

Palynology and palaeoenvironments of the Silurian Coosglass Slate and Ferriter's Cove formations in the Dunquin Inlier (Dingle Peninsula, Ireland)

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This study documents the first palynological data from the Silurian of the Dunquin Inlier of the Dingle Peninsula and focuses on the lower part of the succession. The previously undated Coosglass Slate Formation contains a low diversity Llandovery to early Wenlock acritarch assemblage, confirming the previously enigmatic Coosglass Slate Formation as the oldest formation in the Silurian succession. The lithofacies and acritarch biofacies suggest the mudstones of the Coosglass Slate Formation represent a low energy, offshore, muddy shelf palaeoenvironment. The Ferriter's Cove Formation, a succession of five offshore to tidal-flat regressive marine cycles yielded more diverse palynological assemblages. Acritarchs and cryptospores from the Ferriter's Cove Formation confirm a Wenlock (Homerian) age for this formation. The integration of palynological and sedimentological data from four of the offshore to tidal-flat regressive cycles reveals three consistent palynomorph distribution trends: (1) offshore and shoreface depositional facies contain the most diverse palynological assemblages in which acritarchs with long and ramified processes dominate; (2) back-barrier tidal-flat facies are characterized by terrestrially derived palynomorphs, particularly cryptospores, together with a restricted acritarch assemblage of mainly micrhystrid and veryhachid forms with small simple processes; (3) back-barrier lagoonal facies with patch reefs are dominated by the sphaeromorph acritarch *Leiosphaeridia*.

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INTRODUCTION

The Silurian rocks of the Dunquin Inlier are located at the western end of the Dingle Peninsula in County Kerry, south-west Ireland. The succession is magnificently exposed in coastal sections and intermittent inland outcrops that represent the most westerly Silurian exposures in Europe (Fig. 1). The 1500 m-thick Silurian succession is referred to as the Dunquin Group (Holland, 1969) and is comprised predominantly of shallow marine siliciclastic and minor coastal plain sediments interbedded with thick volcanoclastic deposits and lavas. These deposits formed in an intra-arc basin on the north-west margin of Eastern Avalonia. Deposition took place around the fringe of large volcanic islands, that were probably isolated from the more extensive continental shelf areas to the east (Boyd and Sloan, 2000).

The stratigraphy and palaeontology of the Silurian rocks in the Dunquin Inlier has been extensively studied by Gardiner and Reynolds (1902), Home (1974, 1976), Watkins (1978),

Holland (1987) and Pracht (1996). The latter author subdivided the Dunquin Group succession into seven formations (Fig. 2) and this stratigraphical scheme is used herein.

The Silurian succession is assigned a Wenlock to Ludlow age based on diverse shelly faunas and rare graptolites obtained from the Ferriter's Cove and Croaghmahrin formations respectively (Holland, 1988). Furthermore, the Ferriter's Cove Formation has yielded the graptolite *Monograptus flemingii warreni* providing a more precise biostratigraphic assignment to the *lungreni* graptolite Biozone of early Homerian age (Benton and Underwood, 1994). However, no biostratigraphic age has yet been obtained from the Coosglass Slate Formation in the lowermost part of the Dunquin Group.

This study is a palynological investigation of the Coosglass Slate and the Ferriter's Cove formations. Its aims are to determine the composition and diversity of the palynological assemblages, to provide new biostratigraphical age data, and to analyse the distribution of the palynomorphs within the different depositional environments as determined by the sedimentology.

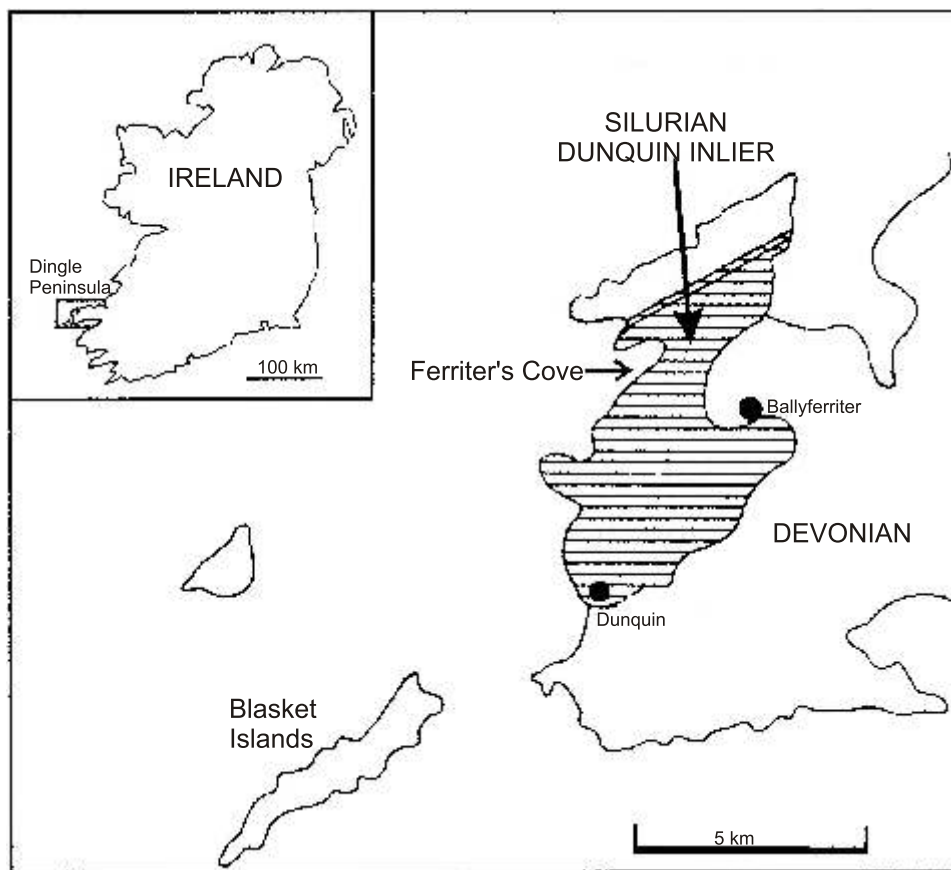


Fig. 1. Location of the Dunquin Inlier and the study area at the western end of the Dingle Peninsula, south-west Ireland

STRATIGRAPHY AND SEDIMENTOLOGY

THE COOSGLASS SLATE FORMATION

The Coosglass Slate Formation is restricted to the inlet and small headland of Coosglass in the northernmost part of the Dunquin Inlier (Fig. 3). Geologically, the formation is fault bounded to the north by the Foilnamahagh Fault and to the south by the Dún an Óir Fault. The formation is composed of a

100 m sequence of monotonous grey, olive-green and purple cleaved mudrocks that contain rare casts of orthoconic nautiloids and horizons of simple and small branching burrows (Todd *et al.*, 1988). These deposits have been regarded as enigmatic, because their age is unknown due to the absence of diagnostic macrofossils and the fact that they are fault bounded. Previous workers have disagreed on the stratigraphic position of these slates within the Silurian succession. For example, Horne (1974) and Holland (1987) assigned the slates to the Drom Point Formation, whereas, Todd *et al.* (1988), using

SILURIAN	LUDLOW	DUNQUIN GROUP	Croaghmahrin Fm.
	WENLOCK		Drom Point Fm.
			Mill Cove Fm.
			Clogher Head Fm.
			Ferriter's Cove Fm.
	?		Foilnamahagh Fm.
	Coosglass Slate Fm.		

Fig. 2. Stratigraphy of the Silurian rocks of the Dunquin Inlier (after Pracht, 1996)

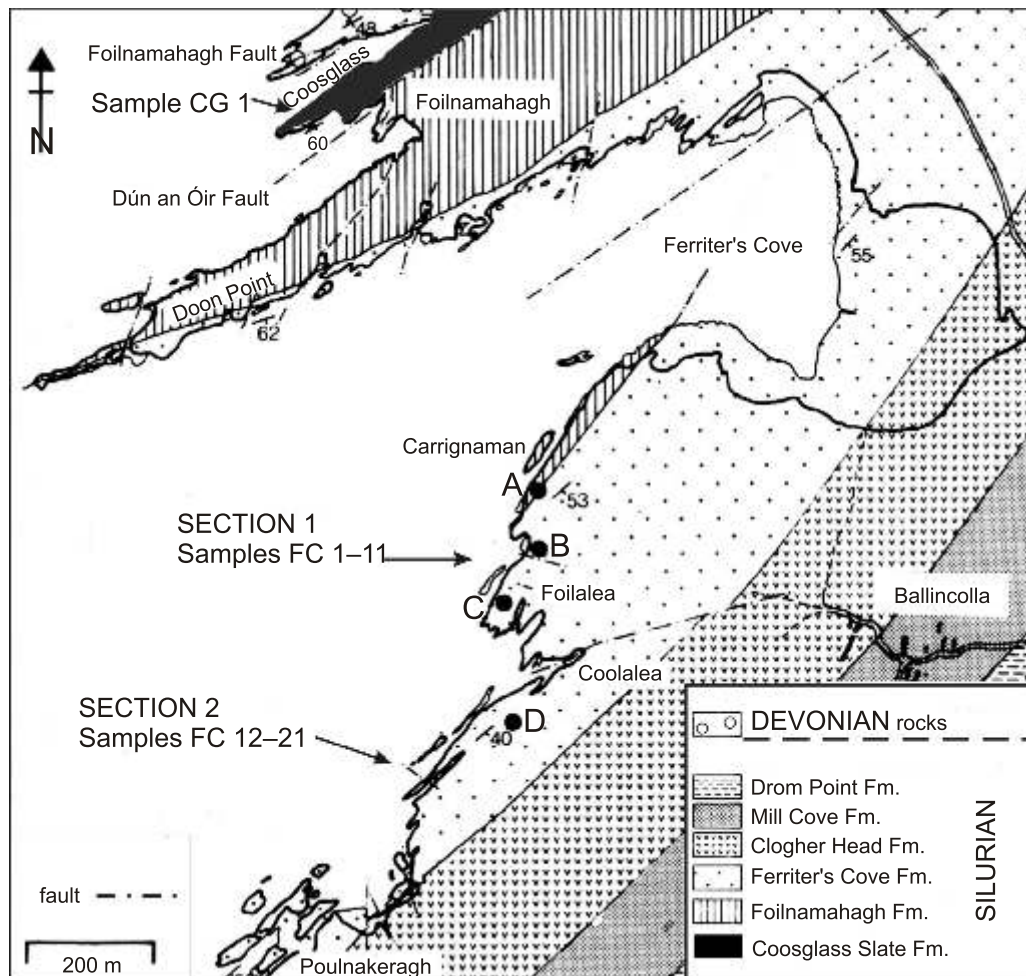


Fig. 3. Geological map of the northern part of the Dunquin Inlier showing the study area and the location of the Coosglass Slate Formation (CG 1) sample and the location of Sections 1 (localities A–C) and 2 (locality D) in the Ferriter's Cove Formation (after Sloan and Williams, 1991)

lithological and structural evidence considered the slates to be older than the Drom Point Formation and placed them at the base of the Wenlock succession. Todd *et al.* (1988) renamed these deposits the Coosglass Slates and they were subsequently given formational status by Pracht (1996). No detailed sedimentological study has been made of this formation and so its specific marine depositional environment has not been defined. However, the homogenous fine-grained mudrock lithofacies suggests low energy sedimentation. The absence of any benthic shelly faunas and the presence of free-swimming nautiloids points to deeper water conditions in a low energy, offshore marine setting. The presence of burrowing activity at some levels suggests aerobic substrate conditions.

THE FERRITER'S COVE FORMATION

The Ferriter's Cove Formation occurs in three sections in the Dunquin Inlier, with the best exposures found in two coastal sections around Ferriter's Cove (Fig. 3). The formation comprises a 150–200 m-thick succession of grey, olive-green, yellow-brown fossiliferous siltstones, sandstones and minor

conglomerates, interbedded with volcanic pyroclastic deposits. The Ferriter's Cove Formation was first formally named and described by Holland (1969). It was subsequently revised by Sloan and Williams (1991) who re-assigned the basal porphyritic lava and overlying red bed sequence (in the lower part of the original Ferriter's Cove Formation) to a new formation called the Foilsnamahagh Formation. Sloan and Williams (1991) made a detailed sedimentological analysis of the nearshore marine siliclastic sediments of the Ferriter's Cove Formation. They identified five stacked coarsening-upward parasequences, which they interpreted as offshore to tidal-flat regressive cycles. The individual parasequences are 10–80 m-thick. Each regressive cycle records a transition from sub-barrier, barrier, to back-barrier environments (Fig. 4). The lower part of each parasequence is characterized by bioturbated mudstones and calcareous (often weathered and de-calcified) siltstones, that in places, contain rich assemblages of tabulate corals, brachiopods, crinoids, gastropods, trilobites and rare graptolites. The sediments are interpreted as offshore shelf facies. These offshore sediments become sandier and less bioturbated upwards and give way to wave rippled siltstones and fine-grained sandstones. The sandstones pass upwards into

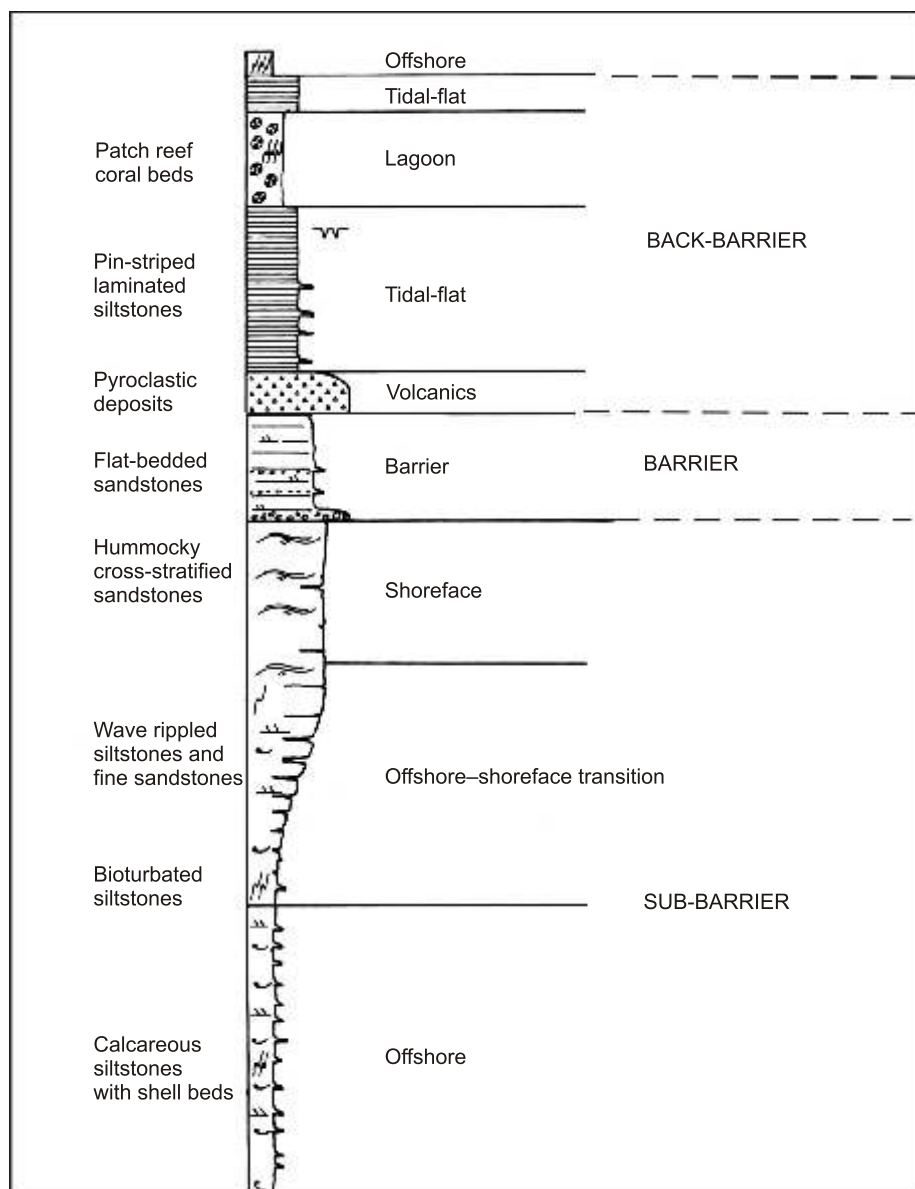


Fig. 4. Generalized sedimentological log of a typical regressive cycle in the Ferriter's Cove Formation

No thickness implied, as cycles vary from 10–80 m in thickness (modified from Sloan and Williams, 1991)

hummocky and swaley cross-stratified (HCS and SCS) fine-grained sandstones, which are interpreted as representing the shoreface facies. Evidence of storm deposition is provided by the common amalgamation of the HCS beds.

The barrier facies is distinguished by 1–4 m-thick planar laminated fine-medium sandstones together with planar and cross-bedded, clast supported conglomerates. The barrier sequence is typically succeeded by volcanic deposits composed of pyroclastic surge and/or pyroclastic fall lapilli tuffs. The volcanic interval is commonly associated with the back-barrier sequence, made up of tidal-flat and sub-tidal lagoonal facies. The tidal-flat facies is characterized by pin-striped laminated beds composed of couplets of fine sand and mud in which the lamination is parallel to undulating at a millimetre scale. In some places these beds have polygonal dessication cracks and are reddened. They have been interpreted as tidal rhythmites

(tidalites). The sub-tidal lagoonal facies are composed of grey mudstones containing abundant monospecific colonies of the tabulate coral *Parastriatopora*. These dense coral accumulations are considered to represent patch reefs growing in a stressed environment experiencing fluctuating salinity conditions (Sloan and Williams, 1991).

In considering the controls of sea level change that produced the regressive cycles of the Ferriter's Cove Formation, Sloan and Williams (1991) discounted the effects of the mid-Silurian eustatic sea level fall and variable rates of sediment supply. Instead, they proposed that local volcano-tectonic activity controlled the relative sea level. The marine regressions (with decreasing water depth) were the result of local sea floor aggradation and gradual volcano-tectonic uplift prior to eruption. The intercycle marine transgressions were the result of subsidence triggered by post-volcanic magma deflation.

PALYNOLOGY

The 22 productive samples come from grey mudstones and siltstones. The 50 g samples were prepared in the laboratory using standard palynology hydrochloric and hydrofluoric acid maceration techniques followed by zinc bromide heavy mineral separation. The organic residue was sieved at 10 µm and strew-mounted using *Elvacite* mounting medium. The organic material is black in colour and thermally mature, therefore, very strong oxidation techniques using *Schultze Solution* (>20 h) were used to lighten the organic material for microscopic identification. The palynomorphs recovered are moderately to poorly preserved and the palynological assemblages are generally of low to moderate taxonomic diversity (7–30 identifiable taxa). Relative abundance data was obtained from counts of 200 palynomorphs from one or more slides of each sample. The occurrence and relative abundance (ie. rare, common and abundant) of the identifiable palynomorph taxa recorded in each sample is shown in [Table 1](#). Palynomorph taxa recorded from the Coosglass and Ferriter's Cove formations are illustrated in [Figures 5–7](#). The studied slides are housed in the micropaleontological collection of the Department of Geology at University College Cork.

COOSGLASS SLATE FORMATION

Ten samples were processed from this formation, however, only one productive sample (sample CG 1) was obtained. The productive sample was collected from a 30 cm-thick, pale grey mudrock bed located in the centre of the small headland south of Coosglass. Stratigraphically, the sample occurs approximately 48 m above the base of the formation. The sample yielded a low diversity acritarch assemblage in which the following acritarch and sphaeromorph acritarch taxa were identified:

Carminella maplewoodensis Cramer, 1968; *Dactylofusa horrida* Le Hérisse, Al-Tayyar and van der Eem, 1995; *Dactylofusa striatifer* (Cramer) Fensome *et al.*, 1990; *Domasia elongata* Downie, 1960; *Domasia trispinosa* Downie, 1960; *Michrhystridium stellatum* Deflandre, 1945; *Oppilatala frondis* (Cramer and Diez) Dorning, 1981; *Multiplicisphaeridium* sp., *Tylotopalla deerlijkianum* (Martin) Martin, 1978; *Veryhachium europaeum* Stockmans and Willière, 1960; *Veryhachium* sp., *Leiosphaeridia* sp. and *Lophosphaeridium* sp.

The presence of the *Domasia trispinosa*–*D. elongata* group, *Carminella maplewoodensis*, *Dactylofusa striatifer* and *Oppilatala frondis* indicate the assemblage is no older than Llandovery, because all of these taxa first occur in the Llandovery (Molyneux *et al.*, 1996). Furthermore, the presence of *Tylotopalla deerlijkianum* is stratigraphically significant as this species disappears just above the Llandovery–Wenlock boundary in Gotland (Le Hérisse, 1989). The limited palynostratigraphic data therefore indicates a Llandovery to early Wenlock age for the Coosglass Slate Formation assemblage. The palynologic data provides the first biostratigraphic age for the Coosglass Slate Formation and confirms it as the oldest Silurian formation in the Dunquin Inlier.

In terms of acritarch biofacies, the presence of a low diversity acritarch assemblage containing a *Domasia* complex appears to support the depositional interpretation of a more distal offshore marine environment for the Coosglass Slate Formation. Le Hérisse and Gourvenec (1995) have noted that on the fringes of northern Gondwana the occurrence of *Domasia* in the Llandovery and early Wenlock is restricted to open marine fine detrital deposits. Beck and Strother (1996) also reported that *Domasia* was present in the fine grained distal marine mudstones of upper Llandovery Ross Brook Formation in Arisaig, Nova Scotia, Canada but was absent in the overlying coarser and more proximal marine facies. However, the *Domasia* acritarch biofacies distribution may not be just water depth related. Molyneux *et al.* (2008) described an unusual acritarch biofacies association from the upper Llandovery Reservoir Formation in the Pentland Hills Inliers of the Midland Valley of Scotland. The Reservoir Formation yielded low to moderate diversity acritarch assemblages containing the *Domasia trispinosa*–*D. elongata* group. A feature of the acritarch assemblages from the upper part of the Reservoir Formation is the common occurrence of the sphaeromorph acritarch *Moyeria cabotti* (Cramer) Miller and Eames, 1982. Previous studies (Gray and Boucot, 1989; Wellman and Richardson, 1993) have shown that *M. cabotti* is typically abundant in near-shore marine and non-marine deposits. The palynologic data in this case reveals conflicting acritarch palaeoecological distributions, as the abundance of the *M. cabotti* suggests a near-shore marine environment, but the compositional diversity of the *Domasia trispinosa*–*D. elongata* acritarch assemblage is more consistent with an offshore shelf environment. Molyneux *et al.* (2008) concluded that the palynologic data do not provide critical evidence to distinguish between deep-water and shallow-water shelf environments in the Reservoir Formation. They suggest the palynologic changes in acritarch diversity in the upper part of the Reservoir Formation reflect changing environmental conditions, with the marine palynomorphs tracking changes in the location of certain physical and chemical properties of water masses, such as, nutrient availability, salinity or temperature.

FERRITER'S COVE FORMATION

Twenty one productive samples were obtained from the Ferriter's Cove Formation occurring in two sections located along the coastal cliffs between Carriganman and Poulakeragh, south of Ferriter's Cove. The studied sections 1 and 2 are equivalent to Sloan and Williams's composite section A–C and section D respectively ([Fig. 3](#)). Eleven samples (FC 1–11) were collected from Section 1 which covers regressive cycle 1 and the basal part of cycle 2 interval. Ten samples (FC 12–21) were collected from Section 2, which covers regressive cycles 3 and 4, and the basal part of cycle 5. The stratigraphic position of these samples is shown in [Figure 8](#). It was not possible to sample the main part of regressive cycle 2 due to inaccessible cliffs throughout this interval.

The 21 samples from the Ferriter's Cove Formation yielded low to moderately diverse palynomorph assemblages and a summary of the taxa identified is given below.

Table 1

The occurrence of all the identified palynomorph taxa in the 22 samples studied, with the relative abundance of the each taxon

SAMPLES	CG 1	FC 1	FC 2	FC 3	FC 4	FC 5	FC 6	FC 7	FC 8	FC 9	FC 10	FC 11	FC 12	FC 13	FC 14	FC 15	FC 16	FC 17	FC 18	FC 19	FC 20	FC 21
ACRITARCHS (process bearing)																						
<i>Ammonidium microcladum</i>		C	C	C	C	R	R				C		C	C	R				R		C	C
<i>Carminella maplewoodensis</i>	R	R		R	R									R	R						R	R
<i>Cymbosphaeridium</i> cf. <i>C. bakidium</i>		R		R	R						R		R	R	R						R	R
<i>Diexallophasis denticulata</i>		C	C	C	C	R	R	R			C	C	C	C	C		R		C	R	C	C
<i>Domasia elongata</i>	R																					
<i>Domasia trispinosa</i>	R																					
<i>Elektoriskos williereae</i>		R	R	R	R						R			R	R				R		R	R
<i>Elektoriskos</i> sp.		R		R							R			R								
<i>Dactylofusa horrida</i>	R																					
<i>Dactylofusa striatifera</i>	R	C		C							R	R		R							R	R
<i>Micrhystridium nannacanthum</i>						C		C	R	R						R		R		C		
<i>Micrhystridium parinconspicuum</i>			C	C	C	C	C	C	R	R	C		C			R		R			C	C
<i>Micrhystridium stellatum</i>	C	C	C	C	C	C	C	C			C	C	C	C	C		C		C	R	C	C
<i>Multiplicisphaeridium</i> sp.	R	C	C		C	R	R				C	C	C	C	R		R				C	C
<i>Multiplicisphaeridium arbusculum</i>		C	C	C							C	C	C	C	C						C	C
<i>Oppilatala frondis</i>	R																					
<i>Oppilatala insolita</i>		C	C	C	R						C	C	C	C	C					C		C
<i>Percultisphaera stiphrospinosa</i>		C		C							C		C	C	C					C		C
<i>Tylotopalla deerlijkianum</i>	R																					
<i>Veryhachium europaeum</i>	C			C		C	R	C			C		C	C	C		R			R		C
<i>Veryhachium</i> sp.	C	C	C	C	C	C	C	C			C	C	C	C	C		C	R		C	R	R
<i>Visbysphaera dilatispinosa</i>		C	C	C	C						C	C	C	C	C					C		C
<i>Visbysphaera jardineae</i>				R							R		R	R						R		R
SPHAEROMORPH ACRITARCHS																						
<i>Leiosphaeridia</i> spp.	C	C	C	R	R	C	C	C	A	A	R	R	R	R	R	A	R	A	R	C	R	R
<i>Lophosphaeridium</i> sp.	R	R	R	R	R				R		R	R	R	R	R	R	R	R	R	C	R	R
PRASINOPHYTES																						
<i>Cymatiosphaera gorstia</i>		R				R		R	R		R			R					R		R	R
<i>Cymatiosphaera octoplana</i>		R	R	R							R			R					R		R	R
<i>Dictyotidium dictyotum</i>						C	C	C							R	R	R	R				R
<i>Dictyotidium faviforme</i>		R				R	C	C	R	R			R	R	R	R	R	R			R	R
<i>Muraticavea wenlockia</i>		R	R	R	R						R	R		R		R	R	R			R	R
CRYPTOSPORES																						
<i>Artemopyra</i> sp.		R				R	R						R				R			R		R
<i>Dyadospora murusattenuata</i>		R				C	C	C	R	R		R	R	R	R		C			R	R	R
<i>Hispanaediscus verrucatus</i>		R				R	R	R				R	R	R	R		R			R	R	R
<i>Hispanaediscus wenlockensis</i>						R	R	R				R	R	R	R		R			R	R	R
<i>Laevolancis divellomedium</i>		R				R	R	R				R	R	R	R		R			R	C	R
<i>Laevolancis plicata</i>		R	R			R	R	R				R	R	R	R		R			R	C	R
<i>Rugosphaera tuscarorensis</i>						R	R						R		R		R			R	C	R
<i>Tetrahedraletes medinensis</i>		R				C	C	C	R	R		R	R		R		C			C	R	R
TRILETE SPORES																						
<i>Ambitisporites avitus</i>		R	R	R	R	R	C	C			R	R	R	R	R	R	R			R	C	R
<i>Ambitisporites dilutus</i>		R	R	R	R	R	C	C	R	R	R		R	R	R	R	C			R	C	R

R – rare (<5%), C – common (5–30%), A – abundant (>30%)

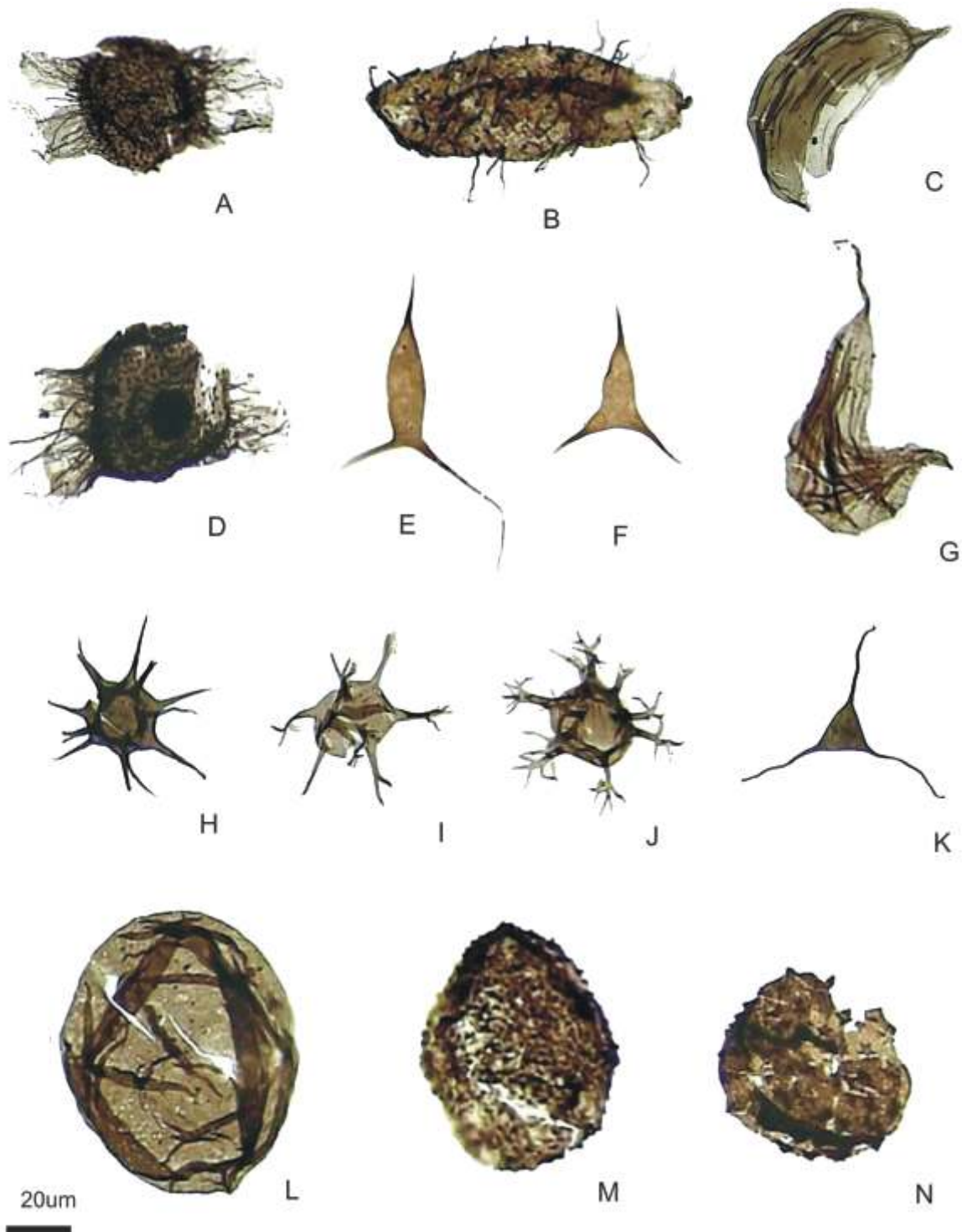


Fig. 5. Selected acritarchs and sphaeromorph acritarchs from the Coosglass Slate Formation

A, D – *Carminella maplewoodensis* Cramer, 1968, CG 1, (c) W34, CG 1, (a) K26; **B** – *Dactylofusa horrida* Le Hérisse, Al-Tayyar and van der Eem, 1995, CG 1 (b) I11; **C, G** – *Dactylofusa striatifera* (Cramer) Fensome *et al.*, 1990, CG 1 (a) F22, CG 1, (a) S10; **E** – *Domasia elongata* Downie, 1960, CG 1 (c), Y11; **F** – *Domasia trispinosa* Downie, 1960, CG 1 (c), U35; **H** – *Micrhystridium stellatum* Deflandre, 1945, CG 1 (a), G27; **I** – *Multiplicisphaeridium* sp. CG 1 (a), Y33; **J** – *Oppilatala frondis* (Cramer and Diez) Dorning, 1981, CG 1 (b), T71; **K** – *Veryhachium* sp. CG 1 (a), R19; **L** – *Leiosphaeridia* sp. CG 1 (b), T23; **M** – *Lophosphaeridium* sp. CG 1 (a), W27; **N** – *Tylotopalla deerlijkianum* (Martin) Martin, 1978, CG 1 (b), Y24; each figured specimen has sample number, slide and England finder slide co-ordinate

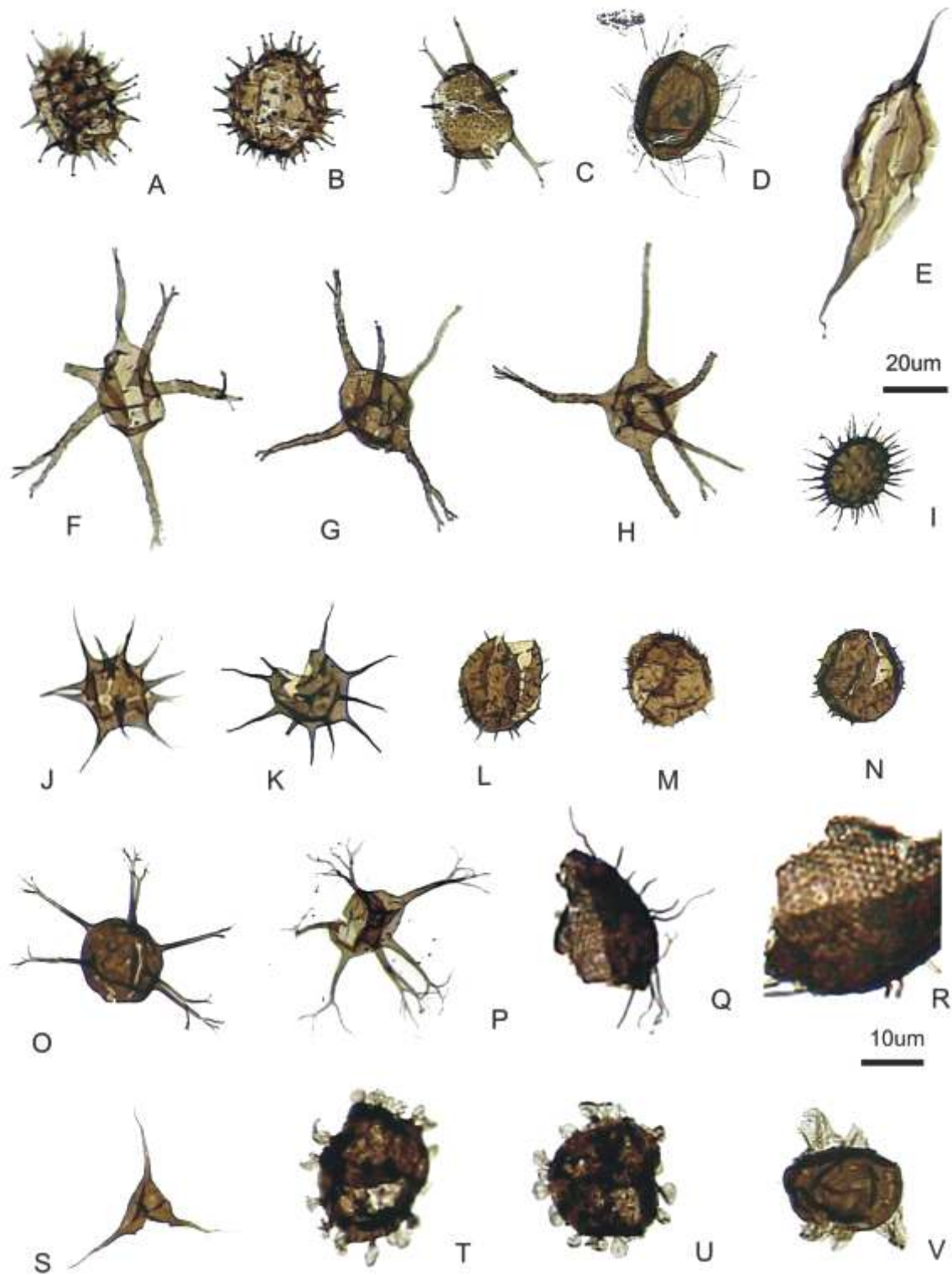


Fig. 6. Selected acritarchs from the Ferriter's Cove Formation

A, B – *Ammonidium microcladum* (Downie) Lister, 1970, FC 1 (a), R17, FC1 (c), S32; **C** – *Cymbosphaeridium* C. cf. *bakidium* Lister, 1970, FC 1 (b), C8; **D** – *Elektoriskos williereae* (Deflandre and Deflandre-Rigaud) Vanguetstaine, 1979, FC 3 (f), F12; **E** – *Dactylofusa striatifera* (Cramer) Fensome *et al.*, 1990, FC 3 (a), F22; **F, G, H** – *Diexallophasis denticulata* (Stockmans and Willierè) Loeblich, 1970, FC 20 (a), W25, FC 20 (a), X20, FC 20 (a), H11; **I** – *Elektoriskos* sp. FC 1 (a), R13; **J, K** – *Micrhystridium stellatum* Deflandre, 1945, FC 21 (b), G29; **L** – *Micrhystridium parinconspicuum* Deflandre, 1945, FC 3 (a), I30; **M, N** – *Micrhystridium nannacanthum* Deflandre, 1945, FC 6 (c), Q23, FC 19 (c), H16; **O** – *Oppilatala insolita* (Cramer and Diez) Dorning, 1981, FC 1 (k), U24; **P** – *Multiplicisphaeridium arbusculum* Dorning, 1981 FC 20 (a), K28; **Q, R** – *Percultisphaera stiphrospinosa* Lister, 1970, FC 1 (a), K13, specimen R at $\times 10$; **S** – *Veryhachium europaeum* Stockmans and Willierè, 1960, FC 20 (c), R24; **T, U** – *Visbysphaera dilatispinosa* Le Hérisse, Al-Tayyar and van der Eem, 1995, FC 20 (a), C14, FC 20 (b), W29; **V** – *Visbysphaera jardineae* (Cramer) Lister, 1970, FC 20 (b), B24; each specimen has sample number, slide and England finder slide co-ordinate

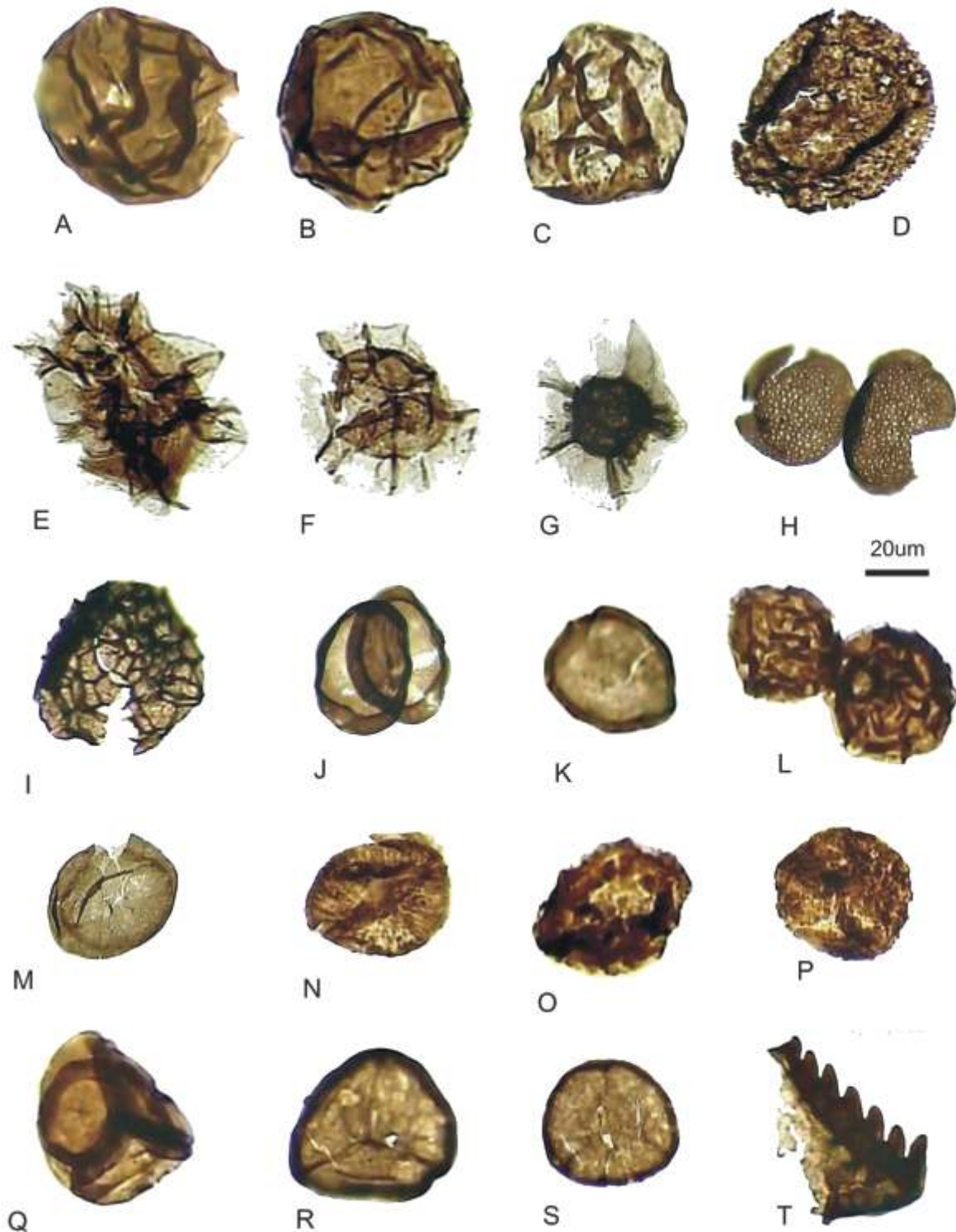


Fig. 7. Selected sphaeromorph acritarchs, cryptospores, trilete spores and scolecodont from Ferriter's Cove Formation

A, B, C – *Leiosphaeridia* sp. FC 17 (c), E15, FC 15 (c), D11, FC 17 (c), R25; **D** – *Lophosphaeridium* sp. FC 15 (c), G18; **E** – *Muraticavea wenlockia* Dorning, 1981, FC 20 (c), C14; **F** – *Cymatiosphaera gorstia* Dorning, 1981, FC 19 (b), G13; **G** – *Cymatiosphaera octoplana* Dorning, 1981, FC 19 (a), W16; **H** – *Dictyotidium faviforme* Schultz, 1967, 16 (a), I14; **I** – *Dictyotidium dictyotum* (Eisenack) Eisenack, 1955, FC 16 (a), T22; **J** – *Dyadospora murusattenuata* Strother and Traverse, 1979, FC 19 (a), F13; **K** – *Laevolancis divellomedium* (Chibrikova) Burgess and Richardson, 1991, FC 19, (b) U30; **L** – *Rugosphaera tuscarorensis* Strother and Traverse, 1979, FC 19 (a), S22; **M** – *Laevolancis plicata* Burgess and Richardson, 1991, FC 19 (a), X13; **N** – *Artemopyra* sp. FC 19 (b), K25; **O** – *Hispanaediscus verrucatus* Cramer emend Burgess and Richardson, 1991, FC 19, (a) V20; **P** – *Hispanaediscus wenlockensis* Burgess and Richardson, 1991, FC 19 (b), Q25; **Q** – *Tetrahedraletes medinensis* Strother and Traverse, 1979, FC 19 (a), M24; **R** – *Ambitisporites avitus* Hoffmeister, 1959, FC 19 (a), G26; **S** – *Ambitisporites dilutus* (Hoffmeister) Richardson and Lister, 1969, FC 19, (a) G28; **T** – Scolecodont, FC 20 (a), R17; each figured specimen has sample number, slide and England finder slide co-ordinate

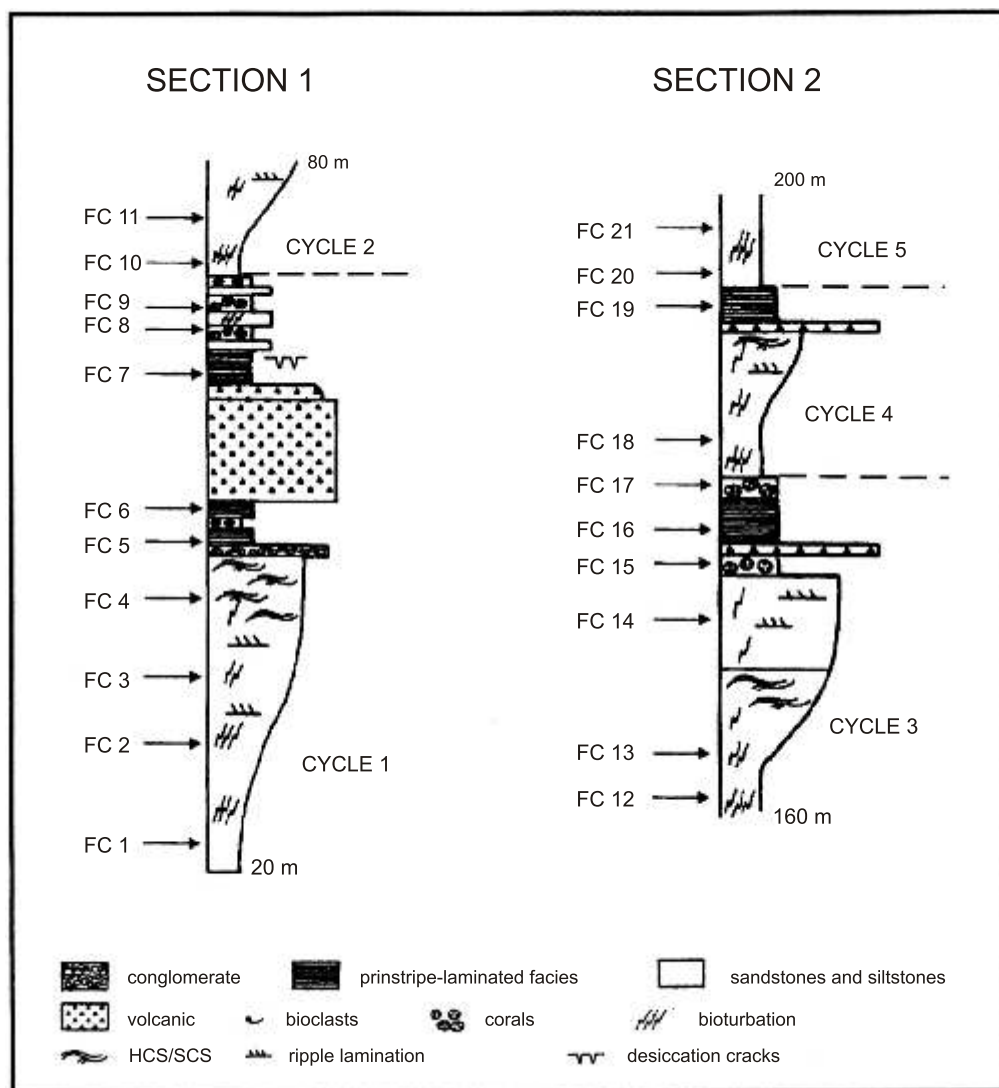


Fig. 8. Stratigraphic logs of sections 1 and 2 showing the positions of the productive samples FC 1–21 within the regressive cycles of the Ferriter's Cove Formation (stratigraphic logs modified from Sloan and Williams, 1991)

Acritarchs with processes – *Ammonidium microcladum* (Downie) Lister, 1970; *Cymbosphaeridium* C. cf. *bakidium* Lister, 1970; *Dactylofusa striatifera*, *Diexallophasis denticulata* (Stockmans and Willierè) Loeblich, 1970; *Elektoriskos williereae* (Deflandre and Deflandre-Rigaud) Vanguetaine, 1979; *Elektoriskos* sp.; *Micrhystridium nannacanthum* Deflandre, 1945; *Micrhystridium stellatum*, *Micrhystridium parinconspicuum* Deflandre, 1945; *Multiplicisphaeridium arbusculum* Dorning, 1981; *Multiplicisphaeridium* sp., *Oppilatata insolita* (Cramer and Diez) Dorning, 1981; *Percultisphaera stiphrospinosa* Lister, 1970; *Veryhachium europaeum*, *Veryhachium* sp.; *Visbysphaera dialatispinosa* Le Hérisse, Al-Tayyar and van der Eem, 1995; *Visbysphaera jardineae* (Cramer) Lister, 1970.

Sphaeromorph acritarchs – *Leiosphaeridia* spp.; *Lophosphaeridium* spp.

Prasinophytes – *Cymatiosphaera gorstia* Dorning, 1981; *Cymatiosphaera octoplana* Dorning, 1981; *Dictyotidium dictyotum* (Eisenack) Eisenack, 1955; *Dictyotidium faviforme* Schultz, 1967; *Muraticavea wenlockia* Dorning, 1981.

Cryptospores – *Artemopyra* sp.; *Dyadospora murusattenuata* Strother and Traverse, 1979; *Hispanaediscus verrucatus* Cramer emend Burgess and Richardson, 1991; *Hispanaediscus wenlockensis* Burgess and Richardson, 1991; *Laevolancis divellomedium* (Chibrikova) Burgess and Richardson, 1991; *Laevolancis plicata* Burgess and Richardson, 1991; *Rugosphaera tuscarorensis* Strother and Traverse, 1979; *Tetrahedraletes medinensis* Strother and Traverse, 1979.

Trilete spores – *Ambitisporites avitus* Hoffmeister, 1959; *Ambitisporites dilutus* (Hoffmeister) Richardson and Lister, 1969.

In terms of biostratigraphy, the acritarchs and cryptospores indicate a Wenlock (Homerian) age for the Ferriter's Cove Formation. This age assignment is based primarily on the occurrence of the ornamented cryptospore taxa *Hispanaediscus verrucatus*, *Hispanaediscus wenlockensis* and *Artemopyra* sp. which allows correlation with the *Artemopyra brevicosta*–*Hispanaediscus verrucatus* spore Assemblage Biozone of Wenlock (Homerian) age (Richardson and McGregor, 1986; Burgess and Richardson, 1995). In addition, the presence of the

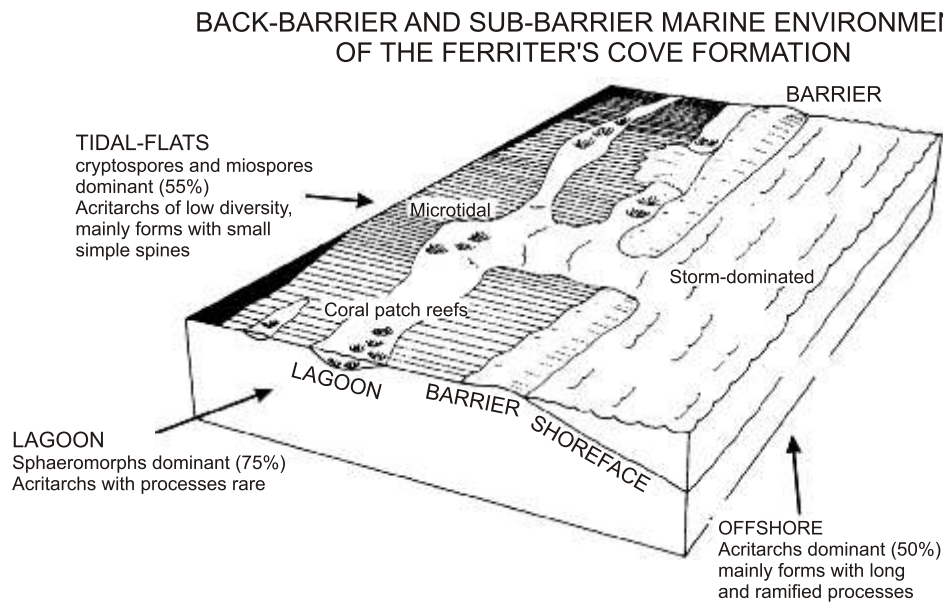


Fig. 9. Relative abundance of palynomorph groups in the offshore, tidal-flat and lagoonal depositional facies of the regressive cycles in the Ferriter's Cove Formation

acritarch taxon *Percultisphaera stiphrospinosa* is stratigraphically important, because this species makes its first appearance in the Homerian (Molyneux *et al.*, 1996).

PALYNOMORPH DISTRIBUTION TRENDS IN THE FERRITER'S COVE FORMATION

The integration of palynologic and sedimentologic data sets permits the analysis of the palynomorph distribution in the sub-barrier and back-barrier marine palaeoenvironments. The palynomorphs were assigned to seven groups, which are: (1) acritarchs with processes, (2) sphaeromorph acritarchs (possible prasinophytes), (3) prasinophytes, (4) chitinozoa, (5) trilete spores, (6) cryptospores and (7) scolecodonts. The marine phytoplankton groups (1–3) are based on the classification of Le Hérisse *et al.* (2009). The relative abundance of these palynomorph groups within the sub-barrier and back-barrier marine depositional facies is shown in Figure 9 and their distribution is discussed below.

Sub-barrier environment – palynomorph data comes from ten samples of the offshore, shallow shelf depositional facies. These are: FC 1–3 from cycle 1; FC 10–11 from cycle 2; FC 12–13 from cycle 3; FC 18 from cycle 4 and FC 20–21 from cycle 5. The offshore, shallow shelf assemblages are dominated by acritarchs with processes (50%), sphaeromorphs (20%) and prasinophytes (5%). Terrestrially derived cryptospores and trilete spores comprise 15 and 5% of the assemblage respectively. The most commonly occurring acritarch genera in the offshore assemblages are, *Diexallophasis*, *Micrhystridium*, *Multiplicisphaeridium* and *Oppilatala*. In addition, two samples FC 4 (cycle 1) and FC 14 (cycle 3) from the sub-barrier shoreface depositional facies showed almost an identical palynomorph composition and diversity as those from the offshore shallow shelf facies. This is probably the result of mixing of the shelf and shorefacies

palynomorphs during storm events that characterise this part of the regressive cycle.

Back-barrier environment – palynomorph data from the back-barrier environment can be differentiated into the lagoonal and the tidal-flat depositional facies, which are described separately. Palynomorph data from five samples of the tidal-flat depositional facies. These are: FC 5–7 from cycle 1; FC 16 from cycle 3 and FC 19 from cycle 4. The assemblages in this facies are dominated by cryptospores (45%), particularly the genera *Laevolancis* and *Dyadospora* and roughly equal minor amounts of trilete spores (10%), scolecodonts (5%), sphaeromorphs (15%), prasinophytes (10%) and acritarchs with processes (15%).

The latter group is markedly reduced in number and diversity compared to the offshore facies and is mostly represented by short-processed forms of *Micrhystridium* and *Veryhachium*. Palynomorph data from the lagoonal facies came from five samples. These are: FC 8–9 from cycle 1; FC 15–17 from cycle 3. These assemblages are dominated by the sphaeromorph acritarch *Leiosphaeridia* (75%) with only minor amounts of cryptospores (12%), trilete spores (3%), scolecodonts (4%) and prasinophytes (5%). Notably acritarchs with processes (1%) are very rare.

The summary of the palynomorph distribution trends recorded from the various depositional facies of the sub-barrier and back-barrier marine environments is shown in Table 2.

Studies of Paleozoic acritarch/prasinophyte palaeoecology have been reviewed by Molyneux *et al.* (1996), Stricanne *et al.* (2004), Le Hérisse *et al.* (2009) and others. The palynomorph distribution trends from the Ferriter's Cove Formation are compared with other similar Silurian palyno-ecological studies and are in broad agreement with those reported by Dorning (1981) and Dorning and Bell (1987) from the Wenlock and Ludlow carbonate-rich shelves of the Welsh Borderlands. Dorning (1981) identified near-shore, offshore shelf, and deep-water assemblages. The near-shore and deep-water assemblages are

Table 2

Palynomorph distribution trends within the depositional facies of the sub-barrier and back-barrier marine environments of the regressive cycles in the Ferriter's Cove Formation (modified from Sloan and Williams, 1991)

Palynomorph group	Offshore facies	Tidal-flat facies	Lagoonal facies
Acritarchs with processes	50%	15%	1%
Sphaeromorph acritarchs	20%	15%	75%
Prasinophytes	5%	10%	5%
Trilete spores	5%	10%	3%
Cryptospores	15%	45%	12%
Chitinozoa	2%	0%	0%
Scolecodonts	3%	5%	4%

characterized by low acritarch diversity and dominated by sphaeromorph acritarchs, whereas the offshore shelf assemblages contain the most diverse acritarch and prasinophyte taxa. The near-shore low diversity acritarch assemblage with abundant sphaeromorphs described by Dorning (1981) is comparable to that recovered from the back-barrier depositional facies of the Ferriter's Cove Formation. The more diverse offshore assemblage of acritarchs (Dorning, 1981) is comparable to the sub-barrier offshore environment of the Ferriter's Cove Formation. Dorning and Bell (1987) also reported very high percentages (93–99%) of sphaeromorph acritarchs (*Leiosphaeridia*) in the reef limestones of the Wenlock shallow shelf carbonate environment. They suggested that the large numbers of *Leiosphaeridia* in the reef environment were produced by the benthonic algae that colonised the reefs and associated shallow-water substrates. A similar high percentage of *Leiosphaeridia* is recorded here from the patch reefs of the restricted and marginal marine environment of the back-barrier lagoons of the Ferriter's Cove Formation. However, Dorning and Bell's suggestion that the sphaeromorph *Leiosphaeridia* was the cyst stage of a benthonic alga is highly speculative, because its specific biological affinity and palaeoecology are still unresolved (Le Hérisse *et al.*, 2009). Sphaeromorph dominated assemblages are generally regarded as characteristic of either near-shore or deep marine environments, at the opposite ends of the marine environmental spectrum (Molyneux *et al.*, 1996). It may be that sphaeromorph acritarchs, such as *Leiosphaeridia*, are generally more abundant in stressed environments when other phytoplankton are absent or severely reduced in number.

Beck and Strother (1996) documented the distribution of acritarchs in a very thick (1.2 km) mudstone-siltstone succession at Arisaig, Nova Scotia, Canada. Most of this succession was deposited in proximal shelf marine environments. Throughout the succession they found that the diverse acritarch assemblages were "well-mixed and do not record events in ecological time" (Beck and Strother, 1996, p. 321). They considered that this was probably due to storm reworking and extensive bioturbation. A similar situation is recorded here in the shoreface and offshore assemblages in the sub-barrier marine

environment of the Ferriter's Cove Formation, where both storm influence and bioturbation is common.

Stricanne *et al.* (2004) made a detailed quantitative study of the acritarch and prasinophyte distribution along an inshore–offshore transect in the Gorstian (lower Ludlow) of Gotland. Their analysis revealed four important palynomorph distribution trends: (1) an increase in process-bearing acritarchs from the inshore (37%) to the distal offshore shelf (72%); (2) an increase in genera and species diversity of the process-bearing acritarchs from the inshore (4 genera, 12 species) to the distal offshore shelf (12 genera, 17 species), particularly acritarchs that have longer and more ramified processes e.g., *Evittia* (= *Diexallophasis*), *Multiplicisphaeridium* and *Percultisphaera*; (3) a decrease in sphaeromorphic acritarchs from inshore (57%) to the distal offshore shelf (19%); (4) *Micrhystridium* morphotypes with shorter and simple processes characterizing the inshore facies, e.g., *M. nannacanthum* and *M. parinconspicuum*, whereas, *Micrhystridium* morphotypes with longer and branched processes e.g., *M. stellatum* and *M. imitatum* are more common in the distal offshore shelf. All of the palynomorph distribution trends identified by Stricanne *et al.* (2004) in the Gorstian of Gotland have been observed in the Wenlock offshore to tidal-flat regressive cycles of the Ferriter's Cove Formation.

CONCLUSIONS

1. This study records the first palynological data from the Silurian of the Dunquin Inlier.
2. The acritarch assemblage recorded from the Coosglass Slate Formation is assigned a Llandovery to early Wenlock age. This is first biostratigraphic data from the Coosglass Slate Formation and confirms that it is the oldest formation in the Silurian succession of the Dunquin Inlier.
3. The lithofacies and the acritarch biofacies of the Coosglass Slate Formation are considered to represent a low energy offshore muddy shelf palaeoenvironment.
4. Acritarchs and cryptospores recorded from the Ferriter's Cove Formation are assigned a Wenlock (Homeric) age,

which is consistent with the previous age assignment based on macrofossils.

5. The integration of palynological and sedimentological data from the offshore to tidal-flat regressive cycles of the Ferriter's Cove Formation reveal three consistent palynomorph distribution trends: (1) offshore and shoreface facies contain the most diverse palynological assemblages in which acritarchs with long and ramified processes dominate; (2) the inshore

tidal-flat facies are characterized by terrestrially-derived palynomorphs, particularly cryptospores, together with a restricted acritarch assemblage of mainly micrhystrids and veryhachids with small, simple processes; (3) the back-barrier lagoonal facies are dominated by the sphaeromorph acritarch *Leiosphaeridia*. The very high abundance *Leiosphaeridia* in this facies is possibly the result of a stressed environment.

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