Kaimanawa Mountains to the Kaweka Range over a distance of 30 miles. Earthquake damage is not important but has probably occurred in two localities along the East Coast fault. Catastrophe of one kind or another whose traces will persist for 100 years or more is in fact a normal hazard of the higher forests, and tends to obscure longer term trends.

REFERENCES

HOLLOWAY, J. T., 1954. Forests and climate in the South Island of N.Z. *Trans. Roy. Soc. N.Z.* 82: 329–410.

WARDLE, P., 1962. Subalpine forest and scrub of the Tararua Range. *Trans. Roy. Soc. N.Z.* (*Bot.*) 1: 77–89.

VERNACULAR — SPECIFIC NAMES

Kahikatea	*Podocarpus dacrydioides.*
Rimu	*Dacrydium cupressinum.*
Silver Beech	*Nothofagus menziesii.*
Red Beech	*N. fusca.*
Black Beech	*N. solandri* var. *solandri.*
Mountain Beech	*N. solandri* var. *cliffortioides.*
Manuka	*Leptospermum scoparium.*
Leatherwood	*Olearia colensoi;* also *Senecio elaeagnifolius.*

EVIDENCE FOR ECOLOGICALLY SIGNIFICANT CHANGES IN CLIMATE DURING THE POST-GLACIAL PERIOD IN NEW ZEALAND*

C. A. FLEMING,

New Zealand Geological Survey, Lower Hutt.

Compared with the vast changes in geography, topography, climate, and biota during the rest of geological time, the changes of the post-glacial period are so slight that a geologist may perhaps be forgiven if he writes them off as negligible. But in fact, a universal human weakness offsets this reaction: man views the past through spectacles that exaggerate the perspective. We look back down a logarithmic time scale so that objects and events close to us have a significance far exceeding their order of importance when viewed on a linear time scale. The post-glacial period of some 15,000 years saw the spread of Neolithic and modern man and is thus infinitely more important to us than any previous period of equal duration. Moreover, the latter part of the post-glacial, the last two millenia (on which this symposium has been concentrated), overlaps the life-span of some organisms still living, to wit the slow-growing conifers, so that the botanist and ecologist must add the parameter of time to their data and think dynamically and historically, not just descriptively. The post-glacial, in consequence, becomes a notable field of overlap of disciplines.

Historically, the approach to New Zealand post-glacial changes has come from several independent types of study. The first conspicuous evidence of change came from discoveries of moa bones, and Haast, a geologist, got off on a false lead when he suggested that their extermination by an autochthonous race dated from the Quaternary, by which he meant a period much older than the younger post-glacial (see Haast, 1879). The magnitude of the faunal change, extinction of a whole assemblage of birds contemporary with the moa, led to numerous hypotheses of environmental change, some climatic. Post-glacial changes in Europe (especially Scandinavia) early influenced the interpretation of the New Zealand story; for instance Speight's (1911) conclusions that dry steppe climate of the glacial era in Canterbury had given way to moist forest climate and then to modified steppe conditions with wider grasslands to which early human fires had contributed. A threefold division of the post-glacial, with a middle period of warm wet climate, was strongly supported by Cranwell and von

* This paper was delivered as the Chairman's Address concluding the symposium of this title at the Society's annual conference in 1962.

Post's first New Zealand pollen diagrams (1936). Associating moa with open country, Archey (1941) seized on the middle or pluvial period of increasing forests as a contributing factor in the birds' extinction, which by this time was acknowledged to have taken place in the human period, about 1,000 years ago. The Blytt-Sernander pollen-zone chronology for the post-glacial was not at this time securely dated, so that the time gap between the "post-glacial pluvial" or "optimum" and the extinction of moas was perhaps not as obvious as it has become with radio-carbon dating. Perhaps realising this chronological discrepancy Falla (1955) associated the moas' downfall with the opposite trend, increasing desiccation and significant periods of drought.

The climatic changes of the Early Postglacial undoubtedly had greater ecological significance than later climatic changes. This was the period of retreat of the tundra and fell-field to the mountains, and of beech forests southward, chased and locally overtaken by podocarp forest, a progressive warming up, probably punctuated by reversals that have not yet been definitely established in New Zealand. Likewise, the Middle Holocene (Climatic Optimum or Hypsothermal Interval, some 4000 to 6000 years ago) when climate was warmer than now, led to widespread dominance of rimu and to an invasion of Northland by the Sydney mud cockle *(Anadara trapezia)* and probably to other changes relevant to interpretation of modern ecology and distributions. On the whole, however, the perspective spectacles of the biologist and ecologist do not give clear resolution of a situation lying so far back in the past, and the attempts to attribute extinction of moas or varying patterns in vegetation to changes so remote in time have less attraction now than they did 20 years ago when our knowledge was more elementary. To the paleontologist, and to the pedologist and geologist, these more remote Early and Middle Holocene changes are easier to recognise than the more subtle changes inferred for the past 4000 years of the Late Holocene.

In 1948, Raeside found disharmony between soil types and climates in South Canterbury and considered that this and other evidence could be explained by a change of climate from warm moist to cool dry, probably in the fourteenth century, by analogy with changes in the northern hemisphere (Brooks, 1926).

Holloway's classic paper (1954) studied instabilities in South Island forests and found evidence consistent with Raeside's hypothesis. From the data and techniques of pollen analysis, W. F. Harris took cognisance of the same hypothesis in deciding that evidence of replacement of forest by grass at the Snares Islands (1953) and at Pyramid Valley (1955) was possibly due to very late climatic change. The conclusion that the changes were *late* ones (i.e., not the change from Cranwell and von Post's Zone II to III) represents a notable achievement for the progress of pollen studies in dating, and it was subsequently confirmed by the 14C results for Pyramid Valley.

Archaeologists (e.g., Lockerbie, 1959), have also found a hypothesis of late climatic change agreeable to their interpretation of early human history and contributed the suggestion that kumara may once have been cultivated well south of its present area of tolerance.

Quite independently, Powell (1938) found evidence of distributional changes in Northland land mollusca, of local extinction by drifting dunes, and thus of increasing aridity. In 1950 he stated that Northland localities for *Austrosuccinea* showed consistent evidence of a succession from moist coastal climate with rain forest to a presumed dry period when coastal forests died and allowed formation of drifting dunes. Admitting correlation of climatic changes in New Zealand to be conjectural, he nevertheless compared his story with Raeside's tentative history in Canterbury, but then correlated his change from forests to sand dunes with the change from Period II to Period III of the Cranwell-von Post scheme (as presented by Harris, 1950). As some of the *Austrosuccinea* localities are on a substratum dating entirely from Period III (i.e., are post-Climatic Optimum), the correlation cannot be maintained, and the "desiccation," or rather sand-dune advance, however caused, falls in the same general period as the Raeside-Holloway changes, whether climatic or cultural.

Restriction of forest land-shell distribution in a very late period is not merely a North Auckland phenomenon. *Paryphanta,* now very local in the southern North Island, is known subfossil over a much wider area, including the largely de-forested Hawkes Bay to Wairarapa (Dell, 1955). *Rhytida greenwoodi,* a North Island snail ranging into the north-west part of the South Island, is recorded by dead but late Holocene shells in North Canterbury, far from existing forest (Allan, 1937).

Representatives of several disciplines dealing with evidence of late post-glacial change (pedology, forestry, palynology, archaeology, conchology) have tended to lean on each other for support—a natural result of the subtlety of the evidence and of the subjectivity of its interpretation. Cumberland's recent attacks (1961, 1962), even if immediately unpalatable, may therefore have a salutary effect in the long run. This symposium has become, in fact, an "agonising reappraisal" of the evidence for late Holocene climatic change in reaction to Cumberland's conclusion that man the predator established himself very early as the principal agent in the transformation by fire of South Island vegetation and soils, and that any slight climatic change in that period was from warmer and drier to cooler and wetter after about 1200 A.D.

Geological techniques can seldom detect changes as subtle as we must conclude those of the last millenium to have been. Despite the recent tectonic movements in some New Zealand districts, geologists have lately swung towards eustatic interpretation of post-glacial sea levels, at least in Auckland. Schofield's sea-level curve for the Firth of Thames (1960) suggests world cooling from about 400 A.D. to 800 A.D. (ignoring an unkown time-lag), warming from 800 to about 1150 A.D., and a sudden cooling and recovery subsequently. So far as it goes, this last cooling could be correlated with the hypothetical cooling in the early period of human occupation.

The past decade has seen a notable advance in the application of stratigraphic methods to New Zealand archaeology, despite Duff's denials (e.g., 1950) of their usefulness within the short time-scale available. From Wellman's interpretation* of Late Holocene sections, mainly in the North Island, little of climatic significance emerges except that any temperature changes in the past 2000 years have been less than a degree in mean temperature, a result not incompatible with Schofield's data (1963) if the latter are quantified by Wellman's formula of $1^{\circ}C = 50$ ft. This equivalence between eustatic levels and temperature is on a world basis, so that a eustatic difference in New Zealand means a temperature difference somewhere in the world, but not necessarily in New Zealand.

Cox and Mead (1963) have shown that Raeside (1948) misjudged the age of the Orari (Templeton) soils in regarding them as deposited about 1300 A.D. in response to a late climatic change. Fire in Canterbury was not a monopoly of man, but replacement of forest and kanuka by grassland, mainly on well-drained soils, certainly took place since his arrival. Cox offers no firm evidence of climatic change during the period under discussion.

Opportunities as yet unexploited for deduction of past flood magnitudes may in years to come provide another tool for enquiry into post-glacial climatic changes. Such work, envisaged by Campbell (1963), should be closely dove-tailed into studies of pedologists on the history and ages of surface and buried soils.

Pollen analysis has played a leading role in post-glacial chronology. Harris (1963) has been able to assemble a few sections showing significant vegetational changes in the interval following the Hypsothermal. Some are clearly human in contributing cause, like the change to grassland in Cranwell and von Post's Swampy Hill section (see Wardle and Mark, 1956). But other changes can hardly be attributed to man. The inaccessible Lake Monk, for instance, lies in a high rainfall zone where it is hard enough to light a camp-fire in mid-summer, let alone a forest. Intensive pollen studies on a wide selection of peat columns could contribute to solving the problem of late Holocene climatic change.

* Presented orally at this symposium.

I believe that Holloway's 1954 paper was the chief contribution to the study of New Zealand vegetation since Cockayne's death. It is clear that the dynamic patterns of forest regeneration—the reversals, the replacements, the unbalances—that he described in 1954 cannot all be explained away as the effect of man, even if we give man the blame (as I certainly do) for much deforestation, devegetation and for all the faunal extinctions and modifications that have so far been detected. The extinction of the moas, rails, ducks, swan, crow, etc., the restriction of the distribution of *Paryphanta, Rhytida* and other land snails, the stunting of some edible mollusc populations—all these can be attributed to man without climatic changes though in some districts they at first seem to be the result of desiccation. J. D. Cowie (1963) has shown that the last two phases of active sand-dune advance in the Manawatu can be related in time, and thus probably in cause, to the coming of Polynesian man and then of European man. Elsewhere, volcanic events of the Taupo district have started off a notable phase of sand-dune advance on remote coasts that received transported pumice and ash. These are non-climatic events, yet their catastrophic effects in the overwhelming of coastal forest by drifting sands look like the effect of aridity or desiccation, and have been interpreted climatically by Powell and others. From North Island forest studies, too, Elder (1963) finds "nothing very definite so far" in relation to climatic change hypothesis, but is impressed with the importance of catastrophes—man-made (and perhaps volcanic) fires, gales, cloud-bursts, and earthquakes—in giving rise to local anomalies in vegetation that will later puzzle the ecologist ignorant of their cause.

The data before us are not so much conflicting as equivocal and the most I can do in summary is to give you my own subjective reactions as a naturalist unspecialised in the contributing techniques and with feet bogged down in the mires of a much more remote past.

There can be no doubt that a climatic deterioration known as the "Little Ice Age" lasting from about 1650 to 1850 A.D. and with a maximum about 1800 A.D. affected the Northern Hemisphere after the Climatic Optimum. There is also some evidence of an earlier cooling (minimum in 500 B.C.) before the last warm episode of 1000 to 1300 A.D. (Dorf, 1959). The evidence from eustatic sea levels in New Zealand is compatible with the Little Ice Age, but it is evidence of world ice budget, and as noted before, is not direct evidence for local New Zealand temperatures. On the other hand, climatic fluctuations are considered to be "in phase" in the two hemispheres, so that trends in New Zealand must have been parallel to those in the north. We can accept H. C. Willet's thesis (1953) that such fluctuations were in the nature of an alternating expansion and contraction of the belts of "cellular" and "zonal" atmospheric circulation, that the Trade Wind belt moved south in warm periods and that the West Wind belt moved north in cool periods. Though this is (as Cumberland insists) a general change from "warm dry" to "cold wet" the *local* effects on our islands could well result, as Holloway has implied, in the east coasts locally receiving more rainfall and humidity in the warm (trade-wind) phases than in the cool (west-wind) phases when accentuated fohn winds operated. Let us not over-estimate the quantitative extent of such late changes: Wellman's assessment of a fraction of a degree centigrade gives a yardstick for order of magnitude in temperature.

When we come to look at the evidence of change in New Zealand, we find the record disturbed by the effects of man's arrival and spread just about the time of the beginning of the last warm period in Europe. The drastic consequences of his coming are now certain and the cherished principle of economy of hypothesis prevents us from seeking climatic causes for most if not all deforestation (change from forest to grassland), for activation of coastal sand-dunes, for the restriction or extinction of invertebrates such as forest snails, and of vertebrates such as tuatara, moas, other birds and seals, if these events took place in the human period. Other phenomena, including the changes in river courses and in regimes of deposition and erosion, and some of the apparent changes in vegetation, are equivocal: they may be climatic, or human in cause, or due to natural catastrophes not clearly linked to either. Young moraines in South Island glacial valleys will eventually give unambiguous data on Holocene cooling, but as yet they have not been sufficiently studied. We are left with a rather restricted field of data—changes in natural forest succession and regeneration on the one hand, and slow progressive changes in the fossil record of the pollen rain from natural vegetation on the other —which in the opinion of those best qualified to judge suggest subtle changes in temperture and humidity. Our surest conclusion is that the generations that follow will know (or think they know) more than we do.

REFERENCES

ALLAN, R. S., 1937. A note on the distribution of *Rhytida greenwoodi* (Gray) in the South Island. *Rec. Cant. Mus.* 4: 167.

ARCHEY, G., 1941. The Moa: A study of the Dinornithiformes. *Auck. Inst. Mus. Bull.* 1.

BROOKS, C. E. P., 1926. *Climate through the ages.* Ernest Benn, London.

CAMPBELL, A. P., 1963. Methods of obtaining hydrological evidence on climatic change. *Proc. N.Z. Ecol. Soc.* 10: 24–27.

COWIE, J. D. (1963). Dune-building phases in the Manawatu District, New Zealand. *N.Z. J. Geol. Geophys.* 6:268–280.

COX, J. E. and MEAD, C. B., 1963. Soil evidence relating to post-glacial climate on the Canterbury Plains. *Proc. N.Z. Ecol. Soc.* 10: 28–38.

CRANWELL, L. M., and POST, L. von., 1936. Post-Pleistocene pollen diagrams from the Southern Hemisphere. *Geogr. Annaler,* 3–4: 308–47.

CUMBERLAND, K. E., 1961. Man *in* nature in New Zealand. *N.Z. Geographer,* 17(2): 137–154.

CUMBERLAND, K. E., 1962: "Climatic change" or cultural interference? New Zealand in Moahunter times. pp. 87–142 in *Land and Livelihood* (Christchurch).

DELL, R. K., 1955. Some New Zealand subfossil land Mollusca. *Rec. Dom Mus.* 2(3): 135–144.

DORF, E., 1959. Climatic changes of the past and present. *Contr. Mus. Pal. Univ. Michigan* 13(8): 181–210.

DUFF, R., 1950. Moas and man, Pt. II. *Antiquity,* 24: 75.

ELDER, N. L., 1963. Evidence of climatic change from the vegetation of the North Island. *Proc. N.Z. Ecol. Soc.* 10: 45–48.

FALLA, R. A., 1955. New Zealand bird life past and present. *Cawthron Lecture Series No. 29* (Nelson).

HAAST, J. von, 1879. *Geology of the provinces of Canterbury and Westland, New Zealand.* Christchurch.

HARRIS, W. F., 1950. Climate relations of fossil and recent floras. *Tuatara* 3(2): 53–66.

HARRIS, W. F., 1953. The geology of the Snares Islands, Pt. 3. "Peat Samples". *Cape Exped. Ser. Bull.* 13: 33–38.

HARRIS, W. F., 1955. Progress report on pollen statistics from Pyramid Valley Swamp. *Rec. Cant. Mus.* 4: 279–290.

HARRIS, W. F., 1963. Palynological evidence of climatic change. *Proc. N.Z. Ecol. Soc.* 10: 38–44.

HOLLOWAY, J. T., 1954. Forests and climates in the South Island of New Zealand. *Trans. Roy. Soc. N.Z.* 82: 329–410.

LOCKERBIE, L., 1959. From Moa-Hunter to classic Maori in southern New Zealand. pp. 75–110, in *Anthropology in the South Seas.* Thos. Avery & Sons.

POWELL, A. W. B., 1938. The Paryphantidae of New Zealand No. IV, and the genus *Placostylus* in New Zealand. *Rec. Auck. Inst. Mus.* 2: 133–150.

POWELL, A. W. B., 1950. Life history of *Austrosuccinea archeyi,* an annual snail, and its value as a post-glacial climatic indicator. *Rec. Auck. Inst. Mus* 4: 61–72.

RAESIDE, J. D., 1948. Some post-glacial climatic changes in Canterbury and their effect on soil formation. *Trans. Roy. Soc. N.Z.* 77: 153–171.

SCHOFIELD, J. C., 1960. Sea Level Fluctuations during the last 4000 years as recorded by a chenier plain, Firth of Thames, New Zealand. *N.Z. J. Geol. Geophys.* 3: 467–85.

SCHOFIELD, J. C., 1963. Climatic evidence from sea-level fluctuations. *Proc. N.Z. Ecol. Soc.* 10: 21–23.

SPEIGHT, R., 1911. The post-glacial climate of Canterbury. *Trans. N.Z. Inst.* 43: 408–420.

WARDLE, P. and MARK, A. F., 1956. Vegetation and climate in the Dunedin district. *Trans. Roy. Soc. N.Z.* 84: 33–44.

WILLETT, H. C., 1953. *Atmospheric and oceanic circulation as factors in glacial-interglacial changes of climate* in *Climatic Change, Evidence, Causes and Effects.* Ed. Harlow Shapley. Cambridge, Mass. (quoted by Cumberland, 1962).