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The Cosheston Group (Lower Old Red Sandstone) in southwest Wales: age, correlation and palaeobotanical significance

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Abstract – Upper Silurian–Lower Devonian ‘Lower Old Red Sandstone’ facies deposits cropping out in southwest Wales are poorly age-constrained and difficult to correlate. Spore assemblages have been recovered from sequences of these deposits belonging to the lower part of the Cosheston Group. The spore assemblages are equated with the *breconensis–zavallatus* and *polygonalis–emsiensis* Spore Assemblage Biozones and indicate an early Devonian age (late Gedinnian (late Lochkovian)–Siegenian (Pragian)). The new biostratigraphical data enable correlation of the lower part of the Cosheston Group with the Senni Beds from the main outcrop of the Lower Devonian in South Wales and the Welsh Borderland. In addition, the new age data and stratigraphical correlation place important plant megafossil assemblages from the Cosheston Group and Senni Beds in a more secure stratigraphical framework, thus facilitating comparisons with other Lower Devonian plant megafossil assemblages and enhancing palaeobotanical understanding. Evidence from palynofacies analysis supports sedimentological interpretations which suggest that the ‘Lower Old Red Sandstone’ facies deposits belonging to the Cosheston Group accumulated in a continental fluviatile environment.

1. Introduction

The ‘Lower Old Red Sandstone’ deposits of southwest Wales comprise a thick sequence of predominantly continental fluviatile deposits that accumulated in the Anglo-Welsh Basin during the Caledonian orogeny (Figs 1, 2). Age determination and stratigraphic correlation of these deposits has traditionally been hampered by the paucity of biostratigraphically useful fossils, the structural complexity of the area and difficulties of lithostratigraphical correlation. The latter is problematic because ‘Old Red Sandstone’ facies deposits commonly exhibit extensive lateral and vertical facies variation. This report describes spore assemblages recovered from part of the ‘Lower Old Red Sandstone’ sequence of southwest Wales (the lower part of the Cosheston Group) which permit accurate age determinations and stratigraphical correlation with the main outcrop of South Wales and the Welsh Borderland. Furthermore, the new biostratigraphical information provides age constraints for important plant megafossil assemblages recovered from the Cosheston Group and its correlatives. Such integrated palynological and palaeobotanical analyses of plant microfossil and megafossil assemblages provide important insights into the nature of early Devonian terrestrial vegetation.

2. Geological setting

The ‘Lower Old Red Sandstone’ deposits of the Anglo-Welsh Basin represent a post-orogenic molasse sequence, comprising a thick succession of predominantly continental fluviatile deposits, which accumulated during the Caledonian orogeny. The environment of deposition is interpreted as an extensive alluvial plain traversed by streams and rivers flowing out of the Caledonian uplands to the north and draining into the Rheic Ocean to the south (Allen, 1979, 1985; Bluck, Cope & Scrutton, 1992). The ‘Lower Old Red Sandstone’ deposits in southwest Wales are separated from the main outcrop by the Benton Fault, and are divided into two zones of contrasting sequence by the Ritec Fault (see Powell, 1987, and references therein). These deposits are considered to have accumulated in an area of complex relief with syn-depositional faulting (Allen & Williams, 1978; Allen, 1985; Powell, 1987). An outcrop map and stratigraphical successions of the ‘Lower Old Red Sandstone’ in the Anglo-Welsh Basin are illustrated in Figures 1 and 2 respectively.

South of the Ritec Fault, the ‘Lower Old Red Sandstone’ deposits are up to 1500 m in thickness (Dixon, 1921, 1933*a*, 1933*b*; King, 1934; Owen *et al*. 1971; Williams, 1971; Williams, Allen & Marshall, 1982) (Fig. 2). They are divided into the Milford Haven Group (443–995 m) which is unconformably overlain by the Ridgeway Conglomerate Formation (0–427 m). The Milford Haven Group south of the Ritec Fault has in places been dated using spores (Richardson & Lister, 1969) and fish (White, 1938, 1946, 1950) (Fig. 2). The Ridgeway Conglomerate, however, is unfossiliferous. North of the Ritec Fault, the ‘Lower Old Red Sandstone’ deposits cropping out between the Ritec and Benton faults are up to 4000 m in thickness (Strahan *et al*. 1914; Cantrill *et al*. 1916; Allen & Williams, 1978; Allen,

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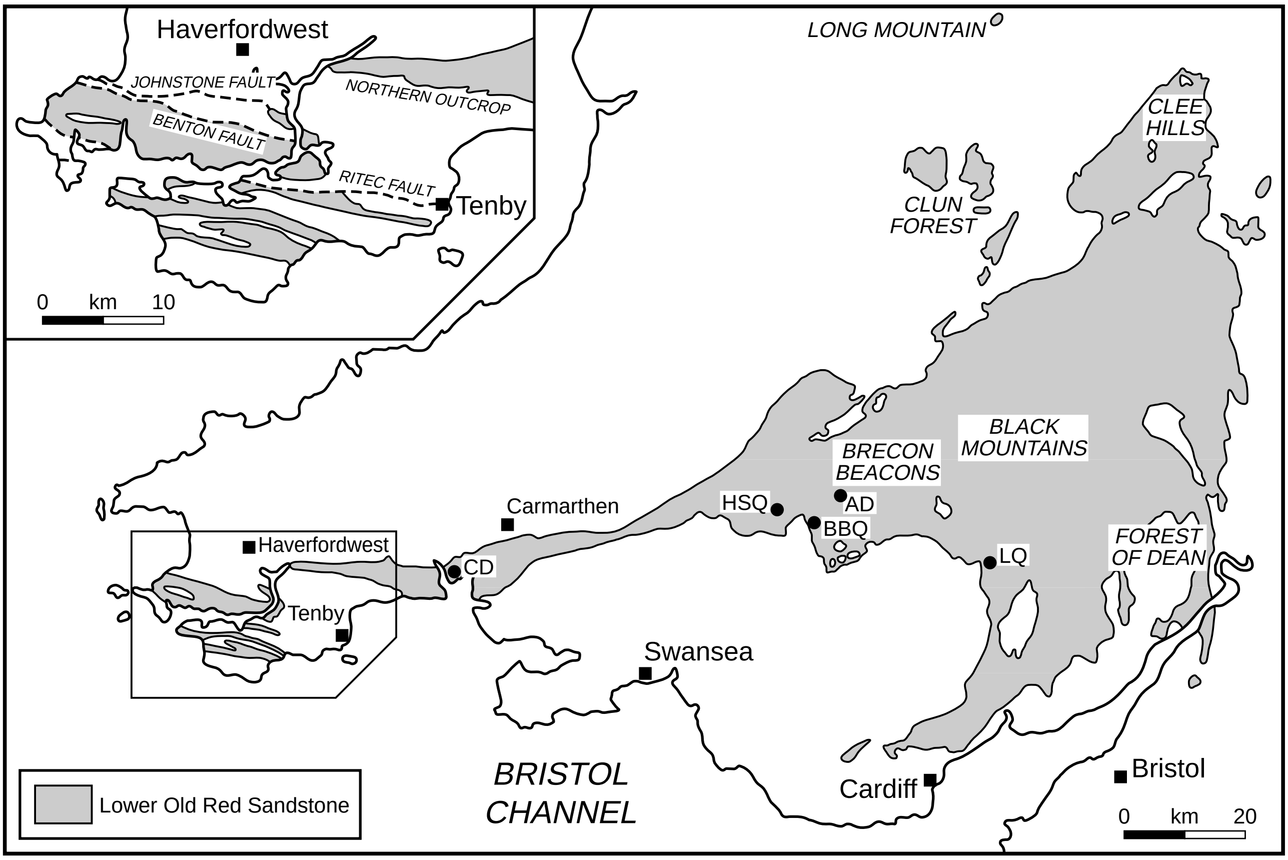

Figure 1. Outcrop of 'Lower Old Red Sandstone' deposits in South Wales and the Welsh Borderland. The inset is an enlargement of the area of southwest Wales. The location of plant megafossil localities in the Senni Beds is indicated (AD = Allt Ddu; BBQ = Brecon Beacons (Storey Arms) Quarry; CD = Craig Ddu; HSQ = Heol Senni Quarry; LQ = Llanover Quarry).

Thomas & Williams, 1982) (Fig. 2). They are divided into the Milford Haven Group (1850–2637 m) which is conformably overlain by the Cosheston Group (1505–1800 m). The Milford Haven Group north of the Ritec Fault has in places been dated using invertebrates, fish and plant remains (Allen & Williams, 1978) (Fig. 2). Plant remains are present in the Cosheston Group but are of limited biostratigraphical value (Strachan *et al.* 1914; Cantrill *et al.* 1916; R. Thomas, unpub. Ph.D. thesis, Univ. Bristol, 1978; P. Kenrick, unpub. Ph.D. thesis, Univ. Wales, 1988).

The Townsend Tuff Bed is an important marker horizon which enables 'Lower Old Red Sandstone' sequences either side of the Ritec Fault to be correlated and tied in with the main outcrop of the Anglo-Welsh Basin (Allen & Williams, 1981, 1982). The Townsend Tuff Bed, which comprises lithologically distinctive and laterally extensive air-fall tuffs, has also been proposed as the local base of the Devonian System in the Anglo-Welsh Basin. However, above the Townsend Tuff Bed, age determination and stratigraphical correlation are problematic due to the paucity of biostratigraphically useful fossils, the complex tectonics of the region and the difficulties of lithological correlation due to extensive lateral and vertical facies variation.

The Cosheston Group is the uppermost group in the 'Lower Old Red Sandstone' sequence south of the Ritec Fault. It conformably succeeds the Milford Haven Group and is unconformably overlain by the 'Upper Old Red Sandstone' Skrinkle Sandstone Group. The Cosheston Group is 1505–1800 m in thickness and consists of green intraformational conglomerates, green sandstones with subordinate red sandstones, and green or red siltstones, arranged in fining-upward sequences. The upper part of the group tends to be coarser grained and red brown and contains breccias and conglomerates composed of a variety of lithologies including intrusive and extrusive igneous rocks, metamorphic rocks and various sandstones. Interestingly, Thomas (R. Thomas, unpub. Ph.D. thesis, Univ. Bristol, 1978) noted that palaeocurrent direction in the Cosheston Group appears to be predominantly from the west. The Cosheston Group has been divided into five formations (R. Thomas, unpub. Ph.D. thesis, Univ. Bristol, 1978; Thomas *in* Friend & Williams, 1978; Allen, Thomas & Williams, 1982) (Figs 2, 3).

3. Cosheston Group spore assemblages

3.a. Methods

Samples were collected from throughout the Cosheston Group sequence and were palynologically processed using standard HCl/HF acid maceration techniques. The

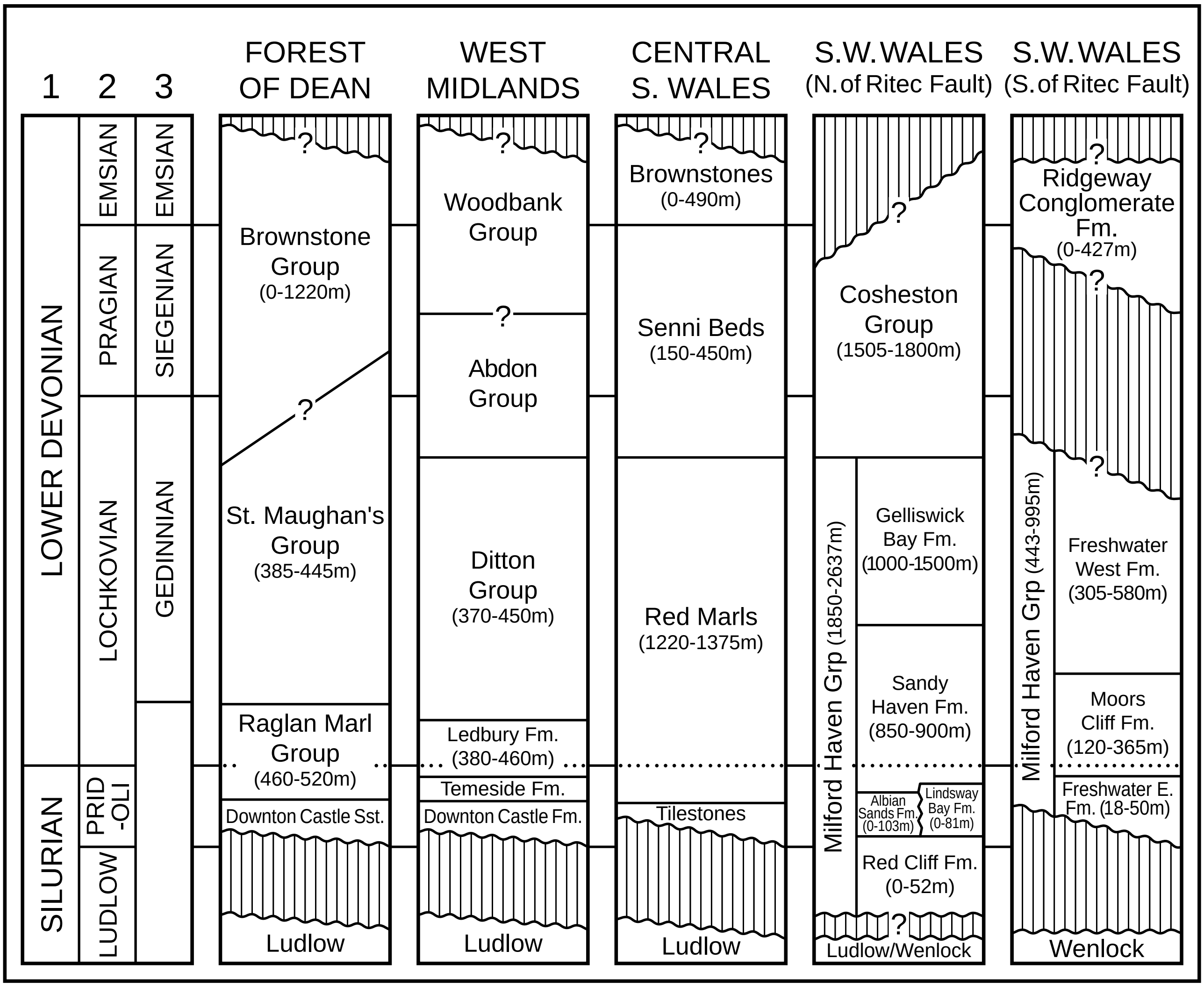

Figure 2. Correlation chart for 'Lower Old Red Sandstone' sequences in the Anglo-Welsh Basin (based on Friend & Williams, 1978, with additional information from Allen, 1979, 1985, and Allen & Williams, 1982). Column 1 = Series; 2 = Standard Epoch/Stages; 3 = Ardennes-Rhenish Stages. The dotted line at the Silurian/Devonian boundary represents the Townsend Tuff. Age correlations are based on the limited available biostratigraphical information derived from studies of vertebrate remains and dispersed spores (see text).

organic residues were oxidized for ¾–3 hours in saturated Schulze's solution in order to clear them for analysis using light microscopy. Productive samples were confined to the Llanstadwell, Burton Cliff, Mill Bay and lowermost Lawrenny Cliff formations (see Fig. 3, Table 1). Spore identifications were based on detailed logging of residues derived from 29 samples (13 localities), which incorporated the maximum stratigraphical coverage and the best preserved samples (see Table 2). All slides are stored in the Department of Geology of the National Museum of Wales, Cardiff.

3.b. Description of the spore assemblages

Eighty-eight spore taxa were recognized in the Cosheston Group spore preparations (R. Thomas, unpub. Ph.D. thesis, Univ. Bristol, 1978). The distribution and abundances of important taxa/morphotypes are outlined in Tables 2 and 3 respectively. The spores are distributed in two distinctive spore assemblages: an 'older' assemblage comprising the spore preparations from the Llanstadwell Formation and a 'younger' assemblage comprising the spore preparations from the Burton Cliff, Mill Bay and lowermost Lawrenny Cliff formations. In the following account the quoted percentages are derived from counts (see Table 3) and are either expressed as ranges or in terms of minimum(mean) maximum values.

Both the 'older' and 'younger' spore assemblages are dominated by smooth-walled miospores (between 60 and 76 %) that are either retusoid, crassitate or patinate and can be accommodated in the genera *Retusotriletes*, *Ambitisporites* and *Archaeozonotriletes*. Some of the species of *Retusotriletes* have proximal thickenings associated with the trilete marks (e.g. Fig. 4f, g). Apiculate retusoid spores are common in the 'older' assemblage

Table 1. Locality details for productive palynological samples (see Fig. 3)

Samples	Formation	Grid reference	Location
NN3 & 15	Llanstadwell Fm.	SM934059	Siltstones at the base of the Llanstadwell Fm. in the section exposed in the railway cutting at Newton Noyes.
WPW1	Llanstadwell Fm.	SM96810583	Siltstone *c.* 1 m above the base of the Llanstadwell Fm. exposed in the section on the western shore of Westfield Pill.
WP4 & 25	Llanstadwell Fm.	*c.* SM937043	Siltstones exposed in the coastal section west of Wear Point.
MB5, 8, 11 & RT25	Llanstadwell Fm.	SM95650558	Siltstones 7, 27 and 43 m above the base of the section exposed in Muscle Bridge Quarry. The quarry is located beside the B4325 road *c.* 250 m southeast of Muscle Bridge Hamlet.
HPE1 & 24	Llanstadwell Fm.	SM972043	Siltstone 59 m below the junction between the Llanstadwell and Burton Cliff formations exposed in the Hobbs Point East coastal section.
HPE43, 44 & 47	Burton Cliff Fm.	SM970042	Siltstone 6 m above the junction between the Llanstadwell and Burton Cliff formations exposed in the Hobbs Point East coastal section.
BC2 & 8	Burton Cliff Fm.	*c.* SM988051	Siltstones exposed in the coastal section at Burton Cliff.
CBP4	Mill Bay Fm.	*c.* SM974046	Siltstones exposed in the coastal section exposed near Cheddar Bridge Pier.
CPW4 & 10	Mill Bay Fm.	*c.* SM983042	Siltstones exposed in the coastal section on the west shore of Cosheston Pill.
BC24	Mill Bay Fm.	*c.* SM990052	Siltstones exposed in the coastal section at Burton Cliff.
MBW17, 45, 69, 84 & 121	Mill Bay Fm.	*c.* SN000050	Siltstones exposed in the Mill Bay West coastal section.
MBE9, 22 & 35	Mill Bay Fm.	*c.* SN005051	Siltstones exposed in the Mill Bay East coastal section.
MBE46	Lawrenny Cliff Fm.	*c.* SN007057	Siltstones exposed in the Mill Bay East coastal section.

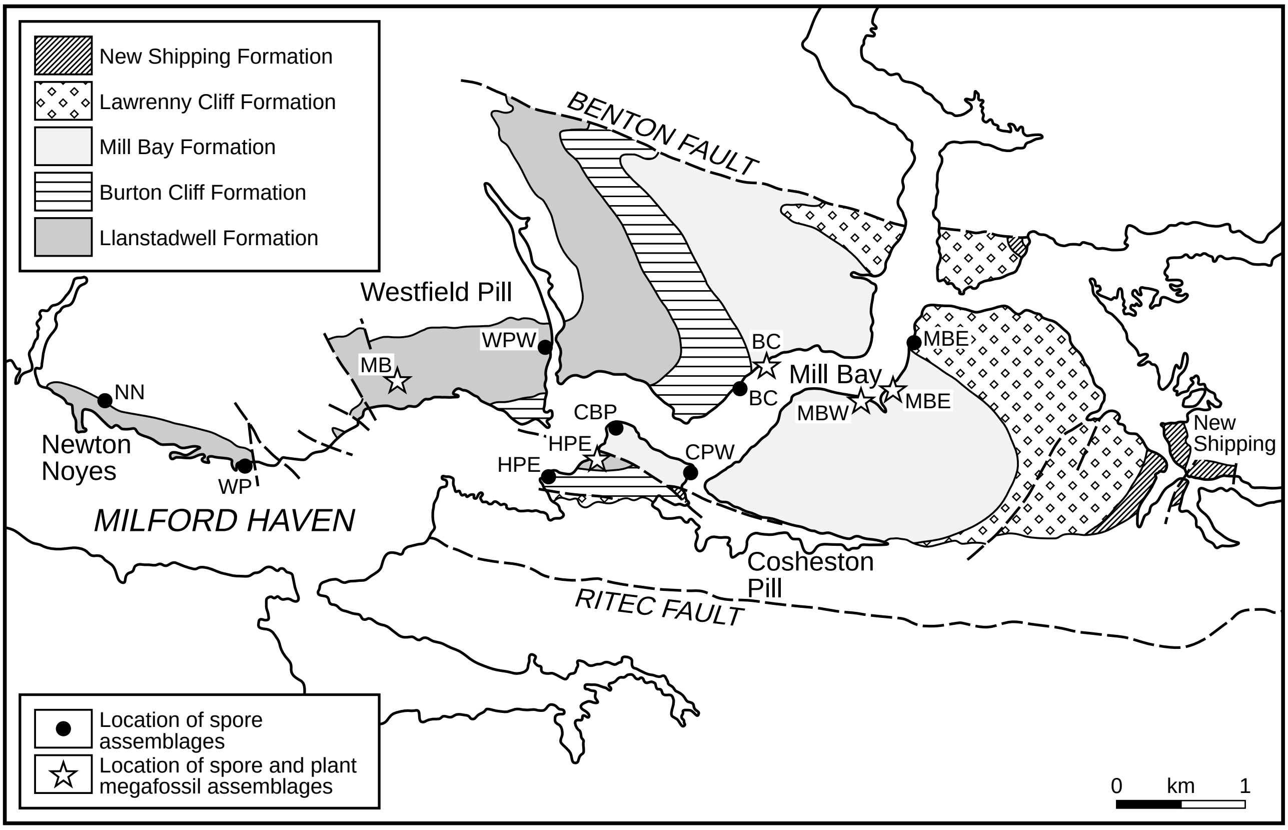

Figure 3. Geological map of the Cosheston Group outcrop in southwest Wales. Location of spore and plant megafossil assemblages indicated (see Tables 1 and 4): BC = Burton Cliff; CBP = Cheddar Bridge Pier; CPW = Cosheston Pill (western shore); HPE = Hobbs Point East; MB = Muscle Bridge Quarry; MBE = Mill Bay East; MBW = Mill Bay West; NN = Newton Noyes; WP = Wear Point; WPW = Westfield Pill (western shore).

Table 2. Occurrence and relative abundance of spore taxa reported from the Cosheston Group

	Spore assemblage, formation and locality (number of samples in parentheses												
	"Older" assemblage					"Younger" assemblage							
	Llanstadwell Fm.					Burton Cliff Fm.		Mill Bay Fm.					L.C.Fm.
Taxa (relative abundance in parentheses)	NN(2)	WPW(1)	WP(2)	MB(4)	HPE(2)	HPE(3)	BC(2)	CBP(1)	CPW	BC(1)	MBW(5)	MBE(3)	MBE(1)
Retusotriletes spp. (C)	X	X	X	X	X	X	X	X	X	X	X	X	X
Retusotriletes spp. with proximal thickenings (M)	X	X	X	X	X	X	X	X	X	X	X	X	X
Apiculatasporites cf. *perpusillus* (M)	X	X	X	X	X	X	X	X	X	X	X	X	X
Apiculiretusispora spp. (C)	X	X	X	X	X	X	X	X	X	X	X	X	X
A. arenorugosa (M)	–	–	–	–	–	–	X	X	X	–	X	X	–
A. cf. *brandtii* (C)	–	?	–	?	?	X	X	X	X	X	X	X	?
A. plicata (C)	X	X	X	X	X	X	X	X	X	X	X	X	?
A. sp.1 (C)	–	–	X	?	X	X	X	X	X	X	X	X	X
A. sp.2 (C)	X	X	X	X	?	?	X	–	X	?	?	X	–
Dibolisporites spp. (M)	X	–	–	–	?	X	X	X	X	X	X	X	?
*D.*cf. *eifeliensis* (R)	X	–	–	–	–	–	?	–	X	?	?	–	–
D. sp.1 (C)	–	–	–	–	?	X	X	X	X	X	X	X	?
D. sp.2 (R)	–	–	–	–	–	X	X	–	X	–	?	?	–
D. sp. 3 (R)	–	–	–	–	–	–	–	?	X	?	X	?	?
Verrucosisporites polygonalis? (R)	X	X	–	–	–	–	–	–	–	?	?	–	–
Brochotriletes spp.(M)	X	–	–	X	?	X	–	–	X	–	X	?	–
B. sp.1 (M)	X	–	–	X	?	X	–	–	X	–	X	?	–
Dictyotriletes spp. (R)	X	?	–	X	–	X	X	?	X	?	X	X	X
D. sp.1 (R)	–	–	–	–	–	X	X	–	X	?	X	?	–
Ambitisporites spp. (C)	X	X	X	X	X	X	X	X	X	?	X	X	X
Aneurospora spp. (M)	X	X	X	X	X	X	X	X	X	?	X	X	X
Aneurospora sp.1 (C)	X	X	X	X	X	X	X	X	X	?	X	X	X
Streelispora newportensis (C)	X	X	X	X	X	X	–	X	X	?	X	X	X
Synorisporites spp. (R)	X	X	X	X	X	–	–	–	–	–	–	–	–
Emphanisporites cf. *decoratus* (R)	X	–	X	X	–	–	X	–	–	–	–	–	–
E. micrornatus (R)	X	X	?	X	X	X	X	–	X	X	X	?	–
E. neglectus? (C)	X	X	X	X	X	X	X	X	X	–	X	X	–
E. obscurus (R)	X	?	X	X	X	X	X	X	X	–	X	X	X
E. rotatus (C)	X	X	X	X	X	X	X	X	X	X	X	X	X
E. zavallatus (C)	X	X	X	X	X	–	X	–	–	–	X	–	?
Amicosporites streelii (R)	–	?	X	–	–	–	–	–	X	–	–	–	–
Iberoespora sp. (M)	X	X	X	X	X	X	X	X	–	?	X	X	X
Archaeozonotriletes chulus var. *chulus* (C)	X	X	X	X	X	X	X	X	X	X	X	X	X
Archaeozonotriletes chulus var. *nanus* (C)	X	X	X	X	X	X	X	X	X	X	X	X	?
Chelinospora spp. (R)	–	–	–	–	–	–	–	–	X	–	–	–	–
Cymbosporites spp. (R)	X	X	X	–	–	–	–	–	?	–	–	X	–
Clivosispora verrucata (C)	X	X	X	X	X	X	X	X	X	X	X	X	X
Camptozonotriletes cf. *aliquantus* (R)	–	–	–	–	–	–	–	–	X	–	–	–	–
cf. *Camptozonotriletes caperatus* (R)	–	–	X	–	–	–	–	–	X	–	X	?	?
Breconisporites breconensis (C)	X	X	X	X	X	X	X	X	X	X	X	X	X

Based on analysis of 29 productive samples from 13 localities (see Table 1). Regarding stratigraphic units: L.C.Fm. = Lawrenny Cliff Formation. Regarding localities (see Table 1): NN = Newton Noyes, WPW = Westfield Pill (west shore), WP = Wear Point, MB = Muscle Bridge Quarry, HPE = Hobbs Point East, BC = Burton Cliff, CBP = Cheddar Bridge Pier, CPW = Cosheston Pill (West Shore), BC = Burton Cliff, MBW = Mill Bay West, MBE = Mill Bay East. Regarding relative abundance of taxa: R = rarely encountered; M = encountered relatively frequently; C = commonly encountered (see Table 3).

Table 3. Abundance (% of total assemblage) of miospore taxa/morphotypes in selected samples

	Assemblage, formation and samples																
	‘Older’ assemblage					‘Younger’ assemblage											
	LFm					BCFm					MBFm						LCFm
Taxon/morphotype	NN3	WPW1	MB8	WP25	HPE24	HPE43	HPE44	HPE47	BC2	BC8	CPW10	MBW17	MBW45	MBW84	MBE9	MBE35	MBE46
Retusoid laevigate	13	20	22	30	38	29	34	30	29	42	38	19	31	31	37	41	36
Crassitate laevigate	18	18	18	18	17	19	20	17	25	17	20	19	20	23	28	20	29
Patinate laevigate	30	30	28	23	14	16	10	13	11	11	14	25	12	11	4	8	11
Apiculiretusispora spp.	10	7	7	8	9	22	24	23	26	22	18	20	27	23	21	24	11
Dibolisporites spp.	1	1	–	–	–	1	6	2	–	3	–	4	3	–	–	1	1
Aneurospora/*Streelispora* spp.	6	4	2	4	4	1	–	4	2	–	1	–	–	3	2	1	1
Emphanisporites spp.	3	5	1	5	4	2	–	3	1	1	1	–	2	1	2	–	2
Amicosporites/*Iberoespora* spp.	2	2	2	–	2	2	–	1	1	1	–	1	–	–	–	1	1
Brochotriletes spp.	1	–	1	–	–	–	–	1	–	–	1	–	–	1	–	–	–
Clivosispora spp.	1	2	1	1	–	–	1	1	–	–	–	–	1	2	–	1	1
Cymbosporites spp.	3	2	1	1	2	1	2	1	1	–	1	3	–	–	–	–	–
Chelinospora spp.	–	–	–	1	–	–	–	–	1	–	1	–	–	–	–	–	–
Zonate (exc. *B. breconesis*)	1	3	–	1	–	2	–	1	1	1	2	1	2	1	1	1	2
Breconisporites breconensis	12	6	17	8	10	5	3	3	2	2	3	8	2	4	5	2	5

Regarding formations: LFm = Llanstadwell Formation; BCFm = Burton Cliff Formation; MBFm = Mill Bay Formation; LCFm = Lawrenny Cliff Formation. See Table 1 for sample locations.

(7(8)10 %) but abundant in the 'younger' assemblage (11(22)27 %), and belong to the genera *Apiculiretusispora* and *Dibolisporites*, and include the taxa *A. arenorugosa* McGregor, 1973; *A.* cf. *brandtii* Streel, 1964; *A. plicata* (Allen) Streel, 1967 and *D.* cf. *eifeliensis* (Lanninger) McGregor, 1973. There are a number of ornamented crassitate spores which belong to *Aneurospora*, *Streelispora* and *Synorisporites*, and include *Streelispora newportensis* (Chaloner & Streel) Richardson & Lister, 1969, but in counts these never comprise more than 6 % of the total spores. Laevigate patinate spores (*Archaeozonotriletes chulus*) are common, but ornamented patinate spores are always rare, although *Chelinospora* and *Cymbosporites* are represented. Spores belonging to *Emphanisporites* comprise up to 5 % of the total spores and include *E.* cf. *decoratus* Allen, 1965; *E. micrornatus* Richardson & Lister, 1969; *E. neglectus*? Vigran, 1964; *E. obscurus* McGregor, 1961; *E. rotatus* McGregor, 1961 emend. McGregor, 1973, and the biostratigraphically important species *E. zavallatus* Richardson *et al*. 1982 (Fig. 5e, i). Other ornamented spores include *Brochotriletes* spp.; *Dictyotriletes* spp.; *Verrucosisporites polygonalis?* Lanninger, 1968; *Amicosporites streelii* Steemans, 1989; *Iberoespora* sp. and *Clivosispora verrucata* McGregor, 1973, but these taxa are always rare. Zonate spores such as *Camptozonotriletes* cf. *aliquantus* Allen, 1965 and cf. *C. caperatus* McGregor, 1973 are rare, but the biostratigraphically important bizonate species *Breconisporites breconensis* Richardson *et al*. 1982 is abundant in the 'older' assemblage (6(11)17 %), although less common in the 'younger' assemblage (2(4)8 %).

The 'older' and 'younger' spore assemblages differ in terms of taxon/morphotype composition and abundance. In terms of composition the 'younger' assemblage is more diverse and contains a number of taxa not present in the 'older' assemblage, namely: *Apiculiretusispora arenorugosa*, *A.* cf. *brandtii*, *Dibolisporites* spp.1–3, and cf. *Camptozonotriletes aliquantus*. In terms of overall composition, the older assemblage is dominated by laevigate spores, but *Breconisporites breconensis* is particularly abundant, and species of *Emphanisporites* with fine proximal ribbing, small *Apiculiretusispora* spp. *Streelispora newportensis* and *Emphanisporites zavallatus* are relatively common. The 'younger' assemblage differs because apiculate spores, including those with biform sculpture (*Dibolisporites* spp.), are far more abundant. Common apiculate spores include *Apiculiretusispora arenorugosa*, *A.* cf. *brandtii*, *A. plicata*, *A.* sp.1 and *A.* sp.2. Some of these taxa are present, but far less abundant, in the 'older' assemblage. *Dibolisporites* is extremely rare in the 'older' assemblage but is commonly present in the 'younger' assemblage where it is represented by *Dibolisporites* cf. *eifeliensis* and *Dibolisporites* spp.1–3.

3.c. Spore biostratigraphy and age determination

Spore zonation schemes for the Lower Devonian have been proposed by Richardson & McGregor (1986) and Streel *et al*. (1987) (Fig. 6). The 'older' Cosheston Group assemblage is assigned to the *breconensis–zavallatus* Spore Assemblage Biozone of Richardson & McGregor (1986). It contains both of the nominal species and, in terms of taxon composition and spore morphotype abundance, is very similar to previously described spore assemblages attributed to this Spore Assemblage Biozone, particularly those described from the Brecon Beacons and Ardennes-Rhenish region (Richardson *et al*. 1982; Richardson & McGregor, 1986; Steemans, 1989). The 'younger' Cosheston Group assemblage is assigned to the *polygonalis–emsiensis* Spore Assemblage Biozone of Richardson & McGregor (1986). Neither of the two nominal species for the zone (*Verrucosisporites polygonalis* and *Dictyotriletes emsiensis*) are present. However, Richardson & McGregor (1986) note that these taxa are also absent from spore assemblages belonging with the *polygonalis–emsiensis* Spore Assemblage Biozone from the Brecon Beacons of South Wales. In terms of taxon composition and spore morphotype abundance the 'younger' Cosheston Group assemblage exhibits many of the characteristics typical of spore assemblages assigned to the *polygonalis–emsiensis* Spore Assemblage Biozone, for example, the occurrence and proliferation of *Dibolisporites*, the paucity of spores with proximal interradial papillae, and the abundance and diversity of *Brochotriletes*, *Dictyotriletes*, coarsely sculptured *Emphanisporites* and, most notably, *Apiculiretusispora*. Furthermore, in addition to the nominal species, Richardson & McGregor considered thirteen other species characteristic of the *polygonalis–emsiensis* zone. Identical, or closely similar, forms of a number of these taxa are present in the 'younger' Cosheston Group assemblage, namely: *A. arenorugosa*, *A. cf. brandtii*, *A. plicata*, *B. breconensis*, cf. *C. caperatus*, *C. verrucata* and *E.* cf. *decoratus*. In the scheme of Richardson & McGregor (1986) the 'older' Cosheston Group assemblage is excluded from the preceding *micrornatus–newportensis* Spore Assemblage Biozone because of the occurrence of *B. breconensis* and *E. zavallatus*. However, certain taxa characteristic of the *micrornatus–newportensis* Spore Assemblage Biozone are present in the 'older' Cosheston Group assemblage and it is possible that some of these spores may have been reworked. The 'younger' Cosheston Group assemblage is excluded from the succeeding *annulatus–sextantii* Spore Assemblage Biozone because of: (1) the absence of the nominal species (*Emphanisporites annulatus* and *Camarazonotriletes sextantii*) and other species characteristic of this zone; (2) differences in general morphological characteristics.

The Cosheston Group spore assemblages can be placed within the BZ and PoW Oppel Zones of Streel *et al*. (1987), which are more or less identical to the *breconensis–zavallatus* and *polygonalis–emsiensis* Spore Assemblage Biozones of Richardson & McGregor (1986) (Fig. 6). A minor difference between the two zonation schemes is that *Dibolisporites wetteldorfensis* replaces *Dictyotriletes emsiensis* as a nominal species for the PoW

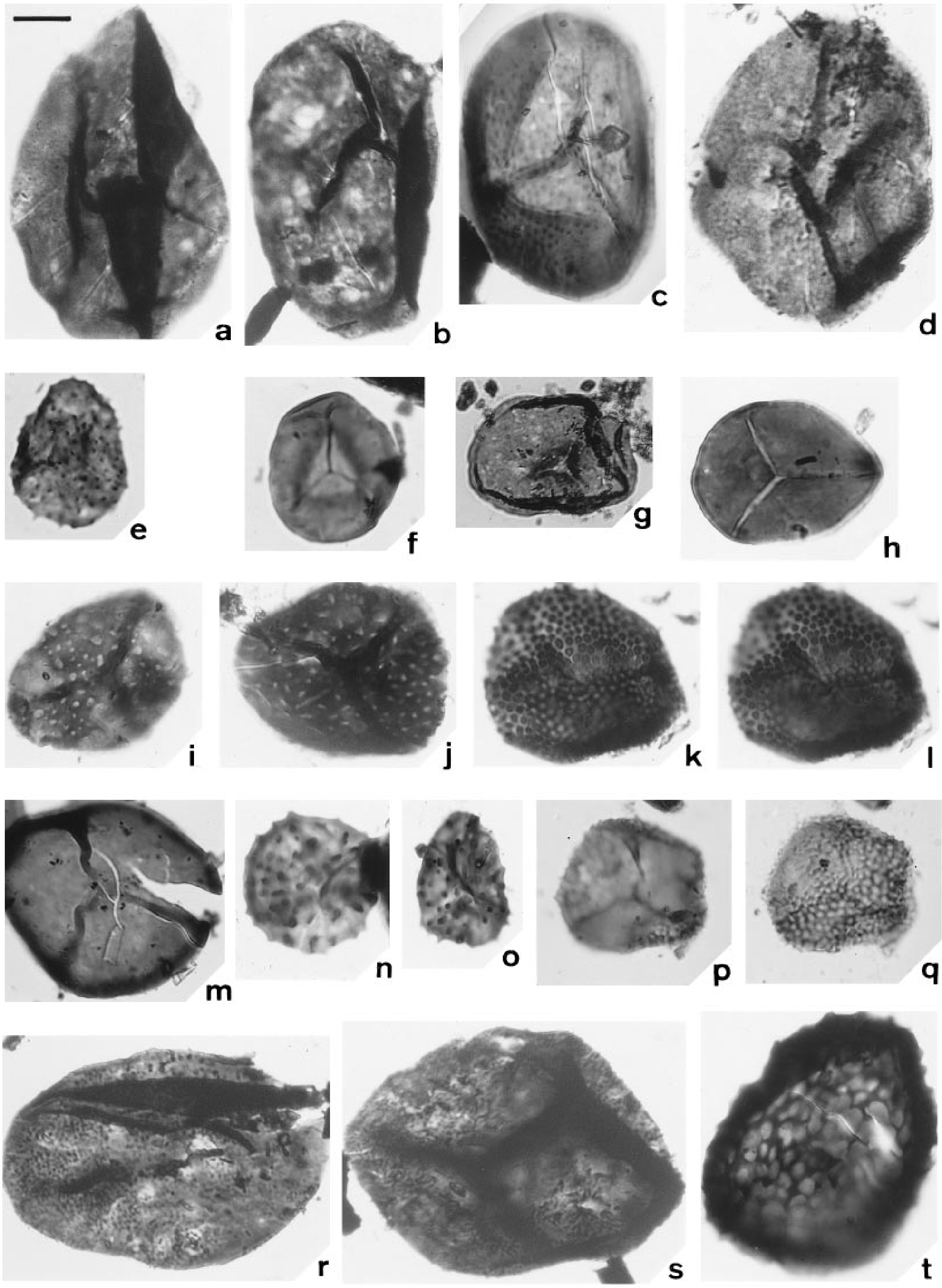

Figure 4. Spores from the Cosheston Group (scale bar in top left hand corner equals 10 µm, except in (a), (b) and (s) where it equals 16 µm, (g) where it equals 20 µm and (r) where it equals 13 µm). E.F. No. = England Finder Number. (a)*Apiculiretusispora arenorugosa* McGregor, 1973. Sample CPW4, Slide NMW97.22G.3, E.F. No. N36/2, Mill Bay Formation, Cosheston Pill (west shore); (b) *Apiculiretusispora arenorugosa* McGregor, 1973. Sample CPW4, Slide NMW97.22G.2, E.F. No. K54/4, Mill Bay Formation, Cosheston Pill (west shore); (c) *Apiculiretusispora* sp.1. Sample CPW4, Slide NMW97.22G.2, E.F. No. M51, Mill Bay Formation, Cosheston Pill (west shore); (d) *Dibolisporites* sp.2. Sample CPW4, Slide NMW97.22G.2, E.F. No. Q33/3, Mill Bay Formation, Cosheston Pill (west shore); (e) *Apiculatasporites* cf. *perpusillus* (Naumova) McGregor, 1973. Sample NN3, Slide NMW97.22G.8,

Oppel Zone in the scheme of Streel *et al*. (1987). One of the reasons for this substitution is that the first appearance of *V. polygonalis* and *D. emsiensis* is variable: *V. polygonalis* occurs earlier than *D. emsiensis* in Gaspé, Canada (McGregor, 1973), but later than *D. emsiensis* in Ontario, Canada (McGregor & Camfield, 1976) and the Ardennes-Rhenish region (Steemans, 1989; Richardson & McGregor, 1986). In the scheme of Streel *et al*. (1987) the Oppel zones are divided into interval zones based on the first appearance of selected taxa. None of the relevant taxa are present in the Cosheston Group spore assemblages so designation to interval zones is difficult. However, *Amicosporites streelii* which occurs throughout the Cosheston Group spore assemblages is not known above the Pa(α) interval zone (Steemans, 1989). This suggests that the Pa(β) and Su interval zones, the uppermost interval zones of the PoW Oppel Zone, may not be represented in the Cosheston Group spore-bearing strata (assuming no reworking of *A. streelii* in the Cosheston Group).

There are considerable difficulties involved with correlation between Upper Silurian–Lower Devonian sequences in Britain, the Ardennes-Rhenish region and the type area of Bohemia because the deposits are represented by different facies and therefore contain different groups of fossils (see Richardson, Rasul & Al-Ameri, 1981; Richardson, 1984; Richardson, Ford & Parker, 1984; Steemans, 1989). The British sequences can be correlated with those in the Ardennes-Rhenish region using spore biostratigraphy (e.g. Richardson *et al*. 1982). However, the Ardennes-Rhenish sequences have to be correlated with the type Bohemian sequence via cross-correlation using different fossil groups (e.g. spores, chitinozoans, fish, invertebrates) between intermediary sequences in Brittany and Podolia. Thus a basic intercorrelation between the four areas is achieved (e.g. Richardson, Rasul & Al-Ameri, 1981; Streel *et al*. 1987; Steemans, 1989), although precise correlation between the type Bohemian stages (Lochkovian and Pragian) and those used in the Ardennes-Rhenish region (Gedinnian and Siegenian) has yet to be accomplished. Nevertheless, current data suggest that the *breconensis–zavallatus*/BZ zone, and hence the 'older' spore assemblages from the Llanstadwell Formation, are of late Lochkovian (late Gedinnian)–earliest Pragian (?earliest Siegenian) age, and the *polygonalis–emsiensis*/PoW zone, and hence the 'younger' spore assemblages from the Burton Cliff, Mill Bay and lowermost Lawrenny Cliff formations, are of early Pragian (?early Siegenian)–latest Pragian (?latest Siegenian) or possibly earliest Emsian age (Richardson & McGregor, 1986; Streel *et al*. 1987; Steemans, 1989).

4. Geological significance

4.a. Stratigraphical correlation

Information on the spore biostratigraphy of the Cosheston Group permits correlation of these deposits with those of the main outcrop of the 'Lower Old Red Sandstone' in South Wales and the Welsh Borderland. Spore assemblages from the Senni Beds of the main outcrop have been investigated by Hassan (A. Hassan, unpub. PhD thesis, Univ. London, 1982) and the main biostratigraphical conclusions summarized in Richardson *et al*. (1982) and Richardson & McGregor (1986). Hassan and Richardson are currently preparing a detailed report on the spore systematics and biostratigraphical interpretation of sporomorph assemblages from the Senni Beds.

Richardson *et al*. (1982) and Richardson & McGregor (1986) report that the lowest spore assemblages recovered from the Senni Beds occur 3–4 m above the base of the unit, and belong to the *breconensis–zavallatus* zone, with spore assemblages belonging with this zone present in the succeeding 64 and 90 m of the unit in the Black Mountains and Brecon Beacons respectively. However, the remainder of the Senni Beds contain spore assemblages belonging to the *polygonalis–emsiensis* zone (Fig. 7). Spore assemblages have not been reported from the Brownstones Group which overlies the Senni Beds.

The 'older' spore assemblages from the Llanstadwell Formation (Cosheston Group) belong with the *breconensis–zavallatus* zone and these strata can therefore be correlated with the lower part of the Senni Beds (Fig. 7). The 'younger' spore assemblages from the overlying Burton Cliff, Mill Bay and lowermost Lawrenny Cliff formations (Cosheston Group) belong with the

E.F. No. S66/1, Llanstadwell Formation, Newton Noyes; (f) *Retusotriletes* with proximal thickening. Sample WP25, Slide NMW97.22G.13, E.F. No. L23, Llanstadwell Formation, Wear Point; (g) *Retusotriletes* with proximal thickening. Sample CPW4, Slide NMW97.22G.2, E.F. No. F47, Mill Bay Formation, Cosheston Pill (west shore); (h) *Ambitisporites* sp. Sample WP25, Slide NMW97.22G.14, E.F. No. N32/4, Llanstadwell Formation, Wear Point; (i) *Brochotriletes* sp.1. Sample CPW4, Slide NMW97.22G.3, E.F. No. D25, Mill Bay Formation, Cosheston Pill (west shore); (j) *Brochotriletes* sp.1. Sample CPW4, Slide NMW97.22G.3, E.F. No. N45/1, Mill Bay Formation, Cosheston Pill (west shore); (k, l) *Verrucosisporites polygonalis*? Lanninger, 1968. Sample NN3, Slide NMW97.22G.7, E.F. No. E50, Llanstadwell Formation, Newton Noyes. View of proximal and distal surface respectively; (m) *Ambitisporites* sp. Sample MB8, Slide NMW97.22G.18, E.F. No. X47/4, Llanstadwell Formation, Muscle Bridge Quarry; (n) *Aneurospora* sp. Sample WPW1, Slide NMW97.22G.19, E.F. No. W20/3, Llanstadwell Formation, Westfield Pill (west shore); (o) *Aneurospora* sp. Sample NN3, Slide NMW97.22G.7, E.F. No. U34, Llanstadwell Formation, Newton Noyes; (p, q) *Dictyotriletes* sp.1. Sample NN3, Slide NMW97.22G.7, E.F. No. X43, Llanstadwell Formation, Newton Noyes. View of proximal and distal surface respectively; (r) *Dibolisporites* sp.1. Sample CPW4, Slide NMW97.22G.3, E.F. No. V17/2, Mill Bay Formation, Cosheston Pill (west shore); (s) *Dibolisporites* sp.1. Sample CPW4, Slide NMW97.22G.3, E.F. No. N38/2, Mill Bay Formation, Cosheston Pill (west shore); (t) *Brochotriletes* sp. Sample RT25, Slide NMW97.22G.20, E.F. No. U49, Llanstadwell Formation, Muscle Bridge Quarry.

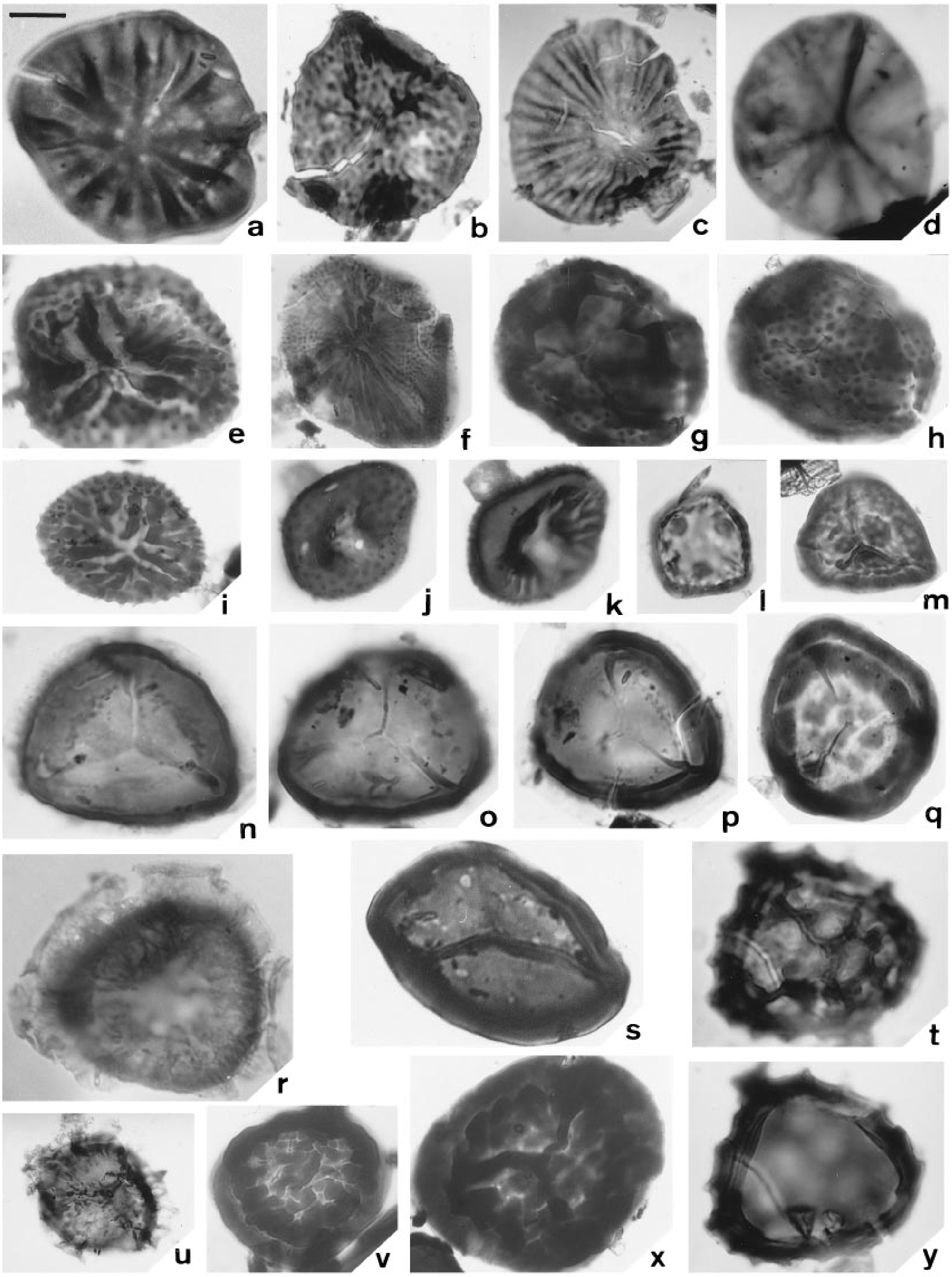

Figure 5. Spores from the Cosheston Group [scale bar in top left hand corner equals 10 µm, except in (u) where it equals 20 µm]. E.F. No. = England Finder Number. (a) *Emphanisporites rotatus* McGregor emend. McGregor, 1973. Sample WP25, Slide NMW97.22G.12, E.F. No. Q56/4, Llanstadwell Formation, Wear Point; (b) *Emphanisporites* cf. *decoratus* Allen, 1965. Sample WP25, Slide NMW97.22G.10, E.F. No. E44, Llanstadwell Formation, Wear Point; (c) *Emphanisporites neglectus*? Vigran, 1964. Sample CPW4, Slide NMW97.22G.3, E.F. No. H36/2, Mill Bay Formation, Cosheston Pill (west shore); (d) *Emphanisporites obscurus* McGregor, 1961. Sample CPW4, Slide NMW97.22G.2, E.F. No. R58/1, Mill Bay Formation, Cosheston Pill (west shore);

polygonalis–emsiensis zone and these strata can therefore be correlated with the middle and upper part of the Senni Beds (Fig. 7).

Thus it seems likely that the deposits of the Senni Beds and Cosheston Group accumulated in different parts of the same basin at approximately the same time. It is therefore not surprising that strong lithological similarities exist between the deposits of the two stratigraphical units (see, for instance, R. Thomas, unpub. Ph.D. thesis, Univ. Bristol, 1978; Allen, Thomas & Williams, 1982). However, thickness of the sedimentary sequence varies considerably with a much greater thickness of sediments accumulating in the region of southwest Wales. The *breconensis–zavallatus* zone is represented by less than 100 m of strata in the Senni Beds of the Black Mountains and Brecon Beacons but by at least 265–340 m of strata in the Cosheston Group of southwest Wales. Similarly, the *polygonalis–emsiensis* zone is represented by at least 100–350 m of strata in the Senni Beds but at least 760–860 m of strata in the Cosheston Group. The greater thickness of strata in the Cosheston Group is not surprising since it is interpreted as accumulating in an area of complex relief with syn-depositional faulting (e.g. Allen & Williams, 1978, 1982; Allen, 1985; Powell, 1987). The Senni Beds accumulated in part of the basin where there was presumably less subsidence and hiatuses are possibly of greater significance.

4.b. Palaeoenvironmental interpretation

The Cosheston Group palynomorph assemblages comprise entirely land-derived forms, apart from extremely rare marine palynomorphs (acritarchs and chitinozoans) which are almost certainly reworked. This strongly suggests that the Cosheston Group spore-bearing strata accumulated in a non-marine environment. Thus evidence from palynofacies analysis supports interpretations based on sedimentological considerations suggesting that these deposits are non-marine and accumulated in a continental fluviatile environment. Both the Cosheston Group (R. Thomas, unpub. Ph.D. thesis, Univ. Bristol, 1978; Allen, Thomas & Williams, 1982) and the Senni Beds (Allen, 1979, 1985; Loeffler & Thomas, 1980; Owen, 1995) are believed to have been deposited by a system of braided streams traversing an extensive alluvial plain.

5. Palaeobotanical significance

Historically, the floras of the Senni Beds have played a pivotal role in the palaeobotanical study of Lower Devonian land plants. In their classic monograph on the Senni Beds, Croft & Lang (1942) provided detailed descriptions from a number of localities. As new material and techniques have become available this work has been substantially extended (Edwards, 1968, 1969*a*,*b*, 1980, 1981; Edwards & Kenrick, 1986; Edwards *et al*. 1986; Edwards, Kenrick & Carluccio, 1989; Kenrick & Edwards, 1988*a*,*b*; Shute & Edwards, 1989; Kenrick, Edwards & Dales, 1991). The outcome is that plant megafossil assemblages from the Senni Beds provide one of the most comprehensive insights into Lower Devonian vegetation and their study mirrors historical developments in the study of Lower Devonian floras. Botanically they are important because of their diversity, both in terms of numbers of taxa and in their composition. The Allt Ddu assemblage in the Brecon Beacons provides evidence for a radiation of vascular plants, particularly zosterophylls, at the end of the Gedinnian (Fig. 7, locality AD, *breconensis–zavallatus* Spore Assemblage Biozone), somewhat earlier than recorded elsewhere in the Old Red Sandstone continent. The succeeding Brecon Beacons assemblages contain the first record of both barinophytes (*Krithodeophyton*: Edwards, 1968) and trimerophytes (*Dawsonites*: Croft & Lang, 1942).

(e) *Emphanisporites zavallatus* Richardson *et al*. 1982. Sample NN3, Slide NMW97.22G.6, E.F. No. P34/4; Llanstadwell Formation, Newton Noyes; (f) *Emphanisporites micrornatus* Richardson & Lister, 1969. Sample NN15, Slide NMW97.22G.9, E.F. No. L61/3. Llanstadwell Formation, Newton Noyes; (g, h) *Streelispora newportensis* (Chaloner & Streel) Richardson & Lister, 1969. Sample NN3, Slide NMW97.22G.5, E.F. No. T34, Llanstadwell Formation, Newton Noyes. View of proximal and distal surface respectively; (i) *Emphanisporites zavallatus* Richardson *et al*. 1982. Sample WP25, Slide NMW97.22G.12, E.F. No. U32/4, Llanstadwell Formation, Wear Point; (j, k) *Emphanisporites* cf. *decoratus* Allen, 1965. Sample NN3, Slide NMW97.22G.7, E.F. No. Q22, Llanstadwell Formation, Newton Noyes. View of distal and proximal surface respectively; (l) *Iberoespora* sp. Sample WP25, Slide NMW97.22G.14, E.F. No. N49/3, Llanstadwell Formation, Wear Point; (m) *Iberoespora* sp. Sample MB8, Slide NMW97.22G.17, E.F. No. D50. Llanstadwell Formation, Muscle Bridge Quarry; (n) *Breconisporites breconensis* Richardson *et al*. 1982. Sample WP25, Slide NMW97.22G.15, E.F. No. E59, Llanstadwell Formation, Wear Point; (o) *Breconisporites breconensis* Richardson *et al*. 1982. Sample WP25, Slide NMW97.22G.10, E.F. No. N37, Llanstadwell Formation, Wear Point; (p) *Breconisporites breconensis* Richardson *et al*. 1982. Sample WP25, Slide NMW97.22G.15, E.F. No. E52, Llanstadwell Formation, Wear Point; (q) *Amicosporites streelii* Steemans, 1989. Sample WP25, Slide NMW97.22G.12, E.F. No. E30/2. Llanstadwell Formation, Wear Point; (r) cf. *Camptozonotriletes caperatus* McGregor, 1973. Sample CPW10, Slide NMW97.22G.4, E.F. No. T61/4, Mill Bay Formation, Cosheston Pill (west shore); (s) *Archaeozonotriletes chulus* (Cramer) Richardson & Lister, 1969. Sample WP25, Slide NMW97.22G.11, E.F. No. M17/3, Llanstadwell Formation, Wear Point; (t,y) *Chelinospora* sp. Sample CPW10, Slide NMW97.22G.4, E.F. No. S40, Mill Bay Formation, Cosheston Pill (west shore) Proximal and distal surface respectively; (u) *Camptozonotriletes* cf. *aliquantus* Allen, 1965. Sample CPW4, Slide NMW97.22G.2, E.F. No. R27/1, Mill Bay Formation, Cosheston Pill (west shore); (v) *Clivosispora verrucata* McGregor, 1973. Sample WP25, Slide NMW97.22G.16, E.F. No. U39/1, Llanstadwell Formation, Wear Point; (x) *Clivosispora verrucata* McGregor, 1973. Sample CPW4, Slide NMW97.22G.1, E.F. No. N23, Mill Bay Formation, Cosheston Pill (west shore).

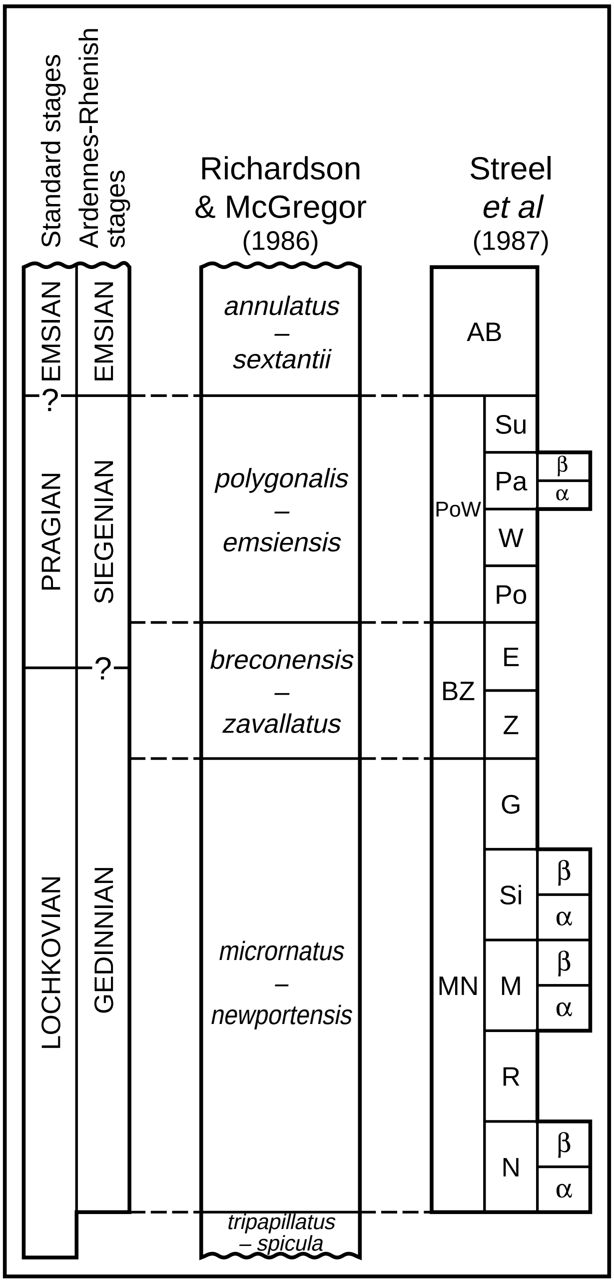

Figure 6. Correlation of spore zonal schemes with Lower Devonian stages. The scheme of Richardson & McGregor (1986) uses spore assemblage biozones. The scheme of Streel *et al*. (1987) uses oppel zones (left hand column) and interval zones (right hand column(s)).

Furthermore, pyrite permineralization in the Brecon Beacons quarry assemblage (Fig. 7, locality BBQ) permits detailed examination of the three-dimensional anatomy of early vascular plants, particularly zosterophylls (e.g. *Gosslingia*: Kenrick & Edwards, 1988*a*). Whether or not these are the oldest permineralizations yet known remains conjectural as precise correlation with the Rhynie Chert silicified plants (dated palynologically as Pragian and radiometrically via ^{40}Ar–^{39}Ar as 396 ± 12 Ma: Rice *et al*. 1995) is not possible.

The presence of plant megafossils in the Cosheston Group was noted by Strahan *et al*. (1914) and Cantrill *et al*. (1916), who could not identify the plants unequivocally and questionably assigned them to *Psilophyton*. Thomas (R. Thomas, unpub. Ph.D. thesis, Univ. Bristol, 1978) recorded the occurrence of plant megafossils in the Cosheston Group and reported that they were most abundant in the Llanstadwell Formation, common in the Burton Cliff Formation and lower part of the Mill Bay Formation, rare in the upper part of the Mill Bay Formation and the Lawrenny Cliff Formation, and absent from the New Shipping Formation. Thomas identified *Zosterophyllum llanoveranum* Croft & Lang, 1942, from the Llanstadwell Formation at Muscle Bridge Quarry and ?*Psilophyton* sp. and an unidentified zosterophyll from the Mill Bay Formation at Mill Bay West. He also noted that *Pachytheca* and *Prototaxites* were commonly associated with plant debris preserved at a number of horizons in the Cosheston Group. Kenrick (P. Kenrick, unpub. Ph.D. thesis, Univ. Wales, 1988) undertook a systematic search for plant megafossils in the Cosheston Group and provided detailed description of the anatomy and morphology of some of the plants. His findings confirmed previous reports of the distribution of plant megafossils in the Cosheston Group, that is, they are abundant in the lower part of the group (Llanstadwell, Burton Cliff and Mill Bay formations) and rare in the upper (Lawrenny Cliff and New Shipping formations). Kenrick recorded five plant-bearing localities (Table 4) and a list of the taxa reported is presented in Table 5 (P. Kenrick, unpub. Ph.D. thesis, Univ. Wales, 1988, with additional information from Edwards, Kenrick & Carluccio, 1989, and Kenrick, Edwards & Dales, 1991). Edwards, Kenrick & Carluccio (1989) published a detailed description of the zosterophyll *Deheubarthia splendens* Edwards, Kenrick & Carluccio, 1989, which occurs in the Llanstadwell and Mill Bay formations, and Kenrick, Edwards & Dales (1991) described the anatomy of specimens of *Sennicaulis hippocrepiformis* Edwards, 1981, from the Mill Bay Formation. Both of these taxa have also been reported from the Senni Beds (see Table 5).

The plant assemblages of the Cosheston Group are less diverse than those of the Senni Beds but demonstrate the widespread occurrence of *Deheubarthia splendens*, *Gosslingia breconensis*, *Zosterophyllum llanoveranum*, *Z.* cf. *fertile* and *Sennicaulis hippocrepiformis* on part of the southern margin of the Old Red Sandstone Continent in the Pragian (Siegenian). Anatomically they provide important information on the ultrastructure of a novel type of tracheid (S-type *sensu* Kenrick & Crane, 1991; Kenrick, Edwards & Dales, 1991), subsequently recognized as one of the distinguishing characters of a new grouping of early vascular plants (the Rhyniopsida) which includes *Rhynia gwynne–vaughanii* (Kenrick & Crane, 1991). However, their usefulness in evolutionary and phytogeographical studies has been constrained by the absence of secure age determination and lack of detailed stratigraphical correlation of the Pembrokeshire sequences. The new spore data provide reliable age determinations for the Cosheston Group plant megafossil

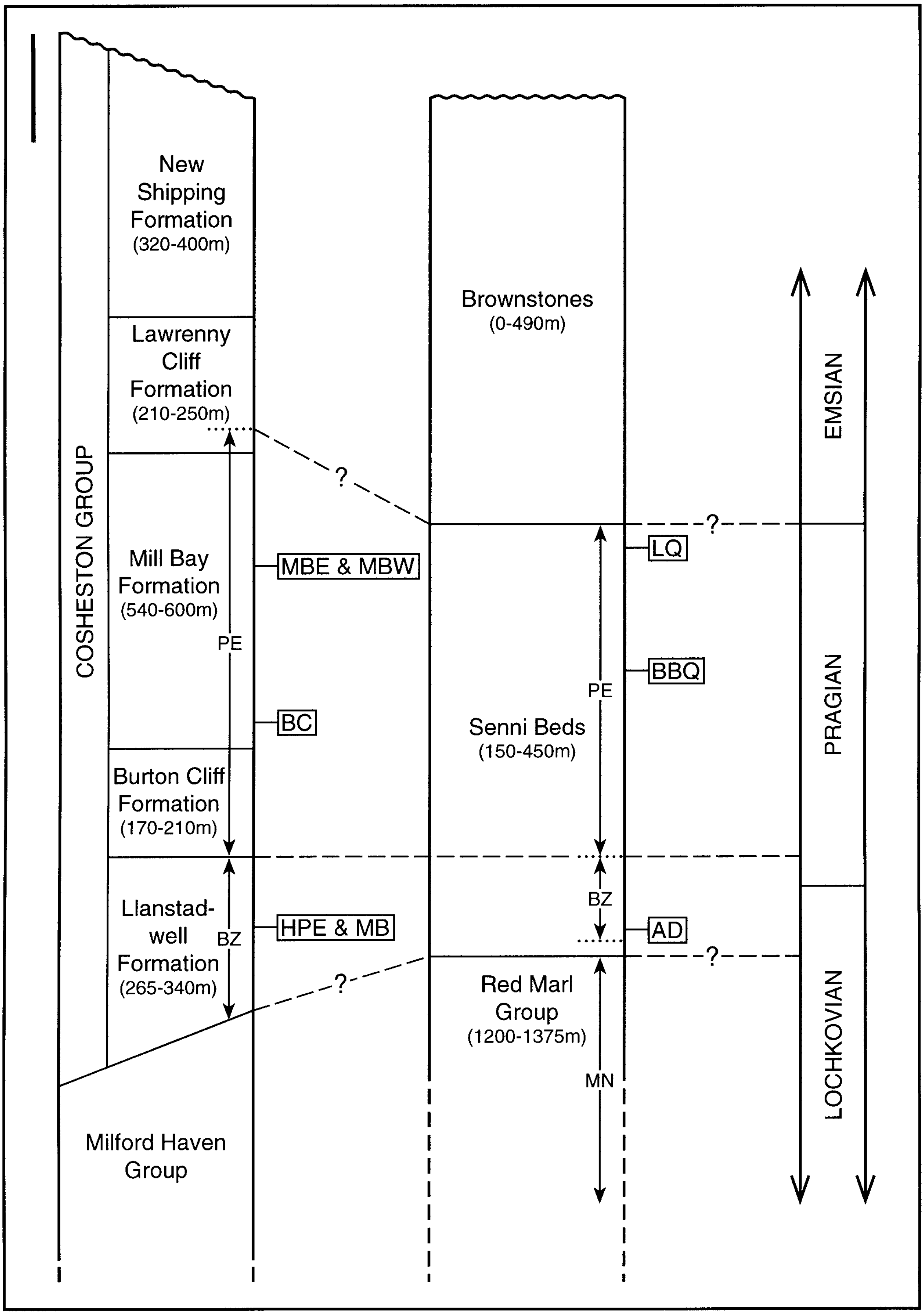

Figure 7. Correlation of the Cosheston Group and Senni Beds indicating the distribution of spore assemblage biozones and the location of plant megafossil assemblages. Regarding spore asemblage biozones (SAB): MN = *micrornatus–newportensis* SAB; BZ = *breconensis–zavallatus* SAB; PE = *polygonalis–emsiensis* SAB. Regarding plant megafossil localities and their relative stratigraphical positions: AD = Allt Ddu; BBQ = Brecon Beacons (Storey Arms) Quarry; LQ = Llanover Quarry; CD = Craig Ddu; MB =Muscle Bridge Quarry; HPE = Hobbs Point East (east of Cheddar Bridge Pier); BC = Burton Cliff (foreshore at Williamson Mountain); MBW = Mill Bay West; MBE = Mill Bay East (references regarding palaeobotanical studies of the Cosheston Group localities are provided in Table 4). Note that the vertical scale for the stratigraphical columns differs. The verticle scale bar (top left-hand corner) represents 200 m for the Cosheston Group and 100 m for the Senni Beds.

Table 4. Locality details for plant megafossil assemblages (see Fig. 3)

Locality	Formation	Grid reference	Location
Muscle Bridge Quarry (MB)	Llanstadwell Fm.	SM95650558	Disused quarry located beside the B425 road c.250m SE of Muscle Bridge Hamlet. See Thomas *in* Friend and Williams (1978), R. Thomas (unpub. Ph.D. thesis, Univ. Bristol, 1978), P. Kenrick (unpub. Ph.D. thesis, Univ. Wales, 1988) and Edwards, Kenrick & Carluccio (1989).
Hobbs Point East (HPE)	Llanstadwell Fm.	SM973044	Exposure in coastal section c.200m east of Cheddar Bridge Pier. See P. Kenrick (unpub. Ph.D. thesis, Univ. Wales, 1988).
Burton Cliff (BC)	Mill Bay Fm.	SN99110532	Exposure in coastal section at Burton Cliff (foreshore at Williamson Mountain). See P. Kenrick (unpub. Ph.D. thesis, Univ. Wales, 1988) and Edwards, Kenrick & Carluccio (1989).
Mill Bay West (MBW)	Mill Bay Fm.	*c.* SN002049	Several plant beds occur in the coastal section exposed to the west of Mill Bay inlet. See Thomas *in* Friend & Williams (1978), P. Kenrick (unpub. Ph.D. thesis, Univ. Wales, 1988) and Kenrick, Edwards & Dales (1991).
Mill Bay East (MBE)	Mill Bay Fm.	*c.* SN005051	Several plant beds occur in the coastal section exposed to the east of Mill Bay inlet. See P. Kenrick (unpub. Ph.D. thesis, Univ. Wales, 1988).

Table 5. Distribution of plant megafossil taxa reported from the Senni Beds and Cosheston Group

	Localities								
	Senni Beds				Cosheston Group				
Taxa	AD^{BZ}	BBQ^{PE}	LQ$^{–}$	CD$^{–}$	MB^{BZ}	HPE^{BZ}	BC^{PE}	MBW^{PE}	MBE^{PE}
Nematothallus sp.		X	X						
Pachytheca sp.		X	X		X	X	X	X	X
Prototaxites sp.		X	X		X	X	X	X	X
cf. *Cooksonia*	?			X			X		
Salopella allenii	X								
cf. *Salopella*				X		X			
Sporogonites exuberans Halle			X						
Taeniocrada sp.			X						
Renalia	?								
Uskiella spargens Shute & Edwards		X	X						
Unidentified Rhyniophyte	X					X	X		
Deheubarthia splendens Edwards et al.	X	X	X	?	X		X		
Gosslingia breconensis Heard	X	X	X				X		X
Thrinkophyton formosum Kenrick & Edwards	?			X					
Z. cf. *australianum* Lang & Cookson			X						
Z. cf. *fertile* Leclercq	X	X	X		X		X		
Zosterophyllum llanoveranum Croft & Lang		X	X		X				
cf. *Zosterophyllum*							X		
Drepanophycus spinaeformis Goppert		X	X						
Dawsonites arcuatus Halle		X	X						
cf. *Dawsonites*							X		
Krithodeophyton croftii Edwards		X							
Hostinella heardii Edwards		X							
Sciadophyton cf. *steinmanii* Krausel & Weyland			X						
Sennicaulis hippocrepiformis Edwards	?	X	X					X	
cf. *Taitia*		X							
Tarella trowenii Edwards & Kenrick		X							

Regarding localities: AD = Allt Ddu: Senni Beds (Edwards, Kenrick & Carluccio, 1989; Edwards, 1990); BBQ = Brecon Beacons (Storey Arms) Quarry: Senni Beds (Mortimer, 1967; Edwards, 1968; Edwards & Richardson *in* Friend & Williams, 1978; Edwards *et al*. 1986; Edwards, Kenrick & Carluccio, 1989; Kenrick & Edwards, 1988*a*); LQ = Llanover Quarry: Senni Beds (Croft & Lang, 1942; Mortimer, 1967; Richardson & Lister, 1969; Edwards, Kenrick & Carluccio, 1989; Shute & Edwards, 1989); CD = Craig Ddu: Senni Beds (Kenrick & Edwards, 1988*b*; Owen, 1995); MB = Muscle Bridge Quarry: Llanstadwell Fm., Cosheston Gp. (Thomas *in* Friend & Williams, 1978; Thomas unpub. Ph.D. thesis, Univ. Bristol, 1978; P. Kenrick, unpub. Ph.D. thesis, Univ. Wales, 1988; Edwards, Kenrick & Carluccio, 1989); HPE = Hobbs Point East (east of Cheddar Bridge Pier): Llanstadwell Fm., Cosheston Gp. (Thomas unpub. Ph.D. thesis, Univ. Bristol, 1978; P. Kenrick unpub. Ph.D. thesis, Univ. Wales, 1988); BC = Burton Cliff (foreshore at Williamston Mountain): Mill Bay Fm., Cosheston Gp. (R. Thomas unpub. Ph.D. thesis, Univ. Bristol, 1978; P. Kenrick, unpub. Ph.D. thesis, Univ. Wales, 1988; Kenrick, Edwards & Dales, 1991). MBW = Mill Bay West: Mill Bay Fm., Cosheston Gp. (Thomas *in* Friend & Williams, 1978; R. Thomas, unpub. Ph.D. thesis, Univ. Bristol, 1978; P. Kenrick, unpub. Ph.D. thesis, Univ. Wales, 1988; Edwards, Kenrick & Carluccio, 1989); MBE = Mill Bay East: Mill Bay Fm., Cosheston Gp. (R. Thomas, unpub. Ph.D. thesis, Univ. Bristol, 1978; P. Kenrick, unpub. Ph.D. thesis, Univ. Wales, 1988); BZ = *breconensis-zavallatus* Spore Assemblage Biozone; PE = *polygonalis-emsiensis* Spore Assemblage Biozone; – = no spore data.

assemblages and allow correlation with those from the Senni Beds.

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