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BOTTOM SEDIMENT ALONG OIL SPILL TRAJECTORY IN PRINCE WILLIAM SOUND
AND ALONG KENAI PENINSULA, ALASKA

Edited by Paul R. Carlson and Erk Reimnitz

Chapter E. Preliminary report on benthic foraminifers from Prince
William Sound, Alaska

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PRELIMINARY REPORT ON BENTHIC FORAMINIFERS FROM PRINCE WILLIAM SOUND, ALASKA

Paula J. Quintero

INTRODUCTION

A U.S. Geological Survey cruise (F5-89-PW) was conducted aboard the R/V FARNELLA from May 11 to May 15, 1989 to assess the effects of the March 24, 1989 Exxon VALDEZ oil spill on near-surface sediment (Carlson and Reimnitz, this volume). Station locations are shown in figures 1 and 2. Foraminiferal faunas and sediment types are described in the Appendix.

Subsamples were taken from the upper 2 cm of 18 box cores, preserved in 70% ethanol, and stained with rose Bengal while onboard ship in order to recognize foraminifers that were living at the time of collection. Samples were washed over a 0.063mm mesh sieve to remove the silt and clay; the residue was air dried and dry sieved using a 0.150mm mesh sieve; the <0.150mm residue was stored in a labelled vial; when necessary, the >0.150mm portion was split with a microsplitter to obtain approximately 300 benthic foraminifers. All specimens in the split fraction were sorted, identified, and counted. Percentages were calculated for "total" benthic taxa (stained + unstained) by dividing the number of specimens (stained + unstained) of each taxon by the total number of specimens in that sample and multiplying by 100. The percentage of "live" (stained) taxa was obtained by dividing the number of stained specimens of each taxon by the total (stained + unstained) number of specimens in that sample and multiplying by 100.

Ninety-one benthic taxa were recognized and are listed in Tables 1, 2, and 3 as percentage of total benthic foraminifers. Both calcareous and agglutinated benthic foraminifers are present. Live (stained) foraminiferal taxa are listed in Table 2. Table 3 lists taxa and their abundances as percentage of total benthic foraminifers in 4 samples (unstained) taken from >2 cm depth in 3 box cores.

Planktonic foraminifers are present in all the samples, but not abundant. In addition, because there are no surface tow samples for comparison with present day planktonics, they will not be discussed further in this report.

RESULTS

Benthic foraminiferal distribution in Prince William Sound is related to sediment type. The foraminiferal faunas present in the coarsest sediment (Box Cores 1, 17B, and 18) are dominated by species of *Cassidulina californica*, *C. limbata*, *C. tortuosa*, and *Cibicides lobatulus* (Figs. 1, 2). Previous workers in the Gulf of Alaska have found similar faunas associated with coarse sediments. Bergen and O'Neil (1979) designated a "gold" fauna dominated by high percentages of *Cassidulina* and *Cibicides*, associated with coarse sediment. Echols and Armentrout (1980) reported a similar group of species in the Gulf of Alaska which occurred only on shelly, gravelly substrates. They called this the *Cassidulina californica* Fauna. Other reports of similar faunas associated with coarse sediment include Todd and Low (1967) and Quintero et al., (1980) in the Gulf of Alaska; Boettcher, (1967) off Oregon; and Bandy (1953), Blake

(1976), and Zalesny (1959) off California.

Low oxygen foraminiferal faunas are frequently found in fine-grained sediments beneath highly productive oceanic waters. An association of species typical of low oxygen environments (<0.5 ml/L of O_2) is present in very fine grained sediments of Prince William Sound. It is best developed at Stations 7 and 8, but is also present at Stations 9 and 10 (Fig. 1). Abundant diatoms, an indication of high productivity, occur in sediments at these sites. The benthic foraminiferal fauna is dominated by *Bolivina pseudobeyrichi*, *Uvigerina juncea*, and *Globobulimina* spp. Poag (1981, 1985) found that high abundances of *Brizalina* (*Bolivina*) and *Uvigerina* in the Gulf of Mexico correlated with an oxygen minimum and with high amounts of organic carbon. A stained specimen of *Bolivina pseudobeyrichi* is figured on the title page (page 1) of this report.

The significance of the low oxygen faunas in the Prince William Sound samples is uncertain, but it should be noted that this fauna is best developed closest to the oil spill (Station 7). Unfortunately, no baseline studies of foraminiferal distribution had been done before the spill; therefore, the composition of previous foraminiferal faunas and any changes since the spill are unknown. Only 4 downcore samples (>2 cm) were available for this report, and give only a general idea of what the past faunas were. Rates of sediment accumulation are not known for this area, so we do not know when the various layers were deposited. Furthermore, Corliss (1985) has found some species living (stained) as deep as 15 cm in deep sea cores, so some of the foraminifers in the Prince William Sound samples from the 2-8 cm intervals may have been living at the time of collection, but this cannot be known since stain was only added to samples from the upper 2 cm of the cores. Table 4 compares the abundances of low oxygen taxa in surface samples 7B, 7C, and 9A with abundances at various depths in cores 7C, 9A, and 9B. Surface samples have greater abundances of the 3 low oxygen taxa than do subsurface samples. Two of these genera, *Bolivina* and *Uvigerina* have also been correlated with high amounts of organic matter in sediment (Poag, 1981, 1985). The greater abundance of the low oxygen (and high organic carbon) fauna in the surface samples might be an indication that the oil spill has affected the benthic foraminifers by altering their environment. However, the observed faunal change is slight and is probably the result of natural environmental processes.

Although no oil was found in the seafloor sediments, the benthic organisms could be affected by changes in the water column caused by the spill. These changes, however, would not necessarily be detrimental to all species of foraminifers. Bandy, Ingle and Resig (1965a,b) in studies of foraminifers in surface sediments around sewage outfalls off the Los Angeles area found that not all species of foraminifers are adversely affected by pollutants. In fact, the greatest number of living foraminifers were found downcurrent from the outfall. In the Prince William Sound samples, the highest percentages of live foraminifers are found at stations in the vicinity of the spill (Table 2). Live specimens of *Bolivina pseudobeyrichi* make up 17%, 8%, 13%, and 6% of the total benthic foraminiferal faunas at Stations 7 (B and C), 8A, 9A, and 10C, respectively. Live percentages of *Uvigerina juncea* are 6%, 3%, 11%, 8%, and 11% at Stations 7B, 7C, 8A, 9A, and 10C respectively. Live percentages of *Globobulimina* spp. make up 8%, 9%, and 4% at stations 7B, 7C, and 10C respectively. It is possible that these species are opportunistic, that is, they are able to tolerate environments that other organisms cannot; therefore, they thrive due to lack of competition.

CONCLUSIONS

Distribution patterns of benthic foraminifers in the surface sediments of Prince William Sound show a relationship to sediment size and also to the distance from the VALDEZ oil spill. Although relationships can be seen, there is not enough evidence to know for certain what the controlling factors are. Good baseline studies are necessary for valid interpretations and, unfortunately, these studies are lacking in Prince William Sound. Future studies should include seasonal sampling of the water column for plankton and the seafloor sediment (both surficial and downcore) and staining of sediment samples from 0-15cm to determine the spatial and temporal distribution of benthic foraminifers.

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APPENDIX. Description of Sediment Type and Foraminiferal Faunas

The station location information and the description of the sediments that follow are taken from Carlson and Reimnitz (this volume).

I have listed below the most abundant species and their relative frequency percentages in each sample. These data are also shown on Figures 1 and 2.

Station 1, Box Core 1

-Location: At the mouth of Montague Strait

-Water depth=160m

-Sediment type: Gray diamict containing abundant angular pebbles and cobbles up to 10 cm in diameter. 60% sand, granules, cobbles.

-"Washed sediment"= (the portion of sample remaining on the 0.063mm sieve after wet sieving to eliminate fines and concentrate foraminifers): Detrital minerals, shell fragments, and a little glauconite (?).

-Fauna: Some tests fresh, some very poorly preserved; many fragments. *Cassidulina limbata* =29%, *Elphidium clavatum* var. =21%, *Cibicides lobatulus* =17%, *Cassidulina californica* =14%.

-Clayey worm tubes, euphausid(?), pelecypod, sponge spicules, echinoderm parts, brachiopod fragments, fish tooth(?).

-Other: One conifer needle.

Station 2, Box Core 2A

-Location: In Montague Strait

-Water depth=246m.

-Sediment type: mottled medium gray clayey silt; no laminations, no bedding.

-Washed sediment: <0.150mm=mostly detrital minerals. >0.150mm=mostly detrital with some clay, worm tubes, shell fragment and minor diatoms.

-Fauna: Diverse, >50 species. *Cibicides lobatulus* =18%, *Angulogerina angulosa* =6%, *Astronion gallowayi* =6%, *Trochammina* spp. =6%

-Rarely some pyrite in foram tests.

-Ostracodes, bryozoan fragments, echinoderm fragments, pelecypods, sponge spicules, pteropods(?).

Station 3, Box Core 3A

-Location: East of Knight Island.

-Water depth=268m.

-Sediment type: Very soft, non-stratified gray silty clay with a 1 cm thick layer of soupy brown material at the surface.

-Washed sediment: <0.150=mostly diatoms. >0.150mm=mostly clay aggregates.

-Fauna: *Adercotryma glomerata* =12%, *Eggerella advena* =12%, *Uvigerina juncea* =9%, *Bolivina pseudobeyrichi* =7%.

-Sponge spicules, worm tube, euphausids(?), ostracodes (rare).

-Other: Diatoms are abundant.

Station 4, Box Core 4A

- Location: In Snug Harbor, Naked Island.
- Water depth=125m.
- Sediment type: Very soft gray, slightly shelly, mottled mud.
- Washed sediment: <0.150mm=mostly diatoms. >0.150mm=mostly clay aggregates.
- Fauna: *Nonionella pulchella* =17%, *Eggerella advena* =9%, *Florilus labradoricus* =8%.
- Ostracodes; small pelecypods abundant.

Station 5, Box Core 5A

- Location: South of Naked Island
- Water Depth=215m.
- Sediment type: Gray silty clay covered by a thin (1cm thick) layer of brown soupy ooze-like mud.
- Washed sediment: <0.150mm=mostly diatoms. >0.150mm=mostly clay aggregates.
- Fauna: *Uvigerina juncea* =24%, *Islandiella norcrossi* =9%, *Elphidium clavatum* var. =8%.
- Ostracodes, worm tubes, pelecypods, euphausiids (?), sponge spicules, *Dentalia* (?)

Station 7

- Location: About 1.5 n.mi. southwest of Bligh Reef, along the trajectory of the oil from the point of spill.
- Sediment type: Very soupy gray, very fine mud; all tops disturbed.

--Box Core 7B

- Water Depth: 398m
- Washed sediment: <0.150mm=Nearly equal amounts of diatoms and clay aggregates; some detrital minerals. >0.150mm=mostly clay aggregates and clayey worm tubes.
- Fauna: *Bolivina pseudobeyrichi* =23%, *Uvigerina juncea* =17%, *Globobulimina* spp. =11%, *Florilus labradoricus* =9%, *Islandiella norcrossi* =9%.
- 2 very large *Hyperammia* sp. aff. *H. arenaria*.
- Clayey worm tubes, pelecypods, ostracodes (rare), euphausiids (?), echinoderm parts, fecal pellets.

--Box Core 7C

- Water Depth: 394m
- Washed sediment: <0.150mm=mostly diatoms. >0.150mm=diatoms and clay aggregates.
- Fauna: *Bolivina pseudobeyrichi* =36%, *Uvigerina juncea* =13%, *Globobulimina* =12%, *Florilus labradoricus* =9%, *Haplophragmoides bradyi* =9%.
- Ostracodes, fish vertebrae (?), echinoderm parts.
- Other: Some plant material.

Station 8, Box Core 8A

- Location: North of Naked Island.
- Water depth=480m.
- Sediment Type: Brown, very soupy mud.
- Washed sediment: <0.150mm=diatoms and clay aggregates. >0.150mm=slightly more clay aggregates than diatoms.

- Fauna: *Uvigerina juncea* =38%, *Bolivina pseudobeyrichi* =16%, *Haplophragmoides bradyi* =8%.
- Radiolarians (trace), ostracodes, pelecypods, insect wing, worm tubes (?), echinoderm parts.
- Other: Some plant material.

Station 9, Box Core 9A

- Location: West of Naked Island in the deepest part of Prince William Sound.
- Water Depth: 755m.
- Sediment Type: One to two cm-thick layer of brown watery mud overlying very soft gray mud.
- Washed sediment: <0.150mm=About equal amounts of clay aggregates and diatoms. >0.150mm=mostly clay aggregates some containing stained foraminifers such as *Uvigerina*.
- Fauna: *Bolivina pseudobeyrichi* =20%, *Uvigerina juncea* =20%, *Haplophragmoides bradyi* =14%.
- Other: Ostracodes (trace).

Station 10, Box Core 10A

- Location: North of Perry Island.
- Water Depth: 340m.
- Sediment type: Very soft light gray silty clay.
- Washed sediment: <0.150mm=more diatoms than clay aggregates. >0.150mm=clay aggregates more abundant than diatoms.
- Fauna: *Uvigerina juncea* =21%, *Haplophragmoides bradyi* =10%, *Bolivina pseudobeyrichi* =9%.
- Other: Ostracodes.

Station 11, Box Core 11A

- Location: Southwest of Perry Island
- Water Depth: 400m.
- Sediment type: Firm, light gray clayey diamict with angular pebbles up to 4cm in diameter overlain by brownish, watery sediment layer 0.5cm thick with numerous tube worms.
- Washed sediment: <0.150mm=mostly detrital sediment. >0.150mm=Networks of sponge spicules make up much of the coarse portion of the sediment; much detrital minerals and some clay.
- Fauna: *Trochammina* spp.=19%, *Reophax scorpiurus* =18%, *Reophax* spp.=13%, *Uvigerina juncea* =11%.
- A few very large agglutinated foraminifers *Nodosinum gaussicum* (?).
- Sponge spicules (net-like) very abundant, ostracodes, worms, brittle star, echinoderm parts.
- Other: Pine needle.

Station 12, Box Core 12A

-Location: In Herring Bay; chosen because of the reports of abundant oil on the beach and intertidal zone.

-Water depth: 183m.

-Sediment type: Thin, brown, soupy layer underlain by gray homogenous mud. Several large burrows (3-4 cm diameter, up to 30 cm deep) filled with very watery, soupy mud.

-Washed sediment: <0.150mm=mostly diatoms. >0.150mm=mostly clay aggregates; diatoms and clayey worm tubes common.

-Fauna: *Uvigerina juncea* =19%, *Islandiella norcrossi* =11%, *Globobulimina* spp. =9%, *Adercotryma glomerata* =8%.

-Fecal pellets.

Station 13, Box Core 13B

-Location: Central part of Knight Island Passage

-Water Depth: 389m.

-Sediment type: Brown mud over gray diamict.

-Washed sediment: <0.150mm=mostly diatoms. >0.150mm= Large masses of net-like sponge spicules; detrital minerals and clay aggregates.

-Fauna: *Angulogerina angulosa* =13%, *Uvigerina juncea* =13%, *Reophax subfusiformis* =9%, *Cibicides mckannai* =8%, *Reophax scorpiurus* =8%.

Station 15, Box Core 15A

-Location: South of Knight Island Island.

-Water Depth: 240m.

-Sediment type: Upper 2 cm is oxidized sand which is underlain by 5 cm of reduced sand and pebbles; the lower part of the core (10cm) is a diamict with pebbles, cobbles, some shell fragments and a large isolated pod of mud.

-Washed sediment: <0.150mm=mostly detrital minerals. >0.150mm=mostly detrital minerals; many large agglutinated foraminifers.

-Fauna: *Cribrostomoides crassimargo* =16%, *Adercotryma glomerata* =14%, *Rhabdammina* spp.=12%. -Sponge spicules.

Station 16

-Location: About 40km southwest of Seward.

-Water depth: 277m.

-Sediment type: Homogenous silty clay.

-Box Core 16A

-Washed sediment: <0.150mm=mostly diatoms. >0.150mm=clay aggregates slightly more abundant than diatoms.

-Fauna: *Nonionella pulchella* =20%, *Globobulimina* spp.=14%, *Florilus labradoricus* =13%. Ostracodes, fish tooth, echinoderm parts, euphausiid (?).

-Other: Diatoms very abundant.

-Box Core 16B:

- Washed sediment: <0.150mm=mostly diatoms. >0.150mm=clay aggregates more abundant than diatoms; some forams in the clay, many stained; some detrital minerals.
- Fauna: *Nonionella pulchella* =21%, *Globobulimina* spp.=18%, *Florilus labradoricus* =15%.
- Ostracodes (trace), worm tubes, echinoderm parts.
- Other: Diatoms very abundant.

Station 17, Box Core 17B

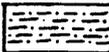
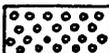
- Location: About 75km southwest of Seward.
- Water Depth: 115m.
- Sediment type: Homogenous muddy coarse sand, brownish surface with tube worms and a brittle star.
- Washed sediment: <0.150mm=detrital minerals and shell fragments. >0.150mm=mostly shell fragments; some detrital minerals and clay aggregates; a little glauconite (?).
- Fauna: *Cassidulina tortuosa* =39%, *C. californica* =26%, *Cibicides lobatulus* =23%.
- Some specimens are fresh-looking, others are dull, broken and/or filled with glauconite.
- Other: Pelecypods, gastropods, worms, ostracods, echinoderm parts.

Station 18, Box Core 18

- Location: About 50km west of Station 16.
- Water depth: 95m.
- Sediment type: A thin layer of oxidized ooze at the surface overlying gravelly, sandy mud with scattered shells.
- Washed sediment: <0.150mm=detrital minerals abundant; some diatoms. >0.150mm=detrital minerals abundant; some diatoms.
- Fauna: *Angulogerina angulosa* =33%, *Cassidulina limbata* =18%, *Cibicides lobatulus* =10%, *Cassidulina californica* =9%.
- Ostracodes (trace), pelecypods, sponge spicules, worms, fibrous brachiopod fragments.
- Other: Diatoms.

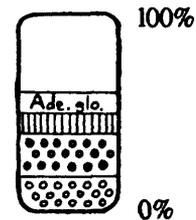
EXPLANATION OF SYMBOLS AND ABBREVIATIONS ON FIGURES 1 AND 2.

"Gold" or *Cassidulina californica* fauna:

<i>Cassidulina californica</i>	
<i>Cassidulina limbata</i>	
<i>Cassidulina tortuosa</i>	
<i>Cibicides lobatulus</i>	

Low Oxygen Fauna:

<i>Bolivina pseudobeyrichi</i>	
<i>Globobulimina spp.</i>	
<i>Uvigerina juncea</i>	



Bar graph

Abbreviations of other taxa on Figures 1 and 2:

- Ade.glo.= *Adercotryma glomerata*
- Ang.ang.= *Angulogerina angulosa*
- Ast.gal.= *Astrononion gallowayi*
- Elp.cla.= *Elphidium clavatum*
- Flo.lab.= *Florilus labradoricus*
- Non.pul.= *Nonionella pulchella*
- Tro.spp.= *Trochammina spp.*

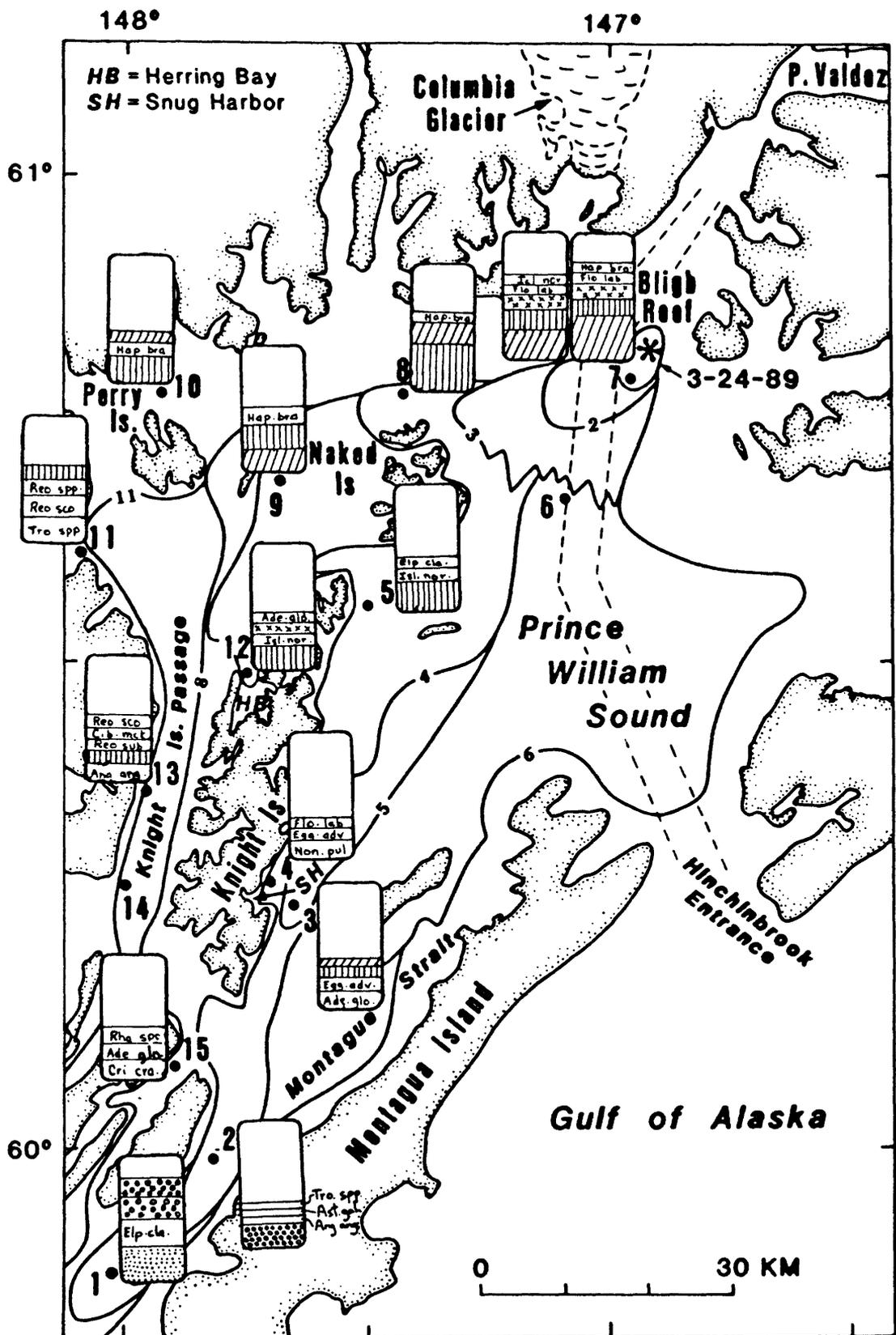


Figure 1. Location map for samples taken in Prince William Sound during cruise F5-89-PW. Bar graphs show percentage of total benthic foraminifera for the most abundant species at each site. See page 13 for explanation of symbols and abbreviations.

SAMPLE NUMBER SPECIES	Box 1	Box 2A	Box 3A	Box 4A	Box 5A	Box 7B	Box 7C	Box 8A	Box 9A	Box 10C	Box 11A	Box 12A	Box 13B	Box 15A	Box 16A	Box 16B	Box 17B	Box 18
	<i>Adercotryma glomerata</i>	1	2	12	4	6	1	1	2	4	3	3	8	2	1	4	4	X
<i>Ammobaculites</i> spp.	-	1	-	X	X	-	-	-	-	-	-	X	-	-	-	X	-	X
<i>Ammodiscus</i> spp.	-	X	3	2	X	X	-	X	-	X	-	X	1	1	-	-	-	X
<i>Ammotium cassis</i>	1	-	-	2	-	-	-	-	-	-	-	1	-	-	-	-	-	1
<i>Angulogerina angulosa</i>	3	6	1	1	2	-	-	-	-	X	3	5	13	3	X	-	2	33
<i>Astacolus</i>	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-
<i>Astrononion gallowayi</i>	1	6	-	1	1	-	X	X	1	2	X	2	1	1	X	1	X	X
<i>Bolivina decussata</i>	X	1	X	1	1	-	X	X	1	1	-	2	2	1	-	-	X	2
<i>B. pseudobeyrichi</i>	-	X	7	-	4	23	36	16	20	9	6	3	4	-	2	4	-	-
<i>B. spp.</i>	-	X	-	1	X	-	-	X	-	-	-	-	1	-	1	X	-	-
<i>Buccella frigida</i>	-	5	2	2	-	-	-	-	-	-	-	-	-	2	-	X	X	3
<i>B. spp.</i>	-	1	-	X	-	-	-	-	X	-	-	-	-	-	X	-	1	-
<i>Buliminella tenuata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	-	-
<i>Cassidulina californica</i>	14	X	-	X	-	-	-	-	-	-	-	-	2	-	-	X	26	9
<i>C. limbata</i>	29	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18
<i>C. minuta</i>	-	1	-	-	X	X	-	-	-	-	-	-	-	1	X	-	-	-
<i>C. tortuosa</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	39	X
<i>C. spp.</i>	X	X	-	X	-	-	X	-	-	1	-	-	-	-	-	-	1	1
<i>Cibicides lobatulus</i>	17	18	-	-	2	-	-	-	-	1	2	2	2	7	X	-	23	10
<i>C. mckannai</i>	2	-	-	-	-	-	-	2	-	1	2	3	8	1	-	-	-	-
<i>C. pseudoungeriana</i>	-	-	-	-	-	-	-	2	1	1	-	1	X	-	-	X	X	X
<i>C. spp.</i>	X	1	X	X	X	1	-	X	1	X	-	-	X	-	-	X	X	X
<i>Cribrostomoides crassimargo</i>	X	-	2	X	4	X	X	-	X	1	3	X	2	16	1	2	-	X
<i>C. jeffreysi</i>	-	-	-	-	-	1	-	-	-	X	1	-	1	2	X	-	-	X
<i>C. subglobosus</i>	-	-	-	-	-	X	-	-	X	-	-	-	-	-	-	-	-	-
<i>C. spp.</i>	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	X
<i>Dentalina</i> sp.	X	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	X	-
<i>Discorbis opercularis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
<i>D. ornatissima</i>	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
<i>D. sp. aff. D. praegeri</i>	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	X
<i>Eggerella advena</i>	-	1	12	9	1	-	3	1	2	-	-	2	-	-	5	3	-	X
<i>E. clavatum</i> var.	21	4	5	3	8	3	1	1	1	-	-	-	X	1	1	1	-	1
<i>E. orbiculare</i>	-	X	X	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-
<i>E.sp. aff. E.frigidum</i>	-	3	-	-	X	-	-	-	-	-	-	-	-	-	-	-	1	1
<i>E. spp.</i>	-	2	-	-	1	-	-	-	-	-	-	-	-	1	-	-	1	1
<i>Epistominella pacifica</i>	-	1	-	X	1	-	-	-	-	X	-	1	X	-	4	4	-	-

Table 1. Percentage distribution of Total (live + dead) species in surface samples.

x =<1%

- =absent

SAMPLE NUMBER SPECIES	Box 1	Box 2A	Box 3A	Box 4A	Box 5A	Box 7B	Box 7C	Box 8A	Box 9A	Box 10C	Box 11A	Box 12A	Box 13B	Box 15A	Box 16A	Box 16B	Box 17B	Box 18
	<i>E. vitrea</i>	-	2	2	3	1	-	X	-	-	3	-	6	2	-	2	-	-
<i>Eponides isabelleanus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
<i>E. leviculus</i>	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	X	X	-
<i>E. spp.</i>	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	X	X	X
<i>Fissurina spp.</i>	1	X	-	-	-	-	X	-	-	-	-	-	-	-	X	X	1	X
<i>Florilus auriculus</i>	1	1	-	-	-	1	-	-	-	-	-	-	X	-	-	-	X	3
<i>F. labradoricus</i>	-	2	3	8	4	9	9	2	6	2	-	1	1	-	13	15	-	X
<i>Fronicularia spp.</i>	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
<i>Fursenkoina spp.</i>	-	X	1	5	1	1	1	X	-	1	1	1	-	-	3	1	-	-
<i>Gaudryina arenaria</i>	X	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	1	2
<i>Globobulimina spp.</i>	X	1	5	4	4	11	12	X	X	6	2	9	1	-	14	18	-	X
<i>Guttulina spp.</i>	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
<i>Haplophragmoides bradyi</i>	-	X	6	4	1	3	9	8	14	10	1	1	2	1	5	5	X	X
<i>Hippocrepina indivisa</i>	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Hormosina orvicula</i>	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-
<i>Hyperammina arenaria</i>	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	X	-
<i>Islandiella norcrossi</i>	1	1	3	2	9	9	X	7	4	6	1	11	5	2	1	1	X	1
<i>I. teretis</i>	-	X	-	X	-	-	-	1	-	-	-	-	2	-	X	-	-	-
<i>Jaculella spp.</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
<i>Lagena spp.</i>	1	-	1	X	1	1	-	X	1	X	-	2	X	-	X	-	-	2
<i>Lenticulina sp.</i>	-	X	-	-	-	-	X	-	X	-	-	-	-	-	-	-	X	-
<i>Meidamonella baccata</i>	X	-	X	-	-	1	-	1	-	-	2	2	X	-	-	-	X	X
<i>Nodosinum gaussicum</i>	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-
<i>Nonionella pulchella</i>	-	3	5	17	X	-	1	-	-	-	-	-	-	1	20	21	-	-
<i>N. turgida digitata</i>	-	X	X	-	X	2	3	X	X	1	-	X	-	-	2	2	-	-
<i>Oolina spp.</i>	-	1	-	X	-	-	-	-	-	-	-	-	-	-	X	-	X	1
<i>Polymorphina spp.</i>	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X
<i>Psammosphaera spp.</i>	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
<i>Pullenia salisburyi</i>	2	2	-	-	-	-	-	1	1	3	1	2	-	X	X	1	-	-
<i>Pyrgo spp.</i>	X	-	-	-	X	-	-	X	X	-	-	X	-	-	X	-	X	X
<i>Quinqueloculina stalkerii</i>	-	2	-	-	-	-	3	-	1	-	-	X	-	-	X	1	-	X
<i>Q. spp.</i>	1	1	2	-	2	X	2	4	-	1	-	X	X	-	1	X	X	-
<i>Recurvoides spp.</i>	X	X	X	5	6	7	1	4	5	4	2	-	2	4	5	4	X	1
<i>Reophax difflugiformis</i>	-	X	-	-	-	-	-	1	-	-	-	-	-	4	-	X	-	-
<i>R. fusiformis</i>	-	4	1	2	2	-	-	-	-	1	-	1	X	8	1	1	-	-
<i>R. scorpiurus</i>	X	X	-	X	2	-	-	-	-	7	18	4	8	2	X	-	X	X

Table 1 continued

SAMPLE NUMBER	SPECIES																	
	Box 1	Box 2A	Box 3A	Box 4A	Box 5A	Box 7B	Box 7C	Box 8A	Box 9A	Box 10C	Box 11A	Box 12A	Box 13B	Box 15A	Box 16A	Box 16B	Box 17B	Box 18
<i>R. subfusiformis</i>	-	X	-	-	-	-	-	-	-	-	3	2	9	-	X	-	-	-
<i>R. spp.</i>	3	-	2	X	5	3	2	7	11	7	13	3	-	-	-	-	X	X
<i>Rhabdammina spp.</i>	X	-	-	-	-	-	-	-	-	-	-	-	-	12	-	-	X	X
<i>Robertinoides charlottensis</i>	-	-	-	X	-	-	-	-	-	-	-	-	-	-	X	-	-	-
<i>Rosalina vilardeboana</i>	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>R. spp.</i>	-	3	-	-	X	-	-	-	-	X	-	-	-	-	-	-	-	-
<i>Rotalia columbiensis</i>	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Silicosigmolina</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
<i>Spirillina sp.</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-
<i>Spiroplectammina biformis</i>	-	X	-	4	-	-	1	X	-	1	X	X	X	6	1	-	-	X
<i>S. spp.</i>	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	X	-	-
<i>Subreophax aduncus</i>	-	-	X	-	-	X	-	-	-	-	-	X	-	-	-	-	-	-
<i>Textularia spp.</i>	-	X	-	1	-	-	-	X	X	1	-	X	X	-	1	X	-	-
<i>Triloculina trihedra</i>	-	-	X	-	X	-	-	-	X	-	-	-	-	-	-	-	-	-
<i>Trochammina squamata</i>	-	1	-	X	-	-	-	-	-	X	-	X	-	1	-	X	-	X
<i>T. spp.</i>	1	6	4	4	4	3	1	3	3	7	19	5	6	7	4	2	X	4
<i>Uvigerina juncea</i>	1	4	9	4	24	17	13	38	20	21	11	19	13	2	5	6	X	1
<i>U. senticosa</i>	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-
<i>Valvulineria sp.</i>	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-
other calcareous	-	1	1	X	-	1	X	-	X	1	1	X	-	-	-	-	X	-
other agglutinated	-	X	4	5	X	-	X	-	-	-	-	X	X	-	-	-	X	-
other miliollids	-	X	3	X	-	1	-	-	-	-	-	-	-	-	X	X	X	X
Number of specimens	339	1157	238	514	249	235	731	785	752	351	348	414	408	179	1172	555	979	655

Table 1 continued

SAMPLE NUMBER																		
	Box 1	Box 2A	Box 3A	Box 4A	Box 5A	Box 7B	Box 7C	Box 8A	Box 9A	Box 10C	Box 11A	Box 12A	Box 13B	Box 15A	Box 16A	Box 16B	Box 17B	Box 18
SPECIES																		
<i>Adercotryma glomerata</i>	x	1	5	2	4	-	1	1	2	2	x	2	x	2	3	3	-	1
<i>Ammobaculites</i> spp.	-	x	-	x	-	-	-	-	-	-	-	x	-	-	-	x	-	x
<i>Ammodiscus</i> spp.	-	-	1	x	x	x	-	x	-	1	-	1	-	-	-	1	-	1
<i>Ammotium cassis</i>	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Angulogerina angulosa</i>	-	x	1	-	1	-	-	-	-	x	1	1	1	-	x	-	x	1
<i>Astacolus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Astrononion gallowayi</i>	-	x	-	1	-	-	-	x	1	1	x	x	x	-	x	1	-	-
<i>Bolivina decussata</i>	-	x	-	x	x	-	-	x	-	-	-	x	x	-	-	-	-	-
<i>B. pseudobeyrichi</i>	-	x	5	-	2	17	17	8	13	6	4	x	2	-	1	2	-	-
<i>B. spp.</i>	-	-	-	1	x	-	-	x	-	-	-	-	-	-	x	x	-	-
<i>Buccella frigida</i>	-	x	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>B. spp.</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-
<i>Buliminella tenuata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	x	-	-
<i>Cassidulina californica</i>	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	1
<i>C. limbata</i>	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
<i>C. minuta</i>	-	x	-	-	-	x	-	-	-	-	-	-	-	-	x	-	-	-
<i>C. tortuosa</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>C. spp.</i>	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-
<i>Cibicides lobatulus</i>	x	x	-	-	x	-	-	-	-	-	x	1	-	1	-	-	x	x
<i>C. mckannai</i>	-	-	-	-	-	-	-	2	-	1	x	1	1	-	-	-	-	-
<i>C. pseudoungeriana</i>	-	-	-	-	-	-	-	1	x	1	-	x	-	-	-	-	-	-
<i>C. spp.</i>	-	x	-	x	-	x	-	x	1	-	-	-	-	-	-	x	-	x
<i>Cribrostomoides crassimargo</i>	x	-	1	-	x	x	x	-	-	-	1	-	x	4	x	1	-	x
<i>C. jeffreysi</i>	-	-	-	-	-	-	-	-	-	x	-	-	x	1	-	-	-	-
<i>C. subglobosus</i>	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-
<i>C. spp.</i>	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x
<i>Dentalina</i> sp.	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Discorbis opercularis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>D. ornatissima</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>D. sp. aff. D. praegeri</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Eggerella advena</i>	-	x	10	5	1	-	2	1	1	-	-	1	-	-	4	3	-	-
<i>E. clavatum</i> var.	x	-	2	x	x	1	-	x	x	-	-	-	-	-	x	-	-	-
<i>E. orbiculare</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-
<i>E.sp. aff. E.frigidum</i>	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>E. spp.</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
<i>Epistominella pacifica</i>	-	x	-	-	-	-	-	-	-	-	-	-	-	-	1	x	-	-

Table 2. Percentage distribution of Live species (calculated as percentage of the Total number of specimens) in surface samples.

x =<1%

- =absent

SAMPLE NUMBER																		
	Box 1	Box 2A	Box 3A	Box 4A	Box 5A	Box 7B	Box 7C	Box 8A	Box 9A	Box 10C	Box 11A	Box 12A	Box 13B	Box 15A	Box 16A	Box 16B	Box 17B	Box 18
SPECIES																		
<i>E. vitrea</i>	-	X	1	2	X	-	X	-	-	2	-	2	-	-	-	-	-	X
<i>Eponides isabelleanus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>E. leviculus</i>	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	X	-	-
<i>E. spp.</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Fissurina spp.</i>	-	-	-	-	-	-	X	-	-	-	-	-	-	-	X	-	-	-
<i>Florilus auriculus</i>	X	X	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	X
<i>F. labradoricus</i>	-	X	3	2	1	8	5	X	2	1	-	-	X	-	2	3	-	-
<i>Fronicularia spp.</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Fursenkoina spp.</i>	-	X	-	4	1	X	1	X	-	1	X	3	-	-	1	1	-	-
<i>Gaudryina arenaria</i>	X	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-
<i>Globobulimina spp.</i>	-	X	3	2	2	8	9	X	X	4	X	1	1	-	9	13	-	-
<i>Guttulina spp.</i>	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Haplophragmoides bradyi</i>	-	X	3	3	X	-	2	1	1	3	1	X	X	-	2	2	X	X
<i>Hippocrepina indivisa</i>	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Hormosina orvicula</i>	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-
<i>Hyperammina arenaria</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Islandiella norcrossi</i>	1	-	-	1	1	3	-	2	1	1	1	X	-	-	X	X	-	-
<i>I. teretis</i>	-	-	1	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-
<i>Jaculella spp.</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Lagena spp.</i>	-	-	-	X	1	-	-	-	X	X	-	-	-	-	-	-	-	-
<i>Lenticulina sp.</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Meidamonella baccata</i>	-	-	-	-	-	X	-	X	-	-	1	1	-	-	-	-	-	-
<i>Nodosinum gaussicum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Nonionella pulchella</i>	-	X	1	10	-	-	X	-	-	-	-	-	-	-	2	3	-	-
<i>N. turgida digitata</i>	-	-	-	-	-	2	2	X	-	-	-	-	-	-	X	1	-	-
<i>Oolina spp.</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Polymorphina spp.</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Psammosphaera spp.</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Pullenia salisburyi</i>	-	X	-	-	-	-	-	-	X	-	2	-	X	-	X	X	X	X
<i>Pyrgo spp.</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Quinqueloculina stalkerii</i>	-	X	-	-	-	-	X	-	-	-	-	-	-	-	X	-	-	-
<i>Q. spp.</i>	1	-	2	-	X	-	1	3	-	X	-	-	-	-	1	X	-	-
<i>Recurvoides spp.</i>	X	X	X	1	2	X	X	X	1	X	1	-	-	1	2	1	-	X
<i>Reophax difflugiformis</i>	-	X	-	-	-	-	-	X	-	-	-	-	-	1	-	X	-	-
<i>R. fusiformis</i>	-	2	1	2	1	-	-	-	-	1	-	1	-	2	X	1	-	-
<i>R. scorpiurus</i>	X	X	-	X	1	-	-	-	-	4	7	2	3	1	X	-	X	X

Table 2 continued

SPECIES	SAMPLE NUMBER																	
	Box 1	Box 2A	Box 3A	Box 4A	Box 5A	Box 7B	Box 7C	Box 8A	Box 9A	Box 10C	Box 11A	Box 12A	Box 13B	Box 15A	Box 16A	Box 16B	Box 17B	Box 18
<i>R. subfusiformis</i>	-	X	-	-	-	-	-	-	-	X	-	-	-	-	X	-	-	X
<i>R. spp.</i>	2	-	X	X	-	-	-	3	4	3	3	-	-	-	-	-	X	X
<i>Rhabdammina spp.</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	X	-
<i>Robertinoides charlottensis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Rosalina vilardeboana</i>	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>R. spp.</i>	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-
<i>Rotalia columbiensis</i>	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Silicosigmolina</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Spirillina sp.</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-
<i>Spiroplectammina biformis</i>	-	-	-	-	-	-	X	X	-	X	-	-	-	4	X	-	-	-
<i>S. spp.</i>	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-
<i>Subreophax aduncus</i>	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-
<i>Textularia spp.</i>	-	-	-	-	-	-	-	X	-	-	-	-	-	-	X	-	-	-
<i>Triloculina trihedra</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Trochammina squamata</i>	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>T. spp.</i>	1	X	3	2	2	-	X	1	1	3	3	1	1	2	2	1	-	X
<i>Uvigerina juncea</i>	-	1	7	3	9	6	3	11	8	11	2	3	1	1	2	3	X	-
<i>U. senticosa</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Valvulineria sp.</i>	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-
other calcareous	-	X	1	X	-	-	X	-	X	X	-	-	-	-	-	-	-	-
other agglutinated	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
other miliollids	-	-	2	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-
Number of specimens	339	1157	238	514	249	235	731	785	752	351	348	414	408	179	1172	555	979	655

Table 2 continued

SAMPLE NUMBER	Box 7C	Box 9A	Box 9A	Box 9B																
	2-8cm	2-8cm	2.5-30cm	270cm																
SPECIES	7C	9A	9A	9B																
<i>R. subfusiformis</i>	-	-	9	-																
<i>R. spp.</i>	X	7	4	-																
<i>Rhabdammina spp.</i>	-	-	-	-																
<i>Robertinoides charlottensis</i>	-	-	-	-																
<i>Rosalina vilardeboana</i>	-	-	-	-																
<i>R. spp.</i>	-	-	-	-																
<i>Rotalia columbiensis</i>	-	-	-	-																
<i>Silicosigmolina</i>	-	-	-	-																
<i>Spirillina sp.</i>	-	-	-	-																
<i>Spiroplectammina biformis</i>	2	X	X	-																
<i>S. spp.</i>	-	-	-	-																
<i>Subreophax aduncus</i>	-	-	-	-																
<i>Textularia spp.</i>	-	2	-	-																
<i>Triloculina trihedra</i>	-	-	X	-																
<i>Trochammina squamata</i>	-	X	-	-																
<i>T. spp.</i>	1	4	1	-																
<i>Uvigerina juncea</i>	12	16	29	25																
<i>U. senticosa</i>	-	-	X	-																
<i>Valvulineria sp.</i>	-	-	1	-																
other calcareous	1	X	X	-																
other agglutinated	X	X		-																
other miliollids	-	X	1	-																
Number of specimens	488	288	506	4																

Table 3 continued

SPECIES	SAMPLE NUMBER						
	Box 7B 0-2cm	Box 7C 0-2cm	Box 7C 2-8cm	Box 9A 0-2cm	Box 9A 2-8cm	Box 9A 25-30cm	Box 9B 270cm
<i>Bolivina pseudobeyrichi</i>	23	36	19	20	13	4	0
<i>Globobulimina</i> spp.	11	12	16	x	0	1	0
<i>Uvigerina juncea</i>	17	13	12	20	16	29	25
% of low oxygen species in each sample	51	61	47	40	29	33	25

Table 4. Percentage of low oxygen species in surface and subsurface samples.
x =<1%