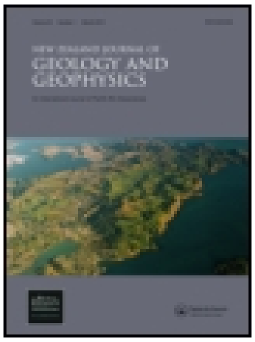

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New Zealand Journal of Geology and Geophysics

ISSN: 0028-8306 (Print) 1175-8791 (Online) Journal homepage: http://www.tandfonline.com/loi/tnzg20

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Anne C. Hinton & Maurice J. McSaveney

To cite this article: Anne C. Hinton & Maurice J. McSaveney (2007) Lithology and hardness of shore platforms and surficial large boulders at Turakirae Head, New Zealand, New Zealand Journal of Geology and Geophysics, 50:1, 27-32

To link to this article: http://dx.doi.org/10.1080/00288300709509817

New Zealand Journal of Geology & Geophysics, 2007, Vol. 50: 27–32
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Lithology and hardness of shore platforms and surficial large boulders at Turakirae Head, New Zealand

ANNE C. HINTON*
MAURICE J. McSAVENEY
GNS Science
PO Box 30368
Lower Hutt 5040, New Zealand
*Present address: Department of Geography, University of Cambridge, Downing Place, Cambridge, CB2 3EN, UK.

Abstract Turakirae Head, at the southern end of the North Island of New Zealand, has a sequence of up to five marine terrace and gravel barrier couplets, believed to be associated with coseismic uplift during the Holocene. Examination of the present shore platform and last raised marine terrace was made in order to provide an indication as to the origin of the material on them. A record of the lithology of the shore platform and boulder material was made and a type N Schmidt Hammer was used to assess the relative hardness of the rocks. Results indicate that the boulders are more resistant than the shore platform material, and they are not derived *in situ* since there are lithological differences with the underlying shore platforms. It is suggested that the large boulders are derived from mass movement processes on the hinterland.

Keywords Turakirae; New Zealand; shore platforms; boulders; marine terraces; Schmidt Hammer; lithology

INTRODUCTION

Turakirae Head lies at the southern end of the North Island of New Zealand, at approximately 41°27′S, 174°55′E. It is at the eastern entrance to Cook Strait and marks the western opening to Palliser Bay (Fig. 1).

Turakirae Head possesses one of the world's finest sequences of Holocene raised marine terraces (Fig. 2), believed to have been formed by coseismic uplift (e.g., Wellman 1967, 1969; Hull & McSaveney 1996; McSaveney et al. 2006) since sea levels reached approximately their present levels in New Zealand c. 6500 yr ago (Gibb 1986). The last raised terrace is understood to have been elevated beyond the reach of all but overwash from storm waves on 23 January 1855, in association with movement on the Wairarapa Fault (Grapes & Downes 1996). Each of the four raised marine terraces plus the modern shore consists of a shore platform, with varying quantities of boulders and finer material overlying it, backed by a gravel barrier (Fig. 3).

The bedrock of the area consists mostly of highly deformed, indurated, Mesozoic (Torlesse) greywacke sandstone (Stevens 1974; Begg & Mazengarb 1996; McSaveney 1997), with the addition of conglomerate near the Head itself, and some argillite/mudstone. In addition, there are some volcaniclastic sediments and spillites, exposed in the Rimutaka Range behind the raised marine terrace sequence just west of Turakirae Head, and also in the Kotumu debris fan in Palliser Bay (Fig. 2). The Rimutaka hills are part of an anticline associated with thrusting in an area where the Wairarapa reverse fault, which runs roughly parallel with the Rimutaka Range, does not provide surface rupture exposure (Beavan & Darby 2005).

Origin of the shore platform sediments

Previous studies at Turakirae Head have examined ages and amounts of uplift of the beach ridges (e.g., Wellman 1967, 1969; Moore 1987; Hull & McSaveney 1996; McSaveney et al. 2006), analysis of shell midden information (Moore & McFadgen 1978), and pollen spectra from peat development on the raised marine terraces (Bagnall 1975; Mildenhall & Moore 1983). However, examination of beach sediments has occurred only west of the Orongorongo River mouth, to the west of the headland at Turakirae (Matthews 1980), and north of the study area around Ocean Beach in Palliser Bay (Matthews 1983) (Fig. 1). The shore platforms vary in width and height around Turakirae Head.

Wellman (1967, p. 125) hypothesised that "the platforms are older than the beach ridges and represent the most resistant part of the greywacke which was eroded when the platform was cut". The aim of this study was to examine Wellman's (1967) hypothesis by determining shore platform lithologies and hardness, together with those of the boulders on the platform, in order to determine the actual lithologies and relative hardness of the shore platforms and boulders. This research also enabled a determination as to whether the boulders may have been derived *in situ*, as proposed by Wellman.

METHODOLOGY

Two sections of the Turakirae coast (TH1 and TH2) were chosen for detailed study, based on differences in aspect and exposure, and locations where the marine terrace sequence was well developed (as shown on Fig. 1 and 2). The intention here was to tie the work in with further studies on the flight of marine terraces. Measurements were made on both the present shore platform and the last raised marine terrace.

Variations in exposure of the shore platform, given the presence of overlying material, and in the numbers of boulders (defined as >256 mm in longest axis by Wentworth (1922), but here applied to rocks of at least 0.5 m in all axes), meant that the aim of sampling 25 boulders and 25 shore platform/marine terrace sites in each location was not achieved. The data were averaged, with the sample count numbers recorded. The boulders sampled did not move in a 3 yr period during the time of the study, despite waves of up to 13.1 m (A. Laing

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G06018; Online publication date 2 March 2007
Received 27 June 2006; accepted 7 February 2007

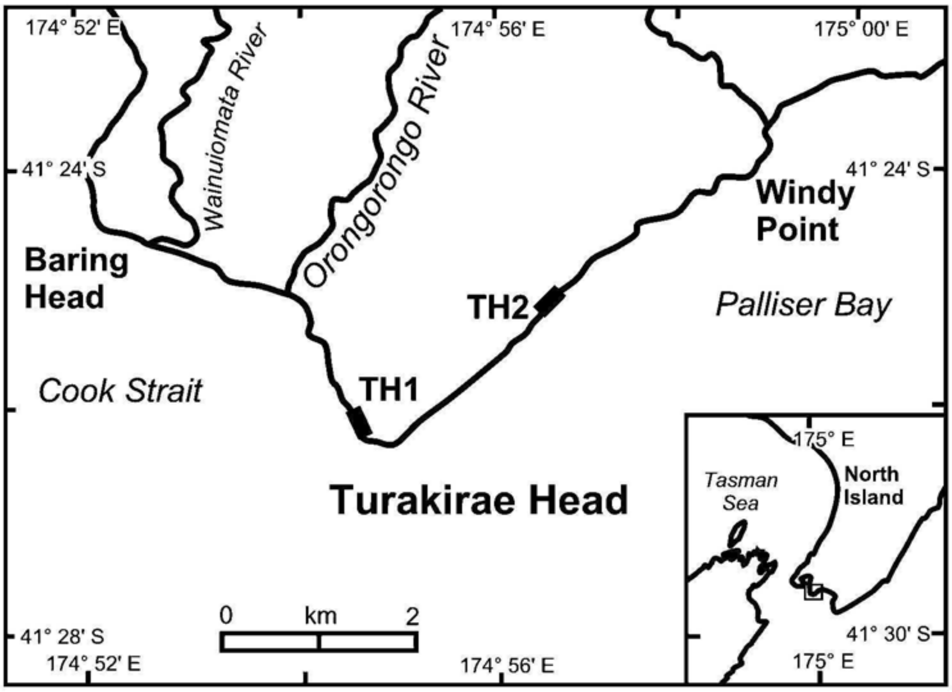

Fig. 1 Location of the field sites, TH1 and TH2, at Turakirae Head, New Zealand.

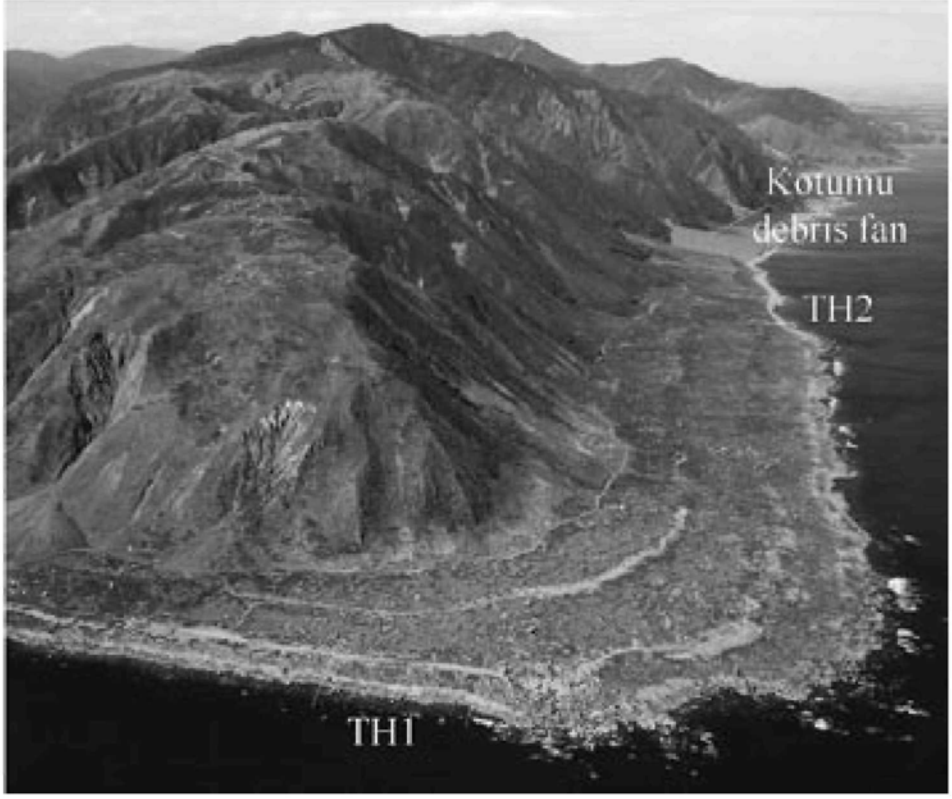

Fig. 2 Oblique aerial image of Turakirae Head, looking northeast. The location of the field sites, TH1 and TH2, and the Kotumu debris fan are shown. Each of the pale lines roughly parallel to the coast represents a gravel barrier behind a boulder-strewn shore platform. In this paper, only the present shore platform and last raised marine terrace are examined. The arcuate scars on the Rimutaka hills indicate locations of present or former mass movement. *(© Lloyd Homer, GNS Science Ltd.)*

pers. comm. 2002) being recorded in Cook Strait, just off Baring Head, 4 km west of Turakirae Head (Fig. 1).

Rock types were determined *in situ* by eye. Rock hardness was measured with a Schmidt Hammer (Schmidt 1951), as this can vary within a lithological unit. A type N Schmidt Hammer, which provides a proxy measure of the compressive strength of rocks, was used to obtain values for rock strength. According to the Swiss manufacturers, Proceq, the R (rebound) values recorded by the Schmidt Hammer may range from 10 to 80. "However, the dispersion of the rebound values achieved on rock is higher [than on the test anvil in the factory]. This has to do with the rather inhomogeneous surface of the rock (in comparison with steel surface). For harder rock, like granite, the dispersion may be less due to

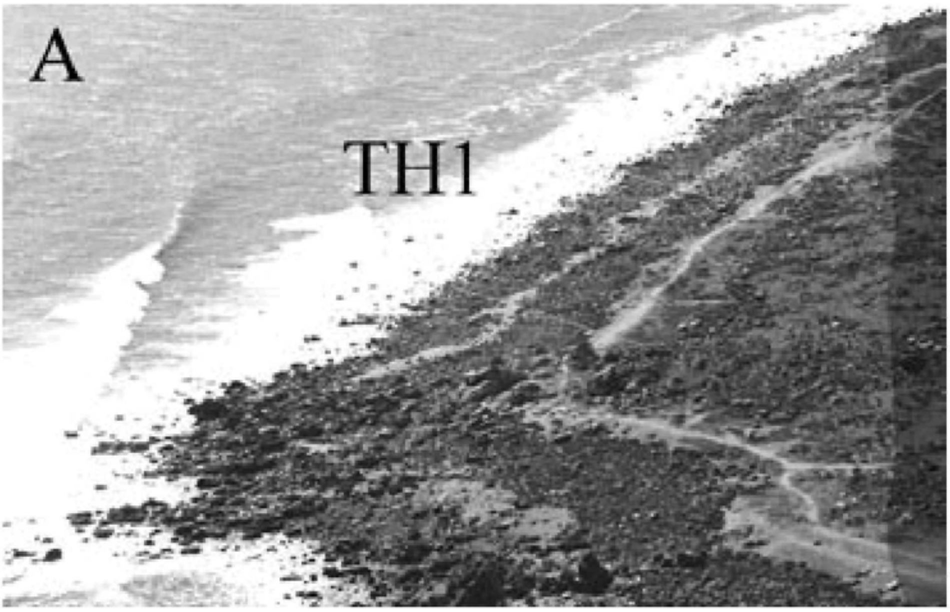

Fig. 3A Oblique aerial image of the TH1 field site, just east of headland, between the two white lines marked on the photo. The upper grey line roughly parallel to the coast is the raised gravel barrier, which has a track along it at TH1. The lower grey line roughly parallel to the coast is the present gravel barrier. The shore platform lies seaward of the modern gravel barrier and the raised marine terrace is between the two gravel barriers. The boulders can be clearly seen throughout the photo. *(©Lloyd Homer, GNS Science Ltd.)*

Fig. 3B TH2 boulder-strewn shore platform at mid-tide, looking northwards into Palliser Bay, This photo shows how very heavily the present shore platform at TH2 is strewn with boulders. *(Photo: M. J. McSaveney.)*

the smoother surface (in comparison with [the] surface of ‘normal’ concrete)” (K. Baumann pers. comm. 2006). A type N Schmidt Hammer was used throughout for the sake of consistency, rather than switching to a type L Schmidt Hammer for assessment of the compressive strength of the weaker lithological materials.

At each individual sample point, 20 readings were taken (following Trenhaile et al. 1998) and the mean value of the readings was then taken in order to estimate the hardness of the rock. Taking the mean of a number of readings allows for the different rebound R values obtained as a result of variations in surface roughness of the rock noted by White et al. (1998). The measurements on boulders were all taken horizontally on the seaward face, whereas the platform measurements were made vertically on to the outcrop. The manufacturer (Proceq) provided a conversion graph according to the angle of use of the Schmidt Hammer and this was used to standardise the values obtained.

The readings were taken on the weathered surface of the rock, but visibly weathered areas/lichen-covered rocks were avoided. All the intertidal readings were taken at, or soon after, low tide to ensure that the rock surface was as dry as possible. It was not possible to remove the weathered surface of the rock in order to take comparative fresh rock surface readings, which would have improved the accuracy of the measurements. This would have required removal of c. 0.5 m of very solid rock, in both the vertical and horizontal directions, in the case of the greywacke, and a considerably greater amount of material in the softer, more fractured mudstones. Tests for consistency in readings from the Schmidt Hammer were made by taking 20 measurements on a large uniform concrete block at frequent intervals during the fieldwork.

Fig. 3C Gravel barrier and boulder-strewn shore platform, looking southwards in Palliser Bay. This photo again shows how heavily boulder-strewn the present shore platform is. It also shows the present gravel barrier and marshy vegetated area behind it which covers the last raised marine terrace. *(Photo: M. J. McSaveney.)*

Fig. 3D Photo taken from the top of the modern gravel barrier, looking inland towards Barney's Whare (the accommodation hut) and showing the vegetated debris fan on which the hut is sited. The pale line of vegetation in the centre of the image runs along the crest of the last raised gravel barrier. Immediately in front of this is the last raised marine terrace with marshy vegetation and boulders. *(Photo: M. J. McSaveney.)*

The Schmidt Hammer was used to assess changes in the relative hardness of both the marine platform and boulders on the present intertidal shore platform and raised marine terrace (marsh) areas. No assessment was made of the variation in rock hardness from lower to higher levels on the platforms/terraces, as in the study by Thornton & Stephenson (2006).

RESULTS

Lithological assessment showed that the shore platform material, in both the present platform and raised marine terraces, is largely mudstone/argillite, whereas the boulders are almost uniformly greywacke sandstone.

The Schmidt Hammer measurements were averaged separately for the shore platform and boulder data in each of the present shore platform and the raised marine terrace areas. The resulting mean 'R' values are presented in Table 1. It is clear that the sample size for the TH2 present shore platform was inadequate as a basis from which to draw any conclusions concerning the data.

The results (Table 1) give consistent data at TH1 and TH2, in that: (1) the raised marine terrace and present shore platform surfaces at each site have similar rock strengths; (2) the boulders on the raised marine terrace at each field site have similar rock strengths; (3) the rock strengths measured for the boulders at each field site are different from the raised marine terrace rock strengths at the same site; and (4) the boulders on the present shore platform have similar rock strengths to the present platform

A comparison between the sites TH1 and TH2 (Table 1) shows that: (1) the four platform/terrace features all have

Table 1 Schmidt Hammer summary data for sites TH1 and TH2. The "R" values are the rebound registered by the Schmidt Hammer. The lower matrix presents Student's '*t*' test results, and examines whether the mean of sample A differs from the mean of sample B.

			TH1				TH2			
			Raised shore platform		Present shore platform		Raised shore platform		Present shore platform	
			Boulder	Platform	Boulder	Platform	Boulder	Platform	Boulder	Platform
Mean "R"			44.17	28.15	46.13	37.91	69	26.58	70.30	42.50
Sample size			23	20	24	21	13	12	20	4
Standard deviation			12.55	13.36	14.96	16.10	11.89	22.53	11.47	20.50
Standard error of the mean			2.6	3.0	3.1	3.5	3.3	6.5	2.6	10.3
TH1	Raised	boulder	0.00	2.86	0.35	1.02	**4.20**	1.93	**5.04**	0.13
	shore platform	platform		0.00	2.98	1.50	**6.50**	0.17	**7.59**	1.08
	Present	boulder			0.00	1.25	**3.60**	2.05	**4.30**	0.27
	shore platform	platform				0.00	**4.56**	1.13	**5.33**	0.33
TH2	Raised	boulder					0.00	**4.33**	0.22	1.96
	shore platform	platform						0.00	**4.82**	0.95
	Present	boulder							0.00	2.17
	shore platform	platform								0.00

Bold Student's *t* values indicate significant differences at 95% level; underlined numbers, significant differences at the 90% level; other numbers, no significant difference at the 90% level.

similar rock strengths; and (2) the boulders at site TH2 are significantly different from (harder than) the boulders at site TH1 (and consequently also the platforms at TH1).

There is a tendency for the raised terrace and boulders to be less hard than their modern counterparts, which may be due to weathering (Haslett & Curr 1998).

At site TH2 there was little of the present shore platform exposed owing to a cover of gravel and boulders. As such, only four Schmidt Hammer test sites were possible. Despite this limitation, the boulders on the present platform at TH2 differed from everything else except the boulders on the raised platform at TH2.

DISCUSSION

The lithological differences between the shore platform and boulder material suggest that the boulders have been transported to their present positions, whereas the material eroded from the mudstone/argillite platforms probably disintegrates too rapidly to form boulders at either TH1 or TH2. Shore platforms composed of greywacke sandstone are present also in other areas at Turakirae, together with boulders composed of material other than greywacke.

The greywacke varies in its composition around the coast at Turakirae—incorporating conglomeritic material at the Head itself and varying in the proportion of quartzose veins along the shore. Argillite/mudstone is more localised in its occurrence. The lithology of the Rimutaka hills behind the headland (Fig. 2) is equally variable and may also include volcaniclastic sediments. There are often lithological differences between the boulders and the platforms on which they sit (e.g., there are instances of greywacke boulders overlying argillite/mudstone platform). This supports the thesis that the hard boulders are derived by reworking of boulders that fell from the Rimutaka hills and were not eroded from the rock of the shore platform.

There is geomorphic evidence of past episodic failure (landslides) of the former sea cliff at the top of the Holocene marine cut terrace (Fig. 2), which would have been much more frequent when the cliff was being cut. Some of the variations in boulder frequency on the shore platform appear to be evidence of former mass movement (from rock falls to debris fans), lying as they do opposite arcuate scars on the face of the Rimutaka hills (Fig. 2). Active mass movement is ongoing at Turakirae Head, as is most clearly illustrated by the Kotumu debris fan in Palliser Bay (Fig. 2). In places, some gravel barriers have been emplaced on top of debris fans, whereas elsewhere, and more commonly, many gravel barriers have been overwhelmed by mass movement processes subsequent to their formation. The fact that these boulders have not moved in storms with 13.1 m waves recorded nearby tends to refute an offshore, or alongshore, source.

The Schmidt Hammer results reinforce the findings of the lithological examinations, as is to be expected from the differences in rock hardness presented by greywacke sandstone compared with the mudstone/argillite. These results illustrate that there is less difference in hardness between the boulder and platform locations sampled on the raised marine terrace than on its currently active counterpart. This is likely to be due to weathering. The manufacturer's information on accuracy, mentioned in the Methods section above, suggests that the proportional variation in rebound values is greater for lower readings, such as those obtained on the shore platform/raised marine terrace surfaces.

CONCLUSIONS

Wellman's (1967) assertion that the shore platforms are more resistant than the material lying on top of them is not borne out in the case of the boulders on the raised marine terraces at the sampling sites TH1 and TH2. The boulders on the raised marine terraces are more resistant than the rock on which they lie.

The lithological differences between the boulders and the underlying shore platforms suggest that the boulders were not derived *in situ*. Current processes operating in the coastal zone on the shore platform do not move these large boulders around. We suggest that mass movement processes are responsible for the presence of boulders of differing lithologies from the shore platforms.

ACKNOWLEDGMENTS

The award of a Royal Society of London Overseas Research Fellowship (to ACH), logistic support from the Institute of Geological and Nuclear Sciences Ltd (now GNS Science), permission to carry out scientific research at Turakirae Head from the Department of Conservation, and the loan of the Schmidt Hammer from Department of Earth Sciences, Victoria University of Wellington (VUW) to enable this work, together with Mike Hannah and David Kennedy's (VUW) assistance with this, are gratefully acknowledged. David Kennedy, Grant Dellow, and Mark Falvey (all of GNS) kindly assisted in the field. Dallas Mildenhall's help in providing copies of some of the papers cited is much appreciated. Alan Trenhaile, Mark Dickson, and an anonymous referee kindly provided helpful comments on an earlier draft of the manuscript.

REFERENCES

Bagnall RG 1975. Vegetation of the raised beaches at Cape Turakirae, New Zealand. New Zealand Journal of Botany 13: 367–424.

Beavan J, Darby D 2005. Fault slip in the 1855 Wairarapa earthquake based on new and reassessed vertical motion observations: did slip occur on the subduction interface? In: Townend J, Langridge R, Jones A ed. The 1855 Wairarapa Earthquake Symposium Proceedings. Wellington, Greater Wellington Regional Council. Pp. 31–41.

Begg JG, Mazengarb C 1996. Geology of the Wellington area, scale 1:50 000. Institute of Geological & Nuclear Sciences Geological Map Series 22.

Gibb JG 1986. A New Zealand eustatic sea level curve and its application to vertical tectonic movements. Royal Society of New Zealand Bulletin 24: 377–395.

Grapes R, Downes G 1996. The 1855 Wairarapa, New Zealand, earthquake—analysis of historical data. Bulletin of the New Zealand National Society for Earthquake Engineering 30: 271–369.

Haslett SK, Curr RHF 1998. Coastal rock platforms and Quaternary sea-levels in the Baie d'Audierne, Brittany, France. Zeitschrift für Geomorphologie 42: 507–515.

Hull AG, McSaveney MJ 1996. A 7000-year record of great earthquakes at Turakirae Head, Wellington, New Zealand. Institute of Geological & Nuclear Sciences Client Report 33493B.10 (for The Earthquake Commission, New Zealand).

McSaveney MJ 1997. Beach geology at Turakirae Head, Wellington. Geological Society of New Zealand Annual Conference, November 1997. Field trip guide: field trip 6.

McSaveney MJ, Graham IJ, Begg JG, Beu AG, Hull AG, Kim K, Zondervan A 2006. Late Holocene uplift of beach ridges at Turakirae Head, south Wellington coast, New Zealand. New Zealand Journal of Geology and Geophysics 49: 337–358.

Matthews ER 1980. Coastal sediment dynamics, Turakirae Head to Eastbourne, Wellington. NZOI Oceanographic Summary 17. 21 p.

Matthews ER 1983. Measurements of beach pebble attrition in Palliser Bay, southern North Island, New Zealand. Sedimentology 30: 787–799.

Mildenhall DC, Moore PR 1983. A late Holocene pollen sequence at Turakirae Head and climatic and vegetational changes in the Wellington area in the last 10,000 years. New Zealand Journal of Science 26: 447–459.

Moore PR 1987. Age of raised beach ridges at Turakirae Head, Wellington: a reassessment based on new radiocarbon dates. Journal of the Royal Society of New Zealand 17: 313–324.

Moore PR, McFadgen BG 1978. Excavation of a shell midden at Turakirae Head, near Wellington, and a date for the Haowhenua earthquake of Maori oral tradition. Journal of the Polynesian Society 87: 253–255.

Schmidt E 1951. A non-destructive concrete tester. Concrete 59: 87–95.

Stevens GR 1974. Rugged landscape: the geology of central New Zealand, including Wellington, Wairarapa, Manawatu and the Marlborough Sounds. London, A.H. & A.W. Reed. 286 p.

Thornton LE, Stephenson WJ 2006. Rock strength: a control of shore platform elevation. Journal of Coastal Research 22: 224–231.

Trenhaile AS, Pepper DA, Trenhaile RW, Dalimonte M 1998. Stacks and notches at Hopewell Rocks, New Brunswick, Canada. Earth Surface Processes and Landforms 23: 975–988.

Wellman HW 1967. Tilted marine beach ridges at Cape Turakirae, N.Z. Journal of Geosciences, Osaka City University 10: 123–129.

Wellman HW 1969. Tilted marine beach ridges at Cape Turakirae, N.Z. Tuatara 17: 82–93.

Wentworth CK 1922. A scale of grade and class terms for clastic sediments. Journal of Geology 30: 377–392.

White K, Bryant R, Drake N 1998. Techniques for measuring rock weathering: application to a dated fan segment sequence in southern Tunisia. Earth Surface Processes and Landforms 23: 1031–1043.