

Biostratigraphy and assemblage composition of benthic foraminifera from the Manihiki Plateau, southwestern tropical Pacific

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ABSTRACT - Pleistocene and late Pliocene benthic foraminifera from the Manihiki Plateau (southwestern tropical Pacific) were studied at piston-core 34KL. A new benthic foraminiferal biozonation is proposed. It comprises the *Nodogenerina sagriensis* Partial Range Zone from core base to 566.5 cm and the *Fissurina seminiformis* Partial Range Zone from this level to core top. The boundary is defined by the last occurrence of *Nodogenerina sagriensis* which is time equivalent to the 'Stilostomella extinction' in the Eastern Atlantic. High abundances of *Cibicoides wuellerstorfi* indicate a strong influence of near-bottom currents. The absence of high-productivity sensitive species reveals a low flux of organic matter to the sea floor from which a considerable amount is adduced by lateral advection. *J. Micropalaeontol.* 14(2): 165–175, October 1995.

INTRODUCTION

As with other fossil groups, benthic foraminifera are widely used for biostratigraphical subdivisions. Their early evolution resulted in a high degree of environmental adaptation among species which is often recognized as facies dependency. Accordingly, biostratigraphical correlations by using benthic foraminifera are often difficult in the late Cenozoic. Deep-sea benthic foraminifera display in addition considerable extended stratigraphic ranges as many of them appeared first in the early Cenozoic.

A first subdivision of the Neogene and Quaternary by using benthic foraminifera was attempted by Lutze (1979; fig. 7) who discerned five faunal units, NB5a to NB6c at DSDP Site 397 (Northwest-African continental margin). The extinction of five Pliocene species and genera marks the major faunal change in this section, i.e. the NB5/6 boundary, which roughly correlates with the boundary of Brunhes/Matuyama magnetochrons. This *Stilostomella* extinction event was confirmed from other locations in the eastern Atlantic by Caralp (1984) and compiled by Weinholz & Lutze (1989) who described an irregular extinction pattern of *Stilostomella* and associated taxa over a time interval of more than 160 000 years around the Brunhes/Matuyama boundary. The *Stilostomella* extinction was not recognized, however, by Berggren & Miller (1989) for their Cenozoic bathyal and abyssal foraminiferal zonation.

A benthic foraminiferal biozonation has not been proposed to date for Quaternary deposits from the Pacific. Data suggest that the 'Stilostomella extinction' may also occur in this realm (Gupta, 1993; Resig, 1976, tab. 1; Keller, 1980, tab. 2,3; Schönfeld & Spiegler, in press). However, the last occurrence data of *Stilostomella* and affiliate taxa have not been determined precisely in relation to other biostratigraphic data, oxygen isotope events, or magnetostratigraphic datum levels.

On R.V. *Sonne*-cruise SO67 in 1990, piston core 34KL was taken from the high-plateau area of the Manihiki

Plateau, about 148 km southwest of Manihiki Island (Cook Islands) at 11°0.1'S, 162°15.8'W, and 2612 m waterdepth (Fig. 1; Beiersdorf, 1990). The piston core recovered 1620 cm foraminiferal-nannofossil ooze of light yellowish brown to white color (Fig. 2). The sediment is homogeneously bioturbated; a few distinct burrows, mainly *Zoophycos*, are visible.

As the site is well above the calcite compensation depth and far away from continental sources, core 34KL was chosen for a comparative stratigraphic and palaeoceanographic study. Magnetostratigraphy, nannofossil and planktonic foraminiferal zonations as well as a high-resolution oxygen-isotope stratigraphy were established (Beiersdorf *et al.*, in press; Bickert *et al.*, 1994). The palaeomagnetic polarity scale indicates that the record goes back to the Late Pliocene and that the core base is approximately 2.6 million years old (Fig. 2). A continuous oxygen isotope record reveals that no larger hiatus is present. Core 34KL therefore provides a suitable section to determine stratigraphic ranges of benthic foraminifera in a high pelagic environment and to describe long term variations in assemblage composition. Palaeoenvironmental implications, as inferred from flux rates and the foraminiferal community structure, are discussed.

MATERIAL AND METHODS

Ninety-one volume-defined samples, on average 20 cm³, were taken from core 34KL by using the syringe method. The samples were washed on a 63 µm mesh, the residues were dried and split into two aliquots. From 59 selected samples, benthic foraminifera were picked from the 250–2000 µm fraction of one half-split. This grain-size fraction was chosen because of the better observation of assemblage fluctuations owing to the smaller species number and because of the elimination of smaller forms which are more easily displaced by redeposition (Lohmann, 1978; Lutze & Coulbourn, 1984). Foraminiferal tests were

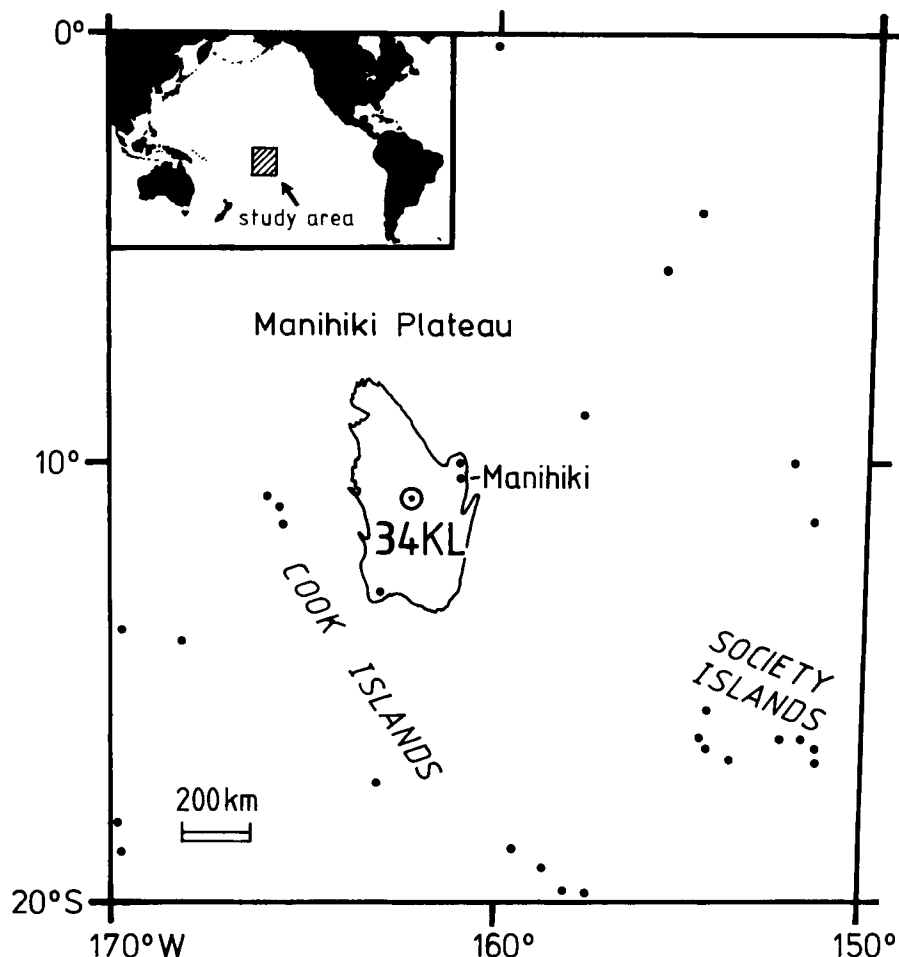


Fig. 1. Geographical setting of the Manihiki Plateau and core 34KL. The plateau is indicated by the 3500 m depth contour (Beiersdorf, 1990).

collected in Plummer cell-slides where they were sorted on species level, fixed, and counted. The total number of tests collected varied from 37 to 167 specimens. The content of benthic foraminifers per gram dry sediment is in the range of 4.1 to 18.8 tests for the 250–2000 μm fraction.

The age model of Beiersdorf *et al.* (1993) which has been developed from the oxygen isotope stratigraphy, was used for the present study. This model is based on the SPECMAP time scale (Imbrie *et al.*, 1984) and the astronomical calibrated timescale of Shackleton *et al.* (1990) which is also applied to the magnetostratigraphy at this core. Ages of biostratigraphic data were determined by linear interpolation between adjacent oxygen isotopic events.

Flux rates were calculated for selected foraminiferal species and assemblages from the census data by using the following equation (after Schönfeld, 1990):

$$\text{FR} = \frac{\text{BF} * \text{AR}}{\text{SW}} \quad [1]$$

where FR is the flux rate of benthic foraminifers [specimens/ $\text{cm}^2 * \text{ky}$], BF is the number of benthic forami-

fers in the whole sample, AR is the sediment accumulation rate [$\text{g}/\text{cm}^2 * \text{ky}$] and SW is the sample weight [g]. The accumulation rates were taken from Beiersdorf, *et al.* (in press).

BENTHIC FORAMINIFERAL ASSEMBLAGES FROM THE MANIHIKI PLATEAU

Sixty-one different benthic foraminiferal species were identified (Tab. 1). The assemblage is dominated by calcareous-perforate species (49), the diversity of arenaceous (5) and miliolid (7) foraminifers is rather low.

Cibicides wuellerstorfi and *Oridorsalis umbonatus* are the dominant faunal elements with mean proportions of 30 and 12% respectively (Table 2). *Melonis pompilioides*, *Pullenia bulloides*, *Anomalina globulosa*, and *Pyrgo murrhina* are frequent species. Common but occasional dominant faunal elements are *Cibicides robertsonianus*, *Eggerella bradyi*, *Gyroidina zelandica*, *Karreriella bradyi*, *Melonis barleeanum*, *Nonion* sp. and *Pyrgo serrata*. This benthic foraminiferal assemblage displays bathyal charac-

Table 1. Benthic foraminiferal species. Note: Taxonomic references were given by Barker (1960) and Ellis & Messina (1940-1978). They are not included in the reference list.

<i>Ammobaculites reophaciformis</i> Cushman, 1911
<i>Ammosphaeroidina sphaeroidiniformis</i> (Brady, 1884)
<i>Anomalina globulosa</i> Chapman & Parr, 1937
<i>Bulimina alazanensis</i> (Cushman, 1927)
<i>Cassidulina subglobosa</i> Brady, 1881
<i>Chilostomella ovoidea</i> Reuss, 1850
<i>Cibicidoides kullenbergi</i> (Parker, 1953)
<i>Cibicidoides pseudoungerianus</i> (Cushman, 1922)
<i>Cibicidoides robertsonianus</i> (Brady, 1881)
<i>Cibicidoides wuellerstorfi</i> (Schwager, 1866)
<i>Dentalina communis</i> Orbigny, 1826
<i>Dentalina comatula</i> (Cushman, 1923)
<i>Dentalina filiformis</i> Orbigny, 1826
<i>Dentalina intorta</i> (Dervieux, 1894)
<i>Eggerella bradyi</i> (Cushman, 1911)
<i>Epistominella exigua</i> (Brady, 1884)
<i>Epistominella umbonifera</i> (Cushman, 1933)
<i>Epistominella rugosa</i> (Phleger & Parker, 1951)
<i>Favocassidulina favus</i> (Brady, 1884)
<i>Fissurina alveolata</i> (Brady, 1884)
<i>Fissurina cf. fimbriata</i> (Brady, 1881)
<i>Fissurina seminiformis</i> (Schwager, 1866)
<i>Fissurina trigono-marginata</i> (Parker & Jones, 1865)
<i>Fissurina wiesneri</i> Barker, 1960
<i>Gavelinopsis translucens</i> (Phleger & Parker, 1951)
<i>Glandulina laevigata</i> Orbigny, 1826
<i>Gyroidina cf. lamarckiana</i> (Orbigny, 1839)
<i>Gyroidina orbicularis</i> Orbigny, 1826
<i>Gyroidina zelandica</i> Finlay, 1939
<i>Karrerella bradyi</i> (Cushman, 1911)
<i>Lagena laevicostata</i> Cushman & Gray, 1946
<i>Lagena striata</i> (Orbigny, 1839)
<i>Laticarinina pauperata</i> (Parker & Jones, 1865)
<i>Lenticulina gibba</i> (Orbigny, 1839)
<i>Melonis barleeianum</i> (Williamson, 1858)
<i>Melonis pompilioides</i> (Fichtel & Moll, 1798)
<i>Nodogenerina sagrinensis</i> (Bagg, 1912)
<i>Nodosaria radícula</i> (Linné, 1758)
<i>Nonion</i> sp. Parker, 1964
<i>Oolina globosa</i> (Montagu, 1803)
<i>Oolina cf. longispina</i> (Brady, 1881)
<i>Oridorsalis umbonatus</i> (Reuss, 1851)
<i>Orthomorphina challengeriana</i> (Thalman, 1937)
<i>Osangularia cultur</i> (Parker & Jones, 1865)
<i>Pleurostomella alternans</i> Schwager, 1866
<i>Pleurostomella brevis</i> Schwager, 1866
<i>Pullenia bulloides</i> (Orbigny, 1826)
<i>Pullenia quinqueloba</i> (Reuss, 1851)
<i>Pyrgo murrhina</i> (Schwager, 1866)
<i>Pyrgo serrata</i> (Bailey, 1861)
<i>Pyrulina angusta</i> (Egger, 1857)
<i>Pyrulina extensa</i> (Cushman, 1923)
<i>Pyrulina cf. fusiformis</i> (Roemer, 1838)
<i>Pyrulina cf. gutta</i> Orbigny, 1826
<i>Quinqueloculina cf. lamarckiana</i> Orbigny, 1839
<i>Quinqueloculina seminula</i> —group Linné
<i>Quinqueloculina venusta</i> Karrer, 1868
<i>Sigmoilinita distorta</i> (Phleger & Parker, 1951)
<i>Textularia australis</i> Parr, 1950
<i>Triloculina tricarinata</i> Orbigny, 1826
<i>Uvigerina auberiana</i> Orbigny, 1839

BENTHIC FORAMINIFERAL BIOZONES

A new benthic foraminiferal biozonation is proposed for the succession at core 34KL. The zones may be further subdivided by stratigraphical restricted acme occurrences.

Stratigraphic ranges of index species and the biozonation are shown in Fig. 2.

Nodogenerina sagriensis Partial Range Zone

Lowermost section part, from core base to 566.5 cm (>2,594–996 ka)

Lower boundary: Not defined

Upper boundary: The last occurrence of *Nodogenerina sagriensis*

The upper boundary of this zone corresponds to the ‘*Stilostomella* extinction’ around the Brunhes/Matuyama boundary described from the Eastern Atlantic. It is located 61.5 cm below this magnetic reversal at core 34KL. The age of the last occurrence of *Nodogenerina sagriensis*, as interpolated between oxygen isotopic events 25 and 29, is distinctively older than those given by Weinholz & Lutze (1989, fig.1) which were calculated by linear interpolation between magnetostratigraphic events. If the age model of Weinholz & Lutze (1989, fig. 1) is applied to the ‘*Stilostomella* extinction’ at core 34KL (Brunhes/Matuyama boundary: 730 ka, top Jamarillo Event: 910 ka), the resulting age of 760 ka is well within the range given by Weinholz & Lutze (1989). As such, the last occurrence of *Nodogenerina sagriensis* at this site in the southwestern tropical Pacific documents a world-wide extinction event.

Nodogenerina sagriensis is the only ‘*Stilostomella*’ recorded at core 34KL. This species survives *Pleurostomella alternans* and *Pleurostomella brevis* which disappear below, at 634 and 670.5 cm respectively. Their last occurrence data are, however, time transgressive. *Pleurostomella brevis* disappears in the Eastern Atlantic later (above top Jamarillo Event) than on the Manihiki Plateau (below Jamarillo Event). *Pleurostomella alternans* is still present in the Eastern Atlantic today: living specimens were found in surface samples off Cape Blanc and from the deep Guinea Basin (Timm, pers. comm.).

From 1070.5 cm (1,980 ka) on, *Nonion* sp. occurs with moderate abundances in most of the samples examined, which is only 29 cm below the base of the nannofossil zone NN19. No corresponding acme occurrence of *Nonion* sp. has been reported to date. This species has been described by Parker (1964) from the experimental Mohole drillsite near Guadalupe Island off Baja California, where it ranges from Middle Miocene to Pliocene.

Dentalina spp. occur with moderate abundances below 957 cm (1,725 ka), but they are rare above. This datum coincides roughly with the top of the Olduvai Event. Downhole increasing abundances of Nodosariacea towards the Pliocene/Pleistocene are documented from many DSDP Sites (e.g. Caralp, 1984; Keller, 1980) but are not constrained to date.

Fissurina seminiformis Partial Range Zone

From 566.5 cm to 13.5 cm (core top) (996 ka to present)

Lower boundary: The last occurrence of *Nodogenerina sagriensis*

Upper boundary: not defined

Fissurina seminiformis occurs above 456.0 cm (0.755 ma) in most of the samples with low abundances, not exceeding 2%. The species is not recorded, however, in a section

Table 2. Accumulation rates of benthic foraminifers and census data of frequent species and epibenthic foraminifers from core 34KL. BF: benthic foraminifers [250–2000 μm] tot.smp.: total sample, AR Sed.: accumulation rate [g/cm²*ky], AR BF: flux rate of benthic foraminifers [specimens/cm²*ky], cnt.spec.: counted specimens, elev.epibe.: cumulative percent of elevated epibenthic species. Anom.glob.: *Anomalina globulosa*, Cib.rob.: *Cibicides robertsonianus*, Cib.wuel.: *Cibicides wuellerstorfi*, Egg.brad.: *Eggerella bradyi*, Gyr.zeel.: *Gyroidina zelandica*, Karr.brad.: *Karreriella bradyi*, Mel.bart.: *Melonis barleanum*, Mel.pomp.: *Melonis pompilioides*, Orid.umbo.: *Oridorsalis umbonatus* Non.sp.: *Nonion* sp., Pull.bull.: *Fullenia bulloides*, Pyrg.murr.: *Pyrgo murrhina*, Pyrg.serr.: *Pyrgo serrata*, Cib.kull.: *Cibicides kullenbergi*, Cib.pseu.: *Cibicides pseudoungerianus*, Epi.exi.: *Epistominella exigua*, Gav.tran.: *Gavlinopsis transluens*.

Sample [cm]	BF		AR BF	AR Sed.	Anom. glob.	Cib. rob.	Cib. wuel.	Cib.	Egg. brad.	Gyr. zeel.	Karr. brad.	Mel. bart.	Mel. pomp.	Orid. umbo.	Non. sp.	Pull. bull.	Pyrg. murr.	Pyrg. serr.	Pyrg. cnt. spec.	Cib. kull.	Cib. pseu.	Cib. wuel.	Epi. exi.	Gav. tran.	elev. epibe.	
	Weight [g]	Smp.																								
28.5	18.20	336	0.40	7.38	-	9.6	25.7	4.8	0.6	0.6	0.6	1.2	8.4	19.2	-	1.8	5.4	-	167	-	-	25.7	0.6	0.6	26.9	
38.5	16.02	310	0.61	11.51	-	8.1	32.2	2.0	5.4	0.7	0.7	0.7	6.0	17.4	1.3	2.0	5.4	1.3	149	-	-	32.2	-	-	32.2	
50.5	16.99	319	0.61	11.46	1.3	1.3	28.2	0.6	1.9	-	-	-	16.7	17.9	3.2	1.9	5.8	1.3	156	-	-	28.2	-	-	28.2	
69.5	15.98	289	0.48	7.49	-	0.8	20.6	3.2	3.2	3.2	3.2	3.2	18.3	19.8	-	9.5	6.2	2.4	126	-	-	20.6	0.8	1.6	23.0	
88.5	16.07	299	0.35	6.24	0.7	-	34.2	2.7	8.7	1.3	0.7	0.7	4.7	16.8	2.0	7.4	6.7	-	149	-	-	34.2	1.3	-	35.5	
99.5	17.41	247	0.35	4.98	-	-	30.0	6.7	-	-	-	-	2.5	25.0	1.7	10.8	5.8	0.8	120	-	-	30.0	-	0.8	30.8	
130.5	15.77	166	0.74	7.80	-	-	30.5	6.1	4.8	-	-	1.2	6.1	18.3	-	9.8	3.7	2.4	82	-	-	30.5	-	1.6	32.6	
140.5	16.82	263	0.74	11.59	-	-	31.0	3.2	4.8	-	-	3.2	7.9	21.4	2.4	6.3	7.9	-	126	-	-	31.0	-	1.6	32.6	
159.5	16.07	227	0.52	7.35	3.6	-	29.1	2.7	9.1	-	-	0.9	1.8	16.4	2.7	3.6	11.8	0.9	110	-	-	29.1	-	1.8	30.9	
160.5	16.28	182	0.54	6.03	1.1	-	25.3	12.1	5.5	-	-	-	6.6	12.6	-	5.5	9.9	2.2	91	-	-	25.3	-	3.3	28.6	
190.5	17.28	197	0.54	6.17	1.1	-	48.4	2.1	4.2	-	-	-	5.3	12.7	-	3.2	6.3	1.1	95	-	-	48.4	-	2.1	50.5	
208.5	15.75	128	0.94	7.63	1.6	-	34.9	1.6	1.6	-	1.6	-	7.0	18.3	-	16.9	4.2	4.2	71	-	-	34.9	-	-	31.0	
229.5	15.72	145	0.59	5.44	-	1.4	31.0	2.8	-	-	1.4	-	3.6	26.5	-	22.9	1.2	-	83	-	-	31.0	-	-	27.7	
250.5	16.18	168	0.34	3.53	2.4	1.2	27.7	1.2	1.2	-	-	-	3.6	26.5	-	17.5	10.0	2.5	40	-	-	27.7	-	-	25.0	
259.5	16.39	81	0.36	5.66	5.0	2.5	25.0	2.5	-	-	-	-	7.5	17.5	-	17.5	10.0	2.5	40	-	-	25.0	-	-	25.0	
309.5	16.72	131	0.74	5.96	4.5	4.5	31.8	10.6	1.5	-	-	1.5	3.0	7.6	-	1.5	6.1	4.5	66	-	-	31.8	-	-	31.8	
329.5	16.82	110	0.34	2.21	1.9	5.6	50.0	1.9	3.7	1.9	1.9	-	3.7	11.1	1.9	1.9	1.9	1.9	54	-	-	50.0	-	-	50.0	
339.5	18.17	113	0.38	2.37	-	2.0	43.1	2.0	2.0	3.9	3.9	-	3.9	7.8	-	15.9	4.5	11.4	44	-	-	43.1	-	-	43.1	
359.5	18.08	87	0.41	1.98	-	-	38.6	2.3	-	2.3	2.3	-	3.9	7.8	-	15.9	4.5	11.4	44	-	-	38.6	-	-	38.6	
369.5	17.17	138	0.41	3.30	1.4	1.4	27.5	-	5.8	4.3	5.8	-	4.3	8.7	2.9	8.7	14.5	-	69	-	-	27.5	-	-	27.5	
389.5	17.39	276	0.72	11.44	4.4	4.4	23.4	0.7	2.2	7.3	6.6	-	4.3	10.2	3.6	2.9	5.8	-	137	-	-	23.4	-	-	23.4	
409.5	18.02	230	0.58	7.40	10.3	0.9	30.2	4.3	0.9	2.6	2.6	-	6.0	13.8	2.6	-	11.2	2.6	116	-	-	30.2	-	-	30.2	
429.5	17.54	178	0.47	4.76	-	5.9	34.1	1.2	1.2	2.4	3.5	-	3.5	10.6	3.5	9.4	-	2.6	85	-	1.2	34.1	-	-	35.3	
450.5	16.64	171	0.34	3.49	5.9	-	32.9	2.4	3.5	-	-	-	5.9	4.7	3.5	9.4	1.2	2.4	85	-	-	32.9	-	1.2	34.1	
460.5	16.49	102	0.34	2.10	3.9	-	31.4	7.8	2.3	2.0	2.0	-	5.9	11.4	3.4	12.5	3.4	5.7	88	-	-	31.4	-	-	31.4	
478.5	17.37	179	0.29	2.99	2.3	3.8	30.7	1.9	4.7	-	-	-	3.4	5.7	11.4	3.4	12.5	3.4	88	-	-	30.7	-	-	30.7	
490.5	17.62	215	0.29	3.54	3.8	0.9	24.5	1.9	4.7	-	-	-	3.8	7.5	12.3	0.9	17.0	1.9	106	-	-	24.5	-	-	29.2	
503.5	16.84	96	0.46	2.62	8.3	8.3	27.1	6.3	-	-	-	-	8.3	7.0	2.1	10.4	2.1	2.1	106	-	-	27.1	-	-	27.1	
531.5	17.42	215	0.46	5.67	10.0	10.0	32.0	1.0	4.0	1.0	1.0	-	6.0	4.8	4.8	3.6	6.0	6.0	100	-	2.0	32.0	-	-	34.0	
541.5	17.12	168	0.46	4.51	2.4	3.6	31.0	-	2.4	-	-	2.4	4.9	7.3	-	4.9	4.9	4.9	41	-	1.2	31.0	-	-	32.2	
561.5	16.42	84	0.44	2.24	-	-	26.8	-	-	-	-	-	4.9	7.3	-	16.0	6.0	-	50	-	-	26.8	-	-	34.1	
571.5	16.15	101	0.44	2.76	2.0	-	30.0	4.0	6.0	2.0	-	-	2.0	6.0	-	16.0	6.0	-	50	-	-	30.0	-	-	32.0	
600.5	17.22	256	0.71	10.54	2.4	1.6	26.4	5.6	1.6	1.6	1.6	-	6.4	16.8	0.8	5.6	1.6	0.8	125	-	1.6	26.4	-	-	28.0	
629.5	15.58	159	0.30	3.07	-	3.8	35.9	1.3	3.8	-	-	1.3	6.4	5.1	5.1	6.4	2.6	-	78	-	-	35.9	-	-	35.9	
641.5	17.20	309	0.30	5.89	2.0	2.0	19.9	4.0	0.7	2.6	2.0	-	7.3	13.9	2.6	13.9	5.3	1.3	151	-	0.7	19.9	-	-	20.6	
660.5	17.63	295	0.30	4.85	0.7	0.7	30.2	0.7	2.2	-	-	-	3.6	15.8	0.7	15.1	3.6	0.7	139	-	1.4	30.2	-	0.7	32.3	
680.5	18.37	225	0.37	4.53	1.8	1.8	27.5	4.6	-	5.5	0.9	-	1.8	16.5	-	1.8	11.9	-	109	-	-	27.5	-	-	27.5	
738.5	15.14	244	0.59	9.50	0.8	0.8	31.1	1.6	3.3	1.6	-	-	4.1	14.8	2.5	11.5	5.7	-	122	-	-	31.1	-	-	31.1	
779.5	17.46	145	0.59	4.91	2.8	1.4	21.1	9.9	-	1.4	1.4	-	5.6	2.8	2.8	14.1	8.5	-	71	-	-	21.1	-	-	21.1	
830.5	17.18	219	0.45	5.73	2.7	-	29.1	2.7	1.8	-	-	-	19.1	5.5	-	10.4	10.4	4.7	106	-	1.8	29.1	-	-	30.9	
860.5	16.80	212	0.55	6.92	2.8	-	32.1	1.9	2.8	-	-	-	16.0	-	-	10.4	10.4	4.7	106	-	1.9	32.1	-	-	34.0	
871.5	16.71	119	0.55	3.94	3.4	3.4	37.3	3.4	-	1.7	-	-	10.2	-	-	1.7	10.2	3.4	59	-	-	37.3	-	-	37.3	
891.5	16.92	149	0.55	4.85	4.0	-	30.7	-	2.7	-	-	-	5.3	2.7	1.3	10.7	8.0	-	75	-	-	30.7	-	-	30.7	
907.5	17.96	246	0.55	7.54	6.7	6.7	25.0	0.8	2.5	3.3	-	-	5.3	2.5	17.5	4.2	0.8	120	-	-	25.0	-	-	27.5		
938.5	16.53	154	0.57	5.31	7.9	-	27.6	9.2	-	-	-	1.3	2.6	5.3	1.3	15.8	5.3	1.3	76	-	2.5	27.6	-	-	27.6	
958.5	17.12	198	0.57	6.59	3.1	-	18.6	-	2.1	1.0	-	-	5.2	7.2	16.5	4.1	13.4	3.1	97	-	1.0	18.6	-	-	19.6	
969.5	17.46	169	0.57	5.51	3.6	3.6	25.0	7.1	7.1	2.4	1.5	-	3.6	6.0	6.0	7.1	4.8	1.2	84	-	-	25.0	-	-	25.0	
990.5	16.95	136	0.36	2.90	-	-	35.8	1.5	4.5	1.5	-	-	6.0	7.5	6.0	6.0	6.0	-	67	-	-	35.8	-	-	35.8	
1008.5	18.60	166	0.36	3.21	1.2	-	50.6	-	4.8	3.6	-	-	1.2	2.4	1.2	4.8	3.6	-	83	-	-	50.6	-	-	50.6	
1048.5	22.35	249	0.37	4.13	12.8	-	31.2	1.6	4.8	1.6	-	-	11.2	8.0	0.8	2.4	2.4	-	125	-	1.6	31.2	-	0.8	33.6	
1092.5	24.36	187	1.04	7.97	21.5	1.1	21.5	17.2	-	-	-	1.1	2.2	8.6	-	2.2	3.2	2.2	93	-	-	21.5	-	-	21.5	
1139.5	25.04	242	1.04	10.06	9.2	-	23.5	5.0	0.8	3.4	1.7	-	11.8	-	-	7.6	5.0	1.7	119	-	0.8	23.5	-	-	24.3	
1180.5	19.06	171	1.24	11.13	3.5	-	30.6	5.9	1.2	3.5	1.2	-	2.4	16.5	-	5.9	2.4	-	85	-	2.4	30.6	-	-	33.0	
1239.5	15.39	138	0.70	6.28	4.3	-	31.9	13.0	2.9	-	-	-	2.9	29.6	2.5	1.4	10.1	-	69	-	2.9	31.9	-	1.4	39.1	
1300.5	16.00	162	0.70	7.08	-	2.5	21.0	1.2	1.2	3.7	1.2	-	12.3	29.6	2.5	1.2	4.9	-	81	-	2.9	21.0	-	-	21.0	
1361.5	17.47	85	0.90	4.40	-	-	23.8	4.8	-	6.1	-	-	8.2	18.4	4.8	-	10.2	4.1	-	42	-	-	23.8	-	-	23.8
1459.5	15.54	101	0.90	5.83	4.0	-	12.0	8.0	-	2.0	2.0	-	2.4	26.0	-	-	16.0	-	50	-	-	12.0	-	-	12.0	
1570.5	17.98	74																								

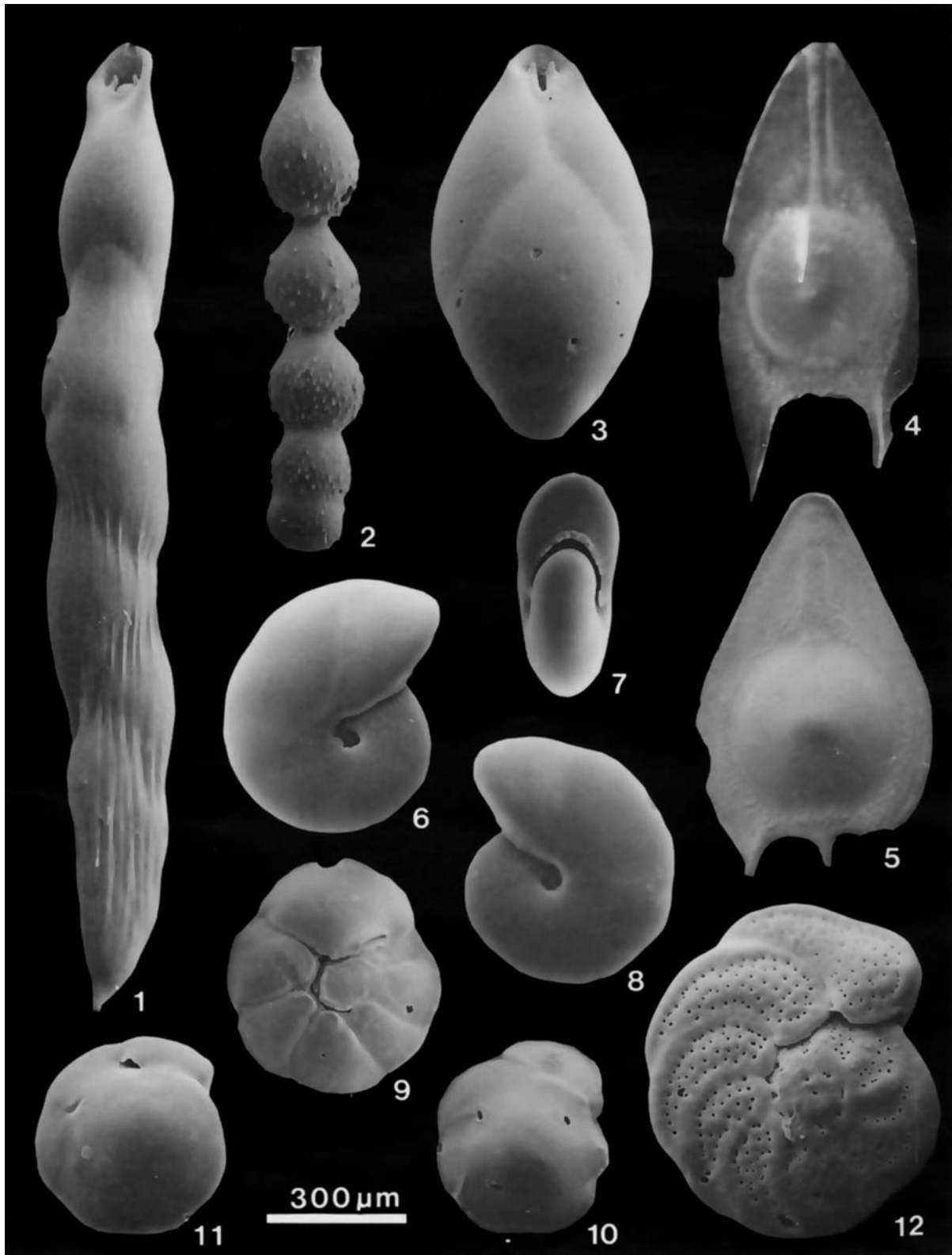


Plate 1

interval between 364.5 and 170.0 cm. A corresponding first-occurrence datum of *Fissurina seminiformis* has not been reported to date. Many authors do not take unilocular benthic foraminifera, e.g. *Fissurina* spp., into consideration because of their low abundances and high species diversification. *Fissurina seminiformis* is recorded, however, from Pacific DSDP Sites 173 (off California, Delaga Fan) and 208 (Lord Howe Rise) where it ranges from the lower Miocene to the Quaternary (Boltovskoy & Guissani, 1990).

Above 199.5 cm (315 ka), *Gavelinopsis translucens* occurs in most of the samples examined with moderate abundances, not exceeding 3%. No corresponding acme occurrence of *Gavelinopsis translucens* has been reported to date.

FORAMINIFERAL COMMUNITY STRUCTURE AND PALAEOENVIRONMENTAL IMPLICATIONS

The benthic foraminiferal assemblage composition allows only limited ecological conclusions. The tests of many living arenaceous species, which are commonly found in surface samples, are not preserved during fossilization or destroyed by sample processing (Schröder, 1986). A single, highly corroded specimen of ?*Cribrostomoides* ssp., which was found in the topmost sample, indicates that this generally observed pattern is also valid for core 34KL. Benthic foraminiferal assemblages from the core samples may therefore not represent the ancient living communities (Lipps, 1983; Murray, 1984). The benthic foraminiferal assemblage composition was, however, certainly not biased by the effects of differential carbonate dissolution as the core site is located above the depth interval between 2.6 and 3.6 km, where the lysocline fluctuated in the western equatorial Pacific during the Quaternary (Wu, *et al.*, 1991).

Palaeoenvironmental implications

Cibicidoides wuellerstorfi and *Oridorsalis umbonatus* are the most frequent species at this core. Palaeoenvironmental implications are thus inferred from their ecology and habitat preferences.

Cibicidoides wuellerstorfi is a passive suspension feeder (Linke & Lutze, 1993). It is found attached to various objects above the sediment/water interface and is assigned, together with *Cibicidoides kullenbergi*, *Cibicidoides pseudoungerianus*, *Gavelinopsis translucens*, and *Epistominella exigua* as 'elevated epibenthos'. The elevated position gives a better chance to catch food particles from slightly streaming water than on the sediment surface (Lutze & Thiel, 1987; Linke, 1989). As such, high abundances of *Cibicidoides wuellerstorfi* indicate an environment which is

characterized by near-bottom currents. The recent bottom-current activity is confirmed by ocean-bottom photographs, taken at the eastern flank of the Manihiki Plateau between 1400 and 2900 m waterdepth, which show oscillation ripples on the sediment surface (Beiersdorf, 1990). The net lateral transport may be, however, rather low as model calculations of water mass movements for the deep Pacific show at the Manihiki Plateau an East to West directed horizontal velocity vector of only 1 cm/s at 2000 m waterdepth (Fujio & Imasato, 1991, fig. 4b).

Oridorsalis umbonatus is detritivore and has an infaunal microhabitat preference (Murray, 1991). It populates the uppermost 2 cm of the sediment (*tener* in Corliss, 1985). Apparently tolerant to changing environmental conditions, *Oridorsalis umbonatus* occurs with high abundances in areas with low flux rates of particulate organic matter (Altenbach, pers. comm.; Haake & Pflaumann, 1989).

The different habitat preferences and the use of different feeding strategies by *Cibicidoides wuellerstorfi* and *Oridorsalis umbonatus* are clearly reflected by their contrary fluctuating percentages (Fig. 3). The contrast is also expressed by a negative correlation coefficient of -0.39 ($n = 59$). The flux rates of both species show, however, congruent fluctuations and are highly positive correlated ($r: 0.65$, $n = 59$). As the flux rate of benthic foraminifera is related to the food supply (Lutze, *et al.*, 1986), it is concluded that the different feeding strategies of these species are linked to one source. The most likely source is lateral advection of particular organic matter by near-bottom currents because the suspension feeding *Cibicidoides wuellerstorfi* dominates the foraminiferal assemblage.

During three short periods at oxygen isotope stages 9, 13 and 65, when the flux rate of benthic foraminifera was very low, *Cibicidoides wuellerstorfi* shows distinct frequency maxima exceeding 45% of the benthic foraminiferal fauna (Fig. 3). An explanation for this pattern which concurs with the above results is that the food supply was reduced drastically during these periods. The elevated epibenthic forms would then have a much better chance to collect food particles from the streaming water than those species settling on the sea-floor. Thus, the portion of elevated epibenthic forms in the total assemblage would increase.

Flux rates of benthic foraminifera and organic matter: an assessment of lateral advection

The absence or scarcity of productivity-sensitive *Bolivina* spp., *Bulimina* spp., *Chilostomella* spp. and *Uvigerina* spp. indicates that the flux of particulate organic matter to the sea-floor at the Manihiki Plateau is rather low (Lutze &

Explanation of Plate 1

Index foraminifera and dominant species from core 34KL. Figures 1–3, 5–12 were made with a CamScan stereoscanning microscope (SEM), fig. 4 was taken with incident light by using a Wild M5A Photomicroscope. All specimens were left on SEM carriers which are stored in the collection of the Bundesanstalt für Geowissenschaften und Rohstoffe (Hanover). Collection numbers are given in brackets where the first number refers to the carrier and the second to the specimen on it. **Fig. 1.** *Pleurostomella alternans* Schwager, 1866. Sample 641.5 cm (BGR596/13). **Fig. 2.** *Nodogenerina sagrinensis* (Bagg, 1912). Sample 641.5 cm (BGR596/14). **Fig. 3.** *Pleurostomella brevis* Schwager, 1866. Sample 680.5 cm (BGR598/5). **Figs 4, 5.** *Fissurina seminiformis* (Schwager, 1866): **4.** Sample 130.5 cm, **5.** Sample 389.5 cm (BGR597/16). **Figs 6–8.** *Nonion* sp. Parker, 1964: **6.** Sample 450.5 cm (BGR596/5), **7.** Sample 450.5 cm (BGR596/6), **8.** Sample 50.5 cm (BGR598/2). **Figs 9, 10.** *Gavelinopsis translucens* (Phleger & Parker, 1951): **9.** Sample 180.5 cm (BGR597/10), **10.** Sample 130.5 cm (BGR596/1). **Fig. 11.** *Oridorsalis umbonatus* (Reuss, 1851). Sample 28.5 cm (BGR595/21). **Fig. 12.** *Cibicidoides wuellerstorfi* (Schwager, 1866). Sample 250.5 cm (BGR595/3).

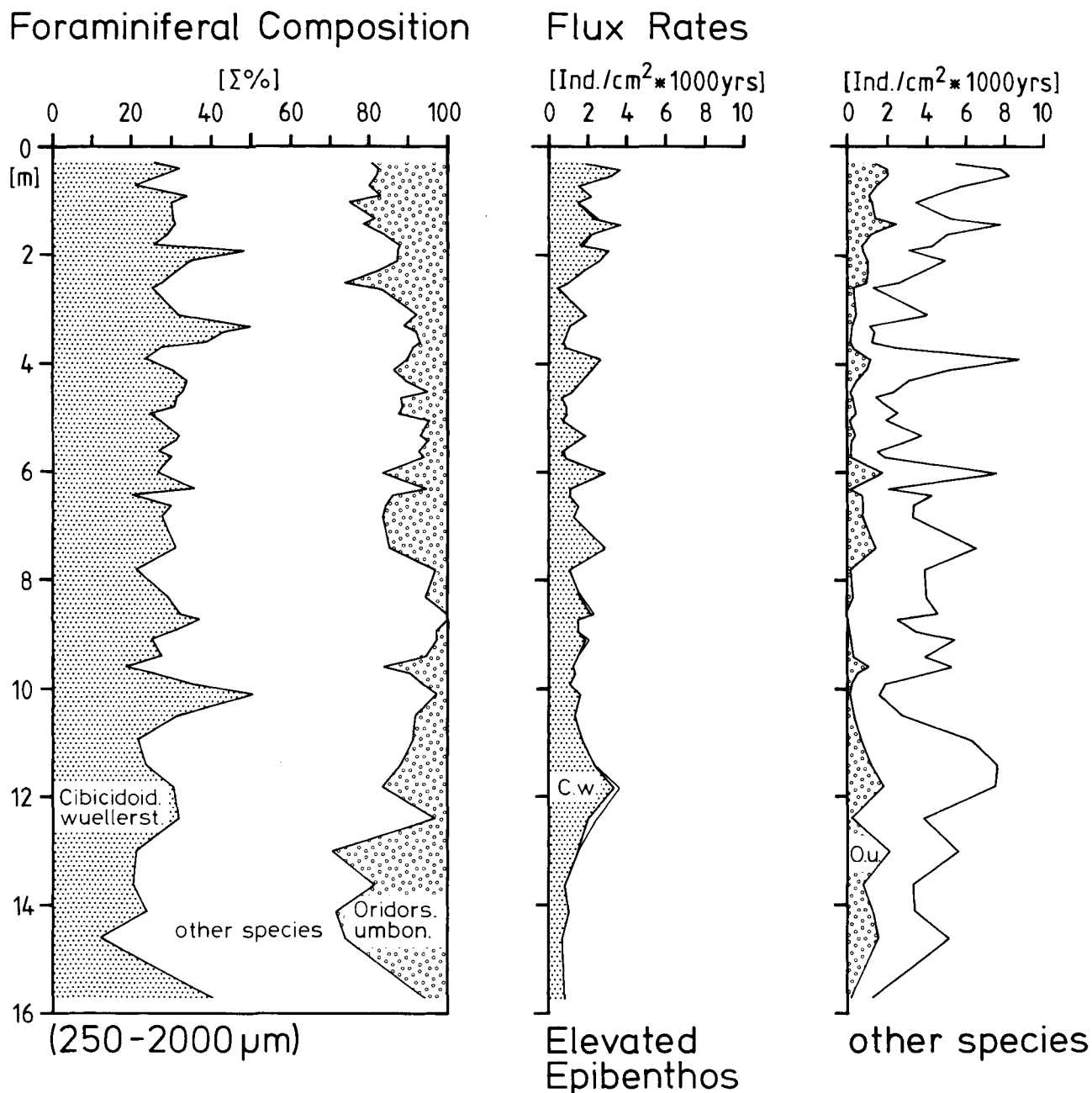


Fig. 3. Benthic foraminiferal composition of the grain-size fraction 250–2000 μm and flux rates of elevated epibenthic and other benthic foraminiferal species. The faunal portions of *Cibicoides wuellerstorfi* and *Oridorsalis umbonatus* are negatively correlated while their flux rates show congruent fluctuations. Maxima of *Cibicoides wuellerstorfi* exceeding 40% are generally related to flux-rate minima. The elevated epibenthos comprises *Cibicoides kullenbergi*, *Cibicoides pseudoungerianus*, *Cibicoides wuellerstorfi*, *Epistominella exigua*, and *Gavelinopsis translucens*.

Coulbourn, 1984; Altenbach & Sarnthein, 1989; Loubere, 1991). A rough estimation of this flux can be made by using the abundance of *Cibicoides wuellerstorfi*. As *Cibicoides wuellerstorfi* was not recorded in any sample with a portion lower than 19%, I assume that this species makes up approximately 20% of the recent dead assemblage in surface sediments at the coring site. Off North-West Africa, where this species occurs in water depths below 2000 m with portions of 10–30% of the dead assemblage (Lutze &

Coulbourn, 1984; Lutze & Thiel, 1987), flux rates of 1–3 $\text{g C/m}^2\cdot\text{a}$ are calculated by Altenbach (1985). *Cibicoides wuellerstorfi* does not usually occur in areas where the flux of particulate organic matter is lower than 1.3 $\text{g C/m}^2\cdot\text{a}$ at the sea floor (Altenbach, pers. comm). If a surface-water productivity of 39 $\text{g C/m}^2\cdot\text{a}$ is assumed to prevail at the Manihiki Plateau (Berger *et al.*, 1987) and the empirical flux-transfer function of Herguera & Berger (1991) is applied, the remaining flux of organic matter at

2600 m waterdepth is estimated as $0.53 \text{ g C/m}^2\text{a}$ which is lower than the above values. Although these values are only rough estimates containing many uncertainties (Berger & Wefer, 1990) it is concluded, however, that lateral advection approximately doubles the flux of organic matter near the sea-floor on the Manihiki-Plateau.

Graf (1989) demonstrated that lateral advection plays an important role in benthic food supply. Lateral advection amplifies the flux of organic matter to the sea-floor by a factor of 4 to 7 during plankton-bloom periods and 2 on an annual basis as revealed from studies in the Kiel Bight (Balzer *et al.*, 1986). These results would support the above conclusion.

In the Quaternary, the productivity in the equatorial Pacific was higher by a factor of 1.2 to 2 during glacial times as estimated by Archer (1991) and Herguera (1992). The test production of benthic foraminifers depends on benthic turnover-rates which are largely triggered by the flux of organic matter (Altenbach, 1992; Gooday, 1988). The accumulation rate of benthic foraminiferal tests should therefore be significantly higher during glacial than interglacial periods as recognized by Burke *et al.* (1993) at the Ontong Java Plateau. Although a single maximum in benthic foraminiferal flux rates coincides with the glacial

stage 16 at 393 cm, no correlation of foraminiferal flux rates and climate fluctuations, as inferred from the oxygen isotope record, is recognized at core 34KL (Fig. 4). The incongruent pattern reveals that lateral advection near the sea-floor on the Manihiki Plateau and surface-water productivity may have fluctuated independently. They may even have balanced each other in a way that when productivity was higher the bottom-current activity may have been lower and thus may have reduced the lateral advection.

SUMMARY

Benthic foraminifera from the Manihiki Plateau (southwestern tropical Pacific) were studied at core 34KL. Sixty-one different species were identified. *Cibicidoides wuellerstorfi* and *Oridorsalis umbonatus* are dominant faunal elements while *Melonis pompilioides*, *Pullenia bulloides*, *Anomalina globulosa*, *Pyrgo murrhina*, *Cibicidoides robertsonianus*, *Eggerella bradyi*, *Gyroidina zelandica*, *Karreriella bradyi*, *Melonis barleeianum*, *Nonion* sp. and *Pyrgo serrata* are also frequent. This assemblage shows close affinities to the 'plate bathyal assemblage' of Resig (1981).

A new benthic foraminiferal biozonation is proposed for this core. The *Nodogenerina sagriensis* Partial Range Zone ranges from core base to 566.5 cm (>2,594–996 ka). The upper boundary is defined by the last occurrence of the index species. This last occurrence datum is time equivalent to the 'Stilostomella extinction' in the Eastern Atlantic (Weinholz & Lutze, 1989) and thus documents this worldwide extinction event in the southwestern tropical Pacific. The *Fissurina seminiformis* Partial Range Zone comprises the upper part of the core from 566.5 cm to core top. The index species occurs above 456.0 cm in most of the samples. *Fissurina seminiformis* ranges, however, from the lower Miocene to the Quaternary at other sites in the Pacific.

The benthic foraminiferal assemblage allows only limited ecological conclusions. High abundances of *Cibicidoides wuellerstorfi* indicate an environment which is characterized by bottom-near currents. The absence or scarcity of high-productivity sensitive species indicates a considerably low flux of particulate organic matter to the sea floor on the Manihiki Plateau. This flux is constrained to be at present in the order of $0.53\text{--}3 \text{ g C/m}^2\text{a}$. As the flux rate calculated from the surface-water productivity is significantly lower than that estimated from benthic foraminifers, it is concluded that lateral advection by bottom-near currents approximately doubles the flux of organic matter near the sea-floor on the Manihiki Plateau. Flux rates of benthic foraminifera show no correlation with the Quaternary oxygen-isotope record. This pattern indicates, that near-surface productivity and lateral advection may have varied independently creating a mixed signal.

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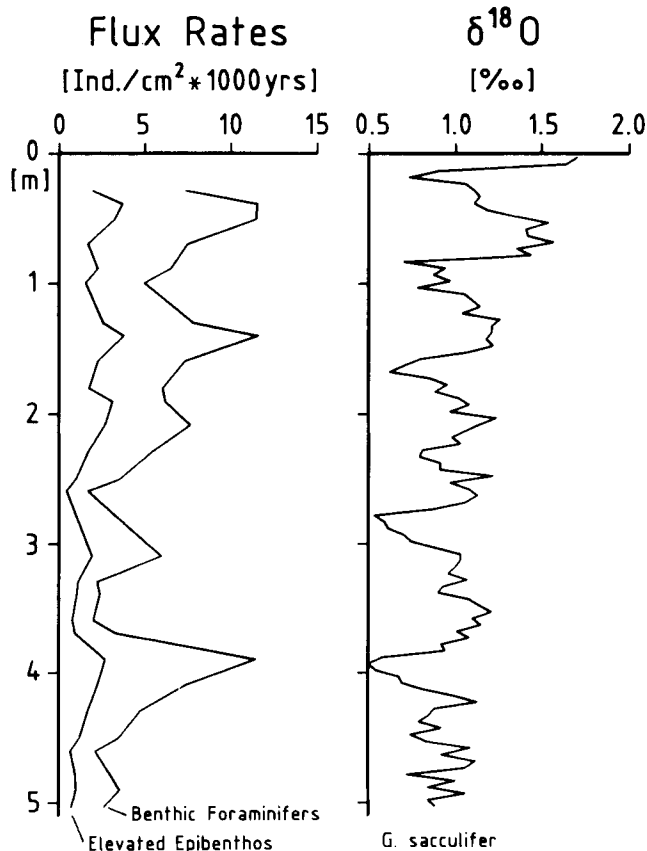


Fig. 4. Benthic foraminiferal flux rates and oxygen isotope record (Bickert, pers. comm.) of the Brunhes magnetochron. No correlation of foraminiferal flux rates and climate fluctuations is recognized.

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