# EVIDENCE FOR POST-GLACIAL CLIMATIC CHANGES IN NEW ZEALAND

**B. P. J. Molloy***

ABSTRACT

New Zealand evidence for major changes in post-glacial climate is examined briefly. Interest is centred on the supposed climatic optimum and the A.D. 1300 deterioration in climate culminating in the 'little ice age'.

The main conclusion reached is that there is no convincing proof of a major change in post-glacial climate other than a general rise in temperature about 10,000 years ago. It is suggested that the weather and climate from about this time has been essentially the same as that of the present day, characterized throughout by variability of meteorological parameters, and punctuated by local and short-term climatic extremes. There is no conclusive evidence that these minor variations were ecologically significant.

## INTRODUCTION

In their recent bibliography of the meteorology and climatology of New Zealand, Sparrow and Healy (1968) list some 600 entries of which only 25 deal specifically with climatic change. The state of knowledge concerning climatic change is best summed up in their following comment: "Climatic change literature from a meteorologist's point of view is almost non-existent, although several writers discuss the application of the concept to New Zealand through the eyes of related disciplines."

Other features of the literature stressed by Sparrow and Healy are its strong agricultural orientation; the sporadic and unco-ordinated nature of early physical and climatological reports; and the apparent lack of published research into the problem of the general circulation and forecasting pertaining to the New Zealand area.

Thus, for information on changes in climate before the period of systematic meteorological recording — the last 100 years — indirect lines of evidence must be used. This paper evaluates briefly some of this evidence and its interpretation in terms of climatic changes accepted elsewhere, mainly in Western Europe.

* Botany Division, Department of Scientific and Industrial Research, Christchurch.

## ACCEPTED PATTERN OF POST-GLACIAL CLIMATE

The following are the major changes in climate which are believed to have occurred in Britain over the last 7,000 years (after West, 1968):

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|---|---|
| present–A.D. 1940 | Warmth decrease. |
| A.D. 1940–1850 | Warmth increase. |
| A.D. 1850–1500 | 'Little ice age'. |
| A.D. 1300 | *Climatic deterioration set in.* |
| A.D. 1000–1300 | Lesser climatic optimum. |
| 500 B.C. | Climatic deterioration of the Sub-Boreal. |
| 3000–5000 B.C. | *Climatic optimum.* Annual mean temperatures about 2 deg. C above present. |

Of these supposed changes, the climatic optimum, and the A.D. 1300 climatic deterioration have influenced scientific opinion most in this country and seem to be widely accepted and somewhat loosely applied, so much so that we are in danger of suffering from a kind of intellectual inertia which accepts that the events of the post-glacial can be explained by major changes in climate, and other factors are discarded.

In the opinion of the author these concepts and their application to New Zealand evidence should be examined with renewed zeal, putting aside for the moment such cherished beliefs as world-wide correlations, for if it finally transpires that they have been accepted without a firm foundation of local evidence, then climatic interpretations of ecological phenomena immediately become suspect and alternative explanations must be sought.

## THE CLIMATIC OPTIMUM

*"that elusive and timeless concept, the climatic optimum, with its misleading overtones of a sort of meteorological garden of Eden."*

Robert Raikes, 1967: p. 11

### Botanical Evidence

The notion of a post-glacial climatic optimum, thermal maximum, or hypsithermal interval as it is variously called was first postulated by Praeger in 1892 following his studies of the estuarine fauna of northern Ireland (Wright, 1937). It arose later in connection with anomalous plant distributions in Western Europe where it was shown that certain plant species, notably hazel, were once more widespread than they are now. From this it was inferred that at some time in the past the climate was more favourable to their spread than present climates. This interval of extended distribution became known as the climatic optimum.

The notion was introduced indirectly to New Zealand by Cranwell and von Post (1936) as a result of their pollen-analytic studies of peat profiles in Otago and Southland. By applying the laws of 'revertence' and 'regional parallelism' to the available pollen statistics they proposed a three-fold division of the post-glacial according to vegetation successions and climatic evolution:

Zone I. Grassland period; severe climate with slight regional differences only.

Zone II. Podocarp-forest period; uniformly wet and, probably, warm climate.

Zone III. *Nothofagus*-forest/grassland-mosaic period; deterioration of the climate. Distinct differentiation into local climatic districts.

The proposed pattern of climatic evolution was based on the assumption that the successions of vegetation were all due to changes of climate comparable to those believed to have occurred in Western Europe. Other causes such as biotic and edaphic factors or historical circumstances, though theoretically possible, were discarded in favour of one cause, climate.

That this three-fold division became accepted is now well enough known. Further, as Walker (1966) points out, it became fashionable to equate it chronologically and climatically with the climatic amelioration, optimum and deterioration of post-glacial Western Europe. The concept of the climatic optimum, supposedly occurring some 2,500–6,500 years ago (Harris, 1963), is firmly entrenched in our literature and appears consistently in support of ecological and hydrological phenomena.

However, from the accumulating data on plant ecology and geography, radiocarbon dating, and pollen analysis itself, it appears that these assumptions and generalizations were premature. Relevant evidence for New Zealand may be summarized as follows:

(1) Pleistocene glaciation has had a profound and continuing effect on post-glacial vegetation history. It is manifested in the flora by a high degree of regional endemism and the discontinuous distribution of certain taxa, attributed both to differential extinction during ice advances, and to differential rates of migration and site adjustment with ice recession (Wardle, 1963a). The fact that *Nothofagus*, a key genus in vegetation history, shows pronounced discontinuity and is still re-occupying areas suited to it is significant (Willett, 1950; Wardle, 1963a, 1964). Thus, there is good reason to believe that the continuing reaction of *Nothofagus* to Pleistocene glaciation is the basic principle underlying its invasion of podocarp forests, and not post-glacial climatic change.

(2) Recent pollen diagrams confirm the grassland-scrub period of the early post-glacial. Accumulating radiocarbon dates show that this period terminated in the South Island with the spread of podocarp forests about 10,000 years ago (Walker, 1966; Moar, 1966). Moar suggests that this registers a sustained rise in temperature following the colder conditions of the last glaciation. However, over the last 10,000 years, changes in forest patterns have occurred

throughout the country, varying in expression from one region to another.

(3) The maximum post-glacial development of podocarps, as reflected in pollen diagrams, is usually attributed to the warm, moist conditions of the climatic optimum. However, podocarp forests are difficult to interpret climatically because of the number of species involved and their different ecological amplitudes, and because of the range of habitats from which pollen statistics have been drawn (Walker, 1966). In many places these forests were dominated first by miro (*Podocarpus ferrugineus*), matai (*P. spicatus*) and totara (*P. totara*), which in some areas were replaced later by rimu (*Dacrydium cupressinum*). In other localities these early dominants were less extensive and rimu apparently was absent. In other places still, rimu was dominant from the beginning to recent times (Moar, 1966; Franklin, 1968). Studies by the author, of fossil charcoals presumably derived from natural fires, indicate that *Phyllocladus* was the dominant podocarp in certain mountain districts, preceding *Nothofagus*. Such complexity led Walker (1966) to conclude: "It is impossible to discern any uniform climatic drift applicable throughout New Zealand from the pollen diagrams of this period interpreted ecologically".

(4) The post-glacial spread of *Nothofagus* is usually interpreted as a response to a deterioration of climate, e.g. increasing cold or increasing dryness. However, it is difficult to interpret the event climatically for the same reasons mentioned for podocarp forest, and for reasons referred to previously. Also to be considered are the short life and slow dispersal of *Nothofagus* relative to the podocarps, and the difficulty of separating the pollen of *Nothofagus* species, except silver beech (*N. menziesii*) (Moar, 1966). It is not surprising therefore, that available radiocarbon dates strongly suggest that the replacement of podocarps by *Nothofagus* is metachronous (Walker, 1966; Moar, 1966). In fact the mounting evidence for this is confirmation of the slow dispersal of *Nothofagus* from refugia since the last glaciation.

(5) Any major change in post-glacial temperature should be reflected in an altitudinal shift of vegetation belts, particularly the timber line. In New Zealand the timber line is generally abrupt, remarkably level and regular in the case of beech forest, and broadly correlated with summer warmth (Zotov, 1938; Wardle, 1965). However, no compelling evidence useful to the present discussion has yet come forward. Those irregular and depressed timber lines that are known can be explained by existing environmental variations (Wardle, 1965), past fires (Molloy *et al.*, 1963), fog (Zotov, 1938) and catastrophic storms (Elder, 1963).

(6) Evidence is still accumulating on the strong anthropogenic control of vegetation successions during the last millennium, and perhaps even earlier. Fire especially was widely used during this

period of the human occupation of New Zealand. In addition, pre-human fires, apart from those associated with volcanism, have been dated as early as 6,500 years ago (Cox and Mead, 1963; Molloy *et al.*, 1963). Indeed, man-made fire has displaced climate as a major controlling factor over wide areas since about A.D. 1000 and could be responsible for some changes reflected in fossil pollen sampled near the surface of peat profiles, especially the so-called revertence of grass pollen (cf. Cranwell and von Post, 1936; Harris, 1963). Fire is discussed further in relation to recent climatic change.

To summarize, the botanical evidence to hand does not point to any major change in the post-glacial climate of New Zealand other than a general rise in temperature of unknown magnitude and seasonal distribution about 10,000 years ago (Walker, 1966; Moar, 1966).

**Other Evidence**

Evidence derived from other sources lends little support to the notion of a climatic optimum for New Zealand. Two lines of evidence will suffice to illustrate this point.

The first concerns post-glacial sea-level fluctuations. The main issue at stake here is whether there was a post-glacial eustatic sea level higher than the present level which could be correlated with a climatic optimum. Schofield (1963) sustains the idea of a higher sea level in New Zealand about 4,000 years ago (and subsequent minor oscillations) but is unsure of its relationship with the supposed climatic optimum. Evaluating this and other work, Jelgersma (1966) accepts tectonic movement as the reason for the apparent high sea level of Schofield and others, and concludes that a post-glacial sea level higher than the present one is suggested, but certainly not proven.

Using radiocarbon-dated offshore samples from the Christchurch region, which is thought to be substantially unaffected by tectonics, Suggate (1968) has drawn a sea-level curve indicating a rise of sea level from 9,400 years ago, reaching the present level about 5,000 years ago. Subsequent fluctuations could not be judged from the sparse data available.

Although it is generally agreed that sea-level changes during the Pleistocene were controlled by the world ice budget, hence due to major changes in world climate, no such agreement exists for the comparatively small oscillations of post-glacial sea level. This is due to the divergent opinions on the eustatic movements of sea level, particularly during the last 5,000–6,000 years; the difficulty of separating eustatic from isostatic and tectonic movements; and the uncertain relationship between climate and the behaviour of contemporary glaciers.

The post-glacial sea-level rise may have modified local climates slightly and must have affected coastal drainage systems, producing local effects simulating climatic change (cf. Raikes, 1967). In coastal Canterbury at least, it is partly responsible, by its effect on sedimentation and drainage, for the evolution of swamp and lower-flood-plain forest in an otherwise marginal forest environment.

The second line of evidence concerns paleopedology, the study of paleosols or old soils, i.e. those that carry residual evidence of previous conditions. Paleosols occur abundantly in New Zealand, buried by successive layers of volcanic ash, loess beds, wind-blown sands, colluvium and alluvium. At one exposed ash site, eight periods of soil development have been separated by radiocarbon dating and these span an interval of 7,000 years between 1,900 and 9,000 years ago (Healy *et al.*, 1964). At another, a sequence of paleosols interbedded with nine layers of volcanic ash and lapilli has formed in the last 500 years, as shown by tree-ring counts of the oldest living trees (Druce, 1966). Many other examples involving loess, alluvium and wind-blown sands could be cited.

The question is whether paleosols differ in nature from present-day soils, which would suggest a difference between past and present soil environments. These differences might be expected, for example, in the transition zones between major soil groups.

In brief, most paleosols studied do not indicate post-glacial environments significantly different from the present. Those that do differ from present soils are known to have formed much earlier in geological times (Vucetich and Pullar, 1969; H. S. Gibbs, pers. comm.). Generally the nature of post-glacial paleosols conforms to the nature of present-day soils. Minor differences observed can be explained either by changes in the texture of parent material, or by the time involved between successive periods of soil formation. It should be emphasized, however, that these studies are not exhaustive and interpretations may alter as new information becomes available.

## A.D. 1300 CLIMATIC DETERIORATION AND THE LITTLE ICE AGE

The concept of this supposed climate shift is now difficult to trace accurately. Lamb (1965, 1966) gives probably the best review of arguments for and against the event, including indirect evidence drawn from New Zealand.

It is probable that Raeside (1948) introduced the idea to New Zealand, but Holloway (1954) certainly gave it added impetus. Their now-classic papers are well known and the views they advanced became firmly established in the literature. However, their interpretation of soil and forest anomalies in terms of climatic change was challenged by Cumberland (1962) who placed greater stress on anthropogenic control and saw little need to postulate a climatic cause.

The immediate outcome of Cumberland's timely criticism has been a shift of emphasis from wholly climatic causes to the recognition of other factors, notably catastrophes of various kinds (cf. Fleming, 1963; Molloy, 1968). Accordingly Raeside's list of evidence for climatic change has been substantially eroded, while Holloway's basic concept — forest instability — is still sustained though not necessarily in detail. These two aspects, catastrophes and forest instability, are discussed briefly.

## SIGNIFICANT CATASTROPHES

The manifold effects of catastrophic disturbance are familiar to ecologists and hydrologists. Disturbance of one kind or another has been a constant feature of our post-glacial environment, especially volcanism, fire, violent storms and other, short-term vicissitudes.

Few parts of central North Island have escaped the effects of volcanism. Volcanicity in this environment may be likened to glaciation in the South Island. The effects of both events on the environment were very marked in some areas but barely discernible in others; the effects of both still persist, perhaps even more in the case of continued volcanicity.

In discussing regional volcanic histories, Nicholls (1963), Vucetich and Puller (1963) and Druce (1966) describe associated soil and vegetation patterns, geomorphic alterations and increased erosion potentials. The intricate pattern that emerges, compounded later by other natural catastrophes and by cultural interference, suggests that no great confidence can be placed on climatic interpretations in these regions.

Fire has also caused significant ecological and hydrological changes and its influence extended beyond regions of volcanic activity and throughout the post-glacial period. The known history of fire in New Zealand can be summarized as follows:

(1) Periodic, local or widespread fires linked with volcanism (see references above).
(2) Periodic natural fires of undetermined extent and frequency (Cox and Mead, 1963; Molloy *et al.*, 1963).
(3) Widespread and catastrophic fires of the early Polynesian culture between 500 and 1,000 or more years ago (Molloy *et al.*, 1963).
(4) Local and regional fires associated with pre-European Maori agriculture during the early nineteenth century (Cameron, 1964).
(5) Extensive and destructive fires in connection with early European agriculture and forest exploitation.
(6) Intermittent man-made fires from about 1,000 years ago to present times (e.g. Grant, 1963; Esler, 1963; Elder, 1963).

Only recently has the significance of fire been fully recognized, and so far we have barely scratched the surface of our complex fire history, particularly in the North Island. In the South Island, for instance, natural fires alone are known to have occurred at six different times between 2,000 and 6,500 years ago at intervals of 500 to 1,000 years. Various combinations of natural and man-made fires may be represented at one site in the South Island, and it is possible that similar combinations may yet be found in the North Island.

That a large area of the environment was affected by fire cannot now be disputed. It remains to be shown just how much was affected and how often. Nonetheless, present evidence suggests that fire has displaced climate as a major controlling factor over 50–75 percent of New Zealand during the last millennium.

Another factor to be considered in climatic interpretations is the local and short-term climatic extreme. Cloudbursts, floods, violent winds and drought are not infrequently recorded and seem to be normal events and a constant feature of our post-glacial environment (cf. Sparrow and Healy, 1968; and the series of papers by P. J. Grant in this journal). Some notable disruptions of natural vegetation by these means are described, e.g. Grant (1963), Elder (1963), and examples of storm-modified hydrological systems have been reported in past numbers of this journal.

A point of mutual interest to ecologists and hydrologists is the close link between fire or volcanicity and subsequent erosion. Many examples exist but the one most familiar to the author is the continuing cycle of landscape instability initiated in eastern South Island by Polynesian burning and further aggravated by European cultural systems and climatic extremes (Molloy, 1962, 1968).

## FOREST INSTABILITY

The strong anthropogenic control of vegetation since about A.D. 1000 limits the search for the evidence of a climatic shift as recent as A.D. 1300 to those few regions where natural successions have been controlled solely by climate. In one of these regions — western Southland — Holloway (1954) developed his main hypothesis of forest instability in respect to present climate and later extended it to other parts of the South Island. In recent defence of this hypothesis Holloway (1964) has sought refuge in these same forests.

The more one studies Holloway's description of these Southland forests the more one suspects that the focal point of his hypothesis was the instability of the podocarp elements, especially rimu, and not *Nothofagus*. But, true or not, current information on the post-glacial behaviour of *Nothofagus* forest makes it difficult to interpret existing patterns solely on the basis of a deterioration in climate beginning about A.D. 1300. We are left then with the inherent instability of the podocarp forests, a fact by no means novel.

Briefly stated, this instability is reflected in the predominance of mature and overmature gymnosperms with correspondingly fewer seedlings, saplings and young trees: the 'regeneration gap'. Nicholls (1956), Grant (1963) and Wardle (1963b) discuss the principal views advanced in explanation of this apparent anomaly. Cameron (1960) lists other arguments concerning seed production and dispersal. All agree, however, that the gap is real and widespread, and Wardle (1963b) has marshalled some quantitative data in support. With these few facts all agreement ceases.

Opinions vary as to the beginning and duration of the regeneration gap, and by inference, the onset and duration of the supposed deterioration of climate, e.g.:

| | | |
|---|---|---|
| Holloway (1954): | A.D. 1200 | |
| McKelvey (1953): | A.D. 1600 | |
| Nicholls (1956): | A.D. 1650 | |
| Grant (1963): | A.D. 1500 | (possibly A.D. 1250 but intense since A.D. 1700) |
| Wardle (1963b): | A.D. 1300 | (intense between A.D. 1600–1800) |

Since the regeneration gap has been demonstrated in forests of different ages (and environments) its synchroneity throughout New Zealand remains doubtful. The absolute chronology is also doubtful as it is based on interpretation of growth layers in some cases and estimates in others. Only one worker (Wardle, 1963b) has recorded a subsequent upsurge in regeneration in places, beginning some time after A.D. 1800; others claim that regeneration is still inadequate.

Opinions are equally divergent on the nature of the supposed climatic change. Some workers emphasize temperature, others moisture, and others still a combination of the two. The direction of change is also not always clearly stated.

A seemingly incompatible feature is the striking evidence of vigorous podocarp regeneration when so-called stagnant forests are destroyed. In general there is a tendency for the resulting young (seral?) stands to develop an even-aged structure, and younger plants are scarce. There are exceptions of course, but these are not the rule, to judge from published accounts. It may not unreasonably be concluded therefore, that certain endogenous mechanisms control succession and stability in podocarp forests and that periodic rejuvenation may be a prerequisite to their continued existence.

Summarizing the results of regeneration studies, it can only be concluded that they suggest, but certainly do not prove, a deterioration of climate some time after A.D. 1300.

Clearly, then, our interest should shift away from a preoccupation with population structure and single-factor interpretations which are difficult. if not impossible to measure. At the same time, interest should shift towards a better understanding of the autecology of the species concerned. Information along these lines is beginning to appear in published accounts, though direct experiment in controlled environments is lacking. The way is also open to more exhaustive studies of plant-animal interrelationships in respect to the fate of seed and seedlings, and investigation of such aspects as soil impoverishment, mycorrhizae, root grafting and possible biochemical reactions, e.g. allelopathy.

## CONCLUDING REMARKS

There are several aspects of post-glacial history which have not been referred to. as for example the record of glacier behaviour. changes in the level of closed basin lakes, paleolimnology and landform analysis. Current information on these varies from scant to detailed local records. In some cases their relationship with climate is not fully understood, and interpretations of climatic and ecological changes are therefore difficult to substantiate. The majority reflect climatic variability irrelevant to the present discussion.

The conclusion is that there is no convincing proof of a major change in our post-glacial climate other than a general rise in temperature about 10,000 years ago. For the most part since that time the climate has been essentially the same as that of the present day. The mounting evidence for local and relatively short-term fluctuations of weather and climate is not disputed but is regarded as a characteristic feature of the environment. However, there is no conclusive evidence that those minor variations were of sufficient amplitude and geographic extent to be ecologically significant.

This view accords with the argument of Raikes (1967) and. in general, with the following statement of Cumberland (1962): "The present argument does not deny the possibility of climatic change. It suggests, however, that this particular issue is complex; that 'climate' is in any case an intellectual concept; that it is the day-to-day realities of weather that matter; that soil and intravegetational climates are more important in determining vegetation patterns than is the climate of the free atmosphere evaluated simply in terms of yearly means of but two meteorological elements; that weather from day to day and from year to year (and thus also climatic averages) is in a constant state of both irregular and cyclic flux; that in any decade or century there have certainly always been weather sequences of drier than 'normal', wetter than 'normal', and warmer and cooler than normal'."

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