

Tremadoc-Arenig acritarchs from the Annascaul Formation, Dingle Peninsula, Co. Kerry, Ireland

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ABSTRACT – The Annascaul Formation occurs in the southeast part of the Dingle Peninsula and occupies a narrow outcrop strip running from Minard Bay northeastwards to Caherconree Mountain. It comprises the oldest rocks in the peninsula and is composed of a >500 m succession of deep marine mudrocks, siltstones, turbiditic sandstones, and mud-matrix melange deposits. The formation was traditionally considered to be Silurian in age; however lithological, structural, and metamorphic evidence indicated a much older age, although, diagnostic palaeontological evidence was lacking. Preliminary palynological study in 1996 revealed the presence of Early Ordovician acritarchs in two samples from Minard Bay. In the present study, acritarchs are recorded from 15 samples from the formation at Minard Bay and from inland exposures around Annascaul. Despite high thermal maturity, the acritarchs are moderately well preserved. The majority of the taxa are well-established species; one new species, *Cymatiogalea vanguestainei*, is erected. Four distinctive but low-diversity acritarch assemblages are described; these indicate an age range of early Tremadoc to early-mid Arenig for the Annascaul Formation.

RIASSUNTO – [Acritarchi del Tremadoc-Arenig della Formazione di Annascaul, Penisola Dingle, Capo Kerry, Irlanda] – La Formazione di Annascaul si trova nella parte sudorientale della Dingle Peninsula e forma uno stretto affioramento allungato che decorre in direzione nordorientale dalla Minard Bay alla Caherconree Mountain. Questo affioramento comprende le più antiche rocce della penisola ed è formato da una successione, maggiore di 500 m, di argilliti, siltiti, arenarie torbiditiche e depositi di "melange" a matrice argillitica. Questa formazione era tradizionalmente considerata di età siluriana; ma le caratteristiche litologiche, strutturali e metamorfiche indicavano un'età assai più antica, anche se mancavano prove paleontologiche determinanti. Un lavoro palinologico preliminare del 1996 ha rivelato la presenza di acritarchi dell'Ordoviciano inferiore in due campioni della Minard Bay. Nel presente studio, vengono documentati acritarchi nella Formazione di Annascaul alla Minard Bay e in affioramenti dell'entroterra intorno ad Annascaul. Nonostante l'alta maturità termale, gli acritarchi sono moderatamente ben preservati. La maggior parte dei taxa è riferita a specie già conosciute; una nuova specie, *Cymatiogalea vanguestainei*, viene fondata. Sono descritte cinque associazioni di acritarchi, ben differenziate anche se a bassa diversità. Esse indicano un'età Tremadoc inferiore-Arenig inferiore-medio della Formazione di Annascaul.

INTRODUCTION AND GEOLOGICAL SETTING

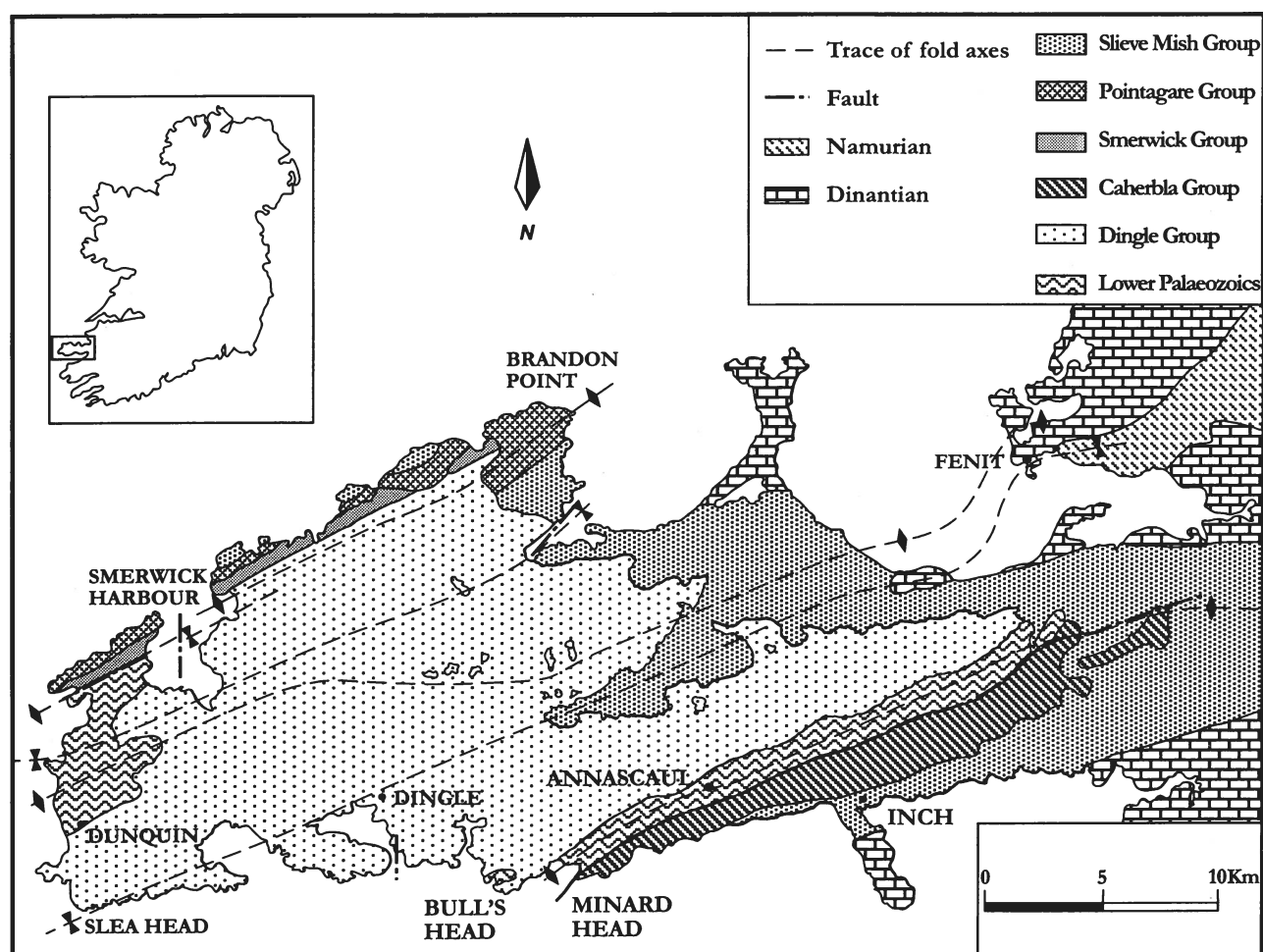
The Annascaul Formation comprises the oldest rocks within the Dingle Peninsula (Pracht, 1996), consisting of a >500 m (Horne, 1974) deep marine sequence of red, green, and grey mudrocks and siltstones, turbiditic and slumped sandstones, and mud-matrix conglomerates and breccias. The latter are interpreted as volcanic mud flow deposits by Parkin (1976) and as melange deposits by Todd (1989). The Annascaul Formation occupies an elongate strip stretching from the coast at Minard Bay (grid reference V527 982), north-eastwards to the western slopes of Caherconree Mountain (Text-fig. 1). The most extensive exposures occur as coastal outcrops at Minard Bay and Bull's Head; only small and intermittent outcrops occur inland.

AGE OF THE ANNASCAUL FORMATION

Dating of the Annascaul Formation is controversial. Parkin (1976) assigned a Silurian age to the entire Annascaul Formation based on the presence of a Wenlock shelly fauna in the Ballynane Member, a

sequence of tuffaceous shale, limestone, and secondary dolomite occurring at the top of the formation. Pracht (1996) revised the stratigraphy of the Annascaul Formation and raised the Ballynane Member to formational status. Furthermore, he considered the Ballynane Formation to rest unconformably on the relatively unfossiliferous deep water mudrocks and turbidites of the revised Annascaul Formation.

The argument for an unconformity is based on several lines of evidence, briefly mentioned by Pracht (1996) and documented in detail by Todd *et al.*, (in prep.). These authors point out the marked contrast in structure, metamorphism, and depositional facies between the two formations. For instance, the Annascaul Formation displays a much more complex deformational history and is of low grade greenschist facies metamorphism, neither of which is featured by the overlying Ballynane Formation. Moreover, the contact between the Annascaul Formation and the Ballynane Formation, well-exposed at Coostorrig north of Bull's Head, is now interpreted as a low angle unconformity. Accordingly, Pracht (1996) and Todd *et al.*, (in prep.) suggest that the Annascaul Formation was affected by an additional pre-Ballynane deforma-



Text-fig. 1 - Geographic location and stratigraphy of the Dingle Peninsula.

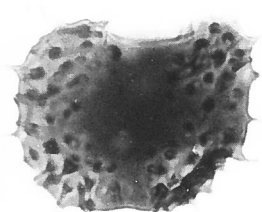
tion. This deformation may reflect an early Caledonian orogenic peak, similar to the Monian, which deformed the structurally and lithologically similar rocks of the Ordovician Oaklands Formation of the Ribband Group of southeast Ireland (Tietzsch-Tyler & Sleeman, 1994; Todd, 1989). Hence Pracht (1996, p. 12) suggested that the Annascaul Forma-

tion is of Ordovician age. However, there was no palaeontological evidence to support this age assignment. Until 1996, relatively few fossils had been found in the Annascaul Formation; these comprise small, simple trace fossils and some crinoid stems and ossicles of little biostratigraphic value. The first diagnostic evidence of age was provided by a preliminary

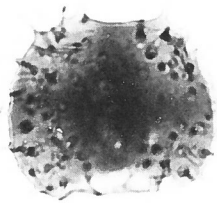
EXPLANATION OF PLATE 1

- Figs. 1, 2 - *Acanthodiacrodium? dilatatum* Molyneux in Molyneux & Rushton, 1988. 1) MB6, V65/1; 2) MB6, T49/2.
 Figs. 3-6 - *Acanthodiacrodium? sp. 1 sensu* Servais & Molyneux, 1997. 3) MB6, O64/2; 4) FW4, P53/2; 5) BC16, D32/2; 6) FW4, T54/2.
 Fig. 7 - *Acanthodiacrodium-Coryphidium* transient; bipolar arrangement of processes with incipient striations. MB9, W50/2.
 Fig. 8 - *Baltisphaeridium* sp. BC16, O29/4.
 Figs. 9, 10 - *Acanthodiacrodium golubii* Fensome *et al.*, 1990. 9) AR2, K59/3; 10) AR2, N53/4.
 Figs. 11-18 - *Caldariola glabra* (Martin) Molyneux in Molyneux & Rushton, 1988 var. *glabra*. 11) FW4, R52/1; 12) BC16, H24/1; 13) BC16, K12/4; 14) BC16, K16/1; 15) MB2, J49/2; 16) BC16, O3/3; 17) BC16, C24/4; 18) BC16, N33/4.
 Figs. 19, 20 - *Caldariola* sp. cf. *C. glabra* (Martin) Molyneux in Molyneux & Rushton, 1988 var. *glabra*. 19) MB2, R56/1; 20) BC16, D28/2.

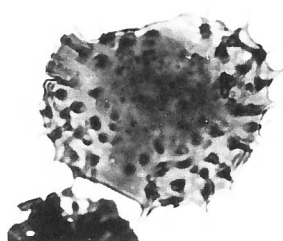
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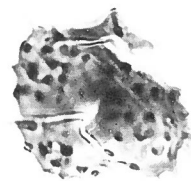
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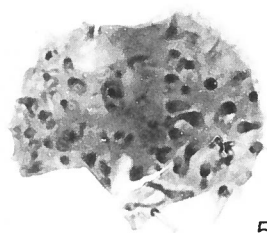
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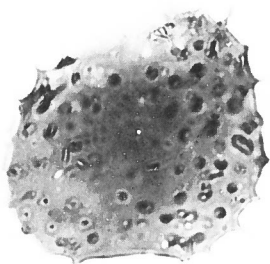
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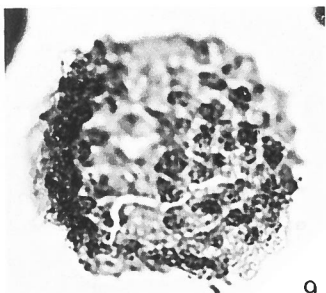
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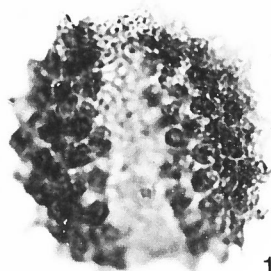
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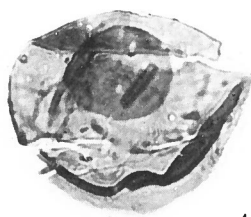
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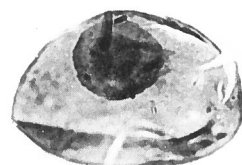
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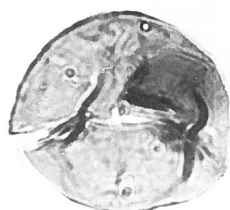
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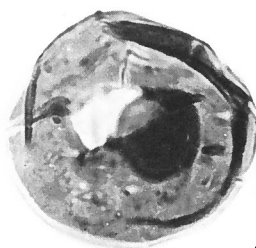
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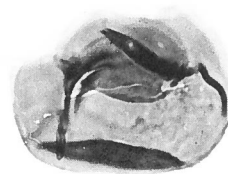
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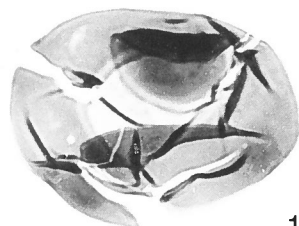
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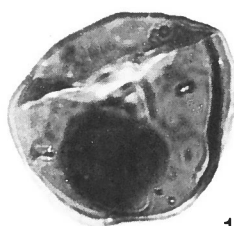
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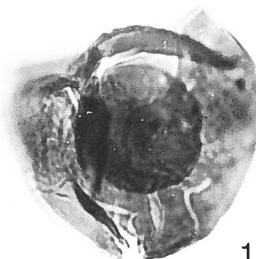
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Annascaul Inlier		
Ludlow	Derrymore Glen Formation	
	Caherconree Formation	
Wenlock	Ballynane Formation	
Ordovician	unconformity	Bealacoon Member
	Annascaul Formation	Illauglass Member
		Tinal Member
		Killelton Member
		Farranacarriga Member

Text-fig. 2 - Stratigraphy of the Annascaul Inlier (Todd *et al.*, in prep.). Dashed lines indicate no stratigraphic contact observed.

palynological study carried out by Higgs & Callaghan (1996), who obtained acritarchs from two mudrock samples (BC15 and BC16) of the Annascaul Formation at Minard Bay. (Text-fig. 3). The presence of such taxa as *Caldariola glabra* (Martin) Molyneux in Molyneux & Rushton, 1988, *Cymatiogalea cuvillieri* (Deunff) Deunff, 1964, *Stelliferidium trifidum* (Rasul) Fensome *et al.*, 1990, *Coryphidium* spp., and *Vavrdovella* sp., indicated an early Ordovician (Tremadoc-Arenig) age. Higgs & Callaghan (1996) cautioned that these early Ordovician acritarchs may have been reworked into younger (possibly Silurian) sediments and foreshadowed more detailed palynological sampling of the Annascaul Formation. Hence the present study is aimed at palynologically defining the age of the formation and resolving the question of possible reworking.

STRATIGRAPHY

The newly defined Annascaul Formation has been divided into five lithostratigraphic members by Todd *et al.*, (in prep.); see Text-fig. 2. A brief summary of each member is given below. The contacts between three of the members can be mapped in the coastal sections from Minard Bay to Coosatorrig on the north side of Bull's Head. These three members are described first, in ascending stratigraphical order.

TINAL MEMBER

This member is characterized by green to yellow-green, phyllitic mudrocks, which have a characteristic striped appearance due to variations in colour and/or grain size on a millimetre to centimetre scale. Burrows and rare crinoid stems (Parkin, 1976) occur in the green shales at some localities. The otherwise monotonous shales feature thin beds of silicified siltstone or very fine sandstone.

ILLAUNGLASS MEMBER

The lithologies of the Illauglass Member are similar in many respects to those of the Tinal Member, except that the striped and ribboned mudrocks are pervasively haematized producing red and purple colouration. In some places, the purple shale grades laterally into green striped shales indicating that the colour variation is secondary. Sandstones and thin dark grey laminated mudstones occur infrequently throughout the member and two horizons of melange are exposed between Foilaniska and Cooneenagoug in Minard Bay.

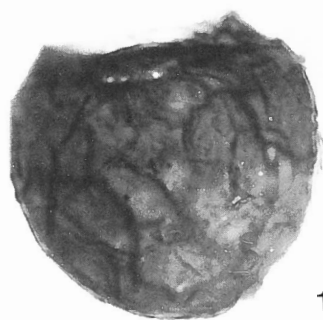
BEALACOOON MEMBER

This member comprises a thick development of mud-matrix supported, chaotic melange of angular to subrounded clasts of greywacke, green and black shale, brecciated andesite, and silicified dolomite. The matrix is a foliated, silvery grey to black

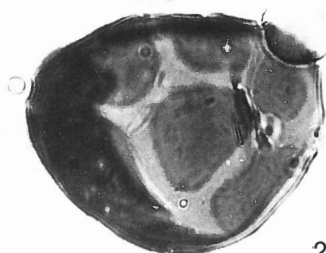
EXPLANATION OF PLATE 2

- Fig. 1 - *Caldariola* sp. A. MB6, T54/4.
 Figs. 2, 3 - *Caldariola glabra* (Martin) Molyneux in Molyneux & Rushton, 1988 var. *annulifera* Servais & Molyneux, 1997. 2) FW4, Y65/1; 3) FW4, J65/2.
 Fig. 4 - *Coryphidium bohemicum* Vavrdová, 1972. MB9, Y56/4.
 Fig. 5 - *Coryphidium elegans* Cramer, Allam, Kanes & Díez, 1974. BC16, M20/1.
 Fig. 6 - *Coryphidium* sp. cf. *C. elegans*. Cramer, Allam, Kanes & Díez, 1974. MB2, N61/4.
 Fig. 7 - *Dictyotidium* sp. MB9, N5/3.
 Fig. 8 - *Coryphidium* sp. aff. *C. elegans sensu* Molyneux & Leader, 1997. BC16, P11/4.
 Fig. 9 - *Coryphidium* sp. cf. *C. almohadillum* Cramer & Díez, 1976. BC16, J30/2.
 Fig. 10 - *Cymatiogalea cuvillieri* (Deunff) Deunff, 1964. BC15, J21/4.
 Figs. 11, 12 - *Cymatiogalea* sp. cf. *C. cuvillieri* (Deunff) Deunff, 1964. 11) FA1, L68/3; 12) FA1, S64/4.
 Figs. 13-15 - *Cymatiogalea vanguetaini* sp. nov. 13) BC15, O19/2 (holotype); 14) BC15, M14/3; 15) BC15, K32/2.

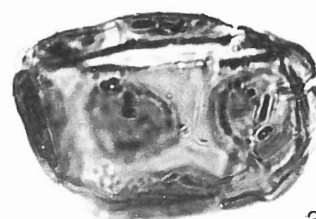
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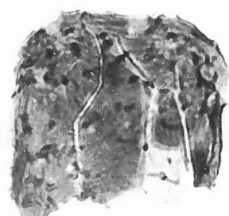
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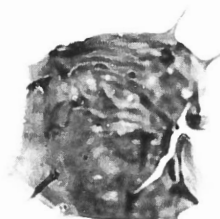
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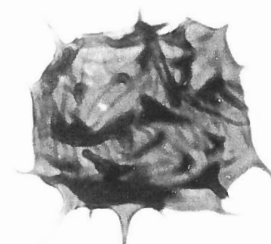
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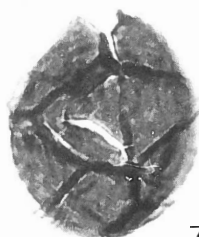
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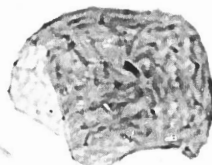
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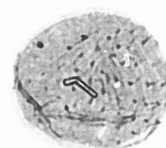
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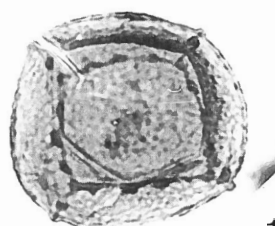
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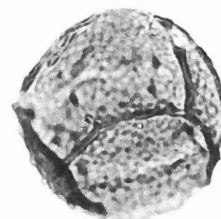
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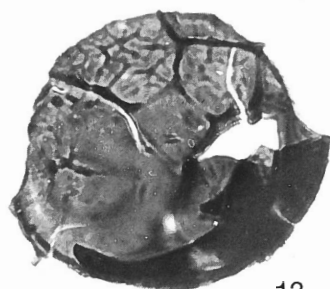
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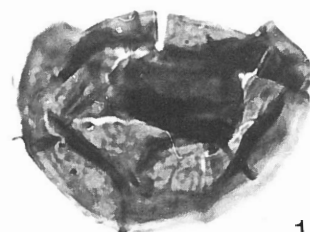
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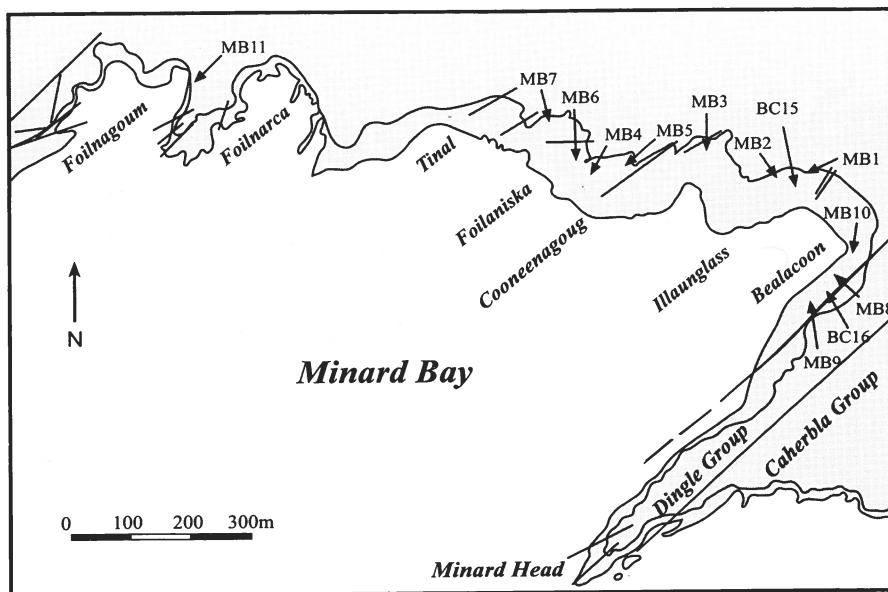
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Text-fig. 3 - Location of principal sample locality at Minard Bay. Samples BC15 and BC 16 of Higgs & Callaghan (1996).

mudrock. The melange crops out at several localities; it is best seen in Bealacoon Cove (Text-fig. 3), where blocks of greywacke are up to 10 m long.

The two remaining members of the Annascaul Formation are only seen in scattered inland exposures. The stratigraphic relationships of these members remain uncertain.

FARRANACARRIGA MEMBER

This dark fine-grained unit is dominated by black, graphitic, foliated mudrocks and siltstones. These occur in outcrop strips exposed in the Owenascaul River in the village of Annascaul (Jukes & Du Noyer, 1863; Parkin, 1976); on a road cut in the townland of Farranacarriga; and in Coumastabla Wood (Parkin, 1976, p. 586).

KILLELTON MEMBER

This member, exposed in a stream separating the townlands of Killelton and Commons (Parkin, 1976), is characterized by an association of massively bedded green sandstone with shale partings, greyish-

red to purple ferruginous sandstone, yellowish orange sandstone, and a poorly sorted microconglomerate.

MATERIAL AND METHODS

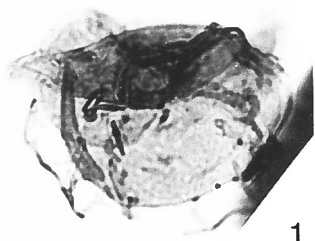
LOCATION OF SAMPLES

Twenty-four samples of predominantly dark grey to black mudstones and siltstones were collected for palynological analysis from various intervals throughout the study area. The principal sampling locality is the coastal section at Minard Bay (Text-fig. 3), located at the southern extremity of the Annascaul Inlier. Here there is almost continuous coastal outcrop of the Tinal, Illaunglass, and Bealacoon Members. The 11 samples collected from this section are prefixed MB; their location, and that of the two productive samples (BC 15 and BC 16), of Higgs & Callaghan (1996) are shown on Text-fig. 3. An additional coastal section was sampled at the smaller Bulls Head Inlier. Six samples, prefixed CT and FW, were collected in two small inlets at Coosatorrig and Foilnaweelaun (Text-fig. 4), north of Bull's Head (grid reference V496 973). The samples are from

EXPLANATION OF PLATE 3

- Fig. 1 - *Cymatiogalea deunffii* Jardiné, Combaz, Magloire, Peniguel & Vachey, 1974. MB5, F26/3.
 Figs. 2, 3 - *Cymatiogalea messaoudensis* Jardiné, Combaz, Magloire, Peniguel & Vachey, 1974 var. *messaoudensis*. 2) MB5, H29/4; 3) MB5, E12/4.
 Figs. 4-7 - *Cymatiogalea messaoudensis* Jardiné, Combaz, Magloire, Peniguel & Vachey, 1974 var. *inconnexa*. Servais & Molyneux, 1997. 4) circular pylome and smooth to finely granulate vesicle, MB5, C26/2; 5) MB2, T66/2; 6) MB2, V64/4; 7) MB5, C26/2.
 Figs. 8-12 - *Cymatiogalea cristata* (Downie) Rauscher, 1974. 8) large polygonal pylome and coarse granulation of vesicle. MB5, J27/3; 9) MB5, G18/1; 10) FW4, R66/1; 11) MB5, G17/1; 12) MB5, D51/3.

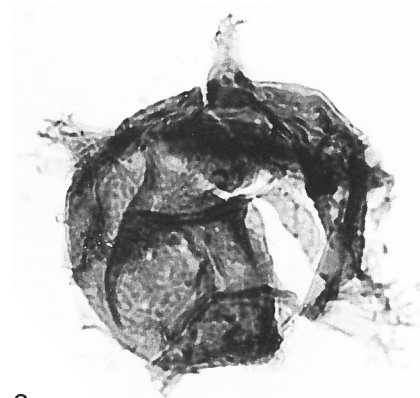
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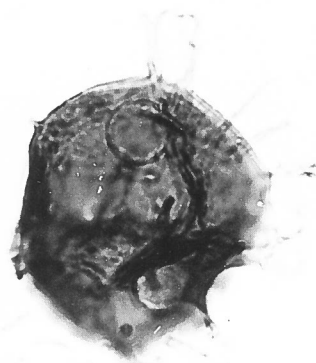
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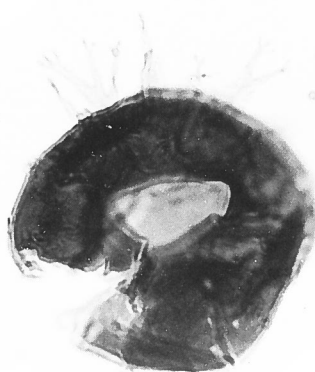
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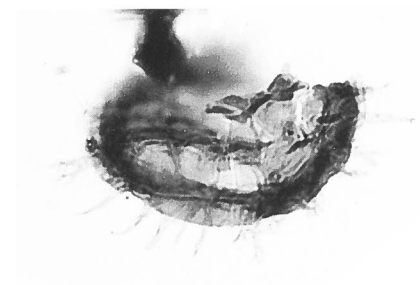
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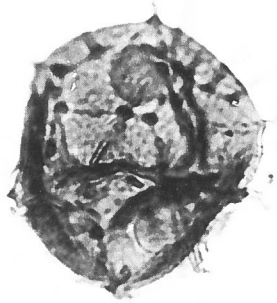
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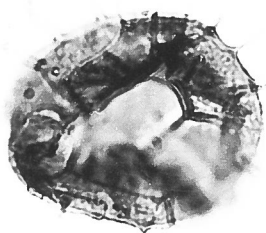
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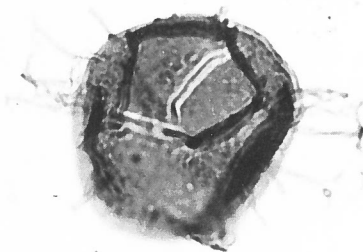
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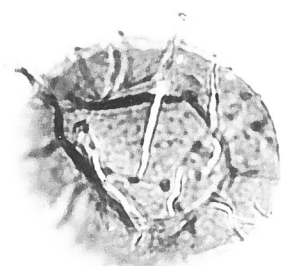
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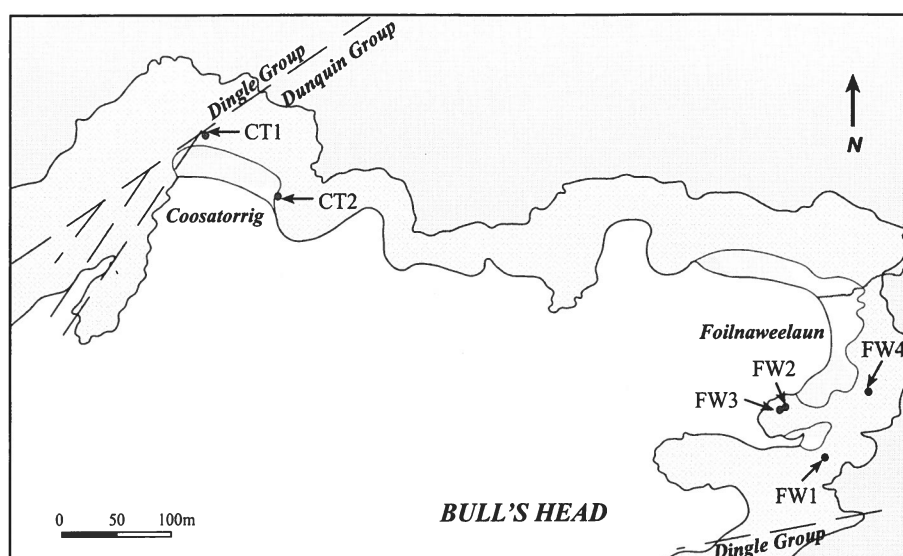
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Text-fig. 4 - Location of sample sections from Coosatorrig and Foilnaweelaun at Bull's Head.

undifferentiated Annascaul Formation; however, the Foilnaweelaun (FW) samples were obtained from a sequence containing a melange unit, which indicates a level either in the Illaunglass or the Bealacoon Member at this locality.

Collection of inland samples proved difficult due to limited outcrops and the lack of palynologically favourable lithologies. Three spot samples, prefixed AR and FA, were obtained from exposures of the Farranacarriga Member near Annascaul Village (Text-fig. 6). Two spot samples, prefixed BN, came from the exposures of undifferentiated Annascaul Formation in Ballynane Bog (Text-fig. 5). Finally, one sample, prefixed FR, was collected from the Farranacarriga Member in the Fionglass River section, Coumastabla Wood, at the eastern extremity of the Annascaul Inlier.

PREPARATION OF SAMPLES

All samples were processed using preparation methods adopted at the palynological laboratory of the Geology Department, University College Cork. This involved: HF to remove the silicates; heavy liquid separation (with $ZnBr_2$ solution) to remove very fine residual minerals; and sieving of the organic

residues (via 10 μm mesh). The particulate organic matter is black and therefore of a high grade of thermal maturity, indicative of a Thermal Alteration Index (TAI) 4.5 - 5 on the Staplin (1969) scale, suggesting palaeotemperatures $>250^\circ$. The organic residues required oxidation with Schulze Solution for 18 hours to render them light enough in colour for microscopic identification. Despite the high thermal maturity and relatively low yields, the palynomorphs obtained are surprisingly well preserved. The palynological residues are mounted as permanent strewn mounts using Cellosize as the dispersal agent and Elvacite© as the cold mounting medium. All the slides and figured specimens are catalogued and stored in the micropalaeontology collection of the Geology department, University College Cork.

PALYNOLOGICAL AND BIOSTRATIGRAPHIC RESULTS

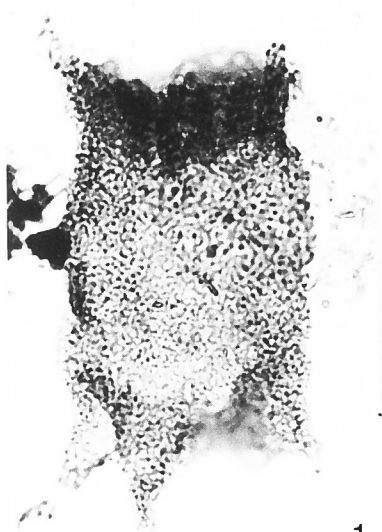
ACRITARCHS

Twenty-four samples were processed for palynological investigation: 15 proved productive; the other nine samples were either totally barren or, at best, yielded only sparse, indeterminate particulate organic matter. In the productive samples the taxonomic

EXPLANATION OF PLATE 4

- Figs. 1-5 - *Dasydiacrodium* sp. cf. *D. palmatilobum* Timofeev, 1959 ex Downie & Sarjeant, 1965. 1) AR2, H58/4; 2) AR2, L50/3; 3) AR2, N58/3; 4) AR2, K60/4; 5) AR2, K52/4.
 Figs. 6-8,10 - *Dasydiacrodium* sp. 6) FA1, X64/1; 7) FA1, J54/1; 8) FA1, X64/1; 10) FA1, J64/1.
 Fig. 9 - *Ooidium* sp. MB9, H47/1.
 Fig. 11 - *Lophodiacrodium valdaicum* (Timofeev) Downie & Sarjeant, 1965. FW4, E62/3.

All magnifications $\times 1000$.



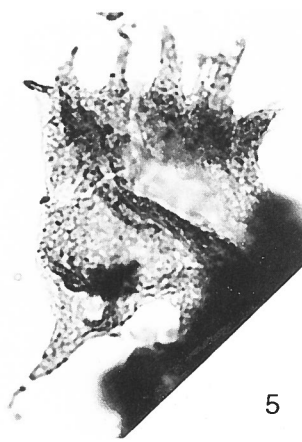
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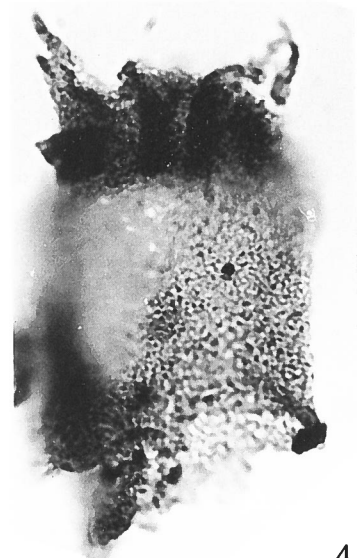
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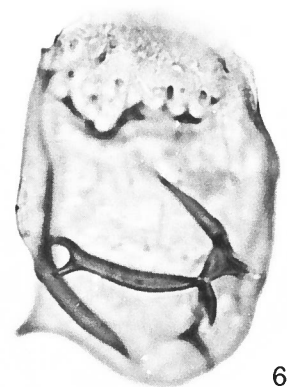
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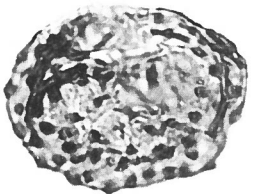
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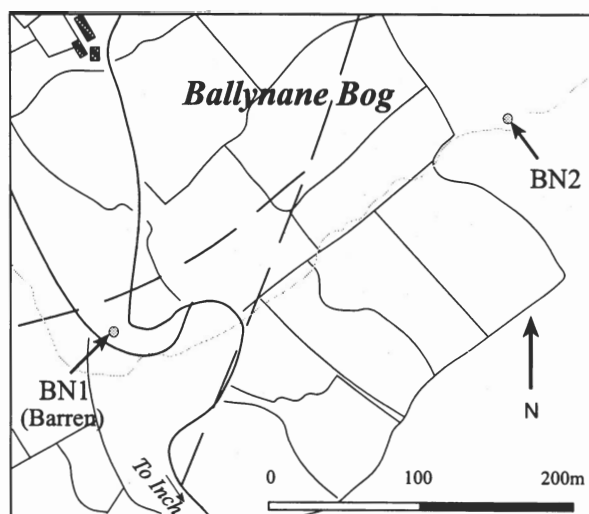
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Text-fig. 5 - Location of samples studied from Ballynane Bog.

diversity and relative abundance of identified palynomorphs are relatively low. However, the vast majority of these palynomorphs are sufficiently well preserved to allow identification. An inventory of the acritarch and prasinophyte taxa identified is given below.

Acanthodiacrodium? dilatatum Molyneux in Molyneux & Rushton, 1988

Acanthodiacrodium-Coryphidium transient

Acanthodiacrodium? sp. 1 sensu Servais & Molyneux, 1997

Acanthodiacrodium golubii Fensome *et al.*, 1990

Baltisphaeridium sp.

Caldariola glabra (Martin) Molyneux in Molyneux & Rushton, 1988 var. *glabra*

Caldariola sp. cf. *C. glabra* (Martin) Molyneux in Molyneux & Rushton, 1988 var. *glabra*

Caldariola glabra (Martin) Molyneux in Molyneux & Rushton, 1988 var. *annulifera* Servais & Molyneux, 1997

Caldariola sp. A

Coryphidium bohemicum Vavrdová, 1972

Coryphidium elegans Cramer, Allam, Kanes & Díez, 1974

Coryphidium sp. cf. *C. elegans* Cramer, Allam, Kanes & Díez, 1974

Coryphidium sp. aff. *C. elegans* Cramer, Allam, Kanes & Díez, 1974, *sensu* Molyneux & Leader 1997

Coryphidium sp. cf. *C. almohadillum* Cramer & Díez, 1976

Dictyotidium sp.

Cymatiogalea cristata (Downie) Rauscher, 1974

Cymatiogalea cuvillieri (Deunff) Deunff, 1964

Cymatiogalea sp. cf. *C. cuvillieri* (Deunff) Deunff, 1964

Cymatiogalea deunffii Jardiné, Combaz, Magloire, Peniguel & Vachey, 1974

Cymatiogalea messaoudensis Jardiné, Combaz, Magloire, Peniguel & Vachey, 1974 var. *messaoudensis*

Cymatiogalea messaoudensis Jardiné, Combaz, Magloire, Peniguel & Vachey, 1974 var. *inconnexa* Servais & Molyneux, 1997

Cymatiogalea vanguetainae sp. nov.

Dasydiacrodium sp. cf. *D. palmatilobum* Downie & Sarjeant, 1965

Dasydiacrodium sp.

Leiosphaeridia sp.

Lophodiacrodium valdaicum (Timofeev) Downie & Sarjeant, 1965

Lophosphaeridium sp. A

Lophosphaeridium sp. B

Lophosphaeridium sp. of Volkova, 1990

Lophosphaeridium? sp.

Micrhystridium sp. cf. *M. acuminosum* Cramer & Díez, 1977

Ooidium sp.

Peteinosphaeridium micranthum (Eisenack) Eisenack, Cramer & Díez, 1973.

Peteinosphaeridium sp.

Polygonium gracile Vavrdová, 1966

Polygonium sp.

Stelliferidium stelligerum (Deunff) Deunff, Górka & Rauscher, 1974

Stelliferidium trifidum (Rasul) Fensome *et al.*, 1990

Stelliferidium sp.

Striatotheca? sp.

Timofeevia phosphoritica Vanguetaine, 1978

Vavrdovella areniga (Vavrdová) Loeblich & Tappan, 1976

Veryhachium sp.

Veryhachium sp. cf. *V. lairdii* (Deflandre) ex Deunff, 1959.

EXPLANATION OF PLATE 5

Figs. 1, 6 - *Peteinosphaeridium micranthum* (Eisenack) Eisenack, Cramer & Díez, 1973. 1) MB5, J11/1; 6) FW4, V66/2.

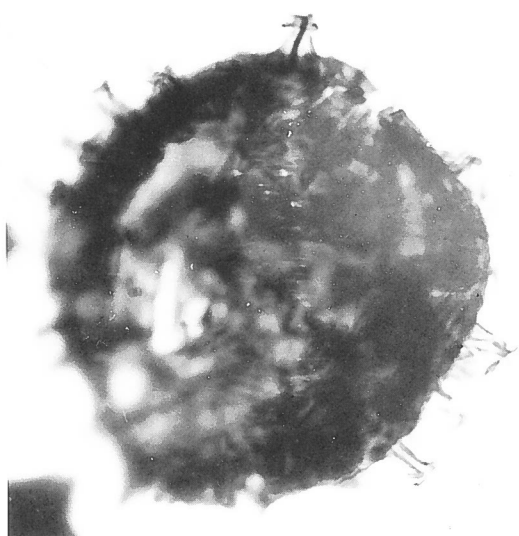
Figs. 2-5 - *Lophodiacrodium valdaicum* (Timofeev) Downie & Sarjeant, 1965. 2) FW4, D14/3; 3) MB5, G27/4; 4) FW4, S47/4; 5) MB5, C32/1.

Fig. 7 - *Micrhystridium* sp. cf. *M. acuminosum* Cramer & Díez, 1977. BC16, K3/4.

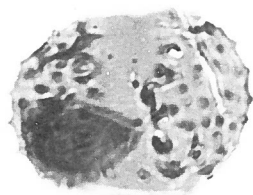
Figs. 8, 11 - *Peteinosphaeridium* sp. 8) MB5, H25/2; 11) MB5, G14/3.

Figs. 9, 10 - *Polygonium* sp. 9) MB9, S55/2; 10) MB9, E49/1.

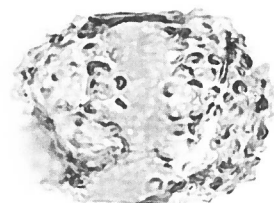
All magnifications $\times 1000$.



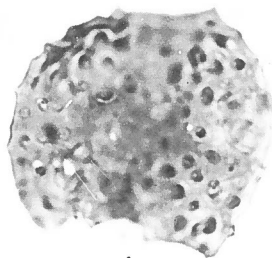
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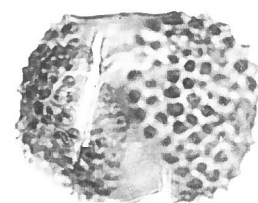
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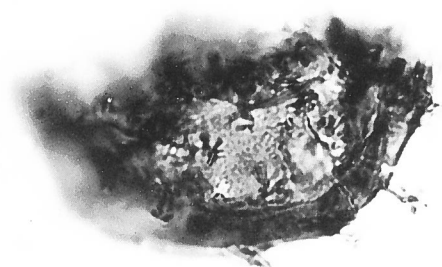
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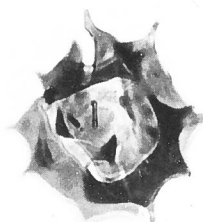
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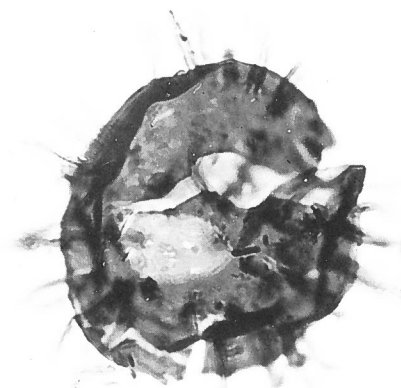
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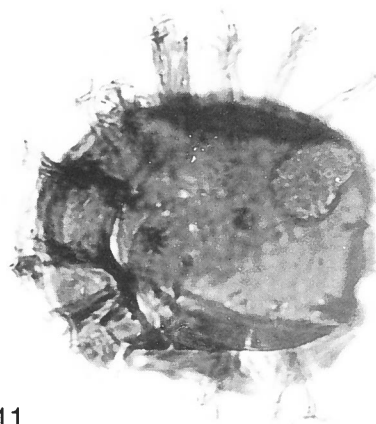
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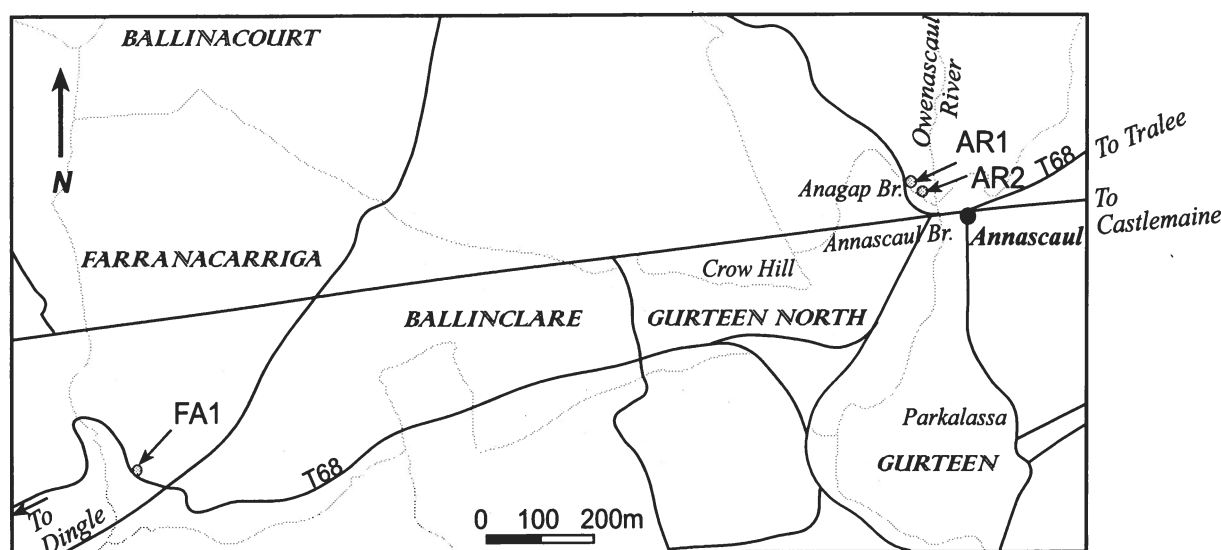
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Text-fig. 6 - Location of samples studied from the inland region of Annascaul Village.

PALYNOMORPH ASSEMBLAGES

The palynomorph assemblages obtained from this investigation are described in ascending stratigraphic order.

Farranacarriga Member

The oldest acritarch assemblages were obtained from two samples (AR1, AR2) of the Farranacarriga Member in the Owenascul River section. Distinctive taxa present include *Lophodiacrodium valdaicum*, *Lophosphaeridium* sp., *Acanthodiacrodium* sp. cf. *A. golubii*, *Timofeevia phosphoritica*, and *Dasydiacrodium* sp. cf. *D. palmatilobum*. This very limited assemblage lacks age-diagnostic forms, with taxa ranging from Late Cambrian to early Ordovician (Tremadoc); however, the assemblage has an early Tremadoc affinity, but the possibility that it may be Late Cambrian cannot be ruled out.

Sample FA1, from the Farranacarriga Member exposed in the road cutting just west of Annascaul Village, yielded an assemblage characterized by *Stelliferidium stelligerum*, *Cymatigalea* sp. cf. *C. cuvillieri*, *Caldariola glabra* var. *glabra*, *Micrhy-*

stridium sp. cf. *M. acuminosum*, *Timofeevia phosphoritica*, *Acanthodiacrodium* sp., *Dasydiacrodium* sp., and *Leiosphaeridia* sp. The presence of *S. stelligerum* indicates a late Tremadoc age (see Vecoli, 1996). An almost identical but less well preserved assemblage was obtained from sample FR1 collected from black mudrocks in Coumastabla Wood.

Illaunglass Member

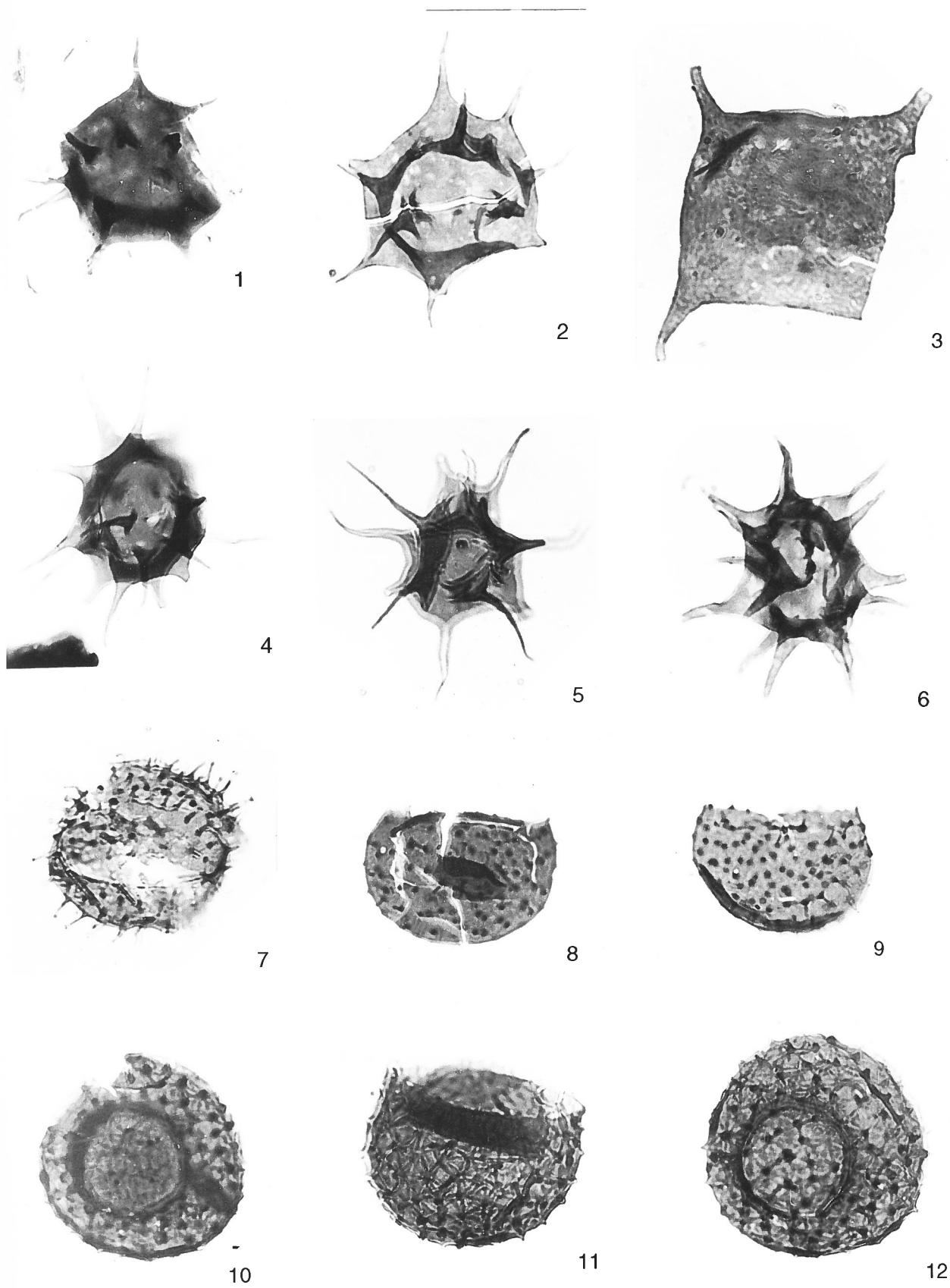
Most of the productive samples studied herein are from dark grey mudrocks of the Illaunglass Member. In particular, samples MB2, MB4, MB5, MB6, MB7, and BC16 from Minard Bay yielded the most diverse and best-preserved acritarchs. The assemblages are characterized by the following taxa: *Caldariola glabra* var. *glabra*, *Stelliferidium trifidum*, *Cymatigalea messaoudensis* var. *messaoudensis*, *C. messaoudensis* var. *inconnexa*, *C. cristata*, *C. deunffii*, *Vavrdovella areniga*, *Acanthodiacrodium?* *dilatatum*, *Coryphidium elegans*, *C. sp. aff. C. elegans*, *Veryhachium* sp. cf. *V. lairdii*, and *Polygonium* sp.

Samples FW3 and FW4 (from dark grey mudrocks adjacent to a melange unit in Foilnaweelaun north of Bull's Head), yielded well-preserved acritarch assem-

EXPLANATION OF PLATE 6

- Figs. 1,2 - *Polygonium* sp. 1) BC15, S12/4; 2) MB9, V52/4.
 Fig. 3 - *Striatotheca?* sp. 3) MB5, O55/3.
 Figs. 4-6 - *Polygonium gracile* Vavrdová, 1966. 4) MB2, U55/3; 5) MB5, F25/1; 6) MB9, X51/1.
 Figs. 7-9 - *Stelliferidium trifidum* (Rasul) Fensome, Williams, Barss, Freeman & Hill, 1990. 7) FW4, T54/3; 8) BC16, J15/2; 9) BC16, T18/4.
 Figs. 10-12 - *Stelliferidium stelligerum* (Deunff) Deunff, Górká & Rauscher, 1974. 10) FA1, K58/1; 11) FA1, R55/4; 12) FA1, J69/4.

All magnifications $\times 1000$.



blages identical in composition to those from the Illaunglass Member in Minard Bay. This strongly indicates that the melange sequence at Foilnaweelaun is within the Illaunglass Member. In two of the Illaunglass Member samples (MB5, FW3) there is the rare but notable occurrence of specimens belonging to the distinctive and palaeogeographically significant genus *Peteinosphaeridium* Staplin, Jansonius & Pocock, 1965 emend. Playford, Ribecai & Tongiorgi, 1995. One species is positively identified as *P. micranthum*. The only previous occurrence of this in the Perigondwana Province was by Fournier-Vinas (1985, table 1; pl. 4, fig. 15) from within the Tremadoc-Llanvirn sequence of Morocco, however, this identification was questioned by Playford *et al.* (1995).

A very sparse acritarch assemblage (sample BN2) was obtained from dark grey shales exposed in a stream section at Ballynane Bog, east of Annascaul Village. The taxa present include: *Stelliferidium trifidum*, *Cymatiogalea messaoudensis* var. *inconnexa*, *Caldariola glabra* var. *glabra*, *Vavrdovella areniga*, *Coryphidium* sp., *Veryhachium* sp. cf. *V. lairdii*, and *Polygonium* sp. The composition of this assemblage indicates a correlation with the Illaunglass Member. Assemblages from the Illaunglass Member are assignable to the well-documented *messaoudensis-trifidum* assemblage, which is dated by graptolites in the Skiddaw Group of northwest England as latest Tremadoc to early Arenig. Moreover, the presence of *Coryphidium* in these assemblages is significant, as true representatives of this genus first appear in sub-assemblage 3 of the *messaoudensis-trifidum* assemblage, within the Watch Hill Formation, at a level close to the base of the Arenig in northwest England (Cooper *et al.*, 1995; Molyneux & Leader, 1997).

Bealacoon Member

Three productive samples (MB9, MB8, BC15) have been obtained from this member at Minard Bay. The assemblages contain most of the taxa recorded from the Illaunglass Member. However, some notable compositional differences include the appearance of *Coryphidium bohemicum*, together with abundance of *Vavrdovella areniga* and *Polygonium* spp., absence of *Cymatiogalea messaoudensis* (*sensu lato*), and rarity of *Caldariola glabra* (*sensu lato*).

The age of the acritarch assemblages of the

Bealacoon Member is determined by the occurrence of *Coryphidium bohemicum*, which in northwest England and other regions of Europe and southwest China (Molyneux & Leader, 1997) first appears in the early to mid Arenig. In the Skiddaw Group in the Northern Fells (English Lake district), *Coryphidium bohemicum* first appears in the Loweswater Formation, close to the *Didymograptus varicosus* / *D. simulans* graptolite zonal boundary (see Text-fig. 7).

CONCLUSIONS

Well-preserved acritarchs recovered from the Farranacarriga, Illaunglass, and Bealacoon Members of the Annascaul Formation facilitate recognition of four distinct assemblages, thus:

Assemblage 1, from the Farranacarriga Member at the Owenascaul River near Annascaul Village, is dominated by species of *Acanthodiacrodium*, *Lophodiacrodium*, *Dasydiacrodium*, and *Lophosphaeridium* and is of probable early Tremadoc age.

Assemblage 2, from the Farranacarriga Member of the road cut section at Farranacarriga and of the stream section at Coumastabla Wood, is characterized by *Stelliferidium stelligerum*, *Cymatiogalea* sp. cf. *C. cuvillieri*, *Caldariola glabra* var. *glabra*, and *Dasydiacrodium* sp. and is dated as late Tremadoc.

Assemblage 3, from the Illaunglass Member, and is the most taxonomically diverse assemblage; its composition correlates closely with sub-assemblage 3 of the *messaoudensis-trifidum* assemblage of Cooper *et al.* (1995) which indicates a latest Tremadoc to early Arenig age.

Assemblage 4, from the Bealacoon Member, is correlative with the *Coryphidium bohemicum* assemblage of Cooper *et al.* (1995) and is attributable to the early to mid Arenig. The possibility that these early Ordovician acritarchs have been introduced by reworking into younger Silurian sediments is discounted, as no Silurian acritarchs have been recorded in the 15 productive samples studied. Consequently, the palynological data presented here unequivocally support the other geological evidence for an early Ordovician age of the Annascaul Formation.

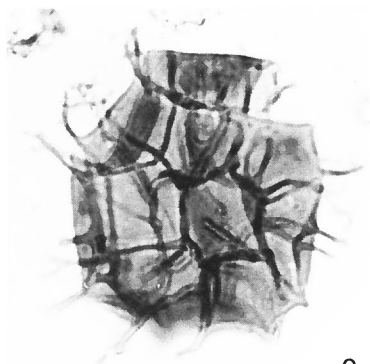
EXPLANATION OF PLATE 7

- Fig. 1 - *Stelliferidium trifidum* (Rasul) Fensome, Williams, Barss, Freeman & Hill, 1990. BC15, F25/1.
 Figs. 2, 3, 6 - *Timofeevia phosphoritica* Vanguetaine, 1978. 2) MB5, K20/2; 3) MB6, O55/4; 6) MB9, U65/2.
 Fig. 4 - *Stelliferidium* sp. BC15, W23/1.
 Figs. 5, 8, 9 - *Vavrdovella areniga* (Vavrdová) Loeblich & Tappan, 1976. 5) BC15, M5/4; 8) BC15, G5/1; 9) MB9, P48/2.
 Fig. 7 - *Veryhachium* sp. MB9, P55/2.
 Figs. 10-12 - *Veryhachium* sp. cf. *V. lairdii* (Deflandre) ex Deunff, 1959. 10) BC16, K5/3; 11) BC16, S14/2; 12) MB6, H50/4.

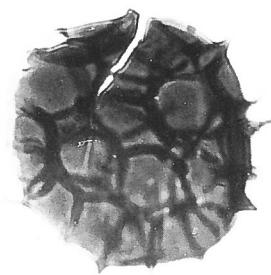
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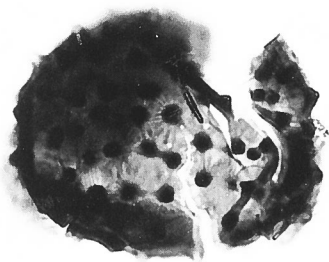
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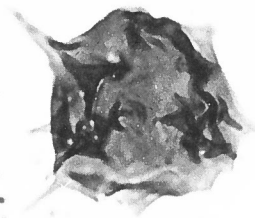
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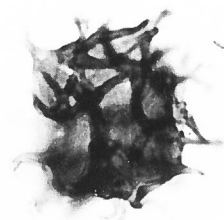
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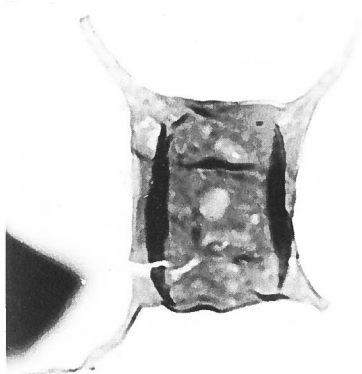
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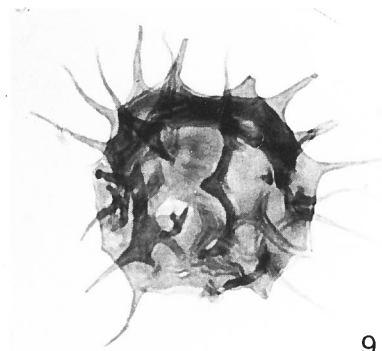
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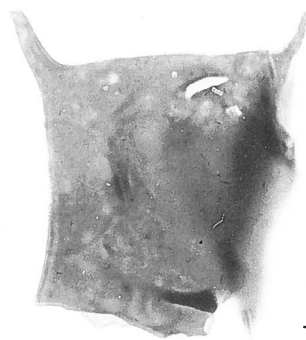
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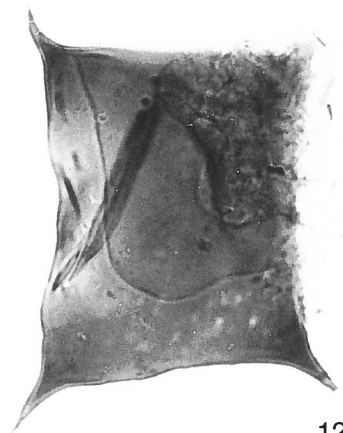
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Ma (est.)	Series and stages	Northern Fells Lithostratigraphy	Skiddaw Group Acritarch assemblages	British graptolite biozones	Annascul Formation Acritarch assemblages
469	Llanvirn	?		<i>Didymograptus murchisoni</i> etc.	
				<i>Didymograptus artus</i> [= <i>D. bifidus</i>]	
	Fennian	Kirkstall Formation	<i>Frankea hamata</i> - <i>Striatotheca rarirrugulata</i>	<i>Didymograptus hirundo</i>	
476	Whitlandian		<i>Stelliferidium</i> sp. nov.	<i>Isograptus gibberulus</i>	
	Arenig	Loweswater Formation	 [interzone]	<i>D. simulans</i> [= <i>D. nitidus</i>]	Bealacoon Member Assemblage
			<i>Coryphidium bohemicum</i>	<i>Didymograptus varicosus</i> [= <i>D. deflexus</i>]	
479	Moridunian	Hope Beck Formation	<i>S. trifidum</i> - <i>C. bohemicum</i>	?	
			5		
484	?	Watch Hill Formation	4	<i>Tetragraptus phyllograptoides</i>	Illaunglass Member Assemblage
			3		
			2	Equivalent to the Hunnegraptus copiosus Biozone	
487	upper Tremadoc (part)	Bitter Beck Formation	1	<i>Araneograptus murrayi</i>	
490					

Text-fig. 7 - Biostratigraphic correlation of the Illaunglass and Bealacoon acritarch assemblages with the acritarch and graptolite biostratigraphy of the Skiddaw Group of northwest England (after Cooper *et al.*, 1995).

SYSTEMATIC PALAEONTOLOGY

With the exception of one new species, no formal systematic descriptions are presented, as the majority of the taxa recorded are well-established species and have been extensively described in the palynological literature. Instead, brief informal systematic notes and comments are given on specimens that are identified at confer level and in open nomenclature. Plates 1-8 illustrate the majority of the acritarch and prasinophyte taxa identified.

ACRITARCHS

Incertae sedis "group" ACRITARCHA Evitt, 1963

Genus ACANTHODIACRODIUM Timofeev, 1958, emend. Deflandre & Deflandre-Rigaud, 1962

Type species (by original designation) – *Acanthodiacrodium dentiferum* Timofeev, 1958.

ACANTHODIACRODIUM-CORYPHIDIUM transient Pl. 1, fig. 7

1985 *Acanthodiacrodium* - *Coryphidium* transient RUSHTON, p. 330.

Comments – The specimen displays features typical of *Acanthodiacrodium*, such as bipolar distribution of homomorphic spinose processes, together with characteristic attributes of *Coryphidium*, such as quadrate vesicle and faint striations parallel to vesicle margins.

Genus BALTISPHAERIDIUM Eisenack, 1958 *ex* Eisenack, 1959 emend. Eisenack, 1969

Type species (by original designation) – *Baltisphaeridium longispinosum* (Eisenack *ex* O. Wetzel) Eisenack, 1959.

EXPLANATION OF PLATE 8

- Fig. 1 - *Leiosphaeridia* sp. MB2, X60/1.
Figs. 2, 3, 5 - *Lophosphaeridium* sp. A. 2) MB2, T56/4; 3) BC15, C25/3; 5) MB5, H17/1.
Fig. 4 - *Lophosphaeridium* sp. B. MB5, D26/1.
Fig. 6 - *Lophosphaeridium* sp. C. MB5, D27/3.
Figs. 7, 8 - *Lophosphaeridium* sp. Volkova, 1990. 7) AR2, X51/4; 8) AR2, Z61/1.

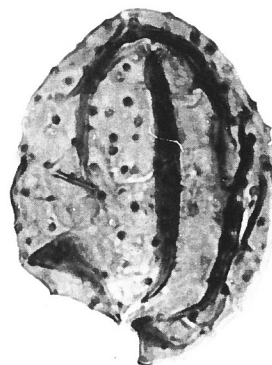
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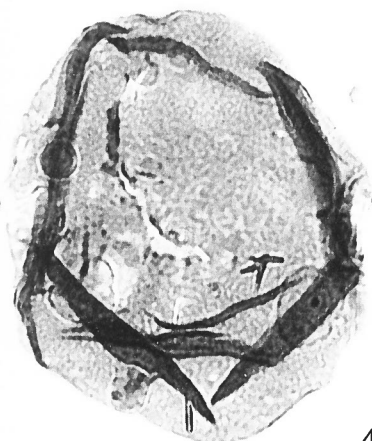
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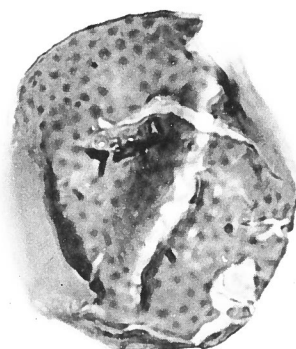
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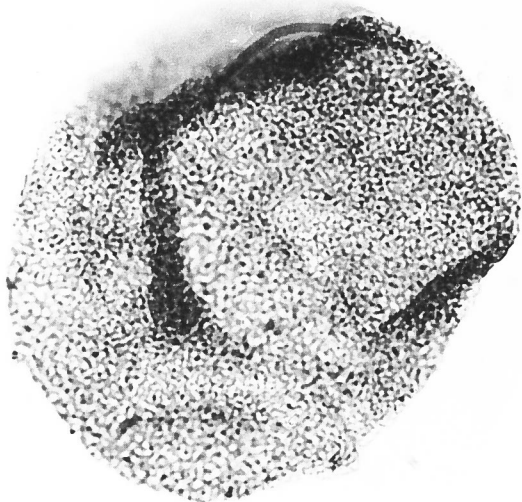
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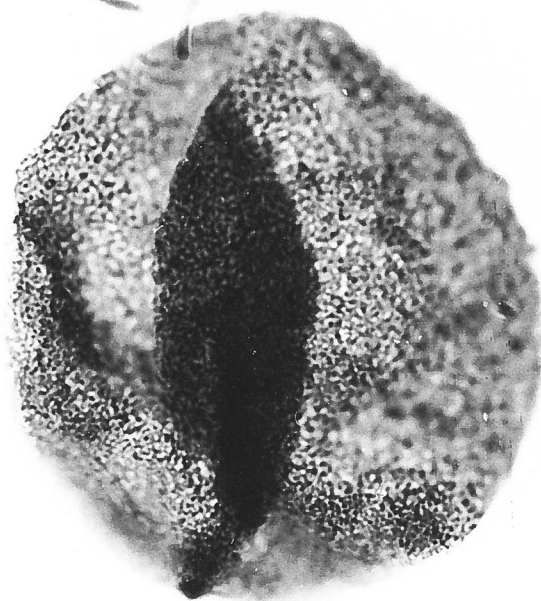
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BALTISPHAERIDIUM sp.
Pl. 1, fig. 8

Comments – A very small vesicle with small simple spines that are densely and regularly distributed.

Genus CALDARIOLA Molyneux in Molyneux & Rushton, 1988

Type species (by original designation) – *Caldariola glabra* (Martin) Molyneux in Molyneux & Rushton, 1988.

CALDARIOLA sp. cf. *C. GLABRA* (Martin) Molyneux in Molyneux & Rushton, 1988 var. *GLABRA*
Pl. 1, figs. 19, 20

cf. 1988 *Caldariola glabra* MOLYNEUX in Molyneux & Rushton, pp.43; 46-57; figs. 4f, i, l.

Comments – Differ from *Caldariola glabra* in possessing small but distinct plications (wrinkles) of the vesicle surface.

CALDARIOLA sp.
Pl. 2, fig. 1

Comments – Distinguished from *Caldariola glabra* and *C. sp. cf. C. glabra* by its larger size and by the prominent diaphanous folds on the vesicle surface.

Genus CORYPHIDIUM Vavrdová, 1972

Type species (by original designation) – *Coryphidium bohemicum* Vavrdová, 1972.

CORYPHIDIUM sp. cf. *C. ELEGANS* Cramer, Allam, Kanes & Díez, 1974
Pl. 2, fig. 6

cf. 1974 *Coryphidium elegans* CRAMER, ALLAM, KANES & DÍEZ, p. 184; pl. 27, figs. 12-19.

Comments – Differs from *C. elegans* in having both parallel and oblique striations on the vesicle.

CORYPHIDIUM sp. cf. *C. ALMOHADILLUM* Cramer & Díez, 1976
Pl. 2, fig. 9

cf. 1976 *Coryphidium almohadillum* CRAMER & DÍEZ, p. 204; pl.23, figs. 8, 11.

Comments – This form has similar ornamentation to *C. almohadillum* but differs in its subcircular, not quadrate vesicle.

Genus CYMATIOGALEA Deunff, 1961 emend.
Deunff, Górka & Rauscher, 1974

Type species (by original designation) – *Cymatigalea margaritata* Deunff, 1961.

CYMATIOGALEA sp. cf. *C. CUVILLIERI* (Deunff)
Deunff, 1964
Pl. 2, figs. 11, 12

cf. 1964 *Cymatigalea cuvillieri* (Deunff) DEUNFF, p. 124; pl. 1, figs. 2, 3.

Comments – Differs from *C. cuvillieri* in possessing coarse grana which characteristically coalesce to form a dense cateniform pattern on the vesicle surface.

CYMATIOGALEA VANGUESTAINEI sp. nov.
Pl. 2, figs. 13-15

Diagnosis – Vesicle hemispherical to subcircular, with large circular opening. Operculum circular, attached or inside vesicle, diameter up to half that of vesicle. Vesicle surface is divided into 6-10 large polygonal fields, the latter well-defined by narrow low ridges, 2-3 µm wide. Short broad-based conical processes, 2-5 µm high, arising at angles of polygons. Vesicle surface within polygonal fields displaying fine network of delicate ridges and irregular small fields.

Dimensions – Vesicle diameter 35 (43) 56 µm, based on 12 specimens.

Holotype – Plate 2, fig. 13, sample BC 15.

Type locality – Bealacoon Member, Bealacoon Cove, Minard Bay, Co. Kerry, Ireland.

Derivation of name – In honour of Professor Michel Vanguetstaine who first recorded this species from the Tremadoc rocks of Belgium in an unpublished thesis (Vanguetstaine, 1974).

Comments – This species is distinguished from others of the genus by its characteristic vesicle surface; i.e., divided into two orders of fields, giving a doubly reticulate appearance.

Genus DASYDIACRODIUM Timofeev, 1958 ex
Deflandre & Deflandre-Rigaud, 1962

Type species (designated subsequently by Deflandre & Deflandre-Rigaud, 1962) – *Dasydiacrodium eichwaldii* Timofeev, 1959.

DASYDIACRODIUM sp. cf. *D. PALMATILOBUM*
Timofeev, 1959
Pl. 4, figs. 1-5

cf. 1959 *Dasydiacrodium palmatilobum* TIMOFEEV, p. 91; pl. 8, figs. 5, 5a, 5b.

Comments – The specimens have a coarsely infra-granulate vesicle and darkening (thickenings) along the shorter antapical spines.

DASYDIACRODIUM sp.

Pl. 4, figs. 6-8, 10

Comments – This form is characterized by ovoid to elongate vesicle with a slightly expanded pole bearing an irregular ornament of grana, coni, and small spines ($<2\text{ }\mu\text{m}$ high) while the other pole possesses a few (4-6), larger, wide-based spines ($4\text{--}8\text{ }\mu\text{m}$ high). Oblique and longitudinal compression folds on the vesicle are common.

Genus LOPHOSPHAERIDIUM Timofeev, 1959 *ex*
Downie, 1963 emend. Lister, 1970

Type species (designated by Downie, 1963) – *Lophosphaeridium rarum* Timofeev, 1959 *ex* Downie, 1963.

LOPHOSPHAERIDIUM sp. A

Pl. 8, figs. 3, 5, 6

Comments – Small coni and verrucae are widely distributed over the subcircular to oval vesicle; some of the verrucae have short spinose tips. Longitudinal compression folds are common.

LOPHOSPHAERIDIUM sp. of Volkova, 1990
Pl. 8, figs. 7, 8

Comments – This form is characterized by its large ($65\text{--}90\text{ }\mu\text{m}$) subcircular to ovoid vesicle having dense ornamentation of coarse grana that often coalesce to display a cateniform (chain-like) pattern. Large arcuate compression folds are typically developed, and the form appears to be very close to that figured but not described as *Lophosphaeridium* sp. by Volkova (1990, pl. 14, figs. 7, 8).

LOPHOSPHAERIDIUM? sp.

Pl. 8, fig. 6

Comments – The subcircular to oval vesicle displays a dense vermiculate to microreticulate ornamentation.

Genus OOIDIUM Timofeev, 1957 emend. Norris &
Sarjeant, 1965

Type species (designated by Norris & Sarjeant, 1965) – *Ooidium rossicum* Timofeev, 1957.

OODIUM sp.

Pl. 4, fig. 9

Comments – The ovoid vesicle has heterogeneous bipolar ornamentation, consisting of sinuous to branching fine rugulae at one pole and short wide-based spines and folds at the other. Numerous, fine, parallel striations are developed on the vesicle between the poles.

Genus PETEINOSPHAERIDIUM Staplin, Jansonius &
Pocock, 1965 emend. Playford, Ribecai &
Tongiorgi, 1995

Type species (by original designation) – *Peteinosphaeridium bergstroemii* Staplin, Jansonius & Pocock, 1965 emend. Playford, Ribecai & Tongiorgi, 1995.

PETEINOSPHAERIDIUM sp.

Pl. 5, figs. 8, 11

Comments – A peteinoid acritarch with subcircular vesicle ($40\text{--}45\text{ }\mu\text{m}$ in diameter). Processes are $10\text{--}14\text{ }\mu\text{m}$ long, $2\text{--}5\text{ }\mu\text{m}$ wide, widely spaced, and mainly confined to equatorial region. The columnar process trunks have 3-4 longitudinal laminae. The processes are gradually flaring distally and terminate in 3-4 short flared branches that correspond to the trunk laminae. The process terminations are triangular to quadrangular.

This form shows some similarities to *Peteinosphaeridium velatum* Kjellström, 1971; however, this latter Baltic species differs in its larger size, relatively longer and wider processes, and complex process terminations.

Genus POLYGONIUM Vavrdová, 1966

Type species (by original designation) – *Polygonium gracile* Vavrdová, 1966.

POLYGONIUM sp.

Pl. 5, figs. 9, 10; Pl. 6, figs. 1, 2

Comments – A complex of forms with distinctly polygonal psilate vesicles. The latter bear 10-15, prominent, widely spaced, broad-based, slender, tapering spine-like processes that are usually up to one-half the vesicle diameter in length.

Genus STELLIFERIDIUM Deunff, Górka & Rauscher,
1974

Type species (by original designation) – *Stelliferidium striatulum* (Vavrdová) Deunff, Górka & Rauscher, 1974.

STELLIFERIDIUM sp.

Pl. 7, fig. 4

Comments – Broad- or bulbous-based, spine-like processes are uniformly distributed on the subspherical vesicle. The processes are short, with circular basal outline and distinct stellate striations radiating out from their bases.

Genus STRIATOTHECA Burmann, 1970

Type species (by original designation) – *Striatotheca principalis* Burmann, 1970.

STRIATOTHECA? sp.
Pl. 7, fig. 3

Comments – The specimen has a finely granulate quadrate vesicle, locally with a weak alignment of grana (particularly on the central part of the vesicle). For this reason the specimen is tentatively assigned to *Striatotheca*.

Genus VERYHACHIUM Deunff, 1954, emend. Turner, 1984

Type species (by original designation) – *Veryhachium trisulcum* Deunff, 1951 ex Deunff, 1959.

VERYHACHIUM sp.
Pl. 7, fig. 7

Comments – A small quadrate to rectangular psilate vesicle with 4, long, narrow, spine-like processes, one at each vesicle corner. The processes are approximately equal in length to that of the vesicle and have open communication with the vesicle interior.

PRASINOPHYTE PHYCOMATA

Division CHLOROPHYTA Pascher, 1914
Class PRASINOPHYCEAE Christensen, 1962
Family LEIOSPHAERIDIACEAE Timofeev, 1956 nom.
corr. Mädlar, 1963

Genus LEIOSPHAERIDIA Eisenack, 1958 emend.
Turner, 1984

Type species (by original designation) – *Leiosphaeridia baltica* Eisenack, 1958.

LEIOSPHAERIDIA sp. A
Pl. 8, fig. 1

Comments – Subcircular to oval, thin, psilate vesicle with a complex development of longitudinal compression folds. No opening seen.

LEIOSPHAERIDIA sp. B
Pl. 8, fig. 4

Comments – Very similar to *Leiosphaeridia* sp. A, except for having predominantly oblique compression folds and a very weakly infragranulate vesicle surface.

REFERENCES

- COOPER, A.H. & MOLYNEUX, S.G., 1990, The age and correlation of Skiddaw Group (early Ordovician) sediments in the Cross Fell inlier (northern England): *Geol. Mag.*, 127: 147-157.
- , RUSHTON, A.W.A., MOLYNEUX, S.G., HUGHES, R.A., MOORE, R.M. & WEBB, B.C., 1995, The stratigraphy and correlation of Skiddaw Group (Ordovician) in the English Lake District: *Geol. Mag.*, 132: 185-211.
- CRAMER, F.H., ALLAM, B., KANES, W.H. & DÍEZ, M.DEL C.R., 1974, Upper Arenigian to lower Llanvirnian acritarchs from the subsurface of the Tadla Basin in Morocco: *Palaeontographica*, B, 145: 182-190.
- & DÍEZ, M.DEL C.R., 1976, Late Arenigian (Ordovician) acritarchs from Cis-Saharan Morocco: *Micropaleontology*, 23: 339-360.
- DEUNFF, J., 1959, Microorganismes planctoniques du primaire Armoricaïn. 1. Ordovicien du Veryhac'h (presque-île de Crozon): *Bull. Soc. Géol. Minér. Bretagne*, n. Sér., 2: 1-41, (imprinted 1958, issued 1959).
- , 1961, Un microplacton à hystrichosphères dans le Trémadoc du Sahara: *Rev. Micropaléont.*, 4: 37-52.
- , 1964, Systématique du microplancton fossile à acritarches. Révision de deux genres de l'Ordovicien inférieur: *Rev. Micropaléont.*, 7: 119-124.
- , GÖRKA, H. & RAUSCHER, R., 1974, Observations nouvelles et précisions sur les acritarches à large ouverture polaire du Paléozoïque inférieur: *Géobios*, 7: 5-18.
- DOWNIE, C. & SARJEANT, W.A.S., 1965, Bibliography and index of fossil dinoflagellates and acritarchs: *Mem. geol. Soc. Amer.*, 94: 1-180.
- EISENACK, A., CRAMER, F.H. & DÍEZ, M.DEL C.R., 1973, Katalog der fossilen Dinoflagellaten, Hystrichosphären und verwandten Mikrofossilien, Band III Acritarcha, I. Teil: 1104 pp., E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart.
- FENSOME, R.A., WILLIAMS, G.L., BARSS, M.S., FREEMAN, J.M. & HILL, J.M., 1990, Acritarchs and fossil prasinophytes: an index to genera, species and intraspecific taxa: *Contrib. Ser. amer. Assoc. stratigr. Palynol.*, 25: 1-771.
- FOURNIER-VINAS, C., 1985, Acritarches ordoviens des Zekkara (Maroc oriental): *Géobios*, 18: 807-813.
- GOLUB, I.N. & VOLKOVA, N.A., 1985, New acritarchs of Upper Cambrian, Leningrad district (Ladoga Formation): *Paleont. Zhurn.*, Akad. Nauk SSSR, 4: 89-98. [in Russian].
- HIGGS, K.T. & CALLAGHAN, B., 1996, Early Ordovician acritarchs from the Annascaul Formation, Dingle Peninsula, Co. Kerry, Ireland. In Fatka, O. & Servais, T. (eds.), *Acritarcha in Praha: Acta Univ. Carolinae, Geol.*, 40: 441-443.
- HORNE, R.R., 1974, The lithostratigraphy of the Late Silurian to Early Carboniferous of the Dingle Peninsula, Co. Kerry: *Bull. geol. Surv. Ireland*, 1: 395-428.
- JARDINÉ, S., COMBAZ, A., MAGLOIRE, L., PENIGUEL, G. & VACHEY, G., 1974, Distribution stratigraphique des acritarches dans le Paléozoïque du Sahara algérien: *Rev. Palaeobot. Palynol.*, 18: 99-129.
- JUKES, J.B. & DU NOYER, G.V., 1863, Explanation of sheets 160, 161, 171 and part of 172: *Mem. geol. Surv. Ireland*.
- KJELLSTRÖM, G., 1971, Ordovician microplankton (baltisphaerids) from the Grötlingbo borehole no. 1 in Gotland, Sweden: *Sver. geol. Unders.*, Ser. C (655), Årsb., 65 (1): 1-75.
- LOEBLICH, A.R. JR. & TAPPAN, H., 1976, Some new and revised organic-walled phytoplankton microfossil genera: *J. Paleont.*, 50: 301-308.

- MOLYNEUX, S.G. & RUSHTON, W.A., 1988, The age of the Watch Hill Grits (Ordovician), English Lake District: structural and palaeogeographical implications: *Trans. roy. Soc. Edinburgh, Earth Sci.*, 79: 43-69.
- & LEADER, R.U., 1997, Morphological variation in *Coryphidium* from the Arenigian series (lower Ordovician) of northwestern England: *Rev. Palaeobot. Palynol.*, 98, 81-94.
- PARKIN, J., 1976, Silurian rocks of the Bull's Head, Annascaul and Derrymore Glen inliers, Co. Kerry: *Proc. roy. ir. Acad.*, 76B: 577-606.
- PLAYFORD, G., RIBECAL, C. & TONGIORGI, M., 1995, Ordovician acritarch genera *Peteinosphaeridium*, *Liliosphaeridium*, and *Cycloposphaeridium*: morphology, taxonomy, biostratigraphy, and palaeogeographic significance: *Boll. Soc. paleont. ital.*, 34: 3-54.
- PRACHT, M., 1996, Geology of Dingle Bay. A geological description to accompany the bedrock geology 1:100,000 map series, sheet 20, Dingle Bay: *Geol. Surv. Ireland*: 58 pp.
- RAUSCHER, R., 1974, Recherches micropaléontologiques et stratigraphiques dans l'Ordovicien et le Silurien de la France: *Sci. géol., Mém.*, 38: 1-224.
- RUSHTON, A.W.A., 1985, A Lancefieldian graptolite from the Lake District: *Geol. Mag.*, 122: 329-333.
- SERVAIS, T. & MOLYNEUX, S.G., 1997, The *messaoudensis-trifidum* acritarch assemblage (Ordovician: late Tremadoc-early Arenig) from the subsurface of Rügen (Baltic Sea, NE Germany): *Palaeontographia Italica*, 84: 113-161.
- SIVETER, D.J., 1989, Silurian trilobites from the Annascaul Inlier, Dingle Peninsula, Co. Kerry: *Palaeontology*, 32: 109-161.
- STAPLIN, F.L., 1969, Sedimentary organic matter, organic metamorphism and oil and gas occurrence: *Bull. canad. Soc. Petrol. Geol.*, 17: 47-66.
- TIETZSCH-TYLER, D. & SLEEMAN, A.G., 1994, Geology of Carlow-Wexford: a geological description to accompany the bedrock geology 1:100,000 map series, sheet 19, Carlow-Wexford: *Geol. Surv. Ireland*.
- TIMOFEEV, B.V., 1959, The ancient flora of the Prebaltic and its stratigraphic importance: *Trudy Vsesoyuznyi Neft'yanoi Nauchno-Issledovatel'skii Geologiroazvedochnyi Institut, Leningrad (VNIGRI)*, 129: 1-136. [in Russian].
- TODD, S.P., 1989, Caledonian tectonics and conglomerate sedimentation in the Dingle Basin, southwest Ireland. Unpubl. Ph.D. thesis, Univ. Bristol, England, 352 pp.
- , CONNERY, C., HIGGS, K.T., & MURPHY, F.C., in prep., An Early Ordovician age for the Annascaul Formation of the SE Dingle Peninsula, SW Ireland.
- VANGUESTAINE, M., 1973, Etude palynologique du Cambro-Ordovicien de Belgique et de l'Ardenne française. Systématique et biostratigraphie. Unpubl. Ph.D. thesis, Univ. Liège: 366 pp.
- , 1978, Critères palynostratigraphiques conduisant à la reconnaissance d'un pli couché revinien dans le sondage de Grand-Halleux: *Ann. Soc. géol. Belgique*, 100: 249-276.
- VAVRDOVÁ, M., 1966, Palaeozoic microplankton from central Bohemia: *Čas. Mineral. Geol.*, 11: 409-414.
- , 1972, Acritarchs from Klabva shales: *Vest. ušted. Ust. geol.*, 47: 79-86, Praha.
- VECOLI, M., 1996, Stratigraphic significance of acritarchs in Cambro-Ordovician boundary strata, Hassi-Rmel area: Algerian Sahara: *Boll. Soc. paleont. ital.*, 35: 3-58.
- VOLKOVA, N.A., 1990, Middle and Upper Cambrian acritarchs in the East-European platform: Academy of Sciences of the Soviet Union: Order of the Red Banner of Labour Geological Institute, *Transact.*, 454: 1-120. [in Russian].

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