LATE OTIRAN AND EARLY ARANUIAN GRASSLAND IN CENTRAL SOUTH ISLAND

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SUMMARY: Pollen analysis suggests that in central South Island the late Otiran landscape on both sides of the Main Divide was dominated by grassland. An outstanding exception is the presence of *Nothofagus menziesii* forest at Blue Spur Road, Hokitika. The grassland persisted from about 26000 years to about 12000 years ago and during this time there was little variation in the character of the vegetation. During the period under review there were several well defined glacial advances and retreats and it is suggested that either the periods of time involved were too short to initiate vegetation change or that climate, for whatever reason, inhibited the development of shrubland. in any event the absence of change cannot be taken as evidence of an unchanging climate. The general character of the climate is discussed and it is concluded that a cold and stormy climate influenced the development of the vegetation. The west-east climatic gradient so characteristic of the trans-alpine environment was probably greater than it is today, a feature emphasised by the greater land area available because of the late-glacial lowering of sea-level.

INTRODUCTION

Grassland or grassland-shrub land was an important vegetation type during the late Otiran (late last glacial) and early Aranuian (post-glacial) in cmtral South Island (McKellar, 1960; Harris, in Suggate, 1965; Suggate and Moar, 1970; Moar, 1971; 1973; Lintott and Burrows, 1973; Nathan and Moar, 1973; Soons and Burrows, 1978; Moar and Suggate, 1979; Wardle, 1980). The Aranuian sequence, grassland-shrubland-forest, is well documented, but the late Otiran record and the transition to the early Aranuian is fragmentary. The two most complete sequences come from Blue Spur Road, Hokitika (Moar and Suggate, 1973) and from Wilsons Lead Road, Westport (Moar and Suggate, 1979). The vegetation history of the later stages of the mid Otiran, the late Otiran and the early Aranuian are reco:ded from these two areas. At Blue Spur Road Aranuian podocarp forest of *Dacrydium cupressinum* spread through late Otiran *Nothofagus menziesii* forest, and at Wilsons Lead Road similar podocarp forest followed grassland. The shrubland phase characteristic of the early Aranuian over much of central South Island was absent in both areas and no true grassland phase is recorded from Blue Spur Road.

According to radiocarbon assay the mid Otiran interstade (mild period) in these two areas ended about 26000 years ago. It is generally accepted that the late Otiran cold interval which followed ended about 14000 years ago when ice of the Poulter advance began to retreat (Suggate, 1965). It is difficult to identify vegetation changes in pollen diagrams at this time. At Wilsons Lead Road, for example, obvious changes occurred only with the spread of forest 2000 years later, about 12000 years ago (Moar and Suggate, 1979).

In addition to the sites referred to above there are others, described in this paper, from both sides of the Main Divide which support the view that grassland was the most important vegetation type in central South Island during the late Otiran. The pollen analyses from these will be discussed in relation to data already published and an attempt made to understand the character of the vegetation and the environment which moulded it.

THE SITES AND POLLEN ANALYSES

The locations of the sites discussed in this section are indicated by numerals in Figure 1 and the pollen analyses are detailed in Table 1. Map references for all sites relate to the NZMS I map series. Samples collected for pollen analysis were treated with 40% hydrofluoric acid and standard acetolysis procedures, and the residues stained with basic fuchsin.

Owen River (S25/872 812, Fig. 1, Table 1, 240 m)

More than 14 m of silt, sand and gravel are exposed in a cutting through an aggradation terrace on a farm track 200 m east of the Owen Valley Road and 1 km north-east of the Owen River Hotel. The sediments were deposited in the bed of a minor tributary of the Owen River which was affected by changes in the Buller River during aggradation of the Speargrass Formation (Suggate, 1965). A layer

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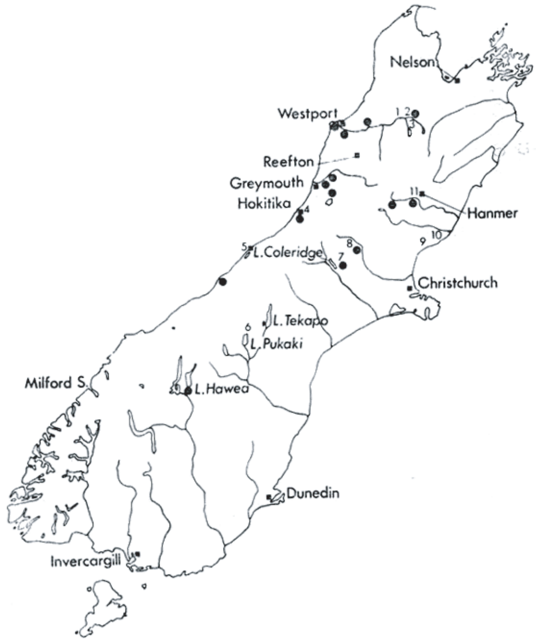

FIGURE 1. *The location of late Otiran and early Aranuian sites discussed in detail are indicated by numbers* 1-11. *Other sites already described for the same period are indicated by the black circles.* 1. *Owen River,* 2. *Buller River Gravel Pit,* 3. *Howard-Buller River Junction,* 4. *Dillmanstown,* 5. *Abut Head,* 6. *Mt Cook Station Road,* 7. *Lyndon Stream,* 8. *Rubicon Creek,* 9. *Teviotdale,* 10. *Wroxham,* 11. *Hanmer.*

of organic silt, about 5 mm thick, was found in a layer of blue clay 6 m below the terrace surface.

The pollen spectrum derived from the organic silt (Table 1) indicates that an open vegetation of grasses and sedges was dominant, and according to radiocarbon assay deposition of the sediments occurred about 22000 years ago (NZ 4541, 22200 ±400 yrs B.P.). One pollen grain of *Nothofagus brassi* type, presumably re-worked from older sediments, and one grain of *Casuarina,* derived from Australia (Moar, 1969) was noted on the slide.

Buller River Gravel Pit (S26/056 786, Fig. 1, Table 1, 390 m)

This site is on the north side of the Buller River 17km downstream from Lake Rotoiti. Gravels, sands and carbonaceous clays accumulated rapidly when a small stream was dammed by aggradation of the Buller River (Speargrass Formation) during the younger Kumara 2 glacial advance (Suggate, 1965) which formed the Black Hill moraines near Lake Rotoiti about 19000 years ago. The sediments, 1.75 m thick, overlie granite gravels of local origin and are buried beneath greywacke gravels (Buller River gravel) derived from the main ranges to the cast. An organic layer 0.70 m-0.75 m below the Buller River gravel is about 19000 years old (NZ 2732, 18 800 ± 350 yrs B.P.). An earlier sample of uncertain position in the column, is about the same age (NZ 1254, 18100 ± 370 yrs B.P.).

Pollen analysis of 8 samples (Table 1) at 0.30 m, 0.50 m, 0.75 m, 0.97 m, 1.15 m, 1.39 m, 1.65 m and 1.75 m within the carbonaceous clays shows that the vegetation was predominantly herbaceous. Besides grasses and sedges, *Bulbinella,* Compositae, including the *Taraxacum* type, and Umbelliferae are consistently present (Table 1). Woody plants are not well represented except for *Phyllocladus* and *Nothofagus*. Neither of these could have been abundant, although in the deepest sample (1.75 m) 15% of the pollen counted was that of *N. fusca* type and 5 % was that of *N. menziesii,* a result possibly influenced by a low pollen count.

Suggate (1965) discusses a site at Station Creek, about 0.5 km east of the gravel pit. The site was re-examined when the gravel pit samples were collected and analysis of one sample yielded a pollen spectrum similar to that of Harris (in Suggate, 1965) and comparable to the gravel pit spectra. The layer collected is about 16500 years old (NZ 444, 16 600 ± 390 yrs B.P.) considerably younger than the gravel pit material. It is about 15 m below the former level of the aggradation surface of the Speargrass Formation.

Howard-Buller River Junction (S26/071 765, Fig. 1, Table 1, ca. 240 m)

Carbonaceous silts, clays and gravels, 3.60 m thick, fill a channel cut through Buller River gravel at the mouth of a small gully draining into the Buller River Valley about I km west of the Howard River bridge on State Highway 63. The sediments are capped by further gravels and lie opposite a large remnant of the Speargrass Formation and about 2 km upstream of the Buller River Gravel Pit site. One sample from the lower, middle and upper layers of carbonaceous silts have been radiocarbon dated (NZ 4830, 19800 ± 550 yrs B.P.; NZ 4829, 18350 ±350 yrs B.P.; NZ 4828, 18900 ±350 yrs P.B.). There are no great differences between these dates, which imply rapid sedimentation and which correlate with the later part of the Speargrass Formation (Suggate, 1965). The site is comparable in age to the nearby Buller River Gravel Pit site and the pollen spectra compare with most other similar sites in central South Island.

Pollen analysis of four samples (Table 1) suggests that the vegetation was similar to that recorded from the gravel pit site.

Dillmanstown (S51/727 627, Fig. 1, Table 1, 150 m)

Discontinuous lenses of carbonaceous silt up to 0.30 m thick were exposed in a cutting on a road skirting the new Kapitea reservoir about 1.80 km south of Dillmanstown. The lenses occurred on both sides of the cutting and were interbedded between an upper grey coloured till and a lower, locally slightly yellow till.

The site lies close to the junction of deposits of the older Kumara 2 advance ($K2_1$) and those of the younger Kumara 2 ($K2_2$) advance (Suggate, 1965). Radiocarbon assay shows that the organic layers were formed towards the end of the younger Kumara 2 advance about 18000 years ago (NZ 4408, 18450 ± 300 yrs B.P.; NZ 4407, 17250 ±250 yrs B.P.).

A sample from the top and one from the bottom of the silts was analysed. Gramineae and Compositae were dominant, and unlike many late Otiran sites, Cyperaceae were of only minor importance. Other plants, as revealed by pollen analysis, were not common, but *Hebe, Cyathodes* and *Myrsine,* generally under-represented in the pollen rain, have been identified from wood remains (Burrows, pers. comm.) and it is assumed that they were growing at the site of deposition.

Abut Head (S63/922 073, Fig. 1, Table 1)

A peat lens, 0.03-0.12 m thick, is embedded in till up to 3.0 m thick, at the base of a coastal cliff about 2 km east of Abut Head. The till underlies eroded lacustrine sediments and may have slumped from adjacent moraine. The peat is about 16500 years old (NZ 4358, 16450 ±200 yrs B.P.) and the pollen spectrum derived from it (Table 1) reflects a less varied and more open grassland than the younger (NZ 479, 13 950 ± 140 yrs B.P.) grassland-shrubland recorded from Omoeroa Bluff (Moar, 1973).

Mt Cook Station Road (S89/847 097, Fig. 1, Table 1, 515 m)

A thin organic layer was found in clay, ponded behind a kame terrace. This early Aranuian site, about 13 500 yrs old (NZ 4541, 13 500 ±250 yrs B.P.) yielded a pollen spectrum characteristic of an open grassland landscape.

Lyndon Stream (S74/156 807, Fig. 1, Table 1,790 m)

A layer of carbonaceous clay, 0.20 m thick, is

TABLE 1. *Pollen analysis of central South Island sites of late-glacial and early post-glacial age.**
1. Owen River, 2. Buller River Gravel Pit, 3. Junction, Howard and Buller Rivers, 4. Dillmanstown, 5. Abut Head, 6. Mt Cook Station Road, 7. Lyndon Stream, 8. Rubicon Creek, 9. Teviotdale, 10. Wroxham, 11. Queen Mary Hospital, Hanmer.

Site	1	2								3						
Depth in metres		0.30	0.50	0.75	0.97	1.15	1.39	1.65	1.75	1.24	1.50	1.97	2.09	2.22	2.86	3.29
NOTHOFAGUS AND TREE CONIFERS																
Dacrydium cupressinum															+	
Nothofagus brassi type	+	+				tr				+						
N. fusca type	1	2	2	5	2	3	3	5	15	1	tr	tr	2	3	tr	tr
N. menziesii		+		tr	tr	tr	+	tr	5						tr	
Podocarpus					+	+		+			+					
P. spicatus	+			+												
OTHER WOODY PLANTS																
Casuarina	tr				+					+	+					
Coprosma	1		tr			+	1	+		tr		+	tr		+	
Coriaria										tr						
Cyathodes colensoi					+	+										
Dacrydium bidwillii type				+	1	tr										
Dracophyllum																
Hebe						tr										
Metrosideros		1					1									
Muehlenbeckia																
Leptospermum																
Myrsine	tr			tr												
Olearia type					+		+									
cf. *Phyllachne*																
Phyllocladus	1	tr	tr	2	2	2	2	3		1	tr	1	1		1	tr
cf. *Proteacidites*						+										
Thymelaeaceae	+	+		tr	tr					+	+					
Weinmannia																

Site	4		5	6	7	8	9	10									11
Depth in metres	Top	Bottom						0.45	3.28	3.79	5.16	5.90	7.08	9.75	11.30	11.50	
NOTHOFAGUS AND TREE CONIFERS																	
Dacrydium cupressinum			1								1	+					
Nothofagus brassi type									tr								
N. fusca type							1		tr			+	1	1		tr	tr
N. menziesii	1	1						+					+				
Podocarpus	tr						+						+				
P. spicatus		+			tr												
OTHER WOODY PLANTS																	
Casuarina	tr																
Coprosma	3	2	4	10	8	tr							tr				2
Coriaria																	
Cyathodes colensoi					2												
Dacrydium bidwillii type	tr				tr												
Dracophyllum		tr			2												
Hebe	1	1															
Metrosideros	tr			tr													
Muehlenbeckia			tr	2	tr					1				1			
Leptospermum			tr														
Myrsine		+		2	1												1
Olearia type																	
cf. *Phyllachne*				2									tr				
Phyllocladus		1			1		1	+		2			+				2
cf. *Proteacidites*																	
Thymelaeaceae	1	2			2							+		tr		+	1
Weinmannia			tr														

Site	1	2								3						
Depth in metres		0.30	0.50	0.75	0.97	1.15	1.39	1.65	1.75	1.24	1.50	1.97	2.09	2.22	2.86	3.29
HERBS																
Acaena	+												tr		tr	
Astelia				tr	tr	1										
Bulbinella			tr		1	1	3	2	1	tr	tr	tr	1	3	24	20
Caryophyllaceae				1						+						
Stellaria gracilenta				+	+	tr									tr	tr
Chenopodiaceae	+	+	+	tr	1						tr	+		+		tr
Cruciferae	1		tr		1	tr		1		+	tr	tr		tr	1	tr
Colobanthus																
Compositae	+	3	3	4	4	7	1	4	2	1	tr	1	3	1	2	6
Cotula																
Taraxacum type	tr	2	2	5	3	7	+	22	12	+			1	+	3	5
Cyperaceae	64	63	52	33	38	29	63	19	19	76	90	78	38	68	14	11
Drosera arcturi																
Epilobium	+	1	1	+	+								+	tr	+	
Euphrasia																
Galium		+														
Gentiana		+	1	tr	+	+		+		tr	tr		tr			
Geranium		+		tr	+	+										
Gramineae	28	25	24	40	43	43	22	42	44	18	8	17	48	22	49	48
Gunnera													1		+	
Haloragis					+	+									1	tr
Empodisma				tr		+									tr	
Liliaceae									1							
cf. *Mitrasacme*			tr		1	1	1									
Montia		+		+	1	+				tr			+	tr		
Myosotis			1							+			1	tr		
Papilionaceae																
Plantago						tr				tr		tr	tr	1	tr	
Ranunculus	1	+	tr	+	+	+					+	+	tr		tr	
Rumex																
Selliera																
cf. *Stackhousia*				+												
Tillaea																
Umbelliferae			1				3	1			+	2	1	1	2	7
Anisotome/Aciphylla		tr	tr	1	1	tr				1			tr		tr	1
Centella		+														
Daucus																
Gingidia type		tr		tr	tr											
Hemiphues															tr	
Hydrocotyle	+														tr	
Lilaeopsis		tr	12	2	1	3	1			+					1	tr
Oreomyrrhis			tr			tr									tr	tr
Schizeilema			+	1		tr	1								tr	
Wahlenbergia				+				tr		+			tr			
AQUATICS																
Myriophyllum																
Potamogeton																
Pediastrum (algae)	+															
SPORES																
Lycopodium						+				+						
Monolete fern spores						tr	1	1	2						tr	
Ophioglossum	+															
Phymatodes				tr	+											
Trilete fern spores					+	tr		2	3							

Site	4		5	6	7	8	9	10									11
Depth in metres	Top	Bottom						0.45	3.28	3.79	5.16	5.90	7.08	9.75	11.30	11.50	
HERBS																	
Acaena																	
Astelia																	
Bulbinella																	tr
Caryophyllaceae																	
Stellaria gracilenta					1												
Chenopodiaceae	tr		2					tr	11	3	3	6	3	3	1	21	tr
Cruciferae				1					tr			tr	2	tr		tr	
Colobanthus	tr							+	2	1	1	1	1		1		
Compositae	13	10	6	13	33	5		3	5	6	9	10	5	3	2	tr	15
Cotula												tr			tr		
Taraxacum type	tr				1	tr	92	tr	6	1	4	2	4	2		2	10
Cyperaceae	4	1	10	30	3	67	1	52	42	70	68	55	55	46	88	23	51
Drosera arcturi						+											
Epilobium		tr		tr													
Euphrasia					+			tr		1		+					
Galium	tr					+							+				
Gentiana	tr	+	2					tr	tr		1	tr		1	tr	+	
Geranium																	
Gramineae	70	79	70	22	36	19	3	31	23	40	10	12	19	13	7	51	16
Gunnera							1										
Haloragis	tr			tr		+											
Empodisma					+	+		+								+	
Liliaceae																	
cf. *Mitrasacme*																	
Montia								1		1		tr					
Myosotis	2	2				+			tr	1	1	tr					tr
Papilionaceae				tr				+					tr				
Plantago			1					+	1			1					
Ranunculus					+	+		tr								+	
Rumex								tr								+	tr
Selliera																1	
cf. *Stackhousia*										1							
Tillaea				tr					3								
Umbelliferae	tr		1	14	4	8		1	tr	3	1	4	7	6		tr	2
Anisotome/Aciphylla	1		1														
Centella												tr					
Daucus								2									
Gingidia type																tr	
Hemiphues																	
Hydrocotyle	tr				1	tr								tr		tr	
Lilaeopsis					2									2			
Oreomyrrhis	tr							2	1	2	1	4		2			
Schizeilema	tr								1	+		tr	tr				
Wahlenbergia																	
AQUATICS																	
Myriophyllum											1						
Potamogeton												tr				tr	
Pediastrum (algae)		+				+							+				
SPORES																	
Lycopodium	2	+		2	1												
Monolete fern spores	1	tr	3	5	2		1									tr	
Ophioglossum	tr	tr			1												
Phymatodes																	
Trilete fern spores		+			tr												

*The figures represent the percentage of pollen types based on the total count of pollen of land plants.
tr represents less than 1% of the pollen sum.
\+ represents pollen noted after formal counting finished.

exposed in fan gravels which have been eroded by Lyndon Stream in the low pass linking the Rakaia and Waimakariri drainage systems. The organic layer lies 1.90 m beneath the present surface and about 4.0 m above the Lyndon Stream flood plain. Deposition of the organic layer began in the early Aranuian about 13 000 years ago (NZ 4265, 12950 ±200 yrs B.P.) when Compositae were dominant in the local vegetation (Table 1).

About 200 m downstream (south-west) there are exposed thick lake sediments which have been described by Soons and Burrows (1978). These sediments, capped by layers of *Sphagnum* took some three thousand years to accumulate between about 22000 and 19000 years ago (NZ 3940, 22200 ±750 yrs B.P.; NZ 4298, 19200 ±550 yrs B.P.). The basal layers contain numerous macro-remains of *Myriophyllum elatinoides* (Simpson and Burrows, 1978) and pollen analysis provides evidence of an open herbaceous vegetation in which woody plants were scarce (Soons and Burrows, 1978).

Rubicon Creek (S74/338 832, Fig. 1, Table 1,420 m)

Rubicon Creek, a tributary of the Kowai River, has cut a deep channel some 10 m deep through Aranuian and late Otiran deposits of gravel, silt, organic silt, mud and clay. The most continuous exposures are found on the south bank and span the shrubland and forest phases of the Aranuian. The late Otiran, not so well represented, consists of silt, gravel and clay layers between 7.0 m and 10.0 m below the surface. Pollen analysis of these late Otiran sediments indicates the presence of an open vegetation of sedges, grasses and Compositae from which woody plants, except for some *Coprosma* and *Myrsine,* were absent (Table 1). These sediments are not dated, but dates are available for late Otiran and early Aranuian organic beds on the northern bank opposite. One of these, 0.30 m thick, and about 0.75 m above the stream bed, is about 13 000 years old (NZ 1391, 12750 ±210 yrs B.P.). Another, about 50 m downstream and 2.40 m above the stream is about 1000 years older (NZ 1392, 14100 ±240 yrs B.P.). According to pollen analysis this oldest site was dominated by sedges and grasses, Compositae were frequent and other herbs included *Drosera arcturi*. *Hydrocotyle, Myosotis, Nertera* and *Ranunculus*. Woody plants were not recorded except for one pollen grain of *Coprosma* and one identified as *Eucalyptus,* a consequence of contamination or of long distance dispersal from Australia.

The younger sample (NZ 1391) contained too few pollen grains for reliable counts, but the pollen of *Bulbinella,* Chenopodiaceae, Compositae, *Coprosma,* Cyperaceae, *Gentiana,* Gramineae and *Gunnera* were noted. *Carex* utricles and *Juncus* seeds were identified from this layer.

Teviotdale (S68/ 160 035, Fig. 1, Table 1, 30 m)

Kohn (1979) describes the white rhyolitic ash layer (Tiromoana ash) 4-8 mm thick within deep loess deposits in a coastal section 2 km north of the Waipara River near Teviotdale. The fission track date for this ash, 20300 ±7100 yrs B.P., together with mineral analyses, led Kohn to the conclusion that it was a correlative of the Kawakawa tephra derivd from the Taupo volcanic zone (20000 yrs B.P.).

Four samples, two below and two above the ash, were collected for pollen analysis, but only one, 0.75 m below the ash contained pollen. The pollen was scarce and 100 pollen grains were counted on the whole slide (40 X 20 mm cover glass). Of these 100 grains, 92 were of the *Taraxacum* type and there were noted a few grains of Cyperaceae, Gramineae, *Gunnera* and *Phyllocladus* (Table 1).

Road Cutting, Wroxham (S62/362 258, Fig. 1, Table 1, 170 m)

At this site, a road cutting 5 km north of Motunau on Highway 1, there are more than 12 m of interfingering layers of gravels, silts and carbonaceous silts and clays. The gravels and silts accumulated in a series of small fans at the base of greywacke hills on either side of the Greta River Valley and the organic layers developed in poorly drained depressions between them (Suggate, 1965). Accumulation of about 12 metres of sediment (Andrews, 1973) began more than 22000 years ago (NZ 3066, 22 100 ± 500 at 11.30-11.35 m below the present surface) and ceased about 15000 years ago (NZ 3067, 15250 ±250 yrs B.P. at 1.45-1.47m below the present surface), a period of about 7000 years.

Suggate (1965) reports a date of about 21 000 years from the site (NZ 706, 20900 ±260 yrs B.P.) but the exact location of this sample and its relation to the other dated samples is not known. According to Harris (in Suggate, 1965) the vegetation at this time was dominated by grasses, and trees and shrubs were rare. A similar result was obtained with pollen analysis of nine samples (Table 1) lying between 1.45 m and 11.50 m below the present

surface. Other samples between were scanned, but as there was no differences, formal counts were not attempted. Chenopodiaceae pollen was relatively frequent, especially in the lower-most sample (11.50 m) and Compositae, including the *Taraxacum* type, were regularly present. *Selliera* was recorded in the deepest sample and along with the sedges provides evidence of the moist, swampy and possibly saline conditions in which the sediments accumulated. There is no evidence that trees or shrubs were present, either locally or regionally, throughout the period of deposition, although the occasional record of Thymelaeaceae pollen suggests that *Pimelea* or *Drapetes* were growing about the site.

Queen Mary Hospital, Hanmer (S54/193 784, Fig. 1, Table 1, 360 m)

A layer of clay and peat, 0.40 m thick, was recorded between 5.1 m and 5.5 m in poorly sorted greywacke gravels from a test bore at Queen Mary Hospital. The peat was formed about 13 000 years ago (NZ 3969, 13 000 ± 200 yrs RP.) and contains the record of a predominantly herbaceous vegetation in which sedges and grasses were dominant (Table 1). *Taraxacum* type pollen was relatively abundant (6% of total pollen) and pollen of other herbs. including *Bulbinella*. *Myosotis* and Umbelliferae, was present albeit in low frequencies.

Discussion

Vegetation

The pollen spectra derived from the sites reported in this paper, and from many of those already published have certain characteristics in common.

1. Gramineae and Cyperaceae pollen is always present and usually in high frequencies.

2. Compositae pollen is consistently represented. The pollen grains are identified as *Taraxacum* type (including *Kirkianella* and *Microseris), Cotula,* and Compositae derived from unidentified Tubuliflorae. Other herbs represented include Chenopodiaceae, *Bulbinella* (especially at Buller River Gravel Pit), *Gentiana,* Caryophyllaceae, *Epilobium* and Umbelliferae. The Umbelliferae include pollen of the *Anisotome / Aciphylla* type, *Centella, Daucus, Gingidia* type, *Hemiphues, Hydrocotyle, Lilaeopsis, Oreomyrrhis* and *Schizeilema*.

3. Pollen grains of woody plants are not frequent and no type is characteristic of every site examined, although *Nothofagus fusca* type is consistently present in sites west of the Main Divide. Other grains recorded include *Casuarina, Coprosma, Dacrydium bidwillii, D. cupressinum, Phyllocladus* and Thymelaeaceae. Of these *Nothofagus* and *D. cupressinum* may have been derived from refugia, as at Blue Spur Road, and it is believed that *Casuarina* pollen has its source in Australia (Close *et al.,* 1978).

4. The pollen analyses suggest that a more diverse flora was present west of the Main Divide.

The pollen analyses reinforce earlier impressions (except Blue Spur Road) that most late Otiran and early Aranuian landscapes in central South Island were dominated by grassland. This grassland persisted for about 14000 years, from about 26 000-12 000 years ago, some thousands of years more than the Aranuian forests which succeeded it have so far survived (Moar, 1971). Detailed interpretation is difficult because the sites are scattered, occur at different altitudes, and often span a short period of time. Interpretation is further complicated because the data are biased towards plant communities of wetter habitats. Thus many of the pollen types listed in Table] are derived from plants characteristic of damp or swampy situations in grassland and include *Bulbinella, Drosera arcturi, Montia, C!aytonia,* Cyperaceae, *Gunnera, Hydrocotyle, Lilaeopsis, Liparophyllum, Mitrasacme, Plantago, Schizeilema* and *Selliera*. At Wroxham saline soil conditions similar to those occurring in parts of Central Otago (Raeside and Cutler,]966) are suggested by the high frequencies for Chenopodiaceae and by the record of *Selliera* pollen from the deepest sample at 11.50 m.

Shrubs were better represented in the vegetation at sites west of the Main Divide. *Phyllocladus,* the most consistently recorded, occurred in most western sites, but in less than half those from Canterbury. However, pollen frequencies were so low that shrubs were not an important element in the vegetation and must have been restricted to the most favourable situations. Some shrubs are under-represented in the pollen rain, e.g., *Dracophyllum* (Fleming *et al.,* 1976) and *Hebe,* and their role in the vegetation may be greater than the pollen record suggests. At Dillmanstown the few records of *Hebe* pollen (Table I) are supported by wood remains (Burrows, pers. comm.) which offer conclusive proof of the local presence of this plant.

Frequencies of *Nothofagus fusca* type are generally between 1-6 % of total land pollen counted and therefore are unlikely to have been derived locally unless from small relict stands in well sheltered situations. The Blue Spur Road is an outstanding exception and the forest there may have been the source of some of the pollen recorded. However, the late Otiran dominant at Blue Spur Road was *N. menziesii,* the pollen of which is not widely dispersed (McKellar, 1973). The infrequent occurrence of *N. fusca* type pollen in Canterbury sites is surprising especially as the record in Aranuian sites, as at Cass, suggests some forest not too far beyond the ice limits (Moar, 1971; Lintott and Burrows, 1973). However, these must have been restricted to the most sheltered situations, for at

Rubicon Creek, near Springfield, there are only occasional records of beech pollen until the spread of *Nothofagus* thousands of years later (Moar and Lintott, 1977). The search must continue for more rewarding sites from this point of view for there is little doubt that there were forest refugia in Canterbury (Wardle, 1963).

Moar (1971) commented that a more diverse woody flora distinguished the earliest Aranuian vegetation from late Otiran vegetation. Available data supports this generalisation, but it is also clear that much depends upon site factors. Because continuous sequences are rare the true nature of the transition must remain uncertain until more data are to hand. Lintott and Burrows (1973) comment that early Aranuian vegetation was "relatively sparse" with grass, herbs and shrubs, and there is certainly no reason to suppose that there was a continuous plant cover at any site during this time, especially in montane sites such as Cass.

Climate

The constraints imposed by the data apply as much to climatic interpretations as to attempts at vegetation reconstruction. The long period of grassland at Wilsons Lead Road suggests an unchanging climate throughout the late Otiran and early Aranuian after the mid Otiran-late Otiran cooling at about 26000 years RP. (Moar and Suggate, 1979). However, at Blue Spur Road, about 160 km to the south, *Nothofagus* forest was the dominant vegetation type during the late Otiran so that cJimate there could not have been too severe. Indeed there is increasing evidence from other sources (Gage, 1965; Soons, 1978) that the Otiran climate was relatively mild although site factors may have caused marked departures from the regional norm.

The glacial advances and retreats which occurred during the late Otiran imply a period of oscillating climate during which changes in vegetation might be expected. That these changes did not occur, or were of a minor nature, may relate to the short period of about 1000 years, or less, between advances, or because the climate changes were not great enough to affect the vegetation. That Aranuian shrubland usually required 2000 years to develop after the major retreat of ice began 14000 years ago, and that forest usually required even more time, supports either possibility, but does not necessarily support the inference of an unchanging climate as suggested by the pollen data.

There is no reason to suppose that west-east climatic gradients were any less marked during the Otiran and early Aranuian than they are today. Continuing records of Australian pollen types in late Otiran and Aranuian sediments (cf. Macphail, 1979), indicating west-east wind flow, and distribution of loess in Canterbury and the increase in cirque floor altitudes eastwards across the Main Divide (Gage, 1965) emphasise this point. Thus an oceanic climate west of the Main Divide would contrast then, as now, with a drier and more continental east.

The reduction in temperature during the Otiran may have been no more than 4-5°C and it may have been accompanied by increased, rather than reduced, precipitation (Soons, 1978). The presence of forest at Blue Spur Road implies that neither precipitation nor temperature were too low to inhibit its development, and the *Nothofagus menziesii* forest recorded suggests a wet, cool montane environment. The Westport and inland data suggest much more rigorous conditions, but regional changes of such magnitude that either precipitation or temperature or both would inhibit forest in one coastal area and support it in another are unlikely. Other factors need to be considered.

Wardle and Campbell (1976) have discussed the effect of frost controlling post-glacial shrubland in inland sites and Wardle (1974) had drawn attention to the influence of cold air drainage on the development of grassland in mountain valleys. The inland grasslands may well have been influenced by frost in valleys and basins where cold air assess. However, bathymetric data show that, during the late Otiran, sea-level would have been at least 110 m lower than at present (Norris, 1972; 1978; van der Linden and Norris, 1974). Therefore, besides the consequent increase in altitude, sites would also have been at least 20 km further inland (see also Carter and Hertzer, 1979) and so removed from a maritime environment.

Soons (1978) comments that the Otiran environment was a stormy one and it can be implied that frequent and strong winds would have an important influence on the vegetation. Nevertheless the differences between Westport and Hokitika cannot be explained in terms of wind, precipitation or temperature. unless there were marked differences ill regional climate. Although the pollen data suggests such differences the evidence for them is by no means secure. Perhaps the deep Hokitika Canyon {Norris. 1978'- which must have formed a spectacular break in the late Otiran coastline. may have modified the local environment enough to produce the milder climate necessary for the survival of the *Nothofagus* forest recorded at Blue Spur Road.

Canterbury evidence presents no such difficulty, although the possibility that forest refugia existed cannot be overlooked. Grassland at inland stations may well have been influenced in part by frost, but in areas outside the influence of westerly rain, precipitation and temperatures may have been critical. A colder, drier climate, combined with strong fohn winds and inhospitable stony soils of the plains and riverbeds may have created the necessary conditions for the open grasslands discussed above. Cold, dry conditions would also account for the high soil salinity suggested for the Wroxham area. These factors may explain why late Otiran sites are difficult to find in Canterbury and why most of those known are dated at about the Otiran / Aranuian transition when conditions began to improve.

Conclusion

Tile botanical evidence suggests that climatic conditions were bleak and that west / east gradients were probably more pronounced than they are at present. While precipitation is not seen as a critical factor west of the Main Divide, it is considered to have been so in Canterbury. The same comments apply to the temperature regime, although the rugged, diverse topography would allow for marked differences locally, and it is possible that a complex climatic regime controlled a vegetation for which there is no modern analogue.

Connor and McCrae (1969) describe the evolution of grassland in Canterbury following the destruction of forest by fire in Polynesian times. The downward migration of the alpine grassland into new habitats and its mingling with, replacement of, or co-existence with the short tussock grasslands which spread from riverbeds and small enclosures within forests offers some insight into the character of these grasslands. The mosaic of communities, controlled to a great extent by local factors such as drainage, slope and aspect, which were established in Canterbury when Europeans first explored the area may well have been a modern version of the complex pattern which existed so many thousands of years ago.

There was no large scale destruction of forest in Westland until European times, and no development of induced indigenous grassland as in Canterbury. In this context there is no recent counterpart of late Otiran or early Aranuian grassland west of the Main Divide, although many of the genera recorded by pollen analysis occur in natural grasslands on river flats or in montane and subalpine sites.

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