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Pliocene Benthic Foraminifera from CRP-2 (Lithostratigraphic Unit 2.2), Victoria Land Basin, Antarctica

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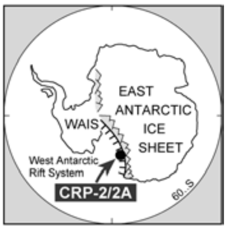
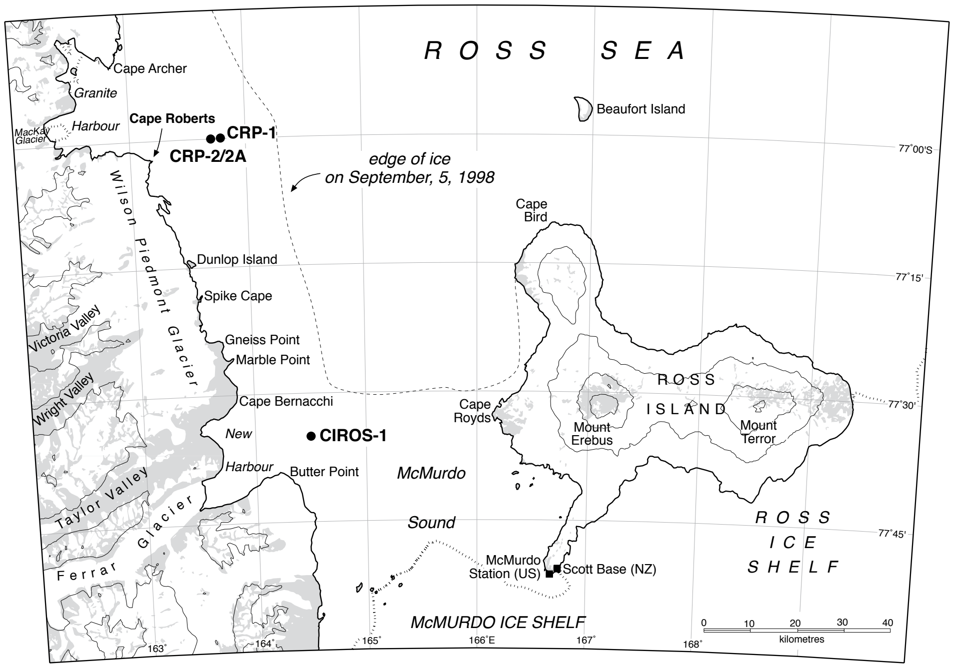
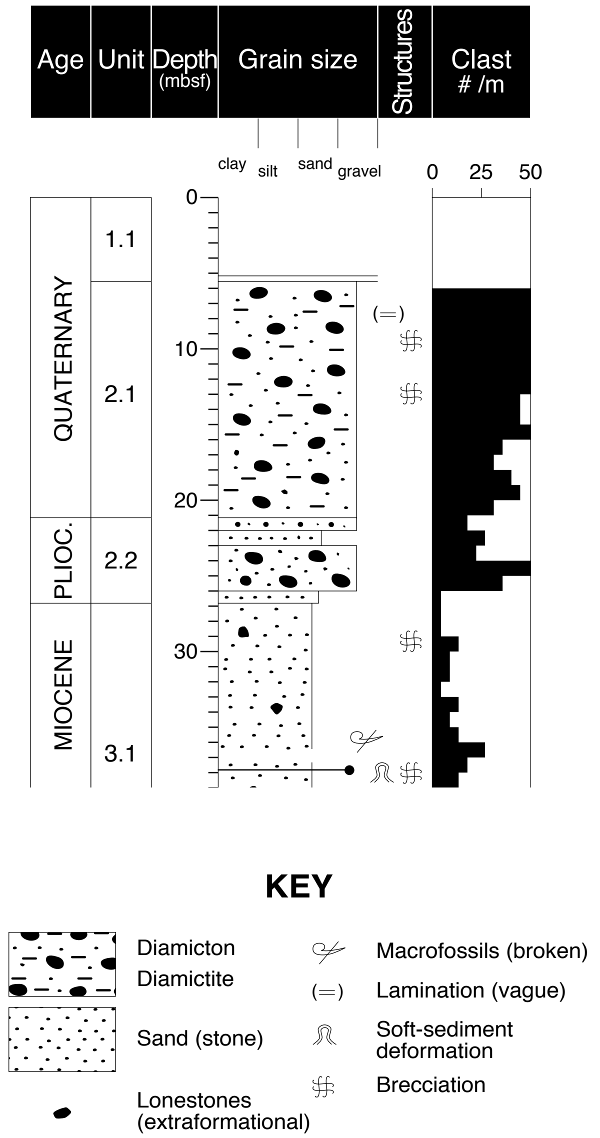


Abstract – The stratigraphic distribution, assemblage content, paleoecology and age of foraminifera recovered in fourteen of sixteen samples from the 5.63 m thick CRP-2 (Lithostratigraphic Unit 2.2) are discussed. LSU 2.2 comprises four discrete lithologic beds. The upward sequence is informally referred to as the *lower sand bed*, *diamicton bed*, *middle sand bed*, and *upper sand bed* and it is surmised that these four units are closely related in time. The *lower sand bed (~1.5 m)*, which overlies lower Miocene sediments and from which it is separated by the Ross Sea Unconformity, contains traces of recycled Miocene diatoms but is otherwise barren of biogenic material. The *diamicton bed* (~2.42 m) contains 21 species of benthic foraminifera, with assemblages consistently dominated by *Cassidulinoides porrectus*, *Ammoelphidiella antarctica*, *Rosalina* cf. *globularis*, *Cibicides refulgens*, and *Ehrenbergina glabra*. The overlying *middle sand bed* (~1.9 m) contains 13 species, with *C. porrectus* and *E. glabra* dominant and *A. antarctica* less common than in the underlying *diamicton bed*. The *upper sand bed* (~0.46 m) contains four species and very few tests. The *diamicton bed* and *middle sand bed* assemblages are considered to be near *in situ* thanatocoenoses; and sediments interpreted as marine in origin but influenced by hyposaline waters and nearby ice. Planktic taxa are absent, perhaps indicating the presence of tidewater glaciers, sea ice and/or hyposaline surface waters. The small assemblage in *the upper sand bed* is more problematic and may be recycled. On the basis of foraminifera in the *diamicton* and *middle sand beds*, LSU 2.2 is assigned to the Pliocene. The overlying diamicton in LSU 2.1 contains abundant Quaternary foraminifera.

INTRODUCTION

In the preliminary report on Cape Roberts Project drillhole CRP-2/2A, the authors documented Pliocene foraminifera in seven samples from the 5.63 m thick Lithostratigraphic Unit (LSU) 2.2 and assumed the enclosing sediments to be the same age (Cape Roberts Science Team, 1999) (Figs. 1, 2). In this study, the total number of samples from this unit has been increased to sixteen, providing an average sample spacing of 0.33 m, and





the foraminiferal fauna of all samples examined in greater detail. Each sample consisted of 6-8 cm of a quarter HQ (diameter 61mm) core, or approximately 30-40 cc. Our objective here is to, document the foraminiferal content more completely, determine relative abundances among the taxa, consider whether these assemblages are *in situ,* or if not, the degree to which they have been modified or transported, decipher biostratigraphic distribution relationships within the suite of samples, and re-examine our earlier interpretation that LSU 2.2 is Pliocene in age.

BACKGROUND

STRATIGRAPHY

The CRP-2/2A drillhole is located 14 km east of Cape Roberts (77.006°S; 163.719°E) (Fig. 1). The drillhole was spudded-in at a water depth of 178 m. In CRP-2, ~27 m of Pliocene-Quaternary glacial sediments (LSU 1.1, 2.1 and 2.2) overlie a late Paleogene-early Neogene succession, from which they are separated by the Ross Sea Unconformity (Cape Roberts Science Team, 1999) (Fig. 2). At nearby CRP-1, *c.* 0.6 km to the east, 43 m of Quaternary sediments overlie this regionally widespread unconformity. Abundant Pliocene foraminifera were recovered from these Quaternary sediments at CRP-1 but *in situ* Pliocene sediments were not encountered (Webb and Strong, 1998a, b; Cape Roberts Science Team, 1998).

The subject of this investigation, LSU 2.2 (21.16-26.79 mbsf), consists of ~5.63 m of diamicton and sand. The subunit is an unconsolidated, massive, very poorly sorted, clast-rich sandy diamicton, and well-sorted fine to coarse sand (Fig. 2).

The 1:20 detailed logs (Cape Roberts Science Team, 1999 – Supplement volume, pp. 8-9) and summary core log (Cape Roberts Science Team, 1999 – Initial Report volume p. 20) separate LSU 2.2 into four discrete sedimentary beds (see also Fig. 2), *i.e.*,

- sand (21.16-21.60 mbsf) *upper sand bed*
- sand (21.60-23.50 mbsf) *middle sand bed*
- diamicton (23.50-25.92 mbsf) *diamicton bed*
- sand 26.28-26.79 mbsf) *lower sand bed*

In discussing the occurrence and distribution of foraminifera below, we adopt the four informal lithostratigraphic descriptors shown above in italics. Note that the logs document three coring gaps within the ~5.63 m LSU 2.2. These gaps total ~1.1 m.

PALEONTOLOGY

Preliminary investigation of fossil material recovered from CRP-2/2A was reported in the project's Initial Report (Cape Roberts Science Team, 1999). Fossil material present in LSU 2.2 includes marine and non-marine diatoms, ebridians, calcareous nannoplankton, foraminifera, sponge spicules, echinoderm spines, bivalves (pectinids), terrestrial and marine palynomorphs, and fossil wood. All macrofossil material is fragmentary.

Twenty-eight samples within the interval 6.25 to 26.79 mbsf (LSU 2.1 and 2.2) were examined for diatoms, with most samples proving barren or containing only trace quantities of diatoms. A large flora was recovered from a ~2 m (21.60-23.5 m) unconsolidated sand (the *middle sand bed* as used herein) interval in the upper part of LSU 2.2 (Cape Roberts Science Team, 1999, Tab. 1.19). Diatom assemblages yielded mixed ages, including late Miocene, early Pliocene and latest Pliocene-earliest Pleistocene, and the suggestion was made that all diatoms might be allochthonous. A maximum age is indicated by *Thalassiosira elliptipora*, which has a well-defined stratigraphical range of 2.4–0.70 Ma. The occurrence of *T. elliptipora*, among other late Pliocene-Pleistocene diatoms, and the absence of *Thalassiosira antarctica* indicates deposition of LSU 2.2 no earlier than the latest Pliocene to earliest Pleistocene. Samples directly above the unconformity at 26.8 mbsf (base of LSU 2.2) contain lower Miocene diatoms, which were interpreted as being reworked from sediments below the Ross Sea Unconformity.

Tab. 1 - Distribution of foraminifera, pre-Pliocene foraminifera, and macrofossil debris in CRP-2, Lithostratigraphic Unit (LSU) 2.2. Sample numbers refer to metres below sea level with only the upper value of the 6-8 cm long sample shown. Stratigraphic distribution of informal bed notation, e.g. *diamicton bed*, is indicated in Fig.2. Samples are quarter cores of 6-8 cm length (30-40 cc). Number totals shown in specimen/sample and species/sample columns refer to tests recovered during exhaustive picking of each residue. Other than recycled lower Miocene diatoms, no biogenic material was recovered from the *lower sand bed*.

CRP-2	lower sand bed		diamicton bed										middle sand bed		upper sand bed	
	26.62	26.37	25.74	25.42	25.20	24.95	24.75	24.60	24.42	24.32	24.00	23.60	22.60	22.34	21.42	21.19
Cassidulinoides porrectus			3	30	2	1		1	4	10	8	3	6	19	6	
Ammoelphidiella antarctica			4	19	5	14	11	9	7	11	6	8	4	4	3	1
Quinqueloculina sp.				1	1	1										
Lagena costata				1							1					
Lenticulina gibba				1			1	1			1	1				
Fissurina alveolata				1												
Fissurina subcircularis				1					1	1	2			1		
Cassidiulinoides parkerianus				1				1								
Rosalina cf. *globularis* (large)				12			6	1	1	3	1	1		1		
Heronallenia kempi				1												
Patellina corrugata				1	1											
Cribroelphidium incertum				2						3	2			2		
Cibicides refulgens				2	2	1	3	1	1			2	4	2	2	2
Ehrenbergina glabra				7		2			1	1	3	1		11	1	1
Oolina globosa					1					1		1	1			
Miliolidae							1			1						
Globocassidulina subglobosa									1		2			2		
Lagena gracilis									1							
Oolina hexagona									1	1						
Rosalina globularis										1						
Globocassidulina crassa											1	1	1			
Oolina squamosulcata														1		
Trifarina earlandi														5		
Astrononion antarcticum														1		
Total specimens/sample	0	0	7	80	12	19	22	14	18	32	27	18	16	49	12	4
Total species/sample	0	0	2	14	6	5	5	6	9	10	10	8	5	11	4	3
Pre-Pliocene Foraminifera				x	x	x	x	x		x	x	x				
Sponge spicules			x	x	x	x		x	x	x	x	x	x	x	x	x
Echinoderm spines			x	x	x	x	x	x	x	x	x	x		x	x	x
Bivalve debris			x	x	x	x	x	x	x	x	x	x	x	x	x	x
Wood												x				

The benthic foraminifer *Ammoelphidiella antarctica* was recorded in moderate numbers in five of the seven samples examined during the on-site characterization phase and was the basis on which a Pliocene age was proposed for LSU 2.2.

NOTES ON FORAMINIFERA

SAMPLE AND ASSEMBLAGE PREPARATION

Sixteen 6-8 cm long (30-40 cc) quarter-core (HQ) samples were disaggregated in water, dried, and sieved into 2000, 1000, 500, 250, 125, 63 μm fractions. All fractions were picked to completion. Flotation techniques were not employed.

FORAMINIFERA

Foraminiferal tests are not abundant. Eighty tests were the most recovered from any single sample (Tab. 1). It was not possible, therefore, to employ standard 300 test census counting procedures in determining detailed population structure. A total of 17 genera and 24 species of benthic foraminifera have been documented in LSU 2.2. Neither agglutinated nor planktic taxa are represented. With one exception (*Rosalina* cf. *globulosa*), all species have been reported previously and/or illustrated from Antarctic Pliocene and/or Quaternary sediments (Gazdzicki & Webb, 1996; Ishman and Rieck, 1992; Ward, C, 1997; Ward and Webb, 1986; and Webb, 1974). All foraminiferal species recovered from LSU 2.2 are listed in Table 1, with notes on selected taxa provided below.

Cassidulinoides porrectus (Heron-Allen & Earland) – This species and *Ammoelphidiella antarctica* are consistently dominant taxa in LSU 2.2 (*diamicton bed* and *middle sand bed*). *C. porrectus* occurs in 12 of 16 samples and exhibits a full range of ontogenetic development. It is also a dominant element in many Quaternary assemblages from CRP-1 (Webb and Strong, 1998b) and CRP-2 (Cape Roberts Science Team, 1999). Tests recovered from CRP-2 (LSU 2.2) are about half the size of those encountered in overlying Quaternary sediments at both drillsites.

Trifarina earlandi Parr – Only a few specimens were recovered, all from the *middle sand* (22.34-22.42 mbsf) near the top of LSU 2.2.

Rosalina cf. *globularis* d'Orbigny (large inflated variety) – This form is compared here to *R. globularis* but further study may show that it represents a new species, as it is much larger, higher spired and more inflated than the normally accepted form of this species. It is presently known only from LSU 2.2 and not previously documented from either Pliocene or Quaternary sediments in the region. Twenty-six specimens were recovered. *R.* cf. *globularis* is most abundant in the *diamicton bed*, particularly at 25.42-25.50 mbsf, and less common above this level. Tests are robust, with a well developed high trochospire of inflated chambers. Periphery rounded. Chambers on the umbilical side are also inflated. Sutures are depressed and strongly recurved. Megalospheric tests have diameters between 0.20 to 0.30 mm and four chambers arranged in a single whorl. Microspheric tests range up to 0.60 mm, have two and one half whorls of chambers, 4-5 chambers in the final whorl, and possess a much higher trochosphire of chambers than is the case in megalospheric tests. Sinistral coiling dominates in both generations. Chamber surfaces on the spiral side are characterized by dense areas of coarse pores. It is probable that this is a free-living rather than an attached form.

Ammoelphidiella antarctica Conato & Segre – Occurs in 14 samples between 21.19 and 25.80 mbsf (Tab. 1). The species occurs most abundantly in the *diamicton bed* of LSU 2.2, is absent in the *lower sand*, and poorly represented in the *middle* and *upper sand beds*. A single poorly preserved specimen reported in CRP-2-LSU 2.1 (16.30 to 16-38 mbsf) is considered to have been reworked into Quaternary sediments (Cape Roberts Science Team, 1999, Fig. 1.10). This species is a persistent member of inshore and fjordal Pliocene sediments from several areas of Antarctica (Gazdzicki and Webb, 1996; Ishman and Rieck, 1992; Quilty *et al*., 1990; Webb, 1974). The 106 tests recovered from LSU 2.2 exhibit a wide range of sizes. Microspheric tests range up to 1.5 mm diameter and consist of three to four whorls of chambers with about eight chambers in the final whorl. Megalospheric tests have diameters of 0.2 to 0.4 mm with four to six chambers in the final whorl. These dimensions and morphologies parallel populations of *Trochoelphidiella onyxi* Webb (=*Ammoelphidiella antarctica* Conato & Segre) from the Pliocene Pecten Gravels, Wright Valley (Webb, 1974). A variety of preservation states (large red ferruginous-stained to usually much smaller pristine white tests) may be natural, but might also indicate the combining of more than one assemblage.

Ehrenbergina glabra Heron-Allen & Earland – Present in 9 of 16 samples and most abundant near the base of the *diamicton bed* (25.42-25.50 mbsf) and *middle sand bed* (22.34 - 22.42 mbsf). Tests of *E. glabra* from LSU 2.2 are much smaller than those in overlying Quaternary sediments. Two test variants are present. The dominant variant is unrolled and possesses a rounded periphery without spinose projections (*E. glabra* var. *obesa* of Cape Roberts Science Team, 1999, Table 1.10). The more typical form of *E. glabra*, with sharp periphery and spinose projections, is common in the *middle sand bed* near the top of LSU 2.2.

DISCUSSION

STRATIGRAPHIC DISTRIBUTION OF FORAMINIFERA

There appears to be a relationship between the lithostratigraphy of LSU 2.2 and the occurrence, test abundance and number of foraminiferal species (Table 1, Fig. 2). The *lower sand bed* contains no foraminifera. The *diamicton bed* is the most fossiliferous, and provided a total of 21 species. The greatest number of species (14 species) and tests (80 tests) occurs low in the *diamicton bed* at 25.42 mbsf. For the *middle sand bed* the greatest number of species (11) and number of tests (49) occurs at 22.34 - 22.42 mbsf. (Table 1). The *upper sand bed* contains only 4 species and test numbers are also very low.

Webb and Strong (1998a,b) demonstrated at CRP-1, that well preserved, diverse and test-rich assemblages of Pliocene foraminifera are recycled into a shell bed and sands containing even more abundant and diverse Quaternary foraminiferal assemblages. The Pliocene element was dominated by *Cassidulinoides porrectus*, *Trifarina earlandi*, *Cibicides lobatulus*, *Cibicides refulgens*, *Ehrenbergina glabra*, *Ammoelphidiella antarctica*, *Globocassidulina crassa*, and *Globo-cassidulina subglobosa*. Contrasting states of preservation and the occurrence of the Pliocene index *A. antarctica* provided the principal criteria for separating Pliocene and Quaternary elements within each assemblage. In the absence of *in situ* Quaternary taxa these sediments might have been assigned to the Pliocene rather than to the Quaternary. It is possible, then, for both terrestrial and marine glacial processes to recycle individual microfaunas without major disruption of original population structure. Most of the Pliocene taxa observed in CRP-1 are also present in CRP-2 (LSU 2.2).

The experience with CRP-1 compels us to consider several scenarios in explaining and interpreting the foraminiferal assemblages of CRP-2/LSU 2.2. Four interpretations are possible: (1) they represent a Pliocene biocoenosis and are the same age as the enclosing sediments, (2) they are depauperate Pliocene assemblages associated with the deposition of LSU 2.2 but are taphocoenoses, (3) they are products of glacial recycling processes, perhaps involving glacial transport from a distant or local Pliocene source but redeposited into slightly younger Pliocene sediments, or (4), they were derived from a distant or local Pliocene source and were deposited into unfossiliferous Quaternary sediments. We will show evidence suggesting that the second interpretation is the more likely of the four possibilities. The Cape Roberts Science Team (1999, p. 20) discussed stratigraphic and sedimentological evidence and considered two options, *i.e*., that LSU 2.2 might be a basal till or a proximal glacimarine deposit.

If recycling from a distant or local outcrop occurred, then the barren *lower sand* might be expected to contain Pliocene fossil material. This apparently is not the case. The argument for derivation and redeposition from a local or distant source would also be strengthened if fossil-bearing Pliocene sedimentary clasts were present in LSU 2.2. Again, this is not the case.

We contend that the case for the Pliocene foraminifera and LSU 2.2 being coeval is strengthened if it can be demonstrated that there is a close degree of assemblage similarity at multiple stratigraphic levels within LSU 2.2. As a result of close sampling it is apparent that the same taxa are dominant in two (*diamicton bed* and *middle sand bed*) and possibly three of the four lithofacies (Table 1). These taxa are *Cassidulinoides porrectus*, *Ammoelphidiella antarctica*, *Rosalina* cf. *globularis*, and *Ehrenbergina glabra*. The fact that these four species exhibit a variety of test sizes and growth stages, and in the case of *A. antarctica,* the presence of both megalospheroic and microspheric generations, provides an argument against their occurrence being simply a matter of size sorting during transport. Unlike the situation at CRP-1, these Pliocene foraminifera do not occur in association with Quaternary foraminifera (Webb and Strong, 1998a).

It might be argued that the sediments of LSU 2.2 are actually Quaternary in age but contain no fossils of this age. This possibility is difficult to disprove. The presence of Quaternary foraminiferal faunas in overlying LSU 2.1 suggests that the LSU 2.2/LSU 2.1 contact represents the Pliocene-Quaternary boundary at this site. Almost all taxa cited in Table 1 and cited or discussed above are elements of *in situ* Pliocene assemblages at other localities in Antarctica (Gazdzicki and Webb, 1996; Ishman and Rieck, 1992; Quilty *et al*., 1990; and Webb, 1974).

PALEOECOLOGY

Available evidence suggests to us that the assemblage recovered from LSU 2.2 represents a near-*in situ* taphocoenosis. The *diamicton bed* and *middle sand bed* are considered, largely on the basis of their benthic foraminiferal content, to be coastal marine deposits. Similar *in situ* Pliocene assemblages (with common *Ammoelphidiella antarctica*) occur in fjordal and littoral environmental settings around the Antarctic margin (see discussion in Gazdzicki and Webb, 1996). The fact that these assemblages are associated at CRP-2 with a clast-rich diamicton points to survival beneath a coastal ice cover, perhaps an ice shelf or tidewater glacier; or coastal waters subject to rain-out of debris from ice bergs. The barren basal *lower sand bed*, and foraminiferal-poor *upper sand bed*, may represent phases of elevated freshwater input (*i.e.* hyposalinity). The absence of planktic taxa throughout LSU 2.2 could be attributed to several factors, including the existence of floating glacier ice, sea ice, low salinity surface meltwaters, proximity to the coastline, or some combination of these.

AGE OF CRP-2 (LSU 2.2)

Ammoelphidiella antarctica is a key taxon in assigning a Pliocene age to most or all of CRP-2 (LSU 2.2). This species is unknown in either Miocene or Quaternary sediments and its value as a Pliocene index species has been confirmed by several techniques, including radiometric dating of associated or subjacent volcanic rocks, relationships to Pliocene diatom zonal taxa and magnetostratigraphic data, in studies from Taylor Valley (Transantarctic Mountains), Larsemann Hills (East Antarctica), and Cockburn Island (Antarctic Peninsula) (see review of literature by Gazdzicki and Webb, 1996).

The LSU 2.2 assemblage closely resembles the assemblage reported from the *Ammoelphidiella antarctica* Zone (3.4 to 3.7 Ma) in the DVDP-10 drillhole, eastern Taylor Valley (Ishman and Rieck, 1992). In DVDP-10, the zone has a thickness of 2.16 m (153.86 to 151.70 metres below sea level). Sediments consist of sandstone, pebbly sandy mudstone and granule conglomerate, and the top and bottom of the zone coincides with hiatuses which separate this short succession from overlying and underlying Pliocene strata.

The lowermost Quaternary assemblage recorded above CRP-2 (LSU 2.2) occurs immediately above the boundary between LSU 2.2 and LSU 2.1, at 21.03-21.09 mbsf (Cape Roberts Science Team, 1999**;** Fig. 2). This contact separates two obviously different faunas and marks the highest stratigraphic occurrence of *Ammoelphidiella antarctica*. We adhere then, to the view expressed earlier, that LSU 2.2 (*diamicton,* and *middle sand beds*) are Pliocene in age. Lack of evidence precludes an age being assigned to LSU 2.2 (*lower sand bed*) close to the contact with underlying LSU 3.1 (lower Miocene). The age of LSU 2.2 (*upper sand bed*) is probably Pliocene on the basis of its sedimentological affinities with the underlying Pliocene rather than overlying Quaternary deposits, but the possibility that Pliocene taxa are reworked into otherwise barren sediments of Pliocene or Quaternary age cannot be totally rejected.

RECYCLED FORAMINIFERA

Eight of the sixteen samples contain reworked pre-Pliocene foraminifera. These are confined to the *diamicton bed* and occur in samples between 23.60 and 25.50 mbsf. They are particularly common near the base of the *diamicton bed* (25.42 - 25.50 mbsf). It is noteworthy that the *lower*, *middle* and *upper sand* beds of LSU 2.2 contain no reworked pre-Pliocene foraminifera. Preservation is poor and brown ferruginous staining allows these tests to be easily distinguished from the more numerous Pliocene taxa. Most are trochospiral agglutinated (*Trochammina*) and calcareous benthics (*Cibicides*, *Gyroidinoides,* etc.), although a few tiny planktic *Globorotalia*-like forms are also present. Members of the agglutinated Ataxophragmiidae are present but rare. None of this reworked element has been encountered in upper Oligocene-lower Miocene sediments drilled at either CRP-1 or CRP-2A (Strong and Webb, 1998, this volume), or in Oligocene and Miocene sediments of DSDP 270 and 272 from the central Ross Sea (Leckie and Webb, 1986; Steinhauff, 1985). It is unlikely that this material is middle or late Miocene in age as foraminifera from Neogene sites such as DSDP 270-273 are normally well preserved. It is possible that the reworked foraminifera from CRP-2 (LSU 2.2) have an origin in the Eocene or older sediments of the Victoria Land Basin.

MACROFOSSIL DEBRIS

Broken and abraded sponge spicules, echinoderm spines, and fragments of bivalves occur in the microfossil residues from the *diamicton*, *middle* and *upper sand* beds of LSU 2.2. Fragmentary pectinid debris was also reported from macroscopic examination of the archive and working half cores (Cape Roberts Science Team, 1999). Rare, dark coloured fragments of fossil wood are present in an uppermost *diamicton bed* sample at 23.60-23.68 mbsf.

ROSS SEA UNCONFORMITY

The results presented above provide an approximate youngest age of Pliocene, probably mid Pliocene, for the Ross Sea Unconformity at CRP-2. Because lower Miocene sediments underlie Pliocene LSU 2.2 and some 15-18 m.y. of time and sedimentary record is unrepresented, this is not a useful site for constraining the maximum age of the event or events which produced the Ross Sea Unconformity. It is unclear whether Ishman and Rieck's (1992) infra-Pliocene hiatuses H1, H2 and H3 (4.5 to 3.0 Ma) in drillholes at the mouth of Taylor Valley are related to the Ross Sea Unconformity, including its expression in the region of the CRP-2 drillhole on Roberts Ridge.

PLIOCENE-QUATERNARY DEFORMATION ACROSS THE TRANSANTARCTIC MOUNTAIN FRONT

The base of the Pliocene at CRP-2 (*i.e.*, base of LSU 2.2) is located at ~205 m below sea level (mbsl) compared with ~154 mbsl for the base of the *Ammoelphidiella antarctica* Zone in the DVDP-10 drillhole (Taylor Valley). If these two thin hiatus-bound Pliocene successions are temporal correlatives, as is suggested above, a vertical difference of ~ 51 m must be explained. Four options include, a deepening bathymetric gradient away from the coast towards the Ross Sea in the original environment, a low angle stratal dip towards the east, normal fault displacement along the Transantarctic Mountain Front, slumping of strata towards the Ross Sea, or perhaps some combination of these.

The situation is significantly more complex when one considers jointly the Pecten Gravels of Wright Valley (Webb, 1972, 1974), a likely Pliocene correlative of CRP-2 (LSU 2.2), and the strata of the *Ammoelphidiella antarctica* Zone of eastern Taylor Valley. The Pecten Gravels are located at ~153 m above sea level, *i.e.*, ~307 and ~358 metres above the equivalent horizons in DVDP-10 (Taylor Valley) and CRP-2 (Roberts Ridge) respectively. One possible interpretation of these data is that since the middle Pliocene (*i.e.*, ~3.5 Ma) there has been a significantly greater amount of uplift or upwarping to the north of Taylor Valley in the Wright-Victoria Valley part of the Transantarctic Mountains (TAM) (Wrenn and Webb, 1982), and that fault displacement across the Transantarctic Mountain Front is also greater in the north (in the latitude of Cape Roberts-Robert Ridge), than in the south. Dated middle to late Pliocene volcanic rocks are common in the eastern part of this uplifted block and some appear to be associated with fault lineaments. If one ascribes the contrasted vertical differences of Pliocene strata to fault displacements and tilting of uplifted blocks, and assumes that displacements commenced at ~ 3.5 mybp, differences in rates of displacements across the Transantarctic Mountain Front varies between ~ 14 m/my (CRP-2 = 205 mbsl and DVDP10/Taylor Valley = 154 mbsl, for a difference of 51m) and ~102 m/my (CRP-2 = 205 mbsl and Wright Valley = 153 masl for a difference of 358 m). Because inception of displacement is arbitrarily set at ~ 3.5 mybp and faulting may have been active after this time, and may have been sporadic in nature, these displacement rates must be considered as minimum average values.

The bathymetric range of the *Ammoelphidiella antarctica* biotope is interpreted as ranging from littoral (Cockburn Island; Gazdzicki and Webb, 1996) to perhaps as much as 100 metres in fjordal and offshore environments (Webb, 1972, 1974). The Wright Valley Pecten Gravels have been elevated well above present day and Pliocene sea level. We suggest that at 200-205 mbsl the present position of the *A. antarctica* biotope in CRP-2 is over-deepened. This is most reasonably explained as due to post-depositional fault-related subsidence. Roberts Ridge appears to have had an active structural history, one that involved upwarping of Paleogene-lower Miocene sediments towards the TAM Front after the early Miocene, erosional planning before the middle Pliocene in relatively shallow water depths, deposition of middle Pliocene sediments in shallower-than-present water depths, followed by fault-related subsidence in the late Pliocene and Quaternary. These data have yet to be integrated with recent studies of tectonic and structural geology derived from the marine geophysical studies in the Cape Roberts and Roberts Ridge area where normal faulting has been documented close to and at the sea floor (Hamilton et al., 1998).

CONCLUDING REMARKS

We conclude from this investigation that the benthic foraminifera and sediments of CRP-2 (LSU 2.2) are both Pliocene in age. The foraminiferal assemblage closely resembles that documented in the *Ammoelphidiella antarctica* Zone (~3.4 to 3.7 Ma) of the DVDP-10 drillhole, Taylor Valley, and the Pecten Gravels of Wright Valley (Ishman and Rieck, 1992; Webb, 1974).

Sedimentation occurred in a marine environment, probably under the influence of floating glacier and sea ice. The assemblages are best characterized as taphocoenoses. The fact that the same dominant taxa are repeated through much of the succession is seen as evidence for the existence of an *in situ* or nearly *in situ* biotope. Had there been erosion and transport of foraminifera in ice, followed by redeposition at the sea floor, one might expect more variability in the content and population structure of the microfaunas and perhaps the occurrence of reworked sediment clasts with Pliocene fossil material. These were not recovered, whereas lower Miocene sediment clasts derived presumably from subjacent successions in the margins of the Victoria Land Basin are present.

The presence of pre-Pliocene foraminifera and macrofossil debris in LSU 2.2, particularly in the *diamicton bed*, indicates that transported fossil material was introduced to LSU 2.2 via ice transport.

The lack of *in situ* or recycled Quaternary foraminifera in LSU 2.2 suggests as unlikely that the Pliocene foraminifera have been transported and redeposited into Quaternary age sediments, as was the case at CRP-1 (Webb and Strong, 1998a, b).

At Roberts Ridge, the Ross Sea Unconformity underlies a thin 27 metre Pliocene-Quaternary sedimentary succession and is located ~205 m below present sea level. This is the shallowest depth for Pliocene sediments yet reported from the Ross Sea region. The age of the Ross Sea Unconformity is no younger than ~3.5 Ma. Because the Ross Sea Unconformity at CRP-2 represents a stratigraphic hiatus of approximately 15-18 m.y., the oldest possible age for the unconformity cannot be determined at this site. Infra-Pliocene hiatuses recognized in the Taylor Valley drillhole records (Ishman and Rieck, 1992) may correlate with the Ross Sea Unconformity at CRP-2.

Vertical displacement of the thin Pliocene successions with *Ammoelphidiella antarctica* at CRP-2 (Roberts Ridge), DVDP-10 (Taylor Valley) and Pecten Gravels (Wright Valley) provides insight into mid Pliocene-Recent deformation across the Transantarctic Mountain Front. It appears that Pliocene-Holocene displacements were greater between Wright Valley-Roberts Ridge/CRP-2 (~358 m) than between eastern Taylor Valley and Roberts Ridge/CRP-2 (~ 51 m).

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