On New Zealand Climate Within the Last 1000 Years

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ABSTRACT

This paper outlines the pitfalls in attempting to assess the climatic history of New Zealand within the last thousand years. The main problems are the difficulty of estimating, from the proxy evidence, the amplitude of changes in climatic parameters and the imprecision of dating of events. Stress is placed on the need to build up a local picture of climatic history, independent of those derived elsewhere.

Evidence from glacial moraines and closed basin lakes enables a broad pattern of climatic variation to be perceived, in which there have been many fluctuations of relatively small amplitude. Until a dendrochronological record has been established here, dating of events must remain imprecise.

Keywords: NEW ZEALAND PALAEOCLIMATE, PROXY DATA, DATING, DENDROCHRONOLOGY, GLACIAL MORAINES, CLOSED BASIN LAKES.

INTRODUCTION

This paper was prompted by one by Foss Leach (1981), on the prehistory of the southern Wairarapa, in which he makes confident statements about palaeoclimate conditions there during the last 1000 years. He (as do other archaeologists) uses terms like "Little Climatic Optimum" and "Little Ice Age" and indicates times of climatic deterioration and improvement, with great precision. As well as some local information, he uses some overseas data to support his statements. He does not, however, refer to some of the more recent New Zealand evidence (Burrows 1976, Burrows and Greenland 1979, Grinsted and Wilson 1979, Healy 1975, Dunwiddie 1979). [N.B. all dates in the following account are given according to the BC-AD system. Radiocarbon dates are given corrected for secular variation in the formation of radiocarbon by dendrochronology, and according to the new half-life of 5730 years for radiocarbon. The dates, thus, are approximately equivalent to solar years.]

I want to suggest that Leach's approach to the documentation and interpretation of evidence for climatic conditions is misleading and a source of trouble for archaeologists and others who refer to his work uncritically.

In support of my criticism I wish to point out that:

1. We have no climate records earlier than about A.D. 1860 and therefore have to rely on proxy information for earlier times.

2. There are very considerable difficulties in dating most of the proxy records and considerable difficulties, also, in interpreting the climatic significance of some of them (cf. Burrows and Greenland 1979).

3. It is most unwise to assume that palaeoclimate data from anywhere else in the world applies to New Zealand. We must first construct our own palaeoclimate record, from local evidence. There is, also, great regional variability of weather and climate patterns within New Zealand so that extrapolation from one part of the country to another is often far from easy (cf. Salinger 1981a, b).

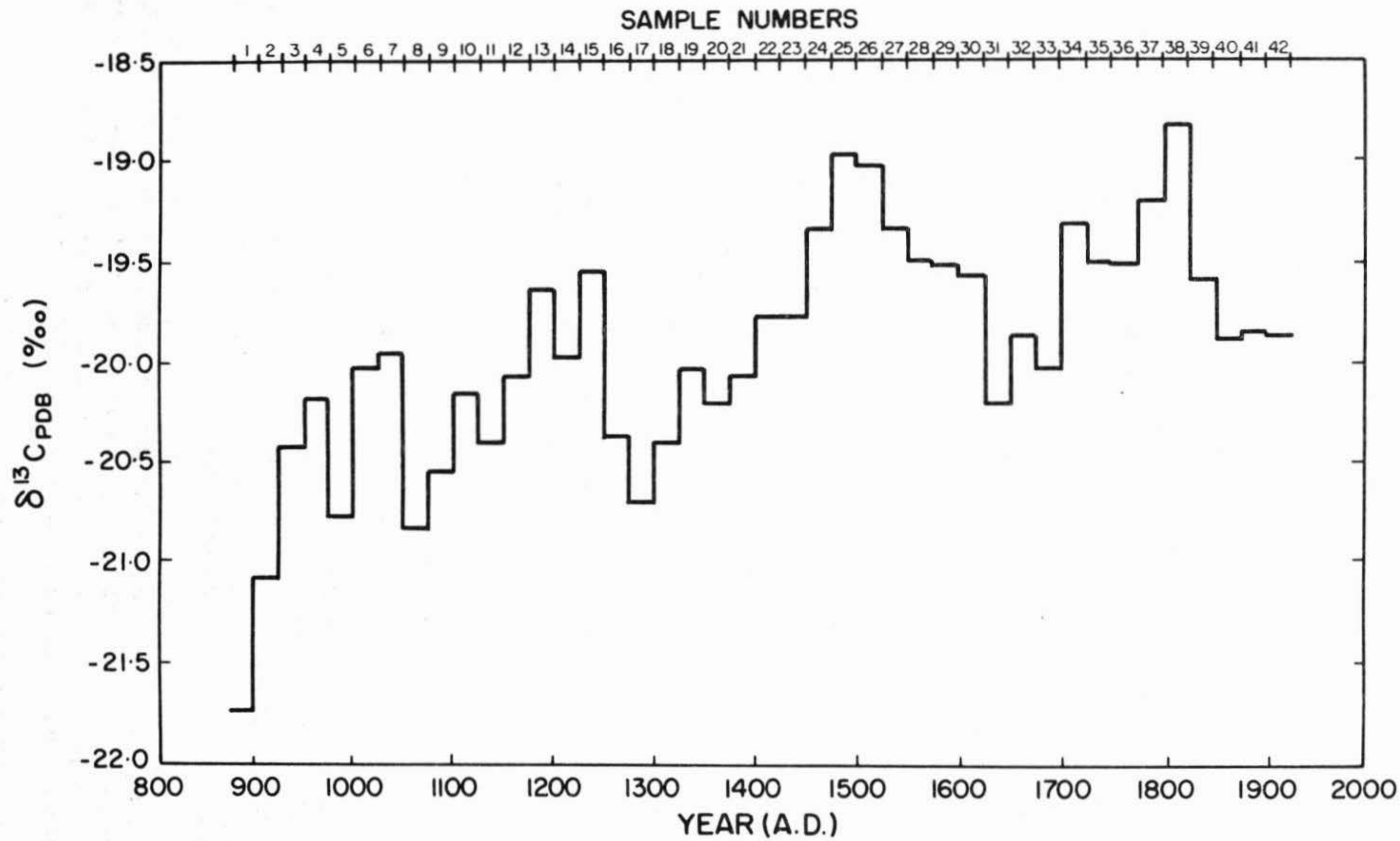

Figure 1: $\delta^{13}C$ variations for the past thousand years in cellulose from an *Agathis australis* tree (After Grinsted and Wilson 1979).

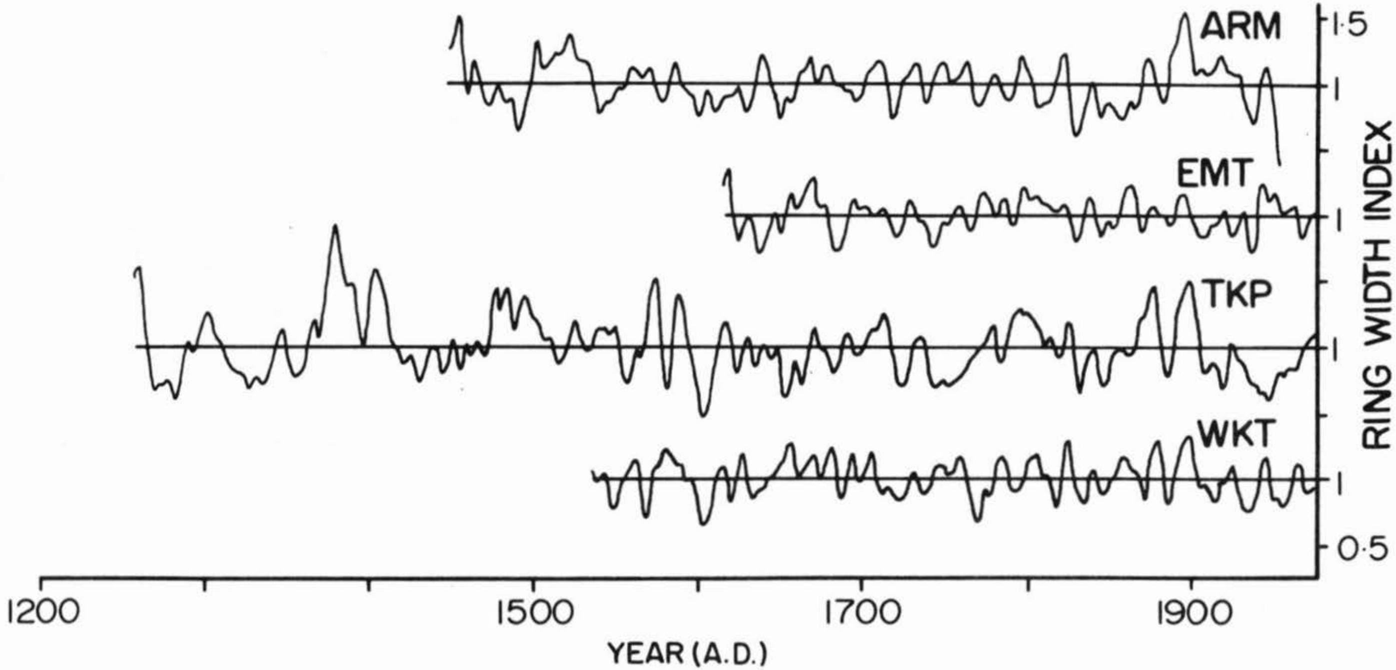

Figure 2: Chronologies showing varying widths of growth layers for three stands of *Libocedrus bidwillii* (ARM, EMT, TKP) and one of *Phyllocladus glaucus* (WKT), smoothed using a low-pass filter (After Dunwiddie 1979).

THE APPLICATION AND USEFULNESS OF PROXY RECORDS

Desirable characteristics of proxy records to be used for palaeoclimate reconstruction are that:

1. There should be a continuous, long-term, dateable sequence which provides a faithful record of individual climatic parameters (or, at least, clear-cut, integrated effects of several parameters).
2. There should be the possibility of calibration of the modern part of the sequence with instrumental records.

The potentially most useful of the proxy records, the parameters estimated and the precision of the climatic element and of its dating are indicated in Table 1; the figures (Fig. 1-4) and Table 2 show the results of various studies. The reader should refer to the original papers for the dating and other methods. Precision of dating cannot be better than ± about 50 years for those events dated by the radiocarbon method, even if one has absolute faith in the calibration of this method by tree-rings to get an approximation to solar years. The only totally reliably dated proxy sequences are the kauri tree-ring, carbon isotope curve of Grinsted and Wilson (1979) and the dendrochronologic sequences of Dunwiddie (1979), mostly for *Libocedrus bidwillii*. The rises and falls of the carbon isotope curve in Grinsted and Wilson's study (Fig. 1) probably indicate temperature fluctuations, but the amplitude of the effects has not yet been determined. Unfortunately, Dunwiddie's curves (Fig. 2) have not yet been correlated with any climatic parameter. Wilson, Hendy and Reynolds' (1973) speleothem temperature curve (Fig. 3) is imprecisely dated. From about A.D. 1400 on it agrees well with Grinsted and Wilson's curve, but, by comparing the curves it may be seen that, earlier than that, the dating seems to be in error by 200-250 years. There is also some uncertainty about the amplitude of the temperature fluctuations (Grinsted and Wilson 1979).

A method which might have been expected to be useful, pollen analysis, has not so far proved to be so, mainly because of Polynesian disturbance of vegetation by fire (Molloy *et al.* 1963, Burrows and Greenland 1979). Even in sites unaffected by fire there are no clear indications of climate variation. Holloway's (1954) hypothesis of climate change, based on observations of apparent anomalies in forest distribution or tree population structure in the South Island, has only recently been rigorously tested (by John Bathgate: pers. comm.), but this work has not yet been published. Holloway gave no estimates of climatic parameters, and the assumptions he made, both about climate and vegetation, can all be called in question. The evidence is equivocal. Wardle (1963) carried out some testing of Holloway's hypothesis, but his sampling does not appear to have been extensive enough.

Compared with one another, the most reliable of the long records considered so far give by no means a clear picture of the history of climate change. Partly this arises from experimental error and partly from insufficiency of information which could be used for interpretation.

Potentially the most useful method, if the appropriate climatic correlations can be made, is dendroclimatology (Fritts 1971). It has the inbuilt advantage of precise dating. Dendrochronology may also be useful for deriving temperatures by isotope analysis or densitometry. Work is ensuing (by V. La Marche in Arizona, John Ogden at Auckland University and David Norton at the University of Canterbury).

Glacial moraines (Table 2) do not fit some of the desirable criteria for useful proxy data — they tend to be somewhat sporadic in occurrence, gaps in the record are common and information on warm periods is often hard to find. They are also hard to date and the connection with climate may not be simple. However, along with some other kinds of records, they enable us to fit together a somewhat

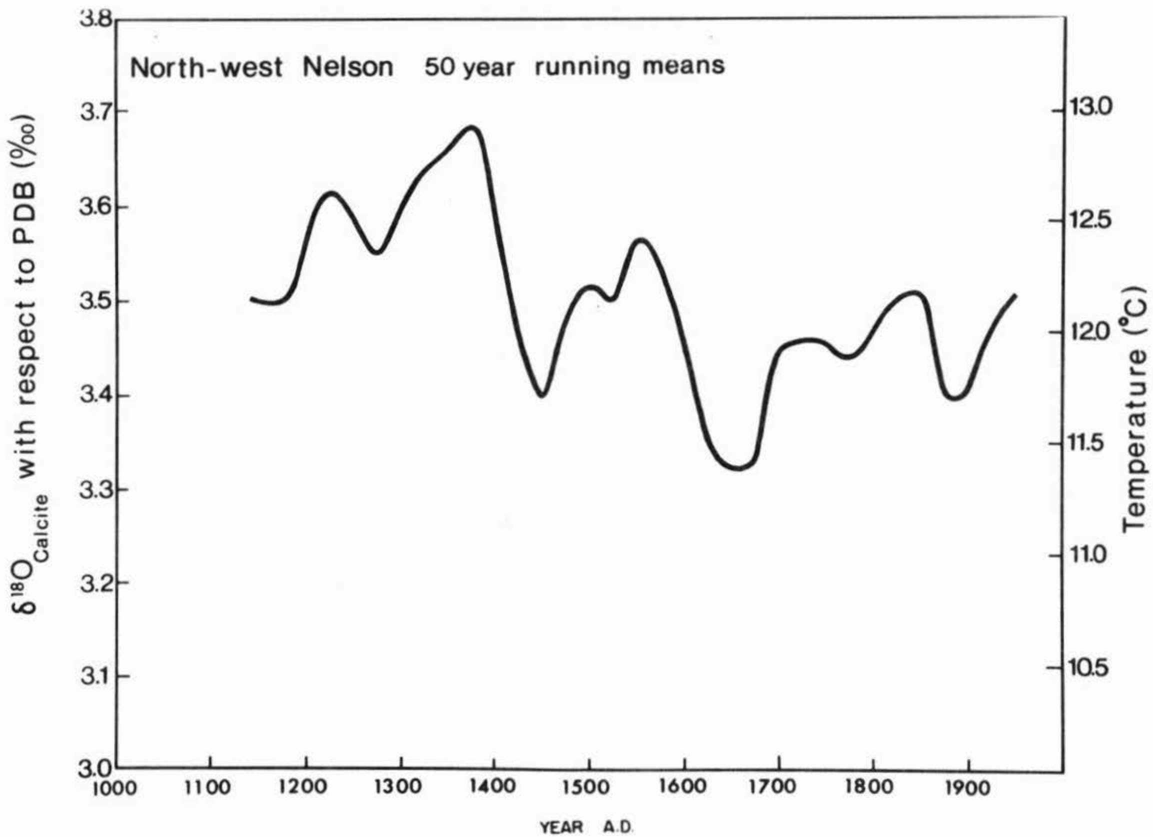

Figure 3: Speleothem palaeotemperature curve from a cave in Nelson (After Wilson, Hendy and Reynolds 1973).

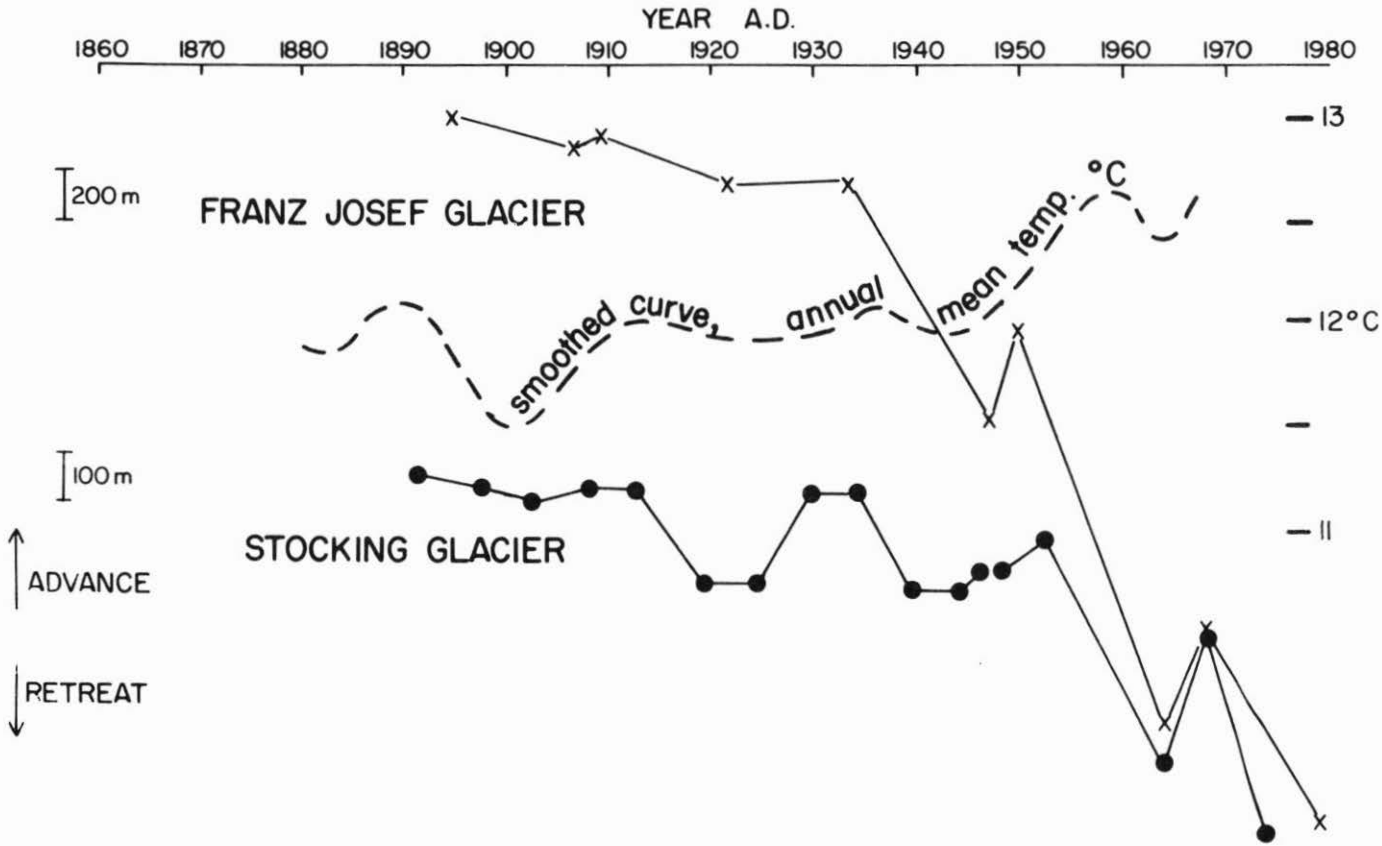

Figure 4: Curves for movements of the termini of Franz Josef and Stocking Glaciers, compared with a smoothed curve for annual mean temperature in New Zealand (After Heine and Burrows 1980). Temperature curve after Salinger (1979).

TABLE 1
PROXY RECORDS FOR CLIMATIC PARAMETERS

Method	Brief description of basis for climatic estimation. [parameter estimated.]	Precision of estimate, based on comparison of results with instrumental record.	Precision of dating.
Tree ring palaeotemperature	Temperature-dependent changes in ratios of carbon isotopes in cellulose of trees. [Air temperature.]	Possibly good, but not yet adequately tested.	Very precise.
Dendroclimatology	In cool sites (temperature) or dry sites (precipitation), dependence of annual growth layer widths of trees on climate conditions. [Air temperature, precipitation, usually during growing season.]	Possibly good, but appropriate correlations have yet to be made for available data.	Very precise.
Speleothems	Temperature-dependent changes in ratios of oxygen isotopes in calcium carbonate of stalactites and stalagmites. [Cave temperature, which is equivalent to damped-down air temperature.]	Possibly good, but not yet adequately tested.	Imprecise — available data are based on 50-year running means and radio-carbon dates.
Glacier moraines	Fluctuations in temperature are reflected by evidence for glaciers undergoing expansion and contraction; this seems to result from changes in position of mean freezing level which causes (a) More or less precipitation to fall in the form of snow in the accumulation season. (b) Greater or lesser amounts of melting during the ablation season. [Mean temperature.]	Extrapolation to past conditions, probably not very precise, but testing so far indicates that the method is valid.	Not very precise — dating is by weathering-rind measurements and the radio-carbon method.
Anomalies in plant population age structure or plant and vegetation distribution.	In theory, the plant population age structure and the distribution of plants and vegetation reflect the dependence of these on climatic conditions. Trees are most useful in this respect. [Possibly extreme conditions of low temperature, drought, storm damage.]	Imprecise until the population dynamics and ecology of plants and vegetation, with respect to climate, are well known. Interpretation is complicated by competitive effects.	Potentially precise for trees, but no apparent anomalies are well dated, so far.

TABLE 1 Continued

Icebergs	Abnormal northward extension of Antarctic icebergs indicating times of cold airflow on to the country. The only relatively long-term (about 200 year) observational data available. [Generally lowered temperature.]	Imprecise	Precise (based on ship's logs).
Closed basin lakes	Relative heights of lake shorelines indicate fluctuating trends in precipitation. [Mean precipitation.]	Reasonably precise, but extrapolation to past conditions may be difficult because of the lack of unequivocal data.	Not very precise for times before official records (dating based on genealogical and radiocarbon methods).

TABLE 2

GLACIER EXPANSION PERIODS IN THE SOUTHERN ALPS DURING THE LAST THOUSAND YEARS*

20th century: Major recession in most glaciers, broken by minor advances of some steep glaciers about 1908, 1930 and very minor advances 1950 and 1970.

19th century: Glaciers were enlarged during advances about mid-century and 1890.

18th century: Possibly glaciers were enlarged about mid-century.

17th century: Glaciers underwent at least one substantial advance and possibly others this century.

16th century: An advance occurred of the Tasman Glacier, Mount Cook early in the century. (Radiocarbon date N.Z. 5330, A.D. 1525 ± 58.)

15th century: At least one advance occurred in several glaciers about the beginning of the century. (Radiocarbon dates N.Z. 687, A.D. 1380 ± 50 from Cameron Glacier, Arrowsmith Range; and N.Z. 4016, A.D. 1400 ± 70 from Colin Campbell Glacier, Rangitata Valley.)

14th century: No definite evidence.

13th century: At least one advance occurred in several glaciers mid-late in the century. (Radiocarbon dates N.Z. 4015, A.D. 1270 ± 40 from Colin Campbell Glacier, Rangitata Valley; N.Z. 711, A.D. 1290 ± 40 from Tasman Glacier, Mount Cook; N.Z. 4774, A.D. 1275 ± 59, McCoy Glacier, Rangitata Valley.)

12th century: An advance occurred of the Tasman Glacier, Mount Cook, about the beginning of the century. (Radiocarbon date N.Z. 5331, A.D. 1109 ± 63.)

11th century: At least one advance occurred in some glaciers about the beginning of the century. (Radiocarbon dates N.Z. 4509, A.D. 970 ± 50 from Mueller Glacier, Mount Cook; and N.Z. 4507, A.D. 1000 ± 60 from Tasman Glacier, Mount Cook.)

* From early 16th century to mid 19th century the only dating so far available for South Island moraines has been by lichen measurements and by use of tree ages (Burrows 1973, Wardle 1973). Dates for Mount Cook moraines obtained by lichen measurements (Burrows 1973) have been shown recently, by Anne Gellatly (pers. comm.), to be unreliable and she will be producing a new chronology based on rock weathering rind measurements. Corrections will also be needed for chronologies for Cameron and Lyell Glacier moraines (cf. Table 2, p.327, Burrows and Greenland 1979). The tree-ring chronology of Wardle (1973) shows that Franz Josef, Fox and Strachan Glaciers in Westland advanced before about A.D. 1620-1635, before A.D. 1780-1790 and before A.D. 1840.

imperfect picture of New Zealand climate in the last 1000 years. We can calibrate the glacial moraine record fairly readily with general temperature conditions in New Zealand. Since about A.D. 1900 fluctuations of the Stocking Glacier at Mt Cook and Franz Josef Glacier in Westland have corresponded closely (Fig. 4) and, in turn, they correspond with changes in the smoothed mean temperature curve for New Zealand (Salinger 1979, 1982). Therefore, it is assumed that evidence for expansion of the glaciers generally indicates cooling and retreat indicates warming — which will have been experienced everywhere in New Zealand.

THE BROAD PATTERN OF CLIMATIC VARIATION IN NEW ZEALAND IN THE LAST MILLENNIUM

On the basis of the glacier evidence, there appear to have been cool periods in the late 10th-early 11th century, early 12th century, mid-late 13th century, early 15th century, early 16th century, also in the 17th century, possibly in the 18th century and in the middle and late 19th century. Grinsted and Wilson's (1979) tree-ring isotope results show that warm periods appear to have occurred about A.D. 1000, 1200, 1500, and 1800. The first and third of these dates conflict with the glacier evidence. Insensitivity of the glacier indicator and/or the experimental error inherent in radiocarbon dating, or in the tree-ring isotope method, could account for such discrepancies.

There has been an unprecedented warm period, beginning about A.D. 1900 and continuing to the present, broken only by minor coolings. The glacial data suggest fluctuations of mean temperature, probably not much more than $\pm$ 0.5 °C, during the rest of this millennium. The sizes of moraines suggest that each cooling was of roughly comparable magnitude and the mid and late 19th century coolings seem to have been about as great as earlier ones. The general rise of temperature since 1900 (about 1 °C, on average) seems to have been the warmest, or the longest warm period, in about the last 2000 years, possibly more. This latter statement is based on observations of the collapse, in the last few decades, of glacier moraines containing dated soils. These moraines are collapsing because, through ice shrinkage, they have lost the support of the glaciers which formerly lay between them.

Icebergs drifted near New Zealand about 1850 and 1890, when glaciers were expanded. Minor iceberg irruptions into unusually low latitudes also occurred about 1902 and in the early 1930s when air temperatures were cool (Burrows 1976).

Precipitation data have been difficult to find, though more may emerge when dendroclimatological data become available. The only reasonably good information comes from Healey's (1975) work on Rotorua closed basin lakes. Dates of Maori sites, now below lake level, indicate low levels in the 17th and 18th centuries and they were also low in the 19th century. The lakes rose to an all time high about 1970 as a result of increasing precipitation. There seems to be a reasonable correlation between low lake levels near Rotorua and advancing glaciers along the main divide of the Southern Alps and, conversely, between high lake levels and shrinking glaciers. The climatic connection is that the prevalence of warm, moist northerly air streams promotes high lake levels in the Bay of Plenty and shrunken glaciers in the Southern Alps. The prevalence of cool snow-laden southerlies and westerlies causes glaciers to expand, but causes dry conditions in the Bay of Plenty (and probably the east coast of both islands) (Burrows and Greenland 1979).

I do not intend to compare these conclusions in detail with those of Leach (1981), but scrutiny of his paper will show the considerable divergence.

FINAL NOTE

Finally I wish to suggest that archaeologists should forget about trying to fit the proxy data to their sequences in any precise way, until a continuous dendrochronological record is available. The non-scientific, and, I think, spuriously-applied terms "Little Ice Age" and "Little Climatic Optimum" should be abandoned. We should develop our own framework for climatic variation in the late Aranuian period without being hindered by such concepts, which were developed elsewhere and are, in any case, dubiously applicable there.

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