Palaeontologia Electronica
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AN ILLUSTRATED GUIDE TO THE BENTHIC FORAMINIFERA OF THE HEBRIDEAN SHELF, WEST OF SCOTLAND, WITH NOTES ON THEIR MODE OF LIFE

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ABSTRACT

The Hebridean shelf presents a contrast in substrate type between higher energy open shelf sands, which are influenced by storm waves and lower energy muddy sands in depositional sinks called 'deeps'. The latter reach outer shelf depths (>100 m) even when situated close to land (e.g., Muck Deep). The primary purpose of this paper is to illustrate the majority of the benthic foraminifera. For most species, information is provided on whether they are epifaunal or infaunal, based on their distribution in rose Bengal stained samples. Since the redox boundary is shallow in this area (less than 4-5 cm), infaunal taxa are most abundant in the top 1 cm of sediment and decrease in abundance down to 2 or 3 cm with no subsurface maxima as recorded elsewhere. Some dead tests are infilled with glauconite which preserves the form of the species even when the shell is lost. The organic-cemented agglutinated fauna was concentrated by treating the samples with dilute acid to dissolve the calcareous forms. The species diversity of the resultant acid-treated assemblage (ATA) has been compared with that of the original dead assemblage (ODA). The pattern for the Hebridean shelf matches that recorded from other northwest European shelf seas. This procedure has allowed the following agglutinated species to be recorded from the area for the first time: **Cuneata arctica, Eggerella europea, Eggerelloides medius, Morulaeplecta bulbosa, Portatrochammina murrayi,** and **Recurvoides trochamminiformis.** In addition, the following calcareous taxa are also newly recorded from the area: **Cornuloculina balkwilli, Ammonia falsobeccarii, Nonionella iridea, Robertina subcylindrica** and **Rosalina anomala.**

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Submission: 21 May 2002. Acceptance: 21 October 2002
KEY WORDS: foraminifera, benthic, SEM micrographs, mode of life

Murray, John W., 2003. AN ILLUSTRATED GUIDE TO THE BENTHIC FORAMINIFERA OF THE HEBRIDEAN SHELF, WEST OF SCOTLAND, WITH NOTES ON THEIR MODE OF LIFE. **Palaeontologia Electronica** 5(1):31pp, 1.4MB;
http://palaeo-electronica.org/paleo/2002_2/guide/issue2_02.htm

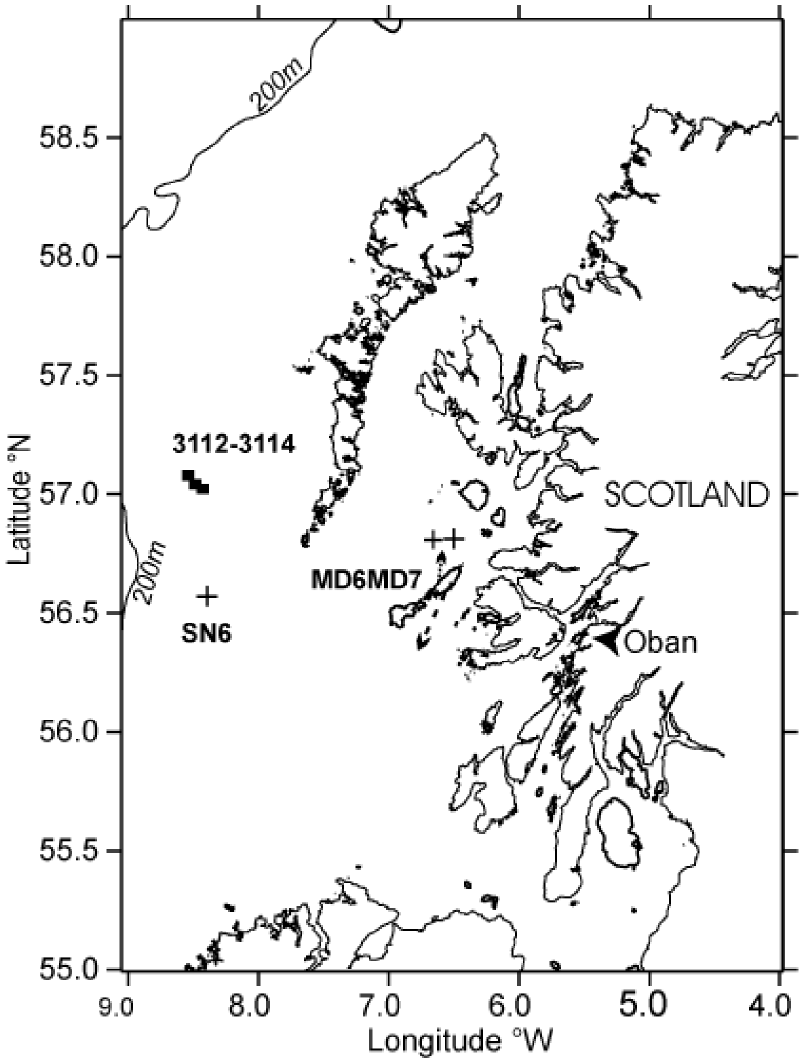

Figure 1. Map of the Hebridean shelf to show the sample localities. MD = Muck Deep, SN = Stanton Deep (Murray, in press). Shelf samples 3112-3114 (Murray, 1985).

INTRODUCTION

The aim of this paper is to illustrate the majority of hard-shelled modern benthic foraminifera encountered on the Hebridean shelf west of Oban, Scotland, and to provide some notes on its mode of life. It complements separate studies which discuss the ecology and development of the dead assemblages (Murray 1985, in press). This paper brings together data from the open outer shelf and from shelf depressions known as 'deeps'. The latter have muddy sand substrates: Muck Deep (maximum depth 230 m) on the inner shelf and Stanton Deep (maximum depth 167 m) on the outer shelf (Murray, in press) (Figure 1). The samples from the higher energy shelf exposed to the influence of storm waves have previously been discussed by Murray (1985) and are from sandy substrates. As live and dead forms have been treated separately, it is possible to specify which taxa are infaunal and which are epifaunal, either on the sediment surface or, more commonly, attached to firm substrates such as shells, hydroids, etc.

The first major work on the modern foraminifera of Britain was that of Williamson (1858) in which he illustrated and named taxa from a wide range of localities, some of which were from the west coast of Scotland – Arran, Skye, Loch Fyne. Later major works on the taxonomy of foraminifera from the UK continental shelf include Murray (1971, revised 2000), and Haynes (1973). Distributional/ecological studies include various inner shelf-localities (Heron-Allen and Earland 1916), North Minch Channel (Edwards 1982), open shelf and deeps (Murray 1985, in press; Murray and Whittaker 2001), and Clyde Sea (Hannah and Rogerson 1997). Only Murray and Hannah and Rogerson have distinguished live (stained) from dead.

The Shelf Environment:

The summer mean bottom salinites are 35.25 and 34.5-35.0 psu for the outer shelf (Stanton Deep area and open shelf samples) and inner shelf (Muck Deep area) respectively, and a mean summer bottom temperature of ~10°C. According to Elliott et al. (1991) the January bottom water temperature is around 8°C on the outer shelf and around 7.5°C on the inner shelf; whereas during the summer months the waters are stratified over the outer shelf, and they are vertically mixed throughout the year over the inner shelf. Both outer and inner shelf have a maximum surface tidal current speed of 1-2 knots (51-102 cm s^{-1}) at spring tides (Lee and Ramster 1981) but there are no published bottom current measurements. From a mathematical analysis of tides, Pingree and Griffiths (1979) concluded that the interaction of the M_2 (principal lunar semi-diurnal constituent) and M_4 (shallow water, quarter diurnal harmonic) tides is the main cause of the direction of sediment transport. Wave measurements on an adjacent area of shelf (South Uist, Stanton, 1984) show that the 50 year significant wave height is around 12-13 m. Over a seven year period of observations, wave height/periodicity varied from <1 m/3 secs to 11 m/12 secs. The increasing wave heights recorded in this area during the latter part of the twentieth century is coincident with the long-term rise in the North Atlantic Oscillation (Woolf, et al., in press). In order to mobilise bottom sediment on the shelf at a water depth of 80 m, a minimum wave height of 10 m is required. This may be very rarely be achieved (Woolf, pers. comm., 2002). Thus, it appears that the shelf in general is subject to disturbance from tidal currents and also intermittently from storm waves. The deeps are lower energy depositional areas.

The open shelf sediments are rich in biogenic carbonate (Wilson 1979, 1982) because no major rivers flow into the area so there is low input of terrigenous detritus. Sand patches with a rippled surface and locally very variable composition (Belderson et al. 1971, figure 8) rest on a basal transgressive conglomerate. Published radiocarbon dates based on bulk surface sediment samples gave ages of 3772 ± 55 and 7935 ± 60 years and for a glauconite-infilled bryozoan 870 ± 200 years (Stride et al. 1999). Thus the shelf sediments are a mix of contemporary and older material (from lower sea level and Holocene transgression) and probably accumulated rather slowly. During the Plio-Pleistocene glacial events, elongate basins were eroded across the shelf. They were subsequently wholly or partially infilled with sediments (>200 m Quaternary deposits, Fyfe et al. 1993). The incompletely filled examples now form the 'deeps'. In muddy areas, there is no clear separation between the modern sediments and the underlying late to postglacial clays. The surface sediments in the deeps have a variable clay content (Table 1).

MATERIAL AND METHODS

The material used in this paper is from the open outer shelf at water depths of 134-145 m (samples 3112-3114, from approximately the top 1 cm of sediment, Murray 1985; collected with a grab, Murray and Murray 1987) and from shelf deeps at water depths of 167-218 m (samples MD6, MD7, SN6, with replicates **a** and **b** from two separate deployments of the multicorer, Murray, in press; MD = Muck Deep, SN = Stanton Deep). All were stained with rose Bengal to distinguish live (stained) from dead (unstained). In addition to staining in the outer chambers, many of the live foraminifera contained green protoplasm which partly remained unstained by rose Bengal, especially in the innermost chambers. Therefore, live tests were easily distinguished from empty dead ones (see Murray and Bowser 2000). All samples were washed over a 63 µm sieve. In order to concentrate the agglutinated forms, some samples were treated with dilute acid to remove the calcareous component following the method of Alve and Murray (1994). The residue is termed an acid treated assemblage (ATA) and is distinct from the original dead assemblage (ODA). The digital images in Figures 2-10 were taken on a Jeol 6400 SEM and captured on a PGT IMIX-PTS system.

RESULTS

The occurrence of the more abundant foraminifera which form the living and dead assemblages has previously been described by Murray (1985, in press). In this paper there is more comprehensive coverage of the occurrence of species rather than assemblages. Data on live (stained) forms are given for the surface layer (approximately 1 cm thick) for samples 3112-3114 and for the 0.0-0.5, 0.5-1.0, and 1.0-2.0 cm samples of all cores and for core MD7 for 2.0-3.0 cm also (Table 1). Samples deeper than this contained too few stained forms to pick. Data on dead forms are given for the surface samples only (Table 2), but a few additional species which occur as dead individuals deeper than 1 cm are also included in the taxonomic list and plates. Some foraminiferal tests are infilled with a green mineral presumed to be glauconite or glauconie. Because this mineral expands,

Table 1. Live (stained) distributions.

		Muck Deep														Stanton Deep			Shelf
	Lat. °N	**56 48.9**	**57 48.9**	**58 48.9**	**59 48.9**	**60 48.9**	**61 48.9**	**56 48.8**	**57 48.8**	**58 48.8**	**58 48.8**	**59 48.8**	**60 48.8**	**61 48.8**	**62 48.8**	**56 33.8**	**57 33.8**	**58 33.8**	
	Long. °W	**06 40.5**	**7 40.5**	**8 40.5**	**9 40.5**	**10 40.5**	**11 40.5**	**06 30.2**	**7 30.2**	**8 30.2**	**8 30.2**	**9 30.2**	**10 30.2**	**11 30.2**	**12 30.2**	**08 23.0**	**9 23.0**	**10 23.0**	
	Water depth m	**170**	**170**	**170**	**170**	**170**	**170**	**218**	**218**	**218**	**218**	**218**	**218**	**218**	**218**	**167**	**167**	**167**	**134–145**
	Depth of redox boundary cm	**1-2**	**1-2**	**1-2**	**1-2**	**1-2**	**1-2**	**3-4**	**3-4**	**3-4**	**3-4**	**3-4**	**3-4**	**3-4**	**3-4**	**4-5**	**4-5**	**4-5**	
	Wt. % clay	**6.7**			**4.3**			**60.2**				**65.6**				**36.6**			**0**
Mode of life	**Sample**	**MD6a**	**MD6a**	**MD6a**	**MD6b**	**MD6b**	**MD6b**	**MD7a**	**MD7a**	**MD7a**	**MD7a**	**MD7b**	**MD7b**	**MD7b**	**MD7b**	**SN6b**	**SN6b**	**SN6b**	**3112–3114**
	cm downcore	**0.0-0.5**	**0.5-1.0**	**1.0-2.0**	**0.0-0.5**	**0.5-1.0**	**1.0-2.0**	**0.0-0.5**	**0.5-1.0**	**1.0-2.0**	**2.0-3.0**	**0.0-0.5**	**0.5-1.0**	**1.0-2.0**	**2.0-3.0**	**0.0-0.5**	**0.5-1.0**	**1.0-2.0**	**surface**
I	**Adercotryma wrighti**	8	1	1	12	3	1	0	11	3	0	67	16	0	0	12	0	0	
I	**Ammoscalaria pseudospiralis**	1	0	0	0	0	0	9	0	5	2	22	12	2	0	24	0	0	
E	**Cribrostomoides jeffreysii**	4	0	0	3	0	1	0	0	0	0	0	0	0	0	12	0	0	L*
E	**Deuterammina rotaliformis**	0	1	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	
I	**Eggerelloides medius**	0	1	0	3	1	0	123	100	23	19	649	73	2	0	0	0	0	
I	**Eggerelloides scaber**	23	4	0	40	5	1	0	0	0	0	0	0	0	0	0	0	0	
E	**Gaudryina rudis**	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	
I	**Haplophragmoides bradyi**	0	0	0	0	0	0	0	0	0	0	22	0	0	0	0	0	0	
I	**Liebusella goesi**	13	12	1	15	2	1	47	20	23	34	67	20	2	0	0	0	0	
I	**Recurvoides trochamminiformis**	14	2	0	25	1	0	79	53	5	6	224	36	2	0	12	0	0	
I	**Reophax fusiformis**	10	4	0	4	0	0	9	0	0	0	0	4	0	0	0	0	0	
	Siphotextularia catenata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
E	**Textularia sagittula** group	0	0	0	0	0	0	0	0	0	0	22	0	0	0	12	0	0	L
I	**Textularia tenuissima**	42	7	1	68	9	1	63	47	11	3	179	24	0	0	0	0	0	
E	**Tritaxis fusca**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	L*
	Biloculinella depressa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	
I	**Cornuspira involvens**	0	0	0	1	0	0	0	0	0	0	0	0	0	0	118	782	26	
E	**Miliolinella subrotunda**	0	0	0	1	1	0	0	0	0	0	112	0	0	0	0	0	0	L*
	Pyrgo williamsoni	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	
E	**Quinqueloculina seminulum**	0	0	0	0	0	0	3	0	0	0	0	0	0	0	47	0	0	
	Ammonia falsobeccarii	0	0	0	0	0	0	0	0	0	0	45	0	0	0	0	0	0	
	Amphicoryna scalaris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	

Table 1. (continued).

Mode of life		Muck Deep														Stanton Deep			Shelf
	Lat. °N	56 48.9	57 48.9	58 48.9	59 48.9	60 48.9	61 48.9	56 48.8	57 48.8	58 48.8	58 48.8	59 48.8	60 48.8	61 48.8	62 48.8	56 33.8	57 33.8	58 33.8	
	Long. °W	06 40.5	7 40.5	8 40.5	9 40.5	10 40.5	11 40.5	06 30.2	7 30.2	8 30.2	8 30.2	9 30.2	10 30.2	11 30.2	12 30.2	08 23.0	9 23.0	10 23.0	
	Water depth m	170	170	170	170	170	170	218	218	218	218	218	218	218	218	167	167	167	134–145
	Depth of redox boundary cm	1-2	1-2	1-2	1-2	1-2	1-2	3-4	3-4	3-4	3-4	3-4	3-4	3-4	3-4	4-5	4-5	4-5	
	Wt. % clay	6.7			4.3			60.2				65.6				36.6			0
	Sample	MD6a	MD6a	MD6a	MD6b	MD6b	MD6b	MD7a	MD7a	MD7a	MD7a	MD7b	MD7b	MD7b	MD7b	SN6b	SN6b	SN6b	3112–3114
	cm downcore	0.0-0.5	0.5-1.0	1.0-2.0	0.0-0.5	0.5-1.0	1.0-2.0	0.0-0.5	0.5-1.0	1.0-2.0	2.0-3.0	0.0-0.5	0.5-1.0	1.0-2.0	2.0-3.0	0.0-0.5	0.5-1.0	1.0-2.0	surface
I	Bolivina pseudoplicata	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	
I	Bolivinellina pseudopunctata	3	1	0	9	1	0	3	8	0	0	0	0	0	0	0	0	0	
	Brizalina difformis	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
I	Brizalina spathulata	6	0	0	4	0	0	6	3	0	0	22	8	0	0	24	0	0	
I	Bulimina marginata	49	13	1	80	9	10	279	109	34	22	493	105	0	0	107	0	0	
	Cancris auricula	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	
I	Cassidulina laevigata	59	11	0	96	6	2	3	6	0	3	22	4	0	0	118	0	0	L
I	Cassidulina obtusa	6	3	0	12	1	0	3	6	0	2	45	0	0	0	107	0	0	L
E	Cibicides lobatulus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	L*
E	Cibicides refulgens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	L*
I	Epistominella vitrea	68	8	1	76	13	4	82	56	3	8	336	32	0	0	36	0	0	L
	Fissurina spp.	0	0	0	1	0	0	6	0	0	0	112	4	0	0	0	0	0	
	Fursenkoina schreibersiana	0	0	0	0	1	0	0	6	0	0	22	0	0	5	0	0	0	
E	Gavelinopsis praegeri	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	L*
	Globocassidulina subglobosa	0	0	0	4	0	0	0	0	0	0	22	0	0	0	0	0	0	
	Hyalinea balthica	3	0	0	0	0	0	9	0	0	0	22	0	0	0	59	0	0	
	Lenticulina	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	
I	Melonis barleeanum	3	0	0	0	0	0	13	0	2	2	45	12	0	0	47	0	0	
	Nonion pauperatus	0	0	0	0	0	0	0	0	0	0	22	0	0	0	0	0	0	
I	Nonionella iridea	0	0	0	0	1	0	9	20	0	0	0	36	0	0	0	0	0	
I	Nonionella turgida	25	18	12	13	0	11	16	20	48	51	112	73	52	5	0	0	0	
	Robertina subcylindrica	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	

Table 1. (continued).

Mode of life		Muck Deep														Stanton Deep			Shelf
	Lat. °N	**56 48.9**	**57 48.9**	**58 48.9**	**59 48.9**	**60 48.9**	**61 48.9**	**56 48.8**	**57 48.8**	**58 48.8**	**58 48.8**	**59 48.8**	**60 48.8**	**61 48.8**	**62 48.8**	**56 33.8**	**57 33.8**	**58 33.8**	
	Long. °W	**06 40.5**	**7 40.5**	**8 40.5**	**9 40.5**	**10 40.5**	**11 40.5**	**06 30.2**	**7 30.2**	**8 30.2**	**8 30.2**	**9 30.2**	**10 30.2**	**11 30.2**	**12 30.2**	**08 23.0**	**9 23.0**	**10 23.0**	
	Water depth m	**170**	**170**	**170**	**170**	**170**	**170**	**218**	**218**	**218**	**218**	**218**	**218**	**218**	**218**	**167**	**167**	**167**	**134–145**
	Depth of redox boundary cm	**1-2**	**1-2**	**1-2**	**1-2**	**1-2**	**1-2**	**3-4**	**3-4**	**3-4**	**3-4**	**3-4**	**3-4**	**3-4**	**3-4**	**4-5**	**4-5**	**4-5**	
	Wt. % clay	**6.7**			**4.3**			**60.2**				**65.6**				**36.6**			**0**
	Sample	**MD6a**	**MD6a**	**MD6a**	**MD6b**	**MD6b**	**MD6b**	**MD7a**	**MD7a**	**MD7a**	**MD7a**	**MD7b**	**MD7b**	**MD7b**	**MD7b**	**SN6b**	**SN6b**	**SN6b**	**3112–3114**
	cm downcore	**0.0-0.5**	**0.5-1.0**	**1.0-2.0**	**0.0-0.5**	**0.5-1.0**	**1.0-2.0**	**0.0-0.5**	**0.5-1.0**	**1.0-2.0**	**2.0-3.0**	**0.0-0.5**	**0.5-1.0**	**1.0-2.0**	**2.0-3.0**	**0.0-0.5**	**0.5-1.0**	**1.0-2.0**	**surface**
E	**Rosalina anomala**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	L*
I	**Stainforthia fusiformis**	6	3	1	0	1	2	25	3	0	5	67	0	0	0	71	0	0	
	Trifarina angulosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	L
	Uvigerina peregrina	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	
	Others	6	4	0	22	1	0	22	11	10	0	269	12	2	0	12	0	13	
	Total	349	93	20	506	56	35	823	477	168	157	3022	477	61	10	852	782	39	
	H(S)	2.54	2.50		2.52	2.3		2.25	2.26	2.02	1.94	2.67	2.42			2.47			
	alpha	7	7		7.5			7.5	4.75	3.5	4	10	6.5						
	Agglutinated %	34	36		54	27		40	49	42	41	41	39	13	0	8	0		
	Porcellaneous %	0	1		1	1		2	0	0	0	7	0	0	0	22	100		
	Hyaline %	66	64		63	61		57	50	54	59	51	61	88	100	69	0		

Notes: * on Ditrupa. Mode of life: I = infaunal, E = epifaunal. Number of live foraminifera per 10 cm^3 sediment. The redox boundary lies in the 1-2 cm layer for MD6, 3-4 cm layer for MD7 and the 4-5 cm layer for SN6. Shelf data from Murray (1985).

≥10 individuals

Table 2. Dead distributions, percentages..

	Muck Deep			Stanton Deep			Shelf			Williamson 1858	HA & E 1916	Edwards 1982
Lat. °N	**56 48.9**	**57 48.9**	**56 48.8**	**57 48.8**	**56 33.8**	**57 33.8**	**57 5.1**	**57 3.6**	**57 3.6**			
Long. °W	**06 40.5**	**7 40.5**	**06 30.2**	**7 30.2**	**08 23.0**	**09 23.0**	**08 35.7**	**08 33.2**	**08 33.2**			
Water depth m	**170**	**170**	**218**	**218**	**167**	**167**	**134**	**144**	**145**			
Depth of redox boundary cm		**1.0-2.0**		**3.0-4.0**		**4.0-5.0**						
Sample	**MD6a**	**MD6a**	**MD7a**	**MD7a**	**SN6b**	**SN6b**	**3112**	**3113**	**3114**			
cm downcore	**0.0-0.5**	**1.0-2.0**	**0.0-0.5**	**1.0-2.0**	**0.0-0.5**	**1.0-2.0**	**surface**	**surface**	**surface**			
Adercotryma wrighti	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0			
Ammoscalaria pseudospiralis	0.0	0.8	0.0	0.0	0.3	0.0	0.0	0.0	0.0	x		x
Cribrostomoides jeffreysii	0.0	0.0	0.0	0.3	0.0	0.0	0.0	2.6	0.0	x		x
Deuterammina rotaliformis	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.4	0.0		x	x
Eggerella europea	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
Eggerelloides medius	0.0	0.2	0.2	0.0	0.0	0.0	0.4	0.0	0.0			
Eggerelloides scaber	0.4	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	x	x	x
Gaudryina rudis	1.2	4.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0		x	x
Haplophragmoides bradyi	0.2	0.0	0.2	0.0	0.0	0.3	0.0	0.0	0.0			x
Liebusella goesi	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0			
Recurvoides trochamminiformis	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0			
Reophax fusiformis	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0		x	x
Siphotextularia catenata	0.4	0.0	0.0	0.0	0.3	0.3	0.0	0.4	0.0			
Textularia sagittula group	16.9	21.2	0.7	0.3	4.4	2.9	29.9	31.6	28.0		x	x
Textularia tenuissima	0.0	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0			
Textularia truncata	1.4	0.0	3.7	3.7	0.0	0.0	0.0	0.0	0.0			
Tritaxis fusca	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	x		
Biloculinella depressa	0.4	0.4	0.0	0.3	0.0	0.0	0.0	0.0	0.0		x	
Cornuloculina balkwilli	0.0	0.2	1.3	1.8	0.0	0.0	0.0	0.0	0.0			
Cornuspira involvens	0.2	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0		x	x
Miliolinella subrotunda	0.8	0.5	1.4	1.8	0.3	0.3	0.4	0.8	1.1		x	x
Pyrgo williamsoni	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			x
Quinqueloculina lata	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0			
Quinqueloculina oblonga	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		x	x
Quinqueloculina seminulum	3.2	2.7	0.0	0.0	1.9	0.0	2.5	0.0	0.0		x	x
Spiroloculina excavata	0.4	0.9	0.0	0.0	0.0	0.0	0.4	0.0	0.0		x	x
Acervulina inhaerens	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		x	x
Ammonia beccarii	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.4	0.0		x	x
Ammonia falsobeccarii	2.6	4.9	0.0	0.0	0.3	0.3	0.0	0.0	0.0			

Table 2. (continued).

	Muck Deep			Stanton Deep			Shelf			Williamson 1858	HA & E 1916	Edwards 1982
Lat. °N	**56 48.9**	**57 48.9**	**56 48.8**	**57 48.8**	**56 33.8**	**57 33.8**	**57 5.1**	**57 3.6**	**57 3.6**			
Long. °W	**06 40.5**	**7 40.5**	**06 30.2**	**7 30.2**	**08 23.0**	**09 23.0**	**08 35.7**	**08 33.2**	**08 33.2**			
Water depth m	**170**	**170**	**218**	**218**	**167**	**167**	**134**	**144**	**145**			
Depth of redox boundary cm		**1.0-2.0**		**3.0-4.0**		**4.0-5.0**						
Sample	**MD6a**	**MD6a**	**MD7a**	**MD7a**	**SN6b**	**SN6b**	**3112**	**3113**	**3114**			
cm downcore	**0.0-0.5**	**1.0-2.0**	**0.0-0.5**	**1.0-2.0**	**0.0-0.5**	**1.0-2.0**	**surface**	**surface**	**surface**			
Amphicoryna scalaris	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0			x
Asterigerinata mamilla	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			x
Bolivina pseudoplicata	0.8	0.2	0.0	2.1	0.9	2.1	0.0	0.0	0.0			
Bolivinellina pseudopunctata	0.0	0.0	2.8	1.2	0.0	0.8	0.0	0.0	0.0			x
Brizalina difformis	1.8	1.3	8.3	6.1	9.1	8.1	0.4	0.0	1.8		x	
Brizalina spathulata	0.0	0.1	0.3	0.0	0.3	0.8	0.0	0.0	0.0	x		x
Bulimina gibba/ elongata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		x	x
Bulimina marginata	7.2	5.7	2.3	0.9	18.9	22.1	0.7	1.5	1.8		x	x
Buliminella elegantissima	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	x	x	
Cancris auricula	0.0	0.1	0.0	0.0	0.0	0.0	0.7	1.2	0.0			x
Cassidulina carinata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			x
Cassidulina laevigata	4.8	4.2	0.7	2.1	6.9	5.7	12.1	12.4	19.3	x	x	
Cassidulina obtusa	2.0	0.4	5.2	5.2	4.7	7.0	1.4	1.2	9.8	x	x	
Cibicides lobatulus	13.5	16.8	12.0	14.7	8.5	9.1	13.5	21.4	15.6	x	x	x
Cibicides refulgens	0.0	0.0	0.0	0.0	0.0	0.0	13.9	0.8	0.4		x	
Dentalina subarcuata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	x		x
Discorbinoides millettii	0.0	0.3	1.7	1.2	1.3	0.5	0.0	0.0	0.0		x	
Elphidium earlandi	0.2	0.2	0.3	1.2	1.3	0.3	0.0	0.0	0.0			
Elphidium excavatum	0.0	0.4	0.6	0.6	0.0	0.0	0.7	0.0	0.0			x
Elphidium gerthi	0.6	0.2	1.1	0.0	0.0	0.0	0.0	0.0	0.0			x
Elphidium magellanicum	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0			
Epistominella vitrea	0.8	0.2	4.2	6.7	3.1	1.3	0.0	0.0	0.4			x
Eponides repandus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		x	x
Fissurina spp.	1.0	0.5	2.9	2.8	1.9	1.8	1.1	1.2	1.1			x
Fursenkoina schreibersiana	0.2	0.1	0.0	0.0	0.3	0.3	0.0	0.0	0.0		x	
Gavelinopsis caledonia	1.2	0.0	1.0	0.6	0.9	1.3	0.0	0.0	0.0		x	
Gavelinopsis praegeri	5.2	1.5	10.3	7.1	8.8	6.3	1.4	1.2	4.0			x
Globocassidulina subglobosa	1.0	0.6	3.5	3.1	2.8	2.1	2.2	0.0	4.0		x	x
Hyalinea balthica	8.3	10.6	0.0	0.0	7.2	8.9	0.7	1.9	2.9			x
Lagena clavata (+Procerolagena)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	x	x	x
Lagena interrupta	0.0	0.1	0.0	0.0	0.0	0.3	0.0	0.0	0.0			x

Table 2. (continued).

	Muck Deep			Stanton Deep			Shelf			Williamson 1858	HA & E 1916	Edwards 1982
Lat. °N	**56 48.9**	**57 48.9**	**56 48.8**	**57 48.8**	**56 33.8**	**57 33.8**	**57 5.1**	**57 3.6**	**57 3.6**			
Long. °W	**06 40.5**	**7 40.5**	**06 30.2**	**7 30.2**	**08 23.0**	**09 23.0**	**08 35.7**	**08 33.2**	**08 33.2**			
Water depth m	**170**	**170**	**218**	**218**	**167**	**167**	**134**	**144**	**145**			
Depth of redox boundary cm		**1.0-2.0**		**3.0-4.0**		**4.0-5.0**						
Sample	**MD6a**	**MD6a**	**MD7a**	**MD7a**	**SN6b**	**SN6b**	**3112**	**3113**	**3114**			
cm downcore	**0.0-0.5**	**1.0-2.0**	**0.0-0.5**	**1.0-2.0**	**0.0-0.5**	**1.0-2.0**	**surface**	**surface**	**surface**			
Lagena substriata	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0			x
Lamarckina haliotidea	0.0	0.0	0.9	0.3	0.0	0.0	0.0	0.0	0.0		x	
Melonis barleeanum	11.7	9.4	0.1	0.0	1.6	2.1	0.4	0.4	0.0	x		x
Nonion depressulus	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0		x	
Nonion pauperatus	0.0	0.0	0.6	0.3	0.6	0.0	0.0	0.0	0.0		x	
Nonionella iridea	0.2	0.3	1.6	0.9	0.6	0.3	0.0	0.0	0.0			
Nonionella turgida	0.8	0.3	1.7	4.0	1.6	2.3	0.0	0.4	0.0	x	x	x
Oolina spp.	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0			x
Patellina corrugata	0.0	0.0	0.6	0.0	0.3	0.3	0.0	0.0	0.0	x	x	
Planorbulina mediterranensis	1.4	0.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0		x	x
Robertina subcylindrica	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0			
Rosalina anomala	1.2	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.7			
Rosalina globularis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			x
Spirillina vivipara	0.0	0.0	0.3	0.6	0.0	0.0	0.0	0.0	0.0		x	x
Stainforthia fusiformis	3.4	1.8	11.1	16.0	4.4	3.6	0.0	0.0	0.4			x
Trifarina angulosa	0.4	0.3	0.1	0.6	0.3	0.5	5.7	18.0	9.8	x	x	x
Uvigerina peregrina	0.4	0.3	0.0	0.0	0.6	0.8	0.0	0.0	0.0			x
H(S)	3.02	2.54	3.15	3.08	2.94	2.90	2.35	2.01	2.21			
alpha	13.5	12.5	13	15	12.5	13	8	6.5	6			
Agglutinated %	21	28	6	6	5	6	31	34.6	28			
Porcellaneous %	7	7	6	6	2	2	4	2.0	1.5			
Hyaline %	72	66	88	87.7	93	92	65	63.4	70.5			

Notes. Shelf data from Murray (1985).

≥5% (shaded)

tests are commonly broken and incomplete; in extreme conditions, all that remains is an infill of the chambers. Examples are illustrated in Figure 10, 7-9. The ATAs of the dead assemblages were determined on the 1.0-2.0 cm samples as these were of greater volume than the surface samples (Table 3). Agglutinated taxa with a calcareous cement were destroyed during the acid treatment.

DISCUSSION

The microhabitat of epifaunal taxa foraminifera can only satisfactorily be determined from direct observation of living individuals. Strictly speaking, epifaunal refers to living either on the sediment surface or else on a firm substrate, such as a shell or other structure, on or above the sediment surface. If the sediment is soft, the distinction between epifaunal and shallow infaunal may be negligible. Examination of stained samples from depth slices below the surface provides data on infaunal taxa but the resolution is dependent on the thickness of the sediment slices. However, as the sediment-water interface forms the upper surface of the topmost sediment sample it is impossible to separate those epifaunal on the sediment surface from those having a shallow infaunal modes of life. In this study, the samples from the open shelf were ~1 cm thick while the topmost samples from the deeps were 0.5 cm thick. Thus, the **Textularia**

Table 3. Acid treated assemblage (ATA) distributions.

ATA Percent	morphotype	MD6a 1.0-2.0	MD7a 1.0-2.0	SN6b 1.0-2.0
Adercotryma wrighti	B3	4.9	3.2	5.0
Ammoscalaria pseudospiralis	C1	0.2	0.4	10.0
Cribrostomoides jeffreysii	B3	5.8	4.8	8.0
Eggerelloides medius	C1	47.0	10.8	38.0
Eggerelloides scaber	C1	2.2	19.1	
Haplophragmoides bradyi	B3	2.0	1.6	13.0
Morulaeplecta bulbosa	C1	2.2	6.0	
Paratrochammina murrayi	B3	6.7	6.0	5.0
Reophax fusiformis	C1	5.6	2.4	12.0
Textularia tenuissima	B1	9.6	24.3	1.0
flat trochamminids	D	3.3	13.2	0
ATA tests as proportion of ODA		2.35	1.00	0.07
alpha ATA		5.5	5.5	3.5
H(S) ATA		2.08	2.39	1.96
alpha ODA		12.5	15	13
H(S) ODA		2.54	3.08	2.9
B1		11	0	0
B2		0	0	0
B3		21	17	32
C1		63	69	67
C2		0	0	0
D		2	13	1

Notes. ODA = original dead assemblage. Morphotypes after Jones and Charnock (1985).

sagittula group which is known to be epifaunal (see Murray 1991, plate 3, fig. b) occurs in the 0.0-0.5 cm sample of Muck Deep (core MD7b). Because of this sampling problem Corliss (1991) extended the use of the term epifaunal to include those living in the surface 1 cm of sediment (the most common thickness of a sediment sample). This method has been followed by other authors (Barmawidjaja et al. 1992), and they extended its use down to 2 cm. However, although it may be convenient to do this it may lead to confusion or erroneous conclusions. For instance, live **Ammonia beccarii,** observed in freshly collected sediment from near Southampton, are rarely seen at the sediment surface as they live just below the sediment-water interface (personal observation) and are therefore considered to be infaunal. However, Barmawidjaja, et al. (1992) describe this species as 'apparently epifaunal'. Even infaunal taxa are not consistently present at the same depth in different areas (Corliss and Van Weering 1993; Jorissen 1999) because the controls on their position in the sediment, which are mainly food availability/type and sediment porewater geochemistry, vary both spatially and temporally. Nevertheless, it is important to gather data on microhabitat in order to define the limits of variability so that it might be applied to the interpretation of the fossil record.

With the exception of Muck Deep core MD7a, live forms are abundant only in the top 1 cm of sediment. The upper layers of replicate core MD7a were disturbed by a burrow of the polychaete worm **Pectinaria** and, as a consequence of this, live forms extended more abundantly to a greater depth (Murray, in press). Beyond the observation that most living forms are in the topmost 0.5 cm layer, there are no clear depth preferences evident. Living forms do not extend down deeper than the redox boundary; in the case of SN6, they do not extend down even close to that boundary (Table 1). In Stanton Deep core SN6b there is an anomalously abundant occurrence of **Cornuspira involvens** which must be due to a local bloom.

As described above, there are no major differences of temperature or salinity across the shelf. The bottom waters must be well-oxygenated as the redox boundary in the surface sediments is located at 1 cm or greater. However, there are differences in sediment grain size and sorting with muddy sediments being confined to the enclosed deeps. This is in turn related to the effects of storm waves and tidal currents. There may also be differences in the availability of food. Based on macroscale hydrodynamic modelling, Delhez (1998) calculated that annual mean primary production for 1989 for the areas of Muck and Stanton deeps was 150 and 75 g orgC m^{-2} $year^{-1}$, respectively. However, there is almost certainly advection of organic detritus into the deeps as this is likely to be transported with the fine-grained sediment. The precise controls on the niches of individual species remain unknown.

Although Heron-Allen and Earland (1916) had some samples from deeper water to the west of Scotland, most were from the inner shelf, and their faunas include diverse miliolids not seen in this study. They recorded 324 benthic species and varieties, 27 of which were new records for British seas. In the present study, several additional species have been found which have not previously been recorded from the Scottish shelf. These species include **Cuneata arctica, Eggerella europea, Eggerelloides medius, Morulaeplecta bulbosa, Portatrochammina murrayi, Recurvoides trochamminiformis, Cornuloculina balkwilli, Ammonia falsobeccarii, Nonionella iridea, Robertina subcylindrica,** and **Rosalina anomala.**

The relationship between shape of agglutinated taxa (morphogroups) and environment was explored by Jones and Charnock (1985). The ATAs of both Muck Deep and Stanton Deep (Table 3) are dominated by morphogroup C1 (elongate tests) with subsidiary B3 (flattened or lenticular, essentially planispiral and globular trochoid tests). According to Jones and Charnock this composition is correct for Muck Deep (geographically inner shelf but with outer shelf water depth) but not for Stanton Deep (outer shelf position and water depth). In comparison with the diversity for ODAs, the ATAs fit well with the pattern from other studies. For the Fisher alpha index, the three deeps samples fall in the field previously defined for shelf basins (Murray and Alve 2000); for the information function, H(S), they fall in the area of overlap of shelf, shelf basin, fjords, and bathyal/abyssal (Figure 11). Thus, again it is confirmed that although the ATAs are drawn from only a tiny proportion of the ODAs (0.07-2.35%, Table 3), they still preserve useful ecological information.

FAUNAL LIST

Assignment to genus generally follows that of Loeblich and Tappan (1987) except where later revision has taken place. The synonymy is restricted mainly to works relating to the UK area. Taxa are listed alphabetically by suborder. For agglutinated forms, the wall has an organic cement unless otherwise indicated.

Suborder Textulariina

Adercotryma wrighti Brönnimann and Whittaker, 1987
Figure 2.1-2.2

1987 **Adercotryma wrighti** Brönnimann and Whittaker: p. 27, figs 3B, 7A-J

Remarks:
Infaunal. This has commonly been included in **Adercotryma glomeratum** (Brady). The two are readily separated as **A. wrighti** has three chambers in the last whorl whereas **A. glomeratum** has four.

Ammoscalaria pseudospiralis (Williamson)
Figure 2.3

1858 **Proteonina pseudospiralis** Williamson: p. 2, pl. 1, figs 2, 3.
1947 **Ammoscalaria pseudospiralis** (Williamson); Höglund: p. 159-162, pl. 31, fig.1.

Remarks:
Infaunal. Recorded as **Haplophragmium pseudospirale** (Williamson) by Heron-Allen and Earland (1916) who noted its great variability of form. Adult individuals are large (length commonly in excess of 1 mm). Young forms have an incompletely developed uniserial section.

Bigenerina nodosaria d'Orbigny, 1826
Figure 2.4

1826 **Bigenerina nodosaria** d'Orbigny: p. 261, pl. 11, figs 9-12.

Remarks:
The wall has a calcareous cement. Only rare dead individuals.

Cribrostomoides jeffreysii (Williamson)
Figure 2.5

1858 **Nonionina jeffreysii** Williamson: p. 34-35, pl. 3, figs 72, 73.
1971 **Cribrostomoides jeffreysii** (Williamson); Murray: p. 23, pl. 4, figs 1-5.

Remarks:
Epifaunal. Considered by Sturrock and Murray (1981) to be epifaunal, attached but also able to move freely. Placed in **Veleroninoides** by Jones (1994). Recorded as **Haplophragmium canariense** (d'Orbigny) by Heron-Allen and Earland (1916).

Cuneata arctica (Brady)
Figure 2.6

1881a **Reophax arctica** Brady: p. 405, pl. 21, figs 2a, b.
1979 **Cuneata arctica** (Brady); Fursenko, in Fursenko et al.: p. 21, pl. 3, figs 13, 14.

Remarks:
This is rare and was found only through ATA studies. In the seas off southern England, this species is abundant only on the inner shelf (Murray and Alve 2000) where the waters are vertically mixed throughout the year.

Deuterammina rotaliformis (Heron-Allen and Earland)
Figure 2.7-2.8

1911 **Trochammina rotaliformis** J Wright ms: Heron-Allen and Earland, p. 309 (availability of name).
1983 **Deuterammina (Deuterammina) rotaliformis** (Heron-Allen and Earland); Brönnimann and Whittaker: p. 349, figs 1-8, 25.

Remarks:
Likely to be epifaunal from its morphology. Pre-1983 records of this species are considered to be unreliable due to the absence of a type illustration (Brönnimann and Whittaker, 1983).

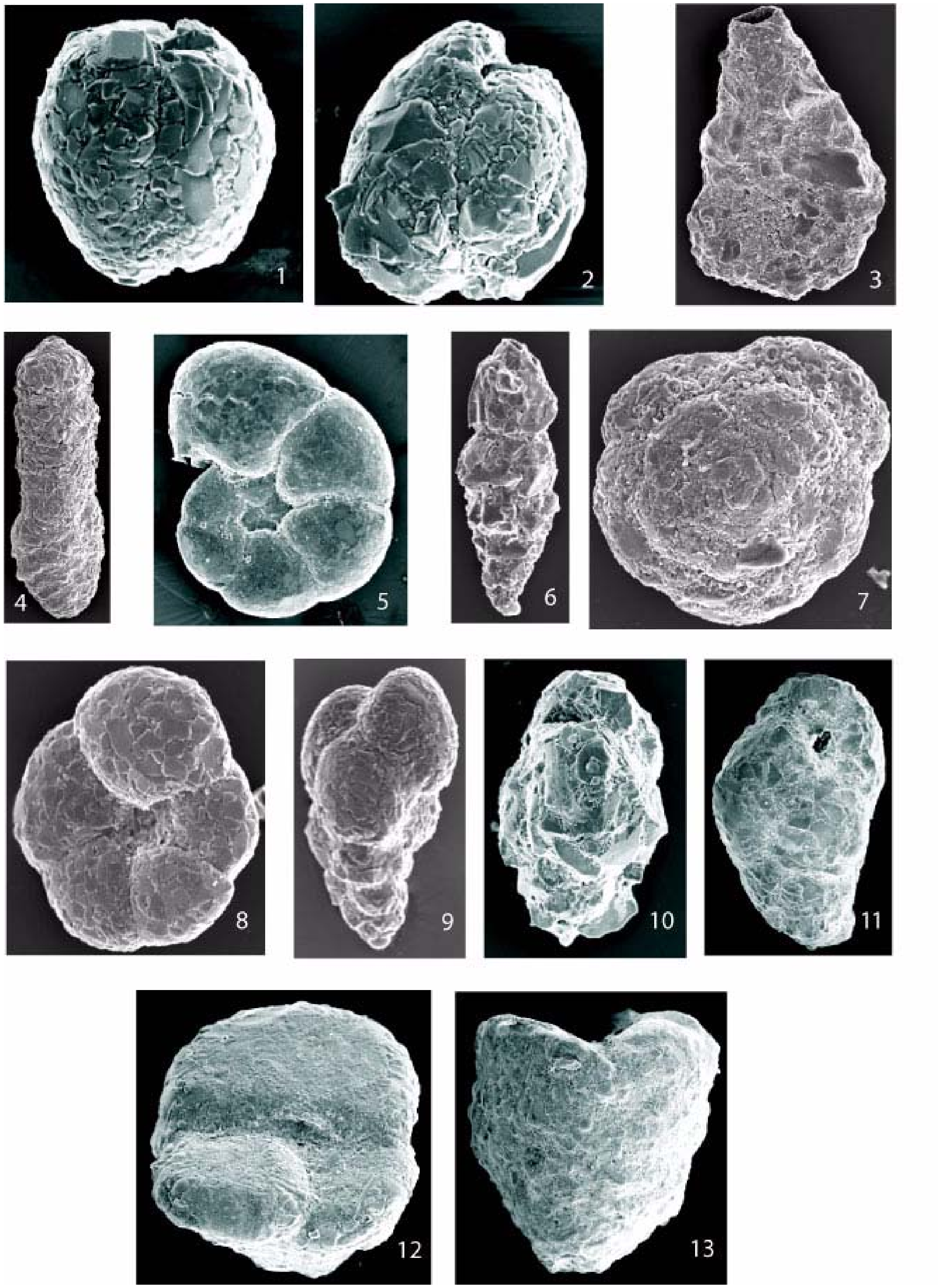

Figure 2. L = length, D = greatest diameter. **1-2. Adercotryma wrighti** Brönnimann and Whittaker, L 170 µm. **3. Ammoscalaria pseudospiralis** Williamson, L 830 µm. **4. Bigenerina nodosaria** d'Orbigny, L 1200 µm. **5. Cribrostomoides jeffreysii** (Williamson), D 400 µm. **6. Cuneata arctica** (Brady), L 200 µm. **7-8. Deuterammina rotaliformis** (Heron-Allen and Earland), D 145 µm. **9. Eggerella europea** (Christensen), L 165 µm. **10. Eggerelloides medius** (Höglund), L 250 µm. **11. Eggerelloides scaber** (Williamson), L 460 µm. **12-13. Gaudryina rudis** Wright, D 300, L 920 µm.

Eggerella europea (Christiansen)
Figure 2.9

1958 **Verneuilina europeum** Christiansen: p. 66; new name for **Verneuilina advena** Cushman of Höglund, 1947, p. 185, pl. 13, fig. 11, text-fig. 169.
2000 **Eggerella europeum** (Christensen) (*sic*); Murray and Alve: p. 325, pl. 1, figs 15-17.

Remarks:
This is a tiny form which is easily overlooked and was found only through the ATA analyses. It is readily separated from **Eggerelloides scaber** not only on size but also because it has a more elongated tapered test.

Eggerelloides medius (Höglund)
Figure 2.10

1947 **Verneuilina medius** Höglund: p. 184-185, pl. 13, figs 7-10, pl. 30, fig. 21.
2000 **Eggerelloides medius** (Höglund); Murray and Alve: p. 325, pl.2, figs 16, 17.

Remarks:
Infaunal. This species differs from **Eggerelloides scaber** in having a much coarser and rougher wall texture, with somewhat overhanging proximal chamber margins, a less tapered test, and commonly a brownish wall colour. In southern UK waters, **E. medius** is confined to water depths >90 m where some mud is present in the sediment (Murray and Alve, 2000).

Eggerelloides scaber (Williamson)
Figure 2.11

1858 **Bulimina scabra** Williamson: p. 65, pl. 3, figs 136, 137 (labelled **B. arenacea** on plate caption).
1973 **Eggerelloides scabrum** (Williamson) (*sic*); Haynes: p. 44, pl. 2, figs 7, 8, pl. 19, figs 10, 11, text-fig. 8, nos 1-4.

Remarks:
Infaunal. See remarks on **E. medius**. It is likely that these two species have been grouped together in past studies of UK foraminifera and that is certainly so for southern England (Murray, 1970, 1979; see also Murray and Alve, 2000). Recorded by Heron-Allen and Earland (1916) as **Verneuilina polystropha** (Reuss).

Gaudryina rudis Wright, 1900
Figure 2.12-2.13

1900 **Gaudryina rudis** Wright: p. 53, pl. 2, fig. 1a, b.

Remarks:
Epifaunal. The wall has a calcareous cement. **Gaudryina** has a solid wall so Loeblich and Tappan (1989) erected the genus **Connemarella** for forms with the same morphology but with a canaliculate wall and named **G. rudis** as the type species. However, this generic name is rarely used in the literature.

Haplophragmoides bradyi (Robertson)
Figure 3.1-3.2

1887 **Trochammina robertsoni** Brady: p. 893, no type figure.
1891 **Trochammina bradyi** Robertson: p. 388; new name for **Trochammina robertsoni** Brady, 1887.
1971 **Haplophragmoides bradyi** (Robertson); Murray: p. 25, pl. 5, figs 1, 2.

Remarks:
Infaunal. This is a distinctive form having a deep brown colour and a shiny, very finely agglutinated, test wall.

Liebusella goesi Höglund, 1947
Figure 3.3

1947 **Liebusella goesi** Höglund: p. 194-198, pl. 14, figs 4-8, text-figs 177-179.

Remarks:
Infaunal.

Morulaeplecta bulbosa Höglund, 1947
Figure 3.4-3.5

1947 **Morulaeplecta bulbosa** Höglund: p. 165-167, pl. 12, fig. 2, text-figs 142a, b.

Remarks:
This form is rare and was found only through the ATA studies.

Portatrochammina murrayi Brönnimann and Zaninetti, 1984
Figure 3.6-3.7

1984 **Portatrochammina murrayi** Brönnimann and Zaninetti: p. 72, pl. 5, figs 7, 12-15.

Remarks:
This rare form was only through the ATA analyses. Previously reported from the Celtic Sea, Bristol Channel, and Western Approaches to the English Channel but common only at depths >80 m (Murray and Alve, 2000) where the waters show seasonal thermohaline stratification.

Recurvoides trochamminiformis Höglund, 1947
Figure 3.9-3.10

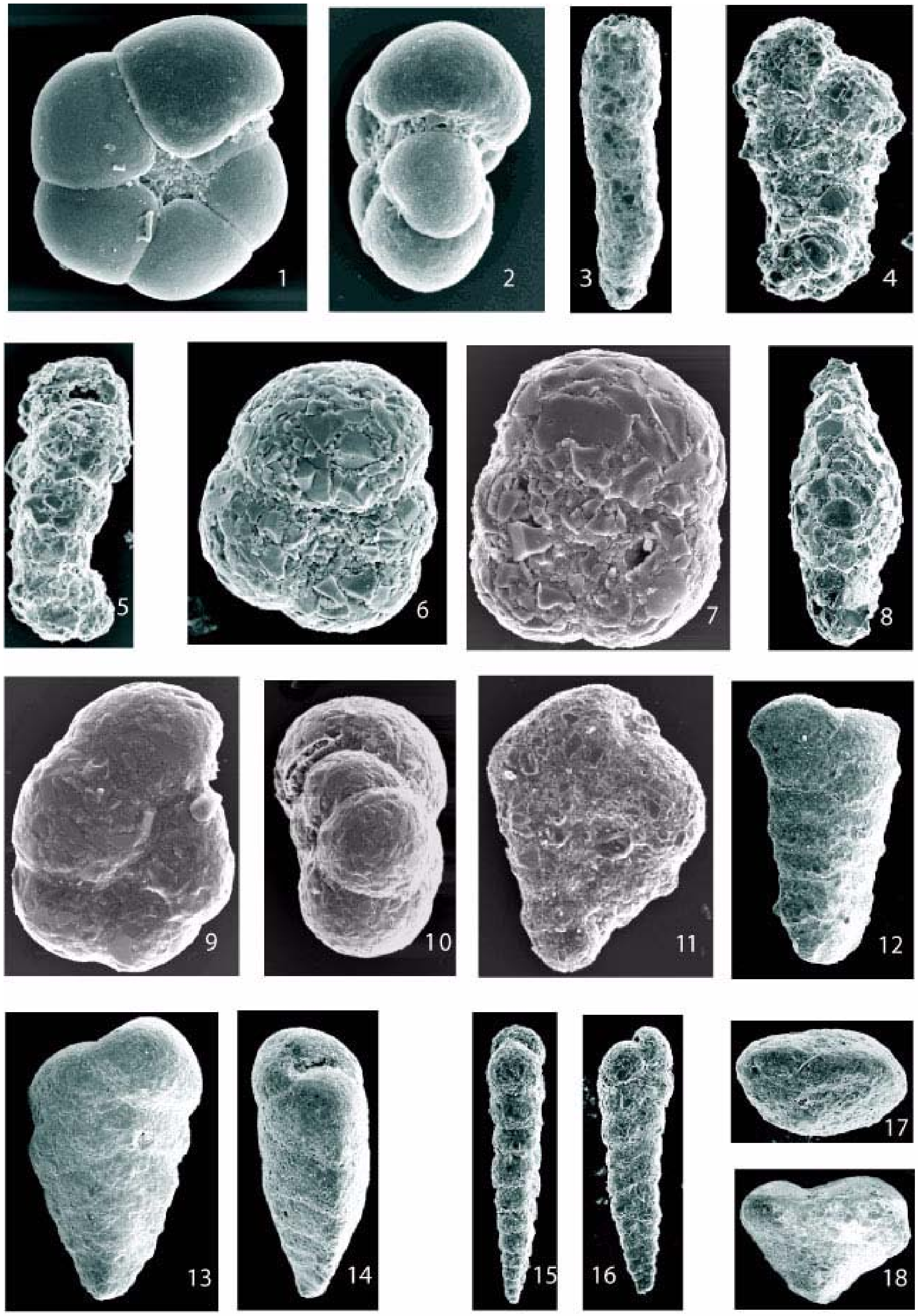

Figure 3. L = length, D = greatest diameter. **1- 2. Haplophragmoides bradyi** (Robertson), D 230 µm. **3. Liebusella goesi** Höglund, L 1200 µm. **4- 5. Morulaeplecta bulbosa** Höglund, L 240 µm. **6- 7. Paratrochammina murrayi** Brönnimann and Zaninetti, D 90, D 130 µm. **8. Reophax fusiformis** (Williamson), L 600 µm. **9-10. Recurvoides trochamminiformis** Höglund, L 235, L 220 µm. **11. Siphotextularia flintii** (Cushman), L 210 µm. **12-14. 'Textularia sagittula** group' of Murray (1971), illustrated form is **Spiroplectammina wrightii** (Silvestri) of authors, L 830, L 730, L 870 µm. **15-16. Textularia tenuissima** Earland, L 360 µm. **17-18. Textularia truncata** Höglund, D 210, D 315 µm.

1947 **Recurvoides trochamminiforme** Höglund (*sic*): p. 149-150, pl. 11, figs 7, 8, pl. 30, fig. 23, text-fig. 120.

Remarks:
Infaunal. Distribution as for **P. murrayi**.

Reophax fusiformis (Williamson)
Figure 3.8

1858 **Proteonina fusiformis** Williamson: p. 1, pl. 1, fig. 1.
1884 **Reophax fusiformis** (Williamson); Brady: p. 290, pl. 30, figs 7-11.

Remarks:
Infaunal.

Siphotextularia flintii (Cushman)
Figure 3.11

1911 **Textularia flintii** Cushman: p. 21, text-figs 36a, b.

Remarks:
Very rare dead. The wall has a calcareous cement.

'Textularia sagittula Defrance group' of Murray (1971)
Figure 3.12-3.14

1824 **Textularia sagittula** Defrance: p. 177, pl. 13, figs 5, 5a.
1971 **Textularia sagittula** Defrance group of Murray: p. 31, figs. 1-9.

Remarks:
Although not recorded in life position in this study, it is known to attach itself aperture down to substrates such as shells and hydroids (e.g., Heron-Allen and Earland, 1916). Considered by Sturrock and Murray (1981) to be epifaunal, attached but also able to move freely. This is a broad grouping of textularians having a calcareous cemented wall. It includes **Spiroplectammina wrightii** (Silvestri 1923) as illustated in Figures 3.12-3.14.

Textularia tenuissima Earland, 1933
Figure 3.15-3.16

1933 **Textularia tenuissima** Earland: p. 95, pl. 3, figs 21-30.

Remarks:
Infaunal. See Höglund (1947) for a lengthy discussion of this species.

Textularia truncata Höglund, 1947
Figure 3.17-3.18

1947 **Textularia truncata** Höglund: p. 175-176, pl. 12, figs 8, 9, text-figs 147-149.

Remarks:
Rare dead. The wall has a calcareous cement.

Suborder Spirillinina

Spirillina vivipara Ehrenberg, 1843
Figure 4.1

1843 **Spirillina vivipara** Ehrenberg: p. 323, pl. 3, fig. 41.

Remarks:
Epifaunal and attached (Heron-Allen and Earland, 1916). Considered by Sturrock and Murray (1981) to be epifaunal, attached but also able to move freely. Rare dead.

Suborder Miliolina

Biloculinella depressa (d'Orbigny)
Fig. 4.2-4.3

1826 **Biloculina depressa** d'Orbigny: p. 298.
2000 **Biloculinella depressa** (d'Orbigny): Murray, p. 44.

Remarks:
Rare living precludes determination of habitat.

Cornuloculina balkwilli (Macfadyen)
Fig. 4.4

1939 **Ophthalmidium balkwilli** Macfadyen: p. 166, text-fig. 2.
1981 **Cornuloculina balkwilli** (Macfadyen); Sturrock and Murray: p. 253.

Remarks:
Rare dead. Considered by Sturrock and Murray (1981) to be epifaunal, attached but also able to move freely.

Cornuspira involvens (Reuss)
Figure 4.5

1850 **Operculina involvens** Reuss: p. 370, pl. 46, figs 20a, b.
1994 **Cornuspira involvens** (Reuss); Jones: p. 26, pl. 11, figs. 1-3.

Remarks:
Infaunal. Exceptionally abundant living megalospheric individuals in one sample from Stanton Deep; this is presumed to be a bloom (Murray, in press). Heron-Allen and Earland (1916) also commented on the greater abundance of megalospheric tests.

Miliolinella subrotunda (Montagu)
Fig. 4.6

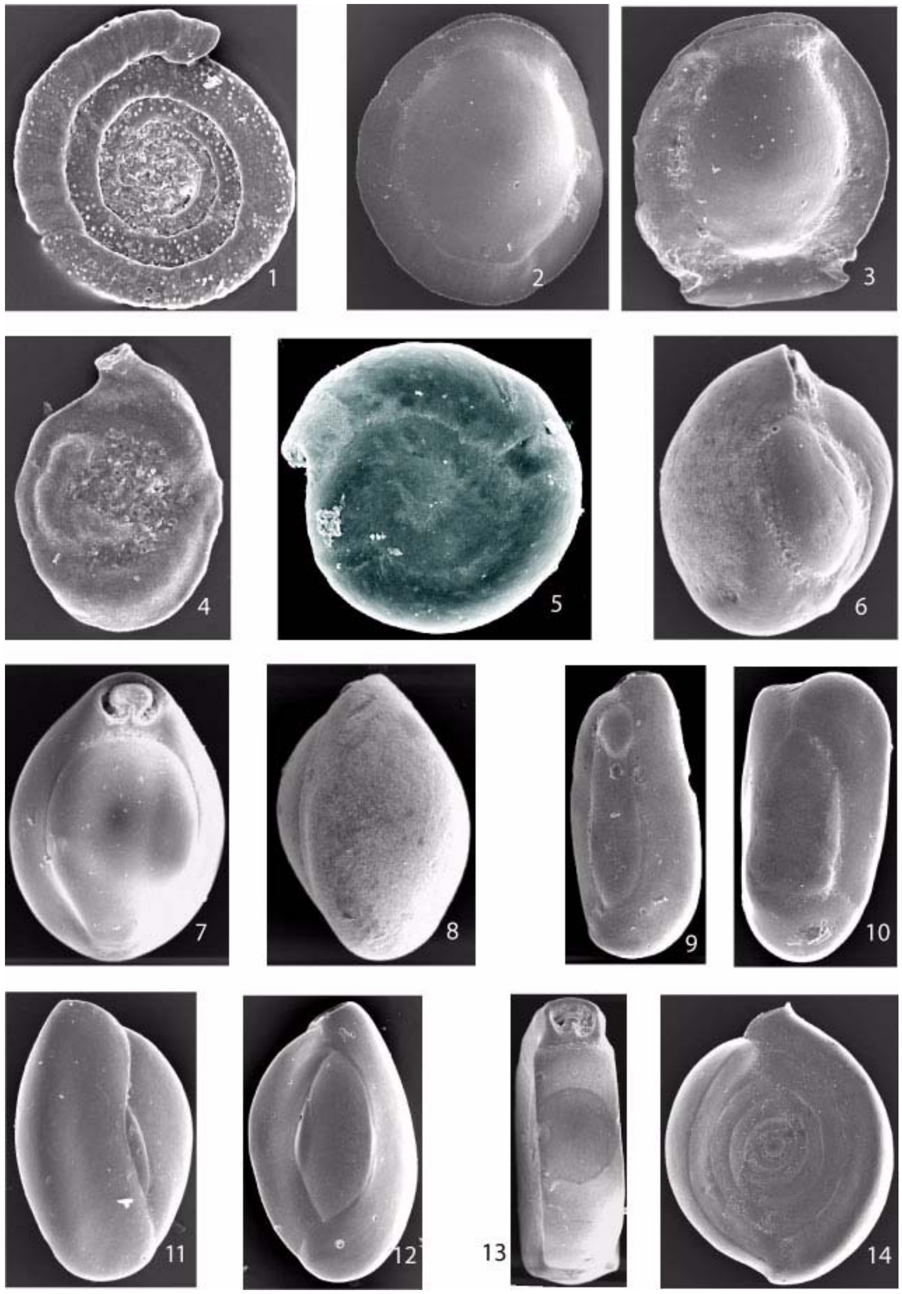

Figure 4. L = length, D = greatest diameter. **1. Spirillina vivipara** Ehrenberg, D 650 µm. **2-3. Biloculinella depressa** (d'Orbigny), L 750, L 650 µm. **4. Cornuloculina balkwilli** (Macfadyen), L 340 µm. **5. Cornuspira involvens** (Reuss), D 190 µm. **6. Miliolinella subrotunda** (Montagu), L 270 µm. **7-8. Pyrgo williamsoni** (Silvestri), L 575 µm. **9-10. Quinqueloculina lata** Terquem, L 540, L 350 µm. **11-12. Quinqueloculina seminulum** (Linné), L 360, L 550 µm. **13-14. Spiroloculina excavata** d'Orbigny, L 550, L 520 µm.

1803 **Vermiculum subrotundum** Montagu: p. 521. Figured by Walker and Boys (1784), pl. 1, fig. 4.
1973 **Miliolinella subrotunda** (Montagu); Haynes: p. 36, pl. 5, figs 5, 6, 12; pl. 32, figs 8, 9; text-fig. 11, nos 1-4; text-fig. 12, nos 1-11.

Remarks:
Probably epifaunal but occurs in top 0.5 cm of sediment.

Pyrgo williamsoni (Silvestri)
Figure 4.7-4.8

1923 **Biloculina williamsoni** Silvestri: p. 73. Figured by Williamson (1858), as **Biloculina ringens** typica, pl. 6, figs 169-170.
1973 **Pyrgo williamsoni** (Silvestri); Haynes: p. 61, text-fig. 14, nos 1-3.

Remarks:
Dead only.

Quinqueloculina lata Terquem,1876
Figure 4.9-4.10

1876 **Quinqueloculina lata** Terquem: p. 82, pl. 11, figs 8a-c.

Remarks:
Dead only.

Quinqueloculina seminulum (Linné)
Figure 4.11-4.12

1758 **Serpula seminula** Linné: p. 786. Figured by Plancus (1739), pl. 2, fig. 1a-c.
1973 **Quinqueloculina seminulum** (Linné); Haynes: p. 74, pl. 7, figs 14, 19; pl. 8, figs 1-3; text-fig. 18, nos 1-4.

Remarks:
Epifaunal.

Spiroloculina excavata d'Orbigny, 1846
Figure 4.13-4.14

1846 **Spiroloculina excavata** d'Orbigny: p. 271, pl. 16, figs 19-21.

Remarks:
Dead only.

Suborder Lagenina

Amphicoryna scalaris (Batsch)
Figure 5.1

1791 **Nautilus (Orthoceras) scalaris** Batsch: p. 1, 4, pl. 2, figs 4a, b.
1971 **Amphicoryna scalaris** (Batsch): p. 77, pl. 29, figs 1-4.

Remarks:
Recorded by Heron-Allen and Earland (1916) as **Nodosaria scalaris** (Batsch).
Live in the 0.0-0.5 cm sample in Muck Deep, MD7b.

Dentalina subarcuata (Montagu)
Figure 5.2

1803 **Nautilus subarcuatus** Montagu: p. 198, pl. 6, fig. 5.
1971 **Dentalina subarcuata** (Montagu); Murray: p. 79, pl. 30, figs 4, 5.

Remarks:
Rare.

Fissurina marginata (Montagu)
Figure 5.3-5.4

1803 **Vermiculum marginatum** Montagu: p. 524. Figured by Walker and Boys (1784), pl. 1, fig. 7.
1971 **Fissurina marginata** (Montagu); Murray: p. 97, pl. 39, figs 4-6.

Remarks:
Rare.

Fissurina orbignyana Seguenza, 1862
Figure 5.5-5.6

1862 **Fissurina orbignyana** Seguenza: p. 66, pl. 2, figs 19, 20.

Remarks:
Rare.

Lagena substriata Williamson, 1848
Figure 5.7

1848 **Lagena substriata** Williamson: p. 15, pl. 2, fig. 12.

Remarks:
Rare.

Laryngosigma lactea (Walker and Jacob)
Figure 5.8-5.9

1798 **Serpula lactea** Walker and Jacob: p. 634, pl. 14, fig. 4.
1973 **Laryngosigma lactea** (Walker and Jacob); Haynes: p. 103, text-fig. 21, nos 8-12.

Remarks:
Rare.

Oolina williamsoni (Alcock)
Figure 5.10

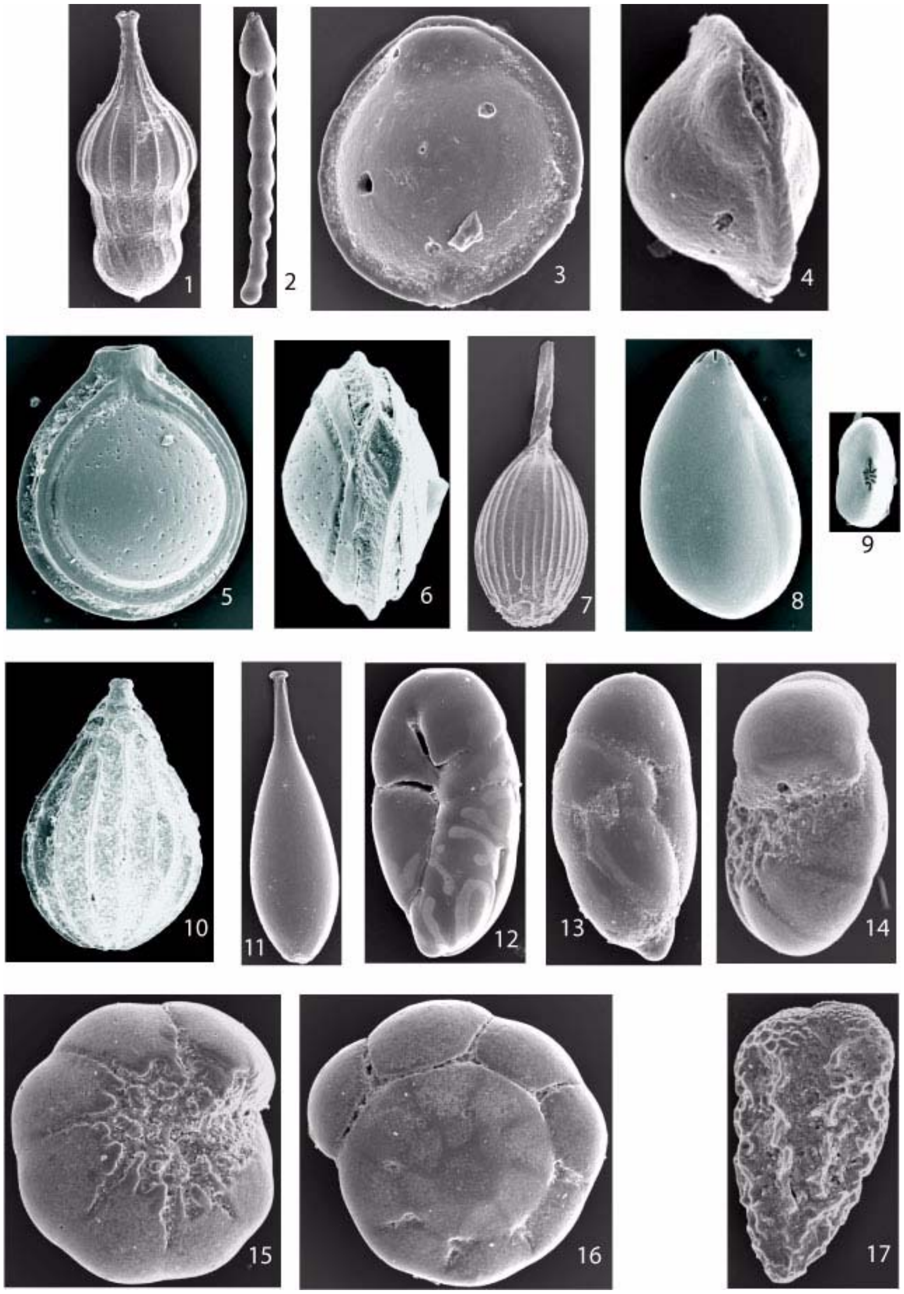

Figure 5. L = length, D = greatest diameter. **1. Amphicoryna scalaris** (Batsch), L 600 µm. **2. Dentalina subarcuata** (Montagu), L 1.9 mm. **3-4. Fissurina marginata** (Montagu), L 165, L 145 µm. **5-6. Fissurina orbignyana** Seguenza, L 600 µm. **7. Lagena substriata** Williamson, L 600 µm. **8-9. Laryngosigma lactea** (Walker and Jacob), L 210, L 450 µm. **10. Oolina williamsoni** (Alcock), L 500 µm. **11. Procerolagena clavata** (d'Orbigny), L 600 µm. **12-13. Robertina subcylindrica** (Brady), L 370, L 325 µm. **14-16. Ammonia falsobeccarii** (Rouvillois), D 400, L 340, D 430 µm. **17. Bolivina pseudoplicata** Heron-Allen and Earland, L 240 µm.

1865 **Entosolenia williamsoni** Alcock: p. 193. Illustrated by Wright (1876-7), pl. 4, fig. 14 (as **Lagena williamsoni**).
1971 **Oolina williamsoni** (Alcock); Murray: p. 95, pl. 38, figs 4-6.

Remarks:
Rare.

Procerolagena clavata (d'Orbigny)
Figure 5.11

1846 Oolina clavata d'Orbigny: p. 24, pl. 1, figs 2, 3.
1994 **Procerolagena clavata** (d'Orbigny); Jones: p. 62, pl. 56, figs 8?, 9.

Remarks:
Rare.

Suborder Robertinina

Robertina subcylindrica (Brady)
Figure 5.12-5.13

1881b **Bulimina subcylindrica** Brady: p. 56.
1994 **Robertina subcylindrica** (Brady); Jones: p. 55: pl. 50, fig. 16.
Remarks:
Rare live and dead.

Suborder Rotaliina

Ammonia falsobeccarii (Rouvillois)
Figure 5.14-15.16

1974 **Pseudoeponides falsobeccarii** Rouvillois: p. 4, pl. 1, figs 1-12.
2001 **Ammonia falsobeccarii** (Rouvillois); Gross: p. 69.

Remarks:
Infaunal. Rare live and dead. This is a southern form, and this record extends its northward distribution.

Bolivina pseudoplicata Heron- Allen and Earland, 1930
Figure 5.17

1930 **Bolivina pseudoplicata** Heron-Allen and Earland: p. 81, pl. 3, figs 36-40.

Remarks:
Infaunal. Rare live and dead.

Bolivinellina pseudopunctata (Höglund)
Figure 6.1

1947 **Bolivina pseudopunctata** Höglund: p. 273, pl. 24, figs 5a, b; pl. 32, figs 23, 24; text-figs 280, 281, 287.
1971 **Brizalina pseudopunctata** (Höglund); Murray: p. 109, pl. 44, figs 3-6.
1994 **Bolivinellina pseudopunctata** (Höglund); Alve and Murray: p. 27.

Remarks:
Infaunal. Rare live and dead.

Brizalina difformis (Williamson)
Figure 6.2

1858 **Textularia variabilis** Williamson var. **difformis** Williamson: p. 77, pl. 6, figs 166, 167.
1971 **Brizalina difformis** (Williamson); Murray: p. 109, pl. 44, figs 1, 2.

Remarks:
Rare dead. Recorded by Heron-Allen and Earland (1916) as **Bolivina difformis** (Williamson).

Brizalina spathulata (Williamson)
Figure 6.3

1858 **Textularia variabilis** Williamson var. **spathulata** Williamson: p. 76, pl. 6, figs 164, 165.
1971 **Brizalina spathulata (**Williamson); Murray: p. 111, pl. 45, figs 1-4.

Remarks:
Infaunal.

Bulimina marginata d'Orbigny, 1826
Figure 6.4-6.5

1826 **Bulimina marginata** d'Orbigny **sensu** Höglund (1947): p. 227, pl. 20, figs 1, 2; pl. 22, fig. 1; text-figs 205-218.

Remarks:
Infaunal. In the Skagerrak, Corliss and Van Weering (1993), found a subsurface maximum at 13-15 cm in muddy sands in two cores. Heron-Allen and Earland (1916) commented on the difficulties of separating species of **Bulimina** because of their variablility. This group intergrades with forms like **Bulimina aculeata** but here they are treated as a single variable group. See also Verhallen (1987), Jorissen (1988), Collins (1989), and Burgess and Schnitker (1990) for a discussion of the problem.

Cancris auricula (Fichtel and Moll)
Figure 6.6-6.7

1798 **Nautilus auricula** Fichtel and Moll: p. 108, pl. 20, figs a-c.
1971 **Cancris auricula** (Fichtel and Moll); Murray: p. 137, pl. 57, figs 1-7.

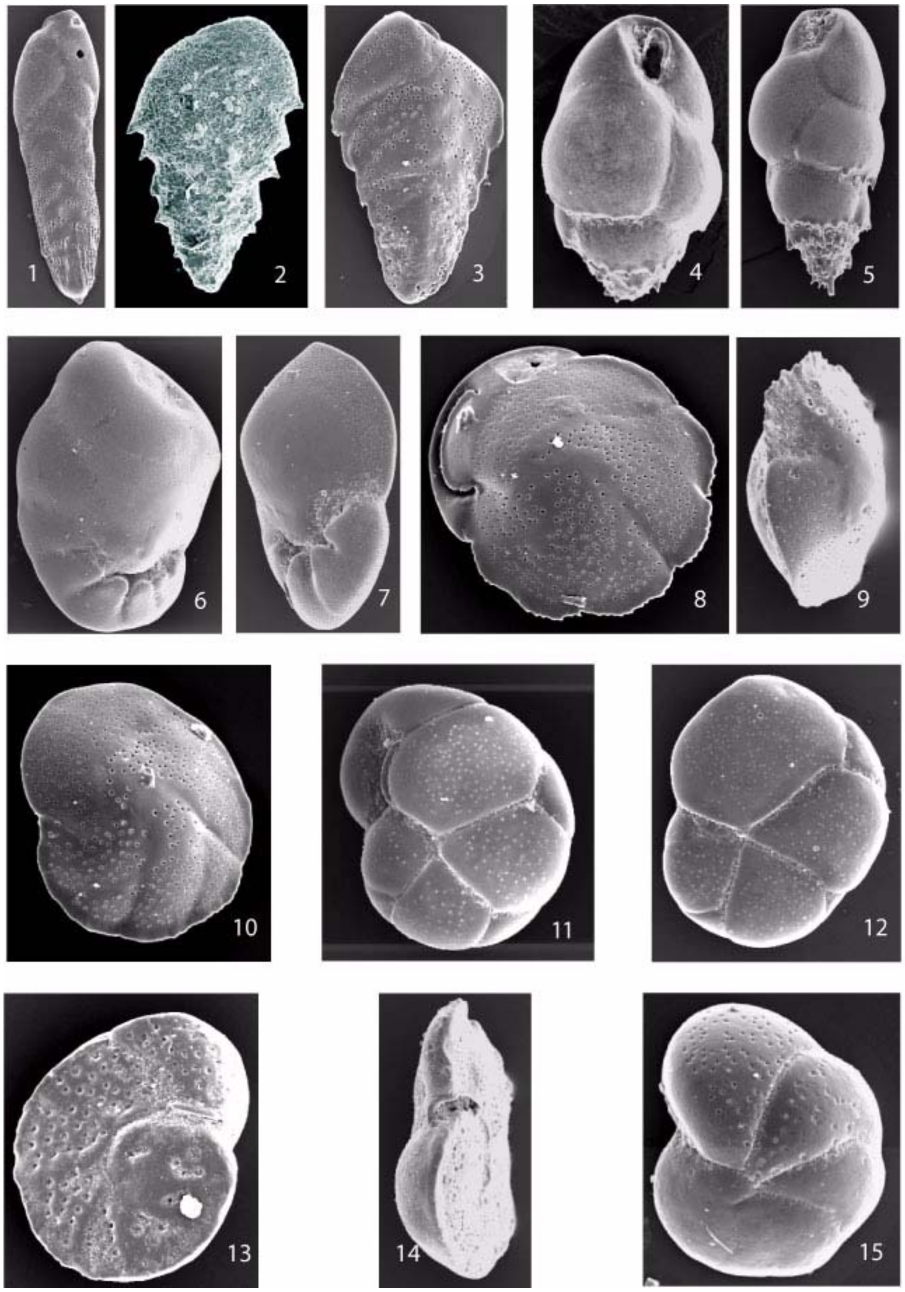

Figure 6. L = length, D = greatest diameter. **1. Bolivinellina pseudopunctata** (Höglund), L 625 µm. **2. Brizalina difformis** (Williamson), L 340 µm. **3. Brizalina spathulata** (Williamson), L 330 µm. **4-5. Bulimina marginata** d'Orbigny, 1826 sensu Höglund (1947) L 320, L 520, L 250, D 260 µm. **6-7. Cancris auricula** (Fichtel and Moll), L 710, L 760 µm. **8-10. Cassidulina laevigata d'Orbigny,** D 300 µm. **11-12. Cassidulina obtusa** Williamson, D230 µm. **13-15. Cibicides lobatulus** (Walker and Jacob), D 300 µm.

Remarks:
Possibly infaunal. Rare live and dead. Recorded by Heron-Allen and Earland (1916) as **Pulvinulina auricula** (Fichtel and Moll).

Cassidulina laevigata d'Orbigny, 1826
Figure 6.8-6.10

1826 **Cassidulina laevigata** d'Orbigny: p. 282, pl. 5, figs 4, 5.

Remarks:
Infaunal. In the Skagerrak this species has maxima at the surface and at 14-15 cm in some cores but just occurs at the surface in another (Corliss and Van Weering, 1993). Heron-Allen and Earland (1916) included both carinate and rounded margin forms. Most recorded here are carinate.

Cassidulina obtusa Williamson, 1858
Figure 6.11-6.12

1858 **Cassidulina obtusa** Williamson: p. 69, pl. 6, figs 143, 144.

Remarks:
Infaunal. Recorded by Heron-Allen and Earland (1916) as **Cassidulina crassa** d'Orbigny.

Cibicides lobatulus (Walker and Jacob)
Figure 6.13-6.15

1798 **Nautilus lobatulus** Walker and Jacob: p. 642, pl. 14, fig. 36.
1971 **Cibicides lobatulus** (Walker and Jacob); Murray: p. 175, pl. 73, figs 1-7.

Remarks:
Considered by Sturrock and Murray (1981) to be epifaunal, attached, and immobile. Dead only. Recorded by Heron-Allen and Earland (1916) as **Truncatulina lobatula** (Walker and Jacob).

Cibicides refulgens de Montfort, 1808
Figure 7.1-7.2

1808 **Cibicides refulgens** de Montfort: p. 122, 31me genre.

Remarks:
Dead only. Recorded by Heron-Allen and Earland (1916) as **Truncatulina refulgens** (Montfort).

Discorbinoides millettii (Wright)
Figure 7.3-7.4

1911 **Discorbina millettii** Wright: p. 13, pl. 2, figs 14-17.
1971 **Glabratella millettii** (Wright); Murray: p. 139, pl. 58, figs 1-4.
2000 **Discorbinoides millettii (**Wright); Murray: p. 44.

Remarks:
Rare dead.

Elphidium earlandi Cushman
Figure 7.5

1936 **Elphidium earlandi** Cushman: p. 85, pl. 15, figs 51, b.

Remarks:
Rare dead.

Elphidium excavatum (Terquem)
Figure 7.6-7.7

1875 **Polystomella excavata** Terquem: p. 25, pl. 2, figs 2a-f.
1971 **Elphidium excavatum** (Terquem); Murray: p. 159, pl. 66, figs 1-7.

Remarks:
Rare dead. This is a variable species which includes the form **Elphidium selseyense** Heron-Allen and Earland according to Miller, et al. (1982).

Elphidium gerthi Van Voorthuysen, 1957
Figure 7.8

1957 **Elphidium gerthi** Van Voorthuysen: p. 32, pl. 23, figs 12a, b.

Remarks:
Rare dead.

Elphidium magellanicum Heron-Allen and Earland, 1932
Figure 7.9-7.10

1932 **Elphidium magellanicum** Heron-Allen and Earland: p. 440, pl. 16, figs 26-28.

Remarks:
Rare dead.

Epistominella vitrea Parker, 1953
Figure 7.11-7.13

1953 **Epistominella vitrea** Parker: p. 9, pl. 4, figs 34-6, 40-1.

Remarks:
Infaunal.

Fursenkoina schreibersiana (C_j_ek)
Figure 8.1

1848 **Virgulina schreibersiana** C_j_ek: p. 147, pl. 13, figs 18-21.
1971 **Fursenkoina schreibersiana** (C_j_ek); Murray: p. 185, pl. 77, figs 6-9.

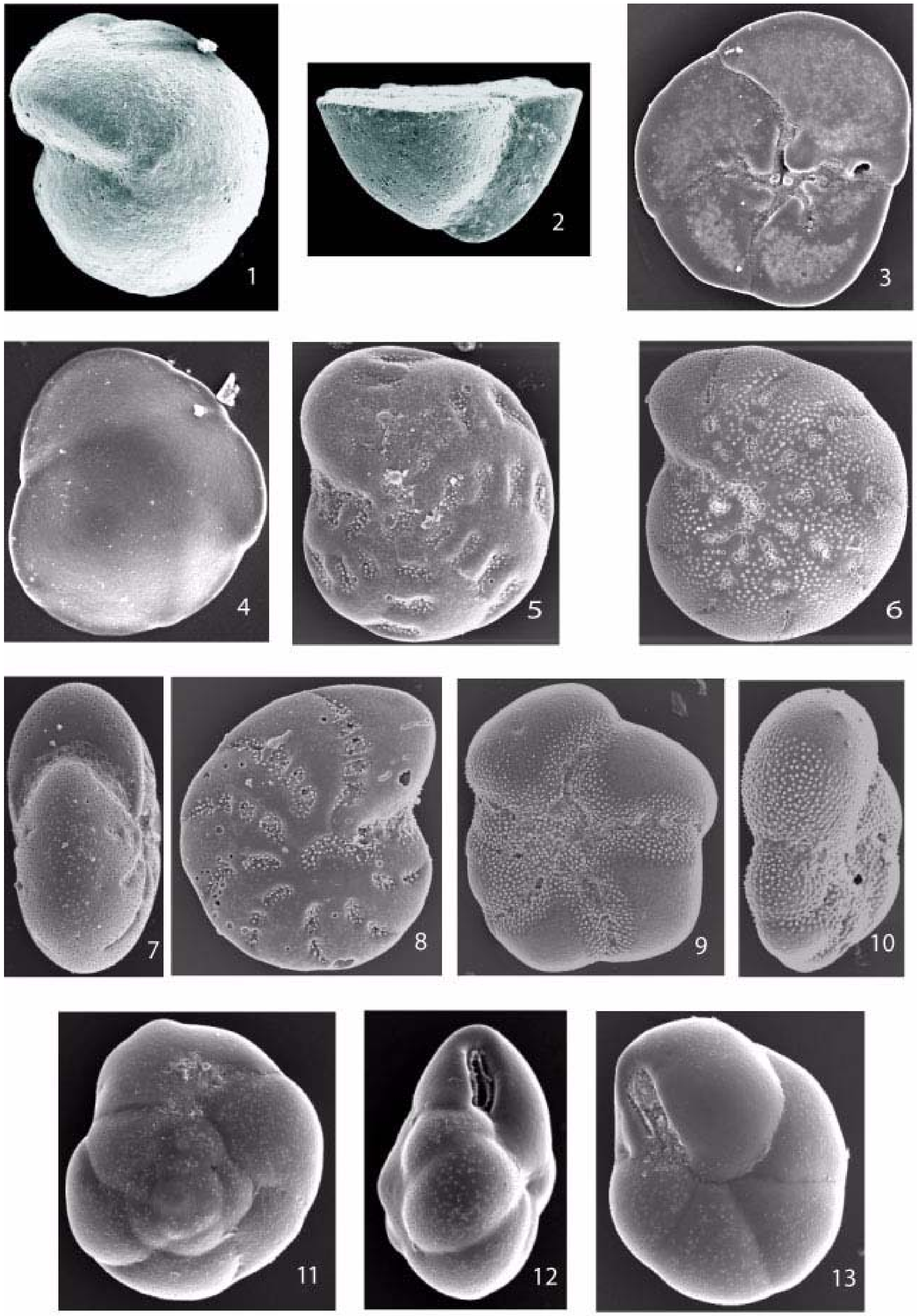

Figure 7. L = length, D = greatest diameter. **1-2. Cibicides refulgens** de Montfort, D 875 µm. **3-4. Discorbinoides millettii** (Wright), D 210, D 150 µm. **5. Elphidium earlandi** Cushman, D 350 µm. **6-7. Elphidium excavatum** (Terquem) (Elphidium selseyense Heron-Allen and Earland of some authors), D 310, D 300 µm. **8. Elphidium gerthi** Van Voorthuysen, D 300 µm. **9-10. Elphidium magellanicum** Heron-Allen and Earland, D 300 µm. **11-13. Epistominella vitrea** Parker, D 150 µm.

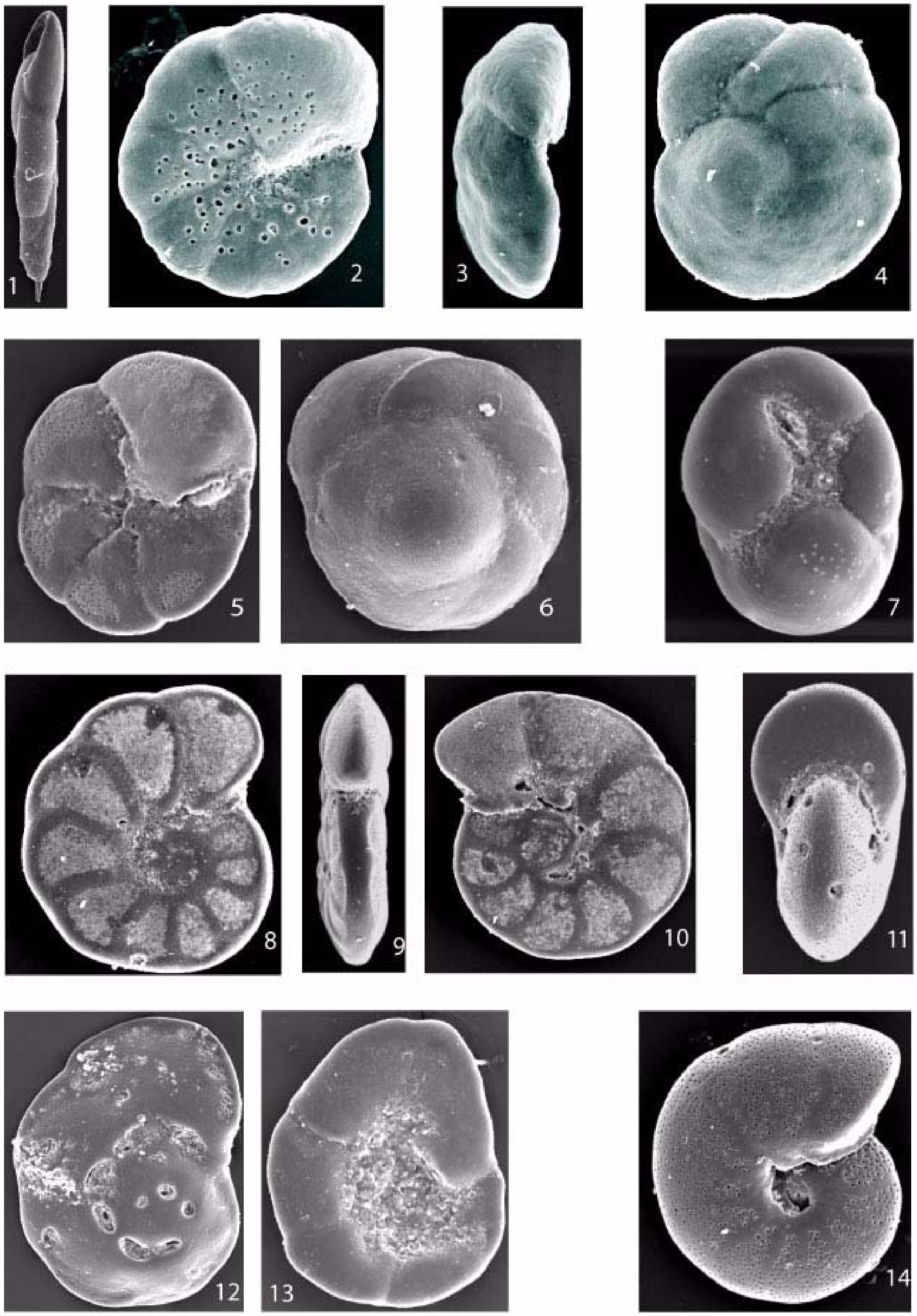

Figure 8. L = length, D = greatest diameter. **1. Fursenkoina schreibersiana** (Czjzek), L 460 µm. **2-4. Gavelinopsis caledonia** Murray and Whittaker, D 130, D 120, D 130 µm. **5-6. Gavelinopsis praegeri** (Heron-Allen and Earland), D 300 µm. **7. Globocassidulina subglobosa** (Brady), L 150 µm. **8-10. Hyalinea balthica** (Schröter), D 450 µm. **12-13. Lamarckina haliotidea** (Heron-Allen and Earland), D230, D 170 µm. **11, 14. Melonis barleeanus** (Williamson), D 450 µm.

Remarks:
Infaunal. Recorded by Heron-Allen and Earland (1916) as **Virgulina schreibersiana**.

Gavelinopsis caledonia Murray and Whittaker, 2001
Figure 8.2-8.4

2001 **Gavelinopsis caledonia** Murray and Whittaker: p. 179, pl. 1, figs 1-10; pl. 2, figs 1-7.

Remarks:
Epifaunal. A specimen in the Heron-Allen and Earland collections (The Natural History Museum, London) is attached to a shell fragment. Recorded by them (1916) as **Discorbina polyrraphes** (Reuss). Rare dead.

Gavelinopsis praegeri (Heron-Allen and Earland)
Figure 8.5-8.6

1913 **Discorbina praegeri** Heron-Allen and Earland: p. 122, pl. 10, figs 8-10.
1971 **Gavelinopsis praegeri** (Heron-Allen and Earland); Murray: p. 133, pl. 55, figs. 1-5.

Remarks:
Dead; sometimes common. Considered by Sturrock and Murray (1981) to be epifaunal, attached but also able to move freely.

Globocassidulina subglobosa (Brady)
Figure 8.7

1881b **Cassidulina sublobosa** Brady: p. 60; figured by Brady (1884), pl. 54, figs 17*a*-c.
1974 **Globocassidulina subglobosa** (Brady); Jones: p. 60: pl. 54, figs 17*a*-c.

Remarks:
Probably infaunal.

Hyalinea balthica (Schröter)
Figure 8.8-8.10

1783 **Nautilus balthicus** Schröter: p. 20, pl. 1, fig. 2.
1971 **Hyalinea balthica** (Schröter); Murray: p. 173, pl. 72, figs 5-7.

Remarks:
Live forms in top 0.5 cm so may be epifaunal. Common dead. Recorded by Heron-Allen and Earland (1916) as **Operculina ammonoides** (Gronovius).

Lamarckina haliotidea (Heron-Allen and Earland)
Figure 8.12-8.13

1911 **Pulvinulina haliotidea** Heron-Allen and Earland: p. 338, pl. 12, figs 8, 9.
1971 **Lamarckina haliotidea** (Heron-Allen and Earland); Murray: p. 205, pl. 86, figs 1-6.

Remarks:
Rare dead.

Melonis barleeanus (Williamson)
Figure 8.11-8.14

1858 **Nonionina barleeana** Williamson: p. 32, pl. 3, figs 68, 69.
1991 **Melonis barleeanum** (Williamson); Corliss: p. 2, figs 9, 10.

Remarks:
Infaunal. Common dead. Corliss (1991) considered this to be intermediate infaunal (~1-4 cm).

Nonion pauperatus (Balkwill and Wright)
Figure 9.1

1885 **Nonionina pauperata** Balkwill and Wright: p. 353, pl. 13, figs 25, 26.
1971 **Nonion pauperatum** (Balkwill and Wright) (*sic*); Gabel: pl. 12, figs 14, 15.

Remarks:
Live in one sample (0.0-0.5 cm) and dead.

Nonionella iridea Heron-Allen and Earland, 1932
Figure 9.2-9.3

1932 **Nonionella iridea** Heron-Allen and Earland: p. 438, pl. 16, figs 14-16.

Remarks:
Infaunal.

Nonionella turgida (Williamson)
Figure 9.4-9.5

1858 **Rotalina turgida** Williamson: p. 50, pl. 4, figs 95-97.
1971 **Nonionella turgida** (Williamson); Murray: p. 193, pl. 81, figs 1-5.

Remarks:
Infaunal. Corliss (1991) considered this to be deep infaunal (>4 cm).

Patellina corrugata Williamson, 1858
Figure 9.6-9.7

1858 **Patellina corrugata** Williamson: p. 46, pl. 3, figs 86-89.

Remarks:
Rare dead.

Planorbulina mediterranensis d'Orbigny, 1826
Figure 9.8

1826 **Planorbulina mediterranensis** d'Orbigny: p. 280, pl. 14, figs 4-6.

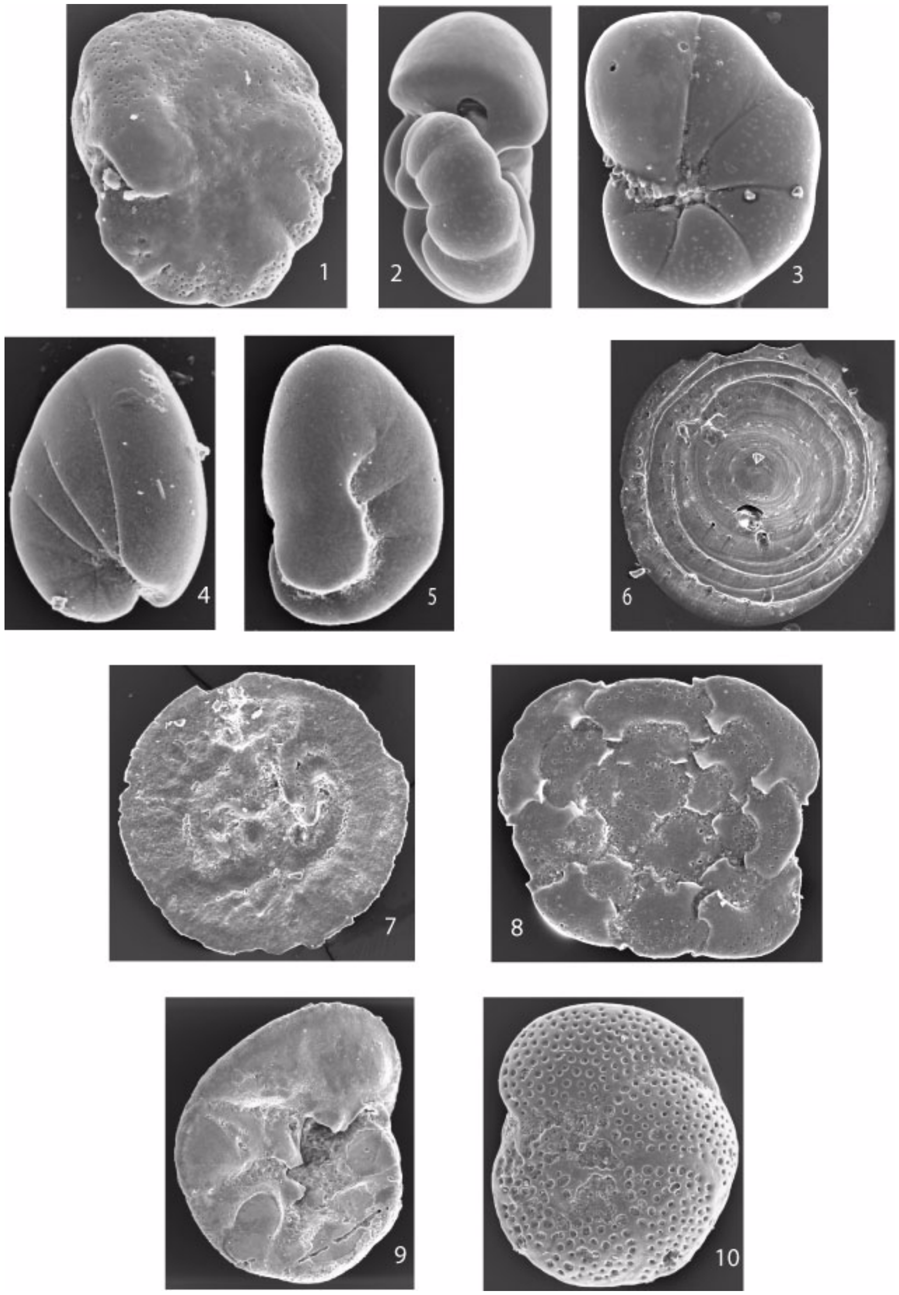

Figure 9. L = length, D = greatest diameter. **1. Nonion pauperatus** (Balkwill and Wright), D 180 µm. **2-3. Nonionella iridea** Heron-Allen and Earland, D 110, D 140 µm. **4-5. Nonionella turgida** (Williamson), D 300 µm. 6, **7. Patellina corrugata** Williamson, D 500 µm. **8. Planorbulina mediterranensis** d'Orbigny, D 490 µm. **9-10. Rosalina anomala** Terquem, D 600, D 550 µm.

Remarks:
Considered by Sturrock and Murray (1981) to be epifaunal, attached but also able to move freely.

Rosalina anomala Terquem, 1875
Figure 9.9-9.10

1875 **Rosalina anomala** Terquem: p. 438, pl. 5, fig. 1.

Remarks:
Considered by Sturrock and Murray (1981) to be epifaunal, attached but also able to move freely.

Stainforthia fusiformis (Williamson)
Figure 10.1-10.4

1858 **Bulimina pupoides** d'Orbigny var. **fusiformis** Williamson: p. 63, pl. 5, figs 129, 130.
1973 '**Stainforthia' fusiformis** (Williamson); Haynes: p.124, pl. 5, figs 7, 8.

Remarks:
Infaunal. Recorded by Heron-Allen and Earland (1916) as **Bulimina fusiformis** Williamson and commonly referred to as **Fursenkoina fusiformis** (e.g., Murray 1971). For lengthy discussions of its morphology and variability see Höglund (1947) and Gooday and Alve (2001).

Trifarina angulosa (Williamson)
Figure 10.5

1858 **Uvigerina angulosa** Williamson: p. 67, pl. 5, fig. 140.
1971 **Trifarina angulosa** (Williamson): Murray: p. 123, pl. 51, figs 1-6.

Remarks:
Rare dead.

Uvigerina peregrina Cushman, 1923
Figure 10.6

1923 Uvigerina peregrina Cushman: p. 166, pl. 42, figs 7-10.

Remarks:
Rare live and dead.

ACKNOWLEDGEMENTS

I am grateful to J. Whittaker, The Natural History Museum, for discussions on taxonomy and for access both to the collections of foraminifera and the Heron-Allen Library. B. Marsh (SOC) kindly adjusted the contrast in figures 2-10. B. Cressey and R. Pearce (SOC) are thanked for gold coating the specimens prior to SEM study.

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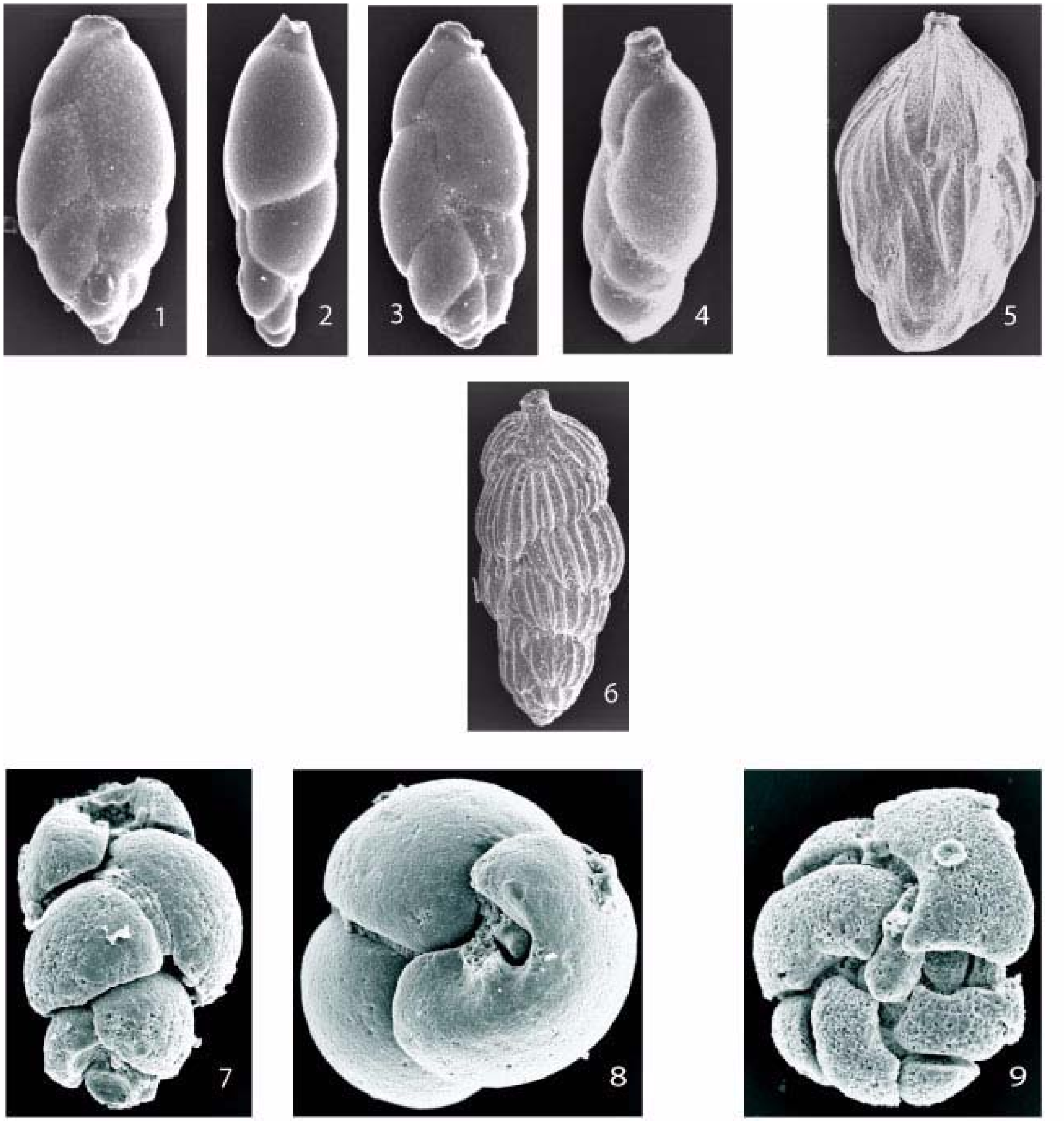

Figure 10. L = length, D = greatest diameter. **1-4. Stainforthia fusiformis** (Williamson), L 280 µm. **5. Trifarina angulosa** (Williamson), L 400 µm. **6. Uvigerina peregrina** Cushman, L 800 µm. **7-8. Bulimina marginata** d'Orbigny preserved as a glauconitic infill, L 240, D 220 µm. **9. Cassidulina obtusa** Williamson preserved as a glauconitic infill, D 110 µm.

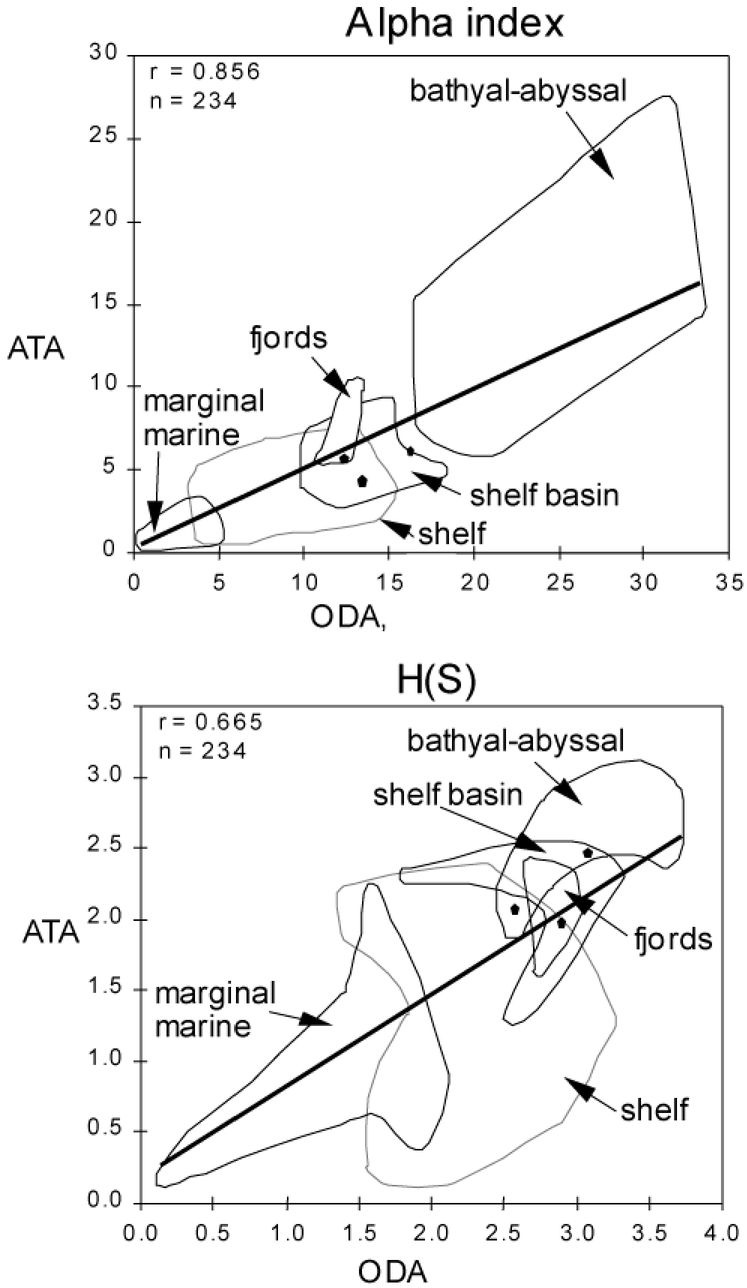

Figure 11. Summary of the diversity fields for ODAs and ATAs plotted for the Fisher alpha index and the information function H(S) (from Murray and Alve 2000). The spots mark the positions of the three samples from Muck and Stanton deeps.

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