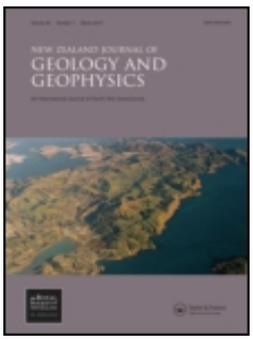

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QUATERNARY SURFACES AND SEDIMENTS AT WAIHI BEACH

By DAVID KEAR and B. C. WATERHOUSE

New Zealand Geological Survey, Department of Scientific and Industrial Research, Otahuhu

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Abstract

Levelling, accurate to 1 ft in height, of coastal terraces in the Waihi Beach area, has indicated past sea levels at 6–10 ft (Waihi Beach Surface, 50–100% preserved), 15–20 ft (Ocean View Surface, about 30% preserved); c.60–70 ft (Athenree Surface, about 15% preserved), and c.110–115 ft (unnamed, preserved solely as accordant ridges) above present sea level. Less accurate levelling by an aneroid barometer showed bench remnants at c.340–390 ft and c.550 ft. (Values indicated by "c." were calculated using the arbitrary assumption that the positions of present and past coastlines were identical). The correlation of levels with those previously established at South Kaipara, is sufficiently good to assume that the Waihi Beach area was relatively stable in at least the late Pleistocene, and to correlate the indicated sea levels with the Post-glacial (6–10 ft), Late Monastirian (15–20 ft), Main Monastirian (c. 60–70 ft), Tyrrhenian (c.110–115 ft), Sicilian (c.340–390 ft), and Calabrian (c. 550 ft) of Europe.

The formations are named after the surfaces below which they accumulated by aggradation, and consist of locally derived clays and sands, with angular pebbles near the hills, rounded pebbles in the river valleys, and dune sands at the coast.

INTRODUCTION

During investigation of the ilmenite-bearing blacksands at Waihi Beach with Messrs H. E. Fyfe and D. S. Nicholson (Nicholson *et al.*, 1958, p. 13), the writers noted that coastal terraces were well exposed there (*see* Bell and Fraser, 1912, p. 50; Morgan, 1924, p. 16). The area, of some 8 square miles, seemed potentially useful for studying the long-range terrace correlations that were initiated by Brothers (1954).

A preliminary investigation of the slopes and heights of the terraces, using an aneroid barometer, failed to provide consistent heights, partly owing to the inaccuracies of some published spot heights. It nevertheless confirmed several distinct terrace levels and led to the detailed levelling of selected traverses.

DETAILED LEVELLING

A base-map was prepared from air photographs, and detailed terrace correlation was attempted with a stereoscope. Three days were subsequently spent in the field, during which the correlations were checked or amended where necessary and seven selected traverses were run using a Cooke, Troughton and Simms S100 survey level and 14 ft staff. High-tide mark (the height of recent debris on the beach) was taken as datum, and was approximately 3 ft above the mean sea level during the time of the field work

(interpolation from *N.Z. Nautical Almanac* for 1958). All heights were eventually adjusted to mean-sea-level datum, and were finally rounded to the nearest foot. Some traverses were closed circuits, while others were closed to high-tide level at both ends. All such traverses (up to $2\frac{1}{4}$ miles) closed well within ± 1 ft. Traverses with floating ends were tied in by long shots (up to 1 mile) on to recognisable points on other traverses. These also closed to ± 1 ft; but in view of the length of shot, the accuracy might be illusory in part. The results are presented as a map (Figs. 2 and 2A) and sections (Fig. 3).

Spot heights were established on adjacent ridges with the use of the level's telescope, compass bearings, and air photographs. These are noted on Fig. 2 as "distant", and have been rounded to the nearest 5 ft.

NOMENCLATURE OF NEW ZEALAND DEPOSITS RESULTING FROM EUSTATIC RISES OF SEA LEVEL

Brothers's (1954, pp. 688–93) observation that terrace levels at South Kaipara (Fig. 1) were similar to those of Europe has led to the adoption of

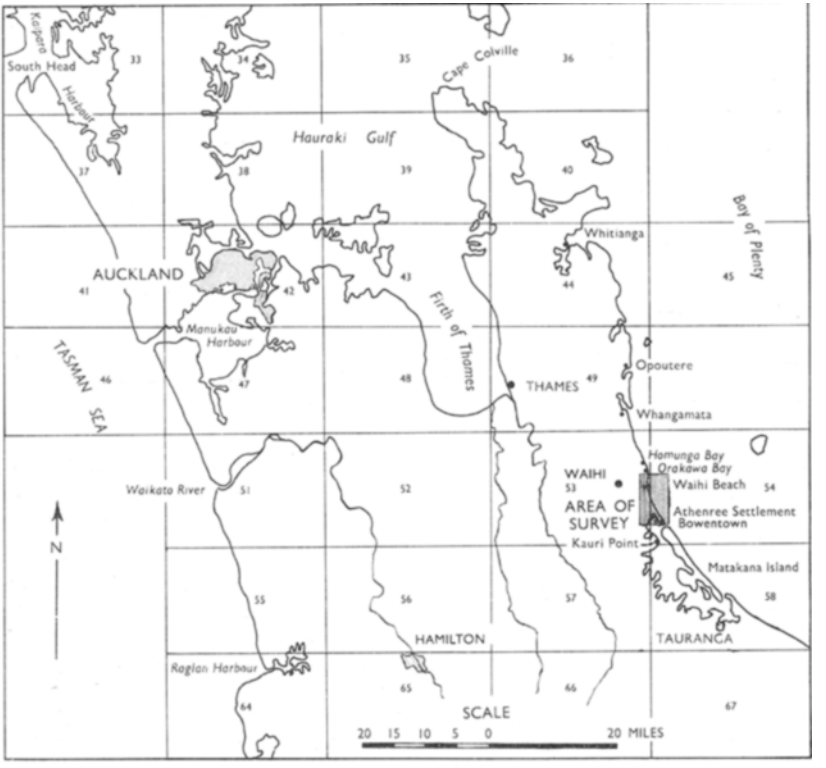


FIG. 1—Locality map.

the European sea-level terminology in the study of New Zealand's eustatic terrace levels. It has proved a useful working framework (e.g., Schofield, 1958; Harrington, 1958; Leamy, 1958; Kear, 1959), and little would be gained by introducing more than the bare minimum of additional terms, at least until firm correlation is established with a South Island glacial chronology (e.g., Gage and Suggate, 1958).

Brothers's (1954) highest level (550 ft) has been correlated by Suggate (1960) with the Calabrian of the European succession. Like the Sicilian (350 ft) level, its acceptance as a consequence of an undoubted sea level at that height should await further confirmatory evidence (e.g., the presence of marine beds at that height, or its recognition in other stable areas). The Milazzian (220–240 ft at South Kaipara) and Tyrrhenian (110–130 ft) need no further comment. Surfaces corresponding to the Main (45–75 ft) and Late (15–25 ft) Monastirian have been recognised elsewhere in New Zealand than at South Kaipara (e.g., at Waihi, *see below;* Porirua, Leamy, 1958; and coastal Otago, Ongley, 1939, pp. 65–6). At Waihi the two levels are broadly similar in preservation, and encourage the double use of the term "Monastirian" in New Zealand. Post-glacial sea-level fluctuations are being actively studied (e.g., Schofield, 1960), and a complex story may emerge. For the purposes of the present paper however, all possible post-glacial high sea levels are treated as one, for which the term "Post-glacial" will be used.

In any specific coastal area, such as Waihi, it is desirable that the detailed local geology should be described in terms of local formations and local terrace surfaces, rather than in terms of European eustatic sea levels. The use of the latter should be restricted to the important task of correlation between areas. In this way, the validity of the morphologic and lithologic descriptions will remain, even if the sea-level correlations are proved subsequently to be incorrect. Not only is it possible that a terrace surface might be correlated with the wrong interglacial sea level, but the differentiation of glacial from interglacial terraces is by no means finally solved throughout New Zealand. In the local nomenclature, new terms will be kept to a minimum if the one name is used for both the terrace surface and the formation that comprises the aggradational sediments below it, and if both are recognised as widely, in a geographic sense, as is prudently possible.

STRATIGRAPHY

The greatest problem in dating terraces is the doubt that often exists as to the precise height of the sea level that is represented. Waihi Beach proved to be no exception. No marine deposits were noted, and the surfaces are assumed to be the result of terrestrial aggradation as a consequence of the rise of sea level. Breaks of slope at the seaward ends of terraces had to be assumed to be the result of erosion, which also would have removed any beach deposits that might have been formed. An idealised diagram, illustrating the sequence of terrace formation is presented as Fig. 4.

Indicated sea level was determined somewhat differently for each particular surface, and for one (Athenree Surface), where no evidence beyond a measured seaward slope was obtained, an arbitrary method of calculation was required. Possibly no numerical value should be deduced in such cases, but

it is considered preferable to infer some indicated sea level for every well developed surface so that sequences in different areas can be compared effectively. The uncertainty of such values must of course be indicated (in this paper by "c."). The arbitrary method adopted here assumes that the position in plan of the coastline at the time of formation of the aggradational surface coincided with that of the present day. Whilst there is no strictly logical reason for this assumption, several points support its adoption as an expediency. First, no other reference line would be any more logical; secondly, this reference line is available in all coastal localities; thirdly, coastal benches may be treated similarly to sloping surfaces; fourthly, correlation of Waihi Beach (c.60–70 ft, *see below*) with South Kaipara (45–75 ft, Brothers, 1954), Porirua (51–54 ft, Leamy, 1958), and Otago (50–60 ft, Ongley, 1939) surfaces implies that the values obtained for correlation may well have some practical use; and fifthly, the assumption has been implicit (although seldom stated) in much of the past work that has contributed usefully to our present knowledge (e.g., Morgan, 1924, p. 16, records three "raised beaches" at Waihi Beach, at 12 ft, 20–25 ft, and 40–50 ft above high-water mark, when the only evidence for their being raised beaches is that they are plane and close to the present coast).

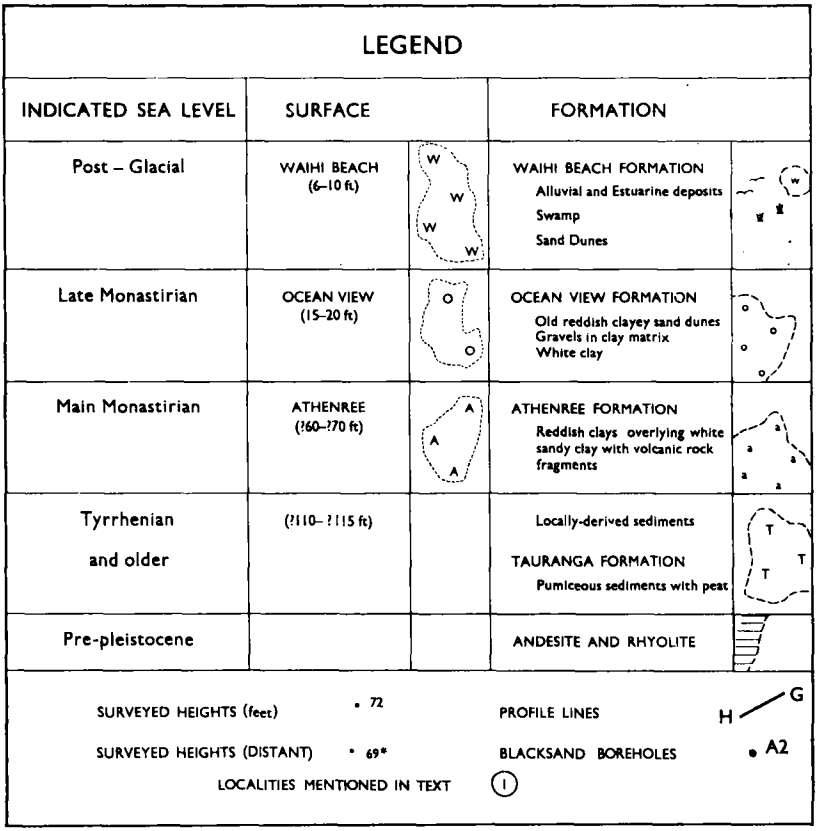
The stratigraphic succession is summarised in Table 1 and illustrated diagrammatically in Fig. 4.

TABLE 1—Surfaces and Formations at Waihi Beach

Sea Level (with South Kaipara levels, Brothers, 1954, in parentheses)	Indicated Sea Level	Surface	Sediments or Remarks
Post-glacial (6–12 ft)	6–10 ft	*Waihi Beach*	*Waihi Beach Formation* Sand dunes, swamp, alluvium, and estuarine mud.
Late Monastirian (15–25 ft)	15–20 ft	*Ocean View*	*Ocean View Formation* Fixed clayey sand dunes, weathered brown clays and sands, weathered brown gravels, white clays.
Main Monastirian (45–75 ft)	c.60–70 ft	*Athenree*	*Athenree Formation* Reddish weathered (?ashy) clays overlying white sandy clays with volcanic and carbonaceous fragments.
Tyrrhenian (110–130 ft)	c.110–115 ft	Remnants (unnamed)	Locally derived clayey sands, with angular and rounded pebbles; pumiceous sediments (Tauranga Formation)
and Milazzian (220–240 ft)	.....	Absent	
Sicilian (350 ft) Calabrian (550ft)	(c.340–390 ft) (c.550 ft)	At Homunga Bay	Slumped rock benches
Pre-Pleistocene	.....	.....	Andesites, rhyolites

Values indicated by "c." have been calculated on the assumption that present and past coastlines were identical.

For mapping purposes, the recognition of formations is essential, and they have been given the same type localities as the surfaces. The type exposures, in low road cuttings, are poor, but are normal for the area as a whole.



Legend for Figs. 2 and 2A.

Air photographs reproduced in Figs 2 and 2A are published by permission of the N.Z. Department of Lands and Survey.

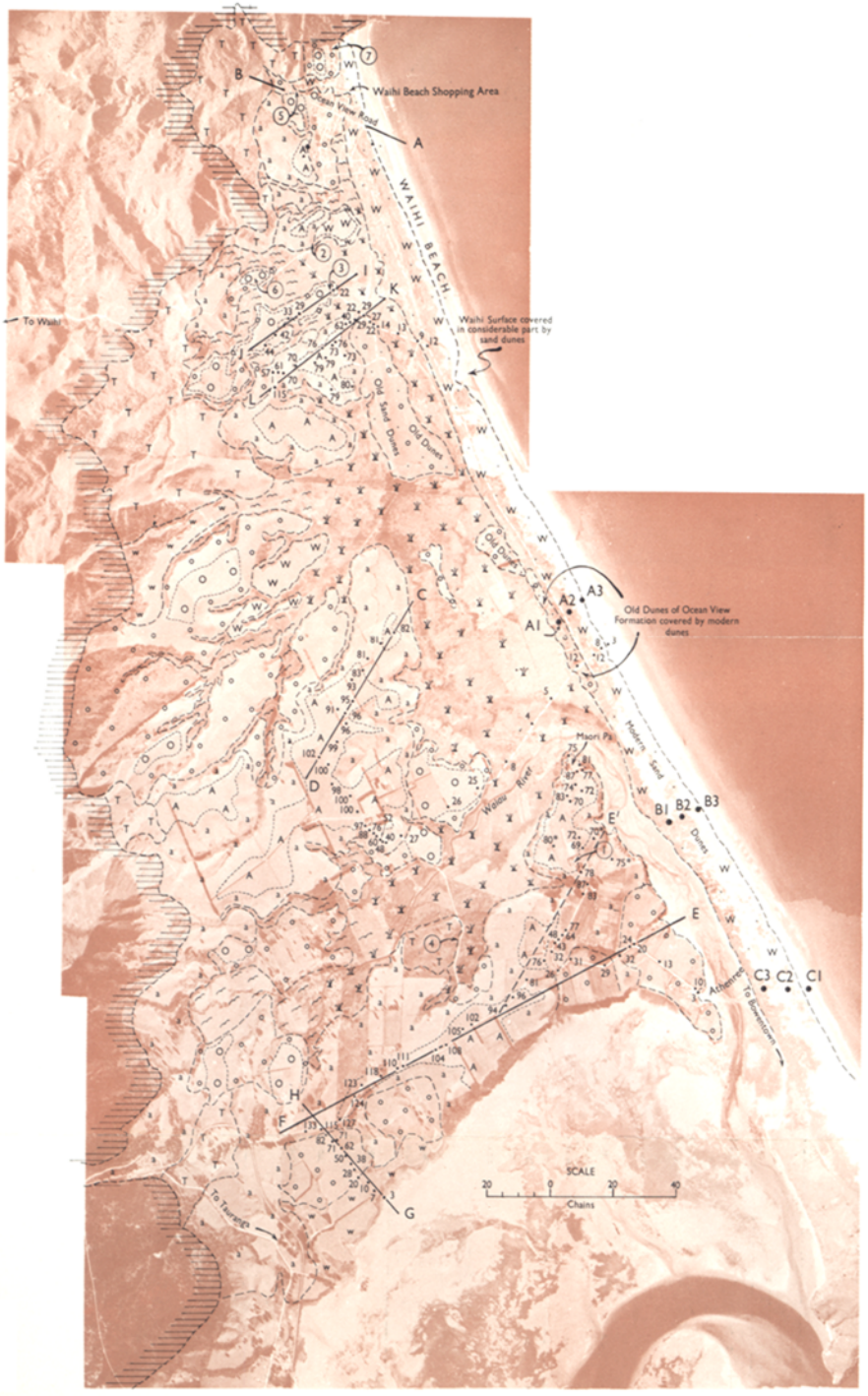


FIG. 2—Quaternary surfaces and sediments, Waihi Beach. For enlargement of northern area, see Fig 2A. For legend see facing page.

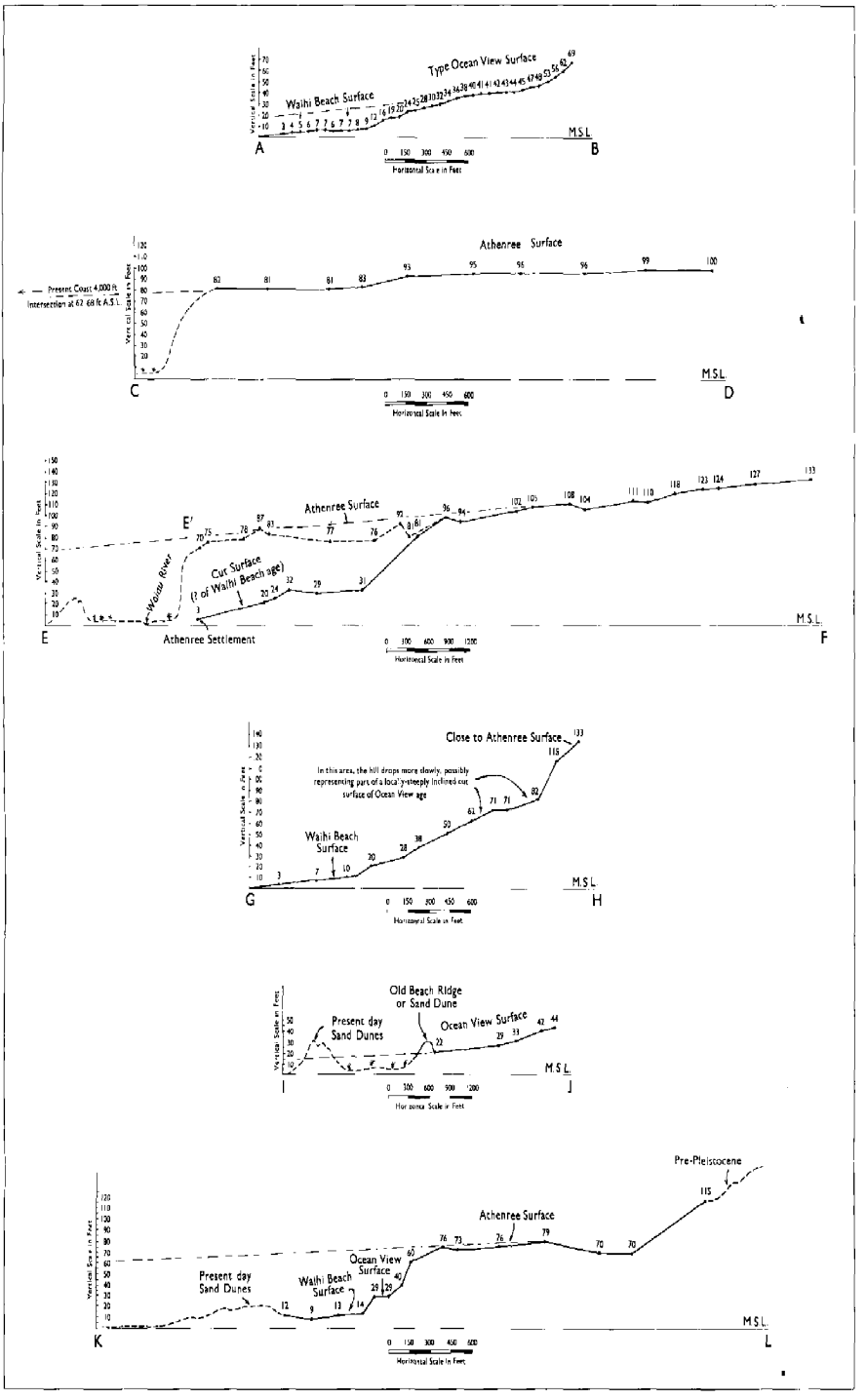


FIG. 3—Profiles of surfaces at Waihi Beach along lines shown in Fig. 2. All vertical scales are exaggerated, AB, CD, GH and KL six times, and EF and IJ twelve times.

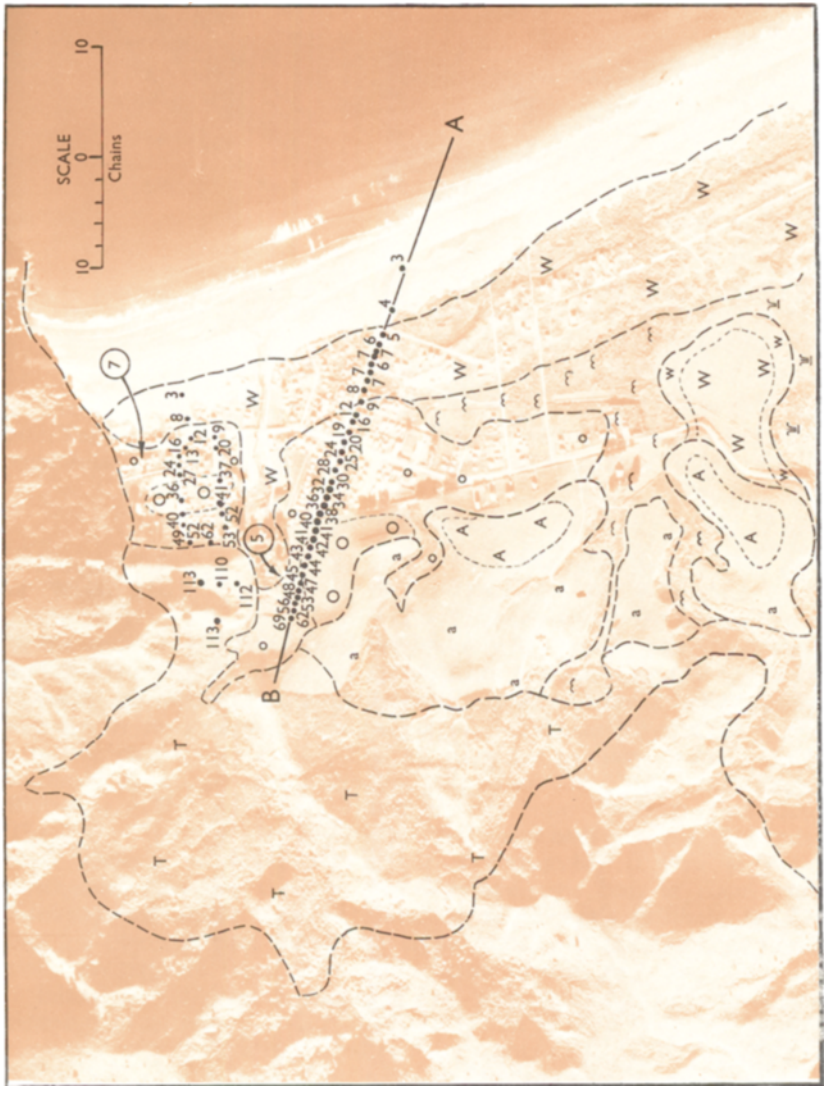


FIG. 2A—Enlargement of northern part of Fig. 2. For legend see page facing Fig. 2.

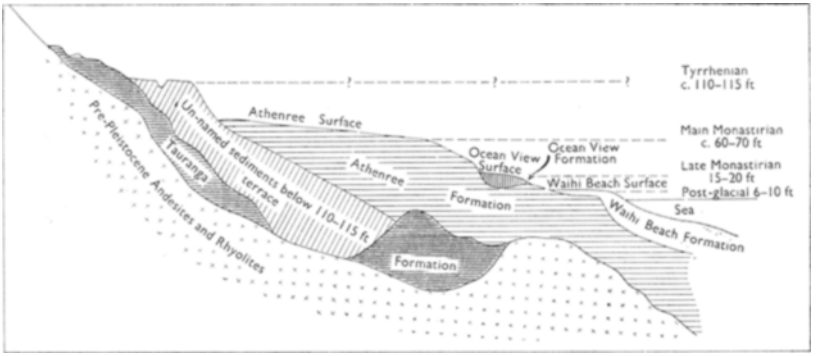


FIG. 4—Idealised diagram of surfaces and formations at Waihi Beach, together with their indicated sea levels, heights, and correlations.

Pre-Pleistocene

The Quaternary rocks of the Waihi Beach area rest unconformably upon late Tertiary rhyolites and andesites that are typical of the Cape Colville Peninsula succession, and form rugged hills inland (Figs. 5, 6).

Older Pleistocene

Morgan (1924, p. 16) recorded that, near Homunga Bay (2 miles north of Waihi Beach, Fig. 1), "there are wave-cut benches at about 160 ft (indistinct), 340 ft, and 550 ft". The higher benches are badly slumped in the andesitic cliffs, and their heights were remeasured recently as 550 ft and 390 ft above sea level. The 160 ft bench was not relocated.

South of Waihi Beach settlement, highly pumiceous sediments are exposed in road cuttings to the south of the Waiau River, about a mile inland from the sea (at "4", Fig. 2). They are overlain, probably unconformably, by younger terrace beds, and may be correlated with Henderson and Bartrum's (1913, pp. 75–7) Tauranga Beds (now Tauranga Formation). The age of the aggradational surface that these beds underlie is uncertain from evidence at Waihi Beach, but is presumably at least as old as Tyrrhenian (compare the 120 ft surface upon the beds at Kauri Point, Katikati) and might well be older. In Mr Tonge's drillhole (at "1", Fig. 2), clay with peat and timber layers, possibly of the Tauranga Formation, was reported from 95 to 145 ft below present sea level.

Inland of Waihi Beach shopping area, accordant ridge tops are the sole remnants of an eroded surface at 110 to 115 ft, which is underlain by white clays with angular locally-derived rock fragments (Fig. 5). Elsewhere in the Waihi Beach area there is no other undoubted remnant of this surface, although inland of the remnants of the Athenree Surface, the spurs and ridges rise irregularly, but not steeply, to the main hills (formed of volcanic rocks). These areas are probably underlain by Pleistocene sediments that were originally below an aggradational surface, only a little higher than the Athenree. They have since been considerably eroded. The weathered clays and conglomerates that are exposed at the Athenree junction on the

Waihi-Tauranga road (Fig. 2) may be representative of them. Insufficient is known of these older beds to name them formally, and they are accordingly styled broadly as "Older Pleistocene".

Athenree Surface and Formation

From a point half a mile north-east of its junction with the Waihi-Tauranga Main Highway, the road towards Athenree settlement is formed along a sloping terrace surface for a distance of just over a mile. This constitutes the type locality of the Athenree Surface. It terminates to the north at a Maori pa (Fig. 2), a little under a mile north-west of Athenree settlement, from which the name is taken.

The distribution of the Surface is shown in Fig. 2 and its form illustrated in Fig. 6. Its minimum height is now 70 ft; and three profiles (Fig. 3, CD, EF, and KL) show that, if extrapolated, the Surface would intersect the present coastline at 62–68 ft, 68 ft, and 60–70 ft in different parts of the Waihi Beach area. The sea level controlling its formation was certainly 70 ft or lower, and was probably between 60 and 70 ft. It could, however, have been lower than 60 ft.

The slope at right angles to the coast appears reasonably constant over the sections measured, and was determined as 30 to 40 ft per mile ($\frac{1}{2}°$). The degree of preservation of the Surface, between Athenree Settlement and Waihi Beach, is highly variable along different lines parallel to the coast; but it is roughly estimated that about 15% of the original terrace surface length remains uneroded.

The Athenree Formation has the same name derivation and type section as the Surface. It comprises light clayey sands overlain by thoroughly weathered reddish-brown clays that may, in part, be volcanic ashes. White clay, with volcanic and carbonaceous fragments, is well exposed at the Bowentown turn-off from the main Waihi highway at Waihi Beach (at "2", Fig. 2).

Ocean View Surface and Formation

Ocean View Road at Waihi Beach (Figs. 2, 2A, and 3) has been constructed predominantly along a sloping surface that is eroded at its seaward end. It constitutes the type locality of, and gives it name to, the Ocean View Surface (distribution, Fig. 2). Extrapolation of profiles AB and IJ (Fig. 3) shows intersections with the present coastline at 15 to 20 ft above mean sea level. A typical view of the surface is shown in Fig. 6 (b).

Somewhat better evidence of the height of contemporary sea level is given by an occurrence of the Ocean View Surface, 22 ft above sea level, 20 chains along the Bowentown road from the main Waihi highway (at "3", Fig. 2; section IJ, Fig. 3). A hillock, immediately seaward of this point, is composed of white clay, typical of the Ocean View Formation elsewhere, overlain by sands. The interpretation is that the sand represents a coastal dune or beach ridge immediately seaward of Ocean View alluvial flats. Similar deposits, showing the same mutual arrangement, may be

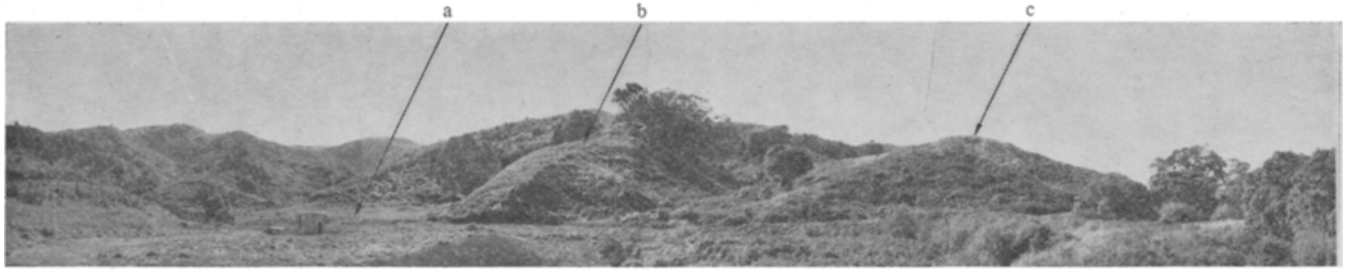


FIG. 5—Ocean View Terrace surface (a) extending up the valley of a small creek at the western end of Ocean View Road ("5" on Fig. 2). Two remnants of the Tyrrhenian surface (110–115 ft A.S.L.) show in spurs (b, c). The hills behind are pre-Pleistocene Andesites.

FIG. 6—Athenree (a) and Ocean View (b) surfaces from Waihi - Waihi Beach road ("6" on Fig. 2); panorama taken in south-east quadrant. High pre-Pleistocene hills (c) show to right, and Waihi Beach alluvium on the left (d).

observed in the present-day cycle in the lower Waiau Valley where the level of the flats is 4 to 5 ft above present sea level. This would imply a sea level of approximately 15 to 20 ft (strictly 17 to 18 ft on these figures) at the time of formation of the Ocean View Surface.

The slope of the Surface is highly variable, ranging from 10 to 60 ft per mile in different sections. Such variation, when compared with the relatively constant slope of the Athenree Surface, no doubt reflects the fact that, while the latter originally extended virtually unbroken from Waihi Beach to Athenree, the Ocean View Surface has been confined to valleys cut in older sediments. It can, for example, be traced from its type locality up the winding valley of a small stream (Fig. 5), as a steeply-sloping alluvial fan. Its slope was therefore dependent upon local variations in supply of sediment and water. Its degree of preservation is less easily determined than for the Athenree Surface, but measurements parallel to the sea suggest that roughly 30% of the length of the original terrace surface remains.

The Ocean View Formation has the same type section and name derivation as the Surface. Its lowest exposed bed is in most places a white unweathered clay. This is generally overlain by sandy clays, but by conglomerates near Waiau River, all of which (including conglomerate pebbles) are very weathered, and brown in colour. Near Waihi Beach township, the sandy clays contain angular rock fragments (commonly $\frac{1}{4}$–$\frac{1}{2}$ in.; rarely 2 in.) derived from the volcanic hills close behind. Sand dunes are present locally, usually on the landward side of present day dunes, but in some places forming the cores of the highest of the latter. The surface beds of these dunes are highly weathered, and are brown and clayey, but 15 ft or so below the surface they grade down to brown clayey sands that are markedly less weathered.

In many areas the formation is overlain by a few feet of less weathered sand that is slightly younger than the bulk of the formation.

Differentiation of Athenree from Ocean View sediments is difficult, and may indicate that the Ocean View Surface represents a still-stand during the fall in sea level from that which gave rise to the Athenree Surface, rather than that a period of low sea level separates the two. The former solution is implied in Fig. 4.

Waihi Beach Surface and Formation

A near-flat surface exists close to the sea at Ocean View Road (6–9 ft above sea level, AB, Fig. 3), and constitutes the type locality of the Waihi Beach Surface. Similar flat surfaces exist at Tauranga Harbour (7 to 10 ft, GH, Fig. 3), and at the Waihi Beach shopping area (where a thin sand layer has built the surface to as high as 12 ft). These surfaces, which show hardly any sign of erosion, are presumed to indicate an old sea level, 6 to 10 ft above the present. Inland, some low terraces, close to the present flood plain and presumably of Waihi Beach age, are more eroded, but more than 50% of the width of the original surface remains.

Over much of the length of the beach, for two miles from its northern end at Waihi Beach, the surface is cut on brown clays of the Ocean View or older formations. Holocene dune and beach sand overlies, but the

clay has been re-exposed locally by bulldozing or by the severe marine erosion of recent years.

All post-Ocean View aggradational sediments are included together in the Waihi Beach Formation. Differentiation on an age basis requires even more detailed treatment (cf. Schofield, 1960) than was afforded in the present survey. Thus the formation comprises swamp, alluvium, dune sand, and estuarine muds.

Prominent dunes, now fixed by lupin, rise to a maximum of about 35 ft, and average 15 to 20 ft above sea level. The highest hills (in the south-east) have a core of older sand dunes of the Ocean View or older formations. Nine post-hole bores, forming part of an ilmenite survey by Messrs H. E. Fyfe and D. S. Nicholson and the present authors (*see also* Nicholson *et al.*, 1958), average 13 ft in depth, 5·9% ilmenite, and 34% TiO_2 in the ilmenite. Table 2 gives the detailed results for the holes shown in Fig. 2.

TABLE 2—Details of Blacksand Boreholes

Hole	Distance from H.W.M. (yds)	Depth (ft)	Ilmenite (%)	TiO_2 in Ilmenite (%)	Remarks
A1	255	20	6·5	n.d.	Yellow clayey sand 10–20 ft.
A2	155	7½	9	n.d.	Includes 1 ft of rich blacksand.
A3	55	9½	14	40	Slightly blacker 5½–9½ ft.
B1	290	17	8	n.d.	Pumice bed at 11 ft. Iron pan at 13 ft.
B2	190	13¾	1	27·2	Rich blacksand 9–10 ft.
B3	90	20	3	n.d.	
C1	10	13	5·5	n.d.	
C2	150	10	1·5	n.d.	Pumice at 6 ft.
C3	340	8½	5	34·4	Iron-staining 4–7 ft.

All boreholes except A1 finished in water (presumably close to sea level) when caving prevented further boring. Analysts: D. S. Nicholson and J. J. Cornes.

Thin pumice beds were found within the sand-dunes in two of the nine holes (C2 and B1), 6 ft and 11 ft below the surface, and probably 4 and 6 ft above sea level. Bore A1 was put down in the highest dune ridge. It penetrated to the older yellow clayey dune sand at 10 ft.

Blacksand is locally present on the modern intertidal beach, which is being actively eroded at its north-western end beside Waihi Beach township.

A coastal terrace, on which Athenree settlement is built, descends to a level of 10 ft above mean sea level. Since the sediments immediately beneath it are brown and clayey, they are referred to the Ocean View Formation; but their upper surface is presumed to have been cut, and is correlated with the Waihi Beach Surface.

CORRELATION AND STABILITY

Evidence that the terrace surfaces at Waihi Beach were formed during interglacial rather than glacial times is indirect. First, the topographic setting of the older-cycle Ocean View Surface is very similar (*see* Fig. 2) to that of the younger-cycle Waihi Beach Surface, which is itself

undoubtedly interglacial. Secondly, except near the courses of the main river valleys and close to hills of volcanic rocks, where coarser material is to be expected, the sediments are relatively fine grained, and clayey sands are typical. Thirdly, similar surfaces at South Kaipara, also without marine fossils, have been recognised as interglacial by Brothers (1954). It is therefore concluded that the terraces were formed during interglacial periods, and that their surfaces may be correlated with eustatic sea levels.

Table 1 shows that the sea-levels indicated at 6–10 ft, 15–20 ft, c. 60–70 ft, and c.110–115 ft, may be correlated with the Post-glacial, Late and Main Monastirian, and Tyrrhenian eustatic sea levels respectively. The c.340–390 ft and c.550 ft slumped rock benches at Homunga Bay may be considered indicative of the Sicilian and Calabrian sea levels, although the degree of certainty is less. There is such close agreement between the levels of surfaces at Waihi Beach and those of the stable South Kaipara area (Table 1) that the conclusion seems inescapable that the Waihi Beach area also has been relatively stable in at least late Pleistocene time.

OTHER NEARBY COASTAL TERRACES

Bell and Fraser (1912, p. 29) record four distinct terraces in Orakawa Bay, a mile north of Waihi Beach (Fig. 1). Three were measured recently as 6 ft, 10–15 ft, and 25–35 ft above sea-level. The 6 ft terrace, composed of loose sand, which is actively being eroded by the sea, contains two Maori midden layers, 18 in. apart, which include shells and charcoal. This terrace is clearly younger than the 6–10 ft Post-glacial level(s). Its comparatively high level may well be due to the observable increased wave activity, which probably also causes the comparative steepness of the present beach there. Thus the two higher surfaces (10–15 ft and 25–35 ft, in sand and gravel) probably represent the Post-glacial and Late Monastirian sea levels, which are each similarly slightly higher than at Waihi Beach. A shell bed up to 1 ft thick, about 6 ft above mean sea level, is composed, predominantly, of broken and crumbling shells of *Struthiolaria papulosa*. It is exposed very locally on the face of the 10–15 ft terrace, and is obviously younger than the latter. Its brown clayey sand matrix suggests that it is older than the Maori middens. No charcoal was seen in it, nor in two similar deposits, one on either side of Whitianga Harbour to the north (national grid references N44/196659 and N44/213630, Fig. 1). It is uncertain whether human agency was involved in the deposition of these beds, or whether *S. papulosa* was temporarily more common in some Post-glacial time, than it is at present. Its shells are present on modern beaches in the area, but are far from predominant.

At Homunga Bay, 1¼ miles north of Orakawa, wave-cut-platform remnants at 10–12 ft and 25–30 ft again probably represent the Post-glacial and Late Monastirian levels (i.e., they would be correlated with the Waihi Beach and Ocean View Surfaces, but would be slightly higher).

Terraces are present at 3 ft, 6–9 ft (with dunes on it), 18 ft, and 24 ft at Opoutere, 8 miles north of Whangamata and 30 miles from Waihi Beach (Mr H. E. Fyfe, pers. comm.). The former two would correspond

with the lowest two terraces at Orakawa Bay. The 18 ft and 24 ft terraces, which are extensive inland around Opoutere, would together represent the Late Monastirian. They are underlain by clays with rare sand and gravel beds.

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