THE DATING AND INTERPRETATION OF DIATOM ZONES IN DRY VALLEY DRILLING PROJECT HOLES 10 AND 11 TAYLOR VALLEY, SOUTH VICTORIA LAND, ANTARCTICA

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***Abstract*:** Reworked and *in situ* diatoms reveal a complex late Miocene and Pleistocene history in Taylor Valley. Lacustrine and reworked glacial sediments overlie marine sediments of the ancient Taylor Valley fjord which existed in the late Miocene and early Pliocene.

1. Introduction

In 1974/5, the Dry Valley Drilling Project (DVDP) obtained three cores from sites in Taylor Valley—DVDP 10 (185.47 m), DVDP 11 (327.96 m) and DVDP 12 (165 m); these provide the most complete Cenozoic successions available to scientists on the Antarctic mainland (Figs. 1 and 2). Various successions in DVDP 10 and 11 cores were dated by Webb and Wrenn (1976, 1979) and Wrenn (1977) who recognised three distinct faunas of benthic foraminifera: Zone 1—Late Miocene/ Early Pliocene, Zone 2—Mid-Pliocene, Zone 3—Pleistocene. These scientists recognise the problem of dating successions using long ranging benthic foraminifera because it is impossible at the present time to define the exact upper and lower time limits of such faunas when other DSDP reference sections do not provide a full and adequate foraminifera record.

Brady (1979) tried to approach the DVDP 10 and 11 successions using diatom biostratigraphy but the zonations defined at that time were not diatom zonations in a strict sense but zonations based on evidence from diatoms, foraminifera and lithology. Diatom studies have now been completed on another fifty samples from critical intervals so that this report is based on 290 samples from DVDP 11 and 86 samples from DVDP 10. Independent diatom zonations are now proposed so that the source of interpretation and argument about any critical interval can be clearly delineated (Figs. 3 and 4). Meaningful interpretations can then be made by comparing the diatom evidence with that from other sources—foraminifera (Webb and Wrenn), silicoflagellates (Ling), geophysical logs (McGinnis), oxygen isotopes (Stuiver and Yang), soil chemistry (Ugolini and Deutsch), stratigraphy and sedimentology (McKelvey, Porter, Beget), paleomagnetics (Elston and Spall) etc.

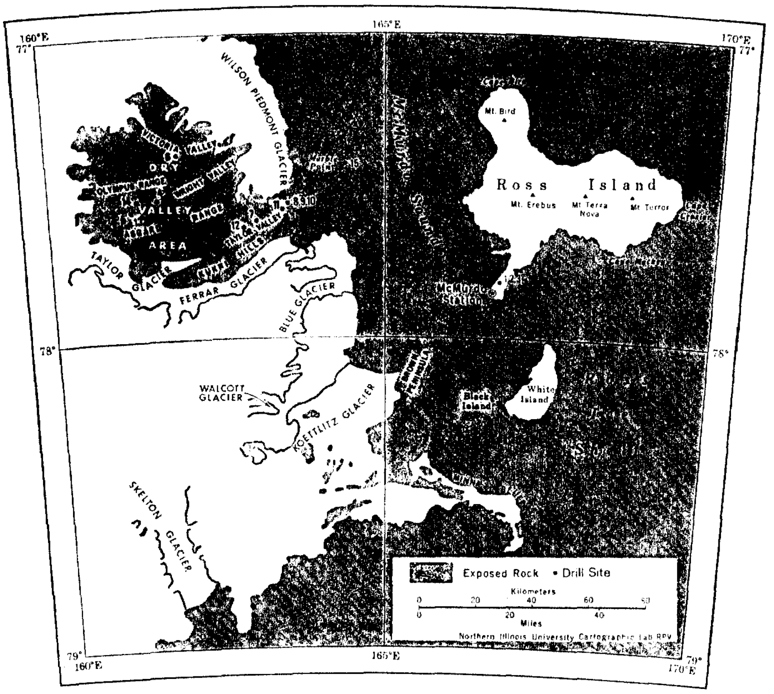

Fig. 1. DVDP drill sites. Map adapted by MCGINNIS *(1977).*

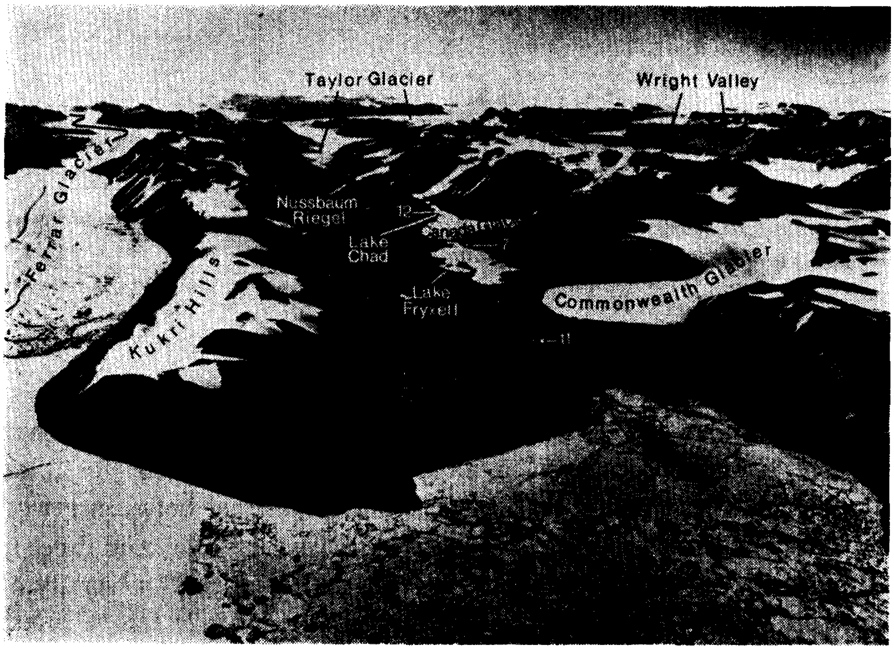

Fig. 2. DVDP drill sites, Taylor Valley. U.S. Navy photo adapted by WRENN *(1977).*

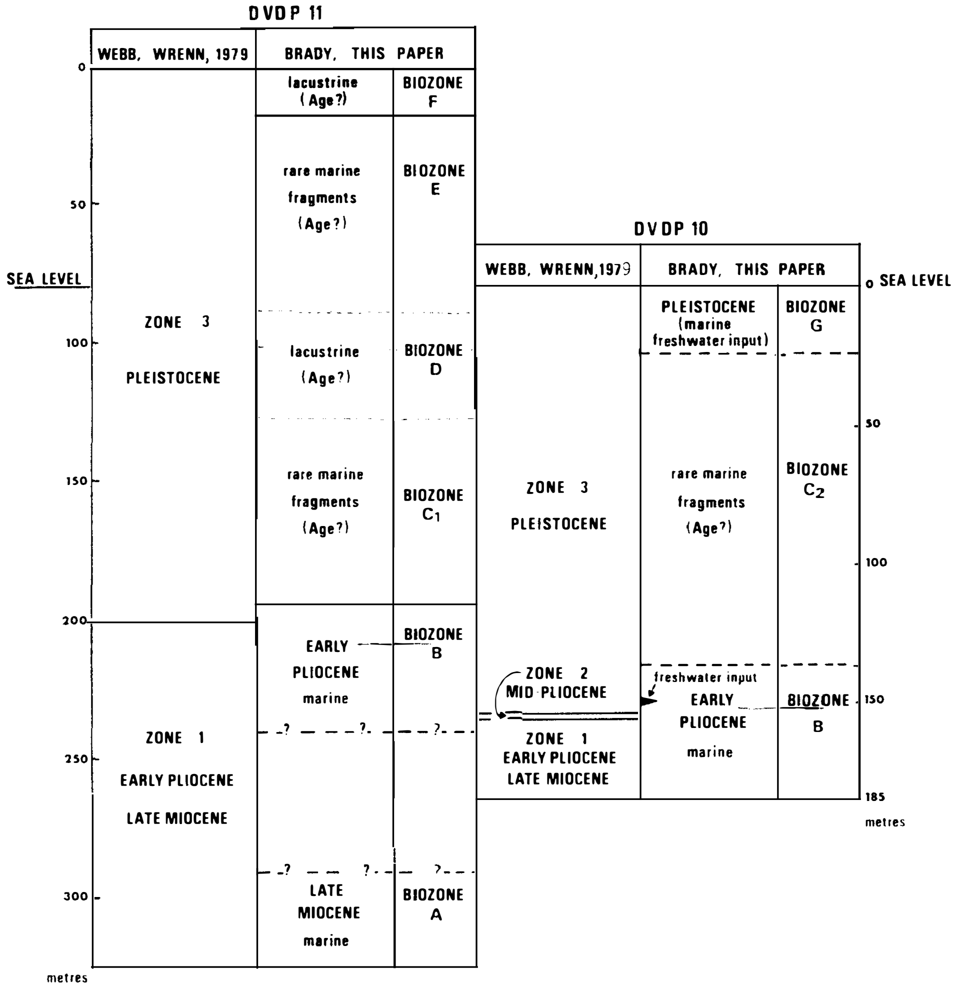

*Fig. 3. Foraminifera Zones (*W*EBB and* W*RENN, 1979) and diatom zonations (*B*RADY, this paper) in DVDP 10 and 11, Taylor Valley.*

The history of Taylor Valley cannot be written just from the analysis of fossil diatoms. Figs. 5 and 6 list all samples studied and it is evident that the majority of samples are barren. However, a clear distinction is often possible between reworked and *in situ* sediments. There is a sharp contrast between reworked diatoms in the Ross glacial tills mapped by DENTON in Taylor Valley and those in normal marine sediments. These tills, inspected by this author at the University of Marine in 1977, are full of broken marine diatom fragments. Whole frustules are rare or absent. The state of preservation of the marine diatoms contrasts sharply with that of non-marine diatoms in the same tills that have come from the freshwater environment associated with the incursion of the Ross Ice Sheets into Taylor Valley. The

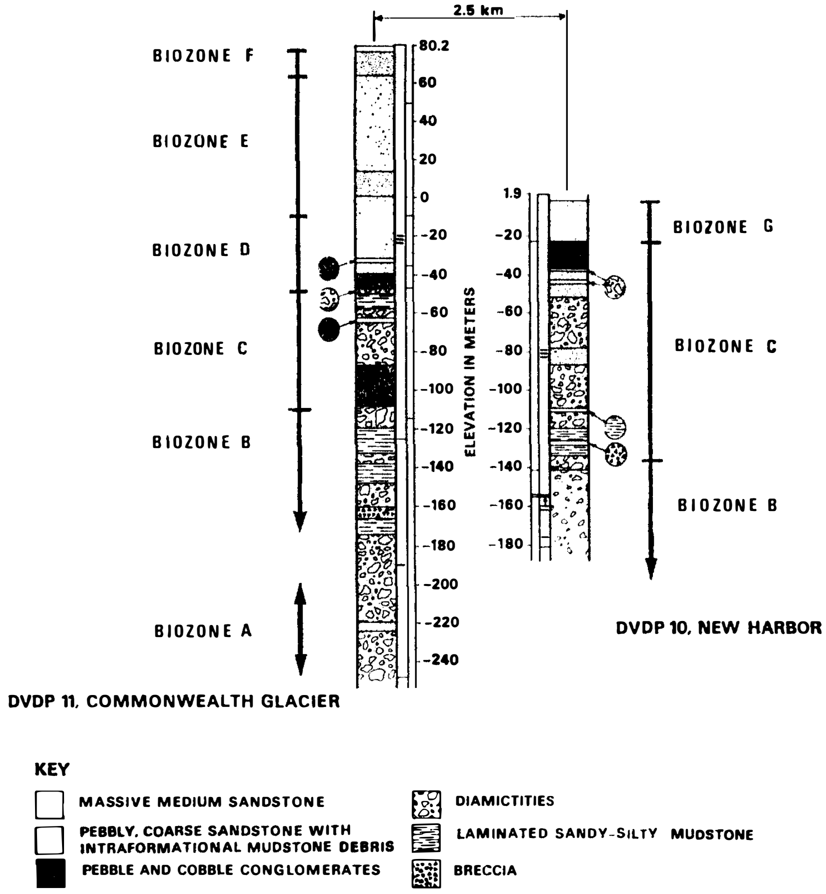

*Fig. 4. Diatom zonations (*Brady*, this paper) and lithology of DVDP 10 and 11, Taylor Valley.*

same phenomenon occurs in glacial tills in Wright Valley where glaciers have disturbed the sediments of the old Wright Valley fjord or where Ross glaciations have moved marine sediments into the valley. This author has used these comparisons in interpreting the DVDP successions and therefore regards (for example) the microfossil evidence that strongly suggests *in situ* marine deposition at the base of DVDP 10 (156–185.47 m) to be more valid than oxygen isotopes at the same interval (Stuiver, 1976) or conductivity values (Ugolini and Deutsch in Washburn, 1977) which suggest a freshwater environment for much of the interval.

Indeed, any interpretations of DVDP 10 and 11 successions based solely on the analysis of pore waters in these cores are extremely suspect. This author considers that interpretations based on electrical conductivity, salinity or oxygen isotope logs in DVDP 10 and 11 are limited because of the real possibility of subsurface water movement and replacement. The drilling of DVDP 11 was terminated when 2000 gallons of oil drilling fluid were lost and the drilling of DVDP 10 was

Depth (m)	Marine diatom fragments	Marine sponge spicules	Non-marine diatoms	Identifiable diatoms	Depth (m)	Marine diatom fragments	Marine sponge spicules	Non-marine diatoms	Identifiable diatoms
5.12	R	B	F	I	142.89	R	R	B	
9.94	R	B	B		143.49	C	F	B	I
16.71	B	B	B		148.90	F	R	B	I
20.05	B	B	B		149.57	C	F	F	I
24.97	C	F	B	I	150.18	A	F	C	I
29.96	R	R	B		151.22	F	F	B	I
34.95	R	B	B		152.10	A	F	C	I
39.93	B	B	B		154.23	R	B	B	
45.05	B	B	B		154.37	R	B	B	
50.21	B	B	B		154.48	B	R	B	
54.65	B	B	B		154.80	R	R	B	
55.63	R	R	B		154.95	R	B	B	
65.29	F	F	B		155.40	R	R	B	
70.31	R	R	B		155.86	C	F	B	I
74.83	R	B	B		156.46	C	F	B	I
80.13	R	B	B		157.04	R	R	B	
85.10	R	B	B		157.64	R	R	B	
90.07	R	B	B		158.00	C	R	B	I
95.07	B	B	B		158.89	F	R	B	
99.93	B	B	B		159.40	R	R	B	
105.05	B	B	B		160.63	R	R	B	
115.00	B	B	B		161.19	F	R	B	I
120.04	B	B	B		161.84	F	B	B	I
125.33	B	B	B		162.35	C	R	B	I
125.85	P	B	B		162.69	C	R	B	I
127.10	B	B	B		164.41	B	B	B	
128.47	B	B	B		164.57	F	F	B	
131.13	B	B	B		167.95	B	A	B	
132.56	B	F	B		170.05	B	R	B	
133.10	B	B	B		170.35	B	R	B	
133.49	R	R	B		172.09	R	R	B	
134.04	R	B	B		173.09	B	R	B	
135.92	R	B	B		174.01	B	R	B	
136.57	B	B	B		174.43	B	R	B	
137.16	C	R	B	I	174.85	B	R	B	
137.37	F	F	B	I	179.25	F	C	B	
137.76	F	F	B	I	179.87	C	C	B	I
138.81	F	F	B	I	180.20	C	F	B	I
139.57	B	B	B		180.33	C	F	B	I
139.93	B	B	B		182.61	A	F	B	I
140.59	B	B	B		182.97	A	F	B	I
141.30	B	B	B		183.00	A	F	B	I
141.92	B	B	B		183.27	A	F	B	I
142.40	B	B	B						

Fig. 5. Diatom abundance and distribution, DVDP 10.
(Key at 1000 × : B-Barren, R-Rare, F-One fragments/5 fields of view, C-Fragments in each field of view, A-Abundant diatoms or fragments)

terminated when the drill penetrated the permafrost and encountered a hydraulic head that caused water to rise within 18 m of the surface. The presence of deep lakes within Taylor Valley blocked by the Ross Ice Shelf with lake levels 300 m above sea level (Denton, in preparation) and their subsequent draining would

Depth (m)	Marine diatom fragments	Marine sponge spicules	Non-marine diatoms	Identifiable diatoms
1.82	R	B	R	I
5.20	B	R	B	
5.69	B	B	B	
6.25	R	B	B	
6.82	B	B	B	
7.30	B	B	B	
8.10	B	R	B	
8.50	B	B	B	
9.12	B	R	R	I
9.50	R	R	B	
10.10	R	R	B	
11.18	B	R	B	
11.66	B	R	B	
12.27	B	B	B	
12.83	R	B	C	I
13.62	B	R	B	
14.02	B	B	R	I
15.20	R	R	B	
16.12	R	R	A	I
16.20	R	R	A	I
16.42	R	R	C	I
16.80	R	R	B	
17.15	B	B	C	I
17.72	R	B	B	
18.84	B	B	B	
19.48	B	B	B	
19.80	R	B	B	
20.48	B	B	B	
20.99	R	B	B	
22.10	R	B	B	
22.70	R	B	B	
23.77	B	B	B	
24.22	B	B	B	
24.79	B	B	B	
26.20	B	B	B	
27.33	B	B	B	
29.25	B	B	B	
29.77	R	B	B	
30.86	B	B	B	
31.49	B	B	B	
32.89	B	B	B	
33.92	B	B	B	
34.81	B	B	B	
35.10	B	B	B	
35.30	B	B	B	
35.68	B	B	B	
36.46	B	B	B	
37.32	B	B	B	
38.64	B	B	B	
39.94	B	B	B	
40.50	B	B	B	
41.08	B	B	B	
41.63	B	B	B	
42.05	B	B	B	
42.70	B	B	B	
43.34	B	B	B	
43.93	B	B	B	
44.45	B	B	B	
45.50	B	B	B	
46.06	B	B	B	
47.25	B	B	B	
48.50	B	B	B	
49.24	B	B	B	
49.86	B	B	B	
50.37	B	B	B	
50.96	B	B	B	
51.44	B	B	B	
52.27	B	B	B	
53.44	B	B	B	
53.90	B	B	B	
54.45	B	B	B	
55.15	B	B	B	
56.38	B	B	B	
58.11	B	B	B	
58.65	B	B	B	
59.09	B	B	B	
59.45	B	B	B	
60.76	B	B	B	
61.04	B	B	B	
62.20	B	B	B	
63.29	B	B	B	
63.82	B	B	B	
65.14	B	B	B	
65.50	B	B	B	
66.55	B	B	B	
67.00	B	B	B	
68.32	B	B	B	
70.12	B	B	B	
70.55	B	B	B	
71.70	B	R	B	
75.76	B	B	B	
77.00	B	B	B	
81.59	B	R	B	
83.48	B	B	B	
85.10	B	B	B	
85.37	B	B	B	
87.58	B	B	B	
88.57	B	B	B	
89.76	B	B	B	
90.30	R	B	R	I
90.93	B	B	R	I
91.20	R	B	R	
92.30	B	B	B	
93.06	B	B	B	
93.62	B	B	B	
94.40	B	B	B	
96.28	B	B	B	
97.55	R	B	B	
98.78	B	B	B	
99.60	R	B	B	I

Fig. 6. Diatom abundance and distribution, DVDP 11.
(Key at 1000× : B-Barren, R-Rare, F-One fragments/5 fields of view, C-Fragments in each field of view, A-Abundant diatoms or fragments)

Depth (m)	Marine diatom fragments	Marine sponge spicules	Non-marine diatoms	Identifiable diatoms
100.70	B	B	B	
101.30	R	B	B	
101.90	B	B	A	I
102.10	B	B	B	
103.17	R	B	B	
103.55	R	B	B	
104.15	R	B	B	
104.70	R	B	B	
104.97	R	B	F	
106.45	R	B	F	
107.10	B	B	B	
107.60	B	B	B	
108.09	B	B	B	
109.60	B	B	B	
110.54	B	B	B	
110.75	B	B	B	
114.16	B	B	B	
115.48	B	B	B	
117.26	B	B	B	
118.50	B	B	B	
120.00	B	B	B	
128.16	B	B	B	
128.94	B	B	B	
129.60	B	R	B	
130.76	B	B	B	
131.58	R	B	B	
132.84	B	R	B	
133.70	B	B	B	
134.36	B	B	B	
136.86	B	B	B	
137.28	B	B	B	
138.55	B	B	B	
140.37	B	B	B	
141.12	B	B	B	
141.75	R	R	B	
142.44	B	B	B	
146.41	B	B	B	
149.99	B	B	B	
150.00	B	B	B	
150.38	B	B	B	
153.11	B	B	B	
154.07	B	B	B	
156.52	B	B	B	
158.30	B	B	B	
160.22	B	B	B	
161.30	B	B	B	
162.49	B	B	B	
164.16	B	B	B	
165.30	B	B	B	
166.36	R	B	B	
166.91	R	R	B	
167.30	R	B	B	
168.09	B	R	B	
169.64	B	B	B	
170.35	B	B	B	
171.83	R	R	B	
173.35	B	B	B	
174.60	R	B	B	
178.80	B	B	B	
183.60	B	B	B	
188.36	B	B	B	
188.50	B	B	B	
190.57	B	B	B	
193.40	B	B	B	
194.80	R	R	B	
194.90	B	B	B	
195.39	A	F	B	I
195.70	R	F	B	
198.55	R	R	B	
199.30	R	A	B	
201.21	C	C	B	I
202.00	C	R	B	
202.80	B	B	B	
203.33	R	B	B	I
204.00	C	R	B	
204.21	B	B	B	
204.25	C	C	B	I
204.35	C	C	B	
204.70	R	B	B	
204.84	B	R	B	
204.97	C	R	B	
206.94	F	R	B	
207.00	F	F	B	I
207.15	C	A	B	I
208.10	B	B	B	
208.52	F	C	B	
208.62	C	C	B	I
209.46	F	R	B	
210.31	C	R	B	I
210.40	A	R	B	
212.68	B	B	B	
214.44	B	B	B	
216.62	B	B	B	
221.26	B	B	B	
223.05	B	B	B	
223.70	B	B	B	
224.68	B	B	B	
227.37	B	B	B	
229.69	B	B	B	
230.40	B	B	B	
232.72	B	B	B	
236.91	B	B	B	
238.60	B	B	B	
238.86	B	B	B	
239.73	C	R	B	I

Fig. 6 (Continued).

Depth (m)	Marine diatom fragments	Marine sponge spicules	Non-marine diatoms	Identifiable diatoms	Depth (m)	Marine diatom fragments	Marine sponge spicules	Non-marine diatoms	Identifiable diatoms
239.74	C	R	B	I	300.30	B	B	B	
239.80	R	B	B		301.07	B	B	B	
240.20	A	F	B	I	303.27	B	B	B	
240.40	C	F	B	I	303.74	B	B	B	
240.61	C	R	B	I	305.50	B	B	B	
241.50	F	R	B	I	307.00	B	B	B	
241.77	C	F	B		308.35	B	B	B	
241.80	F	F	B	I	309.50	B	B	B	
242.00	C	F	B	I	311.62	B	B	B	
244.60	F	R	B		312.50	B	B	B	
244.85	C	R	B		313.83	B	B	B	
244.93	C	R	B		318.57	B	B	B	
247.40	B	B	B		320.40	B	B	B	
247.80	B	B	B		322.55	B	B	B	
247.81	C	F	B	I	322.60	B	B	B	
248.00	R	B	B		324.77	B	B	B	
249.18	B	B	B		324.95	B	B	B	
249.60	B	B	B		326.30	B	B	B	
250.10	B	B	B						
250.20	B	B	B						
250.28	B	B	B						
250.70	B	B	B						
250.77	B	B	B						
252.82	B	B	B						
253.03	B	B	B						
253.34	B	B	B						
253.89	B	B	B						
255.91	B	B	B						
256.14	B	B	B						
257.63	B	B	B						
259.10	B	B	B						
260.46	B	B	B						
262.53	B	B	B						
264.41	B	B	B						
264.68	B	B	B						
266.70	B	B	B						
268.13	B	B	B						
269.55	B	B	B						
270.80	B	B	B						
272.77	B	B	B						
274.10	B	B	B						
275.95	B	B	B						
276.60	B	B	B						
279.90	B	B	B						
281.96	B	B	B						
283.28	B	B	B						
285.76	B	B	B						
287.15	B	B	B						
288.70	B	B	B						
290.15	C	B	B	I					
291.10	C	B	B	I					
291.80	A	B	B	I					
293.02	R	B	B						
294.15	B	B	B						
295.33	B	B	B						
297.30	B	B	B						
297.70	B	B	B						

Fig. 6 (Continued).

cause drastic changes in sub-surface temperatures, removal of the permafrost and the creation of hydraulic pressures that could substantially remove the connate waters in the underlying sediments. These facts should be clearly presented when geophysical or geochemical interpretations are offered (*e.g.* STUIVER *et al.,* 1976; WASHBURN, 1977; McGINNIS and OSBY, 1977; McGINNIS *et al.,* 1979).

2. Diatom Zonations

2.1. Biozone A (DVDP 11, 290.15 m–?)

This interval is part of the succession from 198 m–327.96 m which WEBB and WRENN (1976) and BRADY (1979) consider to be an *in situ* marine sequence. There is a real pattern of diatoms in silty units alternating with foraminifera in diamictites. This suggests cycles of thick ice cover and open water in the Taylor Valley fjord. The faunas and floras are also extensive. LING (in WASHBURN, 1977) suggests a very limited marine influence at 292 meters because of rare silicoflagellates and radiolaria but it must be noted that in bottom grab samples taken by BARRETT and BRADY in McMurdo Sound during the drilling of DVDP 15, 20 km east of Marble Point, no radiolaria were noted in 15 grab samples and the silicoflagellate content was extremely low. It is therefore not possible to use the frequency of these organisms alone to judge the presence of marine environments in McMurdo Sound.

Diatom preservation at 290 meters in DVDP 11 is excellent but the flora contains no small diatoms. This factor could be explained by the winnowing effects of surface currents in the fjord during the productive summer melt season. The flora is dominated by *Thalassiosira torokina* BRADY and *Actinocyclus ingens* RATTRAY. This interval was previously zoned as Early Pliocene by BRADY because no occurrence of *Thalassiosira torokina* BRADY could be found in the late Miocene. An analysis of Islas Orcadas core PC 0775/2 by this author presents the first evidence that the range of this taxon extends into epoch 5 so that its known time range is now from epoch 5 to the 'b' event of the Gilbert (DSDP 266, PC 0775/2, El 34/19). The absence of Pliocene markers species *Nitzschia praeinterfrigidaria* McCOLLUM and *Thalassiosira oestrupi* (OSTENFELD) PROSHKINA-LAVRENKO and the presence of flat forms of *Actinocyclus ingens* RATTRAY which are common in the late Miocene (McCOLLUM, 1975) indicate that a late Miocene date can be validly proposed for this interval from diatom evidence. This date agrees with the date proposed by WEBB and WRENN (1976) from the analysis of benthic foraminifera.

2.2. Biozone B (DVDP 11, 194.80–240.20 m; DVDP 10, 137.16–183.27 m)
Zonule 2, DVDP 11, 194.80–208.62–? m; DVDP 10, 137.10–154.48–? m
Zonule 1, DVDP 11, ? m–239.74–240.20–? m; DVDP 10, ? m–183.27 m

This succession is characterised by the presence of *Thalassiosira oestrupi* (OSTENFELD) PROSHKINA-LAVRENKO and *Thalassiosira torokina* BRADY. No occurrence of

T. oestrupi has been recorded from the Miocene and its defined range is from the Miocene/Pliocene boundary to the Recent. *T. torokina* ranges from epoch 5 (perhaps lower) to the 'b' event of the Gilbert.

There is some ground for making a distinction within this Biozone. Well preserved specimens of *Nitzschia praeinterfrigidaria* McCollum and *Thalassiosira gracilis* (Karsten) Hustedt occur within zonule 2. Many *Nitzschia* fragments occur in zonule 1 but none have been positively identified as *praeinterfrigidaria*. Likewise, no positive specimens of *T. gracilis* have been identified in the same interval.

A clear date can be proposed for zonule 2 using the uppermost time range of *T. torokina* and the earliest occurrence of *N. praeinterfrigidaria*. This date lies between the 'b' event of the Gilbert and includes the 'c' event of the Gilbert. Using the revised time scale of LaBreque *et al.* (1977) this suggests a date between 3.97 and 4.59 m.y. It is possible that the lowermost intervals of Biozone B lie between 4.59 m.y. and the Miocene/Pliocene boundary using the defined range of *T. oestrupi* and presuming that none of the *Nitzschia* fragments are *N. praeinterfrigidaria*. This is by no means clear and the problem is unresolved.

Within this Biozone other important events occur. The Zone 1 foraminifera fauna of Webb and Wrenn is present within Biozone B in DVDP 11 (199.30–240.20 m) and in the lowermost section of Biozone B in DVDP 10 (156.47–185.47 m). However, within Biozone B in DVDP 10, there is an abrupt change from Webb and Wrenn's Zone 1 to Zone 2, mid-Pliocene fauna at 154.80–90 meters. Webb and Wrenn also zoned the upper section of Biozone B as Pleistocene but, in fact, their Pleistocene Zone 3 fauna does not occur below 125.96 meters. A test of their mid-Pliocene marker species *Trochoelphidiella onyxi* Webb occurs at 142.40 meters but was interpreted as reworked.

Another important factor in DVDP 10 (149.22–150.18 m) is the presence of non marine diatoms together with the well preserved marine diatom flora. This raises the possibility that the upper section of Biozone B (137.10–150.18 m) may be a reworked interval but we cannot presume that the non-marine diatom flora of Antarctic lakes and ice shelf pools is restricted to the Pleistocene. The state of diatom preservation and the range of marine taxa are not significantly different from lower sections of Biozone B. The diatom evidence would be consistent with renewed uplift and climatic changes in the early Pliocene associated with changes in the benthic foraminiferal faunas in the Taylor Valley fjord and the establishment of the non-marine diatom flora in non-marine pools of the McMurdo Sound region. Problems associated with this critical evidence may be resolved by paleomagnetic evidence.

Brady (1977) previously zoned the interval between 137–154.20 m as Pleistocene because of the presence of *Nitzschia curta* (Van Huerck) Hasle and *Coscinodiscus lentiginosus* (Janisch) Hasle. The latter is represented by doubtful fragments and *N. curta* forms occur not only at 149.22 m but also at 179.87 m. These forms of

N. curta are similar to *Nitzschia* No. 14 SCHRADER (1976) recorded in the late Miocene (DSDP 278) but they fall within the description of *N. curta.* They do not provide sufficient evidence of a Pleistocene date. This author considers that all diatoms recovered from Biozone B are consistent with an Early Pliocene flora, but recognises that problems exist in the interpretation of the uppermost interval in Biozone B, DVDP 10 from 137–150.18 m.

2.3. *Biozone C_1 and Biozone C_2* (DVDP 11, 127.79?–194.80? m and DVDP 10, 24.86?–137.16? m)

These intervals cannot be considered as diatom zones in a strict sense. Both intervals contain marine diatom fragments and sponge spicules in lithologies where diamictites alternate with conglomerates, sandstones or mudstones. No identifiable diatom floras have been recovered and age designation cannot be based on diatom evidence. The only justification to link the two intervals together stems from similar lithologies.

2.4. *Biozone D* (DVDP 11, 89.76–101.90 m–?)

This interval is characterised by an abundant non-marine diatom flora between 89.76 and 101.90 meters and by the presence of broken (reworked) marine diatoms and sponge spicules. No identifiable marine diatoms are present and consequently no age designation is possible from diatom evidence. The richest non-marine flora so far observed from any DVDP succession is present at 101.90 m. Many diatoms are still attached to each other in their original colonial form and it is evident that the non-marine flora is *in situ* and represents a lacustrine stage in Taylor Valley's complex history. The main flora elements are: *Hantzschia amphioxys* GRUN, *Melosira* spp., *Navicula gibbula* CLEVE *var. peraustralis* W. and G. S. WEST, *Navicula murrayi* W. and G. S. WEST, *Navicula mutica* KUTZ *f. cohnii* (HILSE) GRUN, *Navicula muticopsis f. muticopsis* VAN HUERCK, *Nitzschia antarctica* W. and G. S. WEST, *Navicula seminulum* GRUN, *Pinnularia cymatopleura* W. and G. S. WEST. Throughout this succession the bedding is frequently inclined between 14° and 40°. In present day lake systems in Taylor and Wright Valleys the area of maximum algal mat and diatom productions observed by this author is in zones radiating outwards from small deltas where the input of small streams is a stimulus to algal production. Algal mats and their associated diatoms are easily buried and preserved in these small deltaic systems. This author tentatively links the non-marine succession in Biozone D with a lacustrine deltaic environment but the upper and lower limits of the Biozone are not clearly defined.

2.5. *Biozone E* (DVDP 11, 17.20–89.91 m)

This interval is only a biozone in so far as it contains rare broken marine diatom and sponge fragments. Not identifiable floras have been recovered and no dating is possible using diatom evidence.

2.6. *Biozone F* (DVDP 11, 0–17.20 m)

Broken marine diatoms and sponge spicules are common throughout this interval. Well preserved non-marine diatoms occur but are most common in laminated beds between 15.90 m and 16.42 m. The alternation of silty and sandy laminae in this interval is interpreted by this author as due to cyclic deposition in a lacustrine environment in which meltwater streams are reworking marine sediments in a freshwater lake system. The streams could come from the valley sides as well as from the Ross Ice Shelf blocking Taylor Valley (DENTON, 1968, 1970, 1974). In the latter case the streams could sub-glacial and surficial glacial in origin. It is difficult to interpret the non-marine intervals in the upper part of this Biozone which are not laminated, but the non-marine diatoms are perfectly preserved in sharp contrast to the broken marine material. Only one marine time-range diatom has been recovered from Biozone F (16.12 m–16.42 m *Coscinodiscus vulnificus* GOMBOS—mid Pliocene); but diatom evidence indicates the marine material is reworked.

2.7. *Biozone G* (DVDP 10, 0–24.86 m)

This interval is interpreted as the most recent zone in the DVDP 10 and 11 successions. It contains well preserved marine and non-marine diatoms. Pleistocene diatoms occur such as *Nitzschia curta* (VAN HUERCK) HASLE, *Coscinodiscus lentiginosus* (JANISCH) HASLE, and *Nitzschia angulata* (O'MEARA) HASLE. Diatom evidence would suggest the succession represents marine conditions in an area receiving freshwater input from Wales stream; Shells are also present. The only argument against a shallow marine environment is the absence of benthic marine diatoms which are common in the shallow waters of the McMurdo Sound region. It could be that the freshwater input from Wales stream prevented the formation of a typical benthic marine flora and that only planktonic marine diatoms carried by surface waters, together with shells that can adapt to a brackish environment, have been deposited. The Pleistocene date for this Biozone is also well substantiated by C_{14} dating of shells by STUIVER *et al.* (1976).

3. Conclusion

The revised diatom zonation of this paper suggests the following conclusions:

1. WEBB and WRENN's Zone 1 foraminifera fauna existed in the Late Miocene and early Pliocene.

2. WEBB and WRENN's dating of their mid-Pliocene Zone 2 fauna can be slightly revised. The suggested date was derived from the Scallop Hill fauna and from incomplete DSDP intervals but these sections could not define the fauna's upper and lower time limits. It seems clear that the Zone 1–Zone 2 transition occurred during the Early Pliocene and that this was a period of dramatic change in the region.

3. The interval between 125 and 154 meters in DVDP 10 previously zoned as Pleistocene has not been clearly explained. Zone 3 foraminifera faunas do not occur below 125 m and the previous extension of the Pleistocene by WEBB and WRENN (1979) and BRADY (1979) is not warranted. Diatom evidence suggests an early Pliocene date below 137 meters.

4. Diatom evidence cannot define the lower time limit of WEBB and WRENN's Zone 3 foraminifera fauna. Pleistocene diatoms occur with this fauna in the uppermost succession in DVDP 10 (0–24.86 m) but they provide no evidence for dating the fauna's earliest appearance. It may well have ranged into the late Pliocene and have remained unchanged as a benthic fauna during the late Pliocene and Pleistocene glaciations. More research is necessary to resolve this problem.

5. BRADY's revised date for Biozone B lies between 3.97 m.y. and the Miocene/Pliocene boundary. The interval DVDP 11, 197.80–208.62 m and probably DVDP 10, 137.16–154.48 m lies between 3.97 and 4.59 m.y.

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