SOIL EVIDENCE RELATING TO POST-GLACIAL CLIMATE ON THE CANTERBURY PLAINS

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Introduction

The Canterbury Plains are composed of greywacke alluvial fans, of Last Glaciation and Post-glacial age, deposited by the rivers that drain the Southern Alps. Changes of climate that affected the mountain catchments are reflected in river behaviour on the plains (sedimentation, downcutting). The sedimentation patterns are one line of evidence for climatic history used here.

Much of the plains now has a subhumid climate in summer considered, at best, to be marginal for the requirement of native forest species (although adequate for scrub or low forest species) so from the evidence of the previous widespread occurrence of podocarp forest some inferences about climate are drawn.

Charcoals are found in present-day soils and in buried soils of the plains. In the wetter soils wood and peat are also preserved. There is good evidence that the charcoals originated from fires that burnt plants growing on the sites and were not transported there by wind or water (Cox, in preparation). At numerous sites the species (in some cases family, only) of charcoal has been identified and several samples radiocarbon dated. Using these dates approximate ages of soils have been established. By further dating and identification of charcoals in buried soils, coupled with measurements of soil development characteristics, it may be possible eventually to break pedological history into periods, each with a distinctive influence on soil development. However, the rate of soil profile development is slow because in the greywacke parent materials the minerals are relatively resistant to weathering, so that it will not be easy to measure changes in rates of weathering or leaching that could be taken as direct evidence of climatic changes.

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Area of Detailed Study

Paparua County is the area studied in a detailed soil survey; it lies on the southern side of the Waimakariri River and is roughly 12 miles square (Fig. 1). Average annual rainfall is 24 to 26 in., with a marked deficiency compared with potential evapotranspiration in summer and a surplus of water for through leaching of soil profiles in winter. Rainfall varies considerably in total and in distribution from year to year and hot, drying north-west Foehn winds are common in spring and early summer.

Four periods of fan-building and downcutting by the Waimakariri River, believed to be associated with glacial events and Post-glacial changes in sea-level and sedimentation rates, have been recognised on soil and geological evidence; four age groups of soils occupy the surfaces of the fans (Fig. 1). These soil groups are named Lismore (oldest), Templeton, Waimakariri, and Selwyn (youngest).

Sediments, Soils, and Climates

The Old Fan

Soils of Lismore Age Group

These soils* occupy the surface of the Burnham Formation correlated by Suggate (1958) with the main (Otarama) advance of the Last Glaciation (Gage, 1958). The soil pattern is different from that on the younger surfaces; there are no sand-dunes and no deep fine alluvial sediments; stony gravels are overlain by a thin layer of fine sediment ranging from a few inches to about 24 in.; this is thought to be mainly wind-blown dust carried by north-west winds from the Waimakariri riverbed and

* Soils of the Canterbury Plains have been mapped at 2 miles to 1 inch (Soil Bureau 1954) —Here, later detailed mapping in Paparua County is incorporated and soils are grouped according to age.

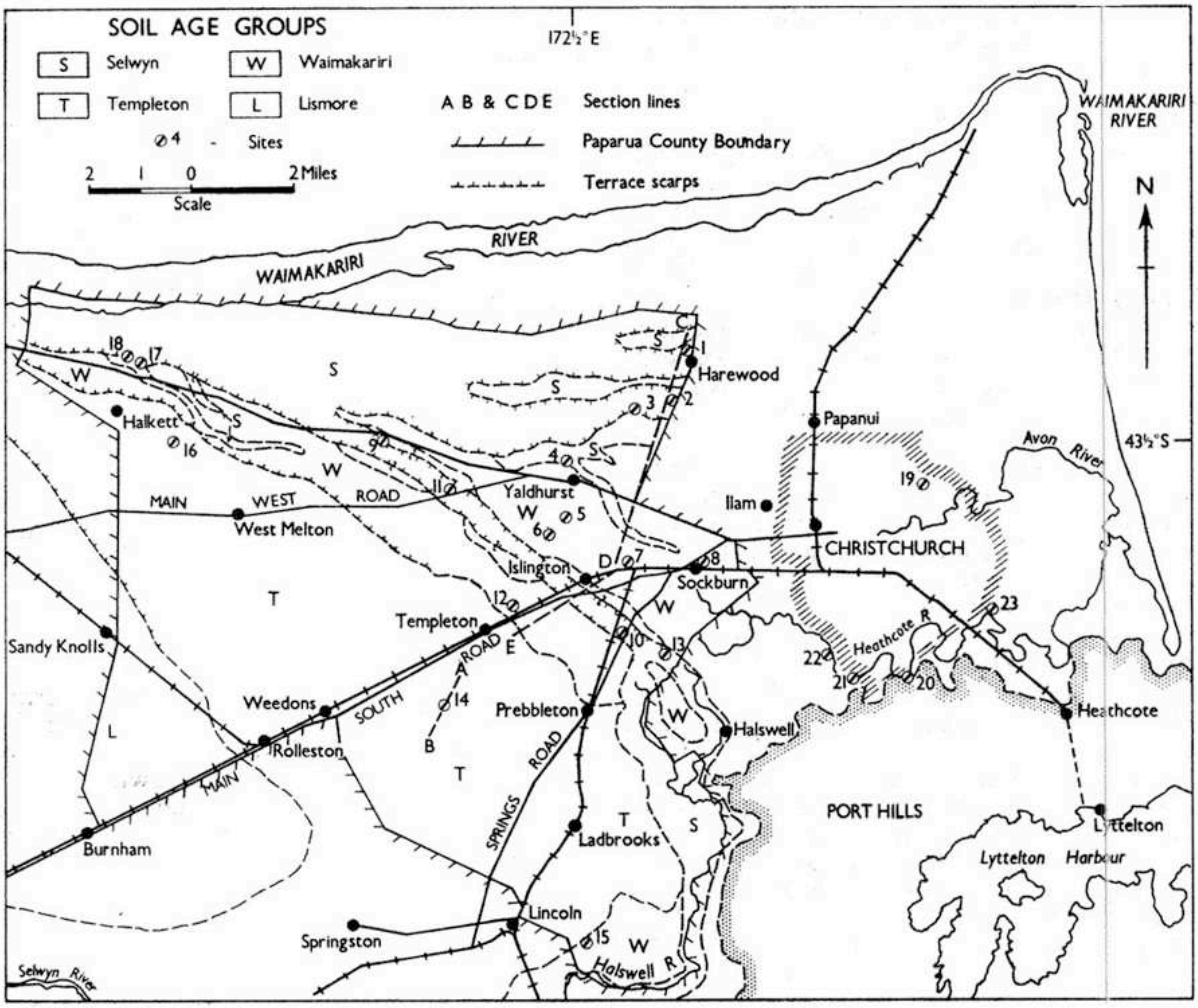

FIGURE 1. *Locality map, with sites and soil age group boundaries.*

accumulated slowly since the deposition of the gravels. West of the county boundary the Burnham Formation is nearer the river, accumulation of dust more rapid, deposits thicker, and the soils (Barrhill, Hatfields soils) are younger. On the north side of the river Lismore soils are stony to the surface.

Two possible explanations of the uniformity of Lismore soils and the lack of deep fine alluvial sediments and sand-dunes found in the younger groups are:

Either—the fan was laid down when it was too cold for vegetation to establish,

Or—it was deposited too rapidly for vegetation to establish before the river abandoned the surface and became entrenched.

The second appears the more probable, but whichever is correct the fan would require glacial conditions in the catchment to supply the volume of sediment. Its age has not been fixed by radiocarbon, but probably exceeds 20,000 years.

THE YOUNGER FANS

In the three younger age groups of soils (Templeton, Waimakariri, Selwyn), successive terrace edges in their up-river portions are capped by sand-dunes, and the terraces bear soils that are mostly shallow or stony; in their down-river portions sand-dunes are rare and there are some strips of soils with stones at the surface, and others where stones. In a few places the fine sediment three to six feet of fine sediment overlie is more than 20 feet thick.

Templeton age group of soils

Suggate (1958) regarded Templeton soils (called Paparua in his paper) as occupying the surface of Springston Formation, correlated with Blackwater ice advances (Gage 1958) thought to have occurred about 20,000 years ago.

As already indicated, the soil pattern is very different from that of the Lismore soils and does not fit the glacial outwash concept. Much of the area occupied by Templeton soils has been subject to major erosion and deposition by the Waimakariri River, within the last 6000 or so years. The presence of peats and swampy mineral soils in the Ladbrooks-Lincoln area, buried at depths from a few feet to more than 30 ft. below the surface by gravels and fine sediments carried down the fan, is typical of proven Post-glacial deposits under Christchurch.

More definite evidence comes from near Templeton (site 14). Here a heavy silt loam soil, mottled wih strong brown and grey veins, was found beneath a less developed fine sandy loam profile, 2 feet thick, with an unmottled yellowish brown B horizon. The buried soil contained charcoal of red beech (*Nothofagus fusca*) and matai (*Podocarpus spicatus*), radiocarbon dated 6495

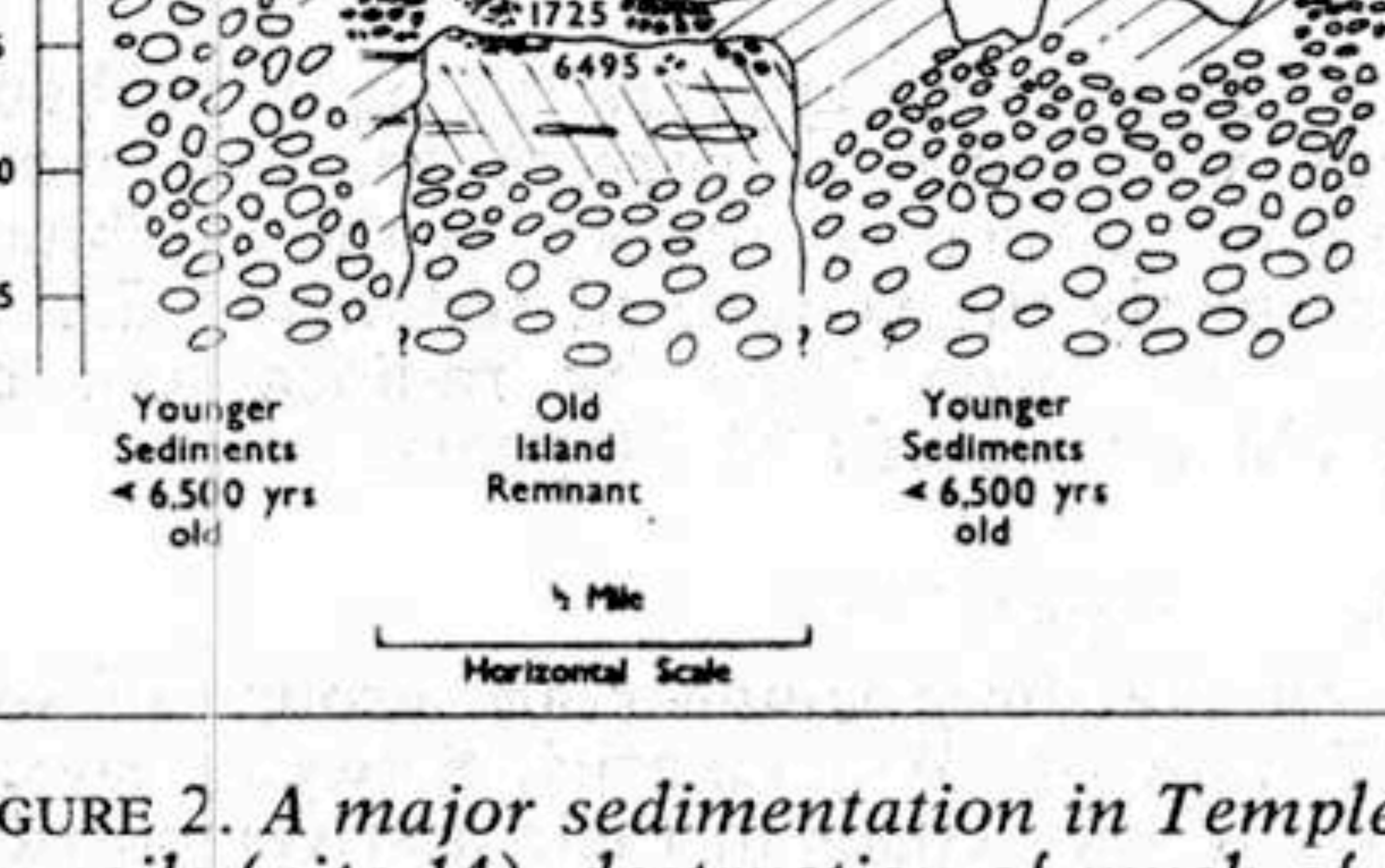

FIGURE 2. *A major sedimentation in Templeton soils (site 14), destruction of much of a previous surface, leaving an island remnant of the old soil buried below a layer of silts and surrounded by fresh sediments. Numbers are 14C dates (years before 1950).*

± 95 years B.P. (datum year for "Present" is 1950). The overlying soil contains charcoal of red beech and podocarp, dated 1725 ± 75 years B.P. The buried soil had formed on deep fine alluvium laid down in an earlier phase of Post-glacial sedimentation, after which there were several thousand years without flooding. This suggests that during this period the river had moved northward and degraded its bed after which renewed aggradation, less than 6500 years ago, caused it to re-enter the area carrying gravels which eroded or buried most of the old surface. In some places remnants escaped overwhelming by gravels and were buried under fine alluvium (Fig. 2).

The riverbed during this incursion must have been 30 to 35 ft. above its present level at the upper end of the fan, 6 miles west of Halkett. Evidence of this aggradation may exist, upriver near Springfield, in the dates of 6050 ± 80 B.P. for wood, and 6050 ± 110 B.P. for peat, 10 ft. beneath the Rubicon Stream terrace which is almost at the same level as the "Otarama" surface. These samples were expected by geologists to date aggradation in the Waimakariri River in the Blackwater ice advance, thought to have been some 20,000 years ago. The results, which are for dried out wood and peat samples, have been carefully checked and the recent dates have been hitherto attributed to contamination. Should they prove correct, however, present views on sedimentation in the middle reaches of the Waimakariri Valley will need review.

At site 15, near Lincoln, mature forest growing on a soil of the Templeton age group, correlated with those laid down less than 6500 years ago, was buried by sediments from the Halswell River at that time acting as an outlet from the overflow channel of the Waimakariri River through Islington. A matai tree at this site was dated 2440 ± 95 B.P., so that the major sedimentation through the areas occupied by Templeton soils is likely to have ceased at least 3000 years ago. Some fresh-looking channels may have carried water later, but whether surface runoff or water from the Waimakariri is uncertain.

Raeside (1948) believed that Templeton soils in South Canterbury ("Orari soils") had not been forested and therefore post-dated forest removal from the catchments of the Orari and other rivers nearby, which he deduced to have occurred about 1300 A.D.* However, the invariable presence of charcoals, derived from burning of forest, in Templeton soils of the Waimakariri and Rakaia fans leaves little doubt that similar evidence of forest will be found in them in South Canterbury.

Waimakariri and Selwyn age groups of soils

The Waimakariri group soils, and the Selwyn group now sub-divided from them, were regarded by Suggate (1958) as having formed on Post-glacial deposits, laid down in the later stages of aggradation with rising sea-level, and in subsequent minor reworking that he envisaged by the Avon and Heathcote rivers in Christchurch in the past 2000 years.

* Raeside (pers comm.) writes "I am now of the opinion Templeton soils cover a longer time span than this."

It is now clear that the Waimakariri has reoccupied and carried gravels in old courses linking with the Heathcote, Avon and Halswell rivers as recently as 900 years ago and with the Avon and Halswell in the past 100 to 300 years.

In Fig. 4 the soils of the Waimakariri age group (W, Ws, K, T) formed on sediments laid down by floods 900 to 700 years ago are indicated by absence of hatching, while Waimakariri soils on older sediments (some perhaps as old as 2400 years) are hatched. The Selwyn group of soils (S) has formed on sediments laid down probably within the past 300 years, and some flooding was still going on at European settlement, before stopbanks were built about 1870.

These time-scales are based on radiocarbon dates and on the assessment of relative degrees of profile development both in present and in buried soils formed on the various flood deposits. A composite

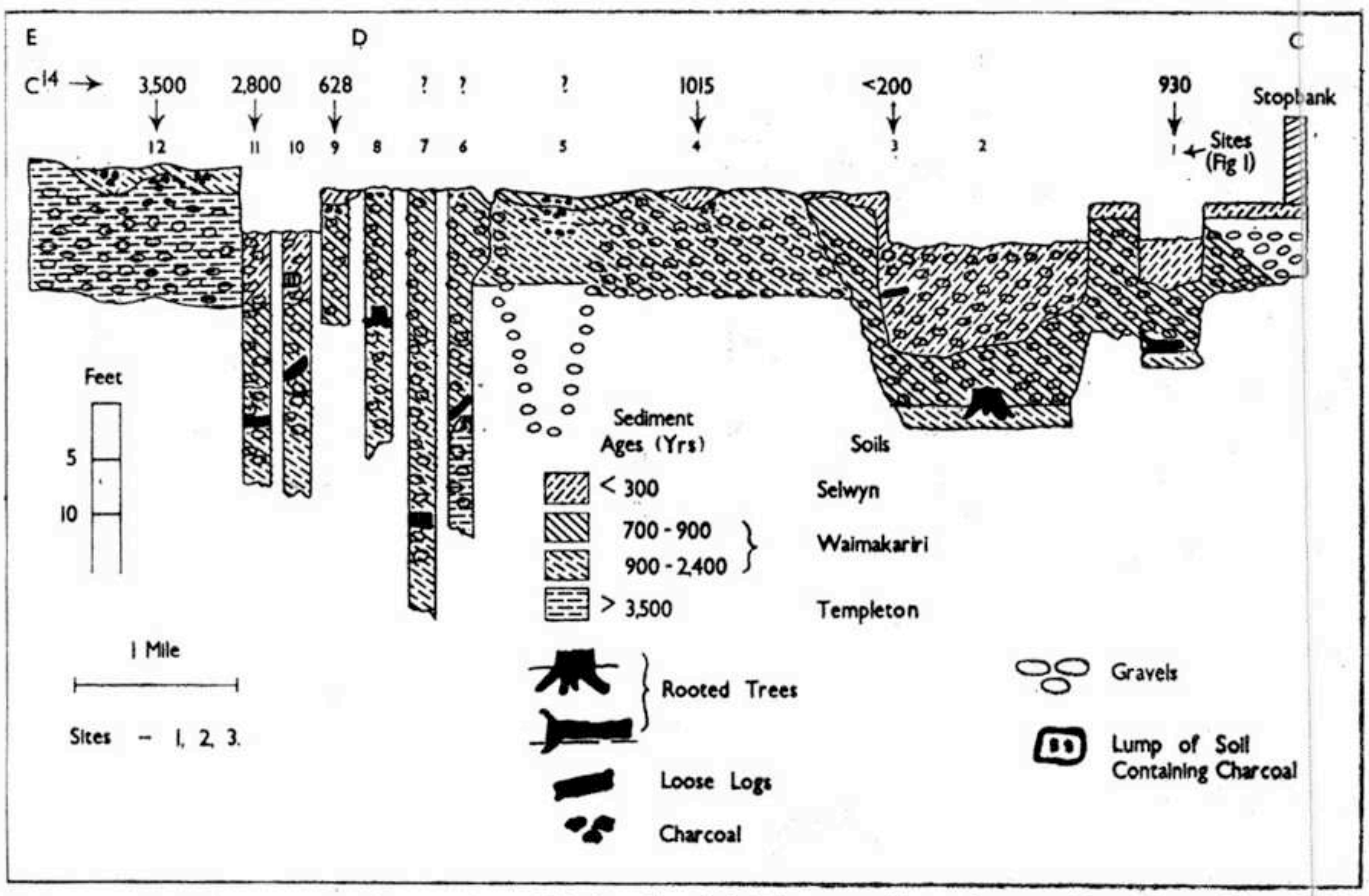

FIGURE 3. *Diagrammatic section Waimakariri River to Templeton. Based on line CDE in Figure 1.*

section (CDE in Fig. 1) in shown in Figure 3. At site 3 a kanuka (*Leptospermum ericoides*) log less than 200 years old, 6 ft. down in the gravels, dates a large flood that passed into the Avon system. At site 9 a Selwyn profile, more developed than at site 3, overlies a Waimakariri profile probably formed on 900 year old deposits. The Waimakariri soil contains charcoal of kanuka dated at 628 ± 40 B.P., and is more developed than the overlying Selwyn soil, so that burial 300 years ago, giving it 600 years to develop, seems a reasonable estimate.

Evidence for widespread deposition about 900 years ago comes from a group of radiocarbon dates listed in Table 1.

TABLE 1. *Samples dating sedimentation about 900 years ago; the last column gives the allowance necessary within the sample to date the flood.*

Site No. (Fig. 1)	Date, B.P.	Material	Allowance
1	930 ± 60	Wood	—30 years, intact kanuka, rooted in soil.
20	940 ± 70	Wood	Likely to be small, in situ.
19	1040 ± 60	Peat	Could be more than 100 years to deduct.

This may have lasted 200 years, for there is a date of 735 ± 55 for wood at site 23, buried by floods from the Waimakariri through either the Heathcote or Avon. There are also the dates of Johnston (1958) referred to by Cumberland (1962, p.109). Johnston (pers. comm.) points out that these were done on a trial machine, at Sydney University, whose reliability is unknown; wood from the outside of a tree rooted in soil at site 8 was dated at 685 ± 60 B.P., a sample from a loose, worn log at site 10 at 890 ± 50, and a similar sample at site 13 gave a date 760 ± 60.

Evidence for an interval between this flooding and that of the Selwyn period is in soil development on the 900 to 700 year old deposits. Vegetation including kanuka (and podocarps at two sites) had grown and been burnt, before renewed flooding brought burial at some sites (e.g., site 9), and destruction of the soil at others (as at site 10 where intact, rounded lumps of the destroyed soil, containing podocarp and kanuka charcoal, are incorporated in the gravels), while large areas escaped flooding (e.g., sites 5 to 8). At site 4 charcoal of matai dated 1015 ± 75 B.P. escaped flooding in the 900 to 700 year old flooding but was buried under Selwyn age deposits later.

The Islington channel was occupied by the river about 2400 years ago, flooding through the Heathcote and Halswell, as indicated by the dates listed in Table 2.

TABLE 2. *Samples dating sedimentation about 2400 years ago.*

Site No. (Fig. 1)	Date, B.P.	Material	Allowance
21	2420 ± 100	Wood	Small loose log. Allowance small.
15	2440 ± 95	Wood	Matai rooted in soil buried under silt. Small deduction.
22	2460 ± 70	Wood	Small log in gravels. Allowance small.
11	2800 ± 96	Wood	Sample 170 rings in from outside of v. worn matai log. Could be 400 years to deduct.

This sedimentation may reflect a climatic change that may have been world wide. Harris (1949) referred to dated pollen sequences showing the onset of cooler and moister climate about 2400 years ago in Europe. Schofield (1960) showed sea-level falling at this time, and reaching 1 ft. below present level 2370 ± 70 B.P. Godwin (1960) in discussing this change presents many radiocarbon results in its support, but qualifies its significance, writing "it may well have been part of a longer and complex system of oscillatory changes."

Charcoals of kanuka and matai in a small remnant of soil below 20 ft. of gravels at site 6 are from a natural fire. The gravels came through with great force and the original profile of more than 4 ft. of heavy silt loam over gravels was destroyed in most places, surviving only in patches a few feet wide. Erosion products were deposited at about the same level and in places up to 8 ft. higher in the column as interbedded silts, sands and fine gravel with charcoal scattered through them. Some worn, but uncharred, wood was found at the same level. Burial of a surface 40 ft. beneath Ilam began about 6000 years ago and from the profile of the plains it seems likely that burial of the soil at site 6 may have begun then and the charcoals in it may have formed in the same fire as those 6495 years old in the buried soil at site 14 (Fig. 2); they may, however, be 3500 years old like those 18 in. deep at site 12, in a Templeton soil under a Waimakariri soil.

The above facts illustrate the complexity of recent sedimentation and the need for special care in dating surfaces on gravel deposits (because of hidden uncomformities in the gravels).

VEGETATION

Records of the vegetation on the Canterbury Plains at the time of European settlement were made by surveyors, e.g. Torlesse and Cass (Johnston, 1961). For the most part the well-drained soils of the plains carried tussock grassland and the swamps flax *(Phormium tenax)* and raupo *(Typha muelleri)*. Forest occupied about 20 square miles of the 3000 square miles of plains. It was made up of matai, totara *(P. totara)*, kahikatea *(P. dacrydioides)* forest and beech forest (*Nothofagus* spp.) that extended onto some humid parts of the plains from neighbouring hills as at Oxford, Alford Forest and Peel Forest, and several small areas of swamp forest near the coast totalling about 2 square miles. Kanuka scrub, not accurately recorded, probably occupied about 300 square miles. The broad vegetation pattern is shown in the New Zealand Atlas (McLintock, 1959).

Radiocarbon dates for wood and peat (where preserved by high water-tables) in buried soils and in alluvium, and for charcoals in present and buried well-drained soils throw some light on the vegetation during the Post-glacial.

On the coastal fringe high water-tables are likely always to have counteracted any deficiency of precipitation for forest needs. Dated samples indicate forest grew here from 9400 years until about 700 years ago and perhaps until later; patches of forest persisted into European times. Two gaps between dates exceed 1000 years but probably forest was continuously present throughout; the few pollen analyses done, show podocarps in the samples before the human era. Wood preserved is mainly of podocarps (matai, kahikatea, some totara) and kanuka.

Evidence of the vegetation on well drained soils comes from charcoal of forest or kanuka scrub burnt on them and incorporated as deep as 18 in. in places.

Charcoal is almost invariably to be found in present soils; the amount ranges from a few specks to charred bases of trees, but the latter are rare. It is finer and sparser in the Selwyn age group soils than in Waimakariri and older groups. No podocarp charcoal has been found in Selwyn soils; a Maori oven in a Selwyn sand-dune at site 18 contained mainly kowhai *(Sophora* sp.) with a little podocarp, but this may have been from river driftwood. Kanuka grew on some Selwyn soils and small clumps remain near West Melton.

Most charcoal samples identified are from areas with less than 30 in. average annual rainfall. Though not exhaustive, sampling has shown a striking difference between shallow soils (Waimakariri and older groups) with less than about 18 in. of "fines" over gravels, and those deeper than this.

In shallow soils only kanuka has been found, whereas in deep soils podocarp has invariably been found, often with kanuka. Matai is the commonest podocarp species. Miro *(P. ferrugineus)* was found at one site. Mr. H. R. Orman (pers. comm.) notes that species like matai and kanuka give firm, durable charcoals and will be overrepresented compared with those forming soft charcoals. However, the universal occurrence of podocarps or kanuka indicates dominance or co-dominance in their respective types.

Destruction of forest by fire and the drastic reduction of kanuka scrub on all the subhumid well drained soils, and on most of the swampy soils and humid well drained soils, took place after the arrival of the Polynesians (Cox et al., 1960; Molloy et al., 1963). Early burning, perhaps 900 years ago, is indicated by two dates for matai

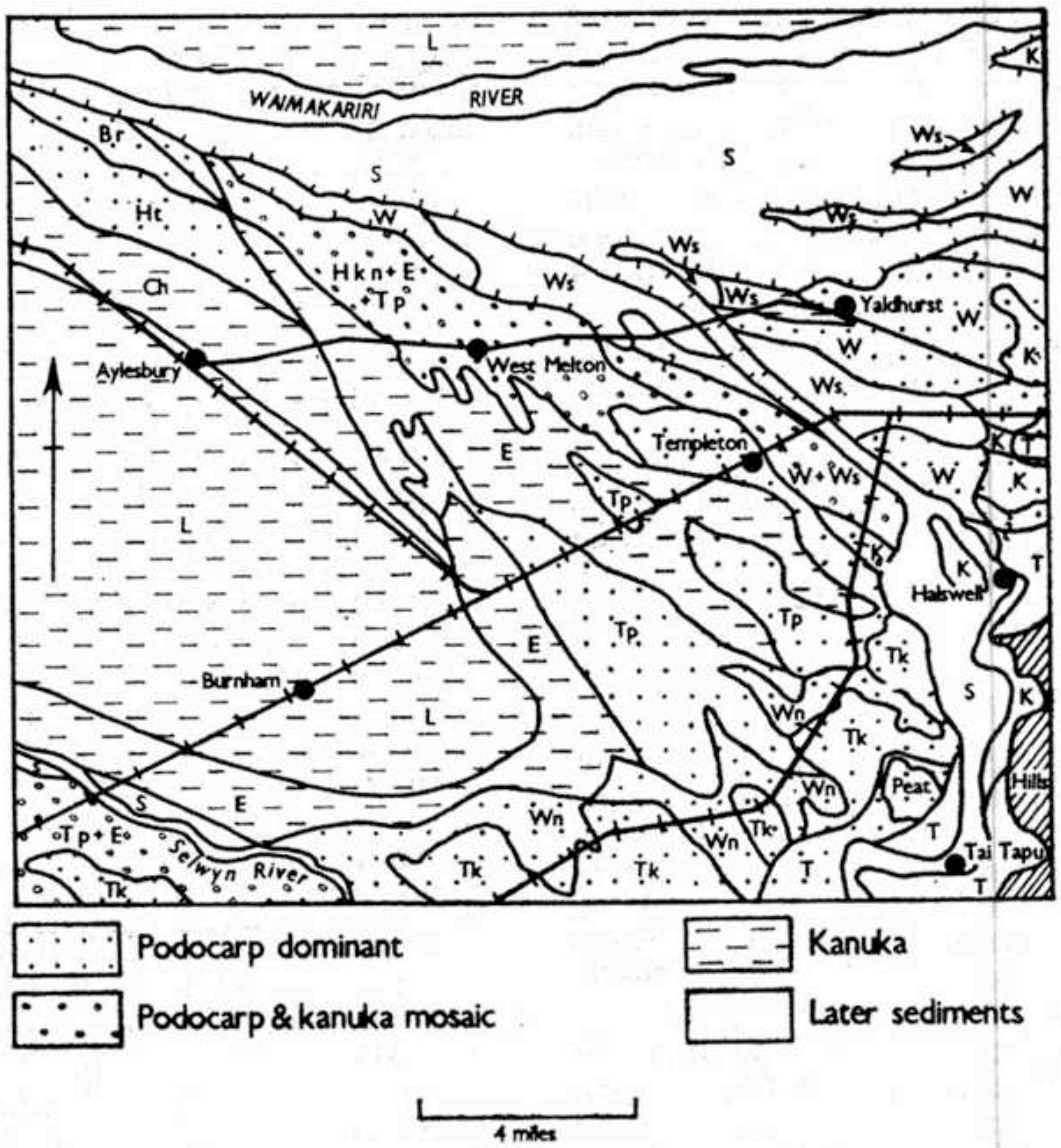

FIGURE 4. *Generalized soil map hatched to show vegetation at about 1000 A.D. (legend in Table 3).*

charcoal—1110 ± 76 B.P. for the base of a tree that grew on a Templeton age sand-dune at site 16, and 1015 ± 75 at site 4 for charcoal mainly from the horizontal burnt exterior of a trunk.

The distribution of forest types ,according to the generalised soil map, is shown at 1000 A.D. (Fig. 4 and Table 3).

Cumberland (1962), using Willett's (1953) climatic cycles, reconstructed con-

TABLE 3. *Soil data and legend to Figure 4.*
Key to columns 1, 2 and 3:

1. Drainage	2. Moisture storage	3. Forest type (*c.* 1000 A.D.)
E—Excessive	L—Low	Pp—Podocarp
F—Free	M—Medium	K—Kanuka
I—Imperfect	H—High	LD—Later deposits
P—Poor		

SOIL AGE GROUP (*Sediment age*)	SYMBOL (*Fig. 4*)	SOIL NAME	1	2	3
Selwyn (<300 years)	S				LD
Waimakariri (700–2,400 yrs.)	W	Waimakariri	F	M	Pp
	Ws	„ shallow	E	L	K
	K	Kaiapoi	I	H	Pp
	T	Taitapu	P	H	Pp
Templeton (3,000–6,000 yrs.) and some older deposits)	Tp	Templeton	F	M	Pp
	E	Eyre	E	L	K
	Hkn	Halkett dune	F	M	Pp
	Wn	Wakanui	I	H	Pp
	Tk	Temuka	P	H	Pp
Lismore (>20,000 yrs. guess)	L	Lismore	F	L	K
	Ch	Chertsey	F	L	K
(Accumulating loess)	Br	Barrhill	F	M	Pp
	Ht	Hatfield	F	M	Pp

ditions here when the Polynesians arrived, about 750 A.D. He says (p. 122) "when this predator reached the areas in which the flightless moas were most heavily concentrated, a somewhat warmer and drier climate than that of the 20th century had, for the best part of a thousand years, provided some stretches of open lowland grassland on the plains, with matai forest handily occupying damp swampy low ground as well as neighbouring downs and foothills." He postulates that forests on the plains, originally established in the Climatic Optimum, were already declining about 750 to 1000 A.D., under Willett's warm-dry period of 400-1000 A.D., and that matai on the plains was at that time restricted to swampy sites. The dated matai charcoals (sites 4 and 16 referred to above) show that this species was then growing (750-1000 A.D.) on deep *well-drained* soils, including sand-dunes, where present average annual rainfall is 24 to 26 in., while charcoals of kanuka in shallow soils indicate a low forest cover and probable total absence of tussock. These communities regenerated on sediments laid down between 900 and 700 years ago, as at sites 17 and 10, so that they were not merely surviving through their own micro-climate but were suited to the climate as it then was. They were later burnt, probably about 600 years ago (cf. kanuka at site 9), and were replaced by tussock. By the time Selwyn soils began forming on sediments laid down about 300 years ago podocarps were absent or rare, kanuka scrub much reduced and kowhai common, suggesting that a tussock community had developed resembling that at European settlement.

If Cumberland is correct in holding that the climate 400-1000 A.D. was warmer and drier than at present, matai would have to be tolerant of extremely dry conditions—well drained sites under an annual rainfall less than 24 in., often poorly distributed—which is much drier than Cumberland himself was willing to suggest. It is probable, however, that his interpretation of Willett's cycles is incorrect and that under the zonal atmospheric circulation of 1200-1900 A.D. the Canterbury Plains would receive less precipitation, and possibly also be warmer in summer through more frequent warm north-west winds, than under the cellular pattern of 400-1000 A.D. with its easterly component. This would then fit both the Holloway-Raeside thesis and the factual evidence of forest distribution and regeneration given above.

The ecological status of kanuka

Kanuka's place in the succession to podocarp forest is shown in the many pole stands, some containing young podocarps, exposed in excavations about Christchurch. It also maintained a position within podocarp forest. On the shallow well drained soils the succession may never have passed kanuka, even in the Climatic Optimum.

Some dense stands of kanuka on the plains contain no tussock and it appears that fire favours invasion or replacement of kanuka by tussock.

Natural fires

Charcoals in many buried soils that must predate man in New Zealand occur in both Paparua County and further afield, north of the Waipara and south of the Rakaia. Two samples have been radiocarbon dated. One at site 14, 6495 ± 95 B.P., containing red beech and matai, was from a deep soil. The other, 3500 ± 70 B.P. (site 12) containing kanuka, was from a silt loam grading through sand to gravels at 25 in. On the overlying soils at both sites forest regenerated and was later burnt; at the kanuka site, where 16 in. of sediment were deposited, podocarps grew.

Natural fires must have produced these ancient charcoals but how they were ignited, or how common or extensive they were is unknown.

A drier climatic period or simply a dry summer may have given the conditions for fire started by lightning (or maybe even by a meteorite) to sweep over large areas of the plains and perhaps into the mountain catchments.

Dates for charcoal from buried soils elsewhere on the plains should indicate any widespread fires, and comparison with dates for sedimentation along the coastal fringe may relate one to the other, or tie

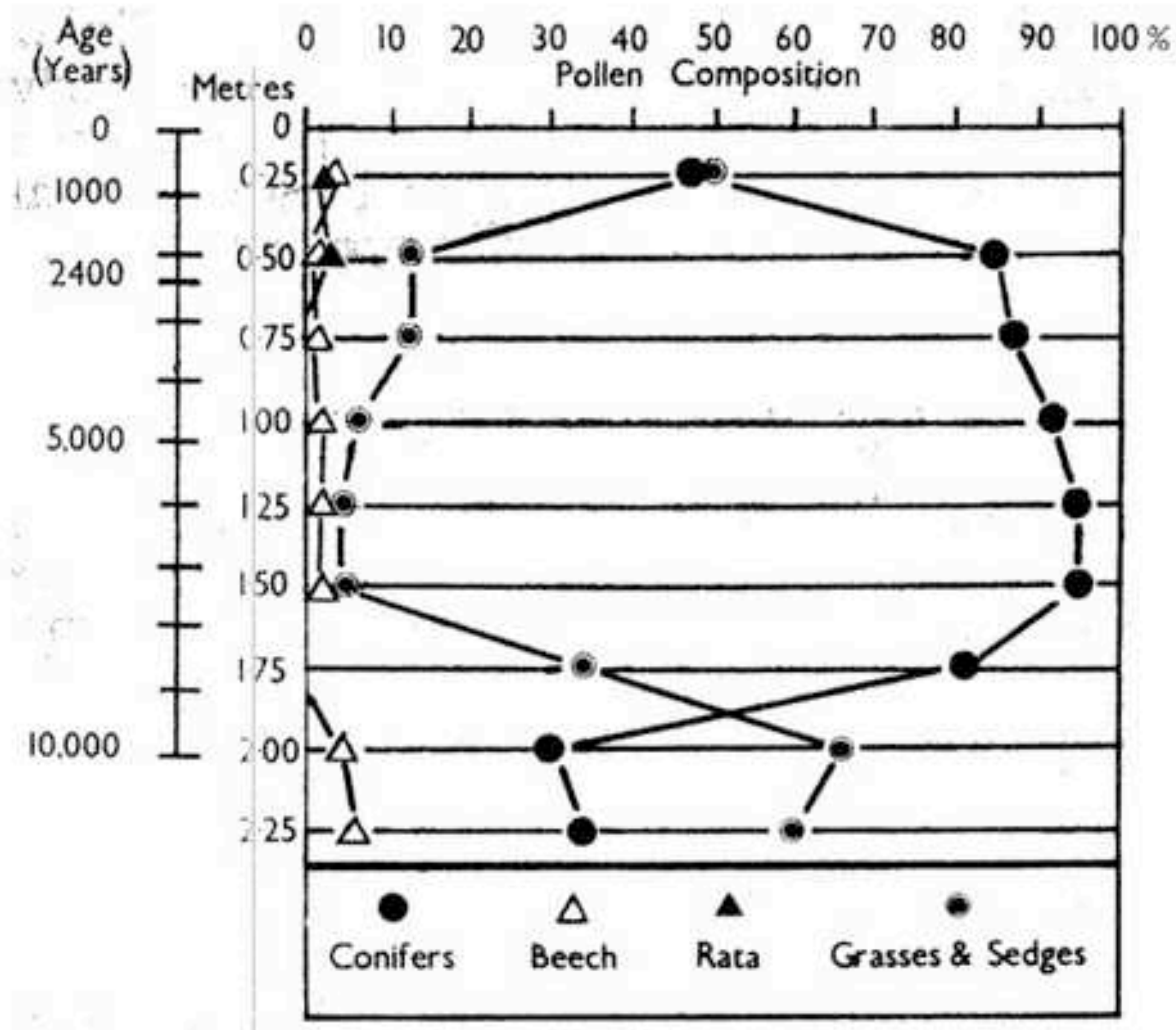

FIGURE 5. *Pollen diagram, for Swampy Hill site, after Cranwell (1938); time-scale for Post-glacial, indicated by Harris (1949), added.*

both to outside evidence of climatic changes.

There is not enough evidence yet from the Canterbury Plains to give a continuous picture of their vegetation during the Post-glacial. The most closely related long record is in the pollen analyses of Cranwell (1938) for a bog at Swampy Hill, near Dunedin. The diagram (Fig. 5) shows a sudden increase in grass and sedge and decrease in conifer pollen between 0.50 and 0.25 metre which was interpreted by Cranwell as reflecting a change from Zone II to drier and colder conditions of Zone III, dated by analogy with Europe at about 450 B.C. (Harris, 1949). Application of this time-scale, however, suggests that the sudden change in pollen took place less than 2000 and possibly less than 1000 years ago. The bog lies in the area studied by Wardle and Mark (1956) who showed that coniferous forest had been destroyed there about 600 years ago; the pollen change almost certainly reflects this recent forest destruction. The previous several thousand years of the diagram show little change and on this evidence it is possible that the forest cover on the plains may have been much as shown in Figure 4 through the last 8000 years (until destroyed in the last 1000 years) with sedimentation and natural fires intermittently affecting the pattern in detail. However, the plains receive less precipitation than Swampy Hill and the vegetation was probably more sensitive to climatic oscillations, perhaps reflecting them in a contraction of podocarp forest and expansion of kanuka during drier cycles, and the converse in wetter cycles.

CONCLUSIONS

From the soil pattern it is concluded that the Lismore age group of soils occupy glacial outwash fans; the age of the fans is probably greater than 20,000 years.

Most of the Templeton group soils have developed on sediments laid down 6000 to 3000 years ago, involving aggradation in the Waimakariri River sufficient for the depositional surface to be mistaken by Suggate (1958) for glacial outwash of the Blackwater Advance. In the Christchurch district, radiocarbon results indicate that sea-level rose more rapidly than alluvium was deposited in the period 7500 to 6000 years ago and that either an estuary or an open sea connection (making Banks Peninsula into an island) was formed round the foot of the Port Hills. Alluvial sediments came in very rapidly in the next 2000 years, the coastline was rapidly prograded, and the dry land connection with Banks Peninsula was re-established. Although the stabilisation of sea-level may have played a part in this change it seems probable that the rates of erosion in the catchment and of deposition were controlled by climate, the low rates in the period 7500-6000 years ago reflecting the maximum warmth of the Post-glacial period. Possible causes of the rapid aggradation in the Waimakariri River about 6000 years ago are the natural fire not long before this, and the onset of the Atlantic period about this time.

Widespread flooding 2400 years ago may reflect a climatic change to cooler and moister conditions (affecting the Waimakariri catchment); such a change is well documented in Europe.

Widespread flooding 900 to 700 years ago, resulting in sediments on which Waimakariri soils developed, was attributed by Cumberland (1962) to Polynesian burning of forests in the mountain catchment of the Waimakariri River, but the connection is not yet proven.

Flooding within the past 300-100 years, of uncertain cause, laid down the deposits on which Selwyn soils formed.

Podocarp-dominant forest has probably been present throughout the whole Post-glacial until the Polynesians' arrival, on all except the shallow well drained soils; on these kanuka was dominant. Tussock has been induced by fires of man. When the Polynesians arrived the forest cover was much more extensive and vigorous than Cumberland suggests and the evidence for its regeneration up to about 600 years ago, followed by failure to regenerate, tends to support the Holloway-Raeside thesis of climatic change; Cumberland may have misinterpreted the influence of Willett's climatic cycles which may also support Holloway and Raeside.

ACKNOWLEDGEMENTS

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SUMMARY

Radiocarbon dates for wood, peat and charcoal in present and buried soils of the Canterbury Plains enable time-scales for the soils to be set up. The soils indicate periods of more active, and of less active, sedimentation by the Waimakariri River. These and the occurrence of natural fires may have been controlled by changes of climate.

Dated samples show podocarp-dominant forest containing much matai (*Podocarpus spicatus*) existed at least 9400 years ago on swampy soils and 6500 years ago on deep well-drained soils, and was present at several later dates. Kanuka (*Leptospermum ericoides*) grew on shallow well-drained soils.

Replacement of forest and scrub by tussock grassland (flax and raupo in swamps) is attributed to Polynesian fires; the climatic change postulated by Raeside (1948) and Holloway (1954) fits the dated evidence of forest better than does Cumberland's (1962) interpretation of Willett's (1953) climatic cycles.

APPENDIX

N.Z. Radiocarbon dates used in text.

AGE, Yrs. Pre 1950	NZ 14C No.	Site No.
< 200	432	3
628 ± 40	382	9
735 ± 55	312	23
930 ± 60	431	1
940 ± 70	86	20
1015 ± 75	434	4
1040 ± 60	305	19
1110 ± 76	429	16
1725 ± 75	430	14
2370 ± 70	269	—
2420 ± 100	26	21
2440 ± 95	433	15
2460 ± 70	311	22
2800 ± 96	428	11
3500 ± 70	383	12
6050 ± 80	97	—
6050 ± 110	93	—
6495 ± 95	384	14

NZ 19—78 N.Z. J. Sci. Tech. B38: 732–749 (1957).
NZ 79—264 N.Z. J. Geol. Geophys. 2: 208–241 (1959).
NZ265—381 N.Z. J. Geol. Geophys. 5: 331–359 (1962).
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PALEO-ECOLOGICAL EVIDENCE FROM POLLEN AND SPORES

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RECONSTRUCTION OF CLIMATE AND VEGETATION HISTORY

I would like to regard the postglacial period as that following the maximum of the last major ice advance, or the last 18,000 years before the present, whichever proves to be the longer. The term postglacial implies that the present day climate differs essentially from a full glacial climate. The difference is such as to produce important changes in the vegetation, which will have adjusted itself to the altered conditions, or is in the process of becoming adjusted. Can we reconstruct this process to any great extent and if so, what do we learn about climate history up to the beginning of European settlement and of historical records? Inevitably time comes into consideration because if we want to reconstruct the pattern of vegetation change, and from this infer climate change, we must have some opinion about the chronological relationship between the pieces of evidence brought to light.

It can be seen at once that reconstruction of vegetation history over the past 18,000 years is an enormously difficult undertaking, since historical records cover only a very small fraction of that time, and the region is topographically complex. If ultimate success in such an undertaking were our only prospect of reward, we might well despair. We are encouraged to pursue this subject, however, by the fact that the project gives us a basis for coordinating a large number of independent observations, and is a means in particular of testing and extending our knowledge of the relation between organisms and environment.

In this very process we are building up a context in which certain types of observation find their significance. This context is probably in a large measure a by-product of various techniques and is in turn the means for improving techniques. To illustrate this, given a technique for extracting pollen from types of sediment which are sufficiently common, and the ability to distinguish the principal pollen types of New Zealand conifers, beeches and grass, let us take as a working hypothesis the generalisation that as beech pollen increases relatively to conifer, the climate is cooler, and when there is much grass pollen with little or no pollen of the beech and conifer types a cold climate is indicated. Here is a technique which is workable, though crude, and which will produce results sufficient to justify persevering with it and trying to improve it.

The underlying hypothesis may be regarded with suspicion by ecologists, and even with some misgiving by the palynologist, but the point has to be appreciated that the palynologist must have *some* hypothesis — or go out of business. The ecologist, on