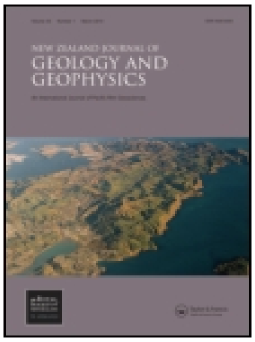

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UPPER QUATERNARY WARPING AND UPLIFT RATES IN THE BAY OF PLENTY AND WEST COAST, NORTH ISLAND, NEW ZEALAND

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with an Appendix

PALYNOLOGIC DETERMINATIONS FROM NORTH TARANAKI RAPANUI TERRACE

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Abstract

Coastal terraces around the Bay of Plenty are examined from Waihi to East Cape. The tephra stratigraphy described by other authors is extended; in particular a pumiceous tephra formation immediately underlying Hamilton Ash Formation is named the **Little Waihi Formation.** Two terraces can be traced confidently around the Bay; the younger (BOP2) is capped by Rotoehu Ash and younger tephras and the older (BOP3) is capped by Little Waihi or Hamilton ashes and younger tephras. Wave-cut surfaces beneath the mantling deposits vary in height around the Bay, indicating warping. Near Maketu, both BOP2 and BOP3 cut surfaces are within 2 m of sea level; near East Cape they are about 50 m and 100 m, respectively.

West coast terraces are traced from Kaipara and south-west Auckland into north Taranaki and thence to Wanganui. The following formations are correlated: (a) Waioneke—Waiau B—Rapanui; (b) Shelly Beach—Waiau A—Ngarino; (c) Parawai—Brunswick; and (d) Nihinihi and upper Kaihu Formations—Kaiatea Group of Terraces. The highest littoral and marine beds in terraces correlated with the Rapanui Formation are 20–25 m a.s.l. only from Taranaki to Kaipara; the Ngarino equivalents are 40 m, and the Brunswick equivalents are 70 m. Correlation from the west coast to Bay of Plenty is subject to uncertainty about tephra relationships. It is shown that BOP2 is the probable correlative of Ngarino Terrace equivalents along the west coast, and that BOP3 is probably equivalent to Brunswick. The relationship of these terraces to sea-level oscillations which are well identified and dated elsewhere in the world is discussed. Although eight major trangression–regression cycles occurred in the last 250 000 years, only the peaks around 240 000–215 000 years and 140 000–120 000 appear to have generated widespread terraces. It is suggested that these formed the BOP3—Parawai—Brunswick set and the BOP2—Waiau A—Ngarino set, respectively. These results are compatible with radiometric age estimates of about 0·4 m.y. for the Upper Castlecliffian. Uplift rates calculated on this basis in the Bay of Plenty vary from zero at Maketu to 0·4 mm/year at East Cape. For the west coast the rate is essentially constant from Taranaki to near Auckland, at 0·3 mm/year.

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INTRODUCTION

Quaternary terraces have been described from many coastal areas in the North Island of New Zealand by various authors. Their distribution and time-stratigraphic allocations to the Recent, Hawera, and Wanganui Series of the New Zealand stratigraphic codes are indicated on the "Geological Map of New Zealand 1: 250 000" series (e.g., Hay 1967).

Quaternary tectonic movements in some areas are simply demonstrated by variations in terrace altitude, especially in regions around Wanganui (Fleming 1953), Hawkes Bay–Dannevirke (Kingma 1971), and Wellington–Wairarapa (Vella 1963; Wellman 1969). For other areas, Quaternary tectonic stability has been assumed, especially in Northland where the flight of terraces in the South Kaipara district (Brothers 1954) have become something of a standard reference succession in North Island geology. Altimetric correlations, supported by stratigraphy, between the Kaipara terraces and similar sequences south-west of Auckland have been proposed by Chappell (1970) and Ward (1972). These are among the most recent examples of arguments often made in support of the idea of tectonic stability in the Auckland region.

This paper, firstly, is concerned with tracing a connection between Pleistocene terraces in the unstable southern part of the Island and the assumed stable northern area. It is based on previous work of others, and on recent observations by the writer; the coastal areas considered are shown in Fig. 1. Secondly, possible relationships are examined between the younger terraces and Upper Quaternary sea levels determined and dated elsewhere in the world.

Differential movement cannot be traced straightforwardly across the many discontinuities in the coastal terrace record. In particular, relationships between Auckland Province terraces and those of the Hawera Series in Wanganui are not clearly defined. On the "Geological Map of New Zealand 1: 250 000" series the specific allocations of terraces are often to "portmanteau" groupings within the Hawera and Wanganui Series. However, exact terrace-by-terrace correlation is necessary for estimation of differential movements. This is attempted here by re-examining the coastal terraces south of Auckland, and then tracing the terraces down into Taranaki and thence to Wanganui. Coastal terraces from south of Auckland are described from the west coast by Chappell (1970), and from Waihi on the east coast by Kear & Waterhouse (1961), and are correlated by these authors with Kaipara mainly on an altimetric basis. Recent work at Waihi (Selby *et al.* 1971) gives closer detail for the upper Quaternary record than reported from Kaipara (Brothers 1954). Not only are low-lying terraces more numerous at Waihi but also they are tied into the late Pleistocene tephra stratigraphy of Vucetich & Pullar (1969).

Observations at Waihi and the Bay of Plenty have indicated to the writer a record even more detailed than reported by Selby *et al.* (1971), and this area is used as a starting point. In the Bay of Plenty field evidence, an important part is played by the late Pleistocene tephra stratigraphy of Vucetich & Pullar (1969). Also important are the dense brown tuffs identified in the Bay of Plenty area by these writers and by Selby *et al.* (1971)

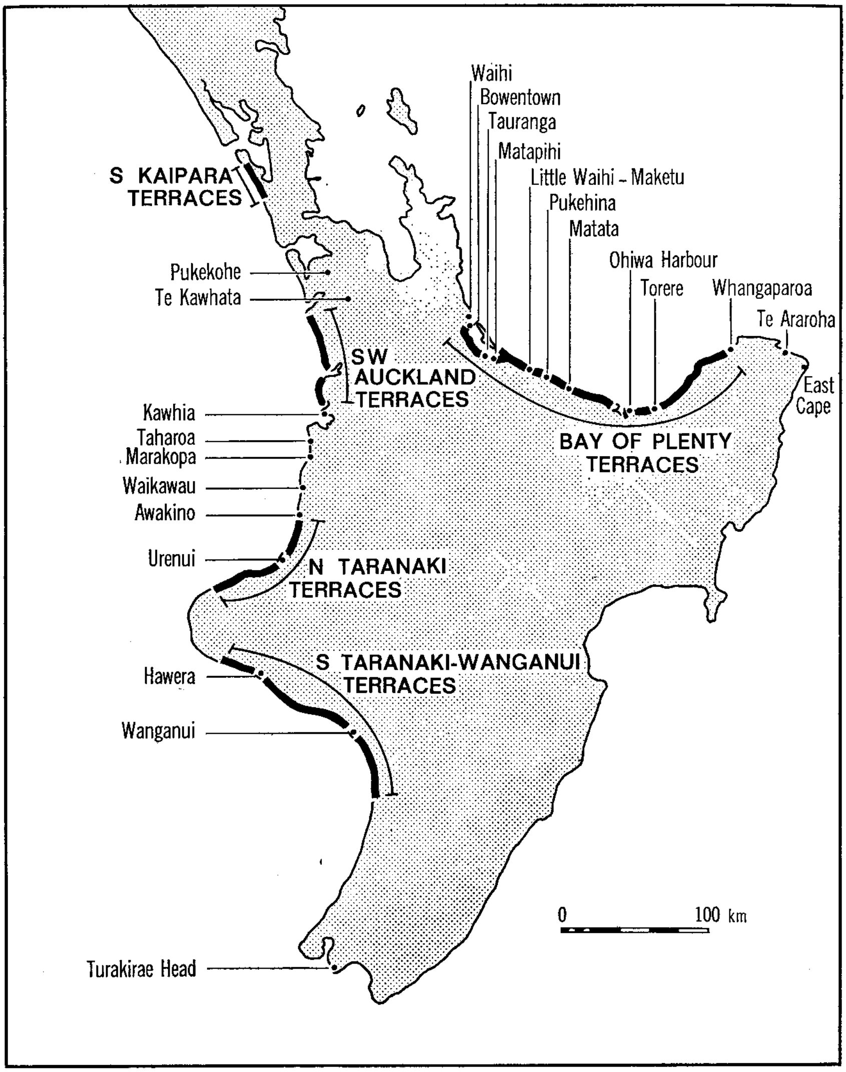

FIG. 1—Localities, and areas of coastal terraces, discussed in the text. (*For* Te Araroha, *read* Te Araroa.)

as probable equivalents of the Hamilton Ash and Kauroa Ash Formations, which are described from the lower Waikato Basin by Ward (1967).

The following terminology is used in this paper: **Terrace**, as in "Athenree terrace", refers to the physiographic surface of such a feature; **surface** as in "Athenree sub-Hamilton Ash surface", or "Athenree erosion surface", refers to any specified stratigraphically defined surface within, or immediately beneath, the deposits building a terrace. Such deposits will be referred to the name of the associated terrace, with appropriate stratigraphic formality, e.g., "Athenree terrace deposits", "Parawai Formation". The descriptions given by previous workers will be translated into these terms. Finally, tephra sedimentary terminology follows the recommendations of Cole & Kohn (1972) and Pullar *et al.* (1972).

BAY OF PLENTY TERRACES

Waihi

The succession at Waihi reported by Selby *et al.* (1971), with associated ash deposits, is: (youngest) Waihi Beach terrace at 1·8 to 3 m a.s.l.; Ocean View terrace at 4·6 to 6·1 m, with Rotoehu Ash (age = 42 000 years B.P.) as oldest ash deposits; Athenree terrace at 18·3 to 21·3 m, with Rotoehu Ash + Hamilton Ash Formation + Kauroa Ash (lowest), above the Athenree erosion surface; and the Tauranga terrace at 33·5 to 35 m, with ash deposits down to the Kauroa and weathered rhyolite and rhyolite pebbles below that. A separate low terrace near Bowentown has Rotoehu Ash as its oldest ash cover, 2 m a.s.l.; Selby *et al.* do not propose a relationship between the Bowentown terrace and those at Waihi, but Kear & Waterhouse (1971) suggest that the Bowentown terrace is younger than the Ocean View, presumably because it is lower.

On the basis of the writer's field observations, the following revisions are suggested.

(1) The Ocean View terrace, reported by previous authors to lie between 4·6 and 6·1 m a.s.l., has a seaward gradient of about 4° and passes, without breaking slope, down to beneath a swamp 1 m above high water level (h.w.l.) (N53/423927*). Selby *et al.* (1971) report dune sand below Rotoehu Ash to a depth of at least as low as 2 m a.s.l., and possibly lower. At Athenree (N53/446890) dune sands beneath the Ocean View terrace overlay a cut surface in rhyolite at 0 to 0·2 m above h.w.l. The height is not known for the presumed notch at the inland margin of this cut surface, but is suspected to be less than 2 m. The Ocean View terrace therefore appears to be built over a surface which developed at a sea level 0 to 2 m above the present, with respect to the Waihi area.

The Bowentown terrace, seen on the harbour side of Bowentown tombolo, is built of a thin veneer of weathered sand below the Rotoehu Ash, overlying a surface cut over weathered rhyolite at 0 to 0·3 m above h.w.l. It seems likely that this is the same surface as that underlying the Ocean View deposits. It is suggested that the Bowentown–Ocean View erosion surface developed at a

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*Grid reference based on the national thousand-yard grid of the 1: 63 360 topographical map series (NZMS 1).

sea level of 0 to +2 m with respect to the Waihi coast, and that the cover of mainly dune sand beneath the Rotoehu Ash accumulated during subsequent regression of the sea.

(2) The areas mapped as Athenree surface by Kear & Waterhouse (1961) and Selby *et al.* (1971) are smooth terrace surfaces, intersected by shallow valleys and terminating seawards in low cliffs, or in steep slopes which may represent previous cliffs. The terrace is composite, and is not built of a single stratigraphic sequence as suggested by these previous authors. These are two surfaces, one with a seaward dip of 5° to 7°, descending to a lower limit of 10 m from an inland margin at about 24 m. The other surface is subhorizontal, between 16 and 22 m a.s.l. The dipping surface is apparently the younger of this pair, as shown by the stratigraphy.

The column recorded by Selby *et al.* (1971) is from N53/422932, and is in the subhorizontal part of the Athenree terrace. The deposits include 4·7 m of Hamilton Ash Formation, overlying 1 m of Kauroa Ash. By comparison, the deposits beneath the seaward sloping part of the terrace, seen in a cutting at Steele Road corner (N53/639891) below the terrace at 20 m, are as follows (from top to bottom):

	Depth (m)
Late Pleistocene ash with Rotoehu Ash at base.	0–1
Hamilton Ash with nodules of halloysite and manganese at base. These and higher beds approximately conform with the terrace surface.	1–2
Silty pumice sand, partly truncated by overlying Hamilton Ash, and weathered yellow.	2–2·5
Silty pumice sands and pebbly pumice sands, yellow.	2·5–3·4
Brown weathered sand, over alternating greasy pumice ash and fine ash in layers 0·05–0·2 m thick.	3·4–4+

From sections around the Waihi area seen by the writer, it is not possible to clearly identify the relationship between these deposits and those below the subhorizontal part of the Athenree terrace. However, evidence from the Maketu–Matata area in the central Bay of Plenty (outlined below) strongly suggests that the lower 2+ m of yellow pumice ash and sand, in the Steele Road section, is part of a widespread set of deposits separating the Hamilton and Kauroa Ashes in this region.

Maketu to Matata: Little Waihi Formation

The Maketu–Little Waihi headland, about 30 km south-east of Tauranga (Fig. 1), stands like an island between the lowlands of the Kaituna and Pongakawa Rivers. The headland crest is a well formed terrace, 60–66 m a.s.l. About 1·5 km inland of the sea cliffs the land descends to a lower terrace which slopes generally inland towards lower terraces in the Kaituna lowlands, from about 38 m down to about 20 m. The following column occurs beneath the high terrace, best exposed just inside the Pongakawa River estuary (Little Waihi, N59/942503):

	Elevation a.s.l. (m)
Late Pleistocene ash and lapilli with 2 m Rotoehu Ash at base.	53 (cliff edge)–43
Hamilton Ash Formation.	43–41
Medium pumice lapilli, pale yellow. This bed is truncated by the Hamilton Ash, and varies in thickness from 0 to 4·5+ m in exposures around Little Waihi headland.	41–39

	Elevation a.s.l. (m)
Banded pumice beds: alternating fine pumice lapilli and medium-fine ash beds; the latter are greasy with a fine pumice ash component; grey colour.	39–35·5
Medium pumiceous gravel, apparently fluvial.	35·5–35
Medium pumice lapilli, pale yellow.	35–29
Pumice silt, white.	29–28·9
Parallel-bedded medium pumice lapilli, pale yellow, with lowest 1 m showing large scale or "torrent" cross-bedding, over a scoured and channelled surface with up to 2 m of relief.	28·9–21
Coarse pumice lapilli, massive and containing blocks and boulders up to 2 m on their longest diameter.	21–3·5
Beneath an erosion surface at the base of the overlying coarse lapilli are parallel-and cross-bedded medium sands, pumice grits, and grey/white alternating thin beds of pumiceous silt and sand. These are referred to as the **basal beds** in this succession.	3·5–0·5

There are several particular features to note.

(1) The "banded pumice beds" between 35·5 and 39 m have a highly distinctive appearance; the fine lapilli are usually cream, and the medium-fine ash layers are black on the exposed surface; both are white and greasy within. About 12 bands stand out, but many of the bands are themselves composite. The detailed succession (Little Waihi road section, N68/935497) is: 0·2 m medium ash, 0·1 m fine lapilli, 0·15 m ash, 0·25 m lapilli, 3 × 70 mm ash layers, 0·3 m lapilli, 2 × 0·1 m ash, 0·35 m lapilli, 3 × 0·15 m ash, 0.12 m lapilli, 4 × 0.15 m ash (top).

(2) The "basal beds" superficially resemble the "banded pumice beds", in their regular banded appearance and alternation of dark and light colours. They are denser, however, and considerably better compacted than the overlying tephras. The important difference in the basal beds is the occurrence of medium to fine scale cross-bedding, indicating subaqueous deposition in a fairly low energy environment.

(3) Although the blocks and boulders within the main coarse lapilli are dominantly rhyolite and ignimbrite, about 2% are irregular blocks of material very similar to the basal beds.

The entire succession from the erosion surface over the basal beds up to the base of the Hamilton Ash is interpreted as having a common volcanogenic origin. The main coarse lapilli unit (up to 18 m thick) represents a major eruption, and the coarse boulders within it suggest that the eruptive centre was nearby. Rapid fluvial reworking is represented by the scour channels and "torrent bedding" over this unit. The uppermost 12 m, including the "banded pumice beds", represent successive air falls with intermittent fluvial reworking. The beds dip to 290° at 6°, and are cut by high angle normal faults with observed throws of 6+ m.

This succession can be identified extensively around the Bay of Plenty but thins rapidly away from the Little Waihi headland. These beds, thus, constitute a stratigraphic assemblage similar to the younger tephra formations described by Vucetich & Pullar (1969), such as the Rotoiti Breccia Formation. The sequence of lapilli, ash, and fluvially reworked material overlying the erosion surface at 3·5 m, at the Pongakawa River estuary (Little Waihi), and extending up to the Hamilton Ash Formation will from now on be referred to as the **Little Waihi Formation.**

As will be shown, the Little Waihi Formation is important in the interpretation of Bay of Plenty terraces. For higher-level terraces the stratigraphy beneath this formation is also significant. A particular problem is the position of the putative "Kauroa Ash", identified by Selby *et al.* (1971) as directly underlying the Hamilton Ash in the Athenree Terrace deposits at Waihi. At Little Waihi, no trace was found of dark brown ashes, other than that classified here as Hamilton Ash (in keeping with Vucetich & Pullar 1969), lying beneath Rotoehu Ash and above Little Waihi Formation. At the Little Waihi sections, deeper stratigraphy cannot be seen, because the Little Waihi Formation overlies an erosion surface 0–3 m above sea level. This stratigraphy can be seen, however, in roadside cliffs running south from near Pukehina to Matata, where gentle tilting has exposed a sequence extending from Late Quaternary ashes down to fossiliferous Castlecliffian beds. In this section (Fig. 2A) the sub-Little Waihi Formation erosion surface is developed over dense, banded pumice silts and fine sands, grey, white, and sometimes pink in colour. These appear to pass continuously down through pumiceous sandy beds and lapilli, into fossiliferous marine sands assigned a Castlecliffian age by Healy *et al.* (1964) (best exposures: Herepuru Road area). These bedded pumice silts and fine sands, beneath the Little Waihi Formation, are not internally differentiated in this paper, and will informally be referred to as **the undifferentiated pumiceous beds.***

The question of the stratigraphic position of "Kauroa Ash" remains. Either this air fall did not reach the central Bay of Plenty, or it fell when Castlecliffian seas occupied the area, or it fell onto the landscape developed on the undifferentiated pumiceous beds but was partly eroded before deposition of the Little Waihi Formation. Sections near Ohiwa Harbur, to the south-east, help to clarify the matter.

Ohiwa Harbour to Torere: Ohiwa Gravels, and Undifferentiated Pumiceous Beds

Sea cliffs, and cuttings in the coastal road, in this area expose the stratigraphy beneath terraces rising to about 40 m above sea level. The easternmost of the exposures referred to here is Torere (Fig. 2B), which shows the Little Waihi Formation in a position similar to that in the Little Waihi—Matata area; in particular, the Little Waihi Formation overlies an erosion surface developed on the undifferentiated pumiceous beds.

The cliffs east of the entrance of Ohiwa Harbour show a different stratigraphy (Fig. 2B). The basal pumice ash of the Little Waihi Formation here rests on a 1-m-thick, mid to dark-brown firm ash, with nutty to blocky structure. This in turn overlies 5 m of yellow compact silty sands, which overlie 10+ m of iron stained and moderately cemented fluvial gravels. These

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*NOTE ADDED IN PROOF:

Tephras beneath the Hamilton Ash along the Bay of Plenty coast have been referred to by Pullar as Pahoia Tuffs (W. A. Pullar pers. comm.). This is a portmanteau term, and includes at least Little Waihi Formation, plus probably most of the undifferentiated pumice beds.

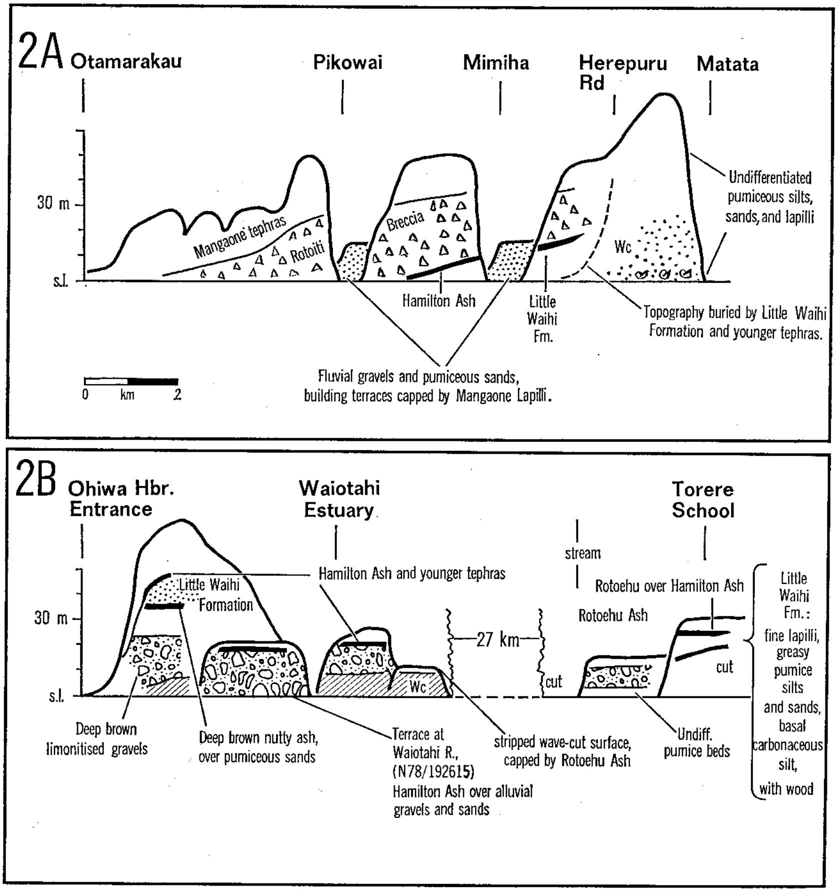

FIG. 2—Reconnaissance sketch of Quaternary tephras and other beds, in Bay of Plenty sections: (A) exposures in cliffs along coast road north of Matata, and (B) sea cliff and road cut exposures near Opotiki.

distinctive gravel beds will be referred to informally in this paper as the **Ohiwa gravels.** The relationship of the Ohiwa gravels to the undifferentiated pumiceous beds was not seen, but it is likely that the gravels are the younger of the two because: (a) the overlying nutty brown ash, and the Little Waihi Formation above it, appears conformable with the gravel surface; and (b) the undifferentiated pumiceous beds appear to pass directly down into marine Castlecliffian beds (Matata—Herepuru Road area: Fig. 2A). This suggestion is not pressed strongly here, however, and the Ohiwa gravels and undifferentiated pumiceous beds may be coeval.

The nutty brown ash above the Ohiwa gravels rests conformably beneath the Little Waihi Formation. Relationships outlined above suggest that it mantled a landscape which elsewhere was partly eroded into the undifferentiated pumiceous beds. It was evidently removed in areas of coastal recession (such as Little Waihi to Matata) prior to the eruptions leading to the Little Waihi Formation. This nutty brown ash is tentatively correlated with the similar brown ash which disconformably underlies the Hamilton Ash in the Athenree terrace deposits at Waihi, and which is correlated with the Kauroa Ash by Selby *et al.* (1971).

Correlations Between Terraces

Sequences of terraces at seven coastal areas around the Bay of Plenty, from Waihi in the north-west around to East Cape, are correlated on the basis of tephra stratigraphy, as shown in Fig. 3. Terrace elevations are not considered in making correlations. The terraces which most readily can be correlated are those related to relatively high glacio-eustatic sea levels, as evidenced by a wave-cut bench beneath the terrace deposits. A correlation is accepted if the tephra succession overlying the erosion surface is similar between terrace localities.

On the Bowentown terrace near Waihi, Rotoehu Ash is the oldest tephra and the base is a cut surface over rhyolite, within 0·5 m of present sea level. Correlated with this is a low terrace occurring around south Tauranga Harbour (localities, Fig. 1), where the terrace surface is underlaid by 4 m of Rotoehu Ash and younger ashes. The sub-tephra surface is about 1 m above sea level, on weathered brown littoral sands and silty sands.

Correlatives can be readily traced south-eastwards. At Pukehina (Fig. 1) an extensive terrace at 10 m occurs behind the coastal dunes and rises to about 12 m near Pongakawa, about 6 km inland. The terrace is underlaid by about 7 m of Mangaone Lapilli over 2 m of Rotoehu Ash, with tephra base at about sea level. The terrace gradient steepens inland of Pongakawa possibly reflecting a junction between sub-tephra coastal plain and fluvial surfaces. This coastal terrace is correlated with the Bowentown terrace, and can readily be traced eastwards around the Bay of Plenty where, beyond Whakatane (between Matata and Ohiwa Harbour), the elevation of the sub-tephra surface steadily increases. At eastern Ohiwa Harbour the equivalent terrace is 16 m above sea level, with 6 m of tephra (Rotoehu Ash at base) over a wave-cut surface on Castlecliffian rocks. Where this terrace occurs at Torere, Rotoehu Ash is the basal tephra, overlying littoral and fluvial gravels, at 12 m above sea level. The same terrace can be traced intermittently around the coastal bays to the Whangaparoa area, where it becomes the Te Papa terrace described by Chapman-Smith & Grant-Mackie (1971). The cliff notch at the back of the Te Papa terrace, beneath about 3 m of Rotoehu Ash and younger ashes, is about 30 m above sea level (Chapman-Smith & Grant-Mackie (1971). The cliff notch at the back of the Te Papa terrace, beneath about 3 m of Rotoehu Ash and younger ashes, is about 30 m above sea level (Chapman-Smith & Grant-Mackie 1971; Pullar 1972). The easternmost extensions of the terrace identified by the writer are small and partly stripped remnants behind the township of Te Araroa, with a cliff-base cut surface at about 48 m.

All Bay of Plenty correlatives of the Bowentown terrace of Waihi are grouped together as **Bay of Plenty terrace 2 (BOP2)**. The wave-cut surface

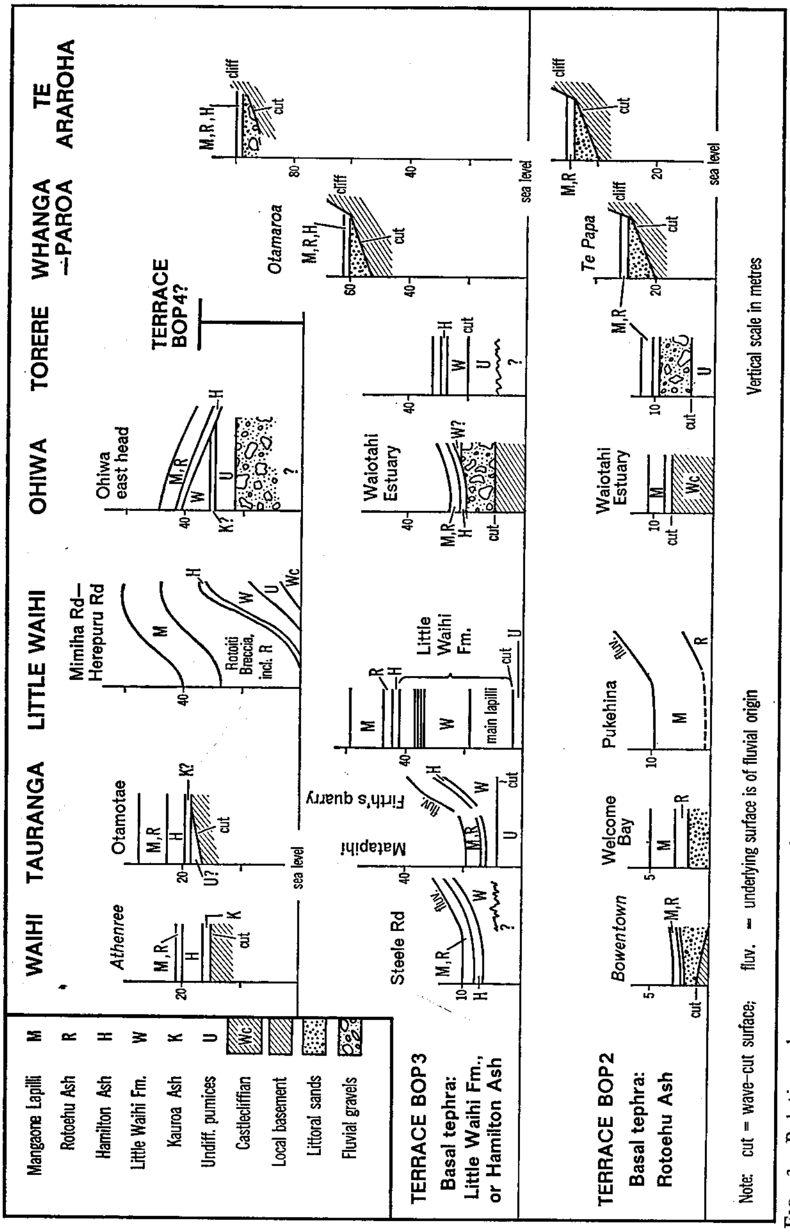

FIG. 3—Relations between terrace sections from Waihi to Te Araroha. Note that different vertical scales are used on different sections.

(*For* Te Araroha, *read* Te Araroa.)

of this terrace increases in elevation to the east from sea level at Waihi to 30 m at Whangaparoa, and finally to about 48 m at Te Araroa. Similar changes are shown by the older, higher terraces; the most complete record of this warping appears to be from the cut platform beneath the next terrace above BOP2, i.e., **BOP3**.

Terrace **BOP3** is characterised by having the Little Waihi Formation as the oldest tephra overlying the erosion surface except in easternmost sections, which appear to lie beyond the range of this tephra fall; there Hamilton Ash is the oldest. The simplest development of this terrace is in easternmost Bay of Plenty, especially at Whangaporoa, where it is the Otamaroa terrace described by Chapman-Smith & Grant-Mackie (1971) and Pullar (1972). Correlated sections of BOP3 are shown in Fig. 3. Tracing westwards from the Whangaparoa area into central Bay of Plenty, both the form of the terrace and its underlying stratigraphy become more complex. The basal erosion surface, beneath the Little Waihi Formation, is clearly seen at several places between Torere and Ohiwa Harbour, and again at Little Waihi and western Tauranga (e.g., Firth's quarry area, Fig. 3; N58/610530). At Waihi the pumiceous silty sands underlying Hamilton Ash in the Steele Road section of the (lower) Athenree terrace are tentatively identified as Little Waihi Formation (N53/439891; see under *Waihi* above). Nearby at the Waiau inlet (N53/445891), ferruginised pumice sands, which built a terrace up to Hamilton Ash at about 10 m, may be a reworked littoral equivalent of the same Formation.

Discussion: Warping, and Other Elements of the Terrace Record

Where seen, the erosion surface beneath BOP3 is at its lowest elevation in the Little Waihi area (2–3 m a.s.l.), and it rises steadily eastwards from Ohiwa Harbour. This tracing (Fig. 3) of the erosion surfaces beneath both BOP2 and BOP3 indicates Upper Pleistocene warping around the Bay of Plenty; this topic is developed later in the paper.

The tracing of BOP3 also puts the fragmentary higher terraces into perspective. Correlations between these are not attempted, beyond the possible relationships sketched in Fig. 3. For example, the Athenree terrace of Selby *et al.* (1971) at Waihi (N53/416924) occurs around Tauranga Harbour, but was not traced by the writer through to its tentative correlative (**BOP4**) at Ohiwa Bluff (Fig. 3). This correlation is merely postulated because these fragments are the next terrace above BOP3, and both have possible Kauroa Ash at the base. Such older terraces are unclear in the Maketu–Matata area, due to the great thickness of Little Waihi Formation and all younger tephras in that region. Additionally, the coast-parallel cliffs from Pukehina to Matata (Fig. 2A) truncate the Upper Pleistocene coast, eliminating many developments of BOP2 and 3, and probably BOP4, that may have existed in that area.

In the Bay of Plenty area there is at least one pre-Holocene terrace younger than BOP2. This is well developed in tributary valleys of the Pongakawa swamps (south of Little Waihi headland), and as small within-valley terraces in Pikowai and Mimiha Streams (Fig. 2A). The terrace is fluviatile, constructed of bedded sands and gravels, and passes beneath Pongakawa swamp with a gradient of 3°. It is overlain by Mangaone Lapilli but not by Rotoehu Ash, and thus its age is firmly bracketed between 28 000 and 42 000 years B.P. (ages of tephras from Pullar & Heine 1972).

Correlation of Bay of Plenty coastal terraces with those elsewhere in the northern part of the North Island is complicated by warping around the Bay of Plenty itself, as evidenced by BOP2 and BOP3.

TERRACES OF THE WEST COAST

North of Taranaki

A striking characteristic of terraces bordering the west coast of Auckland–Northland Provinces is their apparent constancy of elevation, for more than 200 km. Brothers (1954) describes a flight of six coastal Pleistocene terraces in the South Kaipara district, with their surfaces at approximately 8, 20, 40, 70, 110, and 170 m (all heights previously reported in feet and here converted to metres). The 20, 40, and 170 m terraces are shown by Brothers to represent culminations of substantial marine transgressions.

From the south-west Auckland coastal region I have described terraces at very similar elevations, and showed that all except the 8 m terrace developed at culminations of major marine transgressions; these were correlated with the Kaipara terraces (Chappell 1970). Between south-west Auckland and Kaipara lie the Manukau Harbour lowlands, beneath which the Lower Pliocene (Opoitian) beds are depressed about 30 m compared with their position in south-west Auckland (see Laws 1940; 1950). Whether this relative warping continued into Pleistocene times cannot be determined from the data given by Brothers (1954) or Chappell (1970).

Valid correlation of these west coast Pleistocene terraces with those of the Bay of Plenty is not simple. General stratigraphy and morphology of the flights differ between the two areas. In the east only BOP2 and BOP3 are widespread and relatively undissected, and the sub-tephra erosion surfaces of both these are less than 12 m a.s.l. in north and central Bay of Plenty. Contrasting are the west coast terraces, where the lower terraces (8 m and 20 m) are not extensive by comparison with the higher 40, 70, and 110 m surfaces. Thick transgressive littoral, eolian, and shallow marine sequences built the west coast terraces, and several periods of mantling dune sands are widespread.

Application of the tephra stratigraphy is not straightforward for correlation between the east and west coasts. Air fall of the important Upper Pleistocene tephras (Rotoehu Ash and Mangaone Lapilli) appears not to have extended west of the Hamilton lowlands (Vucetich & Pullar 1969). Only the brown tuffs of the Hamilton and Kauroa Ash Formations appear to cross the island, and accounts of their relationships with the west coast terraces are contradictory. Evidence presented by Schofield (1958) suggests that Hamilton Ash is younger than the 40 m terrace of south-west Auckland. The Hamilton Ash Formation overlies the Franklin Basalts, which in turn appear to overlie a terrace at about 40 m near Pukekohe. Ward (1967; 1972) argues that Hamilton Ash is older than the 40 m terrace, noting that it occurs beneath alluvium which forms an extensive 40 m terrace around the

Te Kawhata area. The localities discussed by Schofield and by Ward are 40–50 km apart, and whether the terraces referred to are related to the same former sea level is unclear. Waterhouse (1967) reported a red-brown ash overlying a 35 m terrace at the nearby Kellyville tuff ring, but this was re-examined by Ward (1972) who discounted it as Hamilton Ash.

The disparity between Ward's evidence and Schofield's for the relationship of Hamilton Ash to the 40 m coastal terrace of south-west Auckland, cannot be resolved from their papers. Nor can it be resolved from my accounts of the coastal terraces themselves (Chappell 1964; 1970); undifferentiated brown tuffs occur both within and overlying the sediments building the 110 m and 70 m terraces, and also over eolian sands which themselves post-date dissection of the 70 m terrace (Chappell 1964, pp. 71–82). The only conclusion that may be drawn is that the Hamilton Ash and Kauroa Ash Formations are older than the 20 m west coast terrace, and are in part, at least, older than the 40 m terrace.

The problem of correlating Bay of Plenty and west Auckland coastal terraces is now clear. The Athenree Terrace of Kear & Waterhouse (1961), (i.e., BOP4? of the preceding section) has its sub-tephra erosion surface at 11 m a.s.l., at the section measured by Selby *et al.* (1971). Kear & Waterhouse (1961; 1971) suggest that this terrace is the equivalent of that at about 20 m around Kaipara, on altimetric grounds. However, if the brown tuffs on the Athenree terrace are Hamilton and Kauroa Ashes, as Selby *et al.* (1971) suggest, then it is equivalent to either the 40 m terrace or the 70 m terrace on the west coast. Further discussion of this matter, and of the implied Pleistocene tilting across the Island, is deferred until later in the paper.

Taranaki and Wanganui

Pleistocene sediments and associated terraces in the Taranaki coastal area are discussed by Henderson & Ongley (1923), and are more fully described in Chappell (1964). These formations are mapped by Hay (1967), who extends the Pleistocene terrace formations defined in the Wanganui Subdivision by Fleming (1953). The north Taranaki terrace sequence is critical for the task of tracing the terraces of south-west Auckland through to the raised and warped terraces of Wanganui.

The long straight coast of north Taranaki, running north from White Cliffs (N100/100160; north of Urenui) to beyond Awakino, is characterised by a narrow coastal plain bounded by sea cliffs 20–50 m high, and buttressed on the inland side by higher dissected cliffs and narrow but clear terrace remnants. Further north, between Tirua Point (north of Waikawau) and Kawhia Harbour where the coast is developed in Mesozoic rocks, terrace remnants are scattered and indefinite, and direct tracing through from Taranaki to south-west Auckland is, therefore, difficult. Southwards from White Cliffs, the coastal plain and higher terraces broaden and pass into the more complex stratigraphy of the Egmont volcanic ring plain (Hay 1967; Grant-Taylor 1964.) From the Egmont area south-east into Wanganui the Pleistocene terraces are not simple structures representing different culminations of glacio-eustatic sea-level rise, but are more complex, incorporating cycles of sediments passing from warm climate and high relative-sea-level deposits, through cool climate and low sea-level terrestrial sediments, and back to warm climate high sea-level deposits (see Fleming 1953, pp. 262–78, "Rapanui Formation").

The narrow coastal plain of North Taranaki, generally 25 m to 45 m a.s.l., provides evidence which allows stratigraphic correlation with Wanganui terraces. This coastal plain is built of fluvial, littoral, and eolian sediments, together with minor peats and mantled overall by brown tuffs; these deposits overlie a cut surface which rises 40–42 m at its near margin. Figure 4 shows representative sections, which indicate two phases of terrace building. Valleys cut through the basal erosion surface and passing below sea level indicate a low relative sea level subsequent to cutting of the surface at 42 m. For convenience, this earlier phase will be referred to as **NT3 (North Taranaki 3)**; remnants of estuarine and fluvial deposits associated with its formation and with the subsequent regression are sometimes present (e.g., Fig. 4A). Younger littoral and estuarine beds, filling the cuts and valleys in NT3, rise to 20 m and are mantled by dune sands capped by weathered basic ashes and by extensive landslide debris (Fig. 4A–C).

The younger deposits building the north Taranaki coastal plain will be referred to as **NT2**. Palynologic determinations for four samples from peats within NT2 may be summarised as "rimu dominant assemblages, characteristic of warm maxima and adequate rainfall . . . the forest is suggestive of coastal or semi-coastal conditions" (W. F. Harris *in* Chappell 1964; these palynological determinations are listed in the appendix to this paper).

North of the White Cliffs, NT2 deposits dominate the coastal plain; in the Urenui area immediately to the south, the terraces broaden and NT2 becomes subordinate to NT3 (Fig. 4D). Tracing the terraces from this area through the Egmont ring plain to the Wanganui standard succession appears relatively straightforward. In the Taranaki area, Hay (1967) correlates the terrace and associated deposits here called NT2 with the Rapanui Formation of Wanganui (Fleming 1953) and NT3 with Ngarino Formation (the latter Formation was not named in Wanganui by Fleming 1953, but has subsequently been recognised there; Grant-Taylor 1964 and per. comm.; Dickson *et al.* 1974). In accepting these stratigraphic identifications, it is important to recognise that the north Taranaki cut surfaces and overlying littoral and estuarine beds correspond only to the warm climate, high sea-level parts of the Upper Pleistocene formations to Wanganui. To illustrate, southward tracing from Awakino of the littoral beds of NT2 indicates that these correspond to the fossiliferous Rapanui marine sand outcropping in sea cliffs near Hawera (Fig. 4), which in turn continues south-east into the Wanganui Subdivision. However, the thick overlying cover of Rapanui Formation terrestrial beds in this southern area (Fleming 1953), which contain palynologic evidence for cool climates (Grant-Taylor pers. comm.), is unimportant in north Taranaki.

Higher terraces in north Taranaki are fragmentary to the extent that connections through to Wanganui has not yet been traced confidently. Figure 5 summarises the evidence and indicates that the Brunswick Formation of Wanganui has been recognised as far north as Urenui by Hay (1967). Further north, slumping of soft Upper Tertiary sediments has all but eliminated traces of the older terraces.

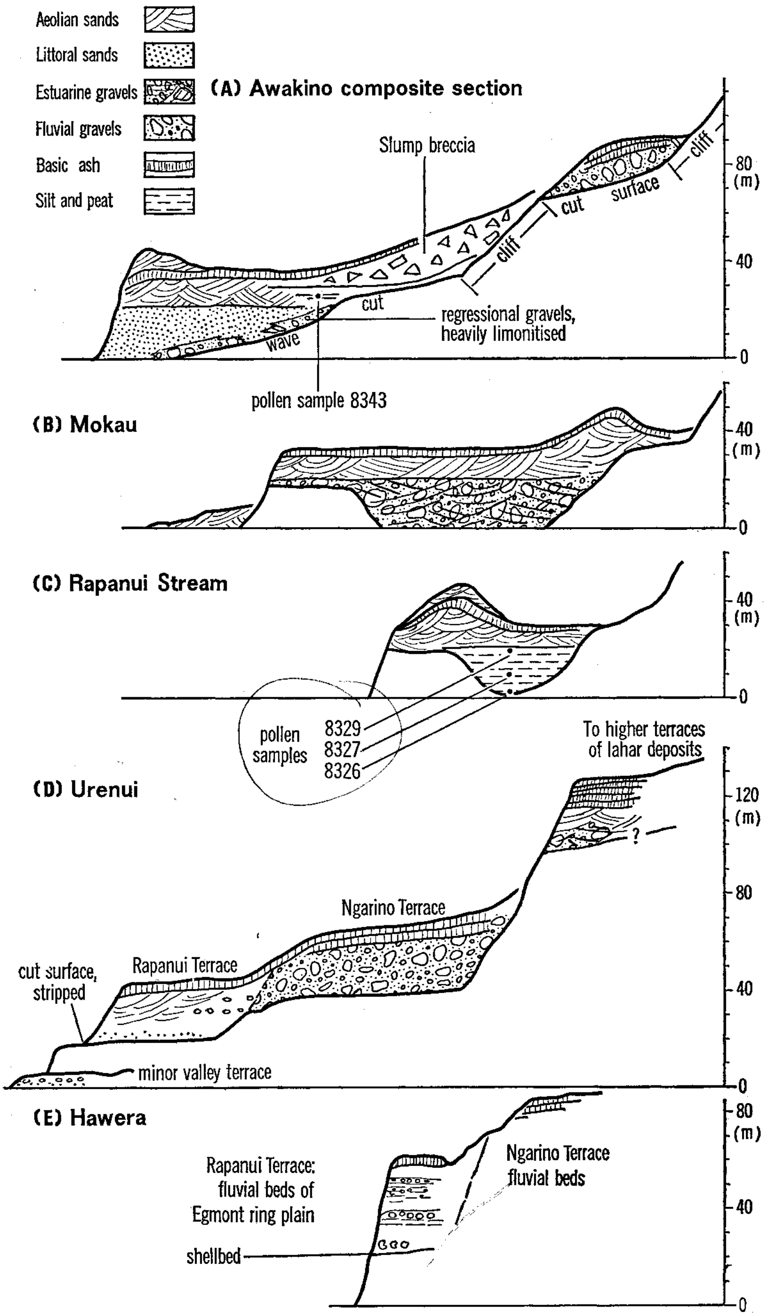

FIG. 4—Sections of the lower terraces in North Taranaki, especially correlatives of the Rapanui and Ngarino Terraces of Wanganui.

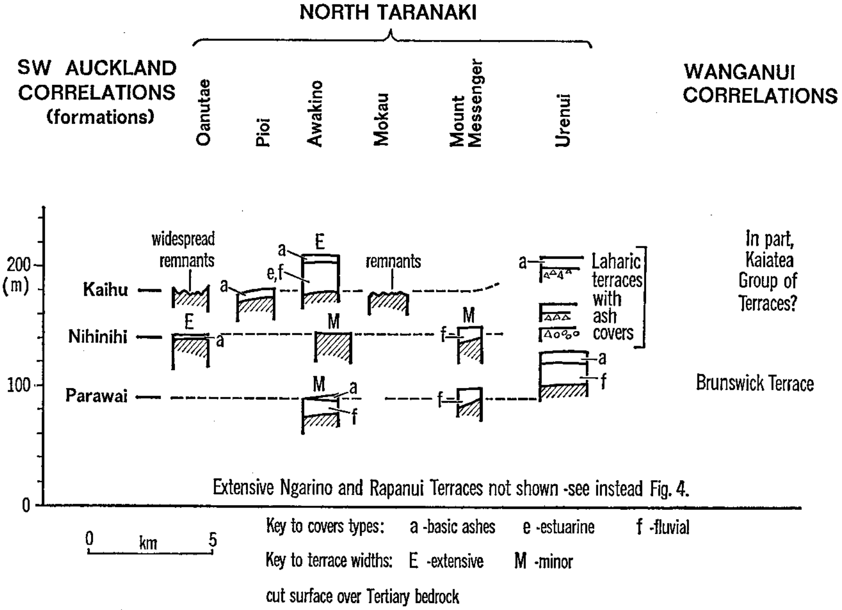

FIG. 5—Fragmentary evidence of higher terraces in north Taranaki, and suggested correlations with south-west Auckland and Wanganui.

Figure 5 indicates that Upper Pleistocene warping parallel to the coast has been only slight in Taranaki. The terraces become warped as they pass into the Wanganui Subdivision, especially in a direction normal to the coast, as is well described by Fleming (1953). To the north of Taranaki, identification of any differential movements rest on successful correlation of terraces through to south-west Auckland.

CORRELATION OF COASTAL TERRACES IN TARANAKI, SOUTH-WEST AUCKLAND, AND BAY OF PLENTY*

The Problem

The fact that coastal terraces of Auckland Province cannot be traced directly through to Wanganui underlies the past tendency of Auckland geologists to refer terrace correlations to the South Kaipara successions described by Brothers (1954), who in turn made altimetric correlations with European interglacial terraces, as synthesised by Zeuner (1959). As a consequence there is a tendency in the New Zealand literature to refer to

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*Grant-Mackie (1972) also discusses correlation of Bay of Plenty terraces.

terraces of the Auckland Province by Mediterranean names, rather than in New Zealand time-stratigraphic terms. Even if such international correlations were tenable—itself extremely unlikely (discussed below)—such a practice not only inhibits development of regional time stratigraphy, but also reinforces the dangerous tendency to make altimetric correlations between terraces within New Zealand (this latter pitfall has been discussed above).

The problem of correlation between coastal terraces of Taranaki, south-west Auckland, and Bay of Plenty can be potentially resolved by tephrochronology. The critical tephra relationships, yet to be determined, are between the Hamilton Ash Formation of the Waikato Basin (Ward 1967) and the numerous tuffs overlying the Urenui flight of terraces (cf. Fig. 4). Without this key, tentative correlation might be essayed in terms of succession of transgression–regression cycles, counting back from the present. On this basis, I correlated (Chappell 1970) the deposits underlying the 20 m terraces of south-west Auckland (Waiau B Formation) and Kaipara (Waioneke Formation), with the Rapanui Formation of Wanganui. Similarly, those underlying the 40 m terrace (Waiau A and Shelly Beach Formations) were correlated with the Brunswick Formation. In suggesting this latter equivalence, I erred by not taking into account the Ngarino transgression–regression cycle; this is probably the most likely correlative of the 40 m terrace formations of south-west Auckland and Kaipara.

Although backward counting of such transgression–regression cycles is an appealing basis for correlation, differential tectonic movements affect the record in such a way that this method can be as unreliable as altimetric correlation, as the following discussion shows.

Relationship between Coastal Terrace Flights and Dated Quaternary Sea-Level Oscillations

Until the last decade, syntheses of Quaternary sea-level changes of the sort advanced by Zeuner (1959), or Fairbridge (1962), were widely regarded as providing the frame of reference for interpreting coastal terrace flights. These schemes took their time scales from the Milankovitch astronomical curves (Zeuner), or correlations made with dated deep-sea cores (Fairbridge), and both incorporated the widely held idea of progressive lowering of Quaternary interglacial sea levels. Although criticised by Cotton (1963), Russell (1964), and others, it is the advent in the current decade of widespread dating of coral reef terraces by $^{230}Th/^{234}U$ which has proven the obsolescence of the earlier syntheses. A reference sea level of +6 m between 120 000 and 125 000 years B.P. has been established by dated shore lines in widely separated areas remote from plate boundaries, such as Bermuda, Bahamas, Florida, Seychelles, Mauritius, Western Australia, and various Pacific Islands (reviewed *in* Chappell 1974b and Bloom *et al.* 1974).

Such stable areas do not provide records of Quaternary sea-level oscillations, which instead are to be found in those rapidly rising areas where coastal processes are conducive to the positive recording of every relative sea level change. The best evidence known so far is at Barbados (Broecker *et al.* 1968; James *et al.* 1972; Steinen *et al.* 1973) and Huon Peninsula, New Guinea (Veeh & Chappell 1970; Chappell 1974b; Bloom *et al.* 1974). The New

Guinea record is the better of the two, showing relatively high sea levels dated at 5, 28, 42, 60, 84, 106, 118–125, 140, 170, 220, and 240 thousand years, with several higher terraces as yet not well dated. From these two areas, estimates of former sea levels have been made by the workers cited, based on numerous surveyed traverses of the terrace flights and using the 120 000 year, +6 m reference bench mark together with certain tectonic assumptions. The results given by Chappell (1974b) are founded on a constrained non-uniform uplift assumption; those given by other authors from New Guinea (Bloom *et al.* 1974) or Barbados (Broecker *et al.* 1968) are based on the assumption of uniform uplift rate at any given traverse. The justification of the latter assumption, which neglects tilting normal to the coast, is that most of the definitive traverses are short (less than 2 km), and there is no strong evidence for such tilting at the selected sections. Resultant estimates of former sea levels by these different authors are similar, and for those terraces common to Barbados and New Guinea, viz., the 60, 84, 106, and 125 thousand year terraces, the associated sea-level estimates agree within 4 m (Bloom *et al.* 1974), and there is, therefore, a firm basis for confidence in the results. The New Guinea sea-level curve for the past 250 000 years is shown in Fig. 6.

A striking feature of Fig. 6 is that, of the eight major regression–transgression cycles shown, only those culminating around 210–220, 125, and 6 thousand years achieve the datum of present sea level. The implication for our earlier argument, concerning correlation by counting back from the present is clear: the number of cycles potentially recordable increases with the rate of uplift. Thus, the number of cycles identified in New Guinea is greater than Barbados, because maximum uplift rates are greater by an order of magnitude.

In addition to considerations of uplift versus sea-level change, the potential for recording any oscillation varies with the magnitude and duration of the oscillation itself. On actively prograding coasts, such as coral reef or deltaic areas, the potential is high for recording even small oscillations, as long as uplift rates are high. (Both of these types occur in New Guinea, giving the detailed record of Fig. 6; see Chappell 1974b.) Contrasting are cliffed coasts fringed by wave-cut platforms; here the recording potential is much lower, so that only those major transgressions followed by more prolonged relative stillstands are likely to be recorded. Such a situation, on a rapid uplift coast, is found around Cape Turakirae at the southern end of the growing Rimutaka Range, New Zealand (Fig. 1). Here, the later Flandrian Transgression is represented by a broad platform mantled by coarse boulder beach ridges, behind which rise high dilapidated cliffs, with high-level benches at about 130 m and 250 m (described by King 1930, and Wellman 1969). These high surfaces probably represent major deglaciation transgression–interglacial "stillstand" events and are possibly the same events represented by the very broadest reef terraces in New Guinea.

Discussion: Tentative Correlation of Selected Terraces, and Implied Pattern of Warping

For correlation from Wanganui and Taranaki through to south-west Auckland, the Ngarino–Rapanui Formations are the initial key. The maximum heights of the associated strandlines run at 40–42 m and 18–20 m,

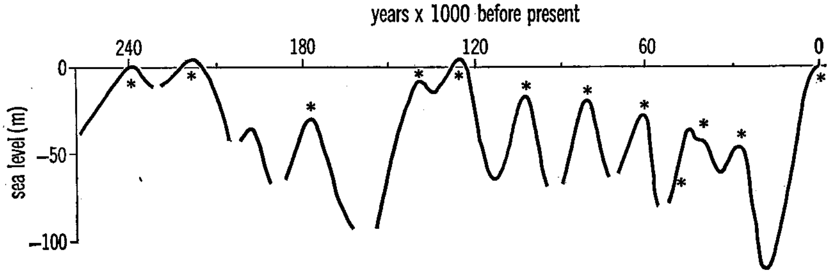

FIG. 6—New Guinea sea-level curve for last 250 000 years. Every oscillation is identified stratigraphically (from facies geometries within separate raised reefs) and every point marked "*" is dated by several reproducible $^{230}Th/^{234}U$ dates (curve from Chappell 1974; Bloom *et al.* 1974).

respectively, from Kai Iwi beach near Hawera northward to Awakino (Figs 1, 4). Farther north, remnants of a cut surface at 35–40 m occur near Waikawau, Marakopa, and Taharoa (Fig. 1); this is assumed to be the wave-cut bench beneath the Ngarino Formation. The 40 m strand maximum of the Waiau B deposits of south-west Auckland is thus correlated with the Ngarino, and Waiau A (20 m) with the Rapanui Formation. If correct, this correlation implies an absence of post-Ngarino differential movement along the entire west coast from Hawera to south-west Auckland and thence to Kaipara. Correlation of the Brunswick Terrace in north Taranaki (strand maximum, 70–75 m; Fig. 5) with the Parawai Formation and associated terrace in south-west Auckland (strand maximum, 66–68 m; cf. Chappell 1970) is consistent with this lack of movement.

The problem of correlation between south-west Auckland and the Bay of Plenty has been outlined above. If the identification of Hamilton Ash in the Bay of Plenty by Vucetich & Pullar (1969) and Selby *et al.* (1971) is correct, then the evidence of Ward (1967; 1972) strongly suggests that BOP2 is equivalent to the 40 m terrace of south-west Auckland, as both apparently immediately post-date the Hamilton Ash Formation. Terrace BOP3 is thus the apparent correlative of the 70 m south-west Auckland terrace. The full set of suggested equivalences are: (a) BOP2—Shelly Beach Formation—Waiau A Formation—marine component of the Ngarino Formation; and (b) BOP3—Parawai Formation—marine component of the Brunswick Formation. An apparent problem, in the raised eastern Bay of Plenty, is the absence of a clear counterpart of the 20 m west coast terrace (Waioneke—Waiau B—marine Rapanui). This may reflect the fact that the sub-Ngarino wave-cut bench is very much more extensive, in north and south Taranaki, than cut surfaces associated with the Rapanui phase.

The pattern of deformation supports this correlation. In the Wanganui area, the Rapanui and Ngarino Formations cohere as a pair (and were undifferentiated by Fleming 1953), and thus appear relatively closely associated in time. The relative deformation of the Brunswick Terrace, however, is approximately double that of the Rapanui—Ngarino association (cf.

Fleming 1953). The same doubling relationship of relative deformation holds between BOP2 and BOP3, as they approach the high uplift area at East Cape (Fig. 3).

It is possible now to relate these two major periods of terrace formation to the "absolute" sea-level curve of Fig. 6. It was argued above that major cut platforms are developed during the major transgression-plus-stillstand events. The last such event prior to the Holocene terminated 120 000 years ago, with absolute sea level at +5 ± 3 m (Fig. 6). The hypothesis that this represents the 40 m west coast terrace may be checked as follows. The implied uplift rate is (40−5)/120 = 0·3 mm/year. The absolute sea levels at 104 000 and 83 000 transgression maxima are −14 m and −15 m respectively. Thus at 0·3 mm/year, these two peaks should be represented by terrace strandlines at (104 × 0·3)−14 = 17 m, and (83 × 0·3)−15 = 10 m. These values are very close, respectively, to the 18–20 m strand height of the Waiau B—Waioneke terrace, and the 10 m estimate for the unamed lower terrace of Kaipara and south-west Auckland.

The hypothesis appears to be supported that the 40 m west coast "Ngarino" terrace is about 120 000 years old. However, other alternatives must be checked. These are the possibilities that the 120 000 termination is represented either by the 20 m "Rapanui" terrace, or by the small unnamed 10 m terrace. These are eliminated, as follows:

(1) If the 20 m terrace = 120 000 years, then uplift rate ≃ (20 − 5)/120 = 0·12 mm/year. At this rate, the projected height of the 104 000 peak is (104 × 0·12)−14 = −2 m. The clear though small 10 m terrace is thus unexplained by this hypothesis.

(2) If the 10 m terrace = 120 000 years, then uplift rate is [10 − (5 ± 3)]/120 = a maximum estimate of 0·07 mm/year.

This would imply that the Parawai—Brunswick terrace at 70 m is about 1 million years old, presuming that it formed at a sea level similar to the present. The age of the Brunswick Formation is known to be significantly less than 0·4 m.y., however, because it is younger than: (a) the Castlecliffian stage, the top of which is fission-track dated at 0·37 ± 0·6 m.y. by Seward (1973); and (b) the Kaiatea terraces of Wanganui, which are equivalent in age to the Kaitake volcanics dated at 0·5 m.y. by Stipp (reported *in* Chappell 1968).

In the light of these points, the hypothesis is adopted that cutting of the Ngarino Terrace terminated a 120 000 years B.P., and that the Brunswick Terrace is about 220 000 years old. The foregoing discussion is conveniently summarised in Fig. 7, which shows the relationship between uplift rate and the heights of terraces formed at the principal sea-level maxima of Fig. 6. The terraces associated with the major transgression culminations of 125 000 years B.P. and 220–240 000 years B.P. are shown in heavy shaded bands, to emphasise that these are likely to be larger features than terraces developed at the other, lesser, transgression peaks. It can be noted that the first high-level bench at Turakirae, at 120 m, is the logical correlative of Ngarino bench, and that Wellman (1969) estimated its age at "about 100 000", by extrapolating his estimates of Holocene uplift in the area.

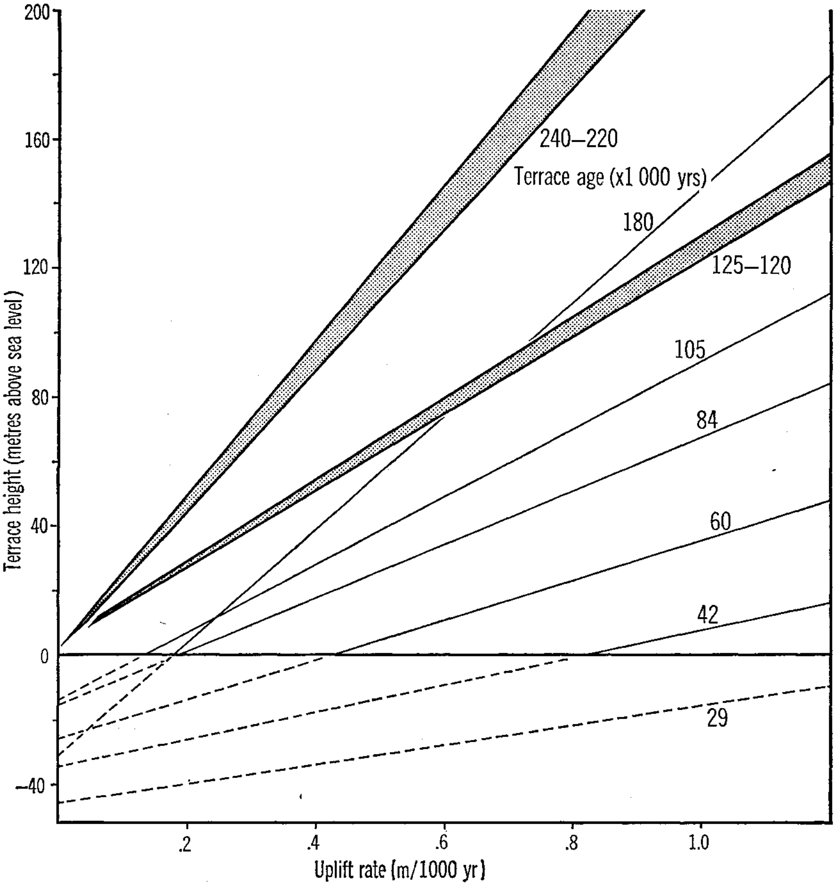

FIG. 7—Relationship between uplift rate and heights of terraces formed at the major sea-level maxima shown in Fig. 6. Terraces associated with culminations of major transgressions at 125 000 years and around 240 000 years are shown as broad bands. Dashed lines indicate that the transgression peak will be recorded as a buried surface, if at all.

Certain implications of these age assignations must be discussed. Firstly, the age of the Hamilton Ash Formation must be between 120 000 and 210 000 years B.P. This disagrees with Ward (1972), who suggests an age between 0·38 m.y. and 0·76 m.y., on the basis of certain international altimetric correlations for the west coast 40 m and 70 m terraces. Ward's argument can be faulted in two particulars.

(1) He accepts an uplift rate of zero on the basis of an alleged international correlation supporting a sea level of about +3 m at around 30 000 years B.P. All cases suggesting this event have been closely examined in an important review by Thom (1973) and shown to be deficient either in stratigraphic control, or certainty of ^{14}C dating, or both. This putative event is discredited by the careful ^{230}TH/^{234}U dating of raised coral reefs in New Guinea and Barbados (see Fig. 6), and in the fast-rising Ryukyu Islands (Konishi *et al.* 1970; 1974).

(2) Ward supports his age estimate for Hamilton Ash by correlating it with the 0·67 m.y. ash layer C in oceanic cores taken east of New Zealand (Ninkovich 1968). This correlation cannot be substantiated. In the cores close to north-east New Zealand only ash layer E (0·27 m.y.) occurs.

The second implication of the age of 120 000 for termination of Ngarino Terrace cutting arises from the implied uplift rate of 0·3 mm/year for the west coast. At this rate, the ages of the transgressions represented in south-west Auckland by the Nihinihi Formation (highest strand at 100 m; Chappell 1970), and the uppermost Kaihu Formation (highest strand at 155 m), are respectively about 0·37 m.y. and 0·5 m.y. This is consistent with these transgression maxima being correlated with the Kaiatea Group of Terraces in Wanganui, a correlation consistent with the Parawai—Brunswick and Ngarino—Waiau A equivalences. A new perspective on the Kaihu Formation emerges. The lower part of this Formation previously has been regarded as Nukumaruan (Lower Pleistocene) (Kear 1957; Chappell 1970). If the top is Kaiatea equivalent, then the Kaihu Formation spans Nukumaruan to Upper Castlecliffian (Middle Pleistocene) time, and should contain evidence of the cold Okehuan. Although such was not discerned in the pollen analyses from the Formation by Harris (*in* Chappell 1970), at least one and possibly three reversals in the general Kaihu transgression have been noted (Chappell 1964; 1970, p. 140). Closer study of this Formation would be useful.

The final implication of the correlations presented here concern a differential uplift around the North Island coast. Figure 8 summarises the proposed correlations and inferred uplift rates. The most interesting feature is the contrast between the very uniform uplift of the west coast, as against the upwarping eastwards from the Bay of Plenty basin. The west coast line of uniform uplift, north from Hawera, traverses zones which underwent substantial differential uplift after Southland (mid-Miocene) times. Minor differential movement, north of the deformed Wanganui basin area, is indicated by the correlatives of the highest Kaiatea terrace; apparently this variability had declined by Terangian times. It is interesting that commencement of steady emergence of the west coast, after termination of the Kaihu transgression, was synchronous with final diminution and emergence of the Wanganui marine basin. The uniform epeirogenic uplift of the west coast, over a distance of at least 350 km, cannot be caused by emergence of

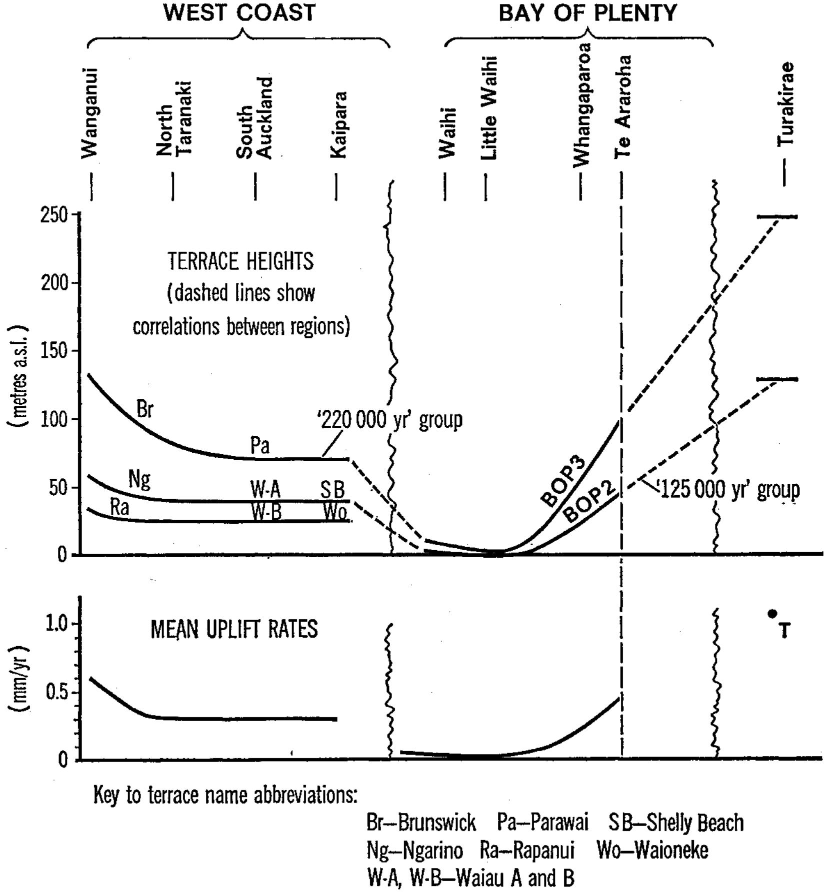

FIG. 8—Deformation and uplift rates for the west coast and Bay of Plenty.
(*For* Te Araroha, *read* Te Araroa.)

Wanganui, for such would imply an abnormally high flexural rigidity of the lithosphere. Rather, emergence of both must have a common deep tectonic cause. Analysis of this and of the Bay of Plenty deformation, by geophysical means such as are given in Walcott (1970) and Chappell (1974a), is the subject of a separate paper (in preparation).

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APPENDIX

PALYNOLOGIC DETERMINATIONS FROM NORTH TARANAKI RAPANUI TERRACE

W. F. HARRIS

Pollen and spore counts are given for each of the four samples located in Fig. 4. The data are based on preparations made at Auckland University by J. Chappell and originally reported in Chappell (1964). The samples are now with the N.Z. Geological Survey, Lower Hutt.

	N.Z. Fossil Record File Numbers			
	8326	8327	8329	8343
	Sample Grid References (Sheet N100)			
	135241	135241	135241	175412
Determinations	Counts			
FERNS				
Gleichena sp. *circinata* type			3	
Dicksonia squarrosa (Forst.f.) Sw.	5	7	10	
Total *Cyathea*	314	499	303	15
Phymatodes diversifolium (Willd.) Pic.Ser.	3			3
Histiopteris incisa (Thumb) J. Smith		2	1	
Paesia scaberula (A.Rich.) Kuhn	2			
Unidentified ferns	17	14	3	1