[redacted]

ECOLOGY OF THE ALPINE AND TIMBERLINE VEGETATION OF BIG WHITE MOUNTAIN, BRITISH COLUMBIA

by

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Appendix 2.

Soil Types of Big White Mountain classified according to the American, German and World FAO/UNESCO Classifications

Canadian	American	German	World FAO/UNESCO
Order: Brunisolic	Order: Inceptisol	Class: Braunerden	Order: Cambisol
	Suborder: Ochrept		
Great Group: Dystric Brunisol	Great Group: Dystrochrept	Type: Braunerde	Soil Unit: Dystric Cambisol
Subgroup: Alpine Dystric Brunisol			
Order: Regosolic	Order: Entisol	Class: A-C-Böden	Order: Rhegosol
Great Group: Regosol	Suborder: Orthent		
Subgroup: Orthic Regosol	Great Group: Udorthent or Cryorthent	Type: Ranker	
Order: Gleysolic		Class: Gleye	Order: Gleysol
Great Group: Humic Gleysol	Order: Inceptisol		Soil Unit: Humic Gleysol
	Suborder: Aquept		
Subgroup: Orthic Humic Gleysol	Great Group: Humaquept	Type: Anmoorgley	
: Rego Humic Gleysol	: Haplaquept	: "	
: Fera Humic Gleysol	: Humaquept	: "	
	Order: Entisol		
Great Group: Gleysol	Suborder: Aquent		Soil Unit: Haplic Gleysol
Subgroup: Rego Gleysol	Great Group: Haplaquent	Type: Gley	

Canadian[1]	American[2]	German[3]	World FAO/UNESCO[4]
Order: Podzolic	Order: Spodosol	Class: Podsole	Order: Podzol
Great Group: Humic Podzol	Suborder: Humod	Type: Podsol	Soil Unit: Humic Podzol
Subgroup: Orthic Humic Podzol	Great Group: Haplohumod		
Great Group: Ferro-Humic Podzol	Suborder: Orthod	Type: Podsol	Soil Unit: Humo-Ferric Podzol
Subgroup: Mini Ferro-Humic Podzol	Great Group: Haplorthod		
Subgroup: Sombric Ferro-Humic Podzol			
Great Group: Humo-Ferric Podzol	Suborder: Orthod	Type: Podsol	Soil Unit: Humo-Ferric Podzol
Subgroup: Sombric Humo-Ferric Podzol			

1 The Canadian system follows Canada Soil Survey Committee (1970).
2 The American system follows U.S.D.A. (1960).
3 The German system follows Mückenhausen (1965), after Kubiena (1953).
4 The World FAO/UNESCO system is taken from Canada Soil Survey Committee (1970).

Appendix 3.

Iron and Aluminum Determinations

Community	Plot No.	Horizon	% Fe	% Al	% Fe+Al	ΔFe+Al	O.M./Fe
Antennaria - *Sibbaldia* Association							
Antennaria - *Sibbaldia* - *Salix* Variation	10	Bm	0.49	0.83	1.32	0.31	13.02
		C	0.26	0.75	1.01	--	7.27
	13	Bf	1.13	0.95	2.08	1.01	4.27
		Cgj	0.69	0.38	1.07	--	1.32
Carex breweri Variation	45	Bf	0.74	0.98	1.72	0.89	4.78
		Cg	0.32	0.51	0.83	--	2.41
Juncus parryi Association	8	Bhf	1.06	0.98	2.04	1.22	13.21
		C	0.43	0.39	0.82	--	11.49
	12	Bfh	0.87	1.46	2.33	1.13	8.84
		Cg	0.39	0.81	1.20	--	7.36
	30	Bm	0.84	0.98	1.82	0.57	11.60
		C	0.63	0.62	1.25	--	8.92
	40	Bhf	1.02	1.06	2.08	0.83	15.93
		Bm	0.63	1.32	1.95	0.70	16.43
		C	0.41	0.84	1.25	--	17.29
	68	Bfh	0.64	1.38	2.02	0.79	10.83
		C	0.51	0.72	1.23	--	7.41
Antennaria lanata Association	3	Bm	0.63	1.06	1.69	0.69	7.67
		Cgj	0.41	0.59	1.00	--	5.29
	4	Bfh	0.49	0.96	1.45	0.87	18.22
		C	0.21	0.37	0.58	--	10.33

Community	Plot No.	Horizon	% Fe	% Al	% Fe+Al	ΔFe+Al	O.M./Fe
Antennaria lanata Association (continued)	16	Bm	0.49	0.68	1.17	0.35	23.24
		C	0.43	0.39	0.82	--	5.16
	32	Bhf	1.12	1.46	2.58	1.14	11.71
		Cl	0.61	0.83	1.44	--	6.54
Phyllodoce - *Antennaria* Association							
Phyllodoce - *Antennaria* Variation	5	Bf	0.85	1.63	2.48	1.88	5.65
		Cg	0.21	0.39	0.60	--	10.48
	6	Bm	0.53	0.71	1.24	0.25	14.02
		C	0.49	0.50	0.99	--	6.33
	19	Bm	0.61	0.92	1.53	--	10.21
		Cg	0.84	1.33	2.17	--	1.20
	27	Bm	0.73	0.89	1.62	0.74	16.63
		C	0.42	0.46	0.88	--	5.90
	31	Bfh	0.83	1.37	2.20	1.35	9.29
		C	0.26	0.59	0.85	--	9.35
	37	Bf	1.32	1.28	2.60	1.39	3.17
		C	0.48	0.73	1.21	--	18.77
	57	Bm	0.61	0.97	1.58	0.55	18.38
		C	0.40	0.63	1.03	--	11.48
	66	Bm	0.38	0.74	1.12	0.65	19.29
		C	0.15	0.32	0.47	--	25.13

Community	Plot No.	Horizon	% Fe	% Al	% Fe+Al	ΔFe+Al	O.M./Fe
Phyllodoce - Antennaria Variation (continued)	72	Bhf	1.22	1.63	2.85	0.90	10.59
		C	0.75	1.20	1.95	--	6.51
	76	Bm	0.48	0.84	1.32	0.55	18.27
		C	0.31	0.46	0.77	--	5.45
Antennaria - Vaccinium Variation	7	Bm	0.68	1.23	1.91	--	17.78
		C	0.49	1.46	1.95	--	12.22
	20	Bm	0.76	0.84	1.60	0.55	17.42
		C	0.53	0.52	1.05	--	9.96
	23	Bm	0.81	1.31	2.12	0.56	11.17
		C	0.47	1.09	1.56	--	5.19
	29	Bm	0.35	0.73	1.08	0.47	18.00
		C	0.20	0.41	0.61	--	10.85
	41	Bm	0.37	1.06	1.43	0.29	26.14
		Cg	0.41	0.73	1.14	--	6.37
Abies lasiocarpa Association	44	Bhf	0.74	0.93	1.67	0.87	15.88
		BC	0.28	0.52	0.80	--	37.36
Abies - Picea - Vaccinium Association	51	Bh	0.32	0.48	0.80	0.15	41.56
		C	0.28	0.37	0.65	--	23.57
	54	Bhf	1.26	1.37	2.63	0.83	11.21
		C	0.74	1.06	1.80	--	6.04

Community	Plot No.	Horizon	% Fe	% Al	% Fe+Al	ΔFe+Al	O.M./Fe
Abies - *Picea* - *Vaccinium* Association (continued)	61	Bhf	0.72	0.84	1.56	0.84	14.86
		Cg	0.27	0.45	0.72	--	20.26
	70	Bhf	0.58	1.05	1.63	0.84	18.28
		C	0.32	0.47	0.79	--	20.25
Abies - *Valeriana* Association	56	Bm	0.47	1.02	1.49	0.22	27.19
		C	0.53	0.74	1.27	--	21.64
	62	Bm	0.63	0.94	1.57	0.60	17.86
		C	0.28	0.69	0.97	--	16.54
	74	Bm	0.61	0.53	1.14	--	19.85
		C	0.51	0.74	1.25	--	5.80
Carex spectabilis Association	11	Bm	0.64	0.59	1.23	0.02	20.19
		C	0.73	0.48	1.21	--	5.47
	14	Bhf	0.92	0.78	1.70	0.95	14.28
		C	0.32	0.43	0.75	--	8.44
	18	Bm	0.57	0.83	1.40	0.62	9.63
		C	0.31	0.47	0.78	--	11.81
Valeriana - *Castilleja* Association							
Valeriana - *Castilleja* Variation	34	Bhfg	0.71	1.38	2.09	0.87	18.04
		C	0.39	0.83	1.22	--	15.92
Trollius laxus Variation	24	Bg	0.27	0.63	0.90	0.03	39.70
		Cg	0.16	0.71	0.87	--	11.69

Community	Plot No.	Horizon	% Fe	% Al	% Fe+Al	ΔFe+Al	O.M./Fe
Carex nigricans Association *Carex* - *Polytrichadelphus* Variation	1	Bm	0.55	0.89	1.44	0.08	14.02
		Cg	0.43	0.93	1.36	--	4.21
	2	Bm	0.71	1.26	1.97	0.23	14.10
		Cgj	0.64	1.10	1.74	--	2.61
	15	Ahf	0.70	1.28	1.98	0.95	24.54
		Bhf	0.80	1.70	2.50	1.47	19.85
		Bm	0.74	0.99	1.73	0.70	16.55
		C	0.39	0.64	1.03	--	19.23
	35	Bhfg	0.86	1.50	2.36	0.84	14.90
		Cg	0.54	0.98	1.52	--	7.87
	71	Ah	0.43	0.86	1.29	0.41	55.79
		Cg	0.57	0.31	0.88	--	10.53
	77	Bm1	0.74	1.32	2.06	0.49	10.23
		Bm2	0.83	0.94	1.77	0.20	3.37
		C	0.51	1.06	1.57	--	5.73
Polytrichum norvegicum Association	79	Bf	0.74	1.32	2.06	1.10	6.07
		Cg	0.32	0.64	0.96	--	5.47

Appendix 4.

Class Limits for Environmental Variables

The limits chosen are based on the range of values present for each variable.

Variable	Limits	Variable	Limits
Altitude	H 7500-7600 ft.	Silt	H 39-49%
	M 7400-7500 ft.		M 28-38%
	L<7400 ft.		L 17-27%
Slope	H 25-40%	Clay	H 8-11%
	M 10-25%		M 4-7%
	L 0-10%		L 0-3%
Humus	H 66-100%	pH	H>5.5
	M 33-66%		M 5.0-5.5
	L 0-33%		L 4.5-5.0
Mineral Soil	H 12-18%	Ca (me/100g.)	H>0.8
	M 6-12%		M 0.5-0.8
	L 0-6%		L 0.2-0.5
Rock	H 66-100%	Mg (me/100g.)	H>0.18
	M 33-66%		M 0.10-0.18
	L 0-33%		L 0.02-0.10
Soil Depth	H 22-26 in.	Na (me/100g.)	H>0.18
	M 17-21 in.		M 0.10-0.18
	L 12-16 in.		L 0.02-0.10
Sand	H 68-80%	K (me/100g.)	H>0.25
	M 54-67%		M 0.14-0.25
	L 40-53%		L 0.03-0.14

Variable	Limits
CEC (me/100g.)	H>40
	M 25-40
	L<25
O.M.	H 15-20%
	M 9-14%
	L 3-8%
N	H>0.5%
	M 0.4-0.5%
	L<0.4%
P (ppm)	H 12-14
	M 8-11
	L 4-7

Appendix 5.

Statistical Analysis

Table 81

F Values for Environmental Variables[1]

Variable	F Value
Altitude	2.42**
Exposure	2.63**
Slope	4.26**
Wind	15.70**
Relief	0.80
Erosion	8.61**
Hygrotope	44.78**
Humus	20.44**
Mineral soil	1.99*
Rock	20.11**
Depth of soil	2.58**
Sand	3.24**
Silt	2.59**
Clay	4.53**
pH	5.94**
Ca	1.84*
Mg	5.33**
Na	2.41**
K	3.99**
CEC	3.63**
OM	3.86**
N	2.98**
P	1.84*

1 Community degrees of freedom = 18; Error degrees of freedom 63
* Significant at 5% level, ** Significant at 1% level

Table 82

Significant Environmental Variables between Communities[1,2]

Upper-right half contains general environmental variables;
lower-left half contains physical and chemical soil properties.

Community	J.c.	A.-S.	C.p.	C.b.	J.p.	A.l.	P.-A.	A.-V.	Picea	Abies	A.-P.-V.	Abies - V	C.s.	V.-C.	Trollius	C.-P.	J.-C.-D.	P.n.	D.e.
Juniperus communis Association	-	3,9	3,5,7,9	3,7,9	3,5-7,9	3,5-10	3,4,6,7,9	3,6,7,9	6,7	6,7,9	3,6,7,9	4,6,7,9	3,6,7,9	3,4,6,7,9	3,4,6,7,9	3,4,6,7,9	3,4,6,7,9	2-4,6,7,9	3,4,6,7,9
Antennaria - *Sibbaldia* Association																			
Antennaria - *Sibbaldia* - *Salix* Variation	14,17,19, 20,21	-	5	7,9	4-7,9	4-10	4-7,9	4-7,9	5,6	5-7,9	5-7,9	1,4-7,9	4-7,9	4-7,9	4-7,9	4-7,9	4-7,9	2,4-6,9	4-7,9
Carex phaeocephala Variation	11	11	-	7,9	4,6,7,9	4,6-10	4-7,9	4,6,7,9	6	6,7,9	4,6,7,9	4,6,7,9	4,6,7,9	4,6,7,9	4,6,7,9	4,6,7,9	4,6,7,9	4,6,9	4,6,7,9
Carex breweri Variation	14,20	17		-	4-6	4-6	4-6	4-6	5,6	5,6	5,6	4-6	4-6	4-6	4-7	4-7	4-6	4-6	4-7
Juncus parryi Association	19	14	11	14	-	6,8,9	4-7	6,7		6	6	4,6	6,7	4,6,7,9	4,6,7,9	4,6,7,9	4,6,7	2-4,6	4,6,7,9
Antennaria lanata Association	14,19				14	-	5,8	8	6-10	4,8-10	8	1,6,8	6,8	2,6,8,10	2,6,8,10	4,6,8	2,6,8	6,7,9,10	6,8
Phyllodoce - *Antennaria* Association																			
Phyllodoce - *Antennaria* Variation	19						-		4,7,9	4,7	4,7	6,7	6	6	6	6	6	2,5,7,9	6
Antennaria - *Vaccinium* Variation			11-13					-	7,9	4,7	7	1,6,7	6	6	6	4,6	6	2,3,5,7,9	6
Picea engelmannii Association		17							-			1,4,6	6,7,9	4,6,7,9	4,6,7,9	4,6,7,9	4,6,7,9	3,4,6	4,6,7,9
Abies lasiocarpa Association		14,17, 19-21	19	14,19,20	19	14,19,20	19	19	19,20	-		1,4,6	4,6,7	4,6,7,9	4,6,7,9	4,6,7,9	4,6,7	2-4,6	4,6,7,9
Abies - *Picea* - *Vaccinium* Association	19	14		14		14		13		19	-	4,6	6,7	4,6,7	4,6,7	4,6,7	4,6,7	2,4,6	4,6,7
Abies - *Valeriana* Association	19	14,21		14		14				19		-	1,7	7	7	7	6,7	1-3,6	6,7
Carex spectabilis Association		14,20		14		14				19			-			4		2,3,7,9	
Valeriana - *Castilleja* Association																			
Valeriana - *Castilleja* Variation		14,18,20, 21		14,18,20		14,18				19	22			-				2,7,9	2
Trollius laxus Variation	16,17	11,14,16, 18,20,21	16,18	14,16-18, 20	16,18	16,18	16,18	18,18	16,17	16,17,19	16,18	16	16	16	-			2,3,7,9	2
Carex nigricans Association																			
Carex - *Polytrichadelphus* Variation	11,12,19	11,12,21			11,12			11,12		19			12		16,18	-		7,9	
Juncus - *Carex* - *Drepanocladus* Variation	11-14,20	11-14	11,13,14	11,13,14	11-14	11,13,14	11,13,14	11-14	11,13,14	11,13,14, 19,20	11,13,14	11,13,14	11-14,20	11,13,14, 20	11,13,14, 20	11,13,14	-	2,7,9	2
Polytrichum norvegicum Association	13,19-21	13		13	13	13	13	13	13	13,14, 19-21	14	13	13,20	13,16, 20-22	13,16,18, 20	12,13	11,12,14, 16	-	7,9
Drepanocladus exannulatus Association	11,12,14	11,12			11,12,14			11,12		14,19	14	14	12,14	14	14,16,18		11,13,14	12	-

[1] Based on Duncan's New Multiple Range Test (P = 0.05)

[2] See Table 83 for key to environmental variables

Table 83

Key to Environmental Variables

Variable	Assigned Number
Altitude	1
Exposure	2
Slope	3
Wind	4
Erosion	5
Hygrotope	6
Humus	7
Mineral soil	8
Rock	9
Depth of soil	10
Sand	11
Silt	12
Clay	13
pH	14
Ca	15
Mg	16
Na	17
K	18
CEC	19
OM	20
N	21
P	22

from: Karen Eady's Thesis

Table 79

Soil Moisture Percentages for Selected Alpine Communities

Community	Horizon	1/3 atm. (Aver. of 2)	15 atm. (Aver. of 2)	Available	Horizon	July 6/69	July 18/69	Aug.3/69	Aug.29/69
Antennaria - Sibbaldia Association									
Antennaria - Sibbaldia - Salix Variation (Plot 22 - A)	A	39.1	24.1	15.0	A	55.7	37.4	12.1	6.6
	C	26.7	11.1	15.6	C	60.6	38.5	24.3	16.5
Juncus parryi Association (Plot 12 - A)	A	35.6	20.6	15.0	A	55.2	33.3	19.2	18.8
	B	29.3	15.2	14.1	B	44.0	75.9	31.8	23.2
	C	16.7	10.5	6.2	B + C	36.5	46.2	17.8	25.4
Antennaria lanata Association (Plot 4 - A)	A	67.9	31.2	36.7	A	169.6	115.9	99.1	61.1
	B	65.2	22.2	43.0	B	67.9	40.8	60.7	33.1
	C	13.9	6.3	7.6	C	90.1	101.1	44.6	39.0
Phyllodoce - Antennaria Association									
Phyllodoce - Antennaria Variation (Plot 5 - A)	A	49.2	21.2	28.0	A	95.1	75.2	58.9	41.3
	B	41.4	12.8	28.6	B	78.8	67.1	56.4	42.2
	C	23.1	8.2	14.9	B + C	74.9	56.8	48.8	32.2
Abies - Picea - Vaccinium Association (Plot 54 - LA)	A	59.4	30.9	28.5	A	53.1	80.6	12.3	14.4
	B	46.5	26.0	20.5	B	49.8	43.4	25.4	27.7
	C	17.3	10.0	7.3	C	58.2	61.1	25.1	27.1
Valeriana - Castilleja Association									
Valeriana - Castilleja Variation (Plot 38 - LA)	A	54.1	45.5	8.6	A1	245.5	182.3	27.9	47.8
					A2	178.0	115.0	63.0	31.7
Carex nigricans Association									
Carex - Polytrichadelphus Variation (Plot 2 - A)	A	70.2	54.3	15.9	A	215.7	277.5	110.6	52.5
	B	62.5	23.0	39.5	B	25.2	120.3	33.1	32.7

Table 80

Soil Moisture Percentages for Selected Subalpine Communities

Community	Horizon	1/3 atm. (Aver. of 2)	15 atm.	Available	Horizon	July 6/69	July 18/69	Aug. 3/69	Aug. 29/69
Juncus parryi Association (Plot 59)	A	48.6	32.0	16.6	A	70.5	25.5	9.6	10.7
	C	21.7	15.7	6.0	C	13.7	16.8	-	8.4
Phyllodoce - *Antennaria* Association									
Phyllodoce - *Antennaria* Variation (Plot 57)	A	48.1	29.0	19.1	A	73.2	79.3	53.1	47.0
	C	39.0	13.2	25.8	C1	90.1	74.8	63.3	48.7
					C2	78.7	48.0	32.2	-
Abies - *Picea* - *Vaccinium* Association (Plot 61)	A	66.4	37.6	28.8	A	110.6	86.3	26.6	21.2
	B	58.3	21.3	36.5	B + C	79.9	97.0	52.7	37.0
	C	34.2	14.8	19.4	C	39.4	65.9	-	26.3
Valeriana - *Castilleja* Association									
Valeriana - *Castilleja* Variation (Plot 60)	A	75.1	64.6	10.5	A	200.0	303.9	257.9	223.1
	C	23.9	13.3	10.6	C	138.4	54.8	34.5	108.4
Carex nigricans Association									
Carex - *Polytrichadelphus* Variation (Plot 58)	A1	36.8	20.4	16.4	A1	60.5	59.0	17.6	14.1
	A2	34.2	14.3	19.9	A2	49.7	51.1	42.6	30.1
	C	32.9	14.1	18.8	A3	48.7	64.6	43.3	38.7

from: Karen Eady's Thesis

Table 77

Summary of General Environmental Variables[1] for all Communities

Community	Altit.	Expos.	Slope	Relief	Wind	Erosion	Hygrotope	Humus	Mineral Soil	Rock	Soil Depth
Juniperus communis Association	M	S	H	straight	strong	none	xeric	L	L	H	L
Antennaria - Sibbaldia Association											
Antennaria - Sibbaldia - Salix Variation	H	SSW	L	straight-convex	very strong	strong	xeric	L	M	H	M
Carex phaeocephala Variation	M	SE	L	straight	very strong	moderate	xeric	M	L	M	L
Carex breweri Variation	M	SSE	M	convex	very strong	strong	xeric	M	H	L	M
Juncus parryi Association	M	S	M	straight-convex	strong	slight	subxeric	M	M	M	M
Antennaria lanata Association	H	ENE	L	hummocky	moderate	slight	mesic	H	M	L	H
Phyllodoce - Antennaria Association											
Phyllodoce - Antennaria Variation	M	SSW	M	hummocky	moderate	none	mesic	H	L	L	H
Antennaria - Vaccinium Variation	H	S	M	straight	moderate	none	submesic	H	L	L	M
Picea engelmannii Association	H	ESE	H	straight	strong	none	submesic	M	L	M	L
Abies lasiocarpa Association	H	WSW	H	straight-convex	strong	slight	mesic	M	L	M	L
Abies - Picea - Vaccinium Association	M	SW	H	straight	strong	slight	mesic	M	L	L	M
Abies - Valeriana Association	L	WSW	H	concave	moderate	none	subhygric	M	L	L	M
Carex spectabilis Association	H	SSW	M	straight	moderate	none	hygric	H	M	L	H
Valeriana - Castilleja Association											
Valeriana - Castilleja Variation	L	WSW	M	concave	slight	none	hygric	H	L	L	L
Trollius laxus Variation	L	WSW	M	straight-concave	slight	none	hygric	H	L	L	M
Carex nigricans Association											
Carex - Polytrichadelphus Variation	M	SE	L	straight-concave	slight	none	hygric	H	L	L	H
Juncus - Carex - Drepanocladus Variation	M	NNW	L	straight	slight	none	subhydric	H	L	L	M
Polytrichum norvegicum Association	H	-	L	straight	slight	none	subhydric	M	M	M	L
Drepanocladus exannulatus Association	L	-	L	concave	slight	none	subhydric	H	L	L	M

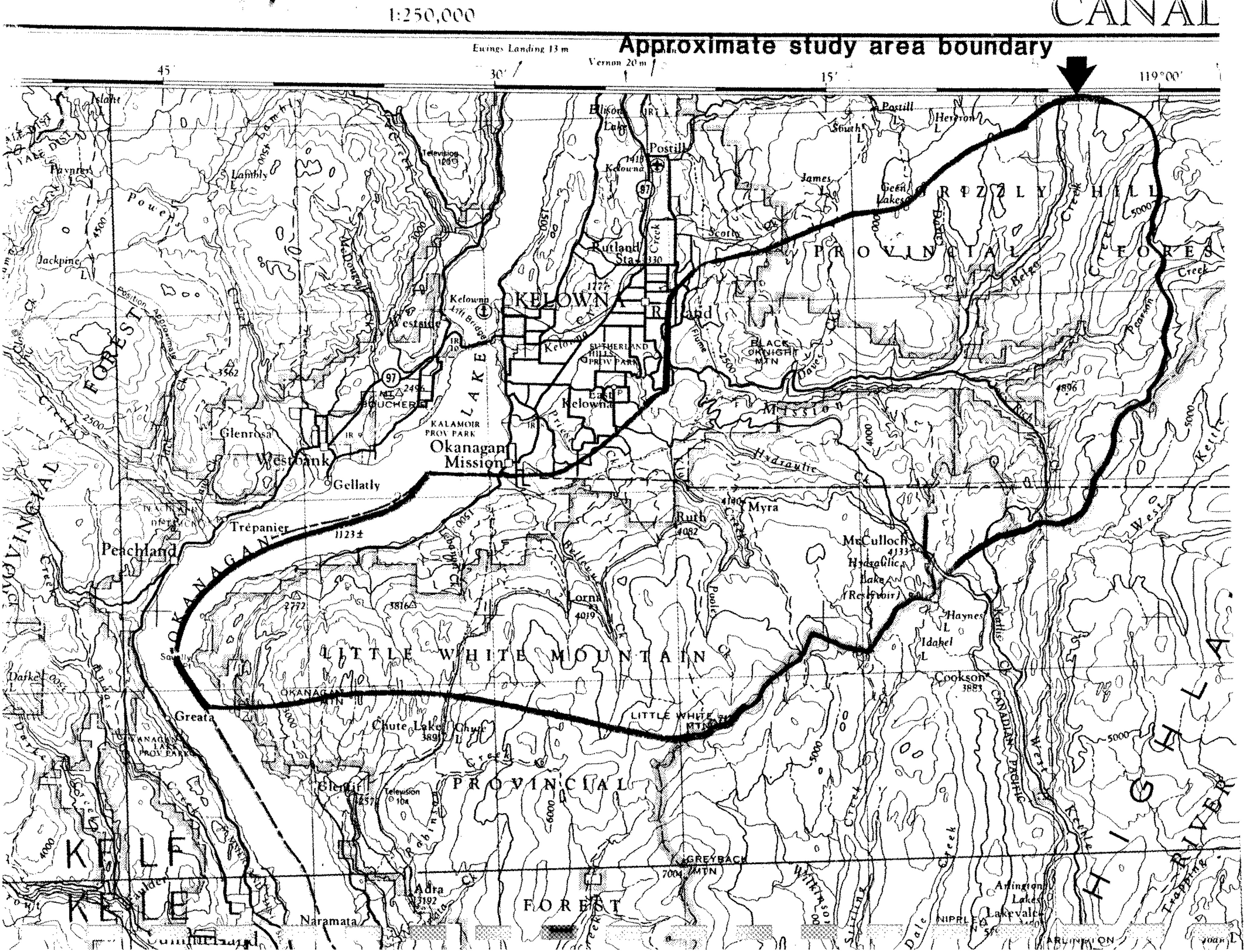
[1] L = low, M = medium, H = high
See Appendix 4 for class limits

Table 78

Summary of Physical and Chemical Soil Data[1] for all Communities

Community	Sand	Silt	Clay	pH	Ca	Mg	Na	K	CEC	OM	N	P
Juniperus communis Association	H	L	L	L	L	L	L	M	H	H	H	H
Antennaria - Sibbaldia Association												
Antennaria - Sibbaldia - Salix Variation	H	L	L	M	H	L	H	L	L	L	L	L
Carex phaeocephala Variation	M	M	M	M	M	L	M	L	M	M	L	H
Carex breweri Variation	H	L	L	M	M	L	L	L	M	L	L	L
Juncus parryi Association	H	L	L	L	L	L	M	L	L	M	M	M
Antennaria lanata Association	H	L	L	M	L	L	M	L	L	L	L	M
Phyllodoce - Antennaria Association												
Phyllodoce - Antennaria Variation	H	L	L	M	L	L	M	L	L	M	L	M
Antennaria - Vaccinium Variation	H	L	L	M	M	L	M	L	M	M	M	M
Picea engelmannii Association	H	L	L	M	H	L	L	M	M	L	L	L
Abies lasiocarpa Association	H	L	L	L	M	M	L	M	H	H	H	H
Abies - Picea - Vaccinium Association	H	L	M	L	L	L	M	L	L	M	L	L
Abies - Valeriana Association	H	L	L	L	L	M	M	M	L	M	H	M
Carex spectabilis Association	H	L	L	L	H	M	H	M	H	M	M	M
Valeriana - Castilleja Association												
Valeriana - Castilleja Variation	H	L	L	L	M	M	M	H	M	H	H	H
Trollius laxus Variation	M	L	L	M	H	H	H	H	M	H	H	M
Carex nigricans Association												
Carex - Polytrichadelphus Variation	M	M	L	M	L	L	H	L	L	M	H	M
Juncus - Carex - Drepanocladus Variation	L	H	H	H	H	H	M	M	L	L	L	L
Polytrichum norvegicum Association	H	L	H	M	L	L	M	L	L	L	L	L
Drepanocladus exannulatus Association	L	H	L	H	L	L	M	L	L	M	M	L

[1] L = low, M = medium, H = high
See Appendix 4 for class limits



1:250,000
CANAL
Approximate study area boundary
Ewings Landing 13 m
Vernon 20 m
45'
30'
15'
119°00'
KELOWNA
Rutland
Okanagan Mission
Westbank
Gellatly
Peachland
Trépanier
Glenrosa
Westside
OKANAGAN LAKE
KALAMOIR PROV PARK
LITTLE WHITE MOUNTAIN
GRIZZLY HILL
PROVINCIAL FOREST
McCulloch
Hydraulic Lake (Reservoir)
Myra
Ruth
Lorna
Greata
Naramata
Chute Lake
Cookson
Idabel L
Haynes L
GREYBACK MTN
BLACK KNIGHT MTN
SUTHERLAND HILLS PROV PARK
Mission
Hydraulic
Pearson
Belgo
Ellison Lake
Postill
James
South L
Hereron L
Lambly L
Jackpine L
Paynter L
Powers
Glenfir
Adra
Arlington Lakes
Lakevale
Kettle River
HIGHLA
KELLE

from: Karen Cady's Thesis

9. Summary and Conclusions

The purposes of this research were to obtain data on vegetation and environment in an alpine-timberline area, to produce an ecosystematic classification of the vegetation, and to determine the environmental factors important in the differentiation of the plant communities. The main results of this study are summarized below:

(1) Fourteen plant associations, with nine variations, are distinguished and described along a general gradient of increasing moisture. The communities are compared with those described in other alpine and subalpine areas.

The Juniperus communis Association occurs over rock outcrops on ridges and slopes in the alpine and low alpine areas.

The Antennaria lanata - Sibbaldia procumbens Association occurs on ridge tops, primarily in the alpine area. The association is subdivided into three variations: Antennaria lanata - Sibbaldia procumbens - Salix cascadensis Variation, Carex phaeocephala Variation, and Carex breweri Variation.

The Juncus parryi Association occurs on south-facing slopes in the alpine and low alpine areas. It is less well developed in the subalpine parkland, occurring there on slopes and ridges with a southern exposure.

The Antennaria lanata Association occurs at the base of slopes, on ridges and on slopes in the alpine and low alpine areas.

The Phyllodoce empetriformis - Antennaria lanata Association occurs mainly on slopes in the alpine, low alpine and subalpine parkland areas. The association is divided into two variations: Phyllodoce empetriformis - Antennaria lanata Variation, and Antennaria lanata - Vaccinium scoparium Variation.

The Picea engelmannii Association, represented only by one plot, occurs on a ridge in the alpine area.

The Abies lasiocarpa Association also occurs on ridges in the alpine area.

The Abies lasiocarpa - Picea engelmannii - Vaccinium scoparium Association occurs mainly on ridges in the alpine, low alpine and subalpine parkland areas.

The Abies lasiocarpa - Valeriana sitchensis Association occurs on seepage slopes in the subalpine parkland.

The Carex spectabilis Association occurs on slopes with temporary seepage, mainly in the alpine and low alpine areas.

The Valeriana sitchensis - Castilleja elmeri Association occurs on seepage slopes in the subalpine parkland and, less frequently, in the alpine and low alpine areas. The association is divided into two variations: Valeriana sitchensis - Castilleja elmeri Variation, and Trollius laxus Variation.

The Carex nigricans Association occurs in snow basins, depressions and temporary ponds in the alpine, low alpine and subalpine parkland areas. The association is divided into two variations: Carex nigricans - Polytrichadelphus lyallii Variation, and Juncus mertensianus - Carex nigricans - Drepanocladus exannulatus Variation.

The Polytrichum norvegicum Association occurs in temporary ponds in the alpine area.

The Drepanocladus exannulatus Association, represented by only one plot, occurs as a narrow band around the edge of a temporary pond in the subalpine parkland.

(2) The soils are classified according to the Canadian system of soil classification (Canada Soil Survey Committee, 1970). The orders and soil types represented in the study area are: Brunisolic - Alpine Dystric Brunisol; Regosolic - Orthic Regosol; Podzolic - Sombric Humo-Ferric Podzol, Sombric Ferro-Humic Podzol, Mini Ferro-Humic Podzol, and Orthic Humic Podzol; Gleysolic - Rego Humic Gleysol, Fera Humic Gleysol, Orthic Humic Gleysol, and Rego Gleysol. The communities associated with each soil type are presented in detail, with a discussion on the lack of close correlation between soil types and vegetation types.

(3) The soils are generally shallow, with weak horizon development (excluding the podzols). Soil development appears to be proceeding slowly. Important chemical properties are the acidic pH, narrow carbon:nitrogen ratios, low cation exchange capacities, and very low amounts of exchangeable cations.

(4) The distribution of the tree species in the area, together with selected diameter, height and age measurements, is discussed. The krummholz growth form of trees occurs on ridges in the alpine area, while trees occur on ridges and seepage slopes in the subalpine parkland. The subalpine trees are much older than those in the alpine area. It is suggested that there has been a recent migration of tree species into the alpine area. There are insufficient data to correlate the migrations with a

climatic change.

(5) The occurrence of conifer seedlings and shrubs in alpine and timberline communities (exclusive of the sampled tree islands) is presented. No conifer seedlings were observed in the tree island communities. More seedlings were found in the Antennaria-Sibbaldia - Salix community than in any other.

(6) A synthesis table including characteristic species and high-presence species for all associations is discussed. In general, both the characteristic species and the high-presence species follow the moisture trend. Species occurring in associations for which they are not characteristic are usually much less important in those associations.

(7) Floristic similarity indices were calculated a) between all plots and b) between all associations and variations. Similarity matrices are included in the description of the communities to show the values of plots within an association. Plots within an association generally have their highest similarities to each other rather than to a plot in another association. Variations of an association show up clearly in the similarity matrix. In comparing the associations and variations with each other, the highest affinities of each community are presented. In general, there is a very low degree of similarity among the communities. It is concluded that the indices of similarity support the classification system.

(8) The topographic-altitudinal relationships of the alpine and subalpine communities are presented.

(9) The environmental data are summarized for each community as being low, medium or high (in relation only to the present

data). The communities are grouped according to hygrotope, and the environmental factors are discussed for each group.

(10) A one-way analysis of variance was done for each environmental variable. All factors are significant at the 1% level except for mineral soil, calcium and phosphorus, which are significant at the 5% level, and relief, which is not significant.

(11) Based on Duncan's New Multiple Range Test, the environmental factors which are significant in differentiating each community are outlined. It is concluded that the general environmental factors are more significant in distinguishing the communities than the physical and chemical soil properties. Hygrotope is the most important of the general environmental factors.

(12) Soil moisture was studied for a number of communities in the alpine and subalpine parkland areas. Available water generally decreases with depth. The amount of available water in the surface and subsurface horizons is compared for corresponding alpine and subalpine communities. A greater amount of available water at depth is proposed as an explanation for the better growth of trees in the subalpine parkland.

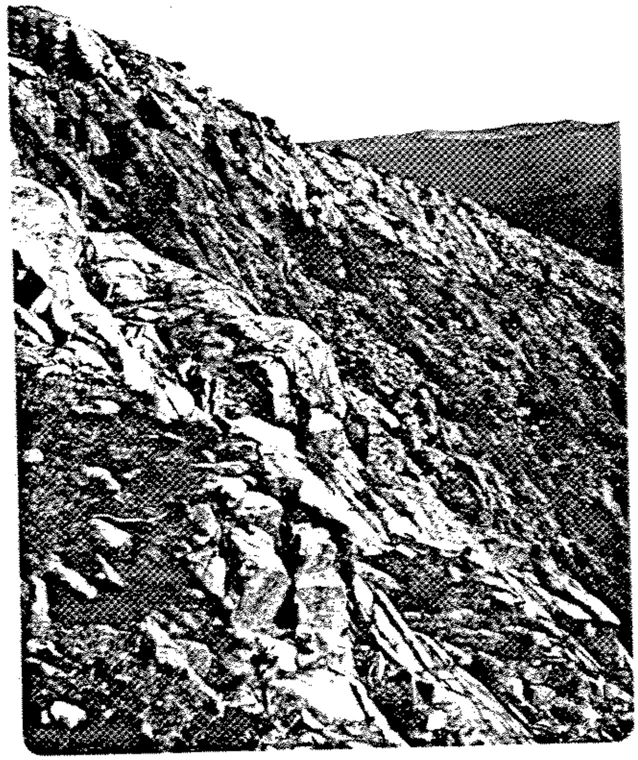
The actual field moisture values are discussed for each community. A number of the communities fall below permanent wilting percentage for part of the summer, and thus undergo soil moisture stress.

(13) A detailed discussion of vegetation zonation is presented. It is concluded that the subalpine parkland area belongs to the Engelmann Spruce - Subalpine Fir Zone, and the alpine and low

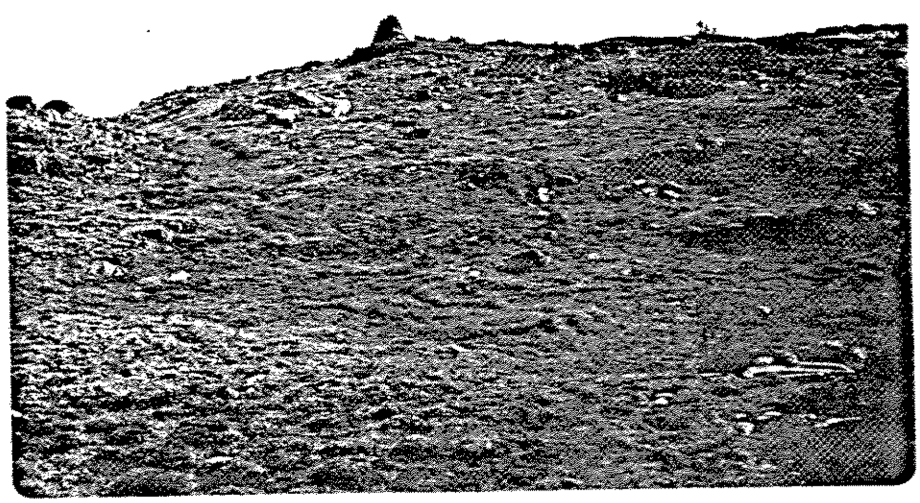
alpine areas comprise the Alpine Zone. The subalpine parkland and parts of the low alpine area constitute the timberline vegetation. The alpine zone in the study area is not as well developed as on the coast or in the Rocky Mountains.

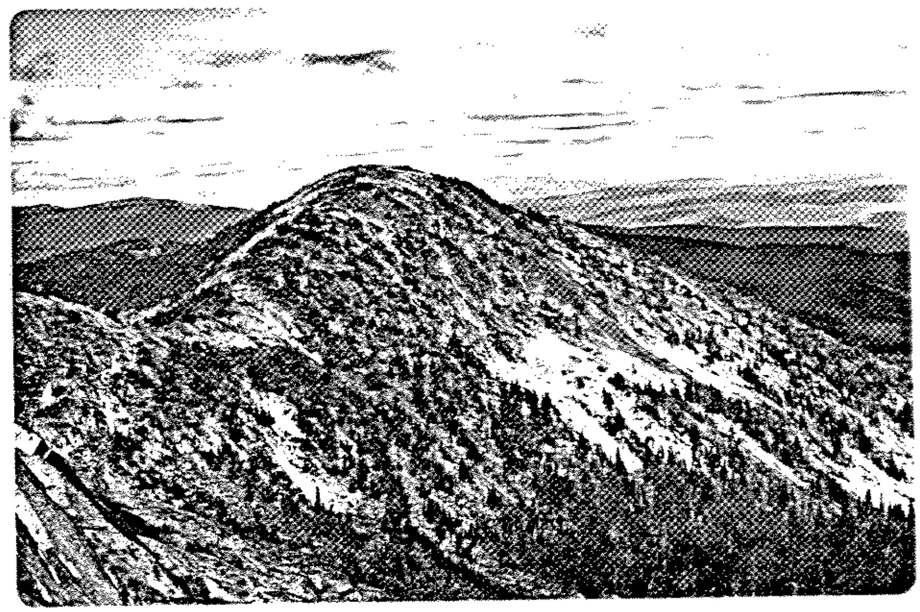
(14) It is concluded that much further work needs to be done in order to properly characterize the alpine zone in British Columbia.

Western slopes of Big White Mountain

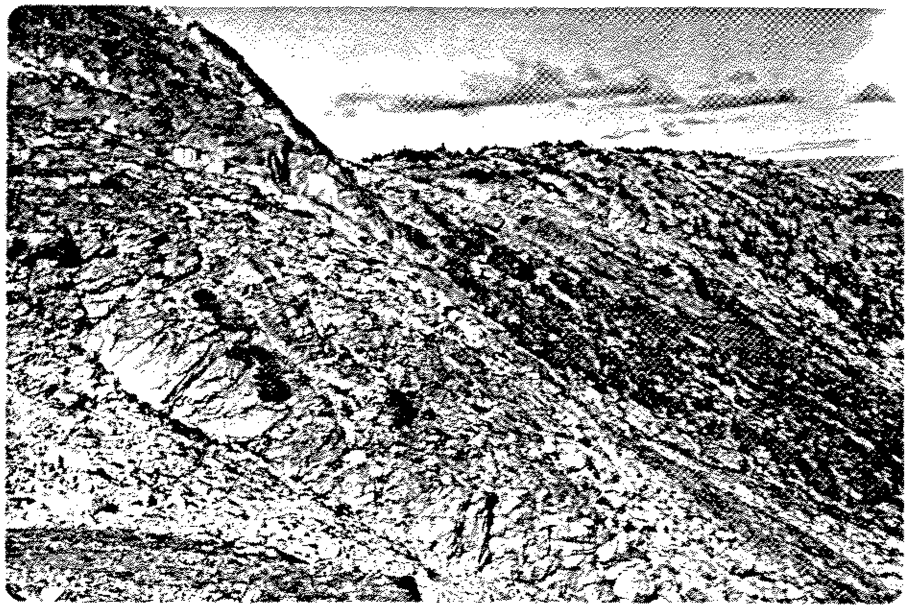


North-west slopes of Big White Mountain (elev. 7603')

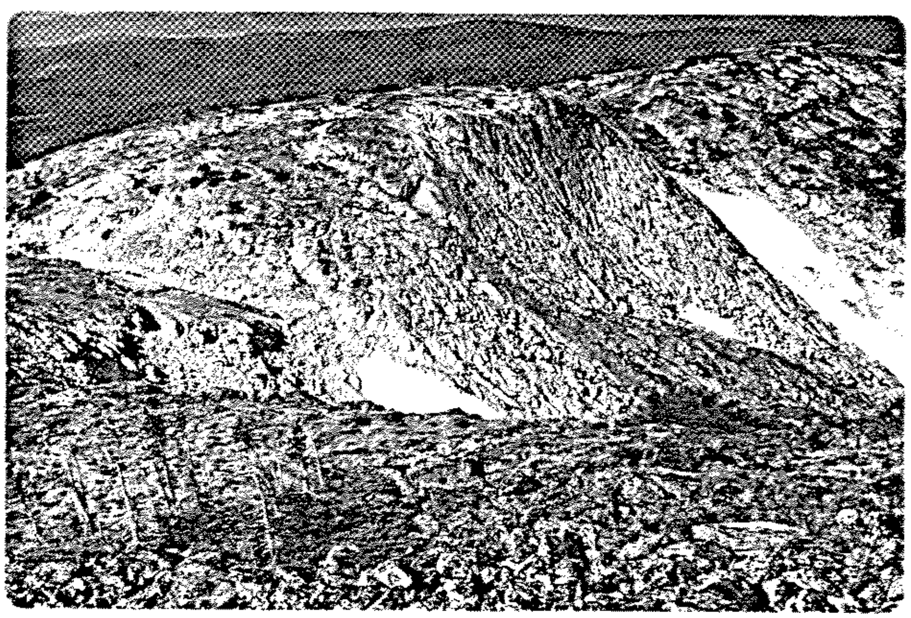


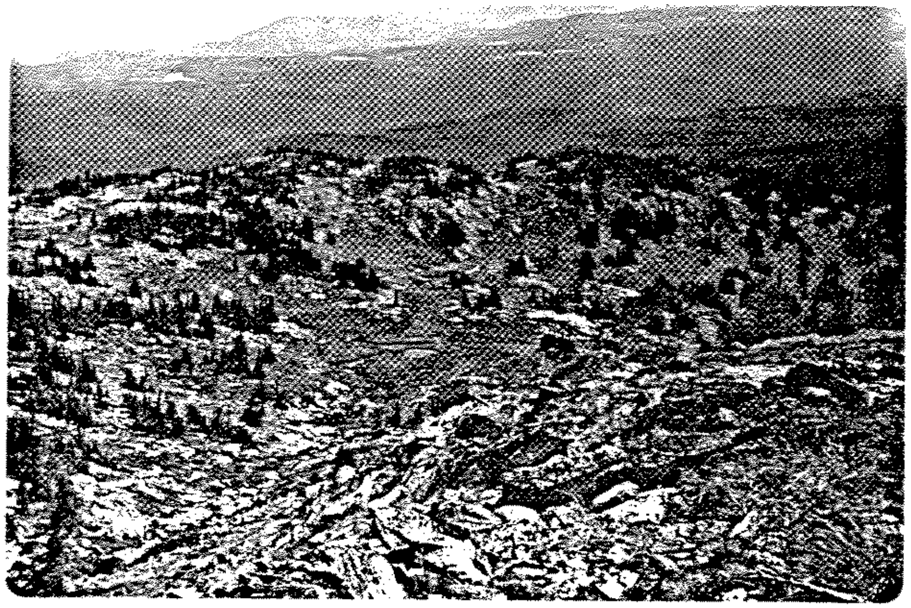


Eastern rim of a glacial kettle of Big White Mountain

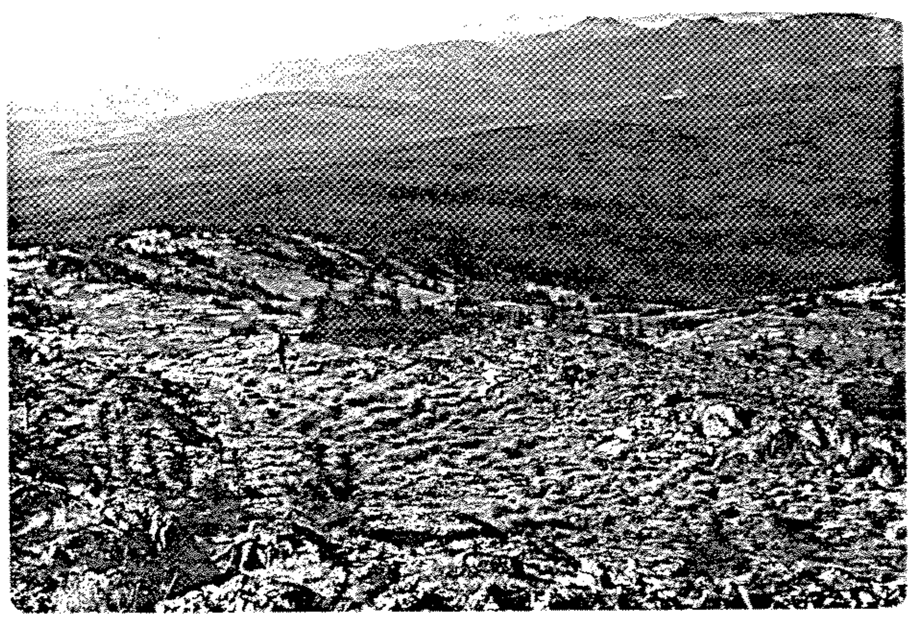


Eastern rim of a glacial kettle of Big White Mountain

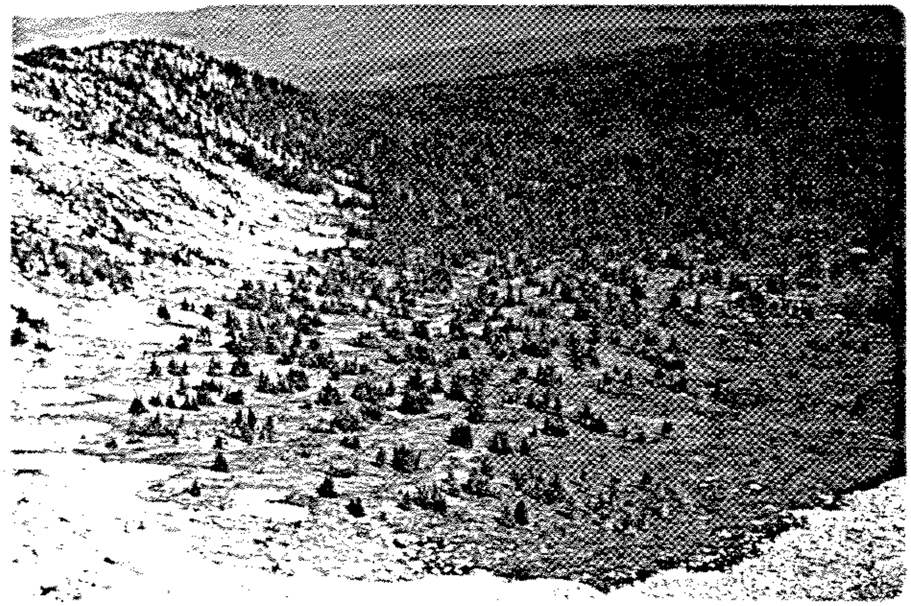




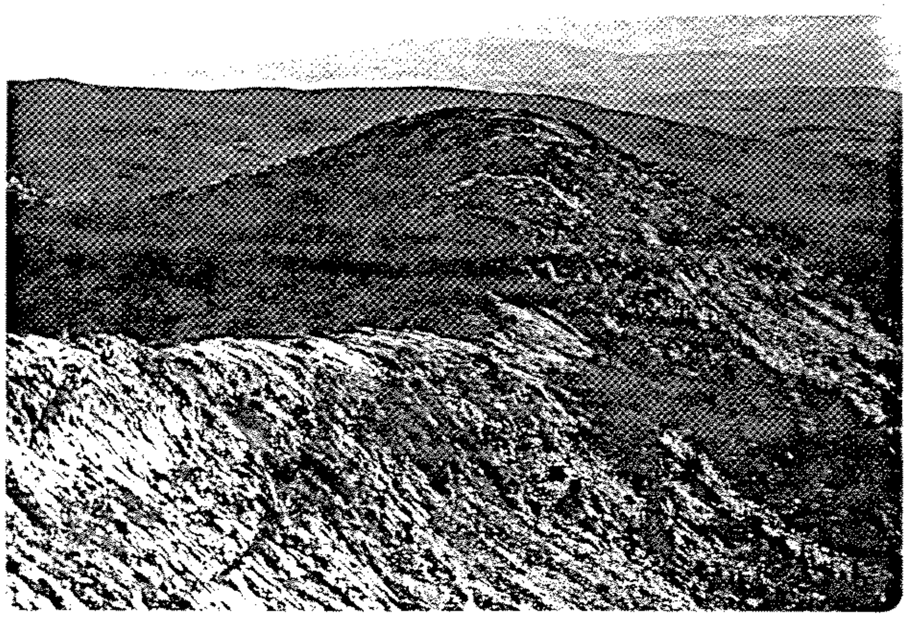
Northwestern slopes of Big White Mountain

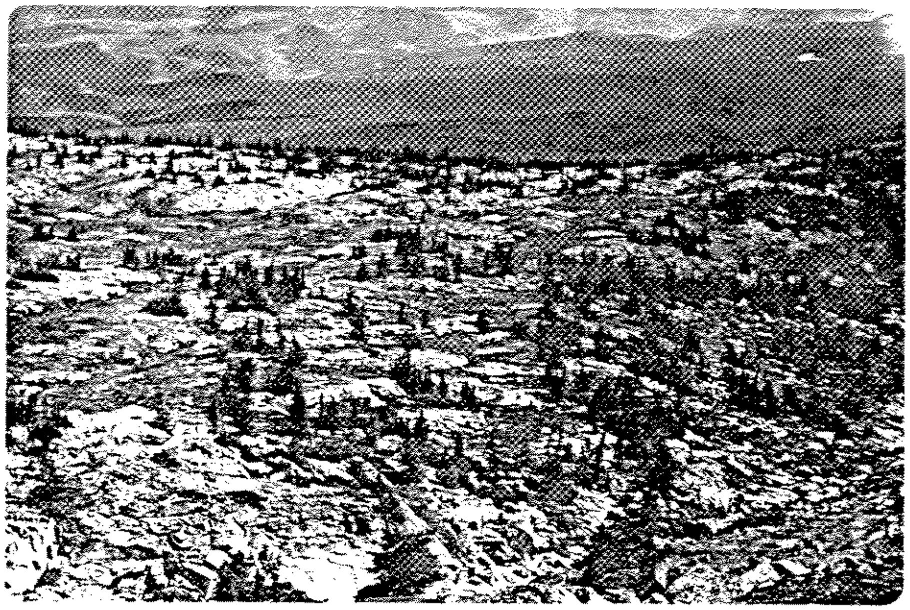


Carex spectabilis Association on north-western slopes of Big White Mountain



Eastern rim of a glacial kettle of Big White Mountain

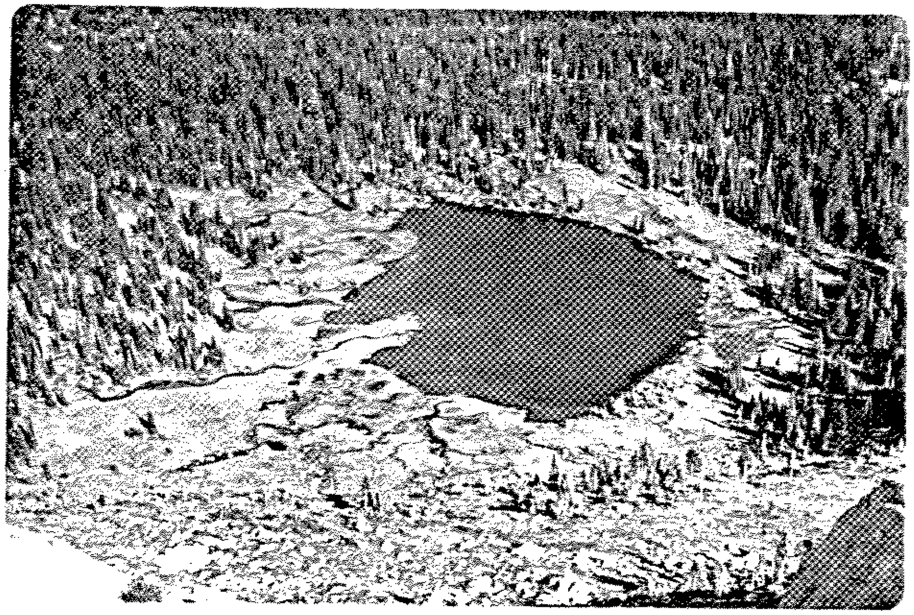




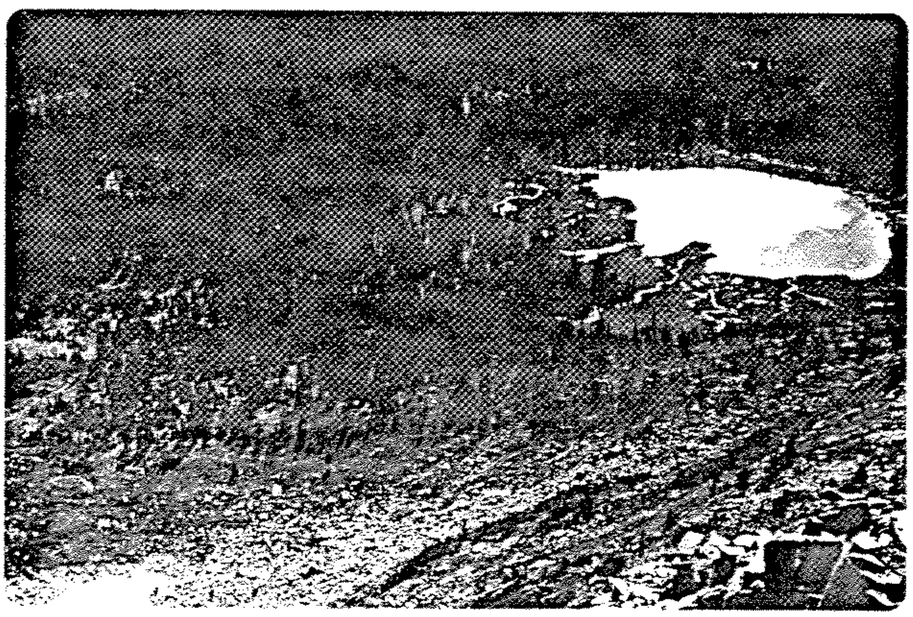
Western slopes of Big White Mountain

Picea engelmannii near the top of Big White Mountain (ca. 7450')

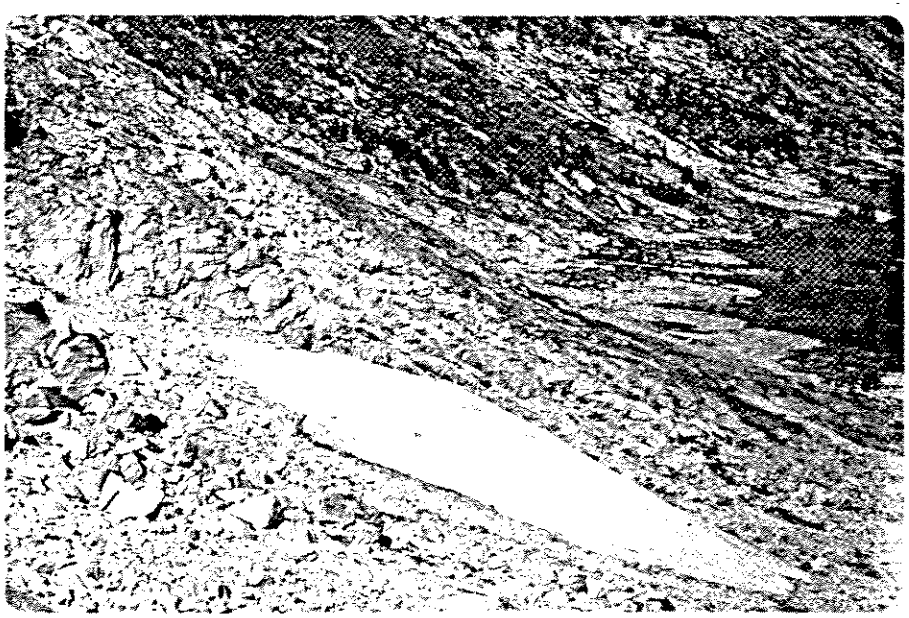
Abies lasiocarpa krummholz growth northwest of the top of Big White Mountain (ca. 7400')

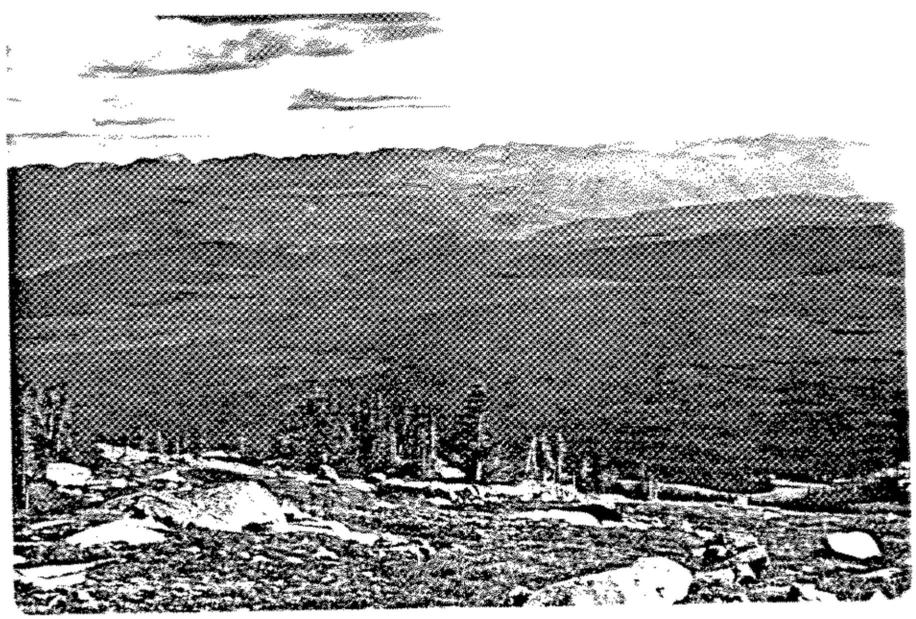


Glacial lake (ca. 6650' above sea) east-south-east of the top of Big White Mountain

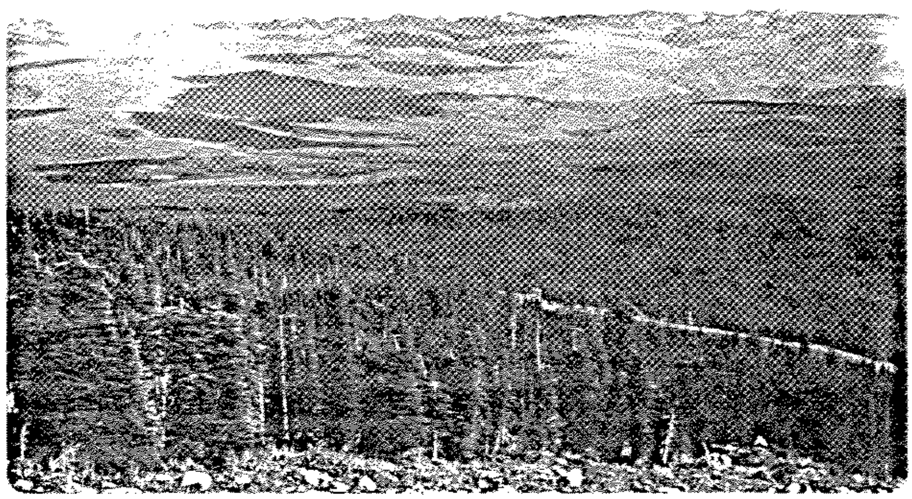


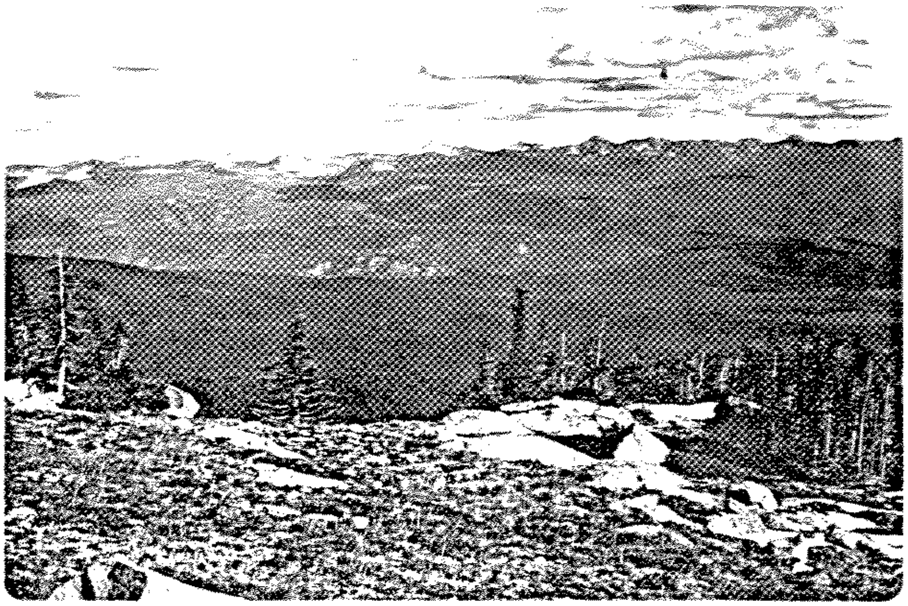
Glacial kettle above the glacial lake, east-south-east of the top of Big White Mountain



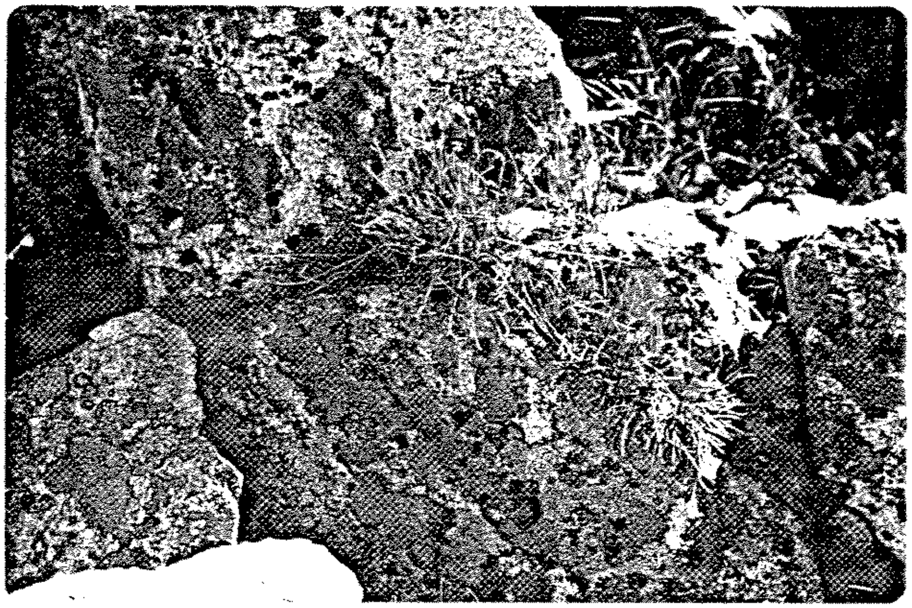


Big White Mountain, a view to the south (over the lodge)

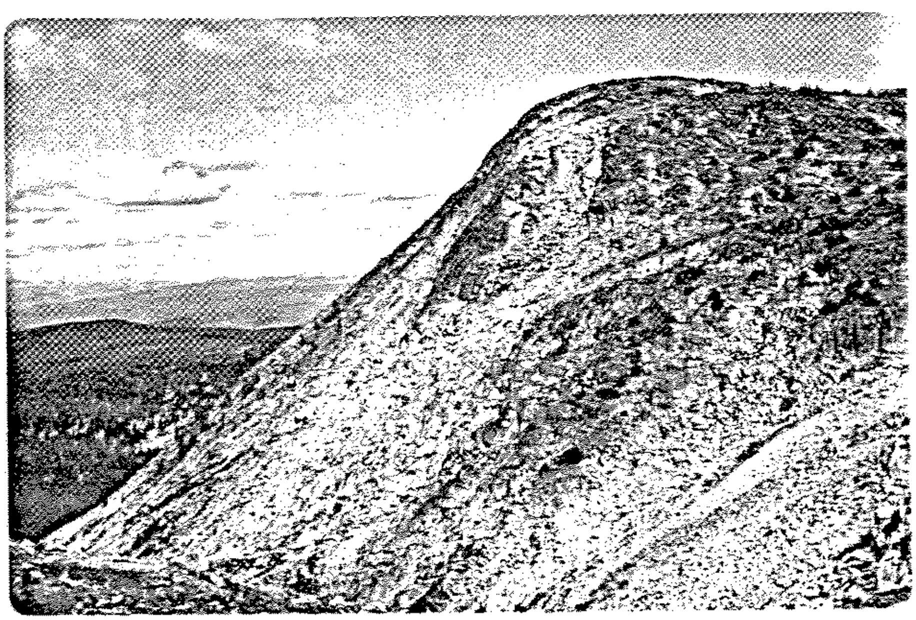




Big White Mountain, a view to the south-east (Picea engelmannii and Abies lasiocarpa are dominant in the Interior Subalpine Forest Zone)



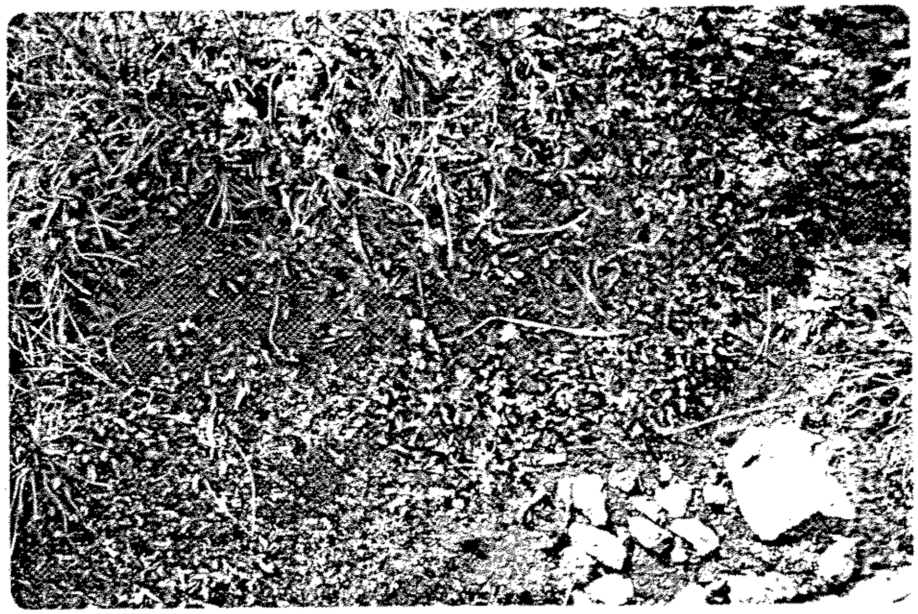
Carex breweri between granitic rocks with the Rhizocarpon lichen association



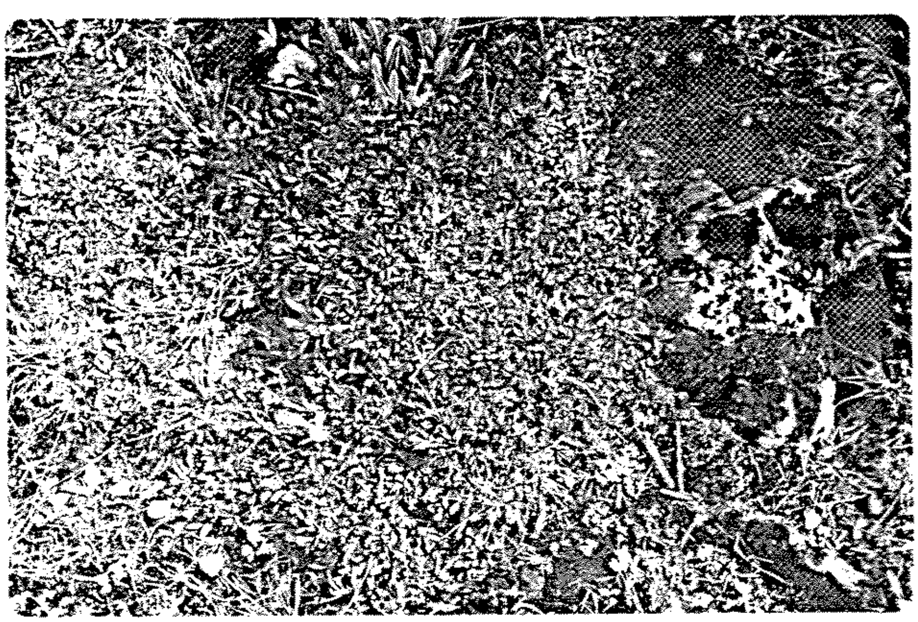
Eastern rim of Big White Mountain

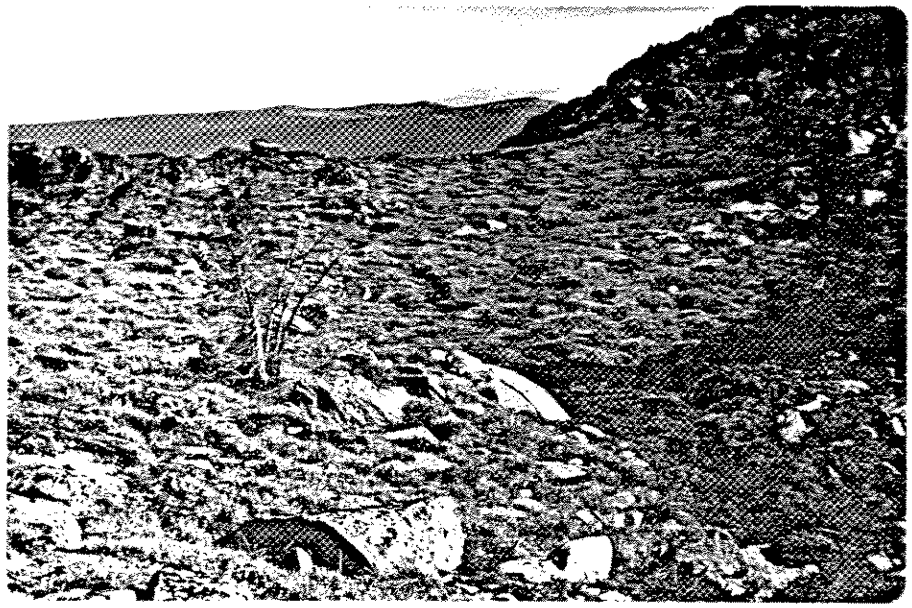
<u>Lupinus latifolius</u> - <u>Anemone occidentalis</u> - <u>Valeriana sitchensis</u> Association

<u>Antennaria lanata</u> - <u>Sibbaldia procumbens</u> Association

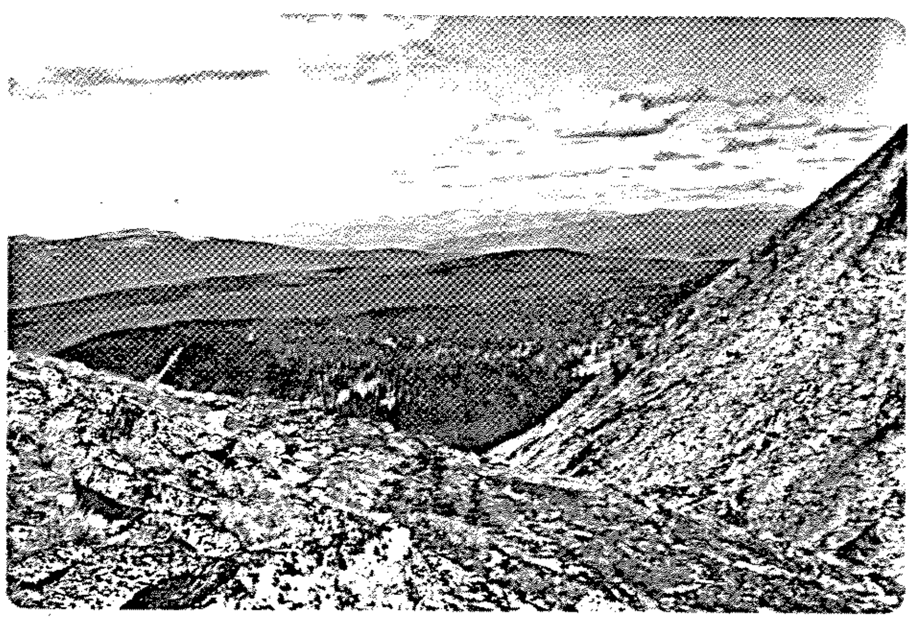


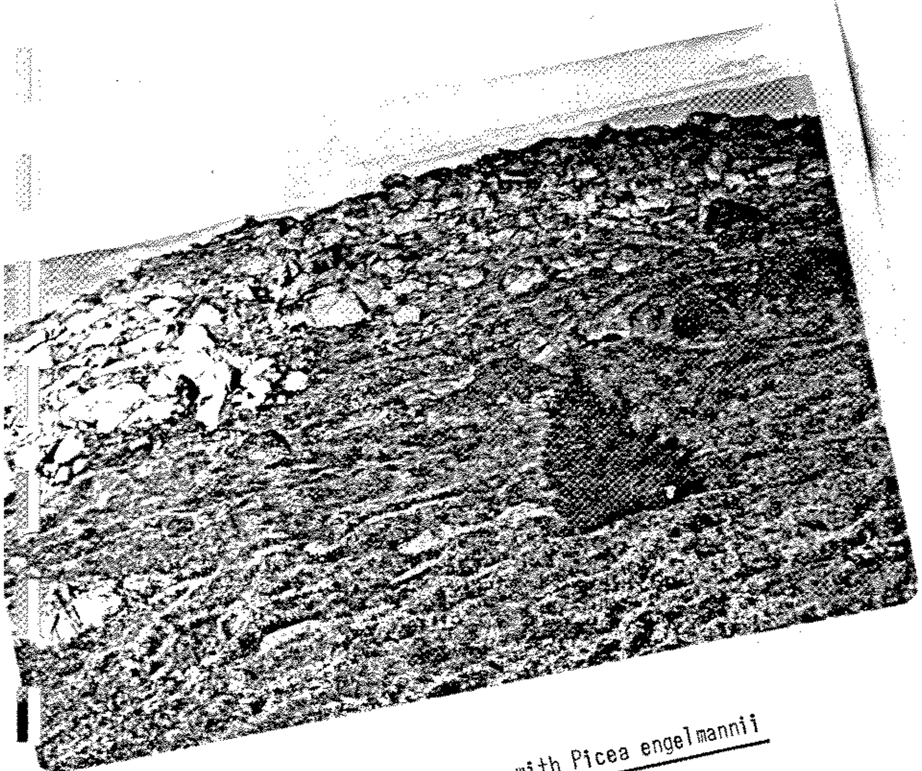
Salix cascadensis in the Antennaria lanata - Sibbaldia procumbens Association, ca. 7450'



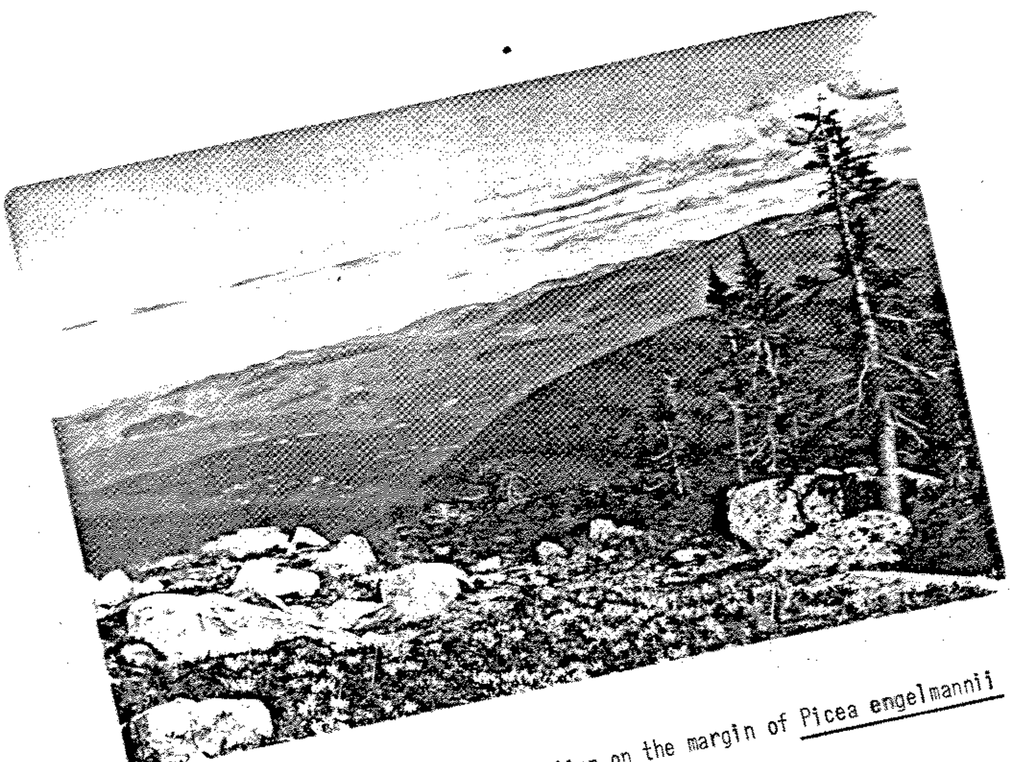


A saddle behind the top of Big White Mountain





Antennaria lanata Association with *Picea engelmannii*



Antennaria lanata Association on the margin of *Picea engelmannii* Association

medium (in the Picea and Abies Associations). Among the physical and chemical soil factors, calcium, cation exchange capacity, organic matter, nitrogen and phosphorus vary among the communities. Sand is high, while silt and clay are low (medium clay in the Abies - Picea - Vaccinium Association). The pH ranges from low in the Abies lasiocarpa and Abies - Picea - Vaccinium Associations to medium in the other communities. Magnesium is generally low (the exception being the Abies lasiocarpa Association). Sodium is medium and potassium is low (exceptions for both being the Picea and Abies Associations).

The hygric group contains five communities: the Abies - Valeriana Association (rated as subhygric), the Carex spectabilis Association, both variations of the Valeriana - Castilleja Association, and the Carex - Polytrichadelphus Variation of the Carex nigricans Association. Altitude, exposure, slope and soil depth are the general environmental factors which vary among the communities. Relief ranges from straight to concave. Wind is moderate in the Abies - Valeriana and Carex spectabilis Associations, and slight in the others. There is no evidence of erosion in any of these communities. Humus is high (except for the Abies - Valeriana Association), mineral soil is low (the exception being the Carex spectabilis Association), and rock is low. Calcium, magnesium, potassium and cation exchange capacity are the soil factors which are variable among the communities. Sand ranges from high to medium, while silt and clay are low (with the exception of silt in the Carex - Polytrichadelphus Variation). The pH ranges from low to medium. Sodium ranges from high to medium. Organic matter is high in the Valeriana - Castilleja Association, and medium in the other communities. Nitrogen is generally high (except for the Carex spectabilis Association), and phosphorus is medium (the exception being the Valeriana - Castilleja Variation).

Three communities make up the subhydric group: the Juncus - Carex - Drepanocladus Variation of the Carex nigricans Association, the Polytrichum norvegicum Association and the Drepanocladus exannulatus Association. Among the general environmental factors, altitude is variable. Exposure is generally neutral (except for the Juncus - Carex - Drepanocladus Variation), slope is low, relief is straight to concave, wind is slight, and there is no erosion. Humus is high, mineral soil and rock are low, and soil depth is medium (the exception in all cases being the Polytrichum norvegicum Association). Among the physical and chemical soil factors, sand is low, silt is high and pH is high (the exception in all cases being the Polytrichum norvegicum Association). Clay is high, while organic matter and nitrogen are low (with the exception of the Drepanocladus exannulatus Association). Calcium, magnesium and potassium are all low (except for the Juncus - Carex - Drepanocladus Variation). Sodium is medium, while cation exchange capacity and phosphorus are low.

The two variations of the Carex nigricans Association were placed in different hygrotope groups in the above discussion. From Tables 77 and 78, it can be seen that these communities do differ from one another mainly on the basis of physical and chemical soil factors. This does not mean that the classification of these communities should be altered, but merely indicates environmental differences between them (which is helpful in subdividing an association). It is interesting to note that the variations of the Valeriana - Castilleja Association also differ mainly due to soil factors. However, the variations of the Phyllodoce - Antennaria Association and the Antennaria - Sibbaldia Association differ equally in respect to both general environmental factors and physical and chemical soil factors.

A one-way analysis of variance was done for each environmental variable to determine which factors are significantly different between communities. The F values are presented in Table 81, Appendix 5. Altitude, exposure, slope, wind, erosion, hygrotope, humus, rock, soil depth, sand, silt, clay, pH, magnesium, sodium, potassium, cation exchange capacity, organic matter and nitrogen are all significant at the 1% level. Mineral soil, calcium and phosphorus are significant at the 5% level. Relief is not significant. In order to distinguish the communities which are significantly different on the basis of each environmental variable, Duncan's New Multiple Range Test was done, a test which has proved to be a very useful tool. The results are shown in Table 82, Appendix 5. Based on this table, as well as Tables 77 and 78, the communities are discussed below, mentioning (in order of importance) the group of environmental factors which are significant in differentiating each community from all others.

The Juniperus communis Association is best differentiated by its low humus, high rock, xeric hygrotope and high slope. It is somewhat less differentiated by its strong wind, high cation exchange capacity and low pH.

In the *Antennaria* - *Sibbaldia* Association, the *Antennaria* - *Sibbaldia* - *Salix* Variation is differentiated by its high rock, strong erosion, xeric hygrotope, low humus and very strong wind. Other less important factors are its medium pH, low nitrogen, low organic matter and high sand. The *Carex phaeocephala* Variation is best separated by its medium rock, medium humus, xeric hygrotope and very strong wind. Another less important factor is its medium sand. The *Carex breweri* Variation is distinguished by its xeric hygrotope, strong erosion and very strong wind, and, to a lesser degree, by its medium pH and medium humus.

The *Juncus parryi* Association is differentiated by its subxeric hygrotope, strong wind and medium humus, and, to a lesser degree, by its medium rock and low pH.

The *Antennaria lanata* Association is best separated by its medium mineral soil and mesic hygrotope, and less by its high soil depth, medium pH, low rock and moderate wind.

In the *Phyllodoce* - *Antennaria* Association, the *Phyllodoce*-*Antennaria* Variation is best distinguished by its mesic hygrotope and, to a lesser degree, by its high humus, moderate wind, lack of erosion and low rock. The *Antennaria* - *Vaccinium* Variation is best differentiated by its submesic hygrotope, and less by its high humus, low rock and moderate wind.

The *Picea engelmannii* Association is separated by its submesic hygrotope and, to a lower degree, by its medium humus, medium rock and strong wind.

The *Abies lasiocarpa* Association is distinguished by its high cation exchange capacity, mesic hygrotope, medium humus and strong wind, and less by its medium rock, low pH and high organic matter.

The *Abies* - *Picea* - *Vaccinium* Association is best differentiated by its mesic hygrotope and medium humus and, to a lesser degree, by its strong wind and low pH.

The *Abies* - *Valeriana* Association is separated by its subhygric hygrotope and medium humus, and less by its moderate wind, low altitude and low pH.

The *Carex spectabilis* Association is best distinguished by its hygric hygrotope, and, to a lower degree, by its high humus, low rock, moderate wind and low pH.

In the *Valeriana* - *Castilleja* Association, the *Valeriana* - *Castilleja* Variation is differentiated by its hygric hygrotope, and less by its high humus, slight wind, low rock and low pH. The *Trollius laxus* Variation is separated by its high magnesium, high potassium, hygric hygrotope and high humus, and, to a lesser degree, by its slight wind and low rock.

In the *Carex nigricans* Association, the *Carex* - *Polytrichadelphus* Variation is distinguished by its hygric hygrotope, slight wind and high humus, and less by its low rock, medium silt and medium sand. The *Juncus* - *Carex* - *Drepanocladus* Variation is best differentiated by its high pH, low sand, high clay and subhydric hygrotope. It is less well differentiated by its high humus, slight wind, high silt, low organic matter and low rock.

The *Polytrichum norvegicum* Association is best separated by its high clay, subhydric hygrotope, medium rock, neutral exposure and medium humus. Other less important factors are its low slope, slight wind and low organic matter.

The *Drepanocladus exannulatus* Association is best distinguished by its subhydric hygrotope and high humus, and less well differentiated by its high pH, slight wind, low rock, high silt and low sand.

From the above discussion, it appears that general environmental factors are more significant in distinguishing the communities than are physical and chemical soil properties. Exceptions to this are the *Trollius laxus* Variation, the *Juncus - Carex-Drepanocladus* Variation, the *Abies lasiocarpa* Association and, to some extent, the *Polytrichum norvegicum* Association. Fonda and Bliss (1969) found that soil fertility levels had no effect on community type distribution. Among the general environmental factors, hygrotope is the only one which constantly contributes highly to the differentiation of the communities. This fact substantiates the statement made earlier that hygrotope is the most important factor in delimiting the various communities.

B. Soil Moisture

Soil moisture was studied in detail because of the previously-mentioned fact that hygrotope is the most important factor in distinguishing the communities. Two main aspects are discussed below - available water and actual field moisture values. Available water is considered to be important because it is the only portion of the water supply which is actually available for plant growth. The primary importance in discussing the actual field moisture values is to see whether this value is less than the permanent wilting percentage, which would cause soil moisture stress to the plants.

Tables 79 and 80 present soil moisture percentages for a selected number of communities in the alpine and subalpine parkland areas.

As expected, available water generally decreases with depth (Fonda and Bliss, 1969) in both the alpine and subalpine communities. However, available water in the Valeriana - Castilleja Variation in the subalpine parkland is approximately the same in the A and C horizons. In the Phyllodoce - Antennaria Variation, available water increases with depth in the subalpine parkland. Available water also increases with depth in the Carex - Polytrichadelphus Variation, in both the alpine and subalpine areas.

The amount of available water in the surface and bottom horizons is similar in both alpine and subalpine communities of the Juncus parryi Association. For the Phyllodoce - Antennaria Variation, the surface horizon has somewhat more available water in the alpine site, whereas the bottom horizon has higher available water in the subalpine site. In the Abies - Picea - Vaccinium Association, the surface horizon has similar quantities of available water in both the alpine and subalpine areas. However, both the B and C horizons have more available water in the subalpine site. Since trees have deep rooting systems, the greater amount of water available at depth may be an explanation

Table 79

Soil Moisture Percentages for Selected Alpine Communities

Community	Horizon	1/3 atm. (Aver. of 2)	15 atm. (Aver. of 2)	Available	Horizon	July 6/69	July 18/69	Aug.3/69	Aug.29/69
Antennaria - Sibbaldia Association, Antennaria - Sibbaldia - Salix Variation (Plot 22 - A)	A	39.1	24.1	15.0	A	55.7	37.4	12.1	6.6
	C	26.7	11.1	15.6	C	60.6	38.5	24.3	16.5
Juncus parryi Association (Plot 12 - A)	A	35.6	20.6	15.0	A	55.2	33.3	19.2	18.8
	B	29.3	15.2	14.1	B	44.0	75.9	31.8	23.2
	C	16.7	10.5	6.2	B + C	36.5	46.2	17.8	25.4
Antennaria lanata Association (Plot 4 - A)	A	67.9	31.2	36.7	A	169.6	115.9	99.1	61.1
	B	65.2	22.2	43.0	B	67.9	40.8	60.7	33.1
	C	13.9	6.3	7.6	C	90.1	101.1	44.6	39.0
Phyllodoce - Antennaria Association, Phyllodoce - Antennaria Variation (Plot 5 - A)	A	49.2	21.2	28.0	A	95.1	75.2	58.9	41.3
	B	41.4	12.8	28.6	B	78.8	67.1	56.4	42.2
	C	23.1	8.2	14.9	B + C	74.9	56.8	48.8	32.2
Abies - Picea - Vaccinium Association (Plot 54 - LA)	A	59.4	30.9	28.5	A	53.1	80.6	12.3	14.4
	B	46.5	26.0	20.5	B	49.8	43.4	25.4	27.7
	C	17.3	10.0	7.3	C	58.2	61.1	25.1	27.1
Valeriana - Castilleja Association, Valeriana - Castilleja Variation (Plot 38 - LA)	A	54.1	45.5	8.6	A1	245.5	182.3	27.9	47.8
					A2	178.0	115.0	63.0	31.7
Carex nigricans Association, Carex - Polytrichadelphus Variation (Plot 2 - A)	A	70.2	54.3	15.9	A	215.7	277.5	110.6	52.5
	B	62.5	23.0	39.5	B	25.2	120.3	33.1	32.7

Table 80

Soil Moisture Percentages for Selected Subalpine Communities

Community	Horizon	1/3 atm. (Aver. of 2)	15 atm.	Available	Horizon	July 6/69	July 18/69	Aug. 3/69	Aug.29/69
Juncus parryi Association (Plot 59)	A	48.6	32.0	16.6	A	70.5	25.5	9.6	10.7
	C	21.7	15.7	6.0	C	13.7	16.8	-	8.4
Phyllodoce - Antennaria Association									
Phyllodoce - Antennaria Variation (Plot 57)	A	48.1	29.0	19.1	A	73.2	79.3	53.1	47.0
	C	39.0	13.2	25.8	C1	90.1	74.8	63.3	48.7
					C2	78.7	48.0	32.2	-
Abies - Picea - Vaccinium Association (Plot 61)	A	66.4	37.6	28.8	A	110.6	86.3	26.6	21.2
	B	58.3	21.8	36.5	B + C	79.9	97.0	52.7	37.0
	C	34.2	14.8	19.4	C	39.4	65.9	-	26.3
Valeriana - Castilleja Association									
Valeriana - Castilleja Variation (Plot 60)	A	75.1	64.6	10.5	A	200.0	303.9	257.9	223.1
	C	23.9	13.3	10.6	C	138.4	54.8	34.5	108.4
Carex nigricans Association									
Carex - Polytrichadelphus Variation (Plot 58)	A1	36.8	20.4	16.4	A1	60.5	59.0	17.6	14.1
	A2	34.2	14.3	19.9	A2	49.7	51.1	42.6	30.1
	C	32.9	14.1	18.8	A3	48.7	64.6	43.3	38.7

for the better growth of trees in the subalpine parkland. In a study by Patten (1963), availability of water was believed to be associated with the most common limiting factors for tree growth and establishment in the particular study area in Montana. It was further stated that if the availability of water were increased, the forested area would expand at the expense of the non-forested areas. Available water in the surface horizon of the _Valeriana_ - _Castilleja_ Variation is similar in the alpine and subalpine parkland areas. For the _Carex_ - _Polytrichadelphus_ Variation, the surface horizon has similar amounts of available water in the alpine and subalpine sites; however, there is much more available water in the subsurface horizon in the alpine site.

The actual field moisture values for each community are discussed below. In general, moisture decreased throughout the summer. For the _Antennaria_ - _Sibbaldia_ - _Salix_ Variation, the surface horizon fell below permanent wilting percentage (PWP) from the beginning of August onward, while the subsurface horizon remained above wilting percentage. In the _Juncus parryi_ Association at the alpine site, the surface horizon fell below PWP at the beginning of August, while the subsurface horizons always remained above field capacity. At the subalpine site, the surface horizon dried out below PWP from the middle of July, and the subsurface horizon remained at or below wilting percentage for most of the summer. The _Antennaria lanata_ Association and the _Phyllodoce_ - _Antennaria_ Variation (in both the alpine and subalpine areas) generally remained above field capacity throughout the summer in the surface and subsurface horizons. In the Abies - Picea - Vaccinium Association, the surface horizon fell below PWP from the beginning of August onward, in both the alpine and subalpine sites. The C horizon at both sites always remained above PWP. However, the B horizon in the alpine area fell below wilting percentage for a period in August. Both surface and subsurface horizons remained above field capacity throughout the summer in the subalpine Valeriana - Castilleja Variation, due to the constant supply of seepage water. In the alpine area, the surface horizon dried out below PWP during a period in August, there being less seepage on an alpine slope than on a subalpine one. In the Carex - Polytrichadelphus Variation, the subsurface horizons remained above PWP throughout the summer, at both the alpine and subalpine sites. At the subalpine site, the surface horizon fell below wilting percentage at the beginning of August, whereas at the alpine site this did not occur until the end of August.

Thus, certain communities in the study area undergo soil moisture stress. This has been reported in a number of alpine areas (Klikoff, 1965; Johnson and Billings, 1962; Billings and Bliss, 1959). In contrast, Bliss (1966) on Mt. Washington, New Hampshire, and Bamberg and Major (1968), working in Montana, found soil moisture not to be critical.

C. Topographic-Altitudinal Relationships

In this section, the communities are discussed according to decreasing altitude within the topographic categories of ridges, slopes and depressions. This arrangement is essentially a reordering of the sequence presented in section 4, in order to show the relationships of the communities from a different aspect. In general, snow cover would increase from ridges, which are wind-blown, to depressions with the greatest accumulation of snow.

In the alpine area, the Antennaria - Sibbaldia Association occurs on the highest ridges. According to Krajina (personal communication), the presence of Sibbaldia procumbens indicates that there is heavy snow cover on these ridges (perhaps as cornices), contrary to the general snow-free condition existing on ridge tops. This community is prabably subhygric at the beginning of the vegetative season, becoming xeric at the end of the vegetative season. The Picea engelmannii and Abies lasiocarpa Associations also occur on ridges in the alpine area, but in mesic habitats. These three associations are not present in the subalpine parkland. The Abies - Picea - Vaccinium Association, which is a mesic community, occurs on lower ridges in the alpine and low alpine areas, and on high ridges in the subalpine parkland. This association is, of course, much more widespread in the subalpine parkland.

Seven communities occur on slopes. The Antennaria lanata Association occurs on very gentle slopes in the alpine area, but is lacking in the subalpine parkland. It is a mesic community. The hummocky terrain found in this association may be the result of frost activity. The Phyllodoce - Antennaria Association, also mesic, is found on medium slopes in both the alpine and subalpine parkland areas. The Juncus parryi Association occurs on somewhat steeper slopes than the _Phyllodoce_ - _Antennaria_ Association. It differs considerably from the latter in being subxeric in hygrotope, and would have shorter snow duration. It occurs in both the alpine and subalpine parkland areas, but is more prevalent in the alpine area. The _Juniperus communis_ Association, a xeric community, is found on very steep slopes in the low alpine and alpine areas only. The _Carex spectabilis_ Association is best represented in the low alpine area on slopes with temporary seepage; it is practically lacking in the subalpine parkland. It is a hygric community. The _Valeriana_ - _Castilleja_ Association, also hygric, occurs on seepage slopes rich in nutrients in the low alpine and subalpine parkland areas. This association is most frequent in the subalpine parkland. The subhygric _Abies_ - _Valeriana_ Association occurs also on seepage slopes in the subalpine parkland. This community is present on the same slopes as, and adjacent to, the _Valeriana_ - _Castilleja_ Association, but is much less frequent.

The _Carex nigricans_ Association, rated as hygric to subhydric, is found in depressions with a long duration of snow. This community is common in the alpine, low alpine and subalpine parkland areas. The _Polytrichum norvegicum_ Association, which is subhydric, occurs in temporary ponds in the alpine area. It has the longest snow duration of all the communities. There is a sorting of rocks in one plot, which may indicate the existence of frost action. A similar habitat in the subalpine parkland is occupied by the subhydric _Drepanocladus exannulatus_ Association. In this case, the pond dries up at a later date than in the

Polytrichum norvegicum Association.

D. Soil Types and Plant Communities

In the community descriptions (section 4), the soils associated with each community were mentioned. Very few communities are confined to one soil type. In this section, the alternative approach is followed: that is, the communities associated with each soil type are presented. None of the soil great groups and only three subgroups are restricted to a particular community. The use of both these approaches is helpful in providing more information about the interrelationships of soils and vegetation.

Alpine Dystric Brunisols are found in eight communities, mainly in the Phyllodoce - Antennaria Association (both variations) and in the Abies - Valeriana Association. Other communities with this soil type are the Carex - Polytrichadelphus Variation of the Carex nigricans Association, the Carex spectabilis Association, the Antennaria lanata Association, the Juncus parryi Association and the Antennaria - Sibbaldia - Salix Variation of the Antennaria - Sibbaldia Association.

Orthic Regosols occur in twelve communities, predominantly the Juniperus communis Association, the Antennaria - Sibbaldia Association (all three variations), the Valeriana - Castilleja Variation of the Valeriana - Castilleja Association, and the Juncus parryi Association. Less frequent occurrences are with the Carex spectabilis Association, the Trollius laxus Variation of the Valeriana - Castilleja Association, the Carex - Polytrichadelphus Variation of the Carex nigricans Association, the

Phyllodoce - Antennaria Variation of the Phyllodoce - Antennaria Association, the Abies lasiocarpa Association and the Picea engelmannii Association.

In the Podzolic Order, Sombric Humo-Ferric Podzols are associated with six communities, mainly the Phyllodoce - Antennaria Variation of the Phyllodoce - Antennaria Association, and the Juncus parryi Association. The other communities are the Antennaria - Sibbaldia Association (Antennaria - Sibbaldia - Salix Variation and Carex breweri Variation), the Antennaria lanata Association, and the Polytrichum norvegicum Association. Sombric Ferro-Humic Podzols occur mainly in the Abies - Picea - Vaccinium Association and the Juncus parryi Association. Other occurrences are in the Carex spectabilis Association, the Phyllodoce - Antennaria Variation of the Phyllodoce - Antennaria Association, and the Carex - Polytrichadelphus Variation of the Carex nigricans Association. Of infrequent occurrence are Mini Ferro-Humic Podzols, associated with the Antennaria lanata Association and the Abies lasiocarpa Association, and an Orthic Humic Podzol found in the Abies - Picea - Vaccinium Association.

In the Gleysolic Order, the predominant soil type is the Rego Humic Gleysol, which occurs mainly in the Valeriana - Castilleja Association (both variations) and the Carex nigricans Association (both variations). It is also found with the Drepanocladus exannulatus Association and the Polytrichum norvegicum Association. The other soil types in this order occur very infrequently. The Fera Humic Gleysol is associated with the Valeriana - Castilleja Variation of the Valeriana - Castilleja

Association, and the _Carex_ - _Polytrichadelphus_ Variation of the _Carex nigricans_ Association. The Orthic Humic Gleysol and Rego Gleysol are both found in the _Trollius laxus_ Variation of the _Valeriana_ - _Castilleja_ Association.

Soils and vegetation have been considered as dependent variables, both depending on the same group of ecosystem factors, according to the following equation (Jenny, 1941; Major, 1951; Crocker, 1952): V and S = f (cl, o, r, p, t) where V is vegetation, S is soil, and the factors are climate, organisms, relief, parent material and time. Thus soils and vegetation are not causally related to each other. A given set of environmental factors produces a certain vegetation type and a soil type.

It is interesting to note that the vegetation types and soil types found in the present study are not very closely related. The Canadian soil classification scheme for alpine soils, as used here, is essentially tentative, as very little work has previously been done in alpine regions. It is not the name of the soil, as such, which is important, but the processes which are acting to produce a given set of horizons which is of significance. Unfortunately, very little is yet known about soil genesis in alpine environments. One reason for the lack of correlation between vegetation and soils may be the relatively young age of the area, not enough time having elapsed since glaciation for the maximum development of the soils. Another explanation may be the fact that physical environmental factors (such as low temperature and frost activity) can reduce the effect of the time element, thus slowing the development of the soils. It is also important to realize that the vegetation and soils were compared at different levels in their respective classification systems. The vegetation unit used is the association (or variation), which is very specific, while the soil subgroup is a more generalized abstract category. A much closer correlation between soil types and vegetation types would be produced if the plant communities were compared with the soil series, since the series is a specific unit of the landscape. However, such a comparison was not possible, as no detailed soil map was available for the study area.

8. Vegetation Zonation

Throughout this thesis, reference has been made to alpine, low alpine and subalpine parkland areas. It is necessary now to explain how these areas fit into an altitudinal zonation scheme.

The lowest area is the subalpine parkland, ranging in altitude from ca. 7100 to 7400 feet. This area is considered as the upper part of the interior Engelmann Spruce - Subalpine Fir Zone. This zone has been divided into three geographic subzones, within which parkland areas occur at the higher altitudes (Krajina, 1969). For the coastal subalpine zone, the parkland area has been described as a subzone of the Mountain Hemlock Zone (Krajina, 1965). The low alpine (ca. 7400-7500 feet) and the alpine (ca. 7500-7600 feet) areas comprise the Alpine Zone (after Krajina, 1965). The timberline vegetation is composed of the subalpine parkland and parts of the low alpine area, and is essentially a transition area or ecotone between the closed subalpine forest and the alpine zone.

Since there is such a small elevational difference between the subalpine parkland and the summit of the mountain, it may be suggested that the entire study area belongs to the Engelmann Spruce - Subalpine Fir Zone. According to Krajina (1959), the Alpine Zone in the southeast of British Columbia extends above 7500 feet. This would place the summit of Big White in the alpine zone.

An examination of species listed as characteristic for the alpine and/or interior subalpine zones by Krajina (1959) revealed the following information about the flora of Big White: 56/73 vascular plants and 33/87 bryophytes and lichens on Big White are characteristic of the alpine zone; 26 vascular plants and 10 bryophytes and lichens are characteristic of the interior subalpine zone. Upon subtracting the number of species listed as characteristic for both the alpine and subalpine zones (18 vascular plants, and 8 bryophytes and lichens), the revised figures are as follows: 38 vascular plants and 25 bryophytes and lichens are characteristic of the alpine zone; 8 vascular plants and 2 bryophytes and lichens are characteristic of the subalpine zone. Therefore, floristically, the study area belongs to the alpine zone. This conclusion can be considered valid, since it is based on a list of plants characteristic of the alpine zone as found throughout British Columbia. However, a comparison can not be made from one geographic area, such as the Rocky Mountains or the coast, to another. As Krajina (1959) stated, "there are possibly several alpine zones which could be separated on the basis of their phytogeographic and macroclimatic characteristics."

The alpine zone has been generally defined as the area above timberline. However, timberline itself is variously interpreted as being the elevation of the forest line (the upper edge of continuous forest), the tree line (altitude of the highest stunted tree), or a point midway across the transition zone between forest and alpine tundra (Daubenmire, 1955). The definitive empirical climatic data which are used by Krajina (1965) to determine the alpine zone are the monthly mean temperatures being below 50°F throughout the year (after Köppen, 1936). Unfortunately, there are no detailed climatic measurements from the study area. However, climatic data from Old Glory Mountain, to the south of Big White, indicate that its summit (7700 feet) belongs to the alpine zone. This suggests that the summit of Big White will also climatically belong to the alpine zone.

Much of the area studied is located in the transition area between the forest and alpine regions, and is called timberline vegetation. However, it is concluded that the upper part of Big White Mountain constitutes the Alpine Zone, although it is certainly not as well developed as it is in the coastal area or in the Rocky Mountains. As there are no other detailed vegetation studies in alpine areas of interior British Columbia for comparison, no generalizations can be drawn from the present study as to the exact characterization of the interior alpine zone. Much further work thus needs to be done in this neglected area of plant ecology in British Columbia.

9. Summary and Conclusions

The purposes of this research were to obtain data on vegetation and environment in an alpine-timberline area, to produce an ecosystematic classification of the vegetation, and to determine the environmental factors important in the differentiation of the plant communities. The main results of this study are summarized below:

(1) Fourteen plant associations, with nine variations, are distinguished and described along a general gradient of increasing moisture. The communities are compared with those described in other alpine and subalpine areas.

The *Juniperus communis* Association occurs over rock outcrops on ridges and slopes in the alpine and low alpine areas.

The *Antennaria lanata* - *Sibbaldia procumbens* Association occurs on ridge tops, primarily in the alpine area. The association is subdivided into three variations: *Antennaria lanata* - *Sibbaldia procumbens* - *Salix cascadensis* Variation, *Carex phaeocephala* Variation, and *Carex breweri* Variation.

The *Juncus parryi* Association occurs on south-facing slopes in the alpine and low alpine areas. It is less well developed in the subalpine parkland, occurring there on slopes and ridges with a southern exposure.

The *Antennaria lanata* Association occurs at the base of slopes, on ridges and on slopes in the alpine and low alpine areas.

The *Phyllodoce empetriformis* - *Antennaria lanata* Association occurs mainly on slopes in the alpine, low alpine and subalpine parkland areas. The association is divided into two variations: Phyllodoce empetriformis - Antennaria lanata Variation, and Antennaria lanata - Vaccinium scoparium Variation.

The Picea engelmannii Association, represented only by one plot, occurs on a ridge in the alpine area.

The Abies lasiocarpa Association also occurs on ridges in the alpine area.

The Abies lasiocarpa - Picea engelmannii - Vaccinium scoparium Association occurs mainly on ridges in the alpine, low alpine and subalpine parkland areas.

The Abies lasiocarpa - Valeriana sitchensis Association occurs on seepage slopes in the subalpine parkland.

The Carex spectabilis Association occurs on slopes with temporary seepage, mainly in the alpine and low alpine areas.

The Valeriana sitchensis - Castilleja elmeri Association occurs on seepage slopes in the subalpine parkland and, less frequently, in the alpine and low alpine areas. The association is divided into two variations: Valeriana sitchensis - Castilleja elmeri Variation, and Trollius laxus Variation.

The Carex nigricans Association occurs in snow basins, depressions and temporary ponds in the alpine, low alpine and subalpine parkland areas. The association is divided into two variations: Carex nigricans - Polytrichadelphus lyallii Variation, and Juncus mertensianus - Carex nigricans - Drepanocladus exannulatus Variation.

The Polytrichum norvegicum Association occurs in temporary ponds in the alpine area.

The *Drepanocladus exannulatus* Association, represented by only one plot, occurs as a narrow band around the edge of a temporary pond in the subalpine parkland.

(2) The soils are classified according to the Canadian system of soil classification (Canada Soil Survey Committee, 1970). The orders and soil types represented in the study area are: Brunisolic - Alpine Dystric Brunisol; Regosolic - Orthic Regosol; Podzolic - Sombric Humo-Ferric Podzol, Sombric Ferro-Humic Podzol, Mini Ferro-Humic Podzol, and Orthic Humic Podzol; Gleysolic - Rego Humic Gleysol, Fera Humic Gleysol, Orthic Humic Gleysol, and Rego Gleysol. The communities associated with each soil type are presented in detail, with a discussion on the lack of close correlation between soil types and vegetation types.

(3) The soils are generally shallow, with weak horizon development (excluding the podzols). Soil development appears to be proceeding slowly. Important chemical properties are the acidic pH, narrow carbon:nitrogen ratios, low cation exchange capacities, and very low amounts of exchangeable cations.

(4) The distribution of the tree species in the area, together with selected diameter, height and age measurements, is discussed. The krummholz growth form of trees occurs on ridges in the alpine area, while trees occur on ridges and seepage slopes in the subalpine parkland. The subalpine trees are much older than those in the alpine area. It is suggested that there has been a recent migration of tree species into the alpine area. There are insufficient data to correlate the migrations with a

climatic change.

(5) The occurrence of conifer seedlings and shrubs in alpine and timberline communities (exclusive of the sampled tree islands) is presented. No conifer seedlings were observed in the tree island communities. More seedlings were found in the *Antennaria-Sibbaldia* - *Salix* community than in any other.

(6) A synthesis table including characteristic species and high-presence species for all associations is discussed. In general, both the characteristic species and the high-presence species follow the moisture trend. Species occurring in associations for which they are not characteristic are usually much less important in those associations.

(7) Floristic similarity indices were calculated a) between all plots and b) between all associations and variations. Similarity matrices are included in the description of the communities to show the values of plots within an association. Plots within an association generally have their highest similarities to each other rather than to a plot in another association. Variations of an association show up clearly in the similarity matrix. In comparing the associations and variations with each other, the highest affinities of each community are presented. In general, there is a very low degree of similarity among the communities. It is concluded that the indices of similarity support the classification system.

(8) The topographic-altitudinal relationships of the alpine and subalpine communities are presented.

(9) The environmental data are summarized for each community as being low, medium or high (in relation only to the present

data). The communities are grouped according to hygrotope, and the environmental factors are discussed for each group.

(10) A one-way analysis of variance was done for each environmental variable. All factors are significant at the 1% level except for mineral soil, calcium and phosphorus, which are significant at the 5% level, and relief, which is not significant.

(11) Based on Duncan's New Multiple Range Test, the environmental factors which are significant in differentiating each community are outlined. It is concluded that the general environmental factors are more significant in distinguishing the communities than the physical and chemical soil properties. Hygrotope is the most important of the general environmental factors.

(12) Soil moisture was studied for a number of communities in the alpine and subalpine parkland areas. Available water generally decreases with depth. The amount of available water in the surface and subsurface horizons is compared for corresponding alpine and subalpine communities. A greater amount of available water at depth is proposed as an explanation for the better growth of trees in the subalpine parkland.

The actual field moisture values are discussed for each community. A number of the communities fall below permanent wilting percentage for part of the summer, and thus undergo soil moisture stress.

(13) A detailed discussion of vegetation zonation is presented. It is concluded that the subalpine parkland area belongs to the Engelmann Spruce - Subalpine Fir Zone, and the alpine and low

alpine areas comprise the Alpine Zone. The subalpine parkland and parts of the low alpine area constitute the timberline vegetation. The alpine zone in the study area is not as well developed as on the coast or in the Rocky Mountains.

(14) It is concluded that much further work needs to be done in order to properly characterize the alpine zone in British Columbia.

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Appendix 1.

Checklist of Vascular Plants, Bryophytes and Lichens

The checklist of plants is arranged alphabetically. The nomenclature of the vascular plants is according to Taylor (1966), Hitchcock et al. (1955-1969), Hultén (1968) and Moss (1959). The nomenclature of the bryophytes follows Schofield (1968a, 1968b), Crum et al. (1965), Schuster (1969) and Nyholm (1958). The nomenclature of the lichens is after Otto and Ahti (1967), Hale and Culberson (1966) and Bird (1966). Voucher specimens of all plants are deposited in the herbarium of the Department of Botany, University of British Columbia.

Vascular Plants

Abies lasiocarpa (Hook.) Nutt.

Agrostis thurberiana Hitchc.

Agrostis variabilis Rydb.

Anemone occidentalis S. Wats.

Antennaria friesiana (Trautv.) Ekman

Antennaria lanata (Hook.) Greene

Antennaria umbrinella Rydb.

Arenaria capillaris Poir. var. americana (Maguire) Davis

Arenaria obtusiloba (Rydb.) Fern.

Arnica latifolia Bong.

Arnica mollis Hook.

Calamagrostis canadensis (Michx.) Beauv.

Caltha leptosepala DC.

Carex brevipes Boott.

Carex breweri Boott.

Carex nardina Fries

Carex nigricans C.A. Meyer

Carex phaeocephala Piper

Carex pyrenaica Wahl.

Carex pyrenaica Wahl. x Carex nigricans C.A. Meyer: intermediate

Carex spectabilis Dewey

Castilleja elmeri Fernald

Castilleja rhexifolia Rydb.

Claytonia lanceolata Pursh

Deschampsia atropurpurea (Wahlenb.) Schule

Dryas octopetala L. var. hookeriana (Juz.) Breit.

Epilobium alpinum L. var. clavatum (Trel.) C.L. Hitchc.

Erigeron peregrinus (Pursh) Greene ssp. callianthemus (Greene) Cronq.

no Equisetum

Festuca brachyphylla Schultes

Festuca saximontana Rydb.

Gaultheria humifusa (Grah.) Rydb.

Gentiana glauca Pall.

Habenaria dilatata (Pursh) Hook.

Haplopappus lyallii Gray

Hieracium gracile Hook.

Juncus drummondii E. Meyer

Juncus mertensianus Bong.

Juncus parryi Engelm.

Juniperus communis L. var. montana Ait.

Kalmia polifolia Wang. var. microphylla (Hook.) Rehd.

Lupinus latifolius Agardh var. subalpinus (Piper & Robins.) C.P. Smith

Luzula arcuata (Wahlenb.) Wahlenb.

Luzula glabrata (Hoppe) Desv.

Luzula glabrata (Hoppe) Desv. x Luzula wahlenbergii Rupr. :
intermediate

Luzula parviflora (Ehrh.) Desv.

Luzula spicata (L.) DC.

Luzula wahlenbergii Rupr.

Mitella breweri A. Gray

Pedicularis bracteosa Benth.

Phleum alpinum L.

Phyllodoce empetriformis (Smith) Don

Picea engelmannii Parry

Pinus albicaulis Engelm.

Pinus contorta Loudon var. latifolia Engelm.

Poa cusickii Vasey var. purpurascens (Beal) C.L. Hitchc.

Potentilla diversifolia Lehm.

Potentilla drummondii Lehm.

Ranunculus eschscholtzii Schlecht.

Salix cascadensis Cook.

Saxifraga bronchialis L. var. austromontana (Wieg.) G.N. Jones

Saxifraga ferruginea Grah.

Sedum lanceolatum Torr.

Selaginella densa Rydb. var. scopulorum (Maxon) Tryon

Senecio triangularis Hook.

Sibbaldia procumbens L.

Silene parryi (S. Wats.) C.L. Hitchc. & Maguire

Solidago multiradiata Ait.

Stellaria laeta Richards.

Trisetum spicatum (L.) Richter

Trollius laxus Salisb.

Vaccinium caespitosum Michx.

Vaccinium scoparium Leib.

Valeriana sitchensis Bong.

Veratrum viride Ait.

Veronica wormskjoldii R. & S.

Bryophytes

Anthelia juratzkana (Limpr.) Trevis

Aulacomnium palustre (Hedw.) Schwaegr.

Barbilophozia barbata (Schmid) Loeske

Barbilophozia hatcheri (Evans) Loeske

Barbilophozia lycopodioides (Wallr.) Loeske

Brachythecium asperrimum (Mitt.) Sull.

Brachythecium collinum (Schleich.) B.S.G.

Brachythecium curtum Lindb.

Brachythecium starkei (Brid.) B.S.G.

Bryum bimum (Brid.) Turn.

Bryum capillare Hedw.

Bryum muehlenbeckii B.S.G.

Bryum pseudotriquetrum (Hedw.) Gaertn., Meyer & Scherb.

Bryum sp.

Cephaloziella rubella (Nees) Douin

Cephaloziella subdentata Warnst.

Cephaloziella sp.

Ceratodon purpureus (Hedw.) Brid.

Desmatodon latifolius (Hedw.) Brid.

Dicranella sp.

Dicranum scoparium Hedw. sens. lat. The specimens closely resemble D. muehlenbeckii B.S.G., but are not identical to it. They are thus retained within D. scoparium Hedw., in the broad sense.

Drepanocladus aduncus (Hedw.) Warnst.

Drepanocladus exannulatus (B.S.G.) Warnst.

Drepanocladus uncinatus (Hedw.) Warnst.

Grimmia alpestris (Web. & Mohr.) Nees, Hornsch. & Sturm

Hypnum revolutum (Mitt.) Lindb.

Kiaeria blyttii (Schimp.) Broth.

Lescuraea baileyi (Best & Grout) Lawt.

Lescuraea incurvata (Hedw.) Lawt.

Lescuraea radicosa (Mitt.) Mönk.

Lophozia alpestris (Schleich.) Evans

Lophozia ? kunzeana (Hüben.) Evans

Lophozia obtusa (Lindb.) Evans

Lophozia ? ventricosa (Dicks.) Dumort.

Mnium blyttii B.S.G.

Orthocaulis floerkii (Web. & Mohr.) Buch

Paraleucobryum enerve (Thed.) Loeske

Philonotis americana Dism.

Pohlia drummondii (C. Müll.) Andr.

Pohlia elongata Hedw.

Pohlia gracilis (B.S.G.) Lindb.

Pohlia nutans (Hedw.) Lindb.

Pohlia wahlenbergii (Web. & Mohr.) Andr.

Polytrichadelphus lyallii Mitt.

Polytrichum formosum Hedw.

Polytrichum juniperinum Hedw.

Polytrichum norvegicum Hedw.

Polytrichum piliferum Hedw.

Rhacomitrium canescens (Hedw.) Brid.

Rhacomitrium sudeticum (Funck) B.S.G. ! Rhytidiopsis robusta

Scapania subalpina (Nees) Dumort.

Scapania undulata (L.) Dumort.

Sphagnum nemoreum Scop.

? Tetraplodon mnioides (Hedw.) B.S.G.

Tortula norvegica (Web.) Wahlenb.

Tortula ruralis (Hedw.) Gaertn., Meyer & Scherb.

Lichens

Alectoria americana Mot.

Alectoria minuscula Nyl.

Cetraria ericetorum Opiz

Cetraria islandica (L.) Ach.

Cetraria pinastri (Scop.) S. Gray

Cetraria subalpina Imsh.

Cladonia carneola (Fr.) Fr.

Cladonia chlorophaea (Flörke) Spreng.

Cladonia coccifera (L.) Willd.

Cladonia deformis (L.) Hoffm.

Cladonia ecmocyna (Ach.) Nyl.

Cladonia macrophyllodes Nyl.

Cladonia pleurota (Flörke) Schaer.

Cladonia pyxidata (L.) Hoffm.

Cladonia sp.

Cornicularia aculeata (Schreb.) Ach.

Icmadadophila ericetorum (L.) Zahlbr.

Lecidea granulosa (Hoffm.) Ach.

Lepraria neglecta (Nyl.) Lett.

Omphalodiscus virginis (Schaer.) Schol.

Parmeliopsis ambigua (Wulf.) Nyl.

Parmeliopsis hyperopta (Ach.) Arn.

Peltigera canina (L.) Willd.

Peltigera canina (L.) Willd. var. rufescens (Weiss) Mudd

Peltigera lepidophora (Nyl.) Vain.

Peltigera malacea (Ach.) Funck

Psoroma hypnorum (Vahl.) S. Gray

Rhizocarpon geographicum (L.) DC.

Solorina crocea (L.) Ach.

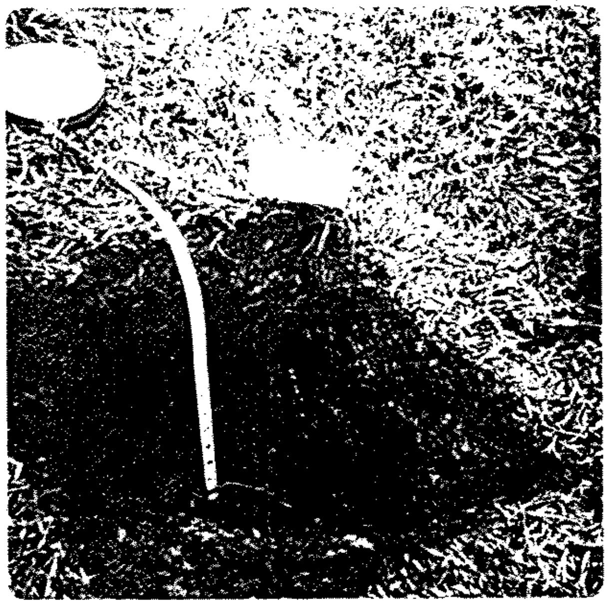
Stereocaulon alpinum Laur.

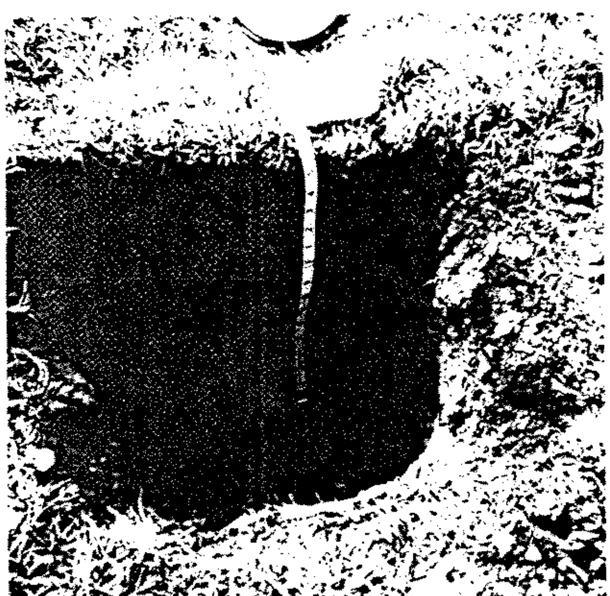
Umbilicaria hyperborea (Ach.) Ach.

Fig. 20. Carex nigricans Association, Carex - Polytrichadelphus Variation, Plot 71. Note late-lying snow. Photo taken July 5,1969.

Fig. 21. Soil profile of *Carex nigricans* Association, *Carex* - *Polytrichadelphus* Variation, Plot 71. This soil is classified as a Rego Humic Gleysol with H, Ah and Cg horizons.

Fig. 22. Soil profile of *Carex nigricans* Association, *Carex* - *Polytrichadelphus* Variation, Plot 77. This soil is classified as an Alpine Dystric Brunisol, with an Ah-Bm1-Bm2-C horizon sequence.





b. Juncus mertensianus - Carex nigricans - Drepanocladus exannulatus Variation

This community is represented by only one plot (81). It occurs in a temporary pond in the low alpine area. The relief shape is straight. Exposure is northwest, with a slope gradient of 2%. Humus covers 96% of the ground surface, and rock 4%. There is no exposed mineral soil. No evidence of erosion is present. The hygrotope ranges from hydric to hygric.

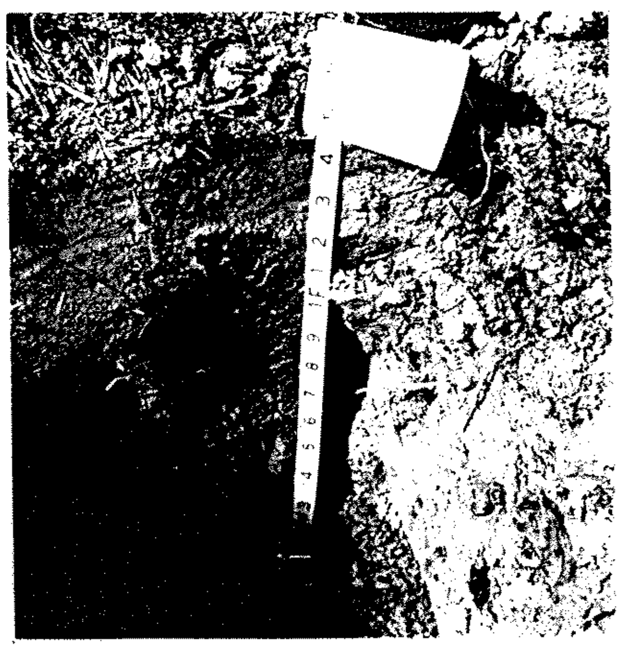
The herb layer and the bryophyte layer have similar coverage values. The C layer covers 45% of the area, and the D layer 50%. There is thus a much lower coverage of plants than in the type variation. The herbs grow mainly in large clumps, which stand up above the water level while the pond is still in existence.

The dominant species in this variation is Juncus mertensianus, with a species significance of 7. Of the important species in the C layer listed for the association, the only one present here is Carex nigricans, with a lower cover than in the type variation. In the D layer, several species differentiate this variation: Drepanocladus exannulatus, which is lacking in the type variation, Drepanocladus aduncus and Cephaloziella rubella, both of which are exclusive to this variation.

The soil is classed as a Rego Humic Gleysol. The soil texture becomes finer with depth, unlike the Carex - Polytrichadelphus Variation. The A horizon is a sandy loam, while the C horizon is a silt loam. The pH increases with depth; the values are higher than for the type variation. Organic matter and

Fig. 23. *Carex nigricans* Association, *Juncus* - *Carex* - *Drepanocladus* Variation, Plot 81. Large clumps are *Carex nigricans*, smaller clumps are *Juncus mertensianus*.

Fig. 24. Soil profile of *Carex nigricans* Association, *Juncus* - *Carex* - *Drepanocladus* Variation, Plot 81. This soil is classified as a Rego Humic Gleysol, with Ah and Cg horizons.



nitrogen decrease with depth, and carbon:nitrogen ratios are narrow. The amount of organic matter present in the A horizon is very low. Phosphorus and sodium decrease with depth, as described for the type variation. However, cation exchange capacity, calcium, magnesium and potassium all increase in amounts with depth. In the A horizon, calcium and magnesium are present in greater quantities than in the type variation; in the C horizon, there is more calcium, magnesium and potassium.

Polytrichum norvegicum Association

(Ref. Tables 64, 65, 66, 67; Fig. 25)

Characteristic Combination of Species

Polytrichum norvegicum
Juncus mertensianus

This association, which is represented by only two plots, occurs in temporary ponds in the alpine area. The relief shape is straight. The exposure is neutral, and thus there is no slope gradient. Humus covers 15-75% of the ground surface, mineral soil 0-15% and rock 25-70%. There is no evidence of erosion. The hygrotope ranges from hydric to hygric.

The D layer is the conspicuous one, covering 60-80% of the area. The C layer is very sparsely developed, coverage being only 10%.

Polytrichum norvegicum is the dominant species, with an average species significance of 8. It is also the only constant bryophyte. Lichens are practically lacking, due to the wetness of the site. The only two constant species in the C layer are Juncus mertensianus and Carex spectabilis, both with lower

Table 64

General Environment

<u>Polytrichum norvegicum</u> Association

Plot No.	79	80
Elevation (ft.)	7575	7575
Physiography		
Landform	temporary pond	
Relief shape	straight	
Exposure	neutral	
Slope gradient (%)	0	0
Layer Coverage (%)		
C layer	10	10
D layer	80	60
Plot Coverage (%)		
Humus	75	15
Mineral soil	0	15
Rock	25	70
Soil		
Hygrotope	hydric-hygric	
Erosion	none	
Horizon depth (in.)		
Ah	0-5	0-5
Bf	5-14	-
Cg	14+	5+
Classification	Gleyed Sombric Humo-Ferric Podzol	Rego Humic Gleysol

Table 65

<u>*Polytrichum norvegicum*</u> Association

	Plot No.		79	80		
	Plot size (m^2)		10	40		
	Extent of type (m^2)		10	40		
	Elevation (ft.)		7575	7575		
	Altitudinal area		A	A		
	C layer				Presence	Aver. Species Significance
1.	Juncus mertensianus		3.1	4.2	2/2	4
2.	Carex spectabilis		4.2	2.2	2/2	3
3.	Juncus drummondii		-	2.2	1/2	1
4.	Phleum alpinum		2.1	-	1/2	1
5.	Poa cusickii		2.1	-	1/2	1
6.	Carex nigricans		-	1.3	1/2	+
	D layer					
	Bryophytes					
7.	Polytrichum norvegicum	Dh	9.6	7.3	2/2	8
8.	Anthelia juratzkana	Dh	-	4.2	1/2	3
9.	Pohlia gracilis	Dh	-	4.2	1/2	3
10.	Kiaeria blyttii	Dh	2.1	-	1/2	1
11.	Aulacomnium palustre	Dh	1.1	-	1/2	+
12.	Bryum sp.	Dh	-	1.1	1/2	+
	Lichens					
13.	Lecidea granulosa	Dh	1.1	-	1/2	+
	Total Species		8	8		

Table 66

Soil Texture

Polytrichum norvegicum Association

Plot No.	79	80
Ah Horizon		
Textural class	SL	LS
Sand (%)	70.8	81.2
Silt (%)	22.8	14.4
Clay (%)	6.4	4.4
Bf Horizon		
Textural class	SL	-
Sand (%)	76.4	-
Silt (%)	16.8	-
Clay (%)	6.8	-
Cg Horizon		
Textural class	SL	SL
Sand (%)	72.0	72.4
Silt (%)	21.2	15.2
Clay (%)	6.8	12.4

Table 67

Soil Chemical Analysis

Polytrichum norvegicum Association

Plot No.	79	80
Ah Horizon		
pH	5.0	5.3
C (%)	7.3	1.8
OM (%)	12.6	3.1
N (%)	0.7	0.2
C/N	10.	11.
P (ppm)	8.	2.
Ca (me/100g)	0.29	0.39
Mg (me/100g)	0.05	0.02
Na (me/100g)	0.12	0.14
K (me/100g)	0.13	0.07
CEC (me/100g)	13.6	8.7
Bf Horizon		
pH	4.8	-
C (%)	2.6	-
OM (%)	4.5	-
N (%)	0.2	-
C/N	16.	-
P (ppm)	4.	-
Ca (me/100g)	0.46	-
Mg (me/100g)	0.01	-
Na (me/100g)	0.12	-
K (me/100g)	0.07	-
CEC (me/100g)	11.0	-
Cg Horizon		
pH	5.0	5.5
C (%)	1.0	0.9
OM (%)	1.8	1.5
N (%)	0.1	0.1
C/N	20.	14.
P (ppm)	2.	3.
Ca (me/100g)	0.39	0.52
Mg (me/100g)	0.01	0.02
Na (me/100g)	0.13	0.16
K (me/100g)	0.04	0.09
CEC (me/100g)	6.3	14.0

Fig. 25. Polytrichum norvegicum Association, Plot 79. In foreground is transition to Carex nigricans Association. In background are clumps of Carex spectabilis.

cover values.

The floristic similarity index for the two plots is 53.

The soils are classified as a Gleyed Sombric Humo-Ferric Podzol and a Rego Humic Gleysol.

Texturally, the soils are fairly fine-textured. The A horizon is either a sandy loam or loamy sand. The B horizon, where present, is a sandy loam. The C horizon is a sandy loam. In plot 80, the texture becomes finer with depth.

Table 67 presents the soil chemical data. The pH increases with depth, and all the values are strongly acidic. Organic matter and nitrogen decrease with depth. There is very little organic matter in the Ah horizon of plot 80. Carbon:nitrogen ratios are generally narrow. Amounts of phosphorus, cation exchange capacity and exchangeable cations have no particular relationship with depth that can be judged from the two representative plots. The quantities of the cations are also variable between the two plots.

<u>Drepanocladus exannulatus Association</u>

(Ref. Tables 68, 69, 70, 71; Fig. 26, 27)

This association, represented by only one plot, occurs as a narrow band around the edge of a temporary pond in the subalpine parkland. The relief shape is concave. Exposure is neutral and therefore there is no slope gradient. The entire surface is covered by humus, with no mineral soil or rock. There is no discernible erosion. The hygrotope varies from hydric to hygric.

Table 68

General Environment

Drepanocladus exannulatus Association

Plot No.	82
Elevation (ft.)	7350
Physiography	
Landform	edge of temporary pond
Relief shape	concave
Exposure	neutral
Slope gradient (%)	0
Layer Coverage (%)	
C layer	8
D layer	95
Plot Coverage (%)	
Humus	100
Soil	
Hygrotope	hydric-hygric
Erosion	none
Horizon depth (in.)	
Ah	0-12
Cg	12+
Classification	Rego Humic Gleysol

Table 69

Drepanocladus exannulatus Association

	Plot No.	82
	Plot size (m^2)	5
	Extent of type (m^2)	5
	Elevation (ft.)	7350
	Attitudinal area	SP
	C layer	
1.	Calamagrostis canadensis	3.1
2.	Juncus mertensianus	2.2
	D layer	
	Bryophytes	
3.	Drepanocladus exannulatus	Dh 9.6
4.	Dicranella sp.	Dh 4.1
5.	Sphagnum nemoreum	Dh 3.1

The D layer is predominant, covering 95% of the area. The C layer is very sparsely developed, with a coverage of 8%.

Drepanocladus exannulatus is the dominant species, with an average species significance of 9. Only two other bryophytes are found here: Dicranella sp. and Sphagnum nemoreum. This community is the only locality for Sphagnum in the research area. The only two species in the C layer are Calamagrostis canadensis and Juncus mertensianus. Calamagrostis is not found in any other community.

The soil is classed as a Rego Humic Gleysol. Texture becomes finer with depth. The A horizon is a sandy loam, while the C horizon is a silt loam. The pH increases slightly with depth, but still remains strongly acidic. Organic matter and nitrogen decrease with depth, and the carbon:nitrogen ratios are narrow. Phosphorus, cation exchange capacity, calcium, magnesium and potassium decrease in amounts with depth, while sodium increases slightly.

Table 70

Soil Texture

Drepanocladus exannulatus Association

Plot No. 82

Horizon	Ah	Cg
Textural class	SL	SiL
Sand (%)	61.4	38.0
Silt (%)	34.8	59.2
Clay (%)	3.8	2.8

Table 71

Soil Chemical Analysis

Drepanocladus exannulatus Association

Plot No. 82

Horizon	Ah	Cg
pH	5.5	5.6
C (%)	6.6	2.5
OM (%)	11.4	4.3
N (%)	0.6	0.3
C/N	11.	9.
P (ppm)	8.	6.
Ca (me/100g)	0.22	0.16
Mg (me/100g)	0.03	0.01
Na (me/100g)	0.12	0.12
K (me/100g)	0.08	0.06
CEC (me/100g)	24.6	21.7

Fig. 26. *Drepanocladus exannulatus* Association, Plot 82, is represented by the narrow, dark band around the margin of the pond. In foreground is part of *Valeriana - Castilleja* Association, with *Senecio triangularis* in flower. Photo taken Aug. 3, 1969.

Fig. 27. Soil profile of *Drepanocladus exannulatus* Association, Plot 82. This soil is classified as a Rego Humic Gleysol, with an Ah-Cg horizon sequence. Photo taken Aug. 29, 1969, after pond has dried out.

5. Distribution of Tree Species

This section presents information on growth habits, distribution patterns, measurements of diameter, height and age, and occurrence of seedlings and shrubs of tree species. These data are somewhat scanty, since they were not the major aim of the research. However, it is believed that they are of value, particularly in judging the future vegetation development of the area; that is, forest versus open vegetation. More detailed autecological work should be done on this aspect in order to draw valid conclusions.

As mentioned previously, there are four tree species present in the study area: *Abies lasiocarpa*, *Picea engelmannii*, *Pinus albicaulis* and *Pinus contorta*. *Pinus contorta* was observed only in one locality (a *Juncus parryi* community), growing as a single very low shrub one and a half feet in height (see Table 74). *Pinus albicaulis* is slightly more frequent, but is still rare. Only two very low shrubs were noted, the remainder of the occurrences being as seedlings. *Abies lasiocarpa* and *Picea engelmannii* are thus the predominant tree species.

In the alpine area[1], *Abies* occurs mostly in low krummholz colonies, while *Picea* occurs as solitary or a few clumped specimens, usually taller than *Abies* and not growing in krummholz form. In the subalpine parkland, *Abies*, in particular, grows much taller, and in some cases is as tall as *Picea*.

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1 Throughout this section, "alpine area" includes the low alpine area.

In the alpine area, the tree species occur on ridges, which have less snow cover than the surrounding terrain, and are thus free of snow earlier in the growing season. This is the situation in a region of high snowfall, as in the coastal alpine zone (Krajina, 1965). In the subalpine parkland the trees occur not only on ridges but also on seepage slopes.

Table 72 presents the diameter, height and age measurements made on the oldest specimens in each tree island community which was sampled. Table 73 summarizes the ages. In considering either the alpine area or the subalpine parkland, *Abies lasiocarpa* is older than *Picea engelmannii*. The more interesting comparison is that the subalpine trees are much older than those in the alpine area. These ages, combined with the fact that no dead wood was observed, suggest that there has been a recent migration of tree species into the alpine area. It was hoped that these migrations could be correlated with a climatic change, but there is insufficient tree mensuration and climatic data to do this. Such a task would be a separate project in itself. Franklin et al. (1966) have correlated tree invasions into subalpine meadows in the Pacific Northwest with a warming trend in the early part of this century. It is possible that this may be the case for the Big White area also.

Table 72

Diameter, Height and Age Measurements[1]

of Abies lasiocarpa and Picea engelmannii

Community	Plot	Species	Diameter Range (in.)	Height Range (ft.)	DBH (in.)	Height (ft.)	Age (yrs.)	at Height (ft)	Estimated Age (yrs.)
Picea engelmannii Association	49 (A)	Picea engel.	-	-	4.0	8	36	2.0	41
							39	0.7	
Abies lasiocarpa Association	44 (A)	Abies lasio.	1-3	2.5-8	3.0	8	52	2.5	109
							86	1.0	
					2.0	7	47	2.5	60
							52	1.5	
	53 (A)	Abies lasio.	-	3-8	2.5	8	36	3.0	51
							48	0.5	
					1.5	6.5	72	2.0	98
							85	1.0	
Abies lasiocarpa - Valeriana sitchensis Association	56(SP)	Abies lasio.	3-5	7-11	6.0	10	43	2.5	98
							65	1.5	
	62 (SP)	Abies lasio.	1.5-8.5	5-15	8.5	15	162	2.0	162+
					7.0	12	105	2.0	229
							167	1.0	
	74 (SP)	Abies lasio.	0.8-8.0	5-18	8.0	18	98	3.0	116
							105	1.0	
					6.0	17	134	2.0	274
							204	1.0	
Abies lasiocarpa - Picea engelmannii - Vaccinium scoparium Association	51 (A)	Abies lasio.	1-2.5	5-6	2.5	6	55	2.0	55+
					1.3	5	31	2.0	31+
		Picea engel.	5-6	-	6.0	12	56	2.5	80
							75	0.5	
					6.0	10	52	2.5	60
							57	1.0	
	54 (LA)	Abies lasio.	-	-	1.5	5.5	23	2.0	53
							38	1.0	
					2.0	5	35	2.0	70
							58	0.7	
		Picea engel.	-	-	7.0	11	49	2.0	67
							58	1.0	
					3.0	11	37	2.0	48
							44	0.7	
	61 (SP)	Abies lasio.	-	3-7	2.5	7	58	2.0	58+
					2.0	7	72	2.0	106
							89	1.0	
		Picea engel.	-	-	9.0	12	57	2.0	91
							74	1.0	
					10.0	13	74	2.0	83
							80	0.7	
	70 (SP)	Abies lasio.	0.5-7	3.5-18	7.0	15	139	2.0	267
							203	1.0	
					6.0	18	126	3.0	315
							189	2.0	
		Picea engel.	0.8-9.5	5.5-18	9.5	18	121	2.0	121+
					4.8	12	55	2.0	105
							80	1.0	

[1] Age of oldest trees

Table 73

Age[1] of Tree Species in Alpine and Subalpine Parkland Areas

Species	Area	Average	Range
Abies lasiocarpa	Alpine[2]	74 (6)	51-109
	Subalpine	201 (7)	98-315
Picea engelmannii	Alpine	59 (5)	41-80
	Subalpine	100 (4)	83-121+

1 Age of oldest individuals

2 Includes low alpine area

Table 74 shows the occurrence of conifer seedlings and shrubs in alpine and timberline communities, exclusive of the sampled tree islands. No conifer seedlings were observed in the tree island communities. *Picea engelmannii* seedlings are the most common, and they are scattered among four communities. More seedlings were found in the *Antennaria* - *Sibbaldia* - *Salix* community than in any other. This corresponds to the statement made earlier that the tree species occur mainly on ridges in the alpine area, since this community occurs on ridges.

Table 74

Occurrence of Conifer Seedlings and Shrubs in Alpine and Timberline Communities[1]

Community	Plot No.	No. of seedlings: Abies	Picea	Pinus a.	Shrubs
Antennaria lanata - Sibbaldia procumbens Association					
Antennaria - Sibbaldia - Salix Variation	10 (A)	--	1	1	--
	22 (A)	2	--	--	1 *Picea*
	13 (LA)	--	--	--	1 *Picea*
Carex phaeocephala Variation	17 (LA)	--	--	1	--
Juncus parryi Association	Outside 68 (SP)	--	--	--	1 *Pinus contorta* (1½ ft.)
Antennaria lanata Association	32 (LA)	--	1	--	--
Phyllodoce empetriformis - Antennaria lanata Association					
Phyllodoce - Antennaria Variation	Outside 27 (A)	--	--	--	*Abies, Picea* (6 ft.)
	Outside 31 (LA)	--	--	--	Several *Picea* (8 ft.)
	57 (SP)	--	1	--	--
Valeriana sitchensis - Castilleja elmeri Association					
Trollius laxus Variation	69 (SP)	--	1	--	--
		2	4	2	

1 Exclusive of sampled tree islands

6. Vegetation Relationships

Relationships between the communities on a vegetational basis are presented in this section. In order to compare all the associations with one another, a synthesis table was constructed (Table 75) in which the major species are listed with their presence and average species significance values shown for all associations. The associations are arranged along a gradient of increasing moisture (as described in section 4). In this manner, it is possible to show the floristic distinctness of some associations and the overlap of species in other associations.

The first half of the table (down to *Juncus mertensianus*) presents species which are characteristic of at least one association. The species which are boxed show the characteristic species for that particular association. The second part of the table (beginning with *Selaginella densa*) lists species which occur in at least one association with a presence of IV or V (or corresponding fraction). The species enclosed by dotted lines are the high-presence species for that association.

It can be seen that there is some overlap of species in the mesic associations, as expected, but in general, both the characteristic species and the high-presence species follow the moisture trend. That is, there is a different group of species which is most important for each community, from the dry associations through to the wet ones. Species occurring in associations for which they are not characteristic are usually much less important in those associations.

Table 75

Synthesis Table for all Associations

	Juniperus communis	Antennaria - Sibbaldia	Juncus parryi	Antennaria lanata	Phyllodoce - Antennaria	Picea engelmannii	Abies lasiocarpa	Abies - Picea - Vaccinium	Abies - Valeriana	Carex spectabilis	Valeriana - Castilleja	Carex nigricans	Polytrichum norvegicum	Drepanocladus exannulatus
Juniperus communis	V.5	IV.+	-	-	-	-	-	-	-	-	-	-	-	-
Carex phaeocephala	V.4	V.5	IV.3	III.+	I.+	-.4	1/2.+	III.1	-	-	-	-	-	-
Arenaria capillaris	V.2	V.3	V.4	III.+	IV.2	-.1	1/2.+	IV.1	-	IV.2	-	I.+	-	-
Festuca brachyphylla	V.2	V.4	II.1	III.2	I.+	-.2	1/2.+	III.1	-	-	-	-	-	-
Tortula ruralis	V.3	-	-	-	-	-	1/2.4	-	-	-	I.+	-	-	-
Peltigera malacea	V.1	-	-	-	I.+	-	-	-	-	-	-	-	-	-
Rhizocarpon geographicum	-	IV.4	-	-	-	-	-	-	-	-	-	-	-	-
Sibbaldia procumbens	IV.1	V.5	V.4	V.3	V.2	-.1	2/2.+	III.1	-	V.3	V.1	III.1	-	-
Umbilicaria hyperborea	-	IV.5	-	-	-	-	-	-	-	-	-	-	-	-
Alectoria minuscula	-	IV.5	-	-	-	-	-	-	-	-	-	-	-	-
Polytrichum piliferum	V.5	V.5	V.6	V.6	V.6	-.4	1/2.2	IV.3	-	V.3	-	II.+	-	-
Antennaria lanata	IV.2	V.5	V.5	V.8	V.7	-.3	1/2.1	V.3	-	V.5	V.4	III.4	-	-
Juncus parryi	III.3	III.+	V.8	V.2	V.4	-	-	-	-	III.4	-	II.2	-	-
Lecidea granulosa	III.+	IV.4	V.5	V.4	V.5	-.1	2/2.1	IV.4	-	II.1	-	II.+	1/2.+	-
Salix cascadensis	-	IV.4	-	V.6	I.+	-	-	-	-	-	-	-	-	-
Gentiana glauca	-	-	-	V.4	-	-	-	-	-	-	-	-	-	-
Phyllodoce empetriformis	-	-	-	V.3	V.7	-	-	IV.5	2/3.3	III.+	IV.2	III.+	-	-
Vaccinium scoparium	IV.4	II.+	IV.4	III.1	V.6	-.2	1/2.2	V.6	3/3.4	IV.3	V.4	-	-	-
Dicranum scoparium	IV.1	-	-	-	V.4	-	1/2.1	V.4	-	II.+	II.1	-	-	-
Picea engelmannii	-	II.+	-	-	-	-.9	-	V.7	-	-	-	-	-	-
Cetraria pinastri	III.+	-	-	-	-	-	1/2.+	V.4	-	-	-	-	-	-
Abies lasiocarpa	-	-	-	-	-	-	2/2.9	V.8	3/3.9	-	-	-	-	-
Parmeliopsis hyperopta	-	-	-	-	-	-.2	2/2.5	V.5	3/3.4	-	-	-	-	-
Arnica latifolia	-	-	-	-	III.3	-	-	-	3/3.5	-	III.4	II.2	-	-
Valeriana sitchensis	-	-	-	-	I.+	-	-	-	3/3.6	-	V.8	-	-	-
Polytrichadelphus lyallii	-	-	II.1	-	II.1	-	-	-	3/3.4	-	II.3	III.6	-	-
Carex spectabilis	-	II.+	II.1	IV.5	IV.4	-	2/2.1	-	2/3.4	V.8	V.6	II.+	2/2.3	-
Castilleja elmeri	-	-	-	-	I.+	-	-	-	3/3.3	-	V.6	-	-	-
Arnica mollis	-	-	-	-	-	-	-	-	2/3.1	II.3	V.5	II.1	-	-
Erigeron peregrinus	III.1	-	III.4	III.1	V.4	-	1/2.+	III.+	2/3.1	V.4	V.5	III.1	-	-
Senecio triangularis	-	-	-	-	-	-	-	-	3/3.3	-	V.5	-	-	-
Ranunculus eschscholtzii	-	-	-	-	-	-	-	-	-	-	IV.2	-	-	-
Aulacomnium palustre	-	-	-	-	-	-	-	-	-	-	IV.6	-	1/2.+	-
Philonotis americana	-	-	-	-	-	-	-	-	-	-	IV.4	-	-	-
Brachythecium asperrimum	-	-	-	-	-	-	-	-	-	-	III.2	-	-	-
Carex nigricans	-	-	II.+	-	IV.2	-	-	-	-	II.2	V.4	V.9	1/2.+	-
Deschampsia atropurpurea	-	-	-	-	IV.1	-	-	-	-	-	IV.3	IV.3	-	-
Claytonia lanceolata	-	-	II.1	-	II.1	-	-	-	3/3.3	II.1	II.1	III.4	-	-
Epilobium alpinum	-	-	-	-	-	-	-	-	-	-	-	II.+	-	-
Polytrichum norvegicum	-	-	-	-	II.1	-	-	-	-	-	-	IV.4	2/2.8	-
Juncus mertensianus	-	-	-	-	-	-	-	-	-	-	II.2	I.3	2/2.4	-.2
Selaginella densa	IV.2	III.+	II.1	-	II.+	-.1	-	-	-	-	-	-	-	-
Barbilophozia hatcheri	IV.1	III.1	-	III.+	I.+	-.4	1/2.2	-	-	-	I.+	I.+	-	-
Luzula spicata	IV.1	IV.3	IV.1	V.1	I.+	-.1	1/2.+	-	-	III.+	-	-	-	-
Peltigera canina	-	IV.+	II.+	-	I.+	-.+	-	-	-	-	-	-	-	-
Trisetum spicatum	III.1	IV.2	II.1	-	I.+	-.1	-	-	-	II.1	I.+	-	-	-
Sedum lanceolatum	-	IV.1	-	-	-	-	-	-	-	-	-	-	-	-
Potentilla diversifolia	III.1	IV.1	-	-	-	-	-	III.+	-	II.1	-	-	-	-
Haplopappus lyallii	-	IV.3	-	-	-	-	-	-	-	-	-	-	-	-
Antennaria umbrinella	-	V.4	V.1	-	-	-.1	-	-	-	-	-	-	-	-
Cladonia carneola	-	IV.2	V.2	V.3	IV.2	-.+	-	-	-	III.2	-	-	-	-
Solorina crocea	III.+	V.3	V.1	V.3	III.+	-.3	-	IV.3	-	-	-	-	-	-
Hieracium gracile	-	-	V.4	-	IV.2	-	-	III.+	-	III.1	I.+	III.1	-	-
Arenaria obtusiloba	III.+	V.3	II.+	IV.1	-	-.1	-	-	-	-	-	-	-	-
Agrostis variabilis	-	IV.3	III.1	IV.3	-	-.1	1/2.+	-	-	II.1	-	-	-	-
Carex pyrenaica	-	-	II.1	V.4	I.+	-	-	-	-	III.3	-	-	-	-
Luzula wahlenbergii	-	-	II.+	V.1	III.2	-	-	-	-	-	-	II.+	-	-
Cetraria islandica	-	III.1	II.1	IV.3	II.+	-	-	-	-	-	-	-	-	-
Cladonia ecmocyna	III.2	II.1	III.2	IV.2	V.3	-	-	V.3	-	II.1	-	-	-	-
Lophozia alpestris	-	II.+	-	IV.+	IV.3	-	-	IV.3	2/3.2	-	II.+	III.2	-	-
Cetraria ericetorum	IV.3	III.3	II.1	III.2	III.1	-.3	2/2.1	IV.1	-	II.+	-	-	-	-
Parmeliopsis ambigua	-	-	-	-	-	-.2	2/2.3	IV.3	2/3.3	-	-	-	-	-
Lupinus latifolius	-	-	II.1	-	I.1	-	-	-	2/3.1	-	I.+	-	-	-
Pedicularis bracteosa	-	-	-	-	-	-	-	-	2/3.2	-	-	-	-	-
Luzula sp.	-	-	II.+	-	II.1	-	-	III.5	2/3.5	-	II.1	II.+	-	-
Veratrum viride	-	-	-	-	-	-	-	-	3/3.3	-	III.2	-	-	-
Mitella breweri	-	-	-	-	-	-	-	-	3/3.3	-	II.1	-	-	-
Caltha leptosepala	-	-	-	-	-	-	-	-	-	-	IV.4	-	-	-
Juncus drummondii	-	-	-	-	-	-	-	-	-	II.3	V.4	III.1	1/2.1	-
Phleum alpinum	-	-	-	-	-	-	-	-	-	III.3	IV.1	I.1	1/2.1	-
Trollius laxus	-	-	-	-	-	-	-	-	-	-	IV.6	-	-	-
Veronica wormskjoldii	-	-	-	-	-	-	-	-	-	III.1	V.2	III.3	-	-

Floristic similarity indices between all the associations and variations are presented in Table 76. The rationale for using this technique has been discussed previously (section 4). By this method, it can be shown that some communities have higher similarities than others. The evaluation of the indices is subjective, since there are no tests of significance of the differences for indices based on dominance (Mark and Burrell, 1966). Despite this limitation, however, general conclusions can still be drawn from the indices.

In Table 76, the communities are arranged in the order in which they were described in section 4. Each community, with its highest affinities, is discussed separately.

The Juniperus communis Association has very low affinities with all the other communities. Its highest similarities are with the Juncus parryi Association and the Carex phaeocephala Variation, but even these values (27% and 26% respectively) are not high enough to draw any conclusions.

The Antennaria - Sibbaldia - Salix, Carex phaeocephala and Carex breweri Variations, which all belong to the Antennaria-Sibbaldia Association, are arranged separately to show their affinities. The Antennaria - Sibbaldia - Salix Variation has its highest similarity with the other two variations, which is what would be expected. The values are 63% and 45%. It has some affinities with the Antennaria lanata Association, having a similarity of 42%; this would be primarily through the presence of Antennaria lanata. The Carex phaeocephala Variation has a similarity value of 63% with the Antennaria - Sibbaldia - Salix

Table 76

Floristic Similarity Indices for all Communities

	J.c.	A-S-S	C.p.	C.b.	J.p.	A.l.	P-A	A-V	Picea	Abies	A-P-V	Abies-V	C.s.	V-C	Trollius	C-P	J-C-D	P.n.	D.e.
Juniperus communis Association																			
Antennaria - Sibbaldia Association																			
Antennaria - Sibbaldia - Salix Variation	23																		
Carex phaeocephala Variation	26	63																	
Carex breweri Variation	19	45	36																
Juncus parryi Association	27	38	39	37															
Antennaria lanata Association	20	42	31	42	44														
Phyllodoce - Antennaria Association																			
Phyllodoce - Antennaria Variation	16	20	24	26	38	44													
Antennaria - Vaccinium Variation	22	27	30	30	50	61	62												
Picea engelmannii Association	24	24	25	23	21	20	10	15											
Abies lasiocarpa Association	13	8	7	7	8	8	7	8	14										
Abies - Picea - Vaccinium Association	16	14	16	14	19	19	34	31	38	44									
Abies - Valeriana Association	7	3	3	5	10	10	19	13	6	53	41								
Carex spectabilis Association	21	23	19	23	34	36	27	36	14	9	16	13							
Valeriana - Castilleja Association																			
Valeriana - Castilleja Variation	7	6	4	8	16	15	23	21	5	4	11	36	34						
Trollius laxus Variation	7	5	4	6	13	13	20	14	4	4	9	26	22	52					
Carex nigricans Association																			
Carex - Polytrichadelphus Variation	6	7	6	7	13	11	17	12	4	4	10	13	18	18	18				
Juncus - Carex - Drepanocladus Variation	1	1	1	0	2	2	4	2	1	1	3	2	5	6	7	20			
Polytrichum norvegicum Association	2	1	1	1	3	7	5	4	1	2	1	4	9	7	6	9	10		
Drepanocladus exannulatus Association	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	25	3	

Variation, 36% with the Carex breweri Variation, and 39% with the Juncus parryi Association. This variation is still considered to be most similar to the association in which it has been placed, since the Antennaria - Sibbaldia - Salix Variation is the type for the association. It is, however, not closely allied with the Carex breweri Variation. It shows some similarity to the Juncus parryi Association, but not enough to be grouped with it. The Carex breweri Variation shows approximately the same similarities with the Juncus parryi Association (37%) and the Antennaria lanata Association (42%) as it does with the Antennaria - Sibbaldia - Salix Variation and the Carex phaeocephala Variation (45% and 36% respectively). However, the values are not high enough to warrant placing this variation in another association.

The Juncus parryi Association has its highest similarity with the Antennaria - Vaccinium Variation of the Phyllodoce - Antennaria Association, with a similarity index of 50%. Other, lower, affinities are with the Antennaria lanata Association (44%), the Phyllodoce- Antennaria Variation (38%), and the Antennaria - Sibbaldia Association (38%, 39%, 37%).

The Antennaria lanata Association has its highest affinities with the Antennaria - Vaccinium Variation (61%). This will be discussed under the Antennaria - Vaccinium similarities. This association has lower similarities with the Phyllodoce - Antennaria Variation (44%), the Juncus parryi Association (44%), the Carex breweri and Antennaria - Sibbaldia - Salix Variations (both 42%).

The *Phyllodoce* - *Antennaria* and *Antennaria* - *Vaccinium* Variations are classed into the *Phyllodoce* - *Antennaria* Association. The *Phyllodoce* - *Antennaria* Variation is most similar to the *Antennaria* - *Vaccinium* Variation, with a value of 62%. It has much lower similarities with the *Antennaria lanata* Association (44%) and the *Juncus parryi* Association (38%). The *Antennaria* - *Vaccinium* Variation has a higher similarity to the *Juncus parryi* Association than the previous variation, with an index of 50%. This variation has its highest affinities with both the *Phyllodoce* - *Antennaria* Variation (62%),which is the type for the association, and the *Antennaria lanata* Association (61%). This fact corroborates the statement made in the description of this association that the *Antennaria* - *Vaccinium* Variation, while classified in the *Phyllodoce* - *Antennaria* Association, is best regarded as a transition community between this association and the *Antennaria lanata* Association.

The *Picea engelmannii* Association has low indices of similarity with all other associations. It has its highest affinity with the *Abies* - *Picea* - *Vaccinium* Association (38%), mainly due to the common presence of *Picea engelmannii*.

The *Abies lasiocarpa* Association has affinities with the *Abies* - *Valeriana* Association (53%) and the *Abies* - *Picea* - *Vaccinium* Association (44%). In this case, the similarity is due to the common presence of *Abies lasiocarpa*.

The *Abies* - *Picea* - *Vaccinium* Association is not too closely allied to the other tree island communities. It does, however, show its highest similarities with these communities:

44% with the Abies lasiocarpa Association, 41% with the Abies - Valeriana Association, and 38% with the Picea engelmannii Association. These affinities are due mainly to the tree species. This association also shows similarities with the Phyllodoce - Antennaria Variation, but at a lower level (34%).

The Abies - Valeriana Association has its highest affinity for the Abies lasiocarpa Association, with a similarity value of 53%. It has a lower similarity to the Abies - Picea - Vaccinium Association (41%). It shows some affinities with the Valeriana - Castilleja Variation (36%), due to the common presence of several meadow species, such as Valeriana sitchensis, Castilleja elmeri, Senecio triangularis and Veratrum viride.

The Carex spectabilis Association has low indices of similarity with the other communities. Its highest similarities are with the Antennaria lanata Association (36%), the Antennaria-Vaccinium Variation (36%), the Juncus parryi Association (34%) and the Valeriana - Castilleja Variation (34%).

The Valeriana - Castilleja and the Trollius laxus Variations are grouped into the Valeriana - Castilleja Association. The Valeriana - Castilleja Variation does have its highest affinity with the Trollius laxus Variation, the similarity index being 52%. It also has affinities with the Abies - Valeriana Association and the Carex spectabilis Association, but at much lower levels of similarity (36% and 34%, respectively). The Trollius laxus Variation is most similar to the Valeriana - Castilleja Variation (52%). It has quite low affinities for any other community: 26% for the Abies -

Valeriana Association, 22% for the Carex spectabilis Association, and 20% for the Phyllodoce - Antennaria Variation. Thus, the initial classification is supported.

The Carex - Polytrichadelphus and the Juncus - Carex - Drepanocladus Variations are classified as the Carex nigricans Association. It can be seen that the Carex - Polytrichadelphus Variation has no high similarity to any other community. It only has a 20% similarity value for the Juncus - Carex - Drepanocladus Variation. The Juncus - Carex - Drepanocladus Variation actually has a slightly higher similarity for the Drepanocladus exannulatus Association (25%), but is included in the Carex nigricans Association because of the high cover of Carex nigricans. This association is thus very homogeneous.

The Polytrichum norvegicum Association has no high affinities for any other community. The similarity values are all extremely low, the highest being for the Carex nigricans Association (9% and 10%) and for the Carex spectabilis Association (9%). This community is also very homogeneous.

The Drepanocladus exannulatus Association has only one similarity value which is greater than 3%; this is a value of 25% for the Juncus - Carex - Drepanocladus Variation. This value is due to the common presence of Drepanocladus exannulatus. However, as mentioned previously, the Juncus - Carex - Drepanocladus Variation is retained in the Carex nigricans Association.

Dahl (1956) gives some general rules for distinguishing different associations, alliances and orders. This can be extended to variations of associations, in which case the variations of an association should have higher indices of similarity with each other than with any other association. Table 76 indicates that all the variations do fulfil this rule.

In general, there is a very low degree of similarity among the communities. This substantiates the fact that they are distinct groupings of species, which are recognisable in the field. Thus, the indices of similarity support the classification system. Similar conclusions were reached by Dahl (1956) and Bliss (1963).

Many of the plant communities recognized on Big White Mountain are ecologically comparable to ones described in the mountains of Scandinavia, Scotland, the United States, the U.S.S.R., Europe, Alberta and other parts of British Columbia.

Juniperus communis communities on exposed rock outcrops have been described from the alpine zone of Garibaldi Park (Archer, 1963), where *Penstemon menziesii*, which is absent on Big White, is a co-dominant. This community is also found in Washington and Oregon in the subalpine parkland (Franklin and Dyrness, 1969). McVean and Ratcliffe (1962) describe a comparable community in the low alpine zone of the Scottish Highlands, in which *Juniperus communis* ssp. *nana* is the dominant.

The *Antennaria lanata* - *Sibbaldia procumbens* Association does not seem to have a counterpart elsewhere. *Dryas octopetala* has a very limited occurrence in this association. *Dryas octopetala* communities have been described in Alberta, Colorado, Montana, Scandinavia, Scotland, the U.S.S.R. and the Pyrenees of Spain and France (Beder, 1967; Marr, 1961; Bamberg and Major, 1968; Johnson and Billings, 1962; Dahl, 1956; McVean and Ratcliffe, 1962; Sukachev, 1965; Braun-Blanquet, 1948). This *Dryas octopetala* community is more widespread on calcareous parent material since the species is calcicolous. The presence of acidic parent material on Big White thus explains its reduced distribution in the area. *Sibbaldia procumbens* associations have been described in Scandinavia (Gjaerevoll, 1956) and British Columbia (Archer, 1963) as snowpatch communities. On Big White, this community occurs on exposed ridge tops. Either these ridges do have a heavy accumulation of snow, or else a different ecotype of the species has developed here which does not require as much moisture as provided in snowbeds.

The *Juncus parryi* Association on Big White may be ecologically equivalent to the dwarf shrub heath-rush community, with *Juncus trifidus*, found in the Presidential Range of New Hampshire (Bliss, 1963). It is also comparable to the *Juncus trifidus* association in Czechoslovakia, which is placed in the order Caricetalia curvulae (Krajina, 1933). Since it is found on warm dry slopes, it may be the community most comparable to the alpine grasslands of Alberta and eastern Oregon and Washington. Alpine grasslands are typical of the east slopes of mountains in western North America because of the rain shadow effect produced there. Therefore, with regard to amount of precipitation, Big White shows greater similarity to the coastal mountains than to the Rockies.

The *Antennaria lanata* Association seems to be unique to the study area. An *Antennaria lanata* variant of the *Carex* nigricans Association has been described in Alberta (Beder, 1967), but the ecology of this community appears to be different, since it occurs in snowpatches. Marr (1961) describes a Willow-Sedge Hummock Stand-Type in Colorado, which is ecologically similar to the Antennaria lanata Association in that the habitat consists of hummocks elevated by ice beneath them. The European counterpart of this association is found in the Caricetalia curvulae of Braun-Blanquet and Jenny (1926).

The Phyllodoce empetriformis - Antennaria lanata Association corresponds to the Phyllodoce glanduliflora - Vaccinium scoparium Association in Alberta (Beder, 1967) and the Phyllodoce coerulea - Vaccinium myrtillus community in Scandinavia (Dahl, 1956). A similar heath community is described in British Columbia and Washington (Archer, 1963; Brooke, 1966; Peterson, 1964; Franklin and Dyrness, 1969; Kuramoto, 1968), which consists of Phyllodoce and Cassiope mertensiana. It is interesting that Cassiope is completely absent from the study area. The European equivalent of this community is found in the Rhodoreto-Vaccinion alliance of Braun-Blanquet and Jenny (1926) and Krajina (1933).

The occurrence of krummholz and tree islands at timberline is a well-documented phenomenon. The tree species present depend on the geographical area. Archer (1963) describes an Abies lasiocarpa - Chamaecyparis nootkatensis association in Garibaldi Park. This area was considered as transitional between the coastal and interior alpine zones. Four tree island communities are distinguished on Big White, all indicative of the interior zone: the Picea engelmannii Association, the Abies lasiocarpa Association, the Abies lasiocarpa - Valeriana sitchensis Association, and the Abies lasiocarpa - Picea engelmannii - Vaccinium scoparium Association. The latter association has been described in Alberta by Ogilvie (1961).

The Carex spectabilis Association has been described in the alpine zone of Garibaldi Park (Archer, 1963) and in the subalpine parkland in Washington and Oregon (Franklin and Dyrness, 1969). This community seems to have coastal affinities, with no reported occurrences in the Rockies.

The Valeriana sitchensis - Castilleja elmeri Association is similar to communities described elsewhere in British Columbia, in Washington and the U.S.S.R. Archer (1963) includes such a community in an alpine meadow group. Fraser (1970) describes a Valeriana - Lupinus - Epilobium angustifolium community on seepage slopes in Garibaldi Park. A Valeriana sitchensis community occurs in the subalpine parkland and in the lower part of the alpine zone in Washington (Franklin and Dyrness, 1969). Subalpine moist meadows with Valeriana, Trollius and Caltha are described in the U.S.S.R. (Sukachev, 1965).

The Carex nigricans snowpatch community is common in North America, in both alpine and subalpine parkland areas. It has been documented in Alberta (Beder, 1967), British Columbia (Archer, 1963; Peterson, 1964; Brooke, 1966) and Washington (Kuramoto, 1968; Franklin and Dyrness, 1969). Comparable communities are the Polytrichum alpinum - Carex bigelowii snowbeds in Scotland (McVean and Ratcliffe, 1962) and the Carex *bigelowii* association in Scandinavia (Gjaerevoll, 1956).

It is well known that bryophytes form the main cover in habitats with an extremely long snow duration. The *Polytrichum norvegicum* Association on Big White has previously been described in British Columbia by Archer (1963) in the alpine zone, Peterson (1964) and Brooke (1966) in the subalpine parkland. Archer's association includes *Gymnomitrium varians* as a co-dominant. This community is also known from Scotland (McVean and Ratcliffe, 1962), where *Dicranum starkei* is a co-dominant, Scandinavia (Gjaerevoll, 1956), Czechoslovakia (Krajina, 1933), central Europe (Braun-Blanquet and Jenny, 1926) and the Pyrenees (Braun-Blanquet, 1948).

Reference to the *Drepanocladus exannulatus* Association was found in a study by Dahl (1956) in Scandinavia and another in the Tatra Mountains of Czechoslovakia by Krajina (1933). This community does not appear to be very common, and has not been previously described from North America.

It can be seen from the above discussion that although floras differ considerably among geographical areas, similarities in environment produce comparable communities. In addition, many of the communities distinguished on Big White are not only ecologically but also floristically similar to those of other alpine and subalpine areas.

7. Vegetation-Environment Relationships

This section presents relationships between communities on an environmental basis. No attempt is made to show causal relations, as this is impossible to prove without detailed autecological studies. The section is subdivided into four parts:

A. An analysis of all environmental variables measured, with the basic aim of determining which factors are important in differentiating the communities

B. A detailed study of soil moisture for a number of alpine and subalpine communities

C. A summary of topographic-altitudinal relationships among the communities

D. A discussion of the communities associated with each soil type

Successional relationships among the communities are not dealt with in the present study for several reasons. One is the fact that the research was not organized for the purpose of studying succession, as only distinct homogeneous stands were chosen for analysis. If transitional areas had also been studied, more could have been said about changes taking place in the communities. Secondly, the vegetation of the study area is developed on parent material of uniform age. Thus, it is not possible to produce a scheme showing changes in vegetation development with different times since deglaciation, as was done by Fraser (1970). Finally, it is believed that the plant communities in such an alpine area are relatively stable and undisturbed, and the rates of development are slow. Therefore, in this environment, the successional approach is of very limited use (Dahl, 1956). On a larger scale, it can be speculated whether forests will take over the alpine area, or whether the alpine area will maintain itself. In section 5, it was suggested that there had been a recent migration of tree species from the sub-alpine to the alpine area. There are insufficient data to determine precisely the direction of change in tree establishment. It appears that in this ecotone area discontinuous changes in climate may cause changes in forest development in a constantly shifting pattern. However, accidental factors such as seed production and dispersal are also important.

A. Analysis of Environmental Variables

General environmental variables and physical and chemical soil data are summarized for all the communities in Tables 77 and 78. Instead of presenting actual values, the terms "high", "medium" and "low" are used. The limits for these terms (given in Appendix 4) were chosen in reference to the present data only. These general terms are believed to be more useful for comparison of the communities. The communities are grouped on the basis of hygrotope, because it is considered to be the most important factor in delimiting the various communities. The communities are discussed in four groups: xeric, mesic, hygric and subhydric.

The xeric group contains five communities: the *Juniperus communis* Association, the three variations of the *Antennaria - Sibbaldia* Association, and the *Juncus parryi* Association (the

Table 77

Summary of General Environmental Variables[1] for all Communities

Community	Altit.	Expos.	Slope	Relief	Wind	Erosion	Hygrotope	Humus	Mineral Soil	Rock	Soil Depth
Juniperus communis Association	M	S	H	straight	strong	none	xeric	L	L	H	L
Antennaria - Sibbaldia Association											
Antennaria - Sibbaldia - Salix Variation	H	SSW	L	straight-convex	very strong	strong	xeric	L	M	H	M
Carex phaeocephala Variation	M	SE	L	straight	very strong	moderate	xeric	M	L	M	L
Carex breweri Variation	M	SSE	M	convex	very strong	strong	xeric	M	H	L	M
Juncus parryi Association	M	S	M	straight-convex	strong	slight	subxeric	M	M	M	M
Antennaria lanata Association	H	ENE	L	hummocky	moderate	slight	mesic	H	M	L	H
Phyllodoce - Antennaria Association											
Phyllodoce - Antennaria Variation	M	SSW	M	hummocky	moderate	none	mesic	H	L	L	H
Antennaria - Vaccinium Variation	H	S	M	straight	moderate	none	submesic	H	L	L	M
Picea engelmannii Association	H	ESE	H	straight	strong	none	submesic	M	L	M	L
Abies lasiocarpa Association	H	WSW	H	straight-convex	strong	slight	mesic	M	L	M	L
Abies - Picea - Vaccinium Association	M	SW	H	straight	strong	slight	mesic	M	L	L	M
Abies - Valeriana Association	L	WSW	H	concave	moderate	none	subhygric	M	L	L	M
Carex spectabilis Association	H	SSW	M	straight	moderate	none	hygric	H	M	L	H
Valeriana - Castilleja Association											
Valeriana - Castilleja Variation	L	WSW	M	concave	slight	none	hygric	H	L	L	L
Trollius laxus Variation	L	WSW	M	straight-concave	slight	none	hygric	H	L	L	M
Carex nigricans Association											
Carex - Polytrichadelphus Variation	M	SE	L	straight-concave	slight	none	hygric	H	L	L	H
Juncus - Carex - Drepanocladus Variation	M	NNW	L	straight	slight	none	subhydric	H	L	L	M
Polytrichum norvegicum Association	H	-	L	straight	slight	none	subhydric	M	M	M	L
Drepanocladus exannulatus Association	L	-	L	concave	slight	none	subhydric	H	L	L	M

[1] L = low, M = medium, H = high
See Appendix 4 for class limits

Table 78

Summary of Physical and Chemical Soil Data[1] for all Communities

Community	Sand	Silt	Clay	pH	Ca	Mg	Na	K	CEC	OM	N	P
Juniperus communis Association	H	L	L	L	L	L	L	M	H	H	H	H
Antennaria - Sibbaldia Association												
Antennaria - Sibbaldia - Salix Variation	H	L	L	M	H	L	H	L	L	L	L	L
Carex phaeocephala Variation	M	M	M	M	M	L	M	L	M	M	L	H
Carex breweri Variation	H	L	L	M	M	L	L	L	M	L	L	L
Juncus parryi Association	H	L	L	L	L	L	M	L	L	M	M	M
Antennaria lanata Association	H	L	L	M	L	L	M	L	L	L	L	M
Phyllodoce - Antennaria Association												
Phyllodoce - Antennaria Variation	H	L	L	M	L	L	M	L	L	M	L	M
Antennaria - Vaccinium Variation	H	L	L	M	M	L	M	L	M	M	M	M
Picea engelmannii Association	H	L	L	M	H	L	L	M	M	L	L	L
Abies lasiocarpa Association	H	L	L	L	M	M	L	M	H	H	H	H
Abies - Picea - Vaccinium Association	H	L	M	L	L	L	M	L	L	M	L	L
Abies - Valeriana Association	H	L	L	L	L	M	M	M	L	M	H	M
Carex spectabilis Association	H	L	L	L	H	M	H	M	H	M	M	M
Valeriana - Castilleja Association												
Valeriana - Castilleja Variation	H	L	L	L	M	M	M	H	M	H	H	H
Trollius laxus Variation	M	L	L	M	H	H	H	H	M	H	H	M
Carex nigricans Association												
Carex - Polytrichadelphus Variation	M	M	L	M	L	L	H	L	L	M	H	M
Juncus - Carex - Drepanocladus Variation	L	H	H	H	H	H	M	M	L	L	L	L
Polytrichum norvegicum Association	H	L	H	M	L	L	M	L	L	L	L	L
Drepanocladus exannulatus Association	L	H	L	H	L	L	M	L	L	M	M	L

[1] L = low, M = medium, H = high
See Appendix 4 for class limits

latter is included even though its hygrotope is rated as subxeric). Among the general environmental factors, exposure, slope, erosion, mineral soil and rock vary among the communities. Altitude is generally medium (except for the Antennaria - Sibbaldia - Salix Variation), relief varies from straight to convex, wind is strong to very strong (in the Antennaria - Sibbaldia Association), humus is medium to low, and soil depth is medium to low. Among the physical and chemical soil factors, calcium, sodium, cation exchange capacity, organic matter, nitrogen and phosphorus are variable among the communities. Sand is generally high, while silt and clay are low (the exception in all cases being the Carex phaeocephala Variation). The pH ranges from medium in the Antennaria - Sibbaldia Association to low in the other communities. Magnesium is low, as is potassium (with the exception of the Juniperus communis Association).

The mesic group consists of six communities: the Antennaria lanata Association, both variations of the Phyllodoce - Antennaria Association (one of which is submesic), the Picea engelmannii Association (rated as submesic), the Abies lasiocarpa Association and the Abies - Picea - Vaccinium Association. Among the general environmental factors, exposure, slope and soil depth are variable. Altitude ranges from high to medium, and relief is generally straight. Wind is strong in the tree island communities and moderate in the others. Erosion varies from none to slight. Humus is medium in the tree island communities and high in the other two. Mineral soil is low, except for the Antennaria lanata Association, and rock is low to

Table 26

General Environment

<u>Phyllodoce empetriformis</u> - <u>Antennaria lanata</u> Association

	Phyllodoce - Antennaria Variation											Antennaria - Vaccinium Variation				
Plot No.	5	6	19	27	31	37	55	57	76	66	72	20	7	23	41	29
Elevation (ft.)	7575	7500	7500	7480	7450	7450	7425	7400	7375	7300	7300	7580	7550	7550	7475	7400
Physiography																
Landform				slope				base of ridge	slope	slope	ridge			slope		
Relief shape	hummocky	hummocky	straight	hummocky	straight to convex	hummocky		concave		straight	hummocky	straight to convex	straight to concave	straight	straight	straight to convex
Exposure	E	NE	SE	S	S	E	SW	NW	NW	NW	W	W	S	E	SW	SE
Slope gradient (%)	15	6	28	12	15	11	27	5	6	14	9	19	23	25	13	15
Layer Coverage (%)																
C layer	80	80	90	80	85	80	75	85	80	85	95	90	85	75	80	90
D layer	40	45	50	50	65	50	45	60	60	75	50	50	50	50	50	60
Plot Coverage (%)																
Humus	98	94	80	70	90	95	95	95	95	95	98	90	83	58	92	94
Mineral soil	2	3	5	20	0	0	0	0	0	0	0	2	2	2	0	0
Rock	0	3	15	10	10	5	5	5	5	5	2	8	15	40	8	6
Soil																
Hygrotope						mesic						mesic		submesic		mesic
Erosion						none								none		slight
Horizon depth (in.)																
L-H	2–0	-	$\frac{1}{2}$–0	-	-	-	-	-	-	-	-	-	4–0	-	-	-
Ah	0–7	0–9	0–2	H-Ah 0–4	0–7	0–3	0–12	0–$3\frac{1}{2}$	0–4	0–8	0–$3\frac{1}{2}$	0–4	0–3	0–3	0–$3\frac{1}{2}$	0–6
B	Bf 7–14	Bm 9–21	Bm 2–14	Bm 4–12	Bfh 7–17	Bf 3–11	-	Bm $3\frac{1}{2}$–$7\frac{1}{2}$	Bm 4–10	Bm 8–13	Bhf $3\frac{1}{2}$–10	Bm 4–12	Bm 3–9	Bm 3–11	Bm $3\frac{1}{2}$–$12\frac{1}{2}$	Bm 6–12
C	Cg 14+	21+	Cg 14+	12+	17+	11–16 Cg 16+	12–18	$7\frac{1}{2}$+	10+	13+	10+	12+	9+	11+	Cg $12\frac{1}{2}$+	12+
R	-	-	-	-	-	-	18+	-	-	-	-	-	-	-	-	-
Classification	Gleyed Sombric Humo-Ferric Podzol	Alpine Dystric Brunisol	Gleyed Alpine Dystric Brunisol	Alpine Dystric Brunisol	Sombric Humo-Ferric Podzol	Gleyed Sombric Humo-Ferric Podzol	Lithic Orthic Regosol		Alpine Dystric Brunisol		Sombric Ferro-Humic Podzol		Alpine Dystric Brunisol		Gleyed Alpine Dystric Brunisol	Alpine Dystric Brunisol

Table 27

Phyllodoce empetriformis - Antennaria lanata Association

	Phyllodoce empetriformis - Antennaria lanata Variation												Antennaria lanata - Vaccinium scoparium Variation							
Plot No.	5	6	19	27	31	37	55	57	76	65	72		20	7	23	41	29			
Plot Size (m^2)	24	24	24	24	24	24	24	24	24	24	24		28	28	28	28	28			
Extent of type (m^2)	96	140	75	189	60	120	32	375	150	165	165		66	96	48	75	50			
Elevation (ft.)	7575	7500	7500	7480	7450	7450	7425	7400	7375	7300	7300		7560	7550	7550	7475	7400			
Altitudinal area	A	LA	A	A	LA	LA	SP	SP	SP	SP	SP		A	A	A	LA	LA			
C layer												Aver.Species Significance						Aver.Species Significance	Presence	Association Aver.Species Significance
1 Phyllodoce empetriformis	8,4	8,4	5,3	8,3	8,3	8,3	8,2	9,3	8,3	8,3	9,3	8	6,2	5,2	5,2	2,2	2,2	5	V	7
2 Antennaria lanata	7,3	6,2	7,2	7,2	7,2	6,2	7,2	8,2	6,2	8,2	6,2	7	8,2	9,2	7,2	8,2	7,2	8	V	7
3 Vaccinium scoparium	6,3	2,1	7,2	6,2	6,2	5,2	7,2	6,2	7,2	6,2	5,2	6	7,2	7,2	7,2	5,2	7,2	7	V	6
4 Erigeron peregrinus	5,2	4,2	4,2	4,2	4,2	4,2	6,2	4,2	2,1	6,2	4,2	5	3,2	3,2	4,2	4,2	4,2	4	V	4
5 Juncus parryi	2,1	2,1	3,2	3,2	2,1	3,2	3,2	-	4,2	-	-	2	5,2	3,2	4,2	2,2	4,2	5	V	4
6 Sibbaldia procumbens	1,1	3,1	1,2	2,2	2,1	2,2	3,1	3,1	1,1	2,1	-	2	3,2	1,1	1,2	1,1	2,2	2	V	2
7 Carex spectabilis	-	3,2	4,2	3,2	4,2	2,2	5,2	-	-	-	1,1	3	5,2	4,2	-	7,2	5,2	5	IV	4
8 Hieracium gracile	-	2,1	3,1	3,2	3,2	4,2	-	3,2	1,1	3,1	-	2	2,1	3,2	3,1	-	3,1	2	IV	2
9 Carex nigricans	3,1	-	2,1	3,2	2,1	3,2	1,1	2,1	4,2	3,2	3,2	3	-	-	-	-	-	-	IV	2
10 Arenaria capillaris	1,1	-	3,2	-	2,2	2,2	1,2	-	1,1	-	-	1	3,2	1,1	1,2	4,2	2,2	3	IV	2
11 Deschampsia atropurpurea	1,1	2,1	-	3,2	2,1	3,2	-	3,1	-	4,1	-	2	1,2	-	-	1,1	1,1	+	IV	1
12 Arnica latifolia	-	-	-	1,2	-	1,2	6,2	3,2	2,1	3,2	5,2	3	-	-	-	-	-	-	III	3
13 Luzula wahlenbergii	4,1	4,2	-	5,2	-	3,2	-	-	-	-	-	3	3,2	-	1,2	1,2	3,2	2	III	2
14 Luzula glabrata	-	-	5,2	-	-	3,2	4,2	-	4,2	-	-	3	-	-	-	-	-	-	II	2
15 Luzula sp.	-	-	-	-	-	-	-	4,2	-	+,2	5,2	2	-	1,1	-	-	-	-	II	1
16 Claytonia lanceolata	-	1,1	-	-	-	-	4,1	1,1	3,1	3,1	3,1	2	-	-	-	-	-	-	II	1
17 Poa cusickii	1,1	-	-	-	-	-	4,2	-	-	-	3,2	1	1,2	-	-	-	-	+	II	1
18 Selaginella densa	-	-	2,1	-	1,1	-	-	-	-	-	-	+	-	1,1	3,1	-	-	1	II	+
19 Lupinus latifolius	-	-	-	-	-	-	-	-	-	+,+	6,2	2	-	-	-	-	-	-	I	1
20 Carex pyrenaica	-	4,1	-	-	-	-	-	-	-	-	-	+	4,2	1,1	-	-	-	1	I	+
21 Vaccinium caespitosum	-	-	-	-	4,2	-	-	-	-	-	-	+	-	3,2	-	1,2	-	1	I	+
22 Castilleja elmeri	-	-	-	-	-	-	1,1	-	-	3,2	3,2	+	-	-	-	-	-	-	I	+
23 Luzula parviflora	-	-	-	-	-	3,2	-	-	-	-	-	+	3,2	-	-	-	-	+	I	+
24 Valeriana sitchensis	-	-	-	-	-	-	2,2	-	-	-	3,2	+	-	-	-	-	-	-	I	+
25 Carex phaeocephala	-	-	-	-	-	-	-	-	-	-	-	-	2,2	-	2,2	-	-	+	I	+
26 Festuca brachyphylla	-	-	-	-	-	-	-	-	-	-	-	-	1,1	2,1	-	-	-	+	I	+
27 Luzula spicata	-	-	-	-	-	-	-	-	-	-	-	-	2,2	1,1	-	-	-	+	I	+
28 Salix cascadensis	-	-	-	2,2	-	-	-	-	-	-	-	+	1,2	-	-	-	-	+	I	+
29 Trisetum spicatum	-	-	-	-	-	-	-	-	-	-	-	-	-	1,1	-	-	2,2	+	I	+
D layer																				
Bryophytes																				
30 Polytrichum piliferum	Dh 6,3	4,2	4,2	5,2	6,2	5,2	7,2	7,2	4,2	5,2	-	5	6,2	7,3	7,2	6,2	6,2	6	V	6
31 Dicranum scoparium	Dh 4,2	3,3	1,1	3,1	3,2	1,2	3,1	5,2	3,1	3,2	6,2	4	3,2	2,1	-	3,2	-	2	V	4
32 Lophozia alpestris	Dh 2,1	3,2	1,1	3,1	-	3,1	-	6,2	5,1	4,1	-	4	2,1	3,1	-	3,1	-	2	IV	3
33 Polytrichadelphus lyallii	Dh -	-	-	-	-	2,2	-	3,1	5,2	-	4,1	2	-	-	-	-	-	-	II	1
34 Polytrichum formosum	Dh -	-	1,1	-	3,2	4,2	-	-	-	-	-	1	3,2	-	-	-	3,1	1	II	1
35 Polytrichum norvegicum	Dh 3,1	4,1	3,2	-	-	-	-	-	-	-	-	1	-	-	1,1	-	-	+	II	1
36 Desmatodon latifolius	Dh 1,1	-	2,1	-	-	-	-	-	-	-	3,1	+	-	-	1,1	-	-	+	II	+
37 Ceratodon purpureus	Dh -	2,1	1,1	-	-	-	-	-	-	-	-	+	2,1	2,1	-	-	-	+	II	+
38 Kiaeria blyttii	Dh -	-	-	3,1	-	-	-	-	3,1	6,2	-	3	-	-	-	-	-	-	I	2
39 Polytrichum juniperinum	Dh -	-	-	3,1	-	-	5,2	-	-	2,1	-	1	-	-	-	-	-	-	I	1
40 Pohlia nutans	Dh -	-	2,1	-	-	-	3,1	-	-	-	-	+	-	-	2,1	-	-	+	I	+
41 Barbilophozia lycopodioides	Dh -	-	-	-	-	-	3,1	-	-	-	1,1	+	-	-	-	-	-	-	I	+
42 Barbilophozia hatcheri	Dh -	-	1,1	-	-	-	-	-	-	-	-	+	2,1	-	-	-	-	+	I	-
Lichens																				
43 Lecidea granulosa	Dh 7,2	6,2	6,2	6,2	6,2	7,2	3,1	7,2	7,2	3,1	3,1	6	6,2	4,2	6,2	7,2	6,2	6	V	6
44 Cladonia ecmocyna	Dh 3,2	2,1	2,2	3,2	4,2	3,2	3,1	5,2	1,2	-	-	3	3,2	3,1	-	2,1	3,2	2	V	3
45 Cladonia carneola	Dh -	-	-	3,2	3,2	3,2	-	2,1	2,1	-	3,1	1	3,2	-	2,1	2,1	3,2	2	IV	2
46 Cetraria ericetorum	Dh 2,1	-	2,2	3,2	-	-	-	3,1	-	-	-	1	-	2,1	2,1	2,2	2,2	1	III	1
47 Solorina crocea	Dh -	+,+	-	-	1,1	2,2	-	-	-	-	-	+	1,1	1,1	2,1	2,1	-	1	III	+
48 Cetraria subalpina	Dh -	3,2	-	-	2,2	3,1	-	-	-	4,2	-	1	-	-	-	-	-	-	II	1
49 Cetraria islandica	Dh -	-	-	-	1,1	-	-	-	2,2	-	3,2	+	3,2	-	-	-	-	-	II	+
50 Cladonia chlorophaea	Dh -	-	-	-	-	-	3,1	-	-	3,1	-	+	-	-	-	-	-	-	I	+
51 Peltigera canina	Dh -	-	-	+,+	-	-	-	-	-	-	-	+	-	-	1,1	-	3,2	1	I	+
52 Peltigera malacea	Dh -	-	-	-	-	-	-	-	-	-	-	-	-	1,+	-	2,1	-	+	I	+
Total Species (incl.sporadics)	19	21	27	25	24	25	24	20	21	21	24		31	23	20	20	19			

Sporadic Species

C layer

53 Agrostis variabilis 20(1,2)
54 Arenaria obtusiloba 7(+,1)
55 Arnica mollis 72(1,1)
56 Carex pyrenaica-nigricans 27(2,2)
57 Castilleja rhexifolia 72(1,2)
58 Epilobium alpinum 27(1,1)
59 Juncus drummondii 72(2,2)
60 Luzula glabrata-wahlenbergii 31(4,2)
61 Pedicularis bracteosa 72(2,2)
62 Phleum alpinum 20(+,1)
63 Picea engelmannii 57(+,+)
64 Potentilla diversifolia 7(1,1)
65 Veronica wormskjoldii 55(2,1)

D layer

Bryophytes

66 Bryum sp. 19(2,1)
67 Orthocaulis floerkii 31(3,1)
68 Rhacomitrium canescens 7(1,1)
69 Tortula norvegica 19(1,1)

Lichens

70 Icmadophila ericetorum 27(1,2)
71 Peltigera canina var. rufescens 12(2,1)

exposed (0-20%). There is usually some rock coverage (0-40%). There is no evidence of erosion. The hygrotope is placed as submesic to mesic.

Two vegetation layers are present - the herb layer and the bryophyte-lichen layer. The C layer has a high coverage, from 75 to 95%. The D layer is fairly well developed, covering 40-75% of the area.

The dominant plants in the C layer are Phyllodoce empetriformis, Antennaria lanata and Vaccinium scoparium. Other constant species of lower coverage are Erigeron peregrinus, Juncus parryi and Sibbaldia procumbens. In the D layer, Polytrichum piliferum and Dicranum scoparium are the constant bryophytes, while Lophozia alpestris, with a presence of IV, is also important. Among the lichens, Lecidea granulosa and Cladonia ecmocyna are constant.

The association is divided into two variations:

a. Phyllodoce empetriformis - Antennaria lanata Variation

b. Antennaria lanata - Vaccinium scoparium Variation

Table 28 gives the floristic similarity indices for the sixteen plots comprising the association. The two variations are shown separately. The values are all very high. The values are higher within each variation than between them.

Table 28

Floristic Similarity Indices for the Phyllodoce empetriformis - Antennaria lanata Association

	5	6	19	27	31	37	55	57	76	66	72	20	7	23	41	29
5		71	79	82	83	78	68	76	75	74	52	65	58	67	63	61
6			73	75	72	76	52	59	68	60	50	55	42	47	41	44
19				83	79	71	66	63	74	63	52	67	62	70	57	64
27					83	79	65	71	74	72	55	65	57	63	55	61
31						79	66	71	68	67	50	71	63	69	60	68
37							54	67	76	68	53	59	47	55	52	54
55								60	59	61	52	59	60	59	50	54
57									68	72	56	61	60	59	59	51
76										67	54	59	49	57	53	52
66											46	56	50	50	54	45
72												34	28	30	24	25
20													76	72	72	76
7														78	69	66
23															66	76
41																74
29																

The variations are described below, by general habitat, floristics and soil data.

a. Phyllodoce empetriformis - Antennaria lanata Variation

This is the type variation for the association. It occurs on slopes in the alpine, low alpine and subalpine parkland areas. Relief shape is predominantly hummocky, but can also be straight or concave. Exposure is variable, and slope gradients range from 5 to 28%. The ground surface is covered by 70-98% humus, 0-20% mineral soil and 0-15% rock. No erosion was observed. The hygrotope is rated as mesic.

The herb layer is very well developed, covering 75-95% of the area. The bryophyte and lichen layer has a coverage of 40-75%.

In addition to the dominant species listed for the association, the following species are important in the differentiation of this variation: Carex nigricans, Arnica latifolia and Claytonia lanceolata in the C layer (these are lacking in the Antennaria - Vaccinium Variation); Dicranum scoparium, Lophozia alpestris (both with a higher cover) and Cetraria subalpina (which has a high preference for this community) in the D layer.

The predominant soils associated with this variation are Alpine Dystric Brunisols (6). Other soils are Sombric Humo-Ferric Podzols (3), Sombric Ferro-Humic Podzol (1) and Lithic Orthic Regosol (1).

Soil texture (Table 29) becomes coarser with depth. Samples of the A and B horizons are classed as loamy sands or sandy loams. The C horizon ranges from sandy loam to sand.

Table 30 presents the soil chemical data. The values for pH are strongly acidic, and increase slightly with depth. Organic matter and nitrogen decrease steadily with depth. Carbon: nitrogen ratios are generally narrow. The percentage of nitrogen in the B horizon of plot 19 is very low. Phosphorus, cation exchange capacity, magnesium and potassium decrease in amounts with depth; calcium and sodium increase in some cases and decrease in others.

b. Antennaria lanata - Vaccinium scoparium Variation

This variation also occurs on slopes, but only in the alpine and low alpine areas. Relief shape is mainly straight, in contrast to the hummocky terrain of the Phyllodoce - Antennaria Variation. Exposure varies, but is never northerly.

Table 29

Soil Texture

Phyllodoce empetriformis - Antennaria lanata Association

	Phyllodoce - Antennaria Variation											Antennaria - Vaccinium Variation				
Plot No.	5	6	19	27	31	37	55	57	76	66	72	20	7	23	41	29
Ah Horizon																
Textural class	LS	LS	LS	LS	SL	SL	SL	SL	SL	SL	SL	SL	SL	LS	LS	S
Sand (%)	73.6	75.6	75.2	72.4	64.0	56.4	66.8	73.0	66.6	58.8	72.2	66.8	56.4	80.8	78.0	86.0
Silt (%)	26.4	24.4	24.8	27.6	36.0	43.8	32.4	23.2	33.4	39.4	22.6	32.6	43.6	19.2	22.0	14.0
Clay (%)	0	0	0	0	0	0	0.8	3.8	0	1.8	5.2	0.6	0	0	0	0
B Horizon																
Textural class	LS	LS	SL	SL	LS	LS	-	LS	SL	LS	SL	S	LS	S	LS	LS
Sand (%)	79.6	74.4	66.2	56.4	75.6	80.8	-	75.0	50.8	84.8	58.4	85.2	81.0	88.4	70.0	77.6
Silt (%)	20.4	25.6	33.8	41.8	24.4	19.2	-	22.4	45.2	10.4	36.4	14.8	19.0	11.6	30.0	22.4
Clay (%)	0	0	0	1.8	0	0	-	2.6	4.0	4.8	5.2	0	0	0	0	0
C Horizon																
Textural class	S	LS	S	LS	S	LS	LS	SL	S	LS	SL	S	S	S	LS	S
Sand (%)	86.4	82.4	91.2	86.4	86.6	76.5	78.0	69.8	87.8	87.4	66.6	92.8	93.8	88.4	78.4	85.6
Silt (%)	13.6	17.6	8.8	11.8	13.4	23.0	18.4	24.0	9.2	5.8	26.6	7.0	6.2	11.6	21.2	14.4
Clay (%)	0	0	0	1.8	0	0.5	3.6	6.2	3.0	6.8	6.8	0.2	0	0	0.4	0

Table 30

Soil Chemical Analysis

Phyllodoce empetriformis - *Antennaria lanata* Association

	Phyllodoce - *Antennaria* Variation											*Antennaria* - *Vaccinium* Variation				
Plot No.	5	8	19	27	31	37	55	57	76	66	72	20	7	23	41	29
L-H Horizon																
pH	-	-	4.3	-	-	-	-	-	-	-	-	-	4.5	-	-	-
C (%)	-	-	17.7	-	-	-	-	-	-	-	-	-	31.4	-	-	-
OM (%)	-	-	30.5	-	-	-	-	-	-	-	-	-	54.0	-	-	-
N (%)	-	-	0.7	-	-	-	-	-	-	-	-	-	1.5	-	-	-
C/N	-	-	25.	-	-	-	-	-	-	-	-	-	22.	-	-	-
P (ppm)	-	-	8.	-	-	-	-	-	-	-	-	-	12.	-	-	-
Ca (me/100g)	-	-	2.44	-	-	-	-	-	-	-	-	-	6.50	-	-	-
Mg (me/100g)	-	-	0.38	-	-	-	-	-	-	-	-	-	0.98	-	-	-
Na (me/100g)	-	-	0.26	-	-	-	-	-	-	-	-	-	0.22	-	-	-
K (me/100g)	-	-	0.96	-	-	-	-	-	-	-	-	-	0.53	-	-	-
CEC (me/100g)	-	-	61.0	-	-	-	-	-	-	-	-	-	61.5	-	-	-
Ah Horizon				H-Ah												
pH	5.2	5.0	4.8	4.4	4.7	4.4	4.7	4.6	4.6	4.8	4.1	4.4	5.2	4.6	4.4	4.7
C (%)	8.9	9.5	8.7	20.0	9.3	15.5	10.0	10.2	16.0	12.2	17.3	16.9	12.9	11.6	12.6	10.8
OM (%)	15.3	16.3	15.0	34.4	15.9	26.7	17.2	17.6	27.6	21.1	29.7	29.1	22.1	19.9	21.7	18.6
N (%)	0.5	0.5	2.5	1.1	0.7	0.9	0.6	0.6	1.0	0.7	0.9	0.9	0.6	0.5	0.8	0.7
C/N	17.	21.	3.	18.	14.	17.	17.	16.	17.	18.	18.	19.	23.	23.	16.	15.
P (ppm)	12.	18.	9.	15.	17.	13.	7.	6.	18.	8.	27.	18.	7.	12.	9.	19.
Ca (me/100g)	0.24	0.39	0.59	0.42	0.26	0.19	0.48	0.36	0.48	0.12	1.14	0.36	0.16	0.50	0.55	0.33
Mg (me/100g)	0.03	0.06	0.07	0.26	0.11	0.14	0.09	0.15	0.22	0.14	0.29	0.13	0.06	0.09	0.16	0.13
Na (me/100g)	0.12	0.12	0.18	0.11	0.11	0.14	0.26	0.13	0.13	0.15	0.14	0.17	0.10	0.33	0.07	0.11
K (me/100g)	0.04	0.06	0.15	0.40	0.13	0.23	0.21	0.18	0.34	0.17	0.40	0.35	0.04	0.25	0.21	0.22
CEC (me/100g)	35.6	41.6	46.3	61.7	63.7	51.6	32.7	16.6	38.6	16.9	61.3	41.9	20.3	34.8	41.6	61.7
B Horizon																
pH	5.6	5.6	5.2	5.1	5.2	5.2	-	5.0	5.0	5.1	5.0	5.0	5.3	5.1	5.2	5.3
C (%)	2.8	4.3	3.6	7.1	4.5	2.4	-	6.5	5.1	4.3	7.5	7.7	7.0	5.3	5.6	3.7
OM (%)	4.8	7.4	6.2	12.1	7.7	4.2	-	11.2	8.8	7.3	12.9	13.2	12.1	9.1	5.7	6.3
N (%)	0.2	0.3	0.0	0.4	0.3	0.2	-	0.4	0.3	0.2	0.4	0.4	0.4	0.3	0.4	0.3
C/N	16.	16.	91.	18.	15.	16.	-	15.	15.	18.	20.	18.	19.	16.	13.	14.
P (ppm)	9.	3.	11.	8.	10.	8.	-	5.	5.	3.	6.	6.	8.	13.	4.	14.
Ca (me/100g)	0.46	0.98	0.42	0.09	0.14	0.33	-	0.18	0.07	0.25	0.10	0.08	0.05	0.42	0.07	0.21
Mg (me/100g)	0.01	0.02	0.01	0.03	0.02	0.01	-	0.03	0.02	0.02	0.03	0.05	0.02	0.02	0.02	0.02
Na (me/100g)	0.13	0.13	0.15	0.10	0.11	0.11	-	0.13	0.13	0.14	0.13	0.12	0.10	0.16	0.27	0.11
K (me/100g)	0.02	0.06	0.04	0.00	0.01	0.00	-	0.07	0.06	0.05	0.06	0.12	0.02	0.07	0.00	0.00
CEC (me/100g)	13.7	7.3	21.9	24.1	16.6	12.4	-	10.8	7.4	8.9	14.9	16.0	7.6	18.0	18.3	23.3
C Horizon																
pH	5.6	5.4	5.0	5.0	5.2	5.2	5.0	5.3	4.8	5.3	5.0	5.0	5.4	5.2	5.2	5.5
C (%)	1.3	1.8	0.6	1.4	1.4	3.1	7.2	2.7	1.0	2.2	2.8	3.1	3.5	1.4	1.5	1.3
OM (%)	2.2	3.1	1.0	2.5	2.4	5.3	12.3	4.6	1.7	3.8	4.9	5.3	6.0	2.4	2.6	2.2
N (%)	0.1	0.1	0.0	0.1	0.1	0.2	0.5	0.2	0.1	0.1	0.2	0.1	0.2	0.1	0.1	0.1
C/N	14.	15.	15.	16.	18.	15.	16.	16.	16.	20.	19.	28.	18.	12.	17.	11.
P (ppm)	8.	4.	5.	4.	5.	5.	8.	2.	9.	4.	5.	8.	2.	6.	4.	13.
Ca (me/100g)	0.85	3.93	0.04	0.31	0.91	0.30	0.25	0.27	0.27	0.32	0.44	0.33	0.23	0.13	0.81	0.39
Mg (me/100g)	0.02	0.03	0.01	0.01	0.01	0.01	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Na (me/100g)	0.14	0.75	0.11	0.09	0.16	0.08	0.25	0.14	0.12	0.14	0.14	0.13	0.10	0.36	0.11	0.11
K (me/100g)	0.02	0.04	0.02	0.00	0.01	0.03	0.10	0.05	0.04	0.04	0.04	0.05	0.01	0.04	0.00	0.00
CEC (me/100g)	11.4	13.0	18.0	18.9	9.6	19.9	22.5	12.4	8.9	14.0	8.6	18.3	5.5	23.6	19.4	19.5

Slope gradients are greater than in the type variation, ranging from 13 to 25%. The ground is covered by 58-94% humus, 0-2% mineral soil and 6-40% rock. There is no erosion. The hygrotope ranges from submesic to mesic.

The herb layer is still of high cover, being 75-90% of the area. There is also a well-developed D layer, covering 50-60%.

There is a shift in the relative dominance of the major species, with Phyllodoce empetriformis being reduced, and Antennaria lanata assuming the primary role, along with Vaccinium scoparium. Juncus parryi is also more important in this community. Carex spectabilis and Arenaria capillaris have higher values of average species significance in this variation than in the type variation. Although this community has been placed in the Phyllodoce empetriformis - Antennaria lanata Association, it is probably best regarded as a transition between this association and the Antennaria lanata Association.

The soils are all classed as Alpine Dystric Brunisols.

Soil texture appears to be coarser than in the type variation. The A horizon samples are sandy loams, loamy sands or sand. The B horizon consists of loamy sands or sands, while the C horizon is predominantly sand.

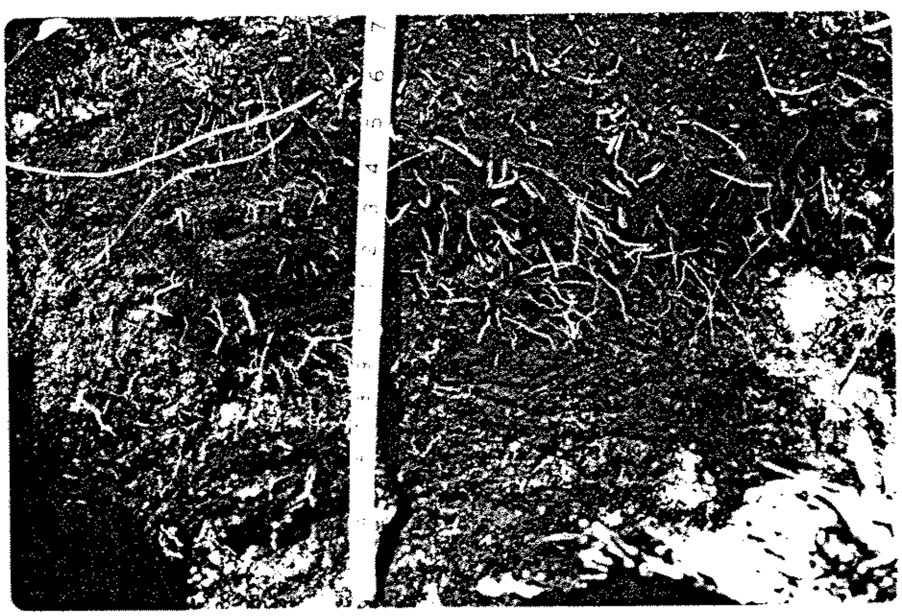
The soil chemical data all appear to be as described for the type variation, except that calcium is present in smaller quantities in the B and C horizons of this variation.

Fig. 11. Phyllodoce - Antennaria Association, Phyllodoce - Antennaria Variation, Plot 31.

Fig. 12. Soil profile of Phyllodoce - Antennaria Association, Phyllodoce - Antennaria Variation, Plot 57. This soil is classified as an Alpine Dystric Brunisol, with an Ah-Bm-C horizon sequence.

Fig. 13. *Phyllodoce* - *Antennaria* Association, *Antennaria* - *Vaccinium* Variation, Plot 7.

Fig. 14. Soil profile of *Phyllodoce* - *Antennaria* Association, *Antennaria* - *Vaccinium* Variation, Plot 7. This soil is classified as an Alpine Dystric Brunisol with L-H, Ah, Bm and C horizons.



Picea engelmannii Association

(Ref. Tables 31, 32, 33, 34)

This association is represented by only one plot in the study area. It occurs on a ridge in the alpine region. The relief shape is straight. Exposure is southeast, with a slope gradient of 29%. Humus and rock each cover 50% of the ground surface. There is no mineral soil exposed. There is no evidence of erosion. The hygrotope is rated as submesic.

There are four vegetation layers in the community. The shrub layer covers 100%, the herb and bryophyte-lichen layers each 15%, and the epiphyte layer 5%.

The plot is composed of one *Picea engelmannii* individual in the B layer, which has a species significance value of 9. There are few species in the other layers. The most important species in the C layer are *Carex phaeocephala* and *Antennaria lanata*. *Barbilophozia hatcheri* and *Polytrichum piliferum* are the most important bryophytes, while *Cetraria ericetorum* and *Solorina crocea* are the dominant lichens. There are just two epiphytes: *Parmeliopsis ambigua* and *Parmeliopsis hyperopta*.

The soil is classified as a Lithic Orthic Regosol, with an Ah-C-R horizon sequence. Texturally, the A horizon is a sandy loam, while the C horizon is a loamy sand. The pH increases from the A to the C horizon, but is strongly acidic in both cases. Organic matter and nitrogen decrease in quantity with depth. The carbon:nitrogen ratios are narrow. Phosphorus, cation exchange capacity and the available cations decrease from the A to the C horizon, with the exception of sodium,

Table 31

General Environment

Picea engelmannii Association

Plot No.	49
Elevation (ft.)	7600
Physiography	
Landform	ridge
Relief shape	straight
Exposure	SE
Slope gradient (%)	29
Layer Coverage (%)	
B layer	100
C layer	15
D layer	15
E layer	5
Plot Coverage (%)	
Humus	50
Mineral soil	0
Rock	50
Decaying wood	0
Soil	
Hygrotope	submesic
Erosion	none
Horizon depth (in.)	
Ah	0-3
C	3-12
R	12+
Classification	Lithic Orthic Regosol

Table 32

Picea engelmannii Association

	Plot No.	49
	Plot size (m^2)	6
	Extent of type (m^2)	6
	Elevation (ft.)	7600
	Altitudinal area	A
	B layer	
1.	Picea engelmannii	9.7
	C layer	
2.	Carex phaeocephala	4.2
3.	Antennaria lanata	3.2
4.	Festuca brachyphylla	2.2
5.	Vaccinium caespitosum	2.2
6.	Vaccinium scoparium	2.2
7.	Agrostis variabilis	1.1
8.	Antennaria umbrinella	1.1
9.	Arenaria capillaris	1.2
10.	Arenaria obtusiloba	1.2
11.	Luzula spicata	1.1
12.	Selaginella densa	1.1
13.	Sibbaldia procumbens	1.1
14.	Trisetum spicatum	1.1
	D layer	
	Bryophytes	
15.	Barbilophozia hatcheri	Dh 4.2
16.	Polytrichum piliferum	Dh 4.2
17.	Bryum capillare	Dh 1.1
18.	Pohlia nutans	Dh 1.1
	Lichens	
19.	Cetraria ericetorum	Dh 3.2
20.	Solorina crocea	Dh 3.2
21.	Lecidea granulosa	Dh 1.1
22.	Cladonia carneola	Dh +.+
23.	Peltigera canina	Dh +.+
	E layer	
24.	Parmeliopsis ambigua	E_B 2.1
25.	Parmeliopsis hyperopta	E_B 2.1

Table 33

Soil Texture

Picea engelmannii Association

Plot No. 49

Horizon	Ah	C
Textural class	SL	LS
Sand (%)	59.2	83.4
Silt (%)	38.0	16.6
Clay (%)	2.8	0

Table 34

Soil Chemical Analysis

Picea engelmannii Association

Plot No. 49

Horizon	Ah	C
pH	4.8	5.3
C (%)	10.2	2.6
OM (%)	17.6	4.4
N (%)	0.7	0.2
C/N	14.	13.
P (ppm)	13.	4.
Ca (me/100g)	1.90	0.60
Mg (me/100g)	0.26	0.03
Na (me/100g)	0.02	0.03
K (me/100g)	0.42	0.08
CEC (me/100g)	58.0	14.5

which increases slightly.

Abies lasiocarpa Association

(Ref. Tables 35, 36, 37, 38)

Characteristic Combination of Species

Abies lasiocarpa
Parmeliopsis hyperopta

This association, represented by only two plots, occurs on ridges in the alpine area. Relief shape is either straight or convex. The exposure is southwest, with a slope gradient of 27-30%. Humus covers 55-65% of the ground surface, rock 35-40% and mineral soil 0-5%. Erosion is slight or none. The hygrotope varies from submesic to mesic.

The shrub layer occupies 95% of the area. There is a very sparse herb layer, coverage being 5-7%. The bryophyte and lichen layer is somewhat better developed, covering 5-30%. The epiphyte layer is very poorly developed in one plot (only 3% cover), but well developed in the other plot (30% cover).

The only species in the B layer is Abies lasiocarpa, with an average species significance of 9. There are only two constant species in the C layer, both with very low average species significance values: Carex spectabilis and Sibbaldia procumbens. No bryophyte species are constant. Cetraria ericetorum and Lecidea granulosa are the constant lichens, both with very low coverage. Among the epiphytes, Parmeliopsis hyperopta, with an average species significance of 5, and Parmeliopsis ambigua, with a value of 3, are constant.

The floristic similarity index for the two plots of the

Table 35

General Environment

Abies lasiocarpa Association

Plot No.	53	44
Elevation (ft.)	7550	7535
Physiography		
Landform	ridge	ridge
Relief shape	straight	convex
Exposure	SW	SW
Slope gradient (%)	27	30
Layer Coverage (%)		
B layer	95	95
C layer	5	7
D layer	5	30
E layer	30	3
Plot Coverage (%)		
Humus	55	65
Mineral soil	5	0
Rock	40	35
Decaying wood	0	0
Soil		
Hygrotope	submesic	mesic
Erosion	slight	none
Horizon depth (in.)		
H	-	2-0
Ah	0-6	0-2
B	-	Bh 2-4 Bhf 4-12 BC 12-17
C	6-13	-
R	13+	17+
Classification	Lithic Orthic Regosol	Lithic Mini Ferro-Humic Podzol

Table 36

Abies lasiocarpa Association

		53	44		
	Plot No.	53	44		
	Plot Size (m^2)	30	25		
	Extent of type (m^2)	96	25		
	Elevation (ft.)	7550	7535		
	Altitudinal area	A	A		
	B layer			Presence	Aver.Species Significance
1	Abies lasiocarpa	9.7	9.7	2/2	9
	C layer				
2	Carex spectabilis	1.2	2.2	2/2	1
3	Sibbaldia procumbens	+.+	1.1	2/2	+
4	Vaccinium scoparium	-	3.2	1/2	2
5	Antennaria lanata	-	2.2	1/2	1
6	Carex phaeocephala	-	1.2	1/2	+
7	Vaccinium caespitosum	-	1.2	1/2	+
8	Agrostis variabilis	-	+.+	1/2	+
9	Arenaria capillaris	-	+.1	1/2	+
10	Erigeron peregrinus	-	+.+	1/2	+
11	Festuca brachyphylla	-	+.+	1/2	+
12	Luzula spicata	-	+.+	1/2	+
	D layer				
	Bryophytes				
13	Tortula ruralis	Dh -	5.2	1/2	4
14	Barbilophozia lycopodioides	Dh -	4.2	1/2	3
15	Bryum capillare	Dh -	4.2	1/2	3
16	Barbilophozia hatcheri	Dh -	3.1	1/2	2
17	Polytrichum piliferum	Dh -	3.2	1/2	2
18	Bryum bimum	Dh 2.2	-	1/2	1
19	Dicranum scoparium	Dh 2.2	-	1/2	1
20	Orthocaulis floerkii	Dh 1.1	-	1/2	+
21	Brachythecium starkei	Dh -	+.2	1/2	+
22	Lescuraea baileyi	Dh -	+.2	1/2	+
23	Lescuraea radicosa	Dh -	+.1	1/2	+
24	Paraleucobryum enerve	Dh -	+.1	1/2	+
	Lichens				
25	Cetraria ericetorum	Dh 2.1	+.2	2/2	1
26	Lecidea granulosa	Dh 2.1	+.2	2/2	1
27	Cladonia macrophyllodes	Dh -	1.1	1/2	+
	E layer				
28	Parmeliopsis hyperopta	E_B 6.1	2.1	2/2	5
29	Parmeliopsis ambigua	E_B 3.1	2.1	2/2	3
30	Cetraria pinastri	E_B -	+.1	1/2	+
	Total Species	10	27		

Table 37

Soil Texture

Abies lasiocarpa Association

Plot No.	53	44
Ah Horizon		
Textural class	LS	LS
Sand (%)	80.8	73.8
Silt (%)	18.0	26.2
Clay (%)	1.2	0
B Horizon		
Textural class	-	LS
Sand (%)	-	72.7
Silt (%)	-	27.3
Clay (%)	-	0
C Horizon		
Textural class	LS	LS
Sand (%)	77.2	78.0
Silt (%)	22.0	22.0
Clay (%)	0.8	0

Table 38

Soil Chemical Analysis

Abies lasiocarpa Association

Plot No.	53	44
H Horizon		
pH	-	4.6
C (%)	-	27.8
OM (%)	-	47.8
N (%)	-	1.7
C/N	-	16.
P (ppm)	-	25.
Ca (me/100g)	-	7.40
Mg (me/100g)	-	1.04
Na (me/100g)	-	0.02
K (me/100g)	-	0.76
CEC (me/100g)	-	163.0
Ah Horizon		
pH	4.7	4.2
C (%)	9.8	17.5
OM (%)	16.8	30.1
N (%)	0.4	1.1
C/N	23.	16.
P (ppm)	15.	16.
Ca (me/100g)	0.22	1.63
Mg (me/100g)	0.07	0.37
Na (me/100g)	0.12	0.03
K (me/100g)	0.13	0.46
CEC (me/100g)	108.0	61.5
B Horizon		
pH	-	4.4
C (%)	-	10.7
OM (%)	-	18.4
N (%)	-	0.6
C/N	-	18.
P (ppm)	-	10.
Ca (me/100g)	-	0.16
Mg (me/100g)	-	0.07
Na((me/100g)	-	0.04
K (me/100g)	-	0.10
CEC (me/100g)	-	50.9
C Horizon		
pH	4.6	4.8
C (%)	12.1	6.1
OM (%)	20.9	10.5
N (%)	0.8	0.3
C/N	15.	18.
P (ppm)	13.	11.
Ca (me/100g)	0.08	0.19
Mg (me/100g)	0.06	0.03
Na (me/100g)	0.12	0.04
K (me/100g)	0.11	0.03
CEC (me/100g)	103.0	33.1

association is 67, which is relatively high.

The soils are classed as Lithic Orthic Regosol and Lithic Mini Ferro-Humic Podzol. Texturally, all the samples from the A, B and C horizons are loamy sands. Among the chemical data, pH generally increases slightly with depth, all values being strongly acidic. In one plot, organic matter and nitrogen decrease in amount with depth; in the other, they increase. The increase in organic matter is probably due to its downward movement and accumulation in the very shallow soil. There should be an ample supply of nitrogen available for higher plants, as indicated by the narrow carbon:nitrogen ratio. Phosphorus, cation exchange capacity, calcium, magnesium and potassium decrease in quantity with depth; sodium increases slightly. In all the chemical data, there is a wide variability between the two plots.

Abies lasiocarpa - Picea engelmannii - Vaccinium scoparium Association

(Ref. Tables 39, 40, 41, 42, 43; Fig. 15, 16)

Characteristic Combination of Species

Abies lasiocarpa
Picea engelmannii
Vaccinium scoparium
Dicranum scoparium
Parmeliopsis hyperopta
Cetraria pinastri

This association occurs mainly on ridges in the alpine, low alpine and subalpine parkland areas. Relief shape varies from straight to convex to concave. Exposure is usually southwest, with slope gradients of 2-25%. Humus covers 40-70% of the

Table 39

General Environment

Abies lasiocarpa - Picea engelmannii - Vaccinium scoparium Association

Plot No.	51	54	61	70
Elevation (ft.)	7540	7500	7350	7300
Physiography				
Landform	ledge	ridge		
Relief shape	convex to concave	straight	straight	concave
Exposure	SW	SW	SW	NW
Slope gradient (%)	25	15	2	24
Layer Coverage (%)				
B layer	95	85	95	95
C layer	7	60	45	60
D layer	10	60	50	25
E layer	5	30	10	20
Plot Coverage (%)				
Humus	70	65	40	60
Mineral soil	0	10	0	0
Rock	30	25	40	30
Decaying wood	0	0	20	10
Soil				
Hygrotope	mesic	mesic	submesic	mesic
Erosion	none	slight	none	none
Horizon depth (in.)				
Ah	0-4	0-4 1/2	0-3	0-3
B	Bh 4-12	Bhf 4 1/2-14 1/2	Bhf 3-11	Bhf 3-12
C	12-19	14 1/2+	Cg 11+	12+
R	19+	-	-	-
Classification	Lithic Orthic Humic Podzol	Sombric Ferro-Humic Podzol	Gleyed Sombric Ferro-Humic Podzol	Sombric Ferro-Humic Podzol

Table 40

Abies lasiocarpa - Picea engelmannii - Vaccinium scoparium Association

						Presence	Aver.Species Significance
	Plot No.	51	54	61	70		
	Plot Size (m^2)	27	30	30	105		
	Extent of type (m^2)	27	30	30	105		
	Elevation (ft.)	7540	7500	7350	7300		
	Altitudinal area	A	LA	SP	SP		
	B layer						
1	Abies lasiocarpa	7.7	7.6	8.6	8.8	V	8
2	Picea engelmannii	5.7	7.6	7.6	6.6	V	7
	C layer						
3	Vaccinium scoparium	4.2	6.2	7.2	5.2	V	6
4	Antennaria lanata	1.2	4.2	3.2	2.2	V	3
5	Phyllodoce empetriformis	-	2.2	4.2	7.3	IV	5
6	Arenaria capillaris	2.2	3.1	+.+	-	IV	1
7	Luzula sp.	-	-	2.1	6.3	III	5
8	Carex phaeocephala	3.2	3.2	-	-	III	1
9	Festuca brachyphylla	2.2	3.2	-	-	III	1
10	Sibbaldia procumbens	1.1	3.1	-	-	III	1
11	Potentilla diversifolia	1.1	2.1	-	-	III	+
12	Hieracium gracile	-	1.1	1.1	-	III	+
13	Erigeron peregrinus	+.+	1.1	-	-	III	+
	D layer						
	Bryophytes						
14	Dicranum scoparium	Ch 1.2	2.1	5.1	5.2	V	4
15	Polytrichum piliferum	Ch 2.2	4.2	3.1	-	IV	3
16	Lophozia alpestris	Ch 1.1	4.1	3.1	-	IV	3
17	Pohlia nutans	Ch 1.1	-	7.2	-	III	5
18	Orthocaulis floerkii	Ch 4.2	2.1	-	-	III	2
	Lichens						
19	Cladonia ecmocyna	Ch 2.2	2.1	3.1	3.1	V	3
20	Lecidea granulosa	Ch +.+	6.2	3.1	-	IV	4
21	Cetraria ericetorum	Ch 3.2	1.1	1.1	-	IV	1
22	Solorina crocea	Ch 1.1	2.1	+.+	-	IV	1
	E layer						
23	Parmeliopsis hyperopta	Ep 3.2	6.1	4.1	4.1	V	5
24	Cetraria pinastri	Ep 3.2	4.1	-	5.1	IV	4
25	Parmeliopsis ambigua	Ep 3.2	-	4.1	4.1	IV	3
	Total Species (incl.sporadics)	31	32	22	14		

Sporadic Species

C layer

26	Agrostis variabilis	51(2.2)
27	Arenaria obtusiloba	54(1.2)
28	Carex spectabilis	54(1.2)
29	Deschampsia atropurpurea	70(2.1)
30	Haplopappus lyallii	51(+.2)
31	Juncus parryi	54(2.2)
32	Luzula spicata	54(1.1)
33	Salix cascadensis	54(2.2)
34	Trisetum spicatum	51(1.2)

D layer

Bryophytes

35	Barbilophozia barbata	54(1.1)
36	Barbilophozia hatcheri	51(+.1)
37	Barbilophozia lycopodioides	70(4.1)
38	Brachythecium starkei	61(3.1)
39	Drepanocladus uncinatus	51(1.1)
40	Kiaeria blyttii	70(5.1)
41	Lescuraea baileyi	61(1.1)
42	Lophozia ? kunzeana	61(4.1)
43	Pohlia elongata	54(3.1)
44	Polytrichadelphus lyallii	61(3.1)

Lichens

45	Cladonia carneola	54(3.1)
46	Cladonia chlorophaea	54(2.1)
47	Cladonia coccifera	51(1.1)
48	Cladonia pleurota	51(1.1)
49	Peltigera malacea	54(1.1)
50	Stereocaulon alpinum	51(+.1)

E layer

51	Alectoria americana	51(1.1)

ground surface and rock 25-40%. Mineral soil is exposed in only one plot. Decaying wood occurs in two plots (10-20%). There is generally no observable erosion. The hygrotope ranges from submesic to mesic, most plots being mesic.

Since this community is a tree island, the B layer is predominant, coverage being 85-95% of the area. The C layer is mainly well developed, covering 7-60%. The D layer is also well developed, with a cover of 10-60%. The E layer covers 5-30%.

The B layer is composed of two species, which are both dominant in the community - Abies lasiocarpa, with an average species significance of 8, and Picea engelmannii, with a value of 7. Vaccinium scoparium dominates the C layer, with an average species significance of 6. The only other constant species in the herb layer is Antennaria lanata. Phyllodoce empetriformis, with a presence of IV and average species significance of 5, is important in most plots. Dicranum scoparium is the dominant bryophyte, while Cladonia ecmocyna is the dominant lichen. Parmeliopsis hyperopta is the only constant epiphyte. Cetraria pinastri, though not constant, is considered a characteristic species, because it reaches its highest cover value in this association.

Table 41 gives the floristic similarity indices for the four plots of the associon. The highest values are obtained between the two alpine plots (51, 54) and between the two subalpine plots (61, 70).

Table 41

Floristic Similarity Indices for the *Abies lasiocarpa* - *Picea engelmannii* - *Vaccinium scoparium* Association

	51	54	61	70
51		60	51	44
54			56	43
61				58
70				

Most of the soils are Sombric Ferro-Humic Podzols. One soil is classified as a Lithic Orthic Humic Podzol.

The subalpine soils are finer-textured than the alpine soils. All the samples from the A, B and C horizons of the subalpine soils are sandy loams. The alpine A horizons are loamy sands; the B horizon is a sandy loam or loamy sand; the C horizon is a loamy sand or sand.

Table 43 presents the soil chemical data. The pH values are all strongly acidic, and increase slightly with depth. Organic matter and nitrogen decrease steadily with depth. The carbon:nitrogen ratios are relatively narrow. Phosphorus, cation exchange capacity, magnesium and potassium decrease in quantity with depth; sodium increases, while calcium decreases from the A to the B horizon, then increases from the B to the C horizon. Organic matter and nitrogen vary widely among the four plots. Phosphorus and cation exchange capacity are similar in the A and C horizons. Calcium and sodium are similar in the B horizon

Table 42

Soil Texture

Abies lasiocarpa - Picea engelmannii - Vaccinium scoparium Association

Plot No.	51	54	61	70
Ah Horizon				
Textural class	LS	LS	SL	SL
Sand (%)	79.6	73.6	71.6	69.6
Silt (%)	20.4	25.0	25.0	28.4
Clay (%)	0	1.4	3.4	2.0
B Horizon				
Textural class	SL	LS	SL	SL
Sand (%)	58.6	79.6	56.6	71.4
Silt (%)	38.8	19.0	41.0	24.2
Clay (%)	2.6	1.4	2.4	4.4
C Horizon				
Textural class	LS	S	SL	SL
Sand (%)	74.6	89.0	58.0	70.4
Silt (%)	24.4	11.0	32.0	20.0
Clay (%)	1.0	0	10.0	9.6

Table 43

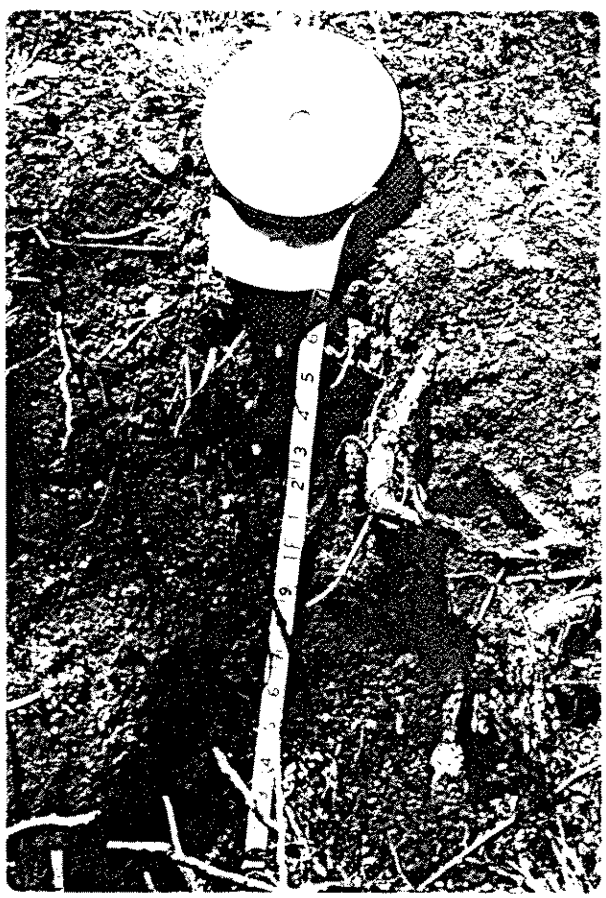
Soil Chemical Analysis

Abies lasiocarpa - Picea engelmannii - Vaccinium scoparium Association

Plot No.	51	54	61	70
Ah Horizon				
pH	4.2	4.1	4.4	4.1
C (%)	13.2	6.8	12.8	9.7
OM (%)	22.6	11.6	22.0	16.7
N (%)	0.7	0.5	0.8	0.5
C/N	20.	14.	16.	18.
P (ppm)	10.	7.	23.	9.
Ca (me/100g)	0.40	1.99	0.15	0.34
Mg (me/100g)	0.17	0.31	0.16	0.21
Na (me/100g)	0.04	0.11	0.29	0.13
K (me/100g)	0.28	0.26	0.20	0.33
CEC (me/100g)	62.8	24.6	29.9	22.0
B Horizon				
pH	4.6	4.8	4.8	4.6
C (%)	7.7	8.2	6.2	6.2
OM (%)	13.3	14.1	10.7	10.6
N (%)	0.4	0.4	0.4	0.3
C/N	20.	20.	16.	23.
P (ppm)	6.	3.	3.	3.
Ca (me/100g)	0.13	0.05	0.09	0.07
Mg (me/100g)	0.04	0.03	0.03	0.03
Na (me/100g)	0.04	0.12	0.13	0.13
K (me/100g)	0.01	0.04	0.04	0.05
CEC (me/100g)	48.4	17.1	7.5	6.1
C Horizon				
pH	4.7	5.0	4.8	4.7
C (%)	3.8	2.6	3.2	3.8
OM (%)	6.6	4.5	5.5	6.5
N (%)	0.3	0.1	0.2	0.1
C/N	14.	26.	18.	27.
P (ppm)	6.	2.	5.	3.
Ca (me/100g)	0.25	0.45	0.42	0.27
Mg (me/100g)	0.03	0.02	0.01	0.02
Na (me/100g)	0.10	0.15	0.27	0.14
K (me/100g)	0.02	0.02	0.03	0.04
CEC (me/100g)	37.3	11.6	12.8	11.6

Fig. 15. *Abies* - *Picea* - *Vaccinium* Association, Plot 51. Taller tree species is *Picea engelmannii*. In left foreground is *Antennaria* - *Sibbaldia* Association.

Fig. 16. Soil profile of *Abies* - *Picea* - *Vaccinium* Association, Plot 54. This soil is classified as a Sombric Ferro-Humic Podzol, with an Ah-Bhf-C horizon sequence.



only. Magnesium and potassium are fairly similar in all horizons.

Abies lasiocarpa - Valeriana sitchensis Association

(Ref. Tables 44, 45, 46, 47, 48)

Characteristic Combination of Species

Abies lasiocarpa
Valeriana sitchensis
Arnica latifolia
Polytrichadelphus lyallii
Parmeliopsis hyperopta

This association occurs on seepage slopes in the subalpine parkland. Relief shape is concave to straight. The exposure is southwest, with a slope gradient ranging from 21 to 39%. The amount of rock covering the ground surface is variable, from 5 to 65%. Humus covers 35-75%, while there is no mineral soil exposed. Decaying wood is present in two plots, with a cover of 10-20%. No evidence of erosion was observed. The hygrotope is rated as subhygric to hygric.

The shrub layer occupies 75-95% of the area. The herb layer coverage varies from 20 to 80%. The bryophyte and lichen layer is sparsely developed, covering only 10% of the plot. The epiphytic layer is better developed, coverage being 5-20%.

Abies lasiocarpa is the only species in the B layer, with an average species significance of 9. *Valeriana sitchensis* and *Arnica latifolia* dominate the C layer, with average species significance values of 6 and 5, respectively. Other constant species, of lower coverage, are *Vaccinium scoparium*, *Senecio triangularis*, *Veratrum viride*, *Claytonia lanceolata*, *Castilleja*

Table 44

General Environment

Abies lasiocarpa - Valeriana sitchensis Association

Plot No.	56	62	74
Elevation (ft.)	7400	7300	7200
Physiography			
Landform		seepage slope	
Relief shape	concave	concave	straight
Exposure	SW	SW	SW
Slope gradient (%)	39	21	22
Layer Coverage (%)			
B layer	85	95	75
C layer	35	80	20
D layer	10	10	10
E layer	5	20	20
Plot Coverage (%)			
Humus	35	70	75
Mineral soil	0	0	0
Rock	65	20	5
Decaying wood	0	10	20
Soil			
Hygrotope	hygric	subhygric	subhygric
Erosion		none	
Horizon depth (in.)			
Ah	0-6	0-3	0-7 1/2
Bm	6-12	3-13	7 1/2-15 1/2
C	12+	13+	15 1/2+
Classification		Alpine Dystric Brunisol	

Table 45

Abies lasiocarpa - Valeriana sitchensis Association

	Plot No.		56	62	74		
	Plot Size (m^2)		41	126	35		
	Extent of type (m^2)		41	126	35		
	Elevation (ft.)		7400	7300	7200		
	Altitudinal area		SP	SP	SP		
	B layer					Presence	Aver.Species Significance
1	Abies lasiocarpa		9.7	9.8	8.6	3/3	9
	C layer						
2	Valeriana sitchensis		6.3	8.3	4.2	3/3	6
3	Arnica latifolia		5.2	6.2	4.2	3/3	5
4	Vaccinium scoparium		3.2	5.2	2.2	3/3	4
5	Senecio triangularis		4.2	2.2	3.2	3/3	3
6	Veratrum viride		2.2	4.3	3.2	3/3	3
7	Claytonia lanceolata		3.2	3.1	2.1	3/3	3
8	Castilleja elmeri		3.2	3.1	1.2	3/3	3
9	Mitella breweri		3.2	3.2	1.2	3/3	3
10	Luzula sp.		-	7.3	2.2	2/3	5
11	Carex spectabilis		4.2	5.2	-	2/3	4
12	Phyllodoce empetriformis		-	4.2	3.2	2/3	3
13	Pedicularis bracteosa		-	3.2	3.2	2/3	2
14	Erigeron peregrinus		-	3.1	1.2	2/3	1
15	Lupinus latifolius		-	2.1	2.2	2/3	1
16	Arnica mollis		2.2	-	1.1	2/3	1
	D layer						
	Bryophytes						
17	Polytrichadelphus lyallii	Dh	2.1	4.1	4.2	3/3	4
18	Lophozia alpestris	Dh	3.1	-	3.2	2/3	2
	E layer						
19	Parmeliopsis hyperopta	E_B	2.1	4.1	4.1	3/3	4
20	Parmeliopsis ambigua	E_B	3.1	-	4.1	2/3	3
	Total Species (incl.sporadics)		26	26	25		

Sporadic Species

C layer

21	Anemone occidentalis	62(2.1)
22	Antennaria lanata	62(3.2)
23	Arenaria capillaris	62(2.1)
24	Deschampsia atropurpurea	74(1.1)
25	Juncus drummondii	56(1.1)
26	Luzula glabrata	56(3.2)
27	Ranunculus eschscholtzii	62(2.1)
28	Saxifraga ferruginea	56(1.1)
29	Sibbaldia procumbens	56(1.1)
30	Trollius laxus	56(2.2)

D layer

Bryophytes

31	Barbilophozia hatcheri	62(+.+)
32	Barbilophozia lycopodioides	56(3.1)
33	Brachythecium curtum	56(2.1)
34	Brachythecium starkei	62(2.2)
35	Bryum ? pseudotriquetrum	56(1.1)
36	Cephaloziella sp.	74(1.1)
37	Ceratodon purpureus	74(1.1)
38	Dicranum scoparium	62(2.1)
39	Kiaeria blyttii	56(2.1)
40	Lescuraea incurvata	62(1.1)
41	Pohlia gracilis	74(1.1)
42	Pohlia nutans	74(1.1)
43	Pohlia wahlenbergii	56(4.1)
44	Polytrichum piliferum	74(2.2)
45	Rhacomitrium sudeticum	56(2.1)
46	Scapania undulata	56(+.+)

E layer

47	Cetraria pinastri	62(4.1)

elmeri and *Mitella breweri*. In the D layer, *Polytrichadelphus lyallii* is the only constant bryophyte. Due to the wet conditions, there are no ground lichens in this community. Among the epiphytes, *Parmeliopsis hyperopta* is a constant dominant.

Table 46 presents the floristic similarity indices for the three plots comprising the association. The values are reasonably high.

Table 46

Floristic Similarity Indices for the *Abies lasiocarpa* - *Valeriana sitchensis* Association

	56	62	74
56		62	61
62			51
74			

The soils are all classed as Alpine Dystric Brunisols, with an Ah-Bm-C horizon sequence.

Soil texture generally becomes coarser with depth. The A horizon samples are classed as sandy loams or loamy sand. The B horizon is a loamy sand. The C horizon ranges from sandy loam to sand.

The soil chemical data are shown in Table 48. The pH is strongly acidic in all horizons, and increases slightly with depth. Organic matter and nitrogen decrease with depth. In plot 56, there is still a considerable amount of organic matter

Table 47

Soil Texture

Abies lasiocarpa - Valeriana sitchensis Association

Plot No.	56	62	74
Ah Horizon			
Textural class	LS	SL	SL
Sand (%)	76.0	63.0	68.0
Silt (%)	23.4	33.6	31.2
Clay (%)	0.6	3.4	0.8
Bm Horizon			
Textural class	LS	LS	LS
Sand (%)	79.6	73.6	73.4
Silt (%)	18.6	24.0	25.2
Clay (%)	1.8	2.4	1.4
C Horizon			
Textural class	S	SL	LS
Sand (%)	87.0	64.0	77.2
Silt (%)	12.2	31.0	16.6
Clay (%)	0.8	5.0	6.2

Table 48

Soil Chemical Analysis

Abies lasiocarpa - Valeriana sitchensis Association

Plot No.	56	62	74
Ah Horizon			
pH	4.7	4.2	4.7
C (%)	13.8	11.0	12.9
OM (%)	23.7	18.9	22.1
N (%)	1.0	0.7	0.9
C/N	14.	15.	14.
P (ppm)	6.	8.	12.
Ca (me/100g)	0.47	1.06	0.30
Mg (me/100g)	0.25	0.26	0.19
Na (me/100g)	0.15	0.27	0.27
K (me/100g)	0.34	0.30	0.34
CEC (me/100g)	44.4	23.5	26.0
Bm Horizon			
pH	4.7	4.7	4.8
C (%)	7.4	6.5	7.0
OM (%)	12.8	11.3	12.1
N (%)	0.5	0.4	0.5
C/N	14.	17.	15.
P (ppm)	11.	11.	8.
Ca (me/100g)	0.39	0.38	0.20
Mg (me/100g)	0.13	0.07	0.06
Na (me/100g)	0.14	0.12	0.15
K (me/100g)	0.18	0.13	0.08
CEC (me/100g)	36.8	13.8	24.3
C Horizon			
pH	4.8	4.9	5.1
C (%)	6.7	2.7	1.7
OM (%)	11.5	4.6	3.0
N (%)	0.4	0.2	0.1
C/N	16.	16.	14.
P (ppm)	8.	4.	7.
Ca (me/100g)	0.69	0.42	0.36
Mg (me/100g)	0.13	0.02	0.02
Na (me/100g)	0.26	0.15	0.15
K (me/100g)	0.16	0.04	0.04
CEC (me/100g)	19.3	8.3	12.0

in the C horizon due to the shallowness of the soil. Carbon: nitrogen ratios are narrow. Cation exchange capacity, magnesium and potassium decrease in quantity with depth. Calcium and sodium decrease from the A to the B horizon, then increase somewhat from the B to the C horizon. Phosphorus decreases down the profile in one plot, but in the others it increases from the A to the B horizon, and then decreases from the B to the C horizon. Organic matter, nitrogen and phosphorus appear to be fairly similar among the three plots, whereas cation exchange capacity is variable. The values for calcium are similar only in the B horizon. Magnesium is similar in the A horizon; in the B and C horizons, plots 62 and 70 are close in value. Sodium has similar values in the B horizon; plots 62 and 70 are similar in the A and C horizons. The three plots are similar in potassium in the A horizon; only plots 62 and 70 are similar in the C horizon.

Carex spectabilis Association

(Ref. Tables 49, 50, 51, 52, 53)

Characteristic Combination of Species

Carex spectabilis
Antennaria lanata
Polytrichum piliferum

This association occurs on slopes with some seepage, mainly in the alpine and low alpine areas. The relief shape is predominantly straight. Exposure is south, west or southwest, with slope gradients ranging from 9 to 50%. Humus covers most of the ground surface, from 70 to 95%. Exposed mineral soil is mostly

Table 49

General Environment

<u>Carex spectabilis</u> Association

Plot No.	11	14	26	39	18
Elevation (ft.)	7575	7500	7500	7475	7475
Physiography					
Landform	depression channel	slope			
Relief shape	straight	straight to concave	straight	straight to convex	straight
Exposure	SW	S	W	SW	S
Slope gradient (%)	9	50	11	26	28
Layer Coverage (%)					
C layer	65	88	96	85	90
D layer	20	5	35	5	40
Plot Coverage (%)					
Humus	70	88	95	75	90
Mineral Soil	25	2	0	0	5
Rock	5	10	5	25	5
Soil					
Hygrotope	hygric	subhygric	subhydric	subhydric	submesic
Erosion	none				
Horizon depth (in.)					
L-H	1-0	-	3-0	-	H-Ah1 0-$1\frac{1}{2}$
Ah	0-3	0-12	0-8	0-6	Ah2 $1\frac{1}{2}$-12
B	Bm 3-7	Bhf 12-18	-	-	Bm 12-18
C	7+	18+	8+	6-13	18+
R	-	-	-	13+	-
Classification	Alpine Dystric Brunisol	Sombric Ferro-Humic Podzol	Orthic Regosol	Lithic Orthic Regosol	Alpine Dystric Brunisol

Table 50

Carex spectabilis Association

		11	14	26	39	18		
	Plot No.	11	14	26	39	18		
	Plot Size (m^2)	30	27	20	24	30		
	Extent of type (m^2)	110	30	35	36	76		
	Elevation (ft.)	7575	7500	7500	7475	7475		
	Altitudinal area	A	LA	A	LA	SP	Presence	Aver.Species Significance
	C layer							
1	Carex spectabilis	8.4	9.5	8.4	9.4	8.4	V	8
2	Antennaria lanata	4.2	5.2	5.2	2.2	5.2	V	5
3	Erigeron peregrinus	2.2	5.2	3.2	4.2	3.2	V	4
4	Sibbaldia procumbens	1.1	1.1	4.2	1.1	4.2	V	3
5	Vaccinium scoparium	1.2	4.2	3.2	-	4.2	IV	3
6	Arenaria capillaris	-	3.1	2.2	3.2	3.2	IV	2
7	Juncus parryi	-	4.2	-	4.2	5.2	III	4
8	Phleum alpinum	4.2	-	4.2	2.2	-	III	3
9	Carex pyrenaica	4.2	4.2	-	-	1.2	III	3
10	Veronica wormskjoldii	1.1	-	3.2	2.2	-	III	1
11	Hieracium gracile	-	-	1.1	1.2	3.2	III	1
12	Luzula spicata	1.1	-	-	+.+	2.1	III	+
13	Phyllodoce empetriformis	1.2	-	1.2	1.2	-	III	+
14	Juncus drummondii	2.2	-	5.2	-	-	II	3
15	Arnica mollis	-	-	5.3	1.2	-	II	3
16	Carex nigricans	4.2	-	3.2	-	-	II	2
17	Potentilla diversifolia	-	-	4.2	-	1.1	II	1
18	Claytonia lanceolata	+.+	4.2	-	-	-	II	1
19	Agrostis variabilis	-	-	-	1.2	3.2	II	1
20	Antennaria friesiana	3.2	-	-	-	1.1	II	1
21	Trisetum spicatum	-	-	1.1	3.2	-	II	1
22	Poa cusickii	1.1	1.1	-	-	-	II	+
	D layer							
	Bryophytes							
23	Polytrichum piliferum	Dh 4.2	3.2	1.1	3.2	3.2	V	3
24	Polytrichum juniperinum	Dh -	-	3.2	2.2	5.2	III	3
25	Polytrichum formosum	Dh 1.1	1.1	3.2	-	-	III	1
26	Dicranum scoparium	Dh 2.1	-	2.1	-	-	II	+
27	Desmatodon latifolius	Dh -	1.1	-	2.1	-	II	+
28	Drepanocladus uncinatus	Dh 2.1	-	1.1	-	-	II	+
29	Pohlia gracilis	Dh -	1.1	2.1	-	-	II	+
	Lichens							
30	Cladonia carneola	Dh 3.1	-	2.1	-	4.2	III	2
31	Cladonia ecmocyna	Dh -	-	2.1	-	4.2	II	1
32	Lecidea granulosa	Dh 1.1	-	-	-	3.2	II	1
33	Cetraria ericetorum	Dh 1.1	-	-	-	2.2	II	+
34	Stereocaulon alpinum	Dh 2.1	-	-	-	1.1	II	+
	Total Species (incl.sporadics)	28	16	33	21	28		

Sporadic Species

C layer

35	Arenaria obtusiloba	18(+.1)
36	Arnica latifolia	39(1.2)
37	Carex phaeocephala	26(1.1)
38	Deschampsia atropurpurea	11(1.1)
39	Festuca brachyphylla	18(4.2)
40	Juncus mertensianus	26(1.2)
41	Juniperus communis	18(1.+)
42	Lupinus latifolius	39(2.2)
43	Luzula glabrata	11(3.2)
44	Luzula wahlenbergii	11(3.2)
45	Luzula sp.	26(3.2)
46	Salix cascadensis	11(6.2)
47	Senecio triangularis	26(1.2)
48	Silene parryi	39(3.2)
49	Solidago multiradiata	18(4.2)
50	Vaccinium caespitosum	39(3.2)

D layer

Bryophytes

51	Barbilophozia hatcheri	26(2.1)
52	Cephaloziella subdentata	14(+.+)
53	Ceratodon purpureus	26(2.1)
54	Kiaeria blyttii	11(4.2)
55	Lophozia alpestris	26(3.1)
56	Orthocaulis floerkii	18(1.1)
57	Pohlia nutans	18(1.1)

Lichens

58	Cetraria subalpina	26(1.2)
59	Cladonia chlorophaea	26(2.1)
60	Cladonia deformis	26(1.1)
61	Cladonia sp.	14(+.+)
62	Peltigera canina	18(2.1)
63	Solorina crocea	18(1.1)

very sparse. Rock covers 5-25% of the area. There is no evidence of erosion. The hygrotope ranges from submesic to subhydric.

The herb layer is predominant in this community, coverage being 65-96%. The bryophyte and lichen layer is moderately well developed, covering 5-40%.

Carex spectabilis, the dominant species, has an average species significance of 8. In the C layer, *Antennaria lanata* is the subdominant, with an average species significance of 5. Other constants are *Erigeron peregrinus* and *Sibbaldia procumbens*. The only important bryophyte is *Polytrichum piliferum*. None of the lichens is of importance in this wet habitat.

The floristic similarity indices for the five plots of the association are shown in Table 51. The values are lower than was the case with many of the previously-described communities. However, these plots all have their highest values of similarity with each other rather than with any other association.

Table 51

Floristic Similarity Indices for the *Carex spectabilis* Association

	11	14	26	39	18
11		54	57	49	50
14			52	75	60
26				51	55
39					54
18					

Table 52

Soil Texture

Carex spectabilis Association

Plot No.	11	14	26	39	18	
Ah Horizon					H-Ah1	Ah2
Textural class	SL	SL	SL	SL	SL	LS
Sand (%)	66.8	50.2	58.0	65.0	54.8	78.4
Silt (%)	33.2	49.4	39.8	32.8	45.2	21.0
Clay (%)	0	0.4	2.2	2.2	0	0.6
B Horizon						
Textural class	LS	SL	-	-	S	
Sand (%)	82.2	70.8	-	-	90.4	
Silt (%)	17.8	27.8	-	-	9.6	
Clay (%)	0	1.4	-	-	0	
C Horizon						
Textural class	S	S	S	S	LS	
Sand (%)	92.4	99.0	90.2	85.4	76.0	
Silt (%)	7.6	1.0	9.8	14.6	23.6	
Clay (%)	0	0	0	0	0.4	

Table 53

Soil Chemical Analysis

Carex spectabilis Association

Plot No.	11	14	26	39	18
L-H Horizon					H-Ah_1
pH	-	-	4.8	-	4.5
C (%)	-	-	30.1	-	15.1
OM (%)	-	-	51.8	-	25.9
N (%)	-	-	0.2	-	1.0
C/N	-	-	167.	-	15.
P (ppm)	-	-	16.	-	17.
Ca (me/100g)	-	-	4.50	-	0.10
Mg (me/100g)	-	-	1.20	-	0.21
Na (me/100g)	-	-	0.25	-	0.32
K (me/100g)	-	-	1.06	-	0.44
CEC (me/100g)	-	-	163.0	-	96.5
Ah Horizon					
pH	4.8	4.6	4.4	4.6	4.9
C (%)	16.1	16.3	12.1	12.1	5.6
OM (%)	27.7	28.1	20.8	20.7	9.7
N (%)	0.1	0.8	0.6	0.5	0.3
C/N	134.	20.	21.	25.	18.
P (ppm)	7.	20.	15.	13.	12.
Ca (me/100g)	0.09	1.28	0.53	1.72	0.15
Mg (me/100g)	0.06	0.23	0.16	0.33	0.02
Na (me/100g)	0.13	0.27	0.21	0.03	0.14
K (me/100g)	0.02	0.54	0.10	0.44	0.04
CEC (me/100g)	51.6	62.8	36.6	61.4	48.6
B Horizon					
pH	5.1	4.7	-	-	5.0
C (%)	7.5	7.6	-	-	3.2
OM (%)	12.9	13.1	-	-	5.5
N (%)	0.4	0.5	-	-	0.1
C/N	18.	17.	-	-	23.
P (ppm)	4.	21.	-	-	6.
Ca (me/100g)	0.29	0.04	-	-	0.22
Mg (me/100g)	0.02	0.08	-	-	0.01
Na (me/100g)	0.15	0.31	-	-	0.17
K (me/100g)	0.03	0.25	-	-	0.02
CEC (me/100g)	14.8	43.9	-	-	13.6
C Horizon					
pH	5.0	5.1	4.7	4.8	5.1
C (%)	2.3	1.6	5.6	7.4	2.1
OM (%)	4.0	2.7	9.6	12.8	3.7
N (%)	0.2	0.1	0.4	0.5	0.1
C/N	15.	26.	16.	14.	16.
P (ppm)	4.	5.	6.	18.	4.
Ca (me/100g)	2.26	0.44	0.38	0.69	0.43
Mg (me/100g)	0.02	0.01	0.06	0.13	0.01
Na (me/100g)	0.49	0.17	0.12	0.04	0.16
K (me/100g)	0.02	0.03	0.04	0.19	0.01
CEC (me/100g)	6.8	7.0	18.3	79.3	19.5

The soils associated with this community are Alpine Dystric Brunisols, Orthic Regosols and a Sombric Ferro-Humic Podzol.

The soils are finer-textured in the surface Ah horizon than in the B or C horizons. Surface horizons are classed mainly as sandy loams. The B horizon, where present, varies from sandy loam to sand. The C horizons are mainly coarse-textured sands.

Table 53 presents the soil chemical data. The pH increases slightly with depth, all values being strongly acidic. Organic matter and nitrogen decrease with depth, and carbon:nitrogen ratios are generally narrow. The values for nitrogen in the L-H horizon of plot 26 and in the Ah horizon of plot 11 are very low. Cation exchange capacity decreases with depth. It is very high in the L-H horizon of plot 26; this is due to the high organic matter content. Phosphorus, magnesium and potassium decrease in quantity with depth. Calcium and sodium are both variable, in some cases increasing with depth and in others decreasing. Most of the chemical data are variable among the plots of the association. Phosphorus is similar in the L-H, Ah and C horizons.

<u>Valeriana sitchensis - Castilleja elmeri Association</u>

(Ref. Tables 54, 55, 56, 57, 58; Fig. 17, 18, 19)

Characteristic Combination of Species

Valeriana sitchensis
Castilleja elmeri
Carex spectabilis
Arnica mollis
Erigeron peregrinus
Senecio triangularis
Ranunculus eschscholtzii
Aulacomnium palustre
Philonotis americana
Brachythecium asperrimum

This association occurs on seepage slopes in the subalpine parkland and, less frequently, in the alpine and low alpine areas. The relief shape is mainly concave or straight. Exposure is variable, with slope gradients ranging from 10 to 28%. The ground surface is predominantly covered by humus (92-100%), with practically no mineral soil exposed. The sites are rarely rocky (rockiness 0-10%). There is no observable erosion. The hygrotope varies from subhygric to subhydric.

Both the herb layer and the bryophyte layer are well developed. The herb layer coverage is 90-100%, while that of the bryophyte layer is 15-95%.

This meadow community is very rich in species. The dominant species in the C layer are Valeriana sitchensis, Castilleja elmeri, Carex spectabilis (all with an average species significance of 6), Arnica mollis, Erigeron peregrinus and Senecio triangularis (all with an average species significance of 5). Other constant species include Antennaria lanata, Vaccinium scoparium, Carex nigricans, Juncus drummondii, Veronica wormskjoldii and Sibbaldia procumbens. Ranunculus eschscholtzii is considered a characteristic species because of its high

Table 54

General Environment

Valeriana sitchensis - Castilleja elmeri Association

	Valeriana - Castilleja Variation							Trollius laxus Variation					
Plot No.	38	42	34	43	60	65	75	25	36	24	64	69	73
Elevation (ft.)	7475	7475	7450	7375	7300	7300	7200	7500	7400	7375	7300	7300	7275
Physiography													
Landform	seepage slope							seepage slope					
Relief shape	concave	straight	straight to concave	convex to straight	concave			straight	concave	straight to concave	straight	concave	convex
Exposure	SW	S	SW	W	SW	SW	SW	W	S	SW	SW	NW	W
Slope gradient (%)	25	16	15	14	10	17	19	26	18	28	17	22	13
Layer Coverage (%)													
C layer	100	90	95	95	100	95	98	92	100	97	95	98	98
D layer	40	15	45	60	65	85	60	60	90	85	95	60	95
Plot Coverage (%)													
Humus	100	90	95	95	100	96	95	89	100	100	100	100	98
Mineral Soil	0	0	5	0	0	2	0	1	0	0	0	0	0
Rock	0	10	0	5	0	2	5	10	0	0	0	0	2
Soil													
Hygrotope	hygric	hygric	subhydric	subhydric	hygric	subhygric	hygric	hygric					
Erosion	none							none					
Horizon depth (in.)													
L-H	-	-	-	-	-	-	-	2-0	H 8-0	-	-	-	-
Ah	0-12	0-8	0-3½	0-12	0-6	0-10	0-8	0-6	-	0-4	0-12	0-12	0-12
B	-	-	Bhfg 3½-7½	-	-	-	-	-	-	Bg 4-8	-	-	-
C	Cg 12-15	Cgj 8-12	7½+	Cg 12-16	Cg 6+	10+	8+	Cg 6+	Cg 0-11	Cg 8+	Cg 12+	Cg 12+	-
R	15+	12+	-	16+	-	-	-	-	11+	-	-	-	12+
Classification	Lithic Rego Humic Gleysol	Gleyed Lithic Orthic Regosol	Fera Humic Gleysol	Lithic Rego Humic Gleysol	Rego Humic Gleysol	Orthic Regosol	Orthic Regosol	Rego Humic Gleysol	Lithic Rego Gleysol	Orthic Humic Gleysol	Rego Humic Gleysol	Rego Humic Gleysol	Lithic Orthic Regosol

Table 55

Valeriana sitchensis - Castilleja elmeri Association

		Layer	Valeriana sitchensis - Castilleja elmeri Variation								Trollius laxus Variation								
	Plot No.		38	42	34	43	53	65	75		25	36	24	64	69	73			
	Plot Size (m^2)		15	15	15	15	15	15	15		10	10	4	10	10	10			
	Extent of type (m^2)		60	45	33	35	104	40	40		12	28	8	40	105	21			
	Elevation (ft.)		7475	7475	7450	7375	7300	7300	7200		7500	7400	7375	7300	7300	7275			
	Altitúdinal area		LA	LA	LA	SP	SP	SP	SP		A	SP	SP	SP	SP	SP			
	C layer									Aver.Species Significance							Aver.Species Significance	Presence	Association Aver.Species Significance
1	Valeriana sitchensis		2.2	7.3	5.2	5.3	7.3	8.3	7.2	6	3.2	4.2	6.2	6.2	6.2	6.2	5	V	6
2	Castilleja elmeri		5.2	5.2	7.2	6.2	5.2	6.2	7.2	6	4.2	2.2	-	5.2	6.2	4.2	4	V	6
3	Carex spectabilis		9.4	8.3	7.3	6.2	3.2	3.1	1.2	6	5.2	5.2	2.2	4.1	2.2	+.+	4	V	6
4	Arnica mollis		7.2	3.2	7.2	6.2	4.2	4.2	2.1	5	6.2	6.2	6.2	4.2	3.2	2.2	5	V	5
5	Erigeron peregrinus		4.2	6.2	3.2	5.2	5.2	6.2	5.2	5	4.2	1.2	3.2	5.2	6.2	5.2	5	V	5
6	Senecio triangularis		6.3	3.2	6.3	7.3	5.2	5.3	5.2	5	+.+	2.2	2.2	5.2	-	4.2	3	V	5
7	Antennaria lanata		2.2	3.2	4.2	1.2	4.2	6.2	5.2	4	6.2	-	1.2	4.2	4.2	3.2	4	V	4
8	Vaccinium scoparium		2.2	1.2	4.2	2.2	4.2	5.2	5.2	4	5.2	1.2	3.2	3.2	-	4.2	4	V	4
9	Carex nigricans		3.2	+.+	4.2	2.2	2.1	-	2.1	2	2.2	6.2	4.2	4.1	3.2	3.2	4	V	4
10	Juncus drummondii		5.2	4.2	3.2	5.2	4.2	3.1	2.1	4	3.2	-	-	2.2	2.2	2.2	1	V	4
11	Veronica wormskjoldii		2.2	2.1	3.2	2.2	2.1	1.1	3.1	2	3.1	2.1	1.1	-	1.1	1.1	1	V	2
12	Sibbaldia procumbens		2.2	1.1	2.2	1.1	3.1	2.1	1.1	2	2.1	1.1	2.2	-	-	+.1	1	V	1
13	Trollius laxus		-	-	1.1	-	-	5.2	5.2	3	8.4	8.4	8.2	9.3	8.2	7.2	8	IV	6
14	Caltha leptosepala		-	-	-	2.2	4.2	-	2.2	1	-	7.2	5.2	2.1	4.2	2.2	5	IV	4
15	Deschampsia atropurpurea		4.2	2.2	3.2	3.2	3.2	-	-	3	2.1	-	4.2	-	3.1	4.2	3	IV	3
16	Phyllodoce empetriformis		-	1.2	-	1.2	2.2	1.2	4.2	2	5.2	-	2.2	-	3.2	2.2	3	IV	2
17	Ranunculus eschscholtzii		4.2	1.1	1.1	1.1	2.1	3.1	1.1	3	-	-	-	-	2.1	2.1	+	IV	2
18	Phleum alpinum		3.2	1.1	3.2	3.2	-	-	-	1	2.1	1.2	1.1	+.+	-	-	+	IV	1
19	Arnica latifolia		-	3.2	2.2	-	3.2	5.2	7.2	4	-	-	-	-	4.2	4.2	2	III	4
20	Castilleja rhexifolia		-	5.2	-	4.2	-	4.2	6.2	4	-	1.1	-	4.2	4.2	-	2	III	4
21	Veratrum viride		-	-	-	5.3	3.2	-	4.2	3	-	+.+	-	+.2	-	2.2	+	III	2
22	Juncus mertensianus		-	-	4.2	4.2	3.2	-	-	2	-	4.2	-	1.1	-	-	1	II	2
23	Claytonia lanceolata		-	-	-	-	2.1	4.1	-	1	-	-	-	4.1	3.1	3.1	2	II	1
24	Luzula sp.		-	-	-	-	3.1	4.2	3.1	2	-	-	-	-	-	2.2	+	II	1
25	Agrostis thurberiana		-	-	-	3.2	-	-	-	+	-	3.1	-	-	-	4.2	1	II	1
26	Mitella breweri		-	-	-	2.2	4.2	2.1	1.1	1	-	-	+.+	-	-	-	+	II	1
27	Poa cusickii		-	-	-	-	-	4.2	3.2	1	1.1	-	-	-	-	-	+	II	+
28	Luzula glabrata		2.2	-	2.2	3.2	-	-	-	1	-	1.2	-	-	-	-	+	II	+
29	Potentilla drummondii		-	1.2	-	1.2	2.2	-	-	1	-	-	-	-	-	-	-	II	+
30	Vaccinium caespitosum		2.2	1.2	2.2	-	-	-	-	+	-	-	-	-	-	-	-	II	+
31	Anemone occidentalis		-	-	-	1.2	-	-	+.+	+	-	-	-	-	-	+.+	+	II	+
32	Lupinus latifolius		-	-	-	-	-	4.2	3.2	1	-	-	-	-	-	-	-	I	+
33	Hieracium gracile		-	-	1.1	-	-	-	-	+	3.1	-	-	-	-	-	+	I	+
34	Trisetum spicatum		2.1	-	-	-	-	-	-	+	1.1	-	-	-	-	-	+	I	+
	D layer																		
	Bryophytes																		
35	Aulacomnium palustre	Dh	2.1	-	2.1	6.2	4.1	7.2	8.2	5	-	7.5	9.2	8.3	-	9.3	7	IV	6
36	Philonotis americana	Dh	-	-	3.2	2.1	5.1	7.2	-	4	+.+	7.5	1.2	1.1	-	-	4	IV	4
37	Brachythecium asperrimum	Dh	3.2	-	2.1	-	5.1	-	-	3	2.1	2.1	-	4.1	-	-	2	III	2
38	Scapania subalpina	Dh	2.1	-	2.1	2.1	4.1	-	-	2	-	-	1.1	+.+	-	-	+	III	1
39	Polytrichadelphus lyallii	Dh	-	-	5.2	1.1	4.1	-	5.2	4	-	-	-	-	6.2	-	3	II	3
40	Polytrichum juniperinum	Dh	-	3.2	-	-	-	4.1	-	1	7.2	-	-	1.1	-	-	4	II	3
41	Polytrichum formosum	Dh	6.2	3.1	-	1.1	-	-	-	3	-	-	1.1	-	-	-	+	II	2
42	Pohlia nutans	Dh	-	-	-	5.2	5.1	-	-	3	1.1	-	1.1	-	-	-	+	II	2
43	Bryum pseudotriquetrum	Dh	-	-	-	-	5.1	-	-	2	+.+	-	1.1	-	-	+.+	+	II	1
44	Brachythecium starkei	Dh	-	-	-	-	-	-	-	-	-	-	1.1	4.1	3.1	3.2	2	II	1
45	Bryum muehlenbeckii	Dh	-	-	-	-	+.1	-	-	+	+.+	-	-	5.2	-	-	2	II	1
46	Dicranum scoparium	Dh	-	-	3.2	-	3.1	3.1	-	1	2.1	-	-	-	-	-	+	II	1
47	Lophozia alpestris	Dh	-	-	1.1	-	2.1	3.1	-	1	2.1	-	-	-	-	-	+	II	1
48	Desmatodon latifolius	Dh	-	-	-	3.1	-	-	-	+	-	-	-	-	6.2	-	3	I	2
49	Ceratodon purpureus	Dh	-	-	-	3.1	-	-	-	+	1.1	-	-	-	-	-	+	I	+
50	Tortula ruralis	Dh	-	-	-	-	-	-	-	-	1.1	-	-	-	3.1	-	+	I	+
51	Barbilophozia hatcheri	Dh	-	-	-	-	-	-	-	-	2.1	-	-	-	+.+	-	+	I	+
52	Dicranella sp.	Dh	-	-	-	+.+	-	-	-	+	+.+	-	-	-	-	-	+	I	+
	Lichens																		
53	Cladonia sp.	Dh	-	1.1	-	-	-	-	-	+	1.1	-	-	-	-	-	+	I	+
	Total Species (incl.sporadics)		22	25	29	36	33	26	27		44	23	24	26	24	26			

Sporadic Species

C layer

54 Antennaria friesiana 25(1.1)
55 Arenaria capillaris 25(2.1)
56 Festuca saximontana 25(1.2)
57 Gaultheria humifusa 24(4.2)
58 Juncus parryi 25(2.2)
59 Kalmia polifolia 36(+.1)
60 Luzula wahlenbergii 25(4.2)
61 Pedicularis bracteosa 75(1.1)
62 Picea engelmannii 69(+.+)
63 Potentilla diversifolia 25(2.2)

D layer

Bryophytes

64 Barbilophozia lycopodioides 69(2.1)
65 Brachythecium curtum 34(1.1)
66 Bryum blmum 25(1.1)
67 Bryum sp. 64(6.3)
68 Cephaloziella subdentata 25(+.+)
69 Drepanocladus exannulatus 25(1.1)
70 Drepanocladus uncinatus 25(1.1)
71 Lophozia obtusa 36(2.1)
72 Mnium blyttii 64(5.2)
73 Pohlia wahlenbergii 25(3.1)
74 Polytrichum norvegicum 43(1.1)
75 Polytrichum piliferum 42(3.2)

Lichens

76 Cladonia chlorophaea 43(1.1)
77 Lepraria neglecta 42(1.1)
78 Peltigera canina var rufescens 25(1.+)

preference for this association. The dominant bryophytes in the D layer are *Aulacomnium palustre* and *Philonotis americana*, which both have a very high preference for this community. *Brachythecium asperrimum* is exclusive to the association, and thus is regarded as a characteristic species. Very few lichens are found, due to the wetness of the habitat.

The association is divided into two variations:

a. *Valeriana sitchensis* - *Castilleja elmeri* Variation

b. *Trollius laxus* Variation

Table 56 gives the floristic similarity indices for the thirteen plots making up the association. The two variations are shown separately. The values within each variation are generally higher than between them.

Table 56

Floristic Similarity Indices for the *Valeriana sitchensis* - *Castilleja elmeri* Association

	38	42	34	43	60	65	75	25	36	24	64	69	73
38		50	64	53	30	23	21	31	24	24	24	18	22
42			45	44	46	43	40	25	16	22	32	42	33
34				60	52	37	42	37	32	30	31	35	28
43					50	42	44	31	38	36	39	33	38
60						55	52	25	23	28	37	44	38
65							65	36	40	35	48	43	49
75								29	27	42	51	45	58
25									43	43	37	40	33
36										61	47	34	42
24											60	45	73
64												51	63
69													51
73													

The variations are described below, by general habitat, floristics and soil data.

a. Valeriana sitchensis - Castilleja elmeri Variation

This is the type variation for the association. It occurs on seepage slopes in the subalpine parkland and the low alpine area. Relief shape varies from concave to straight. Exposure is mainly southwest, and slope gradients range from 10-25%. Humus covers 95-100% of the ground surface, mineral soil 0-5%, and rock 0-10%. There is no evidence of erosion. The hygrotope is rated as subhygric to subhydric.

The herb layer has a very high coverage of 90-100%. The bryophyte layer is less well developed, but still very significant, with a coverage of 15-85%.

In addition to the dominant species listed for the association, the following species are important in the differentiation of this variation: Potentilla drummondii (which is exclusive to this variation) and Vaccinium caespitosum, which are both missing in the Trollius laxus Variation; Mitella breweri, Ranunculus eschscholtzii and Polytrichadelphus lyallii, which are all present in greater quantities in this variation.

The soils associated with this variation are Rego Humic Gleysols (3), Orthic Regosols (3) and Fera Humic Gleysol (1).

Texture generally is coarser at greater depths. The A horizon ranges from sandy loams to loamy sands. The C horizon is mostly sands or loamy sands.

Table 58 presents the soil chemical data. The pH increases slightly with depth, all values being strongly acidic. Organic

Fig. 17. _Valeriana_ - _Castilleja_ Association, _Valeriana_ - _Castilleja_ Variation, Plot 38. Yellow flowers are _Senecio triangularis_ and _Arnica mollis_, red flowers are _Castilleja elmeri_, and light-coloured flowers are _Erigeron peregrinus_.

Fig. 18. Soil profile of _Valeriana_ - _Castilleja_ Association, _Valeriana_ - _Castilleja_ Variation, Plot 38. This soil is classified as a Lithic Rego Humic Gleysol, with an Ah-Cg-R horizon sequence.

Table 57

Soil Texture

<u>Valeriana sitchensis</u> - <u>Castilleja elmeri</u> Association

	Valeriana - Castilleja Variation							Trollius laxus Variation					
Plot No.	38	42	34	43	60	65	75	25	36	24	64	69	73
Ah Horizon													
Textural class	SL	LS	LS	SL	SL	LS	LS	SL	-	LS-S	SL	SL	SL
Sand (%)	61.4	77.6	76.0	50.2	61.2	77.2	72.0	62.4	-	85.0	60.2	68.6	69.6
Silt (%)	38.4	22.0	22.8	48.0	36.0	21.4	28.0	36.8	-	15.0	38.0	30.6	29.0
Clay (%)	0.2	0.4	1.2	1.8	2.8	1.4	0	0.8	-	0	1.8	0.8	1.4
B Horizon													
Textural class	-	-	S	-	-	-	-	-	-	LS	-	-	-
Sand (%)	-	-	85.6	-	-	-	-	-	-	80.8	-	-	-
Silt (%)	-	-	14.4	-	-	-	-	-	-	19.2	-	-	-
Clay (%)	-	-	0	-	-	-	-	-	-	0	-	-	-
C Horizon													
Textural class	S	S	S	LS	LS	LS	SL	S	S	LS	-	SL	-
Sand (%)	92.8	93.2	98.0	72.0	82.2	85.8	69.2	90.4	86.8	80.4	-	65.2	-
Silt (%)	7.2	6.8	2.0	28.0	17.8	11.4	28.4	9.6	13.2	19.6	-	27.4	-
Clay (%)	0	0	0	0	0	2.8	2.4	0	0	0	-	7.4	-

Table 58

Soil Chemical Analysis

Valeriana sitchensis - Castilleja elmeri Association

Plot No.	Valeriana - Castilleja Variation							Trollius laxus Variation					
	38	42	34	43	60	65	75	25	36	24	64	69	73
L-H Horizon													
pH	-	-	-	-	-	-	-	4.6	5.1	-	-	-	-
C (%)	-	-	-	-	-	-	-	33.2	20.9	-	-	-	-
OM (%)	-	-	-	-	-	-	-	57.0	35.9	-	-	-	-
N (%)	-	-	-	-	-	-	-	1.9	1.6	-	-	-	-
C/N	-	-	-	-	-	-	-	17.	13.	-	-	-	-
P (ppm)	-	-	-	-	-	-	-	21.	15.	-	-	-	-
Ca (me/100g)	-	-	-	-	-	-	-	3.88	2.22	-	-	-	-
Mg (me/100g)	-	-	-	-	-	-	-	1.20	0.80	-	-	-	-
Na (me/100g)	-	-	-	-	-	-	-	0.60	0.60	-	-	-	-
K (me/100g)	-	-	-	-	-	-	-	2.84	0.22	-	-	-	-
CEC (me/100g)	-	-	-	-	-	-	-	145.0	29.4	-	-	-	-
Ah Horizon													
pH	4.8	4.2	4.8	5.3	4.7	4.7	4.8	4.5	-	4.7	4.8	5.0	4.9
C (%)	13.2	13.3	16.9	11.5	16.8	8.1	13.7	11.2	-	18.5	11.8	8.8	12.3
OM (%)	22.7	22.8	29.1	19.7	28.9	13.9	23.5	19.2	-	31.9	20.3	15.2	21.2
N (%)	0.9	1.0	1.3	1.0	1.3	0.4	1.0	0.7	-	1.0	0.1	0.7	0.7
C/N	15.	14.	13.	12.	13.	19.	13.	16.	-	18.	118.	14.	18.
P (ppm)	19.	28.	17.	10.	20.	21.	5.	17.	-	6.	8.	8.	11.
Ca (me/100g)	0.72	0.56	0.95	0.51	0.91	0.72	0.59	0.57	-	1.01	0.73	0.73	1.00
Mg (me/100g)	0.30	0.31	0.37	0.20	0.42	0.19	0.26	0.19	-	0.40	0.34	0.18	0.28
Na (me/100g)	0.10	0.08	0.02	0.14	0.84	0.14	0.28	0.23	-	0.34	0.48	0.27	0.28
K (me/100g)	0.57	0.37	0.56	0.29	0.88	0.41	0.60	0.21	-	0.71	0.72	0.30	0.66
CEC (me/100g)	59.7	68.3	53.8	33.6	38.6	28.3	23.4	36.5	-	55.1	19.5	11.0	34.0
B Horizon													
pH	-	-	5.0	-	-	-	-	-	-	5.1	-	-	-
C (%)	-	-	7.5	-	-	-	-	-	-	6.2	-	-	-
OM (%)	-	-	12.8	-	-	-	-	-	-	10.7	-	-	-
N (%)	-	-	0.5	-	-	-	-	-	-	0.4	-	-	-
C/N	-	-	16.	-	-	-	-	-	-	16.	-	-	-
P (ppm)	-	-	13.	-	-	-	-	-	-	5.	-	-	-
Ca (me/100g)	-	-	0.37	-	-	-	-	-	-	0.22	-	-	-
Mg (me/100g)	-	-	0.08	-	-	-	-	-	-	0.08	-	-	-
Na (me/100g)	-	-	0.14	-	-	-	-	-	-	0.11	-	-	-
K (me/100g)	-	-	0.10	-	-	-	-	-	-	0.07	-	-	-
CEC (me/100g)	-	-	29.1	-	-	-	-	-	-	31.4	-	-	-
C Horizon													
pH	4.8	4.9	5.1	5.2	5.0	5.1	5.3	4.7	5.7	5.2	-	5.2	-
C (%)	6.1	6.7	3.6	7.4	3.7	5.3	6.1	4.2	4.6	1.1	-	3.2	-
OM (%)	10.5	11.4	6.2	12.7	6.3	9.2	10.4	7.2	7.8	1.9	-	5.5	-
N (%)	0.3	0.3	0.2	0.5	0.3	0.3	0.3	0.3	0.3	0.1	-	0.2	-
C/N	21.	27.	24.	14.	11.	17.	19.	16.	17.	16.	-	14.	-
P (ppm)	16.	13.	8.	12.	8.	12.	6.	19.	7.	7.	-	9.	-
Ca (me/100g)	0.33	0.21	0.32	0.23	0.35	0.44	0.33	0.50	1.12	0.40	-	0.72	-
Mg (me/100g)	0.09	0.05	0.04	0.09	0.05	0.08	0.05	0.09	0.13	0.02	-	0.06	-
Na (me/100g)	0.06	0.05	0.13	0.08	0.15	0.15	0.16	0.11	0.16	0.12	-	0.19	-
K (me/100g)	0.24	0.05	0.01	0.09	0.09	0.16	0.12	0.08	0.01	0.00	-	0.09	-
CEC (me/100g)	33.8	49.6	9.6	36.8	6.9	12.4	8.9	32.7	22.0	25.6	-	14.8	-

matter and nitrogen decrease with depth, and carbon:nitrogen ratios are narrow. Organic matter is fairly high in some of the C horizons, because the soils are very shallow. Phosphorus, cation exchange capacity and the available cations all decrease in amount with depth. Potassium is present in particularly large quantities in the A horizon of this community.

b. Trollius laxus Variation

This variation also occurs on seepage slopes, but almost exclusively in the subalpine parkland. Relief shape varies from concave to straight to convex. Exposure is variable, with slope gradients ranging from 13 to 28%. Humus covers 89-100% of the ground surface. Exposed mineral soil is only present in one plot (1%), and rocks occur in only two plots (2-10%). There is no discernible erosion. The hygrotope is hygric.

The herb layer in this variation is also very high in coverage, being 92-100%. The bryophyte layer is much better developed than in the type variation, with a coverage of 60-95%.

The dominant species in this variation is *Trollius laxus*, with an average species significance of 8. The dominant species listed for the association are present in somewhat lesser amounts. Other species important in differentiating this variation from the type variation are *Caltha leptosepala*, which is present with much higher cover, and *Brachythecium starkei*, which is lacking in the *Valeriana* - *Castilleja* Variation.

The soils of this variation are classed as Humic Gleysols (4), Rego Gleysol (1) and Lithic Orthic Regosol (1).

The Ah horizon is finer-textured than in the type variation,

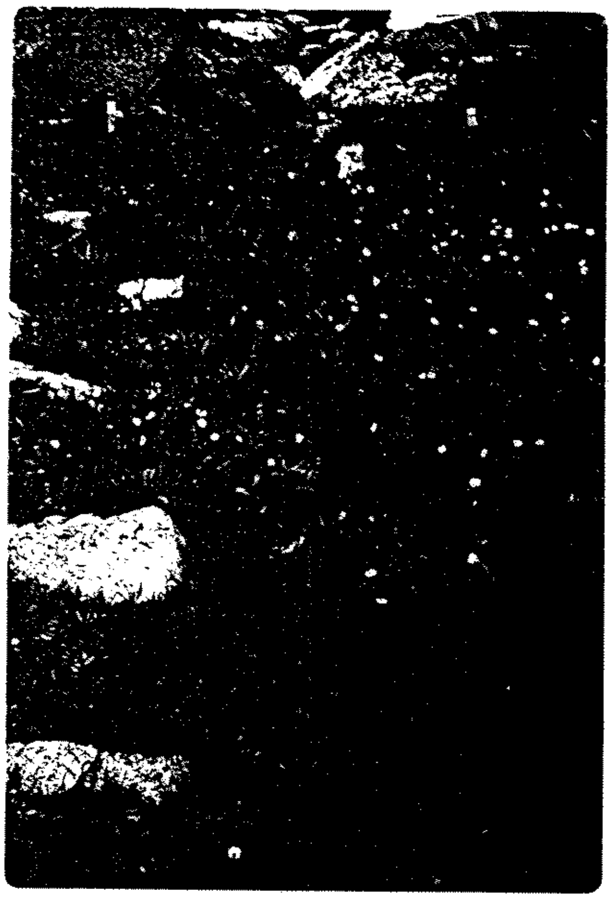


Fig. 19. Valeriana - Castilleja Association,
Trollius laxus Variation, Plot 25.
White flowers belong to Trollius.

being classed mainly as sandy loam. The C horizon is similar to that of the Valeriana - Castilleja Variation, with a range from sandy loam to sand.

The soil chemical data are as described for the type variation, except that phosphorus increases slightly with depth instead of decreasing. The quantity of nitrogen in the Ah horizon of plot 64 is very low. The amounts of calcium and sodium differ between the two variations. There is more calcium in the C horizon and more sodium in the A horizon of this variation than in the Valeriana - Castilleja Variation.

Carex nigricans Association

(Ref. Tables 59, 60, 61, 62, 63; Fig. 20, 21, 22, 23, 24)

Characteristic Combination of Species

Carex nigricans
Deschampsia atropurpurea
Claytonia lanceolata
Epilobium alpinum
Polytrichum norvegicum
Polytrichadelphus lyallii

This association occurs in snow basins, depressions and temporary ponds in the alpine, low alpine and subalpine parkland areas. Relief shape varies from hummocky to straight to concave. Exposure is mainly southeast or southwest, with slope gradients ranging from 0 to 21%. Humus covers most of the ground surface (89-100%). Mineral soil occurs only in two plots, with a cover of 5-10%. There are usually no rocks present. No evidence of erosion was observed. The hygrotope is rated as mesic to hydric.

The herb layer and bryophyte layer are both very well developed. Coverage of the herb layer is 45-100%, while the

Table 59

General Environment

Carex nigricans Association

	Carex – *Polytrichadelphus* Variation									*Juncus* – *Carex* – *Drepanocladus* Variation
Plot No.	1	2	15	33	35	78	58	77	71	81
Elevation (ft.)	7600	7575	7475	7460	7450	7400	7380	7350	7300	7450
Physiography										
Landform	depression	depression	snow channel	snow channel	slope	snow channel	snow basin	snow basin	snow channel	temporary pond
Relief shape	hummocky	hummocky	straight	straight	straight to concave	concave	straight	concave	concave	straight
Exposure	SE	SE	SE	SW	S	SW	SW	neutral	neutral	NW
Slope gradient (%)	1	3	21	11	9	8	10	0	0	2
Layer coverage (%)										
C layer	95	90	97	100	100	99	100	99	100	45
D layer	60	50	5	80	80	85	70	85	85	50
Plot Coverage (%)										
Humus	99	89	95	100	100	100	100	100	100	96
Mineral Soil	0	10	5	0	0	0	0	0	0	0
Rock	1	1	0	0	0	0	0	0	0	4
Soil										
Hygrotope	hygric	hygric	subhydric	—	hygric	—	mesic	subhygric	hygric	hydric – hygric
Erosion	—	—	—	—	none	—	—	—	—	none
Horizon depth (in.)										
L-H	1–0	-	1½–0	½–0	-	-	-	-	H 6–0	-
Ah	0–3	0–3½	Ah 0–2 Ahf 2–4	0–5	0–12	0–9	0–18	0–6	0–5	0–4
B	Bm 3–11	Bm 3½–11½	Bhf 4–6 Bm 6–15	-	Bhfg 12–30	-	-	Bm1 6–9 Bm2 9–15	-	-
C	Cg 11+	Cgj 11½–18 Cg 18+	15+	Cg 5+	Cg 30+	Cg 9–18	18+	15+	Cg 5+	Cg 4+
R	-	-	-	-	-	18+	-	-	-	-
Classification	Gleyed Alpine Dystric Brunisol	Gleyed Alpine Dystric Brunisol	Sombric Ferro-Humic Podzol	Rego Humic Gleysol	Fera Humic Gleysol	Lithic Rego Humic Gleysol	Orthic Regosol	Alpine Dystric Brunisol	Rego Humic Gleysol	Rego Humic Gleysol

Table 60

Carex nigricans Association

			Carex nigricans - Polytrichadelphus lyallii Variation										Juncus mertensianus - Carex nigricans - Drepanocladus exannulatus Variation		
	Plot No.		1	2	15	33	35	78	58	77	71		81		
	Plot Size (m^2)		10	10	10	10	10	10	10	10	10		103		
	Extent of type (m^2)		44	70	120	175	28	162	36	119	120		108		
	Elevation (ft.)		7600	7575	7475	7460	7450	7400	7360	7350	7300		7450		
	Altitudinal area		A	A	LA	LA	LA	SP	SP	SP	SP		LA		
	C layer											Aver.Species Significance		Presence	Association Aver.Species Significance
1	Carex nigricans		9.4	9.4	9.3	9.6	9.6	9.5	9.6	9.6	9.6	9	6.4	V	9
2	Deschampsia atropurpurea		1.+	2.1	+.1	4.2	4.2	4.2	3.1	-	4.1	3	-	IV	3
3	Claytonia lanceolata		-	+.+	7.2	+.+	2.1	-	6.1	-	2.1	4	-	III	4
4	Antennaria lanata		3.2	3.1	6.2	-	-	2.2	5.2	-	1.1	4	-	III	4
5	Veronica wormskjoldii		1.+	2.1	-	-	6.2	5.2	+.+	-	1.1	4	-	III	3
6	Erigeron peregrinus		1.1	3.1	3.2	-	2.2	4.2	-	-	-	2	-	III	1
7	Juncus drummondii		-	3.1	4.2	3.2	1.2	-	-	1.2	-	2	-	III	1
8	Hieracium gracile		-	-	3.2	-	2.1	2.2	-	3.1	1.1	1	1.1	III	1
9	Sibbaldia procumbens		2.1	2.1	2.1	+.+	-	2.1	-	-	-	1	-	III	1
10	Phyllodoce empetriformis		1.1	+.1	-	-	-	1.1	+.+	2.2	-	+	-	III	+
11	Arnica latifolia		-	-	-	-	+.1	1.1	6.2	-	1.1	3	-	II	2
12	Juncus parryi		3.2	-	5.2	-	-	4.2	-	-	-	2	-	II	2
13	Arnica mollis		-	-	-	-	2.2	4.2	-	-	-	1	1.2	II	1
14	Luzula sp.		-	-	-	-	-	2.1	-	3.2	1.1	+	-	II	+
15	Luzula wahlenbergii		-	-	2.2	2.2	1.2	-	-	-	-	+	-	II	+
16	Epilobium alpinum		-	-	1.1	-	2.1	-	-	-	1.1	+	2.1	II	+
17	Carex spectabilis		-	-	-	+.3	-	-	1.2	-	-	+	1.3	II	+
18	Juncus mertensianus		-	-	-	-	-	-	2.1	-	-	+	7.3	I	3
19	Phleum alpinum		-	-	-	-	5.2	1.1	-	-	-	1	-	I	1
20	Luzula glabrata		3.2	4.2	-	-	-	-	-	-	-	1	-	I	1
21	Arenaria capillaris		+.1	-	1.1	-	-	-	-	-	-	+	-	I	+
	D layer														
	Bryophytes														
22	Polytrichum norvegicum	Dh	8.2	1.1	-	-	1.1	2.1	+.+	4.2	3.1	4	2.1	IV	4
23	Polytrichadelphus lyallii	Dh	-	1.1	-	9.2	-	8.2	8.2	8.2	2.2	6	-	III	6
24	Lophozia alpestris	Dh	1.1	1.1	-	-	-	2.1	-	3.1	5.1	2	-	III	2
25	Pohlia nutans	Dh	-	-	-	-	-	2.1	-	1.1	-	+	3.1	II	+
26	Polytrichum piliferum	Dh	-	+.1	3.2	-	-	-	-	1.1	-	+	-	II	+
27	Ceratodon purpureus	Dh	1.1	-	1.1	-	-	2.1	-	-	-	+	-	II	+
28	Pohlia gracilis	Dh	1.1	2.1	1.1	-	-	-	-	-	-	+	-	II	+
29	Polytrichum formosum	Dh	-	7.2	-	-	9.3	-	-	-	-	5	-	I	5
30	Drepanocladus exannulatus	Dh	-	-	-	-	-	-	-	-	-	-	6.2	I	2
31	Brachythecium collinum	Dh	5.1	2.1	-	-	-	-	-	-	-	1	-	I	1
32	Drepanocladus aduncus	Dh	-	-	-	-	-	-	-	-	-	-	5.2	I	1
33	Barbilophozia hatcheri	Dh	2.1	-	-	-	-	-	-	1.1	-	+	-	I	+
34	Cephaloziella rubella	Dh	-	-	-	-	-	-	-	-	-	-	3.2	I	+
35	Cephaloziella subdentata	Dh	-	-	+.+	-	-	-	-	+.+	-	+	-	I	+
	Lichens														
36	Lecidea granulosa	Dh	3.2	1.1	+.1	-	-	-	-	1.1	-	+	-	II	+
37	Cladonia sp.	Dh	+.1	+.+	+.+	-	-	-	-	+.+	-	+	-	II	+
	Total Species (incl.sporadics)		23	20	19	8	16	18	12	14	15		11		

Sporadic Species

C layer

38	Antennaria friesiana	1(1.1)
39	Antennaria umbrinella	15(1.1)
40	Vaccinium scoparium	1(1.1)

D layer

Bryophytes

41	Brachythecium curtum	71(5.1)
42	Brachythecium starkei	58(3.1)
43	Dicranum scoparium	71(4.1)
44	Kiaeria blyttii	2(1.1)
45	Lophozia ? ventricosa	1(1.1)
46	Orthocaulis floerkii	71(7.1)
47	Philonotis americana	1(1.1)
48	Pohlia drummondii	35(1.1)
49	Scapania subalpina	35(1.1)

Lichens

50	Cetraria islandica	1(+.+)

bryophyte layer covers 5-85%.

The dominant species is Carex nigricans, which has an average species significance of 9. It is the only constant species in the association. Other important species in the C layer, all of much lower cover, are Deschampsia atropurpurea, Claytonia lanceolata, Antennaria lanata and Veronica wormskjoldii. Epilobium alpinum is considered as a characteristic species because of its preference for this association. The D layer is dominated by bryophytes,as lichens are very sparse in this wet community. The important species are Polytrichum norvegicum and Polytrichadelphus lyallii. Polytrichum formosum has a very high cover in two plots.

The association is divided into two variations:

a. Carex nigricans - Polytrichadelphus lyallii Variation

b. Juncus mertensianus - Carex nigricans - Drepanocladus exannulatus Variation

The floristic similarity indices for the ten plots of the association are shown in Table 61. Some of the values are not too high, but these plots all have their highest affinity with each other. It can be seen that the Juncus - Carex - Drepanocladus Variation (plot 81) is not very similar to the Carex - Polytrichadelphus Variation. However, it is included within the Carex nigricans Association mainly because of the high coverage of Carex nigricans.

Table 61

Floristic Similarity Indices for the Carex nigricans Association

	1	2	15	33	35	78	58	77	71	81
1		60	52	47	42	52	43	55	50	18
2			58	55	68	56	48	57	55	19
15				48	44	52	59	51	49	18
33					45	78	73	83	52	17
35						53	40	44	48	18
78							71	81	53	20
58								73	47	17
77									54	21
71										20
81										

The variations are described below, by general habitat, floristics and soils data.

a. Carex nigricans - Polytrichadelphus lyallii Variation

This is the type variation for the association. It occurs in snow basins and depressions in the alpine, low alpine and subalpine parkland areas. Relief shape varies from hummocky to straight to concave. Exposure is generally southeast or southwest, and slope gradients range from 0 to 21%. Humus covers 89-100% of the ground surface, mineral soil 0-10%, and rock 0-1%. There is no erosion. The hygrotope ranges from mesic to subhydric.

The herb layer covers 90-100% of the area. The bryophyte layer also has a fairly high coverage, of 5-85%.

The dominant species listed for the association also characterize this snowpatch variation. *Deschampsia atropurpurea*, *Claytonia lanceolata*, *Antennaria lanata*, *Veronica wormskjoldii* and *Polytrichadelphus lyallii*, which are important in this variation, are lacking in the *Juncus* - *Carex* - *Drepanocladus* Variation.

The soils associated with this variation are Rego Humic Gleysol (3), Fera Humic Gleysol (1), Alpine Dystric Brunisol (3), Sombric Ferro-Humic Podzol (1), and Orthic Regosol (1).

Texture is generally coarser at greater depths. The A horizon varies from sandy loam to silt loam, sandy loam being predominant. The B horizon samples are all sandy loams. The C horizon is mainly a loamy sand or a sandy loam.

The soil chemical data are shown in Table 63. The pH values increase with depth, but all the values are strongly acidic. Organic matter and nitrogen generally decrease with increasing depth. There is still a considerable amount of organic matter in some of the C horizons due to the very shallow nature of the soils. The amount of nitrogen in the C horizon of plot 2 appears to be very high, whereas the quantity in the C horizon of plot 78 is very low. The carbon:nitrogen ratios are narrow. Phosphorus, cation exchange capacity, magnesium and potassium decrease in quantity with depth. Calcium and sodium decrease in some cases; in others, they decrease from the A to the B horizon, then increase from the B to the C horizon.

Table 62

Soil Texture

Carex nigricans Association

	Carex - Polytrichadelphus Variation									Juncus - Carex - Drepanocladus Variation
Plot No.	1	2	15	33	35	78	58	77	71	81
Ah Horizon										
Textural class	SL	SL	SL	SL	SiL	SL	SL	SL	L	SL
Sand (%)	65.6	66.8	66.2	60.0	46.4	48.0	63.0	55.2	51.2	51.0
Silt (%)	34.4	32.8	33.3	38.6	50.4	48.6	31.8	40.4	37.6	42.2
Clay (%)	0	0.4	0.5	1.4	3.2	3.4	5.2	4.4	11.2	6.8
B Horizon										
Textural class	SL	SL	SL	-	SL	-	-	SL	-	-
Sand (%)	61.2	52.2	65.2	-	52.4	-	-	48.0	-	-
Silt (%)	38.8	47.4	33.3	-	44.4	-	-	49.5	-	-
Clay (%)	0	0.4	1.5	-	3.2	-	-	2.5	-	-
C Horizon										
Textural class	LS	LS	LS	LS	LS	SL	SL	SL	SiL	SiL
Sand (%)	84.8	80.4	83.0	80.6	84.0	68.0	70.8	62.6	32.2	36.0
Silt (%)	15.2	17.8	16.6	19.4	16.0	31.4	22.4	33.8	63.6	51.2
Clay (%)	0	1.8	0.4	0	0	0.6	6.8	3.6	4.2	12.8

Table 63

Soil Chemical Analysis

Carex nigricans Association

Plot No.	1	2	15	33	35	78	58	77	71	81
	Carex - Polytrichadelphus Variation									*Juncus - Carex - Drepanocladus* Variation
L-H Horizon										
pH	4.5	-	4.3	-	-	-	-	-	4.6	-
C (%)	23.9	-	19.0	-	-	-	-	-	22.1	-
OM (%)	41.1	-	32.6	-	-	-	-	-	38.0	-
N (%)	1.3	-	1.3	-	-	-	-	-	1.6	-
C/N	18.	-	15.	-	-	-	-	-	14.	-
P (ppm)	16.	-	16.	-	-	-	-	-	21.	-
Ca (me/100g)	3.20	-	0.56	-	-	-	-	-	0.12	-
Mg (me/100g)	1.58	-	0.35	-	-	-	-	-	0.25	-
Na (me/100g)	0.23	-	0.26	-	-	-	-	-	0.43	-
K (me/100g)	3.26	-	0.98	-	-	-	-	-	0.35	-
CEC (me/100g)	138.0	-	53.6	-	-	-	-	-	58.4	-
Ah Horizon										
pH	4.8	4.6	4.6	4.9	5.1	4.8	5.0	4.6	5.0	5.6
C (%)	14.1	14.6	12.1	12.5	6.8	13.3	5.6	15.9	14.0	2.5
OM (%)	24.3	25.2	20.9	21.6	11.7	22.9	9.7	27.4	24.0	4.3
N (%)	0.9	1.0	0.7	0.9	0.5	1.0	0.4	0.9	1.1	0.3
C/N	15.	15.	17.	14.	15.	14.	15.	18.	13.	8.
P (ppm)	8.	8.	10.	21.	6.	12.	9.	6.	4.	7.
Ca (me/100g)	0.08	0.25	0.04	0.27	0.61	0.44	0.42	0.03	0.03	0.97
Mg (me/100g)	0.10	0.28	0.06	0.13	0.06	0.15	0.05	0.14	0.03	0.19
Na (me/100g)	0.16	0.13	0.15	0.15	0.44	0.27	0.26	0.27	0.19	0.16
K (me/100g)	0.35	0.59	0.20	0.07	0.00	0.22	0.09	0.27	0.05	0.13
CEC (me/100g)	36.4	41.9	35.1	41.3	24.3	17.0	16.2	31.6	24.1	18.9
B Horizon										
pH	5.4	5.3	4.9	-	5.2	-	-	5.6	-	-
C (%)	4.5	5.8	8.2	-	7.5	-	-	3.0	-	-
OM (%)	7.7	10.0	14.1	-	12.8	-	-	5.2	-	-
N (%)	0.4	0.4	0.5	-	0.5	-	-	0.2	-	-
C/N	12.	14.	18.	-	15.	-	-	15.	-	-
P (ppm)	3.	6.	10.	-	8.	-	-	6.	-	-
Ca (me/100g)	0.03	0.06	0.02	-	0.44	-	-	0.08	-	-
Mg (me/100g)	0.02	0.01	0.02	-	0.04	-	-	0.02	-	-
Na (me/100g)	0.13	0.10	0.13	-	0.24	-	-	0.14	-	-
K (me/100g)	0.05	0.03	0.11	-	0.00	-	-	0.04	-	-
CEC (me/100g)	12.3	18.3	12.7	-	27.6	-	-	13.9	-	-
C Horizon										
pH	5.4	5.4	4.9	5.1	5.5	5.0	5.4	5.2	5.5	6.3
C (%)	1.1	0.9	4.4	4.1	2.5	9.1	4.1	1.7	3.5	1.8
OM (%)	1.8	1.5	7.5	7.1	4.3	15.7	7.1	2.9	6.0	3.0
N (%)	0.1	0.6	0.2	0.2	0.2	0.1	0.3	0.1	0.3	0.2
C/N	13.	2.	18.	18.	15.	76.	16.	14.	11.	9.
P (ppm)	3.	4.	4.	16.	8.	11.	2.	5.	2.	5.
Ca (me/100g)	0.29	0.37	0.19	0.44	0.38	0.09	0.32	0.23	0.11	1.17
Mg (me/100g)	0.01	0.01	0.01	0.03	0.02	0.02	0.02	0.02	0.01	0.23
Na (me/100g)	0.14	0.14	0.12	0.14	0.13	0.13	0.14	0.15	0.14	0.15
K (me/100g)	0.04	0.03	0.10	0.07	0.00	0.05	0.06	0.04	0.03	0.15
CEC (me/100g)	16.1	15.8	8.3	21.6	16.1	21.5	11.6	18.4	22.0	25.1

Table 6

General Environment

Juniperus communis Association

Plot No.	50	47	48	52
Elevation (ft.)	7550	7450	7450	7425
Physiography				
Landform	ledge	slope	ridge	ridge
Relief shape	straight	convex	straight	straight
Exposure	SW	SE	SE	SE
Slope gradient (%)	70	29	35	26
Layer Coverage (%)				
B layer	100	98	98	85
C layer	10	35	30	25
D layer	20	10	7	35
E layer	1	0	1	0
Plot Coverage (%)				
Humus	5	4	10	10
Mineral soil	0	1	0	5
Rock	95	95	90	85
Soil				
Hygrotope	xeric			
Erosion	none			
Horizon depth (in.)				
Ah	0-5	0-6	0-12	0-15
C	5-10	6-12	-	-
R	10+	12+	12+	15+
Classification	Lithic Orthic Regosol			

Table 7

Juniperus communis Association

	Plot No.	50	47	48	52		
	Plot Size (m^2)	12	26	14	14		
	Extent of type (m^2)	12	26	14	14		
	Elevation (ft.)	7550	7450	7450	7425		
	Altitudinal area	A	LA	LA	LA		
	B layer					Presence	Aver.Species Significance
1	Juniperus communis	10.7	9.7	9.7	9.6	V	9
	C layer						
2	Carex phaeocephala	4.2	3.2	5.2	3.2	V	4
3	Arenaria capillaris	1.2	2.2	3.2	3.1	V	2
4	Festuca brachyphylla	2.2	2.2	3.2	1.2	V	2
5	Vaccinium scoparium	1.2	5.2	-	4.2	IV	4
6	Antennaria lanata	1.2	2.2	-	4.2	IV	2
7	Selaginella densa	-	3.1	1.1	2.1	IV	2
8	Sibbaldia procumbens	-	2.1	1.1	1.2	IV	1
9	Luzula spicata	1.1	-	+.+	2.1	IV	1
10	Juncus parryi	-	4.2	-	4.2	III	3
11	Potentilla diversifolia	-	2.2	2.2	-	III	1
12	Erigeron peregrinus	-	2.2	-	1.2	III	1
13	Trisetum spicatum	1.2	-	2.1	-	III	1
14	Arenaria obtusiloba	-	-	1.1	1.2	III	+
	D layer						
	Bryophytes						
15	Polytrichum piliferum	Dh 2.2	4.2	3.1	6.2	V	5
16	Tortula ruralis	Dh 2.2	2.2	3.2	3.1	V	3
17	Barbilophozia hatcheri	Dh 3.2	2.1	+.1	-	IV	1
18	Dicranum scoparium	Dh 1.1	1.2	-	2.1	IV	1
19	Bryum capillare	Dh 1.1	1.1	-	-	III	+
	Lichens						
20	Cetraria ericetorum	Dh 3.2	-	2.1	4.2	IV	3
21	Peltigera malacea	Dh -	3.2	+.+	2.2	IV	1
22	Cladonia ecmocyna	Dh -	1.1	-	4.2	III	2
23	Lecidea granulosa	Dh -	1.1	-	1.1	III	+
24	Solorina crocea	Dh 1.1	1.1	-	-	III	+
	E layer						
25	Cetraria pinastri	EB 1.1	-	+.+	-	III	+
	Total Species (incl.sporadics)	21	25	21	23		

Sporadic Species

C layer

26	Carex spectabilis	47(4.2)
27	Haplopappus lyallii	50(1.2)
28	Hieracium gracile	52(2.1)
29	Saxifraga bronchialis	48(1.2)
30	Vaccinium caespitosum	48(1.2)
	D layer	
	Bryophytes	
31	Barbilophozia lycopodioides	52(1.1)
32	Drepanocladus uncinatus	50(4.2)
33	Hypnum revolutum	48(2.2)
34	Polytrichadelphus lyallii	47(1.1)
35	Rhacomitrium canescens	47(1.1)
36	? Tetraplodon mnioides	52(3.1)
	Lichens	
37	Cetraria islandica	47(2.1)
38	Cladonia carneola	47(1.1)
39	Cornicularia aculeata	50(1.2)
40	Peltigera canina	50(1.1)
41	Stereocaulon alpinum	52(4.1)
	E layer	
42	Alectoria minuscula	48(+.+)
43	Parmeliopsis hyperopta	48(+.+)
44	Psoroma hypnorum	50(1.1)

plot, while the D layer occupies 7-35%. The E layer only occurs in two plots, with a cover of one percent.

Juniperus communis, which is the dominant species in the community, is the only species in the B layer, with a presence of V and average species significance of 9. There are only three constant species in the C layer, all with low cover values. These are Carex phaeocephala, Arenaria capillaris and Festuca brachyphylla. Polytrichum piliferum and Tortula ruralis comprise the constant bryophytes, while there are no lichens with a presence of class V. Peltigera malacea, with a presence of IV, and Tortula ruralis show a high preference for this association.

Table 8 gives the floristic similarity indices for the four plots comprising the association. The values are all very high, indicating that the association is homogeneous.

Table 8

Floristic Similarity Indices for the Juniperus communis Association

	50	47	48	52
50		69	76	63
47			70	74
48				67
52				

The soils are all classed as Lithic Orthic Regosols, having an Ah-C-R horizon sequence.

Both the A and C horizons are coarse textured. All the samples are classified as loamy sands.

Table 9

Soil Texture

Juniperus communis Association

Plot No.	50	47	48	52
Ah Horizon				
Textural class	LS	LS	LS	LS
Sand (%)	77.4	82.8	84.8	79.4
Silt (%)	22.6	17.2	15.2	19.0
Clay (%)	0	0	0	1.6
C Horizon				
Textural class	LS	LS	-	-
Sand (%)	73.9	79.2	-	-
Silt (%)	26.1	20.4	-	-
Clay (%)	0	0.4	-	-

Table 10

Soil Chemical Analysis

<u>Juniperus communis</u> Association

Plot No.	50	47	48	52
Ah Horizon				
pH	4.9	4.9	4.8	4.5
C (%)	12.1	7.8	9.2	12.7
OM (%)	20.8	13.4	15.8	21.8
N (%)	0.1	0.5	0.6	0.9
C/N	201.	17.	15.	15.
P (ppm)	7.	9.	17.	18.
Ca (me/100g)	0.32	0.08	1.39	0.13
Mg (me/100g)	0.12	0.08	0.14	0.09
Na (me/100g)	0.04	0.03	0.02	0.12
K (me/100g)	0.23	0.07	0.25	0.14
CEC (me/100g)	36.6	27.3	74.8	121.0
C Horizon				
pH	5.0	5.2	-	-
C (%)	8.9	5.7	-	-
OM (%)	15.3	9.9	-	-
N (%)	0.8	0.3	-	-
C/N	11.	18.	-	-
P (ppm)	8.	6.	-	-
Ca (me/100g)	0.05	0.27	-	-
Mg (me/100g)	0.07	0.05	-	-
Na (me/100g)	0.04	0.04	-	-
K (me/100g)	0.07	0.02	-	-
CEC (me/100g)	21.5	23.5	-	-

Fig. 3. Juniperus communis Association, Plot 47.

Table 10 presents the soil chemical data for this association. The pH values are slightly lower in the Ah than in the C horizon, but all values are strongly acidic. Organic matter decreases somewhat with depth, but due to the very shallow nature of the soils, there is still a considerable amount of organic matter in the C horizon. Carbon:nitrogen ratios are generally narrow. There is an extremely low percentage of total nitrogen in the Ah horizon of plot 50, thus making the C/N ratio very wide. The amount of phosphorus and sodium is approximately the same in the A and C horizons. Magnesium, potassium and cation exchange capacity decrease with depth; calcium decreases in one case and increases in another. In general, phosphorus, cation exchange capacity and available cations are quite variable among the plots of the association; carbon:nitrogen ratios are similar.

Antennaria lanata - Sibbaldia procumbens Association

(Ref. Tables 11, 12, 13, 14, 15; Fig. 4, 5, 6, 7)

Characteristic Combination of Species

Antennaria lanata
Sibbaldia procumbens
Polytrichum piliferum
Umbilicaria hyperborea
Alectoria minuscula
Rhizocarpon geographicum

This association occurs on ridge tops, predominantly in the alpine area. The relief shape is generally straight. Exposure is variable, being south, southwest, north, northwest or neutral. Slope gradients range from 0 to 28%. The ground surface is covered by 5-85% rock, 5-70% humus and 0-25% mineral

Table 11

General Environment

Antennaria lanata - Sibbaldia procumbens Association

	Antennaria - Sibbaldia - Salix Variation				*Carex phaeocephala* Variation			*Carex breweri* Variation	
Plot No.	10	22	13	28	9	17	67	45	46
Elevation (ft.)	7600	7600	7500	7500	7600	7500	7325	7500	7490
Physiography									
Landform	ridge				ridge			ridge	cliff face
Relief shape	straight	straight to convex	straight	convex to concave	convex to straight	straight	straight	convex	straight to convex
Exposure	N	S	neutral	SW	SW	S	neutral	neutral	NW
Slope gradient (%)	17	6	0	15	13	12	0	0	28
Layer Coverage (%)									
B layer	0	5	2	0	0	0	0	0	0
C layer	35	45	30	35	40	30	50	75	60
D layer	50	85	65	90	60	80	75	15	40
Plot Coverage (%)									
Humus	36	10	38	5	27	20	55	70	58
Mineral Soil	4	10	2	10	3	5	0	25	2
Rock	60	80	60	85	70	75	45	5	40
Soil									
Hygrotope	xeric				xeric			xeric	xeric
Erosion	strong				moderate	strong	none	strong	moderate
Horizon depth (in.)									
L-H	-	-	-	-	$2\frac{1}{2}$-0	-	-	-	-
Ah	Ah1 0-2 Ah2 2-4	0-2	0-3	0-6	0-$3\frac{1}{2}$	0-$4\frac{1}{2}$	0-7	0-6	Ah1 0-7 Ah2 7-10
B	Bm 4-12	-	Bf 3-6	-	-	-	-	Bf 6-15	-
C	12+	2-12	Cgj 6-14	6-14	$3\frac{1}{2}$-12	$4\frac{1}{2}$-13	-	Cg 15+	10+
R	-	12+	14+	14+	12+	13+	7+	-	-
Classification	Alpine Dystric Brunisol	Lithic Orthic Regosol	Lithic Gleyed Sombric Humo-Ferric Podzol	Lithic Orthic Regosol	Lithic Orthic Regosol			Gleyed Sombric Humo-Ferric Podzol	Orthic Regosol

Table 12

Antennaria lanata - Sibbaldia procumbens Association

No.		Antennaria lanata - Sibbaldia procumbens - Salix cascadensis Variation					Carex phaeocephala Variation				Carex breweri Variation				
	Plot No.	10	22	13	28		9	17	67		45	46			
	Plot Size (m^2)	70	70	70	50		120	105	8		6	5			
	Extent of type (m^2)	210	104	500	96		360	105	16		6	5			
	Elevation (ft.)	7600	7600	7500	7500		7600	7500	7325		7500	7490			
	Altitudinal area	A	A	LA	A		A	LA	SP		A	A			
						Aver.Species Significance				Aver.Species Significance			Aver.Species Significance	Presence	Association Aver.Species Significance
	B layer														
1	Picea engelmannii	-	+.+	+.+	-	+	-	-	-	-	-	-	-	II	+
	C layer														
2	Carex phaeocephala	3.2	3.2	4.2	3.2	3	6.3	6.3	7.2	6	4.2	-	3	V	5
3	Antennaria lanata	4.2	5.2	4.2	5.2	5	4.2	3.2	3.2	4	7.2	4.2	6	V	5
4	Sibbaldia procumbens	3.2	4.2	5.2	5.2	5	4.2	4.2	5.2	4	4.2	5.2	5	V	5
5	Antennaria umbrinella	3.2	4.2	5.1	2.1	4	2.1	2.1	5.2	4	3.2	2.1	3	V	4
6	Festuca brachyphylla	4.2	3.1	4.1	4.2	4	4.2	2.2	4.2	4	4.2	3.2	4	V	4
7	Arenaria capillaris	1.1	2.2	1.2	1.1	1	3.2	3.2	6.2	5	2.1	-	1	V	3
8	Arenaria obtusiloba	3.1	3.2	3.2	2.1	3	3.2	3.2	2.1	3	2.2	1.1	1	V	3
9	Salix cascadensis	4.2	5.2	6.2	3.2	5	-	2.2	-	+	5.2	1.2	4	IV	4
10	Haplopappus lyallii	4.2	4.2	4.2	4.2	4	3.3	2.2	-	2	4.2	-	3	IV	3
11	Agrostis variabilis	-	3.1	4.1	4.2	3	-	3.2	4.2	3	3.1	-	1	IV	3
12	Luzula spicata	2.1	2.1	3.1	3.1	3	3.2	3.2	4.2	4	-	-	-	IV	3
13	Trisetum spicatum	2.1	2.1	3.1	3.2	3	3.2	1.1	-	1	2.2	-	1	IV	2
14	Potentilla diversifolia	2.2	2.2	3.2	2.2	3	2.2	2.1	-	1	-	-	-	IV	1
15	Sedum lanceolatum	1.1	1.1	1.1	1.1	1	-	2.1	-	+	1.1	-	+	IV	1
16	Juniperus communis	+.+	1.+	+.+	-	+	1.+	+.+	+.+	+	-	-	-	IV	+
17	Juncus parryi	-	3.2	-	1.2	1	2.2	+.2	-	+	-	-	-	III	+
18	Selaginella densa	-	1.1	1.1	1.1	1	-	1.1	-	+	-	-	-	III	+
19	Carex breweri	-	-	-	-	-	-	-	-	-	8.3	7.2	8	II	5
20	Dryas octopetala	6.3	5.3	-	-	5	-	-	-	-	-	-	-	II	3
21	Carex spectabilis	-	2.2	-	1.2	+	-	2.2	-	+	-	-	-	II	+
22	Vaccinium scoparium	-	-	-	2.2	+	-	-	1.2	+	-	1.1	+	II	+
23	Luzula arcuata	-	-	-	-	-	-	-	-	-	2.1	2.1	2	II	+
24	Saxifraga bronchialis	2.2	2.2	-	-	1	-	-	-	-	-	-	-	II	+
25	Pinus albicaulis	1.+	-	-	-	+	-	+.+	-	+	-	-	-	II	+
	D layer														
	Bryophytes														
26	Polytrichum piliferum	Oh 5.2	5.2	6.2	7.2	6	4.2	5.2	6.2	5	4.2	6.2	5	V	5
27	Barbilophozia hatcheri	Oh -	2.1	-	1.1	+	-	1.1	-	+	3.1	-	1	III	1
28	Orthocaulis floerkii	Oh 2.1	-	2.1	-	1	1.1	-	-	+	-	-	-	II	+
29	Bryum capillare	Oh 1.1	-	-	-	+	1.1	-	-	+	-	-	-	II	+
30	Ceratodon purpureus	Oh -	1.1	-	-	+	-	-	-	-	1.1	-	+	II	+
31	Grimmia alpestris	Dr -	-	1.1	-	+	-	1.1	-	+	-	-	-	II	+
32	Lophozia alpestris	Oh -	-	-	1.1	+	-	-	-	-	-	1.1	+	II	+
	Lichens														
33	Solorina crocea	Oh 3.1	3.2	4.2	4.2	4	2.2	3.1	+.+	2	2.2	4.2	3	V	3
34	Umbilicaria hyperborea	Dr 5.3	6.2	5.3	7.3	6	5.3	6.3	5.1	5	-	-	-	IV	5
35	Alectoria minuscula	Dr 5.3	6.2	5.3	7.3	6	5.3	6.3	-	5	-	-	-	IV	5
36	Lecidea granulosa	Oh 2.1	4.2	-	2.1	3	-	-	8.1	6	1.1	2.1	1	IV	4
37	Rhizocarpon geographicum	Dr 3.1	4.1	3.1	4.2	4	3.1	3.1	5.1	4	-	-	-	IV	4
38	Cladonia carneola	Oh 3.1	4.2	2.1	-	3	-	1.2	3.1	1	2.1	3.1	3	IV	2
39	Peltigera canina	Oh 2.1	+.+	-	1.1	1	1.1	+.2	-	+	2.1	-	1	IV	+
40	Cetraria ericetorum	Oh -	4.2	4.2	-	3	-	3.2	4.1	3	-	2.1	1	III	3
41	Cetraria islandica	Oh 2.1	-	-	3.1	1	3.2	2.2	-	2	2.2	-	1	III	1
42	Stereocaulon alpinum	Oh -	-	1.1	-	+	1.1	1.1	-	+	1.1	-	+	III	+
43	Cornicularia aculeata	Oh 3.1	-	4.2	-	2	-	-	-	-	-	-	-	II	1
44	Cladonia ecmocyna	Oh -	-	-	2.1	+	-	-	3.1	1	3.2	-	1	II	1
45	Cladonia chlorophaea	Oh -	-	-	3.2	+	-	1.2	-	+	-	-	-	II	+
	Total Species (incl.sporadics)	32	34	29	32		27	33	20		24	20			

Sporadic Species

C layer

46 Abies lasiocarpa 22(1.+)
47 Carex nardina 46(6.2)
48 Carex pyrenaica 22(2.2)
49 Erigeron peregrinus 28(1.2)
50 Hieracium gracile 67(3.1)
51 Luzula wahlenbergii 46(4.2)
52 Picea engelmannii 10(+.+)
53 Ranunculus eschscholtzii 45(+.+)
54 Saxifraga ferruginea 9(1.1)
55 Solidago multiradiata 17(1.1)
56 Stellaria laeta 10(1.1)

D layer

Bryophytes

57 Barbilophozia lycopodioides 9(1.1)
58 Dicranum scoparium 13(2.1)
59 Pohlia gracilis 28(1.1)
60 Pohlia nutans 46(1.1)

Lichens

61 Cladonia macrophyllodes 46(2.1)
62 Cladonia sp. 9(2.1)
63 Lepraria neglecta 9(1.2)
64 Omphalodiscus virginis 10(3.2)

soil. Erosion is moderate to strong, wind being the important factor. The hygrotope is rated as xeric.

A poorly-developed shrub layer occurs in only two plots, covering 2-5% of the area. The moderately-developed herb layer covers 30-75%, while the well-developed bryophyte and lichen layer occupies 15-90%.

Antennaria lanata and Sibbaldia procumbens are the dominant species in the C layer. Other constant sub-dominants are Carex phaeocephala, Antennaria umbrinella, Festuca brachyphylla, Arenaria capillaris and Arenaria obtusiloba. Polytrichum piliferum is the only constant bryophyte. Solorina crocea is the only constant lichen, but due to its low cover and low preference for this community, it is not considered as a characteristic species. However, Umbilicaria hyperborea, Alectoria minuscula and Rhizocarpon geographicum are considered to be characteristic species because of their high preference for this association.

The association is subdivided into three variations, based mainly on floristic composition. The variations are:

a. Antennaria lanata - Sibbaldia procumbens - Salix cascadensis Variation

b. Carex phaeocephala Variation

c. Carex breweri Variation

Table 13 shows the floristic similarity indices for the nine plots of the association. The blocked-in areas represent the three variations. It can be seen that the values are generally higher within the variations than among them. The indices are still fairly high between the Antennaria - Sibbaldia - Salix and the Carex phaeocephala variations, but are much lower with the Carex breweri Variation.

Table 13

Floristic Similarity Indices for the Antennaria lanata - Sibbaldia procumbens Association

	10	22	13	28	9	17	67	45	46
10		68	64	53	61	56	33	38	28
22			64	65	51	69	40	42	28
13.				62	57	59	51	40	38
28					51	62	41	36	35
9						72	42	35	22
17							45	32	26
67								24	30
45									46
46									

The variations are described below, by general habitat, floristics and detailed soil data.

a. Antennaria lanata - Sibbaldia procumbens - Salix cascadensis Variation

This variation, which is the type for the association, occurs on ridges in the alpine and low alpine areas, with a relief shape varying from straight through convex to concave. Exposure varies from north to south and southwest. Slope gradients range from 0 to 17%. The ground surface is 60-85% rock, 5-38% humus and 2-10% mineral soil. Erosion is strong, and the hygrotope is xeric.

The bryophyte and lichen layer is the most prominent, covering 50-90% of the area. The herb layer covers 30-45%, while the shrub layer covers 0-5%.

In addition to the dominant species listed for the association, the following species are important in differentiating this variation from the others: Salix cascadensis, Haplopappus lyallii, Sedum lanceolatum (which all show a high preference for this variation), and Dryas octopetala, which is exclusive to this variation.

Soil types associated with this variation are Lithic Orthic Regosol (2), Alpine Dystric Brunisol (1) and Lithic Gleyed Sombric Humo-Ferric Podzol (1).

Generally, the C horizon has a coarser texture than the Ah or B horizons. The textures of the Ah horizon range from sandy loam to loamy sand and sand. The B horizon, where present, is classed as sandy loam or loamy sand. The C horizon is either sand, sandy loam or loamy sand. In one case, fineness of texture increases with depth (clay content increases from 0 to 7%).

The soil chemical data are given in Table 15. The pH increases slightly with depth, but all values are strongly acidic. Organic matter and nitrogen decrease steadily with depth, and the carbon:nitrogen ratios are narrow. Phosphorus, magnesium, potassium and cation exchange capacity decrease with depth. In general, calcium decreases from the A to the B horizon, then increases somewhat from the B to the C horizon.

Table 14

Soil Texture

Antennaria lanata - Sibbaldia procumbens Association

	Antennaria - Sibbaldia - Salix Variation				Carex phaeocephala Variation			Carex breweri Variation	
Plot No.	10	22	13	28	9	17	67	45	46
Ah Horizon									
Textural class	LS	SL	S	LS	LS	LS	SiL	LS	SL
Sand (%)	73.4	67.4	89.4	78.6	75.8	78.4	36.4	71.4	59.1
Silt (%)	26.5	31.8	10.6	21.4	24.2	21.2	56.8	28.6	38.2
Clay (%)	0.1	0.8	0	0	0	0.4	6.8	0	2.7
B Horizon									
Textural class	SL	-	LS	-	-	-	-	LS	-
Sand (%)	63.6	-	84.2	-	-	-	-	81.6	-
Silt (%)	35.6	-	15.8	-	-	-	-	18.4	-
Clay (%)	0.8	-	0	-	-	-	-	0	-
C Horizon									
Textural class	S	LS	SL	S	LS	SL	-	LS	LS
Sand (%)	90.8	82.8	74.0	92.2	73.8	73.8	-	84.0	76.4
Silt (%)	9.2	17.2	19.0	7.8	24.8	21.8	-	15.8	23.2
Clay (%)	0	0	7.0	0	1.4	4.4	-	0.2	0.4

Table 15

Soil Chemical Analysis

Antennaria lanata - Sibbaldia procumbens Association

	Antennaria - Sibbaldia - Salix Variation				Carex phaeocephala Variation			Carex breweri Variation	
Plot No.	10	22	13	28	9	17	67	45	46
L-H Horizon									
pH	-	-	-	-	4.7	-	-	-	-
C (%)	-	-	-	-	16.8	-	-	-	-
OM (%)	-	-	-	-	29.0	-	-	-	-
N (%)	-	-	-	-	0.7	-	-	-	-
C/N	-	-	-	-	24.	-	-	-	-
P (ppm)	-	-	-	-	17.	-	-	-	-
Ca (me/100g)	-	-	-	-	0.94	-	-	-	-
Mg (me/100g)	-	-	-	-	0.20	-	-	-	-
Na (me/100g)	-	-	-	-	0.17	-	-	-	-
K (me/100g)	-	-	-	-	0.08	-	-	-	-
CEC (me/100g)	-	-	-	-	61.8	-	-	-	-
Ah Horizon									
pH	4.7	4.9	4.9	5.1	5.2	4.9	4.9	5.1	5.4
C (%)	9.3	8.4	7.0	7.6	10.1	4.0	8.9	10.0	6.8
OM (%)	16.0	14.5	12.1	13.1	17.3	6.9	15.4	17.2	11.7
N (%)	0.6	0.4	0.4	0.5	0.6	0.2	0.5	0.7	0.5
C/N	16.	20.	18.	15.	18.	18.	20.	14.	14.
P (ppm)	14.	10.	8.	11.	21.	5.	17.	4.	7.
Ca (me/100g)	1.46	1.94	1.06	0.47	0.24	0.27	1.38	0.78	0.42
Mg (me/100g)	0.17	0.28	0.11	0.09	0.03	0.03	0.17	0.09	0.02
Na (me/100g)	0.14	0.23	0.16	0.12	0.10	0.15	0.14	0.05	0.07
K (me/100g)	0.18	0.34	0.20	0.13	0.02	0.08	0.13	0.16	0.00
CEC (me/100g)	33.7	24.6	25.9	37.9	48.3	14.0	28.5	14.9	32.3
B Horizon									
pH	5.5	-	5.1	-	-	-	-	5.3	-
C (%)	3.7	-	2.8	-	-	-	-	2.1	-
OM (%)	6.4	-	4.8	-	-	-	-	3.5	-
N (%)	0.3	-	0.2	-	-	-	-	0.1	-
C/N	12.	-	16.	-	-	-	-	17.	-
P (ppm)	3.	-	7.	-	-	-	-	6.	-
Ca (me/100g)	0.23	-	0.47	-	-	-	-	0.27	-
Mg (me/100g)	0.03	-	0.02	-	-	-	-	0.01	-
Na (me/100g)	0.13	-	0.18	-	-	-	-	0.05	-
K (me/100g)	0.03	-	0.04	-	-	-	-	0.00	-
CEC (me/100g)	8.3	-	19.9	-	-	-	-	22.6	-
C Horizon									
pH	5.6	5.3	5.8	5.2	5.3	5.5	-	5.8	5.7
C (%)	1.1	2.0	0.5	2.1	5.5	1.0	-	0.5	2.9
OM (%)	1.9	3.4	0.9	3.6	9.5	1.7	-	0.8	5.0
N (%)	0.1	0.2	0.0	0.1	0.4	0.1	-	0.0	0.2
C/N	18.	11.	13.	21.	16.	12.	-	15.	19.
P (ppm)	5.	7.	4.	8.	11.	4.	-	6.	5.
Ca (me/100g)	0.33	0.42	0.80	2.23	0.30	0.40	-	0.47	0.80
Mg (me/100g)	0.02	0.03	0.01	0.02	0.02	0.01	-	0.02	0.02
Na (me/100g)	0.14	0.15	0.32	0.55	0.10	0.16	-	0.08	0.09
K (me/100g)	0.02	0.04	0.02	0.00	0.04	0.03	-	0.00	0.08
CEC (me/100g)	16.5	17.9	16.3	12.8	11.7	22.0	-	28.5	31.5

Fig. 4. *Antennaria* - *Sibbaldia* Association, *Antennaria* - *Sibbaldia* - *Salix* Variation, Plot 28. Note high coverage of rock lichens. Krummholz belongs to *Abies lasiocarpa* Association and *Picea engelmannii* Association.

Fig. 5. Soil profile of *Antennaria* - *Sibbaldia* Association, *Antennaria* - *Sibbaldia* - *Salix* Variation, Plot 22. This soil is classified as a Lithic Orthic Regosol, with an Ah-C-R horizon sequence.

In one case, it increases considerably from the A to the C horizon. Sodium increases with depth.

b. Carex phaeocephala Variation

This variation also occurs on ridges, with a straight relief shape. Exposures are south and southwest. Slope gradients range from 0-13%. The ground surface is 45-75% rock, 20-55% humus, and 0-5% mineral soil. Erosion varies from none to strong. The hygrotope is xeric. This variation occurs mainly in the alpine area, with one occurrence in the subalpine parkland.

As in the previous variation, the D layer is the most important, covering 60-80% of the area. The herb layer coverage is approximately the same, occupying 30-50%. There is no shrub layer.

The species important in the differentiation of this variation are Carex phaeocephala and Arenaria capillaris, both with a much higher average species significance than in the other two variations.

The soils are all classed as Lithic Orthic Regosols, with an Ah-C horizon sequence.

The Ah horizon in the alpine sites is a loamy sand, while it is a silt loam in the subalpine plot. The C horizon, where present, is either a loamy sand or sandy loam.

The chemical data on pH, organic matter, nitrogen and carbon:nitrogen ratios are as described for the Antennaria - Sibbaldia - Salix Variation. In plot 9, organic matter is still relatively high in the C horizon because of the shallowness of the soil. Phosphorus, magnesium, potassium and cation exchange capacity decrease with depth, and sodium increases, as in the previous variation. Calcium increases from the A to the C horizon. The available cations are present in smaller quantities in the A horizon of the *Carex phaeocephala* Variation as compared to the *Antennaria* - *Sibbaldia* - *Salix* Variation. In the C horizon, there is less calcium and sodium, and similar amounts of magnesium and potassium.

c. *Carex breweri* Variation

This variation occurs in the alpine area on ridges and cliff faces. The relief shape is convex to straight. Exposure is northwest for one plot and neutral for the other. The slope gradient is 28% in one plot and 0 in the other. The ground surface is only 5-40% rock, which is much less than in the other two variations. There is a much higher cover of humus, occupying 58-70% of the area. Mineral soil ranges from 2-25% of the plot coverage. Erosion is moderate to strong. The hygrotope is xeric.

As in the *Carex phaeocephala* Variation, there is no shrub layer. The herb layer is the most prominent, covering 60-75% of the area. The bryophyte and lichen layer is reduced to 15-40% coverage, this being mainly due to the lack of the rock lichens *Umbilicaria hyperborea*, *Alectoria minuscula* and *Rhizocarpon geographicum*. This community is a closed one, whereas the other two are open.

The important species differentiating this variation are *Carex breweri*, which is exclusive to it, and *Luzula arcuata*,

Fig. 6. *Antennaria* - *Sibbaldia* Association, *Carex phaeocephala* Variation, Plot 9.

Fig. 7. *Antennaria* - *Sibbaldia* Association, *Carex breweri* Variation, Plot 45. Note high coverage of *Antennaria lanata* (light green leaves).

which has a high preference for it.

The soils vary from Orthic Regosol to Gleyed Sombric Humo-Ferric Podzol.

Texture becomes coarser with depth in plot 46. All samples, except for one Ah horizon, are classed as loamy sands. The Ah horizon in plot 46 is a sandy loam.

The pH values for the Ah horizon are slightly higher than in the other two variations, but they increase in the C horizon to similar values. Organic matter, nitrogen, carbon:nitrogen ratio, magnesium and sodium are as described for the other variations. Potassium and calcium decrease with depth in one case, and increase in another. Cation exchange capacity increases with depth or remains the same. In the A horizon, the exchangeable cations are all present in smaller quantities than in the *Antennaria* - *Sibbaldia* - *Salix* Variation. There is more calcium and less sodium than in the *Carex phaeocephala* Variation. In the B horizon, there is less magnesium, sodium and potassium than in the *Antennaria* - *Sibbaldia* - *Salix* community. In the C horizon, there is less sodium and potassium than in the type variation, and less potassium than in the *Carex phaeocephala* Variation.

Juncus parryi Association

(Ref. Tables 16, 17, 18, 19, 20; Fig. 8)

Characteristic Combination of Species

Juncus parryi
Antennaria lanata
Polytrichum piliferum
Lecidea granulosa

This association occurs on south-facing slopes in the alpine and low alpine areas. It is less well developed in the subalpine parkland, occurring there on slopes and ridges having a southern exposure. Slope gradients range from 10 to 35%, the steeper slopes being in the alpine zone. Relief shape varies from straight to convex to concave. The slopes are fairly rocky, rocks covering 15 to 60% of the ground surface. Humus covers 35-82%, while exposed mineral soil occupies only 0-20%. Erosion varies from none to moderate and, in one case, strong. The hygrotope is rated as subxeric.

The herb layer is very well developed, occupying 40-85% of the area. The bryophyte and lichen layer is less well developed, coverage being 15-60%.

In the C layer, Juncus parryi, with an average species significance of 8, and Antennaria lanata, with an average species significance of 5, are the dominant plants. Other constant species are Arenaria capillaris, Hieracium gracile and Sibbaldia procumbens. Vaccinium scoparium and Erigeron peregrinus are prominent in a few plots. In the D layer, Polytrichum piliferum is the only constant bryophyte, with an average species significance of 6. Among the lichens, Lecidea granulosa is the only constant, with an average species significance of 5.

Table 18 gives the floristic similarity indices for the eight plots comprising the association. The majority of the

Table 16

General Environment

Juncus parryi Association

Plot No.	12	8	21	40	30	59	68	63
Elevation (ft.)	7575	7550	7550	7500	7420	7350	7325	7275
Physiography								
Landform	slope						ridge	base of ridge
Relief shape	straight	straight to convex	straight to convex	convex to concave	convex	straight	concave	concave
Exposure	SE	S	S	SW	S	SE	SW	SE
Slope gradient (%)	24	34	25	35	24	10	14	12
Layer Coverage (%)								
C layer	85	70	60	70	65	75	40	75
D layer	15	40	45	40	40	45	60	25
Plot Coverage (%)								
Humus	82	65	35	65	65	55	35	70
Mineral Soil	10	0	5	5	5	5	0	20
Rock	8	35	60	30	30	40	65	10
Soil								
Hygrotope	subxeric							
Erosion	moderate			none	strong	none	none	moderate
Horizon depth (in.)								
L-H	1-0	-	-	-	-	-	-	-
Ah	0-5	0-5	0-6	0-5	0-6	0-9	0-7	0-4
B	Bfh 5-15$\frac{1}{2}$	Bhf 5-16	-	Bhf 5-8 Bm 8-20	Bm 6-12	-	Bfh 7-10	-
C	Cg 15$\frac{1}{2}$+	16+	6-13	20+	12+	9-13	10+	4+
R	-	-	13+	-	-	13+	-	-
Classification	Gleyed Sombric Humo-Ferric Podzol	Sombric Ferro-Humic Podzol	Lithic Orthic Regosol	Sombric Ferro-Humic Podzol	Alpine Dystric Brunisol	Lithic Orthic Regosol	Sombric Humo-Ferric Podzol	Orthic Regosol

Table 17

Juncus parryi Association

		12	8	21	40	30	59	68	63		
	Plot No.	12	8	21	40	30	59	68	63		
	Plot Size (m^2)	10	10	10	10	10	8	8	10		
	Extent of type (m^2)	20	21	27	16	27	15	11	18		
	Elevation (ft.)	7575	7550	7550	7500	7420	7350	7325	7275		
	Altitudinal area	A	A	A	LA	LA	SP	SP	SP		
	C layer									Presence	Aver.Species Significance
1	Juncus parryi	8.2	8.2	8.2	8.2	7.2	8.2	7.2	8.2	V	8
2	Antennaria lanata	4.2	4.2	5.2	5.2	4.2	7.2	4.2	7.2	V	5
3	Arenaria capillaris	4.2	3.2	3.1	2.2	3.2	3.1	-	6.2	V	4
4	Hieracium gracile	6.2	+.2	-	4.2	3.2	6.2	2.1	2.1	V	4
5	Sibbaldia procumbens	4.2	3.2	4.2	5.2	5.2	3.2	4.2	-	V	4
6	Vaccinium scoparium	-	3.1	-	1.2	6.2	5.2	-	3.1	IV	4
7	Carex phaeocephala	2.2	5.2	4.2	2.2	3.2	-	3.2	-	IV	3
8	Antennaria umbrinella	2.1	-	2.2	2.1	2.1	-	3.2	-	IV	1
9	Luzula spicata	1.1	1.1	1.1	-	2.1	-	3.2	-	IV	1
10	Erigeron peregrinus	-	-	-	6.2	3.2	5.2	-	2.2	III	4
11	Agrostis variabilis	1.1	+.1	4.2	-	2.1	-	-	-	III	1
12	Carex pyrenaica	1.2	-	-	-	4.2	-	3.2	-	II	1
13	Carex spectabilis	-	-	2.2	-	4.2	-	2.2	-	II	1
14	Claytonia lanceolata	-	-	-	-	-	4.1	-	4.1	II	1
15	Festuca brachyphylla	-	4.2	1.1	-	3.1	-	-	-	II	1
16	Lupinus latifolius	-	-	-	-	-	1.2	-	4.2	II	1
17	Poa cusickii	+.+	-	-	+.+	-	-	-	5.2	II	1
18	Selaginella densa	1.1	2.1	4.1	-	-	-	-	-	II	1
19	Trisetum spicatum	-	+.1	1.1	-	-	4.2	-	-	II	1
20	Luzula wahlenbergii	2.2	-	-	3.2	1.2	-	-	-	II	+
21	Arenaria obtusiloba	-	-	1.1	-	1.1	-	-	-	II	+
22	Carex nigricans	2.3	-	-	-	-	1.2	-	-	II	+
23	Luzula sp.	-	-	-	-	-	-	3.2	1.2	II	+
	D layer										
	Bryophytes										
24	Polytrichum piliferum	Dh 4.2	7.2	7.3	6.2	5.2	6.1	7.2	5.2	V	6
25	Ceratodon purpureus	Dh -	2.1	-	1.1	1.1	2.1	-	-	III	+
26	Polytrichadelphus lyallii	Dh 2.2	-	-	4.2	-	-	-	3.1	II	1
27	Polytrichum formosum	Dh 3.1	-	-	2.2	1.1	-	-	-	II	+
	Lichens										
28	Lecidea granulosa	Dh -	1.1	3.2	1.1	3.1	4.1	8.2	3.1	V	5
29	Cladonia carneola	Dh -	-	3.2	2.1	4.2	1.1	1.1	-	IV	2
30	Solorina crocea	Dh +.+	-	2.1	3.+	3.1	-	3.1	-	IV	1
31	Cladonia ecmocyna	Dh -	-	3.2	2.1	3.2	4.2	-	-	III	2
32	Cetraria islandica	Dh -	3.1	3.2	2.2	-	-	-	-	II	1
33	Cetraria ericetorum	Dh -	-	-	-	4.2	-	3.1	-	II	1
34	Peltigera canina	Dh +.+	1.1	-	-	1.1	-	-	-	II	+
35	Cladonia sp.	Dh -	2.1	-	-	-	-	-	2.1	II	+
36	Cladonia pyxidata	Dh -	-	2.1	-	1.1	-	-	-	II	+
	Total Species (incl.sporadics)	23	22	25	21	26	18	15	18		

Sporadic Species

C layer

37	Anemone occidentalis	63(2.2)
38	Arnica latifolia	63(1.1)
39	Carex brevipes	63(2.1)
40	Deschampsia atropurpurea	59(3.2)
41	Juniperus communis	21(+.+)
42	Luzula glabrata	12(2.2)
43	Phleum alpinum	12(1.2)
44	Potentilla diversifolia	21(1.2)
45	Sedum lanceolatum	21(+.+)
46	Vaccinium caespitosum	8(1.1)
47	Valeriana sitchensis	63(1.2)
48	Veronica wormskjoldii	12(3.2)

D layer

Bryophytes

49	Barbilophozia hatcheri	21(3.1)
50	Desmatodon latifolius	59(3.1)

Lichens

51	Alectoria minuscula	8(2.1)
52	Peltigera canina var. rufescens	40(+.+)
53	Peltigera lepidophora	21(+.+)
54	Rhizocarpon geographicum	8(4.2)
55	Stereocaulon alpinum	12(1.1)
56	Umbilicaria hyperborea	8(4.2)

values are quite high.

Table 18

Floristic Similarity Indices for the *Juncus parryi* Association

	12	8	21	40	30	59	68	63
12		56	58	64	51	58	45	52
8			74	60	50	54	54	50
21				68	57	57	60	51
40					59	66	53	55
30						50	55	42
59							42	65
68								36
63								

The soils associated with this community are Sombric Humo-Ferric Podzol (2), Sombric Ferro-Humic Podzol (2), Orthic Regosol (3), and Alpine Dystric Brunisol (1). Podzols predominate in the alpine sites, while regosols are the major soil class in the subalpine plots.

The soil texture results are shown in Table 19. Texture becomes coarser with depth. The A horizon samples are mainly loamy sands or sandy loams. The B horizon ranges from sandy loam to sand. Sands predominate in the C horizon. Plot 68, which occurs in the subalpine parkland, is a finer textured soil, all horizons being sandy loams.

Table 20 presents the soil chemical data for the association. The values for pH increase slightly with depth, but all

Table 19

Soil Texture

Juncus parryi Association

Plot No.	12	8	21	40	30	59	68	63
Ah Horizon								
Textural class	LS	LS	LS	SL	LS	SL	SL	LS
Sand (%)	83.2	71.8	82.0	55.4	79.6	68.8	59.8	78.0
Silt (%)	16.8	28.2	18.0	41.4	20.4	28.0	36.4	21.6
Clay (%)	0	0	0	3.2	0	3.2	3.8	0.4
B Horizon								
Textural class	S	LS	-	LS	LS	-	SL	-
Sand (%)	89.4	73.4	-	74.4	84.6	-	54.8	-
Silt (%)	10.6	26.6	-	25.6	15.4	-	42.4	-
Clay (%)	0	0	-	0	0	-	2.8	-
C Horizon								
Textural class	S	S	S	LS	S	S	SL	S
Sand (%)	94.8	93.4	85.6	83.2	90.2	88.4	57.8	87.2
Silt (%)	5.2	6.6	14.4	16.8	9.8	9.8	33.8	12.4
Clay (%)	0	0	0	0	0	1.8	8.4	0.4

Table 20

Soil Chemical Analysis

Juncus parryi Association

Plot No.	12	8	21	40	30	59	68	63
Ah Horizon								
pH	4.7	4.7	5.0	4.8	4.8	4.6	4.6	4.7
C (%)	8.4	15.1	7.9	11.4	6.1	10.5	15.0	7.2
OM (%)	14.4	26.0	13.6	19.7	10.5	18.1	25.9	12.3
N (%)	0.5	0.8	0.8	0.7	0.1	0.6	0.7	0.3
C/N	16.	18.	10.	17.	122.	18.	20.	21.
P (ppm)	6.	13.	18.	9.	10.	17.	14.	7.
Ca (me/100g)	0.29	1.03	0.62	0.11	0.25	0.95	0.12	0.37
Mg (me/100g)	0.05	0.20	0.07	0.07	0.03	0.25	0.05	0.05
Na (me/100g)	0.14	0.12	0.14	0.07	0.12	0.13	0.14	0.14
K (me/100g)	0.14	0.10	0.13	0.09	0.01	0.37	0.10	0.17
CEC (me/100g)	27.5	31.6	38.4	26.4	34.1	28.4	41.2	26.9
B Horizon								
pH	4.9	5.2	-	5.0	4.9	-	5.2	-
C (%)	4.5	8.1	-	7.7	5.7	-	4.0	-
OM (%)	7.7	14.0	-	13.3	9.7	-	6.9	-
N (%)	0.3	0.5	-	0.5	0.3	-	0.2	-
C/N	16.	15.	-	16.	20.	-	19.	-
P (ppm)	5.	6.	-	10.	15.	-	6.	-
Ca (me/100g)	0.05	0.38	-	0.05	0.22	-	0.13	-
Mg (me/100g)	0.04	0.04	-	0.03	0.02	-	0.01	-
Na (me/100g)	0.14	0.12	-	0.05	0.13	-	0.14	-
K (me/100g)	0.08	0.03	-	0.01	0.00	-	0.04	-
CEC (me/100g)	8.9	12.0	-	22.4	13.2	-	7.3	-
C Horizon								
pH	5.1	5.1	5.2	5.1	5.1	4.7	5.1	5.0
C (%)	1.7	2.9	2.1	4.1	3.3	5.1	2.2	2.2
OM (%)	2.9	4.9	3.6	7.1	5.6	8.7	3.8	3.8
N (%)	0.1	0.2	0.1	0.3	0.2	0.3	0.1	0.2
C/N	17.	15.	16.	15.	19.	16.	18.	14.
P (ppm)	3.	5.	6.	6.	5.	11.	5.	2.
Ca (me/100g)	0.32	0.08	0.91	0.23	0.26	0.29	0.27	0.44
Mg (me/100g)	0.01	0.04	0.01	0.02	0.01	0.05	0.01	0.03
Na (me/100g)	0.13	0.13	0.31	0.06	0.13	0.10	0.14	0.11
K (me/100g)	0.09	0.03	0.01	0.00	0.00	0.13	0.03	0.18
CEC (me/100g)	4.6	6.3	7.3	24.9	20.0	17.0	8.9	7.0

Fig. 8. Juncus parryi Association, Plot 8.

values are strongly acidic. Organic matter and nitrogen decrease steadily with depth. Carbon:nitrogen ratios are generally narrow. There is a very low amount of nitrogen in the Ah horizon of plot 30, thus making the carbon:nitrogen ratio very wide. Phosphorus, magnesium, potassium and cation exchange capacity all decrease in quantity with depth; calcium and sodium are variable, decreasing in some plots and increasing in others. Carbon:nitrogen ratios, phosphorus and cation exchange capacity are generally similar among the various plots; the exchangeable cations vary widely.

Antennaria lanata Association

(Ref. Tables 21, 22, 23, 24, 25; Fig. 9, 10)

Characteristic Combination of Species

Antennaria lanata
Salix cascadensis
Gentiana glauca
Polytrichum piliferum

This association occurs at the base of slopes, on ridges and on slopes in the alpine and low alpine areas. The relief shape is hummocky. Exposure is variable, and the slopes are very gentle, ranging from 0-9%. Most of the ground surface is covered by humus (64-90%), with very few rocks (0-12%). There is usually some mineral soil exposed (0-35%). Erosion varies from none to strong. The hygrotope is mesic.

The herb layer is predominant, covering 70-85% of the area. The D layer is fairly well-developed, although there are few species. Coverage is 40-60%.

Antennaria lanata is the dominant species, with an average

Table 21

General Environment

Antennaria lanata Association

Plot No.	3	4	16	32
Elevation (ft.)	7600	7575	7475	7450
Physiography				
Landform	ridge	base of slope	base of slope	slope
Relief shape	hummocky			
Exposure	neutral	NE	neutral	S
Slope gradient (%)	0	1	0	9
Layer Coverage (%)				
C layer	70	70	85	85
D layer	50	40	40	60
Plot Coverage (%)				
Humus	64	73	90	88
Mineral soil	35	25	10	0
Rock	1	2	0	12
Soil				
Hygrotope	mesic			
Erosion	strong	moderate	none	none
Horizon depth (in.)				
L-H	-	-	2 1/2-0	-
Ah	0-6	0-3	0-2	0-2 1/2
B	Bm 6-10	Bfh 3-15	Bm 2-13 1/2	Bhf 2 1/2-8 1/2
C	Cgj 10-19	C 15-21	13 1/2+	C1 8 1/2-16 1/2
	Cg 19+	Cg 21+		C2 16 1/2+
Classification	Gleyed Alpine Dystric Brunisol	Gleyed Sombric Humo-Ferric Podzol	Alpine Dystric Brunisol	Mini Ferro-Humic Podzol

Table 22

Antennaria lanata Association

		3	4	16	32	Presence	Aver. Species Significance
	Plot No.	3	4	16	32		
	Plot Size (m^2)	10	10	10	10		
	Extent of type (m^2)	40	126	196	24		
	Elevation (ft.)	7600	7575	7475	7450		
	Altitudinal area	A	A	LA	LA		
	C layer						
1	Antennaria lanata	8.3	8.3	7.3	7.2	V	8
2	Salix cascadensis	5.2	5.2	7.2	5.2	V	6
3	Carex pyrenaica	4.2	3.2	5.2	3.2	V	4
4	Gentiana glauca	3.1	2.1	4.2	4.2	V	4
5	Phyllodoce empetriformis	1.2	4.2	1.2	4.2	V	3
6	Sibbaldia procumbens	2.1	3.2	3.2	3.2	V	3
7	Juncus parryi	1.1	2.2	2.2	2.2	V	2
8	Luzula spicata	2.1	1.1	2.1	1.1	V	1
9	Luzula wahlenbergii	+.+	1.1	1.2	2.2	V	1
10	Carex spectabilis	1.2	5.3	-	6.2	IV	5
11	Agrostis variabilis	3.1	-	4.2	2.2	IV	3
12	Arenaria obtusiloba	2.1	1.1	2.1	-	IV	1
13	Festuca brachyphylla	-	3.1	4.2	-	III	2
14	Erigeron peregrinus	-	1.1	-	3.2	III	1
15	Vaccinium scoparium	-	-	+.+	3.2	III	1
16	Carex phaeocephala	2.2	-	1.2	-	III	+
17	Arenaria capillaris	-	1.1	+.1	-	III	+
	D layer						
	Bryophytes						
18	Polytrichum piliferum	Dh 7.3	7.3	6.2	5.2	V	6
19	Lophozia alpestris	Dh -	+.+	+.+	2.1	IV	+
20	Barbilophozia hatcheri	Dh -	+.+	-	2.1	III	+
21	Ceratodon purpureus	Dh -	+.+	-	2.1	III	+
22	Pohlia nutans	Dh -	1.1	1.1	-	III	+
	Lichens						
23	Lecidea granulosa	Dh 3.1	3.1	5.2	5.2	V	4
24	Cladonia carneola	Dh 2.1	3.1	1.2	4.2	V	3
25	Solorina crocea	Dh 2.1	2.1	3.2	3.2	V	3
26	Cetraria islandica	Dh 5.2	2.1	2.1	-	IV	3
27	Cladonia ecmocyna	Dh 2.1	-	1.2	4.2	IV	2
28	Cetraria ericetorum	Dh -	-	4.2	3.2	III	2
	Total Species (incl.sporadics)	21	26	31	31		

Sporadic Species

C layer

29	Deschampsia atropurpurea	32(1.1)
30	Hieracium gracile	32(2.2)
31	Juncus drummondii	16(2.2)
32	Juniperus communis	32(+.+)
33	Luzula arcuata	3(+.1)
34	Picea engelmannii	32(+.+)
35	Poa cusickii	4(3.1)
36	Vaccinium caespitosum	32(6.2)

D layer

Bryophytes

37	Bryum capillare	16(1.1)
38	Bryum sp.	16(1.1)
39	Cephaloziella subdentata	16(+.+)
40	Dicranum scoparium	4(1.1)
41	Kiaeria blyttii	32(4.2)
42	Orthocaulis floerkii	16(1.1)
43	Paraleucobryum enerve	32(3.2)
44	Polytrichadelphus lyallii	3(1.+)
45	Polytrichum formosum	16(3.1)
46	Polytrichum ? juniperinum	32(5.2)
47	Polytrichum norvegicum	4(3.1)

Lichens

48	Peltigera canina	32(1.1)
49	Stereocaulon alpinum	16(1.2)

species significance of 8. The other species of high cover in the C layer is Salix cascadensis, with an average species significance of 6. Other constant species are Carex pyrenaica, Gentiana glauca, Phyllodoce empetriformis, Sibbaldia procumbens, Juncus parryi, Luzula spicata and Luzula wahlenbergii. Gentiana glauca is considered as a characteristic species because of its exclusiveness for this association. In the D layer, Polytrichum piliferum is the constant bryophyte, with an average species significance of 6. Constant lichens include Lecidea granulosa, Cladonia carneola and Solorina crocea, all with low cover values.

Table 23 shows the floristic similarity indices for the four plots making up the association. Plots 3 and 4, in particular, have a very high similarity.

Table 23

Floristic Similarity Indices for the Antennaria lanata Association

	3	4	16	32
3		80	63	49
4			59	57
16				54
32				

The soils of this community are classed as Alpine Dystric Brunisols, Gleyed Sombric Humo-Ferric Podzol and Mini Ferro-Humic Podzol.

Table 24

Soil Texture

Antennaria lanata Association

Plot No.	3	4	16	32
Ah Horizon				
Textural class	SL	SiL	SL	LS
Sand (%)	55.6	47.2	60.4	72.0
Silt (%)	44.4	50.0	37.2	28.0
Clay (%)	0	2.8	2.4	0
B Horizon				
Textural class	SL	SiL	SL	SL
Sand (%)	55.2	46.4	57.2	69.6
Silt (%)	43.2	51.0	40.4	30.4
Clay (%)	1.6	2.6	2.4	0
C Horizon				
Textural class	LS	S	S	LS
Sand (%)	83.3	94.7	94.0	81.3
Silt (%)	16.5	5.3	5.6	18.5
Clay (%)	0.2	0	0.4	0.2

Table 25

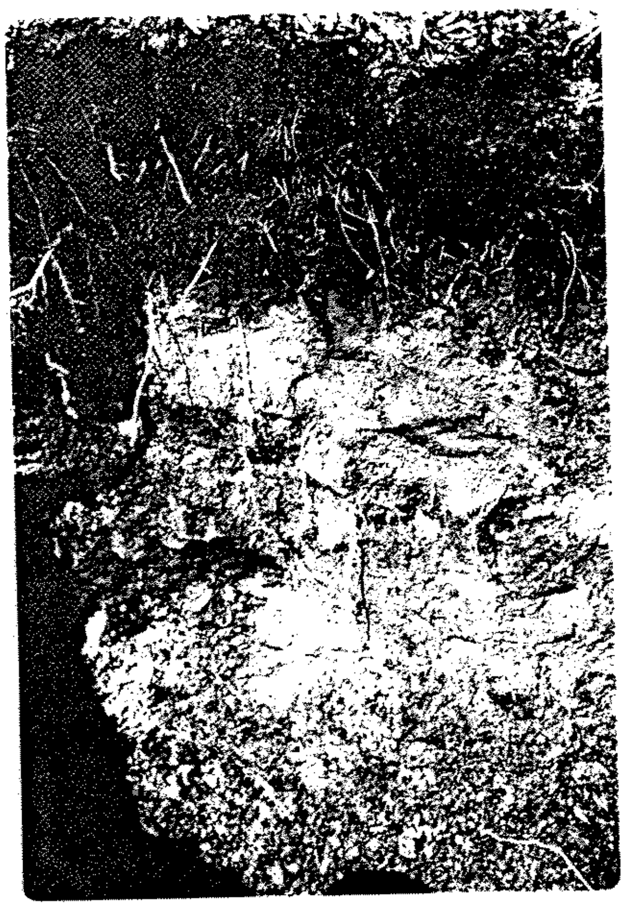
Soil Chemical Analysis

Antennaria lanata Association

Plot No.	3	4	16	32
L-H Horizon				
pH	-	-	4.2	-
C (%)	-	-	19.3	-
OM (%)	-	-	33.3	-
N (%)	-	-	1.5	-
C/N	-	-	13.	-
P (ppm)	-	-	6.	-
Ca (me/100g)	-	-	1.66	-
Mg (me/100g)	-	-	0.31	-
Na (me/100g)	-	-	0.34	-
K (me/100g)	-	-	0.78	-
CEC (me/100g)	-	-	29.9	-
Ah Horizon				
pH	4.9	5.0	4.5	4.5
C (%)	13.0	10.9	13.0	14.0
OM (%)	22.3	18.7	22.3	24.1
N (%)	0.8	0.7	0.1	0.9
C/N	16.	16.	118.	15.
P (ppm)	15.	20.	9.	18.
Ca (me/100g)	0.14	0.16	0.19	0.76
Mg (me/100g)	0.08	0.06	0.08	0.24
Na (me/100g)	0.16	0.13	0.17	0.13
K (me/100g)	0.16	0.12	0.17	0.30
CEC (me/100g)	32.5	71.3	18.3	78.7
B Horizon				
pH	5.8	5.4	5.0	5.1
C (%)	2.8	5.2	6.6	7.6
OM (%)	4.8	8.9	11.4	13.1
N (%)	0.2	0.4	0.5	0.5
C/N	13.	13.	14.	17.
P (ppm)	8.	7.	3.	11.
Ca (me/100g)	0.13	0.19	0.10	0.03
Mg (me/100g)	0.02	0.02	0.02	0.02
Na (me/100g)	0.16	0.18	0.15	0.11
K (me/100g)	0.04	0.04	0.06	0.00
CEC (me/100g)	21.8	22.8	9.9	31.5
C Horizon				
pH	5.9	5.5	5.1	5.2
C (%)	0.8	0.9	1.3	1.9
OM (%)	1.4	1.6	2.2	3.2
N (%)	0.1	0.1	0.1	0.1
C/N	16.	18.	16.	19.
P (ppm)	7.	4.	3.	9.
Ca (me/100g)	0.43	0.33	0.03	0.22
Mg (me/100g)	0.02	0.01	0.01	0.01
Na (me/100g)	0.12	0.10	0.13	0.10
K (me/100g)	0.02	0.02	0.07	0.00
CEC (me/100g)	21.5	6.8	4.6	15.2

Fig. 9. *Antennaria lanata* Association, Plot 3.

Fig. 10. Soil profile of *Antennaria lanata* Association, Plot 3. This soil is classified as a Gleyed Alpine Dystric Brunisol with Ah, Bm, Cgj and Cg horizons.



Soil texture is coarser in the C horizon than in the A or B horizons. The A horizon samples range from silt loam to loamy sand. The B horizon is predominantly loamy sand. The C horizon soils are classed as sands and loamy sands.

The soil chemical data are given in Table 25. The pH values increase with depth and are all acidic. Organic matter and nitrogen decrease with depth. Carbon:nitrogen ratios are narrow. The percentage of nitrogen in the Ah horizon of plot 16 is very low; thus, the carbon:nitrogen ratio is extremely wide. Phosphorus, cation exchange capacity and exchangeable cations decrease in amount with depth, with the exception of calcium, which increases in half the plots. Carbon:nitrogen ratios, phosphorus, sodium and magnesium (the latter in the B and C horizons) are similar among the four plots, while cation exchange capacity, calcium and potassium are variable.

Phyllodoce empetriformis - Antennaria lanata Association

(Ref. Tables 26, 27, 28, 29, 30; Fig. 11, 12, 13, 14)

Characteristic Combination of Species

Phyllodoce empetriformis
Antennaria lanata
Vaccinium scoparium
Polytrichum piliferum
Dicranum scoparium
Lecidea granulosa

This association occurs mainly on slopes, in the alpine, low alpine and subalpine parkland areas. Relief shape varies from hummocky to straight. Exposure is variable, and slope gradients range from 5 to 28%. Humus covers most of the ground surface, from 58-98%. There is very little mineral soil

Abstract

During the summers of 1968 and 1969, a plant ecological study was carried out on Big White Mountain, in the Okanagan Highland of southern British Columbia. The main objectives of the research were to produce an ecosystematic classification of the vegetation, and to determine the environmental factors important in differentiating the plant communities.

The vegetation was studied by the phytosociological methods of Braun-Blanquet, as modified by Krajina. A number of environmental features were noted for each plot, and soil samples were collected by horizon. Physical and chemical analyses of the soils were done in the laboratory.

Fourteen plant associations, with nine variations, were distinguished in the study area. These communities were compared with one another, using an index of floristic similarity. In general, there is a very low degree of similarity among the communities, thus supporting the initial classification system. The communities were compared with those described in other alpine and subalpine areas.

Trees occurring in the subalpine parkland were found to be much older than the krummholz forms found in the alpine area. It was suggested that there has been a recent migration of tree species into the alpine area. The occurrence of conifer seedlings in alpine and timberline communities was presented. No conifer seedlings were found in the tree island communities.

The soils were classified according to the Canadian system of soil classification. Four orders are represented in the research area: Brunisolic, Regosolic, Podzolic and Gleysolic.

The soils are generally shallow, with weak horizon development. Important chemical properties are the acidic pH, narrow carbon: nitrogen ratios, low cation exchange capacities, and very low amounts of exchangeable cations.

In an analysis of environmental variables, the communities were grouped according to hygrotope. The environmental data were summarized for each group. From an analysis of variance, all the factors were significant either at the 1% or 5% level, except relief. Based on Duncan's New Multiple Range Test, each community was discussed, mentioning the environmental factors which were found to be significant in differentiating it. It was concluded that general environmental factors (with hygrotope the most important) are more significant in distinguishing the communities than the physical and chemical soil properties.

Detailed soil moisture data were presented for a number of alpine and subalpine communities. Several of the communities were found to undergo soil moisture stress.

In the zonation of the research area, the subalpine parkland area was placed in the Engelmann Spruce - Subalpine Fir Zone. The alpine and low alpine areas constitute the Alpine Zone. The timberline vegetation is composed of the subalpine parkland and parts of the low alpine area. The alpine zone of Big White Mountain is not as well developed as it is in the coastal area or the Rocky Mountains. It was concluded that much further work needs to be done in order to properly characterize the alpine zone in British Columbia.

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Finally, I would like to thank my husband, Frank, without whose encouragement and support this research would not have been completed.

1. Introduction

The ecology of the alpine region has been little studied in Canada, essentially due to the inaccessibility and the harsh environmental conditions of such areas. In British Columbia, Archer (1963) contributed a synecological study in Garibaldi Park. Krajina (1959, 1965, 1969) has described some general characteristics for the alpine zone. Fraser (1970) studied successional trends on recently deglaciated terrain in Garibaldi Park. The timberline area has been more fully documented in the work of Peterson (1964) and Brooke (1966), who described the vegetation and environment in the parkland subzone of the coastal subalpine zone. Brink (1959) discussed the subalpine forest-heath ecotone in Garibaldi Park. A later work by Brink (1964) dealt with plant establishment in alpine and subalpine regions. Brief mention of the alpine zone in the coastal area has been made by Calder and Taylor (1968) in the Queen Charlotte Islands, and Carl (1944) and Hardy (1955) in the Forbidden Plateau area of Vancouver Island. No detailed ecological work has previously been done in the interior of British Columbia. Cooper (1916) studied successional trends in the subalpine zone of the Mount Robson area, and mentioned the occurrence of an alpine zone. Munro and Cowan (1944) in Kootenay National Park, and Carl and Hardy (1945) in the Columbia Valley briefly discussed alpine vegetation. Raup (1934, 1945) made notes of alpine and timberline vegetation in northern British Columbia. In Alberta, a general description of alpine vegetation was given by Moss (1955). A detailed study was carried out by the author (Beder, 1967).

Recently, Bryant and Scheinberg (1970) studied the interaction of vegetation and frost activity in an alpine fellfield.

A great amount of work has been done in the United States, much of the emphasis being on autecological studies. Important works in this field are Billings and Bliss (1959), Billings and Mooney (1968), Bliss (1956, 1962), Mooney and Billings (1961), Mooney (1963), Spomer (1964), and Spomer and Salisbury (1968). Many valuable synecological studies have also been done. Bliss (1963) worked on alpine communities in the Presidential Range of New Hampshire. Marr (1961) has described the various ecosystems in the Front Range in Colorado. Bamberg and Major (1968) worked in several alpine regions in Montana. Daubenmire has discussed alpine timberlines (1955) and vegetational zonation in the Rocky Mountains (1943). Other discussions of timberline are given in Griggs (1938, 1946). Wardle (1965) compared timberlines in North America with those in New Zealand. A number of recent studies have been done in Washington and Oregon. Franklin and Trappe (1963) and Franklin and Dyrness (1969) described alpine and subalpine meadow communities. Franklin et al. (1966) discussed invasion of subalpine meadows by trees in Mount Rainier National Park. Douglas (1969) worked on subalpine tree groups in the North Cascade Mountains. The upper subalpine zone in the Olympic Mountains was studied by Kuramoto (1968) and by Fonda and Bliss (1969).

The mountain communities of Scotland have been studied by Poore and McVean (1957), and McVean and Ratcliffe (1962). Other British ecologists who have dealt with alpine vegetation are Tansley (1949), Pearsall (1950), and Watt and Jones (1948). In

Australia, Costin (1957) and McVean (1969) have described the alpine vegetation. Billings and Mark (1961), and Mark and Burrell (1966) worked in alpine areas of New Zealand. In central Europe, the Zürich-Montpellier school has studied the classification and ecological relations of communities in the alpine region (Braun-Blanquet and Jenny, 1926; Braun-Blanquet, 1948). Physiological ecology studies include those of Tranquillini (1963, 1964). Krajina (1933) and Hadač (1969), working in Czechoslovakia, and Szafer, Pawlowski and Kulczynski (1923) and Pawlowski (1935), working in Poland, have studied the high mountain vegetation of the Tatra Mountains. In Scandinavia, Nordhagen (1936) studied the subalpine-alpine vegetation of Norway. Dahl (1956) studied the vegetation of Rondane, in southern Norway. Gjaerevoll (1956) has worked on the Scandinavian alpine snowbeds. Detailed alpine ecological work has been done in the U.S.S.R. by many botanists (Sukachev, 1965).

Many of the ecological studies mentioned above also deal with alpine and subalpine soils. For British Columbia, Farstad and Rowles (1960) briefly mentioned several alpine soils. Recently, detailed work has been done by Sneddon (1969) and van Ryswyk (1969). Baptie (1968) studied the soils of an alpine valley in Alberta. The Canadian system of soil classification (Canada Soil Survey Committee, 1970) discussed the distribution of alpine soils. The major segment of information for North America is derived from the work of Retzer (1956, 1962, 1965) in the Rocky Mountains, Nimlos and McConnell (1962, 1965) in Montana, and Johnson and Cline (1965) in Colorado. Kubiena (1953) is the basic reference work for European soils. More recently, Romans et al. (1966) worked on alpine soils in Scotland. In Australia, alpine soils have been described by Costin (1955).

As can be seen from this brief literature review, much work is being done throughout the world, both from synecological and autecological approaches. The original aim of the present study was to provide detailed synecological information on alpine ecosystems in the interior of British Columbia. Although Big White Mountain has only a very limited area of alpine vegetation, it was selected because of its accessibility. The project was then expanded to include the timberline area of the mountain. This ecotone area of timberline, while interesting in itself, is important in an understanding of the alpine zone. The research was carried out during the summers of 1968 and 1969, with the following objectives: 1) to provide data on vegetation and environment in an alpine-timberline area, 2) to produce an ecosystematic classification of the alpine and timberline vegetation, and 3) to elucidate the environmental factors responsible in the formation of different plant communities.

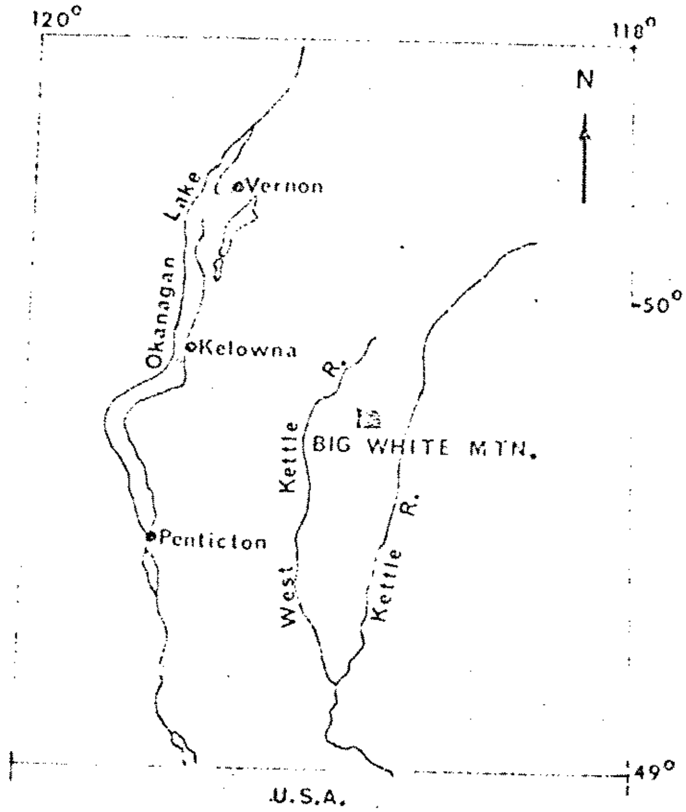
2. Description of Study Area

A. Geographical Location and Physiography

Big White Mountain, with an elevation of 7603 feet, is located approximately thirty miles southeast of Kelowna, in the Okanagan Highland, a subdivision of the Interior Plateau (Fig. 1 and 2). Access is afforded by a gravel road from Highway 33 to the local ski area at 6050 feet. The following summary is based on Holland (1964). The Okanagan Highland lies between the Monashee Mountains to the east and the Thompson Plateau on the west. It consists of rounded mountains and ridges, and gentle slopes. During the Pleistocene, ice covered the highland, but erosion was not great. There was some rounding of surfaces, but the main effect was the deposition of drift. A large part of the area is underlain by Shuswap gneisses. On Big White Mountain, the main rock types are granite and porphyritic granite, which comprise the Valhalla Intrusions, dated to the Lower Cretaceous (Little, 1957). The highland is drained and dissected by the Okanagan and Kettle Rivers and their tributaries. As seen in Fig.1, Big White Mountain is situated between the Kettle and West Kettle Rivers. The valley of the Kettle River actually forms the eastern boundary of the Okanagan Highland.

B. Climate

There are no climatic stations in the alpine and timberline region of the research area. None were set up during the course of study due to the logistic difficulties involved. Table 1 summarizes some approximate climatic data for the general area, based on a number of A.R.D.A. maps (British Columbia, Canada Land Inventory). A few differences between these data and those



Scale 1 inch = 30 miles
Based on B.C. Dept. of Mines & Petroleum Resources
Map No. 1JPS

Fig. 1. Location of Big White Mountain.

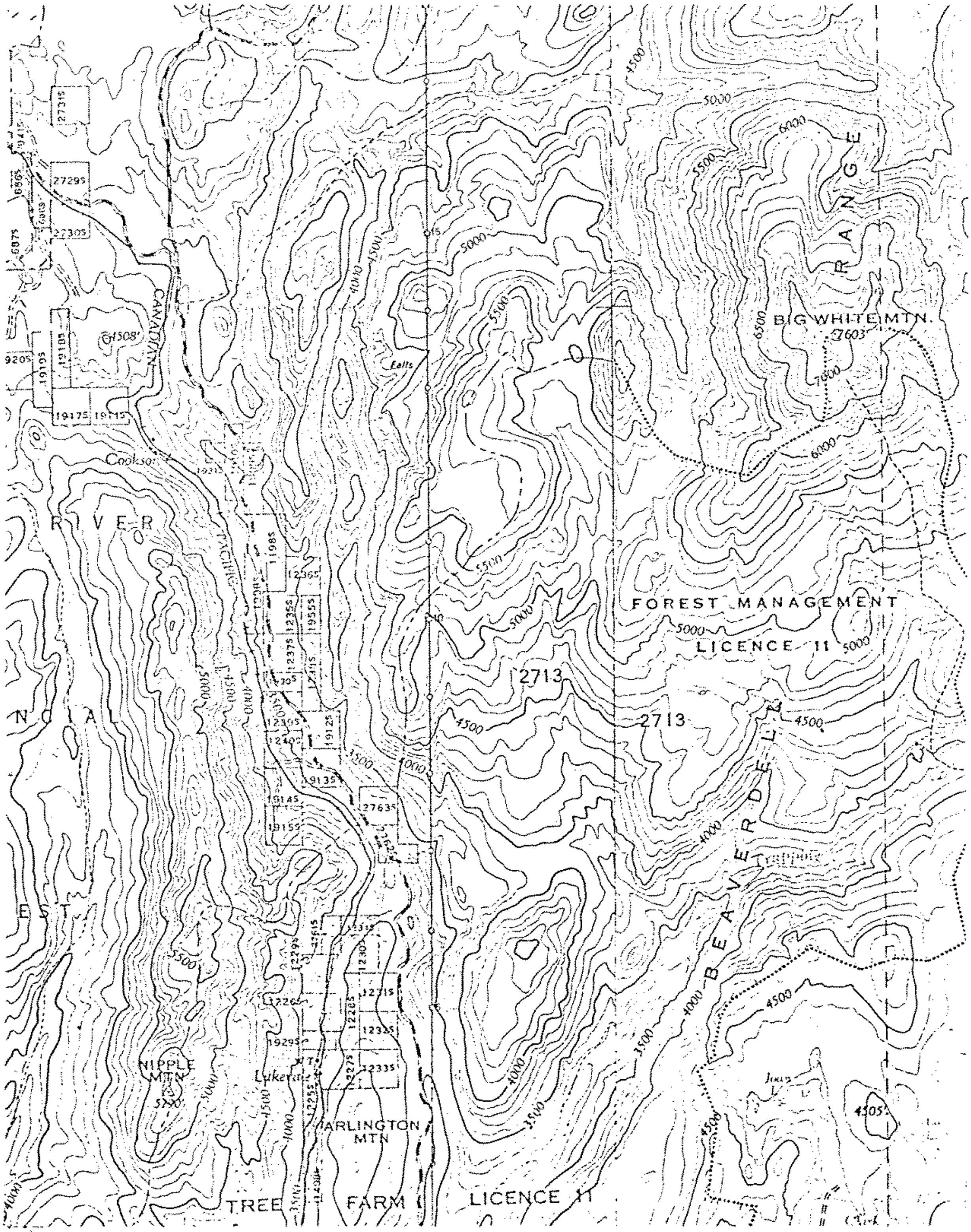


Fig 2. Topographic map of Big White Mountain and surrounding area.

Scale: 1 inch = 2 miles.

Taken from B.C. Department of Lands and Forests, National Topographic Series, Sheets 82 E/NW and 82 E/NE.

presented by Krajina (1959, 1965, 1969) for the Alpine Tundra Zone are the higher mean July temperature (60°F compared to 44-52°F), higher absolute maximum temperature (95°F compared to 70-83°F) and longer frost-free period (60 days compared to less than 25) at Big White.

Temperature and precipitation have been recorded sporadically at an elevation of 6050 feet on Big White. This altitude corresponds to the Engelmann Spruce - Subalpine Fir Zone of Krajina (1965). Tables 2 and 3 present the available information (British Columbia Department of Agriculture, 1965-1968). From these data, it appears that Big White has a maritime precipitation pattern with a winter maximum and summer minimum.

Snow is a very important factor in alpine and timberline areas. Snow may fall during any summer month. In 1969, there were snowfalls on June 28, July 4 and July 6. In 1968, it snowed on August 18. Impassable road conditions during the spring thaw of 1969 prevented any attempt at obtaining snow depth measurements. When the summer field season began during the last week of June, most of the snow had disappeared, with the exception of late-lying snowbanks. The British Columbia Department of Lands, Forests and Water Resources operates a number of snow courses throughout the province. One of these is located on Big White at an elevation of 5500 feet. Measurements have been made since 1966 (British Columbia Department of Lands, Forests and Water Resources, 1966-1969). In 1966, the maximum snow depth of 48.1 inches occurred at the end of February. By the end of May, the snow depth was 7.8 inches. The corresponding figures for 1967 are 71.6 inches at the end of March

Table 1

Some Climatic Data for the Big White Area

		Period of observations
Mean January temperature	15°F	1950-1964
Mean July temperature	60°F	1950-1964
Absolute minimum temperature	-40°F	1930-1964
Absolute maximum temperature	95°F	1930-1964
Average frost-free period	60 days	1950-1964
Mean annual precipitation	30-40 in.	1930-1964
Average precipitation May through September	10 in.	1930-1963
Mean annual snowfall	150-200 in.	1963-1964

Table 2

Mean Monthly Temperature (°F) for Big White Mountain (elev. 6050 ft.)

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1965	-	-	19	-	-	48	55	54	42	41	-	19
1966	17	21	22	33	44	45	-	-	50	35	25	22
1967	20	23	22	29	39	-	55	62	54	33	25	17
1968	16	29	28	28	41	43	-	-	-	-	-	-

Table 3

Precipitation (in.) for Big White Mountain (elev. 6050 ft.)

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1965	-	-	3.80	-	-	0.40	1.92	5.65	2.55	0.86	2.57	5.83	-
1966	4.58	5.43	2.65	3.45	2.51	3.63	2.91	-	1.58	2.90	7.38	8.26	-
1967	11.03	6.39	8.07	6.54	2.41	1.65	1.25	0.53	1.40	9.91	3.39	10.16	62.73
1968	7.05	3.35	4.89	9.32	4.05	4.88	-	-	-	-	-	-	-
	22.66												
$\bar{x}$	7.55	3.95	4.85	6.48	2.93	2.74	2.03	3.03	1.84	4.56	4.45	8.08	52.57

and 35.0 inches at the end of May; for 1968, 59.5 inches at the end of March and 26.0 inches at the end of May; for 1969, 64.0 inches at the end of February and 9.8 inches at the end of May. It must be remembered that the snow depths in the research area, which is approximately 2000 feet higher than the snow course, would be substantially greater. Winter snowfall at the 6050 ft. station on Big White has been reported as being 270.9 inches for the 1965-1966 winter and 479.9 inches during the 1967-1968 winter (British Columbia Department of Agriculture, 1966, 1968). The latter figure seems unusually high, since Hollyburn Ridge in the coastal subalpine mountain hemlock zone averages only 301.5 inches (British Columbia Department of Agriculture, 1966).

C. Vegetation

The portion of Big White which was studied ranged in altitude from ca.7100 to 7600 feet. Three altitudinally-delimited areas have been distinguished: alpine (ca.7500-7600 feet), low alpine (ca.7400-7500 feet), and subalpine parkland (ca.7100-7400 feet). The subalpine parkland and parts of the low alpine areas constitute the timberline vegetation, which is an ecotone between the closed subalpine forest (occurring below 7100 feet on Big White) and the alpine region. A more detailed discussion of zonation is presented in section 8.

Tree species present in the area are Abies lasiocarpa[1], Picea engelmannii, Pinus contorta var. latifolia and Pinus albicaulis. The two species of pine are rare on the mountain.

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1 Authorities of botanical names are listed in Appendix 1.

There seems to be no evidence of recent fire in the study area. However, examination of a core from a subalpine fir in the parkland area revealed that the tree had been burned on one side. This was possibly due to a lightning strike. No evidence of fire was noted from another fir in the same tree island.

Fourteen plant associations have been distinguished in the present study. Their habitats vary from dry ridge tops and rock outcrops to snowpatches and seepage slopes. Although there are few species of bryophytes and lichens present in the area, they constitute an important part of some communities.

D. Soils

Four orders of the Canadian system of soil classification (Canada Soil Survey Committee, 1970) are represented in the study area - Brunisolic, Regosolic, Podzolic and Gleysolic. None of the soil great groups or subgroups are restricted to a particular community.

The Brunisolic Order is represented by the Alpine Dystric Brunisol subgroup, which occurs over a wide range of habitat conditions, from ridges and heather communities to snowpatches and seepage slopes. Orthic Regosols are also in the above-mentioned habitats. The Podzolic Order is dominated by Sombric Humo-Ferric Podzols and Sombric Ferro-Humic Podzols. Sombric Humo-Ferric Podzols are mainly in heather communities and on rocky slopes, while Sombric Ferro-Humic Podzols predominate in tree islands, as well as on rocky slopes. Of infrequent occurrence are Mini Ferro-Humic Podzols and an Orthic Humic Podzol. All the podzolic soils lack an Ae horizon. The Gleysolic Order is represented mainly by Rego Humic Gleysols, and less frequently by Fera Humic Gleysols, Orthic Humic Gleysols and Rego Gleysols. These soils occur only on seepage slopes, in snowpatches and wet moss communities, and usually have an Ah-Cg horizon sequence.

The soils of Big White are generally shallow (less than one foot in depth), with weak horizon development (excluding the podzols). Soil development is proceeding slowly, and has not yet reached the point at which plant communities can be differentiated by their soil types.

The soils are all acidic, with a pH range from 4.1 to 6.3. This is to be expected, as the parent material is predominantly granite, which is an acidic rock. In some of the very shallow soils, organic matter moves downward and accumulates in the C horizon overlying a lithic contact. This occasionally creates a higher organic matter content in the C horizon than in the Ah horizon. The carbon:nitrogen ratios of the soils are generally narrow, ranging from 10 to 20; the value for cultivated soils is between 8 and 15. A narrow carbon:nitrogen ratio indicates that nitrogen should be available for higher plants. There are a number of cases in which the percentage of nitrogen is very low, thus creating a very wide carbon:nitrogen ratio. This can be due either to a loss of nitrogen during the air-drying of the soil sample, or to the presence of undecomposed organic matter in the case of an L-H or Ah horizon. Phosphorus ranges from a low of 2 ppm to a high of 28 ppm. Cation exchange capacities are generally low, ranging from 4.6 to 163.0 me/100 g. (the latter in an L-H horizon). Exchangeable cations are present in very low quantities. The ranges are as follows: calcium 0.02-7.40 me/100 g., magnesium 0.01-1.58 me/100 g., sodium 0.02-0.84 me/100 g., and potassium 0.00-3.26 me/100 g.

3. Methods

A. Vegetation Analysis

The general approach used accepts the fact that while vegetation can be considered to be continuous, it is still possible to distinguish discrete communities (Daubenmire, 1966, 1968). The communities were selected subjectively for homogeneity in vegetation and habitat. Transitional communities were not sampled, with one exception.

A single rectangular plot was used to sample each community. The plot sizes varied considerably, as a single plot size would not have adequately sampled many of the communities. The majority of the plots ranged from 10 to 30 m^2 in area. A total of 82 sample plots were analyzed.

The vegetation analysis was based on the Braun-Blanquet method as modified by Krajina (1933). Subjective estimations of species significance (coverage, combined with abundance, of a species in the plot) and sociability (amount of aggregation or spacing of the individuals of a species) were made separately for each species in the different layers. The percentage coverage of each layer was also estimated. The layers distinguished were:

B layer - shrubs, 20 cm.-10 m in height

C layer - herbs and dwarf shrubs, less than 20 cm. in height

D layer - bryophytes and lichens

E layer - epiphytes

The scales used for estimating species significance and sociability (after Krajina, 1933) are shown in Tables 4 and 5.

Table 4

Species Significance Scale

Class	Description	Midpoint (%)
+	Quite solitary, very low dominance (0-1%)	0.5
1	Seldom, very low dominance (1-2%)	1.5
2	Very scattered, low dominance (2-3%)	2.5
3	Scattered, low dominance (3-5%)	4.0
4	Covering 5-10% of the plot	7.5
5	Covering 10-20% of the plot	15.0
6	Covering 20-33% of the plot	26.5
7	Covering 33-50% of the plot	41.5
8	Covering 50-75% of the plot	62.5
9	Covering 75-less than 100% of the plot	87.0
10	Covering 100% of the plot	100.0

Table 5

Sociability Scale

Class	Description
+	Sociability 0 (individual plants)
1	Groups, up to 4x4 cm^2
2	Groups, up to 25x25 cm^2
3	Groups, up to 50x50 cm^2
4	Groups, up to 1/3 - 3/4 m^2
5	Groups, up to 1-2 m^2
6	Groups, up to 5 m^2
7	Groups, up to 25-50 m^2
8	Groups, up to 100 m^2
9	Groups, up to 200-250 m^2
10	Groups, up to 500 m^2

Collections were made of all vascular plants, bryophytes and lichens. These were later identified in the laboratory.

A number of environmental features were noted for each plot. These included elevation, exposure, slope, land form, wind influence, relief, erosion, and percentage cover of humus, mineral soil and rock. Relief describes the surface shape of the plot (convex, concave, hummocky or straight). Wind influence and erosion were assessed subjectively, on four-point scales (slight, moderate, strong, very strong for wind; none, slight, moderate, strong for erosion).

B. Soil Analysis

One soil pit was dug in each plot, and the horizons described for depth and colour. Soil depth, rockiness, root distribution, and the presence of ground water were noted for each profile. A total of 230 soil samples were collected for physical and chemical analyses. The soils were then classified according to the Canadian system of soil classification (Canada Soil Survey Committee, 1970), based primarily on soil morphology observed in the field. Correlations of the Canadian system with the American, German and World classifications are presented in Appendix 2.

The soil samples were screened through a 2 mm. screen. All analyses, both physical and chemical, were done on the less than 2 mm. size fraction.

The physical properties determined were texture, moisture percentage, and water retention. Texture was done by the revised hydrometer method (Bouyoucos, 1962), using a reciprocal shaker to agitate the soil suspension. The textural classification followed that of the United States Department of Agriculture (sand = 2.00 to 0.05 mm., silt = 0.05 to 0.002 mm., clay = less than 0.002 mm.). The following abbreviations were used in the soil texture tables: S = sand, LS = loamy sand, SL = sandy loam, SiL = silt loam, L = loam. Moisture percentage was determined directly by collecting soil samples, weighing in the field, and oven-drying to constant weight at 105°C (moisture percentage thus calculated on a dry weight basis). A total of 122 samples were collected at three depths (0-3 in., 9-12 in., 15-18 in.), where possible, from 12 sites. Collections were made four times during the summer of 1969. Water retention was studied on the original samples collected by horizon, using a pressure plate and pressure membrane apparatus at 1/3 and 15 atmospheres to approximate field capacity and permanent wilting percentage (Richards and Weaver, 1943; Richards, 1965).

The chemical properties measured were pH, total carbon, total nitrogen, available phosphorus, exchangeable cations, cation exchange capacity, and oxalate-extractable iron and aluminum. The determinations of carbon, nitrogen, phosphorus, cation exchange capacity, iron and aluminum were done by Mr. B. von Spindler of the Department of Soil Science, University of British Columbia. The determinations of pH and exchangeable cations were done in the Department of Botany.

Analysis of pH was done using a Beckman model N pH meter and a Radiometer pH meter, number 24 on soil samples mixed to a paste consistency (Wilde and Voigt, 1955). A Leco total carbon analyzer was used to determine percent total carbon (Allison, Bollen and Moodie, 1965). These figures, when multiplied by the factor 1.72, were used to express percentage of organic matter. Total nitrogen, expressed as a percentage, was measured by the semimicro-Kjeldahl method (Bremner, 1960). Available phosphorus, expressed in parts per million, was determined colorimetrically by the dilute acid-fluoride extraction method of Bray and Kurtz (1945). Exchangeable cations (calcium, magnesium, sodium and potassium) were extracted by leaching soil samples with 1N ammonium acetate (pH adjusted to 7) and filtering gravimetrically (Peech et al., 1947). The concentrations of the cations were determined on a Perkin-Elmer, model 303, atomic absorption spectrophotometer. The results were expressed in milliequivalents per hundred grams of soil (me/100 g.). Cation exchange capacity (CEC), expressed in me/100 g., was analyzed by the KCl saturation method (Jackson, 1958). The methods for the determination of nitrogen, phosphorus, exchangeable cations and cation exchange capacity were those used by the Department of Soil Science, University of British Columbia. Percentages of iron and aluminum were determined only on a selected number of samples, in order to classify the sample as a Bf, Bfh, Bhf or Bm horizon. The samples were ground to 100 mesh and extracted following the acid ammonium oxalate procedure of McKeague and Day (1966). The concentrations of iron and aluminum in the extracts were determined by atomic absorption spectrophotometry. The iron and aluminum determinations are presented in Appendix 3.

C. Vegetation Synthesis

Association tables were made up for each association, showing variations separately, where present. The synthetic values of presence and average species significance were determined for each species. Presence is defined as the percentage of plots of a particular association in which a species occurs. The presence percentages were converted to classes as follows:

Presence Class	% of Plots
I	1-20
II	21-40
III	41-60
IV	61-80
V	81-100

In the cases of communities having fewer than four plots, the fraction of plots in which a species occurred was used instead of presence (eg. 2/3).

In calculating average species significance, the numbers of the species significance class were converted to percentages using the midpoint value (see Table 4). The average percentage was then converted back to a species significance class number.

In the association tables, the species are arranged by layers, by decreasing presence value within each layer, and by decreasing average species significance value within each presence class. Average species significance and sociability are represented by two numbers (eg. 4.2). Sporadic species (those occurring in only one plot) are listed separately by layers. The altitudinal area is indicated as A (alpine), LA (low alpine) or SP (subalpine parkland).

The degree of presence together with the average species significance indicates the importance of a species in the community. The species selected as the Characteristic Combination of Species are those with the highest values of both presence and average species significance, or species which are more or less restricted to the particular community.

A summary of presence and average species significance for the major species together with all the associations is provided in a synthesis table (Table 75). Only species occurring in at least one association with a presence of IV or V (or corresponding fraction) were used. In addition, a few species with a presence less than IV are listed, as they are characteristic species for some associations.

D. Computational Methods

i. Floristic Similarity Index

The Sørensen Index of Floristic Similarity was used to compare the different plots representing a particular association. The index calculated was that based on dominance, K_{sd} (Dahl, 1956), the formula being $K_{sd} = \frac{2c}{a+b} \times 100$

where a = sum of species significance values of all species in one plot

b = sum of species significance values of all species in second plot

c = sum of the lesser of the two species significance values of each species in common to both plots

The index ranges from 0 to 100, the highest value occurring when a = b = c.

This index was also used to compare the different communities with each other.

The indices were calculated using a computer program developed by Ream (1965) and modified by Mr. Stephen Borden of the Biology Data Centre, University of British Columbia.

ii. Environment Analysis

Among the twenty-three environmental variables dealt with in this study, twelve had values taken at several depths in the soil profile. Since all plots did not have the same horizons, comparisons on a horizon basis would not have been possible. It was thus considered that comparisons between plots and communities would be facilitated by having only one value per plot for each environmental factor. In order to do this, the variables were weighted by depth in the following manner (method by Mr. Stephen Borden, Biology Data Centre, University of British Columbia). For every variable which had been measured at several depths, the value for each horizon was multiplied by the depth of that horizon. The sum of these values for all horizons was divided by the total depth of the soil to give an average value for the plot.

A one-way analysis of variance between communities was done for each environmental variable, using the weighted values, where necessary.

In the analysis of environmental variables (section 7A), the terms "low", "medium" and "high" are based on the average (weighted or unweighted) value for each community.

4. Alpine and Timberline Communities

A total of fourteen plant associations, with nine variations, are distinguished in this study. They are described below, arranged along a general gradient of increasing moisture, from the xeric *Juniperus communis* Association to the subhydric *Drepanocladus exannulatus* Association.

An alternative, more conventional, method of arranging the communities would be to group them by altitudinal zone (alpine or subalpine). Within each of these groups, the communities could then be ordered by hygrotope. This method, however, is not well suited to the present study, since the communities do not segregate easily according to altitude. Much of the study area is actually an ecotone between the alpine and subalpine zones; thus, many of the communities are represented in both areas. To present the description of the communities in such a manner would be more confusing than instructive, since it would be repetitious. Hygrotope was found to be the most important factor in delimiting the communities (see section 7A), and is therefore used as the basis for the present arrangement. The altitudinal area (s) for each community is mentioned in the description. Despite using a moisture gradient in the present section, the altitudinal approach is still considered to be a useful one. The topographic and altitudinal relationships of the communities are summarized in section 7C.

In the description of each association, the floristic similarity indices of the plots comprising the association are given. This provides an objective check on the subjective classification, since plots within an association should have their highest similarities to each other rather than to a plot in another association. If the similarity values among all the plots of an association are high, the association is considered to be homogeneous. An association with a very large number of species is usually less homogeneous than one with few species. Few studies have utilized this technique, and thus the evaluation of the indices is strictly empirical. Nonetheless, the method is believed to be of considerable value.

Juniperus•communis Association

(Ref. Tables 6, 7, 8, 9, 10; Fig. 3)

Characteristic Combination of Species

Juniperus communis
Carex phaeocephala
Arenaria capillaris
Festuca brachyphylla
Polytrichum piliferum
Tortula ruralis
Peltigera malacea

This association occurs over rock outcrops on ridges and slopes in the low alpine and alpine areas. The relief shape is generally straight, and the exposure is usually southeast. Slope gradients range from 26 to 70%. Rock comprises 85-95% of the ground surface and humus 4-10%, with very little mineral soil exposed. No erosion was observed. The hygrotope is rated as xeric.

There is a well-developed B layer, ranging from 85-100% of the coverage, poorly developed C and D layers, and an occasional occurrence of an E layer. The C layer covers 10-35% of the