

Letters to the Editor

The Nelson Boulder Bank

Comment

Johnston (2001) promotes the long held assumption that the Nelson Boulder Bank originated by a process of longshore drift. For any discussion of shoreline evolution, the beach profile and particle size data, measured in a systematic and statistical manner, are necessary to provide the basic underlying evidence upon which conclusions about the processes can be based. Johnston's (2001) paper contained no such data and, apart from several radiocarbon dates, it offered little new scientific evidence upon which to support these preconceived assumptions. This discussion, which follows largely from Dickinson & Woolfe (1997), will demonstrate that, although the Nelson Boulder Bank has been modified by the present wave environment, it owes its origin not to longshore drift from a point source but to *in situ* erosion of the underlying gravels, which were deposited by debris flows.

On first impression, the source of granodiorite at Mackay Bluff, angle of incident waves, and apparent decrease in clast size away from Mackay Bluff all combine to make longshore drift a simple explanation for the origin of the Nelson Boulder Bank (Johnston 2001). However, the Boulder Bank is only the largest of several similar features along the rocky coast of eastern Tasman Bay, and to understand it one has to look at the gravel beaches and barriers in Greville Harbour, Croisilles Harbour, and Cable Bay. At these other beaches, longshore drift is untenable because the gravels are in direct contact with their source and show no regularity in clast size distribution.

Collecting physical data on the processes that construct these gravel beaches is not a trivial problem. In fact, Dickinson & Woolfe (1997) published the first profile and clast-size data for the Nelson Boulder Bank. Their data show that the Boulder Bank as well as the other gravel beaches in eastern Tasman Bay have three distinct gravel units: (1) a gravel ridge ("top course" in Johnston 2001), (2) a boulder platform ("base course" in Johnston 2001), and (3) sub-platform gravels. Gravels on the ridge are actively transported in the present wave environment and consist of well-sorted pebbles (4–64 mm) and cobbles (64–256 mm). The boulder platform is exposed only at low tide and its surface is covered by poorly sorted pebbles, cobbles, and boulders (>256 mm). These gravels are immobile (Dickinson & Woolfe 1997; Johnston 2001) and occur as an armoured layer, which in most places is a single clast thick on the platform surface (Fig. 1). The sub-platform gravels lie below this armoured surface and are unconsolidated, poorly sorted, and massive with no apparent sedimentary structure. Apart from several points where measured data from Dickinson & Woolfe (1997) differ from the observations of Johnston (2001), the two papers generally agree that clasts on the gravel ridge are mobile while clasts on the boulder platform are immobile. In addition, both papers clearly demonstrate the poorly sorted nature of the sub-platform gravels.

Coastal bathymetry and sidescan sonar (unpubl. data) show

that the boulder platform of the Nelson Boulder Bank dips gently (1–2°) seaward and extends 300–500 m offshore, where it becomes buried by muds of Tasman Bay. Dredging reported by Johnston (2001) also confirms that platform gravels extend offshore some 500–1000 m at the southwestern end of the Boulder Bank. Large rounded boulders, concentrated as an armour on the surface of the platform (Fig. 1), were not found in the small, sub-platform pits of Dickinson & Woolfe (1997). However, rounded boulders up to 0.9 m in diameter were continuously dredged from the sub-platform gravels to a depth of 8.5 m below mean low tide when the artificial harbour entrance was deepened (D. Calwell, harbour engineer, pers. comm. 1992; Johnston 2001, fig. 9). The occurrence of these large boulders led Dickinson & Woolfe (1997) to assume that the armoured surface developed from the erosion of the sub-platform gravels.

We argue that the key to the origin of the gravel beaches in eastern Tasman Bay is understanding how the poorly sorted, sub-platform gravels were deposited and modified. There are several reasons why these gravels are crucial to the argument: First, the mobile gravel ridge lies on top of the boulder platform. This is clearly seen at Greville Harbour and in a 1943 photograph of the Boulder Bank (Dickinson & Woolfe 1997). Second, the armoured surface of the boulder platform is erosional. Both of these reasons indicate that the sub-platform gravels had to be present before the platform was eroded and before the ridge gravels were deposited.

Johnston's (2001) argument, if we interpret it correctly, is that the sub-platform gravels derive from the ridge gravels. Fundamental to his argument is that all of the gravels are initially transported away from Mackay Bluff by a process of longshore drift. Johnston (2001) suggests that large clasts (0.6–1.0 m) are rolled over the smaller clasts, which act as wheels to facilitate the movement of larger clasts along the ridge crest or transition zone. The problem with this is that over the length of the Boulder Bank, the sub-platform gravels are not only poorly sorted but also do not appear to decrease in size away from Mackay Bluff (Table 1). It is well understood that under falling sediment supply (increasing distance from a source) gravel barriers become increasingly size graded and sorted (Carter et al. 1987).

On appearance alone, the sub-platform gravels (Fig. 1) (Johnston 2001, fig. 9, 11) are distinctly different from the well-sorted, ridge gravels (Fig. 2) (Johnston 2001, fig. 5, 8) deposited by waves. Unfortunately, an accurate particle size distribution of the sub-platform gravels, which could quantify this difference, has yet to be accomplished. Large volumes (5–10 m³) must be size sorted, and this requires a digger and screening apparatus. However, estimates from area and weight percent counts (Table 1) show the sub-platform gravels contain particles ranging in size from –10 to 10 f, but because particle proportions cannot be extrapolated from this data neither average size nor sorting can be calculated.

Sedimentologically, the only processes known to deposit

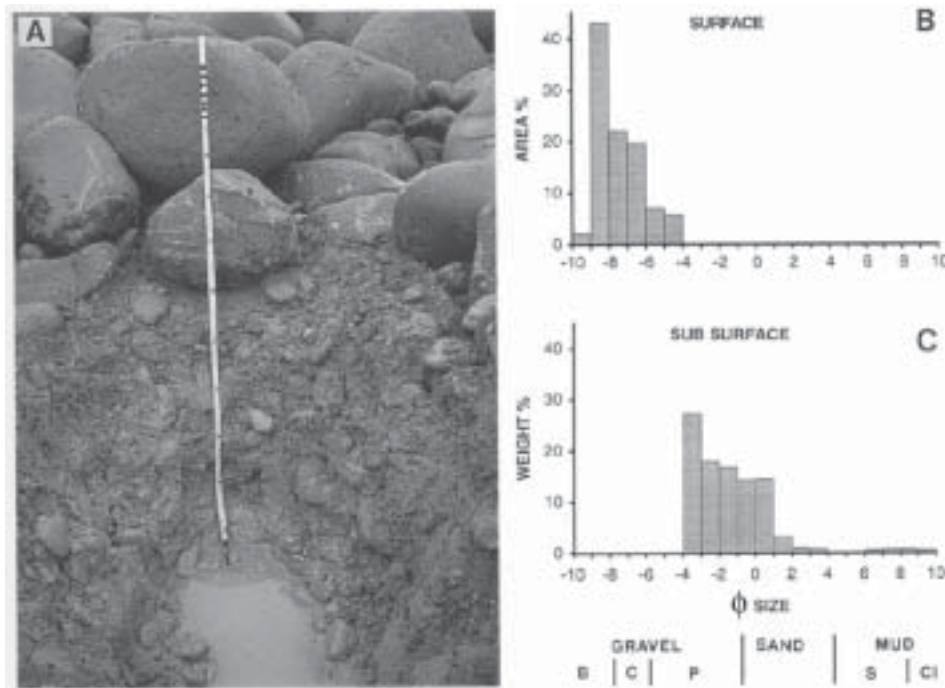


Fig. 1 A, Shallow 1 m deep pit dug in the boulder platform at Schnapper Point shows a boulder lag over poorly sorted and unconsolidated gravels. B, Mean phi size distribution of surface clasts determined by area percent at four locations along the Nelson Boulder Bank. C, Mean size distribution of subsurface clasts (1 m deep) determined by weight percent for $>-4\phi$ fraction at same four locations. Shown are phi divisions for the various size classes: B = boulder; C = cobble; P = pebble; S = silt; Cl = clay (from Dickinson & Woolfe 1997). Measurements by weight percent and area percent are statistically similar according to Adams (1977).

such poorly sorted gravels are related to glaciers and debris flows. The gravels are not glacial because (1) they consist of only a single rock type whereas a till would have a variety of rock types associated with its catchment area (the single rock type argument also excludes fluvial processes), and (2) there is no evidence of coastal glaciation in eastern Tasman Bay. On the other hand, one does not have to look far for an analogy to the debris flow processes. Cliffs and steep slopes shed material into the sea all along the coastline of eastern Tasman Bay where, in the present environment, poorly sorted and massive gravels are deposited. Although these debris flow deposits are reworked and rounded by waves, they would remain a poorly sorted deposit in the geologic record because of a constant supply of material from the retreating cliffs.

As described by Isla (1993), an armoured layer can form on the surface of a poorly sorted deposit under a lower energy wave regime than would be required for a well-sorted deposit. Once entrained, the larger clasts are preferentially deposited as flow velocity decreases forming an armoured layer of large

clasts which protects the underlying gravels from erosion. Clast size on the armoured layer is greater than can be transported by the highest energy waves hitting the coast (Isla 1993). In Tasman Bay, wave energy decreases away from Mackay Bluff along the Boulder Bank, and as a consequence of this, the size of the clasts also decreases on the armoured surface of the boulder platform (Table 1).

The mechanism described by Dickinson & Woolfe (1997) as an *in situ* transgressive barrier model for the origin of the Nelson Boulder Bank is difficult to visualise because it requires that steep cliffs once occupied Nelson Haven and have since eroded into a pile of gravels. In addition, there is little evidence for bedrock along the Nelson Boulder Bank. However, visualisation of this model is not a problem at Greville Harbour, Croisilles Harbour, and Cable Bay where the gravel beaches have boulder platforms that either rest on or are close to bedrock surfaces. For example, at Cable Bay 5 km north of the Boulder Bank, Hartstein & Dickinson (2001) found submerged outcrops of bedrock running parallel

Table 1 Particle sizes for Nelson Boulder Bank¹.

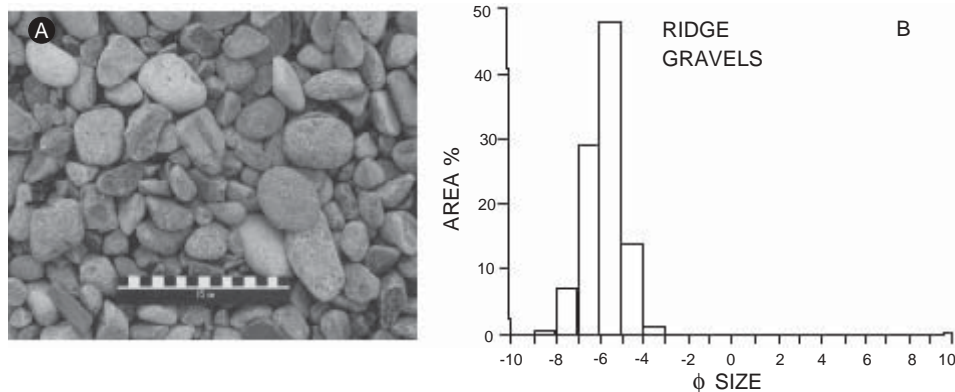
Site ²	Gravel type	Average size (ϕ)	Average size (mm)	Sorting (Folk)	Size (mm) Largest 30%
Schnapper Pt	Ridge	-5.73	53	0.65	88
Schnapper Pt	Platform	-7.02	130	1.30	326
Schnapper Pt	Sub-platform ³	-1.32	2.5	2.44	NA
Lighthouse	Ridge	-5.81	56	0.64	69
Lighthouse	Platform	-6.78	110	1.10	301
Lighthouse	Sub-platform ³	-1.75	3.4	2.27	NA

¹Data from Dickinson & Woolfe (1997).

²See Dickinson & Woolfe (1997) or Johnston (2001) for locations.

³Sieved fraction $>-4\phi$ (<16 mm).

Fig. 2 A, Ridge gravels at Schnapper Point. B, Mean ϕ distribution of ridge gravels at Schnapper Point and the lighthouse (see Dickinson & Woolfe 1997 or Johnston 2001 for locations).



to the mouth of the bay, indicating that a cliff face once extended across the bay. They suggested that gravels migrated shoreward from a bedrock source at the mouth of the bay. As sea level rose during the Holocene, this bedrock was buried by gravel beach deposits, which transgressed inland through roll-over processes, leaving a lag similar to that found at the Nelson Boulder Bank. We argue that the processes which formed Cable Bay also formed the Nelson Boulder Bank.

In the above argument, little has been mentioned about the wave energy which is limited in Tasman Bay and which is even more limited at lower than present sea levels. Tasman Bay is shallow (35 m average) and has a limited fetch. Hindcasting predicts a 4.7 m high wave could propagate from Tasman Bay; however, during Cyclone Yalli (March 1998), the most intense storm in nearly 40 years of wind records, the largest wave measured in the centre of Cable Bay at a water depth of c. 7 m was only 2.7 m high (Hartstein 1999). Maximum orbital velocity on the seabed beneath a 4.7 m wave cannot initiate transport of clasts >0.15 m in diameter (Hartstein 1999). By comparison, a swash run-up method predicts that a wave 4.7 m high can transport clasts no larger than 0.3 m diameter. Thirty percent of the clasts on the boulder platforms have average diameters greater than this, but some clasts may be as large as 1.0 m in diameter (Table 1). It is not scientifically sound to suggest (e.g., Johnston 2001) that large clasts (a 2 m long roller-shaped clast was once dredged from the cut) on the Boulder Bank were “rafted by smaller clasts” over a distance of 13 km from Mackay Bluff during exceptional storm and tsunami events.

We admit there are problems with the *in situ* transgressive barrier model for the Nelson Boulder Bank, but we feel it is a considerable advance on the longshore drift model. We again emphasise that the poorly sorted nature of the sub-platform gravels, limited wave energy of Tasman Bay, and bedrock associated with the other gravel beaches in Tasman Bay are strong arguments that longshore drift processes did not deposit the sub-platform gravels. Clearly, the sub-platform gravels need further study as they hold the key to the origin of the Boulder Bank. We know that all of the gravel features were shaped during Holocene sea-level rise, but we have little insight as to what Tasman Bay looked like for most of the past 100 000 yr when sea level averaged 50 m below the present level. It is important to understand that present sea level has only existed for 6500 yr and a similar level existed for only 5000 yr during the last interglacial. The problem of the origin of the Nelson Boulder Bank is far from solved, and in gathering additional quantifiable evidence we will also learn much about the geology of the Nelson area.

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Reply

Warren Dickinson and N. D. Hartstein reiterate the conclusion of Dickinson & Woolfe (1997) that, from sedimentological data, the Nelson Boulder Bank is the result of *in situ* erosion of cliffs of Cable Granodiorite that extended southwest from MacKay Bluff. This conclusion is at variance with almost all other researchers who have examined the Boulder Bank. However, Dickinson & Hartstein are incorrect to state that in my paper (Johnston 2001) I set out to promote “the long held assumption that the Boulder Bank originated by a process of longshore drift”. The objective of my paper, as stated at the end of a summation of previous explanations as to the bank’s origin (p. 81), was to review the origin of the bank utilising existing and new data. This was more than is implied in the dismissive comment by Dickinson & Hartstein that the paper “offered little new scientific evidence upon which to support ... preconceived assumptions”.

Before commenting in detail on the Dickinson & Hartstein letter, it is pertinent to clear up any misunderstanding with respect to the units comprising the Boulder Bank. The units that I recognised (Johnston 1976, 2001), following Bruce (1962), were “top course” and “base course”; the boulder platform (“pavement” in Johnston 1976) is a veneer developed on the latter. While not clearly defined, it appears that Dickinson & Woolfe used the terms “ridge gravels” and “platform gravels” for top course and base course, respectively. However, Dickinson & Hartstein use, in addition to “ridge gravel”, “platform” and “sub-platform”.

Dickinson & Hartstein, following Dickinson & Woolfe, conclude that the sedimentological data mean that the Boulder Bank can only be derived from till or debris flow deposits that more or less underlie the bank with only the top course being

the product of longshore drift. The presence of till they rightly reject and, therefore, by their reasoning, this only leaves an origin from debris flow deposits with secondary longshore drift. What is not adequately explained is where the debris deposits came from, and to put forward a hypothesis that a line of cliffs, composed of Cable Granodiorite, lay seaward of (Dickinson & Woolfe) or inshore of (Dickinson & Hartstein) the Boulder Bank is not supported by geological and geophysical data. These data, as stated in the 2001 paper, comprise:

- (1) The only known source of the clasts forming the Boulder Bank is the pluton of Cable Granodiorite, part of the Tasman Intrusives, exposed along c. 7 km of the coast from MacKay Bluff to Cable Bay and Pepin Island (Lauder 1964; Johnston 1981). While there are a number of plutons in the Tasman Intrusives, no two are petrologically the same.
- (2) The southern edge of the pluton is well defined at MacKay Bluff.
- (3) The pluton is truncated at MacKay Bluff by the Flaxmore Fault, which is exposed at the start of the Boulder Bank. The fault, which extends southeast onshore to the east of Nelson Haven, is a reverse one with a dextral component (Johnston 1979, 1981). Consequently, the offset portion of the pluton would be expected to lie to the northeast, and not to the southwest, of MacKay Bluff (i.e., fault movement would displace the western part of the pluton away from, not towards, the present position of the Boulder Bank).
- (4) The Flaxmore Fault forms a major tectonic boundary across which there has been considerable crustal shortening (Johnston et al. 1987). As a result, plutons of the Tasman Intrusives are not known northwest of the fault. Instead, both geological and geophysical evidence indicate that Rotoroa Complex rocks are to the northwest of the fault, not Tasman Intrusives.
- (5) The Flaxmore Fault is downthrown to the northwest (consistent with the other major faults in the Waimea-Flaxmore Fault System of which it is a part). The direction of vertical movement is demonstrated both by age of the rock units separated by the faults and the present-day topography (Rattenbury et al. 1998). Thus, the basement rocks are at depth northwest of the Flaxmore Fault.
- (6) Geophysical evidence indicates that the depth to basement is over >1 km (Anderson 1980; Lihou 1992). In considering the deposition of the Boulder Bank, as opposed to discussing the source of the granodiorite clasts, the following points, summarised from Johnston (2001), are relevant.

1. The top course is currently being deposited by longshore drift. While some of the material is being eroded from MacKay Bluff, much of it is being reworked from the bank itself with oblique ridges (each ridge marks a former end of the bank) being replaced by longitudinal ones. As a consequence, the bank is narrowing and this narrowing is progressively extending southwest away from MacKay Bluff.

2. In the process of narrowing, the bank is also migrating southeast over the estuarine deposits of Nelson Haven, as recognised during trenching and also in the deepening of The Cut. Thus, the crest of the bank does not form, in cross-section, the apex of an equilateral triangle. Instead, there is a wedge of granodiorite clasts dipping gently northwest from

the crest of the bank. It would appear that the unpublished sidescan data, referred to by Dickinson & Hartstein, confirms this. However, this is only correct for the Boulder Bank northeast of the lighthouse. Southeast of the lighthouse there is a submerged outer bank of boulders, commonly referred to as the outer shoal, that rises above any projected gently westward dipping surface defining the top of the gravel forming the Boulder Bank. The shipping channel from Nelson Haven into Tasman Bay is dredged to a depth of c. 10 m and clearly shows that the outer bank stands as a boulder bank over which is draped marine sands and silts. Exposed in the channel between the outer bank and the Boulder Bank, a distance of 800 m, are fine-grained marine sediments. As stated in Johnston (2001), the dredging results have been confirmed by video footage of the bed of the channel. Thus, the Dickinson & Hartstein statement that the outer bank forms part of this gently west dipping surface is not correct. The logical place for this submerged, and inferred older, bank to join the Boulder Bank is where the latter changes direction at the lighthouse (see Johnston 2001, fig 1).

The statement by Dickinson & Harstein that boulders up to 0.9 m were "continuously dredged from the sub-platform gravels to a depth of 8.5 m below mean low tide" in The Cut is misleading. When improvements to The Cut were initiated in 1952, the grab dredge *Tasman Bay* did initially raise a significant number of large boulders. However, the boulders were from the boulder platform veneer capping the base course and were difficult to remove both from their size and also their interlocking nature. That there was a considerable number of them was simply because, in both deepening and widening of The Cut, a large area of the veneer was removed. However, once through the veneer, dredging was easily achieved, in part because the boulders were not interlocking, but more importantly because they were very much smaller. As stated in the 2001 paper, this was first demonstrated when trial shafts were sunk in the bank prior to excavation of The Cut in 1906 to determine, amongst other things, whether there was solid rock beneath the bank. The video of the seabed in The Cut and the outer bank, and personal observation of the material being removed during dredging, conclusively confirmed these earlier observations. The largest boulders seen in the dredged samples were 0.7 and 0.5 m in the outer bank and The Cut, respectively. However, the vast majority of the boulders removed in 2000 were <0.4 m and the average size would be considerably less than this figure (see Johnston 2001, fig. 9).

3. On the Tasman Bay side of the Boulder Bank, the boulder platform is a lag deposit that has developed on the erosional part of the bank arising from its southeast migration. Not only Dickinson & Woolfe (1997) but also Johnston (1976 and later references), and perhaps others, came to the conclusion that the boulder platform developed from the erosion of the base course (sub-platform of Dickinson & Hartstein) gravel. The statement by Dickinson & Harstein that I considered the base course gravel to be derived from the present top course ridge gravel is not correct.

4. The base course gravel was deposited during rising sea level whereas the top course gravel resulted when sea level reached its present height. From my own observations, and the observations of others given as personal communications in Johnston (2001), it is clear that the large boulders can move, and rafting on smaller boulders along the bank is one observed way. However, I certainly do not hold to the view that

individual boulders can move the length of the bank in a single event. Once the large boulders, principally eroded from the base course, are incorporated into the veneer forming the boulder platform they are effectively locked in place.

5. Following the Last Glaciation, sea level would have risen sufficiently by c. 9000 yr BP for it to reach the toe of the southern end of MacKay Bluff. It is unrealistic to assume that since then the sea eroded from the hard *in situ* Cable Granodiorite all of the material in the Boulder Bank and transported it southwest. However, if the environment during the Last Glaciation is considered, then an obvious source of gravel becomes apparent. During the Last Glaciation, terrestrial deposits would have accumulated on the exposed seabed of Tasman Bay, at the toe of the fault-line scarp of the Flaxmore Fault, from MacKay Bluff to Cable Bay. The deposits, derived from the Cable Granodiorite, would have included fan, scree, and landslide deposits. Judging from the remnants of terrestrial deposits on MacKay Bluff and at Cable Bay, a large volume would have been available for reworking when the sea reoccupied Tasman Bay. These deposits would not have constituted a "point source" as referred to by Dickinson & Hartstein but an area some 7 km in length with a width of several hundred metres. The extent of fan deposits along the adjacent Waimea Fault (Johnston 1981) also gives some indication of the volume of sediments that must have accumulated at the toe of fault-line scarps during the Last Glaciation. Because of the erosion of the top course gravel as the bank migrates southeast, gravel deposition is still continuing at a greater rate than would occur if only MacKay Bluff was the source.

6. That Last Glaciation terrestrial deposits in Tasman Bay provided a ready source of sediment for reworking, and deposition in the Holocene is also shown at Rabbit Island and other islands at the head of the bay. The sediments comprise gravel in the south (i.e., oldest part of the islands) but are dominated by sand seaward. The gravel, with a large Motueka River component and virtually no Waimea River gravel, represents the postglacial marine erosion of deposits that largely accumulated off Motueka, including during the Last Glaciation (Johnston 1979, 1982). Incorporated into the gravel would be Moutere Gravel clasts, eroded from Last Glaciation talus deposits at the toe of the cliff between Rabbit Island and Motueka. Once the readily eroded gravel had been transported by longshore drift to Rabbit Island, sand became the dominant sediment. Although the clast size is much smaller than in the Boulder Bank, the volume of gravel forming Rabbit Island and other adjacent islands is large and, while no direct comparison has been made, it is probably greater than in the Boulder Bank.

7. Both the Boulder Bank and Rabbit Island demonstrate that longshore drift is very active in Tasman Bay. While it is stated by Dickinson & Woolfe that there is insufficient wave energy to shift the large Boulder Bank boulders, calculations (rather than observations) as to the maximum clast size that can be moved should be treated with caution as it tends to be underestimated. For example, clast size to protect the coastal highway northwest of Rabbit Island was calculated by the Ministry of Works after an assessment of wave energy. Despite this, the protection failed although the marble clasts used proved useful tracers for measuring longshore drift from Ruby Bay to Mapua over the next few years. Inshore fishers will also attest to the unusual waves that can be generated in

Tasman Bay which, although not of great height, can move the clasts seen on the bank. I do not know enough about this to comment further other than to say that reaching a conclusion based on modelling and sedimentological data that longshore drift, contrary to all the other evidence, cannot move the clasts reflects a very narrow appraisal of the origin of the Boulder Bank.

8. The process of extensive deposition of terrestrial gravel at MacKay Bluff during low sea level and erosion of the deposits during high sea level would have been repeated during the latter part of the Pleistocene. Consequently, the bank should be regarded as a late Quaternary feature. What is seen today is Holocene in age but it was probably built on an earlier bank or banks which have been subsequently modified. Any older banks would have been tied to MacKay Bluff and would have provided the foundation for the present bank, which is extending southwest (if The Cut had not been excavated) and migrating southeast.

9. Dickinson & Hartstein argue that poor sorting and an apparent lack of evidence for a decrease in clast size in the base course clasts away from MacKay Bluff, are inconsistent with longshore drift. In considering the clast size, the boulders do decrease in size towards the southwest, although in the base course this is largely masked by the veneer of large boulders comprising the platform. The explanation for the more or less constant size of the boulders in the platform is that anything smaller is likely to be removed by wave action and therefore is not incorporated into the lag deposit. As stated above, the clast size in the base course in The Cut and outer bank is highly variable but the average size is probably in the order of 0.2 m, with recognisable Cable Granodiorite particles as small as coarse sand.

10. The poor sorting and the relatively restricted reduction in clast size in the rising sea level part of the bank (base course), compared to the overlying static sea level part of the bank (top course), can be explained by taking into account the following:

- (a) The Last Glaciation terrestrial deposits, which contributed significantly to the bank, were very poorly sorted with a marked range of clast size and rounding.
- (b) The clasts did not originate at a single point at MacKay Bluff, but were derived from anywhere along a 7 km length of coastline. Consequently, those from the north of the coastline would therefore have travelled a greater distance resulting in better rounding etc.
- (c) There is also the reworking of material from the bank, and this is much more obvious in the top course and explains the generally smaller size and better sorting compared to the base course beneath the boulder lag layer.
- (d) During rising sea level, the clasts were carried into an environment in which fines were rapidly accumulating. The fines are transported by longshore drift from both the western and eastern coasts of Tasman Bay into the head of the bay where the two currents are neutralised, resulting in active sedimentation. The recently described fauna at c. 10 m depth in the centre of The Cut is consistent with this. The shells are in a fine-grained matrix that was deposited penecon-temporaneously with the clasts. Except perhaps in a minor way, the fine-grained matrix has not, as Dickinson & Woolfe argue, infiltrated into the bank later. In contrast, the present-day

sea level, top course gravel is carried along the bank on the upper part of the tidal cycle, with periodic “spillover” onto the estuarine muds of the haven.

In view of the above, it would be surprising if the base course gravel was well sorted.

11. Linking the origin of the Boulder Bank, as proposed by Dickinson & Hartstein, with the very small banks in the east of Tasman Bay is very tenuous. For instance, at Greville Harbour and Cable Bay, the banks are in narrow valleys with their ends anchored to rock. The former is in a drowned river valley (Johnston 1996) and the other in a corridor developed along a fault (Lauder 1962; Johnston 1981). In both instances *in situ* rock on the sides of the valleys are to be expected. The Boulder Bank has *in situ* rock at one end only.

12. Dickinson & Hartstein advocate that the gathering of additional evidence from the Boulder Bank will increase our knowledge of the Nelson area. It is worth noting that a considerable amount is already known about the Nelson area but has been selectively ignored in the letter and the Dickinson & Woolfe paper preceding it.

In conclusion, the Dickinson & Hartstein letter fails in its objective to “demonstrate that ... the ... Boulder Bank ... owes its origin not to longshore drift ... but to *in situ* erosion of the underlying gravels, which were deposited by debris flows”. A substantial body of data shows that Cable Granodiorite does not underlie the general area of the Boulder Bank. It is difficult to envisage, as Dickinson & Hartstein acknowledge, how a landform that gave rise to the postulated debris flows could have disappeared without trace. The bank is also the result of two distinct marine regimes: deposition and erosion during rising sea level to form the base course, and deposition and erosion during a static sea level to form the top course. As the bank grew in length and height, as well as migrating southeast into Nelson Haven, marine erosion on its outer side resulted in the boulder platform. With a lowering sea level there would have been presumably no marine erosion provided the boulder platform remained intact. It is likely that the present bank rests on a foundation of earlier banks, the oldest of which presumably determined the position of the present one. Dickinson & Woolfe and Dickinson & Hartstein are correct in that the Boulder Bank should not be viewed as a simple coastal feature that has arisen from the Holocene marine erosion of *in situ* Cable Granodiorite at MacKay Bluff. That the Boulder Bank is derived by Holocene longshore drift, from Last Glaciation terrestrial deposits at the toe of the bluff and, to a lesser extent, Holocene deposits and the *in situ* erosion of the granodiorite, is consistent with all that is known about this remarkable feature.

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