THE MIOCENE-PLEISTOCENE STRATIGRAPHY OF EASTERN TAYLOR VALLEY—AN INTERPRETATION OF DVDP CORES 10 AND 11

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***Abstract*:** The 185 and 328 m cores recovered from DVDP 10 and 11 respectively in eastern Taylor Valley reflect the Miocene to Pleistocene tectonic and glacial history of the uplifted former fjord. At both drilling sites a Pleistocene regressive glacio-marine sequence disconformably overlies early Pliocene marine tillites, which in turn at DVDP 11 overlie late Miocene marine tillites.

The 139 m of Miocene and Pliocene strata in DVDP 11 indicate both decreasing bathymetry and increasing ice cover in progressively younger horizons. The overlying regressive Pleistocene strata in DVDP 11 exceed 188 m, and in DVDP 10 137 m. The basal disconformity indicates major uplift, with grounding of ice in DVDP 10 and sublittoral reworking in DVDP 11. The Pleistocene marine tillites pass irregularly via younger strandline strata up to glaciofluvial sandstones.

Intraformational detritus is abundant throughout much of the Pleistocene sequence and indicates periods of erosion contemporaneous with sedimentation. Similarly some of the Pliocene and Miocene tillites contain fragments of older tillites. Evidence of resedimentation occurs in DVDP 10.

The petrography of the cores shows their derivation to have been largely from the early Palaeozoic basement complex of southern Victoria Land, and to a much less extent from the Jurassic Ferrar Dolerites. There is evidence to suggest the Pleistocene strata were deposited from ice extending eastwards up the valley, in contrast to the Pliocene and Miocene tillites which were derived from a western ice source flowing down the valley. Basaltic volcanic detritus is present throughout, but is abundant only in the youngest horizons.

1. Introduction

The Taylor Valley extends from the Polar Plateau eastwards down through the southern Victoria Land coastal mountain ranges for a distance of 100 km to McMurdo Sound. Sites 10, 11 and 12 of the Dry Valley Drilling Project are all located within the deglaciated eastern end of Taylor Valley. Site 10 is at the valley mouth on the coast, at an altitude of 2.8 m and approximately 50 m from the edge of the sea ice at New Harbor. DVDP drilling sites 8 and 9 (Chapman-Smith and Luckman, 1974) occupied this same location. Site 11 is approximately 3 km inland, situated on undulating valley floor moraines at an altitude of 80.2 m, near the terminus of the Commonwealth Glacier. Site 12 (CHAPMAN-SMITH, 1975) is located 75 m above sea level, 15 km further inland from DVDP 11. This paper is confined to a discussion of the core obtained from DVDP 10 and 11.

The rocks of both the Kukri Hills and the Asgard Range, bordering the Taylor Valley, consist of late Precambrian or early Palaeozoic Skelton Group metamorphics, and plutons and dike swarms of the lower Paleozoic Admiralty Intrusives. Further inland this crystalline basement complex (LOPATIN, 1972) is overlain nonconformably by cratonic sediments of the Devonian or older, to Jurassic Beacon Supergroup which is intruded by Jurassic Ferrar Dolerite sheets and sills (HASKELL *et al.,* 1965). The floor of the Taylor Valley is mantled by a hummocky surface of Cenozoic moraine diversified by several frozen glacial lakes and scattered basaltic cinder cones (PÉWÉ, 1960; MCCRAW, 1962, 1967).

2. Stratigraphy

Both cores show the same irregular transition from variable pebble grade diamictites at the base to sandstones and pebbly sandstones with subordinate conglomerates at the top. The two cores have been subdivided into 5 and 8 major

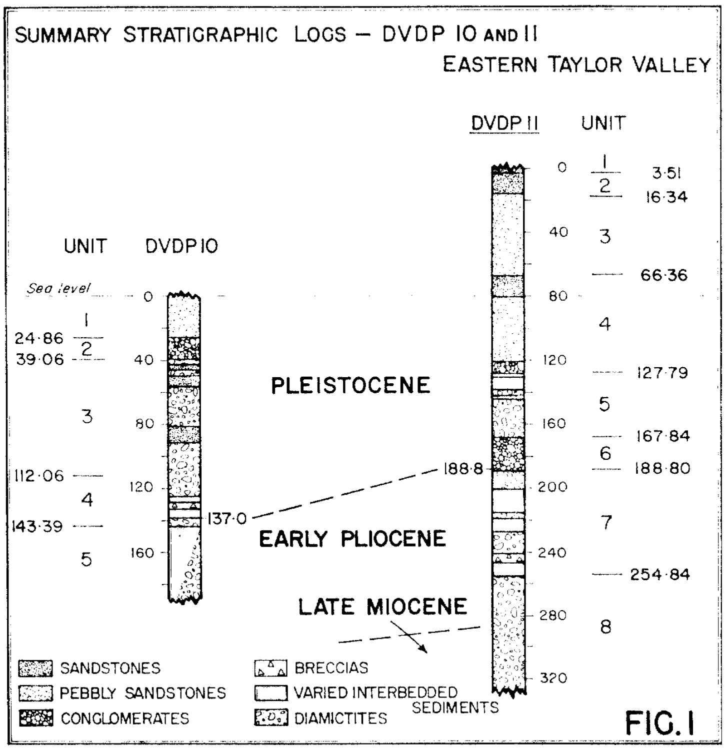

Fig. 1. Summary of the upper Cenozoic stratigraphy of DVDP 10 and DVDP 11, eastern Taylor Valley.

lithostratigraphic units respectively (Fig. 1). No formal stratigraphic status of any of these units is intended. For convenience of description and reference these units have been further subdivided in the detailed logs (McKelvey, 1975, 1979b), generally on the basis of dominant sediment type, into smaller intervals (for example units 6.2, 3.4, and so forth). Alternatively some of these smaller divisions refer to thin intervals characterized by rapid alternation of contrasting sediments, with no one sediment type being really dominant. Unit 5 of DVDP 10 is the one example encountered in either hole of a thick interval characterized by such rapid alternation of sediment types and the use of two hachure patterns in Fig. 1 is intended to portray the progressive downwards increase in abundance of diamictite or marine tillite over the other interbedded lithologies.

3. Biostratigraphy

In Fig. 1 the positions of the Pleistocene-Pliocene disconformity and the Pliocene-Miocene boundary are approximate, and are shown only to indicate the general stratigraphic span of the two cores. Detailed biostratigraphic data obtained from DVDP 10 and 11 is discussed at length elsewhere by Brady (1979a, b), and Webb and Wrenn (1979).

In DVDP 10 the Pleistocene-Pliocene disconformity is placed at 137 m for the following reasons.

(1) Brady (personal communication 2 May 1978) finds early Pliocene floras to extend from 185 m up to 137 m. None occur above 137 m. Webb and Wrenn (1979) in the overlying sequence report their oldest Pleistocene faunas at 125 m overlying a barren interval, and their youngest Pliocene faunas extend down from 154 m.

(2) Within unit 4.7 from 137 m down to 139 m stratal inclination of 30° has been noted (McKelvey, 1979b). This suggests deformation by grounded ice, associated with its erosion of the disconformity. In addition the somewhat different provenance (indicated by the incoming of abundant granitoid clasts) shown by unit 4.7, as compared to strata above 137 m, also suggests the possibility of a disconformity.

In DVDP 11 the oldest Pleistocene faunas of Webb and Wrenn occur in unit 6.2 at 173.4 m, and the youngest Pliocene faunas occur at 205.96 m in unit 7.8. In Fig. 1 the Pleistocene-Pliocene boundary has been somewhat arbitrarily placed at 188.8 m, at the base of unit 6.2 because the conglomerates of this unit appear to be tillites that have undergone winnowing contemporaneous with their deposition. As such they reflect a major modification of the depositional environment when compared with the older tillites of units 7 and 8. However subsequent reexamination of the core shows that unit 7.1 and 7.2 are somewhat similar lithologically to unit 6 and so the Pleistocene-Pliocene boundary, if it is to be placed at a horizon where a change in the depositional environment is indicated, could be lowered to approximately 195.2 m.

BRADY (personal communication 2 May 1978) has found late Miocene floras beneath 291 m, and for this reason the Miocene strata are so indicated in DVDP 11.

4. Dry Valley Drilling Project Site 10

Of the five units making up DVDP 10 (Fig. 1), sandstones, pebbly sandstones (both 5Y 3–5/2), and conglomerates make up the two youngest and overlie at 39 m a highly varied 104 m sequence (units 3 and 4) of diamictites and interbedded pebbly sandstones and sandstones, associated with minor pebble conglomerates, breccias and laminated sandy mudstones. The highly variable basal unit 5 is at least 35.8 m thick and consists largely of diamictites, sandstones and mudstone. The diamictites of unit 5 contrast markedly with those in the Pleistocene units, being thin bedded, frequently graded, and the pebbles and dispersed granule and sand grade detritus is often very sparse. The diamictites recovered at DVDP 10 are all marine tillites reflecting profuse rafting, whereas most of the sandstones and other coarser sediments are marginal marine (*i.e.* strand-line) deposits.

5. Summary Geologic Log of DVDP 10, New Harbor

Unit 1 (21.21 m thick): Pebbly very coarse sandstones with minor granule conglomerates passing irregularly downward to pebbly medium sandstones. Pebble conglomerates (average clast 4 mm) 15.5–16.6 m. Intraformational mudstone debris throughout unit. Stratification indistinct above 10 m, sharper in older horizons. Initial dip averages 15–20 degrees (maximum 30 degrees) above 12.5 m; below 16 m, 0–6 degrees. Pelecypod debris down to 24.1 m.

Unit 2 (14.20 m thick): Granule and pebble conglomerates. Average clast sizes range between 1–10 cm. Maximum clast noted exceeds 22 cm. Interbedded with minor medium-coarse sandstones above 31 m. Intraformational mudstone debris throughout (up to 5 percent). Overall, unit fined upwards; individual beds also fine upwards.

Unit 3 (73.00 m thick): Diamictites, up to 13 m thick, interbedded with coarse pebbly to fine sandstones and minor pebble conglomerates. Rare, laminated, sandy mudstones (less than 12 cm) occur below 50.1 m. Most diamictite matrices indistinctly laminated, poorly sorted, medium-fine sand. Clast component ranges up to 17 percent; average less than 10 percent. Average clast sizes range between 2–10 cm. Maximum clast noted exceeds 50 cm. Lithological contacts gradational to sharp, overall attitude horizontal. Local deformation indicated by strata, inclinations up to 35 percent. Reworked diamictite clasts noted.

Unit 4 (31.33 m thick): Lithologically diverse unit. Diamictites (clasts 3 to 30 percent) interbedded with minor pebble conglomerates, breccias (at 130 m), sandstones and sandy laminated mudstones. Latter strata, in sequences up to 0.8 m (average 2–10 cm) contain scattered (less than 1 percent) pebbles and granules. All gradations between pebbly sandstones and diamictites. Average clast size 1–2 cm. Maximum clast exceeds 32 cm. Stratification overall horizontal. Locally deformed with dips up to 30 degrees.

Unit 5 (at least 35.81 m thick): Olive gray massive and laminated sandy mudstones (diamictites) containing widely dispersed pebbles (frameworks average 0.5 percent), and fine-medium grade poorly sorted sandstone. Rapid lithological variation. Strata frequently graded. Minor thin pebble-conglomerates. Breccias at 170.7 m. Individual sequences relatively thin. Proportion of diamictites increases in older horizons. Scattered bioturbation.

6. Dry Valley Drilling Project Site 11

The 327.96 m core recovered from DVDP 11 is overall very similar to that from DVDP 10 in that it shows a similar irregular transition from pebble-grade diamictites at the base, to sandstones and pebbly sandstones (both 5Y 3–5/2) with subordinate conglomerates at the top. Again the diamictites are marine tillites and reflect both suspension current sedimentation and profuse glacial rafting. The sandstone, pebbly sandstones and conglomerates are in the main products of traction current sedimentation in marginal marine (units 3 and 4) and fluvioglacial (units 1 and 2) environments.

Of the eight lithostratigraphic units recognized (Fig. 1) the youngest four, which total over 127 m in thickness, consist of sandstones, pebbly sandstones and conglomerates. Units seven and eight, which total 139.2 m in thickness are predominantly diamictites and minor sandy mudstones, with some conglomerates present near the top of unit 7. The intervening units 5 and 6 total 61 m in thickness, and together show interstratification of all the above rock types.

7. Summary Geologic Log of DVDP 11, Commonwealth Glacier

Unit 1 (1.94 m thick): Laminated silty sandstones, mudstones and granule conglomerates.

Unit 2 (12.83 m thick): Lithologically uniform. Massive medium sandstones with intraformational mudstone debris. Stratification indistinct. Attitude 0–7 degrees.

Unit 3 (50.02 m thick): Lithologically uniform. Predominantly pebbly coarse sandstones. (Pebbles average 7 percent.) Minor sandstones and granule conglomerates. Sorting moderate to poor. Intraformational mudstone debris. Stratification indistinct. Attitude 0–35 degrees. Basaltic pebble-granule conglomerate 26.35–26.80 m.

Unit 4 (61.43 m thick): Lithologically variable. Medium sandstones overlying conglomerates passing irregularly (at approximately 81 m) through pebbly sandstones and subordinate conglomerates to (at approximately 120 m) pebble and cobble conglomerates. Pebbly sandstones predominate (pebbles average 5–7 percent). Occasional thin mudstones (5Y 3/2), with bioturbation and soft sediment deformation beneath 87.75 m. Overall stratification distinct. Thin lamination apparent beneath 89 m. Attitude of unit 0–20 degrees, maximum 45 degrees, due to deformation. Some cross-stratification.

Unit 5 (40.05 m thick): Lithologically variable, especially unit 5.2, 130.1–139.2 m. Diamictites (marine tillites) interbedded with sandy mudstones, pebble and granule grade conglomerates and minor sandstones. Diamictites highly variable. Clasts average 7–10 percent (maximum 25 percent), average clast size 2 cm. Maximum clast exceeds 1.04 m at 145.2 m. Matrices very poorly sorted, average fine to medium sands. Sandy mudstones show intraformational brecciation and soft sediment deformation. No bioturbation? Bedding contacts sharp to gradational. Attitude horizontal. Locally 5 to 45 degrees, latter due to deformation.

Unit 6 (20.96 m thick): Lithologically uniform. Poorly sorted granule-pebble conglomerates throughout. Considerable textural variation, some horizons nearly diamictites. Unit coarsens irregularly downwards. Average clast sizes range from 1–5 cm, maximum clast exceeds 60 cm. At 176 m clasts greater than 20 cm exceed 40 percent. Stratification indistinct, attitude horizontal. Locally dips of 10–15 degrees. Scattered bivalve(?) debris throughout.

Unit 7 (66.04 m thick): Lithologically variable. Diamictites (marine tillites) interbedded with laminated sandy-silty mudstones. Latter often contain pebbles (less than 1 percent). Minor lithologies include thin bedded (less than 1 m) granule-fine pebble conglomerates, sandstones and pebbly sandstones. Breccias near base (*ca.* 240 m). Diamictite clasts average 7–20 percent, average clast sizes range between 2.5–5 cm. Maximum clast size exceeds 85 cm (236–239 m). Overall bedding horizontal, little apparent deformation. Conglomerates dip at 20 degrees and 15 degrees at 246 and 251 m. Basaltic lapilli tuff, and finer ash scattered between 204.26 m–206.5 m. Gastropods (less than 2 mm) at 205.99 m. Bioturbation widespread.

Unit 8 (at least 73.12 m thick): Lithologically uniform. Diamictites (marine tillite). Clasts average 1–12 percent, average clast size 1.5 cm. Diamictite matrices indistinctly laminated, range from very poorly sorted fine sandstones to sandy mudstones. Minor lithologies include sandy mudstones with rare pebbles (less than

0.5 percent) and thin (less than 0.1 m) coarse sandstones and conglomerates. Attitude horizontal, rarely local soft sediment deformation. No apparent bioturbation.

8. Discussion

In another publication (McKelvey, 1979a) it has been shown that the cores of DVDP 10 and DVDP 11 constitute a regressive glacio-marine to glacio-fluvial sequence. Features of the sediments emphasised in that publication include:

1. The marked lateral facies variation with little correlation in detail between the two cores;
2. The considerable textural variation shown by the diamictites suggesting variation in the glacial regime;
3. The ubiquitous occurrence of intraformational material (including even a few diamictite clasts) indicating erosion and redeposition contemporaneous with sedimentation; and
4. The eastward or coastal provenance of the glacier ice.

Subsequent re-examination of the cores and a revision of the detailed logs (McKelvey, 1979b) has led to some revision and/or refinement of the above findings.

8.1. Provenance

As indicated previously (McKelvey, 1979a) derivation of both cores is from the southern Victoria Land basement complex of metamorphic rocks and associated low Paleozoic intrusive rocks, with smaller contributions from the Jurassic Ferrar Dolerites and the late Tertiary basalts (the latter in only very small quantities). No kenyte detritus was definitely identified. However clasts of two rock types widely exposed throughout the Taylor, Ferrar and Wright Valley systems are almost entirely absent from the cores. These are the widespread and lithologically striking Vida or Irizar Granite, and the sediments of the Beacon Supergroup. It is assumed that the latter disaggregate upon erosion and are now represented by much of the sand grade component in the cores. Although the Irizar Granite is widely exposed further west in Taylor Valley (Haskell *et al.*, 1965) clasts have been observed only rarely in DVDP 11, beneath 187 m (McKelvey, 1979a). (The author has not so far identified the Irizar Granite in DVDP 10 core.) The Irizar Granite is not known to outcrop east of DVDP 10 and 11. This suggests the Pleistocene sequence to have been deposited from ice moving westwards into Taylor Valley from McMurdo Sound, *i.e.* a McMurdo Glaciation event in the sense of Denton *et al.* (1970). On the other hand the presence of Irizar Granite clasts beneath 187 m in DVDP 11 suggests the Pliocene and Miocene sequence to have been derived (at least in part) from Polar Plateau derived ice flowing eastwards down Taylor Valley. Porter and Beget (1978) on other more detailed petrographic evidence reach a similar conclusion but place the boundary between the McMurdo Sound and the Taylor Valley derived diamictites somewhat lower in both cores. The fact that one Irizar Granite clast does occur at the probable disconformable base of the Pleistocene sequence (*i.e.* 187 m) suggests that clast to have been reworked from the underlying older strata.

8.2. Sedimentation

In DVDP 11 the major change in core lithology and hence a major modification of the sedimentation regime broadly coincides with the boundary between unit 4 and unit 5 at 127.7 m. Beneath this horizon the nonsorted diamictites and associated conglomerates of units 5 to 8 contrast markedly in aspect with the better sorted pebbly sandstones and sandstones of units 1 to 4 occurring above it. Clearly traction current sedimentation was of only minor importance beneath 127.7 m. A similar change is seen in DVDP 10 between units 2 and 3 at 39.06 m. The highly varied unit 4 of DVDP 11 can perhaps best be regarded as a transitional or passage unit. Within it above 89.9 m (the boundary between units 4.3 and 4.4) the pebbly sandstones tend to be either non-laminated or else only coarsely so and in general aspect many are similar to those of unit 3. Below 89.9 m relatively fine lamination is common and it is also widespread in older units of the core.

Unit 5, apart from unit 5.4, varies relatively little and so reflects uniform glacial sedimentation with abundant rafting. (However the intensity of this rafting does vary considerably.) The underlying conglomeratic unit 6 and the diamictite units 7.1 and 7.2 give every impression of glacial sedimentation similar to unit 5, but into an environment where current winnowing with the removal of fines was operative. The base of unit 6 at 188.8 m (or alternatively the base of unit 7.2 at 195.22 m) is considered to be a disconformity (see biostratigraphy). However, whether the presence of appreciable bottom currents reflects a decrease in bathymetry due to tectonic movement or alternatively the appearance of meltwater debouching onto the diamictite sedimentation surface is not clear. This author prefers the former alternative although confirmatory evidence is at present lacking.

Although the underlying units 7 and 8 are both indicative of glacial sedimentation ice cover during deposition of the former unit was not continuous. The presence of mudstones containing only scattered lonestones (*e.g.* units 7.7, 7.12, 7.16 etc.) alternating with diamictites clearly reflects this, as does also the presence of pelagic microfaunas (WEBB and WRENN, 1979). But perhaps the main feature of unit 7 is the rapid alternation of relatively thin glacial sequences diversified by rafting with essentially traction current sediments (Fig. 2).

This rapid alternation reflects reworking *in situ* of the original glacigene sediments, *i.e.* as with unit 6 the sedimentation surface has been periodically swept by currents that winnowed and redistributed sand and finer grades from the diamictites. Specific examples apart from the numerous sandstone and thin (lag) conglomerate horizons are: (1) the sandy mudstones containing rare pebbles of unit 7.6 passing up to the conglomerates of unit 7.5; (2) the basal ice cemented breccias of unit 7.18,

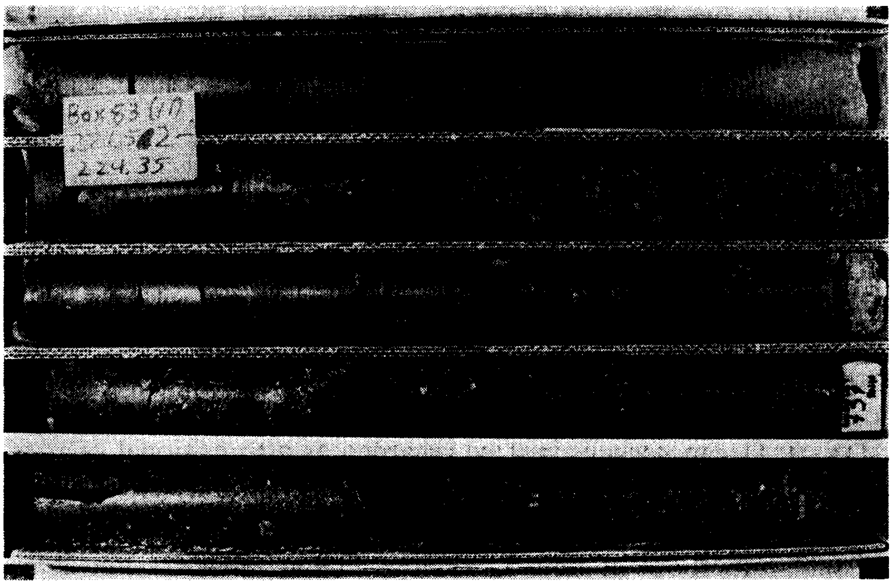

Fig. 2. Glacigene marine sediments, unit 7.16 DVDP 11. Sandy mudstones containing scattered rafted lonestones, interbedded with variable pebble conglomerates, breccias and sandstones. One lonestone (arrowed) exceeds 8 cm. Note rapid alternation of sediment types. Stratification horizontal. Field width approximately 60 cm.

from which the fines have been removed; and (3) the sandy mudstones with occasional pebbles of unit 7.16 which pass up into winnowed breccias. In the light of such reworking this relatively thick part of the DVDP 11 sequence must be regarded as a condensed one and the presence of such repeated current action over a considerable period of time does suggest decreased bathymetry with respect to that of unit 8. In DVDP 10 similar traction current features are present in units 3, 4 and 5, with in addition resedimentation being indicated by the several graded units beneath 150.8 m in unit 5.

Unit 8 on the other hand consists nearly entirely of diamictite with little evidence of any reworking *in situ* (Fig. 3). A quiet current free environment suggesting deeper bathymetry than all younger units is indicated. The variation in clast percentages reflects only differing degrees or else absence (*i.e.* unit 8.4) of ice cover, a view which is again supported by the presence of the planktonic fauna described by WEBB and WRENN.

8.3. Glacial regime

Finally the overall downward decrease in dispersed clast percentage shown by the Pliocene and Miocene diamictites of units 7 and 8 must be considered. For example unit 7.17 (226–240 m; McKELVEY, 1975, p. 55; 1979b) has a dispersed clast component that varies between 10–15 percent. (These clasts are also the largest encountered in DVDP 11, many exceeding 50 cm.) In unit 8.3 (261.6–302.8 m)

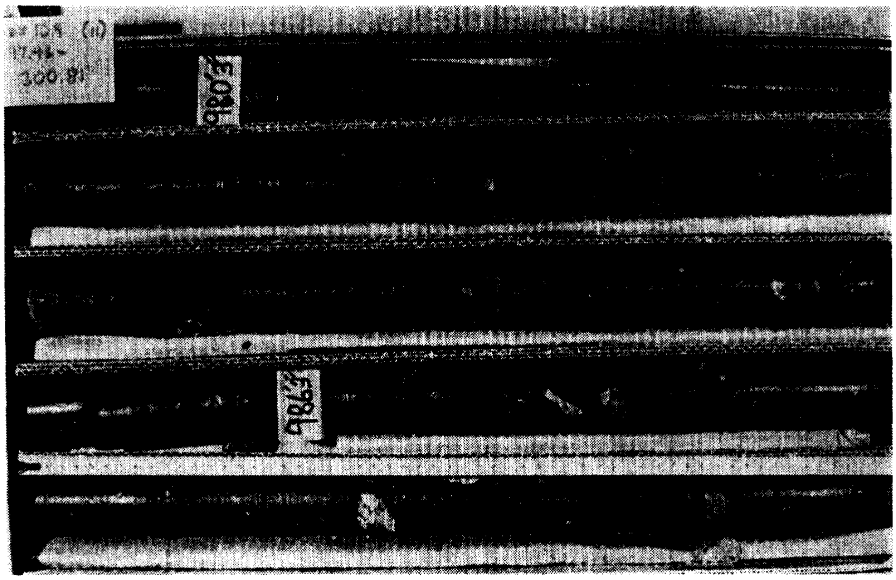

Fig. 3. Marine tillite, unit 8.3 DVDP 11. Relatively uniformly distributed rafted pebbles in a sandy mudstone matrix. Field width approximately 60 cm.

the average clast component generally ranges between 5 and 10 percecmnt. Still lower down the sequence in unit 8.5 (307–328 m) the clast component varies between only 5 to 7 percent generally and in many other intervals of unit 8 it is less than 1percent. There are two alternative interpretations. Either the ice rafting capacity increased in progressively younger Pliocene horizons thereby indicating more severe glaciation; or conversely the downwards decrease in clast percentages is an artifact of a younger wet-base glaciation giving way in older Miocene horizons to dry-base glaciation. In as far as the detailed lithologic logs indicate that the overall decrease in maximum rafted clast size in progressively older diamictite horizons is not paralleled by a decrease in average rafted clast size; then a diminished rafting capacity (*i.e.* thinner floating ice cover) in the older Pliocene and the Miocene is indicated. In other words a less rigorous glacial climate is reflected in the older Pliocene and the Miocene horizons of the DVDP 11 core.

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