regularly. Without observed opening or with a simple single pylome.

The present author also includes the diacromorph acritarchs within this group, as they are generally spinose forms, although they are differentiated from the acanthomorph acritarchs by their polarity.

(c) Polygonomorph acritarchs.

Acritarchs having a pronouncedly polygonal test, without an inner body and without crests. Processes isolated or fusing at the bases, few in number, normally simple, rarely branching [Downie *et al.* 1963], The shape is dependent on the number of the processes.

Dorning and Bell(1987) combine the acanthomorph and polygonomorph acritarchs as the shape of the body is related to the number of processes, i. e. the more processess the more spherical the body will become. These terms are used here in a purely descriptive sense and no phylogenetic implication is suggested.

(c) Herkomorph acritarchs.

Acritarchs having a spherical to ellipsoidal or subpolygonal test without an inner body. Surface of test subdivided by crests into polygonal fields of regular or irregular form: surface within these fields smooth, punctate ot tuberculate. No median girdle present. Rodlike supports or projecting spines present in some at crest junctions. No observed opening, or a simple, circular pylome (Downie *et al.* 1963). In 1987 Dorning further subdivided this group on the basis of the excystment features but this is not applicable to this study.

(d) Netromorph acritarchs.

Acritarchs having an elongate to fusiform test, without an inner body. Surface generally smooth, rarely granular. One or more spines, closed distally, may be present at one or both poles. Openings not observed. (Downie *et al.* 1963).

(e) Pteromorph acritarchs.

These are round or ellipsoidal and have a single equatorial flange (Dorning and Bell 1987).

These groupings will be used only as descriptive terminology and the species will listed alphabetically, and therefore no suprageneric classification will be implied. Tappan (1980) critices the subgroup classification on the basis that lacking rules of priority various authors have proposed informal subgroup names and others Linnaean families, with botanic endings (aceae) and zoological endings (idae), and also the subgroup system has obscured some relationships and separated some groups that should be together eg. *Micrhystridium* and *Veryhachium*.

Of the subgroups used here as descriptive terms sphaeromorphs and herkomorphs are now considered to belong to the Prasinophyta, and *Tasmanites*, *Leiosphaeridia*, *Cymatiosphaera* and *Dictyotidium* although their affinities with the Prasinophyta (Tappan 1980) is acknowledged, will nevertheless be treated here as acritarchs.

The affinities therefore of the acritarchs have become clearer through time for some of the genera. For example *Cymatiosphaera* is now considered to belong to the prasinophycean algae. Genera such as *Peteinosphaeridium* appear also to have close affinities with this group whereas *Micrystridium* may be closer related to the dinoflagellate cysts although the evidence is very slender(Downie 1979).

Lister (1970) hypothesised that most of the Lower Palaeozoic acritarchs were cysts of unarmoured dinoflagellates or unicellular phytoplankton related to them. Sarjeant (1970) remarked on the coincidence of the decline of the acritarchs and the rise of the dinoflagellate cysts thus suggesting that the acritarchs are the dinoflagellates ancestors. This is unlikely due to the large gap between the decline of the acritarchs (Carboniferous) and the blossoming of the dinoflagellates (Triassic). Wall ultrastructure shows that many of the acritarchs such as *Baltisphaeridium Goniosphaeridium,* and *Peteinosphaeridium* are more related to the Palaeozoic *Tasmanites* (Prasinophyta or green algae) than the Pyrrhophyta (dinoflagellates), due to their radially arranged canals (Jux 1971). Kjellström (1968) studied the structure of fossil *Tasmanites* and *Leiosphaeridia,* and found that they were different, and he suggests that the leiospheres should remain in the acritarchs. Ultrastructure studies appear to be important for the future of acritarch affinities but at the moment too little is known of the wall structure to allow it to be used in classifying and elucidating the affinities of the acritarchs (Downie 1973).

Nature of the test

Again this is as poorly known for the acritarchs as it is for the chitinozoans. Acritarchs were initially thought to be composed of an alteration product of cellulose by analogy with the composition of the dinoflagellates when it was thought that they were fossilised theca (Tappan 1980). Eisenack (1963) recorded that their wall chemistry was distinct from cellulose and described it as a macromolecular structure, similar to sporopollenin. When ashed, acritarchs leave a residue of silica that may be original or post-mortally absorbed (Eisenack 1938). Kjellström (1968) showed that the some acritarchs consist of a substance consisting of long chains of aliphatic saturated carbohydrates. He compared the infra-red microspectra of leiospheres under various conditions and recent spores, and shows that there is very little difference in their spectra (Kjellström 1968). The composition of acritarchs appears to be allied to that of the plants (Tappan 1980), and indeed most of the acritarchs that have been chemically analysed or their ultrastructure studied appear to be closer to the Prasinophyta than the Pyrrhophyta.

Palaeoecology

Most acritarchs are from marine or brackish waters. There are recorded ocurrences of fresh water forms (Harland and Sarjeant 1970, and Churchill and Sarjeant (1963) both from the Holocene of Australia), although these have been suggested by Tappan (1980) to be dinoflagellate cysts. However Sarjeant and Strachan (1968) described *Micrhystridium* and *Leiosphaeridia* from peats in the Pleistocene of Staffordshire.

The small size of the acritarchs suggests that they are primary producers, and thus would have been very dependent on light. (Tappan 1980). The distribution of acritarchs in surface waters appears to be independent of the bottom sediments, as the same species are found in different lithologies and therefore they were probably planktonic. Jacobson (1979) shows that they are more abundant in mudstones and biomicrites, and quite rare in biosparites and siltstones. Dorning and Bell (1987) show that the percentage of acritarchs decreases with an increase in the amount of calcium carbonate in the waters. Smith and Saunders (1970) suggest that acritarch preservation is better in the deep open marine sediments and therefore depends on energy of deposition. They are probably limited to the photic zone and bioturbation seems to be a limiting factor in the amount of preservation, as they are destroyed by oxidation.

Cramer (1969a, 1970a,b, Cramer and Díez 1972) regarded latitudinal control as very important in the Silurian, and salinity, light, turbidity, nutrient supply, depth and distance from shore as unimportant, and thus set up a certain number of zones to correspond to palaeolatitudes, while suggesting that similar zones could be found in the Ordovician. Tappan (1980) suggests that local palaeoecological factors may be more important. Nautiyal (1974) showed four biofacies belts in the Devonian, and Vavrdova (1974) established two zones for the Upper Ordovician corresponding to a Baltic and a Mediterranean province. Jacobson (1979) found that his Ordovician assemblages from North America mostly fitted into the Baltic province.

Staplin (1961) in a classic work showed that the distribution of acritarchs in Devonian reefs could be mapped out. His results showed that there were three associations

(1) sphaeromorph acritarchs alone were found within a mile of the reef.

(2) At a distance of greater than a mile thin walled acanthomorph acritarchs

appear

(3) At four miles, acanthomorph acritarchs with thick processes and saccate forms become common.

The absolute abundance of all species increased with increasing distance from the reefs, suggesting optimum environment in quieter water. This distribution is not mirrored by chitinozoans or plant spores (Staplin 1961)

Wall (1965) working on the Jurassic of Britain observed two microfossil groups where there either is a strong domination by a single species (usually *Micrhystridium* or *Baltisphaeridium)* or where there is no domination by any particular species (often with *Veryhachium* and *Leiofusa*). The former is related to an inshore environment and the latter to an offshore open sea.

Jacobson (1979) recognised three marine palaeoenvironments in the Middle and Upper Ordovician: a near shore shallow water environment, a shoal environment, and an open sea environment, represented by a leiosphaerid class, a peteinosphaerid-*Dicommopalla* class, and a baltisphaerid -veryhachid - *Polygonium* class respectively. Variations in the relative abundances of acritarch classes exhibit close similarity to variations in relative abundances of conodonts and chitinozoans in the same rocks.

Dorning (1981) shows three different distance-from-shore assemblages.

(a) Nearshore: Low to moderate abundances (5-15 species per sample). Smooth thin walled sphaeromorph acritarchs are most common, but also contains *Leiosphaeridia, Veryhachium, Micrhystridium, Diexallophasis.*

(b) Offshore shelf: High diversity, moderate abundance 10(25-60)90 species per sample. Often 4-8 genera each of 5-29% will make up something like 70-90% of total. *Veryhachium, Micrhystridium,* and *Cymatiosphaera* are common. *Leiofusa, Percultisphaera, Ammonidium,* and *Dateriocradus* are less common, while *Dictyotidium, Carminella, Duvernaysphaera, Solita,* and *Tunisphaeridium* are less common still.

(c) Deep water: low diversity, low to moderate abundance (2-15 species per sample). Thick walled sphaeromorphs are common, but *Cymatiosphaera, Veryhachium, Micrhystridium, Diexallophasis, Lophosphaeridium,* and *Pterospermella* are also present.

Dorning (1983) concluded that the following distinctive palynomorph assemblages exist:

(a) Deep water shales - graptolites, abundant low diversity acritarchs with moderate numbers of chitinozoa and scolecodonts, and few other marine palynomorphs.

(b) Turbidites - variable assemblages showing evidence of mixing with some palynomorphs derived from adjacent shelf area.

(c) Narrow shelf areas - of silty mudstone and silty sandstone with a low abundance of graptolites and shelly macrofauna contain moderately diverse acritarchs, chitinozoans and scolecodonts with occasionally other marine palynomorphs.

(d) wide shelf areas - abundant moderate diversity with shelly macrofossils many conodonts and ostracods, contain moderate to high diversity of acritarchs, moderate diversity of chitinozoans and scolecodonts some foraminifera and several other palynomorph groups.

(e) nearshore shelf areas - low diversity high abundance shelly macrofossils, low diversity of conodonts and many ostracods, low diversity high abundance acritarchs, low diversity of chitinozoans and scolecodonts, with some fish scales and eurypterids.

Thusu (1972) remarked that acanthomorph acritarchs appear to be more common in inshore basinal environments, while polygonomorphs and netromorphs seemed to prefer the more open sea environment.

Colbath (1980) recognised two communities:

(a) *Baltisphaeridium dasos* containing two species

(b) *Axisphaeridium cylindratum - Dicommopalla macadamii* containing nine species.

He related these to water mass boundary fluctuations while recognising that an alternative model that assumes random sampling of seasonal changes in phytoplankton abundance cannot be excluded (Colbath 1980). However most other workers (Dorning 1981,83, Jacobson 1979) suggest that the distribution patterns are related to water depth and nutrient supply. The depth of the water may be important, as Gray and Boucot (1972) note that distance-from-shore assemblages may really be depth controlled. They suggest that sphaeromorph forms inhabited surface waters and therefore are common in all assemblages, whereas acanthomorph forms lived deeper and therefore are not ubiquitous.

Individual genera can sometimes be used to suggest the palaeoecological conditions in which they lived. For example in the genus *Diexallophasis* , deeper water forms have simple processes and are thin-walled, and faintly granulate, while inshore forms are coarsely granulate or echinate. The genus*Micrhystridium* appears to have longer processes in offshore conditions. *Multiplicisphaeridium* shows its greatest species diversity offshore. The genus *Veryhachium* exhibits species with 3-4 processes on a planar vesicle in an inshore environment and 4-6 processes on an inflated vesicle, offshore. *Leiosphaeridia* appears to be more common in high stress conditions which might be related to instability (inshore conditions) or low nutrients (offshore conditions).

Several general assumptions can thus be made about the distribution of acritarchs. Single-species populations appear to suggest inshore conditions, whereas high diversity suggests off-shore conditions. Reduced processes may be indicative of turbulent conditions. During times of transgressions assemblages will be more varied, whilst during times of regression the diversity will be decreased. Very high and very low salinity appears to be hostile to acritarchs.

Stratigraphical distribution

Sphaeromorphs are abundant in the late Precambrian, although by the Lower Cambrian short spines, crests, closed base processes and polarity were beginning to be developed. The Upper Cambrian shows the beginning of pylome formation, and during the Arenig there was a large diversification in the number of species particularly of the *Baltisphaeridium* type (Downie 1973). The Ordovician is the time that shows the acme of the acritarchs, and there is a general size increase throughout that period. Many common genera decline at the end of the Ordovician and are replaced by new genera in the Silurian eg *Domasia*. A general decline of the acritarchs occurs in the Devonian to very few species in the Carboniferous. In the Mesozoic the acritarchs flourished again, particularly in the Jurassic, but not to the extent that they did in the Lower Palaeozoic (Downie 1973).

Acritarchs generally make up between a thousand and ten thousand per gram of rock provided that diagenesis, metamorphism or abrasion have not affected them (Downie 1973). Downie (1958) reported that acritarchs make up four percent of total rock, one hundred thousand per gramme of rock in the Tremadoc rocks in England. In Brittany three hundred and twenty thousand to nine hundred thousand acritarchs per cubic centimetre have been found in Ordovician rocks, with the genera *Veryhachium, Micrhystridium* and *Cymatiosphaera* making up most of the assemblage (Henry 1969). Acritarchs become very varied in the Silurian and Devonian, but into the Upper Palaeozoic spores become a more important part of the palynological assemblage and 'flood' the assemblages.

Scolecodonts

These are composed of a similar material to chitinozoans, and are elements of the jaw apparatus of annelid worms. The longer stratigraphic range of the scolecodonts compared with the chitinozoans suggests that not all Palaeozoic annelid worms produced resistant organic egg cases (Dorning 1987). Jenkins (1967) points out that the scolecodonts are usually the most resistant of all the microfossils present in the samples from the Welsh Borderlands. Dorning (1983) reports that scolecodonts can vary in abundance between one and five thousand elements per gram, and that their palaeoecological distribution is similar to that of acritarchs and chitinozoans in that on a narrow shelf they show moderate diversity, wide shelf moderate to high diversity and in a basinal environment they are low to moderately diverse. Monospecific chitinozoan assemblages are usually associated with asingle set of scolecodonts, and in particular the large thick elements are usually associated with *Conochitina*(Dorning 1983), although *Conochitina* does appear to be the most common chitinozoan particularly in the Ordovician, and may generate pseudo-relationships.

Spores

These are the reproductive parts of plants. The earliest confirmed land plant spores are from the Soudleyan (Dorning 1987), and they have been reported from the Caradoc/Ashgill of N. Africa (Grey *et al.* 1982). Spores are more abundant in near-shore deposits and usually form less than 1% of the total palynomorphs, though may be reworked in turbidites increasing their percentages (Dorning 1983). These spores usually occur in permanent tetrads, which are common in the Upper Ordovician, and Lower Silurian but not in the rest of the Silurian. Miospore distribution appears to be unrelated to marine palynomorph distribution, but assuming that miospores in the Ordovician are produced by vascular land plants, then this is reasonable. Smith (1979) states that spores can be more abundant in offshore sediments due to being reworked.

GLOSSARY

Below is a list of the more common words that are used in the systematic descriptions of acritarchs and chitinozoans. Various sources are used including Combaz *et al.* (1967), Laufeld (1974), Williams *et al.* (1978), Kjellström (1971a), and Lister (1970). Descriptions are marked by a (c) for chitinozoans, an (a) for acritarchs, or not marked, meaning in either group.

Aboral pole : referring to the closed part of the vesicle opposite the aperture (c).
Acuminate : pointed distal termination to the processes.
Annulus : a thickening (c).
Aperture : the main opening by which the vesicle communicates with the exterior (c).
Basal callus : thickened central part of the base (c).
Basal edge : the convex part of the vesicle constituting the transition between chamber and base (c).
Base : the part of the chamber aborally of the basal edge (c).
Bifurcating : split into two.
Carina : flange at the basal edge (c).
Chamber : the part of the vesicle between the base and the flexure, or, where the latter is lacking, the collar or lip (c).
Collar : the subcylindrical or orally widened part of the vesicle between the aperture and the chamber in forms lacking a collarette (c).
Collarette : encircles the aperture and often terminates in a fringe of fine processes (c).
Copula : tubular element issueing from the endoderm which allows individuals to form chains (c).
Cryptosuture : surface possessing no visible surface manifestation on the cyst. The position of which only becomes obvious when dehiscence has commenced (a).
Diacrodian : an acritarch showing polarity of the processes (a).
Distally : in an outward directionfrom the longitudinal axis of the chitinozoan, or the centre of the vesicle in acritarchs.
Echinate : provided with long or conspicuous and generally long pointed spines (a).
Ectoderm : external wall layer.
Epityche : flap-like opening in the vesicle, presumably along a preferred line of weakness. Also considered an excystment mechanism (a).
Equifurcate : homomorphic branching in which two or more branches arise from the distal extremity of a process. The branches arise from a single node and are more or less equal in length (a).
Evexate : non-pointed distal termination of the process.

Fimbriate : with the margin bordered by long slender processes (c).

Flange : Membranous expansions of the phragma of the test of an acritarch.

Flexure : the concave part of the chamber aboral of the flexure in forms with subcylindrical flanks (c).

Fossulate : marked with irregular depressions (a).

Foveolate : marked with small pitting (a).

Granulate : with small grains, the basal diameter of which does not exceed the height (a).

Laevigate : smooth unornamented surface, even at high magnification (a).

Lambda spines (λ): spines, the bases of which bifurcate (c).

Lip : swelling around the aperture of the neckless and collarless vesicles (c).

Mucron : small process at the base (c).

Multiramose spines : spines with multiple bases (c).

Muri : low ridges separating the lumina of an ordinary reticulum (a).

Neck : the part of the vesicle between the flexure and the lip, or, where the latter is lacking the aperture (c).

Ogival : like a gothic arch (c).

Operculum : thin disk closing the vesicle at transition between the chamber and the collar, or where the latter is lacking, the aperture, or can cover the excystment feature in acritarchs.

Oral pole : referring to the part where the aperture is located (c).

Oral tube : the neck and the collarette (if present) (c).

Ornament : sculpture of the vesicle wall.

Peteinos : veil structure outside the process stem (a).

Pitchfork spines : spines that bifurcate distally ends in the form of a pitchfork (c).

Poles : where there are two conspicuous extremities (a).

Pore : a perforation or depression of the outer surface of a wall layer (a).

Process : excresence of the vesicle formed as an appendage.

Prosome : plug in the neck (c).

Proximally : in an inward direction from the longitudinal axis of the chitinozoan, or the centre of the vesicle in acritarchs.

Pseudostome : opening showing a communication of the central cavity with the middle of the exterior, situated at the outer end of the individual(c).

Psilate : smooth (a).

Pylome : circular excystment feature (a).

Pyriform : test that is broadly triangular and with no neck (c).

Reticulate : muri arranged into nets. The ridges (muri) are as wide as, or not as wide as, the space between them (c).

Rugulate : fine irregularly wrinkled surface (a).

Scabrate : a surface showing a fine grained roughness (a).

Shagreenate : surface roughened, granular; appearing like the surface of a sharkskin (a).

Siphon : the outer layer of the wall extends aborally beyond the base as a hollow cylindrical or flaring open-ended tube (c).

Striate : marked with fine longitudinal parallel lines (a).

Test : body of the chitinozoan, including the chamber and the neck (c).

Thread-like : processes that distally become very thin.

Tubular expansion : one processes that is larger than the others on the vesicle (a).

Verrucate : wall with warty projections greater than $0.5\mu m$(a).

Vesicle : name applied to the central body in acritarchs (a).

Chapter 5 Systematic Palaeontology

Order Chitinozoa Eisenack 1931

Genus *Acanthochitina* Eisenack 1931 emend Jenkins 1967

1931 *Acanthochitina* Eisenack, p. 82.

1967 *Acanthochitina* Eisenack emend Jenkins, p. 443.

Emended diagnosis (Jenkins 1967) : "variable flask-shaped chitinozoans with ornament of uniformly distributed processes standing normal to test wall. At a uniform distance from the test wall each process divides into a number of arms which lie roughly parallel to the test wall. Arms of adjacent processes may unite to form a more or less complete, raised reticulum. Basal margin may bear more strongly developed processes which can be simple or branching. A membrane may unite marginal processes".

Type species : *Acanthochitina barba ta* Eisenack 1931 emend. Jenkins 1967

Acanthochitina barbata Eisenack 1931 emend. Jenkins 1967

(Pl. 1 figs 1-3)

1931 *Acanthochitina barbata* Eisenack, p.82, Pl. 1, figs 10, 11.

1967 *Acanthochitina barbata* Eisenack, emend. Jenkins, p.443-445, Pl. 82, fig. 1-9, Text-fig. 11.

Emended diagnosis (Jenkins 1967) : "elongate, swollen cylindrical chamber, generally greater than two-thirds total length; maximum diameter midway along chamber, 35-60% chamber length; base flat or almost so. Neck cylindrical, about two-thirds maximum diameter in width. Ornament of many closely spaced short processes; arms usually united, forming a fairly complete raised reticulum close to the test wall. Processes on basal margin relatively large, connected by a very thin translucent membrane".

Description : an elongated cylindrical test with the maximum diameter about half way up the test, and with the width of the aperture half the maximum width. The base is convex, and the basal edge is not well marked. The collarette is thinner than the rest of the body and slightly flaring. The aperture is straight but damaged. The wall of the chitinozoan is ornamented with complex spines, many of them multiramose proximally as well as distally. The ornament is randomly preserved in these specimens.

Material : seven specimens.

Dimensions : Length : 283(336)390μm
Maximum width : 110(126)150μm
Width at aperture : 78(88)100μm
Length of ornament : <13μm.
Four specimens measured.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/20, 27, 28).

Previous occurrence : Fjäcka Shale (upper Caradoc), Dalarna, Sweden (Laufeld 1967). *D. complanatus* Zone, Vauréal Formation (Ashgill), Anticosti Island (Achab 1977a); base of *D. prominens elongatus* Zone, Vauréal Formation (Achab 1978a); Caradoc of Shropshire (Jenkins 1967); Glacial erratics, Baltic, (Eisenack 1931, 1962b, 1965, 1976a, b); upper Caradoc/Ashgill, Baltic (Nõlvak 1980); Barren Flags Formation (?*D. complanatus* Zone, Ashgill), Girvan, Scotland (Laufeld 1971); Lower Vauréal Formation (Jansonius 1967); Ashgill, Gotland (Grahn 1982a); Ashgill, Morocco (Elaouad-Debbaj 1986); Caradoc to Ashgill, Portugal (Paris 1981); upper Caradoc to lower Ashgill (Molyneux and Paris 1985).

Remarks : these specimens are apparently smaller than Achab's (1977a) specimens but fit well within the range specified by Laufeld (1967) and Jenkins (1967).

Genus *Ancyrochitina* Eisenack 1955

1955 *Ancyrochitina* Eisenack, p. 163.

Original Diagnosis (Eisenack 1955) : "chitinozoans of which the lower part (1/2 to 1/3 of the total length) is almost cylindrical. The upper part is in the form of a reversed cone, more rarely the form of a sphere. The polar surface is more or less flat; rarely lightly hollowed or feebly bulging. The side of the polar surface is provided with a relatively restrained number (about 4-10, more commonly 5-8) of vigorous processes, commonly long, simple or bifurcating, sometimes also very irregular. Dimensions between 0.1 and 0.33mm". [Translation].

Type Species: *Ancyrochitina ancyrea* (Eisenack) Eisenack1955

Ancyrochitina ancyrea (Eisenack 1931).
(Pl. 1 figs 4 -7, 9; Pl. 26, fig. 2)

1931 *Conochitina ancyrea* Eisenack. p. 88, Pl. 2, fig. 8-11; Pl.4, fig. 4, Text-fig. 2.

1934 *Conochitina metancyrea* Eisenack, p. 64, Pl. 4, figs 22-25.

1937 *Conochitina protoancyrea* Eisenack, p. 224, Pl. 15, fig. 16-20.

1955 *Ancyrochitina ancyrea* (Eisenack) Eisenack, p. 163, Pl. 2, figs 7-15; Pl. 3, figs 1-3; Pl. 4, figs 1-2.

Diagnosis (Eisenack 1931) : length 0.14mm. L:W = about 2:1. This is, in size and shape, almost the same as the above species (*pistilliformis*) with the distinction that the cylindrical and flask-shaped parts (neck and body) join at a significantly smaller angle (always under 90°). Likewise the short spines on the neck are as deficient as those on the body. On the other hand there are occasionally some longer spines on the neck (perhaps 1-3), mostly near the opening. The opening is often expanded outwards. The striking characteristics are, however, six long, hooked spines, springing from the base of the body, they are of a similar size, regularly distributed and for the most part start out crooked at their bases. At their ends these apophyses are almost regularly pronged in two enrolled points, the latter being able to be further divided in the same way. These processes strongly remind one of the holdfasts of *Cristatella mucedo* Cuv. In a few cases these dichotomous branching points are absent and the process is perhaps similar in form to a stagshorn (Eisenack 1931, Text-fig. 2)". [Translation]

Description : a chitinozoan showing a triangular, conical, or spherical chamber and a well differentiated cylindrical neck, generally about half the maximum length, and half the maximum width of the test. There is a marked flexure but shoulders are weak or absent. The maximum width is along the base which is convex with an angular basal edge. The aperture is straight, and usually simple although in some specimens in SU/DL/41 a reticulation is seen along the edge of the aperture. There are usually two or three, rarely more, branching appendices commonly with secondary but more rarely with tertiary bifurcations. The appendices vary in length between 11 and 37µm. The test is apparently smooth in between the appendices.

Material : twenty five specimens

Dimensions : Length 80(119)185µm
Length of chamber 48(63)75µm
Diameter 55(76)85µm
Diameter of neck (24(34) 45µm
Ten specimens measured.

Occurrence : *G. persculptus* and *P. acuminatus* Zones, Main Cliff, Dob's Linn (SU/DL/ 41, 48, 50, 52, 53, 54, 55, 56).

Previous occurrence : upper Ashgill to Lower Llandovery, Skåne, Sweden (Grahn 1978); Ashgill of Anti-Atlas, Morocco, (Elaouad-Debbaj 1984); Ashgill, Gotland (Grahn 1982a); upper Ordovician, Sylen Formation, Finland (Tynni 1975); upper Llandovery to upper Ludlow, Gotland (Laufeld 1971); upper Llandovery to upper Ludlow, Gotland (Laufeld 1974); Restevo Beds (Wenlock), Podolia (Laufeld 1971); upper Wenlock to Ludlow, Portugal (Paris 1981); Llandovery-Wenlock, USA (Grahn 1985); Pridoli, Gotland (Eisenack 1955a,1970); Gotlandian- Devonian, Sahara (Taugourdeau and Jekhowsky 1960); Silurian, Gotland (Eisenack 1964); Silurian and Devonian, Normandy (Rauscher 1974); Lower Silurian, Normandy (Rauscher and Doubinger 1967); Wenlock-Ludlow, Gotland (Taugourdeau 1966a).

Remarks : this species is very similar to *Ancyrochitina merga* Jenkins 1970 and *A. longispina* Achab 1978. It is differentiated by having shorter processes than *A. longispina* (the processes of *A. longispina* are commonly longer than 30µm) and in having more ramifying processes and a generally more conical body than *A* *merga,* though this latter feature may be a product of compression. The spines in *A. merga* appear to be Y or T shaped and rarely show more than secondary branching. Preservation and compression play an important part in this species, altering the shape of the body and the number of branches on the processes. In the present study a few specimens were found that had processes longer than 30µm, but in other ways do not differ from the specimens with shorter processes and thus are included in *Ancyrochitina ancyrea.*

Laufeld (1974) discusses *A. ancyrea* restricting it to specimens that do not have antler-like branching and concluding that it should be conserved as a characteristic Silurian form. Elaouad-Debbaj (1984) uses *A.* gr. *ancyrea* (Eisenack 1931) in the same sense as Laufeld (1974) for forms with a variable silhouette, short or long appendices, which may or may not be ornamented. Elaouad-Debbaj (1984) also restricts *Ancyrochitina merga* Jenkins, removing several of the specimens to *Plectochitina* Cramer 1964 (one of which is the holotype) because of the basally bifurcating processes. In the original diagnosis Jenkins (1970) states that there are eight to twenty-four appendices, although some of his figured specimens have only two appendices. Elaouad-Debbaj (1984) describes *A. merga* as having about ten appendices but figured specimens show only four. There appears to be very little to distinguish specimens of *A. merga* with only a few processes from *A. ancyrea* . It is possible that the specimens of *A. merga* that Elaouad-Debbaj (1984) has not transferred to *Plectochitina* are synonomous with *A. ancyrea,* however the process terminations do differ and *A. merga* appears to have typically Y- or T-shaped branching processes, rarely to more than first order.

Taking all things into consideration it appears to be most sensible to put all the specimens into *A. ancyrea* at the present time, but with the proviso that some of them may be moved to *A. merga* at a later date.

?*Ancyrochitina corniculans* Jenkins 1969

(Pl. 1 fig. 8)

1969 *Ancyrochitina corniculans* Jenkins, p. 8-9, Pl. 1, figs 1-6; Text-fig. 3

Diagnosis (Jenkins 1969) : "small cylindroconical test. Chamber length equal to or slightly greater than oral tube length; maximum diameter approximately equal to chamber length; base flat or slightly convex, margin bluntly rounded. Generally four to six simple or dichotomously branching appendices with pointed or bluntly rounded tips, up to one-third of the maximum diameter in length; rarely branching more than one order of branching. Oral tube cylindrical or slightly flaring for most of its length, about half maximum diameter in width (more strongly flaring near aperture). Aperture up to two-thirds maximum diameter in width, bearing few short (about 1µm in length) spines or cones. Ornament of simple spines and, infrequently, π- spines distributed thinly over the test, absent on base and basal margin".

Description : chitinozoan with a conical body and a reasonably well differentiated neck and body. The neck has convex sides and is about a third of the maximum length. The aperture is straight and serrate. The base is straight, and the basal edge angular with two appendices developed at one side. The maximum width is developed at the base and the neck is about half the maximum width.

Material : one specimen.

Dimensions : Length 160µm
Length of chamber 100µm
Diameter 110µm
Diameter of neck 66µm
Length of spines 14µm.

Occurrence : *P. acuminatus* Zone Main Cliff, Dob's Linn (SU/DL/57).

Previous occurrence : Viola and Fernvale Limestones (Caradoc, Ashgill), Oklahoma (Jenkins 1969)

Remarks : this specimen is not very well preserved, and only two appendages are visible, although there appears to be no ornament on the vesicle. The general overall shape is reminiscent of this species, but it is not confidently assigned.

Ancyrochitina sp A
(Pl.1 fig. 11)

Description : cylindroconical body with a weak shoulder. The aperture is straight and slightly thinner than the rest of the body. There is no surface ornamentation but two broken appendages can be seen at the base, which is convex with a well developed basal edge. The widest part of the test is just above the basal edge.

Material : one specimen.

Dimensions : Length : 178µm
basal width : 105µm
apertural width : 68µm.

Occurrence : *G.persculptus* Zone Main Cliff, Dob's Linn. (SU/DL/50).

Remarks : this species is similar to *Ancyrochitina* sp. illustrated by Miller and Eames (1982), from the lower Llandovery Medina Formation although the present species is shorter, and is wider along the base and the aperture.

Ancyrochitina sp. B
(Pl. 1 fig. 10)

Description : cylindro-conical chitinozoan with a cylindrical neck that passes with a very weak flexure into the conical body, which has about 6 wide conical blunt appendices around the basal edge. The maximum width of the body is developed along the basal margin, above a weakly convex base. The appendices are broad based and blunt tipped. There is no ornamentation of the test wall.

Material : one specimen.

Dimensions : Maximum length 114µm
Maximum width 81µm
Appendices; length 19µm
width 12µm.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/21).

Genus *Angochitina* Eisenack 1931

1931 *Angochitina* Eisenack, p. 82

Diagnosis : (Eisenack 1931) "cuticle with spines". [Translation].

Type species : *Angochitina echinata* Eisenack 1931.

Remarks : Taugourdeau *et al.* (1967) summarise the major features of this genus:- "subspherical body, passage to the neck very progressive, neck a little longer than the chamber, possesses a collarette that is slightly larger and thinner than spiny walls". They continue to say that "the spines are often found on the chamber, are often simple, curved, more rare and shorter towards the pseudostome. The neck is often devoid of spines. In the lower part of the chamber the spines are lightly curved towards the base, in the upper part they are curved the other way". [Translation].

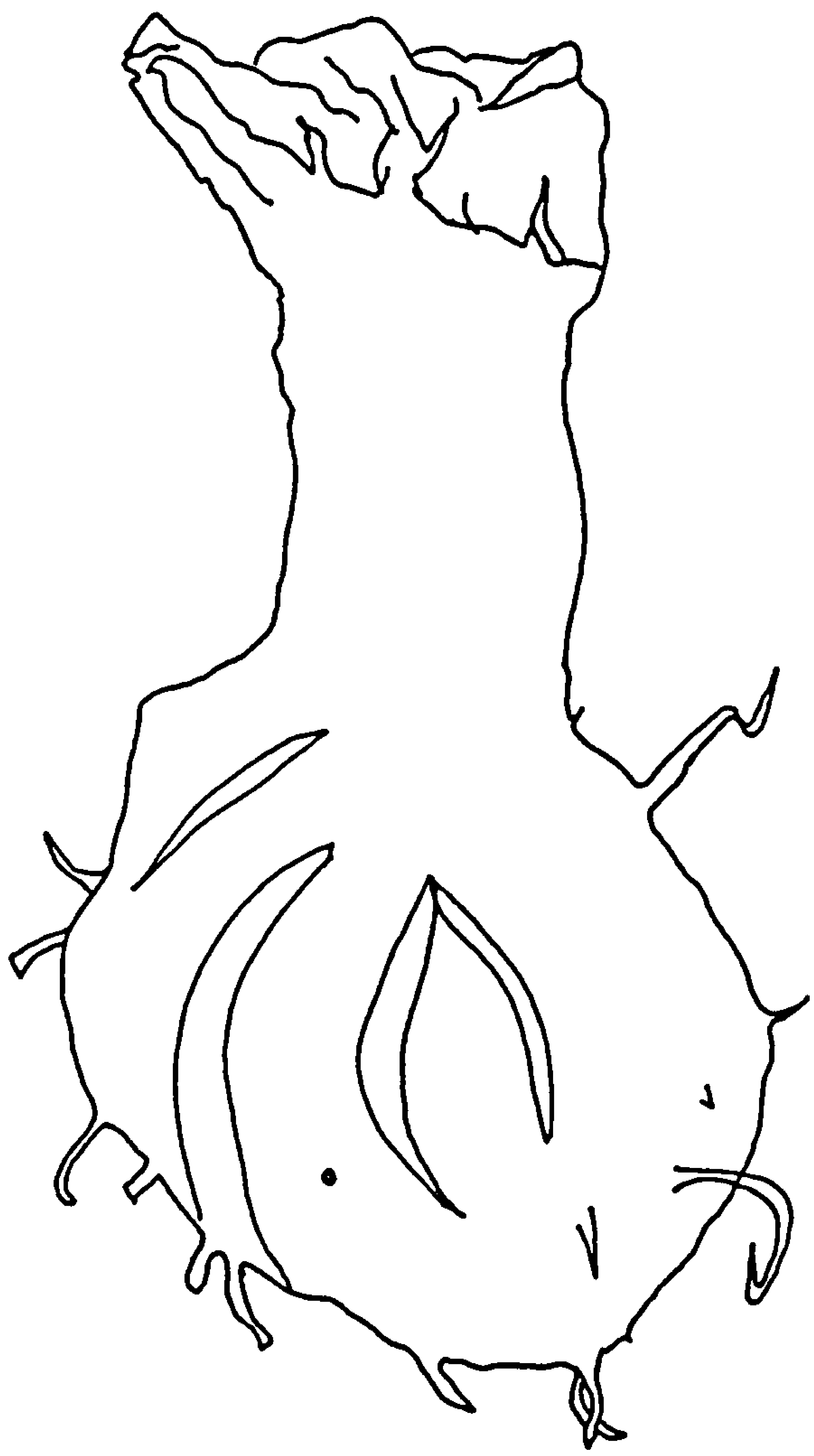
Angochitina woodlandensis n.sp.

(Pl. 2, figs 1(holotype), 2-3; Pl. 26, fig. 9 (holotype); Figure 27)

Type locality : grey shale, 100m below the exposed top of the Shalloch Formation, Woodland Point, Girvan, Strathclyde, Scotland, [NX 21745954].

Holotype : MV/G/23 (1) England Finder Reference G26/2; Pl. 2, fig. 1; Pl. 26, fig. 9; stored in the Hunterian Museum, University of Glasgow; specimen number x1272.

Diagnosis : a chitinozoan with a spherical to ovoid chamber, and a cylindrical neck, sometimes with a flaring collarette. The base is convex and the basal edge poorly developed. The flexure is well developed and the shoulder is poor. The chamber is ornamented with spines that are for the most part simple, and long.



x1150

Figure 27 : Diagram showing *Angochitina woodlande nsis* n. sp.

Description : chamber spherical to ovoid, generally about half to two-thirds of the total length of the chitinozoan. The neck is generally cylindrical, about half the width of the chamber and with a flaring collarette variously developed, with a straight aperture. The maximum width is developed about a third of the way up the chamber. Base is convex, and the flexure is well marked. The ornament consists of spines which are for the most part simple though in some cases a spine may bifurcate at its base. Simple and distally bifurcating spines can be found on the same specimen. The spines are usually acuminate or blunt tipped, and some appear to possess pores. Some specimens have very few spines at all. The oral tube is usually dark but in one or two cases it can be seen that smaller spines are present. The prosome is only seen in one specimen and it is right at the end of the oral tube under the collarette.

Material : eleven specimens.

Dimensions: Range	Holotype
Maximum length 85 (98)106µm	106µm
Maximum width : 47(58)73µm	56µm
width of oral tube : 20(24)32µm	24µm
width of collarette : 25(30)40µm	38µm
length of oral tube : 30(43)50µm	50µm
length of ornamentation : 2-20µm.	5-14µm

Five specimens measured.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/18, 20,23,24,25,27).

Remarks : *Angochitina* is a relatively rare genus in the Ordovician, and this species is apparently different from all other published species, due to its simple or basally bifurcating spines. It is apparently very similar to *A. echinata* Eisenack, although that species is known only from the Upper Silurian. *A. filosa* Eisenack has a much longer neck, also long, well developed spines on the oral tube, and it's spines bifurcate half-way down their length. *A. capillata* Eisenack, has a different shape and its ornament is not as pronounced as in *A woodlandensis* n.sp. *A. dicranum* Jenkins has a more elongated test and pitch-fork spines. *Belonechitina hirsuta* (Laufeld) has an insufficiently rounded chamber, differentiated oral tube, and lambda-based spines. It appears therefore that this species must be considered as new.

Genus *Armoricochitina* Paris 1981

1981 *Armoricochitina* Paris, p.175-176.

Diagnosis (Paris 1981) : "chitinozoan, with an ovoid body, truncated towards the aboral pole; base of the body convex to ogival; shoulder present; flexure very marked, separating the body from a short, but very marked, collarette, aboral margin sharp, situated on the maximum diameter of the cell, an entire membranous carina pseudomorphing a plinth, inserted on the aboral margin; mucron very reduced; operculum discoidal, prolonged in the aboral direction by a thin fringe; test smooth, shagreenate, or microgranular; chains fragile". [Translation].

Type species : *Armoricochitina ceneratiensis* (Paris 1976).

Armoricochitina nigerica (Bouché 1965)
(Pl. 1, fig.12)

1965 *Cyathochitina hymenophora* subsp. *nigerica* Bouché, p. 157-158, Pl. 3, figs. 8,12,13.

1984 *Armoricochitina* aff. *armoricana* (Rauscher and Doubinger); Elaouad-Debbaj, p.52-53, Pl.1, fig. 7; Pl.2, fig. 23; Pl.3, figs 4,13,22,24.

1985 *Armoricochitina nigerica* (Bouché); Molyneux and Paris, Pl.6, fig. 9; Pl.7, figs 1,2,3.

1986 *Armoricochitina nigerica* (Bouché); Elaouad-Debbaj, p. 38, Pl.1, fig. 6, 13-16; Pl.3, fig. 9.

Diagnosis : (Bouché 1965) "forms with a conical body, a short neck and a carina << short, very fine transparent>> which are distinguished from the typical Aquitaine forms by their very short neck, which is poorly marked (1/6 of the total height), the absence of a collarette and their more solidly built aspect. The angle of opening is between 20° and 30°". [Translation].

Description : chitinozoan with a conical body, a very short neck, (one fifteenth of the total length), and a thin carina. The maximum width is along the base which is markedly convex. The width of the neck is half the width of the base. Preservation is too coarse to allow any ornament to be distinguishable.

Material : one specimen.

Dimensions : Length : 150µm
Maximum width : 125µm
Minimum width : 65µm.

Occurrence : *P.linearis* Zone, Little Cliff, Dob's Linn (SU/DL/2).

Previous occurrence : Upper Ordovician of the Sahara, (Bouché 1965); Ashgill of North East Libya (Molyneux and Paris 1985); Ashgill, Morocco (Elaouad-Debbaj 1986)

Remarks : The general shape of this chitinozoan is very diagnostic of this species. Elaouad-Debbaj (1986) discusses this species which appears never to have been formally transferred from *Cyathochitina hymenophora* subsp. *nigerica* Bouché.

Genus *Belonechitina* Jansonius 1964

1964 *Belonechitina* Jansonius, p. 906-907.

Diagnosis : Vesicle elongated conical, club- or pear-shaped, with conical body chamber and cylindrical neck; base flat or more or less convex, basal edge rounded, sometimes very broad; sides straight or convex, shoulder poorly developed, flexure more or less distinct; lip usually distinctly thin-walled vesicle completely ornamented with randomly or evenly spaced spines which may be widely spaced or crowded, very small or strongly developed, separate or grouped in clusters, but not normally in distinct longitudinal rows; cuticle single layered; spines near basal edge usually more strongly developed; operculum and prosome as in *Conochitina* . Chain formation not observed.

Type species : *Belonechitina robusta* (Eisenack) Jansonius 1964.

Remarks : Jansonius (1964) introduced this genus but it is rarely used. The present author however feels that *Conochitina* is too large a genus and has thus assigned all *Conochitina* species with spines to *Belonechitina*.

Belonechitina comma (Eisenack 1959) comb. nov.
(Pl. 2, figs 4-6)

1959 *Conochitina micracantha* subsp. *comma* Eisenack p.7-8, Pl.1,fig.4.

Diagnosis (Eisenack 1959) : "this has the form of a steep conical rod with flat or somewhat indented polar surface and similarly to the previous subspecies, with a somewhat more strongly rounded polar margin, under which the outer envelope goes. The outer envelope tapers to the lower half of the polar margin and occasionally bulges outwards, although this is essentially rare. The ornament is very weak and confined to the polar region, the sides are free from processes. The ornament at the poles can decline to vanishing point, such that a completely smooth form results. [Translation].

Description : elongate *Belonechitina* species with subcylindrical vesicle and cylindrical neck. The base is straight to convex and the basal margin is angular to curved. The maximum width is along the base. The aperture is straight and varies between two-thirds to half of the maximum diameter. In one rare specimen the apertural width is equal to the basal width. The base of test is covered with small conical spines 1-5µm long; rare specimens have no ornament.

Material : more than seventy specimens.

Dimensions : Maximum length 240(357)520µm
Maximum diameter 40(59)80µm
Diameter of aperture 25(46)55µm.
16 specimens measured.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/28).

Previous occurrence : Llanvirn to Caradoc, Öland (Grahn 1981a); Caradoc, North Wales (Atkinson and Moy 1971); Caradoc, Normandy (Rauscher 1974); upper Ordovician Sylen Formation (Tynni 1975); Caradoc, Gotland (Grahn 1982a); Caradoc, Estonia (Eisenack 1959b, 1962b, 1965, 1968b); Molodova Beds (*P. linearis* Zone), Podolia (Laufeld 1971).

Remarks : This species is formally transferred to *Belonechitina* due to the presence of basal spines. While being similar to *Conochitina elegans* , *B. comma* is clearly differentiated from it by the basal ornament and also by the lack of a basal constriction. It differs from *B. micracantha*, mainly by its elongate shape and poor differentiation into neck and chamber.

Belonechitina cf. *hirsuta* (Laufeld 1967) comb. nov.

(Pl.2, figs 7,8,11; Figure 28)

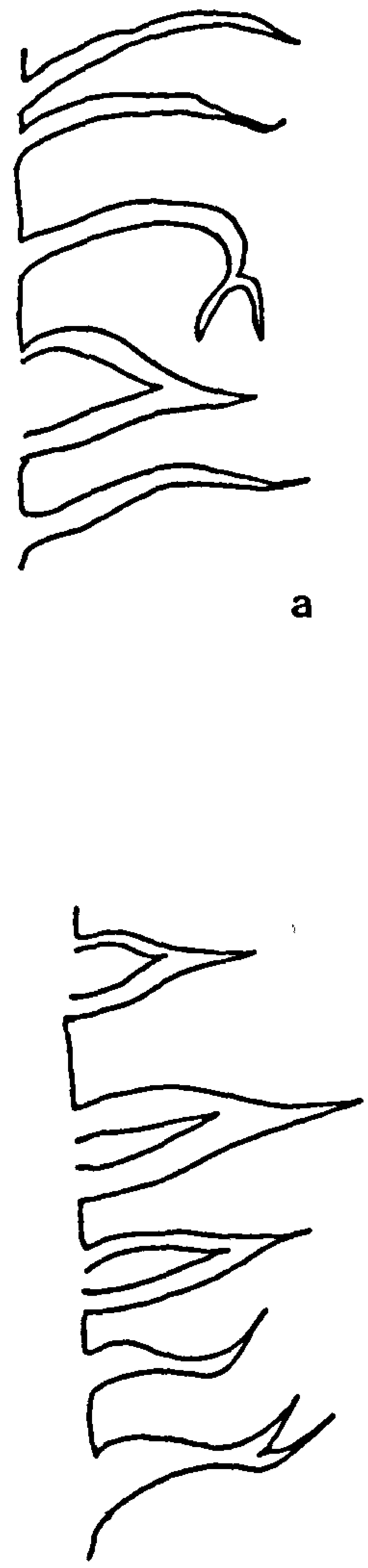
1967 *Conochitina hirsuta* Laufeld, p. 304, fig. 12

1967 *Angochitina communis* Jenkins, p. 450, Pl. 69, figs 14-17.

1981 *Kalochitina ?hirsuta* (Laufeld) Schallreuter, p. 14, Pl. 8, figs1-3.

1984 *Kalochitina* aff. *hirsuta* (Laufeld): Elaouad-Debbaj, p. 58, Pl.1, fig. 2,6,8,9.

Description (Laufeld 1967) : "the body is conical or subconical with slightly convex sides. It has a rounded basal edge and flat to convex base which is often somewhat thickened around the aboral pole. The neck, which comprises around a third of the vesicle length, is often slightly constricted at the flexure, where the operculum is situated, but widens towards the straight or finely fimbriate aperture. Most specimens lack shoulder but when present, it is indistinct and very broadly rounded. The operculum is relatively thick and disc-like and around its edge there is a thin, membranous flange extending aboralwards. In some specimens a thin but somewhat shorter flange protrudes also orally. The vesicle wall consists of a single layer which has the same thickness all over the body and in the oralmost part of the neck. The thickness rapidly decreases oralward of the operculum but is then fairly constant into the aperture. This thinning of the vesicle wall is either gradual or takes place in distinct steps but is always confined to a short zone.The vesicle is provided with an ornamentation of spines and spinose thickenings which



a

b

X1500

Figure 28 : (a) *Belonechitina seriespinosa* ; (b) *Belonechitina* cf. *hirsuta*

are solid. Most spines have thick, multiramose bases (3-8), although simple spines and λ-spines do occur. Usually, the roots are spaced at random but in some specimens most spines on the body have their roots placed in a row parallel to the longitudinal axis of the vesicle. Here the roots can have the appearance of a triangular, fenestrate lamella turned on edge. Sometimes spines are fused in their apices, thus resembling arches. Some have irregular processes but spines ramifying outwards are rarely met with. Vesicles chained together have not been met with".

Description : the general shape of the test is pyriform to cylindro- conical, with a conical body and a cylindrical or subcylindrical neck which varies in length between a quarter and a third of the maximum length. The aperture is lightly fringed, the flexure is weak and there are no shoulders. The oral tube is slightly less than half the maximum width, which is developed just above the base. The basal edge is rounded and the base is straight. The ornamentation consists of spines that are tapering and may be simple, λ-based, or simple and coalescing at their distal ends. The distal ends are acuminate or slightly bulbous.

Material : five specimens.

Dimensions : Maximum length 63(81)105μm
Length of chamber 50(61)80μm
Maximum diameter 57(63)67μm
Apertural diameter 25(27)30μm
Spines 6x1μm
3 specimens measured.

Occurrence : Ardwell Flags, Ardmillan Braes, Girvan (MV/G/6), Shalloch Formation, Woodland Point, Girvan (MV/G/22, 23), a possible very poorly preserved specimen was obtained from Shalloch Formation (MV/G/27).

Previous occurrence : Ordovician, Baltic (Eisenack 1968b); Middle Ordovician, Canada (Achab 1986a); Caradoc of Sweden (*D. multidens* Zone) (Laufeld 1967, Grahn 1981a, 1982a); Ashgill of Anti-Atlas (Elaouad-Debbaj 1984); Sularp Shales, Sweden (*D. multidens* Zone), Skåne, (Schallreuter 1981); *N. gracilis*

Zone, Canada (Achab 1982); Trenton Formation (Caradoc), Anticosti Island (Achab1984); Caradoc, Shropshire (Jenkins 1967); Viola Limestone (Caradoc) Oklahoma (Jenkins 1969); Vauréal Formation, Anticosti Island (Achab 1977a); Caradoc, Oklahoma (Taugourdeau 1965); lower Middle Ordovician (Grahn and Bergström 1984a); Caradoc, Gotland (Grahn 1982a).

Remarks : some of the specimens (MV/G/23, 27) bear a striking resemblance to those illustrated by Achab (1984) pl 2, fig. 1,4 with a reduced neck and fairly simple ornamentation and thus resemble *Kalochitina* more than *Belonechitina*, but these specimens do not possess the type of ornamentation shown by Elaouad-Debbaj (1984). The other specimens (MV/G/6, 22) are typically a *Belonechitina* shape. These specimens are smaller than most published records suggest. *Belonechitina hirsuta* differs from *Kalochitina multispinata* by having a less complex ornament, and by being smaller. *K.inflata* Taugourdeau is not sufficiently well illustrated or described for the ornament to be discerned; it also is larger than *B* . cf. *hirsuta.* The ornament of *B.* cf. *hirsuta* and *B*. *seriespinosa* are compared in Figure 28 and it can be seen that *B.* cf. *hirsuta* more commonly possesses λ based spines than *B. seriespinosa.*Due to the general shape and the presence of the ornamentation this species is hereby transferred to *Belonechitina.*

Belonechitina micracantha (Eisenack 1931) comb. nov.

(Pl. 2, figs 9-10, Pl. 3, figs 1-2)

1931 *Conochitina micracantha* Eisenack (*pars*). p. 84, Pl. 1, fig. 19 (holotype).

1959 *Conochitina micracantha* subsp. *micracantha* Eisenack, p. 7, Pl. 1, fig. 5 (neotype); Pl. 3, fig. 12.

Diagnosis (Eisenack 1931) : "this species resembles the shape *(Conochitina) claviformis,* although it is quite variable as far as its size and shape are concerned. In general only the lower third is cylindrically developed. The basal rim of the body can also be observed here; although there are never any examples with the outwardly growing spines on the distal end that are found in the previous species. The characteristic feature of this species is the possession of very short spines, found preferentially on the distal end, and strongly developed at this point;

often, but not always these spines are also found on the rest of the membrane where they are regularly distributed. The opening has, as in the previous species, appendages, however showing here a somewhat stronger development, and a more regular distribution". [Translation].

Description : cylindrical chitinozoan with poor differentiation of the neck and chamber, though a weak shoulder is sometimes present. The base is flat to convex and the basal edge angular. The aperture is straight, and the flanks are generally straight. A diagnostic constriction is obvious above the basal edge. The ornament consists of small spines covering the whole test but most obvious along the basal edge. In many specimens the ornament is considerably reduced and only visible in transmitted light along the basal edge.

Material : more then twenty five specimens

Dimensions : Maximum length 135(195)270μm
Neck length 40(64)120μm
Basal width 45(83)108μm
Apertural width 33(46)55μm
10 specimens measured.

Occurrence : *D. anceps* Zone, Main Cliff, Dob's Linn (SU/DL/9); Ardwell Flags, Ardmillan Braes, Girvan (MV/G/6), Ardwell Flags, Ardwell Farm (MV/G/7), Jubilation Member, Doularg Hill (MV/G/9), Shalloch Formation, Woodland Point, (MV/G/18,20,21,22,23,24, 26,27,28), Mill Formation Woodland Point, Girvan (MV/G/29).

Previous occurrence : Lower Ordovician, Öland, (Grahn 1980); Llandeilo to lower Ashgill, Sweden (Grahn 1981b); Caradoc, Sweden (Grahn 1984a); Llanvirn to Caradoc, Öland, (Grahn 1981a); Arenig to Caradoc, Tallinn, Estonia (Grahn 1984b); Ostseekalk (Llanvirn to Ashgill) Baltic (Eisenack 1959, 1965); lower Middle Ordovician, USA (Grahn and Bergström 1984a); Llanvirn to Llandeilo, Normandy (Rauscher 1970, 1974); Llanvirn to upper Caradoc, Estonia (Eisenack 1968b); Ordovician, Baltic (Eisenack 1962b); Diplograptus-Kalk; Caradoc to Ashgill, Gotland (Grahn 1982a); Viola Limestone (Caradoc), Oklahoma, USA

(Jenkins 1969); Utica and Lorraine Formations, Québec, (Achab 1986b); Caradoc, North Wales (Atkinson and Moy 1971); upper Caradoc, Baltic (Nõlvak 1980); Caradoc, Newfoundland (Neville 1974); Caradoc, Portugal (Paris 1981); Caradoc-Ashgill, Canada (Martin 1983); Sylen Formation, Finland, (Tynni 1975); Molodova Beds (*P. linearis* Zone), Podolia (Laufeld 1971); Ellis Bay Formation, Anticosti Island (Achab 1978b); Caradoc-Ashgill, Libya (Molyneux and Paris 1985).

Remarks : this is a very variable species but it is identifiable by the constriction above the aboral margin. It differs from *C. robusta* by its marked angular basal edge and flexure, from *C. conulus* by possessing ornament, and from *C. wesenbergensis*, which has longer spines and commonly has a more marked flexure.

Paris (1981) has previously transferred *Conochitina micracantha typica* to *Belonechitina* , however the undivided species does not seem to have been previously reassigned to *Belonechitina*

Belonechitina robusta (Eisenack 1959) Jansonius 1964

(Pl. 3, figs 3,5,6,8)

1959 *Conochitina micracantha* subsp.*robusta* Eisenack, p. 9, fig. 6, Pl. 3, fig. 4,5.

1964 *Belonechitina robusta* (Eisenack) Jansonius, p. 906, Pl. 2, figs 24,25.

1965 *Conochitina micracantha* subsp.*robusta* Eisenack; Eisenack p. 123.

1967 *Conochitina robusta* Eisenack; Laufeld, p. 307, fig. 14.

Description (Laufeld 1967) : "the vesicle is club-shaped or elongated conically with the greatest width at or just oralward of the basal edge. The body is elongated subconically with straight to slightly convex or concave sides. The neck is cylindrical or widens slightly towards the aperture and flexure is absent to rounded, but distinct. Shoulder is lacking and the basal edge is rounded. In many specimens a short but hollow mucro protrudes from the flat to slightly convex to concave base. The vesicle wall apparently consists of a single layer which is thick and of uniform thickness over the entire vesicle except for the oral half of the neck where it tapers rapidly. The aperture is straight to delicately fimbriate, but sometimes well-developed spines reach in front of it. A very conspicuous ornamentation consists of simple and λ-spines and spines with multiramose roots and is best developed in the aboral part of the body. A disk-like operculum with a short, membranous flange is situated within the neck. Chains have never been met with."

Description : elongate chitinozoan with weak differentiation into neck and chamber. The aperture, which is half the maximum width is straight, the flanks flaring, the base is convex and the basal edge is curved. The maximum width is situated just above the base which is well ornamented with apparently simple spines, although ornament is rare on the oral part of the test.

Material : three specimens.

Dimensions : Length 115-350μm
Basal width 70-73μm
Apertural width 37μm
2 specimens measured.

Occurrence : Ardwell Flags, Ardmillan Braes (MV/G/6), Shalloch Formation, Woodland Point, Girvan (MV/G/20, 27).

Previous occurrence : lower Middle Ordovician, USA (Grahn and Bergström 1984a); Laggan Burn Limestone (Caradoc), Ayrshire, Scotland (Jansonius 1964); Ordovician, Baltic (Eisenack 1959b, 62b, 68b); Caradoc of Sweden (Laufeld 1967); Viola Limestone (Caradoc), Oklahoma, (Jenkins 1969); Caradoc, Öland (Grahn 1981a, b); Caradoc, Portugal (Henry *et al.* 1974); Middle and Upper Ordovician, Normandy (Rauscher and Doubinger 1967, Rauscher 1970,1974); Caradoc of south-west Europe (Paris 1981); Caradoc and Ashgill, Baltic (Eisenack 1965b, 72b); Caradoc, Portugal (Paris 1979); Caradoc and Ashgill, Gotland, (Grahn 1982a); Caradoc and Ashgill, Canada (Martin 1983); Trenton and Utica Formations (upper Caradoc), Québec (Martin 1975); Trenton Formation (Caradoc), Anticosti Island (Achab 1984); Middle Ordovician, Québec (Achab 1986a); middle Llandovery, Skåne, Sweden (Grahn 1978);

Remarks : Differs from *Conochitina micracantha* by its curved base and lack of a constriction just above the base. Laufeld (1967) discusses specimens that have ornamentation only in the aboral region.

Belonechitina schopfi subsp *americana ?* (Taugourdeau 1965) comb. nov.
(Pl. 3, fig. 4)

1965 *Conochitina schopfi* subsp *americana* Taugourdeau p. 467, Pl. 1, fig. 21, Pl. 3, fig.55

Description (Achab 1977) : "conical form, neck and body more or less well distinguished, greatest width situated at the edge of the base. Neck cylindrical flaring gently to a transparent collarette. Test covered with generally simple spines but sometimes spines may have a double base. The ornamentation seems under the optical microscope, more developed in the lower part of the body". [Translation].

Description : conical body with a straight base and rounded basal edge. The greatest width is along the base of the body. Neck poorly developed or absent. A weak ornamentation is seen along the basal margins of the specimens.

Material : four specimens.

Dimensions : Length 85-100μm
Width 55-62μm
2 specimens measured.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/18, 21, 27, 28).

Previous occurrence : *D. complanatus* Zone, Anticosti Island (Achab 1977a); *C. prominens elongatus* Zone, Vauréal Formation, Anticosti Island (Achab 1977b); Vauréal formation (Ashgill), Anticosti Island (Achab 1978b); Ordovician, USA (Taugourdeau 1965).

Remarks : This species differs from *B. micracantha* in possessing no neck. This species is here transferred to *Belonechitina* .

Belonechitina seriespinosa (Jenkins 1969) comb. nov.
(Pl. 3, figs 9,12; Figure 28)

1969 *Conochitina seriespinosa* Jenkins, p. 13,14, Pl. 2, figs 5-14, Text-fig. 5.

Diagnosis (Jenkins 1969) : "conical to cylindrical chamber with swollen flanks, about two-thirds total length; base flat, margin rounded. Ornament of slender, simple spines and rare, distally bifurcate, pitch-fork shaped spines with pointed tips; spine bases commonly expanded in a plane parallel with the longitudinal axis of the test. Spines, up to one quarter (rarely one third) maximum diameter in length, distributed thinly in ten to sixteen longitudinal rows extending from base to aperture".

Description : conical to almost spherical body in some specimens, with a cylindrical neck, and a variously developed flexure and shoulder. Sometimes a flared collarette is developed, and the aperture may be straight, faintly serrate, or possessing small spines. The maximum width is developed along the base, or about a third of the way up the chamber, the basal edge is rounded and the base convex. The neck is about half the maximum width, and the chamber length is on average half the maximum length. The ornament consists of mostly simple slightly flaring spines (up to 25µm in length, but more commonly about 12µm), though some have bifurcating bases, which end in acuminate tips, or very rarely pitchfork bifurcations. Specimens vary between being heavily and sparsely ornamented, and in general the ornament is more well developed on the body than on the neck.

Material : twenty six specimens.

Dimensions : Length : 75(102)125µm
Chamber length : 50(67)80µm
Diameter : 42(59)75µm
Oral tube diameter : 22(27)35µm
Apertural diameter : 25(30)37µm
10 specimens measured.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/18,22,23,24,25,26, 27).

Previous occurrence : Viola Limestone (Upper Caradoc), Oklahoma, U.S.A., (Jenkins 1969); Molodova Beds, (*P. linearis* Zone), Podolia, USSR (Laufeld 1971); Orphan Knoll (Caradoc- Ashgill), Labrador Sea (Legault 1982).

Remarks : this is a very common species from the Shalloch Formation, and exhibits quite a wide range of morphologies. The specimens are generally smaller in size than those shown by Jenkins (1969) but this may be related to sample processing. The specimens from Girvan do not show as much diversity in spine type as do Jenkins' (1969) specimens but still fit well within this species. This species fits well within the generic diagnosis for *Belonechitina.*

Belonechitina wesenbergensis (Eisenack 1959)
(Pl. 3, figs 7,10,11)

1931 *Conochitina micracantha (pars)* Eisenack p.84-85, Pl. 2, fig. 21,22

1959 *Conochitina micracantha* subsp *wesenbergense* Eisenack; Eisenack p.10, Pl. 1, fig.11, Pl. 3, fig.8.

1962 *Conochitina micracantha* subsp *wesenbergensis* Eisenack; Eisenack, p.357, Pl. 44, fig.13.

1969 *Conochitina wesenbergensis* Eisenack; Jenkins, p.12, Pl. 1, figs14-16, 22. Pl. 2, figs 1-4.

1972 *Conochitina wesenbergensis* subsp *brevis* Eisenack p.125, pl34, figs 25-28; Pl. 37,figs 2,3.

1984 *Belonechitina wesenbergensis* (Eisenack), Elaouad-Debbaj, p. 39, Pl. 2, fig. 2,13,21.

Description (Grahn 1981a) : "*Conochitina* species with a conical body and a cylindrical neck that may widen at the aperture, which is mostly fringed. The base is flat to convex and the basal edge rounded. The vesicle is covered by simple spines that are best developed at the basal edge".

Description : a chitinozoan with a conical body and a cylindrical neck. There is a weak shoulder and poorly developed or absent flexure. The maximum width is situated at or just above the base, which is straight to convex and the basal edge is rounded. The aperture is slightly flared and the width of the aperture is generally about two thirds maximum width. The aperture may be straight or serrate. The body is covered in simple spines (1-5μm) in length and which are best developed at the base.

Material : nine specimens.

Dimensions : Length 100(133)180μm
Width 45(59) 75μm
Width of the aperture 30 (37) 45μm
9 specimens measured.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/20,22,23,26,27,28).

Previous occurrence : Llanvirn to Caradoc, Tallinn, Estonia (Grahn 1984b); lower Middle Ordovician, USA (Grahn and Bergström 1984a); Llanvirn to Caradoc, Öland, Sweden (Grahn 1981a) Caradoc, Sweden (Grahn 1981b); Bromide Formation (Midddle Ordovician), Oklahoma (Grahn and Miller 1986); upper Ordovician Sylen Formation, Finland (Tynni 1975); upper Caradoc to lower Ashgill, Estonia (Eisenack 1931, 59b, 62b, 65, 68b); Viola Limestone (upper Caradoc), Oklahoma (Jenkins 1969); upper Caradoc to lower Ashgill, Podolia, U.S.S.R. (Laufeld 1971); Caradoc to Ashgill, Gotland (Grahn 1982a); Upper Ordovician Maqueketa Shale, Kansas, (Wright and Meyers 1981); Molodova Beds (*P. linearis* Zone), Podolia (Laufeld 1971); Ashgill, Morocco (Elaouad-Debbaj 1986).

Remarks : Jenkins (1969) discusses the variation in shape that this species exhibits. The present material from Girvan verifies this and the specimens vary between long, thin and short, fat, more flared sided, morphotypes. This species differs from *B.micracantha* by possessing more convex sides, not having a constriction above the basal edge, having longer spines and generally being more bottle shaped. It differs from *B. seriespinosa* by possessing shorter spines and a stronger shoulder and a flatter base.

Belonechitina sp. A
(Pl. 4, fig. 1)

Description : cylindrical chitinozoan with straight sides and broken near the aperture. There is no differentiation into neck and chamber and the sides are straight. The maximum width is developed in the middle of the chamber. There is a sparse ornamentation of simple spines on most of the test, but spines are more common near the base.

Material : One specimen only.

Dimensions : Length 207µm
Width 99µm

Occurrence : Shalloch Formation, Woodland point, Girvan (MV/G/18).

Remarks : This specimen is not ornamented enough to be assigned to *B. micracantha.*

Belonechitina sp. B
(Pl. 4, fig.2)

Description : cylindro-conical chitinozoan with a rounded basal edge and a convex base. The flanks are gently convex and there is a weak flexure but no shoulder. The neck is cylindrical and about one third of the maximum length. The maximum width is situated about the mid point of the chamber. There is one long simple spine at the basal edge.

Material : one specimen.

Dimensions : Maximum length 140µm
Chamber length 90µm
Maximum width 80µm

Apertural width 35μm.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/24).

Genus *Calpichitina* Wilson and Hedlund 1964

1964 *Calpichitina* Wilson and Hedlund, p. 161.

Diagnosis : (Wilson and Hedlund 1964) "tests, single, subspherical, urn shaped, slightly broader than high; oral opening operculata, approximately one-half diameter of the test, with flaring membranous collar which arises from a thickened annulus at the neck; operculum circular, bordered by a narrow membranous flange; aboral end rounded, cupola none; unbleached specimens black, bleached specimens brown to yellow; wall approximately two microns thick, outer part opaque, appears to be composed of a vermiculate network, inner part translucent, smooth, appears structureless".

Type species : *Calpichitina scabiosa* Wilson and Hedlund 1964.

Paris (1981) erected two sub-genera of this genus to distinguish forms that possess mucrons from those that do not.

Calpichitina (Calpichitina) Paris 1981

Diagnosis : "sub-genus of *Calpichitina* devoid of a mucron or any other differentiation of the aboral pole; body lenticular or a flattened spheroid; oral opening generally large; surrounded or not by a collarette or fold; test smooth (with spiny or tuberculate ornementation), but the surface can be smooth, chagrinate, microgranular, felted, or composed of folds of periderm; chains very fragile if they exist". [Translation]

Calpichitina (Calpichitina) lenticularis (Bouché 1965)

(Pl. 4, figs 3-6, ?9)

1965 *Hoegisphaera lenticularis* Bouché, p.160, Pl. 2, figs 14,15.

1967 *Hoegisphaera complanata* (Eisenack) Jenkins, p.462, Pl. 73, figs 4,5.

1979 *Desmochitina lenticularis* (Bouché) Paris, p.36,37, Pl. 2, figs 1-6

1981 *Calpichitina (Calpichitina) lenticularis* (Bouché) Paris, p. 129,130, Pl. 16, figs 18 &22, Pl. 17, figs9,10.

1978 *Desmochitina complanata*, (Eisenack) Achab, p.306, Pl. 2, figs 8-10.

Diagnosis: (Bouché 1965): "lenticular body, base (aboral side) depressed. Neck reduced to an annular fold. Opening relatively narrow (about 1/3 of the diameter), closed by an operculum visible in reflected light. Surface granulo-tuberculate; or sometimes smooth. The flattening is probably secondary". [Translation]

Description : a chitinozoan with a lenticular or discoid body, without a neck, but with a central circular opening. The surface of the test is smooth. The opening of the test is sometimes closed with an operculum, is open, or the opeculum can be found inside the test. Loose opercula are found in the strew mounts. The aperture varies from half to third of the maximum diameter. Folds are common in the walls of the tests.

Material : more than a hundred specimens.

Dimensions : Maximum diameter : 50(56)70µm

Apertural diameter : 14(23)29µm

10 specimens measured

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/18,20,21,22,23, 24,25,26, 27,28).

Previous occurrence : Caradoc, North Wales, (Atkinson and Moy 1971); Sahara (Caradoc/Ashgill), Nigeria (Bouché 1965); Louredo Formation, (Caradoc), Portugal, (Paris 1979). Acton Scott Beds, (Caradoc), Shropshire (Jenkins 1967); Caradoc, Portugal (Paris 1981); Vauréal Formation, (Ashgill), Canada, (Achab 1978a); Caradoc and Ashgill, Gotland, (Grahn 1982a); Ashgill, Morocco, (Elaouad-Debbaj 1984, 1986); Ashgill of White Head Formation, Québec (Martin 1980); Caradoc to Ashgill, Libya (Molyneux and Paris (1985).

Remarks : This species is very common in the samples from Woodland Point. Legault (1973) figures specimens of *Hoegisphaera* cf. *H. glabra*, one of which does not possess and external membrane and bears a striking resemblance to Calpichitina lenticularis.

Calpichitina (Calpichitina)megastrophica Achab 1984
(Pl. 4, figs 8, 12)

1984 *Calpichitina megastrophica* Achab, p. 126, Pl. 1, figs 1-7.

Description (Achab 1984): "we attach to *Calpichitina megastrophica* n.sp. chitinozoans with a globular body, supplied with a large transparent collarette more or less flared. The wall of the test is thin and without ornamentation. the majority of specimens are found longitudinally compressed, which renders it easy to identify them by their collarette. When they are found compressed in a position oral/aboral, they present the form of a lentil, with a slightly wrinkled wall, which, under the optical microscope,makes it difficult to see the transparent collarette. The cell is closed by an operculum which is thicker on its centre and at its border. No chains observed". [Translation]

Description : The test is in the shape of an oblate spheroid, with the maximum width developed at the midpoint of the chamber. There is a small collarette, which is thinner than the rest of the test, and approximately five sixth of the maximum width. The ratio of diameter to length of the chamber is 1:0.8. There appears to be no ornament on the test which is usually found laterally compressed.

Material : ten specimens only.

Dimensions :	Maximum length	50(55)64µm
	Chamber length	42(49)57µm
	Maximum diameter	37(56)65µm
	Apertural diameter	48(51)55µm

Flange thickness 1(6)10µm.

10 specimens measured

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/18,24,27,28).

Previous occurrence : Trenton Formation (Caradoc), Anticosti Island (Achab 1984); Middle Ordovician, Québec, (Achab 1986a)

Remarks : *Desmochitina scabiosa* (Wilson and Hedlund 1964) is less slender than *Calpichitina megastrophica* and it has different ornamentation to the present specimens which appear to be smooth. *Desmochitina lata* Schallreuter has a spinose ornamentation, and is often found in chains. One specimen of *Pterochitina hymenelytrum* has been found in this present work, which is hard to distinguish from *D. lata* and *C. megastrophica* as it appears to be the similar but with a membranous flange . The present author agrees with previous authors who express doubt that specimens so morphological similar should be in two or three genera.

C. megastrophica is differentiated from *Desmochitina lata* by the lack of a basal callus.

Genus *Conochitina* Eisenack 1931 emend. Eisenack 1955

1931 *Conochitina* Eisenack, p.83.

Original Diagnosis (Eisenack 1931): "chitinozoa with generally conical tests, the maximum diameter lying near the base". [Translation in Jenkins 1967].

Emended Diagnosis (Eisenack 1955) : "chitinozoa with conical tests and rounded basal margins. Wall smooth or bearing more or less short spines, which in general are particularly well developed aborally". [Translation in Jenkins 1967].

Type Species: *Conochitina claviformis* Eisenack 1931

Conochitina conulus Eisenack 1955

(Pl. 4, fig. 11)

1955 *Conochitina conulus* Eisenack, p. 312, Pl.1, fig. 1-3.

1967 *Euconochitina conulus* Rauscher and Doubinger, p. 478, Pl. 3, fig. 3.

1968 *Conochitina conulus* Eisenack, p.161, Pl.26, fig. 34.

Description (Grahn 1981a) : "*Conochitina* species with a conical body and a cylindrical neck that widens at the fringed aperture. The base is convex and the basal edge rounded. The vesicle is covered with minute simple spines".

Description : a chitinozoan with a conical body, and a cylindrical neck. The base is convex and has a rounded basal edge. The maximum width is just above the base. The neck is cylindrical and the aperture slightly fringed, and flaring. It is about a quarter of the maximum length and half of the maximum width. The flanks are convex below the strong flexure more or less unornamented but under the scanning electron microscope it can be seen that the base is weakly ornamented.

Material : four specimens.

Dimensions : Length 80(137)231μm

Width 44(59)80μm

Width of aperture 23(31)40μm.

Occurrence : Ardwell Flags, Ardwell Farm (MV/G/7), Shalloch Formation, Woodland Point, Girvan (MV/G/20,21,28).

Previous occurrence : Llanvirn to Caradoc, Tallinn, Estonia, (Grahn 1984b); Llanvirn, Normandy (Rauscher 1970); Llandeilo, Normandy (Rauscher and Doubinger 1967); Llandeilo, Sweden, (Grahn 1981b); upper Llanvirn to Llandeilo, Estonia (Eisenack 1955b); lower Caradoc, Baltic (Eisenack 1968b); Llanvirn to Caradoc, Öland (Grahn 1981a); Upper Ordovician, Sylen Formation, Finland (Tynni 1975); Caradoc-Ashgill, Aquitaine (Taugourdeau 1961); Caradoc to Ashgill, Sahara (Bouché 1965)

Remarks : Grahn (1981a) describes this species as possessing minute, simple spines, however in the remarks he says that Eisenack (1955) describes this species as smooth. The two specimens described here from Girvan are both apparently smooth, although very small spines are seen on the base using the scanning electron microscope, and are here considered to be *C. conulus.* The present specimens have slightly more convex sides than the figured holotype material. This species would be more correctly called *Conochitina conula* as the ending previously given is masculine.

Conochitina cf *elegans* Eisenack 1931
(Pl.4, fig.7)

1931 *Conochitina elegans* Eisenack, p. 87, Pl.2, fig.4 (holotype)

1934 *Rhabdochitina conocephala* Eisenack, p.61, Pl. 4, figs 10-12; Text-fig. 32.

non 1962 *Conochitina elegans* Eisenack; Beju and Danet, p.531, Pl.1, figs 31,32.

non 1964 *Rhabdochitina conocephala* Eisenack; Cramer, p.351, Pl.22, fig.14; Pl.23, figs 7,11,12.

1965 *Rhabdochitina hedlundi* Taugourdeau, p.472, Pl. 3, figs 60-66.

1970 *Pistillachitina elegans* (Eisenack); Rauscher, p. 122, Pl.1, fig. 18.

Diagnosis (Eisenack 1931): "this species is very long, like a staff, the topmost end flaring to a small conical termination. The test is completely smooth. The mouth is a little flared". [Translation]

Description : elongate cylindrical chitinozoan with no differentiation of body and neck, although the aboral end is swollen. A small collarette is developed which is just slightly wider than the width. The base is convex and the basal edge angular. One specimen has a basal process developed.

Material : three specimens only.

Dimensions : Length 335(365)400μm
Width 35(43)55μm
Width of neck 27(34)40μm

Width of collar 43µm.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/25, 28).

Previous occurrence : Llanvirn, Normandy (Rauscher 1970); Llandeilo, Tallinn, Estonia (Grahn 1984b); upper Llandeilo to middle Caradoc, Estonia (Eisenack 1959b, 1962b, 1962c, 1968b); lower Caradoc to upper Caradoc, Welsh Borderlands (Jenkins 1967); Caradoc, North Wales (Atkinson and Moy 1971); Caradoc, Ostseekalk, northen Germany and southern Finland (Eisenack 1965); Sylvan Shale, Oklahoma, (*D.complanatus* Zone) (Jenkins 1970); Caradoc to Ashgill, Gotland (Grahn 1982a); upper Caradoc to Ashgill, Baltic (Nõlvak 1980); Upper Ordovician, Maquoketa Shale, Kansas (Wright and Meyers 1981);

Conochitina minnesotensis (Stauffer 1933) Eisenack 1962

(Pl.5, figs 1-2)

1933 *Rhabdochitina ?minnesotensis* Stauffer, p. 1209, Pl. 60, fig. 39.

1962 *Conochitina minnesotensis* (Stauffer) Eisenack p. 353,357, Text-fig. 1-6.

Original description : (Stauffer 1933) "body elongate, subcylindrical to cylindrical in outline, although it tapers slightly towards the proximal end, suggesting the outline of a baseball bat. Terminal or distal end is smooth and rounded, but some specimens show a small elevation and a flattened apex. Proximal end is slightly smaller and probably had some means of attachment. Surface of the test is smooth, shiny, and black, although undoubtedly it was brownish chitin when the animal was alive. Some of the fossil specimens are still cylindrical and filled with crystalline material, chiefly pyrite, but most of them have collapsed and are more flattened strips of shiny black material, cracked open at the distal end and broken towards the proximal end".

Description : cylindrical chitinozoan with straight sides, a straight aperture, and a curved basal edge. In some case the base has a wide mucron, which varies between flat and convex. Jenkins (1969) illustrates the wide range of basal morphology.

Material : fourteen specimens.

Dimensions : Length : 250(603)1050µm

Width : 70(103)140µm

Width of aperture 80µm

mucron : 10-10µm high, 10-25µm wide

3 specimens measured.

Occurrence : Ardwell Flags, Ardmillan Braes (MV/G/6), Jubilation Member, Doularg Hill (MV/G/9), Shalloch Formation, Woodland Point, Girvan (MV/G/18,20,21,24); *D. anceps* Zone, Main Cliff, Dob's Linn (SU/DL/46).

Previous occurrence : Arenig, Australia, (Combaz and Peniguel 1972); Lower Ordovician, Öland (Grahn 1980); Llanvirn to Caradoc, Öland, (Grahn 1981a); Llandeilo to Caradoc, Tallinn, (Grahn 1984b); Decorah Formation (Caradoc) Minnesotta, (Stauffer 1933); Arenig to Ashgill, Estonia (Eisenack 1962b, 65, 68a, 68b); Dalby and Skagen Limestone (lower to middle Caradoc), Sweden, (Laufeld 1967); Viola Limestone (Caradoc) (Jenkins 1969); Caradoc, Sweden (Grahn 1984a); Caradoc to Ashgill, Canada (Martin 1983); upper Caradoc to Ashgill, Baltic (Nõlvak 1980); Caradoc to Ashgill, Gotland, (Grahn 1982a); Caradoc to lower Ashgill, Västergötland, Sweden (Grahn 1981b); Utica and Lorraine Formations (Ashgill), Québec (Achab 1986b); Ashgill, Morocco (Elaouad-Debbaj 1986),

Conochitina primitiva Eisenack 1939
(Pl.5, fig. 5)

1934 *Conochitina* sp. indet. (ex aff. *C. claviformis)* - Eisenack p. 62; Pl. 4:13.

1939 *Conochitina primitiva* Eisenack, p.138,140,142; Pl. B:7-8.

Description : (In Grahn 1980) "*Conochitina* species with a conical body. The cylindrical neck comprises about 1/2-1/3 of the total length and widens slightly towards the straight aperture. The base is flat to convex and may have a basal process. No ornamentation has been observed. The basal edge is rounded".

Description : chitinozoan with a cylindrical neck (half of the maximum length), and a conical body. There is no shoulder, the base is flat, and the basal edge rounded to angular. The aperture is straight and there is no ornamentation.

Material : one specimen only.

Dimensions : Maximum length : 210µm
Maximum width : 70µm
Oral tube length : 100µm
Oral tube width : 50µm
Apertural width : 60µm.

Occurrence : Balmaha, Loch Lomond (HB/Bal/2).

Previous occurrence : Arenig to Caradoc, Tallinn, (Grahn 1984b); upper Arenig to upper Llanvirn of Sweden (Grahn 1980, 81a); upper Arenig to upper Caradoc, Estonia, (Eisenack 1934,1962a, b,1968b); upper Arenig to Llanvirn (Umnova 1969); Llanvirn, Normandy (Rauscher and Doubinger 1967, Rauscher 1970, 1974); Llandeilo to Caradoc, south-west Europe (Paris 1981); Llandeilo to Caradoc, Gotland (Grahn 1982a); Caradoc of Portugal (Henry *et al* 1974); upper Llandeilo to Caradoc, Sweden (Grahn 1981b); Caradoc? of Westphalia, West Germany, (Eisenack 1939); Caradoc, Kent, England (Lister *et al.* 1969); Caradoc, Sweden Grahn (1984a); Caradoc to Ashgill, Canada (Martin 1983); Ashgill, Morocco (Elaouad-Debbaj 1986).

Remarks : this specimen fits well into the description supplied by Grahn (1980), although in the Highland Border Complex specimen the basal edge is angular on one side. This is probably due to preservation. This species of *Conochitina* differs from others due to its lack of ornament. *Conochitina chydaea* is less conical in the chamber.

Conochitina pygmaea Achab 1986

(Pl. 4, fig. 10)

1986 *Conochitina pygmaea* Achab, p. 1216-1218, Pl. 9, figs. 1-10.

Description (Achab 1986): "a dumpy form, characterised by a globular chamber, with the greatest width situated towards the base. The flanks are strongly convex, the base flat and the basal edge rounded. The chamber is also hardly more long than wide. The neck is of variable length, sometimes almost inexistant (Pl. 9, fig. 8), sometimes well developed (Pl. 9, figs. 1&2), often about a third of the total length. The wall of the test is smooth". [Translation].

Description : a chitinozoan with a globular chamber, and a poorly differentiated neck. A weak flexure is developed. The maximum width is situated about a third of the way up the chamber. The neck is slightly less than half of the maximum length. The basal edge is rounded and the base is flat. The aperture is straight and the surface of the test appears to be smooth.

Material : one specimen only.

Dimensions : Chamber : Length :160μm, width 140μm
Neck Length : 70μm, width 80μm.

Occurrence : *D. anceps* Zone, Main Cliff, Dob's Linn (SU/DL/9).

Previous occurrence : Utica Formation, *P.linearis* Zone , Québec. (Achab 1986b).

Remarks : the neck of this specimen appears to be a little longer than the description would allow for, but the present author thinks that this can reasonably be allowed for by intraspecific variation.

Conochitina tormentosa Taugourdeau 1961

(Pl.5, fig. 9)

1961 *Conochitina tormentosa* Taugourdeau, p. 141, Pl. 2-3, figs, 32,33,34,35,36. (holotype 32).

Diagnosis : (Taugourdeau 1961) "large species of variable proportions; body conical; neck cylindrical (1/3 to 1/2 of the length); mouth poorly marked, slightly thinned, flaring; body covered in irregular hairs, base flat". [Translation].

Description : *Conochitina* species with a conical body, and a cylindrical neck (third of the total length); the maximum width is along the base. The neck is a third of the maximum width. The basal edge is easily distinguished; flexure and shoulder poor. The aperture is straight with a few spines, and there are also apparently spines at the base.

Material : one specimen only,

Dimensions : Length : 265µm
Width : 150µm
Neck : 50 x 85µm.

Occurrrence : *G. persculptus* Zone, Linn Branch section, Dob's Linn (SU/DL/34).

Previous occurrrence : Upper Ordovician of Aquitaine (Taugourdeau 1961).

Remarks : this specimen is easily distinguished from *Conochitina primitiva*, by its greater size, and more angular basal edge. It has a longer neck than *Conochitina conulus.*

Conochitina cf. *tuba* Eisenack 1932

(Pl. 5, fig.3)

1932 *Conochitina tuba* Eisenack, p. 271, Pl. 12, figs 8-10.

Diagnosis (Eisenack 1932): "this form, closely related to *Conochitina claviformis* has an almost cylindrical form, being only a little wider at the base. The planar outer surface passes over a rounded margin, in most cases, into a weakly convex base. An invagination has not been observed, but there is quite often, as in *C. claviformis* a process which is commonly short. The wall is completely smooth.

This species is distinguished from *C. claviformis* only by its different proportions and somewhat shorter length. The protruding parts measure 0.23, 0.24, and 0.21mm. The ratio of length to width is 3-3.1/1. The opening is considerably wider than that of *C. claviformis*; the polar process is broader and the smaller transverse measurement not so different [from the latter], so that this form gives the impression of being a compact version of *C. claviformis*. [Translation].

Description : *Conochitina* species with faintly conical body and no differentiation into neck and body. The basal edge is rounded and the mucron is well developed in the middle of the base. The maximum width is situated at the base of the test. There is a sparsely spinose ornament on the lower part of the body and the aperture is weakly serrate.

Material : one specimen only

Dimensions : Length 110µm
Diameter 60µm
Diameter of neck 32µm
Mucron 12 x12µm
spines 2µm
1 specimen only.

Occurrence : Shalloch Formation, Woodland point, Girvan (SU/DL/27).

Previous occurrence : Caradoc, Normandy (Rauscher and Doubinger 1967), Ordovician, Brittany (Deunff 1959); Upper Ordovician, Sylen Formation, Finland (Tynni 1975); Wenlock, Gotland (Taugourdeau and Jekhowsky 1964); lower Ludlow, Gotland, (Eisenack 1962a, c); Wenlock to Ludlow, south-west Europe (Paris 1981).

Remarks : this specimen is very similar to several other species of *Conochitina*, particularly *C. claviformis*, *C. acuminata*, *C proboscifera*, and *C. pachycephala*. However it is very much smaller than *C. claviformis* and *C. pachycephala*. *C.*

proboscifera has more a gently curved basal edge, and not such a well developed mucron, and is much longer. *C. acuminata* always flares orally which the present specimen does not.

Conochitina sp.A
(Pl.5, fig. 6)

Description : chitinozoan with a cylindrical body, sharp flexure, well marked shoulder and a well differentiated cylindrical neck. The base is slightly convex and the basal edge rounded. The test is smooth and quite thick. The aperture appears to be fringed.

Material : one specimen only

Dimensions : Maximum length137µm
Length of chamber 82µm
Maximum width 37µm
Width of neck 25µm.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/18).

Remarks : this specimen appears to be strangely compressed, and so it appears as though the neck is folded over. It is quite like *Lagenochitina cylindrica* Eisenack but much thinner and shorter and the length to breadth ratio is larger than this specimen.

Conochitina sp.B
(Pl.5, fig.10)

Description : weakly ovoid chamber partially differentiated with a cylindrical neck. The aperture is undulating and just smaller than the maximum diameter which is situated in the middle of the chamber. The neck is about a quarter of the maximum length. The base is more or less straight and the basal edge rounded. The striking feature about this specimen is that it is divided into two layers which are seen to be separated.

Material : one specimen only

Dimensions : Maximum length : 100μm
Chamber length : 75μm
Maximum width : 62μm
Apertural width : 45μm.

Occurrence : *D. clingani* Zone Dob's Linn (SU/DL/3).

Remarks : quite similar to *C. brevis* Taugourdeau and Jekhowsky but too poorly preserved to be identified for certain.

Conochitina sp. C
(Pl.5, fig.8)

Description : poorly preserved chitinozoan with a cylindrical body and a well developed flexure and shoulder. The base is convex and the basal edge rounded. The maximum width is situated along the base, and the body is about four fifth of the total length. The neck is cylindrical and apparently broken.

Material : one specimen only

Dimensions : Maximum length 112μm
Chamber length 89μm
Maximum width 67μm
Apertural width 42μm.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/18).

Conochitina sp. D
(Pl. 5, fig. 7)

Description : elongate, subcylindrical chitinozoan with a very weak flexure. The aperture is straight, the neck cylindrical, the flanks straight, the base convex and the basal edge curved. The neck is about a quarter of the length and about half the maximum width, which is situated in the middle of the chamber. There appears to be a small collarette, but no obvious ornamentation.

Material : one specimen only.

Dimensions : Maximum length 116µm
Length of neck 43µm
Width of base28µm
Width of neck 19µm.

Occurrence : Jubilation Member, Doularg Hill (MV/G/8).

Conochitina sp. E
(Pl.5, fig. 4)

Description : chitinozoan with a cylindrical neck passing via a weak flexure into a conical body. The base is convex and the basal edge rounded. The neck is half the maximum length and half the maximum width which is situated just above the base. There is a small flared collarette at the aperture which is straight. There is no ornament.

Material : one specimen only.

Dimensions : Maximum length 138µm
Length of neck 74µm
Maximum width 82µm
Width of neck40µm
Width of collarette 48µm.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/23).

Conochitina spp. indet.

Various specimens that seem to belong to the genus *Conochitina* but which are not well enough preserved to be assigned to a species are listed below.

MV/G/23, Shalloch Formation, Woodland Point, Girvan.(Pl.12, fig.22)
HB/BB/3, Bofrishlie Burn, Aberfoyle, (Pl. 12, fig.13)
HB/BB/5, Bofrishlie Burn, Aberfoyle, (Pl. 12, fig.14)
HB/NE/3, North Esk River section, Edzell (Pl. 12, fig.15)
HB/LC/7, Limecraig Quarry, Aberfoyle (Pl. 12, fig.5)

Genus *Cyathochitina* Eisenack 1955

1955 *Cyathochitina* Eisenack, p. 313

Diagnosis (Eisenack 1955) : "chitinozoan with a cylindrical neck, body in the shape of a cone or a bell, sometimes divided at the base by a sharp flange. Thus this species has the appearance of a wine glass. The membrane is developed as a thin translucent membrane. The surface is smooth or finely tuberculate, occasionally striated or with longitudinal streaks". [Translation].

Type Species: *Cyathochitina campanulaeformis* (Eisenack 1931).

Cyathochitina calix (Eisenack 1931)
(Pl.6, figs 1-2)

1931 *Conochitina calix* Eisenack, p. 87, Text-fig. 1, Pl. 2, fig.3, Pl. 4, fig.14.
1958 *Cyathochitina calix* (Eisenack) Eisenack, p.400, Pl. 2, fig.26-27.

Description (Grahn 1980): "*Cyathochitina* species with a conical body. The base shows concentric structures. A rounded basal process may be developed at the aboral pole. The basal edge carries a short carina. The body is slightly convex but tapers towards the cylindrical neck. The aperture is straight. the flexure is distinct. The vesicle wall is smooth or provided with spiral thickening".

Description : conical chitinozoan with weak differentiation into neck and chamber. The aperture is straight, there is no shoulder and there is a basal carina. The neck is about a third of the total length. The carina is about one sixth of the maximum length. There appears to be no ornamentation but preservation is poor.

Material : two specimens.

Dimensions : Maximum length 204-230μm
Length of chamber 145-160μm
Length of neck 54-70μm
Maximum width 81-90μm
Apertural width 34-45μm.

Occurrence :*D. anceps* Zone, Main Cliff, Dob's Linn (SU/DL/9); Jubilation Member (MV/G/9).

Previous occurrence : Arenig-Llandeilo, Tallinn, Estonia, (Grahn 1984b); upper Arenig-Lower Llanvirn, Öland (Grahn 1980); Ordovician, Baltic (Eisenack 1948); upper Arenig to upper Llanvirn, Estonia (Eisenack 1958,62b,68b); upper Arenig-Lower Llanvirn, Dalarna, Sweden, (Eisenack 1962a,76a); lower Llanvirn, south-west Europe (Paris 1981); Llanvirn, Normandy (Rauscher 1970); lower Llanvirn, Welsh Borderlands, (Jenkins 1967); Llanvirn to Caradoc, Öland (Grahn 1981a); Llandeilo to Caradoc, Sweden (Grahn 1981b); Middle Ordovician, northern Germany, (Schallreuter 1983); lower Middle Ordovician, USA, (Grahn and Bergstrom 1984a); Llandeilo, Normandy (Rauscher and Doubinger 1967); Middle Ordovician, Bromide Formation, (Grahn and Miller 1986); Caradoc, North Wales, (Atkinson and Moy 1971); Caradoc?, Westphalia, West Germany, (Eisenack 1939); Sularp Shale, (*D. multidens* Zone), Skåne, Sweden (Schallreuter 1981); Upper Ordovician, Sylen Formation, Finland (Tynni 1975); Caradoc-Ashgill, Aquitaine (Taugourdeau 1961); Ordovician to Gotlandian, Sahara (Taugourdeau and Jekowsky 1960)

Remarks : it is possible that the specimen from Dob's Linn is reworked. This species differs from *Cyathochitina conica* Taugordeau 1961 by having a more differentiated neck.

Cyathochitina campanulaeformis (Eisenack 1931)
(Pl. 6, figs 3-5)

1931 *Conochitina campanulaeformis* Eisenack, pp. 86-87; Pl. 2, figs. 1-2; Pl. 4, figs. 1,11-13.

1955 *Cyathochitina campanulaeformis* (Eisenack) Eisenack, p. 313.

1962 *Cyathochitina campanulaeformis* (Eisenack) Eisenack, p. 297, Pl. 14, figs 5 (neotype), 6,7; Text-fig. 3.

Diagnosis (Eisenack 1962 translated in Jenkins 1967) : "oral tube cylindrical, chamber bell or funnel-shaped with a relatively sharp basal margin, which not uncommonly is drawn out into a narrow knife-edge rim. Aperture straight. Wall slightly rough, very finely granular, or with extremely fine grooves like bark".

Description : a chitinozoan with a conoidal chamber and a cylindrical neck, the flexure is weakly developed and a weak shoulder is usually present. The maximum width is usually along the base which varies from straight to slightly convex. The basal edge is well developed. The length to width ratio is 1.09 (1.44) 1.76, and the oral tube varies between a quarter and half of the total length. A few random spines are seen in the specimen from Girvan.

Material : twenty two specimens.

Dimensions : Length : 120 (214) 355µm
Chamber length : 60 (142) 235µm
Oral tube length : 50 (72) 100µm
Maximum diameter : 115 (144) 200µm
Oral tube width : 49 (66) 80µm
10 specimens measured.

Occurrence : *D. anceps, G. persculptus* and *P. acuminatus* Zones Main Cliff, Dob's Linn (SU/DL/9, 49, 54,56,57); Ardwell Flags, Ardwell Farm (MV/G/7), Jubilation Member, Doularg Hill, Girvan (MV/G/9), Shalloch Formation, Woodland Point, Girvan (MV/G/23).

Previous occurrence : Ordovician, Brittany (Deunff 1959); Arenig to Caradoc, Estonia (Grahn 1984b); upper Arenig to upper Ashgill, Estonia (Eisenack 1948, 62a, 62b, 68a,68b); upper Arenig to lower Llanvirn (Grahn 1980); upper Arenig to Caradoc, south-west Europe (Paris 1981); Ordovician, Sahara (Benoit and Taugourdeau 1961); Caradoc of Sweden, (Laufeld 1967); Llanvirn to Llandeilo, Normandy (Rauscher 1974); Llanvirn to Caradoc, Öland (Grahn 1981a); lower Llanvirn to lower Llandeilo, Welsh Borderlands (Jenkins 1967); upper Llanvirn to middle Llandovery, Sweden (Laufeld 1971); upper Arenig to lower Llanvirn, Öland, (Eisenack 1976a); lower Middle Ordovician, USA (Grahn and Bergström 1984a); Middle Ordovician, Anticosti Island (Achab 1984); upper Llanvirn to lower Ashgill, Sweden (Grahn 1981b); Upper Ordovician, Sylen Formation, Finland (Tynni 1975); Caradoc, North Wales (Atkinson and Moy 1971); Caradoc, Kent, England (Lister *et al.* 1969); Caradoc to Ashgill, Canada (Martin 1980, 83); Caradoc- Ashgill, Aquitaine (Taugourdeau 1961); upper Caradoc-Ashgill, Baltic (Nõlvak 1980); Silurian, Montagne Noire (Rausher 1974); Molodova Beds (*P. linearis* Zone), Podolia, (Laufeld 1971); Ashgill, Morocco (Elaouad-Debbaj 1986).

Remarks : this is a very variable species, but has a very distinctive shape from other species of *Cyathochitina.*

Cyathochitina conica Taugourdeau 1961
(Pl.6, fig. 6,9)

1961 *Cyathochitina conica* Taugourdeau, p. 141-142, Pl. 3, fig. 41-43.

Diagnosis (Taugourdeau 1961): "regularly conical form exhibiting practically no differentiation of the neck. The body is covered irregularly with hairs, more or less scattered; the carina is well marked". [Translation]

Description : cylindro-conical chitinozoan with a well developed carina. The aperture is straight and the flexure is poorly developed. the maximum width is situated towards the base of the chamber, and the width of the carina is equivalent to the maximum width. The neck is a third of the maximum length. No ornament is visible.

Material : two specimens.

Dimensions : Length Maximum 140-175 μm

Width neck 32-40μm

Maximum width 70-73μm.

Occurrence :*D. anceps* Zone (SU/DL/46) and *G. perculptus* Zone (SU/DL/ 51) Main Cliff, Dob's Linn.

Previous occurrence : Caradoc and Ashgill of Aquitaine (Taugourdeau 1961); Llandeilo, Normandy (Rauscher and Doubinger 1967).

A possible specimen of this species has been found from Glen Fruin (HB/GF/1), with the dimensions:-

Maximum length		145μm
	neck	15μm
	chamber	95μm
	carina	35μm
Width	neck	25μm
	chamber	80μm
	carina	80μm

?Cyathochitina cf.*fusiformis* Bouché 1965

(Pl.6, figs 11-12)

Description (Bouché 1965) : "body elongated, swollen in the middle part and narrowing towards the extremities. Base relatively narrow with a thin carina, sometimes slimmed down. Neck weakly distinct (1/7th of the total length). The ratio of height to width varies between 4 and 6." [Translation]

Description : elongated cylindrical chitinozoan with a well marked flexure , a weak shoulder and a straight aperture. The neck is one seventh of the length of the body and half of the maximum width. The base is straight, but no carina is visible, although the preservation is not very good. The maximum width is in the centre of the chamber. The ratio of height to width varies from four and a half to six and a half.

Material : two specimens.

Dimensions : Length 163-247μm
Width 36-38μm
Width of neck 15-17μm.

Occurrence : Balmaha, Loch Lomond (HB/BAL/2).

Previous occurrence : Caradoc to Ashgill of Sahara (Bouché 1965); Caradoc, North Wales (Atkinson and Moy 1971).

Remarks : these specimens are very similar in outline to those figured by Bouché (1965), although they are quite a bit smaller, and no carina is visible in the present specimens, however this may be related to preservation. No other chitinozoan appears to have this cylindrical outline, with the maximum thickness in the middle of the chamber.

Cyathochitina granulata Taugourdeau 1961
(Pl.6, fig.10)

1961 *Cyathochitina granulata* Taugourdeau, p.142, Pl. 3, fig. 46, Pl. 6, fig. 86, Text-fig.8.

Diagnosis (Taugourdeau1961) : "chamber conical, swollen, short (half the length); neck cylindrical; carina poorly marked, surface covered with little close-spaced tubercles". [Translation],

Description : cylindro-conical chitinozoan, with a weak flexure; neck about one third the length of the body, with a straight aperture (though this appears to be damaged). the carina is not well marked. No ornamentation can be seen but recrystallisation has occurred. The maximum width is at the base.

Material : one specimen only.

Dimensions : Length : 162µm
Basal width : 135µm
Width at neck : 80µm.

Occurrence : *G. persculptus* Zone, Main Cliff, Dob's Linn (SU/DL/51).

Previous occurrence : Ordovician of the Sahara (Taugourdeau 1961).

Cyathochitina hyalophrys Eisenack 1959
(Pl. 7, fig. 1)

1959 *Cyathochitina hyalophrys* Eisenack, p. 11-12, Pl. 2, figs 6-7, Pl. 3, fig. 15.

Diagnosis (Eisenack 1959) : "the membrane forms a steep-conical rod, conical in the upper half without differentiation in neck and chamber, and cylindrical in the lower half. At the base is a low translucent and sharp rim. The aperture is straight". [Translation].

Description : Elongate, cylindro-conical test with no differentiation into the chamber and the neck. The aperture is straight and approximately half the maximum width which is situated along the base. There is a thin carina about 22µm wide situated along the basal margin. The test is unornamented.

Material : three specimens.

Dimensions : Maximum length 161(296)408µm
Basal width 90(119)136µm
Apertural width 42(61)77µm.

Occurrence : Ardwell Flags, Ardmillan Braes, Girvan (MV/G/6), Shalloch Formation, Woodland Point, Girvan (MV/G/19, 25).

Previous occurrence : Llandeilo, Normandy (Rauscher and Doubinger 1967);

lower Middle Ordovician, USA (Grahn and Bergström 1984a); Caradoc and Ashgill of Baltic (Eisenack 1959b); Lorraine Formation, Ashgill, Québec (Achab 1986b);

Remarks : the shape of the test is less flaring than in *Cyathochitina kuckersiana* and does not have the distinct flexure or shape of *Cyathochitina campanulaeformis.*

Cyathochitina hymenophora Taugourdeau 1961
(Pl.6, figs 7-8)

1961 *Cyathochitina hymenophora* Taugourdeau p. 144, Pl. 3. fig. 47-49.

Diagnosis (Taugourdeau 1961): "body conical with an open angle; neck short (a third of the length); <<collar>> thin, carina thin, very fine; transparent".[Translation].

Description : conical body with convex flanks, the greatest width is situated just above the basal edge, which is distinct. The base is flat; the flexure is visible on one side, as is the shoulder. The neck is cylindrical, about a third of the maximum length, and the aperture is straight. A thin carina is present.

Material : two specimens only

Dimensions : Maximum length : 180-240µm
Maximum width : 80-160µm
Length of chamber : 130-165µm
Length of oral tube : 50-85µm
Width of oral tube : 60-78µm.

Occurrence : *C. ?extraordinarius* (SU/DL/17) , *G persculptus* (SU/DL/50) Zones Main Cliff, Dob's Linn.

Previous occurrence : Caradoc and Ashgill of Aquitaine (Taugourdeau 1961).

Remarks: *Cyathochitina macastyensis* Achab is larger, and the maximum width is higher up the chamber than in *C. hymenophora*. *C. campanulaeformis* has a much more flaring carina.

Cyathochitina jenkinsi Neville 1974
(Pl.7, figs 2-3)

1974 *Cyathochitina jenkinsi* Neville, p.196-197, Pl. III, figs 1-28.

Diagnosis (Neville 1974) : "test usually divided into chamber and oral tube, the latter being between 25-50% of the total length. Oral tube is cylindrical or slightly tapering, may flare a little and is 45-75% of the maximum diameter in width. Shoulders often only weakly developed and occasionally absent. The maximum diameter is 30-60% of the total length and is situated in the lower half of the test, usually between 0.5-0.75 total length from the oral end. Base usually flat to concave, rarely slightly convex, with the basal margin possessing a translucent carina about 5-10μm wide which usually has a slightly thickened margin about 1-1.5μm wide. The wall bears fine longitudinal ribbing which is best developed and often restricted to the aboral end".

Description : a smooth walled test with a cylindrical neck, about half the maximum length and half the maximum diameter, which is situated in the middle of the chamber. There is a well marked flexure, and the shoulder is variably developed. The flanks of the chamber are straight or more often convex. The base is concave with a small carina about 7μm in width. The test is often crumpled which helps to distinguish it from *Cyathochitina protocalix* which latter is preserved in three dimensions in this sample.

Material : seventeen specimens

Dimensions : Maximum length 220(266)308μm
Length of chamber 148(181)240μm
Length of neck 40(84)130μm
Maximum width 90(92)130μm
Apertural width 55(63)88μm
10 specimens measured.

Occurrence : Jubilation Member, Doularg Hill, Girvan (MV/G/9).

Previous occurrence : Caradoc of Newfoundland (Neville 1974); Caradoc of Anticosti Island (Achab 1984); Middle Ordovician, Québec (Jenkins 1986a).

Remarks : as already stated this is distinguished from *Cyathochitina protocalix* by its less rigid shape, but also by its large carina and its more differentiated neck. Its larger carina, more elongate neck, and convex flanks also serves to distinguish it from *Cyathochitina calix.* These specimens do not show the longitudinal ribbing illustrated by Neville (1974).

Cyathochitina kuckersiana (Eisenack 1934)

1934 *Conochitina kuckersiana* Eisenack, pp. 62-63, figs. 30-31; Pl. 4, fig. 14, (holotype); text-figs30 (holotype),31.

1962 *Cyathochitina kuckersiana* (Eisenack) Eisenack p. 298, Pl. 14, fig.8 (neotype); Text-fig.4 (neotype).

Description (Eisenack 1934) : " the species below, the nearest related fossil to which is *Cyathochitina campanulaeformis* is nearly cylindrical, for half and perhaps occasionally more than half of its length, but not less than one third of its length; as in *C. campanulaeformis* it passes into a conical to bell-shaped upper half. The edge of the bell is characteristic. It is very thin, dark brownish, translucent and forms a hat-brim shape on top of the bell; furthermore it is not level, but is undulating. In its outer zone, only when complete, one can see a weak and indistict radial strengthening. A copula has never been observed. Favourably preserved examples show, certainly, a central bulge on the base of the bell. The opening is smooth and the membrane is without tubercles. Size is 0.2 to 0.33mm, length to width ratio is 1.6-1.9:1. *C. kuckersiana* forms with *C. campanulaeformis* and *C. calix* a closely-knit group.

Cyathochitina kuckersiana kuckersiana (Eisenack 1934)

(Pl. 7, fig.4)

1934 *Conochitina kuckersiana kuckersiana* (Eisenack 1934), p. 62-63, Pl. 4, fig. 14, Text-figs 30,31.

Diagnosis : same as for *Cyathochitina kuckersiana*.

Description : a chitinozoan with a very long neck and a reduced body. There is a weak flexure, and no shoulder. At the base of the body there is a well developed but opaque carina, along which the maximum length of the body is seen. The edge of the carina is sharply angular, and its base is undulating.

Material : one specimen only.

Dimensions : Length 150µm
Diameter 110µm
Apertural width 30µm.

Occurrence : *D. anceps* Zone Main Cliff, Dob's Linn (SU/DL/9).

Previous occurrence : Llanvirn, Normandy (Rauscher 1974); Llandeilo, Normandy (Rauscher and Doubinger 1967); upper Llandeilo to upper Ashgill, Estonia (Eisenack 1962a, 68a, 68b); basal upper Caradoc, Welsh Borderlands (Jenkins 1967); Viola Limestone, (Caradoc), Oklahoma (Jenkins 1969); Caradoc, Sweden (Laufeld 1967); upper Caradoc, Quebec (Martin 1975); Ashgill, Anticosti Island, Quebec (Achab 1977b); upper Caradoc-Ashgill, Baltic (Nõlvak 1980); Silurian-Devonian,(Taugourdeau 1966a); Gotlandian, Sahara (Taugourdeau and Jekhowsky 1960); Molodova Beds, (*P. linearis* Zone), Podolia (Laufeld 1971); Caradoc-Ashgill, Sahara (Bouché 1965)

Cyathochitina kuckersiana patagiata Jenkins 1969

(Pl. 7, fig. 5)

Diagnosis : (Jenkins 1969)"a subspecies of *C. kuckersiana* with a very narrow carina".

Description : a chitinozoan with a conical body, and a cylindrical neck, about a third of the maximum length. There is a marked flexure and the flanks are very flaring. the base is slightly convex and the basal edge is angular. No ornament is visible.

Material : one specimen.

Dimensions : Maximum length 120µm
Chamber length 80µm
Maximum width 35µm
Apertural width 30µm.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/24).

Previous occurrence : Viola Limestone (Caradoc), Oklahoma (Jenkins 1969); Caradoc-Ashgill, Canada (Martin 1975,83); Caradoc, Shropshire (Jenkins 1967).

Cyathochitina latipatigium (Jenkins 1969)
(Pl. 7, fig. 7)

1962 *Cyathochitina kuckersiana* forma *brevis* Eisenack, p. 298-300, Fig. 5, Pl. 14, fig. 9

1969 *Cyathochitina kuckersiana latipatigium* Jenkins, p. 19-20, Pl. 4, figs 6-10.

1981 *Cyathochitina latipatigium* (Jenkins) Grahn, p. 32-33, Pl. 11, fig. l.

Diagnosis (Jenkins 1969) : " a subspecies of *Cyathochitina kuckersiana* with a short wide test (maximum diameter and total length approximately equal) and a very wide carina".

Description : chitinozoan with a cylindrical neck and a wide flaring chamber. The base is flat and the basal edge angular. The neck is about a quarter of the total length and half to one third of the total width which is situated along the base.

Material : two specimens.

Dimensions : Length 180-184μm
Diameter 110-153μm
Apertural width 45-47μm.

Occurrence : *G. persculptus* and *P. acuminatus* Zones, Main Cliff, Dob's Linn (SU/DL/51,56).

Previous occurrence : Llanvirn to Caradoc, Öland (Grahn 1981a); Caradoc of Shropshire (Jenkins 1967); Viola and Fernvale Limestones, (Caradoc), Oklahoma, (Jenkins 1969); Caradoc-Ashgill, Canada (Martin 1983); Caradoc, Portugal (Paris 1979); Caradoc-Ashgill, Gotland (Grahn 1982a); Caradoc to Ashgill, south-west Europe (Paris 1981); Caradoc to Ashgill, Québec (Achab 1986b); Vauréal Formation (*C. prominens elongatus* Zone), Anticosti Island (Achab 1977b); Elles Bay Formation (Ashgill), Anticosti Island (Achab 1978b); Ashgill, Morocco (Elaouad-Debbaj 1986).

?*Cyathochitina macastyensis* Achab 1978
(Pl. 7, fig. 6)

1978 *Cyathochitina macastyensis* Achab, p. 305-306, Pl. 2, fig. 5-6,10.

Diagnosis (Achab 1978) : "body conical with convex flanks, and with the greatest width situated in the middle part of the test. There is a distinct shoulder, and the flanks are nearly straight in the lower part of the text. Neck cylindrical, of variable length, well differentiated from the chamber. Base of the chamber flat showing an entire carina which is a thin membrane". [Translation].

Description : chitinozoan with a cylindrical to gently flaring neck, with a straight aperture, strong flexure, and a well marked shoulder. The widest point is at the mid-point of the chamber and the flanks are straight to slightly convex below the middle point. The base is concave, but no carina or ornamentation is seen.

Material : one specimen.

Dimensions : Maximum length 162μm
Length of neck 44μm
Maximum width 94μm
Width of neck 40μm

Occurrence : black shale, Glen Fruin (HB/GF/1).

Previous occurrence : Macasty Formation (Caradoc), Anticosti Island, Québec (Achab 1978a).

Remarks : this specimen does not show a carina, but otherwise is very similar to *Cyathochitina macastyensis* illustrated by Achab (1978) particularly Pl. 2, fig. 5. *Cyathochitina macastyensis* differs from most other similar species of *Cyathochitina* by its straight to slightly convex sides.

Cyathochitina protocalix Paris 1981

(Pl. 7, figs 8-11)

?1939 *Conochitina calix* Eisenack; Eisenack, p. 137, Pl. B, fig. 5.

?1962 *Cyathochitina calix* (Eisenack); Eisenack, p. 296-297, Pl. 14, fig. 3

1981 *Cyathochitina protocalix* Paris, p. 293-295, Pl. 16, figs 1-5, 8-10, 13-15, 17,18; Pl. 8, fig. 19,20.

Diagnosis (Paris 1981) : "subcylindrical chitinozoan, elongated (length/ diameter of chamber equals four), with an undifferentiated neck and chamber; surface smooth to slightly granular; membranous carina developed on the aboral margin; an extension of the flanks; base of the body convex; taking the shape of a flat mucron or perhaps more differentiated". [Translation].

Description : elongate, subcylindrical smooth walled test with little or no differentiation into chamber and neck. The maximum diameter is developed along the base and is about a third of the maximum length (though many of the specimens are broken). The base is generally flat to weakly convex and there is a very thin membranous carina (about 6μm wide) developed. A basal callus is present on the base. The apertural width is about half the maximum width.

Material : approximately twenty five specimens

Dimensions : Maximum length 199(238)284μm
Basal width 94(105)122μm
Apertural width 50(63)84μm
10 specimens measured

Occurrence : Jubilation Member, Doularg Hill, Girvan (MV/G/9).

Previous occurrence : upper Arenig to lower Llanvirn, South-west Europe, (Paris 1981)

Remarks : this species has straigt er sides than *Cyathochitina calix,* does not show such differentiation of neck and chamber, and has a smaller carina.

?*Cyathochitina* cf. *regnelli* Eisenack 1955

(Pl. 8, fig. 1)

1955 *Cyathochitina regnelli* Eisenack, p. 313-314; Pl. 1, fig.7,18
1980 *Cyathochitina regnelli* -Grahn, p.27-28, fig.15,E-G.

Description (Grahn 1980): "*Cyathochitina* species with a subconical vesicle. the base is convex to almost flat, with concentric structures. The basal edge has a transparent carina. Orally of the basal edge the body is concave, then after half to three quarters of the total length becomes cylindrical in a neck that widens towards the aperture. The aperture is straight and very wide compared to the base. The vesicle wall is covered with transverse thickenings".

Description : conical chitinozoan with an undulating but more or less straight base and an angular basal edge. The sides are concave in the chamber and straight in the neck. There is weak differentiation into chamber and oral tube. The maximum width is developed along the base. The oral tube is half of the maximum length, and the aperture is wide (two-thirds of the maximum width) and straight.

Material : one specimen.

Dimensions : Length 90µm
Basal width 90µm
Apertural width 63µm.

Occurrence : *P. acuminatus* Zone, Main Cliff, Dob's Linn (SU/DL/54).

Previous occurrence : upper Arenig to lower Llanvirn, Öland, (Grahn 1980); upper Arenig to lower Llanvirn, Dalarna, Sweden (Eisenack 1955b,1968b); Llanvirn, Tallinn, Estonia (Grahn 1984b).

Remarks : the carina cannot now be distinguished from the basal edge but the general overall morphology and size of this specimen fits in well with the description given by Grahn (1980).

Cyathochitina stentor (Eisenack 1937)

(Pl. 8, fig. 3)

1937 *Conochitina stentor* Eisenack, p.221-222; Pl. 15, figs1-3.
1955 *Cyathochitina stentor* (Eisenack); Eisenack, p.313

Description (Laufeld 1967): "this large species has a cylindrical to subcylindrical neck comprising 30-40 per cent of the vesicle length. The aperture is straight. Flexure and shoulder are weak. The body is constricted in its aboral part and the sharp, very thickened basal edge is provided with a long skirt-like flange which widens rapidly. The vesicle wall is composed of a thick inner layer and a very thin outer one. A few dozen thickened longitudinal ribs support the wall. At the aperture they are finer but aboralward they grow broader and higher. Each single rib is weakly undulated and could be followed from the aperture into the basal flange. They taper in the flange and are inconspicuous in its outermost part. In transverse section the ribs are triangular with the apex protruding in relief from the vesicle wall. This is very conspicuous at the wider part of the body, where a transverse section strongly resembles a cogwheel. Occasionally, the ridges are provided with delicate, triangular appendages. In the grooves between the ridges the outer wall displays a reticulate pattern. This reticulum often disappears on the neck, where the wall is smooth or finely granulated. The neck and body never show any transverse structure. Nevertheless, the basal flange displays a transversal construction. At the attachment of the flange the ribs protrude in relief but aboralward they plunge into or are surrounded by transversal bands. The bands, which are thicker in the aboralward part, where they are also fenestrate, are arranged like roof-tiles. The base has a thickened central part which is surrounded by a thinner portion with concentric thickenings".

Description : cylindrical chitinozoan with slightly flared flanks and a small carina at the base which is greater in width than the maximum width of the body, and approximately one tenth of the maximum length. There is only weak differentiation into neck and chamber, and there is no visible ornamentation, but preservation is not good.

Material : one specimen.

Dimensions : Maximum length 480μm
Length of carina 50μm
Width of carina 110μm
Maximum width of chamber 85μm
Apertural width 30μm.

Occurrence : *P. acuminatus* Zone, Main Cliff, Dob's Linn (SU/DL/57).

Previous occurrence : Llanvirn, Normandy (Rauscher 1970); Kuckers Beds (Caradoc), Estonia (Eisenack 1962a,b, 1968b); Caradoc of Sweden (Laufeld 1967); Herscheider Shale (?Caradoc), Westphalia (Eisenack 1939); upper Llandeilo to Caradoc, Sweden (Grahn 1981b); Caradoc, Sweden (Grahn 1981a, 82a).

Remarks : this specimen is a little too small for the published range but its shape is quite typical of *Cyathochitina stentor.*

Cyathochitina vaurealensis Achab 1977

(Pl. 8, fig. 2)

1977 *Cyathochitina vaurealensis* Achab, p. 420-422, Pl. 4, figs 4, 6-10

Diagnosis (Achab 1977a) : "test generally conical, with body and neck poorly differentiated. The greatest width is found at the base of the body and is equal to half or a third of the total length. The carina is developed as a thin, transparent membrane about 15-20µm wide. The carina does not show radial or concentric structures and falls like a skirt. No constriction is observed at the point of insertion of the carina. The test wall is unornamented". [Translation].

Description : cylindro-conical chitinozoan with a weakly differentiated neck and chamber. The aperture is straight. The chamber has weakly convex sides, and the maximum width is situated along the base where a carina, about 25µm wide, is developed. This specimen is very crumpled but appears to be unornamented.

Material : one specimen

Dimensions : Maximum length 310µm
Maximum width 205µm
Apertural width 65µm.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/24).

Previous occurrence : *D. complanatus* and *C. prominens elegans* Zones

Vauréal Formation, Anticosti Island (Achab 1977a, b, 1978b); Ashgill, Morocco (Elaouad-Debbaj 1984).

Remarks : this specimen is larger than the size ranges specified by Achab (1977a,b), but otherwise appears to fit well within the diagnosis.

Cyathochitina sp. A

(Pl. 8, fig. 4)

Description : large *Cyathochitina* species with a very conical body and a broadly cylindrical neck which flares slightly towards the aperture (a quarter of the maximum width). The flexure is well marked but there is no shoulder. There are some conical spines (~5μm in length) on the flanks near the oral tube. The maximum width is along the base which is convex and presumably carinate. The basal edge is rounded. The neck is a quarter of the length but the specimen is strongly compressed and this may be an erroneous measurement. Apart from the spinose ornament on the flanks the rest of the cell is felted but unornamented.

Material : one specimen

Dimensions : Length 325μm
Width 320μm
Oral tube : 75 x 80μm.

Occurrence : North Glen Sannox, Arran (HB/A/3).

Remarks : this specimen is very like *Cyathochitina kuckersiana latipatigium* (Jenkins 1969) but the flanks of the present specimen are more flaring and it has a much more accentuated flexure. It bears a superficial resemblance to the Devonian form *Sphaerochitina schwalbi* Collinson and Scott (1958), and also to *Clathrochitina eisenacki* Taugourdeau 1961 but that has a much longer neck and a basal reticulum. No other specimens have been encountered with this type of ornamentation.

Cyathochitina sp B

(Pl. 8, fig. 6)

Description : chitinozoan with a small spheroidal chamber, a small carina and a long cylindrical neck. The maximum width is developed in the middle of the chamber, and the carina is two thirds of the maximum width. The neck is cylindrical and the body is a third of the total length. The aperture is straight, and slightly flaring. No ornament is visible.

Material : one specimen

Dimensions : Length neck 200µm
Length of chamber 60µm
Length of carina 10µm
Width of neck 50µm
Width of chamber 65µm
Width of carina 40µm.

Occurrence : *D. anceps* Zone, Main Cliff, Dob's Linn (SU/DL/46).

Remarks : this specimen is quite similar to *Cyathochitina stentor* Eisenack 1937 but the chamber is more conical, the carina less well developed, the neck is too long, and the specimen on the whole is much too small.

Cyathochitina sp. C

(Pl.8, fig. 5)

Description : elongate chitinozoan with straight flanks and a highly convex base. The basal edge is highly angular and a carina may be present but this is not certain. The aperture is straight and there is no flexure or shoulder.

Material : one specimen.

Dimensions : Maximum length 215µm
Maximum width 120µm

Apertural width 93μm.

Occurrence : *D. anceps* Zone, Main Cliff, Dob's Linn (SU/DL/46).

Cyathochitina sp. D
(Pl. 8, fig.11)

Description : cylindrical chitinozoan with no differentiation into neck and chamber. There is no collarette. A well developed and undulating carina is present which flares from the base of the body with a notch at the point of attachment. The maximum width is along the carina. the aperture is straight and two-thirds of the width of the carina.

Material : two specimens

Dimensions : Length 125-271μm
Width of aperture 29-59μm
Width of carina 42-89μm.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/24, 28).

Remarks : this specimen is poorly preserved but it is quite close to *Cyathochitina alata*, and *Cyathochitina fistulosa* Taugourdeau and Jekhowsky (1960) although the carina is much larger, and better developed than both of those. *Cyathochitina stentor* has a similar carina but shows more differentiation into neck and chamber.

Cyathochitina spp. indet.

HB/BB/5, Bofrishlie Burn, Aberfoyle. (Pl. 12, fig. 20)
HB/LC/5, Limecraig Quarry, Aberfoyle (Pl.12, fig. 18)

Genus *Desmochitina* Eisenack 1931

1931 *Desmochitina* Eisenack, p.91.

Diagnosis (Eisenack 1931) : "many individuals in the form of ampoules or bottles, united in colonies or chains. The individuals situated at the extremity of the chains, called the primary individual possesses an external stalk (support) which gives it a different form to the others". [Translation].

Type Species: *Desmochitina nodosa* Eisenack 1931.

Paris (1981) remarks that there are many different morphotypes of *Desmochitina* and thus restricts the genus :-

Diagnosis (Paris 1981) : "chitinozoans with a spheroidal to ovoid body; without a neck, but with a collarette, which is sometimes well developed; the test is thick with a smooth, shagreenate, felted or finely tuberculate external membrane; spinose ornament is absent; aboral pole often has a short mucron, sticking to the operculum of the preceding cell; the operculum is discoidal, simple, level with the oral side, or placed at the base of the collarette; in this genus organisation in chains is common".[Translation].

Paris (1981) erects two subgenera of *Desmochitina* to allow for forms with and without a mucron.

Desmochitina (Desmochitina) Paris 1981

Diagnosis (Paris 1981) : "sub-genus of *Desmochitina* with a cylindro-ovoid body; oral opening generally surrounded by a collarette and closed by a simple operculum; aboral pole carries a short mucron which is fixed to the centre of the operculum of the following cell; that operculum sticks to the mucron and becomes solid; test smooth (devoid of cones, tubercules, spines or hairs) but often with a smooth, shagreenate, felted, spongy, or microgranular surface, or with a folded membrane. Chains resistant". [Translation].

Desmochitina (Desmochitina) bulla Taugourdeau and Jekhowsky 1960

(Pl.8, fig. 7)

1960 *Desmochitina bulla* Taugourdeau and Jekhowsky, p.1225, Pl.vi-vii, figs 87-88.

Diagnosis (Taugourdeau and Jekhowsky 1960) : "very large globular form with a subspherical body. Neck short, funnel shaped over its entire length, operculum rarely in place, copula always broken. Surface generally granulo-tuberculate". [Translation].

Description : Very large chitinozoan with a spherical chamber and a slightly flared cylindrical neck. The copula (one eighth of the maximum length) appears to be very robust, and it is slightly rounded. The neck is a quarter of the length. The maximum width of the chitinozoan is in the central position. Flexure well developed, shoulder weak, base convex, and basal edge very rounded.

Material : one specimen only.

Dimensions : Length:400µm
Width: 280µm.

Occurrence : White limestone, Limestonebank Quarry, Clunie, Perthshire (HB/CQ/1).

Previous occurrence: Arenig, Bohemia (Paris and Mergl 1984); Llanvirn to Llandeilo of the Sahara (Taugourdeau and Jekhowsky 1960); Ordovician, Sahara (Benoit and Taugourdeau 1961).

Remarks : this specimen is similar to *Linochitina pissotensis* Paris, however differs by being very much larger, and much more globular and its neck is more differentiated. Within the genus *Desmochitina* this specimen is similar to several species, *D. bulla, D. urna* Eisenack, *D. urceolata* Benôit and Taugourdeau, and *D. amphorea* Eisenack. However *Desmochitina bulla* is distinguished from the latter three by its greater size and globosity, and by having a longer neck. It should however be noted that this specimen is slightly less globose than the holotype.

Desmochitina (Pseudodesmochitina) Paris 1981

Diagnosis (Paris 1981) : "small *Desmochitina* wider than it is tall; body cylindro-ovoid; aboral pole slightly convex, rounded or truncated ogival; neck absent (or very reduced); collarette absent or present, and in that case often developed; operculum simple, discoidal, often prolonged in the aboral direction by a short membranous expansion; operculum level with the oral side or situated at the base of the collarette; copula always absent; no mucron; test smooth (devoid of spines, hairs, or cones, but often felted, spongy or microtuberculate); chains possible by juxtaposition or simple adherance". [Translation].

Desmochitina (Pseudodesmochitina) minor Eisenack 1931

1931 *Desmochitina? minor* Eisenack, p. 93, Pl. 3, fig. 10-11.
1958 *Desmochitina minor* forma *typica* Eisenack, p. 398, Pl.2, fig. 29
1967 *Desmochitina? minor* Eisenack:Laufeld, p. 328-329, fig. 25, A-D.

Original diagnosis (Eisenack 1931) : "this form has been observed as primary and secondary units, the one being distinguished from the other by the presence of a basal process, [I am inclined to suggest] that these belong together and form a colony, since the technician due to the preparation techniques often causes them to fall [apart] into initial units, or it may be that the chains can fall apart in life. The units are oval in profile, often with flattened bases. The opening springs from a short collar, which has the form of an obtuse cone shape, and with its smaller base sitting on the body. Accordingly an obtuse angled but sharp notch results where the neck and body meet. The periderm appears not to be completely smooth, but to have a somewhat granular outer surface".[Translation].

Remarks : Eisenack's (1931) original diagnosis shows that there were two different forms represented in this species, one with a basal process and one without. Paris (1981) discusses this species in detail, stating that the holotype (which possessed the basal process) of *D. minor* is a junior synonym of *D.*

nodosa, whereas the neotype (no basal process) is not. To avoid confusion he suggests that the species be restricted and the neotype be designated the new holotype. Paris (1981) also suggests that is advisable to keep the 'forma' system in this species as much of the work done on them has been using the silhouette only. Paris' work using the S.E.M. and biometrics, indicates that the ornament could be very important in differentiating one form from another. In his description of this species Grahn (1980) shows the wall of *Desmochitina minor* to be heavily ornamented with spines or spinose thickenings, however this is surely not the case in all specimens of *D. minor* and indeed Eisenack (1931) mentioned only a granular surface.

Desmochitina (Pseudodesmochitina) minor forma *cocca* Eisenack 1931
(Pl.8, fig.9)

1931 *Desmochitina cocca* Eisenack, p. 94, Pl. 3, fig. 14, 15.
1962 *Desmochitina minor* forma *cocca* Eisenack; Eisenack p. 304, Pl. 16, figs 13-15.
1976 *Desmochitina minor* forma *typica* (pars) - Eisenack, p. 189, Pl. 2, fig. 19.

Diagnosis (Eisenack 1931) : "only initial tests found; primary test not found. Form of the test is almost globular, only a little longer than wide. The spherical test has a very short neck but with a gradual transition without a sharp notch. length : breadth ratio of 1.05:1. A copula is not found; indeed one finds also in *D. nodosa and D erratica* likewise forms without connecting [parts]". [Translation].

Description (Grahn 1980) : "*Desmochitina* species with spherical to subspherical vesicle. The collar is short and cylindrical with a straight aperture. Where visible, the operculum is a simple disc. The vesicle wall is perfectly smooth".

Description : small spherical chitinozoan with a small collarette. the flexure is marked but there is no shoulder. The base is convex and the basal edge rounded. The maximum width is situated in the middle of the chamber and the L:B ration is 1.27:1. The collarette is about one eighth of the maximum length and half of the width.

Material : one specimen.

Dimensions : Length 83µm

Width 65µm

Width of collarette 30µm

Length of collarette 10µm.

Occurrence : *D. anceps* Zone , Main Cliff, Dob's Linn (SU/DL/46).

Previous occurrence : upper Arenig to lower Llanvirn, Öland, Grahn (1980, 81a); middle Caradoc, Osterseekalk? Baltic (Eisenack 1931); Llandeilo to middle Caradoc, Estonia (Eisenack 1962a, b); lower Caradoc of Shropshire (Jenkins 1967); Caradoc of Normandy (Rauscher and Doubinger 1967, Rauscher 1974); lower Caradoc, Portugal (Paris 1981). Caradoc, Portugal (Henry *et al.*1974); lower Caradoc, Gotland (Eisenack 1968b); Ordovician, Russian Platform (Umnova 1969); Caradoc, Gotland (Grahn 1982a); Llanvirn to Caradoc, Öland (Grahn 1981a); Llandeilo to Caradoc, Portugal (Paris 1981).

Desmochitina (Pseudodesmochitina) minor forma *elongata* Eisenack 1958

(Pl. 8, fig. 8; Pl. 26, fig. 1)

1958 *Desmochitina minor* forma *elongata* Eisenack, p. 398, Pl. 2, figs 31, 32.

Diagnosis (Eisenack 1958) : "ratio of length to width large; body in the form of a long stretched ellipse out of which a collar emerges; diameter of the collar always smaller than the body. Wall smooth". [Translation].

Description : a chitinozoan with a large ellipsoidal chamber and a small collarette. The maximum width is one third of the way up the chamber. The basal edge is indistinct and the base is convex. No ornament is seen.

Material : two specimens

Dimensions : Length 115-125µm

Width 68-75µm.

Occurrence : Bofrishlie Burn, Aberfoyle (HB/BB/2)

Previous occurrence : Glaukonitkalk (B2) of the Baltic (Llanvirn to Llandeilo), (Eisenack1958a); Öland (upper Arenig to lower Llanvirn) (Grahn 1980); upper Arenig, Estonia (Eisenack 1968b); Llandeilo to middle Caradoc, Estonia (Eisenack 1962b).

Remarks : Although these chitinozoans are not very well preserved, and the surface is felted (caused by recrystallisation), the overall shape of this species is very diagnostic. This species differs from *Desmochitina (Desmochitina) juglandiformis* Laufeld because the latter usually has the operculum of the preceeding specimen attached to its base. *Desmochitina (Pseudodesmochitina) piriformis* Laufeld has a much flatter, straighter base than *Desmochitina (Pseudodesmochitina)* minor *forma elongata.*

Desmochitina (Pseudodesmochitina) minor ? forma A Eisenack 1931

(Pl. 8, fig. 10)

Description: small spherical chitinozoan with a very small collarette, and with the operculum still attached in one or two of the specimens. There is a wide basal process one tenth of the length and a third of the width of the vesicle, and the base is convex. The preservation of these specimens is not very good, however there does not appear to be any ornamentation.

Material : five specimens.

Dimensions : Maximum length 136(149)160µm

Maximum width 120(136)159µm

3 specimens measured.

Occurrence : North Glen Sannox, Arran (HB/A/3).

Remarks : although Grahn (1980) shows the wall of *Desmochitina minor* to be heavily ornamented with spines or spinose thickenings, this is surely not the case in all specimens of *D. minor* and indeed Eisenack (1931) recorded only a granular surface on the holotype of *Desmochitina minor.*

Desmochitina (Pseudodesmochitina) sp. A

(Pl. 9, fig.2)

Description : a species of *Desmochitina* that is greatly recrystallised. Even so it is possible to distinguish a collarette (one tenth of the maximum length, half of the maximum width). The basal edge is rounded and the base convex. The flexure is distinct and the edge of the collarette is straight. The maximum width is situated at the middle point.

Material : one specimen only.

Dimensions : Length : 100μm
Width : 95μm.

Occurrence : Balmaha, Loch Lomond, (HB/Bal/1).

Remarks : this specimen is very similar to *Desmochitina (Pseudodesmochitina) minor*, but it is too recrystallsed to determine correctly to which species it belongs.

Desmochitina (Pseudodesmochitina) sp. B

(Pl.9, fig. 1)

Description: a small spherical chitinozoan with a rounded base and a curved basal edge. There is no shoulder, flexure or collarette, but along the aperture there is a series of splits reminiscent of the apical margin in dinoflagellates with apical archaeopyles. No ornamentation is apparent.

Material : one specimen.

Dimensions : Length 200µm

Width 140µm.

Occurrence : Bofrishlie Burn, Aberfoyle (HB/BB/3).

Genus *Hercochitina* Jansonius 1964 emend. Jenkins 1967

1964 *Hercochitina* Jansonius, p. 908.

1967 *Hercochitina* Jansonius emend. Jenkins, p. 461

Diagnosis (Jansonius 1964) : "vesicle shaped as in *Conochitina* (q.v.); basal edge may be narrow or broad, but always rounded; lip at aperture usually fimbriate; cuticle single layered; vesicle ornamented with more or less straight longitudinal ridges that may interconnect; ridges may be low and solid, or may dissolve into rows of spines interconnected at the tips; aborally the ridges may extend beyond the base as simple, or complex groups of spines; orally the ridges fade, often breaking into rows of small spines which show well on the thin-walled lip; operculum and prosome as in *Conochitina* . Chain formation has not been observed".

Emended Diagnosis (Jenkins 1967): "variable conical or cylindroconical tests with ornament of narrow ridges, or spines of uniform length, standing normal to test wall and arranged in longitudinal rows. Spines in each row connected at their tips by a more or less continuous bar running roughly parallel with test wall".

Type Species: *Hercochitina crickmayi* Jansonius 1964

Hercochitina cf.*turnbulli* Jenkins 1969

(Pl. 9, fig.3)

1969 *Hercochitina turnbulli* Jenkins, pp. 28-29, Pl. 8, figs. 12-17; Pl. 9, figs. 1-5; Text-fig. 9.

Diagnosis (Jenkins 1969) : "chamber conical, two-thirds to three-quarters of the total length; maximum diameter at the base, 75-90% chamber length; base flat, margin bluntly rounded. Oral tube cylindrical or slightly flaring, half to two-thirds maximum diameter in width; aperture bearing few blunt spines (up to 3μm in length). Ornament slender, simple and λ- spines up to 15% maximum diameter in length; arranged in 20-30 longitudinal rows extending from the basal margin to the aperture; longitudinal bars connecting spine tips discontinuous, commonly lacking".

Description : spherical chitinozoan with a weakly differentiated conical neck. The chamber is three quarters the maximum length. the maximum diameter of the test is developed half way up the length of the chamber. Apertural diameter two-thirds maximum diameter, and the oral tube and the aperture are the same width. The base is convex and the basal margin is rounded. The ornament is weakly developed, probably due to corrosion, and appears to be left only as a relic, and consists of six weakly defined longitudinal rows.

Material : one specimen.

Dimensions : Maximum length 70μm
Length of chamber 50μm
Maximum diameter 50μm
Apertural diameter 35μm.

Occurrence : *D. anceps* Zone, Main Cliff, Dob's Linn (SU/DL/9).

Previous occurrence : Viola and Fernvale Limestones (Caradoc and Ashgill), Oklahoma (Jenkins 1969).

Remarks : the specimen from Dob's Linn, although poorly preserved is very similar in shape and ornament to that figured by Jenkins (1969, Pl. 9, fig.4), which he states to be a poor specimen of *H. turnbulli* . My specimen is smaller, and has no prosome but in other respects is similar.

Genus *Kalochitina* Jansonius 1964

1964 *Kalochitina* Jansonius p. 909.

Diagnosis (Jansonius 1964) : "vesicle conical to pear shaped; base flat or rounded; basal edge distinct, rounded; sides convex or nearly straight; shoulder indistinct, flexure more distinct; neck short, cylindrical to conical, rarely indistinct; lip short but distinct, thin-walled; aperture smooth or fimbriate; short membrane attached to operculum; operculum internal but shallow; cuticle single-layered; vesicle completely involved in spinose ornamentation which is reduced near aperture and near the aboral pole; spines may be simple, or branched or multiple, usually very regularly distributed".

Type species : *Kalochitina multispinata* Jansonius 1964.

Kalochitina sp A
(Pl. 9, fig. 5)

1988 *Kalochitina* sp. 1 Whelan p. 43.

Description : small conical chitinozoan with a small collarette one fifth of the maximum length and greater than half the maximum width which is situated at the base. The base is flat and the basal edge angular. A weak shoulder is present. The ornament consists of small, simple, conical spines or conical spines with double terminations.

Material : two specimens

Dimensions : Length 55-90μm
Basal width 52-75μm
Apertural width 32-42μm
Spine length 4-5μm.

Occurrence : *G. persculptus* Zone (SU/DL/35) Linn Branch section; *P. acuminatus* Zone (SU/DL/41), Main Cliff, Dob's Linn.

Kalochitina sp. B

(Pl.9, fig. 4)

Description : Pyriform test with no flexure or shoulder and with convex sides. The base is convex and the basal edge rounded. The surface of the test is ornamented with small simple spines (about 3µm long). There is a mucron on the base and the aperture is slightly fringed. The maximum width is just above the base.

Material : one specimen

Dimensions : Length 145µm
Maximum width 90µm
Width at aperture 26µm.

Occurrence : Jubilation Member, Doularg Hill, Girvan (MV/G/9).

Genus *Lagenochitina* Eisenack 1931

1931 *Lagenochitina* Eisenack, p.80.

Diagnosis (Eisenack 1931 *in* Combaz *et al.* 1967) : "bottle shaped; the greatest width near the middle, the chamber passes unnoticeably into the neck. Walls without ornamentation, op ening smooth. Neck near cylindrical passing unnoticeably into the chamber. Body of the chamber lightly flattened. The ratio of the neck to chamber is variable. Walls thickened presenting a light granulation". [Translation].

Type Species: *Lagenochitina baltica*, Eisenack 1931, p.80-81, Pl.1, fig. 1-3.

?*Lagenochitina brevicollis* Taugourdeau and Jekhowsky 1960

(Pl. 9, fig. 7)

1960 *Lagenochitina brevicollis* Taugourdeau and Jekhowsky, p. 1228, Pl. VIII, figs, 109-110.

Diagnosis (Taugourdeau and Jekhowsky 1960): "body variable, ovoid, globular, sometimes with an angular outline; neck short, flares at the aperture".[Translation].

Description: ovoid chitinozoan with no visible flexure or shoulder. The base is convex and the basal edge curved. there is some development of small spines at the basal edge. The aperture is convex in shape.

Material : one specimen

Dimensions : Length : 300µm
Width : 180µm
Spines : 15µm

Occurrence : North Esk River section, Edzell, (HB/NE/6).

Previous occurrence : Llanvirn to Ashgill, Sahara (Taugourdeau and Jekhowsky 1960); Ordovician, Sahara (Taugourdeau 1966b).

Remarks : the spines developed along the aboral edge of the specimen are perturbing. No other specimen shows spines of this type, coupled with the vesicle shape, and although the neck is more poorly developed in this specimen, its shape appears to fit best with *Lagenochitina brevicollis*.

Lagenochitina obeligis? Paris 1981.

(Pl.9, fig.6)

? 1958 *Lagenochitina estonica* Eisenack p. 395.

1960 *Lagenochitina* cf. *baltica* Eisenack; Taugourdeau and Jekhowsky, p.

1230, Pl. 9, fig. 121.

1960 *Lagenochitina baltica* Eisenack : Taugourdeau and Jekhowsky, p. 1230, Pl. 9, fig. 122.

1961 *Lagenochitina baltica* Eisenack ; Benoît and Taugourdeau, fig. 2.

1968 *Lagenochitina brevicollis* Taugourdeau and Jekhowsky; Rauscher, p. 56, Pl. 3, fig.9.

1968 *Lagenochitina* sp.; Rauscher, Pl. 3, fig. 10.

1979 *Lagenochitina* cf. *baltica* Eisenack; Profichet, p. 59, Pl. 3, fig. 2.

Diagnosis : (Paris 1981) "chitinozoan of the genus *Lagenochitina* with an ovoid chamber; cylindrical neck terminated by a flared collarette; flexure and shoulder present; chamber longer than the neck; diameter of the neck is about half that of the body. Aboral pole carries the impression of a mucron; test thickened and rugulate; chains very rare". [Translation]

Description : chitinozoan with a cylindrical neck, with a flaring collarette, an ovoid body, a very strongly convex base, and an insignificant basal edge. The sides are convex, there is a strong flexure and a weak shoulder. The neck is a third of the length and a third of the maximum width, which is situated at approximately the mid point of the chamber. The specimen is broken and no ornament is visible except for what appear to be small spines on the aboral apex.

Material : one specimen

Dimensions : Maximum length 155μm

Length of neck	50μm
Maximum width	95μm
Width of neck	30μm.

Occurrence : North Glen Sannox, Arran (HB/A/3).

Previous occurrence : Lower Ordovician of Sahara (Taugourdeau and Jekhowsky 1960, Benoît and Taugourdeau 1961); middle Arenig of Montagne Noire (Rauscher 1968); middle Arenig of south-west Europe (Paris 1981).

Remarks : this specimen is very similar to *Lagenochitina estonica* Eisenack

1955, however the present specimen is much shorter and with a more pointed aboral termination. Paris (1981) remarks that *Lagenochitina obeligis* differs from *Lagenochitina ovoidea* Benoît and Taugourdeau (1961) by having a more obvious separation of neck and chamber and a collarette rather than a flaring neck as in *Lagenochitina ovoidea.* It is also similar to *Lagenochitina boja* Bockelie (1980) but is not so elongate or large.

Lagenochitina prussica Eisenack 1931

(Pl. 9, fig.9)

1931 *Lagenochitina prussica* Eisenack, p.81; Pl. 1, figs.4-5.

Diagnosis (Laufeld 1967) : "*Lagenochitina* species with a subspherical body and a subcylindrical neck which is strongly widened towards the straight aperture. the base is strongly convex and the basal edge inconspicuous. The flexure is sharp to shortly rounded and very distinct and the shoulder is lacking. The vesicle wall has the same construction as in *L. baltica* but the granules of the outer layer are less conspicuous. There is no distinct central thickening in the operculum. It is plano-convex with the convexity pointing in the aboral direction. The prosome is not as well developed as in *L.baltica* ".

Description : cylindro-spheroidal body, with a well developed flexure which is characteristic of the species. There is no ornament though some coarse granules can be seen above the shoulder which is weak. The aperture is straight, slightly thinner, and serrate. The widest part is about a third way up from the base which is very convex. There is a small crack at the base.

Material : one specimen.

Dimensions : Maximum length : 126µm

Maximum width : 71µm

Oral tube : 39µm long, 35µm wide.

Occurrence : *D. anceps* Zone, Main Cliff, Dob's Linn (SU/DL/46).

Previous occurrence : Fjäcka Shale (upper Caradoc), Sweden (Laufeld 1967); Orthoceratite (Ordovician) Limestone (Eisenack 1931,1965); Caradoc to Ashgill, Gotland (Grahn 1982a); Molodova Beds (*P. linearis* Zone), Podolia (Laufeld 1971); Ashgill, Estonia (Nõlvak 1980); Ashgill, Morocco (Elaouad-Debbaj 1984).

Remarks : this species differs from *Lagenochitina baltica* by its very marked flexure, which is well seen in the specimen from Dob's Linn.

Lagenochitina cf prussica

(Pl. 9, fig.12)

Description : *Lagenochitina* species with a spheroidal chamber and a short neck about a quarter of the length of the test. Maximum width about a quarter way up from the aboral end. Base convex and basal edge rounded. The flexure is not as distinct as in the specimen from Dob's Linn, as some recrystallisation appears to have occurred.

Material : one specimen.

Dimensions: Length: 280µm
Width : 200µm.

Occurrence: white limestone, Limestonebank Quarry, Clunie, Perthshire (HB/CQ/1).

Previous occurrence: Ordovician of Baltic (Eisenack 1931); Caradoc of Dalarna, Sweden (Laufeld 1967).

Remarks : although the flexure is not as distinct in this specimen as it is in *Lagenochitina prussica* it is still sufficient to distinguish this species from *Lagenochitina baltica.*

Lagenochitina sp. A

(Pl. 9, fig.10)

Description : chitinozoan with a subspherical chamber and a cylindrical neck. The base is flat and the basal edge weakly curved. The flanks are convex. No shoulder, flexure well marked. Neck short, cylindrical slightly flaring with a curved aperture. There is a slight suggestion of small spinose ornament along the base, but it is poorly developed. The maximum width is a third of the way up the chamber, and the width of the aperture a third of the maximum width.

Material : one specimen.

Dimensions : Length 155µm

Length of chamber 37µm

Width 112µm

Width of aperture 37µm.

Occurrence : *D. anceps* Zone, Main Cliff, Dob's Linn (SU/DL/9).

Lagenochitina sp.B.

(Pl. 9, fig.11)

Description : cylindro-ovoid chitinozoan with a rounded basal edge and a convex base. The maximum width is situated in the middle of the chamber and is two thirds of the maximum length. The neck, which is about a third of the maximum length, and half of the maximum width is separated from the chamber by a weak flexure, however there is no shoulder. The neck terminates in a flaring collarette, and the surface of the test is ornamented with intermittent, simple spines up to 35µm in length.

Material : one specimen.

Dimensions : Maximum length 110µm

Length of neck 40µm

Maximum width 74µm

Width of neck 40μm.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/27).

Lagenochitina sp. C.

(Pl. 9, fig. 8)

Description : chitinozoan with a cylindrical neck and a spherical body. The base is convex and the basal edge is rounded, and there is a well marked flexure. The neck is about a fifth of the maximum length and about one third of the maximum width which is situated in the middle of the chamber. There is no ornament, but recrystallisation appears to have occurred.

Material : one specimen.

Dimensions :Maximum length : 118μm
Length of neck : 24μm
Maximum width : 60μm
Width of neck : 25μm.

Occurrence : Achray Sandstone, Limecraig Quarry, Aberfoyle, (HB/LC/1).

Lagenochitina sp. D

(Pl. 10, fig. 1)

Description : chitinozoan with a small cylindrical neck and an ovoid body. The neck varies between about a quarter and a tenth of the maximum length of the body, and is about a third of the maximum width, which is situated in the centre of the chamber. The basal edge is rounded and the base is convex. There is no ornament, but preservation is very poor.

Material : three specimens

Dimensions : Maximum length : 182(304)382μm
Length of neck : 40(47)50μm
Maximum width : 110(173)260μm

Width of neck : 30(62)80µm.

Occurrence : North Glen Sannox, Arran (HB/A/3).

Lagenochitina spp. indet

SU/B/13, Cross Water, Barrhill (Pl. 12, fig. 1)
HB/LC/9, Limecraig Quarry, Aberfoyle (Pl. 12, fig. 2)
HB/LC/11, Limecraig Quarry, Aberfoyle (Pl. 12, fig. 3)
HB/LC/11, Limecraig Quarry, Aberfoyle (Pl. 12, fig.10)
HB/LQ/9, Leny Quarry, Callander (Pl. 12, fig. 17)
HB/LQ/9, Leny Quarry, Callander(Pl. 12, fig. 19)

Genus *Pterochitina* Eisenack 1955

1955 *Pterochitina* Eisenack p. 177

Diagnosis (Eisenack 1955) : "chitinozoans whose two axes are more or less equivalent and which has an annulate wing".[Translation.]

Type Species : *Pterochitina perivelata* (Eisenack1937) Eisenack 1955a

Pterochitina hymenelytrum Jenkins 1969
(Pl. 10, fig. 2)

1969 *Pterochitina hymenelytrum* Jenkins, p.23-25, Pl.7, figs 6-18; Text-fig. 7.

Diagnosis (Jenkins 1969): "oblate spheroidal or wide depressed conical chamber; chamber length about 60% maximum diameter, about 80% total length; maximum diameter of chamber (excluding outer membrane) midway along chamber. Oral tube short, sharply flaring; about 60% maximum diameter at its narrowest point, about 80% maximum diameter at aperture; the latter may be sealed by a disc-shaped apertural cap with narrow membranous flange. Thin outer membrane lacking consistent shape envelops the more rigid inner body, to which it is attached somewhere above and somewhere below the chamber's maximum diameter".

Description : oblate spheroidal chamber with its maximum width in the centre of the chamber. It has a short flaring neck, which thins oralwards. A small thin membrane is attached below the maximum width of the test. The flange has the appearance of a carina, and that and the shape of the body are diagnostic for this species.

Material : one specimen only.

Dimensions : Maximum length 62µm
Chamber length 45µm
Maximum diameter 64µm
Apertural diameter 39µm
Flange 6µm thick.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/18).

Previous occurrence : Viola and Fernvale Limestone (Caradoc and Ashgill), Oklahoma, (Jenkins 1969); Utica and Lorraine Groups of Saint-Roch (Achab 1986); Lotbinière Formation (Utica), (Martin 1983).

Remarks : See remarks under *C. megastrophica*

Genus *Rhabdochitina* Eisenack 1931

1931 *Rhabdochitina* Eisenack, p. 90-91.

Original Diagnosis (Eisenack 1931) : " length 0.5 to about 1mm. Width 0.08 to 0.1mm. The shape is perfectly cylindrical, the aperture where observable is never fringed. The distal end appears generally flattened. Either the flattening is more or less unmodified and only joined to the cylinder through a weakly developed rounded edge, or the cylinder firstly becomes conical in order to pass into the flattening, that than naturally becomes smaller. In a few cases this termination is hemispherical. In the flattened examples one can confirm an invagination. In the hemispherically closed examples the hemisphere sometimes leads into a very short cylinder, or it appears as if it has, which includes here a small opening. One can compare these stalks with small openings with many examples in *Conochitina claviformis* and perhaps also with the connecting stalks in the species of the genus *Desmochitina*. In bleached examples no opening is observable, indeed as yet no examples have been demonstrated with a clear stalk. A pole of a peculiar kind is shown in diagram 3 (Eisenack 1931). [Translation].

Type Species: *Rhabdochitina magna* Eisenack 1931

Rhabdochitina sp. cf. *R. gallica* Taugourdeau 1961

(Pl. 10, fig. 3)

1961 *Rhabdochitina gallica* Taugourdeau, p. 150, Pl. 4-5, fig. 71-75

1988 *Rhabdochitina gallica* Taugourdeau, Whelan, p. 43.

Diagnosis (Taugourdeau 1961) : "body sub-cylindrical, very slightly swollen towards the base, very thickset form (ratio of length/width : 3,5) <<collar>> more or less visible".[Translation].

Description : elongated, sub-cylindrical form with a flat base and a curved basal edge. There is no differentiation of body and neck, and the aperture is broken. There is a small spine near the base, which prevents these specimens from being included unequivocally in *R. gallica*.

Material : two specimens

Dimensions : Maximum length 175-260μm

Maximum width 75-82μm

Apertural width 50-70μm.

Occurrence : *D. anceps* Zone, Main Cliff, Dob's Linn (SU/DL/9).

Previous occurrence : Caradoc-Ashgill, Aquitaine (Taugourdeau 1961); Caradoc of Portugal (Paris 1979); Caradoc, Normandy (Rauscher and Doubinger 1967); Caradoc, North Wales (Atkinson and Moy 1971); Caradoc-Ashgill, Sahara

(Bouché1965).

Rhabdochitina gracilis Eisenack 1962

(Pl. 10, figs 4, 6)

1962a *Rhabdochitina gracilis* Eisenack, p.307-308; Text-fig.6; Pl. 14, fig. 2; Pl. 15, fig. 1.

1988 *Rhabdochitina magna* Eisenack: Whelan, p. 43.

Description (Grahn 1980): "*Rhabdochitina* species with subcylindrical vesicle. The base is convex with a broadly rounded basal edge. The aperture is straight. Some specimens have a basal process. The vesicle wall is perfectly smooth".

Description : subcylindrical chitinozoan with a narrow straight aperture, tapering without any differentiation, into neck and chamber. At the aboral end a basal process and the maximum width are developed. The apertural width is approximately a third of the maximum diameter. The base is flat and the surface smooth.

Material : four specimens.

Dimensions : Length 739-1065µm

Basal width 53-77µm

Apertural width 30µm

2 specimens measured.

Occurrence : *G persculptus* Zone (SU/DL/37), Linn Branch section, Dob's Linn; Shalloch Formation, Woodland Point, Girvan (MV/G/20, 21, 27).

Previous occurrence : upper Arenig to lower Caradoc, Öland (Grahn 1980,1981a); upper Arenig to lower Llanvirn, Sweden (Eisenack 1962a); upper Ashgill, Sweden (Grahn 1978); upper Ashgill, Baltic erratics (Eisenack 1968a); Caradoc and Ashgill of Gotland (Grahn 1982a); Arenig to Llanvirn, Massif Armoricain (Paris 1981); Ashgill of Anti-Atlas (Elaouad-Debbaj 1984); Llanvirn, France (Rauscher 1973); Caradoc, Normandy (Rauscher and Doubinger

1967); Ordovician, Baltic (Eisenack 1962b, 68b).

Rhabdochitina magna Eisenack 1931
(Pl. 10, fig. 5)

1931 *Rhabdochitina magna* Eisenack, p. 90-91, Pl. 3, fig. 16-18; Text-fig. 3-5.

Diagnosis (Eisenack 1931) : Length about 0.5 to *ca.* 1mm. Width 0.08 to 0.5mm. The shape is entirely cylindrical, the aperture, where seen is not flared (?). The distal end usually appears truncated. Either the flattening is produced by a small rounded curve from the cylindrical part (see Eisenack (1931) figure 3) or the cylindrical part firstly becomes conical, and then passing into the flattening, becomes naturally smaller (see Eisenack (1931) figure 4). In a few cases the distal end is hemispherical. One can often categorise forms from flattened examples. In the hemispherical examples the hemispheres sometimes grades into a very short [basal] cylinder, so that it has seemingly the appearence of a smaller aperture. One can find for this "mouthpiece" parallels with the small stalk of many of the examples of *Conochitina claviformis* and perhaps also with the connecting ring in the species of the genus *Desmochitina*. In bleached examples an opening is not observed, though of course there are before few examples with such a "mouthpiece". Especially interesting also is the pole shown in figure 3 (Eisenack 1931). In a fractured and bleached form this species has the appearance of having, at the distal end, a small opening, subsequently closed (Eisenack (1931), figure 3). One can thus explain these forms as one can the splits in *Conochitina claviformis*. This species is very much flattened.

Material : approximately ten specimens.

Dimensions : Maximum length 410(502)811µm

Basal width 49(87)133µm

Apertural width 49(84)99µm

7 specimens measured.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/19,22,24,26).

Previous occurrence : upper Arenig to middle Ashgill, Estonia (Eisenack 1962a, b, 1968b); lower Llandeilo, Welsh Borderlands (Jenkins 1967); upper Arenig to lower Llanvirn, Öland (Eisenack 1976a); Vauréal Formation (lower part and *D. complanatus* Zone), Anticosti Island (Achab 1977a, 1978a); Middle Ordovician, Québec (Achab 1986a); Ordovician, Brittany (Deunff 1959); Llanvirn, France (Rauscher 1974); Llandeilo, Normandy (Rauscher and Doubinger 1967); Caradoc, North Wales (Atkinson and Moy 1971); Caradoc, Portugal (Paris 1979); Llandeilo to Caradoc, south-west Europe (Paris 1981); Ordovician to Gotlandian, Sahara (Taugourdeau and Jekhowsky 1961); Caradoc to Ashgill, Gotland (Grahn 1982a); upper Arenig to Caradoc, Sweden (Grahn 1980, 81a); Caradoc-Ashgill, Sahara (Bouché 1965); Ordovician, Sahara (Benoit and Taugourdeau 1961); Ashgill, Morocco (Elaouad-Debbaj 1984).

Remarks : differs from *Rhabdochitina gracilis* in being more robust and less tapering.

Rhabdochitina striata Eisenack 1958

(Pl.10, figs 8, 10)

1958 *Rhabdochitina striata* Eisenack, p. 396, Pl. 2, figs 24, ?25.

Diagnosis (Eisenack 1958) : "generally cylindrical, long and thin, with straight truncated base and seemingly sharp basal margin, below which the body widens, then becoming quickly cylindrical. The wall is ornamented with stripes, as far as the sharply delineated opening". [Translation].

Description : long cylindrical chitinozoan with no differentiation into neck and chamber. The aperture is straight and has a width roughly half of the maximum width which is developed at the base. The basal edge is strongly angular and the base flat. The surface is ornamented with longitudinal striations that run parallel to the flanks of the vesicle.

Material : one specimen

Dimensions : Length 512μm

Basal width 41μm
Apertural width 22μm.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/28).

Previous occurrence : Llanvirn, Baltic (Eisenack 1958); Ordovician, Baltic (Eisenack 1962b, 68b).

Remarks : this species may possibly reworked although it appears to be in an unworn condition. If this species is not reworked then the range of this form must be extended to Ashgill.

Rhabdochitina sp. A
(Pl. 10, fig. 7)

Description : cylindrical chitinozoan with a straight aperture and no differentiation into neck and chamber. The base is flat and the basal edge weakly rounded. The maximum width is poorly developed but is situated near the base. No ornament is seen.

Material : one specimen.

Dimensions : Length 255μm
Width 50μm.

Occurrence : *P. acuminatus* Zone, Main Cliff, Dob's Linn (SU/DL/57).

Rhabdochitina sp. B
(Pl. 11, fig. 1)

Description : cylindrical chitinozoan with straight sides, a convex base and a curved basal edge. There is no shoulder or flexure. The aperture is marked by large spines (~5μm) and the prosome appears to be protruding from the neck like a cork.

Material : one specimen.

Dimensions : Maximum length 145μm
Length of prosome 15μm
Basal width 33μm
Apertural width 31μm.

Occurrence : Shalloch Formation, Woodland Point, Girvan, (MV/G/27).

Rhabdochitina sp. C
(Pl. 10, fig. 9)

Description : elongate test with a weak flexure and no shoulder. The base appears to be flat with a rounded basal edge. The sides taper gradually towards the straight aperture. The wall of the test is smooth.

Material : one specimen

Dimensions : Length 430μm
Width at base 100μm
Width at aperture 47μm.

Occurrence : Ardwell Flags, Ardmillan Braes, Girvan (MV/G/6).

Rhabdochitina sp.D
(Pl.11, figs 2, 6)

Description : well preserved *Rhabdochitina* which unfortunately is broken. The sides are straight, the base convex and the basal edge curved. There is a well preserved copula on the basal edge which is visible under the scanning electron microscope. The surface is not ornamented.

Material : one specimen

Dimensions : Length 205μm

Width 88μm.

Occurrence : Jubilation Member, Doularg Hill, Girvan (MV/G/8).

Rhabdochitina sp.E

(Pl. 11, fig. 3)

Description : elongated poorly preserved chitinozoan with no differentiation of neck, and chamber, but with a flared collarette and a rounded basal edge.

Material : one specimen

Dimensions : Length 302μm
Width 53μm

Occurrence : Jubilation Member, Doularg Hill, Girvan (MV/G/9).

Genus *Siphonochitina* Jenkins 1967

Diagnosis (Jenkins 1967) : "chitinozoa with variously shaped, generally slender tests. The test wall consists of two layers which separate at the base or near the basal margin, the inner layer forming the convex or hemispherical base, the outer layer extending aborally beyond the base as a hollow, cylindrical or flaring, open-ended tube, the siphon".

Type Species : *Siphonochitina formosa* Jenkins 1967

Siphonochitina sp. A

(Pl. 11, fig. 4)

Description : elongate, slender chitinozoan with no differentiation into neck and chamber. A fringed and flaring collarette is developed. The maximum width is developed at two points, above and below a small central constriction. At the base a possible siphon is developed but it is difficult to tell as this is a poorly preserved specimen.

Material : one specimen.

Dimensions : Length of chamber and neck 114µm

Length of siphon 10µm

Width of chamber 22µ

siphon 17µm

neck 11µm

collarette 14µm.

Occurrence : *D. complanatus* Zone , Main Cliff, Dob's Linn (SU/DL/8).

Genus *Sphaerochitina* Eisenack 1955

Diagnosis (Eisenack 1955; translation in Taugourdeau *et al.* 1967): "chitinozoan with a sub-cylindrical neck, conical, spherical or fungiform, 'overflowing' chamber, smooth wall, covered with tiny tubercles or very fine spines, very close to one another, without large thorns or spines". [Translation].

Type Species : *Sphaerochitina sphaerocephala* Eisenack 1955.

Sphaerochitina cf. *lepta* Jenkins 1970

(Pl. 11, fig. 7)

1970 *Sphaerochitina lepta* Jenkins, p. 279-280, Pl.51, figs 11-13, 16-20, Text-fig. 7.

1984 *Jenkinochitina lepta* Elaouad-Debbaj, p. 57-58, Pl. 2, fig. 24; Pl. 3, figs 20, 23.

Diagnosis (Jenkins 1970) : "small, cylindroconical or fungiform test. Chamber and neck of approximately equal length. maximum diameter 150% chamber length; base flat or convex. Neck one-third to half maximum diameter in width. Aperture straight or fimbriate. Wall smooth, or bearing small, generally simple processes, thinly and uniformly distributed over the entire test".

Description : chitinozoan with a spherical chamber and the maximum width developed in the middle of the chamber. The oral tube is well differentiated from the chamber, and there is a very weak, low shoulder. The aperture is flaring and spinose. The chamber is approximately three fifths of the maximum diameter; the base is highly convex, and the basal edge is very rounded. An ornament of small spines appears to be sparsely distributed over this specimen.

Material : one specimen.

Dimensions : Maximum length 110μm
Length of neck 48μm
Length of chamber 62μm
Maximum diameter 85μm
Diameter of neck 30μm
Diameter of aperture 39μm.

Occurrence : *G. persculptus* Zone, Main Cliff, Dob's Linn (SU/DL/52).

Previous occurrence : Sylvan Shale (Caradoc), Oklahoma (Jenkins 1970); Ashgill, Morocco (Elaouad-Debbaj 1984).

Remarks : it is difficult to tell if this specimen is identical to those figured by Jenkins (1970). It appears to differ only in possessing a shorter neck. It has too little ornament to be *S. schwalbi* Collinson and Scott, and is the wrong shape for *S. actonica* Jenkins.

Sphaerochitina mundana? Taugourdeau 1961
(Pl. 11, fig. 5)

1961 *Sphaerochitina mundana?* Taugourdeau, p. 152, Pl. 5, fig. 81.
1967 *Lagenochitina (?) mundana* (Taugourdeau) Rauscher and Doubinger, p. 317, Pl. 4, fig. 4.

Diagnosis (Taugourdeau 1961) : "body piriform with a fairly flat base; neck long and wide (half of the length, and half of the width); aperture poorly marked, slightly flared; surface covered with small tubercles". [Translation].

Description : chitinozoan with a cylindrical neck (Slightly more than half of the maximum length and half of the maximum width), and straight aperture. There is a weak flexure, and the body is conical with a rounded basal edge and convex base. The maximum width is developed in the lower half of the chamber. Preservation is poor and ornament is not discernable.

Material : one specimen

Dimensions : Maximum length 128µm
Apertural length 70µm
Basal width 60µm
Apertural width 44µm.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/20).

Previous occurrence : Caradoc/Ashgill of Aquitaine (Taugourdeau 1961); Caradoc,Normandy (Rauscher and Doubinger 1967).

Sphaerochitina sp. A
(Pl. 11, fig. 8)

Description : chitinozoan with a straight aperture and a cylindrical neck. There is a marked flexure, but no shoulder. The chamber is in the form of a flattened sphere, giving rise to a conical shape. No ornament is visible.

Material : one specimen.

Dimensions : Length 160µm
Basal width 125µm
Apertural width 65µm.

Occurrence : Jubilation Member, Doularg Hill, Girvan (MV/G/8).

Genus *Spinachitina* Schallreuter1963 emend Laufeld 1967.

1963 *Spinachitina* Schallreuter, p. 396.

1967 *Spinachitina* Schallreuter emend. Laufeld, p. 340

Emended diagnosis : (Laufeld 1967) "chitinozoans with subcylindrical neck and subconical to bell-shaped body with a sharp basal edge which is provided with a single row of strongly developed spines. The spines, which are developed directly from the basal edge and point towards its prolongation outwards, may branch distally. Spines with multiramose roots may occur. Usually, the wider spines have vacuoles or cavities in their interior. Aboralward of this row of strongly developed spines, smaller spines or spinose thickenings may occur on the test wall or a part of it may be completely absent. The flexure is rounded but distinct or may be absent or broadly rounded. The base is flat to slightly convex or concave and the aperture is fimbriate. The vesicle wall consists of a single layer and the operculum is disc-like and supported by a short prosome structure".

Type species : *Spinachitina cervicornis* (Eisenack 1931)

?*Spinachitina bulmani* (Jansonius 1964)
(Pl. 11, fig. 9)

1964 *Conochitina bulmani* Jansonius p.907, Pl. 1, fig. 3-4.

1967 *Ancyrochitina bulmani* (Jansonius) Jenkins, p. 448-449, Text-fig.6.

1970 *Euconochitina bulmani* (Jansonius): Rauscher, p. 120, Pl. 3, fig. 12.

1977 *Conochitina aff bulmani* (Jansonius) Achab, Pl.1, fig.1-6; Pl.2, fig.1-3, 5-6.

1984 *Spinachitina bulmani* (Jansonius) Elaouad-Debbaj, p.61, Pl. 2. fig.?7-8, Pl.3, fig. 6,7?,8,10 and 12.

Description (Jansonius 1964): "body chamber conical with a small to moderate apical angle; base flat, with a light basal callus and scar; basal edge distinct, rounded, with numerous small spines or fewer larger spines, occasionally with multiple bases; sides straight, shoulder weak but usually distinct; flexure broad and gentle; neck subcylindrical, narrowing to a large thin-walled cylindrical lip;

operculum at the base of cylindrical lip, supported by a prosome structure; aperture straight".

Description : cylindrical chitinozoan with a cylindrical neck, weak, broad flexure and achamber with gently flaring flanks. The neck when seen is about a quarter of the maximum length of the body. The sides are slightly convex and gently flaring and it has a flat base, with a curved basal margin. The base is ornamented by several small simple conical spines, though the rest of the test appears to be unornamented.

Material : three specimens.

Dimensions : Length : 190(213)244μm
Basal width 50(73)110μm
Apertural width 30(60)80μm
Spine length 5(7)10μm.

Occurrence : *D. anceps* Zone (SU/DL/9) and *P. acuminatus* Zone (SU/DL/57), Main Cliff, Dob's Linn.

Previous occurrence : Caradoc of Shropshire (Jenkins 1967); Vauréal Formation of Anticosti Island (Achab 1977a,b, 78a, b); Ashgill of Whitehead Formation, Quebec (Martin 1980); Ashgill of Anti-Atlas, Morocco (Elaouad-De bbaj 1984); upper Caradoc to lower Ashgill, Quebec (Achab 1986); Caradoc, Kent, England (Lister *et al.* 1969); lower Caradoc, Girvan (Jansonius 1964); Llandeilo, Normandy (Rauscher 1970); Caradoc-Ashgill, Libya (Molyneux and Paris 1985).

Remarks : these specimens are poorly preserved, and the flexure is poorly represented. However the present specimens closely resemble those figured by Achab (1986b, Pl. 8, fig. 8,9).

Genus *Tanuchitina* Jansonius 1964

1964 *Tanuchitina* Jansonius, p. 910.

Diagnosis (Jansonius 1964) : "vesicle cylindrical or conical; flexure indistinct, shoulder poorly or not developed; neck indistinct, but relatively long; basal edge rounded but may be narrow; a cylindrical flange is usually situated at the base at the inside of the basal edge; cuticle single layered, surface smooth or with minor ornament, usually thinning towards the aperture; inside the neck is a relatively long, complex prosome, often with annular thickening; this prosome is contractile and to some extent retractile; a thin-walled circular operculum may occur at the top or at the base of the prosome.

Type species : *Tanuchitina ontariensis* Jansonius 1964

Tanuchitina anticostiensis ? (Achab 1977a)

(Pl. 11, figs 11, 12)

1977 *Cyathochitina anticostiensis* Achab, p. 422, Pl. 4, figs1-2,5.

1977 *Tanuchitina anticostiensis* (Achab) Achab, p. 2200, Pl. 6, figs 1,2,7.

Diagnosis (Achab 1977) : "large cylindrical test, slightly swollen in the lower part. The greatest width is situated approximately in the middle of the body. The neck is cylindrical, well enough differentited from the body, slightly flared towards the aperture. A transparent carina is developed, about 35µm wide".[Translation],

Description : elongated chitinozoan with a slightly flaring cylindrical neck which is weakly differentiated from the chamber. The neck is about a quarter of the maximum length and about three quarters of the maximum width which is situated in the middle of the chamber. The base is flat with a small carina (10µm wide) developed along the basal edge.

Material : one specimen.

Dimensions : Maximum length 443µm

Length of neck 130µm

Maximum width 136µm

Width of neck 100µm.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/24).

Previous occurrence : *D. complanatus* and *C. prominens elegans* Zones, Vauréal Formation, Anticosti Island (Achab 1977a,b, 1978b); Caradoc-Ashgill, Libya (Molyneux and Paris 1985).

Remarks : this is similar to the illustrated material (Achab 1977a), apart from the carina in the present specimen being much smaller. This species differs from *Cyathochitina agrestis* Jenkins in being smaller and having the maximum width developed higher up.

Tanuchitina cf. *ontariensis ?* Jansonius 1964
(Pl. 11, fig. 10)

1964 *Tanuchitina ontariensis* Jansonius, p. 910-911, Pl. 1, figs 5-6.

1970 *Cyathochitina ontariensis* (Jansonius) Jenkins, p. 274, Pl. 50, figs 1-9.

1986 *Tanuchitina ontariensis* Jansonius, Elaouad-Debbaj, p. 44, Pl.2, figs 5,7,10 and 22.

Description (Jansonius 1964) : "vesicle subcylindrical; body chamber conical with small apical angle; neck almost half of the total length; slightly widening towards the aperture; no shoulder, flexure indistinct, very broad; basal edge rounded, with a thin-walled flange at the side of the aboral pole; aperture finely fimbriate; inside the neck along prosome tube with annular thickenings, apparently contractile; a thin circular operculum often found at the base of the prosome tube".

Description : cylindrical chitinozoan with no differentiation of neck and chamber, and straight sides tapering slightly to the oral end which appears to be broken. The maximum width is at the aboral end which has a short, undulating carina about 9µm wide. The surface is unornamented.

Material : one specimen

Dimensions : Length 178μm
Basal width 103μm
Oral width 81μm.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/18).

Previous occurrence : Upper Ordovician, Canada (Jansonius 1964); Sylvan Shale (Caradoc), Oklahoma, (Jenkins 1970).

Remarks : this specimen is not confidently assigned to this species as it appears to be broken. The carina appears to be attached at the basal edge as opposed to *Cyathochitina ontariensis* where it is attached oralward of the base.

Chitinozoan sp. A
(Pl. 11, fig. 13)

Description : small cylindrical chitinozoan with straight sides and a slightly convex base and a weakly angular basal edge. The neck is widely flaring and the flexure is marked. There is no shoulder. The aperture is straight to serrate. The chitinozoan is widest at the aperture.

Material : one specimen.

Dimensions : Maximum length 165μm
Length of neck 25μm
Basal width 40μm
Apertural width 56μm.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/28).

Chitinozoan spp. indet.

SU/B/13, Cross Water, Barrhill (Pl. 12, fig. 4)
SU/B/10 Cross Water, Barrhill (Pl. 12, fig. 12)

SU/DL/53 Main Cliff, Dob's Linn (Pl.12, fig. 16)

HB/NE/11 North Esk River section, Edzell (Pl.12, fig. 7)

HB/LC/11, Limecraig Quarry, Aberfoyle (Pl.12, fig. 6)

HB/LC/8 Limecraig Quarry, Aberfoyle (Pl.12, fig. 8)

HB/BB/5 Bofrishlie Burn, Aberfoyle (Pl. 12, fig. 9)

HB/BB/3 Bofrishlie Burn, Aberfoyle (Pl. 12, fig. 11)

MV/G/8 Jubilation Member, Doularg Hill (Pl.12, fig. 21).

Algae Incertae Sedis

Group Acritarcha Evitt 1963

Genus *Actinotodissus* Loeblich and Tappan 1978

1978 *Actinotodissus* Loeblich and Tappan, p. 1236-1238

Diagnosis (Loeblich and Tappan 1978) : "a diacrodian with similar processes present on opposite poles, the simple, conical, hollow processes communicating with vesicle interior".

Type Species : *Actinotodissus longitaleosus* Loeblich and Tappan 1978

Actinotodissus woodlandense n. sp.

(Pl. 13, fig.1, Pl. 24, fig. 1 (holotype); Figure 29)

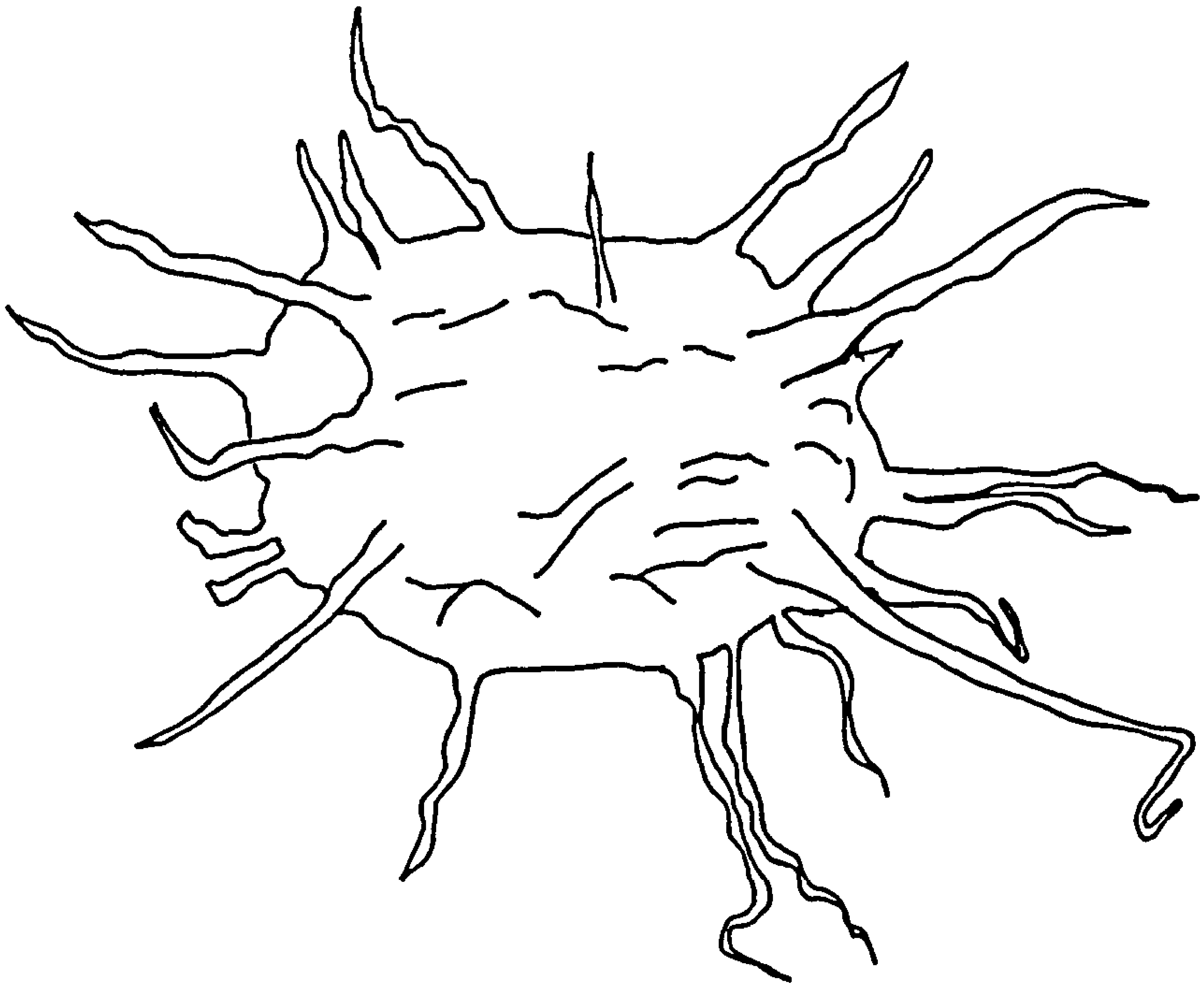
Type Locality : grey mudstone from the highest exposed level of the Shalloch Formation, Woodland Point, Girvan, Strathclyde, Scotland, [NX 21745954].

Holotype : MV/G/18 (1); England Finder Reference U47/2, Pl. 24, fig. 1; stored in the Hunterian Museum, University of Glasgow: specimen number x1560.

Diagnosis : thin walled, smooth, ellipsoidal vesicle with many conical, hollow, acuminate processes which are distally closed but proximally open to the vesicle cavity. The processes show a more concentrated distribution at the poles.

Description : thin walled (less than 1μm, smooth, ellipsoidal vesicle with about twenty five processes which are proximally open to the vesicle cavity. The processes have an angular contact with the vesicle, are thin walled, smooth, simple, hollow, conical and have acuminate tips that often become thread-like. The processes are of variable length but are always shorter than the maximum diameter of the vesicle, usually about half that diameter. There appears to be some differentiation at the poles. No excystment feature has been recorded.

Material : five specimens



X1560

Figure 29 : *Actinotodissus woodlandense* n. sp.

Dimensions :

Diameter : holotype : length 52µm, width 37µm; range :49(53)59µm

Process length : holotype : 10-30µm range:10(27)33µm

Process width : holotype : 3µm range : 2-3µm.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/18,24,28).

Remarks : this species is distinguished from *Baltisphaerdium* by its proximally open processes, from *Goniosphaeridium* by it angular process contact and polarity of the processes. It is differentiated from other species of *Actinotodissus* by its large size, and by the smooth walls between the processes.

Actinotodissus sp. A

(Pl. 13, fig. 4)

1988 *Actinotodissus* sp. 1 Whelan, p. 43.

Description : elongate, to nearly rectangular vesicle with simple conical to acuminate or blunt- tipped polar processes, which have a curving proximal contact with the vesicle, and communicate with the vesicle interior. Wall apparently laevigate but preservation is poor.

Material : one specimen.

Dimensions : Vesicle length : 19µm

Vesicle width : 14µm

Processes : 6µm.

Occurrence : *C.?extraordinarius* Zone, Main Cliff, Dob's Linn (SU/DU/17).

Remarks : this specimen is too poorly preserved to allow any specific attribution.

Genus *Ammonidium* Lister 1970

1970 *Ammonidium* Lister, p. 48-49.

Diagnosis (Lister 1970): "vesicle hollow, spherical to ellipsoidal, single-walled; vesicle wall smooth or sculptured. Processes numerous, evenly spaced, more or less rigid, hollow, tapering, communicating freely with the vesicle cavity; distally the processes have equifurcate terminations. Excystment by cryptosuture, apical or near equatorial".

Type Species : *Ammonidium microcladum* (Downie) Lister 1970

Ammonidium cf. *microcladum* (Downie) Lister

(Pl. 24, fig.2)

1963 *Baltisphaeridium microcladum* Downie, p. 645, Pl. 91, fig. 3, Pl. 92, fig. 6, Text-fig. 3g.

1970 *Ammonidium microcladum* (Downie) Lister, p. 49-50, Pl. 1, figs. 1-5, 7-11; Text-fig. 17a-d

Diagnosis (Downie 1963): "test slightly ellipsoidal, smooth or granular, spines moderately long and numerous, narrow and slightly tapering. Forking only at the tips, bifurcate, trifurcate, or quadrifurcate, branches very short and thin but second order branching may occur".

Description : ellipsoidal test; about sixteen processes visible in optical section, showing curved to angular process contact with the vesicle; processes conical, apparently connecting with the cavity. The spine terminations are bifid, trifid or simple and acuminate. The ornamentation of the wall cannot be determined.

Material : one specimen only.

Dimensions :Vesicle length 29µm

Vesicle width 21µm

Process length 7µm

Process width 1-3µm.

Occurrence : *P. acuminatus* Zone, Main Cliff, Dob's Linn (SU/DL/53).

Previous occurrence : Wenlock Limestone, lower, middle and upper Elton Beds, and from the lower Ludlow near Ledbury (Lister 1970). Downie (1963) described this species from the Buildwas Beds and the Coalbrookdale Beds (Wenlock), Shropshire.

Remarks : in his generic diagnosis Lister (1970) claims that the processes of *Ammonidium* are homomorphic. However in his diagnosis of *Baltisphaeridium microcladum* Downie (1963) describes the processes as being heteromorphic. The processes in the specimen here described appear to be heteromorphic, some of them being simple and acuminate, however this may possibly be a factor of the preservation. This specimen is thus assigned tentatively to this species. If this specimen is correctly assigned then this extends the range of *Ammonidium microcladum* down into the Llandovery.

Ammonidium sp. A

(Pl. 13, fig. 10)

Description : vesicle subquadrate with thin conical, whip-like processes, showing an angular proximal contact with the vesicle. The numerous processes are homomorphic and simple, acuminate. Apart from the processes there appears to be no ornamentation and the wall is smooth.

Material : one specimen.

Dimensions :Diameter 20μm
Process length 11μm
Process width 0.5μm.

Occurrence : Mill Formation, Upper Whitehouse Group, Woodland Point, Girvan (MV/G/29).

Remarks : this species shows no differentiation of the process distal tips and is thus only doubtfully referred to *Ammonidium*.

Genus *Aremoricanium* Deunff 1955

1955 *Aremoricanium* Deunff, p. 229

Original diagnosis (Deunff 1955) : "fossils micro-organisms, preserved as organic material, with a generally yellow to brown colour, rarely black, formed of two concentric shells.

(1) an internal globular body possessing a swelling at one pole sometimes revealing a circular perforation of variable diameter.

(2) an external body, ornamented by long hollow processes, enlarged and open at the base. These processes communicate with the space between the two shells. The external shell

possesses a cylindro-conical expansion, corresponding to the opening of the internal body". [Translation].

Type Species : *Aremoricanium rigaudae* Deunff 1955.

Aremoricanium cf. *deflandrei* Henry 1969

(Pl. 13, fig. 2)

1969 *Aremoricanium deflandrei* Henry, p. 78, Pl. 4, fig. 26-29.

Diagnosis (Henry 1969) : "dark brown micro-organism of which the internal body, which is darker, is not well seen; that shell was probably originally spherical and its average diameter perhaps equalled 30µm. No pore is visible. The external shell, of a clearer colour, carries very numerous slender and supple processes, of which the length perhaps attains 50µm; the tubular expansion measures 20 to 25µm wide and it's length varies from 15 to 20µm. The overall total size measures about 100µm".[Translation]

Description (Kjellström 1971b) : "*Aremoricanium* sp. with a moderately thick, spherical to subspherical, shagreenate internal body surrounded by a thin, psilate vesicle. No excystment structure is recorded. Curved proximal process junction with the vesicle. Free communication between the basal process interior and the space between internal body and vesicle cavity. Processes, about 25 in number, in length less than vesicle dimension, psilate at the base, mostly with strongly developed conical bases extending into thread-like spines, homomorphic, simple with acuminate, whip-like distal terminations. Vesicle with well defined cylindrical expansion".

Description : smooth thin-walled, subspherical vesicle with one large tubular process protruding, apparently basally open, from the vesicle. The other processes are simple and equal to or slightly less in length than the diameter of the vesicle. They are about 2-5µm wide at the base, and taper to acuminate tips. There is no constriction at the base of the processes.

Material : one specimen.

Dimensions : Vesicle 23x30µm
Large process : 20x10µm
processes : length : 16-25µm width : 3-5µm.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/21).

Previous occurrence : Middle Ordovician, Gotland (Kjellström 1971b, 1976); Llanvirn, France (Deunff 1955); Ordovician, Presqu'île de Crozon (Henry 1969); Middle Ordovician, Öland (Kjellström 1972)

Remarks : this specimen is smaller than the published ranges for this specimen (Kjellström 1971b), the processes are more uniform in width than those shown in Kjellström (1971b), otherwise it is concurrent with the published description. This species differs from *A cf. rigaudae* by having longer processes and a [illegible] thinner wall.

Aremoricanium cf *rigaudae* Deunff 1955

(Pl. 13, fig. 3)

1955 *Aremoricanium rigaudae* Deunff, p.229, figs 1-3.

Description (Loeblich and MacAdam 1971) : "vesicle ovate to nearly circular in outline with a prominent tubular extension up to 20µm in length terminating in a pylome; wall thin, less than 0.5µm in thickness; in the light microscope the vesicle wall appears faintly granulate, whereas the tubular neck is faintly granulate and finely striated, but in the scanning electron microscope at magnifications of 20,000 the wall structure is seen to be rugulate-granulate; vesicle ornamented with numerous, broadly-based, long, thin, and flexible processes that taper rapidly, processes hollow in their proximal portion but distally solid, processes appear to communicate with the vesicle interior; no operculum observed in the pylome".

Description : vesicle ovoid, with a thin, apparently smooth wall. A large tubular extension is well developed, and the other processes are conical with curved proximal contacts with the vesicle and tapering to acuminate tips distally. No plugs are seen at the proximal ends of the processes, but they may become distally solid.

Material : two specimens

Dimensions : Vesicle : 25-22.5 x30-39µm
processes : 4-12µm long
Tubular extension : 10x7-9µm.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/ 25, 26).

Previous occurrence : Middle Ordovician Mountain Lake Member of the Bromide Formation (Loeblich and MacAdam 1971); Lower Ordovician, Europe (Burmann 1970); Middle Ordovician, Gotland (Kjellström 1971b); Ordovician, Brittany, (Deunff 1955); Middle Ordovician, Poland (Gorka 1980); Upper Ordovician, Portugal (Elaouad-Debbaj 1978); Lower Silurian, Bulgaria (Kalvacheva 1978).

Remarks : these specimens are smaller than *Aremoricanium rigaudae* described by Loeblich and MacAdam (1971) and Kjellström (1971b), but in all other respects concur with the published diagnoses and so are tentatively assigned to this species.

Aremoricanium sp A

(Pl. 13, fig. 8)

1988 *Aremoricanium* sp. 1 Whelan, p. 43.

Description : *Aremoricanium* sp with a subspherical body. The wall appears to be smooth, although preservation is not good, and the surface may once have been ornamented. It has one large process, generally square in shape, and one smaller one, which could be broken. There is no other ornamentation.

Material : one specimen.

Dimensions : Vesicle : 54x31μm
Tubular expansion : 12x10μm
Process : 5x3μm.

Occurrence : *D. anceps* Zone, Main Cliff, Dob's Linn (SU/DL/10).

Remarks : this specimen is not confidently assigned to any of the known species of *Aremoricanium* because in the absence of other diagnostic features the single process, could place it in a number of the species.

Aremoricanium sp B.

(Pl. 13, fig.7)

Description : spherical body with a single large tubular expansion and a suggestion of vesicular ornamentation, however preservation is poor, and this specimen is almost totally recrystallised to graphite.

Material : one specimen.

Dimensions : Vesicle 67x62μm
Tubular expansion : 11x14μm.

Occurrence : *D. anceps* Zone, Main Cliff, Dob's Linn (SU/DL/11).

Aremoricanium sp. C
(Pl. 24, fig. 3)

1988 *Aremoricanium* sp. 1 Whelan, p. 42.

Description : very small specimen with well preserved spines, which are very thin with the exception of the tubular expansion. the bases are conical and there appears to be no constriction at the junction with the vesicle, and the proximal contact is straight to slightly curved. The vesicle itself is round and psilate. Six thin acuminate processes (1μm wide) arise from the body as well as four broken ones, and the tubular expansion. The base of the tubular expansion is not well marked, and indeed it appears to be continuous with the vesicle.

Material : one specimen.

Dimensions : Vesicle 18x13μm
Tubular expansion : 7x7μm
Processes : length 7-10μm width : 1-2μm.

Occurrence : *C? extraordinarius* Zone, Linn Branch section, Dob's Linn (SU/DL/32).

Remarks : this specimen is not confidently assigned due to its very small dimensions, and the way the vesicle graduates into the tubular expansion.

Aremoricanium sp. D
(Pl. 13, fig. 6; Pl. 26, fig. 6)

Description : large spherical specimen of *Aremoricanium* with a well developed neck-like extension, which appears to have a 'collarette', though this may be due to preservation. It is unornamented but is totally recrystallised, showing now only a very coarse 'felting', although it is possible that it had processes before it was altered.

Material : one specimen.

Dimensions : Vesicle : 64x53μm
Tubular expansion : 15x20μm

Occurrence : North Esk River, Edzell (HB/NE/3).

Genus *Baltisphaeridium* (Eisenack 1958) Eisenack 1969.

Emended Diagnosis (Eisenack 1969) : "shell round, without tabulation, with more or less numerous processes, radial, evenly distributed, in general of similar type and mostly hollow, they are closed at the ends. Usually processes are simple but occasionally there may occur branching processes; only occasionally are all processes branched. The process interior does not usually communicate with the central body. Processes are evenly distributed even when there are few in number. The diameter of the body is in general more than 30μ (mostly 40-60μ) and can be 70μ. The overall diameter may exceed 300μ. The (rare) pylomes are circular (normal pylomes)". [Translation].

Type species: *Baltisphaeridium* (as *Ovum hispidum*) *longispinosum* Eisenack 1931. Holotype lost.
Neotype: *Baltisphaeridium longispinosum* (as *filifera*) *longispinosum* Eisenack 1959.

Baltisphaeridium cf. *bulbosum* Kjellström 1971
(Pl. 13, fig. 9)

1971 *Baltisphaeridium bulbosum* Kjellström, p. 20,21, Pl. 1, fig. 3

Diagnosis (Kjellström 1971a) : "*Baltisphaeridium* sp. with thin, single walled, spherical, shagreenate vesicle. Excystment structure formed as a partial rupture. Curved proximal process contact with the vesicle. Separation of the interior of the process from the vesicle cavity. Processes, about 11 in number, in length about equal to the vesicle diameter, shagreenate, conical, broad bases, homomorphic, simple with bulbous distal terminations, sometimes bilobate".

Description : thin walled, ellipsoidal, shagreenate vesicle with seven processes, which are constricted at their bases. Curved proximal contact with the vesicle. The processes are thin-walled, shagreenate, hollow, bulbous, or evexate tipped, and are shorter than the maximum length of the vesicle. No excystment feature is recorded.

Material : one specimen only.

Dimensions : Vesicle length 71µm
Vesicle width 28µm
Process length 56µm
Process width 10µm.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/23).

Previous occurrence : Middle Ordovician, Gotland (Kjellström 1971a).

Remarks : not all the process tips are bulbous, and the processes are less wide at the base than in the holotype, and so this specimen is not confidently assigned to this species.

Baltisphaeridium hirsuitoides (Eisenack) Eisenack 1958
(Pl. 13, fig. 5)

1931 *Ovum hispidum cf. hirsutum* Eisenack p. 111, Pl. 5, fig. 19.
1938 *Hystrichosphaeridium cf. hirsutum* Eisenack, p. 13, Pl. 1, fig. 11.
1951 *Hystrichosphaeridium hirsuitoides* Eisenack, p. 189, pl.3, fig.8
1958 *Baltisphaeridium hirsuitoides* (Eisenack) Eisenack p. 400.

Diagnosis (Eisenack 1951 translated in Turner 1984) : "vesicle spherical, processes more numerous than with *H. longispinosum* [now *Baltisphaeridium longispinosum*], always shorter than in this species, about the length of the radius or less. Mostly fine and bristle-like and ending in a point. In comparison with *H. multipilosum* the processes are significantly smaller in number and also mostly longer. Forked processes up to now have not been seen".

Description : Central body spherical with a shagreenate wall. The ten processes are a third to half of the maximum diameter and are proximally plugged, simple and acuminate. The occasional process is evexate but this may be due to preservation. The processes show an angular contact with the vesicle wall. No excystment feature was observed.

Material : three specimens.

Dimensions : Vesicle diameter 41(52)62µm
Process length 15(20)25µm
Process width 2µm.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/18,21,26).

Previous occurrence : Arenig, Montagne Noire, (Rauscher 1974); Lower Ordovician, Estonia (Eisenack 1951); Ordovician, Baltic (Eisenack 1931, 38, 59, 62b, 65, 68a); Upper Arenig, Poland (Górka 1969); Middle Ordovician (Gorka 1980); Middle Ordovician, Gotland (Kjellström 1976); Caradoc (Lister *et al.* 1969); Middle Ordovician, Estonia (Bockelie and Kjellström 1979); Llandeilo, Gotland (Kjellström 1971b); Caradoc-Ashgill, Kansas, USA (Wright and Meyers 1981); Upper Ordovician, Portugal (Elaouad-Debbaj 1978); Upper Ordovician, Sylen Formation (Tynni 1975); Upper Ordovician Clays Ferry Formation, Kentucky (Jacobson 1978); Vauréal (Ashgill) Formation (Jacobson and Achab 1985); Silurian, England (Sannemann 1955); Wenlock Shales (Downie 1958).

Baltisphaeridium multipilosum (Eisenack) Eisenack 1958.
(Pl.24, fig. 4)

1931 *Ovum hispidum multipilosum* Eisenack, p. 111, Pl. 5, fig. 20-22.
1938 *Hystrichosphaeridium multipilosum* (Eisenack) Eisenack, p. 12, pl.1, fig. 12-13.
1958 *Baltisphaeridium multipilosum* (Eisenack) Eisenack, p. 400.
1988 *Baltisphaeridium* sp. 1 Whelan, p. 42.

Diagnosis (Eisenack 1959) : "main test spherical, covered with numerous capilliform appendages, their length being at the most equal to the test diameter, though generally shorter than this, being recognisable as quite short and crooked, as well as having a distinctly narrower width. Pylome present, proportionally narrow". [Translation].

Description : ellipsoidal test, apparently smooth, fairly thin walled, with many radiating hair-like, solid, acuminate processes which have an angular proximal contact with the vesicle. They do not appear to communicate with the vesicle cavity and no excystment structure is recorded.

Material : one specimen.

Dimensions : Vesicle diameter 29µm
Process length 2-7µm.

Occurrence : *C? extraordinarius* Zone, Linn Branch, Dob's Linn (SU/DL/32).

Previous occurrence : Ordovician and Silurian, Baltic (Eisenack 1931, 38, 58, 59, 62b, 65, 68a); Middle Ordovician, Gotland (Kjellström 1971a); Caradoc of southern England (Lister *et al.* 1969); Arenig, Poland (Gorka 1969); Arenig, Montagne Noire (Rauscher 1974); Middle Ordovician, Gotland (Kjellström 1972); Upper Ordovician, Portugal (Elaouad-Debbaj 1978); Upper Ordovician Sylen Formation, Finland (Tynni 1975); Caradoc-Ashgill, Canada (Martin 1983); Ashgill, Bohemia (Konzalova-Mazancova 1969); Ordovician, France (Deunff 1959); Middle Ordovician, Estonia (Bockelie and Kjellström 1979).

Baltisphaeridium cf. *paucispinosum* Kjellström 1971
(Pl. 13, fig. 11)

1971 *Baltisphaeridium paucispinosum* Kjellström, p. 38, Pl. 2, fig. 9.

Diagnosis (Kjellström 1971) : "*Baltisphaeridium* species with, thin, single-walled, spherical, psilate vesicle. No excystment structure recorded. Angular proximal process contact with the vesicle. Separation of the interior of the process from the vesicle cavity. Processes, about fourteen in number, in length about a third of the vesicle diameter, widely distributed, psilate, conical, homomorphic, simple with bulbous distal terminations".

Description : spherical vesicle, with nine processes that are psilate, cylindrical, with acuminate, evexate or bulbous terminations. The processes are basally plugged and separated from the vesicle interior. Some of the processes show constricted bases. The excystment mechanism appears to be by a split.

Material : one specimen.

Dimensions : Vesicle diameter 60µm
Process length 20µm
Process diameter 3µm.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/23).

Previous occurrence : Middle Ordovician, Gotland, (Kjellström 1971a); upper Ordovician of Portugal (Elaouad-Debbaj 1978).

Remarks : this specimen is very similar to that described by Elaouad-Debbaj (1978) as *Baltisphaeridium* cf. *paucispinosum.* It is only differentiated from the original by its variability of process terminations. Even though this species exhibits an apparent 'median split' is is not transferred to *Baltisphaerosum* Turner 1984 due to the fact that the preservation is not very good and the split may not be an excystment feature but a mechanical tear.

Baltisphaeridium cf. *psilatum* Kjellström 1971
(Pl. 14, fig. 1)

1971 *Baltisphaeridium* cf. *psilatum* Kjellström, p. 39, Pl. 2, fig. 10.

Diagnosis (Kjellström 1971) : "*Baltisphaeridium* sp. with thin, single walled, spherical, psilate vesicle. No excystment structure recorded. Curved proximal process contact with the vesicle. Faintly defined separation of the interior of the processes from the vesicle cavity. Processes, about 23 in number, in length about a quarter to a fifth of the vesicle diameter, psilate conical, homomorphic, simple with acuminate distal terminations".

Description : spherical, psilate vesicle with only four processes preserved, but exhibiting curved proximal contacts with the vesicle. The processes, which are about a quarter of the vesicle diameter, are conical with acuminate terminations and appear to be separated from the vesicle cavity.

Material : one specimen.

Dimensions : Diameter 48µm

Process length 13µm.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/25).

Previous occurrence : Middle Ordovician, Gotland, Sweden (Kjellström 1971)

Remarks : this specimen has only four processes preserved as opposed to the type which has 23 processes and so this species cannot be confidently assigned.

Baltisphaeridium cf. *regnelli* Kjellström 1971

(Pl. 14, fig. 2)

1971 *Baltisphaeridium* cf. *regnelli* Kjellström, p. 20, fig. 12

Diagnosis : "*Baltisphaeridium* sp. with moderately thick, single walled, shagreenate vesicle, with local, circular, psilate areas (about 5µm in diameter) around each process base. No excystment structure recorded. Curved proximal process junction with the vesicle. Separation of the interior of the process from the vesicle cavity. Numerous short processes, shagreenate, conical, broad base area, homomorphic, simple, with acuminate distal terminations".

Description : spherical thick walled (~2µm) vesicle with numerous conical, hooked, evexate processes. No excystment features seen.

Material : one specimen.

Dimensions : Diameter 26µm
Process length 7µm
Process width 3µm
Process separation 4µm.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/24).

Previous occurrence : Middle Ordovician, Gotland (Kjellström 1971b)

Remarks : this specimen appears to have more processes, with evexate rather than acuminate terminations, and be considerably smaller than the type material. However its general overall appearance is quite distinctive, and merits its tentative incorporation in this species.

Baltisphaeridium sp. A
(Pl. 14, fig. 3)

Description : small spherical to triangulate, fairly thick walled, poorly preserved, apparently smooth vesicle with numerous verrucae about one seventh to one tenth of the maximum vesicle diameter. The internal cavity is filled with pyrite and no excystment structure is recorded.

Material : one specimen.

Dimensions : Vesicle diameter 27µm
Verrucae length 2-4µm
Verrucae width 2µm.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/ 20).

Genus *Baltisphaerosum* Turner 1984

1984 *Baltisphaerosum* Turner, p. 101-102.

Diagnosis (Turner 1984): " vesicle spherical to sub-spherical, bearing radiating processes that are hollow, distally closed, usually simple or rarely branching and do not communicate with the vesicle interior; process and vesicle walls smooth or ornamented. Process bases are always plugged, apparently with solid wall material. Excystment structure is a median split".

Type species : *Baltisphaerosum cristoferi* Kjellström 1976

Baltisphaerosum cristoferi (Kjellström) Turner 1984

(Pl. 14, fig. 4)

1976 *Baltisphaeridium cristoferi* Kjellström, p. 16, fig.9.

1984 *Baltisphaerosum cristoferi* (Kjellström) Turner, p. 103, Pl. 4, figs. 1, 2.

Diagnosis (Kjellström 1976) : "*Baltisphaeridium* species with moderately thin, single-walled, subspherical to spherical, psilate vesicle. Separation of the interior of the process from the vesicle cavity. Well defined proximal plug formed by the separation of the ectoderm at the inside of the basal process cavity. Numerous processes, about thirty, in length not exceeding the vesicle diameter, psilate conical, slender, homomorphic, simple with acuminate distal terminations".

Description : thin walled (~1μm) spherical, smooth vesicle with about seven processes which are not in contact with the vesicle cavity. The processes have an angular contact with the vesicle wall, are shorter than the vesicle diameter, conical, hollow, simple, and with acuminate terminations. The excystment feature is a median split.

Material : four specimens

Dimensions : Vesicle diameter 39 (45)49μm

Process length 33(36)42μm

Process width 2-3μm

3 specimens measured.

Occurrence : Shalloch (MV/G/21,22) and Mill (MV/G/29) Formations, Woodland Point, Girvan.

Previous occurrence : Llandeilo, Sweden (Kjellström 1976); Caradoc, Shropshire (Turner 1984); Caradoc, Libya (Molyneux and Paris 1985).

Remarks : there are far fewer processes in these forms than in Turner's material or in that of the holotype.

Genus *Cymatiosphaera* O. Wetzel ex Deflandre 1954

1933 *Cymatiosphaera* O. Wetzel, p. 27
1954 *Cymatiosphaera* O. Wetzel emend. Deflandre, p. 257-258.

Diagnosis (Downie 1959) : "spherical to ellipsoidal tests of brownish organic matter, surface divided up into polygonal fields by membranes perpendicular to the test surface, no equatorial girdle, no spines".

Type species *Cymatiosphaera radiata* O. Wetzel 1933 subsequent designation by Deflandre (1954, p. 257).

Cymatiosphaera densisepta Miller and Eames 1982
(Pl. 14, fig.5)

1968 *Cymatiosphaera densisepta* Cramer, p. 66, Pl. 1, fig. 2.
1982 *Cymatiosphaera densisepta* Miller and Eames, p. 236, Pl. 1, figs 7-9.

Diagnosis (Miller and Eames 1982) : "vesicle spherical. Surface of vesicle divided into more than 25 polygonal to subcircular fields (averaging about 5µm in the longest direction) by membranous muri, varying from 3-4µm in height".

Description : *Cymatiosphaera* species with a spherical vesicle, divided into a large number of polygonal fields by membranous flanges about 4µm in height. the surface of the vesicle is shagreenate.

Material : one specimen.

Dimensions : overall diameter 34μm

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/22).

Previous occurrence : Middle Silurian Maplewood Shales, New York, (Cramer 1968); Medina Group, (Llandovery) (Miller and Eames 1982).

Genus *Dictyotidium* Eisenack 1955

1955 *Dictyotidium* Eisenack, p.179.

Diagnosis (Eisenack 1955) : "spherical hystrichospheres decorated with low but usually distinct ridges, giving a net-like appearance. Differs from *Dictyosphaera* W. Wetzel 1952 by the much larger mesh and the lack of, or only very short, radial processes. [Translation].

Type species : *Dictyotidium dictyotum* (Eisenack 1938) Eisenack 1955.

Dictyotidium sp. A
(Pl.14, figs 6,10)

1988 *Dictyotidium* sp. 1 Whelan, p. 43.

Description : small spherical vesicle divided up into polygonal fields that measure about 7-8μm in diameter. Vesicle wall is fairly thin, and there are small spines about 2μm high protruding from the junction of two fields. The surface is smooth in between the muri that form the fields, and no excystment structures are recorded.

Material : two specimens

Dimensions : Diameter 29-31μ.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/27);

G.persculptus Zone, Main Cliff, Dob's Linn (SU/DL/40).

Remarks : as the preservation of neither of these specimens is adequate for a full specific determination, they are subsumed into the single species for the purposes of this work.

Dictyotidium sp. B

(Pl. 14, fig. 8)

Description : ovate vesicle with the surface divided into polygonal fields about 4μm in diameter, with small blunt tipped spines protruding about one tenth of the maximum diameter of the vesicle. No excystment feature has been recorded.

Material : One specimen only.

Dimensions : Diameter 43μm

Occurrence : Jubilation Member, Doularg Hill, Girvan (MV/G/8).

Genus *Diexallophasis* Loeblich 1970

1970 *Diexallophasis* Loeblich, p. 714

Diagnosis (Loeblich 1970) : "central body inflated, in life probably spherical or subspherical, of variable outline when compressed; wall thin, no differentiation in wall between central body and processes except in ornamentation, surface of central body with grana and that of processes with small spines; the 4-10 processes are of two types, one smaller, smooth and unbranched and the other spinose, bifurcate or multifurcate and extremely variable in diameter; excystment by simple rupture of the central body".

Type species : *Diexallophasis denticulata* (Stockmans and Willière) Loeblich = *Baltisphaeridium denticulatum* Stockmans and Willière 1963.

Diexallophasis sp. A

(Pl.24, fig. 8)

1988 *Diexallophasis* sp. 1 Whelan, p. 42.

Description : subspherical vesicle, about 1µm thick, with a granulate ornamentation. There are twelve processes which apparently open to the vesicle cavity, have an angular proximal process contact, are hollow, and measure about two thirds of the maximum diameter. The processes are ornamented with small broad based spines, and the processes terminate either with simple conical tips or with bifurcations. No excystment feature was observed.

Material : one specimen.

Dimensions : Diameter 32µm
Process length 20µm.

Occurrence : *D. anceps* Zone, Main Cliff, Dob's Linn (SU/DL/10).

Remarks : this specimen is very distinctive, due to its robustness, and differs from *D. denticulata* by having a larger number of processes, and having much coarser ornament on the processes than *D. denticulata.* It appears to be very similar to species found in the Silurian *M. sedgwickii* Zone (pers. comm. S.G. Molyneux).

Genus *Eupoikilofusa* Cramer 1971

1971 *Eupoikilofusa* Cramer, p. 83-84.

Diagnosis : (Cramer 1971) "vesicles fusiform, elongated with pointed poles. At each pole there may be a simple, equivalent process. Within the same species the length of the polar processes may vary greatly. The vesicle wall is unilayered, and the sculpture distribution symmetry is holomorphic with elements arranged in a pattern parallel to the longitudinal axis, and with decreasing size, number and complexity of elements towards the poles. The ectoderm surface is ornamented with elements of the striate kind: rugulae, striae, fossulae, or micro-echinate elements in longitudinally orientated rows. The vesicle may open by splitting along the axis at approximately an equatorial position. The vesicle axis may be straight or curved, even in the same species".

Type species : *Eupoikilofusa striatifera* (Cramer 1964) Cramer 1971

Eupoikilofusa striata (Staplin, Jansonius and Pocock) Loeblich and Tappan 1978
(Pl. 14, fig.7)

1965 *Poikilofusa striata* Staplin, Jansonius and Pocock, p.186, Pl.18, figs 23,24.

1967 *Dactylofusa striata* (Staplin *et al.* 1965) Combaz *et al.* p. 297.

1978 *Eupoikilofusa striata* (Staplin, Jansonius and Pocock) Loeblich and Tappan, p. 1264, Pl.8, figs, 6,7.

Description (Loeblich and Tappan 1978) : "vesicle fusiform, in the holotype 122µm in length and 36µm in maximum breadth, polar extremities drawn out into blunt-tipped to acuminate processes; vesicle wall ornamented by numerous, longitudinally directed, continuous or discontinuous ridges which in the holotype are more prominent on the central portion of the vesicle and graduallly die out on the polar processes. Surface scabrate between the ridges; wall thin, less than 0.5µm thick; no excystment opening observed".

Description : fusiform vesicle with acuminate or blunt terminations. Walls thin and ornamented with striations, parallel to the vesicle length, about 0.5µm in thickness. Striations become less obvious at the poles. Walls fairly smooth in between the ridges. One specimen is split along the median axis.

Material : three specimens

Dimensions : Length : 155(168)192µm
Width : 32 (36) 40 µm

Occurrence : Woodland Point, Shalloch Formation, Girvan (MV/G/28).

Previous occurrence : Trenton Formation, Anticosti Island (Staplin, Jansonius and Pocock 1965, Loeblich and Tappan 1978); Power Glen Formation (Silurian), New York (Miller and Eames 1982); Caradoc-Ashgill, Sahara (Jardiné *et al.*1974); Vauréal Formation (Ashgill), Anticosti Island (Jacobson and Achab 1985).

Genus *Filisphaeridium* Staplin, Jansonius and Pocock 1965.

1965 *Filisphaeridium* Staplin, Jansonius and Pocock, p. 192.

Diagnosis (Staplin, Jansonius and Pocock) : "vesicles spherical to subspherical; wall proportionally smooth to chagrinate, with several to numerous more or less stiff and wiry spines; spines are cylindrical, unbranched or with distal differentiation (branching, thickening); proximally the spines base is usually thickened".

Type species : *Filisphaeridium setasessitante* (Jansonius) Staplin, Jansonius and Pocock, 1965.

Filisphaeridium sp. A

(Pl. 14, fig. 9)

Description : small, spherical, thin walled, smooth, vesicle with about twelve, solid, cylindrical, thin processes which appear to be bifurcating. There is an angular process contact with the vesicle and no excystment feature was recorded.

Material : one specimen

Dimensions : Diameter 25μm
Process length 4-6μm
Process width 1μm.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/26).

Genus *Goniosphaeridium* Eisenack 1969 emend Turner 1984

1969 *Goniosphaeridium* Eisenack p. 256.

1984 *Goniosphaeridium* Eisenack emend. Turner p. 112,

Emended diagnosis (Turner 1984) : "vesicle hollow, polygonal or sub-polygonal, greater than 20µm in diameter. Wall smooth, thin (0.5-0.75µm), bearing eight or more evenly distributed, hollow, simple, homomorphic processes having acuminate distal terminations; process interiors communicate freely with the vesicle cavity. No apparent differentiation between process and vesicle walls, which merge imperceptibly".

Type species : *Goniosphaeridium polygonale* ex *Ovum hispidum* Eisenack 1931; holotype lost, neotype *Goniosphaeridium (Baltisphaeridium) polygonale* Eisenack 1931 in Eisenack 1959, p.199, Pl.16, fig. 8.

Remarks : Turner (1984) discusses in detail the emendations made to this genus.

Goniosphaeridium conjunctum Kjellström 1971

(Pl. 24, fig. 7)

?1966 *Baltisphaeridium longispinosum* (Eisenack 1931) Timofeev, Pl.33, fig. 6.
1971 *Goniosphaeridium conjunctum* Kjellström, p. 43,44, Pl.3, fig. 4.

Diagnosis (Kjellström 1971a): "*Goniosphaeridium* sp. with a thin, single walled, polygonal shagreenate vesicle. No excystment structure recorded. Curved proximal process contact with the vesicle. Free communication between the process interior and the vesicle cavity. Processes, about 15 in number, in length exceeding the vesicle diameter, shagreenate, broad bases, conical, homomorphic,simple with acuminate distal terminations".

Description : spherical vesicle with a psilate wall, and no separation between the processes and the vesicle cavity. There are six processes which also have psilate walls, and are conical, simple and with acuminate terminations. No excystment structure is recorded. Process length exceeds the vesicle diameter.

Material : one specimen.

Dimensions : Diameter 35µm

Process length 40µm.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/20).

Previous occurrence : Middle Ordovician, Gotland (Kjellström 1971a); Middle Ordovician, Östergötland (Kjellström 1976); *G. cf. conjunctum* Caradoc of Libya (Molyneux and Paris 1985); Caradoc, Canada (Martin 1983).

Remarks : this specimen is very similar to the specimen figured (fig. 22) by Kjellström (1976).

Goniosphaeridium elongatum Turner 1984

(Pl. 14, fig. 11)

1984 : *Goniosphaeridium elongatum* Turner, p.113, Pl. 13, figs 1,2.

Original diagnosis (Turner 1984) : "vesicle smooth, thin-walled (<0.5μm), polygonal to sub-polygonal in outline; bearing a variable number of smooth, simple, hollow, homomorphic processes having wide bases that taper rapidly to form a slender conical stem; this stem then tapers gradually to an acuminate distal termination which may become thread-like. Process interiors open into the vesicle cavity. Process length equal to, or longer than vesicle diameter".

Description : vesicle ellipsoidal in shape, quite small, smooth; with about twenty homomorphic, acuminate and distally thread-like processes arising with a curving proximal contact from the vesicle wall.

Material : three specimens.

Dimensions: Vesicle 19(22)25μm long

processes 11(17)20μm long

Occurrence : Shalloch formation, Woodland Point, Girvan (MV/G/22,23,28).

Previous Occurrence : Middle and Upper Ordovician, Girvan (Turner 1979 m.s.); Caradoc, Shropshire (Turner 1984).

Remarks : this species differs from *G. splendens* as its processes are more slender, from *G. connectum* by having a greater number of processes and acuminate distal terminations and from *G. conjunctum*, which is much bigger.

Goniosphaeridium cf. elongatum

(Pl. 14, fig. 12)

Description : vesicle smooth, small, ellipsoidal, bearing a large number of conical processes which are simple, wide at the base, open to the vesicle cavity, and taper to hair-like acuminate tips. Processes are about half of the vesicle diameter in length.

Material : one specimen

Dimensions : Diameter 20μm
Process length 10μm

Occurrence : Ardwell Flags, Ardmillan Braes, Girvan (MV/G/6).

Remarks : this specimen is not confidently assigned to this species due to all the processes being consistently half the length of the vesicle, which differs from Turner's (1984) description.

Goniosphaeridium girvanense n.sp.

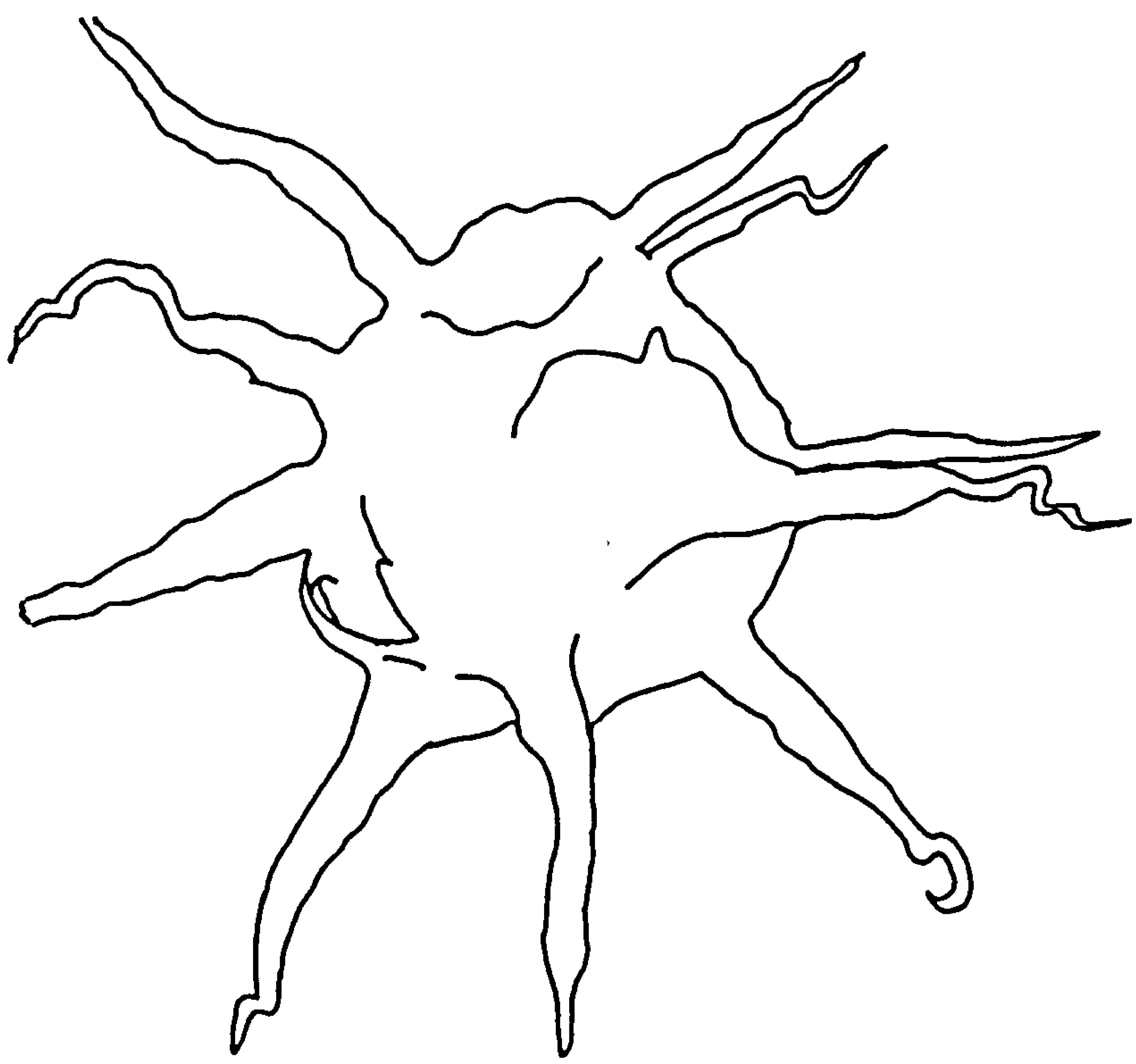
(Pl. 15, fig. 1; Pl. 25, fig. 1 (holotype) Figure 30)

Type Locality : grey shale100m below the exposed top of the Shalloch Formation, Woodland Point, Girvan, Strathclyde, Scotland, [NX 21745954].

Holotype : MV/G/23(1), England Finder Reference R40/4; Pl. 25, fig. 1; stored in the Hunterian Museum, University of Glasgow : specimen number x1568

Diagnosis : spherical vesicle with a variable number of processes which are generally shorter in length than the vesicle diameter, and which open into the vesicle cavity. Processes are simple, acuminate and occasionally become threadlike.

Description : vesicle spherical, shagreenate, bearing a variable number (six to



X1560

Figure 30 : *Goniosphaeridium girvanense* n. sp.

fourteen) of robust, shagreenate, conical, homomorphic, simple processes with gently curved or angular proximal process contact, and a process separation of about ten microns. Processes usually about three-quarters of the vesicle diameter in length and about one tenth of the diameter in width. Excystment may be by a simple split, but this could have been a mechanical rip. Distal terminations occasionally become threadlike. Process interiors open into the vesicle cavity. The wall is less than or equal to one micron in thickness.

Material : thirty two specimens

Dimensions : Diameter : holotype 37µm range : 37(48)62µm
Process length : holotype 27µm; range : 27(34)55µm
Process width : holotype 5µm range : 3(4.5)6µm
11 specimens measured.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/18,21 22,23,24,25, 26,27,28).

Remarks : these specimens are referred to the genus *Goniosphaeridium* because the vesicle is greater that twenty microns in diameter, and there are eight or more simple, homomorphic processes which are open to the vesicle cavity, and which have acuminate distal terminations. Wicander (1984) erected a new genus *Ephelopalla* from the Devonian to which he assigned two new species, *E. elongata* and *E.talea.* These have some secondary infilling distally in their processes. Turner (1984) discusses that genus and concludes that some of the specimens should be assigned to *Baltisphaeridium* and some to *Solisphaeridium*. Apart from the secondary infilling my specimens appear to be similar to both species of *Ephelopalla* . The generic diagnosis of *Solisphaeridium* does not allow inclusion of the present specimens as they have hollow, open processes, and no secondary deposition. This new species may relate to *Ephelopalla* but it is impossible to say without seeing the type material.

Goniosphaeridium splendens (Eisenack 1931) Turner 1984
(Pl. 14, fig. 13; Pl. 24, fig. 5)

1931 *Ovum hispidum polygonale* Eisenack p.113,Pl.4, figs 18,19,(pars).

1970 *Veryhachium splendens* Paris and Deunff p.27, Pl.1, fig.4, Text-fig. 1.

1974 *Goniosphaeridium* cf. *polygonale* Rauscher, p.165, Pl.10, figs 14,15.

1976 *Goniosphaeridium polygonale* Eisenack p.96, Pl.5, fig. 1.

1985 *Polygonium gracile* : Jacobson and Achab, p. 192, Pl.7, figs. 8,9.

Description (Turner 1984) : "the vesicle is hollow, polygonal, smooth, thin-walled (about 0.5μm), bearing a variable number of robust, hollow, smooth, simple, conical, homomorphic processes, the interiors of which open into the vesicle cavity; the processes taper gradually to acuminate tips. The vesicle and process walls are undifferentiated, merging imperceptively via a curving contact. No excystment structure was observed".

Description : vesicle thin-walled, smooth, spherical to ellipsoidal in shape with a variable number of homomorphic processes. The proximal contacts of the processes with the body are gently curving and the simple processes are psilate, conical and distally acuminate. The processes connect with the vesicle cavity, and the process length is generally less than the diameter of the vesicle.

Material : six specimens

Dimensions : vesicle diameter : 18(22)30μm
process length : 8-16μm
3 specimens measured.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/ 21, 28); *D. anceps*, (SU/DL/10), *G. persculptus* (SU/DL/51) and *P. acuminatus* (SU/DL/56) Zones, Main Cliff, Dob's Linn.

Previous occurrence : Ordovician erratics, Baltic (Eisenack 1931), Llanvirn, France (Paris and Deunff 1970), Ordovician, France (Rauscher 1974b); Caradoc, Shropshire (Turner 1984), Middle and Upper Ordovician, Girvan (Turner 1979 m.s.); Vauréal Formation, Anticosti Island (Jacobson and Achab 1985).

Remarks : this is an extremely variable species as seen from Pl.13, figs. 3, 4,and 5 of Turner (1984). Jacobson and Achab (1985) illustrate a species that is apparently identical to that illustrated by Turner (1984) but under the name

Polygonium gracile.. It seems likely that these two species are synonomous, and the present author agrees with Turner (1984) that *Goniosphaeridium* and *Polygonium* are probably synonomous, but that the type material would need to be examined before such a major change could be made.

Goniosphaeridium sp. indet.
(Pl. 15, fig.6)

Description: small spherical body with nine processes apparently simple and acuminate but with possible bifurcate tips. Preservation is too poor for a more definite determination to be made.

Material : one specimen only

Dimensions : Diameter 25µm
Process length 7-12µm.

Occurrence : *P. acuminatus* Zone Main Cliff, Dob's Linn (SU/DL/54).

Genus *Leiofusa* (Eisenack)Eisenack 1934 emend. Combaz *et al.* 1967

1934 *Ovum hispidum fusiformis* Eisenack, p. 65, Pl. 14, fig. 19

1938 *Leiofusa* Eisenack, p. 28

1967 *Leiofusa* Eisenack emend. Combaz, Lange and Pansart, p. 297.

Restricted diagnosis (Cramer 1971) : "vesicle hollow, fusiform, with simple pointed processes at each pole. Processes varying in length from less than a tenth to as much as five times the length of the body. Vesicle wall unilayered, psilate to microgranulate. Sculptural elements not arranged in longitudinal rows. The long axis of the vesicle coincides with the longitudinal vesicle symmetry axis. Vesicle symmetry longitudinal, holomorphic. Longitudinal axis straight or essentially so. Pylome circular, slit shaped or formed by equatorial splitting".

Type Species : *Leiofusa fusiformis* (Eisenack 1938) Cramer 1971.

Leiofusa aspilis ? Loeblich 1970
(Pl. 15, fig. 2)

1970 *Leiofusa aspilis* Loeblich, p. 723, Pl.17, figs A-C.

Diagnosis (Loeblich 1970) : "inflated, hollow, fusiform central body with no clear differentiation from the hollow, blunt to sharp pointed processes at each end; wall thin and transparent, less than 1μm in thickness, wrinkled and folded during burial, smooth to slightly shagreenate surface; no excystment structure observed".

Description : smooth, fusiform vesicle with polar processes. The conical, blunt processes are about one seventeenth of the maximum vesicle length. The wall is about 0.5μm in thickness.

Material : two specimens.

Dimensions : Length 85-172μm
Width 22-37μm.

Occurrence : Jubilation Member, Doularg Hill, Girvan (MV/ G/8).

Previous occurrence : Middle Silurian Maplewood Shales (Loeblich 1970).

Remarks : the polar processes on these specimens are very short for this genus. At one of the polar processes in the present specimens it is possible that the process is separated from the central cavity, but the preservation is not very good, and it is difficult to be certain.

Leiofusa sp. A
(Pl. 15, fig. 3)

Description : vesicle smooth, fusiform, with polar processes which are presumable acuminate but are always broken. The wall is about 1μm thick, and unornamented. Processes are about a quarter of the maximum length of the vesicle.

Material : four specimens

Dimensions : Length 130(161)220μm
Width 15(23)30μm
4 specimens measured

Occurrence : Jubilation Member, Doularg Hill, Girvan (MV/G/8,9), Shalloch Formation, Woodland Point, Girvan (MV/G/20,22).

Remarks : these specimens are too thick walled to be either *Leiofusa litotes* or *L. fusiformis.*

Genus *Leiosphaeridia* Eisenack 1958 emend. Downie and Sarjeant 1963.

1958 *Leiosphaeridia* Eisenack, p. 2-3.
1963 *Leiosphaeridia* Eisenack emend. Downie and Sarjeant, p. 94.

Diagnosis (Eisenack 1958b) : "hollow ball-shaped, thin-walled organic remains of a very resistant, enduring bright-yellow to dark reddish-brown, transparent organic substance, frequently occurring in compressed discs or alternatively known as irregularly folded (forms). Wall also in mature condition, always without pores (and thus distinct from *Tasmanites*). Pylome present. [Translation].

Type Species : *Leiosphaeridia baltica* Eisenack 1958.

Remarks : Downie and Sarjeant (1963) discuss in detail the various taxonomic changes that this complicated genus has been through. The present author cannot agree with Turner (1984) who suggests that *Leiosphaeridia* should be restricted to forms with a pylome and erects a new genus *Dichotisphaera* (p. 107-108) for forms exhibiting a split an excystment feature, as many of the specimens are very thin-walled and seem quite susceptible to mechanical ripping.

Leiosphaeridia cf. *tenuissima* Eisenack 1958
(Pl. 15, fig. 5)

1958b *Leiosphaeridia tenuissima* Eisenack, p. 8, Pl.2, figs 1,2.

Diagnosis (Eisenack 1958b) : "wall extremely thin and delicate, transparent, glass clear; preserved only as flattened almost circular discs. No pylome observed." [Translation in Turner 1984].

Description : small, spherical, psilate vesicle with a thin, transparent wall (less than 0.5µm), without ornament but with common folding of the wall. A pylome seen in one specimen.

Material : hundreds of specimens

Dimensions : Vesicle diameter 17.5 (35)45µm
10 specimens measured.

Occurrence : Infra-Kilranny mudstones, Dow Hill (MV/G/5), Ardwell Flags, Ardmillan Braes, Girvan (MV/G/6), Ardwell Flags, Ardwell Farm, Girvan (MV/G/7), Jubilation Member, Doularg Hill, Girvan, (MV/G/8,9). Shalloch Formation (MV/G/18,19, 20, 21 , 22, 23, 24, 25, 26, 27, 28) and Mill Formation (MV/G/29), Woodland Point, Girvan.

Previous occurrence : Tremadoc, U.S.S.R. (Eisenack 1958b); Undivided Palaeozoic, North Africa (Combaz 1966); Caradoc/Ashgill, Kansas, USA (Wright and Meyers 1981); Caradoc, Shropshire (Turner 1984).

Remarks : these specimens are much smaller than those described by Eisenack (1958) and also Turner (1984), and so this species is not confidently assigned.

Leiosphaeridia cf. *voigtii* Eisenack 1958
(Pl. 15, fig. 4)

1958 *Leiosphaeridia voigtii* Eisenack, p. 392, Pl. 1, figs 4-6.

Diagnosis (Eisenack 1958b) : "wall thin, translucent, red-brown, without pores; often in a compressed state, in a circle or spindle form (?). Diameter about 260µm, frequently with a small, double bordered pylome, about 10µm in diameter or 20µm inclusive of the edge". [Translation].

Description : small to medium sized, spherical, thick-walled (1μm or greater) sphaeromorph acritarch, which is unornamented. No excystment feature is recorded.

Material : hundreds of specimens

Dimensions : Vesicle diameter 35(62)95μm.
10 specimens measured.

Occurrence : Infra-Kilranny mudstones, Dow Hill (MV/G/5), Ardwell Flags, Ardmillan Braes (MV/G/6), Ardwell Flags, Ardwell Farm (MV/G/7), Jubilation Member, Doularg Hill (MV/G/8,9), Shalloch (MV/G/18,19,20,21,22,23, 24,25,26,27,28) and Mill (MV/G/29) Formations, Woodland Point, Girvan.

Previous Occurrence : Ordovician of the Baltic (Eisenack 1958b); Middle and Upper Ordovician, Girvan (Turner 1979 m.s.); Caradoc of Shropshire, (Turner 1984).

Remarks : this species is differentiated from *L.* cf *tenuissima* by its greater size and thicker wall. It is smaller than the type material and thus not confidently assigned.

Leiosphaeridia sp. A
(Pl. 15, fig. 7)

Description : thick walled (greater than 2μm), spherical to ovate form with an irregular, slightly pitted surface. No excystment feature recorded.

Material : hundreds of specimens.

Dimensions : Vesicle diameter 30(38)50μm.

Occurrence : Shalloch (MV/G/18,19,20,21,22,23,24,25,26,27,28) and Mill (MV/G/29) Formations, Woodland Point, Girvan.

Remarks : it is possible that this species also contains corroded chitinozoan bases and spores.

Leiosphaeridia sp. B.

(Pl. 15, fig. 8)

1988 *Leiosphaeridia* sp. 1 Whelan, p. 43

Description : thick walled, large, compressed form often with what appear to be pores, and rarely with small spines.

Material : hundreds of specimens.

Dimensions : Vesicle diameter : 58(83)102μm
10 specimens measured.

Occurrence : *C. wilsoni, D. clingani, P. linearis, D. complanatus D. anceps, C? extraordinarius, G. persculptus* and *P. acuminatus* Zones, Dob's Linn (SU/DL/2, 3,4,6,7,9,10,11,12,13,14,15,17,31,32,33,38,39,40,41,45,46,47,48,49,50,51,52,53, 54,55,56,57). Cross Water, Barrhill (SU/B/1,3,4,8,10). Shalloch Formation, Woodland Point, Girvan (MV/G/26).

Previous occurrence : ?Ordovician, Baltic (Eisenack 1953); Silurian, Pomerania (Eisenack 1972a).

Remarks : this is identical to Eisenack's (1953) specimen figured as *Leiosphaera* (Pl.1, fig. 12).

Leiosphaeridia sp. C

(Pl. 15, fig. 9, 12)

1988 *Leiosphaeridia* sp. 2 Whelan, p. 43

Description : thin-walled (about 1μm), spherical *Leiosphaeridia* species with a granular wall and common folding.

Material : hundreds of specimens

Dimensions : Vesicle diameter 39(47)64µm
10 specimens measured.

Occurrence : *C. peltifer, C. wilsoni, D. clingani, P. linearis, D. complanatus D. anceps, C? extraordinarius, G. persculptus* and *P. acuminatus* Zones, Dob's Linn (SU/DL/1,2,3,4, 5,6,7,9,10,11,12,13,14,15,16,31,32,33,34,35,36, 39,44,46,47,48,49,50,51,52,53, 54,55,56,57). North Esk River, Edzell (HB/NE/3, 4, 6, 8, 12, 14); Bofrishlie Burn, Aberfoyle (HB/BB/1,2); Stonehaven (HB/S/2) ; Limecraig Quarry, Aberfoyle (HB/LC/2,3,4,5); Leny Quarry, Callander (HB/LQ/1,2,3,4,5,6); Glen Fruin (HB/GF/1); North Glen Sannox, Arran (HB/A/3); Cross Water, Barrhill (SU/B/1,3,6,8,12).

Remarks : this species is thinner walled and generally smaller than *Leiosphaeridia* sp. B.

Leiosphaeridia sp.D
(Pl. 15, fig. 15)

Description : pale, relatively thick-walled (~1µm) sphaeromorph with a rugulate-foveolate wall and a rip which might be an excystment feature.

Material : one specimen.

Dimensions : Diameter 43µm

Occurrence : Jubilation Member, Doularg Hill, Girvan (MV/G/9).

Leiosphaeridia sp. E
(Pl. 15, fig. 13)

Description : spherical sphaeromorph acritarch with very large bulbous verrucae giving a petaloid or botryoidal appearance to this specimen. The verrucae are about 10µm across, and the wall is reticulate in between and on the verrucae.

Material : one specimen

Dimensions : Diameter 36μm

Occurrence : Infra-Kilranny mudstones, Dow Hill, Girvan (MV/G/5)

Leiosphaeridia sp. F
(Pl. 15, fig. 14)

Description : spherical to quadrate, folded brown granular leiosphere.

Material :approximately a hundred specimens.

Dimensions : Diameter 24(33) 41μm
5 specimens measured

Occurrence : Cross Water, Barrhill (SU/B/1,3,6,14,16)

Leiosphaeridia sp. G
(Pl. 15, fig. 10)

Description : thick walled spherical verrucate form.

Material : two specimens.

Dimensions : Diameter 23-25μm.

Occurrence : Cross Water, Barrhill (SU/B/4), Ardwell Flags, Ardmillan Braes, Girvan (MV/G/6).

Leiosphaeridia sp. H
(Pl. 15, fig. 11)

Description : spherical, relatively thick walled, apparently zoned and commonly folded, possibly convoluted sphaeromorph acritarch.

Material : sixty six specimens.

Dimensions : Diameter 22(24)27µm
5 specimens measured.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/21,22, 23).

Genus *Micrhystridium* Deflandre 1937 emend. Downie and Sarjeant1963

1937 *Micrhystridium* Deflandre, p. 79-80

1963 *Micrhystridium* Deflandre emend. Downie and Sarjeant p. 83-84

Emended Diagnosis (Downie and Sarjeant 1963) : "hystrichospheres with spherical to oval shells not divided into fields or plates, bearing processes with closed tips, most often simple, rarely branching or ramifying, without distal connections of any kind. The processes are generally of one type only. Mean and modal diameter of shell less than 20µm".

Type Species: *Micrhystridium inconspicuum* Deflandre 1937 as *Hystrichosphaera inconspicua* Deflandre 1935

Remarks: see Turner (1984) for discussion of this genus. Many species of this genus have been described, but due to their generally poor illustrations, comparison is difficult. Therefore the species in this study are assigned only sp. A-D, although they could probably be included in more than four previously published species.

Micrhystridium sp. A
(Pl. 16, figs 1,2,4)

1988 *Micrhystridium* sp. 3 Whelan, p. 43.

Description : small spherical (sometimes slightly triangular) smooth, reasonably thick walled (~1µm) vesicle with a variable number of processes (5-18), which are small conical, acuminate, simple, hollow, and open to the vesicle cavity. No excystment feature recorded.

Material : eleven specimens

Dimensions : Vesicle diameter 14(17)21µm
Process length 3(7)10µm
Process width 1-3µm
8 specimens measured

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/23,24,25,26); *C. peltifer, D. anceps and P. acuminatus* Zones, Main Cliff, Dob's Linn (SU/DL/1,10,57).

Micrhystridium sp. B
(Pl. 16, fig. 3)

Description : small spherical, thin walled psilate vesicle with a variable number (6-14) of process which are conical, slender, simple, open, smooth, acuminate and communicate with the interior of the vesicle. The processes have a curved contact with the vesicle wall, and are quite wide at the base. No excystment feature has been noted.

Material : eight specimens

Dimensions : Vesicle diameter 14(17.5)21µm
Process length 11(13)16µm
Process width 1-4µm
7 specimens measured.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/20,23,25,26,28); *D. anceps* Zone, Main Cliff, Dob's Linn (SU/DL/46).

Remarks : this species is differentiated from *Micrhystridium* sp. A by its longer more slender processes.

Micrhystridium sp. C

(Pl. 16, figs 5-6; Pl. 26, fig. 8)

1988 *Micrhystridium* sp. 1 Whelan, p. 43.

Description : small spherical vesicle with a small number of very short conical, wide based processes which are apparently open to the vesicle, and are simple and have acuminate tips. This species is often black and ripped due to carbonisation .

Material : Seven specimens

Dimensions : Vesicle diameter 27(31)35μm

Process length 3μm

Process width 2-3μm

3 specimens measured.

Occurrence : *P. linearis, D. anceps and C? extraordinarius* Zones, Main Cliff, Dob's Linn (SU/DL/4,10,12,44,17), Cross Water, Barrhill (SU/B/16).

Remarks : this species may be conspecific with *M.* sp. A, but generally has very short wide processes, while *M* sp. A can have reasonably long conical processes.

?Micrhystridium sp. D

(Pl. 24, fig. 6)

1988 *Micrhystridium* sp.2 Whelan, p. 43

Description : very thick walled spherical vesicle with numerous processes, some of which are acuminate and some evexate, though all appear to communicate with the interior of the vesicle. The specimen is quite large.

Material : one specimen only.

Dimensions : Vesicle diameter 40μm

Process length 2-10μm

1 specimen only.

Occurrence : *C?extraordinarius* Zone, Main Cliff, Dob's Linn (SU/DL/17).

Remarks : this specimen is very large (larger in fact than the generic diagnosis allows for), and has heteromorphic process terminations, though this may be due to preservation. It is therefore possible that it should be incorporated in another genus but for the present time it is doubtfully assigned to *Micrhystridium.*

Genus *Moyeria* Thusu 1973

1973 *Moyeria* Thusu, p. 141,142.

Diagnosis : (Thusu 1973) "elongate, subspherical rounded ovoid vesicle, clear brown, wall moderately thick, ornamentation composed of spiral striations and apparently forming an reticulation of two sets of crests crossing each other presenting a diamond, pad shaped, or rectangular surface in compressed specimens".

Type Species : *Moyeria cabotti* (Cramer 1971) Miller and Eames 1982

Moyeria cabotti (Cramer 1971) Miller and Eames 1982
(Pl. 16, figs 7,8)

1971 *Eupoikilofusa cabotti* Cramer p. 87, Pl.4, figs 66,97, Figure 25h.

1973 *Moyeria uticaensis* Thusu, p. 142, Pl.2, figs 18-22.

1974 *Schizaeoisporites* sp 1 Martin, p. 32. Pl. 4, figs 115,116,123, Pl.7, figs 233, 266.

1982 *Moyeria cabotti* (Cramer) Miller and Eames, p.242, Pl.3, fig.3.

1984 *Eupoikilofusa cabotti* Cramer -Turner, p. 109, Pl.12, figs, 3,6.

Original diagnosis : (Cramer 1971) :vesicle hollow, varying from ellipsoidal to fusiform in outline. Vesicle axis straight or crescent-shaped. No processes at poles. The vesicle wall contains about twenty thicker, longitudinally oriented parallel muri. These muri form a more or less helicoidal pattern, with the longitudinal vesicle axis as rotation centre. The vesicle wall is 0.5μm thick at the intermural areas, and about 1μm at the muri. The vesicle wall appears to be unilayered. No preferential splitting patterns or other pylome structures are known".

Emended diagnosis (Miller and Eames 1982) : "vesicle hollow, ovoidal to ellipsoidal in shape. polar processes absent. Ornamentation with helical folds which merge at the poles. Wall unilayered".

Description : ovoidal, ellipsoidal, or rhomboid vesicle, lacking polar features, ornamented with thicker muri (0.5-2μm wide), arranged in a helical manner, which merge at either end of the vesicle. The wall is generally psilate in between the muri.

Material : sixty eight specimens.

Dimensions : Vesicle length : 38 (51) 88μm
Vesicle width : 30 (46) 52μm
7 specimens measured.

Occurrence : Shalloch (MV/G/18,19,20,21,22,23,24,25,26,27,28) and Mill (MV/G/29) Formations Girvan; *P. acuminatus* Zone, Main Cliff, Dob's Linn (SU/ DL/54).

Previous occurrence : Neahga Shale, New York, Ontario, Llandovery (Cramer 1971); Ashgill-Llandovery, Belgium (Martin 1974); Middle Ordovician, Gotland (Kjellström 1971a); Caradoc, Shropshire (Turner 1984); Middle and Upper Ordovician, Girvan (Turner 1979 m.s.); Lower Llandovery Medina Group, USA (Miller and Eames 1982); Wenlock L'llion shale, New York (Thusu 1973); Caradoc, Kent (Lister *et al.* 1969); Middle Llandovery to Gedinnian, Spain (Cramer 1964b, 1966); Red Mountain Formation, Alabama (Cramer 1968).

Remarks : the genus *Eupoikilofusa* was erected in 1971 by Cramer to include all forms with fusiform, elongated vesicles with pointed poles, ornament in rows parallel to the longitudinal axis, and with or without polar processes. Although Cramer (1971) in the diagnosis of *Eupoikilofusa cabotti* did stress that there were no polar processes in that species. Miller and Eames (1982) transferred the species to *Moyeria* Thusu 1973 keeping *M. uticaensis* as the type species. However Turner (1984) emended the genus *Eupoikilofusa* to allow for forms without polar processes and with helical ornamentation. He considered *M. uticaensis* to be a junior synonym of *E. cabotti* and thus made the genus *Moyeria* invalid. The present author considers that *Eupoikilofusa* is not a suitable genus for generally ellipsoidal forms without polar processes and that *Moyeria* would be a more valid genus in which to place these specimens. As *M. uticaensis* is now a synonym of *E. cabotti*, the type species of this genus should be *Moyeria cabotti*.

The sample from the Mill Formation (MV/G/29) contains many specimens of this species though they appear to be more thick walled than the ones from the Shalloch Formation. One possible specimen from Dob's Linn is recorded.

Genus *Multiplicisphaeridium* Staplin 1961 restr. Staplin *et al.* 1965.

1961 *Multiplicisphaeridium* Staplin, p. 410

1965 *Multiplicisphaeridium* Staplin restr. Staplin *et al.* p. 182

1970 *Multiplicisphaeridium* Staplin emend. Lister, p. 83-84.

Diagnosis (Staplin *et al.* 1965): "vesicles ellipsoidal, subspherical or spherical; processes separate, proximally slender, distally multifurcate, expanded, dissected or otherwise modified with closed tips; processes on one vesicle all of one kind or variations of one type, not differentiated into more or orders or kinds of processes; wall smooth or with minor ornamentation; no differentiation between vesicle wall and processes; spine cavity in open connection with vesicle interior.

Emended Diagnosis (Lister 1970): "vesicle hollow, spherical to ellipsoidal, single-walled; processes with closed tips, heteromorphic, simple or compound branching, wall smooth or with minor ornamentation; no differentiation between vesicle wall and processes; process cavity in open connection with vesicle interior. Excystment by cryptosuture, apical or near equatorial".

Type Species: *Multiplicisphaeridium ramispinosum* Staplin 1961

Multiplicisphaeridium alloiteaui (Deunff 1955) Kjellström 1976
(Pl. 16, fig. 10)

1955 *Micrhystridium alloiteaui* Deunff, p. 148, Pl.4:3.
1963 *Baltisphaeridium alloiteaui* (Deunff) Downie and Sarjeant p. 89.
1976 *Multiplicisphaeridium alloiteaui* (Deunff) Kjellström, p. 32, Fig. 26.

Diagnosis: Not found.

Description : spherical vesicle with thirteen processes, showing curved proximal contacts with the vesicle. Processes about a third of the vesicle diameter. Some processes apparently simple with evexate terminations, others bifurcating. No obvious surface ornamentation, and no excystment feature seen.

Material : one specimen.

Dimensions : Diameter 25µm
Process length 10µm
1 specimen only.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/ 28).

Previous occurrence : Caradoc, Kent, England, (Lister *et al.* 1969); Ordovician of Brittany (Deunff 1959); Upper Ordovician, Sylen Formation, Finland (Tynni 1975); Ordovician, Belgium (Martin 1965, 69); Middle Devonian of Canada (Kjellström 1976).

Remarks : this specimen is very much smaller than that described by Kjellström(1976).

Multiplicisphaeridium bifurcatum Staplin, Jansonius and Pocock 1965.
(Pl. 16, figs 9, 11)

1965 *Multiplicisphaeridium bifurcatum* Staplin, Jansonius and Pocock, p.182, Pl.18, fig. 13.

Diagnosis (Staplin Jansonius and Pocock 1965): "vesicle subspherical, numerous semi-cylindrical spines, tapering at the distal end, branching into two tips (as a snake's tongue)".

Description : vesicle spherical; smooth to shagrinate; showing about eleven processes, and exhibiting curved proximal contact with the vesicle. The processes bifurcate at their distal ends. No excystment feature is seen.

Material : two specimens only

Dimensions : Vesicle diameter 18-20μm
Process length 8-10μm
2 specimens only.

Occurrence : *D. clingani* Zone, Main Cliff, Dob's Linn (SU/DL/3) ; Shalloch Formation, Woodland Point, Girvan (MV/G/28).

Previous occurrence : Middle Ordovician, Gotland (Kjellström 1971a); Trenton Formation, Anticosti Island (Staplin, Jansonius and Pocock 1965, Loeblich and Tappan 1978); Caradoc of Kent, England, (Lister *et al.* 1969); Upper Ordovician, Sylen Formation, Finland (Tynni 1975); Caradoc-Ashgill, Maquoketa Shale, Kansas (Wright and Meyers 1981); Upper Ordovician, Portugal (Elaouad-Debbaj 1978); Vauréal Formation (Ashgill), Anticosti Island (Jacobson and Achab 1985).

Multiplicisphaeridium irregulare Staplin, Jansonius and Pocock 1965
(Pl. 16, figs 12-13)

1965 *Multiplicisphaeridium irregulare* Staplin, Jansonius and Pocock, p. 183, Pl.18, fig. 18 *non* fig. 17.

1968 *Baltisphaeridium irregulare* (Staplin *et al.*) Martin, p. 55, Pl. 5, fig. 216.

Diagnosis (Loeblich and Tappan 1978): "a species of *Multiplicisphaeridium* ornamented with hollow flexible processes that communicate with the vesicle interior, processes of two types, the majority being simple and conical, but others are alternately branched (rarely) or dichotomously branched; wall thin, of equal thickness in both the vesicle and the processes, both also with a laevigate surface".

Description : spherical vesicle, with about five to twelve long conical processes, which are not separated from the interior of the cavity. Some of the processes are simple and acuminate and others are bifurcating at their distal ends; the processes are of varying lengths with respect to the vesicle diameter, and vary between 1 and 2μm in thickness. The surface of the wall is smooth, and no excystment feature is seen.

Material : three specimens.

Dimensions : Vesicle diameter 12 (13.66) 14μm
Process length 9(13)15μm.

Occurrence : Shalloch Formation, Woodland Point, Girvan, (MV/G/20, 27), *G. persculptus* Zone, Main Cliff, Dob's Linn (SU/DL/ 50).

Previous occurrence : Middle Ordovician, Trenton Formation, Anticosti Island (Staplin *et al.* 1965); Caradoc of Kent, England, (Lister *et al.* 1969); Middle and Upper Ordovician, Girvan (Turner 1979m.s.); Ordovician of Belgium (Martin 1968); Upper Ordovician, Sylen Formation, Finland (Tynni 1975); Caradoc-Ashgill, Maquoketa Shale, Kansas (Wright and Meyers 1981); Vauréal Formation (Ashgill), Anticosti Island (Jacobson and Achab 1985).

Remarks : the specimen from Dob's Linn has much shorter processes than the Girvan specimens.

Multiplicisphaeridium ramusculosum (Deflandre) Lister 1970.
(Pl. 16, figs 14-15)

1942 *Hystrichosphaeridium ramusculosum* Deflandre, p. 476, fig. 2-6.
1945 *Hystrichosphaeridium ramusculosum* Deflandre, p. 63, Pl. 1, figs 8-16,

Text-figs 38,39.

1959 *Baltisphaeridium ramusculosum* (Deflandre) Downie, p. 59, Pl. 11, fig. 13.

1970 *Multiplicisphaeridium ramusculosum* (Deflandre) Lister, p. 92-93, Pl.11, fig. 8, 11-14; Text-fig. 25a.

1981 *Oppilatala ramusculosa* (Deflandre) Dorning, p. 196.

1988 *Multiplicisphaeridium* sp. 2 Whelan, p. 43.

Diagnosis (Translation of Deflandre (1945) in Lister (1970): "globular vesicle in some cases ellipsoidal or subspherical, ornamented with processes which are usually greater in length than half the shell diameter, and perhaps equal to the diameter. The processes are of two types. some are simple and pointed. The others very characteristic, are ramified in an irregular manner and in addition often carry spines on the main trunk of the process".

Description : spherical vesicle with a thin smooth wall, and an angular proximal process contact with the vesicle. Processes are either simple with blunt ends or show bifurcations up to the third order. The length of the processes is extremely variable but is usually about a third of the diameter. The excystment feature is shown as a simple split.

Material : many specimens.

Dimensions : Vesicle diameter13(20.5)30μm
Process length 2(6)10-9(10.8)12μm
10 specimens measured.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/20,21, 22,23,24,25,27, 28) , *D. anceps* Zone Main Clif, Dob's Linn (SU/DL/10).

Previous occurrence: Ordovician to Devonian (see Elaouad-Debbaj (1978).

Multiplicishaeridium cf. *wrigtii* Jacobson and Achab 1985

(Pl. 17, fig. 1)

1985 *Multiplicisphaeridium wrightii* Jacobson and Achab, p. 186-188, Pl.6, figs. 4,7,8.

Diagnosis (Jacobson and Achab 1985) : "spherical to subspherical smooth vesicle with seven to ten broad hollow cylindrical processes. Processes often longer than the vesicle diameter. Process width at least a quarter of vesicle diameter and rarely with isoloated grana. Furcations begin at least three-quarters of the process length from the vesicle, are concentrated distally and can be third order or more. Furcations are often irregular, rarely dichotomous, giving a ragged appearance. Length of the terminal furcae rarely as long as one-fifth process length and frequently much longer".

Description : spherical, psilate, vesicle with seven broad hollow proceses, showing an angular proximal process contact with the vesicle. The processes are open to the vesicle cavity. Processes are about half the length of the vesicle diameter. Processes are multi-furcated and the complex furcations begin about half way down the process, giving what is described as a ragged appearance in the diagnosis. The process widths vary from one fifth to one tenth of the vesicle diameter. No excystment feature is seen in the one specimen of this species.

Material : one specimen.

Dimensions : Vesicle diameter 20μm
Process length 10μm
Process width 2-4μm.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/22).

Previous occurrence : lower Ashgill Maquoketa Shale, Kansas, (Wright and Meyers 1981); Vauréal Formation, (Ashgill), Québec, (Jacobson and Achab 1985).

Remarks : this specimen appears to be very similar to both *M. wrightii* and *M. continuatum* Kjellström (1971). Although the processes are a little too short, and some of them are a little too narrow for *M. wrightii,* this species is closer to *M. wrightii,* than to *M. continuatum.*

Multiplicisphaeridium sp. A

(Pl. 17, fig. 3)

1988 *Multiplicisphaeridium* sp. 1 Whelan, p. 43.

Description : spherical to ellipsoidal vesicle apparently smooth walled, with an angular to curved proximal process contact. Processes are about a quarter of the vesicle diameter. Processes are heteromorphic, either acuminate, evexate or bifurcating. No excystment feature seen.

Material : eight specimens.

Dimensions : Diameter 24(30)37μm
Process length 7(8)10μm
5 specimens measured.

Occurrence : *D, anceps, C? extraordinarius, G. persculptus,* and *P. acuminatus* Zones, Main Cliff, Dob's Linn (SU/DL/14, 15, 39, 49, 51, 56, 57).

Remarks : this species is usually quite well preserved, however it is possible due to its extensive range that it is a bucket species, and better preservation would allow more than one species to be recognised.

Multiplicisphaeridium sp. B

(Pl. 17, fig. 7)

Description : ellipsoidal vesicle with acuminate, blunt-tipped or rare bifurcating processes showing an angular proximal contact. Processes vary in length from a quarter to a half of the vesicle diameter, and in width from 0.5 to 2 μm. No excystment feature seen.

Material : one specimen.

Dimensions : Diameter 28μm
Process length 6-14μm.

Occurrence : *G. persculptus* Zone, Main Cliff, Dob's Linn (SU/DL/52).

Multiplicisphaeridium sp. C
(Pl. 17, fig. 4)

Description : spherical, shagrinate vesicle with a curved proximal process contact. There are about eight processes showing both acuminate and more rarely bifurcating terminations. The processes are open to the interior of the vesicle, and no excystment feature is seen.

Material : one specimen only

Dimensions : Diameter 18μm
Process length 10μm.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/ 27).

Genus *Navifusa* Combaz, Lange and Pansart 1967

1967 *Navifusa* Combaz Lange and Pansart, p. 293-295.

Original Diagnosis (Combaz *et al.* 1967): "vesicle having the form of a more or less elongate ellipse, or rod-like with rounded extremities without processes. Wall simple, smooth or ornamented". [Translation].

Type Species: *Navifusa navis* ex *Leiofusa navis* Eisenack 1938

Navifusa similis (Eisenack 1965) Turner 1984
(Pl. 25, fig. 4)

1965 *Leiovalia similis* Eisenack, p.139, Pl.12, figs. 5,6.
1984 *Navifusa similis* (Eisenack) Turner, p. 122, Pl. 10, fig. 5.

Original Diagnosis (Eisenack 1965a in Turner 1984) : "elongate vesicle with a thin smooth wall and well rounded poles". [Translation].

Description : thin walled elongate vesicle with sub-parallel to parallel sides. The surface is unornamented, and the poles are broadly rounded. Folds in the walls are common.

Material : twenty nine specimens.

Dimensions : Length 62(76)96µm
Width 20(31)41µm
5 specimens measured.

Occurrence : Shalloch Formation (MV/G/20,23,24,25,26,27,28); Mill Formation (MV/G/29), Woodland Point, Girvan.

Previous Occurrence : Upper Ordovician, Baltic (Eisenack 1965a); Llandeilo, W.Australia (Combaz and Peniguel, 1972); Upper Ordovician, Sylen Formation, Finland (Tynni 1976), Edenian, Kentucky (Jacobson 1978), Caradoc of Girvan and Shropshire (Turner 1984); Middle and Upper Ordovician (Turner 1979 m. s.); Ashgill, Libya (Molyneux and Paris 1985).

Remarks : the present specimens appear to be identical to those of Turner (1984), though many of his specimens attained much larger sizes. One specimen only exhibits a median split but the evidence that this could be an excystment feature is still equivocal.

Navifusa sp. A

(Pl. 17, fig. 2)

Description : elongate, naviform body with broadly ronded ends, one of the polar regions is sometimes larger than the other. Very thin walled (<1µm), and commonly folded. No excystment feature is seen.

Material : four specimens.

Dimensions : Length 95-111µm

Width 12-16μm.

2 specimens measured.

Occurrence : Infrakilranny mudstones, Dow Hill (MV/G/5), Shalloch Formation, Woodland Point, Girvan (MV/G/18,27).

Navifusa sp. B

(Pl. 17, figs 5-6)

Description : vesicle elongate, with broadly rounded ends and apparently a fairly coarse granulation, though preservation is poor.

Material : twenty two specimens

Dimensions : Length 55(78)118μm

Width 18(23)29μm.

5 specimens measured.

Occurrence : *P. linearis, D. complanatus* and *D. anceps* Zones, Main Cliff, Dob's Linn (SU/DL/4,6,47,); River North Esk, Edzell (HB/NE/12); North Glen Sannox, Arran (HB/A/3).

Navifusa sp. C

(Pl. 17, fig. 8)

Description : elongate naviform, vesicle, apparently smooth, but coated in mineral, with a moderately thin wall and no ornament. No excystment feature is recorded.

Material : one specimen only

Dimensions : Length 161μm

Width 26μm.

1 specimen only

Occurrence : Jubilation Member, Doularg Hill, Girvan (MV/G/8).

Remarks : this species differs from *Navifusa similis* by being longer, thinner and thicker walled than the other specimens that have been recorded.

Navifusa sp. D
(Pl. 17, fig. 9)

Description : very thin faintly granulate navifusid with one pole much wider than the other.

Material : one specimen

Dimensions : Length 137µm
Width 30µm at widest pole
12.5µm at narrowest pole.

Occurrence : Limecraig Quarry, Aberfoyle (HB/LC/4).

Genus *Neoveryhachium* Cramer 1971

1971 *Neoveryhachium* Cramer p. 110-112.

Diagnosis (Cramer 1971) : "vesicle symmetry regular, morphology determined by number of processes. Central body polygonal. The processes are the simple and unbranched of the veryhachid kind; ornamentation by sculpture minor. The vesicles open through pylomes. Vesicle wall double; the ectoderm is tightly enveloped by a third wall layer, the periderm".

Type species : *Neoveryhachium carminae* (Cramer 1964) Cramer 1971

Neoveryhachium sp. A
(Pl. 17, fig. 10)

1988 *Neoveryhachium* sp. 1 Whelan, p. 43.

Description : vesicle quadrate with the four processes radiating from each corner.

The processes are small (about a third of the maximum length). There appears to be no ornamentation, but a thin periderm (<1μm thick) stretches between the processes. No excystment mechanism is observed.

Material : two specimens

Dimensions : Length 31-40μm
Width 22-28μm
Periderm width 3-6μm.

Occurrence : *D. anceps, C? extraordinarius* Zones, Main Cliff, Dob's Linn (SU/DL/47, 17).

Remarks : while the preservation is relatively good it cannot be ruled out that this is a reworked Lower Ordovician form such as *Aureotesta* .

Genus *Orthosphaeridium* Eisenack 1968 emend. Turner 1984

1968 *Orthosphaeridium* Eisenack p. 211.

1984 *Orthosphaeridium* Eisenack emend. Turner p. 125.

Emended diagnosis (Turner 1984) : "vesicle hollow, rectangular to circular in outline, bearing few (2-8) long, hollow, simple processes that taper to a sharp point; rarely a process may divide. Process interior is always separated from the vesicle cavity by a solid proximal plug. Excystment structure is an apparently straight split in a medium or equatorial position".

Type Species : *Orthosphaeridium rectangulare* ex *Baltisphaeridium rectangulare* Eisenack 1963b.

Orthosphaeridium chondrodora ? Loeblich and Tappan 1971.
(Pl.17, fig. 12)

1971 *Orthosphaeridium chondrodora* Loeblich and Tappan, p. 184, figs 2-6.

Diagnosis (Loeblich and Tappan 1971): "central vesicle ovate with inflated sides between the four long hollow processes; wall of vesicle 1.3µm in thickness, surface ornamented with low grana clearly visible in the light microscope, but the scanning electron microscope shows the structure to consist of grana of various sizes and outline, from low conical to slightly elongate ones, with the area beetween these showing smaller granules and a minutely rugulate pattern; processes with walls about 0.6µm in thickness, only slightly constricted at the junction with the vesicle where it pluggged for a distance of about 4µm, hollow except for the plug and an area at the distal sharp tip which is solid for a distance of 2.6µm, process surface ornamented by prominent grana throughout the entire length; excystment by a median splitting into two halves at right angles to the long dimension of the central vesicle".

Description : spherical to quadrate vesicle with four processes which are proximally plugged, generally longer than the vesicle diameter, and about a tenth of the diameter in width. The surface of the vesicle is faintly granular and about 1µm in thickness. The processes are hollow, and become acuminate at their distal ends. No obvious excystment feature is seen, though two of the specimens appear to be ripped.

Material : four specimens

Dimensions : Diameter 30(47)65µm
Process length 30(51)73µm
Process breadth 3(6)7µm.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/22, 24,25,).

Previous occurrence : Eden Formation, (Caradoc) Indiana (Loeblich and Tappan 1971, Colbath 1979); Caradoc of Shropshire (Turner 1984); Caradoc (as *O.* cf. *chondrodora*) of Libya, (Molyneux and Paris 1985); Upper Ordovician, Sylen Formation, Finland (Tynni 1975); Caradoc, Portugal (Elaouad-Debbaj 1978).

Remarks : these specimens are tentatively assigned to this species, because it is not possible to see proximal plugs in all the processes, also the granulation is quite faint, and the shape is often spherical.

Orthosphaeridium ? sp. A

(Pl. 17, fig. 11)

Description : *Orthosphaeridium* species with a granulate wall. There is clear separation of the process and the vesicle cavity. The processes are conical, simple and acuminate, but do not appear to be plugged. They are twice as long as the vesicle diameter, and only very slightly constricted at the base.

Material : one specimen.

Dimensions : Diameter 20µm
Process length 20µm
Process breadth 4µm
1 specimen only.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/28).

Remarks : this single specimen is poorly preserved, but on the basis that the processes are separated from the vesicle it is tentatively assigned to Orthosphaeridium.

Genus *Peteinosphaeridium* Staplin, Jansonius and Pocock 1965 emend. Eisenack 1969

1965 *Peteinosphaeridium* Staplin, Jansonius and Pocock, p. 194

1969 *Peteinosphaeridium* Staplin, Jansonius and Pocock, emend. Eisenack, p. 253-254.

Emended diagnosis (Eisenack 1969 translated in Turner 1984) : "vesicle spherical, fairly sturdy, solid or hollow, similar, uniformly distributed processes; process terminations closed and here they divide into two three or more irregularly formed branches. These vary from outward slanting to almost tangentially directed branches. Small scale secondary branches may also be developed. The branches, as with the process stems, may develop more or less broad membranes that run down the stems. These wings may be reduced or even disappear altogether or conversely be so strongly developed as to envelop the terminal branches. Pylomes (normal or raised) common".

Type species : *Peteinosphaeridium trifurcatum trifurcatum ex P. bergstromii* Staplin, Jansonius and Pocock 1965.

?*Peteinosphaeridium nudum* (Eisenack) Eisenack 1969

(Pl. 18, fig. 1)

1959 *Baltisphaeridium trifurcatum nudum* Eisenack, p. 203, Pl. 17, figs 4,5,6.

1965 *Baltisphaeridium nudum* Staplin, Jansonius and Pocock, p. 190, Pl. 20, figs.2,6,7,8; fig.12

1969 *Peteinosphaeridium nudum* (Eisenack), p. 255

Original diagnosis (Eisenack 1959 translated in Turner 1984) : "the size and shape, particularly of the processes, is like *Baltisphaeridium trifurcatum* forma *typica*, however the processes are without membranes".

Description : ovate vesicle, thin walled, smooth with numerous processes which are smooth and trifurcate and show an angular to curved proximal process contact with the vesicle. Processes appear to be open to the central cavity but are generally obscure. No excystment feature is observed.

Material : one specimen.

Dimensions : Vesicle length 32μm
Vesicle width 24μm
Process length 9μm.

Occurrence : Shalloch Formation, Woodlands Point, Girvan (MV/G/23).

Previous occurrence : Arenig, Montagne Noire, (Rauscher 1974); Middle Ordovician, Baltic (Eisenack 1959, 1962a, 1965a, 1968a). ?Wenlock, Belgium (Martin 1969). Middle Ordovician, Poland (Górka 1980). Middle Ordovician, Baltic (Kjellström 1971b). ?Ashgill, Silurian, Belgium (Martin 1974);

Caradoc, Kent, England (Lister *et al.* 1969); Upper Ordovician, Sylen Formation (Tynni 1975); Middle Ordovician, Öland (Kjellström 1972); Trenton Formation (Staplin *et al.* 1965); Middle Ordovician, Estonia (Bockelie and Kjellström 1979); Llandeilo, Llandeilo (Turner 1985); Caradoc, Libya (Molyneux and Paris 1985).

Remarks : this specimen has only a few processes and thus differs from the material. illustrated by Turner (1984). However in all other respects this species appears to be very similar, though the preservation is not very good.

Peteinosphaeridium sp. A
(Pl. 18, fig. 2)

Description : spherical vesicle with relatively thin granulate wall and nine processes, some of which are acuminate but most appear to be trifurcate. There is an angular contact of the proceses with the vesicle wall and no excystment features. The preservation is very poor.

Material : one specimen.

Dimensions : Vesicle diameter 21μm
Process length 14μm.

Occurrence : *C. peltifer* Zone, Main Cliff, Dob's Linn (SU/DL/1).

Peteinosphaeridium sp. B
(Pl. 18, fig. 3)

Description : ovoid vesicle, with six visible processes which appear to possess peteinos and to be furcate (possible to second order) though the preservation is not good.

Material : one specimen.

Dimensions : Vesicle diameter 39μm

Process length 6μm

Occurrence : Cross Water, Barrhill (SU/B/16).

Genus *Pterospermella* Eisenack 1972

1972 Pterospermella Eisenack, p. 597.

Diagnosis (Eisenack 1972): " microfossils of organic material, on inspection consisting of a central capsule, which in axial section, is usually elongate oval but seldom circular, and in equatorial and concentric view is determined as a ring-shaped double walled form with a smooth or notched winged edge. This form can be smooth or have radial folds. The method of opening is unknown. [Translation].

Type species : *Pterospermella aureolata* (Cookson and Eisenack 1958)= *Pterospermella aureolata* Cookson and Eisenack 1958.

Pterospermella sp. A

(Pl. 18, fig. 5)

Description : central body ellipsoidal and thicker than the outer flange which is marked by folding. There appears to be a pylome in the central body, though this may be a preservational feature.

Material : two specimens

Dimensions : Central body 23-26μm

Total diameter 37-39μm.

Occurrence : *D. anceps* and *G. persculptus* Zones, Main Cliff, Dob's Linn (SU/DL/50, 47).

Genus *Rhiptosocherma* Loeblich and Tappan 1978

1978 *Rhiptosocherma* Loeblich and Tappan,p.1284

Diagnosis (Loeblich and Tappan 1978) : "stellate cyst, ornamented with broad-based, low to elongate-conical, bluntly rounded to dull pointed hollow processes that radiate outward in all directions; wall thin, ornamented with grana and rugulae; processes with prominent longitudinal ridges".

Type Species: *Rhiptosocherma improcera* (Loeblich) Loeblich and Tappan1978

Rhiptosocherma improcera (Loeblich) Loeblich and Tappan 1978

(Pl. 18, fig. 6)

1970 *Estiastra improcera* Loeblich, p.720,figs 14 A-D.

1978 *Rhiptosocherma improcera* (Loeblich) Loeblich and Tappan,p.1284,Pl. 15, figs 1-4.

Diagnosis Loeblich and Tappan (1978) : "stellate cyst, ornamented with broad-based, low to elongate-conical, bluntly rounded to dull pointed hollow processes that radiate out outwards in all directions; wall thin, ornamented with grana and rugulae; processes with prominent longitudinal ridges".

Description : stellate vesicle, with simple, conical processes, some of which appear to be bifurcating, but it is likely that there are other processes compressed beneath them. No ornament is seen.

Material : one specimen.

Dimensions: Total diameter : 80µm
Vesicle diameter : 35µm.

Occurrence : Bofrishlie Burn, Aberfoyle, (HB/BB/2)

Previous Occurrence : Bromide Formation, Middle Ordovician of U.S.A.(Loeblich 1970), Middle to Late Ordovician of USA (Loeblich and Tappan 1978).

Remarks : although the ornament has been destroyed by recrystallisation to graphite, in all other respects this specimen fits the diagnosis. The general outline of this specimen is typical of the children's game 'jackstraws' (Loeblich and Tappan 1978).

Genus *Solisphaeridium* Staplin, Jansonius and Pocock 1965

1965 *Solisphaeridium* Staplin, Jansonius and Pocock, p. 183-184

Diagnosis (Staplin *et al.* 1965) : "vesicles spherical, wall relatively firm and rigid; several to numerous firm spines, hollow or solid, relatively long and slender, tapering continuously towards the closed tips. Spines have a tendency to reduce their cavity through secondary deposition of wall material but, if present, the cavity communicates freely with the vesicle".

Type Species: *Solisphaeridium stimuliferum* (Deflandre 1938) Staplin *et al.* 1965 (= to *Hystrichosphaeridium stimuliferum* Deflandre 1938)

Remarks : Sarjeant(1968) emended this genus to show excystment by splitting and to limit the genus to forms greater in size than 20μm.

Solisphaeridium cf. *nanum* (Deflandre 1942) Turner 1984

(Pl. 18, fig. 8; Pl. 25, figs 2,5)

1942 *Hystrichosphaeridium brevispinosum* var *nanum* Deflandre p.476, figs. 1, 16.

1945 *Hystrichosphaeridium brevispinosum* var *nanum* Deflandre p. 62, Pl. 1, figs 5, 7, ?18

1959 *Baltisphaeridium brevispinosum* var *nanum* - Downie p.59, Pl. 10, fig.9.

1959 *Baltisphaeridium brevispinosum* var *wenlockensis* - Downie p.59, Pl. 10, fig.4.

1960 *Baltisphaeridium brevispinosum* var *nanum* - Stockmans and Willière p.5, Pl. 1, figs. 18,19.

1962 *Baltisphaeridium nanum* - Stockmans and Willière, p.54, Pl. 1, figs. 21, 22, and 25.

1962 *Baltisphaeridium wenlockensis* - Stockmans and Willière, p.90, Pl. 1, figs. 16.

1963 *Baltisphaeridium wenlockense* Downie and Sarjeant, p.98.

1978 *Polygonium nanum* (Deflandre) Jacobson, p. 297-298, Pl. 1, fig. 12.

1984 *Solisphaeridium nanum* - Turner p. 136-137, Pl. 14, figs. 1,2.
1988 *Solisphaeridium nanum* - Turner, Whelan, p. 42.

Original Diagnosis (Deflandre 1945 translated in Turner 1984): "the vesicle is spherical and is provided with simple spines that in length are about one third of the vesicle diameter, corresponding closely to those displayed by *Baltisphaeridium brevispinosum* Eisenack, which has a similar outline. However in Eisenack's species, the vesicle measures 57-61µm reaching about 109µm with the processes. Here the size is about half this, the type measuring 27µm in diameter and 45µm with the processes. This justifies separation of this form into the variety *nanum*".

Description (Turner 1984): "the vesicle is hollow, spherical to sub-spherical, and has a smooth, thin (<0.5µm), apparently single-layered wall. It bears a variable number of hollow, smooth, simple, homomorphic, somewhat flexible processes with relatively wide bases tapering to slender acuminate distal terminations and that are proximally open. There is no differentiation between the vesicle and process walls which merge via a curving contact. No excystment structure was observed".

Description : Spherical to ovoid vesicle, with a smooth wall, bearing numerous, simple, homomorphic, acuminate processes, which tend to be curved. They have a curved proximal contact with the vesicle, and taper rapidly to hair-like spines. Process length variable within a given specimen.

Material : seven specimens.

Dimensions: Vesicle length : 33(35)38µm
vesicle width : 18(22)25µm
Process length : 3(4.5)7 to 8(11)15µm
Process number : 17-24
4 specimens measured

Occurrence: Shalloch Formation, Woodland Point, Girvan (MV/G/18,20,21,22, 23,24); *D. anceps* Zone Main Cliff, Dob's Linn (SU/DL/12).

Previous Occurrence : Ashgill-Wenlock, Montagne Noire (Deflandre 1942,45);

Wenlock Shales, Welsh Borderlands (Downie 1959). Upper Devonian,Belgium (Stockmans and Williere 1960,1962a). Arenig, Llandeilo,Sweden,(Kjellström 1971a); Arenig, Caradoc, Montagne Noire (Rauscher 1974); Caradoc of Belgium (Martin 1968); Llandeilo, Llandeilo (Turner 1985); Caradoc of Shropshire (Turner 1984); upper Caradoc Clays Ferry Formation, Kentucky (Jacobson 1978); upper Llandovery to Wenlock (Martin 1966a); Ludlow, Shropshire (Lister 1970); Middle Devonian, Brittany (Deunff 1954).

Remarks: Staplin, Jansonius and Pocock (1965) commented in their remarks on this genus that the spines did not widen at their bases but had an angular contact with the vesicle. This indicates that this species would perhaps be better accommodated within the genus *Goniosphaeridium* . However it is precipitate for the present author to do this on only 7 specimens. The type material has been examined and Pl. 14, fig. 1 could not be found. The processes in Pl. 14, fig. 2 are considerably smaller than the specimen from Dob's Linn, but apparently more or less the same as the ones from Girvan

Genus *Stellechinatum* Turner 1984

1984 *Stellechinatum* Turner p.137.

Diagnosis (Turner 1984) : "vesicle hollow with polygonal or sub-polygonal outline. Wall thin (<1μm), single layered. Eight or more simple, hollow, proximally open, tapering processes having wide bases, curving proximal contacts and acuminate distal terminations. Process stems ornamented with small grana or spines that may become hair like distally. This ornament may extend onto the vesicle surface".

Type Species: *Stellechinatum celestum* (Martin 1969) Turner 1984

Stellechinatum cf. *brachyscolum* Turner 1984

(Pl. 25, fig. 7)

1984 *Stellechinatum brachyscolum* Turner p. 137-138, Pl. 14, figs.6,7.

1988 *Stellechinatum brachyscolum* Turner, Whelan, p. 42.

Diagnosis (Turner 1984): "vesicle hollow, polygonal in outline, formed by the merging of wide process bases. Vesicle wall thin (1µm or less) smooth, apparently single layered. Processes hollow, proximally open, cone-shaped with wide bases, having curving proximal contacts and acuminate distal terminations. Processes randomly distributed and for any one individual all are approximately equal size. Ornament restricted to the processes, and consisting of initially robust, thorn-like spines branching irregularly from the main process stem and tapering rapidly to become slender and delicate. These spines, 2 to 4µm in length are developed most strongly near the distal tip and diminish proximally".

Description : small polygonal, hollow, smooth vesicle, with nine processes of equal length which have wide bases and curving proximal contacts with the vesicle and taper to acuminate distal terminations. the distal ends of the spines are ornamented with small spines (1µm in length). There are usually about 6 spines on each process, and they are only found at the distal end.

Material : one specimen.

Dimensions: Vesicle diameter 22µm
Process length 11-12µm.

Occurrence: *D. anceps* Zone Main Cliff, Dob's Linn (SU/DL/12).

Previous Occurrence: Caradoc of Shropshire (Turner 1984)

Remarks: the type material of this species has been examined, and in the present specimen the processes are smaller but much more robust.

Genus *Tasmanites* Newton 1875

1875 *Tasmanites* Newton, p. 341.

Diagnosis (Newton 1875): no particular diagnosis given, but there is a general discourse on *Tasmanites* and Tasmanite.

Type species : *Tasmanites punctatus* Newton 1875.

Tasmanites sp. A

(Figure 31)

Description : Thick walled form (~2μm) with a split which may be the excystment feature.

Material : one specimen.

Dimensions : Diameter 39μm.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/20).

Tasmanites sp. B

(Pl. 18, fig. 9; Figure 31)

Description : Very thick walled (>2μm) form showing many pores. No excystment mechanism recorded.

Material : one specimen.

Dimensions : Diameter 34μm
1 specimen only

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/20).

Tasmanites sp. C

(Pl. 18, fig. 4, Figure 31)

Description : Spherical, moderately thick walled (~1.5μm) granulate vesicle with a possible pylome.

Material : three specimens.

Dimensions : Diameter 19(25)37μm.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/18);

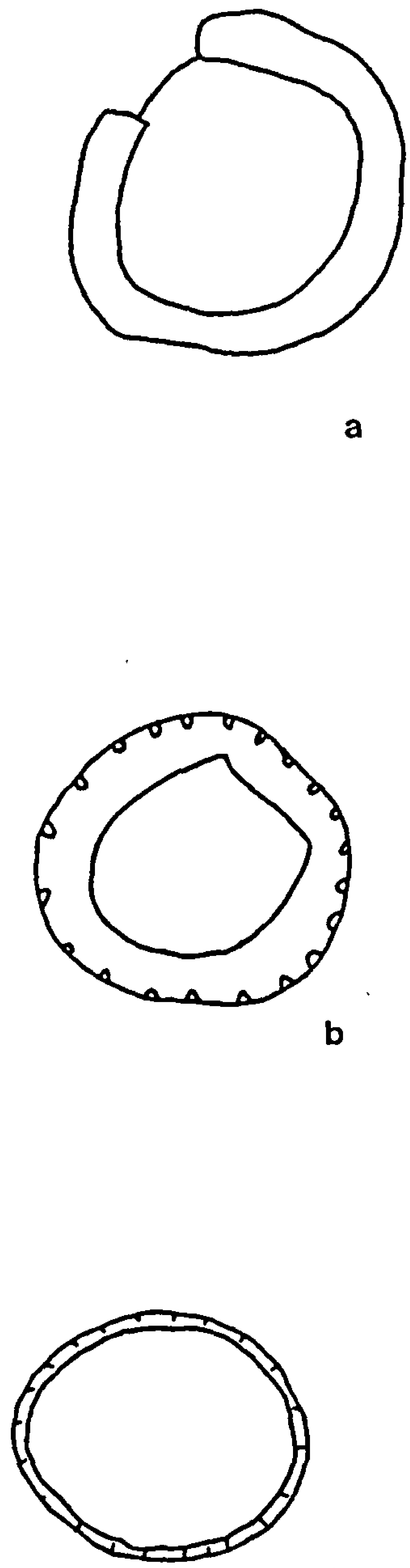


Figure 31 : (a) *Tasmanites* sp. A (x1577); (b) *Tasmanites* sp. B; (c) *Tasmanites* sp. C. All X1000

Jubilation Member, Doularg Hill, Girvan (MV/G/9).

Genus *Tylotopalla* Loeblich 1970

1970 *Tylotopalla* Loeblich, p.737-738.

Diagnosis (Loeblich 1969) : "an acritarch of small size, with circular to subcircular inflated central body whose interior communicates freely with the numerous short processes; processes terminate in a point or in short bifurcations with a feather or rosette of small spines just below their distal end. Surface variously ornamented, scabrate or psilate.

Type Species : *Tylotopalla digitifera* Loeblich 1970.

Tylotopalla sp. A
(Pl. 18, fig. 7)

Description : subspherical vesicle, with a variable number of conical to subcylindrical heteromorphic processes which either have bifurcate, trifurcate, or occasionally evexate distal terminations. The vesicle appears to communicate with the processes, and the processes have angular proximal contact with the vesicle. The ornamentation on the vesicle surface is hard to determine due to the poor preservation, however it appears to be ornamented with small spines or verrucae.

Material : twelve specimens

Dimensions: Vesicle diameter : 26 (30) 34µm
Process length : 3-8µm
Process width (at base) : 4(5)7µm.
Process number : 11-17.
5 specimens measured.

Occurrence : *G. persculptus* and *P. acuminatus* Zones, Main Cliff, Dob's Linn (SU/DL/48,52, 55,56,57).

Remarks : this specimen is similar to *Tylotopalla digitifera* Loeblich, however that species appears to have more complex process terminations than the present material, and does not have simple evexate terminations to any of the processes. These specimens are also similar to *Palaiosphaeridium* sp. A Turner, differing only in having longer conical rather than cylindrical processes.

Genus *Veryhachium* Deunff 1954 ex Downie and Sarjeant 1963

1954 *Veryhachium* Deunff p. 306.

1969 *Veryhachium* Deunff emend. Loeblich and Tappan, p. 55.

Emended Diagnosis (Loeblich and Tappan 1969): "vesicle thin-walled, polygonal, with processes from the angles forming an integral part of the vesicle, major processes in a single plane, commonly with accessory processes at various positions on the vesicle, processes distally closed and simple. Surface may be ornamented with grana or may be smooth. Excystment is by the formation of an epityche".

Type Species: *Veryhachium trisulcum* (Deunff 1951) Deunff 1959 ex Downie 1959

Remarks : Loeblich and Tappan (1969, 1976) and Turner (1984) discuss in detail the complicated history of this genus.

Veryhachium lairdii (Deflandre 1946) Deunff 1959 ex Downie 1959

(Pl. 25, fig.3,6)

1946 *Hystrichosphaeridium lairdi* Deflandre card 1112. (nom. nud.).

1954 *Hystrichosphaeridium lairdi* - Deunff p.306.

1959 *Veryhachium lairdi* - Deunff p. 28, Pl. 8, figs 75-79.

1964 *Veryhachium valiente* - Cramer p.34 (nom nud.).

1964 *Veryhachium lairdi* - Cramer p. 309, Pl. 11, fig.16; Pl. 12, figs. 1,2; Text- fig. 27-10, 11.

1964 *Veryhachium valiente* - Cramer p.311, Pl. 12, figs.3,4,6; Text-fig. 28-7, 9.

1966 *Veryhachium valiente* -Martin p.14, fig.16.

1966 *Veryhachium lairdi* - Martin p. 376.

1969 *Veryhachium valiente* complex-Cramer p.486.

1970 *Veryhachium lairdii* - Loeblich p.741.

1970 *Veryhachium valiente* - Loeblich, p.744

1984 *Veryhachium lairdii* - Turner p.141-143, Pl. 11, fig.4.

Original Diagnosis (Deunff 1959): "the vesicle, pale clear brown to bright orange measures 10-30μm in width. The maximum overall size of specimens observed in the formations of Veryhac'h ranges between 55 and 100μm. The general form of the vesicle corresponds to that of a pillow, more or less inflated, with a spine at each angle. The vesicle may be square, rectangular or lozenge-shaped". [Translation].

Description (Turner 1984): "the vesicle is hollow, compressed square to rectangular but the outline varies from slightly convex through straight sided to concave forms. The wall is moderately thin (0.5-1μm) and smooth. Each of the four angles bears a hollow, simple, smooth process arising in the same plane as the compression of the vesicle; the processes taper distally to acuminate tips and open into the vesicle cavity; processes widen gradually towards the base and merge with the vesicle via a curving contact. The process length is variable but commonly is approximately equal to the vesicle length. The excystment structure is a simple split between two process bases".

Description : vesicle square to rectangular in outline usually with concave sides. Four processes arise from the corners of the square usually one or more of these is broken. They have curved proximal contacts and taper into acuminate tips. The processes are generally less than or equal to the length of the vesicle. The wall is smooth and thin. Process length can vary greatly within a single specimen.

Material : six specimens.

Dimensions: Vesicle length : 18(29)36μm
width : 15(19)25μm
Process length : 11(16)26 -15(24)32μm
5 specimens measured.

Occurrence: *C? extraordinarius* Zone, Main Cliff, Dob's Linn (SU/DL/39);

Shalloch Formation, Woodland Point, Girvan (MV/G/20,24,25).

Previous occurrence: Middle and Upper Ordovician sediments, Girvan (Turner 1979 m.s.); Worldwide from Ordovician, Silurian and Devonian rocks (see Elaouad-Debbaj 1978).

Veryhachium oklahomense Loeblich 1970
(Pl. 18, fig. 11)

1970 *Veryhachium oklahomense* Loeblich, p.742, fig. 36, F.G.

Original diagnosis (Loeblich 1970) : "central body rectangular to nearly square in outline, sides nearly straight, corners of central body drawn out in the plane of the central body into four relatively long thin, flexible processes that at the distal end become almost hair-like; processes hollow for a good portion of their length and communicate freely with the central body but become solid at their distal end; rarely a fifth process arises on the face of the central body and is directed at right angles to the body plane; wall thin, less than 1μm in thickness, smooth; excystment by development of a small epityche".

Description : vesicle, square with straight sides. Four processes arise from the corners, showing proximal curving contacts. The processes are slightly longer than the vesicle length with acuminate distal tips. The wall is smooth and very thin.

Material : one specimen.

Dimensions : Vesicle length : 16μm
width : 11μm
Processes : 15-21μm.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/ 20).

Previous occurrence : Caradoc, Canada (Martin 1983); Upper Ordovician Sylvan

Shale, Oklahoma (Loeblich 1969); Caradoc-Ashgill, Libya (Molyneux and Paris 1985); Caradoc to Ashgill, Maquoketa Shale, Kansas (Wright and Meyers 1981).

Remarks: this species is smaller than *V. lairdii* and more quadrate is outline. Its walls are also considerably thinner, and this appears to be a distinguishing feature.

Veryhachium reductum (Deunff) Jekhowsky 1961

(Pl. 18, fig. 12)

1959 *Veryhachium trisulcum* var. *reductum* Deunff, p. 27, Pl. 1, figs 1,3,8,10-12,14, 16-17, 22-23.

1961 *Veryhachium reductum* (Deunff) Jekhowsky, p. 210-212, Pl. 2, figs. 22-44.

Diagnosis (Jekhowsky 1961) : "the Permo-Triassic individuals shown here under this name have a triangular central body, generally convex, sometimes straight, even slightly concave, measuring about 10-25μm along the sides. At each apex is developed a process 5-20μm long, about 1-3μm wide at the base, acicular, rigid enough, hollow, communicating with the central body, closed at its extremity. It is polymorphous and one can distinguish three <<forms>> corresponding to three areas of morphological variation, limited but distinct (?).

Forma *trispinoides* : central body flat, sometimes slightly concave, processes well developed.

Forma *reductum* : central body convex, processes of medium length

Forma *breve* : central body bulging, processes short". [Translation].

Description : triangular vesicle with three poorly developed processes (about one tenth of the vesicle length) communicating with the cavity. The sides are straight to slightly convex. No excystment feature or ornament is recorded.

Material : two specimens.

Dimensions : Vesicle sides 30-35μm

Process length 1-3μm.

Occurrence : *D. anceps* and *C? extraordinarius* Zones Main Cliff, Dob's Linn (SU/DL/ 10, 39).

Previous occurrence : Permo-Triassic of Africa (Jekhowsky 1961); Caradoc/Ashgill, Libya (Molyneux and Paris 1985); Ordovician of Sart-Bernard, Belgium (Martin 1965a); Ordovician of Brittany (Deunff 1959); Llanvirn, France (Paris and Deunff 1970); Llanvirn - Llandeilo of France (Rauscher 1974).

Remarks : These specimen are closest to the Forma *breve* described by Jekhowsky (1961).

Veryhachium cf. *subglobosum* Jardiné *et al.* 1974
(Pl. 18, figs 10, 14)

1974 *Veryhachium subglobosum* Jardiné *et al.* p. 115-116, Pl. 1, fig. 2.
1988 *Veryhachium corpulentum* Colbath, Whelan, p. 43.

Diagnosis (Jardiné *et al.* 1974) : "body triangular, rounded with convex sides, globular outline; with a thick, smooth membrane, three plain, long, slender processes, neatly delimiting the central body, the structure is analagous to the membrane of the central body and appears to thicken at its base". [Translation].

Description : small, smooth vesicle with convex flanks, and three conical, hollow processes that are acuminate at their distal ends. The processes communicate with the cavity and have a curved proximal process contact with the vesicle. Folds are common in the Girvan specimen, and the Dob's Linn specimen shows a split which could be an excystment feature. The wall of both specimens is unornamented and fairly thin.

Material : two specimens.

Dimensions : Vesicle length 27-30µm
Process length 22µm (Girvan)
7-10µm (Dob's Linn)

Occurrence : *C? extraordinarius* Zone, Main Cliff, Dob's Linn (SU/DL/39); Shalloch Formation, Woodland Point, Girvan (MV/G/20).

Previous occurrence : Upper Ordovician, Sahara (Jardiné *et al* 1974); Caradoc/Ashgill of Libya, (Molyneux and Paris 1985).

Remarks : both specimens, but particularly the Dob's Linn specimen have processes that are smaller than noted in the original diagnosis, but the general shape of this species is quite diagnostic.

Veryhachium triangulatum Konzalová-Mazancová 1969

(Pl. 18, fig. 13)

1969 *Veryhachium triangulatum* Konzalová-Mazancová, p. 89, Pl. 16, figs. 11,12,Text-fig. 5.

Diagnosis (Konzalová-Mazancová 1969 translated in Turner 1984) : "form with a triangular outline having concave or at most, straight sides, with three, unbranching, wide projections that merge gradually into the vesicle".

Description : hollow, smooth, triangular vesicle with straight sides, merging into three, hollow, smooth, acuminate processes that become distally thread-like and are just slightly shorter than the maximum length of the vesicle. The process interiors are open to the central cavity of the vesicle; the wall is about 0.5μm, unornamented, and no excystment features are observed.

Material : one specimen.

Dimensions : Vesicle length 30μm
Process length 22-25μm.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/28).

Previous occurrence : lower Ashgill, Bohemia (Konzalová-Mazancová 1969); Upper Ordovician Sylen Formation, Baltic (Tynni 1975); Caradoc, Shropshire (Turner 1984).

Remarks : This species is distinguished by its straight sides.

Veryhachium trispinosum (Eisenack 1938) Deunff 1954 ex Downie 1959.
(Pl. 19, fig. 1)

1938 *Hystrichosphaeridium trispinosum* Eisenack, p. 14, figs. 2, 3.
1959 *Veryhachium* cf. *trispinosum* Deunff, p. 29, Pl. 1, figs. 5-7, 9.
1959 *Veryhachium trispinosum* Downie, p. 68, Pl. 12, fig. 7.

Diagnosis (Eisenack 1938 translated in Turner 1984) : "vesicles are equilateral triangles with long twisted or curved spines. Spherical vesicles are seldom seen. The distance between two spines amounts to 80-100μm".

Description : the vesicle has very concave sides. The processes communicate with the interior of the vesicle cavity, and are hollow, conical and have acuminate tips. The wall is unornamented, and thin and no excystment features are recorded.

Material : two specimens.

Dimensions : Vesicle length 20-22μm
Process length 18-20μm.

Occurrence : Jubilation Member, Doularg Hill (MV/G/9), Shalloch Formation, Woodland Point, Girvan (MV/G/28).

Previous occurrence : Middle and Upper Ordovician sediments, Girvan (Turner 1979 m.s.); common Ordovician and Silurian form (see Elaouad-Debbaj (1978).

Remarks : this species is distinguished by its concave sides.

Veryhachium sp. A
(Pl. 19, fig. 2)

Description : triangular vesicle with convex sides and three conical processes apparently connecting with the vesicle. The vesicle wall is faintly granular. Process length about half of the vesicle diameter. Preservation poor. No excystment feature recorded.

Material : one specimen.

Dimensions : Vesicle sides 36µm
Process length 18µm.

Occurrence : *D. anceps* Zone Main Cliff, Dob's Linn (SU/DL/47).

Veryhachium sp. B.
(Pl. 19, fig. 3)

Description : very small quadrate vesicle with approximately six processes, four radiating from the corners in the equatorial plane, and the fifth and the sixth from the middle of the vesicle in a different plane. Processes appear to communicate with the vesicle cavity and vary in length between a quarter and a half of the maximum vesicle diameter.

Material : one specimen.

Dimensions : Maximum vesicle diameter 16µm
Process length 4-8µm.

Occurrence : *P. acuminatus* Zone, Main Cliff, Dob's Linn (SU/DL/55).

Veryhachium sp. indet.
(Pl. 19, fig. 4)

Description : small triangular body with weakly convex sides, and relatively long processes, which communicate with the cavity. Only two processes are preserved and the general preservation is poor.

Material : one specimen.

Dimensions : Vesicle diameter 20µm
Process length 7-15 µm

Occurrence : *C. peltifer* Zone, Little Cliff, Dob's Linn (SU/DL/1).

Spores.

Genus *Nodospora* Strother and Traverse 1979

Diagnosis (Strother and Traverse 1979) : "tetrads of inaperturate spores or spore-like palynomorphs, spherical to subspherical in outline, which are arranged in a cross configuration; a continuous band of thickened wall follows the line of contact of the individual spore margins; tetrad may be enclosed in a membranous sac; tetrad diameter ranges from 38 to 82µm; walls may be smooth or ornamented".

Nodospora sp. A
(Pl. 19, fig. 7)

Description: spherical tetrad with the contact of the four spores producing a pattern like a double figure of eight. The walls are smooth and thin except in the contact area which is about 4µm wide.

Material : one specimen.

Dimensions : Diameter 44µm.

Occurrence : Shalloch Formation, Woodland Point, Girvan (MV/G/18).

Remarks : The contact areas are not as wide as those illustrated by Strother and Traverse for *Nodospora burnhamensis* nor is the diameter as large.

Genus *Tetrahedraletes* Strother and Traverse 1979

1979 *Tetrahedraletes* Strother and Traverse, p. 8.

Diagnosis (Strother and Traverse 1979) : "tetrads of inaperturate, subtriangular spores or spore-like palynomorphs arranged in tightly adhering tetrahedral configuration; spore walls collapsed toward tetrad center; contact margins between the individual spores thickened, forming a dark ring around the margin of each spore".

Type species : *Tetrahedraletes medinensis* Strother and Traverse 1979.

Tetrahedraletes medinensis Strother and Traverse 1979
(Pl. 19, figs 5-6, 10; Pl. 25, fig 8)

1979 *Tetrahedraletes medinensis* Strother and Traverse, p. 8,9, Pl. 1, figs. 5, 14-17.

Diagnosis (Strother and Traverse 1979) : "as for the genus but with the added size restriction of 35 to 70μm tetrad diameter and psilate wall surface".

Description : permanent tetrads, presumably of triangular spores, with thickenings at the contact areas. This appears to be a certain foveolate ornament on some of the specimens. The walls are smooth and about 1.5μm in thickness.

Material : hundreds of specimens.

Dimensions : tetrad diameter : 31(40)54μm
10 specimens measured.

Occurrence :Shalloch Formation (MV/G/18,19,20,21,22, 23,24,25,26,27, 28), and Mill Formation (MV/G/29), Woodland Point, Girvan.

Previous occurrence : Llandovery and Wenlock, Pennsylvania, U.S.A. (Strother and Traverse1979).

Remarks : there appear to be two types of specimens, one very similar to the illustrations of Strother and Traverse (1979), and the other ones showing a thinner wall and thinner thickening in the contact area. However this could be due to preservation and is not considered great enough to warrant the splitting into two separate species.

Genus *Dyadaspora* Strother and Traverse 1979

1979 *Dyadaspora* Strother and Traverse, p. 15

Diagnosis (Strother and Traverse 1979) : "palynomorphs consisting of two inaperturate spores or spore-like palynomorphs occurring in a dyad configuration; individual spores spherical to subspherical to hemispherical in outline; walls psilate; overall length of flattened dyad body 25 to 50µm".

Type species : *Dyadaspora murusattenuata* Strother and Traverse 1979.

Dyadaspora sp. A

(Pl. 19, figs 9,11)

Description : permanent dyads, with psilate walls and a thickening at the contact point. Both spores are hemispherical. The wall is about 2µm in thickness.

Material : thirty six specimens.

Dimensions : Dyad length 29(32)36µm
6 specimens measured

Occurrence : Ardwell Flags, Ardwell Farm (MV/G/7), Jubilation Member, Doularg Hill (MV/G/8), Shalloch Formation Woodland Point, (18,22,23,24,25,26,27), Girvan.

Trilete spore A

(Pl. 19, fig. 8)

Description : small, pale yellow, spherical, permanent tetrad with raised, darkened contact margin, roughly 2µm wide, and a faintly granular surface.

Material : one specimen.

Dimensions : Diameter 23µm

Occurrence : Infra-Kilranny mudstones, Dow Hill, Girvan (MV/G/5).

Scolecodonts (Pl.20, figs 1-16)

Scolecodonts are found in the following samples; Woodland Point (MV/G/18-29); Ardwell Flags (MV/G/6,7); Jubilation Member (MV/G/8,9); Dob's Linn (SU/DL/3,7,10,11,12, 38,50,55); Barrhill (SU/B/1,3,4,16,17,19); Highland Border Complex (HB/NE/1,12 , 13; HB/BB/2,5; HB/BAL/1,2; and HB/LC/2,10,11).

While no attempt has been made to use the scolecodonts for biostratigraphical purposes it is noted that one sample from Woodland Point (MV/G/18) containes a fused cluster of scolecodonts which suggests that they could be used biostratigraphically at Girvan.

Small Shelly Fossils (Pl. 21, figs 1,3,6, ?14)

These have been found in the limestones north of the Highland Boundary Fault at Leny Quarry, Callander. Two species of *Torellella* have been found, one of which has been verified as phosphatic. These fossils are thought to be worm tubes (Brasier 1986) and are extremely useful in Precambrian-Cambrian sediments (Conway Morris 1987) as *Torellella* Holm 1893 as a genus ranges from the Tommotian (Precambrian) into the Atdabanian (Cambrian) (Brasier 1986), but only a very small fauna has been retrieved from these sediments. Their importance in this study has not yet been fully assessed but it shows that the Dalradian rocks are as young as the very late Precambrian or Lower Cambrian. No such fossils has been found in the contiguous Highland Border Complex rocks at Leny Quarry.

Miscellaneous fossils and contamination

Various fossils have been found which have not been discussed in the systematic palaeontology, and these are listed below.

Cuticle	(MV/G/27)	Pl. 21, fig. 15
Macrofossil remains	(MV/G/8)	Pl. 22, fig. 1
	(SU/DL/36)	Pl. 22, figs 2,3
Graptolite debris	(SU/DL/1,16)	Pl. 22, figs 4,7,10
Conical fossils	(SU/DL/5)	Pl. 22, figs 5,14
Graphite	(HB/NE/1)	Pl. 22, fig. 6

Organic tube	(SU/DL/12)	PL. 22, fig. 11
Sponge spicule	(HB/CQ/1)	Pl. 22, fig. 16
Pyrite framboids	(SU/B/4)	Pl. 21, figs 5,8

Major types of contamination are shown on Pl. 21, figs 4,7,9,11 and 13 (all modern day plant fragments), and Pl. 23, figs 6,14 (amoebal cysts)7, 12 and 13(fresh-water diatoms), 8,11 (modern jaw fragments), 9, 16 (fly ash), 3,10, and 15 (unknown). Pl. 23, fig. 17 is a common fibrous mineral and all the other objects shown on Plates 21, 22 and 23 are either unknown fossils or possibly other forms of contamination. The specimens shown in Pl. 23, figs 9, 16 were initially thought by Eisenack (1962d) to be problematical microfossils but Reid and Allit (1981) showed that they were contaminants.

Chapter 6 - Discussion

The three main achievements of this project are the dating of the sediments, the palaeoecological conclusions and the thermal history of the sediments that can be reconstructed from the palynology. Each topic will be considered separately within each area and then comparisons made. All the data are qualitative, except for Woodland Point, Girvan, where numbers of specimens were great enough to allow four hundred to be counted for each sample. All the species data are listed in the appendix.

BIOSTRATIGRAPHY

HIGHLAND BORDER COMPLEX

Seventy one samples have been processed from nine localities of the Highland Border Complex. Of these forty five have yielded microfossils of one kind or another, in varying states of preservation, and thirty three samples have yielded palynomorphs or small shelly fossils that are identifiable to generic level. Only six samples have produced palynomorphs that are able to be assigned to species level, but even though this is a very small number it is still very encouraging for rocks that have been subjected to such intense deformation. Samples will be dealt with by localities from south-west to north-east within the Complex.

Arran

Acritarchs have previously been reported by Dorning (1985) from this locality. They indicate a probable Ordovician age but cannot be more precise. Six samples have been processed from North Glen Sannox (Figure 3), of which two are barren, two have yielded poorly preserved acanthomorph acritarchs only, and one yielded a chitinozoan *Lagenochitina* sp. indet. indicating a Tremadoc to Devonian age for the fine grained siltstone. The sixth sample, a black shale, has yielded a fine assemblage of chitinozoans *Desmochitina* cf. *minor* forma. A, *Lagenochitina obeligis*?, *Lagenochitina* sp. D, *Cyathochitina* sp. A, *Navifusa* sp. B, *Leiosphaeridia* sp. C and poorly preserved acanthomorph acritarchs. *Desmochitina minor* Eisenack 1931 has a known range extending through most of the Ordovician, and *Lagenochitina obeligis* Paris 1981 is found in the Arenig of south-west Europe (Paris 1981) and, if his synonymy list is correct, then it is also found in the Lower Ordovician of the Sahara. This sample therefore must be Lower Ordovician in age.

Glen Fruin (Figure 4)

In this study only one sample, a black shale, has been processed. It has yielded *?Cyathochitina conica* Taugourdeau 1961, *?Cyathochitina macastyensis* Achab 1978 and *Leiosphaeridia* sp. C. *Cyathochitina conica* has a range of Llandeilo to Ashgill and Cyathochitina macastyensis has been described from the Macasty Formation (Caradoc) of Anticosti Island. This black shale is therefore probably Caradoc in age.

Balmaha (figure 5)

At this locality there is a carbonate rock exposed unconformably below a black shale, and palynomorphs have been retrieved from both lithologies. The carbonate has yielded the heavily recrystallised palynomorphs *Desmochitina* sp. A, a scolecodont and poorly preserved acanthomorph acritarchs. The black shale contained a specimen of *Conochitina primitiva?* Eisenack 1939, two specimens of *?Cyathochitina* cf. *fusiformis* Bouché 1965, and a scolecodont. *Conochitina primitiva* has been found in Arenig to Ashgill rocks and *Cyathochitina fusiformis* is more restricted and has only been found in the Caradoc-Ashgill of the Sahara and the Caradoc of North Wales. Thus this black shale must be Upper Ordovician in age (if the specific determinations are correct). As the black shale is younger than the carbonate (on sedimentological evidence), then the latter must be Tremadoc or Arenig to Caradoc in age.

Aberfoyle

Bofrishlie Burn

This area is heavily forested, which has made the fieldwork very difficult, and it is geographically uncertain as to where the samples were collected from (though their approximate position is shown in Figure 6, and their stratigraphical position is shown in Figure 12). A chert collected from here proved to be barren but a siltstone yielded *Desmochitina* sp. B, *Conochitina* sp. indet. and an indeterminate chitinozoan. Three black shales were sampled and although one of them yielded only *Leiosphaeridia* sp. C and poorly preserved acanthomorph acritarchs, the second contained *Cyathochitina* sp. indet., indeterminate chitinozoans and a scolecodont, while the third black shale yielded the acritarch

Rhiptosocherma improcera (Loeblich) Loeblich and Tappan 1978, the chitinozoan *Desmochitina minor* forma *elongata* Eisenack 1958, *Leiosphaeridia* sp. C and a scolecodont. *Rhiptosocherma improcera* has a range of Middle Ordovician to ?Upper Ordovician, whereas *Desmochitina minor* forma *elongata* is a Llanvirn to Caradoc form. It is therefore suggested that this a Llanvirn to Llandeilo assemblage, which substantiates the age given by Burton and Curry (In Curry et al. 1984) for the black shale. It is possible that the siltstone is correlatable with the Achray Sandstone at Limecraig Quarry, and therefore younger than the black shales.

Limecraig Quarry (Figure 7)
Many samples have been collected from this newly re-excavated quarry at Aberfoyle and all have yielded something. The Dounans Limestone was sampled in three places and yielded *Leiosphaeridia* sp. C, poorly preserved acanthomorph acritarchs, and a scolecodont in one sample, *Leiosphaeridia* sp. C alone in the second sample, and *Cyathochitina* sp. indet. and *Leiosphaeridia* sp. C in the third sample which also contained the conodont *Parapanderodus striatus* (Graves and Ellison 1941), which suggests an age of latest Tremadoc to latest Arenig (M.P. Smith pers. comm.). This complements the earlier work done on the silicified fauna but the palynological assemblage is not able to refine this age. The matrix of the Limecraig Conglomerate has been processed and yielded *Leiosphaeridia* sp. C and *Navifusa* sp. D, which may indicate that it is Ordovician in age, and a black shale found loose on the scree yielded a large indeterminate spine.

Samples of shale from the Achray Sandstone have yielded *Conochitina* sp. indet. and an indeterminate chitinozoan, whereas sandstones from the same unit contained *Lagenochitina* sp. indet., an indeterminate chitinozoan, a scolecodont and a spine. This work is thus not able to confirm the evidence presented by Burton and Curry (in Curry et al. 1984) which showed a reworked Middle Ordovician and an Upper Ordovician fauna, though the latter is fairly convincing.

Leny Quarry, Callander (figure 8)
Limestones and shales collected north of the Highland Boundary Fault, and probably belonging to the Dalradian outcrop have yielded various indeterminate small shelly fossils as well as a sphaeromorph acritarch and two specimens of *Torellella* sp., (M. Brasier pers. comm.) which is a typical late Precambrian to early Cambrian

form (Brasier 1986), thus giving a reasonably convincing age for the youngest Dalradian, and being perhaps the first small shelly fauna obtained from the Dalradian. Samples of black limestones and shales from south of the Highland Boundary Fault have yielded *Leiosphaeridia* sp.C, and a poorly preserved acanthomorph acritarch. Their age is therefore equivocal in terms of palynomorphs, although the trilobite age of Lower Cambrian is still accepted.

A grit (again from the south side of the Highland Boundary Fault) has yielded *Lagenochitina* spp. indet. along with another indeterminate microfossil (possibly a squashed sphaeromorph acritarch) and suggests an age of Arenig or younger.

Limestonebank Quarry, Clunie (Figure 9)

At this quarry five samples have proved to be barren, while the sixth is productive. This latter sample, a white limestone has yielded *Lagenochitina* cf. *prussica* Eisenack 1931 which has a range of Upper Ordovician and *?Desmochitina bulla* Taugourdeau and Jekhowsky 1960 which ranges from Arenig to Llandeilo (although Paris and Mergl (1984) suggest that it may be restricted to the Arenig), as well as a sponge spicule. Therefore the age of this sample seems to be difficult to ascertain. Taugourdeau *et al.* (1967) claim that *Lagenochitina prussica* has a longer range, of Arenig to Ludlow, and in association with this suggestion and the data of Burton and Curry (in Curry et al. 1984) which records an age of Arenig to Llandovery for *Euconochitina brevis* (Taugourdeau and Jekhowsky 1960), (although Taugourdeau et al. (1967) illustrate a range of Llanvirn to Llandovery for this species) it is most likely that this sample has a Middle Ordovician age.

North Esk River, Edzell (Figure 10)

Out of eighteen samples collected at this locality eight proved to be barren. The others are referred to the two separate blocks in order to be described in context.

South-eastern structural block

Samples from the pale grey/yellow greywackes and mudstones have yielded only poorly preserved acanthomorph acritarchs, an indeterminate chitinozoan and an organic tube. The red and grey shales yielded a specimen of *?Lagenochitina brevicollis* Taugourdeau and Jekhowsky 1960, which indicates a range of Llanvirn to Ashgill for that sample. The samples from the purple dolomites have yielded only a broken scolecodont and corroded acanthomorph acritarchs, whereas from the purple and grey shales scolecodonts, *Leiosphaeridia* sp. C and poorly preserved acanthomorph acritarchs have been retrieved.

North-western structural block

The Jasper and Greenrock beds yielded reasonably preserved acritarchs for Downie et al. (1971) although these results could not be repeated, all four samples from this unit proving to be barren, and so the age of Arenig to ?Llanvirn of Downie et al. (1971) cannot be refined. The conglomerate overlying this group was not sampled but the shales and carbonates next to it yielded *Aremoricanium* sp. D, *Conochitina* sp. indet., *Leiosphaeridia* sp. C, and poorly preserved acanthomorph acritarchs. *Aremoricanium* Deunff 1955 is a common Middle and Upper Ordovician form which suggests that this sample is of that age. Further up the succession the sandstones and shales have yielded only *Leiosphaeridia* sp. C, but from the Margie Limestone *Leiosphaeridia* sp. C and corroded acanthomorph acritarchs have been retrieved. Subordinate black shales within the Margie Limestone have yielded *Leiosphaeridia* sp. C, *Navifusa* sp. B and a scolecodont as well as poorly preserved graptolite debris. The age specified by Burton *et al.* (1984) as Caradoc cannot be substantiated due to insufficient new data.

Stonehaven (Figure 11)

Five samples (four black shales and a limestone) were processed from this locality, of which three were barren and the other two yielded only *Leiosphaeridia* sp. C, poorly preserved acanthomorph acritarchs, an organic tube and a spine. Thus no biostratigraphical data for Stonehaven can be specified within this present study.

The data that have be obtained from this work have been combined with more fieldwork (carried out be B.J. Bluck), and a chart showing the correlation between localities is shown in Figure 12.

SOUTHERN UPLANDS

Barrhill (Figure 13)

At Cross Water ten samples were processed which have yielded palynomorphs identifiable to generic level, but they have not been assigned to species due to the poor preservation. Thus no biostratigraphical evidence is advanced here, merely a note of the palynological content :- *Leiosphaeridia* sp. B, *Leiosphaeridia* sp. C, *Leiosphaeridia* sp. F, *Leiosphaeridia* sp. G, poorly preserved acanthomorph acritarchs, *Conochitina* sp. indet., an indeterminate chitinozoan, scolecodonts, organic tubes, graptolite debris and a spine. The two extra samples that were collected by J. Floyd, contained only poorly preserved scolecodonts.

Coldingham Bay (Figure 16)

All four samples proved to be barren, from this enigmatic locality, and nothing can be added to the work of Molyneux (1987).

Dob's Linn (Figure 14)

Forty three samples have been processed from Dob's Linn and only one of them was barren, although many of them contained only *Leiosphaeridia* spp., graptolite debris and organic tubes which are biostratigraphically unimportant, and the latter two fossil types will not be mentioned in the following discussion. Range charts for the acritarchs and chitinozoans are given in Figures 32 and 33.

Little Cliff

Two samples have been processed from this locality. The first from the *C. peltifer* Zone has yielded *Micrhystridium* sp. A, *Peteinosphaeridium* sp. A, *Veryhachium* sp. indet. *Leiosphaeridia* sp. C, and poorly preserved acanthomorph acritarchs which do not allow comparison of this sample with the graptolite debris. The second sample from this locality is

from the *C. wilsoni* Zone and contains *Armoricochitina nigerica* (Bouché 1965), *Leiosphaeridia* sp. B, *Leiosphaeridia* sp. C and poorly preserved acanthomorph acritarchs. Comparisons of chronostratigraphy and biostratigraphy suggest that this Zone is lower Caradoc in age and although *A. nigerica* was originally described from the Caradoc/Ashgill of Niger, it is more common in the Ashgill.

Main Cliff

D. clingani Zone

One sample from this locality has yielded *Conochitina* sp. B, *Multiplicisphaeridium bifurcatum* Staplin *et al.* 1965, *Leiosphaeridia* sp. B, *Leiosphaeridia* sp. C and a poorly preserved scolecodont. *Multiplicisphaeridium bifurcatum* is common in Caradoc and Ashgill sediments and was first described from the Trenton Formation, Anticosti Island. Jacobson (1987) reports it to be a useful Upper Ordovician guide fossil.

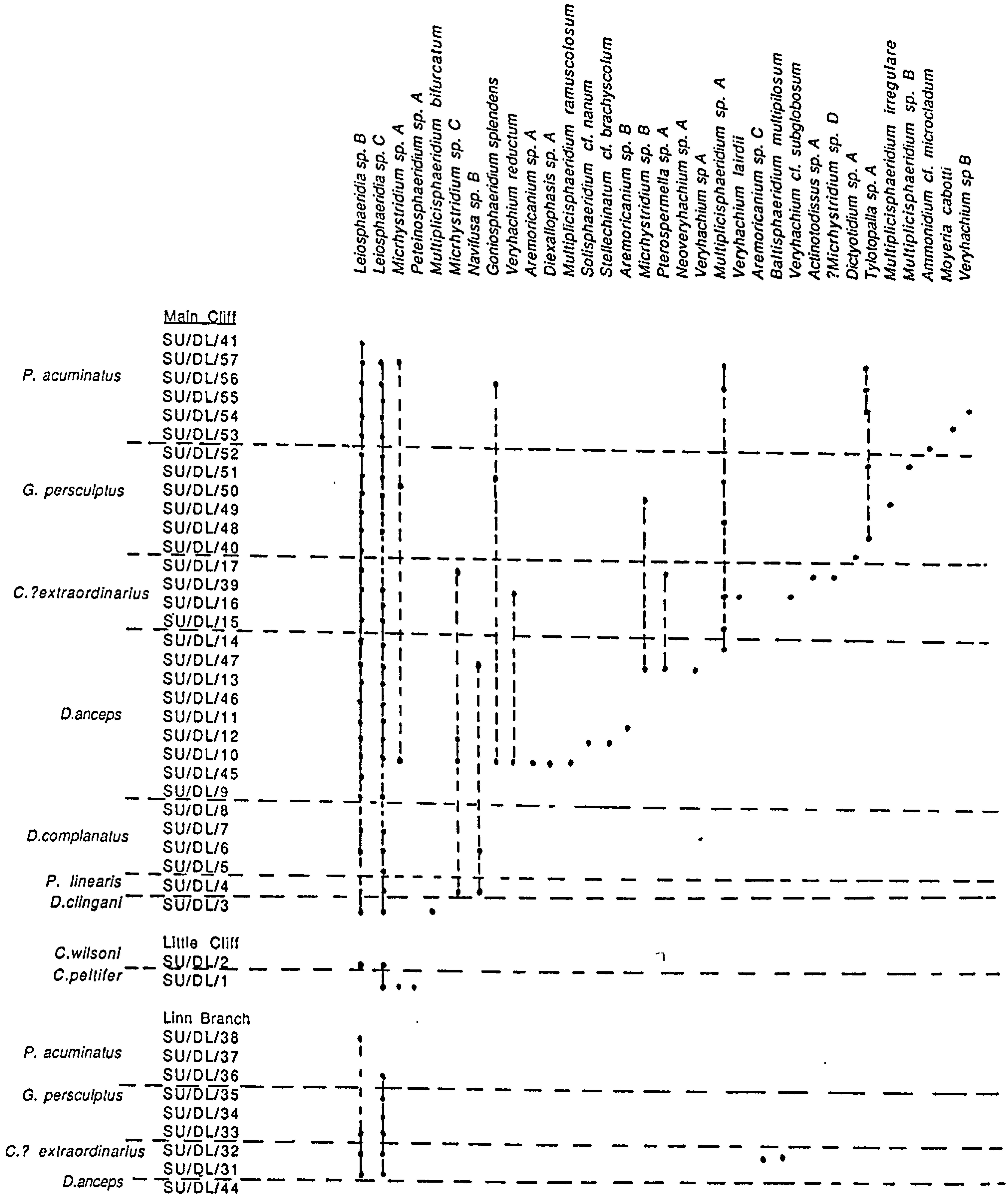


Figure 32 : Range chart of acritarch taxa found at Dob's Linn.

P. linearis Zone

One sample from this Zone contains only *Micrhystridium* sp. C, *Navifusa* sp. B, *Leiosphaeridia* sp. B and *Leiosphaeridia* sp. C, none of which are biostratigraphically useful. This zone is probably Onnian in age (Ingham and Wright 1970).

D. complanatus Zone

Four samples have been processed from this Zone at Main Cliff, which is Pusgillian in age (Williams 1987) , but nothing biostratigraphically diagnostic has been found, the constituents being :- *Leiosphaeridia* sp. B, *Leiosphaeridia* sp. C, *Navifusa* sp. B, *Siphonochitina* sp. A, possible macrofossil debris and some possible conodonts.

D. anceps Zone

At Main Cliff nine samples have yielded a diverse selection of acritarchs and chitinozoans, this being the most productive Zone. The chitinozoans consist of *Belonechitina micracantha* (Eisenack 1931), *Conochitina minnesotensis* (Stauffer 1933), *Conochitina pygmaea* Achab 1986, *Cyathochitina calix* (Eisenack 1931), *Cyathochitina campanulaeformis* (Eisenack 1931), *Cyathochitina conica* Taugourdeau 1961, *Cyathochitina kuckersiana kuckersiana* (Eisenack 1934), *Cyathochitina* sp. B, *Cyathochitina* sp. C, *Desmochitina minor* forma *cocca* Eisenack 1931, *Hercochitina* cf. *turnbulli* Jenkins 1969, *Lagenochitina prussica* Eisenack 1931, *Lagenochitina* sp. A, *Rhabdochitina* cf. *R. gallica* Taugourdeau 1961, *?Spinachitina bulmani* (Jansonius 1964). *D. anceps* Zone is considered to be Ashgill in age and most of these chitinozoans have a range ′ rs that includes the Ashgill with the exception of *Desmochitina minor* forma *cocca* which has not previously been recorded above the Caradoc, and *Conochitina pygmaea* which was originally described from the *P. linearis* Zone of Anticosti Island, and the range of which must now be extended into the *D. anceps* Zone. *Cyathochitina calix* is more common in the Lower Ordovician (although it has been recorded from the Upper Ordovician) and it is possible that it is reworked.

The acritarchs *Aremoricanium* sp. A, *Aremoricanium* sp. B, *Diexallophasis* sp. A, *Goniosphaeridium splendens* (Eisenack)Turner 1984, *Leiosphaeridia* sp. B, *Leiosphaeridia* sp. C, *Micrhystridium* sp. A, *Micrhystridium* sp. B, *Micrhystridium* sp. C., *Multiplicisphaeridium*

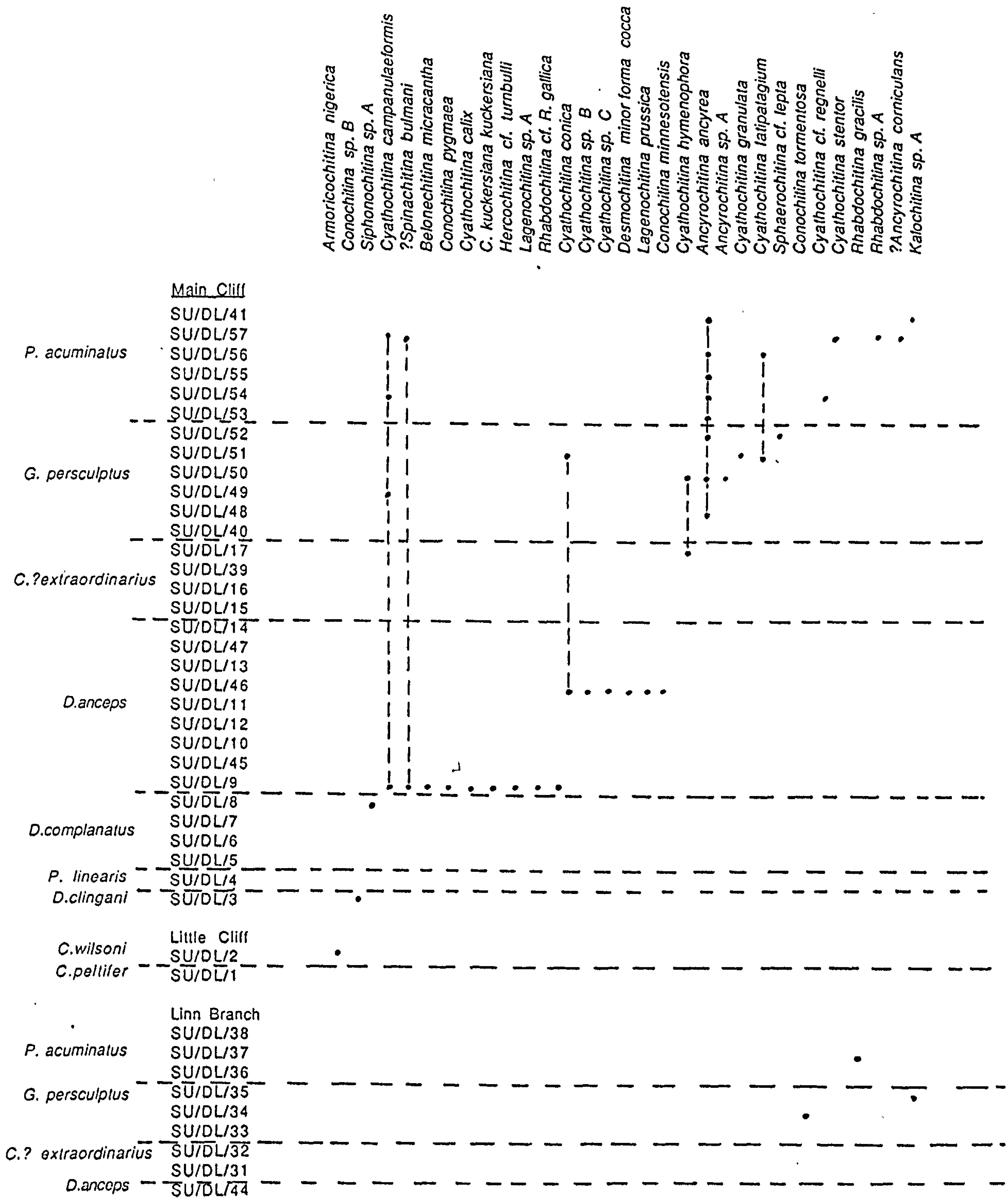


Figure 33. Diagram showing the range of chitinozoan species found at Dob's Linn.

ramusculosum (Deflandre) Lister 1970, *Multiplicisphaeridium* sp. A, *Navifusa* sp. B, *Neoveryhachium* sp. A, *Solisphaeridium* cf. *nanum* (Deflandre) Turner 1984, *Stellechinatum* cf. *brachyscolum* Turner 1984, *Veryhachium reductum* (Deunff) Jekhowsky 1961, and *Veryhachium* sp. A as well as poorly preserved acanthomorph acritarchs have been recovered from this Zone. The five specifically attributed acritarchs are all fairly long ranging (i.e. Ordovician to Devonian or younger) with the exception of *G. splendens* which has been recorded in Llanvirn to Ashgill sediments and *S.* cf. *brachyscolum* which has previously only been described from the Caradoc. If the comparison is excepted then it is necessary to extend its range. Williams (1986) suggests that this zone is early Cautleyan to late Rawtheyan in age.

***C? extraordinarius* Zone**

Four samples from this probably Hirnantian aged zone have yielded *Cyathochitina hymenophora* Taugourdeau 1961 previously recorded from the Upper Ordovician of Aquitaine, *Actinotodissus* sp. A, *Micrhystridium* sp. C, *Micrhystridium* sp. D, *Multiplicisphaeridium* sp. A, *Neoveryhachium* sp. A, *Veryhachium* cf. *subglobosum* Jardiné *et al.* 1974, *Veryhachium lairdii* (Deflandre) Deunff 1959 ex Downie 1959, *Veryhachium reductum* (Deunff)Jekhowsky 1961, *Leiosphaeridia* sp. B and *Leiosphaeridia* sp. C. The acritarchs again are quite wide ranging with the exception of *Veryhachium* cf. *subglobosum* which has only been described from the Upper Ordovician.

***G. persculptus* Zone**

Six samples from this location have yielded the acritarchs *Dictyotidium* sp. A, *Multiplicisphaeridium* sp. A, *Multiplicisphaeridium* sp. B, *Pterospermella* sp. A, *Goniosphaeridium splendens* (Eisenack)Turner 1984, *Tylotopalla* sp. A, *Leiosphaeridia* sp. B, *Leiosphaeridia* sp. C, and poorly preserved acanthomorph acritarchs as well as *Multiplicisphaeridium irregulare* Staplin *et al.* 1965 which is a common Upper Ordovician form.

The chitinozoans *Ancyrochitina ancyrea* (Eisenack 1931), *Ancyrochitina* sp. A, *Cyathochitina conica* Taugourdeau 1961, *Cyathochitina campanulaeformis, Cyathochitina granulata* Taugourdeau 1961 *Cyathochitina hymenophora* Taugourdeau 1961, *Cyathochitina latipatagium* (Jenkins 1969), *Sphaerochitina* cf. *lepta* Jenkins 1970 have been found in this sample, all of which are common in the Ashgill. A lower most Llandovery age is given to this zone by Williams (1983).

Also found in this zone were possible conodonts, some scolecodonts and possible macrofossil debris.

P. acuminatus Zone

Again six samples were processed from Main Cliff and from them the chitinozoans *Ancyrochitina ancyrea* (Eisenack 1931), *?Ancyrochitina corniculans* Jenkins 1969, *Cyathochitina campanulaeformis* (Eisenack 1931), *Cyathochitina* cf. *regnelli* Eisenack 1955, *Cyathochitina stentor* (Eisenack 1937), *Kalochitina* sp. A, *Rhabdochitina* sp. A, *?Spinachitina bulmani*, most of which again give a range of Upper Ordovician although this Zone is the lowest in the Llandovery. *Cyathochitina* cf. *regnelli* is more common in the Llanvirn and may be reworked if the identification is correct.

The acritarchs found here are :- *Ammonidium* cf. *microcladum* (Downie) Lister 1970, *Goniosphaeridium splendens*, *Goniosphaeridium* sp. indet., *Moyeria cabotti* (Cramer) Miller and Eames 1982, *Micrhystridium* sp. A, *Multiplicisphaeridium* sp A, *Tylotopalla* sp. A, *Veryhachium* sp.B, *Leiosphaeridia* sp. B, *Leiosphaeridia* sp. C, and poorly preserved acanthomorph acritarchs. Of these only *Ammonidium* cf. *microcladum* is a typically Silurian form. Also found in this Zone were possible conodonts, some scolecodonts and possible macrofossil debris.

Linn Branch section

This is the international stratotype section of the Ordovician-Silurian boundary and two samples from the *D. anceps* Zone have been processed, one is barren and the other contains *Leiosphaeridia* sp. C and *Micrhystridium* sp. C. Two samples from the *C? extraordinarius* Zone yield along with macrofossil debris, *Leiosphaeridia* sp. B, *Baltisphaeridium multipilosum* (Eisenack) Eisenack 1958, and *Aremoricanium* sp. C, both the former species and the latter genus are common in the Ordovician, particularly the Middle and Upper. The *G. persculptus* Zone contains *Leiosphaeridia* sp. B, C, *Conochitina tormentosa* Taugourdeau 1961, which is an Upper Ordovician form, *Kalochitina* sp. A, poorly preserved acanthomorph acritarchs and macrofossil debris. While from the *P. acuminatus* Zone, *Rhabdochitina gracilis* Eisenack 1962, *Leiosphaeridia* sp. B, *Leiosphaeridia* sp. C, poorly preserved acanthomorph acritarchs, scolecodonts and macrofossil debris have been retrieved. *Rhabdochitina gracilis* is a common Upper Ordovician form.

It appears from the palynomorphs present that there is no obvious break between the top of the Ordovician and the lowest Silurian, that is between the *G. persculptus* and the *P. acuminatus* graptolite biozones. Although *Moyeria cabotti* has been found in the Ordovician at Woodland Point it appears to be acommon Silurian species, *Ammonidium* cf. *microcladum* is a common Silurian acritarch and *Tylotopalla* is a common acritarch genus in the Silurian, and *Tylotopalla* sp. A may possibly be similar to *Tylotopalla caelamenicutis* Loeblich 1970 described by Molyneux (1987), from the Linkim Beds of the Southern Uplands. *Tylotopalla* sp. A is also found at the top of the Ordovician. All the chitinozoans are typically Ordovician, perhaps with the exception of *Ancyrochitina ancyrea* which is more typically a Silurian chitinozoan although it has previously been recorded in the Ashgill. There thus appears to be a certain amount of mixing of assemblages in the Ordovician-Silurian boundary beds. Many of the species found in the Silurian sediments have been recorded from the Ordovician but the acritarchs show more Silurian affinities than the chitinozoans.

At Dob's Linn the majority of the chitinozoan species are found in only one sample (Figure 33), however six of the thirty one chitinozoan species are found in more than one sample. *Cyathochitina conica* is found in the *D. anceps* and *G. persculptus* Zones, while *Cyathochitina hymenophora* is found in the *C ? extraordinarius* and *G. perculptus* Zones. *Cyathochitina campanulaeformis* is present in the *D. anceps, G. perculptus* and *P. acuminatus* Zones. *Spinachitina bulmani* is present in the *D. anceps* and *P. acuminatus* Zones while *Ancyrochitina ancyrea* and *Cyathochitina latipatigium* are found in the *G. persculptus* and *P. acuminatus* Zones, and thus the latter four species span the Ordovician-Silurian boundary. *A. ancyrea* is quite an abundant species and is found in eight samples of the Birkhill Shale, does not coincide with the graptolite biozones and thus apparently the chitinozoan changes cannot be correlated with those of the graptolites. All of the chitinozoan species found in the Silurian samples are previously recorded from the Ordovician.

The acritarchs show a similar pattern to the chitinozoans but with eleven of the thirty three acritarch species being found in more than one sample, the ranges of which can be seen in Figure 32. Particularly important is *Tylotopalla* sp. A which has been found in five samples from the *G. persculptus* and *P. acuminatus* Zones, and together with *Leiosphaeridia* sp. B, sp. C, *Goniosphaeridium splendens*, and *Multiplicisphaeridium* sp. A, makes up the six species that cross the Ordovician-Silurian boundary.

The graptolite and palynomorph biostratigraphy do not coincide but although only six species of acritarch cross the Ordovician-Silurian boundary and six species cross the *C? extraordinarius- G. perculptus* zonal boundary, nine species have ranges that cross the *D. anceps-C? extraordinarius* boundary and so it is more logical to assume that any significant break is above that boundary. The pattern at this level however is not mirrored in the chitinozoans where three species cross the *D. anceps-C?extraordinarius* boundary, four species cross the *C? extraordinarius- G. persculptus* boundary and five species cross the *G. persculptus-P. acuminatus* boundary.

Of course the evidence is not full enough and a better yield of both groups would probably provide further data.

To sum up no significant pattern in palynomorph distribution can be seen and the biostratigraphy cannot be correlated with that of the graptolites. The presence of significant numbers of *Tylotopalla* sp. A and *Ancyrochitina ancyrea* may prove to be significant as they are not found below the *G. persculptus* Zone but may equally well be ecologically controlled as they are not present in the Upper Hartfell Shales and become quite important in the Birkhill Shale.

GIRVAN

Pinbain Beach and Laigh Knocklaugh (Figure 17)

A limestone from the olistostrome on Pinbain Beach has yielded only Leiosphaeridia sp. C, while another limestone from Laigh Knocklaugh contained *Leiosphaeridia* sp. C and a spiny fragment. A black shale from the same locality contained a possible poorly preserved chitinozoan and poorly preserved acanthomorph acritarchs.

Dow Hill (Figure 17)

The Infra-Kilranny mudstone contained a very poor assemblage of *Leiosphaeridia* cf. *tenuissima*, Eisenack 1958, *Leiosphaeridia* cf. *voigtii* Eisenack 1958, *Leiosphaeridia* sp. E, *Navifusa* sp. A and a trilete spore sp. A, thus allowing no biostratigraphical interpretation to be applied to this sample.

Ardmillan Braes (Figure 17)

This sample from the Ardwell Flags yielded an assemblage consisting of the acritarchs *Goniosphaeridium* cf. *elongatum* Turner 1984, *Leiosphaeridia* cf. *tenuissima*, *Leiosphaeridia* cf. *voigtii*, *Leiosphaeridia* sp. G, and the chitinozoans *Belonechitina* cf. *hirsuta* (Laufeld 1967), *Belonechitina micracantha* , *Belonechitina robusta* (Eisenack 1959), *Conochitina minnesotensis* , *Cyathochitina hyalophrys* (Eisenack 1959) and *Rhabdochitina* sp. C, as well as scolecodonts, organic tubes and graptolite debris. All the chitinozoans have ranges of Lower or Middle Ordovician to Upper Ordovician, however the one specifically attributed acanthomorph acritarch has only previously been described in the Caradoc, if the comparison is accepted, which is the known age of the Ardwell Flags.

Ardwell Farm (Figure 17)
This sample from the top of the Ardwell Flags contains *Leiosphaeridia* cf. *tenuissima*, Eisenack 1958, *Leiosphaeridia* cf. *voigtii* Eisenack 1958, *Dyadaspora* sp. A, *Belonechitina micracantha*, *Conochitina conulus* Eisenack 1955, and *Cyathochitina campanulaeformis*, as well as scolecodonts, graptolite debris and organic tubes. None of the chitinozoans are of great biostratigraphical value as *Belonechitina micracantha* ranges from Arenig to Ashgill, *Conochitina conulus* Llanvirn to Ashgill and *Cyathochitina campanulaeformis* Arenig to Silurian.

Doularg Hill (Figure 17)
Two samples were processed from the Jubilation Member of the Doularg Formation of the Albany Group and have yielded quite a diverse flora and fauna. The acritarchs are *Leiosphaeridia* cf. *tenuissima*, *Leiosphaeridia* cf. *voigtii*, *Leiosphaeridia* sp. D, *Leiofusa aspilis?* Loeblich 1970, *Leiofusa* sp. A, *Navifusa* sp. C, *?Dictyotidium* sp. B, *Tasmanites* sp. C, and *Veryhachium trispinosum* (Eisenack) Deunff 1954 ex Downie 1959 as well as poorly preserved acanthomorph acritarchs, of which *Leiofusa aspilis* has previously been found in the Silurian, and *Veryhachium trispinosum* is a common Ordovician and Silurian acritarch.

The chitinozoans retrieved from these samples are *Cyathochitina campanulaeformis*, *Cyathochitina calix*, *Cyathochitina jenkinsi* Neville 1974, *Cyathochitina protocalix* Paris 1981, *Belonechitina micracantha*, *Conochitina minnesotensis*, *Conochitina* sp. D, *Kalochitina* sp. B, *Sphaerochitina* sp. A, *Rhabdochitina* sp. D, and *Rhabdochitina* sp. E, as well as indeterminate broken chitinozoans. Also found in this assemblage are *Dyadaspora* sp. A, scolecodonts, and organic tubes.

Cyathochitina campanulaeformis, C. calix, Belonechitina micracantha and *Conochitina minnesotensis* have ranges from Arenig to Ashgill or younger. *Cyathochitina jenkinsi* ranges from Middle Ordovician to Caradoc, while *Cyathochitina protocalix* is upper Arenig to lower Llanvirn in age which must therefore be the age of this sample.

Woodland Point

Twelve samples were processed from this locality and in all but one of them four hundred specimens were counted, from two slides with ease, all these samples were from the Shalloch Formation. The twelfth sample (MV/G/29), however, from the Mill Formation of the Upper Whitehouse Group contained two hundred and eleven specimens, and so one hundred were counted in each of two slides. All samples were collected at twenty metre intervals, and decreasing in age from the Mill Formation (MV/G/29) which has been dated by graptolites as belonging to the *D. complanatus* Zone to the top of the Shalloch Formation (MV/G/18) at Woodland point which is considered to belong to the *D. anceps* Zone. *Leiosphaeridia* cf. *tenuissima*, *Leiosphaeridia* cf. *voigtii*, *Leiosphaeridia* sp. A, *Tetrahedraletes medinensis* Strother and Traverse 1979, *Moyeria cabotti*, and scolecodonts are common to all the samples and will not be discussed further in this section. The range charts for the acritarchs and the chitinozoans from Woodland Point are shown in Figures 34 and 35

MV/G/29

This sample contains a very poor assemblage of *Navifusa similis* (Eisenack) Turner 1984, *Baltisphaeridium cristoferi* (Kjellström) Turner 1984, ?*Ammonidium* sp. A, poorly preserved acanthomorph acritarchs, *Belonechitina micracantha* and other poorly preserved chitinozoans. Thus no biostratigraphical interpretation can be applied to this sample as *N. similis* ranges from Llandeilo to Ashgill, *B. micracantha* from Arenig to Ashgill, *Baltisphaeridium cristoferi* has a previously published range of Llandeilo to Caradoc and as this sample is of Ashgill age, then its range must be extended.

MV/G/28

This is a very diverse assemblage being dominated by the discoid chitinozoan *Calpichitina (Calpichitina) lenticularis* (Bouché 1965) which forms nearly half of the assemblage and is common in Caradoc and Ashgill sediments from many

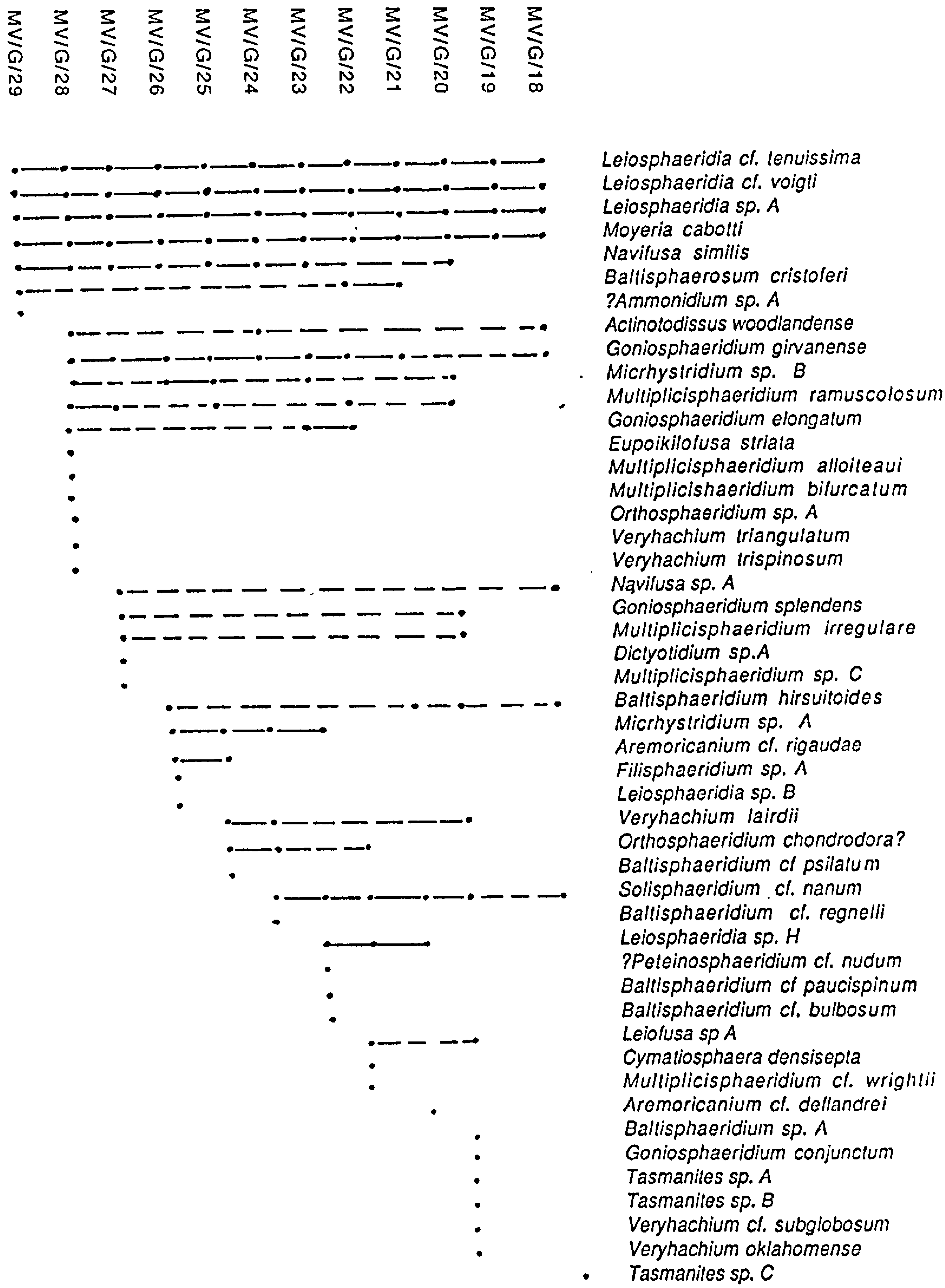


Figure 34 : range chart showing the acritarch species found at Woodland Point.

places. Other chitinozoans found here include *Calpichitina (Calpichitina) megastrophica* Achab 1984, which has previously only been described from from the Llanvirn to Caradoc, *Belonechitina comma* (Eisenack 1959), from the Llanvirn to Caradoc, *B. micracantha, B. wesenbergensis* (Eisenack 1959) from the Llanvirn to Ashgill, *B. schopfi americana* (Taugourdeau 1965) from the *D. complanatus* and *C. prominens elongatus* Zones of Anticosti Island, *Conochitina conulus, Conochitina* cf. *elegans* Eisenack 1931, Llanvirn to Ashgill, *Acanthochitina barbata* Eisenack emend. Jenkins 1967, which is a common Caradoc and Ashgill chitinozoan, *Rhabdochitina striata* Eisenack 1958 previously only described from the Llanvirn, *Cyathochitina* sp. D, and chitinozoan sp. A. It is obvious that most of these chitinozoans are long-ranging forms, although some of them such as *Calpichitina megastrophica* and *Belonechitina comma* have never previously been described from Ashgill rocks. The chitinozoans such as *Calpichitina lenticularis* and *Acanthochitina barbata* are more useful biostratigraphical indicators. If *Rhabdochitina striata* has not been reworked then its range must be extended.

The acritarchs found in this sample are *Actinotodissus woodlandense* n. sp., *Goniosphaeridium girvanense* n. sp., *Navifusa similis, Multiplicisphaeridium ramusculosum, Veryhachium trispinosum, Veryhachium triangulatum* Konzalová-Mazancová 1969, a Caradoc to Ashgill acritarch, *Eupoikilofusa striata* (Staplin *et al.*) Loeblich and Tappan 1978, common in the Upper Ordovician, *Goniosphaeridium elongatum* Turner 1984 (Caradoc), *G. splendens, Multiplicisphaeridium alloiteaui* (Deunff) Kjellström 1976 , *M. bifurcatum*, which as already stated is a common Upper Ordovician acritarch and *Orthosphaeridium* sp. A. Poorly preserved acanthomorph acritarchs are also common in this assemblage.

MV/G/27

C. lenticularis is again a common chitinozoan along with *C. megastrophica, B. wesenbergensis*, and *B. micracantha. B. seriespinosa* (Jenkins 1969) which has previously been found in the Caradoc, and possibly the lower Ashgill makes its first appearance here as does *Angochitina woodlandense* n. sp., *Conochitina* cf. *tuba* Eisenack 1932 which is an Upper Ordovician form but is more common in the Silurian. *Belonechitina* cf. *hirsuta, Rhabdochitina* sp. B, *Belonechitina schopfi americana, Acanthochitina barbata, Belonechitina robusta, B. comma, Lagenochitina* sp. B and *Rhabdochitina gracilis* are also present and again the

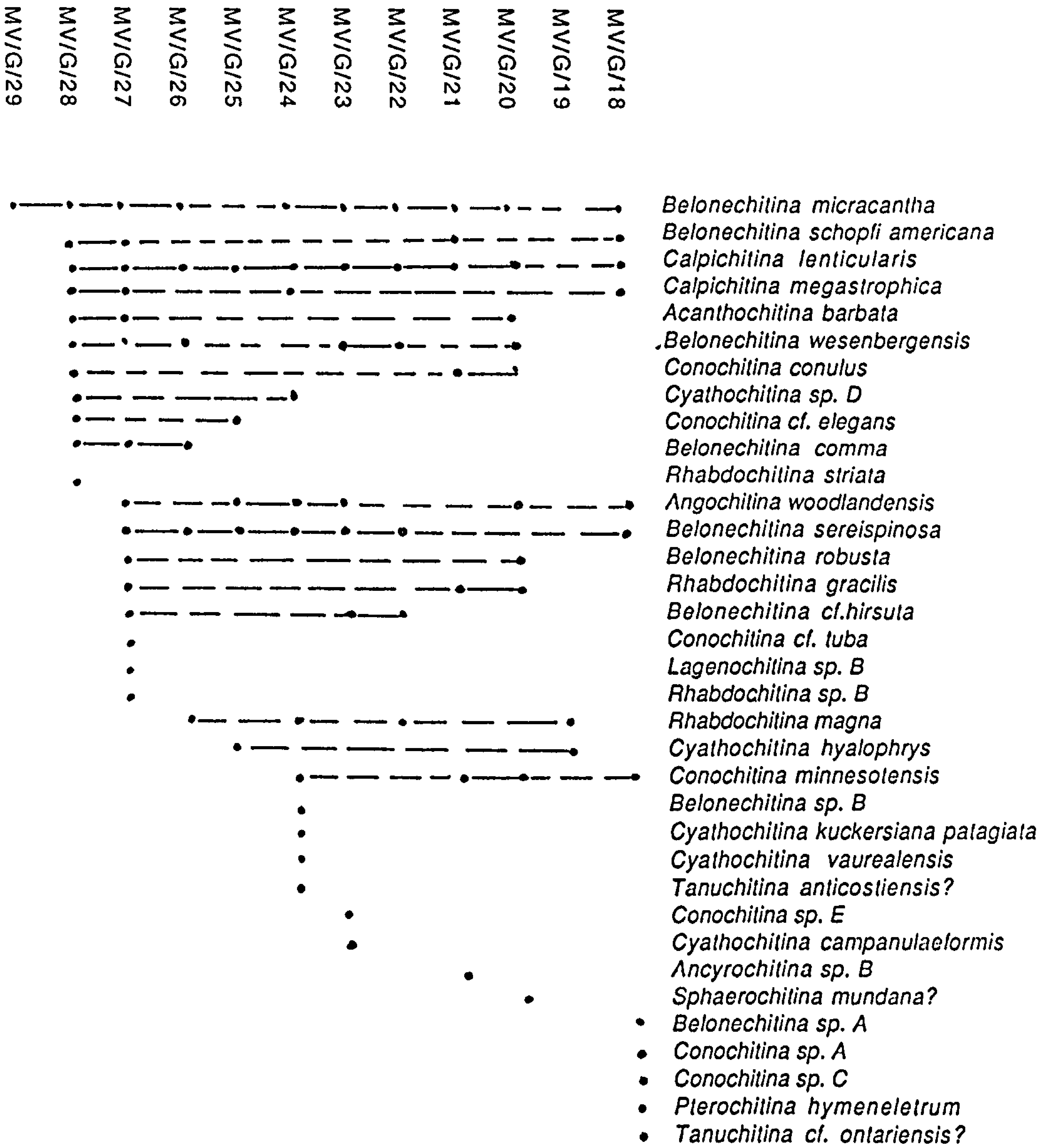


Figure 35. Diagram showing the ranges of chitinozoans found at Woodland Point, Girvan.

majority of them are Upper Ordovician forms. Acritarchs include *Navifusa similis, N.* sp. A, *Multiplicisphaeridium ramuscolosum, M. irregulare* and *M.* sp. C as well as *Goniosphaeridium girvanense* and *Dictyotidium* sp. A. The spore *Dyadaspora* sp. A is also present here and in addition a small piece of cuticle was found.

MV/G/26

Among the common forms already mentioned there are also *Micrhystridium* sp. A *Micrhystridium* sp. B, *Filisphaeridium* sp. A, *Leiosphaeridia* sp. B, *Baltisphaeridium hirsuitoides* (Eisenack) Eisenack 1958, *Aremoricanium* cf. *rigaudae* Deunff 1955 and *Rhabdochitina magna* Eisenack 1931, which make their appearance in this sample and are common and long ranging forms. *Dyadaspora* sp. A is also present.

MV/G/25

The acritarchs *Veryhachium lairdii* (Deflandre) Deunff 1959 ex Downie 1959, *Orthosphaeridium chondrododora?* Loeblich and Tappan 1971, and *Baltisphaeridium* cf. *psilatum* Kjellström 1971 appear for the first time in this sample. The chitinozoans are represented by the common forms such as *Calpichitina lenticularis, Angochitina woodlandensis* and *Belonechitina seriespinosa*, as well as *Cyathochitina hyalophrys* Eiseanck 1959, a Llandeilo to Ashgill form. *Dyadaspora* sp. A is also a common species present as well.

MV/G/24

This sample contains as well as the common acritarchs *Solisphaeridium* cf. *nanum* and *Baltisphaeridium* cf. *regnelli* Kjellström 1971. In addition to the chitinozoans already encountered this sample contains *Tanuchitina anticostiensis?* Achab 1977 and *Cyathochitina kuckersiana patagiata* Jenkins 1969 previously described from the Caradoc and Ashgill sediments as well as *Belonechitina* sp. B.

MV/G/23

This sample contains many species that have been described already as well as *Leiosphaeridia* sp. H, *Conochitina* sp. indet, *Baltisphaeridium* cf. *paucispinosum* Kjellström 1971, *Baltisphaeridium* cf. *bulbosum* Kjellström 1971, *Peteinosphaeridium nudum?* (Eisenack) Eisenack 1969 which are commonly considered to be Middle or Upper Ordovician forms and *Conochitina* sp. E.

MV/G/22

This sample contains one specimen of the acritarch species *Multiplicisphaeridium* cf. *wrightii* Jacobson and Achab 1985, which is a typical Ashgill acritarch, but apart from this all the other species have been encountered in previous samples.

MV/G/21

Aremoricanium cf. *deflandrei* Henry 1969 and *Ancyrochitina* sp. B are the only species in this assemblage that have not been described from previous samples.

MV/G/20

This sample differs quite a lot to the others in that it contains three species of *Veryhachium* - *Veryhachium lairdii, Veryhachium oklahomense* Loeblich 1970, and *Veryhachium* cf. *subglobosum*, as well as *Baltisphaeridium* sp. A, *Goniosphaeridium conjunctum* Kjellström 1971, *Tasmanites* sp. A, *Tasmanites* sp.B and *Sphaerochitina mundana?* Taugourdeau 1961, previously described from the Caradoc, as well as common species of the assemblage. *Goniosphaeridium conjunctum* was originally described from the Middle Ordovician but has since been recognised in Caradoc sediments and its range is here extended into the Ashgill.

MV/G/19

This sample is very low in diversity and contains seven species of acritarchs and chitinozoans, none of which have not occurred in this section previously.

MV/G/18

This sample which is the youngest in the section contains many of the common acritarchs and chitinozoans in addition to *Tasmanites* sp. C, *Nodospora* sp. A, *Pterochitina hymenelytrum* Jenkins 1969, *Conochitina* sp. A, *Conochitina* sp. C, *Tanuchitina* cf. *ontariensis* Jansonius 1964 and *Belonechitina* sp. A.

About fifty percent of the thirty five species of chitinozoans and forty seven species of acritarchs are present in more than one sample at Woodland Point (Figures 34,35), and there is a significant rise in species numbers of both palynomorph groups from the Mill Formation sample (MV/G/29) to the oldest Shalloch Formation sample (MV/G/28) although there appears to be no obvious place to site the *D. complanatus-D. anceps* zonal boundary.

There are only four species of chitinozoan species in common with Woodland Point and Dob's Linn :- *Belonechitina micracantha, Rhabdochitina gracilis, Conochitina minnesotensis*, and *Cyathochitina campanulaeformis*, while there are twelve species of acritarch common to the two localities :- *Moyeria cabotti, Micrhystridium* sp. B, *Multiplicisphaeridium ramusculosum,* *Multiplicisphaeridium bifurcatum*, *Goniosphaeridium splendens*, *Multiplicisphaeridium irregulare*, *Dictyotidium* sp. A, *Micrhystridium* sp. A, *Leiosphaeridia* sp. B, *Veryhachium lairdii*, *Solisphaeridium* cf. *nanum* and *Veryhachium* cf. *subglobosum*. These are mostly common Upper Ordovician palynomorphs and due to the poor, almost random, yield that has been obtained from the Dob's Linn samples no attempt will be made here to correlate with the Woodland Point samples in order to assess which Zone they belong to.

The genus *Veryhachium* appears to have quite an interesting distribution. It is a relatively rare genus, but when present there are usually more than one species represented, e.g. MV/G/28 has both *Veryhachium triangulatum* and *V. trispinosum*. In one sample from Dob's Linn (SU/DL/39) from the *C? extraordinarius* Zone and one sample from Woodland Point (MV/G/20) presumably from the *D. anceps* Zone there are three species of *Veryhachium*, both samples containing *Veryhachium lairdii* , and *V.* cf. *subglobosum* while the Woodland Point sample also contains *Veryhachium oklahomense* and the Dob's Linn sample contains *Veryhachium reductum*. From a general review of the literature it appears that *Veryhachium* is more important in the Silurian but may have reached its acme by the very late Ordovician, although Downie (1973) shows that the greatest number of species of *Veryhachium* can be found in the Devonian.

PALAEOECOLOGY

Nothing can be said about the palaeoecology of the Highland Border Complex or Barrhill due to the paucity and quality of the palynomorphs. The palaeoecology of the miscellaneous samples from Girvan (MV/G/1,2,3,5,6,7,8,9) is not discussed here due to their isolated nature.

DOB'S LINN

All data shown here are qualitative.

The palaeoecology of a locality such as this where palynomorphs are rare and diversity is low is difficult to assess but one or two generalisations can be made. Figure 36 shows the distribution of various components at all the sections, compared to the lithology.

Sphaeromorph acritarchs

These are present in all but three of the forty three samples, and as two of those

Graptolite Zone	Sample	Sphaeromorph acritarchs (1)	Acanthomorph acritarchs (2)	Netromorph acritarchs (3)	Polygonomorph acritarchs (4)	Herkomorph acritarchs (5)	Chitinozoans	Graptolite debris (c)	Graptolite debris (r)	Organic tubes (c)	Organic tubes (r)	Corroded acanthomorph acritarchs	Indeterminate chitinozoans	Scolecodonts	Conical fossils	?Trilobite debris	Cuticle with pyrite	?Fish debris.
	Main Cliff																	
P. acuminatus	SU/DL/41					X	X	X		X		X						
	SU/DL/57	X				X	X	X		X					X			
	SU/DL/56	X				X	X	X		X		X				X		
	SU/DL/55	X		X		X	X	X		X		X		X	X			
	SU/DL/54	X	X			X	X	X		X		X						
	SU/DL/53	X				X	X	X		X			X					
G. persculptus	SU/DL/52	X				X	X	X		X								
	SU/DL/51	X				X	X	X		X		X			X			
	SU/DL/50	X			X	X	X	X		X		X		X				
	SU/DL/49	X				X	X	X		X		X						
	SU/DL/48	X				X	X	X		X		X			X	X		
	SU/DL/40				X	X			X		X	X					X	X
C.?extraordinarius	SU/DL/17	X		X		X	X		X									
	SU/DL/39	X		X		X			X									
	SU/DL/16					X		X		X		X						
	SU/DL/15	X				X											X	X
D.anceps	SU/DL/14	X				X			X									
	SU/DL/47		X	X	X	X									X			
	SU/DL/13					X			X			X						
	SU/DL/46	X				X	X	X		X			X					
	SU/DL/11	X				X		X		X		X	X	X				
	SU/DL/12	X				X				X		X		X			X	X
	SU/DL/10	X		X		X		X		X				X		X		
	SU/DL/45					X						X						
	SU/DL/9					X	X	X		X		X						
D.complanatus	SU/DL/8						X											
	SU/DL/7					X			X					X		X		
	SU/DL/6		X			X					X	X						
	SU/DL/5					X												
P. linearis	SU/DL/4	X	X			X			X		X	X						
D.clingani	SU/DL/3	X				X	X		X		X	X		X				
	Little Cliff																	
C.wilsoni	SU/DL/2					X	X		X		X	X						
C.peltifer	SU/DL/1	X		X		X		X		X		X						
	Linn Branch																	
P. acuminatus	SU/DL/38					X		X		X		X		X				
	SU/DL/37						X	X		X								
	SU/DL/36					X		X		X		X				X		
G. persculptus	SU/DL/35					X	X	X		X		X						
	SU/DL/34					X	X	X		X						X		
	SU/DL/33					X		X		X		X				X		
C.? extraordinarius	SU/DL/32	X				X			X		X	X					X	X
	SU/DL/31					X												
D.anceps	SU/DL/44	X				X												

Figure 36. Diagram showing the relationship of graptolite Zone, lithology, sample number and major palynological constituents.

Column 1 = Acanthomorph acritarchs
2 = Netromorph "
3 = Polygonomorph "
4 = Herkomorph "
5 = Sphaeromorph "

contain other palynological constituents then in all likelihood there absence is an original feature. The third sample without sphaeromorph acritarchs is completely barren and this is probably due to the extreme weathering of the sample. Sphaeromorph acritarchs are generally taken as representing either shallow or deep water (i.e. highly stressed conditions), and in view of the sedimentological evidence for this locality it is more likely that the sphaeromorph acritarchs represent an *in situ* deep water flora.

Acanthomorph acritarchs

These are relatively common being found in twenty three of the forty three samples, and they appear to be as common in black shales as they are in the grey mudstones. Thus there appears to be no particular distribution pattern represented by the acanthomorph acritarchs as a group.

Netromorph acritarchs

These are found in only four samples, all but one of which are black shales. Netromorph acritarchs are commonly found in deeper water samples (Dorning 1987), and the presence of *Navifusa* sp. B in a grey mudstone, particularly so far removed stratigraphically from the other two samples that contain this species, may suggest that it has been reworked, although this is circumstantial.

Polygonomorph acritarchs

These acritarchs belonging to the genera *Veryhachium* and *Neoveryhachium* are found in only six samples at Dob's Linn, and appear to be equally common in the grey mudstones and the black shales. However one of the grey mudstone samples (SU/DL/39) has three species of *Veryhachium*, which may suggest that they have been brought in with distal turbidite material.

Herkomorph acritarchs

These are relatively rare at Dob's Linn and are found in only three samples and are of no apparent significance.

Chitinozoans

Although chitinozoans are found in the grey mudstones the majority of the chitinozoans are found in black shales. Samples that contain three or more species of chitinozoans (Figure 37) are always black shales, in fact samples that contain more than one species of chitinozoan are black shales. One sample (SU/DL/46) is a grey mudstone that has yielded more than three species of chitinozoans but this can be explained by the fact that when it was collected this sample had a small amount of Anceps Band D adhering to it, which presumably is the source of the

Zone	Sample	Two or more species of non-sphaeromorph acritarchs	Three or more species of non-sphaeromorph acritarchs	Two or more species of chitinozoans	Three or more species of chitinozoans.
	Main Cliff				
P. acuminatus	SU/DL/41			X	
	SU/DL/57	X	X	X	X
	SU/DL/56	X	X	X	
	SU/DL/55	X			
	SU/DL/54	X		X	
	SU/DL/53			X	
G. persculptus	SU/DL/52	X		X	
	SU/DL/51	X		X	X
	SU/DL/50	X		X	X
	SU/DL/49				
	SU/DL/48				
	SU/DL/40				
	SU/DL/17	X	X		
	SU/DL/39	X	X		
	SU/DL/16				
	SU/DL/15				
D.anceps	SU/DL/14				
	SU/DL/47	X	X		
	SU/DL/13				
	SU/DL/46			X	X
	SU/DL/11				
	SU/DL/12	X	X		
	SU/DL/10	X	X		
	SU/DL/45				
	SU/DL/9			X	X
D.complanatus	SU/DL/8				
	SU/DL/7				
	SU/DL/6				
	SU/DL/5				
P. linearis	SU/DL/4	X			
D.clingani	SU/DL/3				
	Little Cliff				
C.wilsoni	SU/DL/2				
C.peltifer	SU/DL/1	X	X		
	Linn Branch				
P. acuminatus	SU/DL/38				
	SU/DL/37				
	SU/DL/36				
G. persculptus	SU/DL/35				
	SU/DL/34				
	SU/DL/33				
D.anceps	SU/DL/32	X			
	SU/DL/31				
	SU/DL/44				

Figure 37. Diagram illustrating samples at Dob's Linn, that contain good assemblages of palynomorphs

chitinozoans. This abundance has important consequences for the biostratigraphy, in view of the fact that the Ordovician-Silurian boundary is in the black Birkhill Shales. Although chitinozoans are always more common in black shales they are not always present.

Miscellaneous debris

Obviously graptolite debris is more common in the black shales but organic tubes are often abundant in grey mudstones, although they are more commonly found in black shales, and thus may be related not only to graptolites which are rare in the grey mudstones but to other macrofossil and/or microfossil groups. Scolecodonts are found in black shales and grey mudstones but are not particularly common in either, thus supporting the findings of Williams (m.s. 1981).

Small conical fossils have been found in six samples and are particularly abundant in SU/DL/5 from the *D. complanatus* Zone at Main Cliff. These may be conodonts that have been preserved by fluoritisation, although this is by no means certain, and they are found in both the grey mudstones and the black shales. Spiny debris has been found in seven samples, is more common in the black shales, and they are assumed to be the hard parts of some macrofaunal group, although again this is uncertain.

Objects that have been taken to be fish debris (or possibly eurypterid fragments) and yellow platy material with pyrite crystals (taken to be cuticle) were originally considered to be original, however they were both found together in the same four samples, which were processed and collected at the same time. Samples collected and processed subsequently have not yielded either of these particles and it is assumed that they may be contamination of some form.

The overall picture shows that the black shales are more likely to contain chitinozoans than the grey mudstones but that acritarchs are more common in grey mudstones though black shales can provide abundant (greater than three species) assemblages of acritarchs. Graptolite fragments are more common in black shales while organic tubes and scolecodonts are slightly more abundant in the black shales but are present in grey mudstones, and other miscellaneous groups are randomly distributed.

WOODLAND POINT

Listed below are the constituents of the samples MV/G/29 to MV/G/18 from Woodland Point. Percentages are specified for a count of four hundred per sample (or two hundred for MV/G/29), a full species list is given in the appendix. The percentage of acritarchs, chitinozoans (including *Calpichitina lenticularis*), spores and scolecodonts and for *Calpichitina lenticularis* alone for each sample are given, followed by the percentage of sphaeromorph, acanthomorph, netromorph (including *Moyeria cabotti*), polygonomorph, herkomorph acritarch types and *Moyeria cabotti* alone (taking the counted percentage of acritarchs as one hundred percent) is given, and then the total number of each palynomorphs (except for corroded acanthomorphs, cuticle, indeterminate *Incertae sedis* and chitinozoans and scolecodonts). Finally the number of each type (for the whole sample) is listed. Corroded acanthomorph acritarchs and indeterminate chitinozoans shown in the percentage list are not counted in the number of species of acanthomorph acritarchs or chitinozoans respectively. No statistics are carried out as the number counted is too small for them to have any meaning.

MV/G/29

	no.	%
Leiosphaeridia cf. *voigtii*	79	39.50
Leiosphaeridia sp. A	41	20.50
Leiosphaeridia cf. *tenuissima*	27	13.50
Tetrahedraletes medinensis	21	10.50
Moyeria cabotti	15	7.50
Navifusa similis	6	3.00
Scolecodonts	5	2.50
Baltisphaerosum cristoferi	2	1.00
Chitinozoan sp. indet.	2	1.00
Corroded acanthomorph acritarchs	1	0.50
?Ammonidium sp. A	1	0.50

% acritarchs	86.00
% chitinozoans	1.00
% spores	10.50
% scolecodonts	2.50
% *Calpichitina lenticularis*	0.00

% sphaeromorph acritarchs	85.50
% acanthomorph acritarchs	2.50
% netromorph acritarchs	12.00
% polygonomorph acritarchs	0.00

% herkomorph acritarchs	0.00	
% *Moyeria cabotti*	8.70	
Total number of species		10
No. of species of sphaeromorph acritarchs	3	
No. of species of acanthomorph acritarchs	2	
No. of species of netromorph acritarchs	2	
No. of species of polygonomorph acritarchs	0	
No. of species of herkomorph acritarchs	0	
No. of species of chitinozoans		1
No. of species of spores		1
No. of others (types)		1

MV/G/28

Calpichitina lenticularis	165	41.25
Leiosphaeridia cf. *voigtii*	80	20.00
Tetrahedraletes medinensis	46	11.50
Leiosphaeridia cf. *tenuissima*	37	9.25
Leiosphaeridia sp. A	37	9.25
Goniosphaeridium girvanense	7	1.75
Corroded acanthomorph acritarchs	5	1.25
Multiplicisphaeridium ramuscolosum	3	0.75
Scolecodonts	3	0.75
Moyeria cabotti	3	0.75
Calpichitina megastrophica	2	0.50
Belonechitina comma	2	0.50
Veryhachium trispinosum	1	0.25
Conochitina conulus	1	0.25
Veryhachium triangulatum	1	0.25
Actinotodissus woodlandense	1	0.25
Belonechitina micracantha	1	0.25

% acritarchs	44.75	
% chitinozoans	43.00	
% spores	11.50	
% scolecodonts	0.75	
% *Calpichitina lenticularis*	41.25	
% sphaeromorph acritarchs	86.00	
% acanthomorph acritarchs	8.50	
% netromorph acritarchs	4.50	
% polygonomorph acritarchs	1.00	
% herkomorph acritarchs	0.00	
% *Moyeria cabotti*	2.00	
Total number of species		30

No. of species of sphaeromorph acritarchs	3
No. of species of acanthomorph acritarchs	9
No. of species of netromorph acritarchs	3
No. of species of polygonomorph acritarchs	2
No. of species of herkomorph acritarchs	0
No. of species of chitinozoans	12
No. of species of spores	1
No. of others (types)	1

MV/G/27

Leiosphaeridia cf. *voigtii*	120	30.00
Tetrahedraletes medinensis	86	21.50
Leiosphaeridia sp. A	77	19.25
Calpichitina lenticularis	71	17.75
Leiosphaeridia cf. *tenuissima*	24	6.00
Belonechitina seriespinosa	8	2.00
Scolecodonts	5	1.25
Moyeria cabotti	2	0.50
Belonechitina wesenbergensis	2	0.50
Belonechitina micracantha	1	0.25
Navifusa sp. A	1	0.25
Dyadaspora sp. A	1	0.25
Dictyotidium sp. A	1	0.25
Goniosphaeridium girvanense	1	0.25

% acritarchs	56.50
% chitinozoans	20.50
% spores	21.75
% scolecodonts	1.25
% *Calpichitina lenticularis*	17.75

% sphaeromorph acritarchs	98.00
% acanthomorph acritarchs	0.50
% netromorph acritarchs	1.00
% polygonomorph acritarchs	0.00
% herkomorph acritarchs	0.50
% *Moyeria cabotti*	0.80

Total number of species	28
No. of species of sphaeromorph acritarchs	3
No. of species of acanthomorph acritarchs	4
No. of species of netromorph acritarchs	3
No. of species of polygonomorph acritarchs	0
No. of species of herkomorph acritarchs	1
No. of species of chitinozoans	15
No. of species of spores	2
No. of others (types)	2

MV/G/26

Tetrahedraletes medinensis	113	28.25
Leiosphaeridia cf. *voigtii*	107	26.75
Leiosphaeridia sp. A	87	21.75
Leiosphaeridia cf. *tenuissima*	32	8.00
Calpichitina lenticularis	29	7.25
Moyeria cabotti	10	2.50
Scolecodonts	6	1.50
Belonechitina seriespinosa	3	0.75
Dyadaspora sp. A	2	0.50
Belonechitina micracantha	2	0.50
Navifusa similis	2	0.50
Corroded acanthomorph acritarchs	1	0.25
Micrhystridium sp. A	1	0.25
Micrhystridium sp. B	1	0.25
Goniosphaeridium girvanense	1	0.25
Filisphaeridium sp. A	1	0.25
Leiosphaeridium sp. B	1	0.25
Belonechitina wesenbergensis	1	0.25

% acritarchs	61.00
% chitinozoans	8.75
% spores	28.75
% scolecodonts	1.50
% *Calpichitina lenticularis*	7.25

% sphaeromorph acritarchs	93.00
% acanthomorph acritarchs	2.00
% netromorph acritarchs	5.00
% polygonomorph acritarchs	0.00
% herkomorph acritarchs	0.00
% *Moyeria cabotti*	4.00

Total number of species	20
No. of species of sphaeromorph acritarchs	4
No. of species of acanthomorph acritarchs	6
No. of species of netromorph acritarchs	2
No. of species of polygonomorph acritarchs	0
No. of species of herkomorph acritarchs	0
No. of species of chitinozoans	6
No. of species of spores	2
No. of others (types)	1

MV/G/25

Leiosphaeridia cf. *voigtii*	116	29.00
Leiosphaeridia sp. A	101	25.25
Tetrahedraletes medinensis	75	18.75
Leiosphaeridia cf. *tenuissima*	44	11.00
Calpichitina lenticularis	22	5.50
Scolecodonts	10	2.50
Moyeria cabotti	8	2.00
Dyadaspora sp. A	8	2.00
Navifusa similis	7	1.75
Corroded acanthomorph acritarchs	3	0.75
Veryhachium lairdii	2	0.50
Aremoricanium cf. *rigaudae*	1	0.25
Angochitina woodlandensis	1	0.25
Micrhystridium sp. A	1	0.25
Chitinozoan indet.	1	0.25

% acritarchs	70.75
% chitinozoans	6.00
% spores	20.75
% scolecodonts	2.50
% *Calpichitina lenticularis*	5.50

% sphaeromorph acritarchs	92.00
% acanthomorph acritarchs	1.50
% netromorph acritarchs	5.50
% polygonomorph acritarchs	1.00
% herkomorph acritarchs	0.00
% *Moyeria cabotti*	2.80

Total number of species	21
No. of species of sphaeromorph acritarchs	3
No. of species of acanthomorph acritarchs	7
No. of species of netromorph acritarchs	2
No. of species of polygonomorph acritarchs	1
No. of species of herkomorph acritarchs	0
No. of species of chitinozoans	6
No. of species of spores	2
No. of others (types)	1

MV/G/24

Leiosphaeridia cf. *voigtii*	133	33.25
Leiosphaeridia sp. A	114	28.50
Tetrahedraletes medinensis	66	16.50
Leiosphaeridia cf. *tenuissima*	27	6.75
Moyeria cabotti	17	4.25

Scolecodont	10	2.50
Calpichitina lenticularis	8	2.00
Goniosphaeridium girvanense	7	1.75
Dyadaspora sp. A	7	1.75
Multiplicisphaeridium ramuscolosum	4	1.00
Navifusa similis	2	0.50
Solisphaeridium cf. *nanum*	1	0.25
Cyathochitina sp. D	1	0.25
Calpichitina megastrophica	1	0.25
Baltisphaeridium cf. *regnelli*	1	0.25
Belonechitina seriespinosa	1	0.25

% acritarchs	76.50
% chitinozoans	2.75
% spores	18.25
% scolecodonts	2.50
% *Calpichitina lenticularis*	2.00

% sphaeromorph acritarchs	90.00
% acanthomorph acritarchs	4.00
% netromorph acritarchs	6.00
% polygonomorph acritarchs	0.00
% herkomorph acritarchs	0.00
% *Moyeria cabotti*	5.50

Total number of species	27
No. of species of sphaeromorph acritarchs	3
No. of species of acanthomorph acritarchs	7
No. of species of netromorph acritarchs	2
No. of species of polygonomorph acritarchs	1
No. of species of herkomorph acritarchs	0
No. of species of chitinozoans	12
No. of species of spores	2
No. of others (types)	2

MV/G/23

Leiosphaeridia cf. *voigtii*	109	27.25
Tetrahedraletes medinensis	86	21.50
Leiosphaeridia sp. A	57	14.25
Leiosphaeridia cf. *tenuissima*	56	14.00
Scolecodonts	20	5.00
Leiosphaeridia sp. H	14	3.50
Moyeria cabotti	14	3.50
Calpichitina lenticularis	10	2.50
Dyadaspora sp. A	8	2.00
Belonechitina seriespinosa	6	1.50

Conochitina spp. indet	3	0.75
Angochitina woodlandensis	2	0.50
Goniosphaeridium girvanense	2	0.50
Multiplicisphaeridium ramuscolosum	2	0.50
Micrhystridium sp. A	2	0.50
Baltisphaeridium cf. *paucispinosum*	1	0.25
Goniosphaeridium elongatum	1	0.25
Navifusa similis	1	0.25
Baltisphaeridium cf. *bulbosum*	1	0.25
Micrhystridium sp. B	1	0.25
Chitinozoan indet.	1	0.25
Cyathochitina campanulaeformis	1	0.25
Belonechitina cf. *hirsuta*	1	0.25
Belonechitina wesenbergensis	1	0.25

% acritarchs	65.25
% chitinozoans	6.25
% spores	23.50
% scolecodonts	5.00
% *Calpichitina lenticularis*	2.50

% sphaeromorph acritarchs	90.50
% acanthomorph acritarchs	3.50
% netromorph acritarchs	6.00
% polygonomorph acritarchs	0.00
% herkomorph acritarchs	0.00
% *Moyeria cabotti*	5.30

Total number of species	26
No. of species of sphaeromorph acritarchs	4
No. of species of acanthomorph acritarchs	9
No. of species of netromorph acritarchs	2
No. of species of polygonomorph acritarchs	0
No. of species of herkomorph acritarchs	0
No. of species of chitinozoans	9
No. of species of spores	2
No. of others (types)	1

MV/G/22

Leiosphaeridia sp. A	140	35.00
Leiosphaeridia cf. *voigtii*	79	19.75
Tetrahedraletes medinensis	75	18.75
Leiosphaeridia cf. *tenuissima*	49	12.25
Leiosphaeridia sp. H	34	8.50
Calpichitina lenticularis	8	2.00

Dyadaspora sp. A	6	1.50
Corroded acanthomorph acritarchs	3	0.75
Scolecodonts	2	0.50
Moyeria cabotti	1	0.25
Goniosphaeridium girvanense	1	0.25
Multiplicisphaeridium ramuscolosum	1	0.25
Multiplicisphaeridium cf. *wrightii*	1	0.25

% acritarchs	77.25
% chitinozoans	2.00
% spores	20.25
% scolecodonts	0.50
% *Calpichitina lenticularis*	2.00

% sphaeromorph acritarchs	98.00
% acanthomorph acritarchs	1.70
% netromorph acritarchs	0.30
% polygonomorph acritarchs	0.00
% herkomorph acritarchs	0.00
% *Moyeria cabotti*	0.30

Total number of species	22
No. of species of sphaeromorph acritarchs	4
No. of species of acanthomorph acritarchs	7
No. of species of netromorph acritarchs	2
No. of species of polygonomorph acritarchs	0
No. of species of herkomorph acritarchs	1
No. of species of chitinozoans	6
No. of species of spores	2
No. of others (types)	2

MV/G/21

Leiosphaeridia sp. A	164	41.00
Leiosphaeridia cf. *voigtii*	132	33.00
Leiosphaeridia cf. *tenuissima*	39	9.75
Tetrahedraletes medinensis	31	7.75
Scolecodonts	10	2.50
Moyeria cabotti	9	2.25
Leiosphaeridia sp. H	4	1.00
Calpichitina lenticularis	3	0.75
Multiplicisphaeridium ramuscolosum	2	0.50
Solisphaeridium cf. *nanum*	1	0.25
Corroded acanthomorph acritarchs	1	0.25
Conochitina conulus	1	0.25
Baltisphaerosum cristoferi	1	0.25
Baltisphaeridium hirsuitoides	1	0.25

Goniosphaeridium girvanense	1	0.25

% acritarchs	88.75
% chitinozoans	1.00
% spores	7.75
% scolecodonts	2.50
% *Calpichitina lenticularis*	0.75

% sphaeromorph acritarchs	95.50
% acanthomorph acritarchs	2.00
% netromorph acritarchs	2.50
% polygonomorph acritarchs	0.00
% herkomorph acritarchs	0.00
% *Moyeria cabotti*	2.50

Total number of species	20
No. of species of sphaeromorph acritarchs	4
No. of species of acanthomorph acritarchs	7
No. of species of netromorph acritarchs	1
No. of species of polygonomorph acritarchs	0
No. of species of herkomorph acritarchs	0
No. of species of chitinozoans	7
No. of species of spores	1
No. of others (types)	3

MV/G/20

Leiosphaeridia sp. A	129	32.25
Leiosphaeridia cf. *voigtii*	99	24.75
Tetrahedraletes medinensis	90	22.50
Leiosphaeridia cf. *tenuissima*	57	14.25
Moyeria cabotti	11	2.75
Scolecodonts	5	1.25
Navifusa similis	2	0.50
Veryhachium lairdii	1	0.25
Veryhachium oklahomense	1	0.25
Veryhachium cf. *subglobosum*	1	0.25
Micrhystridium sp. B	1	0.25
Multiplicisphaeridium irregulare	1	0.25
Tasmanites sp. A	1	0.25
Baltisphaeridium sp. A	1	0.25

% acritarchs	76.25
% chitinozoans	0.00
% spores	22.50
% scolecodonts	1.25
% *Calpichitina lenticularis*	0.00

% sphaeromorph acritarchs	94.00
% acanthomorph acritarchs	1.00
% netromorph acritarchs	4.00
% polygonomorph acritarchs	1.00
% herkomorph acritarchs	0.00
% *Moyeria cabotti*	3.70

Total number of species	28
No. of species of sphaeromorph acritarchs	5
No. of species of acanthomorph acritarchs	6
No. of species of netromorph acritarchs	3
No. of species of polygonomorph acritarchs	3
No. of species of herkomorph acritarchs	0
No. of species of chitinozoans	10
No. of species of spores	1
No. of others (types)	1

MV/G/19

Leiosphaeridia sp. A	166	41.50
Leiosphaeridia cf. *voigtii*	143	35.75
Leiosphaeridia cf. *tenuissima*	83	20.75
Leiosphaeridia spp. indet	5	1.25
Moyeria cabotti	1	0.25
Tetrahedraletes medinensis	2	0.50

% acritarchs	99.50
% chitinozoans	0.00
% spores	0.50
% scolecodonts	1.25
% *Calpichitina lenticularis*	0.00

% sphaeromorph acritarchs	99.70
% acanthomorph acritarchs	0.00
% netromorph acritarchs	0.30
% polygonomorph acritarchs	0.00
% herkomorph acritarchs	0.00
% *Moyeria cabotti*	0.30

Total number of species	12
No. of species of sphaeromorph acritarchs	8
No. of species of acanthomorph acritarchs	0
No. of species of netromorph acritarchs	1
No. of species of polygonomorph acritarchs	0
No. of species of herkomorph acritarchs	0
No. of species of chitinozoans	2
No. of species of spores	1

No. of others (types)	1

M V / G / 1 8

Leiosphaeridia sp. A	210	52.50
Leiosphaeridia cf. *tenuissima*	65	16.25
Leiosphaeridia cf. *voigtii*	59	14.75
Tetrahedraletes medinensis	24	6.00
Scolecodonts	23	5.75
Calpichitina lenticularis	9	2.25
Dyadaspora sp. A	3	0.75
Tasmanites sp. B	3	0.75
Belonechitina seriespinosa	1	0.25
Goniosphaeridium girvanense	1	0.25
Navifusa sp. A	1	0.25
Solisphaeridium cf. *nanum*	1	0.25

% acritarchs	85.00
% chitinozoans	2.50
% spores	6.75
% scolecodonts	5.75
% *Calpichitina lenticularis*	2.25

% sphaeromorph acritarchs	99.00
% acanthomorph acritarchs	0.65
% netromorph acritarchs	0.35
% polygonomorph acritarchs	0.00
% herkomorph acritarchs	0.00
% *Moyeria cabotti*	0.00

Total number of species	25
No. of species of sphaeromorph acritarchs	4
No. of species of acanthomorph acritarchs	4
No. of species of netromorph acritarchs	2
No. of species of polygonomorph acritarchs	0
No. of species of herkomorph acritarchs	0
No. of species of chitinozoans	12
No. of species of spores	3
No. of others (types)	3

A general diagram plotting the percentage of acritarchs, chitinozoans, spores and scolecodonts is shown in Figure 38. The general trend shows that acritarchs are most important in sample MV/G/29 but decrease into MV/G/28 where chitinozoans are more important. From MV/G/28 the acritarchs show a general increase while the other three groups generally become less important.

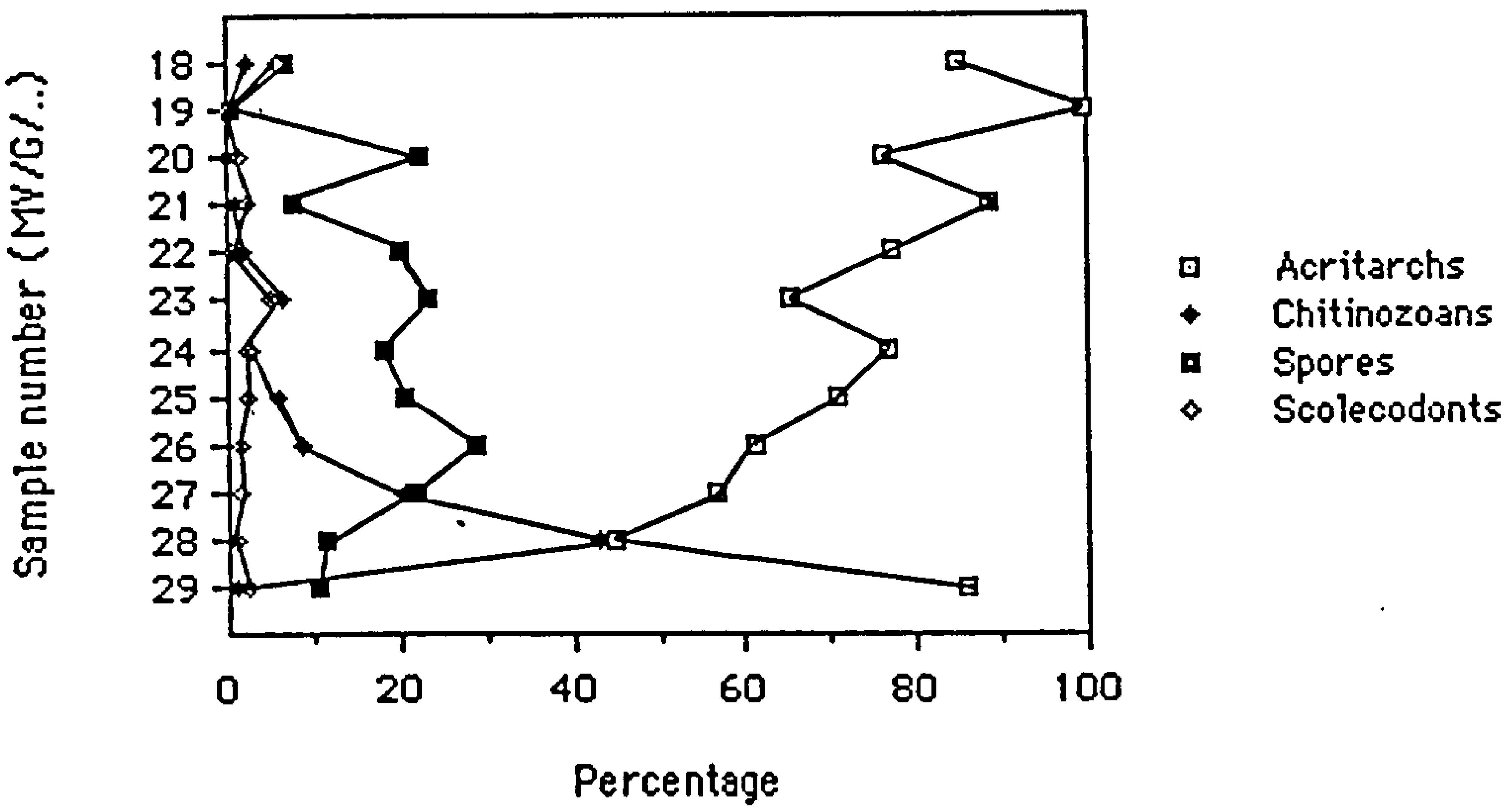


Figure 38 : the relationship between acritarchs, chitinozoans, spores and scolecodonts at Woodland Point

Spores are most important is MV/G/26 which may suggest that the sample was deposited closest to land or there may have been an influx of terrestrial material brought in by turbidity currents. The relationship between percentages of chitinozoans and scolecodonts is similar which is to be expected if they were both parts of related animals. Scolecodonts are not generally numerically important but are found in all samples. The relationship between percentages of acritarchs and chitinozoans is not similar, which may be related to the method of counting of specimens such as in MV/G/28 where one species of chitinozoan is particularly important there are correspondingly less acritarchs counted, or it may be related to the environmental conditions. One would need to count many more specimens per sample in order to be able to clarify this problem. Acritarchs never fall below forty five percent of the total assemblage and on average make up about seventy five percent of the assemblage. Chitinozoans vary in absolute numbers between one per twenty five grammes of rock in MV/G/29, and about two or three for every gramme of rock as in MV/G/28.

If the distribution of the percentage of total chitinozoans is plotted against the percentage of the chitinozoan *Calpichitina lenticularis* (Figure 39) it can be seen that *C. lenticularis* is the most important chitinozoan species in all but one of the samples, although in sample MV/G/23 it is relatively less important. Judging by the exponential decline of *C. lenticularis* and the other chitinozoans from MV/G/28 upwards, *C. lenticularis* may be reworked in all the other samples. There are no specimens of *C. lenticularis* in MV/G/29.

If the relationship between sphaeromorph acritarchs and other groups is considered (Figure 40, 43), it can be seen that the sphaeromorph acritarchs are considerably more abundant, and never fall below eighty five percent of the acritarch assemblage. In four samples, MV/G/27, 22, 19 and 18 they are particularly abundant forming greater than ninety eight percent of the acritarch assemblage. In percentage terms netromorph acritarchs are nearly always the second most important group, although as will be seen later there are few genera representing this subgroup. The acanthomorph acritarchs contain a greater diversity but with usually only a few specimens of each species. Taking the diagram of Dorning (1987), shown in Figure 41, for the Caradoc this seems to suggest that the area of deposition was offshore, as netromorph acritarchs are not thought to be found inshore (Thusu 1972). Sphaeromorphs are thought to be either nearshore or offshore, and the thinner walled forms may represent material washed in, while the thicker walled sphaeromorphs may be the *in situ* assemblage. Figure 42

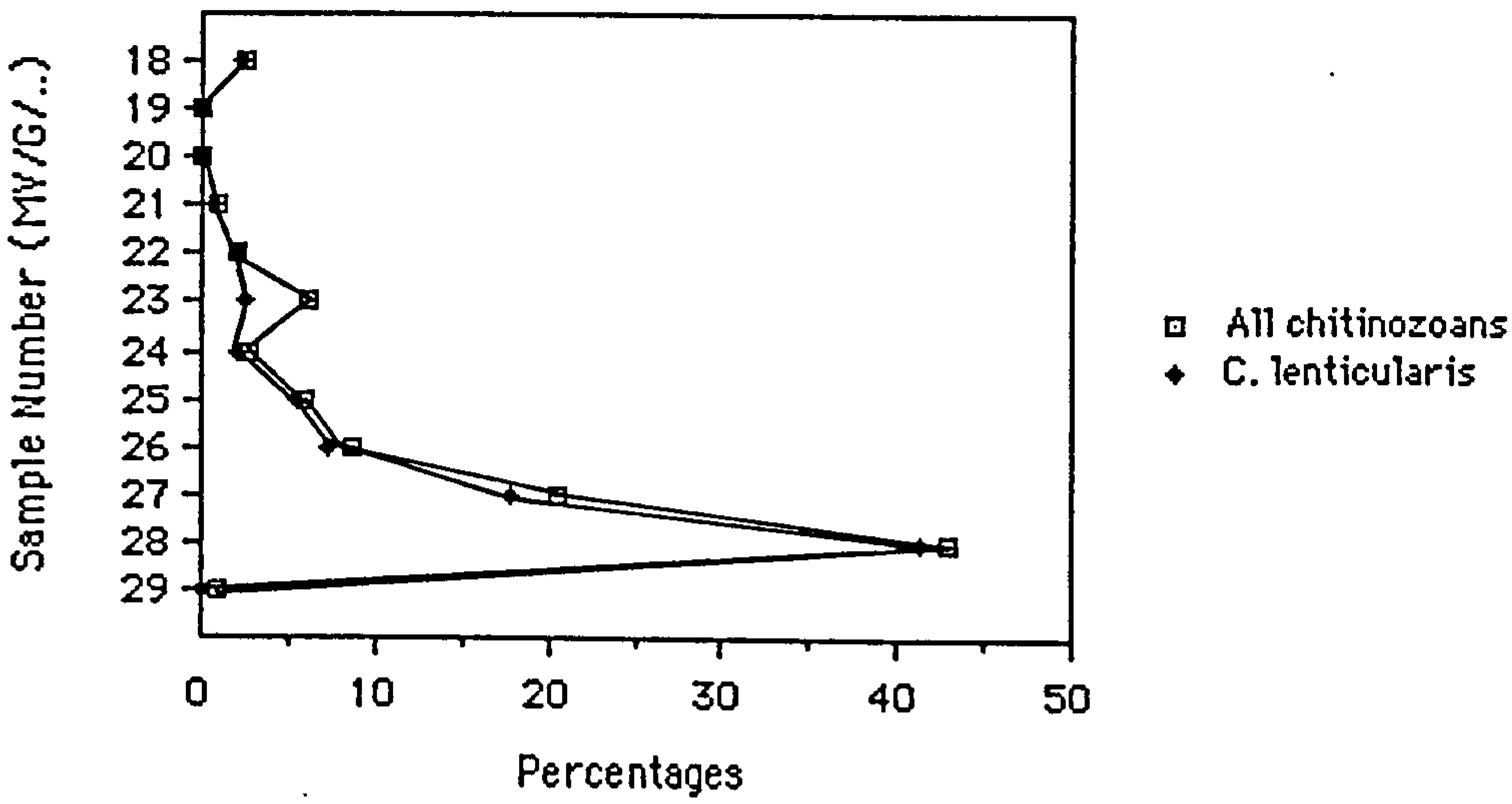


Figure 39 : the relationship between chitinozoans and Calpichitina lenticularis

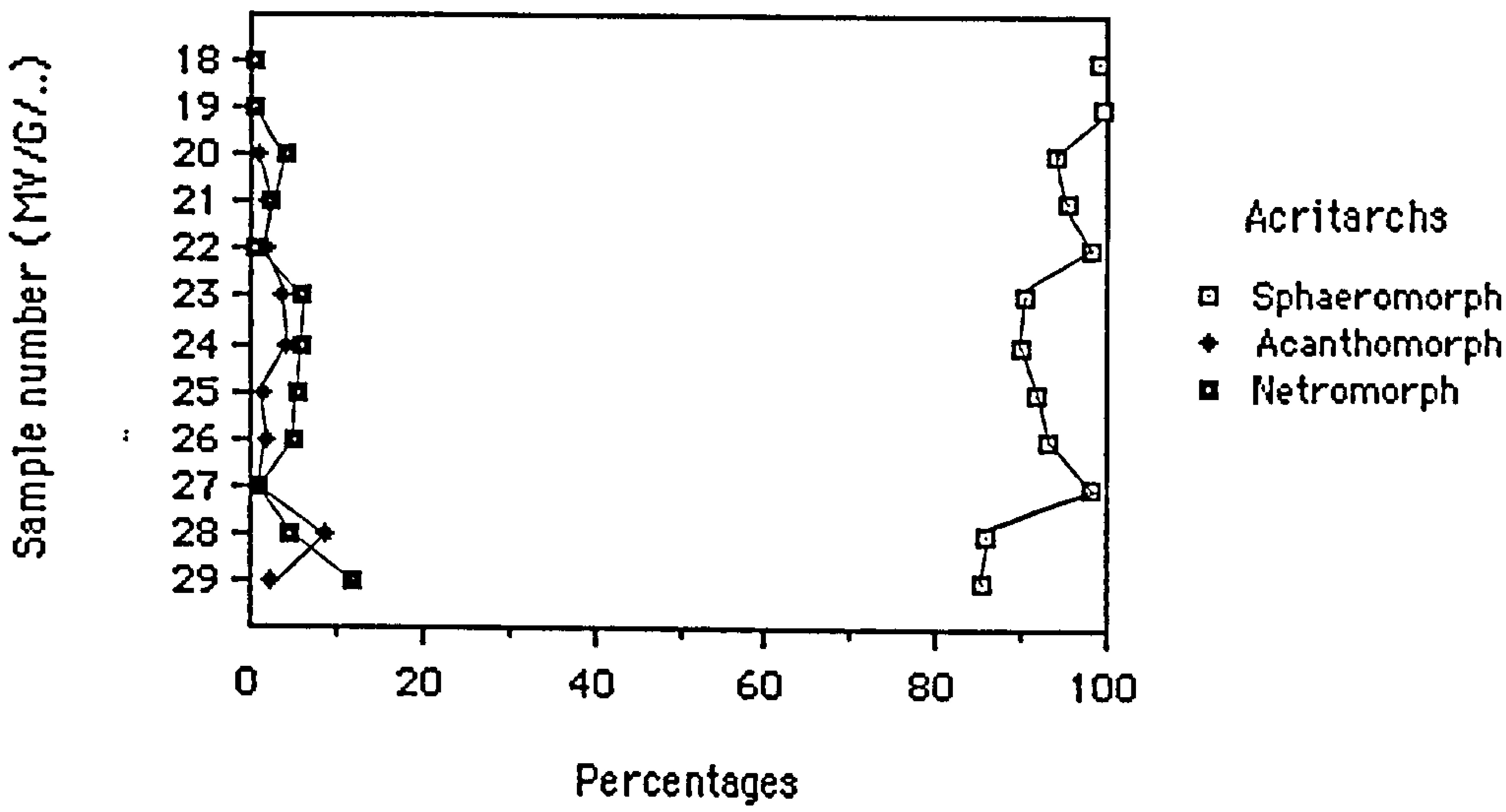
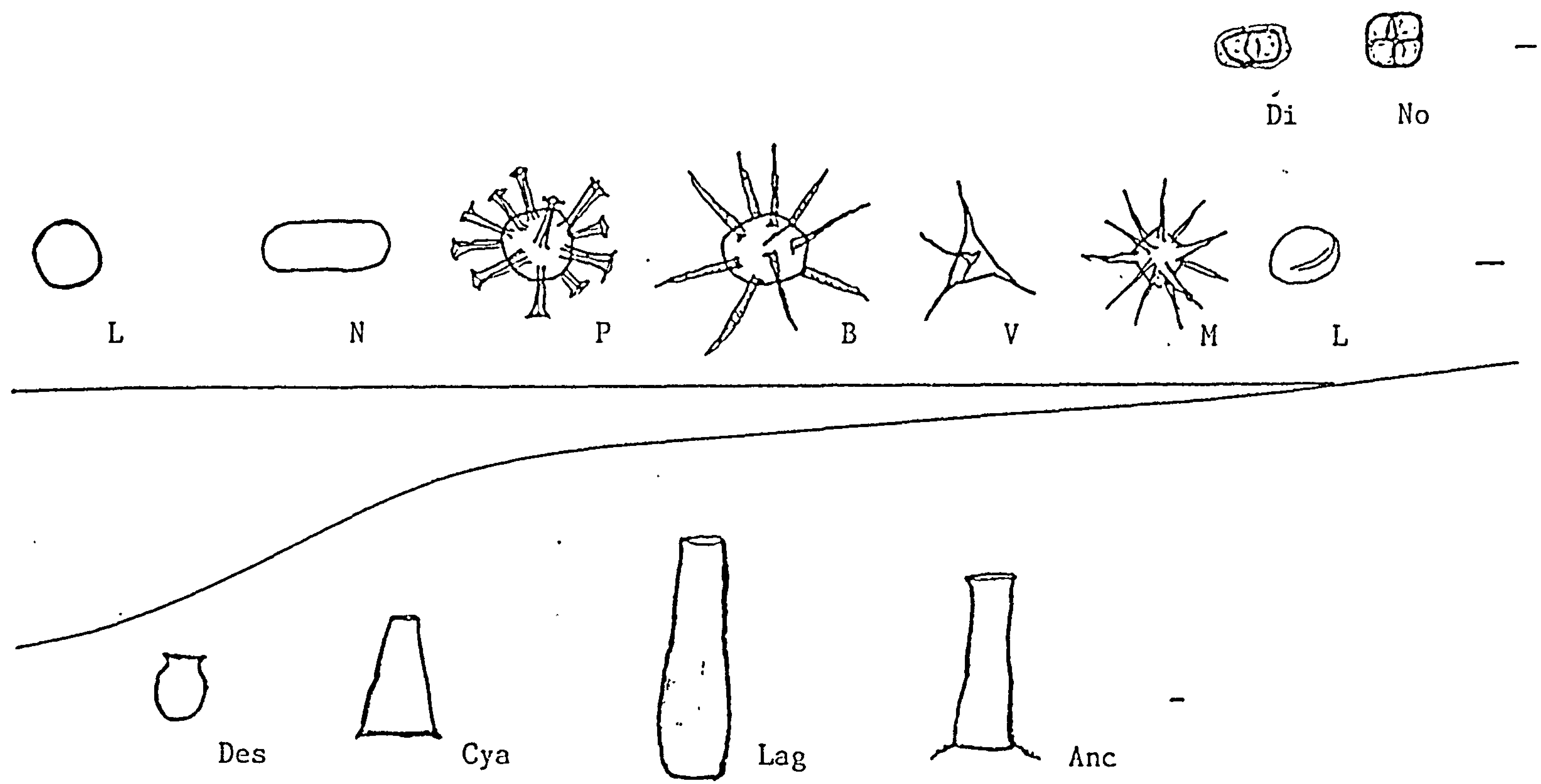


Figure 40 : the relationship between sphaeromorph, acathomorph and netromorph acritarchs

Ordovician: Caradoc



Ordovician organic palaeontology: diagrammatic sketch of selected palynomorph distribution from the Caradoc carbonate shelf. L. Leiosphaeridia, N. Navifusa, P. Peteinosphaeridium, B. Baltisphaerosum, V. Veryhachium, M. Micrhystridium, Spores: Di. Dyadospora, No. Nodospora. Chitinozoans: Des. Desmochitina, Cya. Cyathochitina, Lag. Lagenochitina, Anc. Ancyrochitina.

after Dorning (1987)

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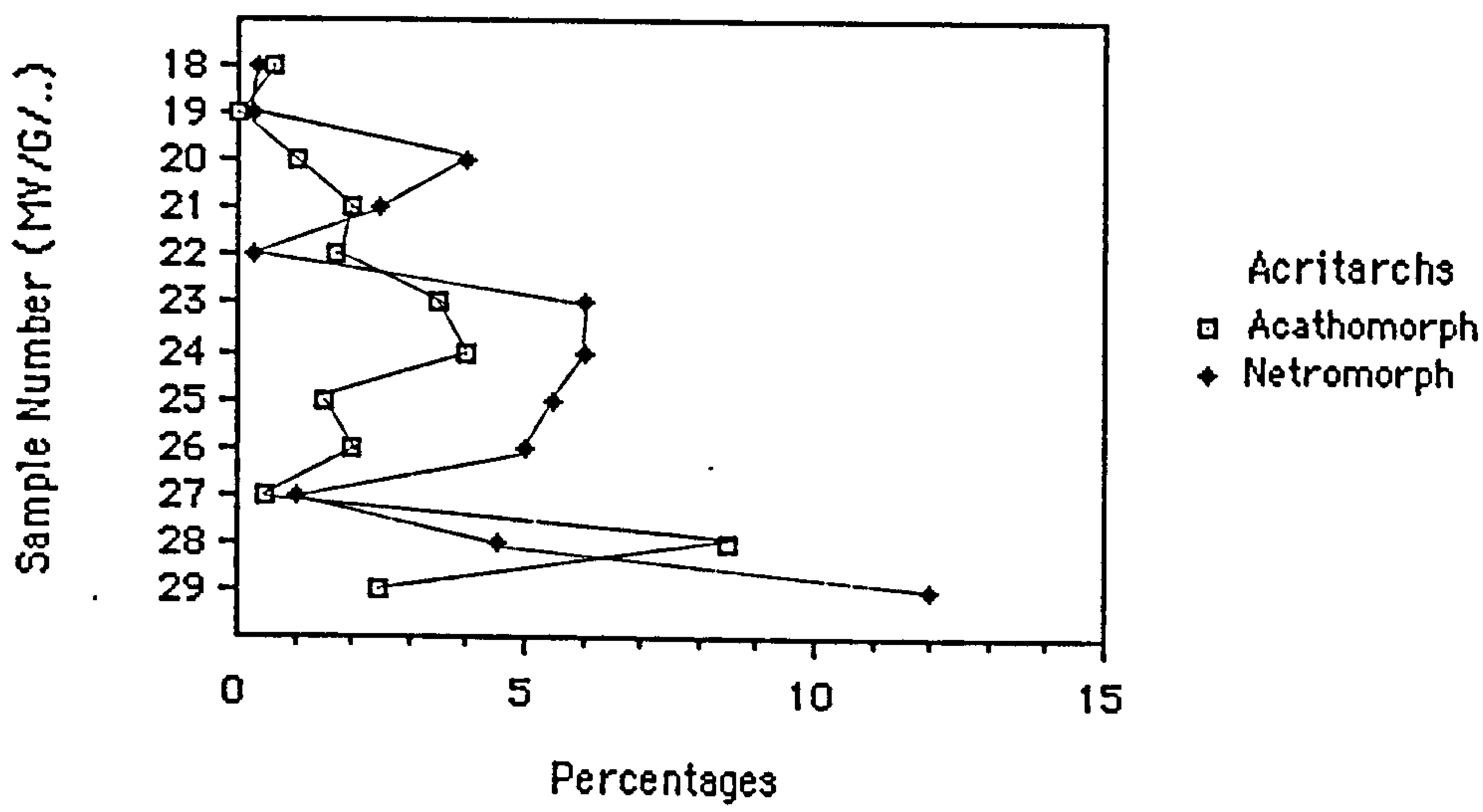


Figure 42 : relationship between ~~sphaeromorph~~, acanthomorph and netromorph acritarchs

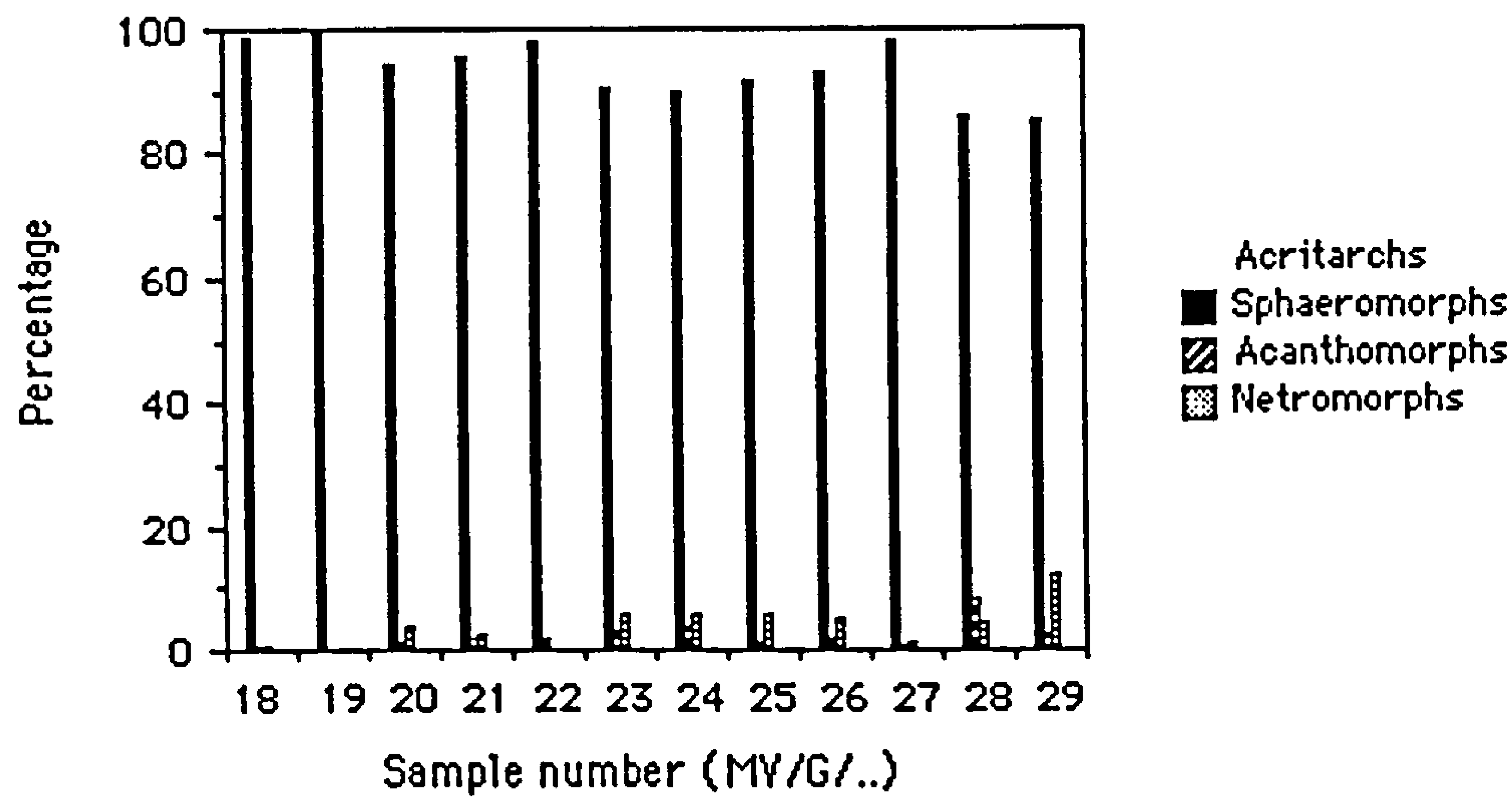


Figure 43 : histogram showing the relationship between sphaeromorph, acanthomorph and netromorph acritarchs at Woodland point.

shows that generally the percentages of both netromorph and acanthomorph acritarchs decrease up the section and that netromorphs are numerically more important, and this could possibly be explained by the netromorph acritarchs representing the *in situ* offshore assemblage with the acanthomorph acritarchs washed into the system with turbidity currents. Polygonomorph and herkomorph acritarchs are relatively unimportant.

Figure 43 shows that there is a switch from relatively important netromorph acritarchs in the sample MV/G/29 to relatively important acanthomorph acritarchs in MV/G/28, which may be related to environment, possibly changing from an offshore to an onshore environment from the Mill to the Shalloch Formations and then from MV/G/27 netromorph acritarchs become more important again, and conditions become more offshore again.

Looking at the netromorph acritarchs in more detail, there are only four genera and five species represented at Woodland Point, *Moyeria cabotti, Eupoikilofusa striata, Leiofusa* sp. A, *Navifusa similis* and *Navifusa* sp. A., and among these *M. cabotti* makes up a significant part of the assemblage (Figure 44). It is not certain if *Moyeria* is in fact a netromorph acritarch although the species originally belonged to *Eupoikilofusa*. It is possible that it is a type of spore (and thus fresh-water, Dorning pers. comm.) but until more data becomes available it will be considered to be a netromorph acritarch and thus more offshore marine.

If the absolute number of species of each palynomorph group are studied (Figure 45, a-h) it can be seen that the total number (Figure 45a) of palynomorph species varies between ten and thirty, being ten in the Mill Formation increasing to thirty in the oldest Shalloch Formation sample with an average of twenty two throughout the Shalloch Formation, the majority of the samples having a greater number of species than the average. Sample MV/G/19 demonstrates a very low diversity containing mostly sphaeromorph acritarchs and little else. The reason for this is not known but it may be related to it being a more offshore sample, as there are hardly any spores in it. On the whole, however, the general diversity seems relatively high when compared to other published material.

Sphaeromorph acritarchs show a fairly even distribution of species number (Figure 45b) except for MV/G/19 which as already mentioned has an anomalously high number of species of these acritarchs.

Acanthomorph acritarchs (Figure 45c) show a general increase from

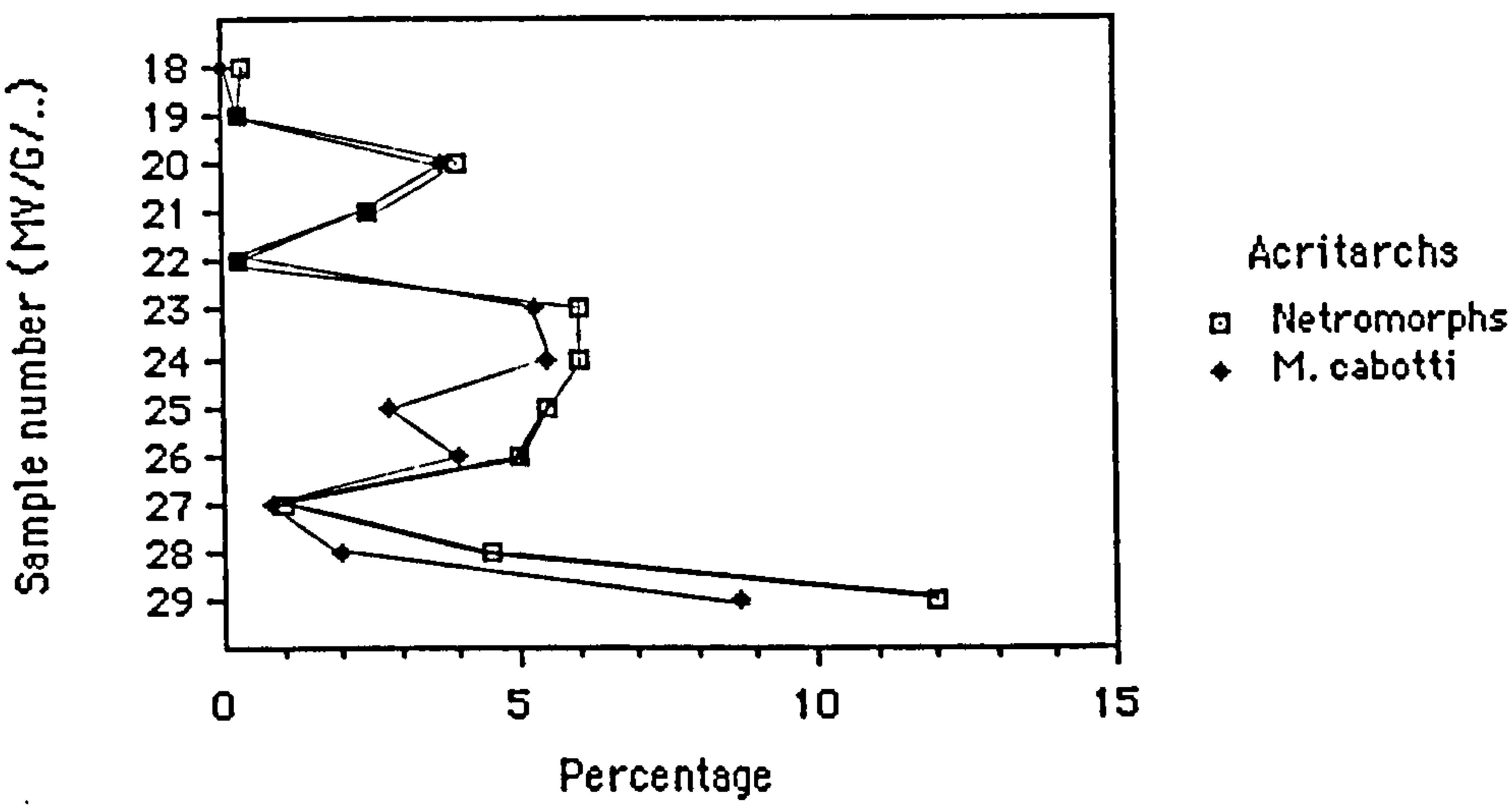


Figure 44 : relationship between netromorph acritarchs and <u>Moyeria cabotti</u>

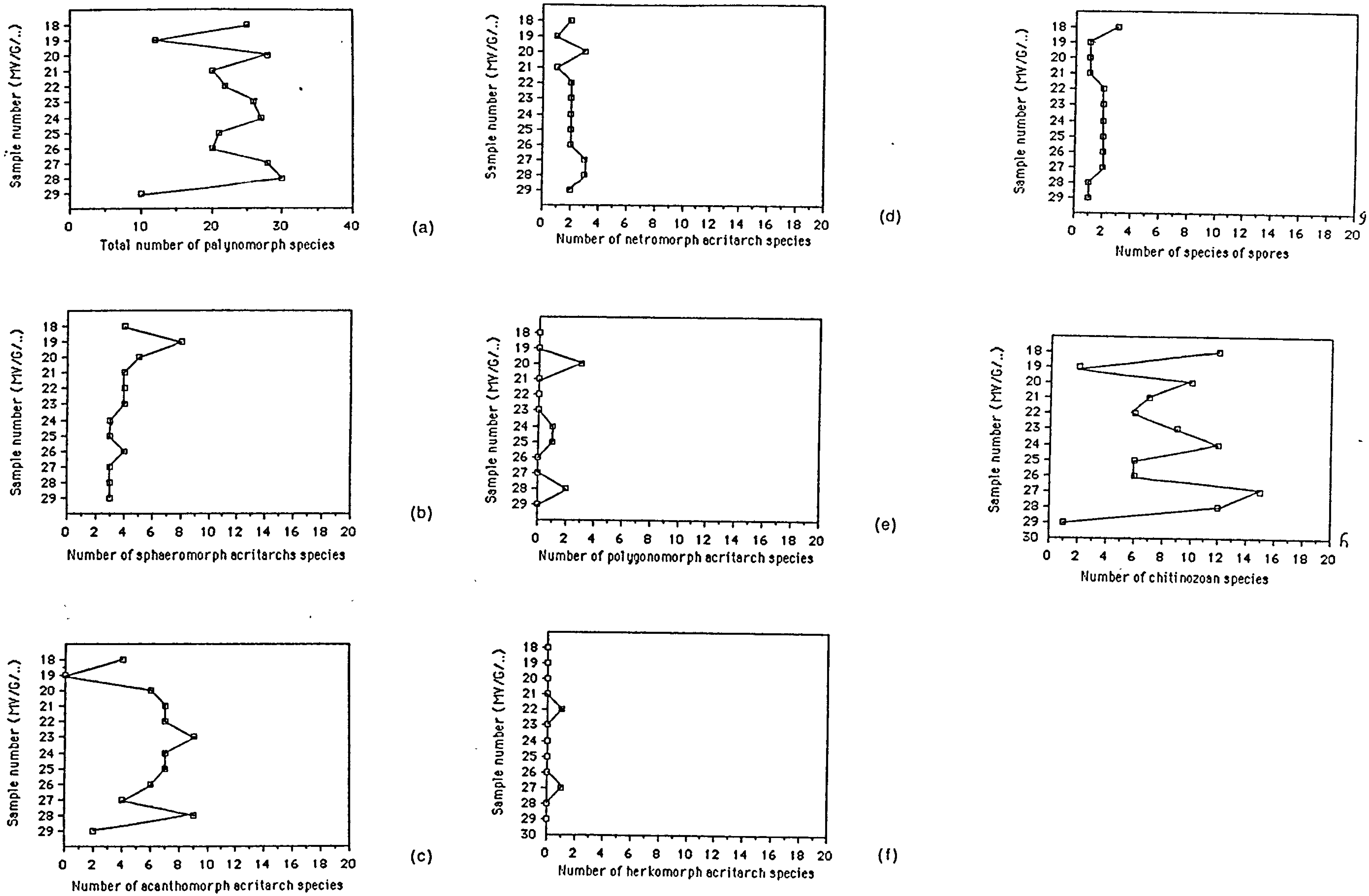


Figure 45 : absolute number of species of (a) total acritarchs and chitinozoans; (b) sphaeromorph acritarchs; (c) acanthomorph acritarchs; (d) netromorph acritarchs; (e) polygonomorph acritarchs; (f) herkomorph acritarchs; (g) .spores; (h) chitinozoans.

MV/G/29 to MV/G/28 and then a general average decrease which could suggest more offshore conditions. Netromorph acritarchs on the other hand do not show much variation (Figure 45d) but as already stated there are only five species recognised from this group.

Polygonomorph acritarchs (Figure 45e) are poorly represented being present in only four samples and show neither an increase nor a decrease up the section although as already noted MV/G/20 has three species of *Veryhachium* which may prove to be significant. Herkomorph acritarchs (Figure 45f) again are poorly represented being present in only two samples.

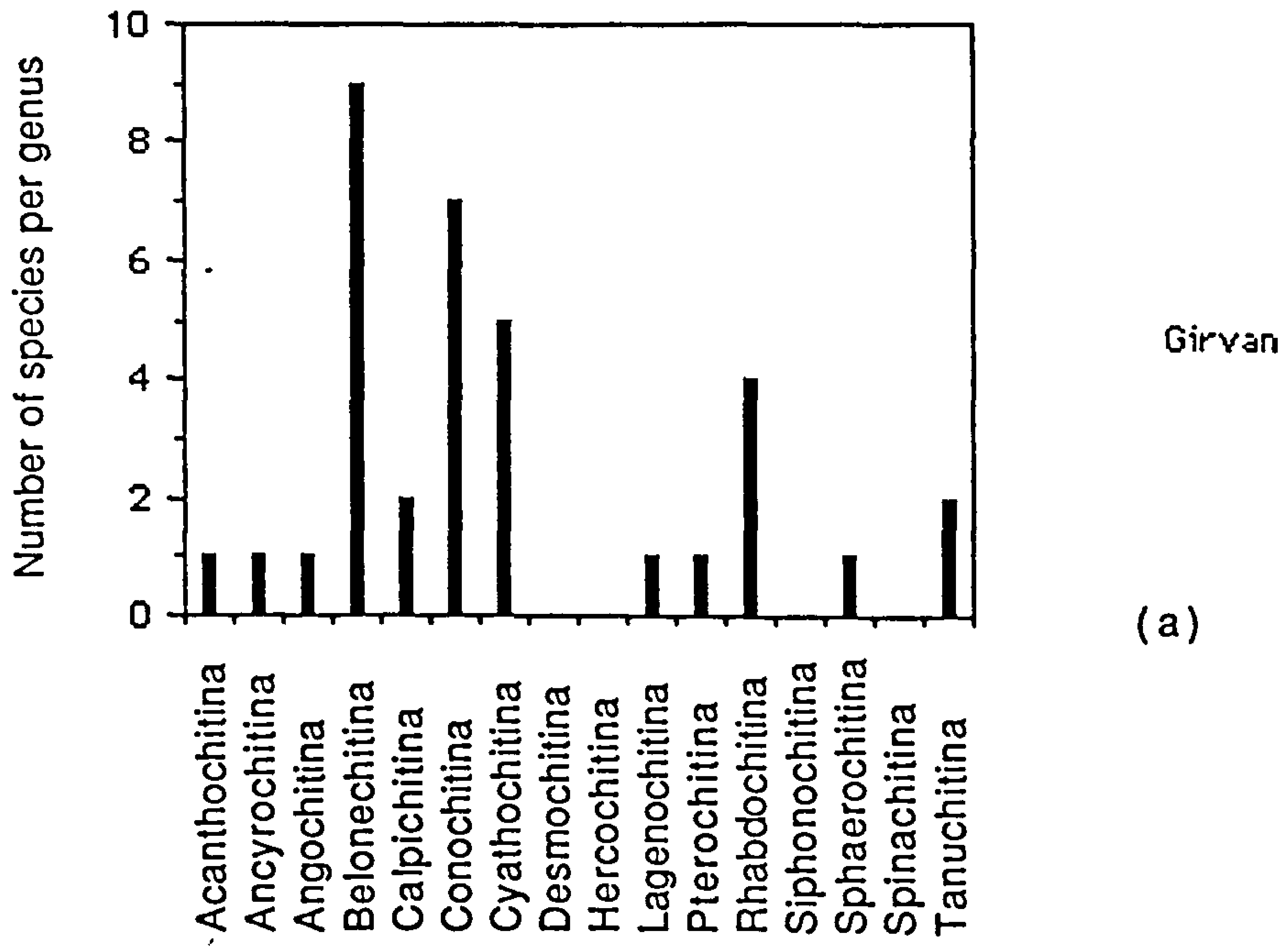
The distribution of spore species (Figure 45g) do not show very much, as at a maximum there are only three species. It may however be significant that the sample with three species in is the youngest in the section, although this may be coincidence.

Looking at the absolute numbers of chitinozoans (Figure 45h) it can be seen that numbers increase significantly from MV/G/29 (one species) to MV/G/28 (twelve species) and then are more or less equally divided about the average (with the exception of MV/G/19) number of eight. Other than this there appears to be no obvious trend.

To sum up the palaeoecology discussed so far does not seem to show much, although there is a significant break, which may be evolutionary or ecological, between the Mill and Shalloch Formations. It is difficult to assess the palaeoecology in the light of the fact that these sediments are taken to be distal turbidites and as such there will be times when material will be being flushed into the system. Thus there is a complicated system with the distance from shore, and the amount of material being deposited by turbidity currents fluctuating. However the amount of material put into the system from these currents probably varied with distance from shore and thus for the purposes of this work can be taken as equating to the same thing.

It seems logical to compare the generic distribution of samples from Woodland Point with samples from the corresponding Zones (*D. complanatus* and *D. anceps*) at Dob's Linn.

Considering the total number of species per genera for all the samples at Dob's Linn and Woodland Point (Figure 46 a,b) it is obvious that *Belonechitina* is much more important at Girvan than at Dob's Linn as there are nine species at the



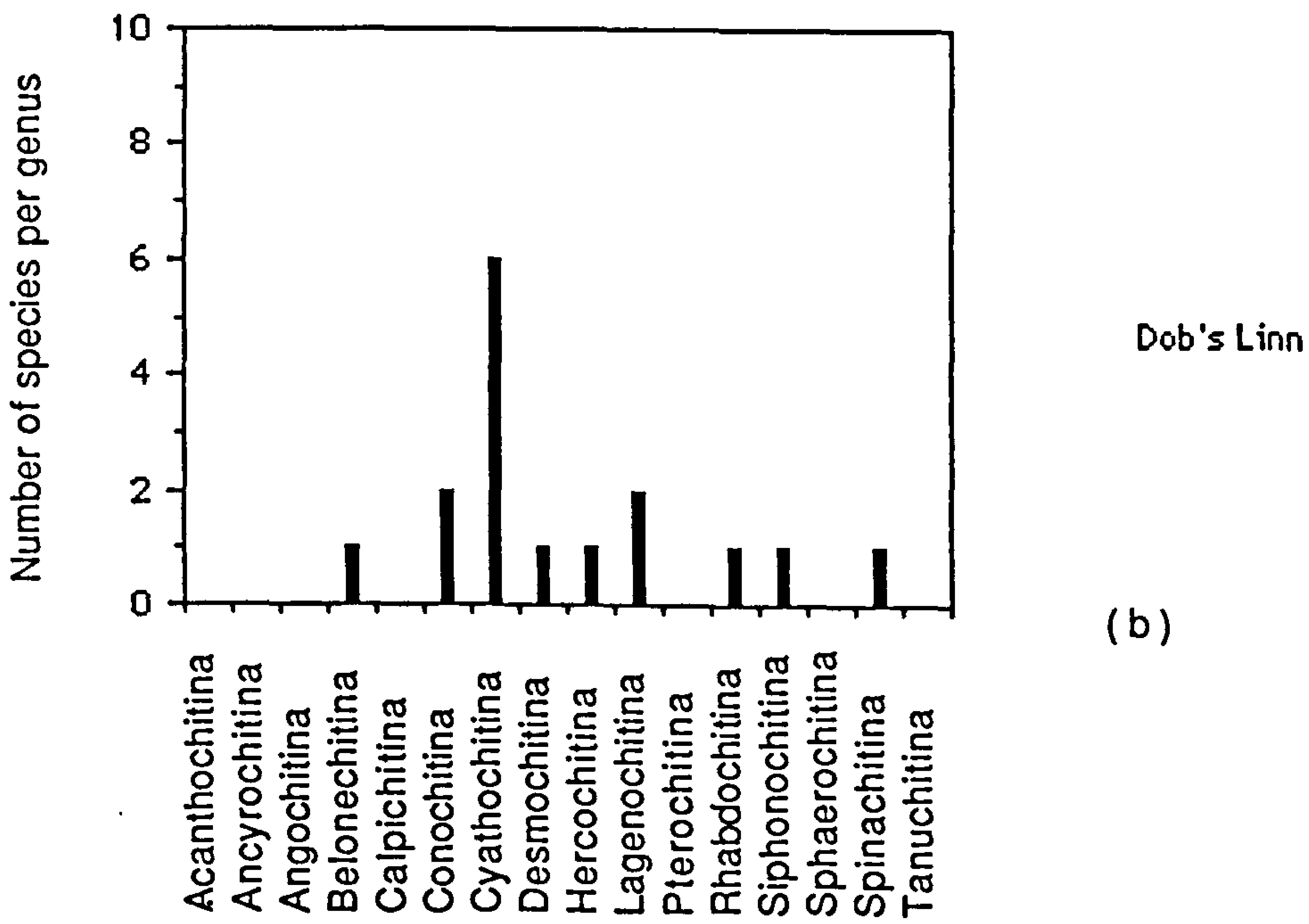


Figure 46 : number of species of each of the genera at (a) Woodland Point and (b) Dob's Linn

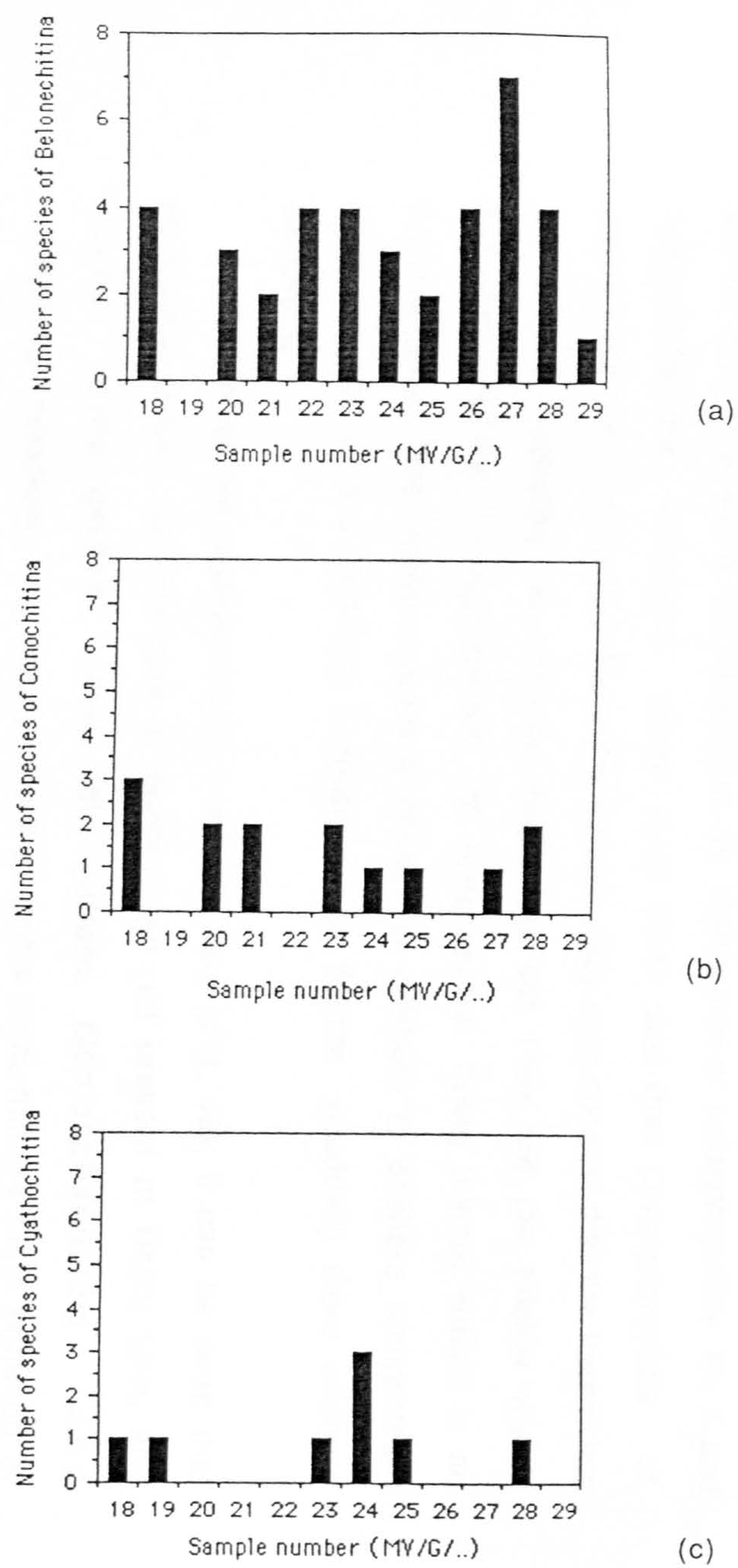
former and only one at the latter. Equally there are seven species of *Conochitina* at Girvan but only two at Dob's Linn. *Cyathochitina* conversely shows six species at Dob's Linn and five at Woodland Point and while this is not significantly different it must be noted that the six species at Dob's Linn are from just two samples whereas *Cyathochitina* is represented in six samples at Woodland Point, one species in each of five samples and three in the sixth sample (Figure 47). Of the other genera there are four species of *Rhabdochitina* at Girvan and only one represented at Dob's Linn. These four genera are considered to be the most important as all the other ones have only one or two species over both the sections.

Looking at all the samples from Dob's Linn but concentrating on the four genera mentioned Table 17 below has been constructed.

	Girvan	Dob's Linn *D. complanatus* and *D. anceps* Zones	Dob's Linn All Zones	Dob's Linn Black shales only
Belonechitina	9	1	1	1
Conochitina	7	2	4	2
Cyathochitina	5 or 7 including *Tanuchitina*	6	11	9
Rhabdochitina	4	1	3	3

Table 17 showing the number of species in the genera *Belonechitina, Conochitina, Cyathochitina* and *Rhabdochitina* at Dob's Linn and Woodland Point.

It can be seen that even if the genus *Tanuchitina* is included with *Cyathochitina* there are many more species of *Cyathochitina* at Dob's Linn. Even if only the black shale samples are considered then *Cyathochitina* is still a very important genus. Dorning (1987) illustrates *Cyathochitina* as being an offshore genus, and this appears to be reinforced by the evidence presented here. It would also appear that *Belonechitina* could be a nearshore genus, possibly washed in with turbidity currents at Girvan. *Conochitina* is also apparently a shallow water species and thus is better represented at Woodland Point than at Dob's Linn.



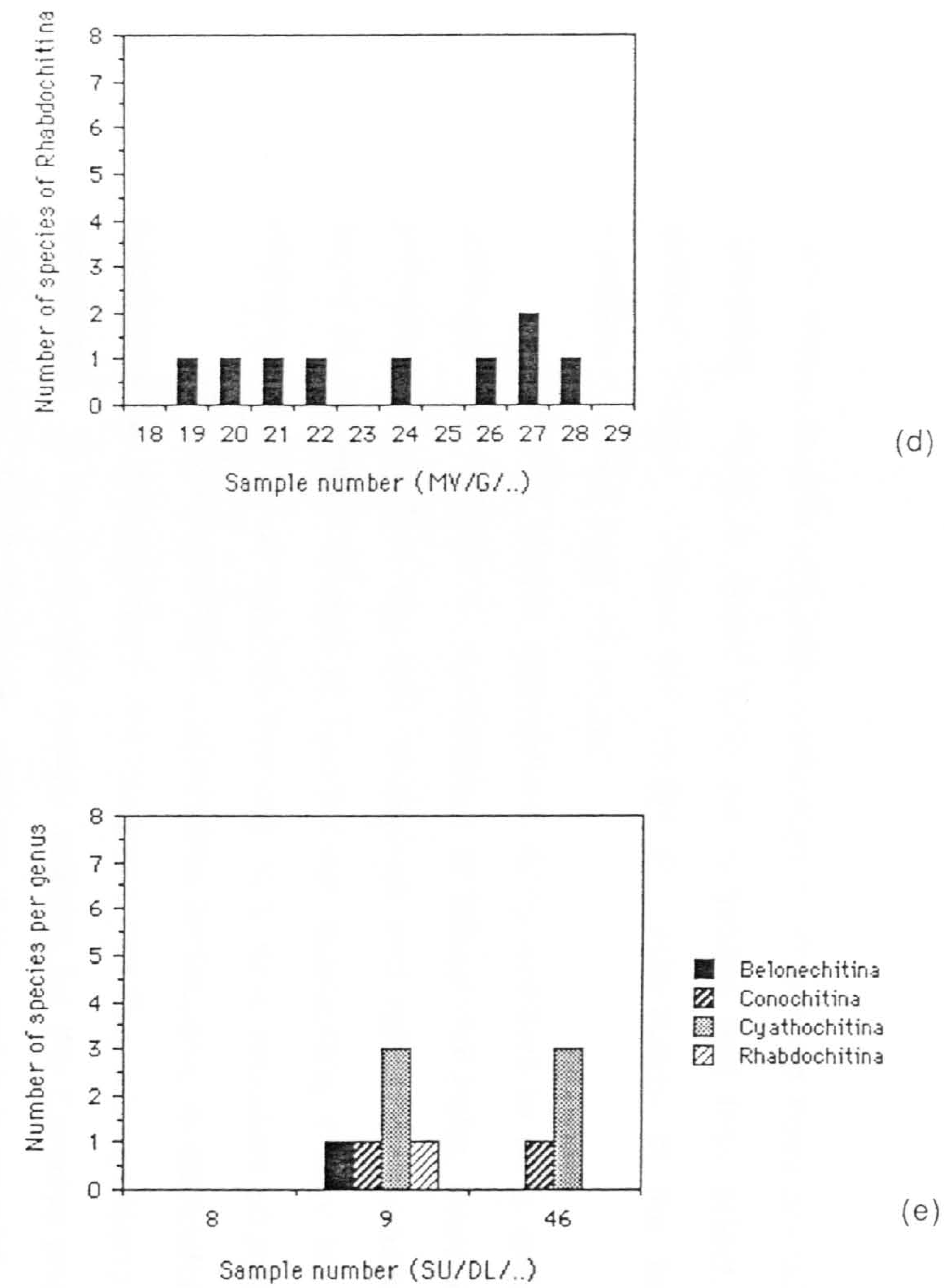


Figure 47 : number of species of four of the genera per sample at Woodland Point and Dob's Linn (*D. complanatus* -*D. anceps* Zones).

This shows that the offshore sediments at Woodland Point are within range of distal turbidites, whilst at Dob's Linn the turbidites had less effect, especially in the Birkhill Shales. Figure 47 shows the distribution of the four genera in the samples in which they are found.

Dorning (1987) also shows *Ancyrochitina* to be a nearshore genus, and although this species is represented at Woodland Point, there is only one poorly preserved specimen but well preserved and relatively abundant specimens are found in the black shales at Dob's Linn, suggesting it may be a more important offshore genus (or at least *A. ancyrea* is a more important offshore species).

At Woodland Point *Calpichitina lenticularis, Acanthochitina barbata,* and *Belonechitina seriespinosa* are common, but they are not found at Dob's Linn. *C. lenticularis* is an important marker species for the Caradoc and Ashgill (F. Paris pers. comm.), as *A. barbata* appears to be, and it is possible that all three are shallow water species.

If the generic make-up of the acritarch assemblage is considered it is obvious that *Leiosphaeridia* is the most important genus, however its distribution in the samples at Girvan does not really show very much (Figure 48), although it can be seen that with a few exceptions the distribution of *Leiosphaeridia* sp. A and *Leiosphaeridia* cf. *voigtii* mirror each other and that *Leiosphaeridia* cf. *tenuissima* does not follow the same pattern. This may suggest that the former two are related, possibly, to offshore sediments (as they are the thicker walled species) and the *Leiosphaeridia* cf. *tenuissima* being thinner walled is an inshore form. This would support a change of offshore to onshore environment from the Mill to the Shalloch Formation and thence gradually more offshore conditions.

Among the acanthomorph acritarch taxa (Fig. 49), it can be seen that *Baltisphaeridium* is important at Girvan, but not present at Dob's Linn, and indeed many genera show this pattern. *Goniosphaeridium* and *Multiplicisphaeridium* are both present at Dob's Linn, but are more common at Woodland Point, and there does not appear to be an obvious pattern.

Netromorph acritarchs are more common (Figure 49) at Girvan than at Dob's Linn, which in view of the accepted depositional environment of Dob's Linn as offshore, and the view of Dorning (1987) that netromorph acritarchs are an offshore form, may suggest that the sediments at Girvan were deposited in more offshore conditions, although with a greater influx of turbiditic material, and this

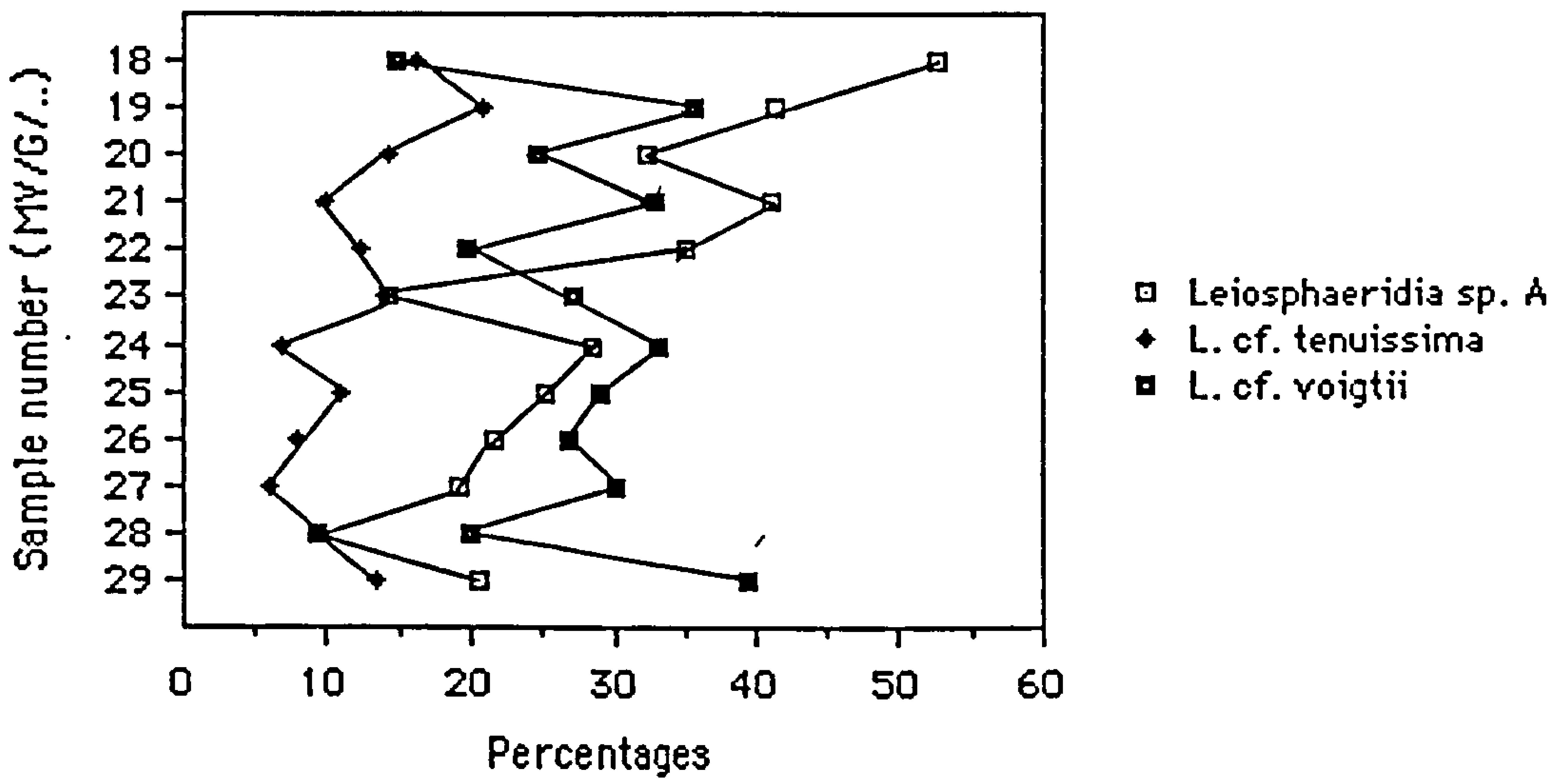


Figure 48 : distribution of three species of Leiosphaeridia at Woodland Point

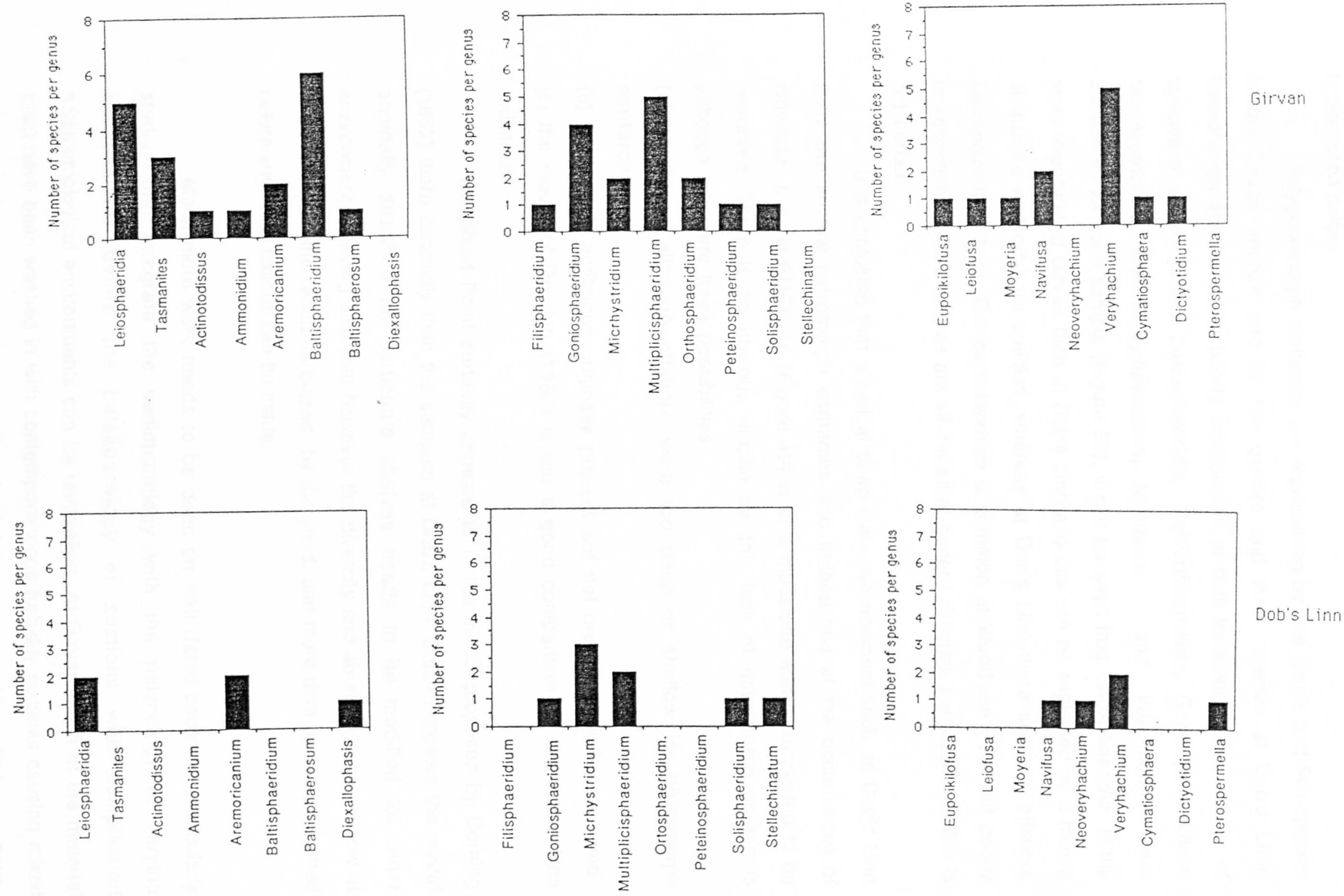


Figure 49 : generic composition of acritarchs at Woodland Point and Dob's Linn.

is discussed below.

Polygonomorph acritarchs are represented by one genus and five species in the Girvan section and by two genera and three species at Dob's Linn. Herkomorph acritarchs are poorly represented at both localities. If the number of species of seven genera *Leiosphaeridia, Baltisphaeridium, Goniosphaeridium, Micrhystridium, Multiplicisphaeridium, Navifusa* and *Veryhachium* are considered for each sample (Figure 50), it can be seen that *Leiosphaeridia* is the more important at Girvan than at Dob's Linn and this can be explained by a mixing of inshore and offshore species, whereas at Dob's Linn there are only offshore *Leiosphaeridia* taxa. *Goniosphaeridium* is common at Woodland Point but poorly represented at Dob's Linn as are all the other genera although the reason for this is not certain.

It is confusing that a typical deep water environment such as Dob's Linn there are so few netromorph acritarchs and indeed one of the occurrences of *Navifusa i. e.* in SU/DL/46 (Figure 49) is in a mudstone and is suspected to be reworked. There is no obvious reason for this lack of netromorph acritarchs although there are three possibilities

(a) conditions although offshore were too deep or shallow for netromorph acritarchs

(b) netromorph acritarchs originally present but not preserved and/or retrieved

(c) the model of Dorning (1987) is not a good comparison for the Dob's Linn sediments.

Woodland Point certainly appears to fit the model proposed by Dorning (1987) more concisely than the samples at Dob's Linn, which suggests the model originally descibed for carbonate shelves needs to be modified for other environments. Having said that however the diversity and abundance are so low at Dob's Linn that the record is biased by the yield, and more data must be obtained before any modifications can be made.

Much more work needs to be done on well dated sections, particularly studies that integrate the sedimentology with the palynology of varying environments before the palaeoecology of sections with complicated sedimentological environments can be unravelled. At Girvan much of the material must have been washed in with contemporaneous turbidity currents causing mixed palynomorph assemblages and clouding the palaeoecological picture. This may have

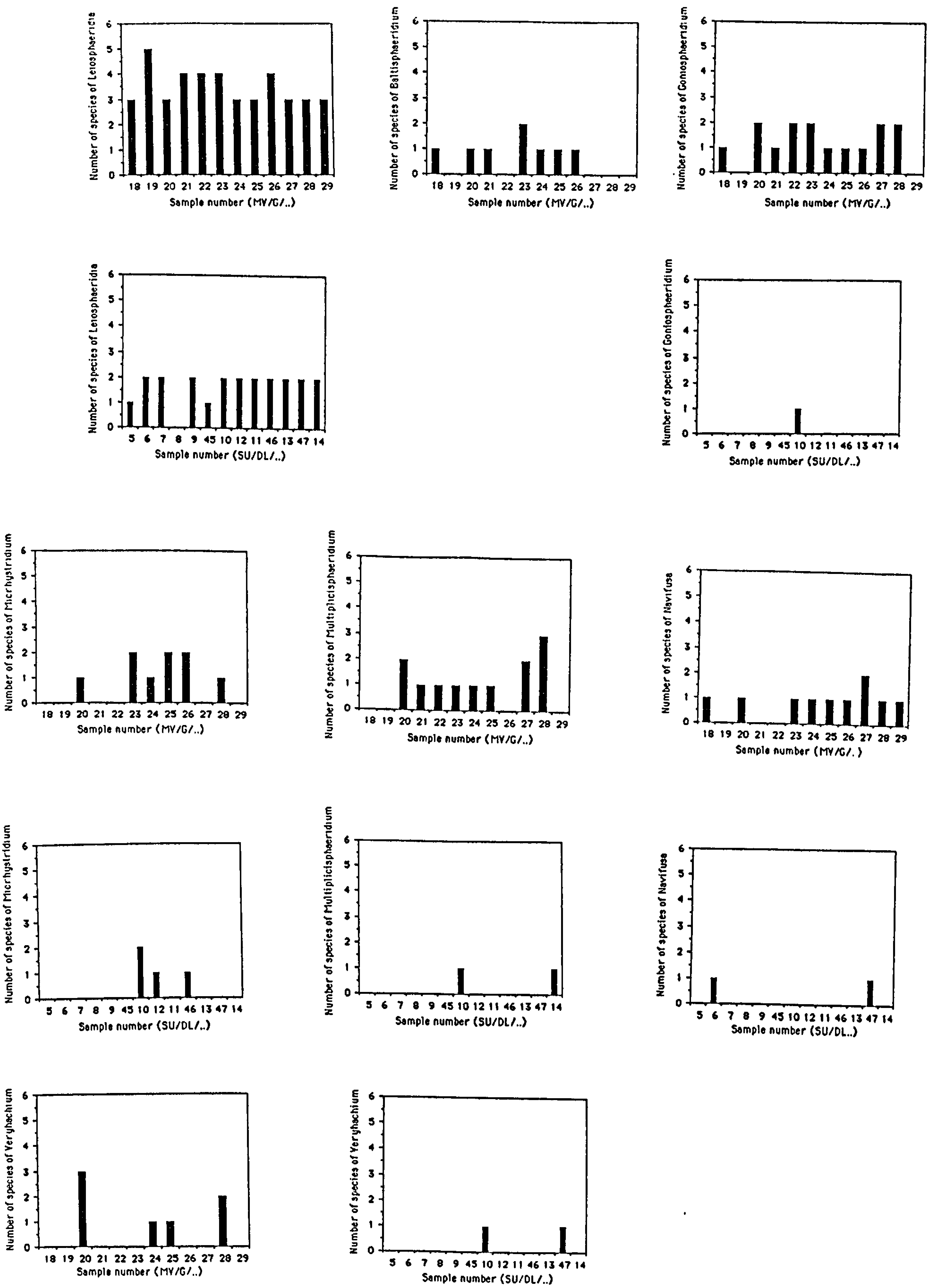


Figure 50 : number of species per sample of important acritarch genera at Woodland Point and Dob's Linn.

also happened at Dob's Linn but probably not to the same extent.

COMPARISON WITH PREVIOUS STUDIES

Turner (1979 m.s.) discusses the acritarch assemblages from sediments at Girvan, noting the poor preservation and stratigraphical distribution, as a number of species are present in only one sample, which he relates to ecological controls. He plots the relative abundance of sphaeromorph acritarchs, the genus *Navifusa* ,and the acanthomorph acritarchs, throughout his samples and on the Girvan foreshore he shows a decrease in the percentage of *Navifusa* to none in the Upper Whitehouse Group and the Shalloch Formation, withsphaeromorph acritarchs generally increasing from about thirty to eighty percent and acanthomorph acritarchs increasing initially to about twenty eight percent and then decreasing to about twenty percent of the acritarch assemblage.

Turner (1979 m.s.) remarks that *Navifusa* is absent in the Shalloch Formation, which is plainly not the case, and that acanthomorphs become more important, both facts he relates to facies control of the contemporary acritarch population, and he states that the sphaeromorph/acanthomorph acritarch ratio can be taken as a fairly sensitive palaeoenvironmental indicator which in this case suggests upwards deepening of the sequence. He also supports Hubert's (1966) contention that the Ardwell Beds are shallow water deposits due to the large proportion of sphaeromorph and rare acanthomorph acritarchs, coupled with a large *Navifusa* percentage (Turner 1979 m.s. p.294). This appears on the contrary to suggest deeper water with the sphaeromorph acritarchs either being deeper water forms or washed in with turbidity currents. Turner (1979 m.s.) concludes that the Upper Whitehouse Group and the Shalloch Formation were deposited offshore in presumably deeper water ~~but still in a shallow shelf environment~~, which seems to be born out by this present study.

The important thing to note however is although many of Turner's (1979 m.s.) conclusions may be right they are grossly oversimplified by the large sample spacing. He collected only one sample from the Upper Whitehouse Group and one from the Shalloch Formation and thus has failed to detail many of the changes that occurred throughout the section. It seems important that samples are not collected at random and with a large space if the palaeoecology is to be reasonably correct.

Grahn (1982b) discusses the host sediment for various chitinozoans classifying the fauna into chitinozoans with a preference for high water energy, chitinozoans with a preference for low water energy and chitinozoans 'independent' of the sediment type. Several of the species that Grahn (1982b) mentioned are present in this study, and some appear to have lived in similar environments to those postulated by Grahn (1982b) whilst others differ to his conclusions. However it seems to be pointless to discuss it further due to the complex sedimentary regime under which the sediments, particularly those at Woodland Point were deposited.

Paris (1981) discusses in detail many factors relating to the chitinozoan group as a whole, and considering the long stratigraphical range of that study, it suggests ample material for a major work on chitinozoans. Particularly interesting is the section on provincialism in which Paris (1981) suggests that it is not particularly important. This appears to be substantiated by this study, which shows, in the following part that the chitinozoan assemblages (and acritarchs) from Dob's Linn and Woodland Point are often equally similar to assemblages from North America, the Baltic and Africa. Paris (1981), however, reports an absence of *Hercochitina* which is common in the Canadian material of Achab, and the American material of Jenkins (1969), but is absent from Grahn (1982a) and from this present study, apart from one specimen in the *D. anceps* Zone at Main Cliff, Dob's Linn. This may be related to provincialism. Jenkins (1969) records that *B. seriespinosa* shows alignment of spines but this has not been seen at Woodland Point, which may be related to preservation, or ecophenotypic variations.

Several workers have applied zonal schemes (e.g. Paris 1981) which will not be applied here, due to relatively poor preservation and poor similarity with the zonation schemes already published. Also it is felt that a combined world-wide (if possible) zonal scheme would be better than a plethora of local schemes. The construction of such a scheme is inappropriate to this work for the above reasons.

In order to compare the assemblages found here, several typical Upper Ordovician papers are considered and compared using a Similarity Index defined by Sokal and Sneath (1963)

$$S = \frac{p+n}{p+n+m}$$

where   p is the number of positive matches

n is the number of negative matches

and   m is the number of mismatches.

However n would equal the total number of chitinozoan or acritarch species known from the Upper Ordovician and this is impractical to include. Thus the equation becomes

$$S = \frac{p}{p+m}$$

which is Jacquard's Coefficient and gives a measure of similarity between the published literature and the present study. For ease of handling the Dob's Linn material has been split into two groups

(a) *D. complanatus, D. anceps* and *C? extraordinarius.*

(b) *G. persculptus* and *P. acuminatus.*

The average Jacquard Coefficient of all the samples compared here is 0.08, and a higher value is taken as a good match and thus a similar assemblage. The results can be seen in Tables 18, 19, 20 and 21 which are shown below. Rows marked with an asterisk are those with a Jacquard Coefficient of 0.08 or greater.

The acritarchs are compared with twenty three previous reports of Upper Ordovician or Lower Silurian acritarch assemblages. At Girvan (Table 18) eight show a Jacquard Coefficient of 0.08 or greater, these are the *D. complanatus* to *C? extraordinarius* Zones at Dob's Linn; the Middle Ordovician of Sweden (Kjellström 1971a, 1976); the Ashgill of Anticosti Island (Jacobson and Achab 1985); the Upper Ordovician of Kansas (Wright and Meyers 1981); the Caradoc of the Type Area (Turner 1984); the Caradoc/Ashgill of Libya (Molyneux and Paris 1985) and the Middle and Upper Ordovician at Girvan (Turner 1979 m.s.). The latter three show Jacquard Coefficients of 0.17, 0.16, and 0.14 respectively which shows that they are very similar with those published works. At Dob's Linn (a) only two studies show Jacquard Coefficients of 0.08 or greater (Table 19a), these are Molyneux and Paris (1985) and the present samples from Woodland Point, whilst at Dob's Linn (b) (Table 19b) only one study has a Jacquard Coefficient of 0.08 or greater and that is Turner (1979 m.s.).

The chitinozoans are compared with thirty six previously recorded chitinozoan assemblages and show a greater degree of similarity than the

Table 18 Girvan acritarchs (47 species)

Compared assemblage	no. of spp.	p	m	s
Dob's Linn (a)	24	5	61	0.08*
Dob's Linn (b)	13	3	54	0.05
Kjellström 1971a	52	8	83	0.09*
Kjellström 1971b	22	2	65	0.03
Turner 1984	59	16	74	0.17*
Kjellström 1976	29	6	64	0.09*
Jardiné *et al.* 1984	23	4	62	0.06
Jacobson 1978	18	3	59	0.05
Jacobson and Achab 1985	42	7	75	0.08*
Gorka 1980	25	4	64	0.06
Elaouad-Debbaj 1978	69	7	102	0.06
Colbath 1979	53	1	98	0.01
Duffield and Legault 1981	16	1	61	0.02
Thusu 1973	33	2	76	0.03
Hill and Dorning 1984	43	1	88	0.01
Loeblich and Tappan 1978	48	2	91	0.02
Loeblich 1970	47	2	90	0.02
Staplin *et al.* 1965	16	4	55	0.07
Wright and Meyers 1981	27	6	62	0.09*
Molyneux and Paris 1985	18	9	47	0.16*
Martin 1983	45	4	85	0.04
Martin 1980	10	0	57	0.00
Miller and Eames 1982	27	5	64	0.07
Turner 1979 m.s.	25	9	54	0.14*

Table 19a Dob's Linn (a)acritarchs (24 species)

Compared assemblage	no. of spp.	p	m	s
Girvan	47	5	61	0.08*
Kjellström 1971a	52	2	72	0.03
Kjellström 1971b	22	0	46	0.00
Turner 1984	59	4	75	0.05
Kjellström 1976	29	0	53	0.00
Jardiné *et al.* 1984	23	2	43	0.04
Jacobson 1978	18	1	40	0.02
Jacobson and Achab 1985	42	1	64	0.01
Gorka 1980	25	0	49	0.00
Elaouad-Debbaj 1978	69	3	83	0.03
Colbath 1979	53	0	77	0.00
Duffield and Legault 1981	16	1	38	0.02
Thusu 1973	33	1	57	0.02

Hill and Dorning 1984	43	1	65	0.01
Loeblich and Tappan 1978	48	0	72	0.00
Loeblich 1970	47	1	69	0.01
Staplin *et al.* 1965	16	0	40	0.00
Wright and Meyers 1981	27	0	51	0.00
Molyneux and Paris 1985	18	3	36	0.08*
Martin 1983	45	1	67	0.01
Martin 1980	10	0	34	0.00
Miller and Eames 1982	27	1	49	0.02
Turner 1979 m.s.	25	3	43	0.06

Table19b Dob's Linn (b) acritarchs (13 species)

Compared assemblage	no. of spp.	p	m	s
Girvan	47	3	54	0.05
Kjellström 1971a	52	0	65	0.00
Kjellström 1971b	22	0	35	0.00
Turner 1984	59	3	66	0.04
Kjellström 1976	29	0	42	0.00
Jardiné *et al.* 1984	23	0	36	0.00
Jacobson 1978	18	0	31	0.00
Jacobson and Achab 1985	42	1	53	0.02
Gorka 1980	25	0	38	0.00
Elaouad-Debbaj 1978	69	3	82	0.03
Colbath 1979	53	0	66	0.00
Duffield and Legault 1981	16	0	29	0.00
Thusu 1973	33	1	44	0.02
Hill and Dorning 1984	43	1	54	0.02
Loeblich and Tappan 1978	48	1	60	0.02
Loeblich 1970	47	0	60	0.00
Staplin *et al.* 1965	16	1	27	0.04
Wright and Meyers 1981	27	1	38	0.03
Molyneux and Paris 1985	18	0	31	0.00
Martin 1983	45	0	58	0.00
Martin 1980	10	0	23	0.00
Miller and Eames 1982	27	1	38	0.02
Turner 1979 m.s.	25	3	32	0.09*

Table 20 Girvan chitinozoans (35 species)

Compared assemblage	no. of spp.	p	m	s
Dob's Linn (a)	17	3	46	0.06
Dob's Linn (b)	14	2	45	0.04
Achab 1977a	11	6	34	0.15*
Achab 1977b	16	4	43	0.08*
Achab 1978a	12	4	39	0.09*
Achab 1978b	20	4	47	0.08*
Achab 1986b	23	4	50	0.07
Achab 1984	9	3	38	0.07
Achab 1986a	20	4	47	0.08*
Atkinson and Moy 1971	18	6	41	0.13*
Bouché 1965	27	3	56	0.05
Elaouad-Debbaj 1984	31	5	56	0.08*
Elaouad-Debbaj 1986	31	8	50	0.14*
Grahn 1982a	43	13	52	0.20*
Grahn 1981a	35	10	50	0.17*
Grahn 1981b	24	7	45	0.13*
Grahn 1984b	27	8	46	0.15*
Grahn 1984a	9	4	36	0.10*
Jansonius 1964	6	1	39	0.02
Jenkins 1967	34	5	59	0.08*
Jenkins 1969	22	8	41	0.16*
Jenkins 1970	11	2	42	0.04
Laufeld 1967	27	5	52	0.09*
Laufeld 1971	9	5	34	0.13*
Paris 1979	36	5	61	0.08*
Taugourdeau 1961	45	4	72	0.05
Neville 1974	18	1	51	0.02
Nolvak 1980	14	5	39	0.13*
Martin 1975	16	4	43	0.08*
Paris 1981	21	4	48	0.08*
Molyneux and Paris 1985	14	4	41	0.09*
Martin 1983	35	8	54	0.13*
Martin 1980	6	1	39	0.02
Wright and Meyers 1981	4	2	35	0.05
Miller and Eames 1982	2	1	47	0.11*
Grahn 1985	13	1	46	0.02
Tau. and Jekhowsky 1960	78	2	109	0.02

Table 21a Dob's Linn (a) chitinozoans (17 species)

Compared assemblage	no. of spp.	p	m	s
Girvan	35	3	46	0.06
Achab 1977a	11	1	26	0.04
Achab 1977b	16	1	31	0.03
Achab 1978a	12	1	27	0.04
Achab 1978b	20	2	33	0.06
Achab 1986b	23	4	32	0.08*
Achab 1984	9	0	26	0.00
Achab 1986a	20	0	37	0.00
Atkinson and Moy 1971	18	5	25	0.17*
Bouché 1965	27	2	40	0.05
Elaouad-Debbaj 1984	31	3	42	0.07
Elaouad-Debbaj 1986	31	3	42	0.07
Grahn 1982a	43	7	46	0.13*
Grahn 1981a	35	6	40	0.13*
Grahn 1981b	24	5	31	0.14*
Grahn 1984b	27	5	34	0.13*
Grahn 1984a	9	3	20	0.13*
Jansonius 1964	6	1	21	0.04
Jenkins 1967	34	4	43	0.08*
Jenkins 1969	22	4	31	0.11*
Jenkins 1970	11	0	28	0.00
Laufeld 1967	27	4	36	0.10*
Laufeld 1971	9	4	18	0.18*
Laufeld 1971 (Sil.)	7	0	24	0.00
Paris 1979	36	5	43	0.10*
Taugourdeau 1961	45	7	48	0.13*
Neville 1974	18	1	33	0.03
Nolvak 1980	14	5	21	0.19*
Martin 1975	16	3	27	0.10*
Paris 1981	21	3	32	0.09*
Molyneux and Paris 1985	14	2	27	0.07
Martin 1983	35	2	48	0.04
Martin 1980	6	1	21	0.04
Wright and Meyers 1981	4	0	21	0.00
Miller and Eames 1982	2	1	17	0.05
Grahn 1985	13	1	28	0.03
Tau. and Jekhowsky 1960	78	2	91	0.02

Table 21b Dob's Linn (b) chitinozoans (14 species)

Compared assemblage	no. of spp.	p	m	s
Girvan	35	2	45	0.04
Achab 1977a	11	1	23	0.04

Achab 1977b	16	2	26	0.07
Achab 1978a	12	2	22	0.08*
Achab 1978b	20	1	32	0.03
Achab 1986b	23	2	33	0.06
Achab 1984	9	0	23	0.00
Achab 1986a	20	0	34	0.00
Atkinson and Moy 1971	18	2	28	0.07
Bouché 1965	27	0	41	0.00
Elaouad-Debbaj 1984	31	4	37	0.10*
Elaouad-Debbaj 1986	31	4	37	0.10*
Grahn 1982a	43	5	47	0.10*
Grahn 1981a	35	4	41	0.09*
Grahn 1981b	24	3	32	0.09*
Grahn 1984b	27	3	35	0.08*
Grahn 1984a	9	1	21	0.04
Jansonius 1964	6	1	18	0.05
Jenkins 1967	34	2	46	0.02
Jenkins 1969	22	2	32	0.06
Jenkins 1970	11	1	23	0.04
Laufeld 1967	27	2	37	0.05
Laufeld 1971	9	1	21	0.04
Laufeld 1971 (Sil.)	7	1	19	0.05
Paris 1979	36	2	46	0.04
Taugourdeau 1961	45	5	49	0.09*
Neville 1974	18	0	32	0.00
Nolvak 1980	14	1	26	0.04
Martin 1975	16	1	28	0.03
Paris 1981	21	1	33	0.03
Molyneux and Paris 1985	14	2	24	0.08*
Martin 1983	35	1	47	0.02
Martin 1980	6	1	18	0.05
Wright and Meyers 1981	4	0	18	0.00
Miller and Eames 1982	2	1	14	0.07
Grahn 1985	13	2	23	0.08*
Tau. and Jekhowsky 1960	78	1	90	0.01

acritarchs with twenty five studies at Girvan (Table 20) showing a Jacquard Coefficient of 0.08 or greater. The best matches are from the Caradoc of North Wales (Atkinson and Moy 1971); the Ashgill of Anticosti Island (Achab 1977a), the Ashgill of Morocco (Elaouad-Debbaj 1986), the Middle and Upper Ordovician of Sweden (Grahn 1982a, 1981a, 1981b, 1984a, 1984b), the Caradoc and Ashgill of Oklahoma (Jenkins 1969), the Ashgill of Russia (Laufeld 1971), the Ashgill of Poland (Nolvak 1980), the Upper Ordovician of Québec (Martin 1983) and the Lower Silurian of New York State (Miller and Eames 1982). The chitinozoans at Dob's Linn (a) show Jacquard Coefficient of 0.08 or greater with sixteen assemblages (Table 21a), the greatest Jacquard Coefficients being found with the Caradoc of North Wales (Atkinson and Moy 1971); the Middle and Upper Ordovician of Sweden (Grahn 1982a, 1981a, 1981b, 1984a, 1984b); the Caradoc and Ashgill of Oklahoma (Jenkins 1969), the Caradoc of Sweden (Laufeld 1967); the Ashgill (*P. linearis* Zone) of Podolia (Laufeld 1971), the Caradoc of Portugal (Paris 1979), the Upper Ordovician of Sahara (Taugourdeau 1961), the Ashgill of Poland (Nolvak 1980) and the Upper Ordovician of Québec (Martin 1975). The chitinozoans from the *G. persculptus* and *P. acuminatus* Zones (Table 21b) matched well with ten assemblages, and particularly well with the Ashgill Saharan material of Elaouad-Debbaj (1984,86) and the Upper Ordovician of Sweden (Grahn 1982a).

There are three possible reasons for a high Jacquard Coefficient between the assemblages

(a) the samples compared are close in age

(b) the samples compared are not very close in age but are from a similar facies

(c) it cannot be ruled out that the similarity is a false one imposed by the subjectivity of identifying species, and is related to the comparative material available.

However for the present this last possibility will be ignored and it is assumed that the similarity of age is the most likely reason for a high Jacquard Coefficient. The reasons for the higher Jacquard Coefficient in chitinozoans than in the acritarchs is not certain, but it does suggest that chitinozoans are more useful for world-wide biostratigraphical correlations than acritarchs. In the table below the Jacquard Coefficient is compared for samples that have both acritarchs and chitinozoans are compared (Table 22), and show that in all cases except for Martin (1980,1983) the Jacquard Coefficient is higher for the acritarchs than it is is for the chitinozoans. This is presumably because there are usually more species of acritarchs recorded than chitinozoans but the reason for the anomalous similarities with Martin (1980, 83) is uncertain.

	1	2	3	4	5	6	7
Chitinozoans	0.06	0.04	0.09	0.05	0.03	0.13	0.02
Acritarchs	0.08	0.05	0.16	0.09	0.07	0.04	0.00

Table 22 : Compares the Jacquard Coefficient (for Woodland Point) for studies which are concerned both with acritarchs and chitinozoans. 1 = Dob's Linn (a); 2 = Dob's Linn (b); 3 = Molyneux and Paris (1985); 4 = Wright and Meyers (1981); 5 = Miller and Eames (1982); 6 = Martin (1983); 7 = Martin (1980).

The chitinozoans from the *D. complanatus, D. anceps* and *C ? extraordinarius* Zones from Girvan and Dob's Linn are most similar to the assemblage descibed by Grahn (1982a), which is Caradoc to Ashgill in age, while the chitinozoans from the Silurian are closely similar to Grahn (1982a) and Elaouad-Debbaj (1984,86) from the Ashgill. It has a similarity of 0.08 to Grahn (1985) which is from the Silurian of America, and thus while similar to the Silurian is more similar to the Upper Ordovician assemblages.

Of all the published literature of Anticosti Island the chitinozoan samples from Girvan are most closely related to those of Achab (1977a) which is from the American *D. complanatus* Zone, which although not identical in range to the British Zone is very similar to it.

The acritarchs and chitinozoans from Woodland point are most closely related to those from the *D. complanatus* to *C? extraordinarius* Zones from Dob's Linn, which is logical as they are most closely related in time. The acritarchs from the Silurian at Dob's Linn show as much similarity with the Ordovician as the Silurian but this may be an error in not comparing the assemblages with more Silurian material.

PALYNOLOGY AT THE ORDOVICIAN-SILURIAN BOUNDARY

The distribution of palynomorphs across the Ordovician-Silurian boundary at Dob's Linn is shown in Figures 32 and 33 and is discussed in Whelan (1988), and Whelan and Burton (1988). Here the distribution at other localities will be discussed in comparison with Main Cliff, Dob's Linn.

Grahn (1978) discusses the boundary at Skåne in Sweden where there are only four species of chitinozoans in four genera, two of which are almost totally mutually exclusive, which Grahn (1978) attributes to *Conochitina* being benthic and *Ancyrochitina* planktic. Chitinozoans occur in greater numbers in the black shales than in the grey mudstones, which is the same as Dob's Linn (although absolute numbers of chitinozoans are not available for this present study). In samples of black shales at Skåne *Ancyrochitina ancyrea* appears to generally be more common, which is similar to Dob's Linn although *Conochitina robusta* is not present at the latter. Grahn (1978) suggests that *C. robusta* is a benthic species that is more abundant during times of transgression.

Duffield and Legault (1981) and Achab and Duffield (1982) discuss the Ordovician-Silurian boundary on Anticosti Island. Very few of the species found by either of them are present at Dob's Linn possibly due to the more Silurian affinities of even the Upper Ordovician taxa on Anticosti Island, as well as to the different lithologies present. Samples from the boundary area are practically barren due to the presence of bioherms, which is a limiting factor not seen at Dob's Linn, although the other lithologies on Anticosti Island appear to contain more diverse assemblages than Dob's Linn.

Achab and Duffield (1982) comment on the presence of *Conochitina taurgourdeaui* just below the bioherms, a species which is used to define the boundary in east Baltic and Estonia. This is not present at Dob's Linn, and due to the small number of common species it appears that it will be difficult to correlate the two very important sections.

Grahn and Bergström (1985) discuss the Ordovician-Silurian boundary in Ohio and Kentucky where there is a hiatus related to Gondwanan glaciation from the *D. complanatus* to the early Llandoverian *C. cyphus* Zone and thus is not comparable to this present study.

It can be concluded that although chitinozoans are neither as well preserved nor apparently as diverse as on Anticosti Island, they much better represent the Ordovician-Silurian boundary sequence than was first anticipated. Whilst on Anticosti Island the acritarchs are a mixture of Ordovician and Silurian below the boundary and Silurian only above, the reverse is true at Dob's Linn with an Ordovician flora only below the boundary and an Ordovician and Silurian one mixed above.

THERMAL HISTORY OF THE SEDIMENTS

Relatively little work has been on the thermal alteration of acritarchs and the other palynomorph groups which makes estimation of palaeotemperatures difficult. However the work done will be reviewed and its implications discussed.

Temperatures of the sediments can be estimated from the palynomorph colours, because as they are composed of organic material they alter on heating, becoming progressively darker. Booth (1979 m.s.) states that "the colour changes that affect organic microfossils are progressive with increasing temperature, and are due to the chemical alteration of the wall material, leading to a higher amount of fixed carbon". Booth (1979 m.s.) illustrates a table for comparing colour, fragmentation and corrosion (Table 23) to be used only with acritarchs. This table differs slightly to the results found here as he remarks that when acritarchs are dark brown in colour then the central body is incomplete, and this is clearly not the case at Dob's Linn. Booth (1979 m.s.) also notes that wall thickness plays an important part in the colour of the acritarch and possibly also composition, and he concludes that thin-walled forms remain translucent up to about 120°C, whereas thick-walled acritarchs are opaque by that temperature and that all organic matter is reduced to amorphous carbon or graphite above 180°C.

Gutjahr (1966) measured the carbonisation of spores and pollen, while Correia (1967) favoured amorphous kerogen, followed by sporopollenin, acritarchs, chitinozoans, wood and tissue fragments for measuring the colour changes. He remarks that colour changes depend on depth of burial, temperature, lithology and geological age. Both these authors however used chemicals that may have changed the colour of the fossils.

Staplin (1969, 1977) reviewed the thermal history of organic material and proposed a thermal alteration index (TAI) shown below in Table 24

TAI	Organic matter	Temperature
1	fresh yellow	<32°C
2	brownish yellow	32-100°C
3	brown	100-170°C
4	black	170-200°C
5	black with additional evidence of rock metamorphism	>200°C

Table 24 : thermal alteration index, comparative colour changes and

A	
Grade	Degree of carbonisation as indicated by colour
1	clear yellow
2	light brown
3	mid (reddish) brown
4	dark brown
5	grey or black
6	black only

B	
Grade	Degree of fragmentation
A	none
B	superficial
C	central body with splits, but more or less complete, some processes damaged
D	central body incomplete, but at least one process intact
E	central body incomplete, no processes intact
F	detached fragments only

C	
Grade	Degree of corrosion
a	unaffected
b	superficial, small corrosion patches, but no perforations
c	general corrosion, with or without perforation
d	severe general corrosion, and/or extensive perforation

Table 23 : comparison of corrosion, fragmentation and colour changes (from Booth 1979m.s.)

Note: these columns are not intended to be aligned.

proposed temperatures (Staplin 1969, 1977).

Correia (1967) and Staplin (1969) suggested that spores provide more reliable data than acritarchs for measuring carbonisation, whilst Dorning (1986) states that marine organic fossils are more reliable than spores and pollen for measuring the palaeotemperatures of the rocks.

Legall, Barnes and Macqueen (1981) compared acritarch colours with the Conodont Alteration Index (CAI), noting that different parts of the acritarch may vary differently in colour, and that sphaeromorph acritarchs are good geothermal indicators from 60-150°C, above which they suggest that acritarchs do not survive. Their work was done on *Leiosphaeridia* due to its relatively large size, lack of structural complexity and its ubiquitous presence in Lower Palaeozoic rocks. Legall *et al.* (1981) proposed the following Acritarch Alteration Index (AAI) as shown in Table 25

AAI	Palynomorph colour	Temperature
1	colourless to light yellow	<60°C
2	light yellow to pale yellow	
3	pale yellow to orange	
4	orange to dark brown	
5	brown to black and indistinguishable	90-185°C

Table 25 : acritarch alteration index, colour changes and proposed temperatures as shown by Legall *et al.* (1981).

Nowlan and Barnes (1987) compare the CAI and the AAI (Table 26) and use the data to determine the geothermal history of many samples in Canada. Dorning (1986) suggests that colour changes occur at higher temperatures in acanthomorph acritarchs than in sphaeromorph acritarchs, and that palynomorphs can give carbonisation data over the range 50-400°C, which is considerably higher than the data shown by other authors. Molyneux (1987) discusses palaeotemperatures for Scottish acritarchs, subjected to temperatures towards the high end of the range of 90-200°C, and a AAI of 5.

CONODONTS			PALYNOMORPHS			VITRINITE	
CAI	Temperature range °C	Approximate overburden (m)	AAI	Translucency index AMOCO	Weight per cent carbon in kerogen	Reflectance	Per cent fixed carbon.
1	<50 - 80	< 1200	1	1 - 5	<82	<0.8	<60
1½	50 - 90	1200 - 2400	2-3	5 - upper 5	81-84	0.70 - 0.85	60-65
2	60 - 140	2400 - 3600	4-5	5 - 6	81-87	0.85 - 1.30	65-73
3	110 - 200	3600 - 5500	Black to disintegrated	upper 5 - 6	83-89	1.40 - 1.95	73-84
4	190 - 300	5500 - 8000		6	84-90	1.95 - 3.60	84-95
5	300 - 400	8000+		upper 6 - 7	90+	3.60+	95+
6-8*	6: 350-435°C	6½: 425-500°C		7: 480-610°C		8: 600°C+	

Table 26 : comparison of conodont alteration index (CAI) and acritarch alteration index (AAI) (taken from Nowlan and Barnes 1987).

Plates 24-26 show the variation in colour of acritarchs, chitinozoans and scolecodonts from the Highland Border Complex, Dob's Linn, Barrhill and Woodland Point, Girvan. Spores were found at Woodland Point but not at the other localities. Most of the temperatures that the rocks have been taken to is a direct consequence of regional heating, and not related to dykes or granites, although rocks from the Highland Border Complex may have been subjected to thermal effects from igneous rocks that are not now preserved, and thus it is difficult to be certain. There is also the added complication that folding and severe faulting may have caused greater temperatures at the latter locality.

Most palaeotemperature studies are comparative works, but it is not possible to compare the same species from all the sections, except in a few rare cases. The species *Solisphaeridium* cf. *nanum* and *Veryhachium lairdii* are found at both Girvan and Dob's Linn (Pl. 25), and it is obvious that the specimens at Dob's Linn are much darker than those at Girvan.

As to actual temperatures, these are difficult to assess, but on average the acritarchs from Girvan are pale yellow to light brown (TAI 1-2, AAI 2-3)and thus probably the sediments have been taken to temperatures less than 100°C , at Barrhill pale brown to dark brown (TAI 3, AAI 4) with temperatures in the region of 100-170°C, Dob's Linn (TAI 3-4, AAI 5) suggesting temperatures of 90-200°C, and as Molyneux (1987) states for the Linkim Beds which are in a similar state, probably towards the end of that range. Finally the Highland Border Complex sediments have been heated probably to temperatures greater than 200°C (TAI 5, AAI 5).

The general trend then is for the sediments at Girvan to be the least heated, then Barrhill, Dob's Linn and finally the sediments of the Highland Border Complex have been subject to the greatest palaeotemperatures. This is all done on the acritarchs, the chitinozoans begin much darker, as they are thicker and of different composition, and do not show such obvious colour changes, but show the same general trend.

Whelan and Burton (1988) discuss the inferences of the temperatures to which the Ordovician-Silurian boundary sediments have been taken. Lespérance *et al.* (1987) claim that the sediments fall in the CAI 5-7 range which by comparison with Nowlan and Barnes (1987) suggests a temperature of about

300°C which would cause the acritarchs to disintegrate, which is clearly not the case. Graptolite reflectance work (Leith pers. comm.) suggests that the temperature may be as low as 200°C, and this as already stated is a more reasonable palaeotemperature for Dob's Linn sediments.

Wall thickness clearly is important and Plate 24 shows *G. splendens* and *Diexallophasis* sp. A which are both from the same sample but the latter is much darker due to its thicker wall. The spore illustrated in Pl. 25, fig. 8 is from Woodland Point and would suggest a TAI of 2-3 and AAI of 3-4 both of which are higher than the data obtained from the acritarchs. Care must therefore be taken when using palaeotemperatures.

Table 23 as already mentioned illustrates the different degrees of colour, fragmentation and colour for acritarchs from all the samples. Fragmentation and corrosion obviously increase with colour due to the loss of volatiles, but an interesting feature is that within the Highland Border Complex the degree of fragmentation, corrosion and recrystallisation increases from the southwest to the northeast, possibly related to the more intense deformation in the northeast.

Chapter 7 - Conclusions

Samples have been collected from all major transects of the Highland Border Complex, as well as from the adjacent terranes of the Southern Uplands to the south (Coldingham Bay, Barrhill and the Type section of the Ordovician-Silurian boundary at Dob's Linn) and from the Midland Valley (Girvan).

From seventy one samples of the Highland Border Complex, fifteen species in four genera of chitinozoans have been recognised as well as indeterminate chitinozoans from the same genera. Five species of acritarchs in four genera are also present, along with a sponge spicule, scolecodonts, indeterminate spiny objects and other unidentifiable and questionable microfossils. Preservation is not good and the fossils have probably been raised to temperatures in excess of 200°C and possibly greater than 300°C. Preservation of chitinozoans is better than acritarchs and this suggests that the former are better at withstanding deformation and metamorphism than acritarchs.

The palynomorphs allow the dating of several samples, of which the most likely and best constrained dates are detailed here. A black shale from Arran has yielded an assemblage of chitinozoans dating it as Lower Ordovician. At Glen Fruin and Balmaha, black shales have been dated as Caradoc on the basis of their chitinozoans, whilst at Bofrishlie Burn, a fourth black shale contains a chitinozoan and an acritarch that suggest a Middle Ordovician age.

At Leny Quarry the Leny Limestone has proved disappointing but a limestone from north of the Highland Boundary Fault, that is from within the outcrop of Dalradian rocks, has yielded a limited fauna of small shelly fossils that gives a minimum age for the Dalradian of Lower Cambrian. An Ordovician component to the Leny succession allows its inclusion in the Highland Border Complex and shows that the Highland Border basin may have existed from the Cambrian. At Clunie to the east a white limestone has yielded two chitinozoans of most likely Middle Ordovician age, whilst at North Esk several samples are dated though no particularly well preserved assemblages were found. At Stonehaven no biostratigraphical information is available.

It is can be seen that preservation of the assemblages is generally better in the west than in the east possibly related to a lesser degree of deformation in the west, and also that it is the black shales which divulge the most information. The black shales were probably deposited from the Lower Ordovician (if the Arran age is correct) throughout the whole of the Middle Ordovician and up into the Caradoc, though why there appear to no Middle Ordovician black shales at Balmaha is unknown. The Highland Border Complex limestones were deposited at four separate stages, the oldest being the Leny Limestone, then the Arenig limestones at Dounans and other places, followed by the possibly Middle Ordovician Clunie Limestone, and then the Caradoc Margie Limestone that may be a correlative of the Achray Sandstone Group. In all it is obvious that the samples of the Highland Border Complex span the whole of the Ordovician making it impossible that this Complex could have been formed as stated by Henderson and Robertson (1982) and it must have been formed in a marginal basin as shown by Curry *et al.* (1984).

Samples from the Southern Uplands have yielded variable results. Those from Coldingham Bay on the east coast are barren, whilst samples from Cross Water, Barrhill have yielded only very poorly preserved sphaeromorph and acanthomorph acritarchs, a few scolecodonts and some poorly preserved chitinozoans.

At Dob's Linn forty three samples have yielded thirty three species of acritarchs in eighteen genera, thirty one species of chitinozoans in thirteen genera as well as scolecodonts, graptolite and other macrofossil debris, organic tubes, conical fossils and other miscellaneous objects. The acritarch and chitinozoan assemblages do not show the same pattern as the graptolites, and samples from the Ordovician contain typically Ordovician palynomorphs whilst, Silurian samples contain a mixed assemblage of Ordovician and Silurian affinities. *Tylotopalla* sp. A and *Ancyrochitina ancyrea* are both common in the beds that span the boundary.

At Girvan samples have been processed from the Midland Valley, including various miscellaneous localities along with twelve samples from a measured section at Woodland Point. The samples from the olistostrome at Pinbain and Laigh Knocklaugh and the Infra-Kilranny mudstones at Dow Hill are poor in palynomorphs and no biostratigraphical interpretation is made.

Two samples from the Ardwell Beds which are Caradoc in age, are only tentatively dated as such by the palynology as most of the species are long ranging. Samples from Plantation Burn, Doularg Hill have yielded an assemblage which dates the Jubilation Member as upper Arenig to lower Llanvirn.

The twelve samples from the *D. complanatus* and *D. anceps* zones (and thus probably Pusgillian to late Rawtheyan in age) Mill and Shalloch Formations at Woodland Point contain thirty five species of chitinozoans in twelve genera, including one new species *Angochitina woodlandensis* , and five new combinations *Belonechitina comma* (Eisenack 1959), *B. hirsuta* (Laufeld 1967), *B. micracantha* (Eisenack 1931), *B. schopfi* subsp. *americana* (Taugourdeau 1965), and *B. seriespinosa* (Jenkins 1969). There are forty seven species of acritarch in twenty one genera, including two new species *Actinotodissus woodlandense* and *Goniosphaeridium girvanense* , and also three species of spores in three genera, scolecodonts and miscellaneous microfossils. The samples mostly show important Upper Ordovician taxa and several of the species e.g. *Calpichitina lenticularis* and *Acanthochitina barbata* appear to be useful biostratigraphical indicators. The boundary between the *D. anceps* and the *D. complanatus* Zones which exists somewhere in the Shalloch Formation cannot however be delineated on the basis of the palynomorphs.

Sphaeromorph and acanthomorph acritarchs are common at Dob's Linn in both black shales and grey mudstones, although netromorph acritarchs are much rarer than expected. Polygonomorph acritarchs are not common but one sample contains three species of the genus *Veryhachium* which may prove to be important. This is also seen at Woodland Point but the samples are not from the same zone. Chitinozoans are more common in black shales than grey mudstones and small conical fossils found in several samples may be simple cone ~~scolecodonts~~ conodonts. Scolecodonts are rare supporting the conclusion of Williams (1981 m.s.).

At Woodland Point a palaeoecological picture is available which although detailed has many unexplainable facts. It suggests that the Mill Formation was deposited in more offshore conditions than the oldest sample of the Shalloch Formation, although conditions gradually become more offshore throughout the Shalloch Formation. Sphaeromorph acritarchs never fall below eighty percent of the acritarch assemblage, and the other acritarchs switch from acanthomorph acritarch dominated conditions in the oldest Shalloch Formation to predominantly netromorph acritarch dominated in the other samples, possibly related to distance from land. Turner (1979 m.s.) states that the ratio of sphaeromorph to acanthomorph acritarchs is a good indication of proximity to shore-line, but it does not appear that things are quite so clear cut. The highest percentage of spores is found in sample MV/G/26 which possibly was the closest to the shore. In addition to a change from acanthomorph to netromorph acritarch dominated conditions in MV/G/28 there is also a large percentage of *Calpichitina lenticularis* which appears to be a shallow water species, probably washed in with turbidites. *Calpichitina lenticularis* decreases exponentially up the Shalloch Formation which may mean that it is reworked in the younger sediments. *Moyeria cabotti* is important in all the samples and is here taken to be a netromorph acritarch, but it may be a terrestrial form. It appears that the sample collected from the Mill Formation had been deposited in quite offshore conditions and that the oldest Shalloch Formation sample was much closer to the palaeoshore (and thus more material is input into the system) after which there may have been a progressive change to more offshore conditions, although the environment was one of deposition by distal turbidites which makes the system complicated, and difficult to analyse.

Comparing Dob's Linn and Woodland Point it becomes clear that at Dob's Linn *Cyathochitina* is more important whereas at Woodland Point *Belonechitina* is the more important genus. At Girvan where there is a greater number of species washed in then it seems logical that *Belonechitina* is a near-shore species whereas the quieter more offshore conditions of Dob's Linn suggest that *Cyathochitina* is an off-shore genus. *Ancyrochitina* appears also to be an off-shore genus.

Leiosphaeridia is represented by more species at Woodland Point possibly related to in-shore and off-shore species resulting in mixed assemblages. *Baltisphaeridium* is common at Woodland Point but is not found at Dob's Linn, and thus must be a genus that favours near-shore conditions.

Netromorph acritarchs are more common at Woodland Point than at Dob's Linn which could be related to the samples at Woodland Point being more off-shore but not necessarily deeper than Dob's Linn. This suggests that the Dob's Linn assemblages were not controlled by material from distal turbidites so much as the samples at Woodland Point. This appears to be substantiated by the sedimentology. It cannot, however, be overlooked that the model proposing netromorph acritarchs to be an offshore group may need modification due to the poor representation of netromorph acriatrchs at Dob's Linn.

The samples at Dob's Linn and Woodland Point are compared with previously published works on the Upper Ordovician and Lower Silurian and a Similarity Index, the Jacquard Coefficient, is applied to these previous works expressing the similarity of the present material with them. The Woodland Point samples are more like the Ordovician assemblages at Dob's Linn which was expected. Jacquard Coefficients are generally higher for chitinozoans than for acritarchs, though the reason for this is not known. Jacquard Coefficients appear to be higher when comparing samples of the same age range, although at Dob's Linn the assemblages from the Silurian show a greater similarity with the Ordovician assemblages than the Silurian.

The distribution of palynomorphs at the Ordovician-Silurian boundary is compared with assemblages of roughly the same time interval in Sweden, Anticosti Island and America. On Anticosti Island there is more diversity and abundance than at Dob's Linn, and the chitinozoan *Conochitina taugourdeaui* is used to mark the boundary. In Sweden *Ancyrochitina ancyrea* is present and is a common species spanning the boundary as at Dob's Linn. In the United States the boundary sediments are missing.

The thermal history of the samples are compared and previous work done on the subject discussed and it is suggested that the temperatures at Woodland Point, Girvan are below 100°C, at Barrhill 90-170°C, Dob's Linn 90-200°C and samples from the Highland Border Complex in excess of 200°C and possibly quite a bit higher. It is noted that the wall thickness plays an important part in the colour of the palynomorphs.

So to sum up, samples from very deformed rocks, less deformed rocks and from only minimally deformed rocks have all yielded palynomorphs that are able to provide imformation of varying degrees of usefulness. Although the material from the Highland Border Complex is very poorly preserved, it is the most useful data that has been obtained from large parts of the Complex, and as such is more valuable than the material retrieved from the better preserved assemblages. The samples at Dob's Linn do not show excellent preservation but are important due to their being collected from the International stratotype section of the Ordovician-Silurian boundary. The material from Girvan shows excellent preservation and suggests that it would prove very useful for a combined sedimentology and palynology project to be carried out on the large amounts of Upper Ordovician and Lower Silurian sediments that are exposed at that locality.

REFERENCE LIST

Achab, A. 1977a.Les chitinozoaires de la Zone à *Dicellograptus complanatus*, Formation de Vauréal, Ordovicien supérieur, Ile d'Anticosti, Québec. *Can. J. Earth Sci.*, **14**, 413-425.

Achab, A. 1977b. Les chitinozoaires de la Zone à *Climacograptus prominens-elongatus* de la Formation de Vauréal, Ordovicien supérieur, Ile d'Anticosti, Québec. *Can. J. Earth Sci.*, **14**, 2193-2212.

Achab, A. 1978a. Sur quelques chitinozoaires de la Formation de Vauréal et de la Formation de Macasty (Ordovicien supérieur), Ile d'Anticosti, Québec, Canada. *Rev. Palaeobot. Palyol.*, **25**, 295-314.

Achab, A. 1978b. Les chitinozoaires de l'Ordovicien Supérieur, Formations de Vauréal et d'Elles Bay, de Ile d'Anticosti, Québec. *Palinologia*, **num. extraord 1**, 1-19.

Achab, A. 1982. Chitinozoaires de l'Ordovicien de l'Arenig supérieur (Zone D) de Formation de Levis, Québec, Canada. *Can. J. Earth Sci.*, **19**, 1295-1307.

Achab, A. 1984. Chitinozoaires de l'Ordovicien moyen de subsurface de l'Ile Anticosti. *Rev. Palaeobot. Palynol.*, **43**, 123-143.

Achab, A. 1986a. Succession de chitinozoaires dans l'Ordovicien moyen du Québec et de l'est du Canada. *Rev. Palaeobot. Palynol.*, **48**, 269-294.

Achab, A. 1986b. Chitinozoaires du Caradoc supérieur- Ashgill inférieur du Québec, Canada. *Can. J. Earth. Sci.*, **24**, 1212-1234.

Achab, A. and Duffield, S.L. 1982. Palynological changes at the Ordovician-Silurian boundary on Anticosti Island, Québec. *Palaeont. Contr. Oslo*, **280**, 3.

Albani, R., Lelkes-Felváry, Gy. and Tongiorgi, M. 1985. First record of Ordovician (Upper Arenigian, Acritarchs) beds in Bakony Mts., Hungary. *N. Jb. Geol. Paläont. Abh.*,

170, 45-65.

Anderson, J.G.C. 1947. The geology of the Highland Border: Stonehaven to Arran. *Trans. R. Soc. Edin.*, **61**, 479-515.

Anderson, J.G.C. and Pringle, J. 1944. The Arenig rocks of Arran, and their relationship to the Dalradian Series. *Geol. Mag*, **81**, 81-87.

Atkinson, K. and Moy, R.L. 1971. Lower Caradocian (Upper Ordovician) chitinozoa from North Wales. *Rev. Palaeobot. Palynol.*, **11**, 239-250.

Bär, P. and Riegel, W. 1980. Mikrofloren des höchsten Ordovizium bis tiefen Silurs aus der Unteren Sekondi- serie von Ghana (West Afrika) und ihre Beziehung den Itaim-Schicten des Maranhao-Beckens in N.E. Brasilien. *N. Jb. Geol. Paläont. Abh.*, **160**, 42-60.

Barnes, C. R. and Williams, S.H., 1988. Conodonts from the Ordovician-Silurian Boundary Stratotype, Dob's Linn, Scotland. *In* Cocks, L.R.M., and Rickards, R.B., (eds) : *A Global Analysis of the Ordovician-Silurian Boundary.* (in press).

Barnes, R.P., Anderson, T.B. and McCurry, J.A. 1987. Along-strike variation in the stratigraphical and structural profile of the Southern Uplands Central Belt in Galloway and Down. *J. Geol. Soc. London,* **144**, 807-816.

Barrow, G. 1901. On the occurrence of Silurian (?) rocks in Forfarshire and Kincardineshire along the eastern border of the Highlands. *Q. J. Geol. Soc. London,* **57**, 328-345.

Bates, C.D., Coxon, P. and Gibbard, P.L., 1978. A new method for the preparation of clay-rich sediment samples for palynological investigation. *New Phytologist,* **81**, p. 459-463.

Beju, D. and Danet, N. 1962. Chitinozoaire siluriene din Platforma moldoveneasca si Platforma moezica. *Pet. Si Gaze,* **13**, 521-568.

Benoit, A. and Taugourdeau P., 1961. Sur quelques Chitinozoaires de l'Ordovicien du Sahara. *Rev. Inst. Franç. du Pétrole,* XVI, **12**, 1403-1421.

Bergström S.M. 1986. Biostratigraphic integration of Ordovician graptolite and conodont zones- a region review. *In* Hughes, C.P. and Rickards, R.B. (eds), 1986, *Palaeoecology and Biostratigraphy of Graptolites,* Geological Society Special Publication, No. **20**, 61-78.

Berry, W.B.N., 1987. The Ordovician-Silurian boundary: new data, new concerns. *Lethaia,* **20**, p. 209-216.

Berry, W.B.N. and Wilde, P. 1978. Progressive ventilation of the oceans - an explanation for the distribution of Lower Palaeozoic Black Shales. *Am. J. Sci.,***278**, 257-275.

Berry, W.B.N. , Orth, C.J., Wilde, P., Hunt, M.Q. and Gilmore, J.S. 1984. Chemostratigraphy at Dob's Linn, Scotland indicates major change in oceanic ventilation in Ordovician-Silurian boundary interval. *Geological Society of America Abstracts with programs,***16**, 546.

Bluck, B.J. 1982. Hyalotuff deltaic deposits in the Ballantrae ophiolite of south west Scotland : evidence for crustal position of the lava sequence. *Trans. Roy. Soc. Edin.,***72**, 217-228.

Bluck, B.J. 1984. Pre-Carboniferous history of the Midland Valley of Scotland. *Trans. R. Soc. Edin.,* **75**, 275-295.

Bluck, B.J. and Leake, B.E. 1986. Late Ordovician to Early Silurian amalgamation of the Dalradian and adjacent Ordovician rocks in the British Isles. *Geology,* **14**, 917-919.

Bliss, G.M. 1977. The micropalaeontology of the Dalradian. Ph.D. thesis, University of London (unpublished).

Bockelie, T.G. 1978. Comments on chitinozoan classification. *Norsk geol. Tiddsskr,* **58**, 301-308.

Bockelie, T.G. 1980. Early Ordovician chitinozoa from Spitsbergen. *Palynology,* **4**, 1-14.

Bockelie, T.G. and Kjellström, G. 1979. Middle Ordovician acritarchs from the Island of Odisholm, Estonia. *Geol. Foren. Stock. Forhand.,* **101**, 205-216.

Booth, G.A. 1979. Lower Ordovician acritarchs from successions in England and

North Wales. Unpublished Ph.D. thesis, University of Sheffield.

Bouché, P. M. 1965. Chitinozoaires du Silurien du Djado. *Rev. de Micropal.*, **8**, 151-164.

Brasier, M. 1986. The succession of small shelly fossils (especially conoidal microfossils) from English Precambrian-Cambrian boundary beds. *Geol. Mag.* **123**, p.237-256.

Brown, P.E., Miller, J.A., Soper, N.J. and York, D. 1965. Potassium-argon age pattern of the British Caledonides. *Proc. Yorks geol. Soc.*, **25**, 103-138.

Bulman, O.M.B. 1963. In *Summ. Prog. Surv. Gt. Britain for 1962*, 57.

Burmann, G. 1968. Diacrodien aus dem unteren Ordovizium. *Paläont. Abh.*, Abt. B, **2**, 639-652.

Burmann, G. 1969. Inkohlung und mechanische deformation. *Zritschrift für ang. Geol.*, **15**, 355-362.

Burmann, G. 1970. Weitere organische Mikrofossilien aus dem unteren Ordovizium. *Paläont. Abh.*, Abt. B, **3**, 289-332.

Burton, C.J., Hocken, C., MacCallum, D., and Young, M.E. 1984. Chitinozoa and the age of the Margie Limestone of the North Esk. *Proc. Geol. Soc. Glasgow* , **124/125**,27-32.

Campbell, R. 1911. Preliminary note on the geology of south-eastern Kincardineshire. *Geol. Mag.* **48**, 63-69.

Campbell, R. 1913. The geology of south-eastern Kincardineshire. *Trans. R. Soc. Edin.*, **48**, 923-960.

Chaiffetz, M.S. 1972. Functional interpretation of the sacs of *Ancyrochitina fragilis* Eisenack and the Paleobiology of the Ancyrochitinids. *J. Paleont.*,**46**, 499-502.

Churchill, D.M. and Sarjeant, W.A.S. 1963. Freshwater microplankton from Flandrian (Holocene) peats of southwestern Australia. *Grana Palynol.* **3**, 29-53.

Clough, C. T. 1895. In *Annual rep. geol. Survey for 1895*, 189.

Cloud, P. and Germs, A. 1971. New Pre-Palaeozoic nannofossils from the Stoer group (Torridonian), northwest Scotland. *Bull. geol. Soc. Am.*, **82**, p. 3469-74.

Cocks, L.R.M., 1985. The Ordovician-Silurian boundary. *Episodes*, **8**, p.98-100.

Cocks, L.R.M. and Toghill, P. 1973. The biostratigraphy of the Silurian rocks of the Girvan district, Scotland. *J. Geol. Soc. London*, **129**, 209-243.

Cocks, L.R.M., Toghill, P. and Ziegler, A.M. 1970. Stage names within the Llandovery. *Geol. Mag.*, **107**, 79-87.

Colbath, G.K., 1979. Organic-walled microphytoplankton from the Eden Shale (Upper Ordovician) Indiana, U.S.A. *Palaeontographica* , Abt. B, **171**. p. 1-38.

Colbath, G.K. 1980. Abundance fluctuations in Upper Ordovician organic-walled microplankton from Indiana. *Micropalaeontology*, **26**, 97-102.

Collinson, C. and Schwalb, H. 1955. North American Paleozoic chitinozoa. *Illinois*

State Geol. Surv., Report of Investigation, **186**, 33pp.

Colthrust, J.R.J. and Smith, D.G. 1977. Palaeontological evidence for the age of the lower Palaeozoic rocks of Slievenamon Inlier, County Tipperary. *Proc. R. Ir. Acad.*, **77B**, 143-58.

Combaz, A. 1966. Remarques sur les niveaux à Tasmanacées du Paléozoique Saharien. *Palaeobotanist*, **15**, 29-34.

Combaz, A., Calandra, F., Jansonius, J., Millepied, P., Poumot, C., and van Oyen, F.H. 1967. Microfossiles organiques du Paléozoique. Les chitinozoaires (II); Morphographie. C.I.M.P. Centre National de la Recherche Scientifique, Paris, 43pp.

Combaz, A. and Poumot, C. 1962. Observations sur la nature des chitinozoaires. *Rev. Micropaléont.*, **5**, 147-160.

Combaz, A., Lange, F.W., and Pansart, J., 1967. Les <<Leiofusidae>> Eisenack 1938. *Rev. Palaeobot. Palynol.*, **1**, p. 291-307.

Combaz, A. and Peniguel, G. 1972. Étude palynostratigraphique de l'Ordovicien de quelques sondages du Bassin de Canning (Australia occidentale). *Bull. Centre de Recherches de Pau*, **6**, 121-167.

Conway Morris, S. 1987. The search for the Precambrian-Cambrian boundary. *American Scientist*, March-April, 157-167.

Correia, M. 1967. Relations possible entre l'etat de conservation des éléments figurés de la matière organique (micrfossiles palyno-planctologiques) et l'existence de gisements d'hydrocarbures. *Inst. Fr. Petròle.*, **23**, 1285-1306.

Craig, G.Y and Walton, E.K. 1959. Sequence and structure in the Silurian rocks of Kirkcudbrightshire. *Geol. Mag.*, **96**, 209-220.

Cramer, F.H. 1964a. Some acritarchs from the San Pedro Formation (Gedinnien) of the
Cantabric Mountains in Spain. *Bull. Soc. Belge. Géol. Paléont. Hydrol.*, **73**, p. 33-38.

Cramer, F.H. 1964b. Microplankton from three Palaeozoic Formations in the province of Leon (N.W. Spain). *Leidse geol. Meded.*, **30**, p. 253-361.

Cramer, F.H. 1966. Palynomorphs from the Siluro-Devonian boundary in north-west Spain, *Notas y comuns.* I.G.M., Espãna, **85**, 71-82.

Cramer, F.H. 1968. Palynologic microfossils of the Middle Silurian Maplewood Shales in north-west New York, *Rev. Micropaléont.*, **11**, 61-70.

Cramer, F.H., 1969. Possible implications for Silurian paleogeography from phytoplankton assemblages of the Rose Hill and Tuscarora Formations of Pennsylvania. *J. Paleont.*, **43**, p. 485-491.

Cramer, F.H. 1970a. Middle Silurian continental movement estimated from phytoplankton-facies transgression. *Earth Plan. Sci. Letters*, **10**, 87-93.

Cramer, F.H. 1970b. Acritarchs and chitinozoans from the Silurian Ross Brook Formation, Nova Scotia. *J. Geol.*,**78**, 745-749.

Cramer, F.H. 1971. Distribution of selected Silurian acritarchs. *Rev. Espanola.*

Micropalaéont, Núm extraord 1, 1-203.
Cramer, F.H. and Díez, M.C.R. 1972. North American Silurian palynofacies and their spatial arrangement: Acritarchs. *Palaeontographica,* Abt. A, **138**, 107-180.
Curry, G.B. 1986a. Tailor-made geology 3: Lime Craig Quarry, Aberfoyle, Scotland. *Geology Today,* January-February, 25-27.
Curry, G.B. 1986b. Fossils and tectonics along the Highland boundary Fault in Scotland. *Journ. Geol. Soc. London,* **143**, 193-198.
Curry, G.B., Bluck, B.J., Burton, C.J., Ingham, J.K., Siveter, D.J. and Williams, A. 1984. Age, evolution and tectonic history of the Highland Border Complex, Scotland. *Trans. R. Soc. Edinburgh* ,**75**, 113-133.
Curry, G.B., Ingham, J.K., Bluck, B.J. and Williams, A. 1982. The significance of a reliable Ordovician age for some Highland Border rocks in Central Scotland. *J. Geol. Soc. London.* **139**, 451-454.
Cummins, W.A. 1966. Stratigraphic correlation of the Dalradian rocks in the south-west Highlands of Scotland. Scott. *J. Geol.,* **2**, 316-317.
Cwynar, L.C., Burden, E., and McAndrews, 1979. An inexpensive method of sieving for concentrating pollen and spores from fine grained sediments. *Can. J. Earth Sci.,* **16**, 1115-1120.
Davey, R. 1970. Non-calcareous microplankton from the Cenomanian of England, northern France and North America, II; *Bull. Br. Mus. (Nat. Hist.) Geol. Ser.,* **18**, 333-397.
Davies, K.A. 1929. Notes on the graptolite faunas of the Upper Ordovician and Lower Silurian. *Geol. Mag.,* **66**, 1-27.
Deflandre, G., 1936. Microfossiles de silex crétacés. I. Généralités. Flagellés. *Annls Paléont.,* **25**, 151-191.
Deflandre, G., 1937. Microfossiles de silex crétacés II. Flagellés incertae sedis. Hystrichosphaeridés. Sarcodinés. Organismes divers. *Annls. Paléont.,* **26**, p. 51-103.
Deflandre, G., 1938. Microplancton des mers jurassiques conservé dans les marnes de Villers-sur mer (Calvados). Etude preliminaire et considérations générals. *Trav. Stat. Zool. Wimereux,* **13**, p.147-200.
Deflandre, G., 1942. Sur les Hystrichospheres des calcaires Siluriens de la Montagne Noire. *C.R. Acad. Sci. Paris.,* **215**, p. 475-476.
Deflandre, G., 1945. Microfossiles des Calcaires Siluriens de la Montagne Noire. *Annals. Paléont.,* **31**, p. 41-75.
Deflandre, G., 1946. Hystrichosphaerides. III. Especes du Primaire. *Fich. micropaléont. ser. 8, arch. orig. Serv. Document CNRS* , **257**, fiches I-V: p. 1096-1185.
Dempster, T.J. 1984. Localised uplift in the Scottish Dalradian. *Nature,* **307**, 156-7.
Deunff, J. 1954. *Veryhachium,* genre nouveau d'Hystrichosphères du Primaire. *C.R. Somm. Soc. Géol. Fr.,* **13**, p. 305-307.

Deunff, J. 1955. *Aremoricanium,* genre nouveau d'Hystrichosphères du Silurien Breton. *C.R. Somm. Séanc. Soc. Géol. Minér. Bretagne,* n. sér., **2**, 5-14.

Deunff, J. 1959 ("1958"). Microorganisms planctonique du Primaire Armoricain.1. Ordovicien du Veryhac'h (Presque'île de Crozon). *Bull. Soc. Géol. Minér. Bretagne* , **2**, p.1-41.

Dewey, J.F. 1971. A model for the Lower Palaeozoic evolution of the southern margin of the early Caledonides of Scotland and Ireland. *Scott. J. Geol.,* **7**, 219-40.

Diez, M. del C.R. and Cramer, F. H. 1974. Range chart of selected Lower Palaeozoic acritarch taxa. *Rev. Palaeobot. Palynol.,* **18**, 155-170.

Diez, M. del C.R. and Cramer, F. H. 1977. Range chart of selected Lower Palaeozoic acritarch taxa II, Index to parts I and II. *Rev. Palaeobot. Palynol.,* **24**, 1-48.

Dorning, K.J., 1981a. Silurian acritarchs from the type Wenlock and Ludlow of Shropshire. *Rev. Palaeobot. Palynol.,* **34**, 175-203.

Dorning, K.J 1982. Early Wenlock acritarchs from the Knockgardner and Straiton Grit Formations of Knockgardner, Ayrshire. Scott. *J. geol.* **18**, p. 267-273.

Dorning, K.J. 1983. Distribution of Silurian palynomorphs from Wales and the Welsh Borderland. *British Lower Palaeozoic Palynomorph Working Group Rep.,*1983, 4-5.

Dorning, K.J., 1985. Acritarch microflora from the Ordovician of North Glen Sannox, Isle of Arran, Scotland. *British Lower Palaeozoic Palynomorph Working Group Report,* 1985, 9-13.

Dorning, K.J. 1986. Organic microfossil geothermal alteration and interpretation or regional tectonic provinces. *J. geol. Soc. Lond.,* **143**, 219-220

Dorning, K.J., 1987. The organic palaeontology of Palaeozoic carbonate environments. *In* Hart. M.B. (editor). *Micropalaeontology of carbonate environments.* Ellis Horwood Ltd., Chichester, 256-265.

Dorning, K.J. and Bell, D.G. 1987. The Silurian carbonate shelf microflora : acritarch distribution in the Much Wenlock Limestone Formation. *In* Hart. M.B. (editor). *Micropalaeontology of carbonate environments.* Ellis Horwood Ltd., Chichester, 265-287.

Downie, C. 1958. An assemblage of microplankton from the Shineton Shales (Tremadocian). *Proc. Yorkshire Geol. Soc.,* **31**, 331-350.

Downie, C. 1959. Hystrichospheres from the Silurian Wenlock Shale of England. *Palaeontology,* **2**, p. 56-71.

Downie, C. 1962. So-called spores from the Torridonian. *Proc. geol. Soc. London,* **1600**, p. 127-8.

Downie, C. 1963. 'Hystrichospheres' (acritarchs) and spores of the Wenlock Shales (Silurian) of Wenlock, England. *Palaeontology,* **6**, 625-652.

Downie, C. 1966. The geological history of the microplankton. *Rev. Palaeobot.*

Palynol., **1**, p. 269-281.

Downie, C. 1967. The geological history of the microplankton. *Rev. Palaeobot. Palynol.*,**1**, 269-281.

Downie, C. 1973. Observations on the nature of the acritarchs. *Palaeontology,* **16**, 239-261.

Downie, C. 1975. The Precambrian of the British Isles : Palaeontology. *In* Harris, A.L., Shackleton, R.M., Watson, J., Downie, C., Harland, W.B. and Moorbath, S. (eds). A
correlation of Precambrian rocks in the British Isles. *Geol. Soc. London. Spec. Rep.*, **6**, p. 57-60.

Downie, C. 1979. Acritarchs. Unpublished report, University of Sheffield.

Downie, C. 1982. Lower Cambrian acritarchs from Scotland, Norway, Greenland and Canada. *Trans. Roy. Soc. Edin.* , **72**, p. 257-287.

Downie, C. 1984. Acritarchs in British stratigraphy. *Geol. Soc. London. Spec. Rep.*, **17**, 26pp.

Downie, C. 1985

Downie, C., Evitt, W.R. and Sarjeant, W.A.S. 1963. Dinoflagellates, hystrichospheres and
the classification of the acritarchs. *Stanford University Publications,* **17(3)**, p.
3-16.

Downie, C. and Ford, T.D. 1966. Microfossils from the Manx Slate Series. *Proc. Yorks. geol. Soc.*, 35, p. 307-322.

Downie, C., Lister.T.R., Harris, A.L. and Fettes, D.J. 1971. A palynological investigation of the Dalradian rocks of Scotland. *Rep. Inst. Geol. Sci. London*, **71/9**.

Downie, C., and Sarjeant, W.A.S., 1963. On the interpretation and status of some Hystrichosphere genera. *Palaeontology*, **6**, p.83-96.

Downie, C., and Tremlett, W. E. 1968. Micropalaeontological evidence on the age of the Clara Group (south-east Ireland). *Geol. Mag.*, **105**, 401.

Downie, C., Williams, G.L. and Sarjeant, W.A.S. 1961. Classification of fossil microplankton. *Nature*, **192**, 471.

Duffield, S.L. and Legault, J.A. 1981. Acritarch biostratigraphy of Upper Ordovician to Lower Silurian rocks, Anticosti Island, Québec : preliminary results. Subcommission on Silurian Stratigraphy, Ordovician-Silurian boundary working group. Field meeting, Anticosti-Gaspé, Québec, 1981, II, stratigraphy and palaeontology. Lesperence, P.J. (ed.), 91-99.

Eisenack, A. 1930. Neue Mikrofossilien des baltischen Silurs (Vorläufige Mittelung). *Die Naturwissenschaften*, **18**, 880-881.

Eisenack, A. 1931. Neue Mikrofossilien des baltischen Silurs I. *Palaeont. Z.*, **13** p.74-118, 5 fig., 5 pl., h.-t., Berlin.

Eisenack, A. 1932. Neue Mikrofossilien des baltischen Silurs II. *Paläont. Z.*, **14**, 257-277.

Eisenack, A. 1934. Neue Mikrofossilien des baltischen Silurs III. *Palaeont. Z.*, **16**

p.52-76, 35 fig., 2 pl.h.-t., Berlin.
Eisenack, A. 1937. Neue Mikrofossilien des baltischen Silurs IV. *Palaeont. Z.*,19,217-243.
Eisenack, A.1938. Hystrichosphaerideen und verwandte Formen in Baltischen Silur. *Ztschr. Geshieb. Flachlandgeol.*, **14**, p. 1-30.
Eisenack, A. 1939. Chitinozoen und Hystrichosphaerideen im Ordovicium des Rheinschen Schiefergebirges. *Senckenberg. Leth.*, **21**, 135-152.
Eisenack, A. 1948. Mikrofossilien aus Kieselknollen des böhemischen Ordoviziums. *Senckenberg. Leth.*, **28**, 105-117.
Eisenack, A. 1951. Über Hystrichosphaerideen und andere Kleinformen aus baltischen Silur und Kambrium. *Senckenberg. Leth.*, **32**, 187-204.
Eisenack, A. 1955a. Chitinozoen, Hystrichosphären und andere Mikrofossilien aus dem *Beyrichia*-Kalk. *Senckenberg. Leth.*, **36**, 157-188.
Eisenack, A., 1955b. Neue Chitinozoan aus dem Silur des Baltikums und dem Devon der Eifel. *Senckenberg. Leth.*, **36**, p.311-319.
Eisenack, A., 1958a. Mikrofossilien aus dem Ordovizium des Balticums I. *Senckenberg. Leth.*, **39**, no. 5-6, p. 389-405.
Eisenack, A. 1958b. *Tasmanites,* Newton 1985, and *Leiosphaeridia* n. g. als gattungen der Hystricohosphaeridia. *Palaeontographica, Abt. A*, **110**, 1-19.
Eisenack, A. 1959a. Neotypen baltischer Silur- Hystrichosphären und neue Arten. *Palaeontographica*, Abt. A. **112**, p. 193-211.
Eisenack, A. 1959b. Neotypen baltischer Silur-Chitinozoen und neue Arten. *Neues Jb. für Geologie und Paläontologie*, Abh. **108**, 1-20.
Eisenack, A. 1962a. Neotypen baltischers Silur-Chitinozoen und neue Arten. *Neues Jb. Geol. Palaeont. Abh.*, **114**, 291-316.
Eisenack, A. 1962b. Mikrofossilien aus dem Ordovizium des Baltikums, 2, Vaginatenkalk bis Lyckholmer Stufe. *Senckenberg Leth*, **43**, 349-366.
Eisenack, A. 1962c. Chitinozoen aus Sedimenten Gotlands. *Neue. Jb. Geol. Paläont. Mh.*, 218-219.
Eisenack 1962d. Neue problematische Mikrofossilien. *N. Jb. Geol. Paläont., Abh.*, **114**, 135-141.
Eisenack, A. 1963. Die Bestimmung des Alters von Kiesel schiefer-Geröllen mittels Mikrofossilien. *Senckenberg. Leth.*, **34**, 99-103.
Eisenack, A. 1964. Mikrofossilien aus dem Silur Gotlands. *N. Jb. Paläont Abh.*, **120**, 308-342.
Eisenack, A. 1965. Die Mikrofauna aus dem Ostseekalk, I, Chitinozoen, Hystrichosphären. *Neues Jb. Geol. Palaeont. Abh.*, **123**, 349-366.
Eisenack, A. 1968a. Mikrofossilien eines Geschiebes der Borkholmer Stufe, baltisches Ordovizium, F_2. *Mitt. geol. St Inst. Hamb.*, **37**, 81-94.
Eisenack, A. 1968b. Uber Chitinozoen des baltischen Gebietes, *Palaeontographica*, Abt. A, **131**, 137-198.
Eisenack, A. 1969. Zur systematik einiger paläozoischer Hystrichosphären

(Acritarcha) des baltischen Gebietes. *Neues Jb. Geol. Paläont. Abh.*, **133**, p. 245-266.

Eisenack, A. 1970. Mikrofossilien aus dem Silur Estlands und der Insel Ösel. *Geol. För. Stockh. Förh.*, **92**, 302-322.

Eisenack, A. 1972a. Chitinozoen und andere mikrofossilien aus dem bohrung leba, Pommern. *Palaeontographica, Abt. A*, **139**, 64-87.

Eisenack, A. 1972b. Beiträge zur Chitinozoen-Forschung. *Neues Jb. Geol. Palaeont., Monatscefte*, **H10**, 596-601.

Eisenack, A. 1976a.Weiterer Beitrag zur Chitinozoen forschung. *Neues Jb. Geol. Palaeont., Monatscefte*, 641-652.

Eisenack, A. 1976b. Mikrofossilien aus dem Vaginatenkalk von Hälludden, Öland. *Palaeontographica*, Abt. A, , 181-203.

Elaouad-Debbaj, Z. 1978. Acritarches de l'Ordovicien Supérieur du Synclinal de Buçaco (Portugal). *Bull. soc. géol. Minéral. Bretagne, C*, **102**, 1-101.

Elaouad-Debbaj, Z. 1984. Chitinozoaires Ashgilliens de l'Anti-Atlas (Maroc). *Geobios*, **17**, 45-68.

Elaouad-Debbaj, Z. 1986. Chitinozoaires de la Formation du Ktaoua inférieur Ordovicien supérieur de l'Anti-Atlas (Maroc). *Hercynia*, **11**, 35-55.

Elles, G.L. and Wood, E.M.R. 1901-1918. A monograph of British Graptolites. *Monogr. Palaeontogr. Soc. London*, **i-clxxi**, 1-539.

Evitt, W.R. 1963. A discussion and proposals concerning dinoflagellates, hystrichospheres, and acritarchs, I, II. *Proc. natn. Acad. Sci. U.S.A.*, **49**, 158-164, 298-302.

Gardiner, P.R.R. and Vanguestaine, M. 1971. Cambrian and Ordovician microfossils from southeast Ireland and their implications. *Bull. geol. Surv. Ireland*, **1**,163-210.

Glaessner, M.F., 1948. Principles of micropalaeontology. Melbourne University Press.

Górka, H. 1969. Microorganismes de l'Ordovicien de Pologne, *Palaeontologie Polonica*, **22**, 7-100.

Górka, H. 1980. Le microplancton de L'Ordovicien Moyen de Strabla (Pologne). *Acta. Pal. Polonica*, **25**, 261-277.

Graham J.R. and Smith D.G. 1981. The age and significance of a small Lower Palaeozoic Inlier in County Mayo. *J. Earth Sci. R. Dublin Soc.*, **4**, 1-5.

Grahn, Y. 1978 Chitinozoan stratigraphy and palaeoecology at the Ordovician-Silurian boundary in Skåne, southernmost Sweden. *Sveriges Geol. Undersökning*, C, **744**, 16pp.

Grahn, Y. 1980. Early Ordovician chitinozoa from Öland. *Sveriges Geol. Undersökning*, C, **775**, 41pp.

Grahn, Y. 1981a. Middle Ordovician chitinozoa from Öland. *Sveriges Geol. Undersökning*, C, **784**, 51pp.

Grahn, Y. 1981b. Ordovician chitinozoa from the Stora Asbotorp boring in Västergötland, south-central Sweden. *Sveriges Geol. Undersökning*, C,

787, 40pp.
Grahn, Y. 1982a. Caradocian and Ashgillian chitinozoa from the subsurface of Gotland. *Sveriges Geol. Undersökning*, C, 788, 66pp.
Grahn, Y. 1982b. Chitinozoophoran palaeoecology in the Ordovician of Öland. *Sver. Geol. Undersökning, C*, 792, 17pp.
Grahn, Y. 1984a. Early Caradoc chitinozoa from Ostergötland, south central Sweden. *Gëol. Fören. Stockholm Förhandl.*, 105, 269-272.
Grahn, Y. 1984b. Ordovician chitinozoa from Tallinn, Northern Estonia. *Rev, Palaeobot. Palyn.*,43, 5-31.
Grahn, Y. 1985. Llandoverian and Early Wenlockian chitinozoa from Southern Ohio and Northern Kentucky, U.S.A. *Palynology*, 9, 147-164.
Grahn, Y. and Afzelius, B.A. 1980. On the affinity of chitinozoa (abstracts only) 5th International Palynological Conference Abstracts, Cambridge 1980.
Grahn, Y. and Bergström, S. 1984a. Lower Middle Ordovician chitinozoa from the Southern Appalachians, United States. *Rev. Palaeobot. Palyn.*, 43, 89-122.
Grahn, Y. and Bergström, S. 1985. Chitinozoa from Ordovician-Silurian boundary beds in eastern Cincinatti Arch region of Ohio and Kentucky. *Ohio J. Sci.*, 85, 175-183.
Grahn, Y. and Miller, M.A. 1986. Chitinozoa from the Middle Ordovician Bromide Formation, Arbuckle Mountains, Oklahoma, U.S.A. *N. Jb. Geol. Paläont Abh.*, 172, 281-403.
Graves, R.W. and Ellison, Jr., S.P. 1941. Ordovician conodonts of the Marathon Basin, Texas. *Missouri Univ. School Mines Met., Bull., tech. ser.*, 14, 26pp.
Gray, J and Boucot, A.J. 1972. Palynological evidence bearing on the Ordovician-Silurian paraconformity in Ohio. *Bull. Geol. Soc. Am.*, 83, 1299-1314.
Gray, J., Massa, D. and Boucot, A.J. 1982. Caradocian land plant microfossils from Libya. *Geology*, 10, 197-201.
Gunn, W., Geikie, A., Peach, B.N. and Harker, A. 1903. The geology of North Arran, South Bute and the Cumbraes with part of Ayrshire and Kintyre. *Mem. geol. survey Scotland* 1903.
Gunn, W. 1907. Torridonian: Coigach to Loch Maree. *In*: The Geological structure of the North-west Highlands of Scotland. *Great Brit. Geol. Surv. Mem.*, p. 309-321.
Gutjahr, C.C.M. 1966. Carbonisation measurements of pollen-grains and spores and their application. J.J. Groen and Zoon, Leiden, 29pp.
Hall, J., Powell, D.W., Warner, M.R., El-Isa, Z.H.M., Adesanya, O. and Bluck, B.J. 1983. Seismological evidence for shallow crystalline basement in the Southern Uplands of Scotland. *Nature*, 305, 418-420.
Harland, R. and Sarjeant, W.A.S. 1970. Fossil freshwater microplankton (Dinoflagellates and acritarchs) from Flandrian (Holocene) sediments of Victoria and Western Australia. *Proc. R. Soc. Vict.*, 83, 211-234.

Harland, W.B. and Gayer, R.A. 1972. The Arctic Caledonides and earlier Oceans. *Geol. Mag.* ,**109**, 289-314.

Harper, D.A.T. 1979. The environmental significance & some faunal changes in the Upper Ardmillan succession (upper Ordovician), Girvan, Scotland. *In* Harris, A.L., Holland, C.H. and Leake, B.E. (eds) *The Caledonides of the British isles-Reviewed. Geol. Soc. London Spec. Publ.*, **8**, 439-45.

Harris, A.L. 1969. The relationship of the Leny Limestone to the Dalradian. *Scott. J. Geol.*, **5**, 187-190.

Harte, B., Booth, J.E., Dempster, T.J., Fettes, D.J., Mendum, J.R. and Woods, D. 1984. Aspects of post-depositional evolution of Dalradian and Highland Border Complex rocks in the Southern Highlands of Scotland. *Trans. R. Soc. Edin.*, **75**, 151-64.

Hedley, R.H. 1962. *Gromia oviformis* (Rhizopodea) from New Zealand with comments on the fossil Chitinozoa. *N. Zeal. Journ Sci.,5,* 121-136.

Henderson, W.G. and Fortey, N.J. 1982. Highland Border rocks of Loch Lomond and Aberfoyle. *Scott. J. Geol.*, **18**, 227-245.

Henderson, W.G. and Robertson, A.H.F. 1982. The Highland Border rocks and their relation to marginal basin development in the Scottish Caledonides. *J. Geol. Soc. London*, **139**, 433- 450.

Henry, J.L. 1969. Micro-organismes incertae sedis (acritarches and chitinozoaires) de l'Ordovicien de la Presqu'île de Crozon (Finistère), Gisements de Mort-Anglaise et de Kerglintin. *Bull. Soc. Géol. Minér. Bretagne* (1968), 59-100.

Henry, J.L., Nion, J. Paris, F. and Thadeu, D. 1974. Chitinozoaires, Ostracodes et Trilobites de l'Ordovicien du Portugal (Serra de Buçaco) et du Massif Armoricain: essai de comparaison et signification paléogéographique. *Comm. Serv. geol. Portugal*, **57**, 303-345.

Hill, P.J and Dorning, K.J. 1984. The Llandovery Series of the type area. *In* Cocks L.R.M., Woodcock, N.H., Rickards, R.B., Temple, J.T. and Lane, P.D. (eds). *The Llandovery Series of the Type Area.* Bull. British Museum (Natural History), Geology Series, **38**, 174-177.

Holm, G. 1893. Sveriges Kambrisk-Siluriska Hyolithidae och Conulariidae. *Sveriges Geologiska Undersökning (Afhandlingar), Series,* **112**, 172pp.

Hubert J.F. 1966. Sedimentary history of Upper Ordovician Geosynclinal Rocks, Girvan, Scotland. *J. Sed. Pet.*, **36**, 677-99.

Hutton, D.H.W. and Murphy, F.C. 1987. The Silurian of the Southern Uplands and Ireland as a successor basin to the end-Ordovician closure of Iapetus. *J. Geol. Soc. London,* **144**, 765-772.

Ikin, N.P. and Harmon, R.S. 1984. Tectonic history of the ophiolitic rocks of the Highland Border Fracture Zone, Scotland: Stable isotope evidence from rock-fluid interactions during obduction. *Tectonophysics,* **106**, 31-48.

Ingham, J.K. 1974. The Moffat district. *In* Bassett, M.G., Ingham, J.K. and Wright, A.D. (eds). *A field excursion guide for Palaeontological Association*

Ordovician System Symposium, Birmin:ʼgham 1974, 45-49.

Ingham, J.K. 1978. Geology of a continental margin 2: middle and late Ordovician transgression, Girvan. In Bowes, D.R. and Leake, B.E. (eds) Crustal Evolution in northwestern Britain and adjacent regions. *Geol. J. Spec. Issue.*, **10**, 163-76.

Ingham, J.K., Curry, G.B., and Williams, A. 1985. Early Ordovician Dounans Limestone fauna, Highland Border Complex, Scotland. *Trans. R. Soc. Edin.*, **76**, 481-513.

Ingham, J.K. and Williams, A. 1974. The Girvan district.*In* Bassett, M.G., Ingham, J.K. and Wright, A.D. (eds). *A field excursion guide for Palaeontological Association Ordovician System Symposium, Birminingham 1974*, 50-59.

Ingham, J.K. and Wright, A.D. 1970. A revised classification of the Ashgill Series. *Lethaia*, **3**, 233-42.

Jacobson, S.R. 1978. Acritarchs from the Upper Ordovician Clays Ferry Formation, Kentucky, U.S.A. *Palinologica*, **num. extraord 1**, 293-303.

Jacobson, S.R. 1979. Acritarchs as paleoenvironmental indicators in Middle and Upper Ordovician rocks Kentucky, Ohio and New York. *J. Paleont.*, **53**, 1197-1212.

Jacobson, S.R. 1987. 'Middle Ordovician' acritarchs are guide fossils to the upper Ordovician. *Lethaia*, **20**, 91-92.

Jacobson, S.R. and Achab, A. 1985. Acritarch biostratigraphy of the *Dicellograptus complanatus* graptolite Zone from the Vauréal Formation (Ashgillian), Anticosti Island, Quebec, Canada. *Palynology*, **9**, 165-198.

Jansonius, J. 1964. Morphology and Classification of some chitinozoa. *Bull. Can. Pet. Geol.*, **12**, 901-918.

Jansonius, J. 1967. Systematics of the chitinozoa. *Rev. Palaeobot. Palyn.*, **1**, 354-360.

Jansonius, J. 1970. Classification and stratigraphical application of chitinozoa. *Proc. N. American Paleontological Convention*, 789-808.

Jansonius, J. and Jenkins, W.A.M. 1978. Chitinozoa. *In* Haq B.U. and Boersma, A. (eds), *Introduction to marine micropalaeontology*, Elsevier Press, 341-357.

Jardiné, S., Combaz, A., Magloire, L., Peniguel, G. and Vachey, G. 1974. Distribution stratigraphique des acritarches dans le Paléozoique du Sahara Algérien. *Rev. Palaeobot. Palyn.*, **18**, 99-129.

Jehu, T.J. 1912. Discovery of fossils in the Boundary Fault Series, near Aberfoyle. *Geol. Mag.*, **49**,469-470.

Jehu, J.T. and Campbell, R. 1917. The Highland Border Rocks of the Aberfoyle district. *Trans R. Soc. Edin.*, **52**,175-212.

Jekhowsky, B. de 1961. Sur quelques hystrichosphères Permo-Triasiques d'Europe et d'Afrique. *Rev. Micropal.*, **3**, 207-212.

Jenkins, W.A.M. 1967. Ordovician Chitinozoa from Shropshire. *Palaeontology*, 10, 436-488.

Jenkins, W.A.M., 1968. Chitinozoa. *Geoscience and Man*, **1**, p. 1-22.

Jenkins, W.A.M., 1969. Chitinozoa from the Ordovician Viola and Fernvale Limestones of the Arbuckle Mountains, Oklahoma. *Special Papers in Palaeontology*,5,

Jenkins, W.A.M. 1970. Chitinozoa from the Ordovician Sylvan Shale of the Arbuckle Mountains, Oklahoma. *Palaeontology*, **13**, 261-288.

Jenkins, W.A.M. and Legault, L. A. 1979. Stratigraphic ranges of selected chitinozoa. *Palynology*, **3**, 235-264.

Johnson, M.R.W. and Harris, A.L. 1965. Is the Tay Nappe post-Arenig? *Scott. J. Geol.*, **1**, 217-229.

Johnson, M.R.W. and Harris, A.L. 1967. Dalradian-? Arenig relations in part of the Highland Border, Scotland, and their significance in the chronology of the Caledonian orogeny. *Scott. J. Geol.*, **3**, 1-16.

Jux, U. 1971. Über den Feinbau der Wandungen einiger paläozoischer Baltispaeridiaceen. *Palaeontographica*, Abt. B., **136**, 115-128.

Kalvacheva, R. 1978. Acritarch stratigraphy of the Lower Palaeozoic Formations in the west Balken Mountains, Bulgaria. *Palinologia*, **núm. extraord. 1**, 303-311.

Kelling, G., Davies, P. and Holroyd, F.C. 1987. Style, scale and significance of sand bodies in the Northern and Central Belts, southwest Southern Uplands. *J. Geol. Soc. London*, **144**, 787-806.

Kjellström, G. 1968. Remarks on the chemistry and ultrastructure of the cell wall of some Paleozoic leiospheres. *Geol. Fören. I Stockholm För.*, **90**, 221-228.

Kjellström, G. 1971a. Ordovician microplankton (Baltisphaerids) from Grötlingbo Borehole No. 1 in Gotland, Sweden. *Årsb.Sveriges Geol. Unders*, **65** (15), Ser. C, n. 655, 1-75.

Kjellström, G. 1971b. Middle Ordovician microplankton from the Grötlingbo Borehole No. 1 in Gotland, Sweden. *Årsb.Sveriges Geol. Unders*, **65** (15), Ser. C, n. 669, 1-35.

Kjellström, G. 1972. Lower Viruan microplankton from a boring in Öland, Sweden. *N. Jb. Geol. Paläont. Mh.*, H, **12**, 713-719.

Kjellström, G. 1976. Lower Viruan (Middle Ordovician) microplankton from the Ekön Borehole No. 1 in Ostergötland, Sweden. *Årsb.Sveriges Geol. Unders*, **65** (15), Ser. C, n. 724, 1-44.

Konzalová-Mazancová, M. 1969. Acritarchs Evitt 1963 aus dem Unter-Ashgill Böhmens. *Palaeontographica*, Abt. B, **125**, 81-92.

Kozlowski, R. 1963. Sur la nature des chitinozoaires. *Acta Palaeontologica Polonica*, **8**, 425-449.

Lamont, A. and Lindström, M. 1957. Arenigian and Llandeilian cherts identified in the Southern Uplands of Scotland by means of conodonts, etc. *Trans. Edin. geol. Soc.*, **17**, 60-70.

Lapworth, C. 1878. The Moffat Series. *Ouart. J. geol. Soc. London, 34*, 240-346.

Laufeld, S., 1967 Caradocian Chitinozoa from Dalarna, Sweden. *Geologiska Föreningens i Stockholm Förhandlingar* , 89, 275-349.

Laufeld, S. 1971. Chitinozoa and correlation of the Molodova and Restovo Beds of Podolia, U.S.S.R. Colloque Ordovicien-Silurien, *Extrait du Mémoire du B.R.G.M.*, **73**, 291-300.

Laufeld, S., 1974. Silurian chitinozoa from Gotland. *Fossils and Strata*, **5**, 130pp.

Legall, F.D., Barnes, C.R. and MacQueen, R.W. 1982. Thermal maturation, burial history and hotspot development, Paleozoic strata of southern Ontario-Quebec, from conodont and acritarch colour alteration studies.*Bull. Can. Pet. Geol.*, **29**, 492-539.

Legault, J.A. 1973. Mode of aggregation of *Hoegisphaera* (Chitinozoa). *Can. J. Earth Sci.*, **10**, 793-797.

Legault, J.A. 1982. First report of Ordovician (Caradoc-Ashgill) palynomorphs from Orphan Knoll, Labrador Sea. *Can. J. Earth Sci.*, **19**, 1851-1856.

Leggett, J.A. 1978. Eustacy and pelagic regimes in the lapetus Ocean during the Ordovician and the Silurian. *Earth, planet. Sci. Lett.*, **41**, 163-169.

Leggett, J.K. 1980. British Lower Palaeozoic black shales and their palaeo-oceanographic significance. *J. geol. Soc. London*,**136**, 755-770.

Leggett, J.K. 1987. The Southern Uplands as an accretionary prism: the importance of analogues in reconstructing palaeogeography. *J. geol. Soc.*, **144**, 737-752.

Leggett, J.K., McKerrow, W.S., Morris, J.H., Oliver, G.J.H., and Phillips, W.E.A., 1979. The north-western margin of the lapetus Ocean. *In* The Caledonides of the British Isles - reviewed, *Geological Society of London*, p. 499-512.

Lespérance, P.J. 1985. Faunal distributions across the Ordovician-Silurian boundary, Anticosti Island and Percé, Québec, Canada. *Can. J. Earth Sci.*,**22**, 838-849.

Lespérance, P.J., Barnes, C.R., Berry, W.B.N., Boucot, A.J. and Mu En-Zhi, 1987. The Ordovician-Silurian boundary stratotype: consequences of its approval by the IUGS. *Lethaia*, **20**, p.217-222.

Lindstrom, M. 1957. Two Ordovician conodont faunas with zonal graptolites. *Geol. Fören Stockholm Förhandl*, **79**, 161-178.

Lister, T.R., 1970. The acritarchs and chitinozoa from the Wenlock and Ludlow Series of the Ludlow and Millichope areas, Shropshire. *Palaeontogr. Soc. [Monogr.]* **124**, p. 1-100.

Lister. T.R., Burgess, I.C. and Wadge, A.J. 1968. Microfossils from the cleaved Skiddaw Slates of Murton Pike and Brownber (Cross Fell Inlier). *Geol. Mag.*, **106**, 97-99.

Lister, T.R., Cocks L.R.M. and Rushton, A.W.A. 1969. The Basement Beds in the Bobbing Borehole, Kent. *Geol. Mag.* **106**, 601-603.

Loeblich, A.R. Jr. 1970 . Morphology, ultrastructure and distribution of Paleozoic acritarchs. *Proc. N. Amer. Paleont. Conv.* G,705-788.

Loeblich, A.R. and MacAdam, R.B. 1971. North American species of the Ordovician acritarch genus *Aremoricanium.* *Palaeontographica* ,Abt. B, **135**, 41-47, pls 1-4.

Loeblich, A.R. Jr. and Tappan, H., 1969. Acritarch excystment and surface ultrastructure with descriptions of some Ordovician taxa. *Rev. Esp. Micropaleontol.*, **1**, p. 45-57.

Loeblich, A.R. Jr. and Tappan, H., 1971. Two new *Orthosphaeridium* (Acritarcha) from the Middle and upper Ordovician. *Trans Amer. Micros. Soc.*, **90**, 182-188.

Loeblich, A.R. Jr. and Tappan, H., 1978. Some Middle and Late Ordovician microphytoplankton from Central North America. *J. Paleont.*,**52**, p. 1233-1287.

Lohmann, H. 1904. eier und sogenannte Cysten der Plankton-Expedition. Anhang: Cyphonautes. *Ergebnisse der Plankton-Expedition Humboldt-Stiftung*, new ser., **4**, 1-62

Longman, C.D., Bluck, B.J., and van Breeman, O. 1979. Ordovician conglomerates and the evolution of the Midland Valley. *Nature*, **280**, 578-581.

Locquin, M.V. 1977. Fungi of the Lower Palaeozoic. Second International Conference of Mycology, Symposium on Fossil Fungi. March 1977, Tampa U.S.A.

Lyell, C. 1825. On a dike of serpentine, cutting through sandstone, in the county of Forfar. *Edin. J. Sci.*, **1**, 112-8.

MacCulloch, J. 1924. On the limestone of Clunie, in Perthshire, with remarks on the Trap and Serpentine. *Edin. Journ. Sci.*, **1**,1-16.

Mädler, K. A. 1963. Die figurierten organischen Bestandteile der Posidonienschiefer. *Beih. Geol. Jb.*, **58**, 287-406.

Mädler, K.A. 1967. Hystrichophyta and acritarchs. *Rev. Palaeobot. Palyn.*, **5**, 285-290.

Martin, F., 1966a (1965). Les acritarches de Sart-Bernard, (Ordovicien, Belge). Bull. Soc. belge. Géol. Paléont. Hydrol., **74**, p. 423-444.

Martin, F., 1966b (1965). Les acritarches du sondage de la brasserie Lust, à Kortrijk, (Courtrai), (Silurien-Belge). *Bull. Soc. belge. Géol. Paléont. Hydrol.*, **74**, p. 354-400.

Martin, F., 1969 (1968). Les acritarches de L'Ordovicien et du Silurien Belges. Détermination et valeur stratigraphique. *Mem. Inst. R. Sci. nat. Belge.*, **160**, p. 1-175.

Martin, F. 1974 (1973). Ordovicien supérieur et Silurien inférieur a Deerlijk (Belgique). Palynofa cies et Microfa cies. *Mém, Inst. R. Sci. nat. Belge*, **174**, 1-71.

Martin, F. 1975. Sur quelques chitinozoaires Ordoviciens du Québec et de l'Ontario. *Can. J. Earth Sci.*, **12**, 1006-1018.

Martin, F. 1980. Quelques chitinozoaires et acritarches Ordoviciens supérieurs de la Formation de White Head en Gaspésie, Québec. *Can. J. Earth Sci.*, **17**, 106-119.

Martin, F. 1983. Chitinozoaires et acritarches Ordoviciens de la plate-forme du Saint-Laurent (Québec et Sud-est de l'Ontario). *Bull. Geol Soc. Canada,* **310**, 99pp.

McCurry, J.A. 1986. Obduction accretion in the Southern Uplands Terrane. Suspect Terranes Conference, Cardiff, October 1986, (abstract only).

McKerrow, W.S., Leggett, J.K., and Eales M.H., 1977. Imbricate thrust model of the Southern Uplands of Scotland. Nature, **267**, p. 237-239.

Miller, M.E. and Eames, L.E. 1982. Palynomorphs from the Silurian Medina Group (lower Llandovery) of the Niagara Gorge, New York, USA. *Palynology,* **6**, 221-254.

Mitchell, A.H.G. and McKerrow, W.S. 1975. Analagous evolution of the Burma orogen and the Scottish Caledonides. *Geol. Soc. Am. Bull.*, 86, 305-315.

Molyneux, S. G. 1979. New evidence for the age of the Manx Group, Isle of Man. *In* Harris, A.L, Holland, C.H. and Leake, B.E. (Eds): *The Caledonides of the British Isles Reviewed,* Geol. Soc. London, Spec. Publ., 8, 415-423.

Molyneux, S. G. 1987. Probable early Wenlock acritarchs from the Linkim Beds of the Southern Uplands. *Scott. J. Geol.*, **23**, 301-313.

Molyneux, S.G. and Paris, F. 1985. Ordovician acritarchs and chitinozoa. In *The Palynostratigraphy of north-east Libya.* Thusu, B. and Owens, B. (*eds*). *J. Micropal.*, **4**, 11-26.

Molyneux, S.G. and Rushton, A.W.A. 1984. Discovery of Tremadoc rocks in the Lake District. *Proc. Yorks Geol. Soc.*, **45**, 123-127.

Morris, J.H. 1987. The Northern Belt of the Longford-Down Inlier, Ireland and Southern Uplands, Scotland: an Ordovician back-arc basin. *J. Geol. Soc. London*, **144**, 773-787.

Moseley, F. 1977. Caledonian plate tectonics and the place of the English Lake District. *Bull. Geol. Soc. Amer.,* **88**, 704-768.

Moseley, F. 1978. The geology of the English Lake District. An introductory review. *In* Moseley, F. (ed.). *The geology of the Lake District. Yorks geol. Soc. Occ. Publ.,* **3**, 1-16.

Muir, M.D. and Sutton, J. 1970. Some fossiliferous Pre-Cambrian chert pebbles from the
Torridonian of Britain. *Nature,* **226**, p. 443-445.

Murphy, F.C. and Hutton, D.H.W. 1986. Is the Southern Uplands really an accretionary prism? *Geology,* **14**, 354-357.

Naumova, S.N. and Pavlovsky, E.V. 1961. The discovery of plant remains (spores) in the Torridonian shales of Scotland. *Akad. Nauk. SSR Doklady,* **141**, p. 181-2 (in Russian).

Nautiyal, A.C. 1977. The paleogeographic distribution of Devonian acritarchs and biofacies belts. *J. Geol. India,* **18**, 53-64.

Needham, D.T. and Knipe, R.J. 1986. Accretion- and collision- related deformation in the Southern Uplands accretionary wedge, southwestern Scotland.

Geology, **14**, 303-306.

Newton, E.T. 1875. On "Tasmanite" and Australian "White Coal". *Geol. Mag.*, **12**, 337-343.

Neville, R.S.W. 1974. Ordovician chitinozoa from western Newfoundland. *Rev. Palaeobot. Palyn.*, **18**, 187-221.

Nichol, J. 1850. Observations on the Silurian strata of the south-east of Scotland. *Q. J. Geol. Soc. London*, **6**, 53-65.

Nicholson, H.A. 1867a-d. Graptolites of the Moffat Shale. *Geol. Mag.*, **4**, 108-113, 135-136, 238-239, 256-263.

Nõlvak, J. 1980. Chitinozoa and biostratigraphy of the north east Baltic Ashgillian : a preliminary report. *Acta Palaeontologia Polonica*, **25**, 253-260.

Nowlan, G.S. and Barnes, C.R. 1987. Thermal maturation of Paleozoic strata in eastern Canada from conodont colour alteration index (CAI) data, with implications for burial history, tectonic evolution, hotspot tracks and mineral and hydrocarbon exploration. *Bull. Geol. Surv Canada*, **367**, 47pp.

Oliver, G.J., Smellie, J.L., Thomas, L.J., Casey, D.M., Kemp, A.E.S., Evans, L.J., Baldwin, J.R. and Hepworth, B.C. 1984. Early palaeozoic metamorphic history of the Midland valley, Southern Uplands-Longford Down Massif and the Lake District, British Isles. *Trans R. Soc. Edin., Earth Sci.*, **75**, 245-258.

Oyen, F.H. van and Calandra, F. 1963. Note sur les chitinozoaires. *Revue de microplaeontologie*, **6**, 13-18.

Packham, G.H. 1962. Some diplograptids from the British Lower Silurian. *Palaeontology*, **5**, 498-526.

Pacltová, B., 1986. Palynology of metamorphic rocks (a methodological study). *Rev. Palaeobot. Palynol.*, **48**, 347-356.

Paris, F. 1976. Les chitinozoaires. *In* Les schistes et calcaires éodévonians de Saint-Cénére (Massif Armoricain, France). Sédimentologie, Paléontologie, Stratigraphie. *Ann. Soc. géol. Nord.*, **91**, 241-251.

Paris, F. 1979. Les chitinozoaires de la Formation de Louredo, Ordovicien superieur du synclinal de Buçaco (Portugal). *Palaeontographica*, Abt. A, **164**, 24-51.

Paris, F., 1981 Les chitinozoaires dans les Paléozoiques du sud-ouest de l'Europe. *Mem. Soc. géol. minéral. Bretagne*, **26**, 412 pp.

Paris, F. and Deunff, J. 1970. Le paléoplancton Llanvirnien de la Roche-au-Merle (commune de Vieux-Vy-sur-Couesnon, Ille et Vilaine). *Bull. Soc. geol. mineral. Bretagne*, série C, **2**, 25-43.

Paris, F. and Mergl. M. 1981. Arenig chitinozoans from the Klabava Formation, Bohemia. *Rev. Palaeobot. Palyn.*, **43**, 33-65.

Peach, B.N. and Horne, J. 1899. The Silurian rocks of Britain, vol. 1, Scotland. *Mem. geol. Surv.*, 749pp.

Pringle, J. 1939. The discovery of Cambrian trilobites in the Highland Border rocks near Callander, Perthshire. *Rept. Br. Ass. Advmt. Sci.*, p.252.

Pringle, J. 1941. On the relationship of the Green Conglomerate to the Margie Grits in the North Esk, near Edzell; and on the probable age of the Margie Limestone. *Trans. Geol. Soc. Glasgow*, **20**, 136-140.

Profichet, P. 1979. A propos de la morphologie de Chitinozoaires du Paléozoique saharien. *Ann. Paléont. (Invertébrés), 65*, 53-68.

Rauscher, R. 1968. Chitinozoaires de l'Arenig de la Montagne Noire (France). *Rev. Micropal.*,**11**, 51-60.

Rauscher, R. 1970. Les chitinozoaires de l'Ordovicien du synclinal de May-sur Orne (Calvados). *Bull. soc. linn. Normandie*, **101**, 117-127.

Rauscher, R. 1974. Recherches micropaléontologiques et stratigraphiques dans l'Ordovicien et le Silurien en France. Etude des Acritarches, des Chitinozoaires et des spores. *Sciences géologiques* (Université Louis Pasteur de Strasbourg, Institut de Géologie), **38**, 224pp.

Rauscher, R. and Doubinger, J. 1967. Associations de Chitinozoaires de Normandie et comparaisons avec les faunes déjà décrites. *Bull. Serv. Carte géol. Als. Lorr.*, **20**, 307-328.

Reid, P.C. and Allitt, U. 1981. Comments on the pseudo-microfossil Linotolypen. *Rev. Palaeobot. Palynol.*,**34**, 263-267.

Reid, P.C. and John, A.W.G. 1978. Tintinnid cysts. *J. Marine Biol. Ass. U.K.*,**58**, 551-557.

Rickards, R.B. 1979. New information on some Ordovician-Silurian boundary sections in Great Britain. *Izv. Akad. Nauk. Kazakj. S.S.R. Geol.*,**4**, 103-107.

Riding, J.B. 1981. The nature and affinity of chitinozoa - a review. *J. Univ. Sheffield, Geol. Soc.*, **7**, 262-268.

Robertson, A.H.F. and Henderson, W.G. 1984. Geochemical evidence for the origins of igneous and sedimentary rocks of the Highland Border, Scotland. *Trans R. Soc. Edin.*, **75**, 135-150.

Ross, R.J. and Ingham, J.K., 1970. Distribution of Toquima-Table Head (Middle Ordovician Whiterock) faunal realm in the northern hemisphere. *Geol Soc. Am. bull.*, **81**, 393-408.

Rowell, A.J. 1963. In *Summ. Prog. Surv. Gt. Britain for 1962*, 57.

Rushton, A.W.A., Stone, P., Smellie, J.L. and Tunnicliff, S.P. 1986. An early Arenig age for the Pinbain sequence of the Ballantrae Complex. *Scott, J. Geol.*, **22**, 41-54.

Sannemann, D. 1955. Hystrichosphaerideen aus dem Gotlandium und Mittel-Devon des Frankenwaldes und heir feinbau. *Senckenbergiana Leth.*, **36**, 321-346.

Sarjeant, W. A. S. 1970. Acritarchs and tasmanitids from the Chhidru Formation, uppermost Permian of West Pakistan. *In* Kummel, B. and Teichert, C., *Stratigraphic boundary problems: Permian and Triassic of West Pakistan.*

Univ. Kansas Dept. Geol., Spec. Publ., **4**.

Sarjeant, W. A. S. and Strachan, I. 1968. Freshwater acritarchs in Pleistocene peats from Staffordshire, England. *Grana Palynol.*, **8**, 204-209.

Schallreuter, R. 1981. Chitinozoen aus dem Sularpschiefer (Mittel-Ordoviz) von Schonen, (Schweden). *Palaeontographica*, Abt. B, **178**, 89-142.

Schallreuter, R. 1983. Sularpschiefer (Mittelordoviz) als Geschiebe in Norddeutschland. *Mitt. Geol. Paläont. Inst. Univ. Hamburg*, **54**, 55-64.

Shackleton, R.M. 1958. Downward facing structures of the Highland Border. *Q. Jl. Geol. Soc. London*, **113**, 361-78.

Shiells, K.A.G., and Dearman, W.R., 1963. Tectonics in the Coldingham Bay area of Berwickshire, in the Southern Uplands of Scotland. *Proc. Yorks Geol. Soc*, **34**, p. 209-234.

Siveter, D.J., Ingham, J.K. Rickards, R.B., and Arnold, B. 1980. Highest Ordovician trilobites and graptolites from County Cavan, Ireland. *J. Earth Sci. R. Dublin Soc.*, **2**, 193-207.

Smith, D.G. 1977. Lower Cambrian palynomorphs from Howth, County Dublin. *Geol. Journ.*, **12**, 159-168.

Smith, D.G. 1979. The distribution of trilete spores in Irish Silurian rocks. *In* Harris, A.L., Holland, C.H. and Leake, B. E. (eds), *The Caledonides of the British Isles-Reviewed. Geol. Soc. Lond. Spec. Publication*, **8**, 423-433.

Smith, N.D. and Saunders, R.S. 1970. Paleoenvironments and their control of acritarch distribution : Silurian of east-central Pennsylvania. *J. Sed. Pet.*, **40**, 324-333.

Sokal, R. R. and Sneath, P. H. A. 1963. Priciples of numerical taxonomy. W.H. Freeman, San Francisco, 359pp.

Staplin, F.L., 1961. Reef controlled distribution of microplankton in Alberta. *Palaeontology*, **4**, p. 394-424.

Staplin, F.L. 1969. Sedimentary organic matter, organic matter, organic metamorphism, and oil and gas occurrence. *Bull. Can. Petroleum Geology*, **17**, 47-66.

Staplin, F.L. 1977. Interpretation of thermal history from color of particulate organic matter- a review. *Palynology*, **1**, 9-18.

Staplin, F.L., Jansonius, J. and Pocock, S.A.J.,1965. Evaluation of some acritarchous hystrichosphere genera. *Neues Jb. Geol. Paläont. Abh.* **123**, p. 167-201.

Stauffer, C.R. 1933. Middle Ordovician Polychaeta from Minnesota. *Bull. geol. Soc. America*, **44**, 1173-1218.

Stockmans, F., and Willière, Y., 1960. Hystrichosphères du Dévonien belge (Sondage de l'Asile d'Aliénés à Tournai). *Senckenberg. Leth.*, **41**, p. 1-11.

Stockmans, F., and Willière, Y., 1962. Hystrichosphères du Dévonien belge (Sondage de l'Asile d'Aliénés à Tournai). *Bull. Soc. belge. Géol. Paléont. Hydrol.*, **71**, p.41-77.

Stockmans, F and Willière, Y. 1963. Les hystrichosphères ou mieux les acritarches du Silurien belge, Sondage de la Brasserie Lust à Courtrai (Kortrijk). *Bull. Soc. belge. Géol. Paléont. Hydrol.*, **71**, p.450-481.

Stone, P. Floyd, J. D., Barnes, R.P. and Lintern, B.C. 1986. A sequential back-arc and foreland basin thrust duplex model for the Southern Uplands of Scotland. Suspect Terranes Conference, Cardiff, October 1986, (abstract only).

Stone, P. Floyd, J.D., Barnes, R.P. and Lintern, B.C. 1987. A sequential back-arc and foreland basin thrust duplex model for the Southern Uplands of Scotland. *J. Geol. Soc. London*, **144**, 753-764.

Strother, P.K. and Traverse, A. 1979. Plant microfossils from Llandoverian and Wenlockian rocks of Pennsylvania. *Palynology*, **3**, 1-21.

Tappan, H. 1966. Chitinozoan classification. *J. Paleont.*, **40**, 1394-1396.

Tappan, H. 1968. Primary production, isotopes, extinctions and the atmosphere. *Palaeogeogr. Palaeoclimat. Palaeoecol.*,**4**, 187-210.

Tappan, H. 1980. The paleobiology of the plant protists. 1028pp. Freeman, San Francisco.

Tappan, H. and Loeblich, A. 1971. Surface sculpture of the wall in Lower Paleozoic acritarchs. *Micropaleontology*, 17, 385-410.

Taugourdeau, P. 1961. Chitinozoaires du Silurien d'Aquitaine. *Revue de Micropal.*,**4**, p. 135-154, pls.1-6, Paris.

Taugourdeau, P. 1965. Chitinozoaires de l'Ordovicien de USA. Comparison avec les faunes de l'ancien monde. *Revue de l'Institut Français de Pétrole*, **20**, 463-485.

Taugourdeau, P. 1966a. Les chitinozoaires : techniques d'études, morphologie et classification. *Nouvelle série-Tome XLV - Fasc. 1 - Feuilles 1 a 4, Mémoire*, **104**, 64pp.

Taugourdeau, P. 1966b. Néotypes de chitinozoires. *Rev. de Micropaléontologie*, **9**, 258-264.

Taugourdeau. P., Bouché, P., Combaz, A., Magloire, L. and Millepied, P. 1967. Microfossiles organiques du Paléozoique I: les chitinozoaires. C.I.M.P., Paris, Editions du Centre National de la Recherche Scientifique.

Taugourdeau, P. and Jekhowsky, B. de, 1960. Répartition et description des Chitinozoaires siluro-dévoniens de quelqes sondages de la C.R.E.P.S., de la C.F.P.A. et de la S.N. REPAL au Sahara. *Rev. Inst Franç. du Pétrole*, **XV**, **9**,p.1199-1260, 19 figs., 13 pls., 1 dpl. h.-t., Paris.

Taugourdeau, P. and Jekhowsky, B. de, 1964. Chitinozoaires siluriens de Gotland; comparison avec les faunes Sahariennes. *Rev. Inst Franç. du Pétrole*, **7-8**, 845-871.

Taugourdeau, P. and Magloire, L. 1964. Les dimorphisme chez les chitinozoaires. *Bull. soc. géol. de France*, **7**, 674-677.

Thusu, B. 1972. Depositional environments of the Rochester Formation (Middle Silurian) in southern Ontario. *J. Sed. Pet.*,**42**, 930-934.

Thusu, B. 1973. Acritarches provenant de l'Ilion Shales (Wenlockien), Utica, New York. *Rev. de Micropaléont.*, **16**, 137-146.

Timofeev, B.V. 1966. Mikropaleofitologicheskoe isseldovanie drevnikh svit [Micropalaeontological investigations of ancient strata]. *Akad. Nauk. SSSR, Lab. geol. Dokembriya, Moscow,* 147pp.

Toghill, P. 1986a. The stratigraphical relationships of the earliest Monograptidae and the Dimorphograptidae. *Geol. Mag.*, **105**, 46-51.

Toghill, P. 1968b. The graptolite assemblages and zones of the Birkhill Shales (Lower Silurian) at Dobb's Linn. *Palaeontology,* **11**, p. 654-668.

Toghill, P. 1970. The south-east limit of the Moffat Shales in the upper Ettrick valley region, Selkirkshire, *Scott. J. Geol.*, **6**, 233-42.

Turner, R.E. 1979. Acritarchs of Llandeilo and Caradoc age from classic localities in Britain. Ph.D. Thesis, University of Sheffield (Unpublished).

Turner, R. E. 1982. Reworked acritarchs from the type section of the Ordovician Caradoc Series, Shropshire. *Palaeontology,* **25**, 119-143.

Turner, R.E. 1984. Acritarchs from the Type Area of the Ordovician Caradoc Series, Shropshire, England. *Palaeontographica*, Abt.B, **190**, p. 87-157.

Turner, R.E. 1985. Acritarchs from the type area of the Ordovician Llandeilo Series, South Wales. *Palynology,* **9**, 211-234.

Tynni, R. 1975. Ordovician hystrichospheres and Chitinozoans in limestone from the Bothnian Sea. *Geol. Surv. Finland,* **279**, 5-54.

Voss-Foucart, M.F., and Jeuniaux, Ch., 1972. Lack of chitin in a sample of Ordovician chitinozoa. *J. Palaeont.*, **46**, p. 769-770.

Umnova, N.I. 1969. Distribution of the chitinozoa in the Ordovician of the Russian Platform, *Paleont. Journ.*, **3**, 326-240. [Translation of Rasprostraneniye chitinozoa v. ordovike Ruskoy platformy. *Paleont. Zhur.*, **3**, 45-62.

Urban, J.B. and Kline, J.L. 1970. Chitinozoa of the Cedar city Formation, middle Devonian of Missouri. *J. Paleont.*,**44**, 69-76.

Vavrdova, M. 1974. Geographic distribution of Ordovician acritarch assemblages in Europe. *Rev. Palaeobot. Palynol.*, **18**, 171-176.

Wadge, A.J., Owens, B. and Downie, C. 1967. Microfossils from the Skiddaw Group. *Geol. Mag.*, **104**, 506-507.

Wall, D. 1965. Microplankton, pollen and spores from the Lower Jurassic in Britain. *Micropaleontology*,**11**, 151-190.

Walton, E.K. 1983. Lower Palaeozoic stratigraphy, structure and palaeogeography. *In* Craig G.Y. (editor) *Geology of Scotland,* Scottish Academic Press, 105-166.

Wetzel, O. 1933. Die in organischer Substanz erhaltenen Mikrofossilien des baltischen Kreidefeuersteins. *Palaeontographica Abt. A,* **77**, 141-188.

White, M.C. 1862. Discovery of microscopic organisms in the siliceous nodules of the Palaeozoic rocks of New York. *Am. J. Sci.*, ser. 2, **33**, 385-386.

Whelan, G. M., 1988. Preliminary Acritarch and Chitinozoan Distribution across the Type Ordovician-Silurian Boundary at Dob's Linn, Scotland. *In* Cocks, L.R.M., and Rickards, R.B., (eds) : *A Global Analysis of the Ordovician-Silurian Boundary.* (in press), *Bull. British Museum (Natural History) Geology Series.*

Whelan, G.M., Bluck, B.J. and Burton, C.J. A preliminary biostratigraphy for the Highland Border Complex (in prep.).

Whelan, G.M. and Burton, C.J. 1988. Acritarchs and chitinozoans from the Ordovician-Silurian boundary stratotype sediments. *Lethaia,* **21**, 38.

Wilde, P., Hunt, M.Q., Berry, W.B.N. and Orth, C.J. 1984. Anoxic facies in the Lower Paleozoic ocean. *Geological Society of America Abstracts with Programs,* **16**, 694.

Wilde, P., Berry, W.B.N., Quinby-Hunt,M.S., Orth, C.J., Quintana, L.R., and Gilmore, J.S., 1986. Iridium Abundances Across the Ordovician-Silurian Stratotype. *Science,* **233**, p. 339-341.

Williams, A. 1962. The Barr and Lower Ardmillan Series (Caradoc) of the Girvan District, south-west Ayrshire. *Mem. geol. Soc. London,* **3**, 1-267, pls 1-25.

Williams, G.L. 1978. Dinoflagellates, acritarchs and tasmanitids. *In* Haq, B.U. and Boersma, A. (eds), *Introduction to marine micropalaeontology,* Elsevier Press, 293-326.

Williams, S.H., 1980. An excursion guide to Dob's Linn. *Proc. Geol. Soc. of Glasgow,* **121/122**, 13-18.

Williams, S.H., 1981. The Ordovician and Lowest Silurian Graptolite Biostratigraphy in
Southern Scotland. Unpublished Ph.D.Thesis, University of Glasgow.

Williams, S.H., 1982a. The late Ordovician graptolite fauna of the Anceps Bands at Dob's Linn, southern Scotland. *Geol. Palaeontol.,* **16**, 29-56.

Williams, S.H., 1982b. Upper Ordovician graptolites from the top Lower Hartfell Shale (*D. clingani* and *P. linearis* zones) near Moffat, southern Scotland. *Trans. R Soc. Edin. Earth Sci.,* **72**, 229-255.

Williams, S.H., 1983. The Ordovician-Silurian boundary graptolite fauna of Dob's Linn, southern Scotland. *Palaeontology,* **26**, 605-639.

Williams, S.H., 1986. Top Ordovician and lowest Silurian of Dob's Linn. *In* Hughes, C.P. and Rickards, R.B. (eds), *Palaeoecology and Biostratigraphy of Graptolites, Geol. Soc. Spec. Publ.,* **20**, 165-171.

Williams, S.H. 1987. Upper Ordovician graptolites from the *D. complanatus* Zone of the Moffat and Girvan districts and their significance for correlation. *Scott. J. Geol.,* **23**, 65-92.

Williams, S.H. 1988. Dob's Linn - the Ordovician-Silurian boundary stratotype. *In* Cocks, L.R.M., and Rickards, R.B., (eds) : *A Global Analysis of the Ordovician-Silurian Boundary. Bulletin British Museum (Natural History) Geology Series* (in press).

Williams, S.H. and Ingham, J.K., (in prep.) Graptolites and stratigraphy of the

Upper Ordovician D. complanatus Zone in Scotland. *Scott. J. Geol.*

Williams, S.H. and Lockley, M.G., 1983. Ordovician inarticulate brachiopods from graptolitic shales at Dob's Linn, Scotland ; their morphology and significance. *J. Paleont.*, 57, 391-400.

Williams, S.H. and Rickards, R.B.,1984. Palaeoecology of graptolitic black shales. *In* Bruton, D.L. (ed). *Aspects of the Ordovician System. Palaeont. Contr. Univ. Oslo* , 295, 159-166. Universitetsforlaget.

Wilson, L.R. 1958a. A chitinozoan faunule from the Sylvan Shale of Oklahoma. *Oklahoma Geol. Survey notes*, 18, 67-71.

Wilson, L.R. 1958b. Microfossil faunule from Sylvan Shale of Oklahoma. *Bull. Geol. Soc. Amer.*, 69, 1663.

Wilson, L.R. and Dolly, E.D. 1964. Chitinozoa in the Tulip Creek Formation, Simpson Group (Ord.) of Oklahoma. *Oklahoma. Geol. Survey Notes*, 24, 224-232.

Wilson, L.R. and Hedlund, R.W. 1964. *Calpichitina scabiosa*; a new chitinozoan from the Sylvan Shale (Ordovician) of Oklahoma. *Oklahoma Geological Survey Notes*, 24, 161-164.

Wright, R.P. 1978. Biogeography of Middle Devonian Chitinozoa of the Midwestern United States. *Palinologia*,num. extr. 1, 501-505.

Wright, R.P. and Meyers, W.C. 1981. Organic-walled microplancton in the subsurface Ordovician of north-east Kansas. *Kansas Geol. Surv. Subsurface Geol.*, Ser. 4, 1-53.

Wrona, R. 1980. Lower Silurian to Lower Devonian chitinozoa from the subsurface of south east Poland. *Palaeontologia Polonica*, 41, 103-165.

Dorning, K.J (1981b). Silurian acritarch distribution in the Ludlovian shelf sea of South Wales and the Welsh Borderland. In Neale, J.W. and Bradier, M.D. (eds). Microfossils from Recent and fossil shelf seas. Ellis Horwood Ltd., Chichester, 31-36

Read, H.H. (1961). Aspects of Caledonian magmatism in Britain. Lpool Manchester. geol. J., 2, 653-683.

Williams, G.L., Sarjeant, W.A.S and Kidson, E.J. (1978). A glossary of the terminology applied to dinoflagellate amphiesmae and cysts and acritarchs. American. Assoc. Strat. Palynologists, Contrib. Ser., 2A.

Plates

Abbreviations

H.M. no. : Hunterian Museum specimen number

E.F.R. : England Finder Reference number

Mag. : Magnification

Plate 1

	H.M. no.	Sample	E.F.R.	Mag.
1. *Acanthochitina barbata* Eisenack emend. Jenkins 1967				
	x1260	MV/G/28(3)	H30/1	150
2. *Acanthochitina barbata* Eisenack emend. Jenkins 1967				
	x1261	MV/G/28		150
3. *Acanthochitina barbata* Eisenack emend. Jenkins 1967				
	x1262	MV/G/27		400
4. *Ancyrochitina ancyrea* (Eisenack 1931)				
	x1263	SU/DL/41(7)	D44/3	400
5. *Ancyrochitina ancyrea* (Eisenack 1931)				
	x1264	SU/DL/56(4)	A36/3	320
6. *Ancyrochitina ancyrea* (Eisenack1931)				
	x1265	SU/DL/41(5)	U62/2	500
7. *Ancyrochitina ancyrea* (Eisenack1931)				
	x1266	SU/DL/41(5)	R50/4	400
8. ?*Ancyrochitina corniculans* Jenkins 1967				
	x1267	SU/DL/57(2)	F19/2	220
9. *Ancyrochitina ancyrea* (Eisenack1931)				
	x1268	SU/DL/54(1)	E30/2	400
10. *Ancyrochitina* sp. B	x1269	MV/G/21		500
11. *Ancyrochitina* sp. A	x1270	SU/DL/50(1)	L50/2	200
12. *Armoricochitina nigerica* (Bouché1965)				
	x1271	SU/DL/2(2)	K33/1	250

PLATE 1

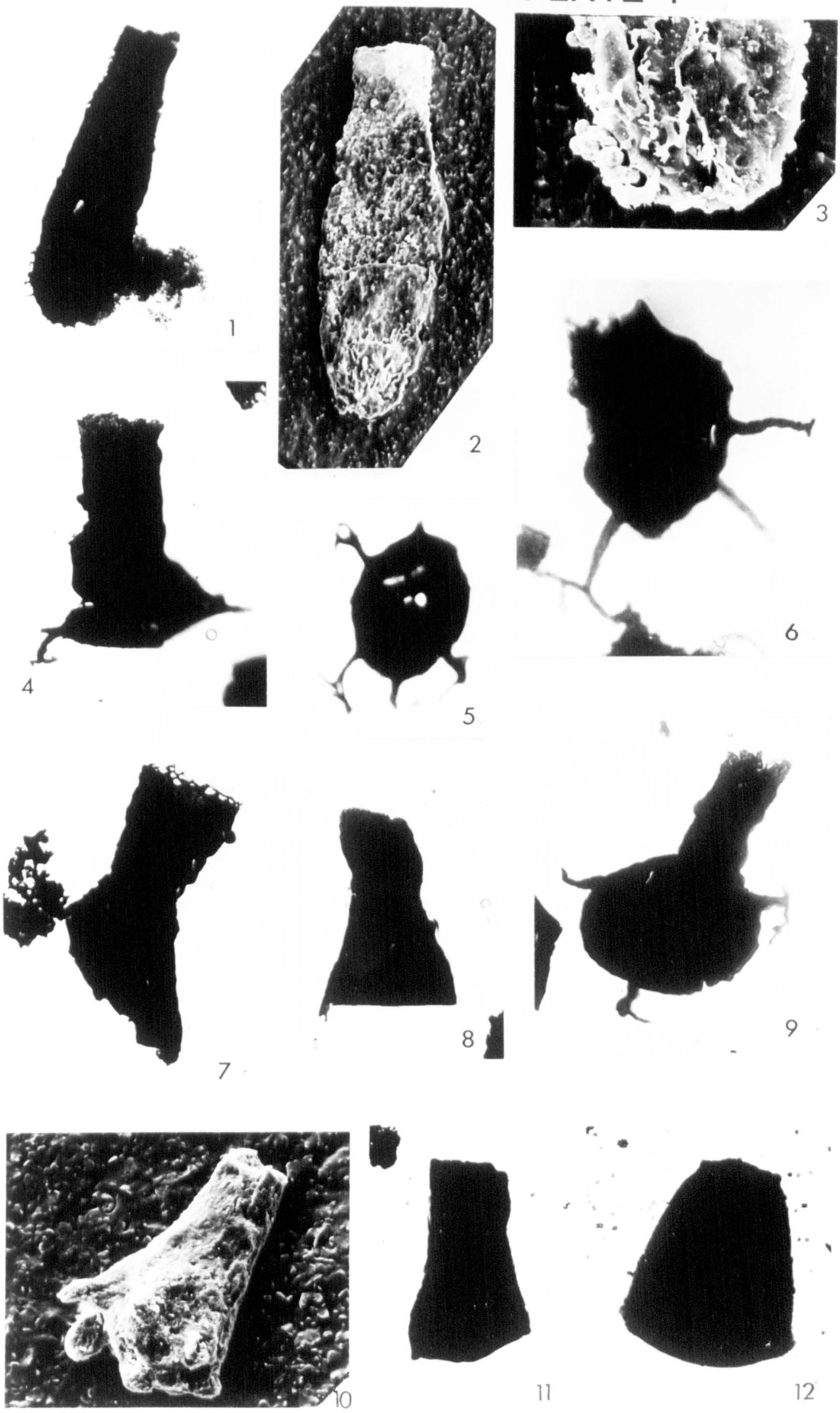


Plate 2.

	H.M. no.	Sample	E.F.R.	Mag.
1. *Angochitina woodlandensis* n. sp.				
	x1272	MV/G/23(1)	G26/2	500
2. *Angochitina woodlandensis* n. sp.				
	x1273	MV/G/25(1)	V41/3	400
3. *Angochitina woodlandensis* n. sp.				
	x1274	MV/G/23(1)	K41/3	500
4. *Belonechitina comma* (Eisenack 1959)				
	x1275	MV/G/28(3)	V49/1	200
5. *Belonechitina comma* (Eisenack1959)				
	x1276	MV/G/28		800
6. *Belonechitina comma* (Eisenack1959)				
	x1277	MV/G/28		150
7. *Belonechitina* cf.*hirsuta* (Laufeld 1967)				
	x1278	MV/G/23(2)	R26/1	500
8. *Belonechitina* cf.*hirsuta* (Laufeld 1967)				
	x1279	MV/G/22(1)	S31/3	500
9. *Belonechitina micracantha* (Eisenack 1931)				
	x1280	MV/G/26(2)	M27/3	500
10. *Belonechitina micracantha* (Eisenack 1931)				
	x1281	MV/G/23		230
11. *Belonechitina* cf.*hirsuta* (Laufeld 1967)				
	x1282	MV/G/6(1)	H41/4	400.

PLATE 2

Plate 3

	H.M. no.	Sample	E.F.R.	Mag.
1. *Belonechitina micracantha* (Eisenack 1931)				
	x1283	MV/G/18(2)	S46/2	300
2. *Belonechitina micracantha* (Eisenack 1931)				
	x1284	SU/DL/9(1)	O46/1	150
3. *Belonechitina robusta* (Eisenack 1959)				
	x1285	MV/G/6		500
4. *Belonechitina schopfi americana* (Taugourdeau 1965)				
	x1286	MV/G/18(3)	H30/3	400
5. *Belonechitina robusta* (Eisenack 1959)				
	x1287	MV/G/20		500
6. *Belonechitina robusta* (Eisenack 1959)				
	x1285	MV/G/6		250
7. *Belonechitina wesenbergensis* (Eisenack 1959)				
	x1288	MV/G/22		400
8. *Belonechitina robusta* (Eisenack 1959)				
	x1287	MV/G/20		400
9. *Belonechitina seriespinosa* (Jenkins 1969)				
	x1289	MV/G/18(1)	D31/2	400
10. *Belonechitina wesenbergensis* (Eisenack 1959)				
	x1290	MV/G/28(1)	M50/1	400
11. *Belonechitina wesenbergensis* (Eisenack 1959)				
	x1288	MV/G/22		300
12 *Belonechitina seriespinosa* (Jenkins 1969)				
	x1291	MV/G/27(1)	F54/4	500.

PLATE 3

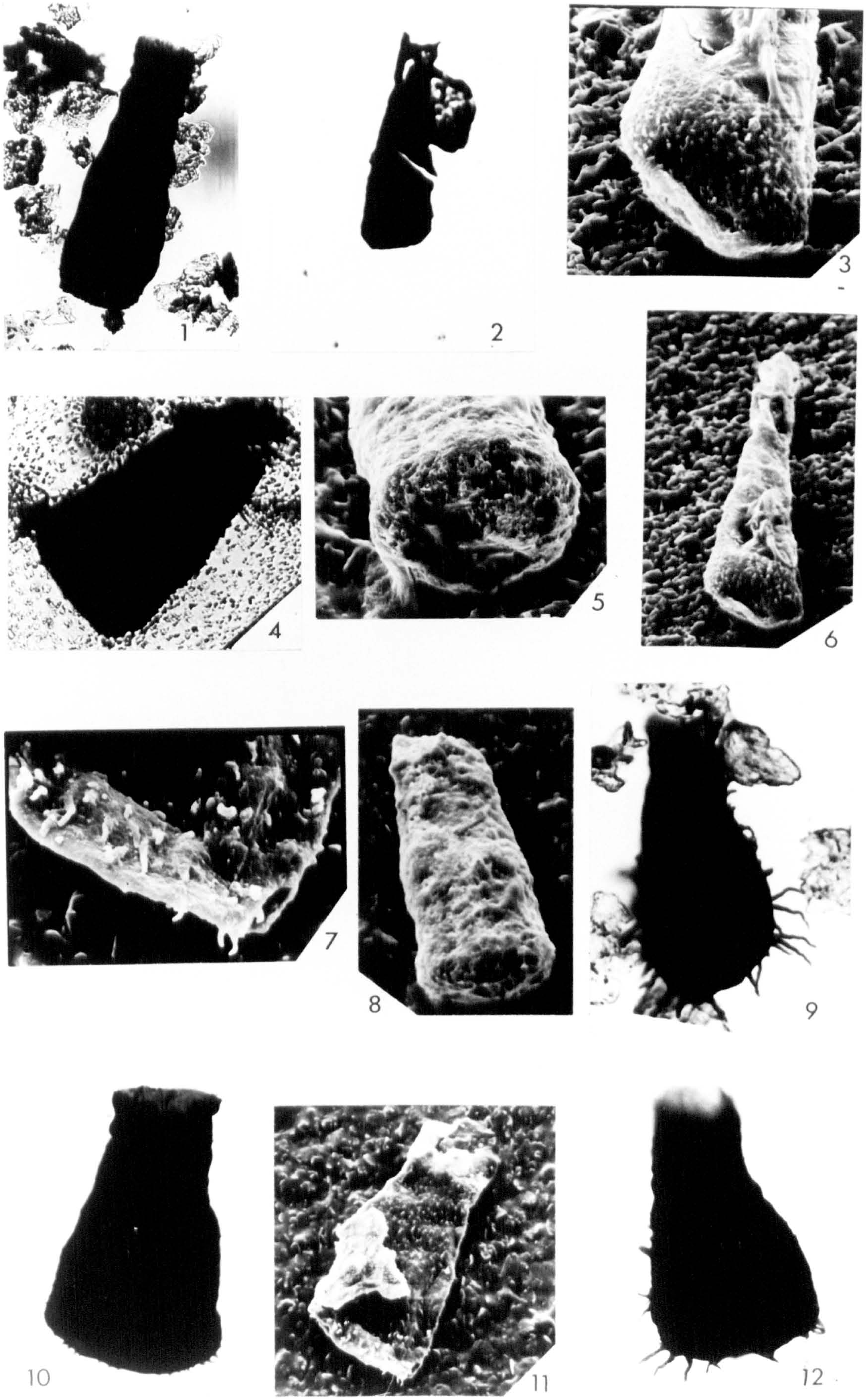


Plate 4.

	H.M. no.	Sample	E.F.R.	Mag.
1. *Belonechitina* sp. A	x1292	MV/G/18		200
2. *Belonechitina* sp. B	x1293	MV/G/24(2)	O27/2	350
3. *Calpichitina lenticularis* (Bouché 1965)	x1294	MV/G/28(1)	R49/2	500
4. *Calpichitina lenticularis* (Bouché1965)	x1295	MV/G/28(4)	M65/3	780
5. *Calpichitina lenticularis* (Bouché 1965)	x1296	MV/G/28		250
6. *Calpichitina lenticularis* (Bouché 1965)	x1297	MV/G/28		500
7. *Conochitina* cf. *elegans* Eisenack 1931	x1298	MV/G/25		180
8. *Calpichitina megastrophica* Achab 1984	x1299	MV/G/28(3)	H40/1	500
9. *Calpichitina lenticularis* (Bouché 1965)	x1300	MV/G/27(2)	C45/2	450
10. *Conochitina pygmaea* Achab 1986	x1301	SU/DL/9(4)	H61/1	225
11. *Conochitina conulus* Eisenack 1955	x1302	MV/G/20(4)	V28/4	400
12. *Calpichitina megastrophica* Achab 1984	x1303	MV/G/28(1)	C49/4	500.

PLATE 4

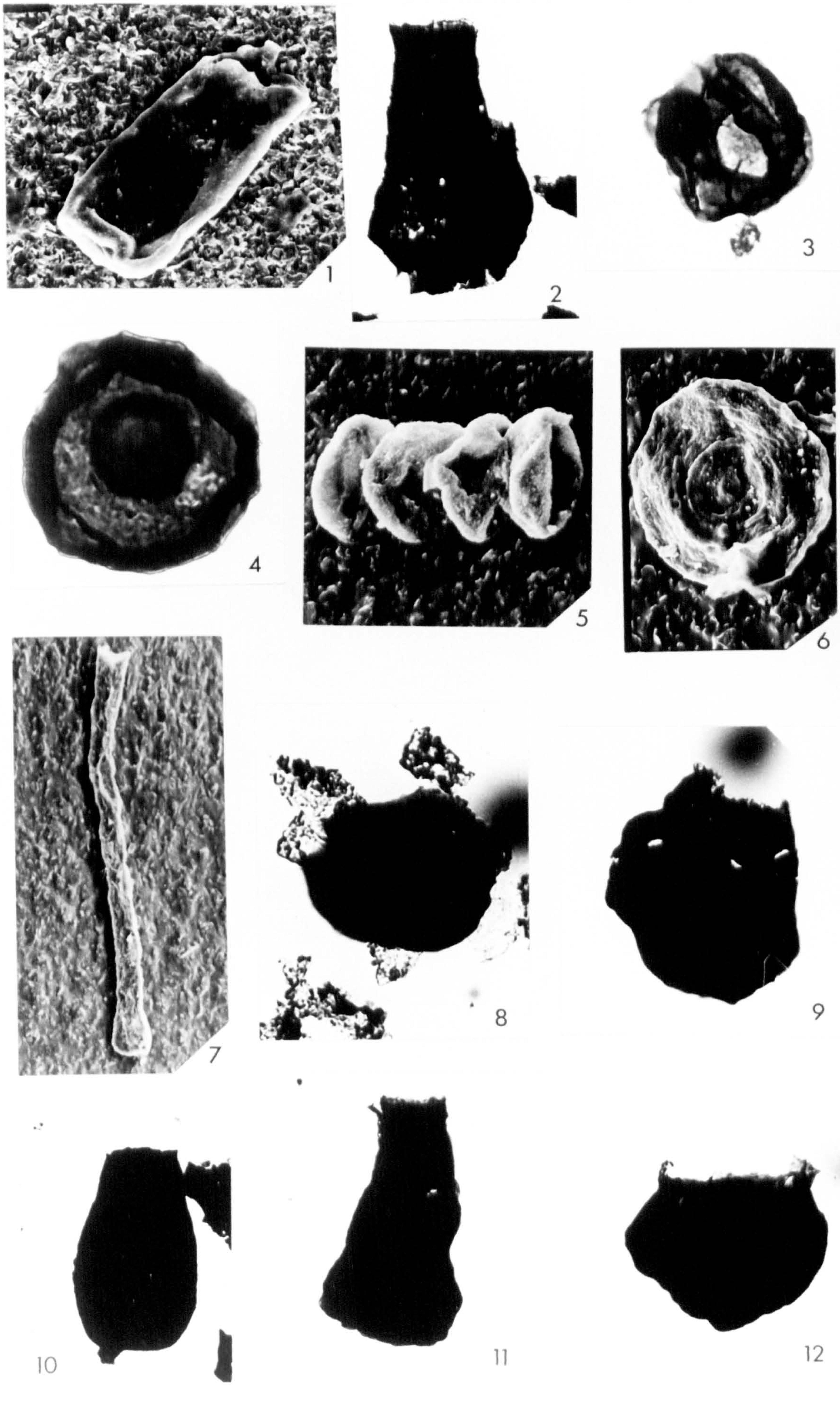


Plate 5

	H.M. no.	Sample	E.F.R.	Mag.
1. *Conochitina minnesotensis* (Stauffer 1933)				
	x1304	SU/DI/46(3)	W46/3	100
2. *Conochitina minnesotensis* (Stauffer 1933)				
	x1305	MV/G/20		220
3. *Conochitina* cf. *tuba* Eisenack 1932				
	x1306	MV/G/27(2)	X31/3	400
4. *Conochitina* sp. E	x1307	MV/G/23		350
5. *Conochitina primitiva* Eisenack 1939				
	x1308	HB/BAL/2(2c)	L58/4	200
6. *Conochitina* sp. A	x1309	MV/G/18(5)	Q27/1	330
7. *Conochitina* sp. D	x1310	MV/G/8(1)	P59/2	350
8. *Conochitina* sp. C	x1311	MV/G/18(3)	O52/1	400
9. *Conochitina tormentosa* Taugourdeau 1961				
	x1312	SU/DL/34(2)	K54/1	200
10. *Conochitina* sp. B	x1313	SU/DL/3(3)	G33/4	350

PLATE 5

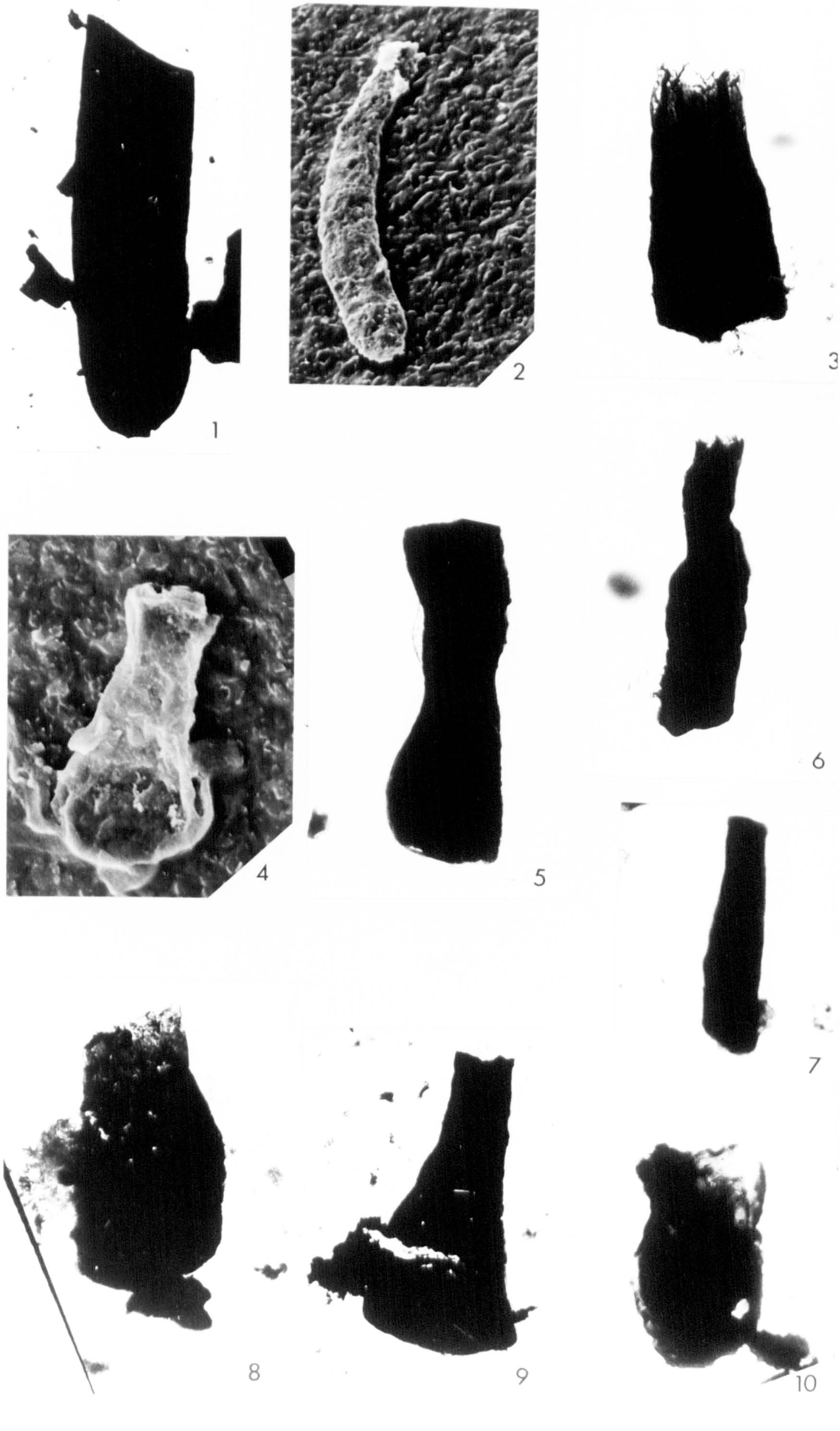


Plate 6

	H.M. no.	Sample	E.F.R.	Mag.
1. *Cyathochitina calix* (Eisenack 1931)				
	x1314	MV/G/9(4)	V41/4	200
2. *Cyathochitina calix* (Eisenack 1931)				
	x1315	SU/DL/9(3)	E30/2	200
3. *Cyathochitina campanulaeformis* (Eisenack 1931)				
	x1316	SU/DL/9(1)	E59/2	200
4. *Cyathochitina campanulaeformis* (Eisenack 1931)				
	x1317	MV/G/9		250
5. *Cyathochitina campanulaeformis* (Eisenack 1931)				
	x1318	MV/G/9(4)	M46/4	150
6. *Cyathochitina conica* Taugourdeau 1961				
	x1319	SU/DL/46(4)	P27/1	250
7. *Cyathochitina hymenophora* Taugourdeau 1961				
	x1320	SU/DL/17		200
8. *Cyathochitina hymenophora* Taugourdeau 1961				
	x1320	SU/DL/17	N61/1	250
9. *?Cyathochitina conica* Taugourdeau 1961				
	x1321	HB/GF/1(2)	R47/2	250
10. *Cyathochitina granulata* Taugourdeau 1961				
	x1322	SU/DL/51(1)	U50/3	200
11. *?Cyathochitina fusiformis* Bouché 1965				
	x1323	HB/BAL/2(3c)	C58/4	200
12. *?Cyathochitina fusiformis*				
	x1324	HB/BAL/2(1c)	M50/2	250

PLATE 6

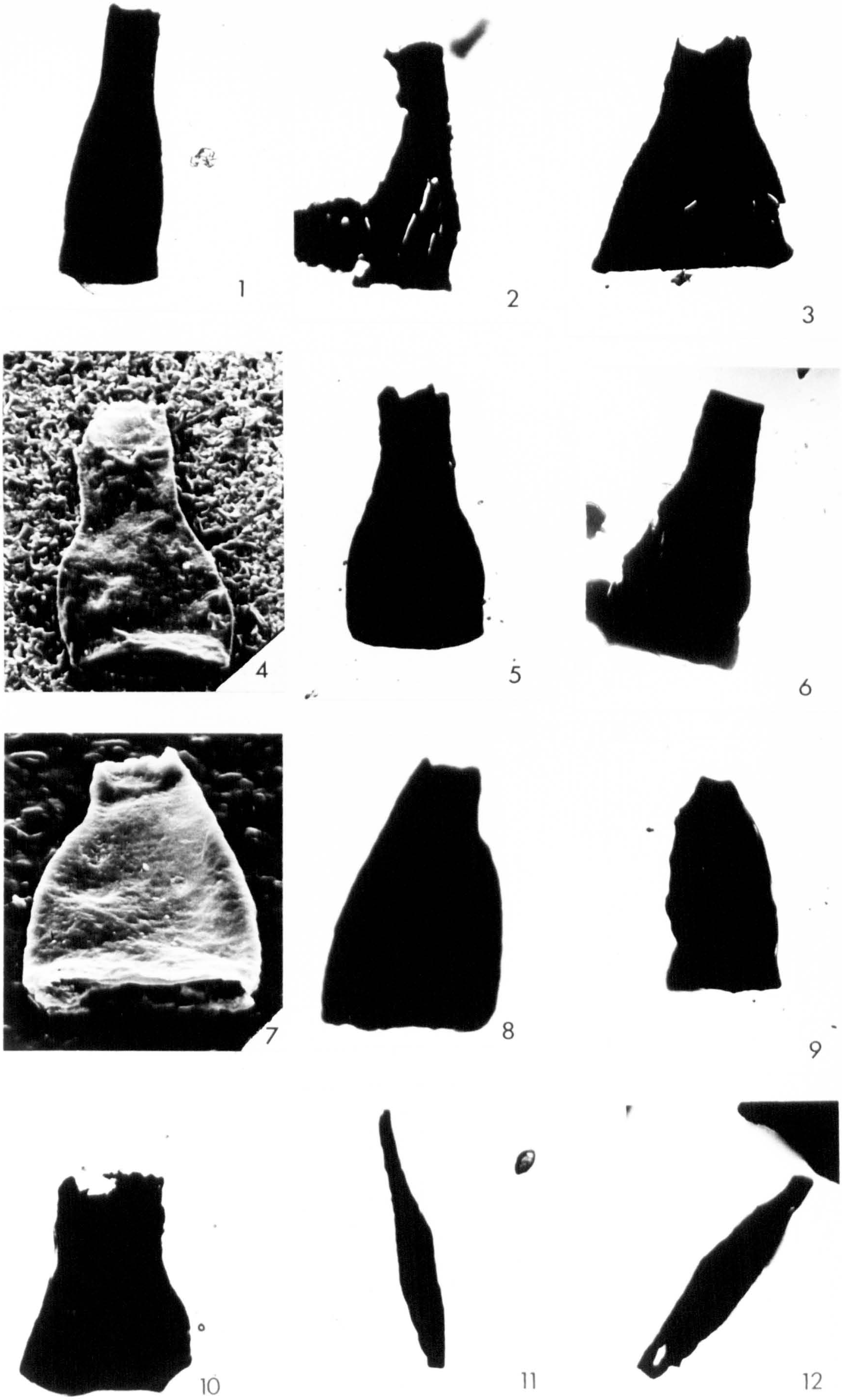


Plate 7

	H.M. no.	Sample	E.F.R.	Mag.
1. *Cyathochitina hyalophrys* Eisenack 1959				
	x1325	MV/G/19		100
2. *Cyathochitina jenkinsi* Neville 1974				
	x1326	MV/G/9(4)	V41/4	200
3. *Cyathochitina jenkinsi* Neville 1974				
	x1327	MV/G/9		200
4. *C.kuckersiana kuckersiana* (Eisenack 1934)				
	x1328	SU/DL/9(1)	H61/1	300
5. *C.kuckersiana patagiata* Jenkins 1969				
	x1329	MV/G/24(2)	N39/4	350
6. ?*Cyathochitina macastyensis* Achab 1978				
	x1330	HB/GF/1(2)	R27/4	250
7. *Cyathochitina latipatagium* (Jenkins 1969)				
	x1331	SU/DL/9(1)	H61/1	250
8. *Cyathochitina protocalix* Paris 1981				
	x1332	MV/G/9(4)	K39/2	250
9. *Cyathochitina protocalix* Paris 1981				
	x1333	MV/G/9		200
10. *Cyathochitina protocalix* Paris 1981				
	x1333	MV/G/9		1000
11. *Cyathochitina protocalix* Paris 1981				
	x1334	MV/G/9		430.

PLATE 7

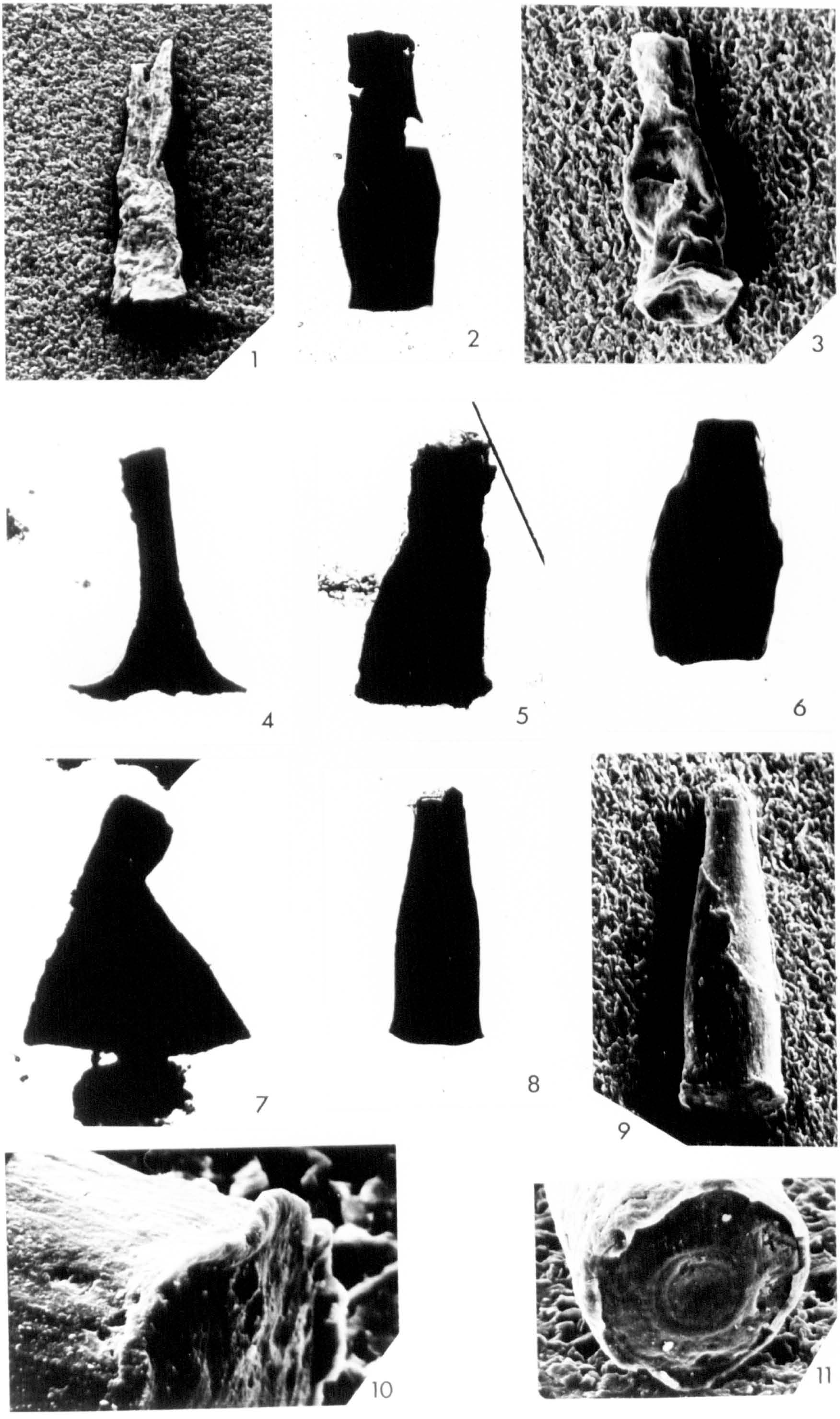


Plate 8

	H.M. no.	Sample	E.F.R.	Mag.
1. ?*Cyathochitina* cf. *regnelli* Eisenack 1955				
	x1335	SU/DL/54(4)	D45/4	500.
2. *Cyathochitina vaurealensis* Achab 1977				
	x1336	MV/G/24		150
3. *Cyathochitina stentor* (Eisenack 1937)				
	x1337	SU/DL/57(4)	J34/2	150
4. *Cyathochitina* sp. A	x1338	HB/A/3(1)	E47/1	200
5. *Cyathochitina* sp. C	x1339	SU/DL/46(6)	S51/3	190
6. *Cyathochitina* sp. B	x1340	SU/DL/46(6)	U43/1	200
7. *Desmochitina bulla* Taugourdeau and Jekhowsky 1960				
	x1341	HB/CQ/1		150
8. *Desmochitina minor* f. *elongata* Eisenack 1958				
	x1342	HB/BB/2(2c)	H49/1	400
9. *Desmochitina minor* f. *cocca* Eisenack 1931				
	x1343	SU/DL/46(4)	W48/4	400
10. *Desmochitina minor* f. A.	x1344	HB/A/3(7)	M35/3	250
11. *Cyathochitina* sp. D	x1345	MV/G/28(3)	W40/1	220.

PLATE 8

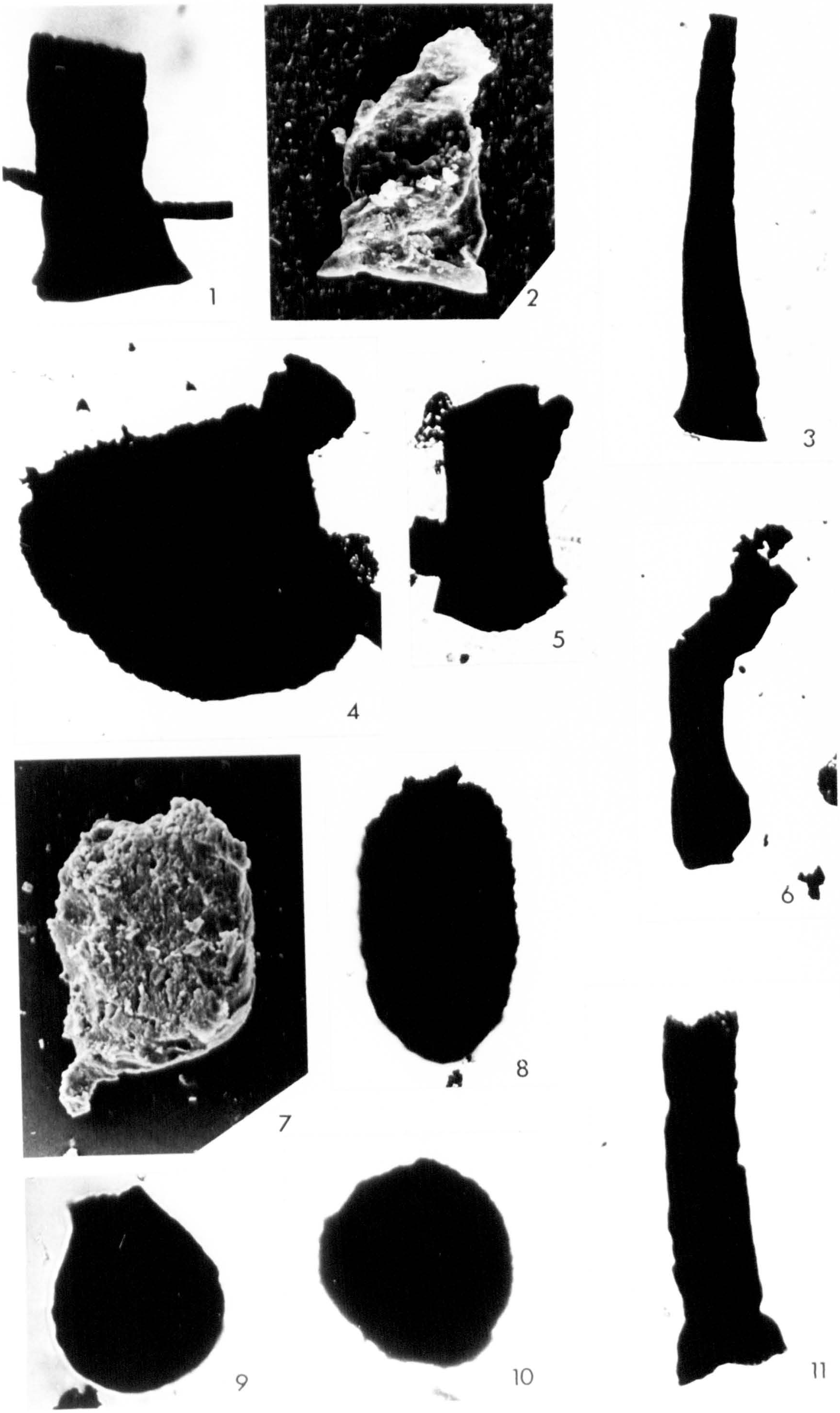


Plate 9

	H.M. no.	Sample	E.F.R.	Mag.
1. *Desmochitina* sp. B	x1346	HB/BB/3		170
2. *Desmochitina* sp. A	x1347	HB/BAL/1(1)	L19/3	400
3. *Hercochitina* cf. *turnbulli* Jenkins 1969	x1348	SU/DL/9(5)	E61/1	500
4. *Kalochitina* sp. B	x1349	MV/G/9		300
5. *Kalochitina* sp. A	x1350	SU/DL/41(5)	V50/4	400
6. *Lagenochitina obeligis?* Paris 1981	x1351	HB/A/3 (2)	K52/3	300
7. *?Lagenochitina brevicollis* Taugourdeau and Jekhowsky 1960	x1352	HB/NE/6		200
8. *Lagenochitina* sp. C	x1353	HB/LC/1(a)	T45/2	300
9. *Lagenochitina prussica* Eisenack 1931	x1354	SU/DL/46(4)	D61/4	400
10. *Lagenochitina* sp. A	x1355	MV/G/27	E33/4	300
11. *Lagenochitina* sp. B	x1356	MV/G/27		300
12. *Lagenochitina* cf. *prussica* Eisenack 1931	x1357	HB/CQ/1		150.

PLATE 9

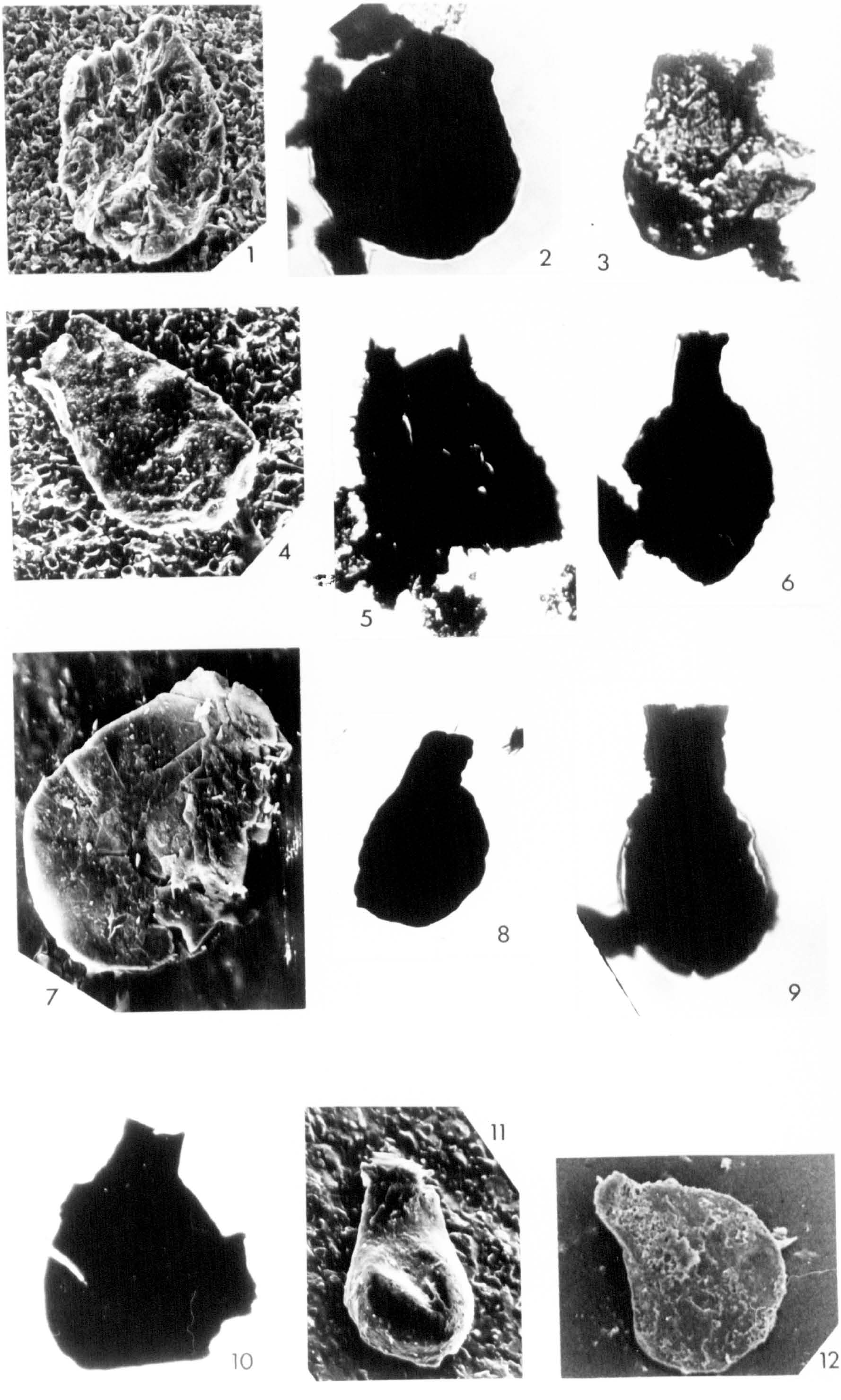


Plate 10.

	H.M. no.	Sample	E.F.R.	Mag.
1. *Lagenochitina* sp. D	x1358	HB/A/3(9)	S40/4	150
2. *Pterochitina hymenelytrum* Jenkins 1969				
	x1359	MV/G/18(3)	B60/2	500
3. *Rhabdochitina* sp. cf. *R. gallica* Taugordeau 1961				
	x1360	SU/DL/9(1)	H35/1	200
4. *Rhabdochitina gracilis* Eisenack 1962				
	x1361	MV/G/27		100
5. *Rhabdochitina magna* Eisenack 1931				
	x1362	MV/G/24		100
6. *Rhabdochitina gracilis* Eisenack 1962				
	x1363	SU/DL/37	M57/1	100
7. *Rhabdochitina* sp. A	x1364	SU/DL/57(1)	L54/2	250
8. *Rhabdochitina striata* Eisenack 1958				
	x1365	MV/G/28		1000
9. *Rhabdochitina* sp. C	x1366	MV/G/6		150
10. *Rhabdochitina striata* Eisenack 1958				
	x1365	MV/G/28		100

PLATE 10

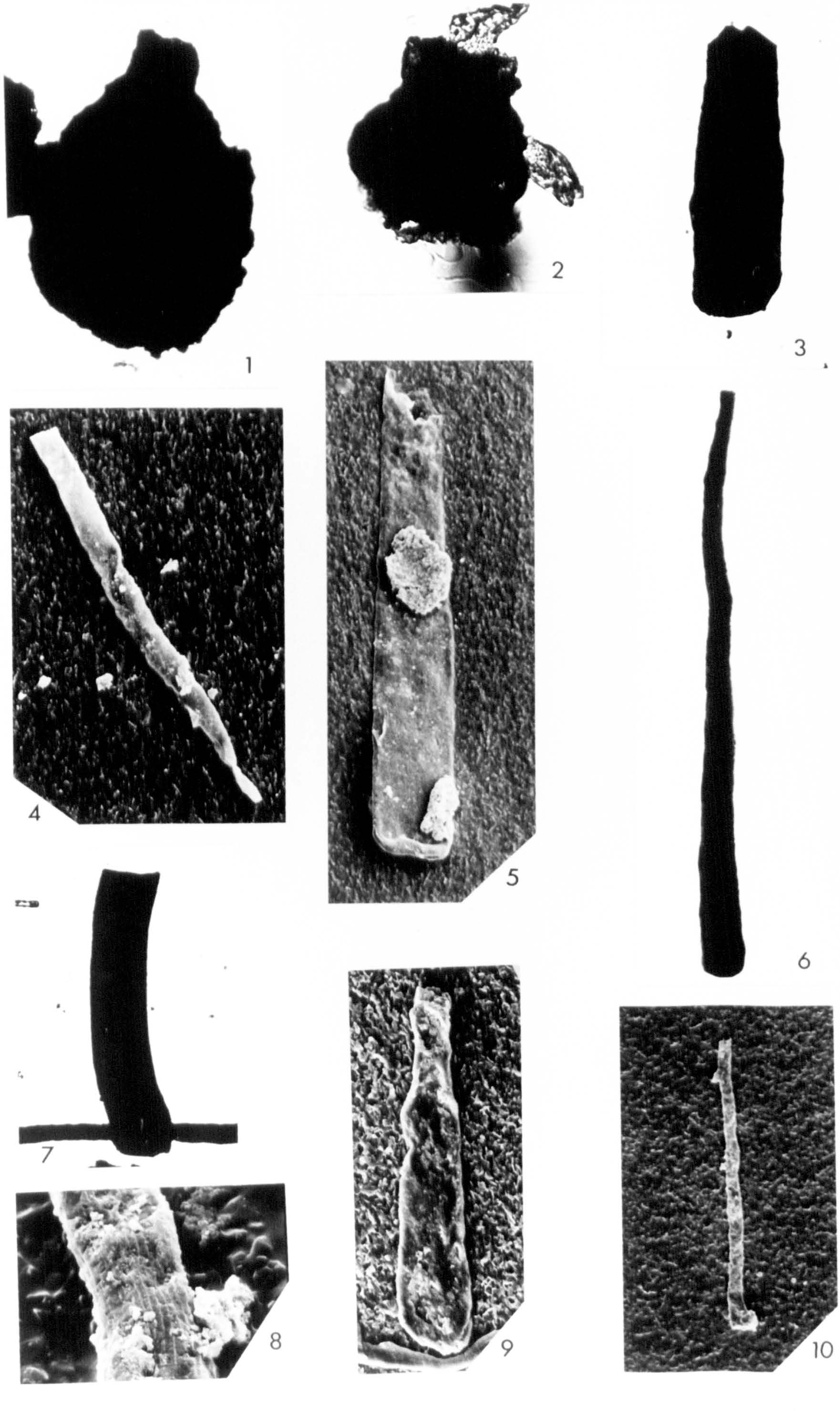


Plate 11.

	H.M. no.	Sample	E.F.R.	Mag.
1. *Rhabdochitina* sp. B	x1367	MV/G/27(2)	L30/4	300
2. *Rhabdochitina* sp. D	x1368	MV/G/8		200
3. *Rhabdochitina* sp. E	x1369	MV/G/9		150
4. *Siphonochitina* sp. A	x1370	SU/DL/8(1)	F53/1	560
5. *Sphaerochitina mundana?* Taugourdeau 1961				
	x1371	MV/G/20		400
6. *Rhabdochitina* sp. D	x1368	MV/G/8		400
7. *Sphaerochitina* cf.*lepta* Jenkins 1970				
	x1372	SU/DL/52(1)	R32/2	400
8. *Sphaerochitina* sp. A	x1373	MV/G/8		300
9. *?Spinachitina bulmani* (Jansonius 1964)				
	x1374	SU/DL/9(1)	M36/3	220
10. *Tanuchitina* cf. *ontariensis* (Jansonius 1964)				
	x1375	MV/G/18		250
11. *Tanuchitina anticostiensis?* Achab 1977				
	x1376	MV/G/24		150
12. *Tanuchitina anticostiensis?* Achab 1977				
	x1376	MV/G/24		500
13. Chitinozoan sp. A	x1377	MV/G/28(1)	P30/1	300

PLATE 11

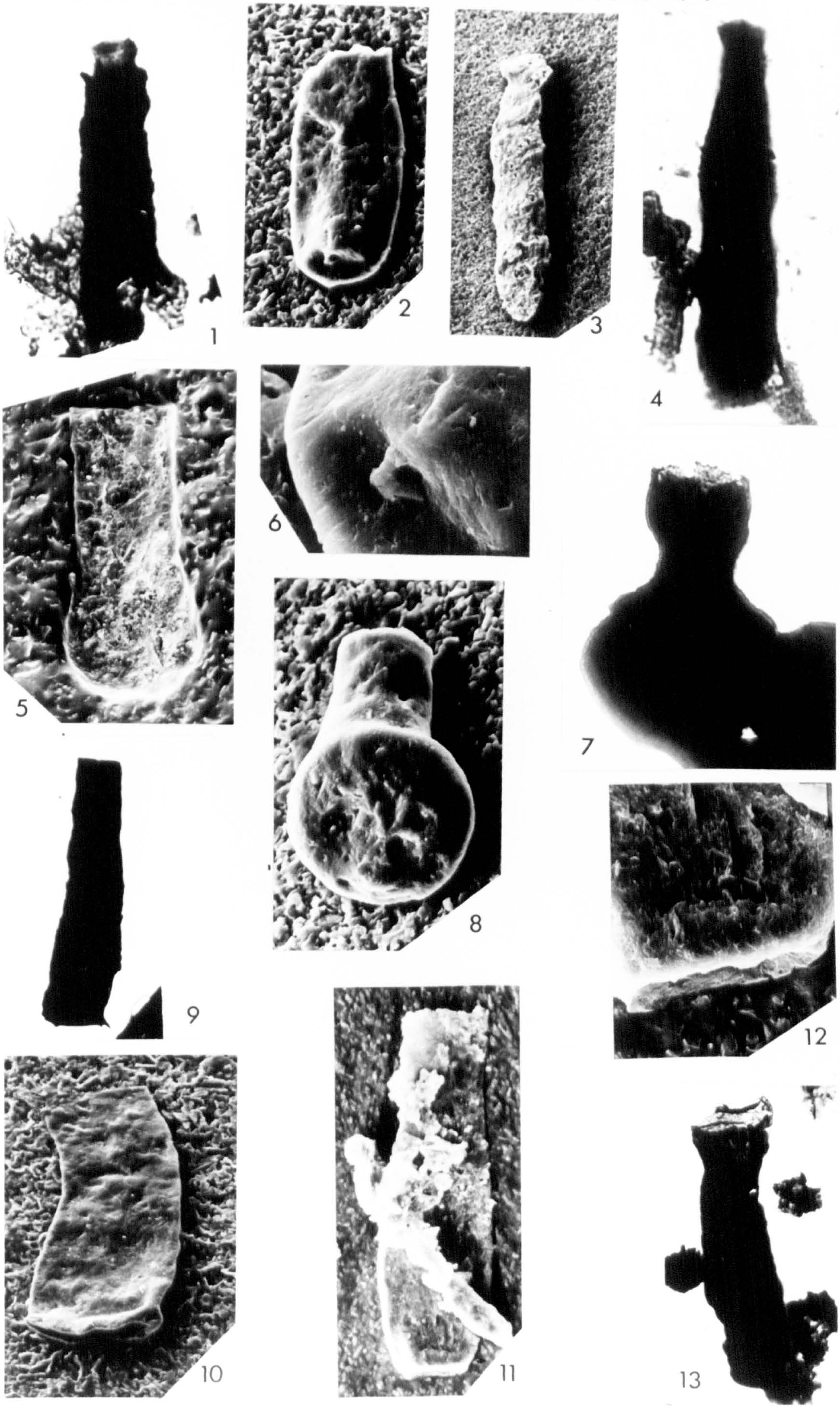


Plate 12

	H.M. no.	Sample	E.F.R.	Mag.
1. *Lagnochitina* sp. indet.	x1378	SU/B/13		100
2. *Lagnochitina* sp. indet.	x1379	HB/LC/9		150
3. *Lagnochitina* sp. indet.	x1380	HB/LC/11		80
4. Chitinozoan sp. indet.	x1381	SU/B/13		150
5. *Conochitina* sp. indet.	x1382	HB/LC/7		230
6. Chitinozoan sp. indet.	x1383	HB/LC/11		230
7. Chitinozoan sp. indet.	x1384	HB/NE/11		230
8. Chitinozoan sp. indet.	x1385	HB/LC/8		100
9. Chitinozoan sp. indet.	x1386	HB/BB/5		100
10. *Lagnochitina* sp. indet.	x1387	HB/LC/11		70
11. Chitinozoan sp. indet.	x1388	HB/BB/3		150
12. Chitinozoan sp. indet.	x1389	SU/B/10		120
13. *Conochitina* sp. indet.	x1390	HB/BB/3		150
14. *Conochitina* sp. indet.	x1391	HB/BB/5(2)	F58/2	500
15. *Conochitina* sp. indet.	x1392	HB/NE/3(1F)	R45/3	440
16. Chitinozoan sp. indet.	x1393	SU/DL/53(3)	L60/2	150
17. *Lagenochitina* sp. indet.	x1394	HB/LQ/9()	Q48/3	150
18. *Cyathochitina* sp. indet.	x1395	HB/LC/5(1F)	P51/1	250
19. *Lagenochitina* sp. indet.	x1396	HB/LQ/9()	G31/4	150
20. *Cyathochitina* sp. indet.	x1397	HB/BB/5(1)	V35/1	430
21. Chitinozoan sp. indet.	x1398	MV/G/8(2)	N61/4	500
22. *Conochitina* sp. indet.	x1399	MV/G/23(2)	C57/4	440

PLATE 12

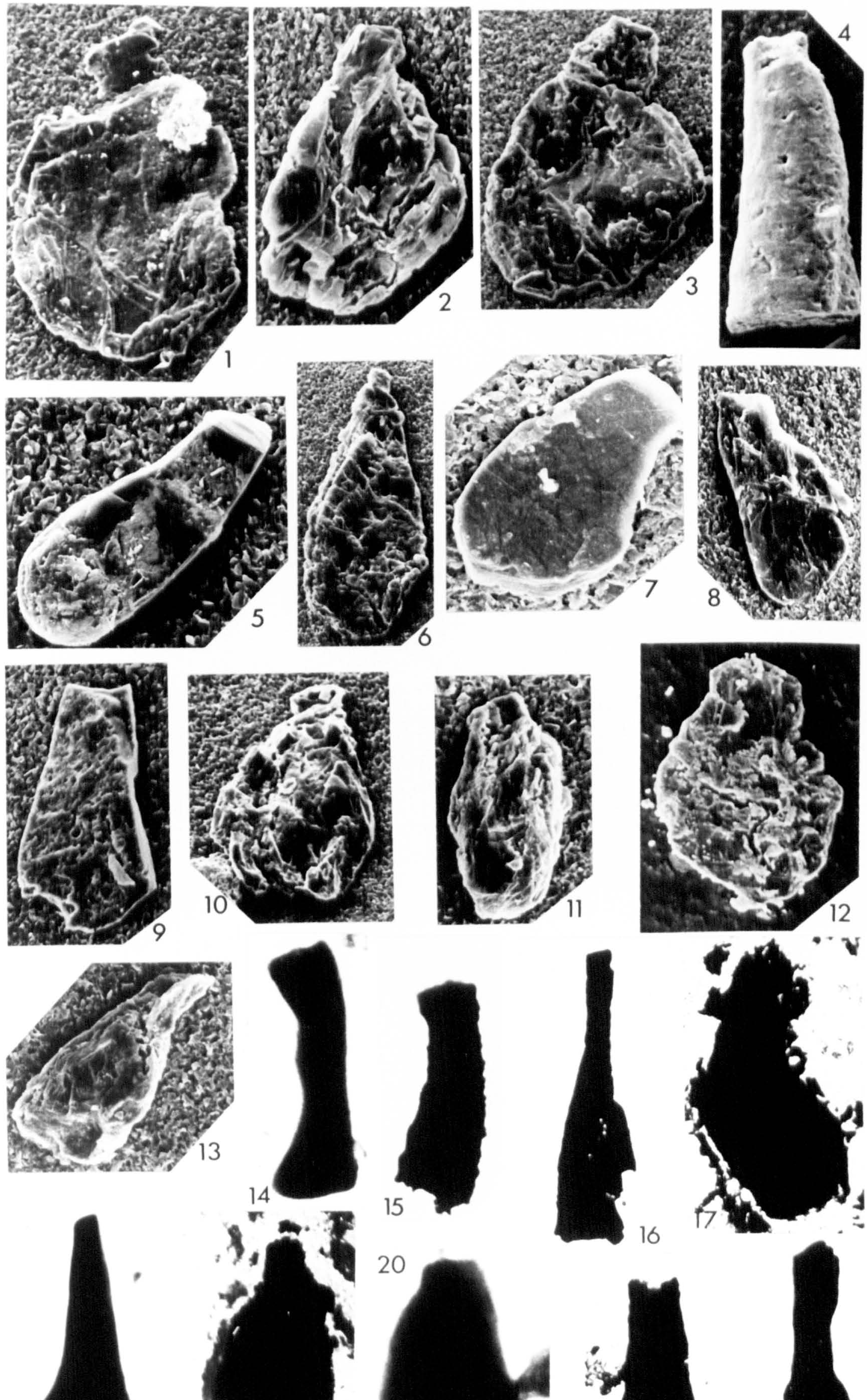


Plate13

	H.M. no.	Sample	E.F.R.	Mag.
1. *Actinotodissus woodlandense* n. sp.				
	x1400	MV/G/27(1)	T59/1	730
2. *Aremoricanium* cf. *deflandrei* Henry 1969				
	x1401	MV/G/21(1)	R46/1	1000
3. *Aremoricanium* cf. *rigaudae* Deunff 1955				
	x1402	MV/G/26(1)	C41/1	1000
4. *Actinotodissus* sp. A	x1403	SU/DL/17(1F)	P40/2	1200
5. *Baltisphaeridium hirsuitoides* (Eisenack) Eisenack 1958				
	x1404	MV/G/26(2)	S33/4	700
6. *Aremoricanium* sp. D	x1405	HB/NE/3(1F)	T39/2	500
7. *Aremoricanium* sp. B	x1406	SU/DI/11(3)	D61/3	500
8. *Aremoricanium* sp. A	x1407	SU/DL/10(2)	O52/1	900
9. *Baltisphaeridium* cf. *bulbosum* Kjellström 1971				
	x1408	MV/G/23(2)	F42/4	500
10. *Ammonidium* sp. A	x1409	MV/G/29(1)	V44/3	1200
11. *Baltisphaeridum* cf. *paucispinosum* Kjellström 1971				
	x1410	MV/G/23(1)	H56/1	700

PLATE 13

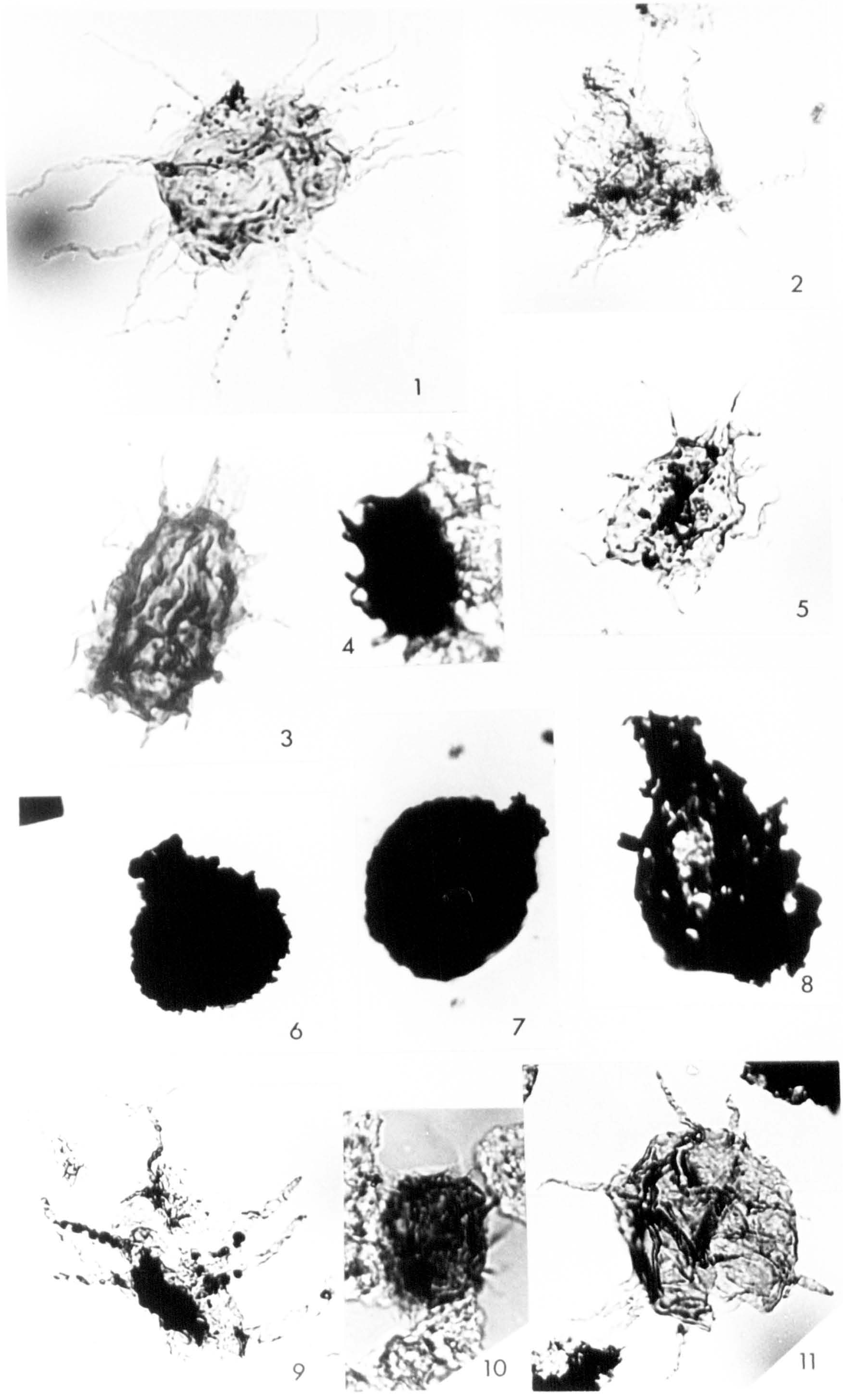


Plate 14

	H.M. no.	Sample	E.F.R.	Mag.
1. *Baltisphaeridium* cf. *psilatum* Kjellström 1971				
	x1411	MV/G/25(2)	Q59/2	580
2. *Baltisphaeridium* cf. *regnelli* Kjellström 1971				
	x1412	MV/G/24(2)	G22/1	1200
3. *Baltisphaeridium* sp. A.	x1413	MV/G/20(3)	K56/3	1200
4. *Baltisphaerosum cristoferi* (Kjellström) Turner 1984				
	x1414	MV/G/21(1)	M47/1	700
5. *Cymatiosphaera densisepta* Miller and Eames 1982				
	x1415	MV/G/22(2)	K37/4	1000
6. *Dictyotidium* sp. A	x1416	MV/G/27(2)	J58/1	1200
7. *Eupoikilofusa striata* (Staplin, Jansonius and Pocock) Loeblich and Tappan 1978				
	x1417	MV/G/28(1)	Y48/4	670
8 *Dictyotidium* sp. B	x1418	MV/G/8(1)	D39/3	1000
9. *Filisphaeridium* sp. A	x1419	MV/G/26(1)	G33/2	1200
10. *Dictyotidium* sp. A	x1420	SU/DL/40(2)	W41/2	1200
11. *Goniosphaeridium elongatum* Turner 1984				
	x1421	MV/G/23(1)	K45/4	1200
12. *Goniosphaeridium* cf. *elongatum* Turner 1984				
	x1422	MV/G/6(1)	D55/1	1500
13. *Goniosphaeridium splendens* (Eisenack) Turner 1984				
	x1423	MV/G/21(1)	Q38/1	1500.

PLATE 14

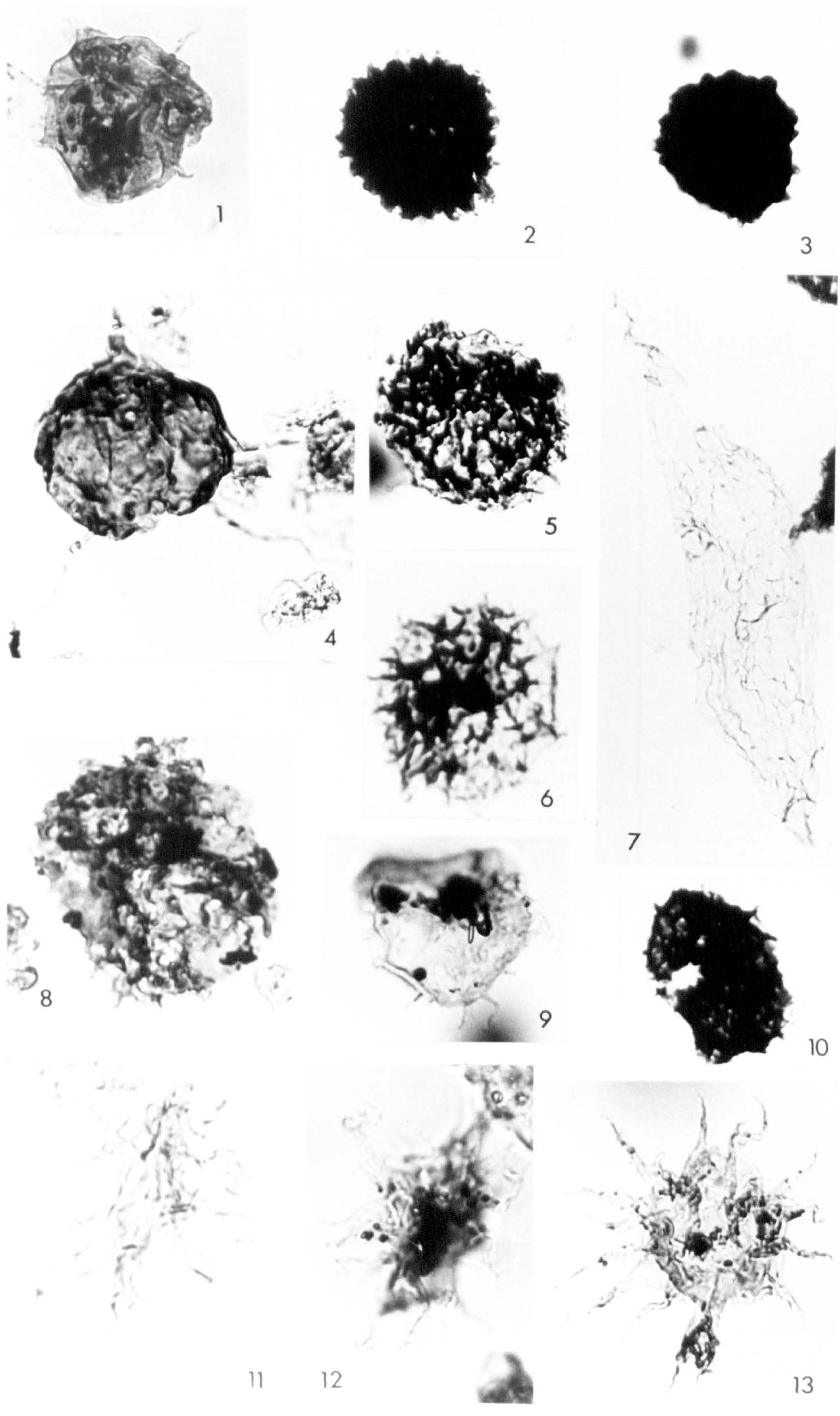


Plate 15

	H.M. no.	Sample	E.F.R.	Mag.
1. *Goniosphaeridium girvanense* n. sp.				
	x1424	MV/G/21(2)	M30/1	1000
2. *Leiofusa aspilis* Loeblich 1970				
	x1425	MV/G/8(1)	L40/1	370
3. *Leiofusa* sp. A	x1426	MV/G/20(2)	T46/3	400
4. *Leiosphaeridia* cf. *voigtii* Eisenack 1958				
	x1427	MV/G/28(1)	V52/2	500
5. *Leiosphaeridia* cf. *tenuissima* Eisenack 1958				
	x1428	MV/G/9(1)	B39/3	1200
6. *Goniosphaeridium* sp. indet.	x1429	SU/DL/54(6)	G39/1	1200
7. *Leiosphaeridia* sp. A	x1430	MV/G/28(1)	P28/1	700
8. *Leiosphaeridia* sp. B	x1431	SU/DL/15(1F)	W35/1	700
9. *Leiosphaeridia* sp. C	x1432	HB/LQ/5(1)	F52/1	700
10. *Leiosphaeridia* sp. G	x1433	SU/B/4(1)	C46/0	700
11. *Leiosphaeridia* sp. H	x1434	MV/G/21(1)	N25/1	700
12. *Leiosphaeridia* sp. C	x1435	SU/DL/13(1F)	J48/3	700
13. *Leiosphaeridia* sp. E	x1436	MV/G/25(1)	E53/3	700
14. *Leiosphaeridia* sp. F	x1437	SU/B/1(1)	K56/3	700
15. *Leiosphaeridia* sp. D	x1438	MV/G/9(2)	H37/3	700.

PLATE 15

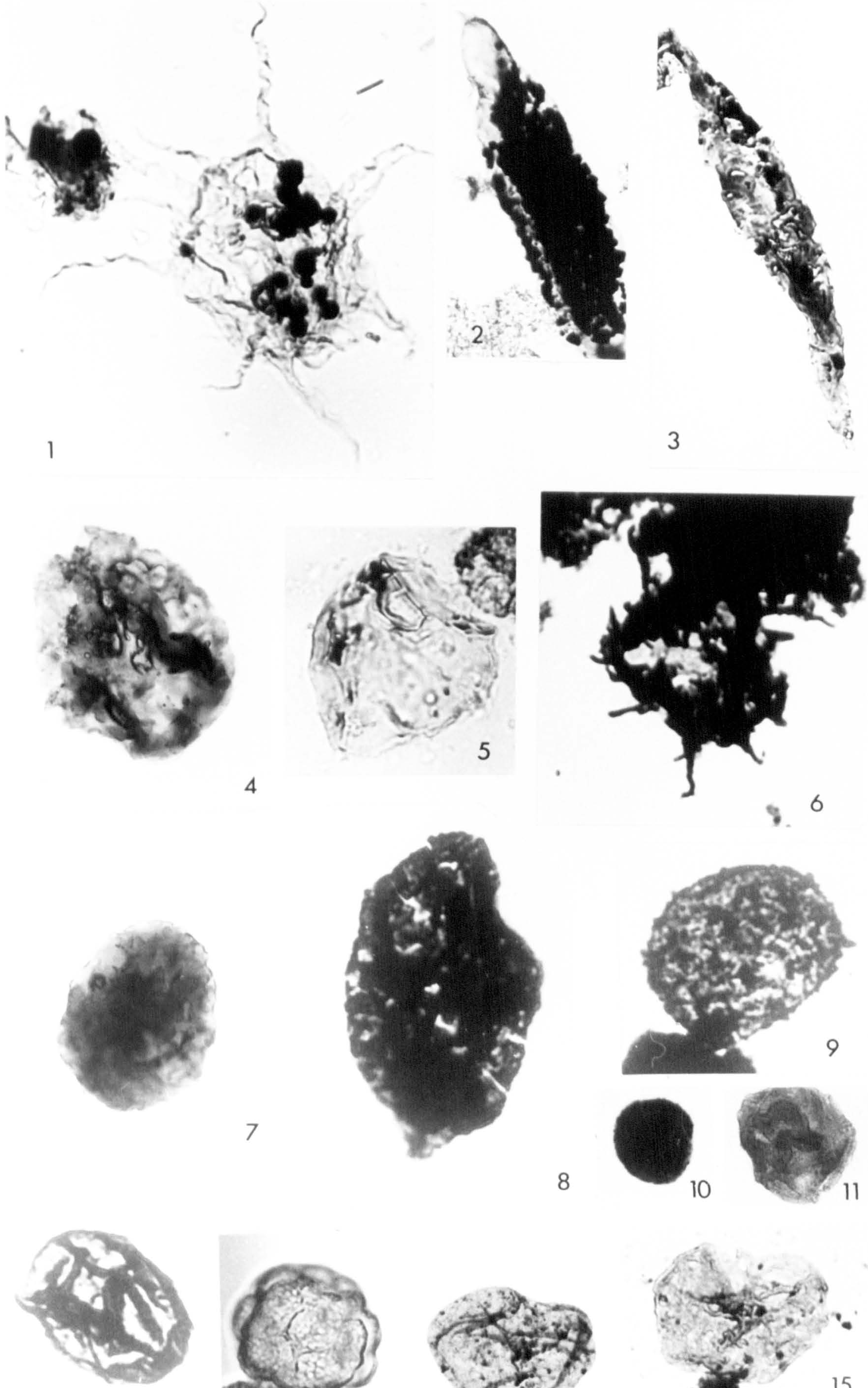


Plate 16

	H.M. no.	Sample	E.F.R.	Mag.
1. *Micrhystridium* sp. A	x1439	MV/G/26(1)	E42/4	1200
2. *Micrhystridium* sp. A	x1440	SU/DL/1(1)	J17/1	1200
3. *Micrhystridium* sp. B	x1441	MV/G/28(1)	K24/1	1200
4. *Micrhystridium* sp. A	x1442	SU/DL/10(2)	L52/4	1200
5. *Micrhystridium* sp. C	x1443	SU/DL/17(2F)	G68/2	1000
6. *Micrhystridium* sp. C	x1444	SU/B/16(1)	H60/4	1200
7. *Moyeria cabotti* (Cramer) Miller and Eames 1982				
	x1445	MV/G/29(1)	T28/1	900
8. *Moyeria cabotti* (Cramer) Miller and Eames 1982				
	x1446	MV/G/20(6)	D60/3	700
9. *Multiplicisphaeridium bifurcatum* Staplin, Jansonius and Pocock 1965				
	x1447	SU/DL/3(4)	H61/1	1200
10. *Multiplicisphaeridium alloiteaui* (Deunff) Kjellström 1976				
	x1448	MV/G/28(4)	G57/2	1200
11. *Multiplicisphaeridium bifurcatum* Staplin, Jansonius and Pocock 1965				
	x1449	MV/G/28(4)	T33/3	1000
12. *Multiplicisphaeridium irregulare* Staplin, Jansonius and Pocock 1965				
	x1450	SU/DL/50(5)	X23/2	1200
13. *Multiplicisphaeridium irregulare* Staplin, Jansonius and Pocock 1965				
	x1451	MV/G/27(2)	R31/1	1500
14. *Multiplicisphaeridium ramuscolosum* (Deflandre) Lister 1970				
	x1452	MV/G/28(1)	C58/4	1200
15. *Multiplicisphaeridium ramuscolosum* (Deflandre) Lister 1970				
	x1453	SU/DL/10(4)	N58/4	1200.

PLATE 16

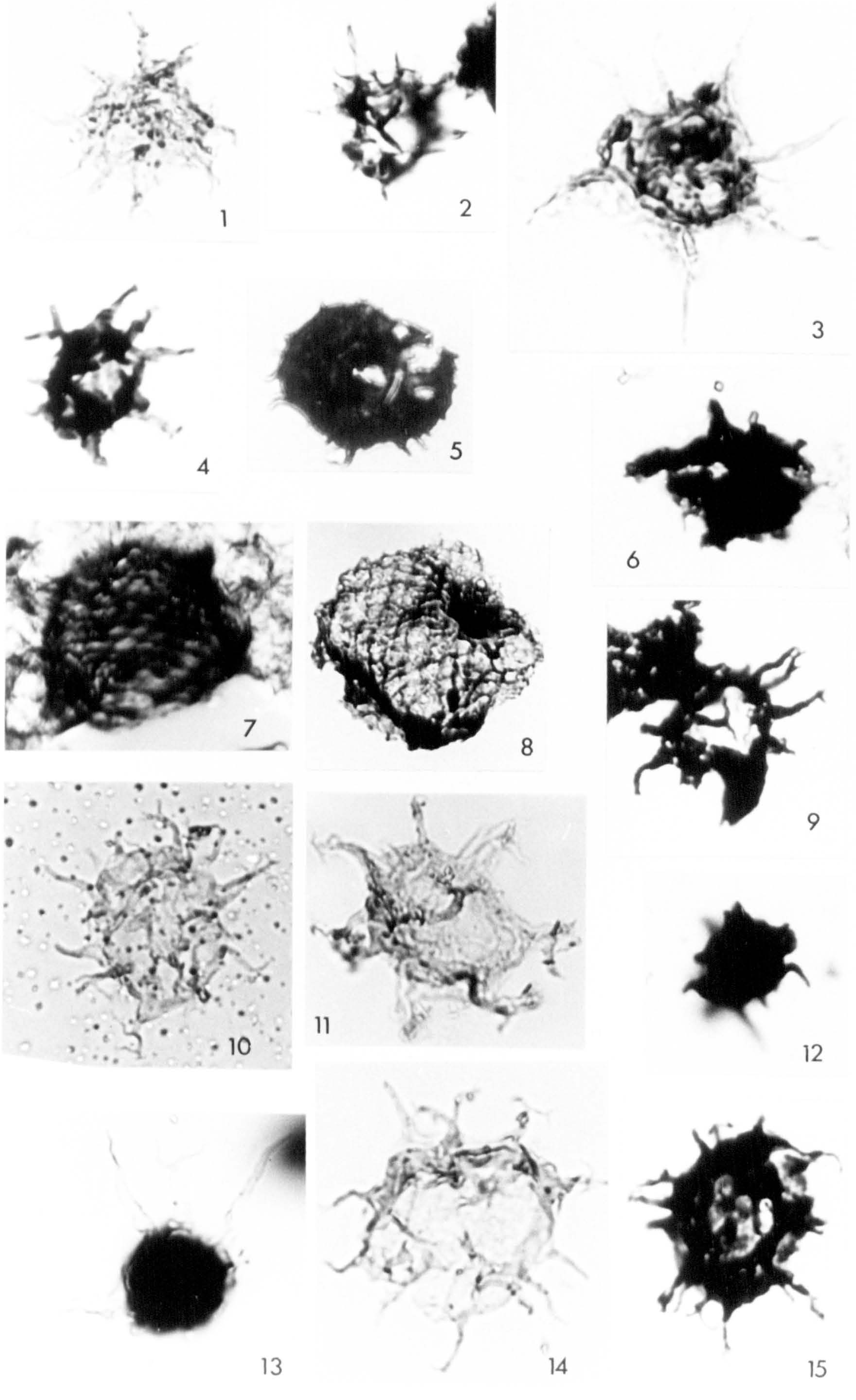


Plate 17.

	H.M. no.	Sample	E.F.R.	Mag.
1. *Multiplicisphaeridium* cf. *wrightii* Jacobson and Achab 1985				
	x1454	MV/G/22(2)	F65/3	1500
2. *Navifusa* sp. A.	x1455	MV/G/18(2)	Q28/4	500
3. *Multiplicisphaeridium* sp. A.	x1456	SU/DL/56(6)	W49/3	1200
4. *Multiplicisphaeridium* sp. C.	x1457	MV/G/27(2)	W57/3	1200
5. *Navifusa* sp. B.	x1458	SU/DL/4(4)	R35/1	580
6. *Navifusa* sp. B.	x1459	HB/NE/12(2)	H58/3	800
7. *Multiplicisphaeridium* sp. B.	x1460	SU/DL/57(6)	R30/4	1200
8. *Navifusa* sp. C.	x1461	MV/G/8(2)	K44/3	500
9. *Navifusa* sp. D.	x1462	HB/LC/4(2)	F45/3	420
10. *Neoveryhachium* sp. A	x1463	SU/DL/17(3F)	J58/4	1200
11. *Orthosphaeridium* sp. A	x1464	MV/G/28(1)	D31/1	1200
12. *Orthosphaeridium chondrododora?* Loeblich and Tappan 1971				
	x1465	MV/G/22(2)	R47/1	800

PLATE 17

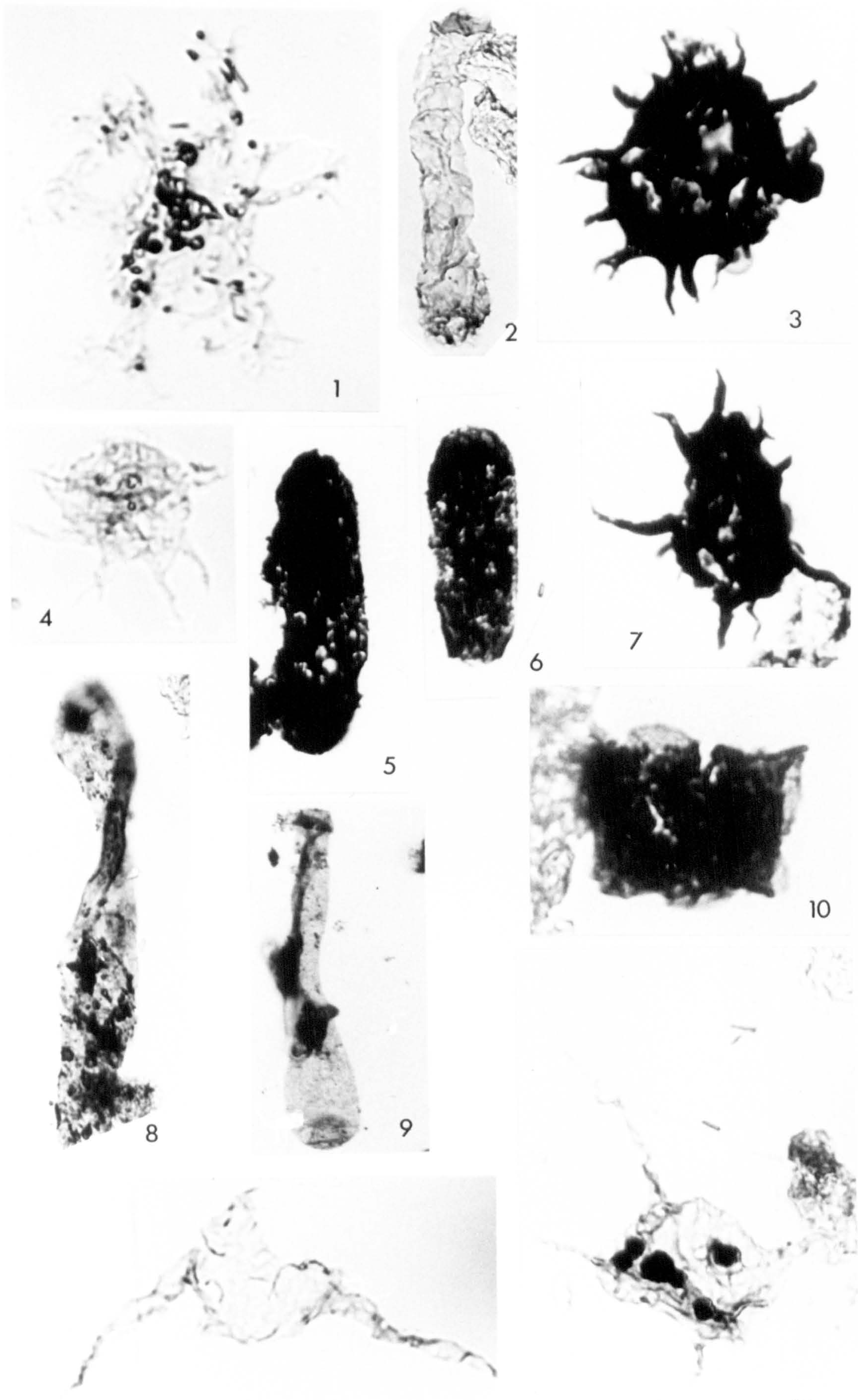


Plate 18

	H.M. no.	Sample	E.F.R.	Mag.
1. *?Peteinosphaeridium nudum* (Eisenack) Eisenack 1969				
	x1466	MV/G/23(2)	E42/4	1200
2. *Peteinosphaeridium* sp. A	x1467	SU/DL/1(1)	P18/2	1200
3. *Peteinosphaeridum* sp. B	x1468	SU/B/16(1)	R60/2	1200
4. *Tasmanites* sp. C	x1469	MV/G/9(1)	B39/3	1200
5. *Pterospermella* sp. A	x1470	SU/DL/50(5)	X38/2	1200
6. *Rhiptosocherma improcera* (Loeblich)Loeblich and Tappan 1978				
	x1471	HB/BB/2(1c)	P22/1	700
7. *Tylotopalla* sp. A	x1472	SU/DL/48(6)	K24/3	1200
8. *Solisphaeridium* cf. *nanum* (Deflandre) Turner 1984				
	x1473	MV/G/21(2)	Q23/4	1200
9. *Tasmanites* sp. B	x1474	MV/G/20(3)	J51/4	1200
10. *Veryhachium* cf. *subglobosum* Jardiné *et al.* 1974				
	x1475	MV/G/20(2)	K42/4	1200
11. *Veryhachium oklahomense* Loeblich 1970				
	x1476	MV/G/20(2)	G22/3	1200
12. *Veryhachium reductum* (Deflandre) Jekhowsky 1961				
	x1477	SU/DL/10(2)	D50/3	1200
13. *Veryhachium triangulatum* Konzalová-Mazancová 1969				
	x1478	MV/G/28(4)	D50/3	700
14. *Veryhachium* cf. *subglobosum* Jardiné *et al.* 1974				
	x1479	SU/DL/39(1)	R37/2	1000.

PLATE 18

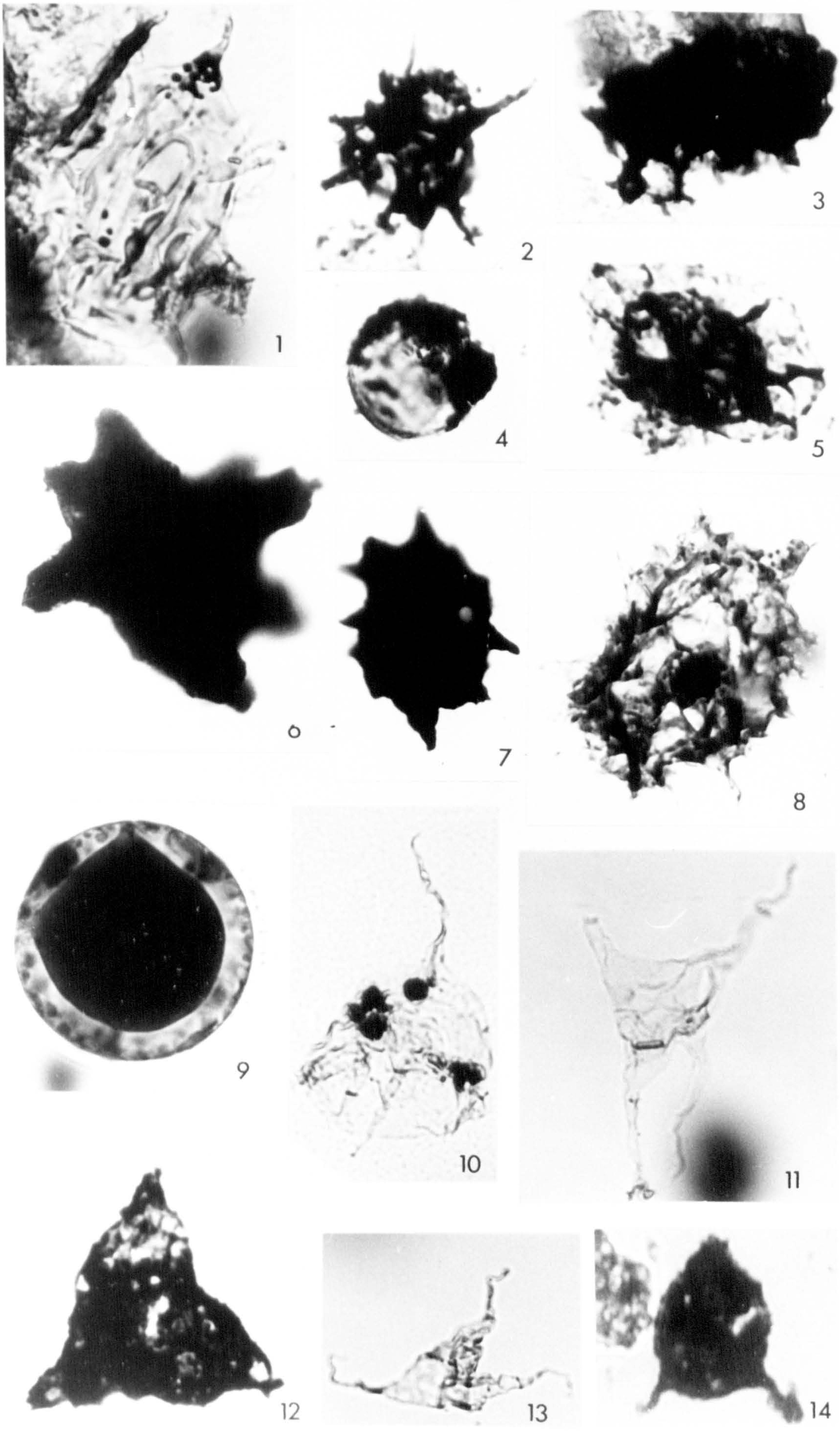


Plate 19

	H.M. no.	Sample	E.F.R.	Mag.
1. *Veryhachium trispinosum* (Eisenack) Deunff ex Downie 1959				
	x1480	MV/G/27(2)	C37/3	830
2. *Veryhachium* sp. A	x1481	SU/DL/47(1)	T61/1	1000
3. *Veryhachium* sp. B	x1482	SU/DL/55(5)	H47/4	1200
4. *Veryhachium* sp. indet.	x1483	SU/DL/1(2)	Q36/4	1200
5. *Tetrahedraletes medinensis* Strother and Traverse 1979				
	x1484	MV/G/21(2)	B54/2	720
6. *Tetrahedraletes medinensis* Strother and Traverse 1979				
	x1485	MV/G/18(1)	Q30/3	1000
7. *Nodospora* sp. A	x1486	MV/G/18(1)	W52/1	750
8. Trilete spore A	x1487	MV/G/5(1)	P60/2	1000
9. *Dyadaspora* sp. A	x1488	MV/G/22(1)	G60/1	1200
10. *Tetrahedraletes medinensis* Strother and Traverse 1979				
	x1489	MV/G/19(1)	O45/4	660
11. *Dyadaspora* sp. A	x1490	MV/G/20(1)	O41/4	750
12. Acanthomorph acritarch	x1491	MV/G/28		500
13. Corroded acritarch	x1492	HB/BAL/1(1)	M16/2	1000
14. Acanthomorph acritarch	x1493	HB/NE/13(2)	N37/2	1000
15. Acanthomorph acritarch	x1494	HB/LQ/6 (1)	D53/4	1200
16. Corroded acritarch	x1495	SU/DL/1(1)	C53/1	800
17. Corroded acritarch	x1496	SU/DL/13(1F)	O47/1	660
18. Corroded acritarch	x1497	HB/LC/2(1)	C38/4	800.

PLATE 19

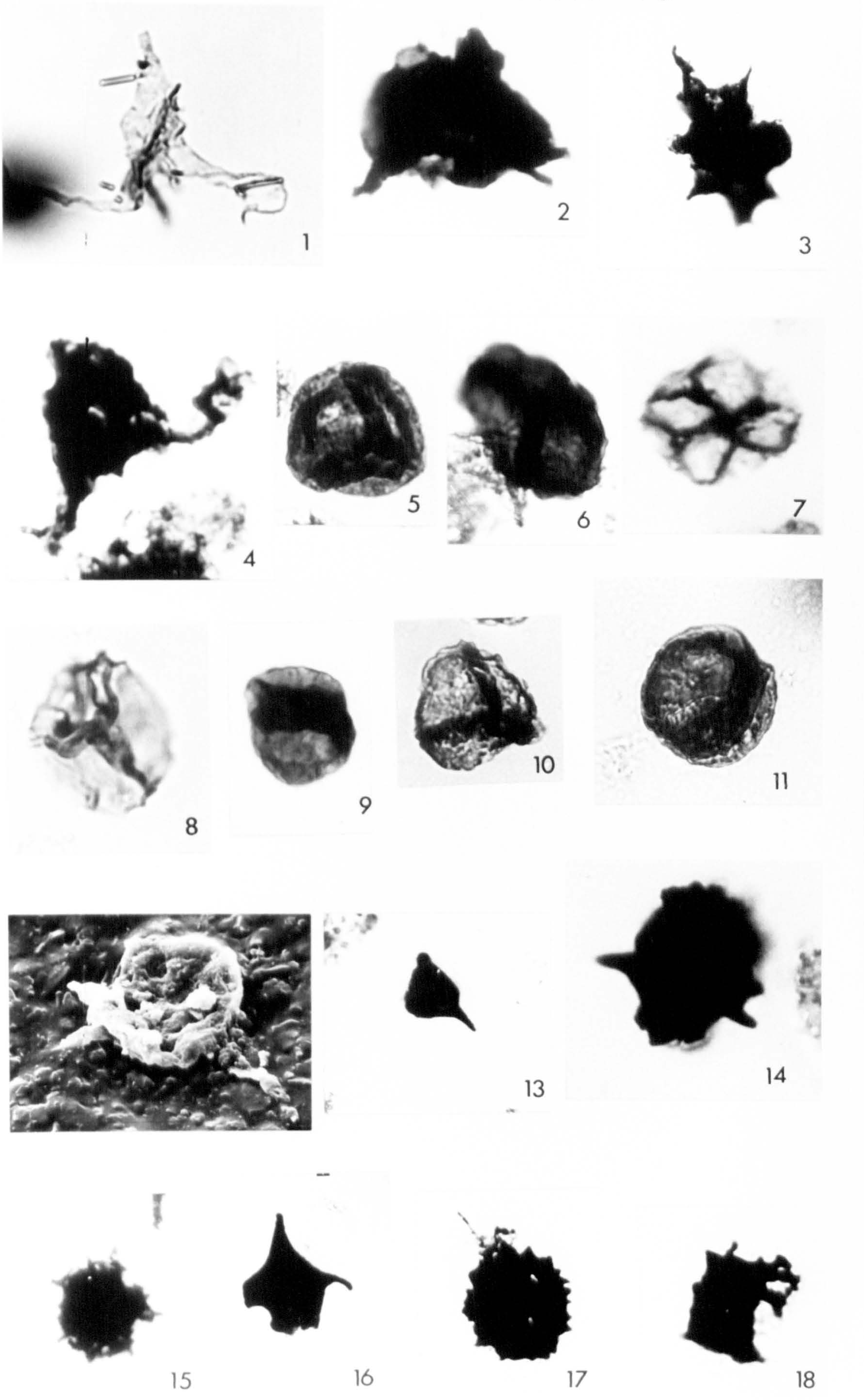


Plate 20

Scolecodonts

	H.M. no.	Sample	E.F.R.	Mag.
1.	x1498	MV/G/18(1)	C35/2	820
2.	x1499	HB/BB/2(1F)	G21/2	1000
3.	x1500	MV/G/24(1)	G24/4	500
4.	x1501	SU/B/1(2)	U30/2	520
5.	x1502	SU/DL/11(2)	G58/1	200
6.	x1503	MV/G/28(4)	M54/1	420
7.	x1504	HB/BAL/1(1)	Q36/4	720
8.	x1505	HB/LC/2(1)	N48/1	380
9.	x1506	MV/G/20(2)	Q44/2	580
10.	x1507	MV/G/9		260
11.	x1508	HB/BAL/2(1F)	L38/3	400
12.	x1509	MV/G/21(2)	V21/1	750
13.	x1510	MV/G/8		150
14.	x1511	MV/G/19		150
15.	x1512	SU/DL/38(1F)	E51/2	520
16.	x1513	MV/G/9		180

PLATE 20

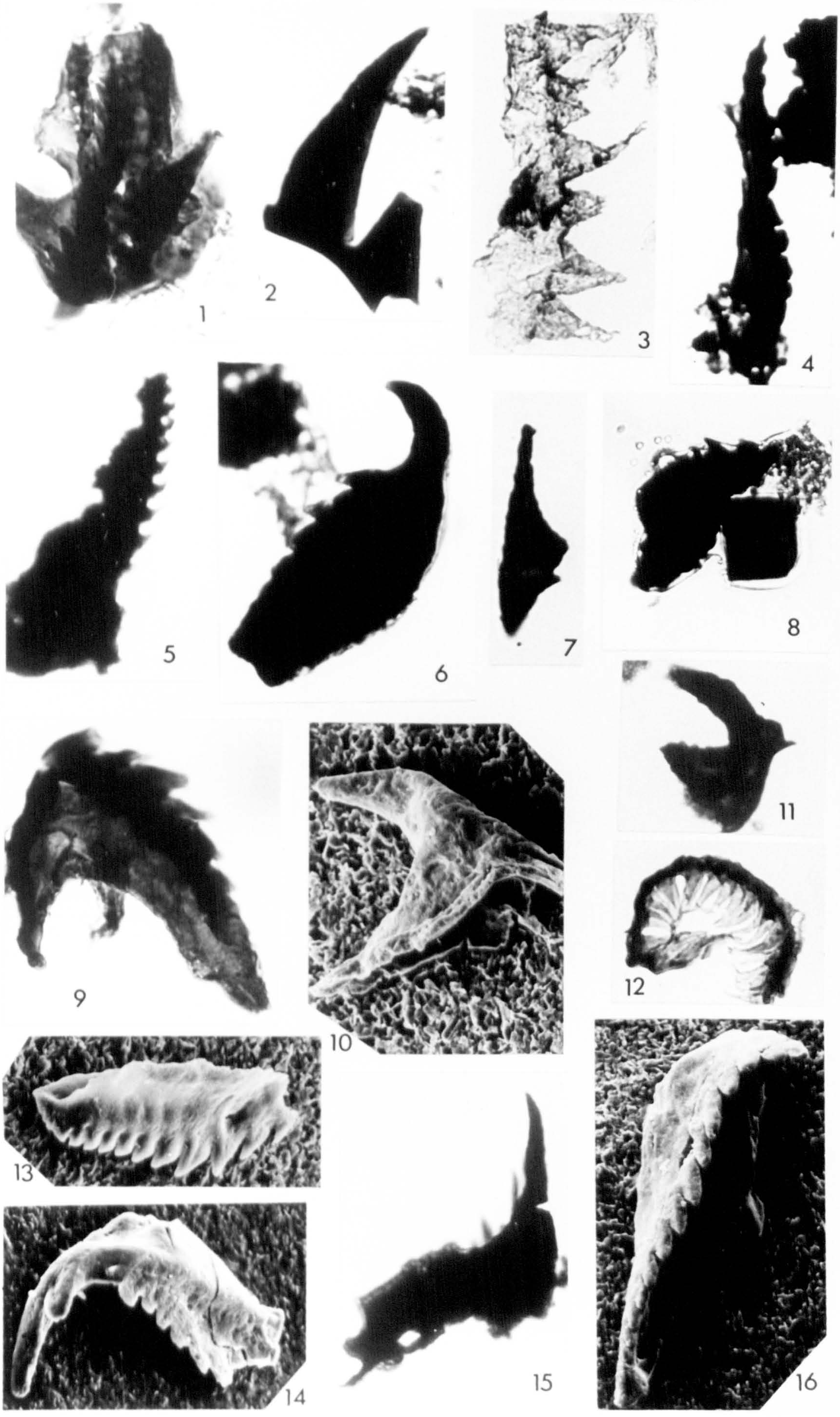


Plate 21

	H.M. no.	Sample	E.F.R.	Mag.
1. *Torellella* sp.	x1514	HB/LQ/14		80
2. ?Sphaeromorph acritarch	x1515	HB/LQ/19		250
3. *Torellella* sp.	x1516	HB/LQ/13		130
4. Contamination	x1517	HB/LQ/19		120
5. Pyrite spherule	x1518	SU/B/4		80
6. Transverse section of Fig. 3	x1516	HB/LQ/13		370
7. Transverse section of Fig. 4	x1517	HB/LQ/19		350
8. Pyrite spherule	x1519	SU/B/4		80
9. Contamination	x1520	HB/LQ/19		70
10.?Squashed leiosphere	x1521	HB/LQ/9		180
11.Contamination	x1522	HB/LQ/19		30
12.Contamination	x1520	HB/LQ/19		370
13.Contamination	x1523	HB/LQ/13		125
14.Contamination or spine	x1524	HB/LQ/13		120
15.Cuticle	x1525	MV/G/27(2)	M34/3	750.

PLATE 21

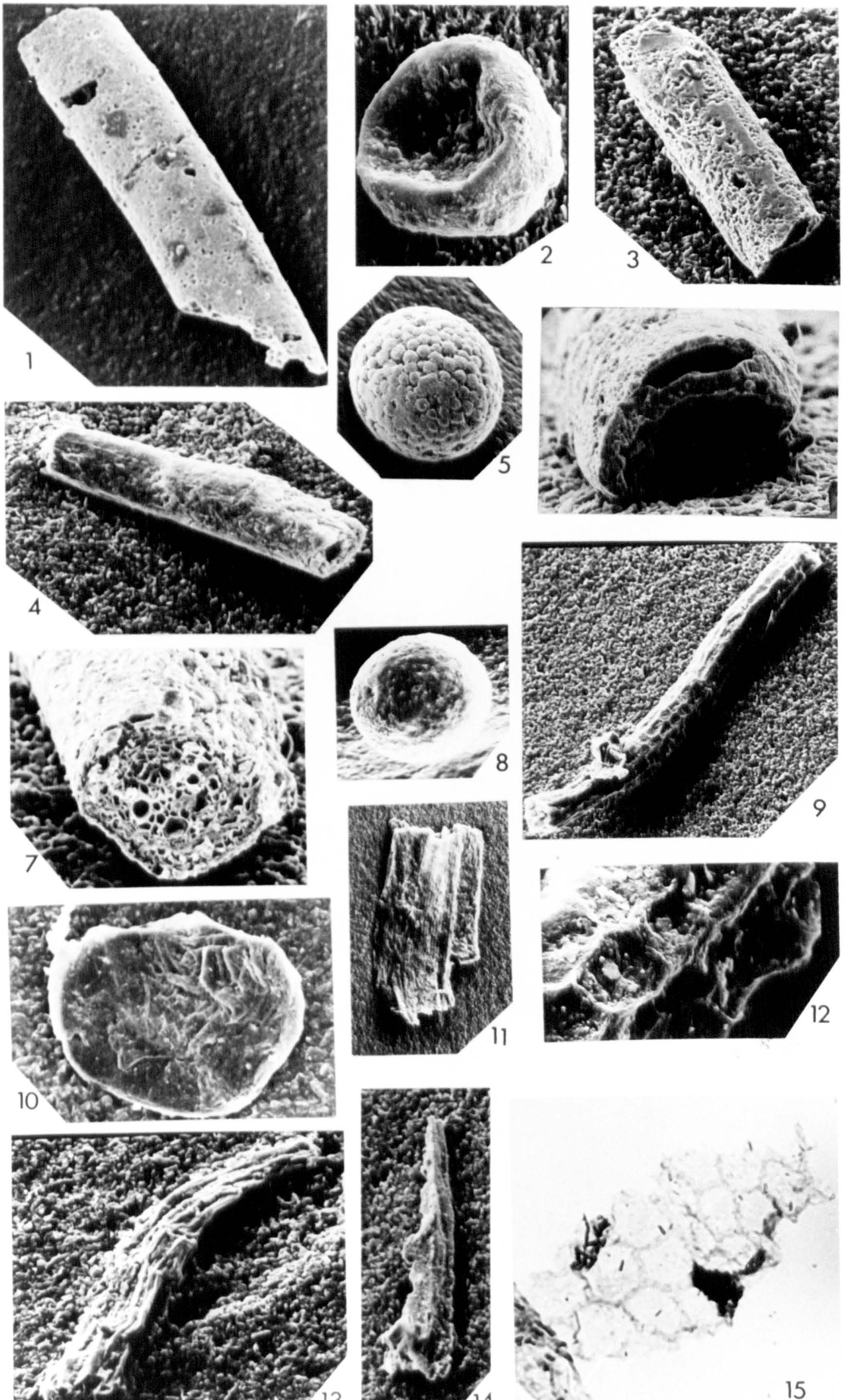


Plate 22

	H.M. no.	Sample	E.F.R.	Mag.
1. ?Macrofossil debris	x1526	MV/G/8		125
2. ?Macrofossil debris	x1527	SU/DI/36(1F)	R63/3	540
3. ?Macrofossil debris	x1528	SU/DL/36(1F)	M69/1	500
4. Graptolite sicula	x1529	SU/DL/1(1)	N24/4	140
5. ?Conodont	x1530	SU/DL/5(1)	R52/3	420
6. Graphite	x1531	HB/NE/1(1F)	N47/3	380
7. Graptolite stipe	x1532	SU/DL/1(1)	H16/3	440
8. Incertae sedis 2	x1533	MV/G/21(1)	D23/3	550
9. Graptolite debris/contamination	x1534	SU/DL/40(1)	O65/3	600
10. Graptolite tissue	x1535	SU/DL/16(1F)	C52/4	420
11. Organic tube	x1536	SU/DL/12(1F)	H39/1	350
12. ?Contamination	x1537	SU/DL/17(2F)	C44/2	380
13. ?Macrofossil debris	x1538	SU/DL/17(2F)	F53/1	420
14. ?Conodont	x1539	SU/DL/5(1)	A51/4	500
15. Incertae sedis 3	x1540	MV/G/18(2)	C36/2	500
16. Sponge spicule	x1541	HB/CQ/1		200
17. Siliceous material	x1542	HB/LQ/9		70.

PLATE 22

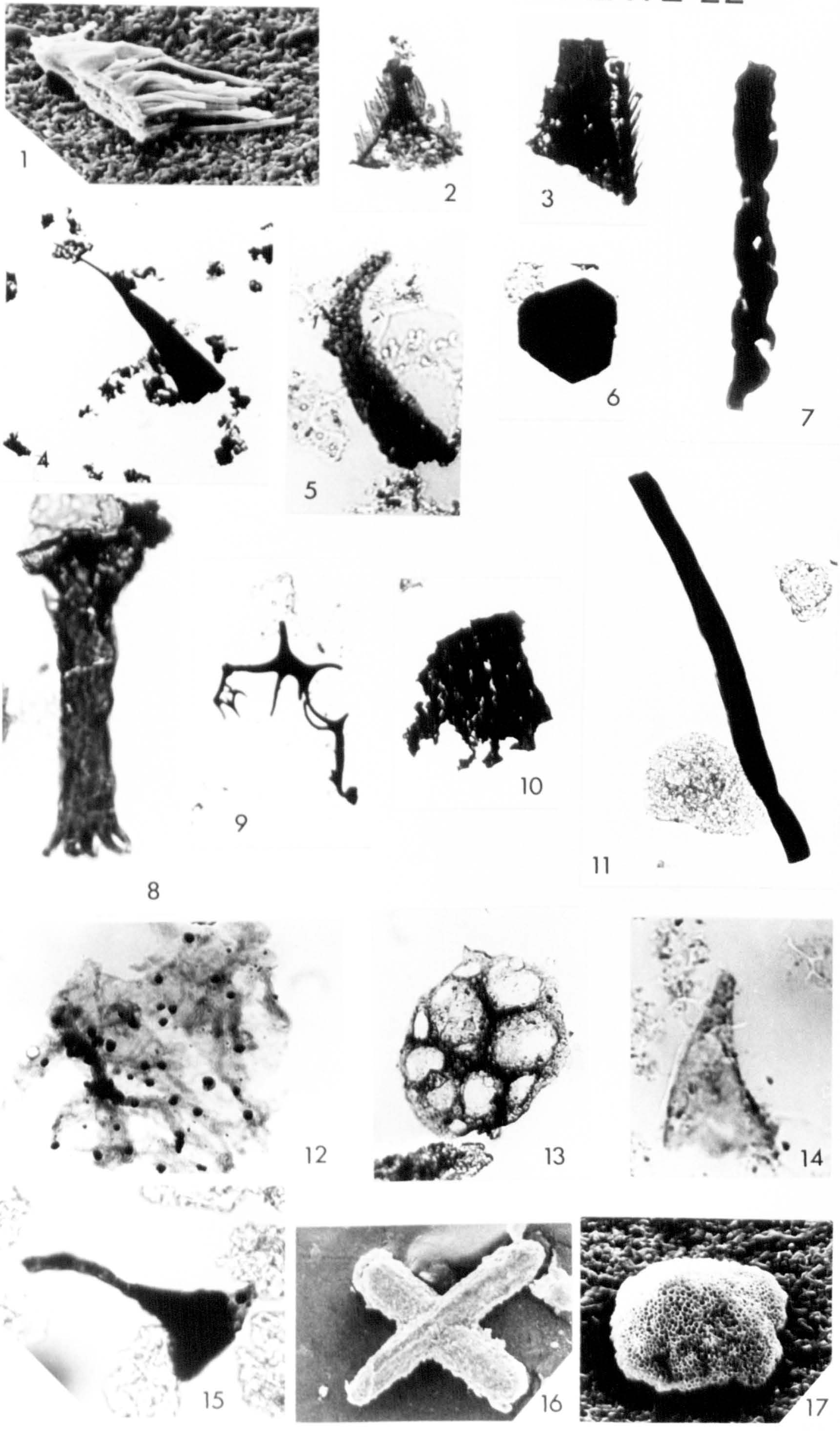


Plate 23

	H.M. no.	Sample	E.F.R.	Mag.
1. Incertae sedis 1	x1543	MV/G/24(2)	D51/2	560
2. Graphite	x1544	SU/DI8(1F)	V44/4	380
3. Contamination	x1545	SU/DL/39(1)	E41/4	440
4. Incertae sedis 4	x1546	MV/G/24(1)	F60/4	280
5. ?*Tasmanites* sp.	x1547	MV/G/21(1)	L44/4	500
6. Contamination-cyst	x1548	HB/LC/2(1)	F58/4	820
7. Modern diatom	x1549	SU/DL/13(2F)	V67/3	500
8. ?Spider's jaw fragment	x1550	HB/NE/4()	)42/3	450
9. Fly ash	x1551	SU/DL/15(3F)	M44/4	600
10.Contamination	x1552	SU/DL/3(3)	T56/1	620
11.?Spider's jaw fragment	x1553	HB/NE/4(6)	H39/2	130
12.Modern diatom	x1554	SU/DL/14(1F)	T44/2	600
13.Modern diatom	x1555	SU/DL/13(2F)	V61/2	380
14.Modern contamination-cyst	x1556	HB/LC/2(1)	C61/4	560
15.Contamination	x1557	HB/CQ/2(1)	E49/4	330
16.Fly ash	x1558	SU/DI15(3F)	G64/0	700
17.Fibrous mineral	x1559	MV/G/28(4)	P28/1	800.

PLATE 23

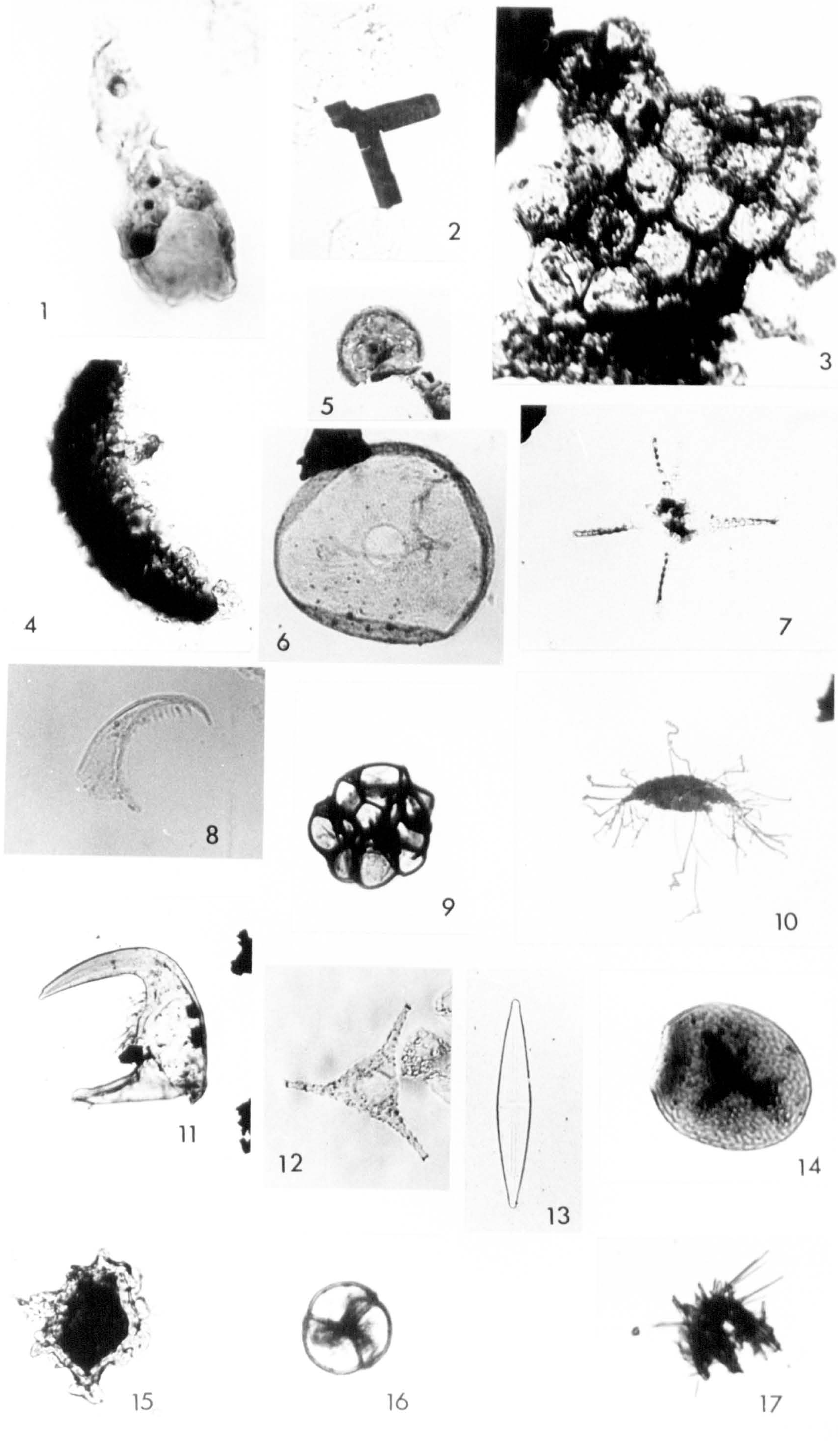


Plate 24

	H.M. no.	Sample	E.F.R.	Mag.
1. *Actinotodissus woodlandense* n. sp.				
	x1560	MV/G/18(1)	U47/2	1000
2. *Ammonidium* cf. *microcladum* (Downie) Lister 1970				
	x1561	SU/DL/53(6)	O40/2	1100
3. *Aremoricanium* sp. C	x1562	SU/DL/32(1)	O66/3	1000
4. *Baltisphaeridium multipilosum* (Eisenack) Eisenack 1958				
	x1563	SU/DL/32(2)	L45/4	1200
5. *Goniosphaeridium splendens* (Eisenack) Turner 1984				
	x1564	SU/DL/10(2)	T44/1	1000
6. *?Micrhystridium* sp. D	x1565	SU/DL/17(3F)	U43/4	1000
7. *Goniosphaeridium conjunctum* Kjellström 1971				
	x1566	MV/G/20(5)	K43/4	1200
8. *Diexallophasis* sp. A	x1567	SU/DL/10(4)	Q59/1	1250

PLATE 24

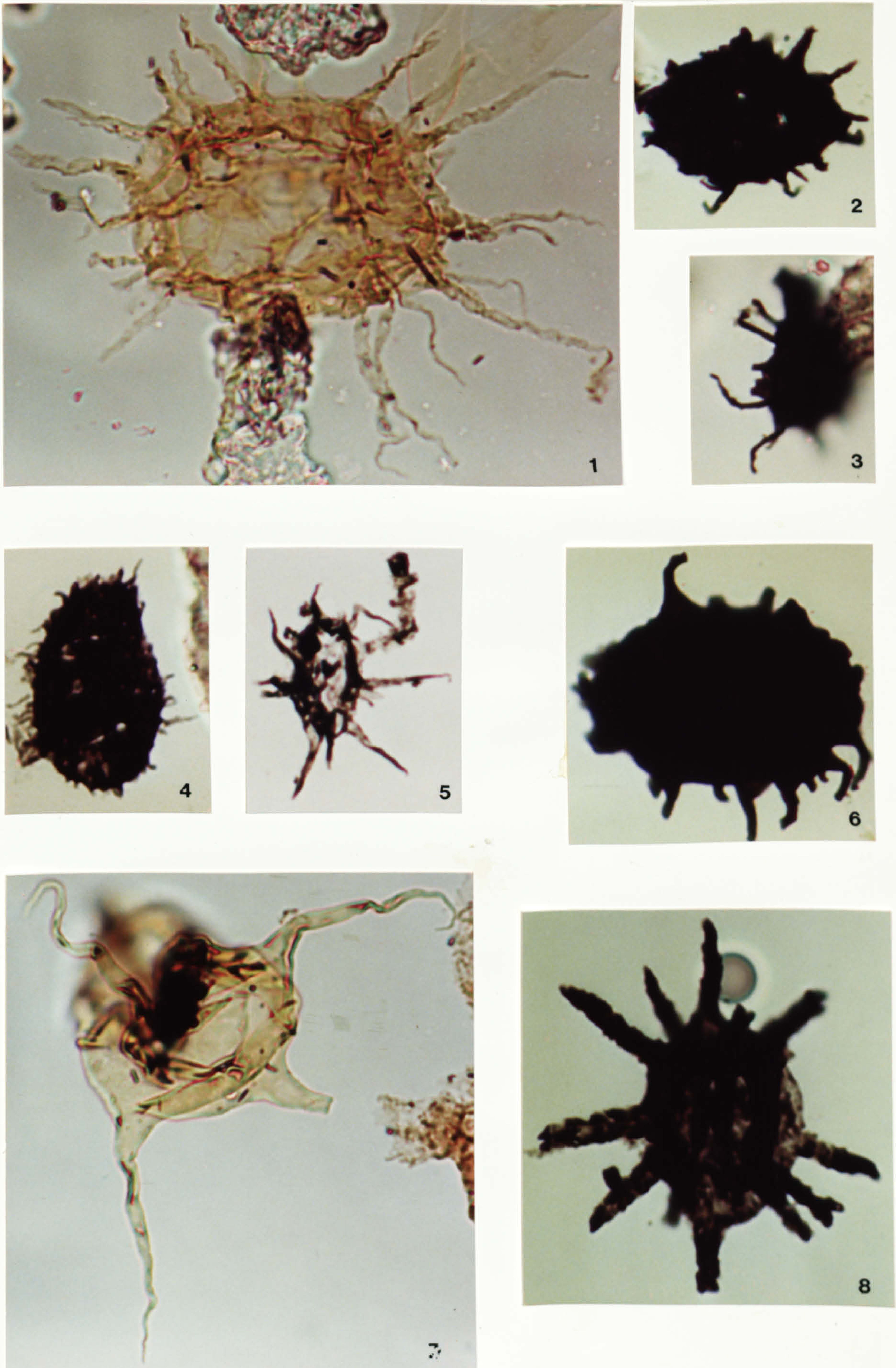


Plate 25

	H.M. no.	Sample	E.F.R.	Mag.
1. *Goniosphaeridium girvanense* n. sp.				
	x1568	MV/G/23(1)	R40/4	1250
2. *Solisphaeridium* cf. *nanum* (Deflandre) Turner 1984				
	x1569	SU/DL/12(2F)	R70/1	1200
3. *Veryhachium lairdi* (Deflandre) Deunff ex Downie 1959				
	x1570	SU/DL/39(3)	F66/3	1200
4. *Navifusa similis* (Eisenack) Turner 1984				
	x1571	MV/G/20(3)	G35/3	1100
5. *Solisphaeridium* cf. *nanum* (Deflandre) Turner 1984				
	x1572	MV/G/20(5)	E56/1	1000
6. *Veryhachium lairdi* (Deflandre) Deunff ex Downie 1959				
	x1573	MV/G/20(2)	N49/1	1000
7. *Stellechitinatum* cf. *brachyscolum* Turner 1984				
	x1574	SU/DL/12(5F)	L38/4	1200
8. *Tetrahedraletes medinensis* Strother and Traverse 1979				
	x1575	MV/G/18(2)	D54/3	1000

PLATE 25

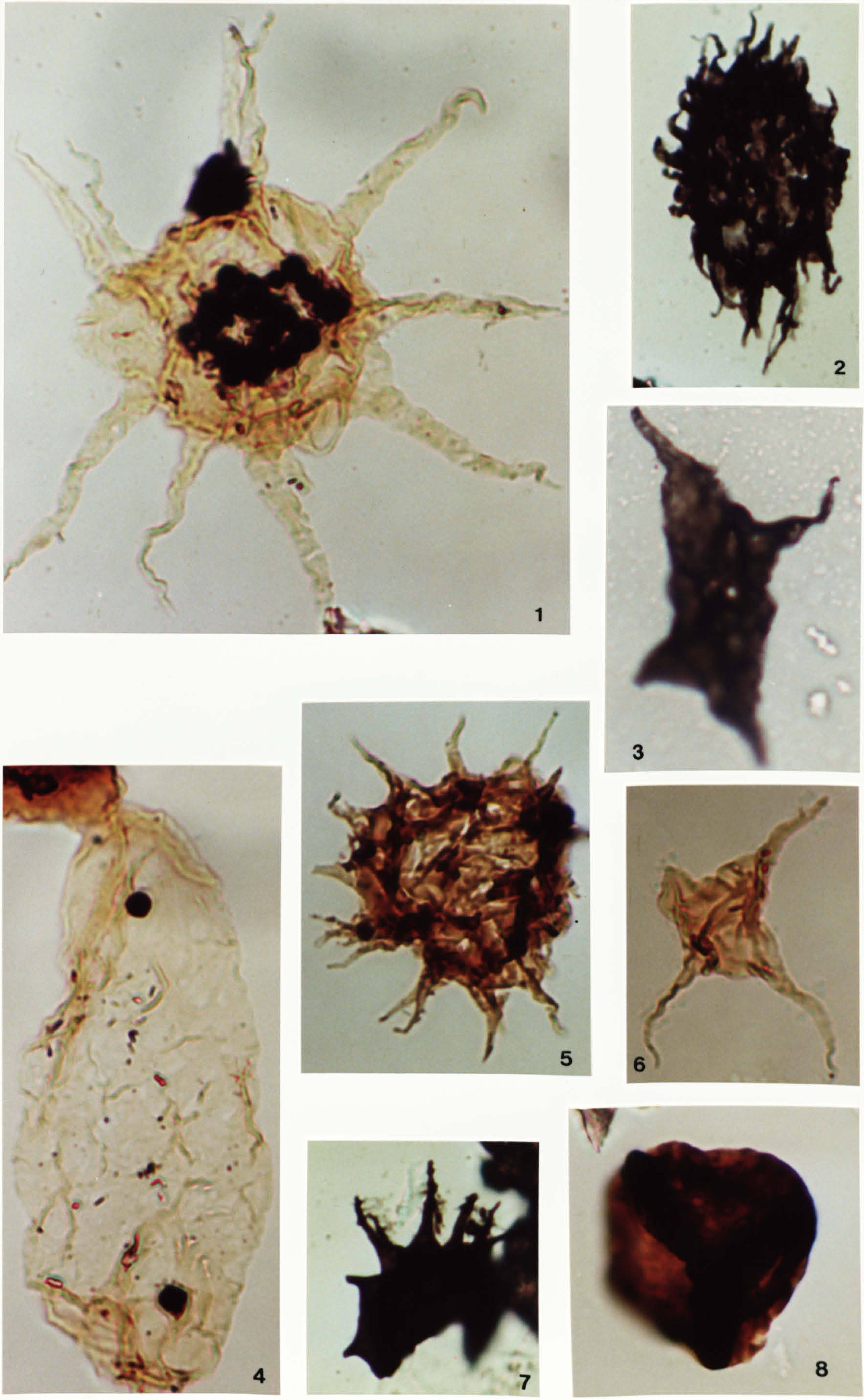
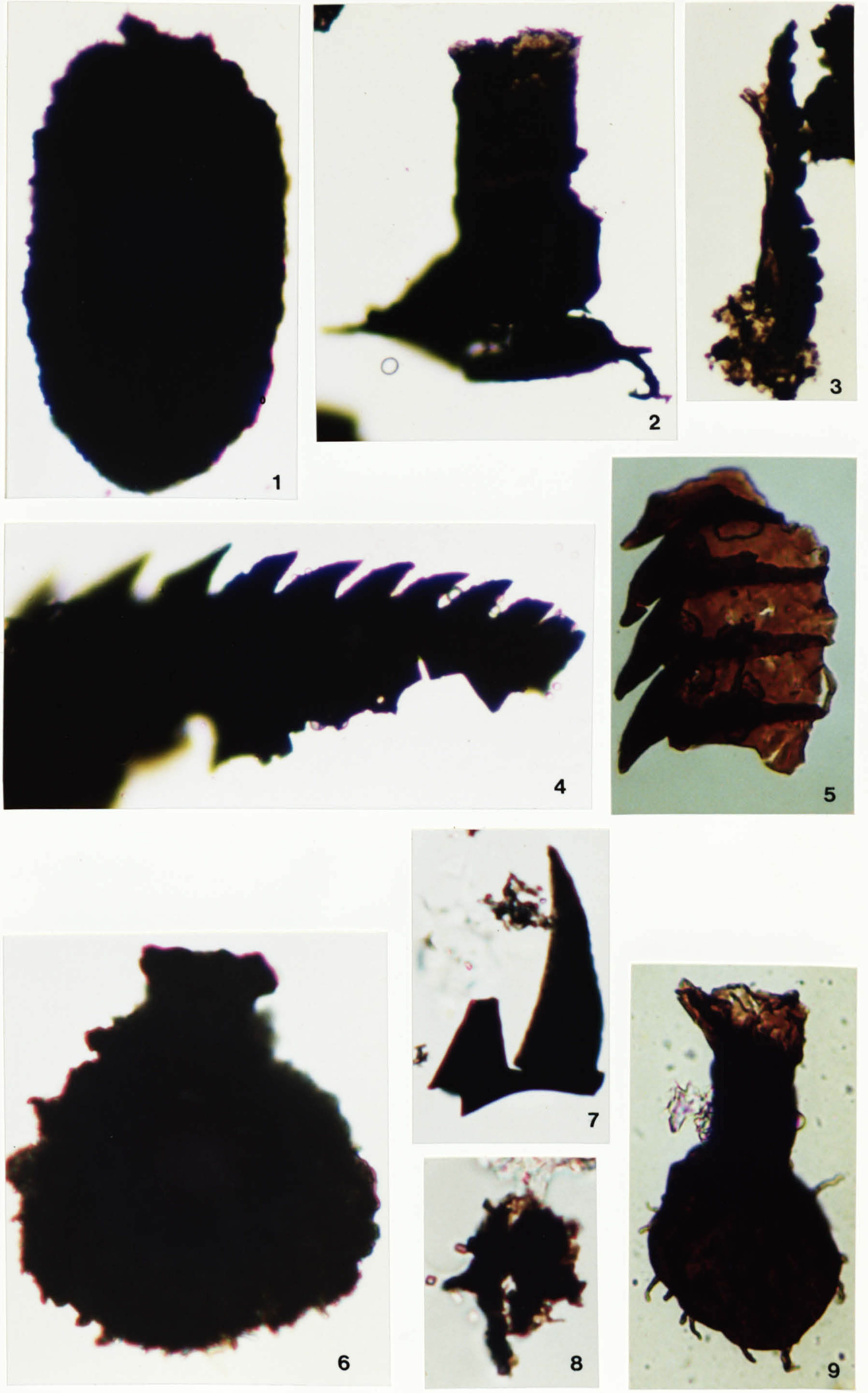


Plate 26

	H.M. no.	Sample	E.F.R.	Mag.
1. *Desmochitina minor* forma *elongata* Eisenack 1958				
	x1342	HB/BB/2(2c)	H49/1	650
2. *Ancyrochitina ancyrea* (Eisenack 1931)				
	x1263	SU/DL/41(7)	D44/3	580
3. Scolecodont	x1501	SU/B/1(2)	U30/2	570
4. Scolecodont	x1502	SU/DL/11(2)	G58/1	570
5. Scolecodont	x1576	MV/G/20(2)	N49/1	570
6. *Aremoricanium* sp. D	x1405	HB/NE/3(1F)	T39/2	1000
7. Scolecodont	x1499	HB/BB/2(1F)	G21/2	1200
8. *Micryhistridium* sp. C	x1444	SU/B/16(1)	H60/4	1200
9. *Angochitina woodlandensis* n. sp.				
	x1272	MV/G/23(1)	G26/2	590

PLATE 26



Appendix

Abbreviations

bs : black shale; lst : limestone; siltst : siltstone; mst : mudstone; congmat : conglomerate matrix; sst : sandstone; blst : black limestone; plst : purple limestone; ps : purple shale; gm : grey mudstone;

HIGHLAND BORDER COMPLEX

Sample number	Lithology	Assemblage
NORTH GLEN SANNOX, ARRAN		
HB/A/1	bs	corroded acanthomorph acritarchs
HB/A/2	lst	barren
HB/A/3	bs	*Cyathochitina sp. A* *Desmochitina (P) cf. minor* subsp. A *Lagenochitina obeligis?* *Lagenochitina* sp. indet *Leiosphaeridia* sp.C *Navifusa* sp. B corroded acanthomorph acritarchs
HB/A/4	bs	small object with good spines
HB/A/5	siltst	*Lagenochitina* sp. indet.
HB/A/6	lst	barren
GLEN FRUIN		
HB/GF/1	slate	*Leiosphaeridia* sp C *?Cyathochitina conica* *?Cyathochitina macastyensis*
BALMAHA		
HB/BAL/1	carbonate	*Desmochitina sp.A* corroded acanthomorph acritarchs scolecodont
HB/BAL/2	bs	*Conochitina primitiva* *?Cyathochitina cf.fusiformis* scolecodont

BOFRISHLIE BURN, ABERFOYLE

HB/BB/1	bs	*Leiosphaeridia* sp. C corroded acanthomorph acritarchs
HB/BB/2	bs	*Rhiptosocherma improcera* *Desmochitina minor*forma *elongata* *Leiosphaeridia* sp. C scolecodont
HB/BB/3	siltst	*Desmochitina* sp. B *Conochitina* sp. indet chitinozoan sp. indet
HB/BB/4	chert	barren
HB/BB/5	bs	*Cyathochitina* sp. indet. *chitinozoan* spp. indet. scolecodont

LIMECRAIG QUARRY, ABERFOYLE

HB/LC/1	mst	*Lagenochitina* sp. C
HB/LC/2	lst	*Leiosphaeridia* sp C scolecodont corroded acanthomorph acritarch
HB/LC/3	lst	*Leiosphaeridia* sp C
HB/LC/4	congmat	*Leiosphaeridia* sp C *Navifusa* sp. D
HB/LC/5	lst	*Cyathochitina* sp. indet *Leiosphaeridia*sp.C
HB/LC/6	shale	large spine
HB/LC/7	shale	*Conochitina* spp. indet.
HB/LC/8	shale	chitinozoan sp. indet.
HB/LC/9	sst	*Lagenochitina* sp. indet.
HB/LC/10	redsst	scolecodont spiny fragment

HB/LC/11	sst	*Lagenochitina* spp. indet. chitinozoan sp. indet scolecodont spines

LENY QUARRY, CALLANDER

HB/LQ/1	blst	*Leiosphaeridia* sp. C
HB/LQ/2	lst	*Leiosphaeridia* sp. C
HB/LQ/3	blst	*Leiosphaeridia* sp. C
HB/LQ/4	blst	*Leiosphaeridia* sp. C
HB/LQ/5	blst	*Leiosphaeridia* sp. C
HB/LQ/6	blst	*Leiosphaeridia* sp. C corroded acanthomorph acritarchs
HB/LQ/7	lst	barren
HB/LQ/9	grit	*Incertae sedis* ?*Lagenochitina* spp. indet
HB/LQ/10	grit	barren
HB/LQ/11	grit	barren
HB/LQ/12	grit	barren
HB/LQ/13	lst(A)	*Torellella* sp. pyrite framboids
HB/LQ/14	lst(A')	*Torellella* sp
HB/LQ/15	lst(B)	barren
HB/LQ/16	white grit	barren
HB/LQ/17	grit	barren
HB/LQ/19	shale(A).	small shelly fossils

LIMECRAIG QUARRY, CLUNIE

HB/CQ/1	white lst.	*Desmochitina bulla* *Lagenochitina* cf. *prussica* Sponge spicule
HB/CQ/2	peperite	barren
HB/CQ/5	peperite	barren
HB/CQ/6	lst	barren
HB/CQ/9	lst	barren
HB/CQ/12	lst	barren

NORTH ESK SECTION, EDZELL

HB/NE/1	plst	broken scolecodont corroded acanthomorph acritarchs
HB/NE/2	lst	barren
HB/NE/3	bs	*Leiosphaeridia* sp.C *Aremoricanium* sp. D *Conochitina* sp. indet. corroded acanthomorph acritarchs
HB/NE/4	blst	*Leiosphaeridia* sp.C corroded acanthomorph acritarchs
HB/NE/6	mst	?*Lagenochitina brevicollis* *Leiosphaeridia* sp.C
HB/NE/7	sst	barren
HB/NE/8	bs	*Leiosphaeridia* sp. C
HB/NE/9	ps	barren
HB/NE/10	mst	corroded acanthomorph acritarchs
HB/NE/11	shale	chitinozoan sp. indet. organic tube

HB/NE/12	bs	*Leiosphaeridia* sp. C *Navifusa* sp.B graptolite debris corroded acanthomorph acritarchs scolecodont
HB/NE/13	ps	scolecodonts corroded acanthomorph acritarchs
HB/NE/14	ps	*Leiosphaeridia* sp. C
HB/NE/15	bs	barren
HB/NE/16	bs	barren
HB/NE/17	siltst	barren
HB/NE/18	bs	barren
HB/NE/19	chert	barren
STONEHAVEN		
HB/S/1	bs	barren
HB/S/2	bs	*Leiosphaeridia* sp. C corroded acanthomorph acritarchs organic tube
HB/S/3	bs	barren
HB/S/4	bs	corroded acanthomorph acritarchs spine
HB/S/5	lst	barren

SOUTHERN UPLANDS

Sample number	Zone	Lithology	Locality	Assemblage
DOB'S LINN				
SU/DL/1	*C.peltifer*	bs	LC	*Micrhystridium* sp. A *Peteinosphaeridium* sp A *Leiosphaeridia* sp C *?Veryhachium* sp indet corroded acanthomorph acritarchs common graptolite debris common organic tubes
SU/DL/2	*C.wilsoni*	bs	LC	*Armoricochitina nigerica* *Leiosphaeridia* sp. B *Leiosphaeridia* sp. C corroded acanthomorph acritarchs rare graptolite debris rare organic tubes
SU/DL/3	*D. clingani*	bs	MC	*Conochitina* sp.B *Leiosphaeridia* sp. B *Leiosphaeridia* sp. C *Multiplicisphaeridium bifurcatum* rare graptolite debris rare organic tubes poor scolecodont
SU/DL/4	*P. linearis*	bs	MC	*Leiosphaeridia* sp. B *Leiosphaeridia* sp. C *Micrhystridium sp. C* *Navifusa sp.B* rare graptolite debris rare organic tubes
SU/DL/5	*D. complanatus*	gm	MC	*Leiosphaeridia* C conical fossils
SU/DL/6	*D. complanatus*	bs	MC	*Leiosphaeridia* sp. B *Leiosphaeridia* sp. C *Navifusa* sp. B corroded acanthomorph acritarchs rare organic tubes
SU/DL/7	*D. complanatus*	gm	MC	*Leiosphaeridia* sp. B *Leiosphaeridia* sp. C poor scolecodont ?macrofossil debris

SU/DL/8	*D. complanatus*	gm	MC	*Siphonochitina* sp. A
SU/DL/9	*D. anceps*	bs	MC	*Belonechitina micracantha* *Conochitina pygmaea* *Cyathochitina calix* *Cyathochitina campanulaeformis* *C. kuckersiana kuckersiana* *Hercochitina* cf. *turnbulli* *Lagenochitina sp.* A *Rhabdochitina* cf. *R. gallica* ?*Spinachitina bulmani* *Leiosphaeridia* sp. B *Leiosphaeridia* sp. C corroded acanthomorph acritarchs common graptolite debris common organic tubes
SU/DL/10	*D. anceps*	bs	MC	*Leiosphaeridia* sp. B *Leiosphaeridia* sp. C *Micrhystridium* sp. A *Micrhystridium* sp. C *Goniosphaeridium splendens* *Veryhachium reductum* *Aremoricanium* sp. A *Diexallophasis sp. A* *Multiplicisphaeridium ramuscolosum* common graptolite debris common organic tubes poor scolecodonts ?macrofossil debris
SU/DL/11	D. anceps	bs	MC	*Leiosphaeridia* sp. B *Leiosphaeridia* sp. C *Aremoricanium* sp. B corroded acanthomorph acritarchs corroded chitinozoans good scolecodonts common graptolite debris common organic tubes
SU/DL/12	*D.anceps*	gm	MC	*Leiosphaeridia* sp. *B* *Leiosphaeridia* sp. *C* *Solisphaeridium* cf. *nanum* *Stellechinatum* cf. *brachyscolum* *Micrhystridium* sp. C poor scolecodonts ?macrofossil debris

SU/DL/13	*D.anceps*	bs	MC	*Leiosphaeridia* sp. B *Leiosphaeridia* sp. C rare graptolite debris
SU/DL/14	*D.anceps*	bs	MC	*Leiosphaeridia* sp. C *Multiplicisphaeridium* sp. A rare graptolite debris
SU/DL/15	*C? extraord.*	gm	MC	*Leiosphaeridia* sp.B *Leiosphaeridia* sp. C *Multiplicisphaeridium* sp.A ?macrofossil debris
SU/DL/16	*C? extraord.*	bs	MC	*Leiosphaeridia* sp. C common graptolite debris common organic tubes
SU/DL/17	*C? extraord.*	gm	MC	*Cyathochitina hymenophora* *Leiosphaeridia*sp. B *Micrhystridium sp.* C ?*Micrhystridium* sp D *Neoveryhachium* sp.A *Actinotodissus*sp.A rare graptolite debris ?macrofossil debris
SU/DL/31	*C? extraord.*	bs	LB	*Leiosphaeridia*sp. B *Leiosphaeridia*sp.C
SU/DL/32	*C? extraord*	gm	LB	*Leiosphaeridia* sp. B *Leiosphaeridia* sp. C *Baltisphaeridium multipilosum* *Aremoricanium* sp.C rare graptolite debris rare organic tubes ?macrofossil debris
SU/DL/33	*G. perculptus*	bs	LB	*Leiosphaeridia* sp. B *Leiosphaeridia* sp. C common graptolite debris common organic tubes ?macrofossil debris
SU/DL/34	*G. perculptus*	bs	LB	*Conochitina tormentosa* *Leiosphaeridia* sp. C common graptolite debris common organic tubes ?macrofossil debris

SU/DL/35	*G. perculptus* bs	LB	*Kalochitina* sp A *Leiosphaeridia* sp. C common graptolite debris common organic tubes corroded acanthomorph acritarchs
SU/DL/36	*P. acuminatus* bs	LB	*Leiosphaeridia* sp. C corroded acanthomorph acritarchs common graptolite debris common organic tubes ?macrofossil debris
SU/DL/37	*P. acuminatus* bs	LB	*R. gracilis* common graptolite debris common organic tubes
SU/DL/38	*P. acuminatus* bs	LB	*Leiosphaeridia* sp. B corroded acanthomorph acritarchs common graptolite debris common organic tubes good scolecodont
SU/DL/39	*C? extraord.* gm	MC	*Leiosphaeridia* sp. B *Leiosphaeridia* sp. C *Veryhachium cf. subglobosum* *Veryhachium lairdii* *Veryhachium reductum* *Multiplicisphaeridium* sp . A rare graptolite debris
SU/DL/40	*G. perculptus* bs	MC	*Leiosphaeridia* sp. B *Dictyotidium* sp. A corroded acanthomorph acritarch rare graptolite debris rare organic tubes ?macrofossil debris
SU/DL/41	*P. acuminatus* bs	MC	*Ancyrochitina ancyrea* *Kalochitina sp. A* *Leiosphaeridia* sp.B corroded acanthomorph acritarchs common graptolite debris common graptolite debris
SU/DL/42	*D. anceps* gm	LB	barren
SU/DL/44	*D. anceps* gm	LB	*Micrhystridium* sp C *Leiosphaeridia* sp. C

SU/DL/45	*D. anceps*	gm	MC	*Leiosphaeridia* sp. B
				corroded acanthomorph acritarchs
SU/DL/46	*D. anceps*	gm	MC	*Leiosphaeridia* sp. B
				Leiosphaeridia sp. C
				Micrhystridium sp. B
				Conochitina minnesotensis
				Cyathochitina conica
				Cyathochitina sp. B
				Cyathochitina sp. C
				Desmochitina minor forma *cocca*
				Lagenochitina prussica
SU/DL/47	*D. anceps*	gm	MC	*Leiosphaeridia* sp. B
				Leiosphaeridia sp. C
				Navifusa sp B
				Neoveryhachium sp A
				Pterospermella sp A
				Veryhachium sp A
				conical fossils
SU/DL/48	*G. persculptus*	bs	MC	*Leiosphaeridia* sp. B
				Leiosphaeridia sp. C
				Ancyrochitina ancyrea
				Tylotopalla sp. A
				corroded acanthomorph acritarchs
				?macrofossil debris
				common graptolite debris
				common organic tubes
SU/DL/49	*G. perculptus*	bs	MC	*Leiosphaeridia* sp. B
				Leiosphaeridia sp. C
				Multiplicisphaeridium sp. A
				Cyathochitina campanulaeformis
				common graptolite debris
				common organic tubes
				corroded acanthomorph acritarchs
SU/DL/50	*G. perculptus*	bs	MC	*Leiosphaeridia* sp. B
				Leiosphaeridia sp. C
				Multiplicisphaeridium irregulare
				Pterospermella sp. A
				Ancyrochitina ancyrea
				Ancyrochitina sp. A
				Cyathochitina hymenophora
				common graptolite debris
				common organic tubes

		corroded acanthomorph acritarchs	
SU/DL/51	*G. perculptus* bs	MC	*Leiosphaeridia* sp. B *Leiosphaeridia* sp. C *Multiplicisphaeridium* sp.A *Goniosphaeridium splendens* *Cyathochitina conica* *Cyathochitina granulata* *Cyathochitina latipatigium* common graptolite debris common organic tubes corroded acanthomorph acritarchs conical fossils
SU/DL/52	*G. perculptus* bs	MC	*Leiosphaeridia* sp. B *Leiosphaeridia* sp. C *Tylotopalla sp. A* *Multiplicisphaeridium sp B* *Ancyrochitina ancyrea* *Sphaerochitina cf. lepta* common graptolite debris common organic tubes
SU/DL/53	*P. acuminatus* bs	MC	*Leiosphaeridia* sp. B *Leiosphaeridia* sp. C *Ammonidium* cf. *microcladum* *Ancyrochitina ancyrea* Chitinozoan sp. indet. common graptolite debris common organic tubes
SU/DL/54	*P. acuminatus* bs	MC	*Leiosphaeridia* sp. B *Leiosphaeridia* sp. C *Moyeria cabotti* *Goniosphaeridium sp indet* *Ancyrochitina ancyrea* *Cyathochitina campanulaeformis* *Cyathochitina* cf. *regnelli* corroded acanthomorph acritarchs common graptolite debris common organic tubes
SU/DL/55	*P. acuminatus* bs	MC	*Leiosphaeridia* sp. B *Leiosphaeridia* sp. C *Tylotopalla* sp. A *Veryhachium* sp. B *Ancyrochitina ancyrea*

			corroded acanthomorph acritarchs common graptolite debris common organic tubes conical fossils poor scolecodont
SU/DL/56	*P. acuminatus* bs	MC	*Leiosphaeridia* sp. B *Leiosphaeridia* sp. C *Tylotopalla* sp. A *Multiplicisphaeridium* sp. A *Goniosphaeridium splendens* *Ancyrochitina ancyrea* *Cyathochitina campanulaeformis* corroded acanthomorph acritarchs common graptolite debris common organic tubes ?macrofossil debris
SU/DL/57	*P. acuminatus* bs	MC	*Leiosphaeridia* sp. B *Leiosphaeridia* sp. C *Tylotopalla* sp. A *Multiplicisphaeridium* sp. A *Micrhystridium* sp. A *?Ancyrochitina corniculans* *Cyathochitina campanulaeformis* *Cyathochitina stentor* *Rhabdochitina* sp. A *?Spinachitina bulmani* corroded acanthomorph acritarchs common graptolite debris common organic tubes conical fossils

BARRHILL

Sample number	Assemblage
SU/B/1	*Leiosphaeridia* sp. B *Leiosphaeridia* sp. C *Leiosphaeridia* sp. F scolecodonts organic tubes graptolite debris
SU/B/3	*Leiosphaeridia* sp. B *Leiosphaeridia* sp. C

	Leiosphaeridia sp. F corroded scolecodont
SU/B/4	*Leiosphaeridia* sp. B *Leiosphaeridia* sp. G corroded acanthomorph acritarchs scolecodonts graptolite debris organic tube pyrite framboid
SU/B/6	*Leiosphaeridia* sp. C *Leiosphaeridia* sp. F
SU/B/8	*Leiosphaeridia* sp. B *Leiosphaeridia* sp. C organic tube
SU/B/10	*Leiosphaeridia* sp B corroded acanthomorph acritarchs chitinozoan sp.indet.
SU/B/12	*Leiosphaeridia* sp C Pyrite spherules spine corroded acanthomorph acritarchs graptolite debris organic tube
SU/B/13	*Lagenochitina* sp. indet. chitinozoan sp. indet
SU/B/14	*Leiosphaeridia* sp. F
SU/B/16	*Leiosphaeridia* sp. F ?*Micrhystridium* sp C. ?*Peteinosphaeridium* sp.B scolecodont organic tube corroded acanthomorph acritarchs
SU/B/17	scolecodont
SU/B/19	scolecodont

MIDLAND VALLEY

Sample number	Lithology	Assemblage
PINBAIN BEACH		
MV/G/1	lst	*Leiosphaeridia* sp. C
LAIGH KNOCKLAUGH		
MV/G/2	lst	*Leiosphaeridia* sp. C spiny fragment
MV/G/3	bs	*?Desmochitina* sp. indet corroded acanthomorph acritarchs
DOW HILL		
MV/G/5	mst	*Leiosphaeridia* cf. *tenuissima* *Leiosphaeridia* cf. *voigtii* *Leiosphaeridia* sp. E *?Navifusa* sp. A trilete spore A
ARDMILLAN BRAES		
MV/G/6	mst	*Goniosphaeridium* cf. *elongatum* *Leiosphaeridia voigtii* *Leiosphaeridia cf. tenuissima* *Leiosphaeridia* sp. G *Belonechitina hirsuta* *Belonechitina micracantha* *Conochitina minnesotensis* *Belonechitina robusta* *Cyathochitina hyalophrys* *Rhabdochitina* sp. C scolecodonts organic tubes graptolite debris
ARDWELL FARM		
MV/G/7	mst	*Leiosphaeridia* cf. *tenuissima* *Leiosphaeridia cf. voigtii* *?Dyadaspora* sp. A *Belonechitina micracantha* *Conochitina conulus* *Cyathochitina campanulaeformis*

		scolecodonts
		graptolite debris
		organic tubes

DOULARG HILL

MV/G/8	lst	*Leiosphaeridia* cf.*tenuissima*
		Leiosphaeridia cf.*voigtii*
		?Dyadaspora sp. A
		Leiofusa aspilis?
		Leiofusa sp. A
		Navifusa sp. C
		?Dictyotidium sp. B
		Conochitina sp. D
		Conochitina sp. indet
		Sphaerochitina sp. A
		Rhabdochitina sp. D
		organic tubes
		scolecodonts
		pyrite framboids
MV/G/9	lst	*Leiosphaeridia* cf. *voigtii*
		Leiosphaeridia cf. *tenuissima*
		Leiosphaeridia sp. D
		Leiofusa sp. A
		Tasmanites sp. C
		Veryhachium trispinosum
		Cyathochitina campanulaeformis
		Cyathochitina calix
		Cyathochitina protocalix
		Cyathochitina jenkinsi
		Belonechitina micracantha
		Conochitina minnesotensis
		Rhabdochitina sp. E
		Kalochitina sp. B
		scolecodonts
		corroded acanthomorph acritarchs
		organic tube

WOODLAND POINT

MV/G/18	mst	*Actinotodissus woodlandense.*
		Baltisphaeridium hirsuitoides
		Goniosphaeridium girvanense
		Leiosphaeridia cf. *voigtii*
		Leiosphaeridia cf. *tenuissima*
		Leiosphaeridia sp. A
		Moyeria cabotti
		Navifusa sp A

		Solisphaeridium cf. *nanum*
		Tasmanites sp. C
		Tetrahedraletes medinensis
		Dyadaspora sp. A
		Nodospora sp. A
		Angochitina woodlandensis.
		Belonechitina micracantha
		Belonechitina schopfi americana
		Belonechitina seriespinosa
		Belonechitina sp. A
		Calpichitina lenticularis
		Calpichitina megastrophica
		Conochitina minnesotensis
		Conochitina sp A
		Conochitina sp C
		Pterochitina hymenelytrum
		Tanuchitina cf. *ontariensis*
		scolecodonts
		Incertae sedis 3
		fused cluster scolecodonts
		?macroscopic remains
		corroded acanthomorph acritarchs
MV/G/19	shale	*Leiosphaeridia* sp. A
		Leiosphaeridia cf. *tenuissima*
		Leiosphaeridia cf. *voigtii*
		Leiosphaeridia spp. indet.
		Moyeria cabotti
		Tetrahedraletes medinensis
		Cyathochitina hyalophrys
		Rhabdochitina magna
		Scolecodonts
MV/G/20	shale	*Baltisphaeridium* sp. A
		Goniosphaeridium conjunctum
		?Leiofusa sp A
		Leiosphaeridia sp. A
		Leiosphaeridia cf. *voigtii*
		Leiosphaeridia cf. *tenuissima*
		Micrhystridium sp B
		Moyeria cabotti
		Multiplicisphaeridium irregulare
		Multiplicisphaeridium ramuscolosum
		Navifusa similis
		Solisphaeridium cf.*nanum*
		Tasmanites sp A
		Tasmanites sp. B
		Veryhachium lairdii

		Veryhachium oklahomense
		Veryhachium cf. *subglobosum*
		Tetrahedraletes medinensis
		Acanthochitina barbata
		Angochitina woodlandensis
		Belonechitina micracantha
		Belonechitina robusta
		Belonechitina wesenbergensis
		Calpichitina lenticularis
		Conochitina conulus
		Conochitina minnesotensis
		Rhabdochitina gracilis
		Sphaerochitina mundana?
		scolecodonts
MV/G/21	shale	*Aremoricanium* cf. *deflandrei*
		Baltisphaeridium hirsuitoides
		Baltisphaerosum christoferi
		Goniosphaeridium girvanense
		Goniosphaeridium splendens
		Leiosphaeridia sp. A
		Leiosphaeridia sp. H
		Leiosphaeridia cf. *voigtii*
		Leiosphaeridia cf. *tenuissima*
		Moyeria cabotti
		Multiplicisphaeridium ramuscolosum
		Solisphaeridium cf.*nanum*
		Tetrahedraletes medinensis
		Ancyrochitina sp.B
		Belonechitina micracantha
		Belonechitina schopfi americana
		Calpichitina lenticularis
		Conochitina conulus
		Conochitina minnesotensis
		Rhabdochitina gracilis
		Incertae sedis 2
		scolecodonts
		corroded acanthomorph acritarchs
		graptolite debris
MV/G/22	shale	*Baltisphaeridium cristoferi*
		Cymatiosphaera densisepta
		Goniosphaeridium elongatum
		Goniosphaeridium girvanense
		Leiosphaeridia sp. A
		Leiosphaeridia cf. *voigtii*
		Leiosphaeridia cf. *tenuissima*
		Leiosphaeridia sp. H

		Leiofusa sp. A
		Moyeria cabotti
		Multiplicisphaeridium ramuscolosum
		Multiplicisphaeridium cf. *wrightii*
		?Orthosphaeridium chondrodora
		Solisphaeridium cf.*nanum*
		Dyadaspora sp. A
		Tetrahedraletes medinensis
		Belonechitina cf. *hirsuta*
		Belonechitina micracantha
		Belonechitina seriespinosa
		Belonechitina wesenbergensis
		Calpichitina lenticularis
		Rhabdochitina magna
		scolecodonts
		corroded acanthomorph acritarchs
		graptolite debris
MV/G/23	shale	*Baltisphaeridium* cf. *bulbosum*
		Baltisphaeridium cf. *paucispinosum*
		Goniosphaeridium elongatum
		Goniosphaeridium girvanense
		Leiosphaeridia cf. *voigtii*
		Leiosphaeridia sp. A
		Leiosphaeridia cf. *tenuissima*
		Leiosphaeridia sp. H
		Micrhystridium sp. A
		Micrhystridium sp B
		Moyeria cabotti
		Multiplicisphaeridium ramuscolosum
		Peteinosphaeridium nudum?
		Solisphaeridium cf. *nanum*
		Navifusa similis
		Dyadaspora sp. A
		Tetrahedraletes medinensis
		Angochitina woodlandensis
		Belonechitina cf. *hirsuta*
		Belonechitina micracantha
		Belonechitina seriespinosa
		Belonechitina wesenbergensis
		Calpichitina lenticularis
		Conochitina sp. E
		Conochitina sp. indet
		?Cyathochitina campanulaeformis
		scolecodonts

MV/G/24	shale	*Actinotodissus woodlandensis*
		Baltisphaeridium cf. *regnelli*
		Goniosphaeridium girvanense
		Leiosphaeridia cf. *voigtii*
		Leiosphaeridia sp. A
		Leiosphaeridia cf. *tenuissima*
		Micrhystridium sp A
		Moyeria cabotti
		Multiplicisphaeridium ramuscolosum
		Navifusa similis
		?Orthosphaeridium chondrodora
		Solisphaeridium cf. *nanum*
		Veryhachium lairdii
		Dyadaspora sp. A
		Tetrahedraletes medinensis
		Angochitina woodlandensis
		Belonechitina micracantha
		Belonechitina seriespinosa
		Belonechitina sp. B
		Calpichitina lenticularis
		Calpichitina megastrophica
		Conochitina minnesotensis
		Cyathochitina kuckersiana patagiata
		Cyathochitina vaurealensis
		Cyathochitina sp. D
		Rhabdochitina magna
		Tanuchitina anticostiensis
		scolecodonts
		Incertae sedis ?
		corroded acanthomorph acritarchs
MV/G/25	shale	*Aremoricanium* cf. *rigaudae*
		Baltisphaeridium cf. *psilatum*
		Goniosphaeridium girvanense
		Leiosphaeridia cf. *voigtii*
		Leiosphaeridia sp. A
		Leiosphaeridia cf. *tenuissima*
		Micrhystridium sp. A
		Micrhystridium sp B
		Moyeria cabotti
		Multiplicisphaeridium ramuscolosum
		Navifusa similis
		?Orthosphaeridium chondrododora
		Veryhachium lairdii
		Dyadaspora sp. A
		Tetrahedraletes medinensis
		Angochitina woodlandensis
		Belonechitina micracantha

		Belonechitina seriespinosa
		Calpichitina lenticularis
		Conochitina elegans
		Cyathochitina hyalophrys
		scolecodonts
		corroded acanthomorph acritarchs
		broken chitinozoan
MV/G/26	shale	*Aremoricanium* cf. *rigaudae*
		Baltisphaeridium hirsuitoides
		Filisphaeridium sp. A
		Goniosphaeridium girvanense
		Leiosphaeridia cf. *voigtii*
		Leiosphaeridia sp. A
		Leiosphaeridia cf. *tenuissima*
		Leiosphaeridia sp. B
		Micrhystridium *sp* A
		Micrhystridium sp B
		Moyeria cabotti
		Navifusa similis
		Dyadaspora sp.A
		Tetrahedraletes medinensis
		Belonechitina comma
		Belonechitina micracantha
		Belonechitina seriespinosa
		Belonechitina wesenbergensis
		Calpichitina lenticularis
		Rhabdochitina magna
		scolecodonts
		corroded acanthomorphs
MV/G/27	shale	*Dictyotidium* sp A
		Goniosphaeridium girvanense
		Leiosphaeridia cf. *voigtii*
		Leiosphaeridia sp. A
		Leiosphaeridia cf. *tenuissima*
		Moyeria cabotti
		Multiplicisphaeridium sp C.
		Multiplicisphaeridium ramuscolosum
		Multiplicisphaeridium irregulare
		Navifusa sp A
		Navifusa similis
		Dyadaspora sp A.
		Tetrahedraletes medinensis
		Acanthochitina barbata
		Angochitina woodlandensis
		Belonechitina comma
		Belonechitina cf. *hirsuta*
		Belonechitina micracantha

		Belonechitina robusta
		Belonechitina schopfi americana
		Belonechitina seriespinosa
		Belonechitina wesenbergensis
		Calpichitina lenticularis
		Calpichitina megastrophica
		*Conochitina*cf.*tuba*
		Lagenochitina sp B
		Rhabdochitina sp B.
		Rhabdochitina gracilis
		scolecodonts
		cuticle
MV/G/28	shale	*Actinotodissus woodlandense*
		Eupoikilofusa striata
		?Goniosphaeridium elongatum
		Goniosphaeridium splendens
		Goniosphaeridium girvanense
		Leiosphaeridia cf. *voigtii*
		Leiosphaeridia cf.*tenuissima*
		Leiosphaeridia sp. A
		Micrhystridium sp. B
		Moyeria cabotti
		Multiplicisphaeridium alloiteaui
		Multiplicisphaeridium bifurcatum
		Multiplicisphaeridium ramuscolosum
		Navifusa similis
		Orthosphaeridium sp. A
		Veryhachium trispinosum
		Veryhachium triangulatum
		Tetrahedraletes medinensis
		Acanthochitina barbata
		Belonechitina comma
		Belonechitina micracantha
		Belonechitina schopfi americana
		Belonechitina wesenbergensis
		Calpichitina lenticularis
		Calpichitina megastrophica
		Conochitina conulus
		Conochitina elegans
		Cyathochitina sp. D
		Rhabdochitina striata
		Chitinozoan sp. A
		corroded acanthomorph acritarchs
		scolecodonts

MV/G/29	shale	*?Ammonidium* sp. A
		Baltisphaerosum cristoferi
		Leiosphaeridia cf. *voigtii*
		Leiosphaeridia sp. A
		Leiosphaeridia cf. *tenuissima*
		Moyeria cabotti
		Navifusa similis
		Tetrahedraletes medinensis
		Belonechitina micracantha
		chitinozoan sp indet
		scolecodont
		corroded acanthomorph acritarchs