1.3.2 Airfall tephra deposits and sea-rafted pumices

Volcanic activity since Miocene time has deposited material in the Tauranga Basin in the form of rhyolitic flows and unwelded tephras (Davies-Colley 1976).

Airfall tephras of Holocene age are widespread in the Western Bay of Plenty (Froggatt and Lowe 1990; Wigley 1990). Two previously recorded on Matakana Barrier are "Taupo Lapilli" and "Kaharoa Ash" (Dahm 1983; Harmsworth 1983; Munro 1994), and we provisionally record the Stent tephra (Alloway *et al.* 1994).

Tephras are derived from relatively short-lived events and therefore make good marker horizons for correlation and dating. However, the tephra deposits are patchy and often difficult to find on the island because of the history of Maori gardening and forest disturbance and, possibly, a longer history of tree throw. Maori gardening characteristically mixes Taupo Lapilli and Kaharoa Tephra into the soil together with shells and charcoal, destroying the tephra stratigraphy. In more recent times, v-blading for forestry has had an even more devastating effect (Sutton 1994).

The provisionally-identified Stent tephra is found at only two places on the barrier. The Taupo Lapilli and Kaharoa Tephra (Froggatt and Lowe 1990) are relatively widespread on the barrier, and because the barrier has a more or less steadily prograding shoreline, the seaward boundaries of the two tephras give a reasonable indication of the shoreline at the time of their eruption.

Stent tephra (Alloway *et al.* 1994) occurs as a yellowish-coloured deposit less than 1 cm thick. It has a mean radiocarbon age of c. 3970 ± 31 yr BP (Alloway *et al.* 1994); which gives a calibrated age of 4520-4300 cal BP. Our adopted age is 4450 cal BP.

Taupo Lapilli is part of the Taupo Tephra Formation (Froggatt and Lowe 1990). It ranges up to c. 8 cm in thickness, is mauve in colour, with abundant pumice lapilli up to c. 1.5 cm in diameter. The mean radiocarbon age for the Taupo Tephra Formation is 1850 ± 10 yr BP (Froggatt and Lowe 1990); which gives a calibrated age of 1815-1725 cal BP. Our adopted age is 1750 cal BP.

Kaharoa Tephra (Froggatt and Lowe 1990) is a basal unit of pumiceous sand c. 3 cm in thickness containing rare lapilli, overlain by a fine, powdery white ash. The tephra varies in thickness from 6 cm to c. 20 cm. It can be identified by its characteristic biotite-rich ferromagnesian assemblage (Pullar *et al.* 1977). We adopt a calibrated age for Kaharoa Tephra of 600 cal BP (D.J. Lowe, pers. comm.).

Sea-rafted pumices disperse quickly and are washed up on beaches soon after their eruption (Coombs and Landis 1966). Identification of primary sea-rafted deposits is always uncertain because all sea-rafted deposits are subject to possible reworking. Nevertheless, they do provide maximum ages for stratigraphically younger deposits.

Sea-rafted pumice deposits useful for correlation on Matakana Barrier are the Waimihia, Taupo and Loisels pumices. None of the three pumice deposits are independently dated, but each occurs in quantity as a pure deposit, and is in its correct stratigraphy order with respect to the others and to the airfall tephras. Taupo Pumice is on the seaward margin of the distribution of Taupo Lapilli on the Relict Foredune Plain (see section 2.2), and Loisels Pumice is on the seaward edge of the Purakau Shoreline (see section 2.2) which post-dates Kaharoa Tephra; the pumices were therefore probably washed ashore not long after they were erupted.

Waimibia pumice is part of the Waimihia Tephra Formation (Froggatt and Lowe 1990). The pumice occurs as rounded clasts up to 5 cm in diameter and was identified by Dr. P. Froggatt, Victoria University, Wellington. It has a mean radiocarbon age of 3280 ± 20 yr BP (Froggatt and Lowe 1990), which gives a calibrated age of 3565-3460 yr BP. Our adopted age is 3500 cal BP.

Taupo Pumice is part of the Taupo Tephra Formation (Froggatt and Lowe 1990). The pumice appears as rounded clasts up to 20 cm in diameter. Its adopted age is 1750 cal BP.

Loisels Pumice (Wellman 1962) is from an unknown source. The pumice occurs as rounded clasts up to 15 cm in diameter. It has a calibrated age range of 660-510 cal BP (McFadgen 1994). Following McFadgen (1994) we adopt an age for the pumice of 590 cal BP.

2. Matakana Island geomorphology

2.1 LANDFORMS OF MATAKANA CORE

2.1.1 Pleistocene terraces

Matakana Core comprises Pleistocene terraces (Fig. 4) mantled with volcanic deposits. Marine deposits exposed in a cliff at Flax Point (Fig. 4) on the harbour side of the island are about 1 m above present sea level, and underlie at least ten metres of tephra and pyroclastic flow material. It appears likely that all terraces of Matakana Core are underlain by marine deposits.

Interglacial relict foredune plain

The lowest Pleistocene terrace is present on both Matakana and Rangiwaea Islands. It appears to have originated as a coastal strandplain in the same fashion as the Holocene barrier to seaward. Its original topography is subdued by Late

FIGURE 4. MAP OF MATAKANA AND RANGIWAEA CORES SHOWING MAIN PLEISTOCENE GEOMORPHOLOGICAL FEATURES. HEAVY DASHED LINE IS THE RELICT PLEISTOCENE MARINE CLIFF. NUMBERS 1-5 ARE WELL-HEAD LOCATIONS. H HIGHER PLEISTOCENE TERRACES; L = LOWEST PLEISTOCENE TERRACE (INTERGLACIAL COASTAL PLAIN SHOWING RELICT FOREDUNE TRENDS); P = PLEISTOCENE PARABOLIC DUNES; BGB = BLUE GUM BAY SECTION.

Pleistocene tephra. Well logs and a section at Blue Gum Bay (GR NZMS 260 U14802987) indicate more than 10 m of tephra overlying sand. The terrace surface is between *c.* 8 m and 10 m above present sea level, and the original surface below the cover beds is at or below sea level. Old ridges and swales aligned roughly parallel to the riser of the older terrace, and to the trend of the present ocean shoreline (Fig. 4), are clearly discernable from the air (Fig. 5, see page 43) and have influenced the development of drainage patterns on the terrace.

We tentatively correlate the lowest terrace with the "BOP2" terrace of Chappell (1974) on the basis of the elevation of its underlying surface (Table 2). The terrace probably formed during the Last Interglacial sea level maximum of c. 125 000 years BP (Chappell 1974), but in view of the thickness of its tephra cover, a greater age cannot be discounted.

Last Interglacial sea level stood c. 4 m to 6 m above present sea level (Roy and Thom 1981; Gibb 1986). Well log data (Table 2) shows the sand surface of the interglacial coastal plain to be now as much as 3 m below present sea level. The average elevation of the Holocene barrier is about 6 m and if of Last Interglacial age, the Pleistocene sand surface would therefore have been about 10 m to 12 m above present mean sea level (the elevation of the Holocene barrier added to the height of the Last Interglacial sea level maximum). For the last 125 000 years, a maximum mean subsidence rate of between 104 mm and 120 mm/1000 years is therefore indicated.

Relict Pleistocene transgressive dunes

Large relict transgressive dunes mantled by Pleistocene tephra occur on the Lowest Pleistocene terrace at Blue Gum Bay (Fig. 6, see page 43) and at Opureora. Their similar orientation to the Holocene relict parabolic dunes indicates that the interglacial wind directions in this region were probably similar to those of the Holocene.

TABLE 2. WELL-HEAD ELEVATIONS, THICKNESSES OF TEPHRA COVER DEPOSITS AND ELEVATIONS OF UNDERLYING SAND SURFACES FOR THE WELLS LOCATED IN FIG. 4.

Source: S. Halliday, Whakatane Regional Council, pers. comm. 1995; M. Carlyle, well driller, pers. comm. 1995.

WELL ID (FIG. 4)	NZMS 260 GRID REFERENCE*	ELEVATION ABOVE MEAN SEA LEVEL (m)*	TEPHRA THICKNESS (m)	ELEVATION OF UNDERLYING SAND SURFACE (m)
1	U14 798968	15.1	12.2	2.9
2	U14 824946	8.5	*c.* 20.0**	*c.* -11.5**
3	U14 824942	11.0	*c.* 12.0	*c.* -1.0
4	U14 819940	12.4	13.0	-0.6
5	U14 817932	10.8	14.9	-4.1

Footnotes:

NZMS 260 grid references and elevations for the well heads were obtained by use of a Trimble Pro-XI. GPS system.

Tephra thickness at well 3 is provisional on account of possible inaccuracies in available well log data.

2.2 LANDFORMS OF MATAKANA BARRIER

Matakana Barrier is an accumulation of coastal sediments, predominantly sand, which has prograded seaward from the earliest Holocene shoreline cut into the Pleistocene cores of Matakana and Rangiwaea Islands, and from a washover ridge southeast of Katikati Entrance (Fig. 7). It is characterised by a series of relict foredunes cut off from the beach as the shoreline prograded, and by relict transgressive sand dunes which formed as a result of erosion of the relict foredunes. The main part of the barrier is a relict foredune plain which shows no visible evidence for any major reversal of steady progradation from the time of its initial formation to the present day, but landforms at each end of the barrier, where the progradational history is more complex, have different characteristics. The *Northwestern End* (Fig. 7) is lower, contains wetlands, and has many ridges which often converge and diverge reflecting past changes in the outline of the harbour entrance. The *Southeastern End* also is lower than most of the barrier and is characterised by hummocky dunes and few indistinct broad shoreline ridges.

Major geomorphological features of the barrier useful for correlating landform features are a prominent continuous relict foredune ridge we call *Long Ridge* which extends almost the entire length of the barrier (Fig. 7), and an erosional shoreline we call *Purakau Shoreline,* after the Maori name of the land block through which it passes, which cuts obliquely across the southern part of the barrier from near the present ocean beach to Duck Bay (Fig. 7). Both features are continuous. Each is thought to have formed along its entire length at the same time, and therefore to represent a chronological marker. Long Ridge we correlate with ridge D1 mapped near the northwestern end of the barrier by Munro (1994).

The Purakau Shoreline separates the regular relict foredune ridges to the northwest from an irregular collection of hummocky and parabolic dunes to the southeast. The area to the southeast narrows towards the northwest and merges with a narrow strip of parabolic dunes which extends continuously to the northwestern end of the barrier (Fig. 7). The strip separates the older relict foredunes from one or two younger relict foredunes immediately behind the present-day foredune.

Progradation of the harbour shoreline in the shelter of the growing barrier resulted in the formation of extensive backbarrier flats. They are best developed to the northwest of the barrier where swampy flats extend between the harbour shore and the washover slope.

The landforms discussed below are, in order. the Earliest Holocene Shoreline, Backbarrier Washover Slope, Relict Foredune Plain, the Contemporary Foredune and Ocean Beach, Barrier Ends, Relict Transgressive Dunes, and Backbarrier Flats. The locations of landforms other than the Relict Transgressive Dunes are shown in Fig. 7.

2.2.2 Earliest Holocene Shoreline

The Earliest Holocene Shoreline is the relict wave-cut cliff along the northeastern side of the Pleistocene core of Matakana and Rangiwaea Islands(Fig. 7). It is more or less parallel with the Holocene relict foredunes and present shoreline of the barrier. The Earliest Holocene Shoreline was formed at the end of the Postglacial Marine Transgression which ended c. 6500 yr BP (Gibb 1986).

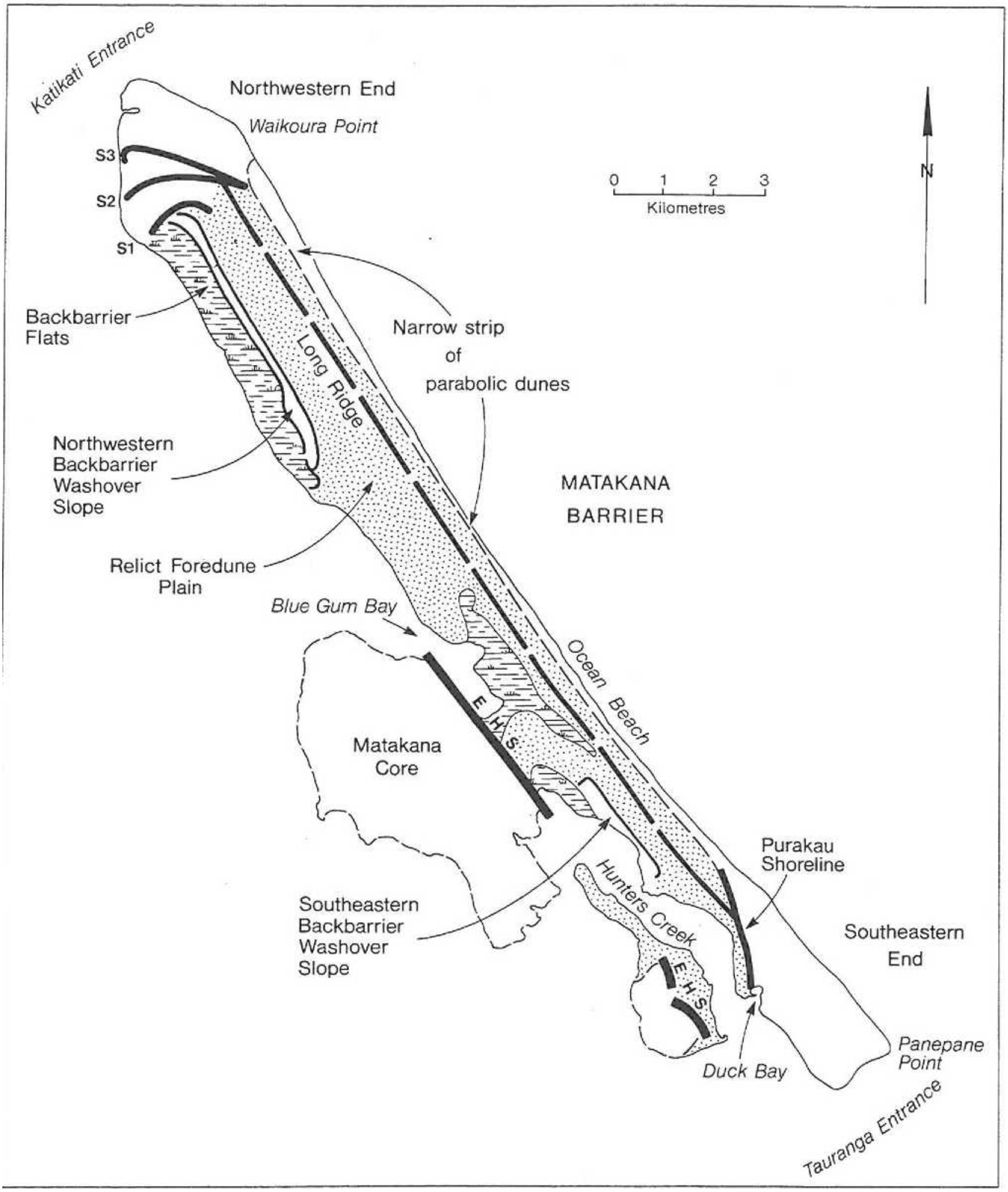

FIGURE 7. MAP OF MATAKANA BARRIER SHOWING LANDFORMS AND FORMER SHORELINES. EHS = EARLIEST HOLOCENE SHORELINE; S1 AND S2 = ERODED SHORELINES; S3 = KAHAROA SHORELINE.

2.2.2 Backbarrier washover slope

The backbarrier washover slope (Tanner 1988) is a surface along the inner margin of the barrier (Fig. 7) which slopes gently harbourward from the back of the innermost relict foredune to the backbarrier flats. It is between 180 m and

360 m wide. The Northwestern Backbarrier Washover Slope is to the northwest of Blue Gum Bay; the Southwestern Backbarrier Washover Slope borders Hunter's Creek.

Washover commonly occurs where a narrow barrier separating an estuary or lagoon from the ocean coast is subjected to large storm waves or a rising sea level (Tanner 1988). Overtopping of the barrier by storm waves (washover) removes sediment from the ocean beach, redepositing it as washover lobes on the landward side of the barrier. A backbarrier washover slope forms where numerous washover lobes coalesce into a regular slope on the inner margin of the barrier.

The processes of erosion and overtopping may cause a narrow barrier to migrate shoreward over the surface of former estuarine or low energy deposits (Dolan *et al.* 1980). The final position of the washover ridge marks the line from which subsequent progradation begins. A borehole through the Northwestern Backbarrier Washover Slope (borehole 1, Fig. 8, Fig. 9a) encountered silty sand at a depth of c. 2 m below mean sea level, and a 0.2 m clay horizon at a depth of c, 3 m overlying poorly sorted silty sand (Fig. 9a). As sediment derived from the ocean beach contains neither silt nor clay, it is apparent that at this site the washover deposits are overlying harbour (estuarine) sediment.

The innermost barrier beach in front of the backbarrier washover slope is comprised of coarse shelly sediments with heavy mineral seams. Two samples of marine shells from the sediments are dated: NZA3879 from 3-4 m below present high water level is 7697 ± 70 yr BP; NZA3878 from about present high water level is 5635 ± 69 yr BP (Table 1). NZA3879 is probably from material carried up with the rising sea level and is a maximum age for the innermost barrier beach and hence backbarrier washover deposits. NZA3878 is a maximum age for the growth of the relict foredune immediately in front of the washover slope.

Kaud gum from peaty soil near the bottom of the backbarrier slope at the northwestern end of the island has an age of 1449 ± 51 yr BP (NZ 8294, Table 1).

2.2.3 Relict foredune plain

Relict foredunes are cut off from the beach as a shoreline progrades and indicate the positions of former shorelines. They are the dominant landform on Matakana island and occupy a wide zone with up to 35 parallel ridges which extends for almost the entire length of the barrier (Fig. 8). They are modified by the formation of transgressive dunes, which are considered separately below.

The relict foredune plain extends from the furakau Shoreline at the southeastern end of the barrier to where the ridges begin to curve at the Katikati Entrance. It excludes the recurved ridges at the Katikati Entrance, but includes recurved ridges formed during coastal progradation along a former entrance through the inner part of the barrier adjacent to Blue Gum Bay.

A narrow band of relict foredunes is present on Rangiwaea island between the Pleistocene core and Hunter's Creek (Fig. 8).

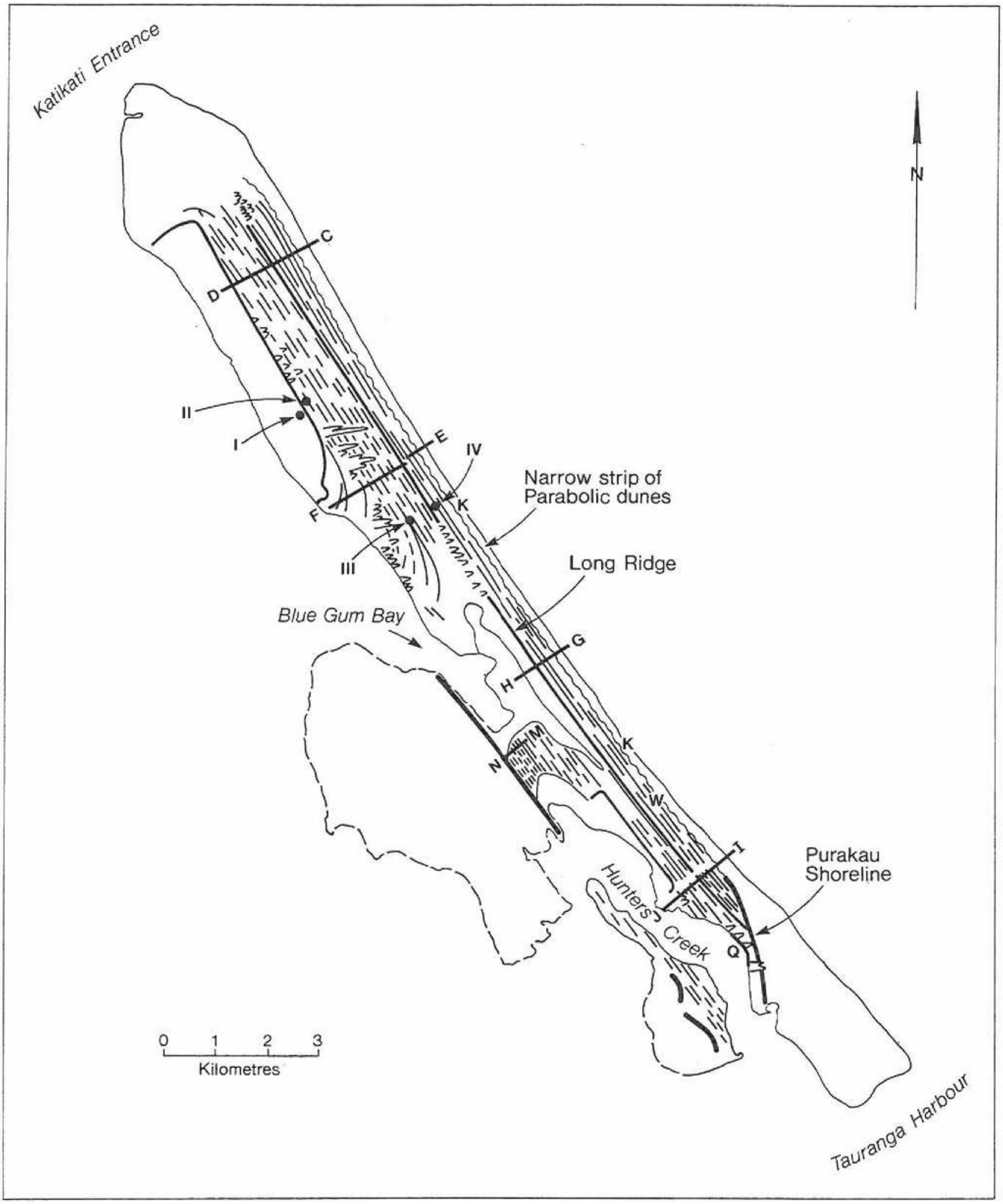

FIGURE S. MAP OF RELICT FOREDUNE PLAIN SHOWING DEEP BOREHOLE LOCATIONS (I, II, III, IV) AND PROFILES (C-D, E-F, G-H, I-J, M-N). K = LOCATIONS OF KAHAROA TEPHRA BENEATH PARABOLIC DUNES OF THE COASTAL STRIP; W = SEA-RAFTED WAIMIHIA PUMICE; Q = HUNTER'S CREEK SECTION WITH PROVISIONALLY IDENTIFIED STENT TEPHRA.

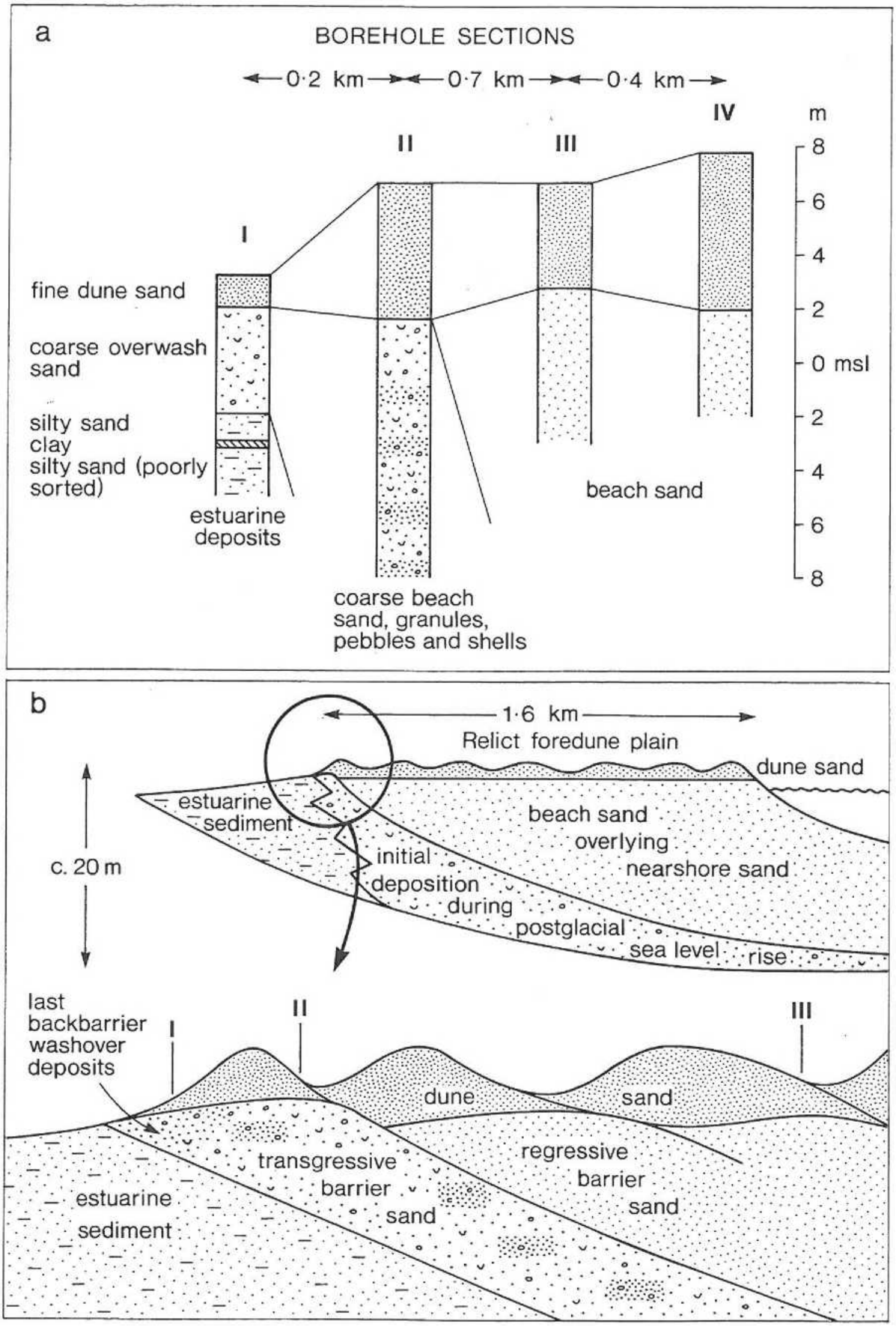

FIGURE 9. BARRIER STRATIGRAPHY:

a. BOREHOLES I-IV (FIG. 8) SHOWING STRATIGRAPHY DETERMINED BY DRILLING. HEIGHTS IN METRES RELATIVE TO MEAN SEA LEVEL.

b. INFERRED BARRIER STRATIGRAPHY BASED ON BOREHOLE DATA.

Foredune formation is an aeolian process whereby sand blown landward from the beach is trapped by sand-binding vegetation. The vegetation germinates from. wave-deposited seeds at the level of spring tide swash, or spreads by rhizome/stolon or shoot growth from an existing vegetated area (Hesp 1984). This process results in the construction of a foredune, which continues to accumulate sand until progradation of the beach allows a new sand vegetation zone to become established to seaward. This new zone becomes the primary zone of accumulation, causing the original foredune to become inactive (relict). Swales are low areas between the dune ridges where deposition is non-existent because most available sand is trapped by seaward vegetation (Hesp 1984).

The heights of the relict foredunes which comprise the main zone of ridges on Matakana Barrier vary from less than 2 m to about 14 m, with spacing between successive foredunes of *c*. 20 m to X100 m (Profiles C-D to I-J, Fig. 8 and 10). Despite the height of the highest dunes, few have been affected by large-scale wind erosion and most ridges have been stable since their formation (Fig. 11).

Sediment texture and mineralogy (Appendix 2; for full details see Betts 1996) are remarkably uniform throughout the relict foredune sequence. The mean grain size of each of 26 foredune sand samples from Profiles C-D to I-J (Figs. 8 and 10) and 9 samples from points along Long Ridge is between 1.9 and 2.7 phi (0.27 mm and 0.15 mm) and all are well-sorted (Fig. 12). The Long Ridge samples tend to coarsen towards the southeast (Fig. 13).

The heavy mineral content of the profile samples (Fig. 14) is generally below 10% but rises to 20-35% towards the inner margin of the barrier along Profiles C-D to G-H. Neither the inner margin of the barrier along Profile I-J nor Long Ridge were sampled. The heavy mineral suite was fairly uniform throughout with hypersthene dominant (50-70%).

The larger light mineral fraction (Fig. 15) is fairly uniform and dominated by quartz (50-70%) and feldspar (20-30%). Except for the Taupo Foredune at Profile E-F, where the glass content is 30%, in all other samples the glass content is less than 7%. Also significant are the lower proportions of rock fragments and glass near the inner margin of the barrier.

Sand in the relict foredunes is finer in three boreholes (II, III , IV, Fig. 8) than the underlying beach and nearshore sand. Borehole II is at the oldest beach on the barrier just seaward of the innermost ridge, III is 0.8 km seaward of the innermost ridge and IV is 0.4 km further seaward. The holes were drilled to depths below mean sea level of 5 m, 3 m and 2 m respectively (Fig. 9a). Beach and nearshore sand in the two seaward holes is only slightly coarser than the dune sand and contained only rare shell fragments; beach and nearshore sand in the innermost hole is very much coarser with heavy mineral seams, abundant shell fragments and rock granules.

Ground disturbance caused by forestry operations has almost completely destroyed the original topsoil and subsoil on the relict foredunes and in many of the Swales. In some Swales, however, the original soil profile is present beneath layers of recently deposited sand and may be podzolised (Table 3; Fig. A7.1, Appendix 7). Some Swales also contain primary deposits of Kaharoa Tephra and Taupo Lapilli, charcoals, undisturbed shell midden and garden soils (Appendix 3). On older parts of the barrier the subsoil shows considerable weathering indicated by strong iron-cementation.