DATA REPOSITORY ITEM

Dating times of dune building

We mapped dune sequences at all five locations using a hip chain and inclinometer. Measurements were taken in transects from the present shore inland to the point where stands of first generation colonizing forest finished. Individual dune ridge-swale units were mapped. The consistency and continuity of dune ridges were verified by walking sub-parallel to the coast along the crests and by repeat landward transects at different positions along the dune sequences. All sequences were characterised by clearly defined dune ridges separated by interdune hollows of varying widths. Each dune-hollow unit comprised what we call a 'dune unit' The Awarua River sequence differed slightly in that dune units included some additional hummocky progradational material between each clearly-defined major dune ridge.

The five dune sequences are largely unmodified by humans, and are covered with indigenous forest. New surfaces in the region are rapidly colonized by trees (Wardle 1980), and so colonizing forest provides an ideal way to date the formation of dunes over the past c. 800 years (Wells and Goff 2006). We took core samples at a height of 1 metre above the ground from a number of trees across each dune sequence, using Mattson increment borers. The aim was to obtain at least 30 trees from each dune unit. This was achieved in most cases, except for three dune units where there were very few mature trees still surviving.

Tree samples were generally taken on each dune unit near the mid-point between the river mouths and alongshore termination point of each dune sequence. This regime avoided sampling problems associated with missing and indistinct dune ridges near the distal end of each sequence, and poor ridge differentiation near the river mouths due to bar formation and river meandering. Samples were often spread across a large expanse of each dune unit, up to 1 km in length. Tree species sampled comprised the long-lived conifers *Dacrydium cupressinum* (rimu), *Prumnopitys ferruginea* (miro), *Podocarpus totara* (totara) and *Dacrycarpus dacrydioides* (kahikatea), as well as some *Nothofagus menziesii* (silver beech) at the Arawhata River sequence. Individuals of the dominant conifer species have an expected maximum lifespan of about 800 years. On many dunes colonizing forest formed dense, even-canopied stands, allowing for easy tree selection and good confidence that sampled trees were the rapid initial colonizers and not later arrivals. However on some dunes the forest canopy was very open with only a few large emergent original colonizing trees present over a lower tier of what appeared to be more recent regeneration. In these cases tree selection was more difficult and there was less confidence that sampled trees were all rapid initial colonizers.

Tree cores were mounted and sanded and the number of rings counted under a microscope. When cores did not intercept the pith, the number of missing rings was estimated using the inner arcs (Duncan 1989), or from the tree's diameter and the growth rate of the innermost 50 rings where no arcs were present. We excluded from our final data all tree ages that had additions for missing parts of the core of > 75 years.

We examined the distribution of tree ages across each sequence, looking for distinct and abrupt changes in tree ages (cohorts) that would signify different dune building phases. Such cohorts would represent the initial trees that colonized newly-formed and stabilised portions of the dune system over time. The oldest tree in each cohort provides the best estimate of the date at which initial colonization of the newly-formed dune surfaces commenced. The actual date of disturbance leading to dune formation will predate this age by the time required to form the dune and for the first trees to germinate and grow to coring height.

The ages of each dune-swale unit identified were compared with the established chronology of large regional earthquakes in South Westland. Dunes that owed their formation to the earthquakes would be expected to have colonizing forest cohorts with oldest trees that post-dated the earthquakes by no more than a few decades (Wells et al. 1999; Wells and Goff 2006).

Details of tree age distributions on dune units across the dune sequences

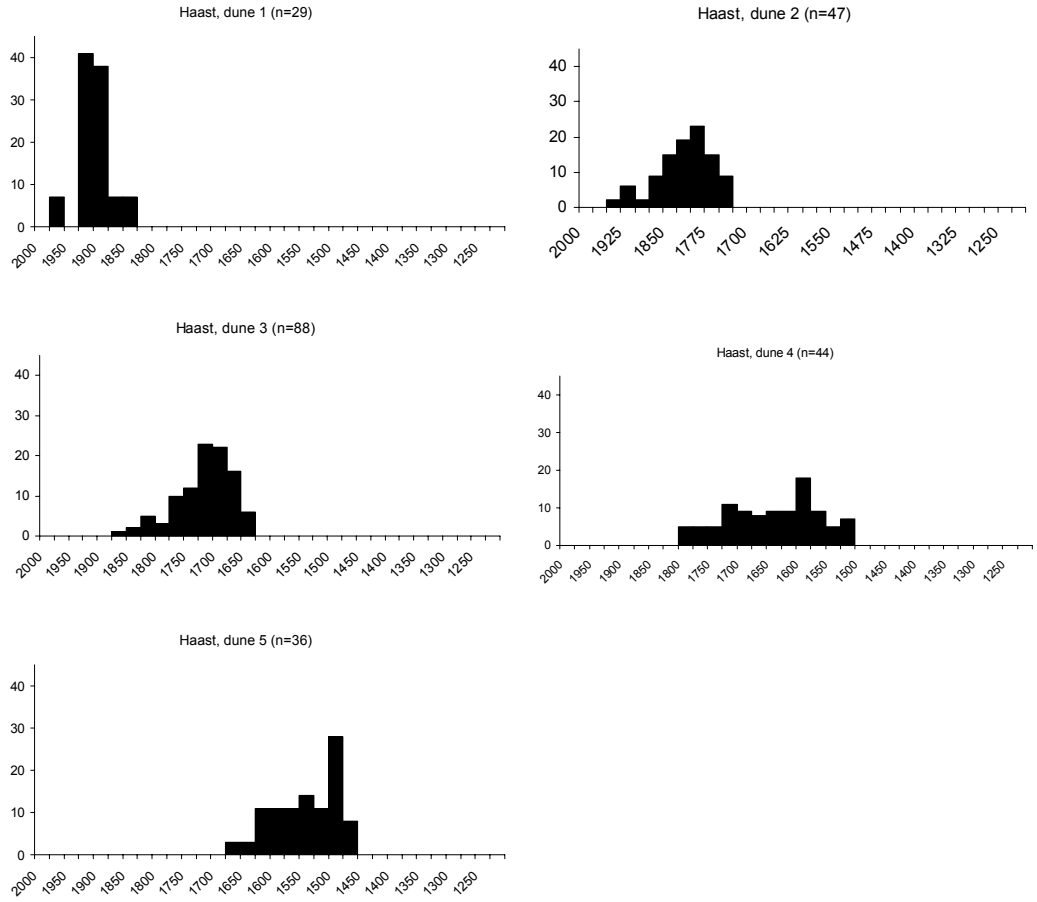
Figure DR1 presents histograms of tree age distributions (cohorts) of sampled trees on each successive dune unit at the five dune sequences. Each cohort spanned from the front of the former dune to the crest of the next dune seaward. All dune units were clearly identifiable, by the abrupt changes in age of oldest trees. At all sites except for the Haast River, we were able to date dune development using colonizing forest back to c. AD 1250 (we could find no remaining colonizing trees at Haast prior to AD 1400). At a few sites it was not possible to find 30 colonizing trees (Arawhata, dunes 3 and 5; Okuru, dune 4), but we still sampled sufficient to allow reliable minimum estimates of dune ages.

Tree ages span much greater time periods the older the dunes get. This is because of ongoing regeneration during the centuries following dune formation. Initially, however, colonizing trees would have formed clear even-aged cohorts, similar to those currently evident on the youngest one or two dune units at each site. It is also interesting to note that much of the secondary regeneration on older dunes occurred synchronously with new episodes of dune building. This presumably reflects disturbance of existing forest by the same earthquake events that initiated new dune building.

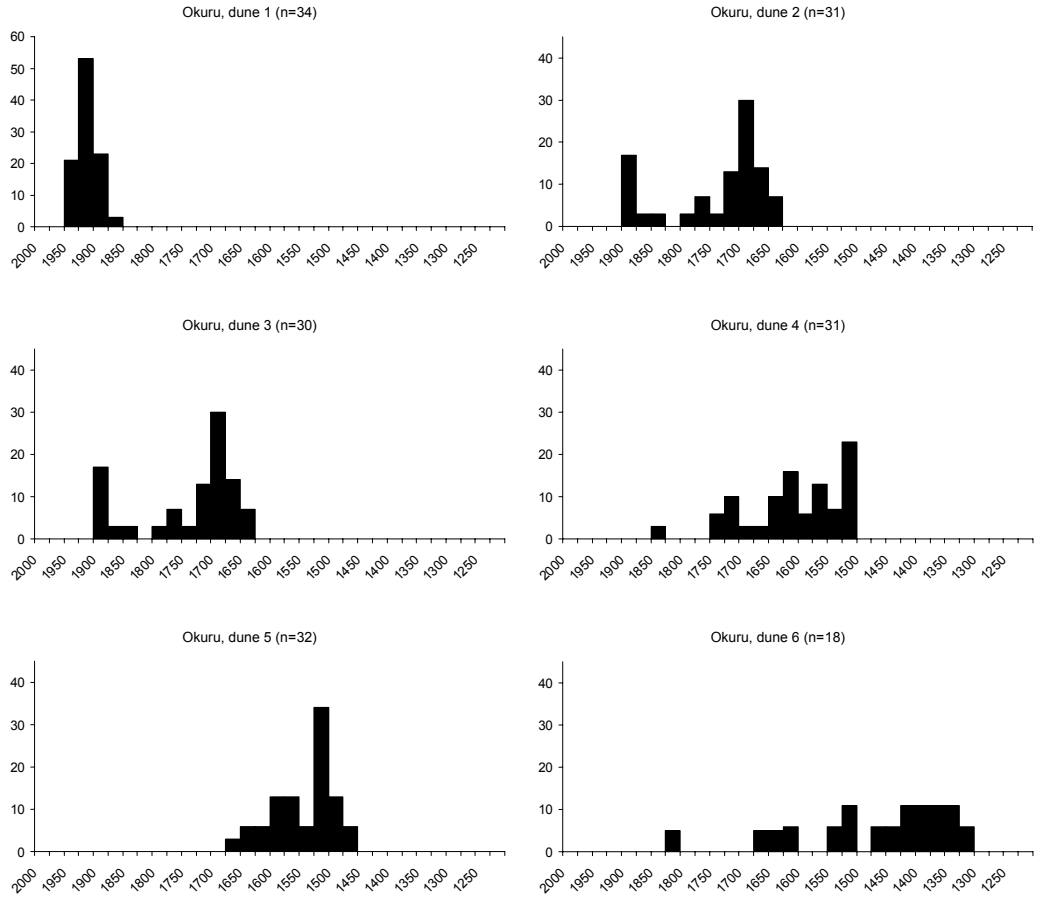
Some age distributions show only a few percent of trees dating to the time of dune formation. These correspond to the dunes with an open forest canopy characterised by a few large emergent colonizing trees over a lower tier of more recent regeneration. Age distributions with high percentages of sampled trees dating to the time of dune formation reflect dune units on which colonizing trees formed dense, even-canopied stands of rapid initial colonizers.

Figure DR1. Age frequency distributions for trees sampled on successive dune units at the Haast, Okuru, Waiatoto, Arawhata and Awarua River dune sequences, South Westland (a-e respectively). The y axis gives percentage of trees, and the x axis gives tree age at sampling height (years AD) in 25 year classes. The number of trees sampled on each dune unit is given by n.

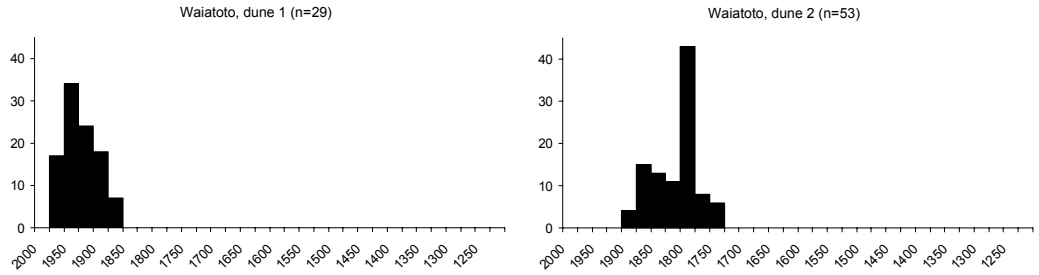
a) Haast River dunes

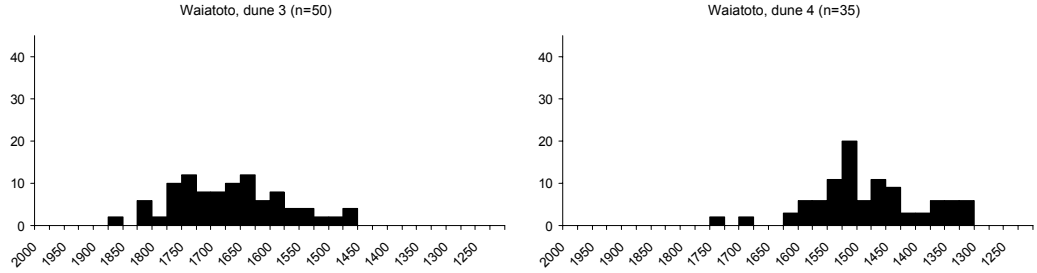


b) Okuru River dunes

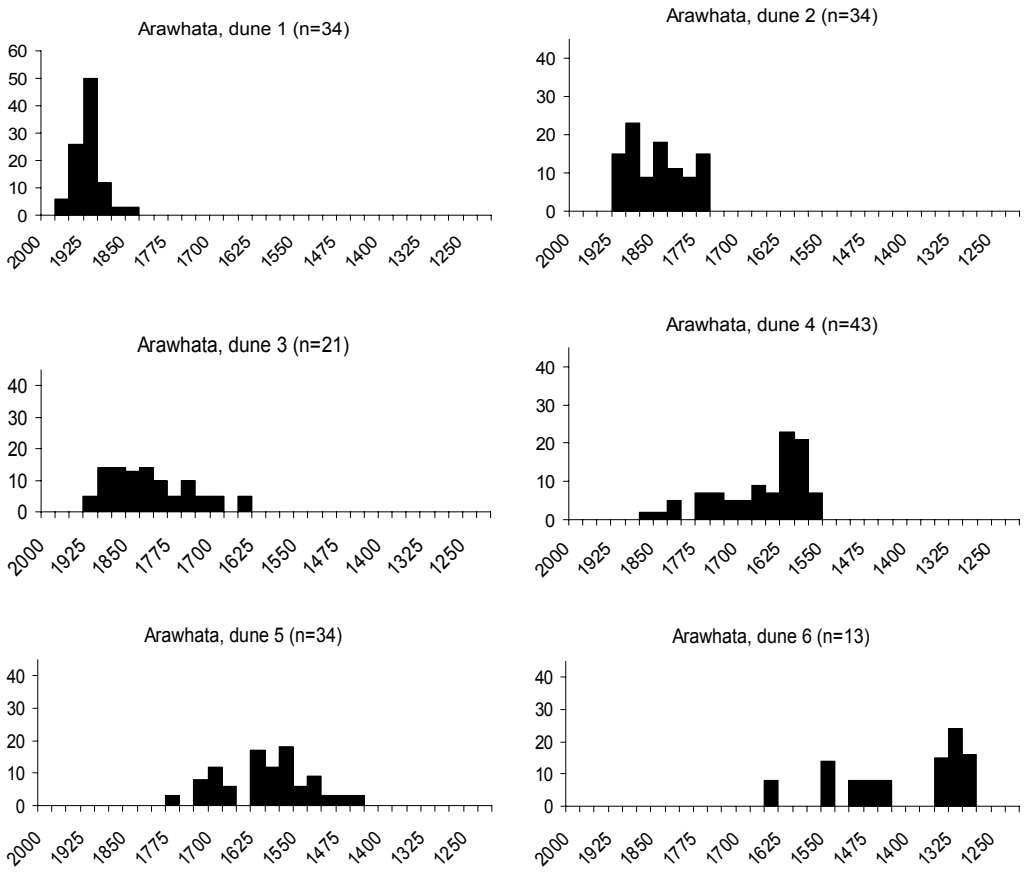


c) Waiatoto River dunes

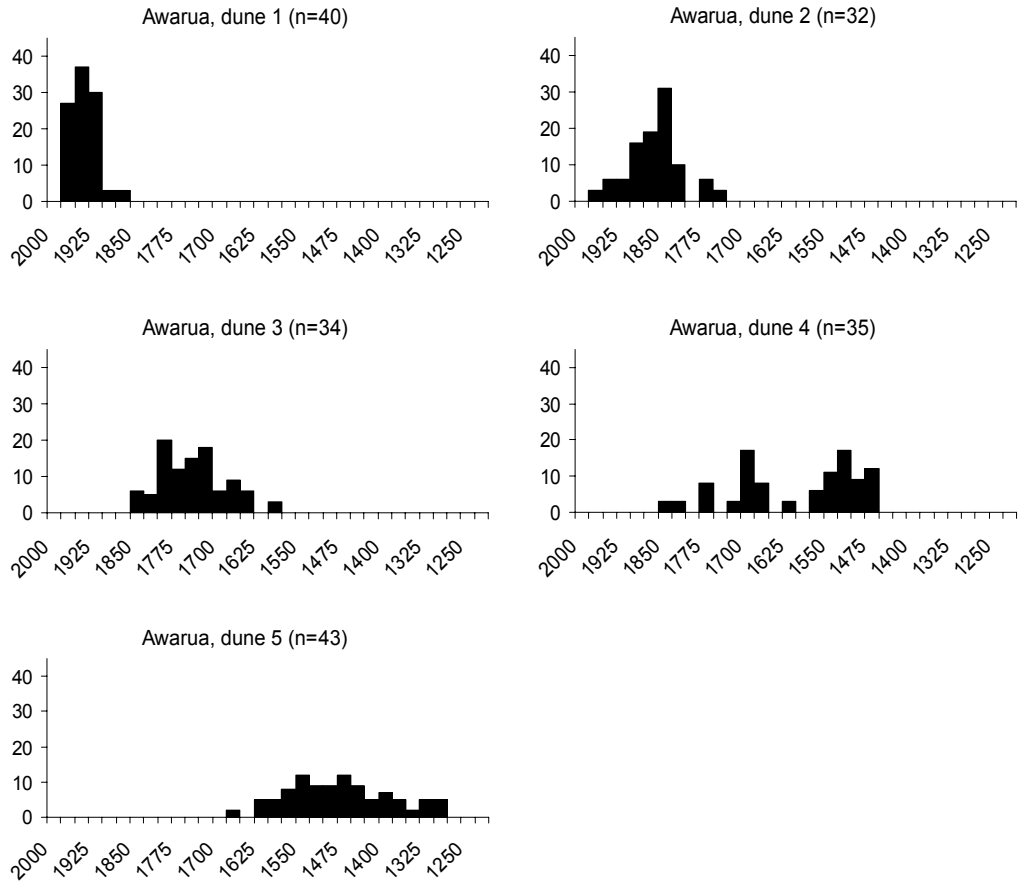




d) Arawhata River dunes



e) Awarua River dunes



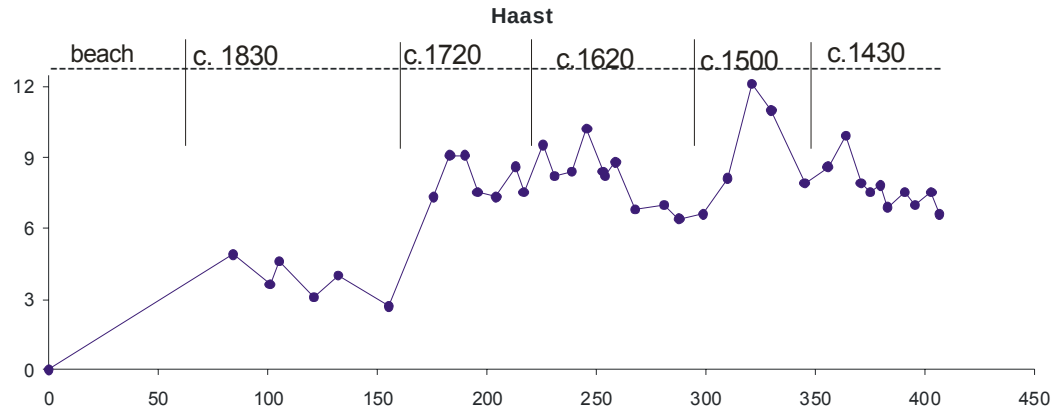
Representative transects through the dune sequences

As stated above, we measured transects through each dune transect using a hip chain and inclinometer. Figure DR2 presents examples of these transects for each of the five dune sequences. The vertical heights are likely to have relatively large errors and should be viewed as approximations only; this reflects the imprecise method used for obtaining heights, and the difficulties of conducting surveys in the dense forest. It should also be noted that we measured at least 3 transects at each site, to confirm consistency across the sequence. In Figure DR2 we present just one transect for each sequence.

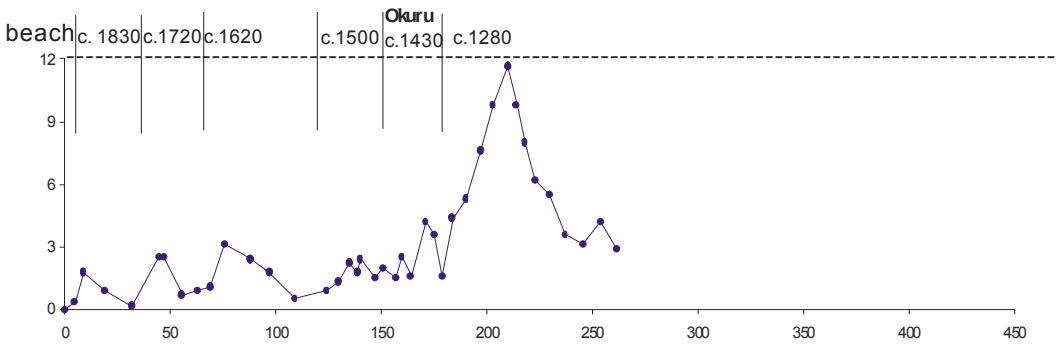
The transects in Figure 2 appear complex, but in the field the dune patterns are easily observable and relatively simple. There is a single clearly discernable dune ridge within each ‘dune unit’ which is a prominent and continuous feature across the length of the dune system. Other apparent ridges in the Figure DR2 diagrams are not prominent in the field, and represent small localised noncontinuous undulations. Tree ages confirm this pattern, as already mentioned, with sharp age discontinuities coinciding with the boundaries of the prominent and continuous dune ridges.

Figure DR2. Diagrams of transects across the dune sequences at Haast, Okuru, Waiatoto, Arawhata and Awarua River dune sequences (a-e respectively). Transects run from the Tasman Sea inland, perpendicular to the dunes. The y axis gives height above high tide level (in metres), and the x axis gives distance inland from the high tide mark at the Tasman Sea (in metres). Dates and dividing lines across the top of each diagram indicate the extent of dune building during the distinct dune building episodes of c. AD 1830, 1720, 1620, 1500, 1430 and 1280 referred to in the text.

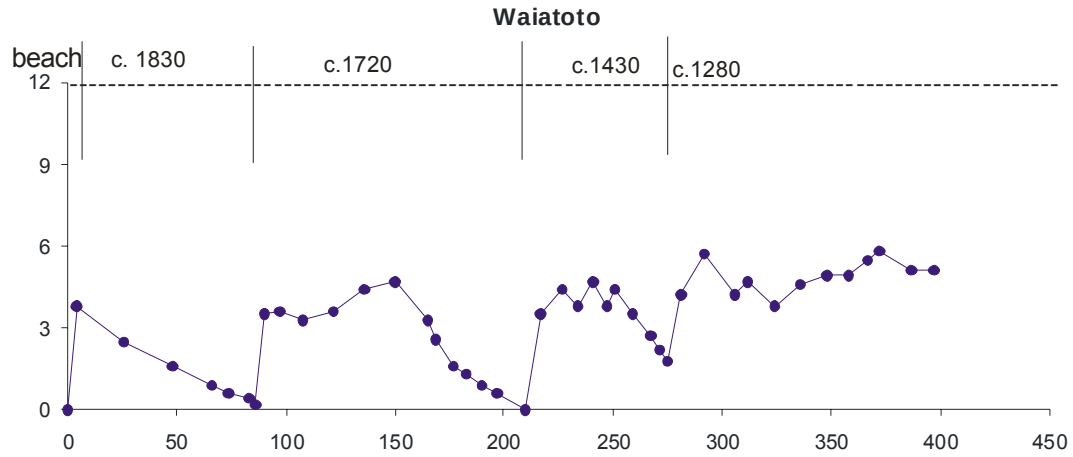
a)



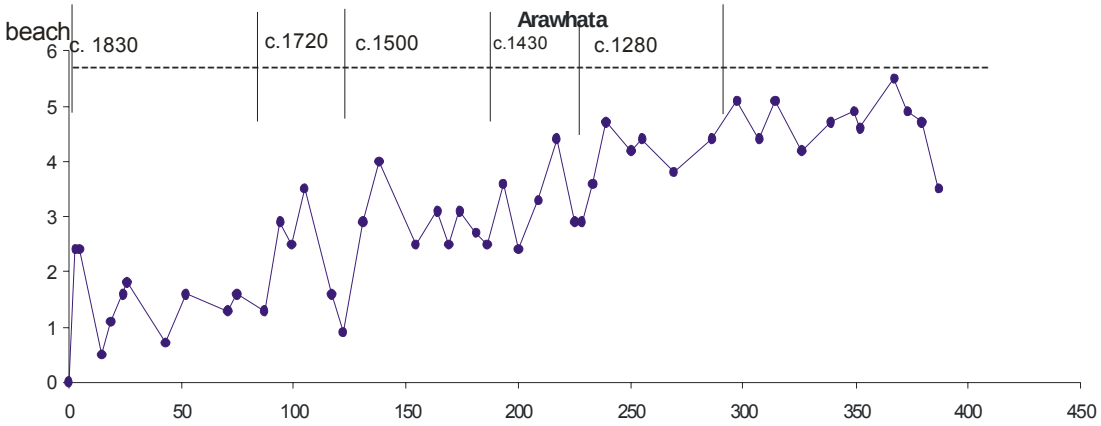
b)



c)


Waiatoto
beach
c. 1830
c.1720
c.1430
c.1280
12
9
6
3
0
0
50
100
150
200
250
300
350
400
450

d)


Arawhata
beach
c. 1830
c.1720
c.1500
c.1430
c.1280
6
5
4
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2
1
0
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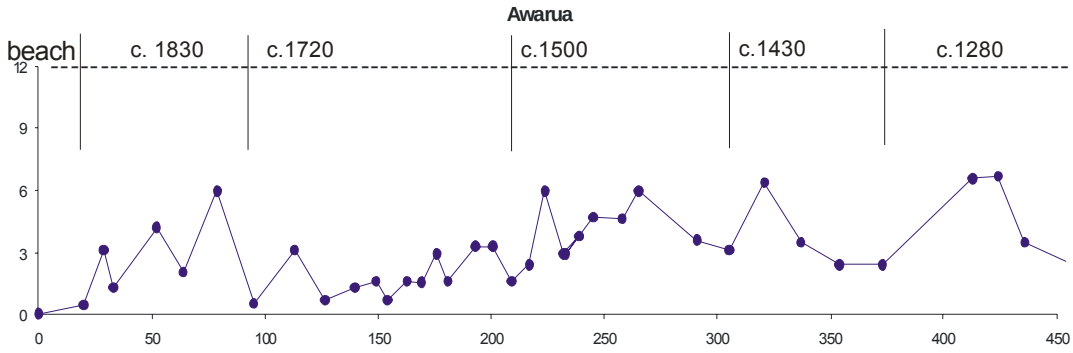
e)


Awarua
beach
c. 1830
c.1720
c.1500
c.1430
c.1280
12
9
6
3
0
0
50
100
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200
250
300
350
400
450

Other Information

All sampled trees were tagged in the field with numbered metal tags, and can be easily relocated if required. All mounted tree core samples have been retained in storage by A. Wells for future access.

References Cited

Duncan, R.P., 1989, An evaluation of errors in tree age estimates based on increment cores in kahikatea (Dacrycarpus dacrydioides): New Zealand Natural Sciences, no. 16, p. 31-37.

Wardle, P., 1980, Ecology and distribution of silver beech (Nothofagus menziesii) in the Paringa District, south Westland, New Zealand: New Zealand Journal of Ecology, no. 3, p. 23-36.

Wells, A., Yetton, M.D., Duncan, R.P., and Stewart, G.H., 1999, Prehistoric dates of the most recent Alpine fault earthquakes, New Zealand: Geology, no. 27, p. 995-998.

Wells, A.; and Goff, J., 2006, Coastal dune ridge systems as chronological markers of paleoseismic activity – a 650 year record from southwest New Zealand: The Holocene, no. 16, 543-550.