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## The "Wooden-Floor" Marker Bed—A New Method of Determining Historical Sedimentation Rates in Some New Zealand Estuaries

Terry M. Hume\* and Jeremy G. Gibb†

A valuable stratigraphic marker bed was found to underlie, at shallow depths, the intertidal sandy sediments of the lower Tairua estuary. It consists of saw dust, wood chip and sawn plank debris derived from the kauri log milling that took place on the estuary shores between 1864 and 1909. Dating the marker bed permits calculation of spatial variation in net sedimentation rates of 2 to 22 mm yr<sup>-1</sup>, averaging 6 mm yr<sup>-1</sup>, since about 1933. This equates with the deposition of about 10,000 ± 2,000 m<sup>3</sup> yr<sup>-1</sup> of sand in the lower estuary between 1933 and 1984. Similar stratigraphic markers derived from logging activities may be found in other New Zealand estuaries, and could be used for the determination of historical sedimentation rates.

*Keywords:* Modern sediments, stratigraphic marker bed, historical sedimentation rates, Tairua estuary.

### INTRODUCTION

The determination of rates of sedimentation in modern sediments has traditionally been difficult to establish, chiefly because of the absence of historical marker beds. We report here the identification of a widespread wood debris layer at shallow depths in intertidal sediments of the lower Tairua estuary. The layer represents waste products from the kauri log mills that operated on the estuary shores between 1864 and 1909. Close to its source the compacted wood debris resembles a wooden floor. Dating the layer has permitted us both to establish the historical sedimentation rates in this estuary and to identify what might be a new means of determining such rates elsewhere.

### GEOLOGY AND SEDIMENTOLOGY

The mouth of the Tairua River (37° 00'S, 175° 51'E) is situated in the eastern Coromandel Peninsula of the North Island. It has an elongate, 13.5 km long mesotidal estuary, separated from the sea by the 2.65 km long Pauanui sand spit to the south, and by the 1.2 km long, Ocean Beach tombolo to the north (Fig. 1). Radiocarbon dating of shells from ancient shorelines along Pauanui spit (Gibb and Aburn, 1986) and the Ocean Beach tombolo (Green, 1967) indicate that these Holocene coastal landforms have formed since the postglacial marine transgression culminated at the present sea-level in New Zealand (6,500 ± 100 years B.P.) (Gibb, 1986).

The 280 km<sup>2</sup> catchment of Tairua estuary, in the steep and rugged Coromandel Range, rises to over 830 m in the headwaters. The catchment lithologies are predominantly weathered andesite, dacite and rhyolite of the Upper Cenozoic Coromandel Group (Schofield, 1967), capped by the late Quaternary tephra (Hogg and McCraw, 1983). The weathered rock and tephra are extremely susceptible to erosion and landslip once the vegetation cover is removed.

In the lower 1.5 km of the estuary involved in this study, extensive tidal sand flats are exposed on both sides of the shell-armoured bed of the Tairua River (Fig. 1). Analyses

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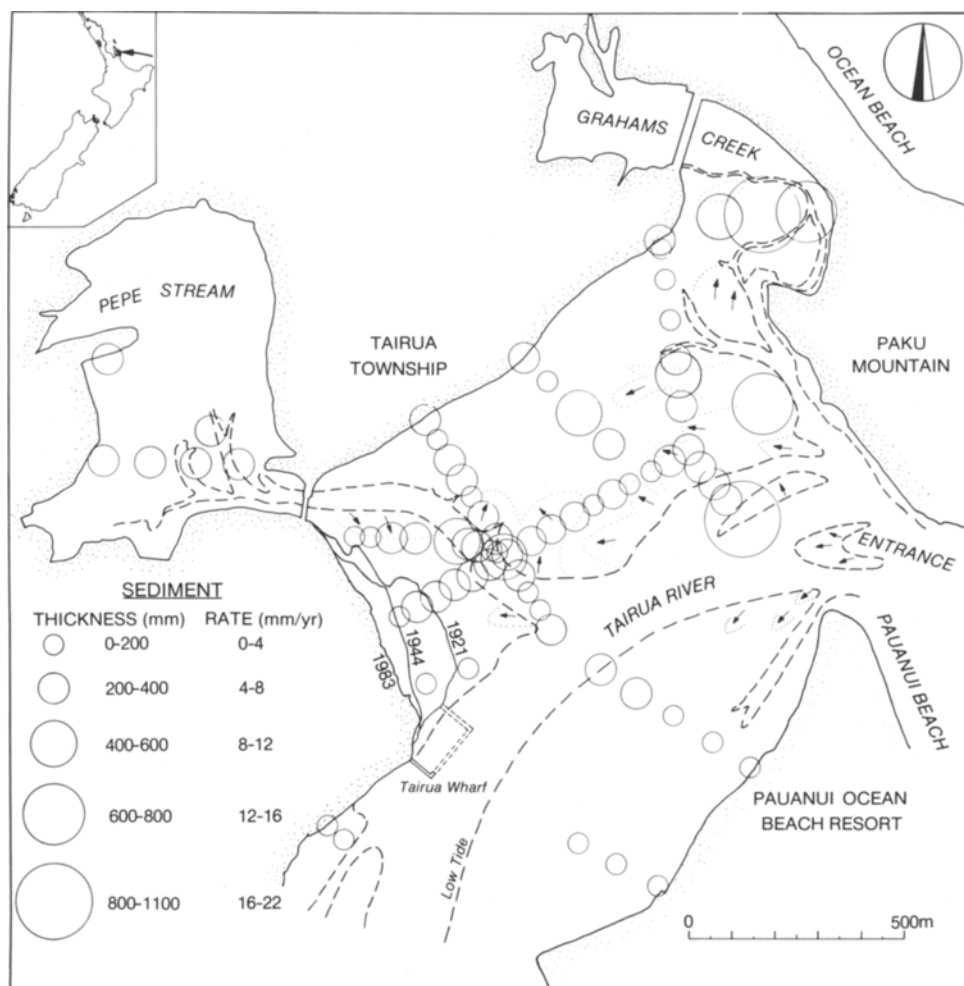


Fig. 1 — Map showing the lower reaches of Tairua estuary with approximate position of low tide channels. Lowest spring tide exposes additional tidal flat area. The approximate position of the 1864-1909 timber mill wharf (dashed line) and existing wharf are shown, along with the 1921, 1944 and 1983 seaward boundaries of the timber debris reclamation. Open circles indicate measurement sites and thicknesses of sediment above the kauri debris marker bed and estimated sedimentation rates, based on an inferred age of 1933 for the marker bed. Arrows indicate sediment transport directions derived from bedform mapping at low tide.

by Gibb (1983) show that the very well to well sorted medium to fine shelly tidal flat sands are supplied from the Tairua River, Pepe Stream, Grahams Creek, the ebb-tide delta beyond the entrance, and from the natural attrition of shells. The sands are composed predominantly (> 50%) of plagioclase feldspar and volcanic glass, with minor amounts (< 5%) of quartz, cristobalite, opaques, pyroxene and hornblende of volcanic origin, and moderate amounts (> 10%) of locally supplied shell fragments.

### FIELD OBSERVATIONS

Coastal erosion between Tairua Wharf and Pepe Stream has shown that the low-lying foreshore bank is composed of sawn kauri planks, each several metres in length, in a matrix of wood chips and sawdust (Figs 1 and 3). Similar kauri debris underlies the adjacent tidal flats, forming the so-called 'wooden floor' (Fig. 4). Old style glass bottles, sometimes filled with sawdust, were also uncovered. Further away from source, the wood

debris changes in character to a horizon of wood chips and sawdust that can be up to 300 mm thick some 150 m from source. Still further away, the horizon thins to a poorly defined layer of sawdust a few millimetres thick that is difficult to identify. Wood chips were generally scarce in sediments on the Pauanui side of the estuary. At most locations traces of sawdust may be found throughout the sediment column above the marker bed, probably as a result of continual erosion and redistribution of foreshore debris and perhaps biogenic reworking. All the wood debris is a light olive brown colour and fresh in appearance.

At all locations, except those near Pepe Stream (Fig. 1), the marker bed immediately overlies a compacted shell bed of disarticulated whole and fragmented estuarine intertidal molluscs, often several decimetres thick. In all the pits dug, the shell bed included abundant cockles (*Austrovenus stutchburyi*), and varying percentages of *Paphies* sp, *Macomona liliana*, *Myadora striata* and *Zediloma subrostrata*. Nowhere above the buried shell bed did we observe other shell beds, only sporadic whole and broken molluscs.

### ORIGIN AND AGE OF MARKER BED

Until the 1800s the rugged Coromandel Peninsula was heavily forested with native podocarp trees including dense stands of kauri. In 1820, European traders began the extraction of kauri timber, initially for ship spars and subsequently for general boat construction, buildings and for the gold mining industry (Sale, 1978). In 1864 the first sawmill operated by the Tairua Saw Mill Company was established at Tairua near the base of the present Tairua Wharf (Fig. 1) and milling of kauri trees in the Tairua catchment began in earnest. At the peak of the trade, a total of five sawmills operated nearby, but the supply of timber soon ran down and by 1909 the last mill, run by the Kauri Timber Company, had ceased operation. Although logging of kauri behind Tairua continued until 1924, all timber was shipped out of the area for milling (Father F. Bennett, *pers. comm.*, 1984). The combination of extensive deforestation, the use of driving



Fig. 2—Pre-1909 photograph looking east over the Tairua estuary tidal flats toward Pauanui sand spit from hills above the Tairua timber mills. The mill buildings are on mid right; stacks of sawn timbers, mid left, lie on the extensive reclamation formed from milled kauri timber and sawdust (Photograph supplied by Father F. Bennett, Tairua.).

dams to bring the timber downstream, followed by gum digging and land clearance for pastoral farming, resulted in severe catchment erosion (Sale, 1978).

Old photographs and plans show that during milling operations, offcuts of mill-sawn kauri planks and sawdust were carted by rail from the mills and spread over 4.2 ha of tidal flats adjacent to the sawmills as a means of waste disposal and, more importantly, to form a raised, flat, dry, timber storage and handling area not available in the hilly land behind the mills (Figs. 1 and 2). The dumping of wood debris ceased along with mill operations in 1909. Historical photographs indicate a thickness of about 1 m on the reclamation: hence, the volume of wood debris in the dump must have been approximately 60,000 m<sup>3</sup>. Today, only a small part of the milling reclamation is preserved, between Tairua Wharf and Pepe Stream.

The source of the extensive marker bed in the sediments of the lower Tairua estuary can only have been the once-extensive reclamation on the tidal flats fronting the mills, described on the 1921 Survey Office Plan 21278 of Tairua Settlement as "Land formed by slab deposits from saw mills".

A comparison of the seaward reclamation boundaries recorded on both S.O. 21278 (1921) and vertical sequential aerial photographs taken in 1944 and 1983 (Fig. 1) reveals net erosion rates up to 4.9 m yr<sup>-1</sup> for the period 1921-1944, which decrease markedly to net rates up to 1.23 m yr<sup>-1</sup> for the period 1944-1983 (Table 1). The erosion was very rapid at first, because when mill operations ceased in 1909 the slabwood, as well as being a constant source of fuel and construction material for local residents, was used by farmers for stakes and fence droppers (F. Bennett, *pers. comm.*, 1985). Then, in 1922 the Tairua Cooperative Dairy Factory was established in the vicinity of the old mill site, and the slab wood was railed from the reclamation, stockpiled for drying, and used to fire the dairy company boilers to supplement the regular manuka fuel (Mrs I. Prescott, *pers. comm.*, 1985). We believe that it was the dairy factory operations which led to the rapid break-up and distribution of the reclamation debris across the lower Tairua estuary, thereby forming the marker bed. After 1944, the rate of erosion of the reclamation decreased (Table 1) and lesser quantities of wood debris were supplied to the estuary. Hence there are only minor amounts present in the sediment column above the marker bed. Local residents report that the reclamation broke up in the mid 1920s, and thereafter was lower in elevation and more often overtopped by waves during storms (I. Prescott *pers. comm.*, 1985). From these observations, we infer that the kauri marker bed was laid down by about 1933 ± 11 years (that is between 1922 and 1944). Thus sedimentation seawards of the 1921 reclamation is inferred to date from 1933 ± 11 years.

### SEDIMENTATION PATTERNS

The sedimentation rates were investigated at the lowest spring tide in June 1983 by digging 74 pits across the tidal flats of the Tairua estuary down to the level of the kauri

Table 1—Shoreline erosion rates derived from measurements made at 1:5000 scale along ten equally spaced cross-sections normal to a 635 m long baseline established between the base of Tairua Wharf (cross-section 0) and Pepe Stream bridge (cross-section 10) (Fig. 1). Values in metres. (–) erosion (+) accretion.

Cross Section	0	1	2	3	4	5	6	7	8	9	10
1921-1944 (23 yr)	0	-17	-79	-112	-99	-90	-73	-24	-41	-10	0
Rate (m yr <sup>-1</sup> )	0	-0.7	-3.4	-4.9	-4.3	-3.9	-3.2	-1.0	-1.8	-0.4	0
1944-1983 (39 yr)	0	+13	-16	-29	-48	-48	-45	-41	-13	0	0
Rate (m yr <sup>-1</sup> )	0	+0.3	-0.4	-0.7	-1.2	-1.2	-1.2	-1.1	-0.3	0	0
Net Rate (m yr <sup>-1</sup> ) (1921-1983)	0	-0.1	-1.5	-2.3	-2.4	-2.2	-1.9	-1.1	-0.9	-0.2	0

debris marker bed (Fig. 1). To aid identification of the marker bed, mapping proceeded along transects away from the source so that gradual changes in the character of the bed could be traced.

Spatial variations in the thicknesses of the sediment above the marker bed are the basis for calculating the net sedimentation rates over the Tairua estuary shown in Figure 1.

Based on the inferred marker bed age of 1933, net sedimentation rates average about  $6 \text{ mm yr}^{-1}$  across the flats but increase markedly close to stream and nearshore sediment sources. For example, net rates are 10 and  $19 \text{ mm yr}^{-1}$  at the entrances to Pepe Stream and Grahams Creek respectively, where the sands are of predominantly fluvial origin (Gibb, 1983), and up to  $22 \text{ mm yr}^{-1}$  on flood-tide shoals near the harbour entrance where the sand is derived predominantly from the ebb-tide delta seaward of the entrance (Gibb 1983). On the southern tidal flats the net rates are relatively low, only about  $3 \text{ mm yr}^{-1}$ . Field observations of bedforms and studies of vertical sequential aerial photographs dating from 1944 support these data. High rates of sedimentation in the inlet area are indicated by the flood tide shoals migrating over the tidal flats in the directions indicated by the arrows in Fig. 1. In contrast, the shoals on the southern tidal flats adjacent to Pauanui appear to be relatively stable, because they have few bedforms and are densely vegetated in places with *Zostera*. From the data in Fig. 1, we estimate the total sediment load deposited above the kauri debris marker bed in the lower 1.5 km reach of Tairua estuary, to be about  $488,000 \text{ m}^3$  (about  $10,000 \pm 2,000 \text{ m}^3 \text{ yr}^{-1}$ ).

The sedimentation rates over most of the Tairua tidal flats, averaging  $6 \text{ mm yr}^{-1}$ , are higher than rates reported from other New Zealand estuaries. For the sandy sediments of Pauatahanui Inlet, Pickrill (1979) measured present-day rates of  $3 \text{ mm yr}^{-1}$ . For the muddy sediments of Lucas Creek, Upper Waitemata Harbour, Hume and McGlone (in press) used sediment input data to calculate rates of  $2\text{--}3 \text{ mm yr}^{-1}$ . The high rates of sedimentation for the Tairua estuary may be due in part to a relatively younger age estimate for the date of the marker bed. However, high sedimentation rates are not surprising in view of the large size and steep relief of the catchment and the vulnerability



Fig. 3—Photograph showing the eroding reclamation of kauri sawn planks in a matrix of sawdust and wood chips exposed above high water mark near Bay Vue Road, Tairua. Plank orientation suggests that the slabs have been systematically laid rather than dumped (rule is one metre). Photo taken on 14 May 1984.



Fig. 4—Photograph taken at low-tide showing medium sands overlying sawdust and sawn kauri planks beneath the surface of the tidal flats off Bay Vue Road, Tairua. The sawdust horizon lies at the base of the tape measure and the planks at the bottom of the shovel blade. Photo taken on 3 June 1983.

of the land to erosion, combined with the considerable erosion that reportedly (Sale, 1978) followed large scale land clearance accompanying kauri logging and gum digging.

Reafforestation with both native and exotic trees is now well advanced in the Tairua catchment, and this should lead to a decrease in catchment erosion rates and in present-day input of sediment to the estuary.

The widespread occurrence of a shell bed immediately beneath the kauri marker bed suggests that the shells accumulated during a period of relative stability when estuarine sedimentation rates were very low. The increase in sedimentation rates after logging began may well have made conditions less favourable for mollusc growth. Paul (1966) noted that the decrease in shellfish stocks in Ohiwa Harbour, 170 km to the southeast of Tairua, was due in part to siltation resulting from land clearance practices early this century.

## CONCLUSION

An extensive layer of sawdust and wood has been discovered at shallow depths in the modern sediments of Tairua estuary. The horizon originated from a waste dump built adjacent to kauri log mills that were situated on the estuary shores between 1864 and 1909. The wood debris layer, laid down about 1933, is a valuable marker for determining historical sedimentation rates. Sediment thickness above the marker indicates net rates of sedimentation of about  $6 \text{ mm yr}^{-1}$  across the Tairua tidal flats, increasing to  $10\text{--}19 \text{ mm yr}^{-1}$  adjacent to creek inputs, and up to  $22 \text{ mm yr}^{-1}$  at the estuary entrance.

There are other estuaries in New Zealand where extensive timber milling was carried out and where land has been reclaimed using the large quantities of wood debris from timber milling operations (*e.g.*, Whangaroa Harbour: Sale, 1978:64). Where these reclaimed areas have subsequently been eroded there may be similar marker beds that can be used for the determination of historical sedimentation rates.

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