ESSO BLACKBACK #3, GIPPSLAND BASIN

Foraminiferal-Biostratigraphic Report on 15 Sidewall Cores

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Summary

An analysis of planktonic foraminifera in 15 sidewall-core samples from Blackback 3 indicates that the sampling interval (2826.2m-1125m) spans the later Eocene to late Pliocene. Although badly preserved, taxa from the lowermost 4 samples (2826.2m-2809m) are found to indicate the later Eocene and early Oligocene. The Miocene sequence is represented by 9 samples between 2798m-1822m, whereas the early and late Pliocene each by one single sample in the uppermost sampling section (1252m and 1125m respectively). A detailed zonation is listed in Table 1 (p. 6).

Among benthic foraminifera, deep-water agglutinated forms characterize the lower 7 samples, but this fauna is replaced by hyaline-walled species at around 2600m, ie. the later part of the early Miocene. A tendency of shallowing-upward is evidenced by the presence of some shelf elements like *Discorbis*, *Elphidium* and *Discorbinella* in the uppermost two samples (Pliocene). A similar feeling was caught up at 2200m, close to the middle and late Miocene boundary, in which a less-diverse fauna is featured by small-sized taxa including *Discorbis*. This shallowing, however, is by no means an equivalent of that in the Pliocene because the Pliocene samples contain a diverse fauna with many benthic as well as planktonic species. Coupled with the shallowing tendency was perhaps an increasing oxygen level in the bottom water that counts for the change from an agglutinants-dominated to a hyaline species-dominated benthic fauna in the later part of the early Miocene onward.

The overal biostratigraphy and depositional environment discussed in this report are similar to the findings by Taylor (1975) from Hapuku 1. Differences, if any, are probably resulted from an up-dated zonation adapted in this presentation using standard N zones, rather than local schemes.

Material and Methods

We received 15 SWC samples in early August 1994. The descriptive statement attached to the material shows that at least 10 samples are clean and devoid of any contamination. Samples between 2200m-2772.4m were broken and more or less penetrated with mud, and thus might contain displaced materials.

Samples were soaked, and washed using a standard 63µm sieve. Residue were dried and separated into two fractions: 63-150µm and >150µm. The 63-150µm fraction may contain specimens described as "small", and the >150µm may have medium (150-250µm) to large (>250µm) specimens.

About 400 foraminiferal specimens were picked from each sample, but this number could not be met in the first sample (2826.2m) where specimens are extremely rare. Important species or species groups were identified and listed in the Appendices (1--plankton and 2--benthic). Neither quantitative counting nor any statistic analysis has been done.

The condition of preservation ranges from poor to moderately good. About half of the samples from the lower part of the section contain many poorly-preserved specimens, for which identifications are tentative or open.

Results

2826.2m (SWC-41)

No plankton was found. Benthics were represented only by a few agglutinated forms, particularly *Cyclammina* cf. *cancellata.*

2823m (SWC-42)

This sample conains a rich, though badly preserved, planktonic fauna. Taxa which could be positively identified include *Subbotina* spp. (*S. eocaena*) and (one specimen of) *Morozovella* sp.

In contrast, benthics are relatively rare, with the following forms: *Cyclammina, Cibicides* cf. *wuellerstorfi, Cibicidoides* spp. and *Uvigerina* sp.

2818m (SWC-43)

Though similarly poorly preserved, the planktonics from 2818m are richer than in the previous sample. Among others, *Subbotina labiacrassata, S. angiporoides* (including subspecies *minima*) and *Globoquadrina venezuelana* were identified. This association suggests an early Oligocene age.

Benthics were also diverse, having many agglutinated and hyline forms (Appendix 2). Deep-water forms such as *Haplophragmium*, *Cyclammina*, *Discammina*, *Stilostomella* and *Pullenia*, indicate a middle slope environment with water depths about 500-800m.

2809m (SWC-44)

Foraminifera in this sample is similar to those found in 2818m in both composition and preservation. The most important characteristic is that many more large-sized specimens occur and several taxa are found for the first time. The newly introduced forms include (planktonic) *Globorotaloides* spp. and *Paragloborotalia nana* and (benthic) *Anomalinoides* sp., *Gyroidinoides* spp. and *Vulvulina pennatula.*

2798m (SWC-45)

The overall faunal character is similar to that found in 2809m. The planktonics are dominated by *Catapsydrax* and *Globorotaloides* groups and the benthics by agglutinated forms including *Cyclammina*, *Discammina*, *Vulvulina*, *Ammodiscus* and *Haplophragmium.* The only difference is that this sample contains such globoquadrine planktonics as *Globoquadrina* sp. and *Gq. tripartita.* A late Oligocene to earliest Miocene age is thus indicated.

2772.4m (SWC-46)

Unlike the prededing two samples, large-sized plankton in this sample are rare, though specimens are still similarly rich. Long-ranging species found include *Catapsydrax dissimilis*, *C. unicavus* and *Globorotaloides* spp. (particularly *G. suteri* and *G.* cf. *testarugosa*). Accompaning these are several good specimens of *Globoquadrina dehiscens*, a stratigraphic marker species first appearing close to the Oligocene/Miocene boundary. This sample thus can be positively dated as early Miocene, zone N4 equivalent.

A sharply decline in the agglutinated benthics was noticed in this sample. On the other hand, several new hyaline forms were found: *Sphaeroidina bulloides*, *Siphonina australis* and *Osangularia* sp.

2770m (SWC-47)

With rare and mainly small-sized specimens, this sample must mark a change in the depositional environment, if not in climate. The occurrence of some fresh, angular quartz grains may be a similar signal.

Though *Catapsydrax dissimilis* was still distinct among the plankton, the influx of the *Globoturborotalita* group (*Gt. woodi* and *Gt. connecta*) is the main feature for this sample. In southern mid latitudes including southern Australia, the *woodi* datum has been widely used as the marker of zone N5 (or later) in the early Miocene.

Several specimens of *Discorbinella* were found in the less diverse benthic fauna, indicating a shelf (to upper slope) deposition.

2600m <u>(SWC-48)</u>
Unlike the previous sample, this sample contains rather diverse fauna with abundant specimens. The *woodi* group dominated the plankton, but several species were newly introduced: *Globorotalia zealandica, Gr. praescitula* and *Globigerinoides trilobus*. This is a later early Miocene (N6-N7), warmer-water association.

Important benthic taxa include *Globocassidulina subglobosa, Astrononion, Discorbinella, Cyclammina* and *Ammodiscus*.

2550m <u>(SWC-50)</u>
Foraminifera in this sample are both rich and large. Among the plankton, the predominance of the *woodi* group is now diluted by the occurrence of *Praeorbulina glomerosa* (sensu lato) and several *Globorotalia* (particularly *Gr. archeomenardii, Gr. praemenardii* and *Gr. miozea*). The first *P. glomerosa* datum is commonly used to mark the early and middle Miocene boundary, and because of this, this sample can be placed in the later N8 zone, or early part of the middle Miocene.

Also perceived is a slight increase of agglutinated, deep-water benthics like *Ammodiscus, Karreriella* and *Trochammina.*

2501m <u>(SWC-52)</u>
This sample bears a planktonic fauna apparently developed from the previous sample. Specimens representing the *woodi-trilobus* lineage are common, and so are those of *Gr. archeomenardii-praemenardii, Gr. miozea* and *Gr. scitula.* The major feature, however, is the incoming of *Orbulina* (mainly *O. suturalis*), a post-N8 marker. Together with these are a small proportion of *Globigerina bulloides* and tenuitellids. It is tentatively dated as representing zones N9-N10, middle Miocene.

There are rare benthic species and specimens, and agglutinated forms are virtually absent.

2400m <u>(SWC-53)</u>
Many large-sized specimens are found in this sample. In the presence of *Orbulina*, the *Gr. miozea-miotumida* complex is the major feature. Other species include *Gr. scitula* and *Gr. praemenardii*, as well as the *woodi-trilobus* lineage. This planktonic association suggest a middle middle Miocene age, or zones N10-N11 equivalents.

Among the benthics, specimens of *Cibicidoides pseudoungerianus, Chilostomella, Nodosaria* and those of the uniloculars are distinct.

2200m (SWC-54)

The plankton in this sample is represented only by a few *Orbulina* and globigeriniforms which cannot be identified due to their small size and bad preservation.

In contrast, small benthics are common and dominated by cassidulinid forms (*Cassidulina margaritae* and *Globocassidulina* spp.). Coupled with these, the presence of *Discorbis* sp. and *Cibicides* spp. may indicate a cooler and shallower depositional environment.

1822m (SWC-56)

This sample contains a diverse fauna with numerous small specimens. The occurrence of *Neogloboquadrina pachyderma* indicates a late Miocene age. This is supported by *Globorotalia conomiozea*, a species first appearing in the middle part of zone N17. Other common species include *Globigerina bulloides, G. quinqueloba, Globorotaloides unicavus, Globorotalia miotumida* and *Orbulina suturalis*.

Benthics are mainly species of *Cibicides, Cassidulina, Globocassidulina, Astrononion, Lagena, Fissurina* and *Uvigerina*, indicating an upper slope to outer shelf environment.

1252m (SWC-59)

A sharp change in the plankton in this sample is evidenced not only by the rich and large-sized specimens but the occurrence of several new forms such as *Globorotalia puncticulata, Gr. crassaformis, Gr. margaritae* and *Sphaeroidinellopsis* sp. Other common species include *Globigerina bulloides, G. falconensis, Gr. scitula, Gr. menardii* s.l. and the *Neogloboquadrina acostaensis-pachyderma* complex. The first appearance of *Gr. puncticulata* is from the earliest Pliocene, while *Gr. margaritae* has a known range only within the early Pliocene. Thus an early Pliocene age, or zones N19-N20 equivalents, is suggested for this sample.

Some benthics are also large, but the change is mainly marked by the introduction of some shallower-water taxa including *Elphidium* and *Quinqueloculina*. Several other forms are also quite distinct: *Cibicidoides pseudoungerianus, Amphicoryna bradyi, Rectouvigerina* sp. and *Nonionella* sp. This is a mid to outer shelf association.

1125m (SWC-60)

This is the uppermost and youngest sample examined in this report. It contains a rich and better preserved fauna. The plankton features the Pliocene *Gr. puncticulata-Gr. crassaformis* association, but the stratigraphically most useful form is *Gr. inflata*, a species with a known first appearance in the late Pliocene. Lacking any younger forms, this sample thus reasonably represents the late Pliocene, or zone N21 equivalent.

Among the benthics, *Uvigerina bassensis* occurred abundantly. Several forms living close to mid-shelf conditions were also present: *Virgulina rotundata, Elphidium* spp., *Discorbinella scopos* and *Cassidulina laevigata.*

Table 1. Planktonic foraminiferal biostratigraphy for Blackback 3.

depth (m)	*sample*	*zone*	*age*	*events*	*correlation to Taylor*
1125	SWC-60	N21	late Pliocene	first *Gr. inflata.*	A-3
1252	SWC-59	N19-N20	early Pliocene	first *Gr. puncticulata & Gr. margaritae*	A-4
1822	SWC-56	N17	late Miocene	first *Gr. conomiozea.*	B-1
2200	SWC-54	?N15-N16		rare and non-diagnostic	B-2 to C
2400	SWC-53	N10-N11	middle Miocene	*Gr. miozea-miotumida* complex.	D-1
2501	SWC-52	N9-N10		first *Orbulina.*	D-2 to E-1
2550	SWC-50	N8		first *P. glomerosa.*	E-1
2600	SWC-48	N6-?N7	early Miocene	*Gr. praescitula & Gr. zealandica.*	G
2700	SWC-47	N5		first *Gt. woodi,* distinct *C. dissimilis.*	G to H-1
2772.4	SWC-46	N4		good *Gq. dehiscens.*	H-1
2798	SWC-45	?N4		good *C. dissimilis & Gq. tripartita.*	H-2 to I-1
2809	SWC-44		early Oligocene	*C. dissimilis & S. angiporoides.*	?J-2
2818	SWC-43			*S. angiporoides & S. labiacrassata.*	
2823	SWC-42		?late Eocene or earlier	*Subbotina eocaena* group.	?K
2826.2	SWC-41			no plankton.	

Discussion

1. Planktonic foraminiferal biostratigraphy

As summarized in Table 1, the planktonic results show that the samples examined cover the deposition from the later Eocene to late Pliocene. Standard N zones (for the Neogene) were correlated based on specific first/last appearance datums and faunal associations. However, we could not positively identify any hiatuses because of the long spacing between most samples.

As they contain only badly preserved specimens, the lower four samples could not be dated into any zones, but overall ages were suggested: late Eocene or earlier for the bottom two samples, and an early Oligocene age for the two samples immediately above. Only from 2798m upward, when preservation was better, did identification of taxa become confident, hence a better resolution in biostratigraphy.

The sample from 2798m show transitional faunal features between those from the unzoned pre-Miocene intervals and from the well-defined Miocene-Pliocene samples. It is tentatively placed in the earliest part of the Miocene because of the occurrence of *Gq. tripartita.* Although it ranges from late Eocene to early Miocene, *Gq. tripartita* became common only from the earliest Miocene *Gq. dehiscens* zone upward (Jenkins, 1985).

Three samples (2772.4m, 2700m, 2600m) are well defined as belonging to the early Miocene. The 2600m sample contains typical *Gr. zealandica* and *Gr. praescitula*, but whether it is a N6 or N7 deposition is not ascertained. McGowran & Li (1995) found these two species mainly within zone N6 in the Lakes Entrance Oil Shaft. The sample may be of zone N6 had these species behaved similarly here, but a further evaluation seems to be inappropriate.

We draw the early/middle Miocene boundary at the first *Praeorbulina glomerosa*, in contrast to Taylor (1975) and Kennett & Srinivasan (1983) who used the first *Orbulina* datum. We do so by following the standard chronobiostratigraphy (McGowran & Li, 1993; Berggren et al., 1995).

At least three samples (2550m, 2501m, 2400m) are of the middle Miocene, respectively representing zones N8 (N8b), N9-N10 and N10-N11. We lack marker species to date more precisely for the latter two samples, but we can verify that the fauna is a pre-N12 association.

The sample from 2200m contain a rare and non-diagnostic fauna, and could not be dated. This feature, however, suggests a cool and shallow environmental condition. Globally such a condition occurred in the latest middle Miocene to earliest late Miocene, so a N15-N16 age equivalent for this sample was suggested.

Only one sample, 1822m, has been positively dated as from the late Miocene. An age in the proximity of upper zone N17 is indicated by the presence of *Gr. conomiozea* in this sample.

The uppermost two samples are of early Pliocene (1252m) and late Pliocene (1125m) respectively, based on contemporary species like *Gr. puncticulata, Gr. margaritae* and *Gr. inflata*. *Gr. puncticulata* and *Gr. crassaformis* appeared successively in the early Pliocene (Taylor, 1975; Kennett & Srinivasan, 1983). The co-existence of these two species in sample 1252m thus suggests that it can be allocated to the *Gr. crassaformis* zone of Kennett & Srinivasan (1983), other than the slightly earlier *Gr. puncticulata* zone.

2. Environmental interpretations

Planktonics and benthics are both important in our following discussion of depositional palaeoenvironments, but the benthics will be emphasized because they reflect more about bottom water conditions including water depth and nutrient level, as well as any climate-imposed effects.

The Eocene and Oligocene deposits at Blackback 3 are thin, with a maximum thickness of about 15m (2826.2m-2809m). The deposits might have been either strongly condensed or truncated with hiatuses. The bad preservation of foram specimens in these sediments hampers better resolution. However, we predict an unconformity in the 11m interval between early Oligocene SWC 44 and early Miocene SWC 45.

(1) Palaeogene agglutinated benthic fauna.
The agglutinates-dominated benthic fauna occurred from Eocene, through Oligocene, to the later part of the early Miocene, where it started to be replaced by hyaline-walled species. Many of these agglutinate taxa are now living near middle bathyal (~ 1000m) or a deeper water depth. A deep-water environment might exist if the agglutinates were indeed deep-water dwellers.

However, species of *Cyclammina, Ammodiscus, Haplophragmium, Discammina* and *Vulvulina* could indicate one of several environments. (i) Comparison with modern distribution might indicate bathyal (to slope) deposition, except that there has been an oceanward shift since the Palaeogene. (ii) Changes in temperature or in oxygen supply could be the cause, but these work in opposite directions. Sluggish circulation is on response to warming. Taylor (1975) demonstrates the same uneasiness about the same assemblages in Hapuku 1, in his suggestion that a lagoonal environment is succeeded by rise and slope environments. The material is not sufficient to resolve this question of benthic agglutinated benthics in the virtual absence of planktonics.

(2) Neogene hyaline benthic fauna.
Hyaline species occurred also in the Eocene-Oligocene, but did not become consistent until sample 2772m (N4), and did not become predominant until sample 2600m (N6-?N7). They subsequently replaced the agglutinates from 2501m (N9-N10) onward. These timings are significant, because three of the Miocene warmings were in the same time periods. The first N4 warming not only caused the radiation of the planktonic *Globoquadrina* lineage but also attracted some subtropical larger benthics (particularly *Amphistegina*) into southern Australia, which was about 15° south of the present latitude. It was the height of the third-order sequence TB1.4 (Haq et al., 1987). The N6 (to N7) warming, representing a high sealevel of sequence TB2.1, caused stratification in the water column attracting *Globorotalia* species (Li & McGowran, 1994). It was the first of several climatic fluctuations in the Miocene, and the most crucial time in the evolution of benthic fauna in the Gippsland and southern Australia (Li & McGowran, 1995). By the time of N9, similar agglutinated forms were no longer surviving at this locality, presumably indicating that a well oxidised bottom water had developed.

The warmest period in the Miocene, however, was between N8-N9 (2550m-2501m), which we termed the Miocene climatic optimum (McGowran & Li, 1993, 1994). The direct faunal evidence is, among others, the evolution of *Pareorbulina-Orbulina* lineage and a large-scale invasion into southern Australian waters of many (sub)tropical larger benthic foraminifera (eg McGowran, 1979; McGowran & Li, 1994; Li et al., 1995). However, little impact has been observed in small benthics at either Lakes Entrance Oil Shaft (Li & McGowran, 1995) or Blackback 3 (Appendix 2).

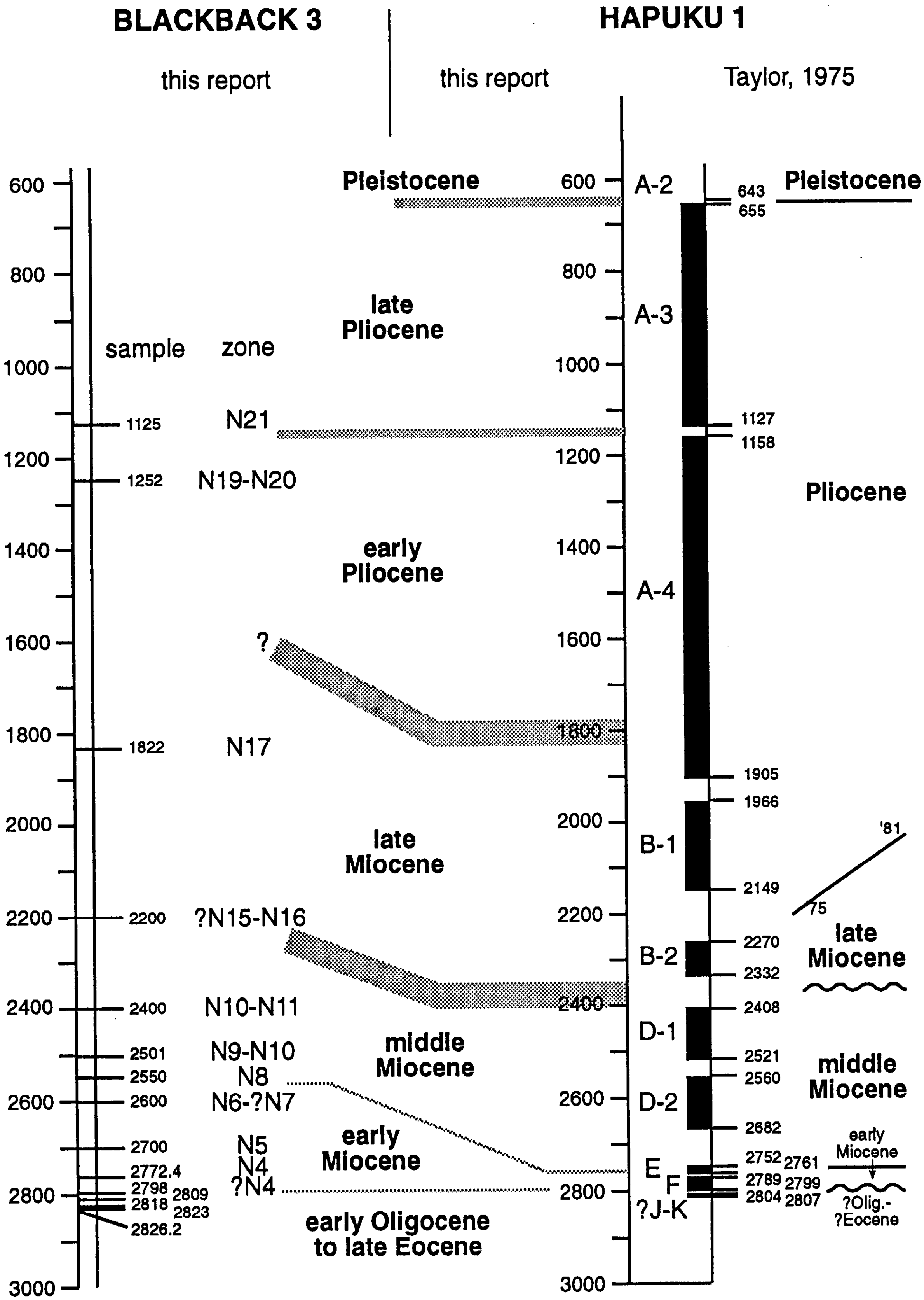

Fig. 1. Planktonic foraminiferal biostratigraphy: Blackback 3 and Hapuku 1.

A general shallowing trend is held for the whole section because of the introduction of some shelf taxa occurring in the uppermost (Pliocene) samples. The large-sized planktonic and benthic specimens found in these samples suggest that it was still rather warm, presumably relating to the early Pliocene (TB3.4) and late Pliocene (TB3.6) warmings respectively.

On the other hand, the late Miocene samples (2200m, 1822m) contain mostly small specimens, indicating a cool condition. In sample 2200m, planktonics are rare, with no diagnostic species, whereas benthics are dominated by small sized cassidulinids. Species from sample 1822m are similarly small, but the majority could be identified. They are the only two samples indicating a cold water condition in a rather shallow (probably shelf) setting.

3. Correlation with Hapuku 1

The overall biostratigraphy and inferred palaeoenvironments are similar to those depicted by Taylor (1975) for Hapuku 1. For a better correlation, we modified Taylor's zonation on the basis of the datums he identified, and this modification is presented in Appendix 3.

Biostratigraphic correlation of Blackback 3 and Hapuku 1 is shown in Fig. 1. It is apparent that differences do exist between these two cores, particularly the thickness of the early Miocene and the boundary between the late Miocene and early Pliocene.

The early Miocene in Blackback 3 is about 200m thick (2600-2809m), compared to only 20m (2761-2799m) in Hapuku 1. However, the level on which Miocene sedimentation commenced is similar between the two cores, ie. about 2800m.

Taylor (1975) used his B-1/B-2 boundary for the late Miocene/early Pliocene boundary, but he later (1981) changed to be within his zone B-1. A scrutiny of his results shows that *Globorotalia puncticulata* (1905m) appeared earlier than *Gr. sphericomiozea* (1783m) at Hapuku 1. This contradicts other observations, and the opposite seems to be true (Kennett & Srinivasan, 1983; Jenkins, 1985). We use the first appearance of *Gr. sphericomiozea* (1783m) for that boundary, by following Kennett & Srinivasan (1983) and Berggren et al. (1995).

Conclusions

1. The sampling interval of Blackback 3 (2826.2m-1125m) covers sequences of the later Eocene, early Oligocene, Miocene and Pliocene. Planktonic foraminiferal datums and faunal associations permit correlation of the Miocene and Pliocene strata to the standard N zones.

2. A sluggish circulation may have existed during the most of the early Miocene and earlier periods. Under this circulation, an oxygen-poor bottom condition developed to support the

agglutinated taxa which dominated the benthic fauna. A deeper water setting, probably slope to bathyal, is suggested for the most of the early Miocene.

3. Changes in the benthic fauna occurred mainly at three levels: 2772.4m, 2600m and 2501m. The first two are marked by the occurrence of many hyaline-walled species, and the last (2501m) by the total disapperance of the agglutinated species. A well-oxidised bottom condition may have developed since the later early Miocene.

4. The biostratigraphy of Blackback 3 is very similar to that found in Hapuku 1, except that the early Miocene in Blackback 3 is about 10 times thicker than in Hapuku 1. At both localities, however, early Miocene sedimentation was initiated at a similar well depth, at about 2800m.

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Appendex 1. Distribution of planktonic foraminifera in Blackback 3 (x=rare; C=common).

	2826	2823	2818	2809	2798	2772	2700	2600	2550	2501	2400	2200	1822	1252	1125
Subbotina eocaena		x	x	x											
S. angiporoides		x	x	x	?										
S. labiacrassata		?	x												
S. spp.		x	x	x	x										
Catapsydrax dissimilis			x	C	C	C	C	x	x						
C. unicavus				C	C	C	C	x	x				x		
Globorotaloides spp.		x	x	x	x	x	x	x							
Globoquadrina sp.					x										
Gq. venezuelata		x	x	x	x										
Gq. tripartita					x										
Gq. dehiscens						C	x								
Gq. globosa													x		
"Globigerina" ouachitaensis		x	x	?											
Globoturborotalita woodi							x	C	C	C	x				
Gt. cf. apertura															x
Globigerinoides trilobus s.l.								x	x	x	x			x	
Praeorbulina glomerosa									C						
Orbulina spp.										C	x	x	x		x
Globorotalia zealandica								x							
Gr. praescitula								x							
Gr. scitula										x	x			x	
Gr. prae-(archeo-)menardii									C	x	x				
Gr. menardii s.l.														x	x
Gr. miotumida											x	x	x		
Gr. miozea									C	x	x	x			
Gr. conomiozea												x	?		
Gr. sphericomiozea													cf.	cf.	
Gr. puncticulata														C	C
Gr. margaritae														x	
Gr. crassula															x
Gr. crassaformis														C	C
Gr. inflata															x
Paragloborotalia nana s.l.			x	x											
P. mayeri s.l.															
P. continuosa							x	x	x						
Neogloboquadrina acostaensis														x	
N. pachyderma													x	x	x
N. dutertrei															x
Sphaeroidinellopsis sp.														x	
Globigerina bulloides										x			x	x	
G. falconensis														x	x
G. ciperoensis					x		?								
Tenuitella spp.										x	x				
Globigerinita spp.										x	x		x		x
Morozovella? (?reworked)		x													
unidentified		C	C	x	x							x			

Appendix 2. Distribution of benthic foraminifera in Blackback 3 (x=rare; C=common).

	2826	2823	2818	2809	2798	2772	2700	2600	2550	2501	2400	2200	1822	1252	1125
Ammodiscus parri				x	x	x		x	x						
Cyclammina cf. cancellata	x	x	x	x	x		x	x							
Haplophragmium sp.			x	x	x										
H. subglobosum					x				x						
Discammina cf. compressa				x	x										
Ammobaculites spp.			x	C	x		x								
Trochammina spp.				x	x		x	x	C						
Karreriella bradyi					x				x						
Eggerina sp.						x									
Glomospira				x											
Valvulina pennatula				x											
Clavulina spp.		x	x		x										
Textularia spp.														x	x
Cibicides sp.			x	C		x						x	x	x	x
C. cf. wuellerstorfi		x													
Cibicidoides sp.		x		x		?									
C. pseudoungerianus										x	x			C	x
Anomalinoides sp.						x						x			
Gyroidinoides spp.				C			x	x	x						
Osangularia sp.						x									
Oridosalis tener									x						
Siphonina cf. australis						x									
Sphaeroidina bulloides						x		x	x	x					
Planulina spp.								x							
Discorbinella scopos +							x	x							x
Discorbis spp.												x			
Pullenia quinqueloba			x	x										x	
P. bulloides			x	x											
Nonion spp.															x
Astrononion								x					x	x	
Nonionella														x	x
Elphidium spp.														x	x
Cassidulina laevigata s.l.										x			C	x	x
C. margaritae							x					x			
Globocassidulina spp.			x						x	x	x	C	C		x
Uvigerina spp.		x				x							x		
Uvigerina bassensis														x	C
Rectouvigerina														x	
Trifarina bradyi			x												
Bulimina cf. inflata															x
Globobulimina pacifica															C
Chilostomella pacifica											C				
Virgulina rotundata															C
Bolivina spp.						x	x			x				x	x
Lagena-Oolina										x	x		x	x	x
Fissurina			x							x	x		x	x	
Amphicoryna			x											x	x
Nodosaria spp.									x	x	x				
Stilostomella			x		x										
Sigmomorphina			x												
Sigmoilina														x	
Quinqueloculina sp.														x	

Appendix 3. Foraminiferal biostratigraphy of Hapuku #1.

depth (ft)	depth (m)	Taylor, 1975		this report	
1995	608.08				
2110	643.13	A-2	Pleistocene	N22	Pleistocene
2150	655.32				
2203	671.47				
2297	700.12				
2400	731.52				
2505	763.52				
2600	792.48				
2700	822.96				
2800	853.44				late
2900	883.92	A-3		N21	Pliocene
2996	913.18				
3096	943.66				
3196	974.14				
3268	996.09				
3300	1005.84				
3400	1036.32				
3500	1066.8				
3590	1094.23		Pliocene		
3700	1127.76				
3800	1158.24				
3900	1188.72				
4005	1220.72				
4090	1246.63			N20	
4200	1280.16				
4280	1304.54				
4350	1325.88				early
4500	1371.6				Pliocene
4700	1432.56	A-4			
4900	1493.52			N19	
5100	1554.48				
5300	1615.44				
5530	1685.54			N18	
5650	1722.12				
5850	1783.08				
6050	1844.04				
6250	1905				
6450	1965.96			N17	
6650	2026.92	B-1			late
6850	2087.88			I	Miocene
7050	2148.84				
7450	2270.76	B-2	late	N16	
7650	2331.72		Miocene		
7900	2407.92			N15	
7970	2429.26	D-1		N14	
8100	2468.88				
8270	2520.7		middle	N12	middle
8400	2560.32		Miocene	N11	Miocene
8600	2621.28	D-2			
8800	2682.24			N9	
9030	2752.34	E			
9060	2761.49			N8	
9150	2788.92		early	N7	
9172	2795.63	F	Miocene		early
9182	2798.67			and	Miocene
9200	2804.16		?early		
9209	2806.9	?J-2	Oligocene	earlier	and
9218	2809.65	or	or		
9221	2810.56	K	?late		earlier
9227	2812.39		Eocene		
9236	2815.13				