FORAMINIFERAL ANALYSIS OF BOREHOLES FROM PLYMOUTH SOUND

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Two boreholes drilled into the sediment infill of the palaeo-Tamar rock valley during 1988 are analysed sedimentologically and palaeontologically. The palaeontology is predominantly concerned with foraminifera. The data, so obtained, are used to reconstruct the palaeoenvironmental history of Plymouth Sound. The sedimentological correlation of the boreholes is poor, but the foraminiferal evidence makes for a good correlation of the environments represented by the cores. Six taxa of foraminifera are dominant, they define three sub-environments, the boundaries of which correlate almost perfectly with prominent seismic reflectors.

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INTRODUCTION

Plymouth Sound is an area of shallow shelf sea directly south of the City of Plymouth. A series of high-resolution seismic surveys carried out in the 1980s by Dr J. M. Reynolds and various students of the then-Polytechnic culminated in the publication of a paper by Eddies and Reynolds (1988). In this they described the existence of a system of buried rock channels below Plymouth Sound. In January 1988 two boreholes (Figure 1) were drilled to assess the nature of the infilling sediment and provide ground-truth for the seismic sections. A preliminary investigation of one of these boreholes (Borehole 1) was described by Eddles and Hart (1989).

Since that time the boreholes have been further investigated and their microfaunas examined. Borehole 1 reached the valley bedrock of Devonian slates (Figure 2) at -39 m O.D., with an almost complete sediment core being recovered. Borehole 2, drilled approximately 300 m north-north-west of Borehole 1, was plagued by bad weather conditions which resulted in rather poor recovery of core down to -25.7 m O.D.

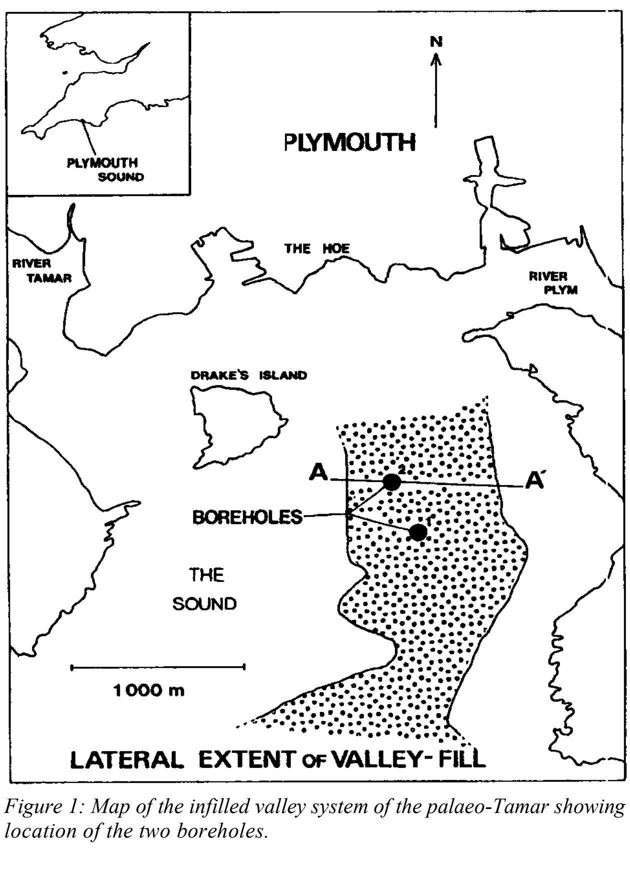

Figure 1: Map of the infilled valley system of the palaeo-Tamar showing location of the two boreholes.

SEDIMENTARY RECORD OF BOREHOLE 1

The top of the succession consists of fine silty sands, although the top few metres of the sequence may be artificial. Between -10 m O.D. and -19 m O.D. are fine to medium-grained sands, coarsening upwards to coarse sands. Between -19 m O.D. and -35 m O.D. are mainly silts and clays, with occasional, localised, pebbles. Between -35 m O.D. and approximately -39.4 m O.D. are coarse gravels ranging from rounded to sub-angular, these contain moderate amounts of slate.

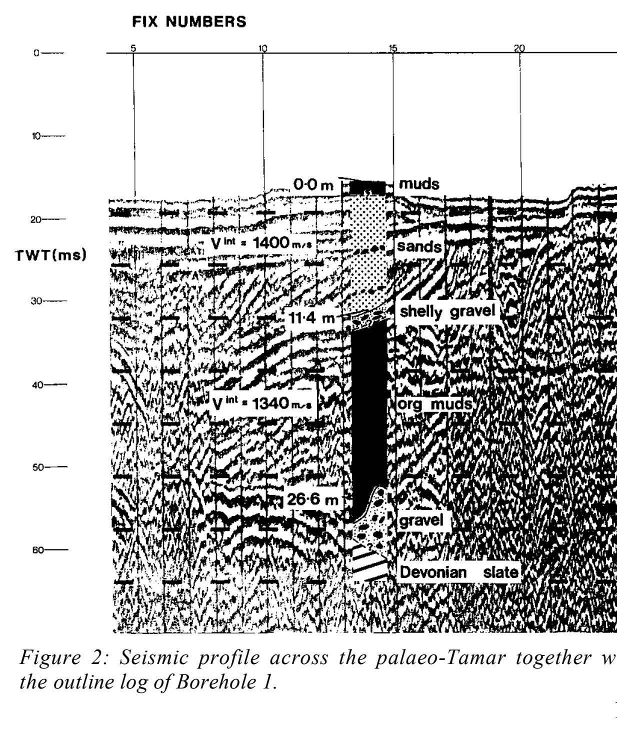

Figure 2: Seismic profile across the palaeo-Tamar together with the outline log of Borehole 1.

TABLE 1

Borehole No 1	21.3-23.0		22.7-22.8		22.3-22.8		23.1-23.8		23.8-24.4		24.3-25.0	
In metres	Aba.	%	Aba.	%	Aba.	%	Aba.	%	Aba.	%	Aba.	%
A. beccarii	42	15	63	33	29	10	7	15	40	25	22	11
Quinqueloculina spp.	4	1	17	9	2	1	0	0	4	3	13	7
E. crispum	8	3	42	22	0	0	2	4	4	3	4	2
H. germanica	36	13	31	16	163	57	26	54	61	38	111	55
E. williamsoni	189	68	39	20	94	33	13	27	50	31	43	22
C. lobatulus	0	0	0	0	0	0	0	0	3	1	6	3
Textularia	0	0	0	0	0	0	0	0	0	0	1	1
S. vivipara	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	279	100	192	100	288	101	48	100	162	101	200	101

Borehole No 1	1.2		1.4		4.25 6-6.9		6.0-7.7		8.3-9.9		9.9-10.9		13.4-13.85			
In metres	Aba.	%	Aba.	%	Aba.	%	Aba.	%	Aba.	%	Aba.	%	Aba.	%	Aba.	%
A. beccarii	107	37	67	16	92	32	122	35	108	39	106	30	169	39	87	48
Quinqueloculina spp.	75	26	175	41	100	36	86	25	46	16	60	17	62	14	17	8
E. crispum	63	22	118	27	85	30	141	40	123	44	185	53	202	47	13	7
H. germanica	4	1	4	1	0	0	0	0	1	0	0	0	1	0	0	0
C. lobatulus	31	11	65	15	6	2	0	0	0	0	0	0	1	0	0	0
Textularia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S. vivipara	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
TOTAL	287 99	99	429	100	286	100	349	100	278	100	352	100	434	100	182	99

Borehole No 1	14.1-14.6		14.8-15.3		14.8-15.3		16.3-17.1		17.1-18.3		18.3-19.1		19.9-20.7		20.7-21.2	
In metres	Aba.	%	Aba.	%	Aba.	%	Aba.	%	Aba.	%	Aba.	%	Aba.	%	Aba.	%
A. beccarii	128	42	166	41	96	45	161	44	108	40	80	36	18	9	24	16
Quinqueloculina spp.	27	9	29	7	31	15	61	17	50	19	20	9	1	1	2	2
E. crispum	43	14	19	5	40	19	96	26	58	22	42	19	2	1	2	1
H. germanica	60	20	92	23	32	15	39	11	92	16	36	16	60	30	29	36
E. williamsoni	48	16	91	23	13	6	12	3	7	3	39	18	118	59	74	51
C. lobatulus	0	0	6	2	0	0	1	0	2	1	2	1	0	0	1	1
Textularia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S. vivipara	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1
TOTAL	306	101	403	101	212	100	370	101	267	101	220	100	199	100	146	100

Borehole No 2	?-1.35		2.05-3.10		3.1-4.3		4.3		4.6		5.8		5.8-7.0		7.0	
In metres	Aba.	%	Aba.	%	Aba.	%	Aba.	%	Aba.	%	Aba.	%	Aba.	%	Aba.	%
A. beccarii	168	53	141	50	159	41	150	55	150	58	94	48	51	33	108	54
Quinqueloculina spp.	61	19	29	10	63	16	17	6	30	11	16	8	33	21	33	17
E crispum	89	28	108	38	61	16	100	37	49	19	16	8	40	26	31	16
H. germanica	0	0	3	1	66	17	4	1	23	9	40	20	15	10	21	10
E williamsoni	1	0	1	0	35	9	3	1	9	3	26	13	17	11	7	3
C. lobatulus	0	0	0	0	4	1	0	0	0	0	6	3	0	0	0	0
S. vivipara	0	0	0	0	3	1	0	0	0	0	0	0	1	1	0	0
Textularia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	319	100	282	99	391	101	274	100	261	100	198	100	156	101	200	101

Borehole No 2	7.1-8.3		8.3-9.5		9.5-10.2		9.5-10.7		10.7-11.9		11.9-12		14.5-15		15.1-15.4		15.4-15.7	
In metres	Aba.	%	Aba.	%	Aba.	%	Aba.	%	Aba.	%	Aba.	%	Aba.	%	Aba.	%	Aba.	%
A. beccarii	167	64	4	36	4	20	0	0	12	12	15	45	2	11	1	4	2	9
Quinqueloculina spp.	32	12	1	9	3	15	39	18	7	7	7	21	6	33	4	17	7	30
E. crispum	47	18	1	9	8	40	31	14	24	23	5	15	8	44	5	22	3	13
H. germanica	16	6	2	18	4	20	102	46	38	36	0	0	1	6	10	44	8	35
E. williamsoni	1	0	3	27	0	0	28	12	20	19	6	18	0	0	3	13	3	13
C. lobatulus	0	0	0	0	1	5	18	8	2	2	0	0	1	6	0	0	0	0
S. vivipara	0	0	0	0	0	0	2	1	1	1	0	0	0	0	0	0	0	0
Textularia	0	0	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0
TOTAL	268	100	11	99	20	100	223	100	104	100	33	99	18	100	23	100	23	100

Abra. Absolute amount.

No foraminifera were found in the coarse gravels which mark the bottom part of the sequence. With the exception of the gravels at its base, Borehole 1 has a fine-grained lower sequence, and a coarsening-upwards sandy upper sequence.

SEDIMENTARY RECORD OF BOREHOLE 2

The lack of sharpness in identifying sediment boundaries is due largely to the nature of the material, the softness of the sediment and its post-drilling storage in bags. The lower part of the succession is generally coarse-grained while the upper part is fine-grained.

From the sediment/water interface (-10m O.D.) to -11.35 m are poorly sorted sands, granules and pebbles, with abundant shells. This zone may be artificial (dredging). Equally it could represent a high energy area in which active deposition has not occurred for some considerable time, so excluding much of the more recent normal marine sequence/fauna.

Between -12 m O.D. and -19 m O.D., grey and brown coloured clays and silts with occasional pebbles and shells are found.

Between -19 m O.D., to -23 m O.D. there are poorly sorted pebbly sands, silts, and clays. At -20 m O.D. is a pebble bed; its exact thickness, and the nature of upper and lower boundaries are not known. At -22 m O.D. a poorly defined pebble bed exists. The sediment has a strong ochre colouring. Well-cemented aggregates of sand containing numerous shells are common; it is probable that the shell material is the source of this very localised carbonate cement. The basal part of the sequence, from -23 m O.D. to -25 m O.D., consists of fine-grained well-sorted sands, with small cemented aggregates of sand, and thin shell fragments.

The sediment correlation between Borehole 1 and Borehole 2 is poor, but this is not surprising, assuming and considering a valley infill depositional setting.

FORAMINIFERAL ANALYSIS

A total of 46 samples were taken from Borehole 1, and 22 from Borehole 2, approximately $^{2}/_{3}$ which contained foraminifera. The samples were dried and sieved, foraminifera were picked using a fine paint brush from the >500, >250 and the >125 micrometres size fractions, 350 individuals were picked where possible from each sample (Table 1).

It was found that 6 taxa represented over 98% of the fauna, one of which, *Cibicides lobatulus* (Walker and Jacob), is relatively abundant in the top one or two metres of Borehole 1 (Eddles and Hart, 1989). This may suggest that this taxon is only a relatively recent inhabitant of the Sound.

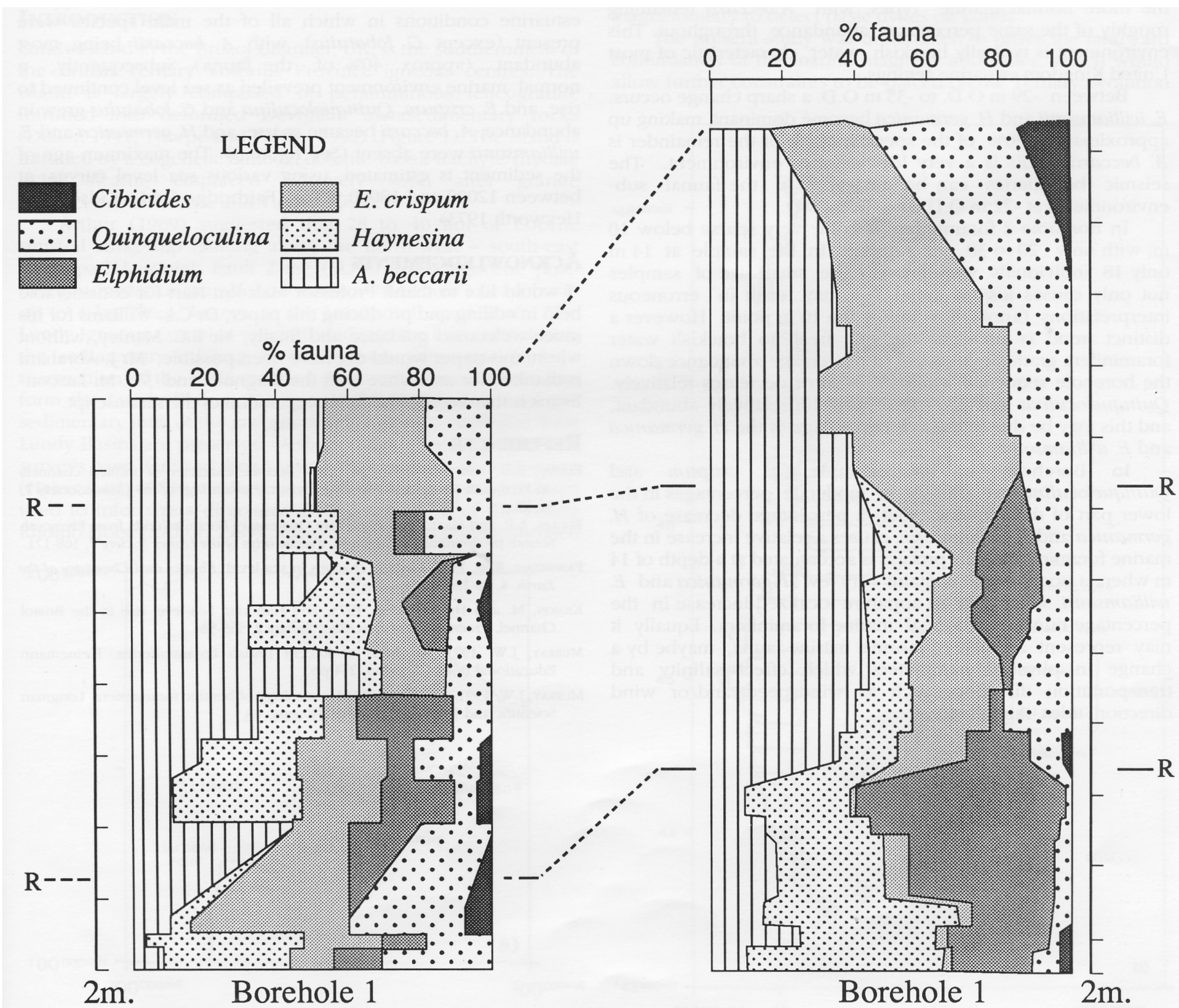

Figure 3: Foraminiferal analysis of the two boreholes. [R=geophysical reflection surface].

The remaining five species, making up over 95% of the foraminiferal assemblage, are as follows:-

Haynesina germanica (Ehrenberg) is a euryhaline taxon often found in hyposaline lagoons and estuaries. This species can tolerate salinities down to 1 per mille (Murray, 1991).

Elphidium williamsoni (Haynes) is very similar to *H. germanica* in terms of its living environment and salinity tolerance.

In this work *Elphidium crispum* (Linné) includes all varieties such as *E. macellum* (Fitchel and Moll); for discussion see Murray (1971)

Ammonia beccarii (Linné) is an important taxon in estuarine and near-shore marine environments.

Quinqueloculina spp. in this work include several species and sub-species. All members of this genus in temperate latitudes are regarded as representative of marine, inner-shelf, environments.

In Borehole 1 three distinct sub-environments are present (Figures 2 and 3). The topmost 12 m of sediment are dominated by *E. crispum, A. beccarii* and *Quinqueloculina,* with a lesser percentage of *C. lobatulus*. This environment is open-marine to slightly brackish. Below approximately -22 m O.D.to -29 m O.D. the fresh or brackish water foraminifera, *H. germanica* and *E. williamsonii* occur in moderate percentages, at the expense of the more normal marine types, with *A. beccarii* remaining roughly of the same percentage abundance throughout. This environment is typically brackish water, characteristic of most United Kingdom estuarine settings.

Between -29 m O.D. to -35 m O.D. a sharp change occurs. *E. williamsonii* and *H. germanica* become dominant, making up approximately 80% of the species; much of the remainder is *A. beccarii.* This is a very low salinity environment. The seismic boundaries can be matched to the faunal sub-environments at -22 m O.D. and -29 m O.D.

In Borehole 2 foraminifera become very sparse below 10 m, with only 20 to 30 per sample. In the sample at 14 m only 18 individuals were found. The small size of samples not only causes loss of detail, but may result in erroneous interpretations (anomalies) below the 10 m point. However a distinct trend is present. The two fresh to brackish water foraminifera gradually increase in percentage abundance down the borehole sequence, while *A. beccarii* decreases relatively. *Quinqueloculina* and *E. crispum* are still relatively abundant, and this may be due to the low percentage of the *H. germanica* and *E. williamsonii.*

In Borehole 1, for example, *E. crispum* and *Quinqueloculina* are present in moderate percentages in the lower part of the sequence, but a percentage decrease of *H. germanica* and *E. williamsonii,* causes a relative increase in the marine foraminifera. This process is accentuated at a depth of 14 m where a poor sample contains very few *H. germanica* and *E. williamsonii,* so causing an apparent localized increase in the percentage number of normal marine foraminifera. Equally it may represent a pulse of normal marine fauna, maybe by a change in physical parameters which effect salinity and transportation direction, such as windspeed and/or wind direction, tides, rainfall etc.

INTERPRETATION

Both Boreholes 1 and 2 show a similar trend, in that the top of each sequence has a normal marine fauna which becomes more brackish and freshwater downwards. Accepting that detail will be lost due to the sparsity of the fauna in parts of Borehole 2, Borehole 1 and Borehole 2 can be tentatively correlated in terms of their foraminiferal content. This correlation suggests that much of the upper sequence is not present in Borehole 2, which fits a valley-infill type of setting. The 12 m marker in Borehole 1 correlates approximately with that of 2 m depth in Borehole 2, in terms of seismic reflectors and foraminifera. This implies that approximately 10 m of the Borehole 2 sequence is absent, possibly due to erosion, non-deposition or both.

It is interesting to note that seismic reflectors correlate very well with the boundaries of the microfaunal sub-environments of both of the two boreholes, suggesting that these reflectors represent time gaps through non-deposition or erosion or both.

In the late Quaternary this area of the Sound was within a fluvially-dominated regime, at which time coarse elastics were deposited and foraminifera were absent. A relative sea-level rise occurred, creating 'fresh/brackish' conditions, in which the *E. williamsonii* and *H. germanica* became very abundant. Sea level continued to rise, and this was reflected in typical estuarine conditions in which all of the main species were present (except *C. lobatulus),* with *A. beccarii* being most abundant (approx. 40% of the fauna). Subsequently, a normal marine environment prevailed as sea level continued to rise, and *E. crispum, Quinqueloculina* and *C. lobatulus* grew in abundance, *A. beccarii* became sparse, and *H. germanica* and *E. williamsonii* were absent (See figure 3). The maximum age of the sediment is estimated, using various sea level curves, at between 12000 and 18000 years (Fairbridge 1961; Kidson and Heyworth 1973).

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