Read at the Annual Conference of the Ussher Society, January 1989.

Late Quaternary Foraminiferida from Plymouth Sound; preliminary investigation

A.P. EDDLES and M.B. HART

Eddies, A.P. and Hart, M.B. 1989. Late Quarternary Foraminiferida from Plymouth Sound; preliminary investigation. *Proceedings of the Ussher Society, 7,* 168-171.

Recent geophysical surveys of Plymouth Sound have identified potential borehole sites that would provide as complete a record as possible of the sediment succession which fills a now buried rock-valley of the palaeo-Tamar. One of these sites was drilled in February 1988 and the borehole samples are now being used to determine the stratigraphical and palaeoenvironmental history of the sound based upon foraminiferal changes. The Foraminiferida are shown to be grouped into three assemblages: *Haynesena germanica* (Ehrenberg, 1840), *Ammonia beccarii* (Linne) and *Quinqueloculina lata* Terquem, 1876. These successive faunal assemblages reflect a rise in sea-level between 12,000 and 4,000 years B.P. Apportioning dates to the succession has been tentatively undertaken by a comparison to sea-level curves.

A.P. Eddles and M.B. Hart. Department of Geological Sciences, Polytechnic South West, Drakes Circus, Plymouth PL4 8AA.

Introduction

The presence of a buried rock-valley *(sensuo* Codrington 1898) in Plymouth Sound has been confirmed (Reynolds 1987; Eddies and Reynolds 1988) by the use of high-resolution seismic reflection surveys. In February 1988 two sites were chosen for rotary drilling in an attempt to penetrate the fill of the rock-valley, based on their completeness of section, which was indicated by the seismic surveys (Eddies and Reynolds 1988). The purpose of this preliminary investigation is to interpret the history of the fill of the palaeo-Tamar rock-valley by examining the first of the two retrieved cores (Borehole 1) for Foraminiferida. It is intended to relate this information to Flandrian sea-level movements and associated environmental change.

Previous foraminiferal studies of coeval material have been undertaken in Swansea Bay (Culver and Banner 1978), the Severn Estuary (Murray and Hawkins 1976), Start Bay (Hails 1975), in a similar rock-valley of the River Exe (Durrance 1969) and also in Vendyssel, Denmark (Feyling-Hanssen *et al.* 1971). Recent foraminiferal studies in Plymouth Sound show diverse faunas (Heron-Allen and Earland 1930; Murray 1965) and detailed data on seasonal variations in population dynamics (Williams and Manley, unpublished work).

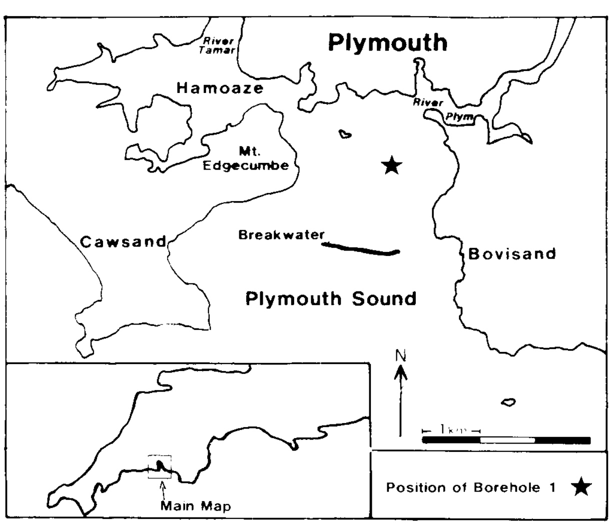

Figure 1. Location map of Plymouth Sound, S. W. Devon, showing the position of borehole 1.

Borehole 1 lies in a central position in Plymouth Sound (E247851, N520720) (Fig. 1) near where the buried rock-valley has a maximum depth of approximately 43m below O.D. (Eddies and Reynolds 1988; Reynolds, in press). Similar depths have been found in most of the estuaries of Cornubia (Codrington 1898; McFarlane 1955; Clarke 1970; Durrance 1971; Kelland 1975). The core from Borehole 1 is 29m in length (Fig. 2) representing almost the full thickness of sediment fill, as the present day sediment/water interface lies at 10m below O.D.

Borehole description

The retrieved core is 29m in length and the succession was initially subdivided on the basis of its seismic signature (Reynolds, in press). The modern sediments lie unconformably on bedrock of Lower Devonian slates at-39m O.D. These slates can be seen on land outcropping to the east and west of Plymouth Sound.

The basal sediments in the core are mainly gravels, from -39m O.D. to -35.6m O.D., deposited in small (< lm) fining upwards sequences, which grade into silts. These are overlain by clays, silts and fine sands between -35.6m and -22.5m O.D. with a similar seismic signature and hence grouped together. A distinct erosional surface separates a thin shelly gravel from the previous seismic package. This gravel lies between -22.5 and -22m O.D. This is overlain in turn by fine to medium grained sands, again with a distinctive seismic signature of low-angle foresets, between -22.5m O.D. and -14.25m O.D. The sands change their bedform and hence signature to planar bedded between -14.25m O.D. and -11.25m O.D. The upper 1.25m of core, between -1 1.25m and -10m O.D. is planar bedded, black, organic-rich muds which drape most of the topography of The Sound and are still being actively deposited today. These muds are often disturbed, whether it be naturally by storms or by dredging of access channels to Devonport Dockyard.

Twelve "Review samples" were taken from the core to (subjectively) best reflect the seismically identified major lithologies (Fig. 2). This accounts for the close spacing between some of the samples, where they were taken above and below a major seismic reflector. The sediment from the core is unlithified and soft, ranging from organic clays, through sands to coarse gravels. The nature of the samples allowed a simple drying and then wet sieving process to separate the smaller size fraction ($<63\mu m$) and leave a residue ($> 63\mu m$) for picking out the foraminiferids using a paintbrush and binocular microscope.

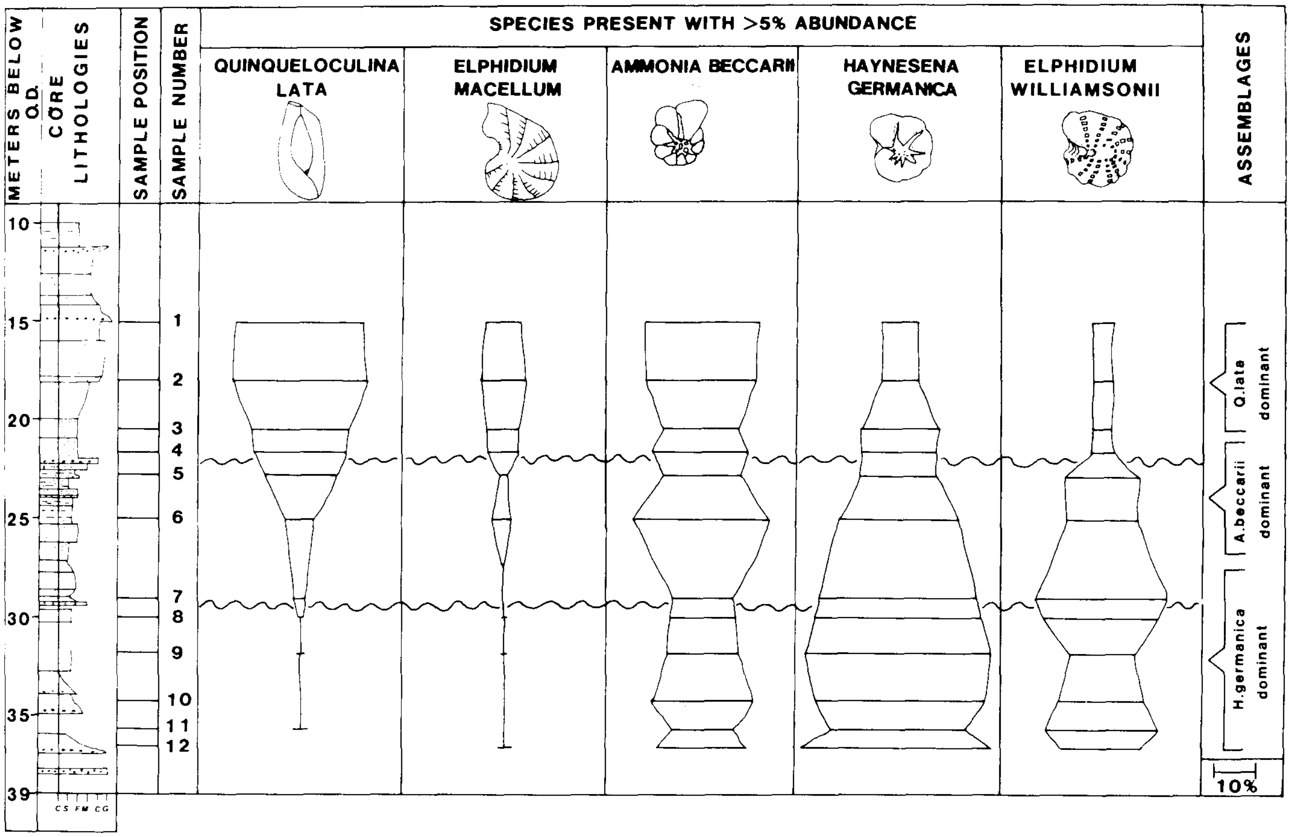

Figure 2. Relative percentages of the 5 species present with > 5% abundance plotted alongside borehole 1 core lithologies for samples 1-12. The oscillating lines show the position of two main seismic reflectors.

Faunal assemblages

A target of 500 individuals was chosen to be attained for each sample. The Foraminiferida are generally well preserved and hence easily identifiable. They are extremely young (less than 12,000 years) and there is no pyrite or glauconite present in the sediment or in the foraminiferids themselves. By counting the mounted individuals at species level, as a percentage of the fauna, three abundance assemblages are recognised. For ease when referring to these assemblages a nominate species has been chosen, which is normally the dominant species (or sometimes co-dominant).

Haynesena germanica (Ehrenberg, 1840) assemblage *Ammonia beccarii* (Linne) assemblage
Quinqueloculina lata Terquem, 1876 assemblage.

These three assemblages can be represented on a "Murray-type" triangular diagram (Fig. 3) and can qualitatively be shown to plot into three (almost) distinct groups; the close proximity of these three groups indicating the closeness of the sub-environments. The assemblages are indicative of three seismically bounded packages of sediment (Fig. 2), although the actual faunal changes do occur gradually and do not just appear at a certain horizon. The main seismic reflectors that can be used to subdivide the assemblages (Fig. 2) are in fact two erosive events. Hence, there is a time lag between the faunal change and the sedimentological indication of the environment change.

All of the assemblage indicator species occur in all of the samples and in the case of some species it is just their relative abundance within the assemblage that varies and not the actual numbers (e.g. *Ammonia beccarii* has a relatively steady population in samples 1 and 5 but the presence of more *Quinqueloculina lata* in sample I suppresses the relative percentage).

This series of assemblages is indicative of sea-level rise, as *Haynesena germanica is* typical of a more hyposaline environment. With rising sea-level the percentage of *Ammonia beccarii* increases, as this is a typically brackish/estuarine species living between 14 and 42m (Murray 1970). When the numbers of *Quinqueloculina lata* and *Elphidium macellum* increase to a point where they become dominant this indicates deeper water, more saline conditions, as these are inner shelf species. As nearly all the species are represented in nearly all the samples it suggests a close proximity of these sub-environments, with mixing of living and dead tests by current, tide and wave action. The indigenous and allocthonous components of the assemblages are difficult to separate due to small transport distances, unless the allocthonous tests show size sorting or etching (as in sample 10). From this preliminary, simplistic view of the fauna the history of sea-level rise would appear to be a gradational one.

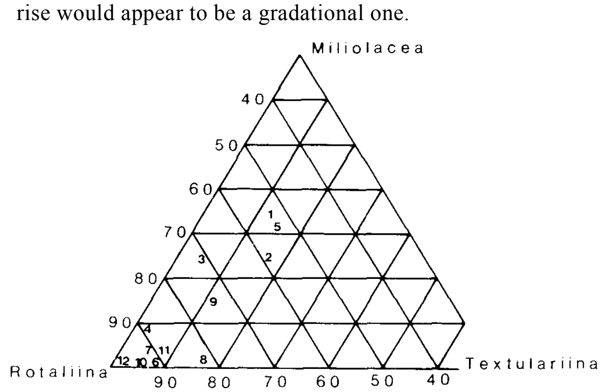

Figure 3. A triangular diagram of the three suborders with numbered samples 1-12.

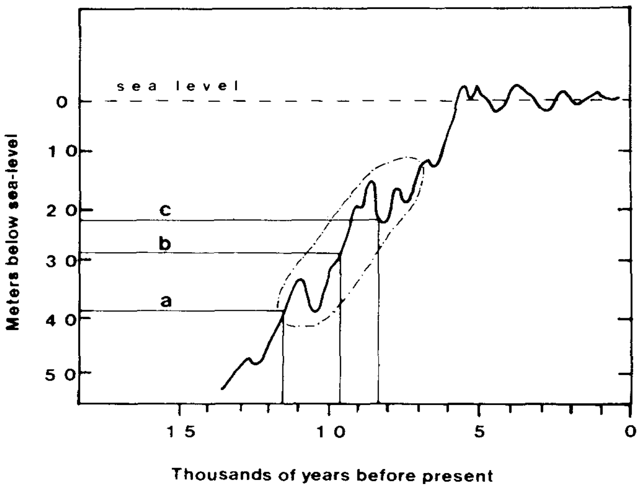

Figure 4. (after Reynolds 1987) The position of major seismic reflectors superimposed on a sea-level curve of the Late-glacial and Holocene transgression (Fairbridge 1961), giving dates of 11,500, 9,500 and 8,300 years before present. The dot-dash line represents the range of dates for the samples.

Timing of the Flandrian sea-level rise

This subject has been well documented for Start Bay (Hails 1975), Swansea Bay (Culver and Banner 1978) and the English Channel (Larsonneur *et al.* 1982). The results from Plymouth Sound appear to agree with this data (Fig. 4).

The palaeo-Tamar valley in Plymouth Sound was formed after a long period of base level downcutting to -43m O.D., during a period of low sea-levels at least 30-40,000 B.P. (Durrance 1971). The seas far off to the southwest then began to rise. Most of the sea-level rise occurred in the Weichselian (Larsonneur *et al.* 1982) from 140km to the southwest, near the continental edge to within 20km of The Lizard in 8,000 years. Fluvial-dominated conditions existed in The Sound as a water/sediment pathway feeding a larger fluvial system that drained the now English Channel to the southwest. Around 12,000 B.P. (dates inferred from Fig. 4) estuarine conditions with ensuing brackish water began to fill the lower part of the paleo-Tamar valley. This environment was one of "very fresh-type brackish water" with a *Haynesena germanica* dominated assemblage along with high percentages of *Elphidium williamsoni* Haynes, 1973 and *Ammonia beccarii.* These samples were not quorate (i.e. less than 500 individuals were collected), were small in size, poorly preserved with etched surfaces and discoloured brown. Then, around 9,500 B.P. (line b on Figure 4) a change occurred in both the sediment type (from fine silts/muds to sands) and in the fauna to an *Ammonia beccarii* dominated assemblage. The arrival of the *Quinqueloculina lata* assemblage probably occurred with further sea-level rise at around 8,000 B.P. It was after this that the breaching of The Bridge (a ridge of low ground that connected Mt Edgecumbe to Drakes Island) occurred and the previously deposited foreset bedded sands in a point-bar sequence (?) changed to planar bedded. This was probably due to the decreased force of water travelling around this estuary bend as some of it would pass over The Bridge. The infilling of the rock valley would also mean that the valley was no longer playing an active role as a sediment/water pathway.

The final change in sediment type to muds (deposited today in areas of slack water in The Sound) occurred within the last 2,000 years. These muds now drape the underlying topography and this is partly due to the infilling of the rock-valley but probably also reflects a change in the flow of the Tamar and Plym as they enter The Sound. This can be seen on Landsat images of The Sound, which show a water mass flow on both sides of the breakwater.

Alternatively, it is changes in the catchments of The Tamar and Plym that caused an increased particulate load e.g. de-forestation on Dartmoor.

Summary

Three assemblages are recognised: *Haynesena germanica, Ammonia beccarii* and *Quinqueloculina lata.* Each is indicative of a specific sub-environment where living conditions and/or reproduction are at an optimum for that species. These assemblages appear to be a direct response to sea-level rise.

There is a close proximity of these sub-environments, with a potential mixing of living and dead faunas by current and tide action. All the environments represented yield foraminiferal faunas of relatively low diversity; the samples always being dominated (> 90%) by the five most abundant species. The majority of the faunal changes are gradual, whereas the sedimentological reflection of these environmental changes are sudden and occur after (i.e. above) the faunal changes. The low numbers of agglutinated foraminifera may be a natural one (i.e. they did not inhabit The Sound at this time) although they are usually found in modern samples (Murray 1965). This may suggest that their loss from the assemblages was due to microbial breakdown after the core was retrieved, and this is being further investigated.

Acknowledgements. We would like to thank all those who helped in the drilling; Dr John Reynolds and Rod Eddies for seismic interpretations and background information; and Professor John Murray for help with identification and taxonomy of some of the Foraminifera.

(Plymouth Sound Research Project Contribution No. 9)

References

Clarke, R.H. 1970. Quaternary sediments off South East Devon. *Quarterly Journal of the Geological Society, London, 12,* 277-318. Codrington, T. 1898. On some submerged Rock Valleys in South Wales, Devon and Cornwall. *Quarterly Journal of the Geological Society, London, 54,* 251-278.

Culver, S.J. and Banner, F.T. 1978. Foraminiferal assemblages as Flandrian palaeoenvironmental indicators. *Palaeogeography, Palaeoclimatology, Palaeoecology, 24,*53-72.

Durrance, E.M. 1969. The buried channels of the Exe. *Geological Magazine, 106,* 174-189.

Durrance, E.M. 1971. The buried channel of the Teign Estuary. *Proceedings of the Ussher Society, 2,* 229-306.

Eddies, R.D. and Reynolds, J.M. 1988. Seismic characteristics of buried rock-valleys in Plymouth Sound and the River Tamar. *Proceedings of the Ussher Society, 7,* 36-40.

Feyling-Hanssen, R.W., Jorgensen, J.A., Knudsen, K.L. and Anderson, A.L. 1971. Late Quaternary Foraminifera from Vendsyssel, Denmark and Sandnes, Norway. *Bulletin of the Geological Society of Denmark, 21,* 67-317.

Hails, J.R. 1975. Some aspects of the Quarternary History of Start Bay, Devon. *Field Studies, 4,* 207-222.

Heron-Allen, E. and Earland, A. 1930. The Foraminifera of the Plymouth District. *Journal of the Royal Microscopical Society, 50,* 46-84, 161-99.

Kelland, N.C. 1975. Submarine geology of Start Bay determined by continuous seismic profiling and core sampling. *Quarterly Journal of the Geological Society, London, 13,* 7-17.

Kidson, M. and Heyworth, A. 1971. The Flandrian Sea-level rise in the Bristol Channel. *Proceedings of the Ussher Society, 2,* 565-584.

Larsonneur, C., Bouysse, P. and Auffret, J. 1982. The superficial sediments of the English Channel and it's Western Approaches. *Sedimentology, 29,* 851-864.

McFarlane, P.B. 1955. Survey of two drowned river valleys in Devon. *Geological Magazine, 92,* 419-429.
Murray, J.W. 1965. On the foraminiferids of the Plymouth region. *Journal of the Marine Biological Association, U.K., 45,* 481.
Murray, J.W. 1970. Foraminifers of the Western Approaches to the English Channel. *Micropalaeontology, 16,* 471-485.
Murray, J.W. and Hawkins, A.B. 1976. Sediment transport in the Severn Estuary during the past 8,000-9,000 years. *Journal of the Geological Society, London, 132,* 385-398.
Reynolds, J.M. 1987. Geophysical detection of buried channels in Plymouth Sound, Devon. *Geophysical Journal of the Royal Astronomical Society, 89, 457.*
Reynolds, J.M. In press. High-resolution seismic reflection surveying of shallow marine and estuarine environments. *In:* Hailwood, E. (ed) *Recent developments in Marine Geological Sampling and Surveying Techniques.* Graham and Trotman.

APPENDIX: FAUNAL REFERENCE LIST

Ammonia beccarii (Linne)
Asteridgerinata mamilla (Williamson)
Bullimina gibba/elongata (Fornasini/d'Orbigny)
Cibicides lobatulus (Walker and Jacob)
Cyclogyra involvens (Reuss)
Elphidium gerthi Van Voorthuysen
E. macellum (Fichtel and Moll)
E. oceanense (d'Orbigny) *E. williamsoni* Haynes, 1973
Fissurina lucida (Williamson)
Gavelinopsis praegeri (Heron-Allen and Earland)
Haynesena germanica (Ehrenberg, 1840)
Miliolinella subrotunda (Montagu)
Oolina melo d'Orbigny, 1839
Planorbulina mediterranensis d'Orbigny, 1826
Quinqueloculina cliarensis (Heron-Allen and Earland)
Q. lata Terquem, 1876
Q. oblonga (Montagu)
Rosalina anomala/globulus (latter by d'Orbigny, 1826)
Spirillina vivipara Ehrenberg, 1843