ALPINE SOIL AND PLANT COMMUNITY RELATIONSHIPS OF THE SUNSHINE AREA, BANFF NATIONAL PARK

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ABSTRACT

Significant relationships were noted between soils, plant community types, and environmental parameters in alpine ecosystems in the Sunshine area, Banff National Park. Alpine Dystric Brunisols with large amounts of amorphous colloids are found in stable slope positions under *Phyllodoce glanduliflora* and *Antennaria lanata* community types, while calcareous Orthic Regosols and Alpine Eutric Brunisols occur on wind-desiccated slopes under *Dryas hookeriana* and *Dryas hookeriana* - *Carex scirpoidea* community types. The *Anemone occidentalis* community type occurs on Cumulic Regosol soils that, on steep slopes, are greatly disturbed by mass wasting processes. *Eriophorum angustifolium*, *E. scheuchzeri*, and *Carex eleusinoides* community types occur on poorly-drained Gleysolic soils formed in ponding basins and seepage areas. Cumulic Regosols on recent alluvial deposits typically support a *Salix barrattiana* community type.

The study area, known locally as Sunshine , is located in the Canadian Rocky Mountains along the Continental Divide, approximately 16 km southwest of Banff townsite (Latitude 51°N, Longitude 115°40'W).

Sunshine is located in the eastern fringes of the Main Ranges structural sub-province of the Rocky Mountains (North and Henderson, 1954; Price, 1971). The study area is centered about a broad, undulating to rolling alpine divide. Geologic structure is complex, with many local folds and faults and northwest trending thrust sheets. Lithology is variable, consisting mainly of Precambrian shales and quartz-pebble conglomerates, and lower Paleozoic limestones, dolomites, and calcareous shales (Price, 1971). The area was glaciated during Pleistocene times and much of it is covered by a thin layer of locally-derived glacial drift. Volcanic ash deposits are common in the area. Ash from one deposit has been identified as Mazama in origin (Westgate[1], personal communication) which is dated at ca 6600 radio carbon years B.P. (Westgate, Smith, and Tomlinson, 1970). Recent deposits of alluvium and colluvium are of local occurrence. Soil creep has caused vertical and horizontal sorting of materials as well as mixing materials of different origin.

The climate is characterized by long, cold winters and short, cool summers, with a winter-high, summer-low distribution of precipitation. Freezing temperatures and snowfall may occur during any month. The nearest meteorological station on the Continental Divide is Lake Louise (1924 m AMSL), where the mean annual temperature is 0°C and more than half of the mean annual precipitation of 780 mm occurs as snow in the

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winter months. The Sunshine area is approximately 660 m higher than Lake Louise, therefore air temperatures are probably cooler with a greater percentage of precipitation falling as snow. A snow cover of 1 - 4 m persists for 8 to 9 months of the year with snow accumulation in depressions and on north- to east-facing mountain slopes often remaining throughout the year. Diurnal temperature changes are extreme, particularly in the summer months. High velocity winds are common.

Timberline in this area is at approximately 2240 m AMSL, varying with aspect, wind exposure, and substratum. Scattered individuals and islands of Picea engelmannii, Larix lyallii, and Abies lasiocarpa displaying krummholz form occur above this elevation.

The alpine ecosystems of the area are bounded at their lower limit by timberline at 2240 m AMSL and at their upper limit by the highest peak, Lookout Mountain, at 2969 m AMSL.

Most of the soils of the area have developed on thin glacial till and colluvial deposits, with bedrock often being within 50 cm of the surface. Coarse rock fragments and volcanic ash are abundant. The ash may occur as thin layers or lenses in the sola, but is often mechanically mixed in with the other soil materials.

Soil development is controlled chiefly by climate (Retzer, 1956, 1965; Duchaufour, 1965), with low temperatures inhibiting biological and chemical processes involved in organic matter transformations and mineral weathering. Soils are characterized by a high content of weakly decomposed organic matter in the surface horizons, weak granular structure, and silt loam textures with low (5-15%) clay content. These characteristics are common in alpine areas in North America (Retzer, 1965; Nimlos and McConnell, 1965; Baptie, 1968; Van Ryswyk, 1969; Sneddon, et al., 1972). Significant amounts of amorphous aluminum and iron compounds (acid-ammonium oxalate extraction) are present. Concentrations of 2 to 4% aluminum and iron are probably partly due to easily hydrolyzable volcanic ash present in the surface horizons; however, high amorphous contents have been reported for alpine soils without volcanic ash (Sneddon, et al., 1972). Podzolic soils, which generally have significant amorphous contents, have been reported in alpine areas by Bliss and Woodwell (1965), Johnson and Cline (1965), and Baptie (1968). The sola are generally acid to very acid (pH 4-5) with pH increasing with depth, especially when the parent material is calcareous.

METHODS

Fifty-five plots representing 16 plant community types were selected and soil and plant characteristics examined at each location. Soils were described and classified according to the System of Soil Classification For Canada (Canada Soil Survey Committee, 1970) and the 7th Approximation (Soil Survey Staff, 1960, 1967, 1968), and plants were identified according to Moss (1959).

Soil samples of major horizons for each pedon were subjected to physical and chemical laboratory analyses. Analytical methods were those used by the Alberta Soil Survey. Particle size analysis was done by the hydrometer method without pretreatment of the sample to remove carbonates; pH was of a 1:1 soil to water paste; organic matter content was measured by wet oxidation; aluminum and iron were extracted with acid ammonium oxalate; calcium carbonate equivalent was determined with a Smolik calcimeter; total nitrogen was determined by the Kjeldahl procedure; and available phosphorus was extracted by the Olsen bicarbonate method.

RESULTS AND DISCUSSION

Phyllodoce glanduliflora and Antennaria lanata community types are common on well-drained, stable slope positions in the undulating to rolling alpine area at Sunshine . Typical soils of these associations have fibrous, densely-rooted turfs underlain by dark-colored Ah horizons with high organic content, and reddish brown B horizons. The sola are of silt loam textures and contain a significant volcanic ash content (site T-13, table 2 and appendix). The area has a thin (1-2 m) veneer of sandy loam glacial till which may be calcareous or acidic depending on the local bedrock. The A and B horizons are strongly acid (pH 4-5) and both contain large amounts of amorphous aluminum and iron compounds, which are of higher concentration in the B horizons. The high content of amorphous sesquioxides appears to be largely a result of the volcanic ash content and while podzolic processes seem to be involved, these soils have been tentatively classified as Alpine Dystric Brunisols (Table 1); that is, turfy alpine soils with brownish sola and low base status, without eluviated (Ae) horizons.

Trottier (1972) reported the occurrence of Alpine Dystric Brunisols and Alpine Eutric Brunisols under Phyllodoce associations 75 km to the southeast at Highwood Pass in the Kananaskis area. Baptie (1968) described Humo-Ferric Podzols occurring under a P. glanduliflora-Vaccinium scoparium association 60 km to the northeast in Snow Creek Valley.

Contrasted to the Phyllodoce glanduliflora and Antennaria lanata areas are the steep, westerly-facing dip slopes of large thrust blocks. Limestones and dolomites are either exposed or covered with thin colluvial rubble in which lenses and layers of volcanic ash may be found. These slopes are exposed to drying winds and are either blown free of snow in winter or have a light snow cover that is removed fairly early in the spring. Dryas hookeriana and Dryas hookeriana-Carex scirpoidea community types grow on these slopes, forming a discontinuous ground cover. "Dryas stripes" and "Dryas-banked terraces" (Benedict, 1970) are common micro landforms. The soils are very calcareous and have black Ah horizons formed by the physical mixing of organic and mineral material (site T-7, Table 2 and Appendix). Surface pH may be as high as 7.9, with 25% calcium carbonate equivalent. The sola are thin (5-10 cm) with very gravelly silt loam textures and organic matter contents of 5-10%. Soil pedons are often buried and truncated and have discontinuous horizons due to soil creep and frost action. The majority of the soils have Ah, C, R horizon sequences and are classified as Lithic Regosols. Some of these soils have weakly developed B horizons and are classified as Lithic Alpine Eutric Brunisols (high base status soils).

Baptie (1968) and Trottier (1972) report soils of similar morphology under Dryas associations on exposed ridges that are acidic in the surface horizons.

Soils of more local occurrence in the study area include those developed on youthful alluvial deposits in meltwater drainage channels. Salix barrattiana communities commonly occur on soils that have Ah, C, Ah, C ... horizon sequences reflecting periodic sediment deposition. Sediments vary from very calcareous to acidic, depending on the source material. These soils are classified as Cumulic Regosols.

On steep (25-60%) northeast-facing slopes that are shaded and sheltered from the prevailing winds, snowbeds remain late in the year. The combination of high moisture from snowmelt, steep slope, and frost action causes soils on these slopes to be susceptible to mass wasting processes. The soil pedons are buried and truncated and often completely churned up as the stony till and colluvium moves downslope. Anemone occidentalis community types form a high percentage of ground cover. The soils have L (turf), Ah, AC, C horizon sequences in which deeply churned (15-30 cm) dark brown Ah horizons with about 10% organic matter are present (site T-21, Table 2 and Appendix). The deep Ah and dark AC horizons (4-8% organic matter) were formed by active soil creep causing churning and mixing of the sola. Buried turf and Ah horizons are present as discontinuous lenses and pockets to depths of 20 cm. These soils have also been classified as Cumulic Regosols. Soil classification at the subgroup level does not allow for differentiation of these soils from those Cumulic Regosols on alluvium.

On slopes where snowbeds persist until mid-August, Saxifraga lyallii communities form a sparse, discontinuous cover. Pedogenic development is minimal, with organic matter accumulating only in zones immediately under the plants and when B horizons are present they are weakly developed (site T-20, Table 2 and Appendix). Soil creep is active, with material continually moving downslope, disrupting and burying soil pedons. Soils on these slopes are classified as Orthic Regosols and Alpine Eutric Brunisols (Table 1).

Cassiope tetragona communities occur on fairly exposed ridges and north-facing slopes that are not strongly desiccated. Soils on these ridges and slopes were developed on a mixture of volcanic ash and colluvium or glacial till, deep (10-12 cm) black Ah horizons are common under a well-rooted turf layer, B horizons are weakly developed and often discontinuous and lenses of pure volcanic ash may be encountered in the lower A and B horizons. Horizon disturbance by soil creep processes is prominent.

These soils have been classified as Orthic Regosols, Cumulic Regosols (where creep is active), and Alpine Dystric Brunisols.

Soils under Kobresia myosuroides community types also have deep, dark black Ah horizons developed under compact, well-rooted turfs. However, these sites appeared to be more stable than those under Cassiope tetragona and the soils are base saturated (Alpine Eutric Brunisols). B horizons are dark brown to yellowish brown with low amounts of amorphous aluminum and iron compounds. The communities examined were developed on calcareous parent materials in southerly exposed positions.

There are several poorly-drained sites occupying basins and depressional areas where snowmelt ponds, and groundwater seepage and springs occur. Carex eleusinoides, Eriophorum scheuchzeri, and E. angustifolium community types occur in these wet areas. There is often an accumulation of water-deposited silts and clays and the water table is at or near the ground surface throughout the summer. Where plant cover is discontinuous or sparse, organic matter content is low, and the soils (Orthic and Rego Gleysols) characteristically have dull gray-blue colors indicating anaerobic conditions. Some of the wet soils sustain a more continuous plant cover and may have 10-15 cm of organic accumulation overlying Ahg horizons with 10-15% organic matter. These Humic Gleysols often have mottled subsurface horizons which indicate periods of less strongly reducing conditions, probably reflecting the slow seepage of oxygenated groundwater through the soils.

A feature of minor distribution but of considerable interest is the earth hummock pattern (Washburn, 1956). Four locations where hummocks occur were examined and in each case the hummocks occupy small, enclosed depressions (ca 30 m diameter), where volcanic ash of Mazama origin occurs in deposits up to 1 m thick. The volcanic ash is underlain by a thin (50 cm) lacustrine deposit, suggesting the ash accumulated in a pond which may account for the unusual thickness of the deposit. The hummocks are approximately 75 cm in diameter and 20-40 cm high. Carex nigricans community types cover the hummocks providing a continuous, densely-rooted turf. The Ah and Bm horizons are contorted and discontinuous due to frost action involved in formation of the hummocks. Coarse silt-sized particles predominate in the ash material, textural class being silt to silt loam. Silt bands were observed in the lower sola, below the zone of turbation. Very high contents of amorphous iron and especially aluminum compounds were found in the lower sola. These soils have not been classified using the Canadian System but would involve a Regosol-Brunisol combination.

Selected data for four characteristic soils (Table 2) illustrate typical values and show the variation between soil types.

The soils at sites T-13, T-7, and T-21 have a silt loam surface texture. The higher clay content in the IIC horizons compared to the sola of T-13, and T-7 is due to silt-sized aeolian material in the sola.

The pH values illustrate the range in pH found in the area. Soils at sites T-13 and T-21 are strongly acid at the surface, grading to neutral in the C horizon, which is characteristic of soils displaying the effects of stronger pedogenesis. The weakly developed soil on calcareous bedrock at site T-7 is moderately alkaline throughout the profile. The weakly developed soil overlying quartzite bedrock at site T-20 is neutral in all horizons.

Acid ammonium oxalate-extractable aluminum and iron is a measure of the amorphous mineral content of a soil which may be active in complexing plant nutrients. Although high values are generally assumed to represent pronounced pedogenic weathering, volcanic ash may weather rather easily to amorphous oxides and hydroxides (Pettapiece, 1970). In the System of Soil Classification for Canada (1970) an increase of 0.80% aluminum plus iron in the B horizon over the IC horizon qualifies the B horizon as a Bf horizon; therefore the soils may be classified in the Podzolic order. The heterogeneity of soil materials (IIC rather than IC) and the presence of volcanic material in the Sunshine area raise problems with respect to classification. As there are no apparent eluvial horizons these soils have been classified as Brunisols rather than Podzols, even when aluminum and iron values are high in the B horizon.

Calcium carbonate equivalent is high for T-7, as is expected of a weakly developed soil on limestone bedrock.

Total nitrogen correlates with organic matter content, being highest in surface horizons and decreasing with depth.

Available phosphorus is low in all soils and decreases with depth.

SUMMARY AND CONCLUSIONS

The study of this alpine ecosystem in the Canadian Rocky Mountains indicates that there are definite relationships between microclimate, geomorphic processes, plant communities, and soil development. Some examples are:

1. Phyllodoce glanduliflora and Antennaria lanata community types occur on Alpine Dystric Brunisols on rolling, well-drained, relatively stable surfaces.

2. Dryas hookeriana and D. hookeriana - Carex scirpoidea community types occur on wind-desiccated west-facing slopes where dolomite and limestone bedrock formations occur at or near the surface. The

soils are highly calcareous, and are classified as Lithic Regosols and Lithic Alpine Eutric Brunisols.

3. *Saxifraga lyallii* community types are common on late snowbeds on east- and north-facing slopes, and occur on Orthic and Lithic Regosols with some weakly developed Alpine Eutric Brunisols.

4. *Kobresia myosuroides* community types are associated with base saturated Alpine Eutric Brunisols on stable slopes with a southerly aspect.

5. *Cassiope tetragona* community types tend to be associated with low base status Alpine Dystric Brunisols. When these community types occur on ridges and steep slopes, mass wasting processes result in profile disruption and the soils are classified in the Regosolic Order.

6. *Salix barrattiana* community types occur on Cumulic Regosols on recent alluvial deposits.

7. *Eriophorum angustifolium*, *E. scheuchzeri*, and *Carex eleusinoides* community types typically favor poorly-drained Gleysolic soils, in areas of runoff ponding and groundwater discharge.

Parent material has an influence on many soil features such as amount of coarse fragment, carbonate content, texture, and structure, but with a few exceptions, does not appear to be an overriding factor in plant distribution or soil development. Certainly the easily hydrolyzable tephra content has an influence on soil characteristics but it seems to affect the rate rather than the kind of development.

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LITERATURE CITED

Baptie, B. 1968. Ecology of alpine soils of Snow Creek Valley, Banff National Park. Unpubl. M.Sc. Thesis, Univ. of Calgary.

Benedict, J. B. 1970. Downslope soil movement in a Colorado alpine region: rates, processes, and climatic significance. Arct. Alp. Res., 2:165-226.

Bliss, L. C., and G. M. Woodwell. 1965. An alpine podzol on Mount Katahdin, Maine. Soil Sci. 100:274-279.

Canada Soil Survey Committee. 1970. The System of Soil Classification for Canada. Canada Department of Agriculture. 249 p.

Duchaufour, Ph. 1965. Précis de Pédologie. 2nd Ed. Masson et Cie (Ed.), 120 Boulevard Saint-Germain, Paris.

Johnson, D. D. and A. J. Cline. 1965. Colorado mountain soils. Adv. in Agronomy, 17:233-281.

Moss, E. H. 1959. Flora of Alberta. Univ. of Toronto Press.

Nimlos, T. J., and R. C. McConnell. 1965. Alpine soils in Montana. Soil Sci., 99:310-321.

North, F. K. and G. G. L. Henderson. 1954. Summary of the geology of the southern Rocky Mountains of Canada. In Alberta Soc. Petrol. Geol., Guidebook, 4th Ann. Field Conf., p. 15-81.

Pettapiece, W. W. 1970. Pedological investigations in the Front Ranges of the Rocky Mountains along the North Saskatchewan River Valley. Unpubl. Ph.D Thesis, Univ. of Alberta.

Price, R. A. 1971. A section through the Eastern Cordillera at the latitude of Kicking Horse Pass. In A Geological Guide of the Eastern Cordillera along the Trans Canada Highway between Calgary and Revelstoke. Alberta Soc. Petr. Geol. p. 17-23.

Retzer, J. L. 1956. Alpine soils of the Rocky Mountains. J. of Soil Sci. 7:22-32.

Retzer, J. L. 1965. Present soil forming factors and processes in arctic and alpine regions. Soil Sci. 99:38-44.

Sneddon, J. I., L. M. Lavkulich, and L. Farstad. 1972. The morphology and genesis of some alpine soils in British Columbia, Canada: I. Morphology, classification, and genesis; II Physical, chemical, and mineralogical determinations and genesis. Soil Sci. Soc. Amer. Proc. 36:100-110.

Soil Survey Staff. 1960, 1967, 1968. Soil Classification. 7th Approximation and Supplements. USDA, SCS. U.S. Govt. Printing Office, Wash., D.C.

Trottier, G. C. 1972. Ecology of the alpine vegetation of Highwood Pass, Alberta. Unpubl. M.Sc. Thesis, Univ. of Calgary.

Van Ryswyk, A. L. 1969. Forest and alpine soils of south-central British Columbia. Unpubl. Ph.D Thesis, Washington State Univ.

Washburn, A. L. 1956. Classification of patterned ground and review of suggested origins. Bull. Geol. Soc. Amer. 67:823-866.

Westgate, J. A., D. G. W. Smith, and M. Tomlinson. 1970. Late quaternary tephra layers in southwestern Canada. In Proceedings, 2nd annual paleo-environmental workshop of the Univ. of Calgary Archaeological Association, The Student's Press, Calgary. pp. 13-34.

APPENDIX

Alpine Dystric Brunisol

Site T-13 is located at latitude 51°02'20 N, longitude 115°47'10 W, west of Quartz Hill, at an elevation of 2348 m, on a 20% south-southeast-facing slope. The rapidly-drained pedon supports a Phyllodoce glanduliflora community type. Aeolian material has been deposited on glacial till and has since been mixed by colluvial action. The following description is of an Alpine Dystric Brunisol typical of this site.

Horizon	Depth (cm)	
L	7-0	Dark yellowish brown (10YR 4/4 d) fibrous turf; abundant, fine random and abundant, medium horizontal roots; medium acid; 5 to 10 cm thick; clear, wavy boundary.
Ah	0-4	Dark brown (10YR 4/3 d) silt loam; weak, fine granular; very friable; few, fine random roots; strongly acid; clear, wavy boundary; 2 to 6 cm thick.
Bm1	4-16	Strong brown (7.5YR 5/6 m), yellowish brown (10YR 5/4 d) silt loam; weak, medium platy; very friable; very few, fine vertical roots; acid; clear, wavy boundary; 10 to 17 cm thick.
IIBm2	16-19	Dark brown (7.5YR 4/4 m) silt loam; moderate, medium platy to moderate, medium subangular blocky; few, fine vertical roots; clear, broken boundary; 0 to 7 cm thick.
IIC	19-60	Yellowish brown (10YR 5/4 m), light yellowish brown (10YR 6/4 d) gravelly silt loam; moderate, medium subangular blocky; firm to friable; few, fine vertical roots to 30 cm; 40% shale fragments; neutral; abrupt, irregular boundary.
R	60+	Shale bedrock occurring at 60 to 100 cm.

APPENDIX

Orthic Regosol

Site T-7 is located at latitude 51°04'55 N, longitude 115°45'01 W, on Lookout Mountain, at an elevation of 2545 m, on an 11% southwest-facing slope. The rapidly-drained pedon supports a Dryas-Carex community type. Paleozoic limestone bedrock is covered with varying thicknesses of colluvium and very calcareous Lithic and Orthic Regosols are present. Classification depends on depth to bedrock, which varies from 10-60 cm. The following description is of a typical Orthic Regosol.

Horizon	Depth (cm)	
L	2-0	Dryas turf; plentiful, fine vertical and abundant, medium horizontal roots; clear, smooth boundary; 1 to 3 cm thick.
Ahk1	0-5	Very dark gray (10YR 3/1 m, 3/1.5 d) gravelly silt loam; weak, fine granular; very friable; plentiful, fine random roots; moderately effervescent; 50% coarse fragments; moderately alkaline; clear, broken boundary; 0 to 15 cm thick.
Ahk2	5-15	Dark brown (10YR 3/2 m), dark grayish brown (10YR 4/2 d) silt loam; weak, fine granular; very friable; few, fine vertical roots; moderately effervescent; 15% coarse fragments; moderately alkaline; abrupt, wavy boundary; 5 to 15 cm thick.
IICk	15-60	Brown (10YR 5/3 m), light brownish gray (10YR 5.5/2 d) very gravelly sandy loam; single grained; loose; few, fine vertical roots to 40 cm; strongly effervescent; moderately alkaline; abrupt, irregular boundary.
R	60+	Bedrock.

APPENDIX

Cumulic Regosol

Site T-21 is located at latitude 51°04'35 N, longitude 115°47'10 W, on Standish Hump, at an elevation of 2205 m, on a 65% east-facing slope. The rapidly-drained (but moist) pedon supports an Anemone occidentalis community type. This is an unstable slope with continual downslope soil movement. The pedon, classified as a Cumulic Regosol, has buried horizons and weak profile differentiation.

Horizon	Depth (cm)	
L	5-0	Fibrous turf; clear, wavy boundary.
Ah	0-8	Dark brown (10YR 3/3 m), grayish brown (10YR 4.5/2 d) silt loam; moderate, fine granular; friable; abundant, fine vertical and abundant, medium random roots; 5% coarse fragments; strongly acid; diffuse, wavy boundary; 2 to 10 cm thick.
AC	8-20	Dark brown (10YR 3/3 m), grayish brown (10YR 4/2.5 d) silt loam; moderate, fine granular; very friable; plentiful, fine vertical roots; 5 to 10% coarse fragments; medium acid; abrupt, wavy boundary; 10 to 15 cm thick.
Ahb	20-21	Dark brown (7.5YR 3/2 m) silt loam; moderate, fine granular; very friable; clear, broken boundary; 0 to 1 cm thick.
Bmb	21-26	Strong brown (7.5YR 4/6 m) silt loam; moderate, fine granular; very friable; clear, broken boundary; 0 to 8 cm thick.
C	26-90+	Yellowish brown (10YR 5/4 m), pale brown (10YR 5.5/3 d) loam; moderate, coarse subangular blocky; friable; 60% cobbles; neutral.

APPENDIX

Alpine Eutric Brunisol

Site T-20 is located at latitude 51°04'25 N, longitude 115°47'30 W, west of Sunshine reservoir, at an elevation of 2265 m, on a 25% northeast-facing slope. The rapidly-drained pedon supports a Saxifraga lyallii community type. The site is located in a seasonal runoff channel with late snowmelt. Weak terracing of the slope is indicative of downslope soil movement, and depth to bedrock is variable, often being less than 50 cm. The following description is of an Alpine Eutric Brunisol.

Horizon	Depth (cm)	
L	5-0	Fibrous turf; abundant, fine random and abundant, medium horizontal roots; abrupt, wavy boundary.
Ah	0-10	Dark brown (10YR 3/3 m), grayish brown (10YR 5/2 d) sandy loam; moderate, fine granular; very friable; plentiful, fine random roots; 15% coarse fragments; neutral; gradual, smooth boundary; 6 to 15 cm thick.
Bm	10-30	Very dark grayish brown (10YR 3/2 m), grayish brown (10YR 5/2 d) shaley sandy loam; moderate, medium subangular blocky; friable; few, fine vertical roots; 40% coarse fragments; neutral; gradual, smooth boundary; 15 to 25 cm thick.
C	30-60+	Dark yellowish brown (10YR 4/4 m), pale brown (10YR 6/3 d) shaley sandy loam; moderate, medium subangular blocky; firm; few, fine vertical roots to 40 cm; 30% coarse fragments; neutral.

Table 1. Correlation of plant community types and soil classification

Community Type	Soil Classification: Canadian	Soil Classification: 7th Approximation
Phyllodoce glanduliflora, *Antennaria lanata*	(Lithic) Alpine Dystric Brunisols	(Lithic) Dystric Cryandepts and (Lithic) Dystric Cryochrepts
Dryas hookeriana, *Dryas hookeriana* - *Carex scirpoidea*	Lithic Alpine Eutric Brunisols and Lithic Regosols	Lithic Eutric Cryochrepts Lithic Cryorthents
Salix barrattiana	Cumulic Regosols	Typic Cryofluvents
Anemone occidentalis	Cumulic Regosols	Entic Cryumbrepts
Saxifraga lyallii	Orthic Regosols and Alpine Eutric Brunisols	Typic Cryumbrepts and Eutric Cryochrepts
Cassiope tetragona	Orthic Regosols, Cumulic Regosols, Alpine Dystric Brunisols	Typic Cryumbrepts, Entic Cryumbrepts, Dystric Cryochrepts
Kobresia myosuroides	Alpine Eutric Brunisols	Eutric Cryochrepts
Carex eleusinoides, *Eriophorum scheuchzeri*, *E. angustifolium*	Rego Gleysols, Orthic Gleysols, and Humic Gleysols	Typic Cryaquents Typic Cryaquepts Humic Cryaquepts
Carex nigricans (earth hummocks)	unclassified	Turbic Dystric Cryandepts

Table 2. Selected physical and chemical data of four soil profiles

Horizon	Depth cm	coarse fragment %	% of <2 mm Sand	Silt	Clay	p^H (H_2O)	organic matter (%)	oxalate Al (%)	oxalate Fe (%)	$CaCO_3$ equiv. (%)	Total N (%)	Avail P ppm
			T-13	Phyllodoce (Alpine Dystric Brunisol)								
L	7-0					5.6	25	-	-	-	1.0	3
Ah	0-4	-	31	56	13	5.4	8	0.23	0.88	-	0.3	1
Bm1	4-16	-	22	70	8	5.6	6	2.18	1.15	-	0.3	<1
IIC	19-60	40	26	55	19	6.7	-	0.09	0.39	-	-	2
			T-7	Dryas-Carex (Orthic Regosol)								
Ahk1	0-5	50	30	67	3	7.9	15	-	-	21.3	0.9	3
Ahk2	5-15	15	30	67	3	8.0	9	-	-	35.0	0.5	0
IICk	15-60	70	60	31	9	8.0	-	-	-	91.4	-	0
			T-21	Anemone (Cumulic Regosol)								
Ah	0-8	5	40	52	8	5.4	9	0.66	1.12	-	0.4	5
AC	8-20	10	41	50	9	5.6	7	0.87	1.10	-	0.3	4
C	26-90	60	43	47	10	7.2	-	0.13	0.72	1.3	-	<1
			T-20	Saxifraga (Alpine Eutric Brunisol)								
Ah	0-10	15	50	44	6	7.1	4	0.42	0.87	0.9	0.2	8
Bm	10-30	40	51	41	8	7.2	4	0.41	0.84	0.7	0.2	8
C	30-60	30	46	46	8	7.3	-	0.11	0.64	0.6	0.1	5

Figure Captions

Figure 1. View of the rolling alpine area at Sunshine , Banff National Park. The Continental Divide is located on the foreground and on Quartz Ridge in the right background.
Photo Aug. 9, 1972; L. Knapik.

Figure 2. Earth hummocks under Carex nigricans community type, with Antennaria lanata and Phyllodoce glanduliflora community types in the background. Photo Aug. 5, 1970; L. Knapik.