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Distribution of subfossil forest remains, eastern South Island, New Zealand

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DISTRIBUTION OF SUBFOSSIL FOREST REMAINS, EASTERN SOUTH ISLAND, NEW ZEALAND

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SUMMARY

The distribution of subfossil forest remains collected in the eastern part of the South Island of New Zealand is outlined. Surface logs, buried wood and charcoals, wind-throw dimples and buried podsols provide convincing evidence of a former widespread forest cover over now-treeless tracts of the South Island. Most of the wood and charcoals discovered have been identified, and collecting sites plotted on a map. A broad distinction can be drawn between probable podocarp and beech forest areas. Radiocarbon dates for a number of wood and charcoal samples are presented and most of these point to forest destruction by fire since the advent of man in New Zealand within the last 1,000 years or so. Older dates presented obviously lie outside the period of human occupation of New Zealand, and the fires that produced these ancient charcoals are assumed to have originated from natural causes. The present vegetation on former forest sites and the distribution of forest remains in relation to existing forest are discussed, and some of the leading opinions as to the causes of forest destruction are briefly reviewed.

INTRODUCTION

The occurrence of totara logs in now-treeless areas in the east of South Island has been noted by many authors, commencing with Buchanan (1875) and Munro (1875). Buried charcoals are even more widespread than totara logs, though they are seldom mentioned in the literature (see, however, Burnett, 1927, p. 52; and Holloway, 1954, p. 362). The aim of the present paper is to record the distribution of these and other subfossil remains of forest, firstly because much of the evidence is disappearing, and secondly, because continuing modification of the existing vegetation makes the interpretation of the evidence increasingly difficult.

NATURE OF THE EVIDENCE

Fallen logs, obviously pre-dating European deforestation, are the most conspicuous evidence of earlier forests. Nearly all logs that lie on the surface are totara (*Podocarpus hallii*, and at lower altitudes, probably also *P. totara*). In the Dunedin district, logs of *Dacrydium biforme* are also abundant (Wardle and Mark, 1956), while Holloway (1954, p. 367) records that logs of rata (probably *Metrosideros umbellata*) occur near Lake Coleridge. Less durable wood belonging to many other species is preserved under conditions of complete burial, especially in swamp deposits, deep alluvium, and accumulated soil profiles at the base of steep slopes.

Charcoals buried in the subsoil appear to be far more durable than unaltered wood. In the mountainous regions they are usually found as thin bands overlying buried soils and may be associated with scorched rock fragments, burnt soil aggregates, and small pieces of unburnt or partly burnt wood. On the Canterbury Plains and downlands they occur most commonly in the present soils, even though they may be degraded forest soils, having become incorporated to depths as great as 18 in. by the long-continued burrowing and casting of earthworms; charcoals on the plains are found also in buried soils, some of which were buried in the past few hundred years, but others several thousand years ago (Cox *et al.* 1960). Charcoals have been recovered also from swamps, alluvium, and slumped soil. Fragments over 1 cm in diameter were often confidently identified as to species in the field, and smaller ones were identified in the laboratory. Samples from the Canterbury Plains, where present vegetation gives little clue as to identity, were identified from prepared sections at the Forest Research Institute. Most charcoals from mountainous localities proved to be either beech (usually assumed to be mountain beech, *Nothofagus solandri* var *cliffortioides*) or gymnosperm, usually assumed to be *Podocarpus hallii*. Red beech (*Nothofagus fusca*) was identified from a locality at 3,700 ft on the Crown Range, western Otago, and at one site on the Canterbury Plains it was found with charcoals of other species, in the present soil and in a buried soil directly below. Carbonised twigs and small-diameter stems were identified only as "dicotyledonous wood other than beech", and *Leptospermum, Dracophyllum* and *Olearia* are almost certainly included. On the Canterbury Plains, Cox *et al.* (1960) recognised principally podocarp charcoal (charred matai seed cases also were common) in the deep soils, and scrub charcoals (*Leptospermum ericoides* almost certainly) in shallow soils underlain by gravel beds. In soils on rolling moraine and terrace land near Lake Tekapo these authors found charcoal and also uncharred seed cases of matai.

Wind-thrown trees leave hummocks of soil and corresponding hollows which often persist as "forest dimples" long after forest has vanished. Charcoals were frequently recovered from such hollows and on the Torlesse and Craigieburn Ranges, North Canterbury, podsol lenses were uncovered in identical hollows both within existing young beech forest and in the surrounding scrub and grassland.

Relict, humus-iron podsols, generally of egg-cup form, were recorded from several localities where the present vegetation consists of subalpine scrub, snow-tussock or fescue-tussock grassland. Most if not all of these

TABLE 1—Radiocarbon Age Measurements

Reference No.	Collector	Sheet and Grid Ref. Lat. and Long.	Locality	Material	Species	Age Years Before 1950
A 295	J. A. Johnston	S29/387910	Lake Grassmere, Marlborough	Wood	*Podocarpus totara*	630 ± 60[6]
NZ 304	B. P. J. Molloy	S74/218857	Porters Pass, Canterbury	Charcoal	*Nothofagus solandri* var. *cliffortioides*	510 ± 50[2]
NZ 391	P. Wardle	S66/595	Craigieburn Range, Canterbury	,,	,,	609 ± 45[4]
H 1051	B. P. J. Molloy	S74/214857	Porters Pass, Canterbury	,,	,,	700 ± 105[3]
H 1053	,,	S74/215863	,,	Wood	,,	725 ± 105[3]
H 1052	,,	,,	,,	,,	,,	900 ± 105[3]
H 1050	,,	S74/218857	,,	Charcoal	,,	950 ± 105[3]
NZ 432	J. E. Cox	S76/914608	Harewood, Canterbury Plains	Wood	*Leptospermum ericoides*	<200[4]
A 269	J. A. Johnston	S84/204313	Hill Top, Banks Peninsula	,,	*Podocarpus totara*	590 ± 50[6]
NZ 382	J. E. Cox and C. B. Mead	S75/821601	Yaldhurst, Canterbury Plains	Charcoal	*Leptospermum ericoides*	628 ± 40[4]
A 676	J. A. Johnston	S84/932552	Sockburn, Canterbury Plains	Wood	*Podocarpus totara*	685 ± 60[6]
NZ 312	B. W. Collins	S84/037543	Christchurch	,,		735 ± 55[3]
A 416	J. A. Johnston	S84/920523	Halswell, Canterbury Plains	,,	*Podocarpus totara*	760 ± 50[6]
A 712	,,	S84/530905	Springs Road, Christchurch	,,	,,	890 ± 60[6]
NZ 431	J. E. Cox and C. B. Mead	S76/928631	Harewood, Canterbury Plains	,,	*Leptospermum ericoides*	930 ± 60[4]
NZ 86	B. W. Collins	S84/009519	Christchurch	,,		940 ± 70[2]
NZ 434	J. E. Cox and C. B. Mead	S83/886593	Yaldhurst, Canterbury Plains	Charcoal	*Podocarpus spicatus*	1015 ± 75[4]
NZ 305	N. T. Moar	S84/018584	Christchurch	Peat	Podocarp pollen present	1040 ± 60[2]
NZ 429	J. E. Cox	S83/750595	West Melton, Canterbury Plains	Charcoal	*Podocarpus spicatus*	1110 ± 76[4]
NZ 430	J. E. Cox and C. B. Mead	S83/842505	Broadfields, Canterbury Plains	,,	*Nothofagus fusca*	1725 ± 78[4]
NZ 383	,,	S83/868542	Templeton, Canterbury Plains	,,	*Leptospermum ericoides*	3500 ± 70[4]
NZ 384	,,	S83/842505	Broadfields, Canterbury Plains	,,	*Nothofagus fusca* and *Podocarpus spicatus*	6495 ± 95[4]
NZ 46	J. D. Raeside	S101/232745	Mt Dalgety, S. Canterbury	Wood	*Podocarpus totara*	1450 ± 70[1]
A 475	J. A. Johnston	S118/420390	Hunter Hills, S. Canterbury	,,	*Podocarpus hallii*	670 ± 50[6]
A 442	,,	S118/106331	Kirkliston Range, N. Otago	,,	,,	710 ± 50[6]
A 428	,,	44°47′S, 169°18′E	Pisa Range, Central Otago	,,	,,	810 ± 50[6]
A 484	,,	44°30′S, 170°50′E	,,	,,	,,	870 ± 50[6]

NZ	47	P. Wardle		Nevis Valley, Central Otago	„	*Podocarpus totara*	660 ± 60[1]
NZ	89	„	S164/100880	Silver Peaks, Dunedin	„	„	650 ± 60[2]
NZ	90	G. T. S. Baylis	S115/120930	„	„	„	670 ± 60[2]
NZ	48	A. F. Mark	S163/847728	Maungatua Range E. Otago	„	*Dacrydium biforme*	620 ± 60[1]

A 269 = Aust. Biolab. No.

H 1050 = Humble Run No.

NZ 46 = N.Z. ^{14}C No.

[1]Fergusson and Rafter (1957).

[2]Fergusson and Rafter (1959).

[3]Grant-Taylor and Rafter (1962).

[4]T. L. Grant-Taylor (pers. comm.).

[5]Geochemical Laboratory, Exploration Department, Humble Oil Refining Company, U.S.A. (pers. comm.)

[6]The late Dr G. Builder, University of Sydney (pers. comm.). For further details on this dating procedure, consult addendum in Johnston (1958).

podsols lie at variance with the position of likely *mor* formers in the present cover, and since they are overlain invariably by beech charcoals their position is interpreted as the exact location of past mor-forming trees, in this case mountain beech. In high rainfall districts near the main divide podsols form discontinuous sheets some of which contain beech charcoals.

RADIOCARBON AGE MEASUREMENTS

Radiocarbon dates play a useful part in establishing approximately the time at which forest was destroyed by fire or burial, but most often are untrustworthy for use in fixing the exact time of forest destruction, because of the following considerations:

1. A fire that burned a forest may have produced charcoals from standing or fallen trees of widely differing ages, and the proportion of young to old wood left as charcoal could give ages varying by as much as 200–300 years between samples. Charcoals from more than one fire could be present also in some samples.

2. Logs sampled are, more often than not, either partly burned, corroded by river action, or decayed on the outside, so that the allowance that should be made within the sample to give the true date of death is not known or, if known, is seldom published.

3. The order of accuracy in the laboratory determinations in New Zealand is ± 50 years for a date of 500 years, and ± 70 for 1,000 years. Jansen (1962) demonstrates even greater actual variations between comparable samples centred on adjacent rings of a 1,000 year old New Zealand kauri tree.

4. The possible correction required to allow for long-term changes in the level of ^{14}C in the atmosphere (Jansen, *op. cit.*).

In Table 1 are listed all the known dated samples (except those of archeologists) from the eastern South Island that relate to forest that grew within the past thousand years or so. The majority of these samples were obtained from surface logs or buried wood and charcoal near the present soil surface. Others belong to much older material from alluvial deposits on the Canterbury Plains. Samples of both wood and charcoal of the principal dominants of some podocarp, beech and low forest types are included, and a reasonable geographical scatter is shown. Death cannot be ascribed with certainty to burning in all instances, as some forests in the Christchurch area had been overwhelmed by flood deposits from time to time before man arrived in New Zealand.

Most of the dates shown in Table 1 fall within the period of human occupation of New Zealand, though it is uncertain whether the date 1450 ± 70 years (N.Z. 46) places the death of this tree before the arrival of man. Even allowing for all the vagaries of radiocarbon dating it is evident that the destruction of forests was not contemporaneous everywhere, and it seems likely that it moved progressively from earlier fires on the coastal plains to later ones in the mountains of the interior. The extent to which the replacement vegetation or even regenerating forest was destroyed by later fires remains an open question.

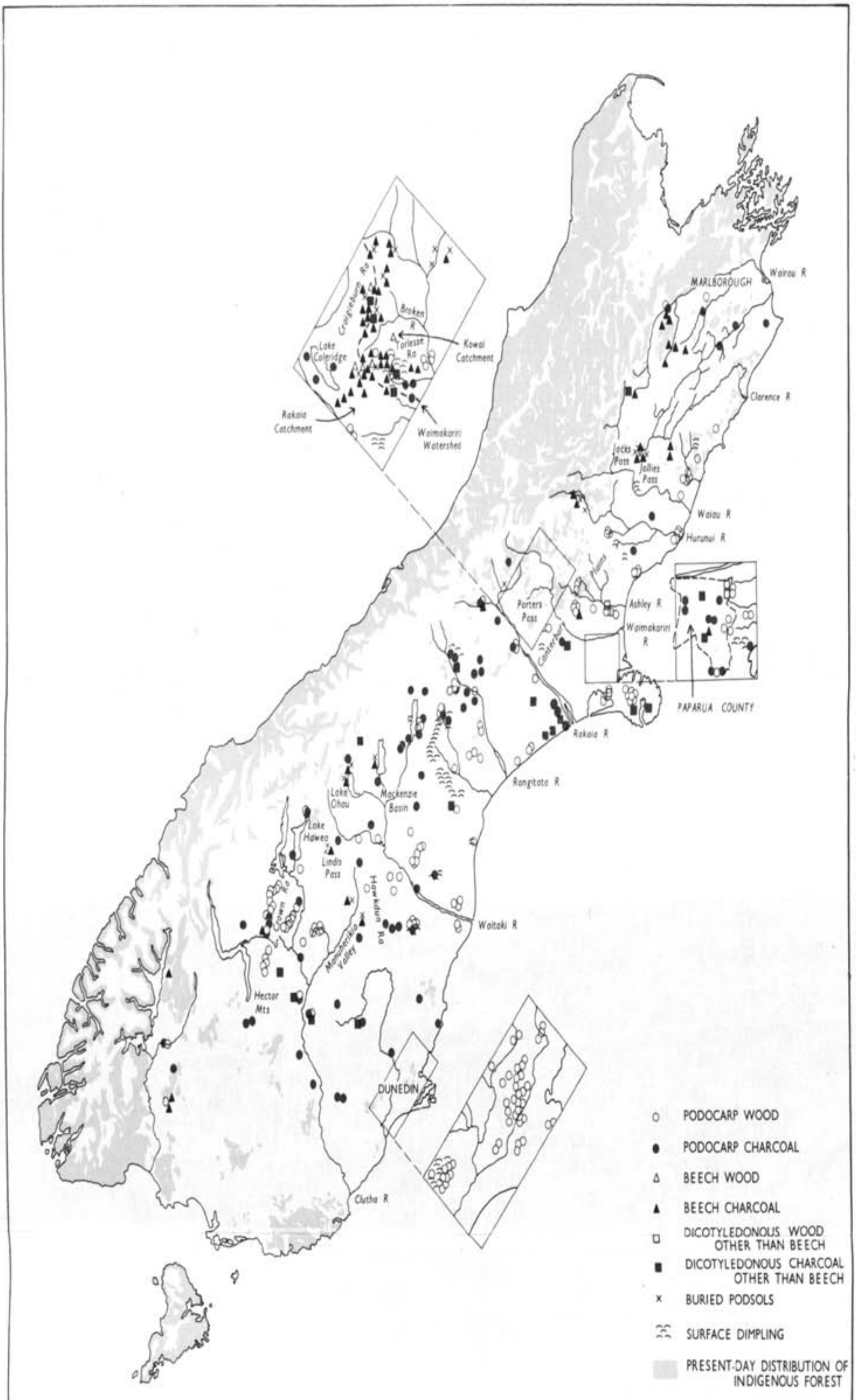
Craigieburn Ra
Broken R
Torlesse Ra
Lake Coleridge
Kowai Catchment
Rakaia Catchment
Waimakariri Watershed
MARLBOROUGH
Wairau R
Clarence R
Jacks Pass
Jollies Pass
Waiau R
Hurunui R
Porters Pass
Canterbury Plains
Ashley R
Waimakariri R
PAPARUA COUNTY
Rakaia R
Rangitata R
Lake Ohau
Mackenzie Basin
Lake Hawea
Lindis Pass
Hawkdun Ra
Manuherikia Valley
Waitaki R
Hector Mts
DUNEDIN
Clutha R
PODOCARP WOOD
PODOCARP CHARCOAL
BEECH WOOD
BEECH CHARCOAL
DICOTYLEDONOUS WOOD OTHER THAN BEECH
DICOTYLEDONOUS CHARCOAL OTHER THAN BEECH
BURIED PODSOLS
SURFACE DIMPLING
PRESENT-DAY DISTRIBUTION OF INDIGENOUS FOREST

FIG. 1

The older dates for samples on the Canterbury Plains almost certainly lie outside the period of human influence in New Zealand. After the two older fires, forest is know to have regenerated on alluvium that buried the sites, and later fires destroyed forest on these younger soils. The fires that produced these ancient charcoals may have been started by lightning. Buried soils, that are almost certainly interglacial, have also been found to contain charcoal, so that natural fires seem of long-standing, but their extent has not yet been established.

DISCUSSION

Distribution of the Evidence

The evidence collected has been plotted on a map (Fig. 1). It is emphasised that the unevenness in density of observations of forest remains is largely a reflection of the time spent in different areas. Many samples were collected for identification over as wide a range as possible outside the areas of intensive study. In general, these represent positive evidence of a former forest cover that was more widely distributed locally than is indicated in Fig. 1.

The bulk of the fallen totara logs lie at elevations between 1,500 ft and 3,500 ft. In drier areas, such as Central Otago, they are mostly on southerly aspects. Most finds of gymnosperm charcoal in the mountains have been in close association with totara logs. Elsewhere on the downlands and plains, gymnosperm charcoals are common in the soil profile mostly in the absence of totara logs. Mountain beech charcoals are most abundant between 3,000 ft and 4,000 ft on steep slopes, and are usually found on the contact surface of buried yellow-brown soils among which patches of podsols had developed. In the Kowai and Rakaia catchments mountain beech charcoals were found in the little-eroded hill and terrace soils at altitudes less than 3,000 ft, adjoining similar terraces which contained gymnosperm and small scrub charcoals. In the Waimakariri watershed, on the other hand, abundant beech charcoal was found in buried soils from the basin floors up to tree line and no undoubted podocarp charcoal. Beech wood contemporaneous with beech charcoal is generally scarce, though it may be recovered in quantity from erosion detritus between 2,500 ft and 4,000 ft in steep mountain gullies, and to a lesser extent from buried soils.

Podsols of the type described are clearly preserved in buried soils of several of the major high-mountain passes, notably Jacks, Jollies, Porters, and the Lindis, while an interesting discovery was recorded in the head of the Manuherikia Valley, Central Otago, on the lower slopes of the Hawkdun Range.

Surface logs and shallowly buried charcoals become progressively more fragmented and difficult to find with decreasing altitude. For two reasons this is more likely to result from poor preservation than to reflect a smaller extent of forest. Firstly, fires were probably hotter and more frequent and decay more rapid at low elevations, so that logs disappeared more quickly. Secondly, vigorous second-growth vegetation and well structured soils resisted erosion following deforestation, therefore charcoal tended to remain on the surface to be destroyed by weathering. At higher altitudes recovery of vegetation would have been slow, so that the weak-structured topsoils were removed in some places and re-deposited as a protective mantle in others. Forest dimples, on the other hand, are more abundant at lower altitudes because of the smaller amount of erosion. The evidence, therefore, points to a complete forest cover below treeline over virtually the whole of the South Island prior to the advent of man, except on some of the brown-grey earths of the driest parts of South Island and on those young soils formed on alluvium in the mountains and on the plains, where insufficient time had elapsed since the earlier destruction of forest by fire or flood to allow complete regeneration.

Present Vegetation on the Ancient Forest Sites

The most extensive present vegetation in areas of former forests is tussock grassland (both snow-tussock and fescue-tussock communities) and bracken fern, but there is a wide range of other communities dominated, for example, by *Leptospermum scoparium, Dracophyllum, Phormium colensoi, Coriaria* or *Blechnum.* In many instances, forest has re-colonised the sites. Thus, at Broken River, charcoal was found in several places under existing mountain beech forest; where the fragments were large, there was undoubtedly destruction of the former forest, but where the fragments are less than 1 mm in diameter, it is possible that they result either from light burning of the undergrowth, or were transported as cinders during the conflagration. Many stands of low forest dominated by kanuka (*Leptospermum ericoides*) predate European settlement, and by analogy with the present behaviour of this species, may have replaced tussock and bracken communities established after destruction of the original forest. Other stands of low forest dominated by *Griselinia littoralis* also may prove to have replaced forests that were dominated by podocarps or beech. Finally, to cite an example from the Ruahine Range (North Island) buried charcoals show that open, scrubby communities containing trees of *Libocedrus bidwillii, Phyllocladus alpinus, Podocarpus hallii* and *Griselinia littoralis* have colonised clearings in mountain beech forest.

On the coastal plains of Marlborough, Canterbury and Southland, on much of the downland, and on parts of the inland basins, the ancient forest sites have been cultivated and are under improved pastures or crops. On most of this land profiles have become rearranged, to varying degrees, by movement of topsoil laterally through cultivation and by a general evening out of surface irregularities. This practice is known to have broken up and spread about many of the charred stumps that were at, or close to, the surface at the time the land was first ploughed.

Relation of the Evidence to Existing Forest

The broad distribution of forest remains may be compared with the present extent of indigenous forests also shown in Fig. 1. In the mountainous regions, living trees of the same species occur within one mile of most finds of logs and buried charcoals. In many instances they are components of still-extensive forests, while in other cases they are merely relicts from the former forest. Such relict beech occurs mainly in gullies, though scattered trees occur on steep bluffs. Relict totara also is often situated in gullies, while slopes of coarse talus are another common refuge. The scale of mapping used in plotting present forest cover does not allow for the complete inclusion of such isolated trees and small groups. Only in Central Otago, the Mackenzie Basin, and on the Canterbury Plains were remains found more than 10 miles from known existing trees. In Central Otago, where forest is absent, there are nevertheless scattered groups of living totara. On the Canterbury Plains the occurrence of buried logs and charcoal of podocarps and other species is reflected in the survival of a few patches of forest into European times in swamps and higher-rainfall areas.

Generally, the past distribution of forest tree species as determined by the present authors compares favourably with the area attained by living representatives of the same species. There are, however, several anomalous distribution patterns worthy of mention. The extent of beech charcoals and the presence of mountain beech on hitherto regarded podocarp sites, particularly on the Hawkdun Range, are important records, but perhaps more surprising is the discovery of red beech charcoals at 3,700 ft on the Crown Range well above the present altitudinal limits of this species (*Ca.* 3,000 ft). Even more surprising is the occurrence of red beech charcoals in Paparua County. At the heads of lakes Ohau and Hawea, and on the lower slopes of the Hector Mountains gymnosperm charcoal was found, but little or no undoubted beech charcoal, despite the fact that *Podocarpus hallii* in these areas is only a minor component of existing beech forest; this may indicate invasion by beech subsequent on destruction of the former forests. In the Waimakariri watershed, however, beech charcoal is widespread in the absence of podocarp charcoal, even though isolated trees of *P. hallii* occur in the present beech forest which has regained some of its former area following the initial destruction (see Table 1, N.Z. 304 and N.Z. 391). This evidence suggests that mountain beech has long been the dominant forest species over the greater part of the watershed. In other localities, notably on the foothills of the Torlesse Range, buried charcoals of beech and podocarp found in the same stratigraphic position suggest a mixed type of forest; again, the principal dominant in the present cover is mountain beech with a few scattered trees of *P. hallii*. The discovery of matai charcoal and uncharred seed cases on Tekapo moraine at some distance from living stands of this species is also of particular interest. The extent of this matai-containing forest has not been determined.

Logs and charcoal were not found above the present altitudinal limits attainable by forest in any of the localities examined. Mountain beech charcoals and associated egg-cup podsols cease abruptly at the present-day altitudinal limit of mountain beech forest (i.e. 3,000–5,000 ft, depending on latitude and local habitat). On the other hand, Raeside (1948) stated that totara logs are found up to 500 ft above the present tree line, giving as an example 4,000 ft on the Kirkliston Range.

Causes of the Deforestation

The earliest writers, Buchanan (1875) and Munro (1875), ascribed the forest destruction to pre-European fires which Munro suggested may have been lit by the Maoris. To Cockayne and Laing (in Speight *et al.* 1910), however, it seemed impossible that this forest, if it existed, was altogether destroyed by fire. These authors sought an explanation in the hypothesis advanced by Speight (1910, p. 419) who stated that "The disappearance had in all probability begun before the arrival of the Maori, following on a period of drier climate after a moist period which favoured its growth." Holloway (1954, p. 373) wrote that "Final destruction of the forests, over wide areas, was undoubtedly by fire. But, also without question, the forests were not burnt until after they had entered the period of instability as a consequence of climatic change." Cumberland (1962) brings the wheel almost full circle by attributing the destruction principally to human activity, though he recognises a smaller and somewhat different change in climate and weather which he thinks may have contributed to forest contraction "especially on light soils and gravel subsoils" prior to the advent of man.

The buried charcoals can scarcely be regarded as originating in any way other than through forest fire, and, if due allowance is made for the age of the tree at the time of destruction, most of the radiocarbon dates of logs and charcoals fall unquestionably into the Polynesian era. In the opinion of the present authors, the question as to whether climatic change had any part in facilitating the destruction of the forest by fires of human initiation depends on evidence from other sources, such as a study of time-stratigraphic units in soils, with the aid of soil-pollen analysis and other techniques of micropedology; further pollen analysis of suitable peat profiles, supported by radiocarbon dates; and a detailed investigation of forest regeneration.

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