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The vascular flora and natural vegetation of abandoned coal mined land, Rocky Mountain Foothills, Alberta.

University — Université

Univ. of Alberta

Degree for which thesis was presented — Grade pour lequel cette thèse fut présentée

M.Sc.

Year this degree conferred — Année d'obtention de ce grade

1980

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THE UNIVERSITY OF ALBERTA

THE VASCULAR FLORA AND NATURAL VEGETATION OF ABANDONED COAL MINED LAND, ROCKY MOUNTAIN FOOTHILLS, ALBERTA

by

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A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

DEPARTMENT OF BOTANY

EDMONTON, ALBERTA

FALL 1980

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "THE VASCULAR FLORA AND NATURAL VEGETATION OF ABANDONED COAL MINED LAND, ROCKY MOUNTAIN FOOTHILLS, ALBERTA" submitted by WILLIAM BACON RUSSELL in partial fulfilment of the requirements for the degree of Master of Science.

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ABSTRACT

A study was made of the vascular plant floras and natural vegetation on abandoned coal mine spoil-heaps in the Rocky Mountain Foothills of west-central Alberta. The major objectives were: 1) to document and compare the vascular plant floras of the six major abandoned coal mines in the central foothills; 2) to describe and compare the vascular plant communities on two of the minesites; and 3) to evaluate and compare the effects of edaphic and topographic factors on total plant cover, species richness, and species abundance on the two intensively studied minesites. Two subalpine minesites in the Mountain Park region were chosen for the intensive study.

A total of 245 vascular plant species were found on the six abandoned minesites. The largest plant families were Compositae (43 species), Gramineae (35), Leguminosae (24), Rosaceae (19), and Cyperaceae (19). The flora consists of 206 native and 39 introduced species. Introduced species are more numerous on the lower elevation study sites and on sites which are (or were) in close proximity to human settlements.

Comparisons among the six minesite floras indicate that they are neither highly similar nor highly dissimilar to one another. Floristic similarity between the sites generally increased with proximity in elevation.

The vegetation of the two intensively studied minesites in the Mountain Park region consists of sparse, mostly herbaceous plant communities dominated by perennial grasses and forbs. Total plant cover is low (usually <15%) and isolated plants are common. Seven plant

community types were recognized, based largely on floristic criteria.

Variation in spoil properties appears to strongly influence plant distribution on both intensive study sites. Total plant cover, species richness, and species abundance were correlated with edaphic factors on both sites. Of the 19 variables measured, correlations were highest with fine earth content (% <2 mm) on the Mountain Park Townsite and with clay content on the Mountain Park West Mine.

Slope position strongly influences plant distribution on the two intensive study sites. Total plant cover, species richness, and the abundance of most species are highest at the slope base and lowest at the upper-slope, mid-slope, and/or crest positions.

The two intensive study sites have no plant communities in common and their floras have a similarity of only 57% (Sørensen's coefficient of community). Since they are only 1.2 km apart, differ *ca.* 30 m in elevation, and have been abandoned for the same length of time (*ca.* 26 years in 1976), these differences are considered significant. Comparisons were made between the two sites based on geographic (includes topographic), biotic, climatic, edaphic, and pyric factors. The major differences were in 1) edaphic factors, 2) floras of the surrounding areas, and 3) size of the minesites, suggesting that these factors are most important in controlling the floristic and community differences between the two sites.

ACKNOWLEDGEMENTS

It is a pleasure to thank my supervisor, Dr. George H. LaRoi for his encouragement and guidance throughout the course of this research; Drs. William McGill and Walter Moser for their advice and valuable suggestions; Bob Richards and Lou Zivot for their very capable field assistance; Madeleine Dumais for many hours of taxonomic assistance; Drs. John Packer, Mary Barkworth, William Dore, and George Argus for verification and identification of plant collections; Jiri Selner for accompanying me on early field trips and for arranging for government field support; Catherine Owen for typing early thesis drafts; Betty Ford for typing the final thesis draft; and my fellow graduate students for advice and encouragement.

Financial support was received from the Alberta Department of Energy and Natural Resources and the Alberta Department of Recreation, Parks, and Wildlife, and is gratefully acknowledged.

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INTRODUCTION

The Rocky Mountains and Foothills of Alberta cover an area of 54,000 km^2, with recoverable coal seams underlying 4,900 km^2 (Alberta Energy Resources Conservation Board 1979). An estimated 31.5 km^2 of land had been disturbed by coal mining prior to 1978 (Thirgood 1978). With increasing world demand for Alberta's low-sulfur coals, the potential for future land disturbance in this region is great.

The Alberta Government requires mining companies to reclaim any lands disturbed by mining:

> "Land reclamation will include the contouring of the mined or disturbed lands, the replacement of the top soil, revegetation for soil stabilization, biological productivity and appearance, and suitable maintenance of the vegetation or, where appropriate, the conversion of the land to agricultural or other desirable use".
>
> (Alberta Department of Energy and Natural Resources 1976).

While there is a large and growing body of literature on reclamation techniques, materials, and equipment that is relevant to Alberta (*see* Sims 1979), very little has been published on the natural recovery of mined lands in Alberta. Root (1976) described the physical environment and more briefly the natural vegetation of an abandoned coal strip mine in the foothills near Cadomin. Schumacher *et al.* (1977) investigated plant succession on abandoned coal mined land in the aspen (*Populus tremuloides**) parkland region of central Alberta.

Studies of natural revegetation of mined lands elsewhere in western North America have been made in: SE Saskatchewan (Jonescu 1979); British Columbia (Errington 1975, Meidinger 1979); Northwest

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*Vascular plant nomenclature follows Moss (1959).

Territories (Taylor 1976); North Dakota (Wali and Freeman 1973, Wali 1980); Montana (Sindelar 1979); Utah (Alvarez *et al.* 1974); New Mexico (Wagner *et al.* 1978); Iowa (Glenn-Lewin 1979); and Minnesota (Leisman 1957). Recently, Wali (1980) has reviewed the literature on succession on mined lands.

Study Objectives

This study was conducted during the summers of 1975 and 1976 and included a floristic survey of six abandoned coal mines in the foothills and a more intensive investigation of the natural vegetation on two of the minesites. The major research objectives were:

1) to document and compare the vascular plant floras of the six major abandoned coal mines in the central foothills of Alberta;

2) to describe and compare the vascular plant communities on two of the minesites; and

3) to evaluate and compare the effects of edaphic and topographic factors on total plant cover, species richness, and species abundance on the two intensively studied minesites.

Two abandoned minesites in the Mountain Park region were chosen for the intensive study. Preliminary observations in 1975 indicated that plant distribution on these sites varies with edaphic factors and slope position. Therefore, the environmental portion of the intensive study concentrated on these factors.

Definition of Terms

Some terms used commonly throughout the thesis are defined here.

'Natural revegetation' is defined as the plant community formation process that occurs without subsidy by man, *i.e.* without application of seed, fertilizer, mulch or other amendments. When begun on substrates that had never before supported any vegetation, *e.g.* most spoil materials in this study, 'natural revegetation' is synonymous with 'primary succession'.

'Overburden' designates materials of any nature, consolidated or unconsolidated, that overlie a deposit of useful materials (Thrush 1968). In the present situation, 'overburden' refers to the soil and rock strata which overlie coal deposits.

A 'strip mine' is an opencut mine in which the overburden is removed from a coalbed before the coal is taken out (Thrush 1968).

'Spoil' refers to 1) the overburden or non-ore material removed in gaining access to the ore or mineral material in surface mining, and 2) debris or waste material from a mine (Thrush 1968). In this study 'spoils' and 'coal spoils' are used interchangeably and include any overburden, coal, mine waste, or other mineral material deposited on the surface as waste.

A 'spoil-heap' is a pile of spoils on the surface of the mine.

STUDY SITES

Floristic Survey Sites

Six abandoned coal mines in the Rocky Mountain Foothills of west-central Alberta were included in the floristic survey, designated as Mountain Park West Mine, Mountain Park Townsite, Cadomin, Nordegg, Sterco-Coal Valley, and Mercoal (Fig. 1). Table 1 provides a brief description of each site.

The Mountain Park sites are just west of the outlying Nikanassin Range at the headwaters of the McLeod River. The Townsite is 16 km S of the village of Cadomin along the Grave Flats Road. The spoil-heaps are along the road, just east of where the village of Mountain Park was once located. The Mountain Park West Mine is 1.2 km NW of the Townsite. The spoil-heaps are accessible from the Grave Flats Road via a road at the Townsite.

The Cadomin (east) strip mine is 1.6 km SE of the village of Cadomin on the eastern slopes of the Nikanassin Range. Access is provided by a bridge across the McLeod River at Inland Cement Industries Co. Ltd. A road from the bridge runs parallel to the river and connects with a haul road to the mine site, 2.7 km N of the bridge.

The Nordegg strip-mine is *ca.* 2 km SW of the village of Nordegg on the NW slopes of the Brazeau Range. A mine road provides access to the site as it connects with Hwy. 40 *ca.* 2 km S of Hwy. 11.

The Sterco and Coal Valley minesites are located on rolling, hilly terrain *ca.* 60 km SW of Edson. They are adjacent to one another and, thus, are considered as one study site for the purposes of the floristic survey. The spoil-heaps occur along the N side of Hwy. 40.

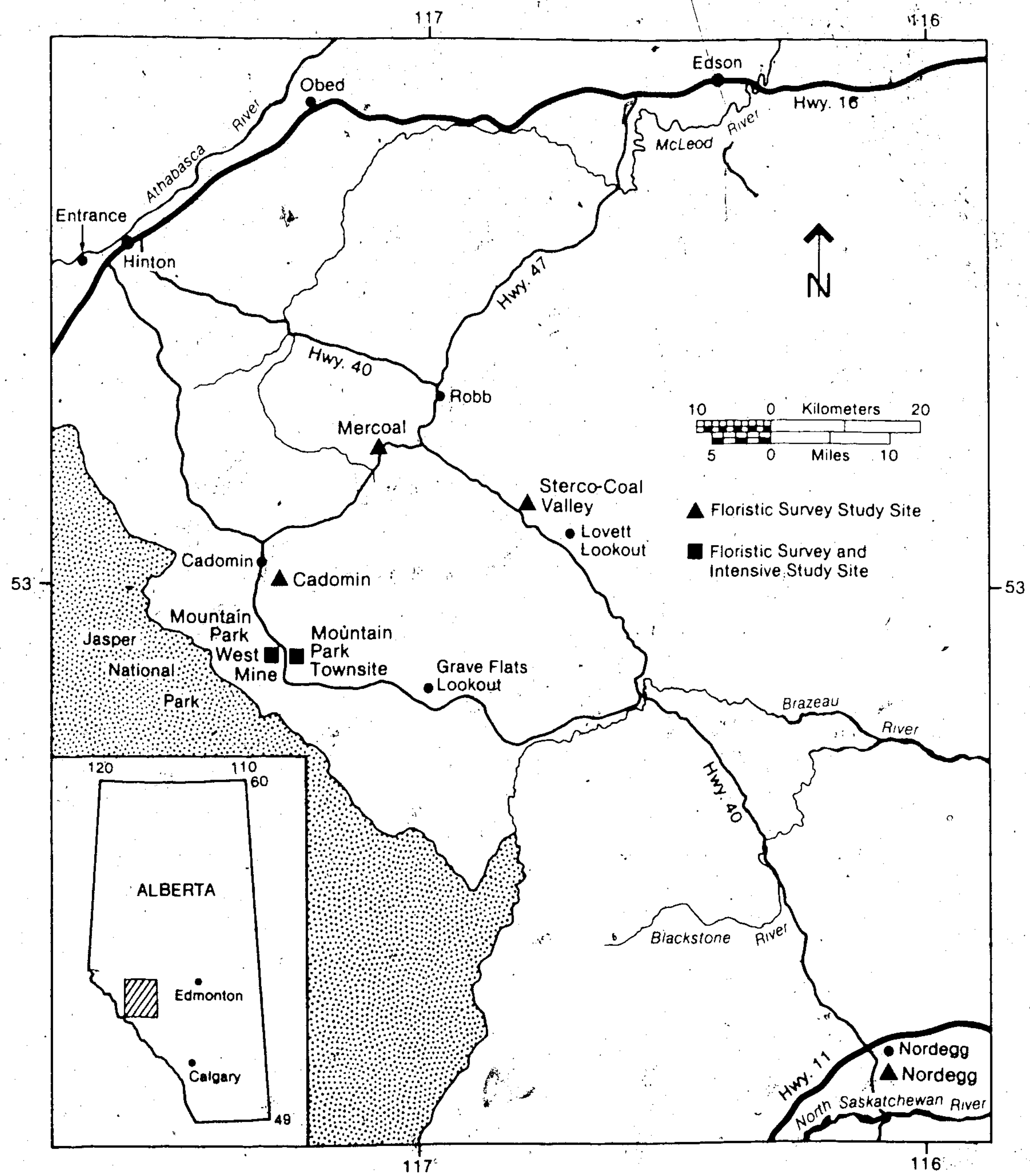


Figure 1. Locations of the six abandoned coal mines selected for study in the Rocky Mountain Foothills of west-central Alberta.

Table 1. Selected site characteristics of the six abandoned coal mines included in the floristic survey.

	Mountain Park West Mine	Mountain Park Townsite	Cadomin East Mine	Nordegg	Sterco, Coal Valley	Mercoal
Location Latitude	52°56'N	52°56'N	53°01'N	52°27'N	53°06'N	53°10'N
Longitude	117°18'W	117°17'W	117°18'W	116°05'W	116°48'W	117°05'W
Coal Mine Registration No.[1]	282	282	693	256	769, 1002	846
Underground (u) or Strip (s) Mine[2]	s	u	u/s	u/s	s,s	u
Dates of Operation[2]	1945-50	1911-50	1944-52	1910-56	1918-50, 1922-55	1920-65
Elevation (m ASL)	1810	1780	1675	1500-1600	1408	1343
Area covered by Spoil-heaps (ha)	34	15	46	12	170	12
Forest Region (Rowe 1972)	Subalpine (SA.1)	Subalpine (SA.1)	Subalpine (SA.1)	Subalpine (SA.1)	lies on border between Upper (B.19c) and Lower (B.19a) Foothills	Upper Foothills (B.19c)

[1]Mine registration numbers are issued by the Mines and Minerals Branch, Alberta Department of Energy and Natural Resources (formerly the Mines Branch, Department of Mines and Minerals).

[2]Sources: Campbell (1967), Lake (1967), and Cormack (1950).

Portions of Hwy. 40 are being rerouted to accomodate a new coal strip mine (owned by Luscar Sterco Ltd.) at Coal Valley. However, this should not affect access to the study spoil-heaps.

Mercoal is *ca.* 19 km SW of Robb on Hwy. 47. The area is characterized by rolling, hilly terrain. The spoil-heaps lie adjacent to the village of Mercoal on poorly drained ground.

Intensive Study Sites

The Mountain Park Townsite and West Mine were selected for more intensive ecological study than the other study sites and, hence, are described in greater detail.

Physiography and Geology

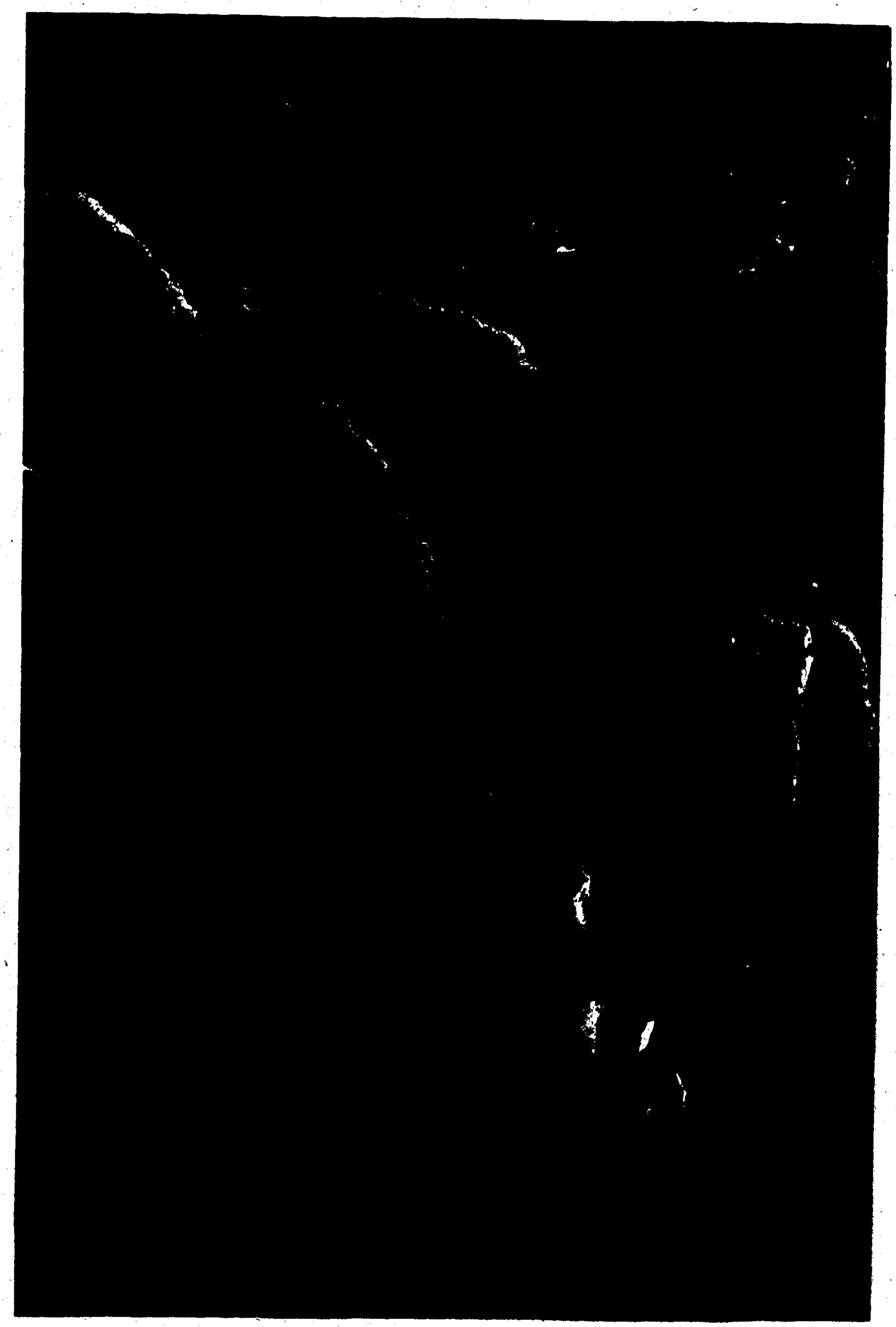
The Mountain Park area lies in a coal basin at the headwaters of the McLeod River. The basin forms a gentle, southeasterly dipping syncline, which lies between the Font Range of the Rocky Mountains and a southwesterly projecting Paleozoic outlier, known as the Nikanassin Range (MacKay 1930). Relief ranges from 1760 m ASL on the basin floor to 2720 m ASL at the summit of Cheviot Mountain. The Townsite and West Mine spoil-heaps lie at 1780 m ASL and 1810 m ASL, respectively (Plate 1).

All coal extracted from the Mountain Park mines came from the upper-beds of the Luscar Formation and is lower Cretaceous in age (Rutherford 1925). The Luscar Formation is composed of soft, grey sandstones interbedded with dark grey shales, several conglomerate lenses, and commercial coal seams in the upper part (MacKay 1930). It is underlain by a resistant chert and quartz-pebble conglomerate called the Cadomin Formation and overlain by a coarse green sandstone and green

Plate 1. Aerial view of the Mountain Park area in the Rocky Mountain Foothills of west-central Alberta, with the Townsite and West Mine spoil-heap areas circled (1973). The fire margin S of the study sites denotes the boundary of an extensive fire in 1913 which burned most of the Mountain Park area. The post-fire forests are dominated by *Pinus contorta* and are recovering slowly.

The West Mine spoil-heaps interrupted drainage from Mt. Cheviot (just out of view to the SW), which resulted in flooding of the main excavation pit.

Spoils at the Townsite are darker than those at the West Mine due to substantially higher coal content.



shale, with lenses of pebble conglomerate called the Mountain Park Formation (Mellon 1966). The stratigraphy of the Mountain Park area has recently been described by Kilby (1978).

The spoils at the Townsite are composed predominantly of 1) waste coal and other rock brought to surface from the underground mine, and 2) clinker and other burnt waste from the mine's power plant. The spoil-heaps are generally flat-topped with steep banks on the western and northern faces (Plate 1). Slope inclines range from 24 to 41° and slope lengths from 8 to 40 m.

In contrast, the spoils at the West Mine consist largely of coal-free overburden materials. This was a stripping operation in which two pits were excavated and the overburden dumped over a wide area to the north. The resulting spoil-heaps display a moderately diverse topography. Mounded areas exist where overburden materials were dumped by the truck-load and not levelled. The majority of the heaps have been levelled on top. Long, steep banks characterize the northern face of the spoil-heap area (Plate 1). Slope angles range from 22 to 40° and slope lengths from 7 to 46 m.

Climate

The climate of the Mountain Park area is classified as Sub-arctic (Dfc) or Cold, Snow-Forest in Köppen's (1936) system of climatic classification (Longley 1970). Cold, humid winters and cool, short summers are characteristic.

Although long-term, continuous climatic data are not available for the study area, air temperature and precipitation were monitored discontinuously at Mountain Park from 1915 to 1924 (Table 2). The average annual total precipitation was 70.2 cm and mean annual temperature

Table 2. Monthly summary of air temperature and precipitation data collected discontinuously from 1915 to 1924 at Mountain Park, Alberta[1]

	J	F	M	A	M	J	J	A	S	O	N	D
Mean Monthly Maximum Temperature (°C)	4	11	9	13	17	22	25	26	20	17	11	8
Mean Monthly Minimum Temperature (°C)	-43	-38	-32	-20	-9	-7	-5	-3	-10	-18	-33	-40
Mean Daily Temperature (°C)	-17	-13	-7	-2	3	7	10	10	5	1	-6	-15
Mean Monthly Precipitation (mm)	87	38	49	90	77	88	65	78	45	50	23	12
N[2]	4	4	4	5	5	5	4	4	5	4	3	4

[1] Source: Canada Department of Marine and Fisheries (1915-1924).

[2] Number of year's data used in calculating the means.

was -2°C. The coldest month was January, with a mean daily temperature of -17°C, and the warmest months were July and August, each with a mean daily temperature of 10°C. The lowest temperature recorded over the period was -49°C and the highest was 31°C.

Vegetation

The Mountain Park area falls within the East Slopes Section of the Subalpine Region (SA.1) in Rowe's (1972) system of forest classification. Climax forests on mesic upland sites are characteristically dominated by *Picea engelmannii* and *Abies lasiocarpa*. Due to an extensive fire in 1913 (Ross 1974), open *Pinus contorta* forests dominate the upland vegetation around the study sites. These forests usually have a well developed shrub layer of *Salix* spp., *Betula glandulosa*, and *Pinus* and *Picea* regeneration. Some of the more common herbs are *Elymus innovatus*, *Hedysarum alpinum*, and *Achillea millefolium*.

The vegetation of the valley bottoms around Mountain Park is treeless and dominated by shrubs, particularly *Betula glandulosa*, *Salix glauca*, and *Salix* spp.

Above treeline, which ranges from 1980 m on N-facing slopes to 2100 m on S-facing slopes (Mortimer 1978), is an extensive zone of alpine vegetation. See (1978) described the alpine macrolichen vegetation of the area. The alpine vascular plant vegetation of Prospect Mountain, *ca.* 8 km W of the Townsite, has been described by Mortimer (1978). She recognized 16 vascular plant community types within five tundra vegetation groups. Dry, rock tundra vegetation has the greatest areal extent and is dominated by *Dryas integrifolia*. Shrub tundra communities occupy the lower alpine slopes just above treeline and are dominated by *Salix arctica*, *S. barrattiana*, and *Dryas integrifolia*.

Snow accumulation hollows are dominated by *Cassiope tetragona*, *Phyllodoce glanduliflora*, and *Salix arctica*. Meadow tundra communities are common on gently sloping or flat areas and are dominated by *Dryas integrifolia*, *Elymus innovatus*, and *Artemisia norvegica*.

The Mountain Park area was described by Packer and Vitt (1974) as a glacial refugium during the Wisconsin period. They present geological and phytogeographical evidence to suggest that the area around Mountain Park stood as a nunatak above the ice, where plants survived the glaciation *in situ*. Their botanical evidence consists of a large number of species with disjunct distributions. Recently, Mortimer (1978) has added to the list of disjunct species with her work on Prospect Mountain. Thus the two intensive study sites occur in, or contiguous to, a proposed Wisconsin glacial refugium.

Mining History

The Mountain Park mining operation was one of the first to be established in the region (Lake 1967). Production began in 1912 to supply coal to steam-powered locomotives of the Canadian National Railroad (CNR) for its transcontinental line through the Yellowhead Pass. Over 39 years of operation the mines produced a total of 7,764,136 metric tons of coal and at peak production in 1940 employed a maximum of 407 people (Lake 1967).

The first mines were located close to the village of Mountain Park (near the Townsite study site) and were underground operations (Ross 1974). Strip-mining did not begin until about 1945 when the West Mine was opened (Cormack 1950). Declining markets, due largely to the switch to diesel powered locomotives by the CNR, caused the closure of the underground mines in 1949. Closure of the strip-mine came in

1950, probably hastened by the inability to control flooding of the pits by underground water seepage (Lake 1967, Ross 1974).

Mountain Park was a company-owned village. When the mines closed, the town was abandoned (Lake 1967). Buildings were either dismantled and moved or burned and buried. No attempt was made to revegetate or in any way reclaim the abandoned landscape (Lake 1967, Cormack 1950).

METHODS

Floristic Survey

A presence list of vascular plant species was compiled during the summers of 1975 and 1976 for each of the six abandoned minesites. An attempt was made to include all species growing on spoil-heaps at each site. Voucher specimens were collected of all species and are deposited in the University of Alberta Herbarium (ALTA). Nomenclature follows Moss (1959) and Packer (1974), except for *Agropyron elongatum*, *Carex bigelowii*, and *Elymus junceus*, which follow Scoggan (1978); and *Potentilla bipinnatifida* and *P. pensylvanica*, which follow Kohli and Packer (1976).

For comparative purposes the numbers of native and introduced species in each of the six floras were determined using Scoggan (1978).

Floristic similarity of the study sites was determined by calculating Sørensen's coefficient of community similarity index for all study site pairs: $CC(A, B) = 200\ c/(a + b)$, where c is the number of species in common and a and b are the total number of species in study sites A and B respectively.

The taxonomic spectra of the Mountain Park Townsite and West Mine floras (intensive study sites) were compared by calculating the percentages of species in each vascular plant family.

Intensive Study

Sampling Procedures

Meteorological observations

Precipitation and max-min air temperatures were monitored *ca.*

weekly from May 27 to September 11, 1976 at the Mountain Park Townsite and West Mine study sites. A Taylor max-min thermometer and two Tru--chek rain gauges (wedge type) were installed at each site. The instruments were mounted on wooden stakes 30 cm above the ground surface and placed in open areas on level ground.

A more accurate Taylor Clear-Vu rain gauge was moved from site to site several times over the summer and used to standardize the Tru-chek gauges. A linear relationship was established, $y = 1.09\,x$, by which the precipitation measured by the Taylor Gauge (y) could be estimated from Tru-chek readings (x; Appendix 1). All Tru-chek readings were corrected in this manner.

Painted wooden dowels were used to assess the abrasiveness and prevailing direction of wind-borne soil, snow, and ice particles. The dowels were *ca.* 1.9 cm in diameter and 1.5 m in length. Each received two light coats of white, latex paint and was driven 0.5 m into the ground in an exposed area. Two dowels were installed on each mine-site in August 1976 and examined in July 1977.

Community Sampling

Uniform stands were delineated at each site to serve as reference areas for sampling the vegetation and spoils. Stands were chosen subjectively based on the following acceptance criteria:

1) reside on spoil materials;
2) naturally revegetating;
3) uniform slope angle and aspect;
4) relatively homogeneous plant cover, species composition, and spoils.

Within these constraints an attempt was made to sample the range of plant communities and spoils on each site.

A total of 34 stands was delineated: 15 at the Townsite and 19 at the West Mine. They were rectangular in shape and ranged in area from 85 to 507 m^2 ($\bar{x}$ = 292 m^2).

Both the tops and sides (slopes) of the spoil-heaps were sampled. Stands located on slopes included only the upper-, mid-, and lower-slope positions; the slope crests and bases were excluded because of the rapidly changing slope angle at these positions. These areas were sampled later using transects.

Because of very low plant cover in some areas, two schemes were employed in sampling the vegetation. Stands for which preliminary estimates of total plant cover were <1% were inventoried, *i.e.* quadrats were not used. Ocular cover estimates in cm^2 for all vascular species, for total bryophytes, and for total lichens, were obtained for the entire stand. 'Cover' was defined as the area covered by the perpendicular projection of the living above-ground parts of a species to the ground surface (Mueller-Dombois and Ellenberg 1974). A metric ruler was used to aid in making the estimates.

Stands for which preliminary estimates of total plant cover exceeded 1% were sampled using a random plot method. A coordinate system was established in each stand and random numbers were used to locate the quadrats. In each quadrat ocular cover estimates in cm^2 were obtained for all vascular species, for total bryophytes, and for total lichens. Sampling adequacy was determined by calculating standard errors of the mean for total plant cover and for cover of the species with the highest cover (Greig-Smith 1964). 'Total plant cover' was taken as the sum of the vascular species, bryophyte, and lichen cover estimates. A stand was considered adequately sampled when the standard error:mean ratio was reduced to <20% for total cover and to <30% for the species with the highest cover. A minimum of 10 quadrats were placed in each stand. Additional vascular species present in the stand but not found in quadrats were noted also.

A 2 x 2 m quadrat was used throughout the study. Smaller quadrats were less efficient for estimating cover. Larger quadrats were unwieldy and more difficult to make estimates in.

For each stand the general topography, aspect, and slope angle were recorded. Voucher specimens of all unknown vascular plants were collected for future identification.

Spoil Sampling

Four randomly located pits were dug to a depth of *ca.* 30 cm in each of the stands. General notes were taken on horizon development, structure, surface crusting, and erosion. Spoil samples were collected from three depths in each pit: 0-5 cm, 13-18cm, and 25-30 cm. It was considered unnecessary to sample any deeper as plant rooting depth rarely exceeded 30 cm. Also, digging beyond this depth was increasingly difficult due to high rock content. The samples were bulked together by depth so that a total of three composite samples (each weighing 2 to 5 kg) was collected per stand, each representing a different depth. All samples were air-dried as rapidly as possible on sheets of plastic and stored in paper bags for future analyses.

Transect Sampling

Transects were run down the sides of spoil-heaps, perpendicular to the contours, to evaluate the influence of slope position on total plant cover, species richness, and species distribution patterns on slopes at the two Mountain Park study sites. Six 2 x 2 m quadrats were placed along each transect, one at each of the six major slope positions - top, crest, upper-slope, mid-slope, lower-slope, and base (Fig. 2). The following information was obtained in each quadrat: an ocular estimate of the cover of each vascular plant species; estimates of total bryophyte and total lichen covers; slope angle (clinometer); aspect (compass); and slope position.

A system of stratified random sampling was used to locate the transects on the spoil-heaps. Each study site was stratified into individual spoil-heaps. An investigator would stand in the center of a spoil-heap area and randomly select compass bearings from a random numbers table. The transects were located by walking in the chosen direction until the crest of a slope was reached. A transect was then run down the slope.

The number of transects placed on each spoil-heap was proportional to the size of the heap. The larger the heap in relation to the total mine area, the more transects it received. Twenty-one transects were run at each study site.

Laboratory Analyses

Spoil Analysis

The air-dried spoil samples were ground, if necessary, and passed through a 2 mm sieve. The <2 mm and >2 mm fractions were weighed and their proportions calculated. The following laboratory analyses were conducted on the <2 mm fraction:

1) mechanical analysis, using the hydrometer method

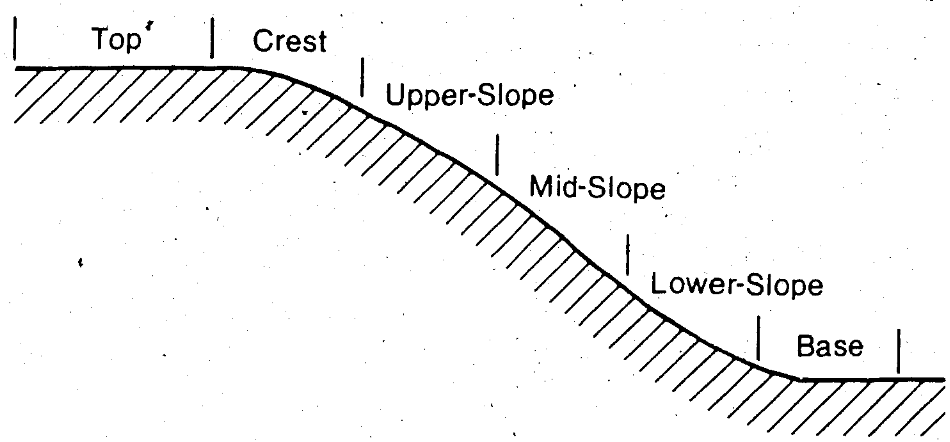


Figure 2. Cross-section of a hypothetical spoil-heap showing the locations of the six slope positions sampled in the transect studies.

(Bouyoucos 1962);

2) soil water retention at 1/3 bar tension on ceramic pressure-plate apparatus and at 15 bars tension on pressure membrane apparatus, expressed on a whole soil basis as a percent of oven-dry weight at 105°C (Richards 1965).

3) pH, measured with a glass electrode and pH meter on a 1:1 soil-water suspension (Peech 1965);

4) electrical conductivity, determined by the Alberta Agricultural Soil and Feed Testing Laboratory (ASFTL) in Edmonton, using a glass electrode and conductivity meter on a 1:2 soil-water suspension and corrected to that of a saturated paste (McKeague 1978);

5) exchangeable ammonium and nitrate, determined by steam distillation using the direct magnesium oxide-Devarda alloy method (Bremner 1965);

6) available phosphorus, determined by the ASFTL by autoanalyzer using the Millar and Axley modification of the Bray method (Hodgins 1977);

7) available potassium, determined by the ASFTL using flame photometry on an ammonium acetate extract (McKeague 1978);

8) total exchange capacity, determined by the ASFTL using ammonium acetate extraction at pH 7 followed by ammonium displacement and macro-Kjeldahl distillation (McKeague 1978); and expressed on a whole soil basis;

9) exchangeable calcium, magnesium, sodium, and potassium, determined by the ASFTL using atomic absorption on an ammonium acetate extraction at pH 7 (McKeague 1978), and expressed on a whole soil basis.

Properties expressed on a whole soil basis (P_w) were calculated from values expressed on the basis of the ≤2 mm fraction (P_f) by the equation: $P_w = P_f [1/(1 + R)]$, where R is the ratio of the weight of the coarse separate (> 2 mm) to the weight of the fine separate (≤ 2 mm; Richards 1965).

A random selection of the spoil samples (10%) were re-analyzed for texture, pH, exchangeable ammonium, and exchangeable nitrate to serve as checks. All water retention determinations were done in duplicate and the averages used. The remaining tests were unreplicated.

Available water holding capacity is a measure of the ability of a soil to retain plant-usable water. It was calculated for each spoil sample by taking the difference in water retention at 1/3 and 15 bars tension, and was expressed on a whole soil basis (Peters 1965).

Ocular estimates were made of the proportions of the different rock types in the >2 mm fraction of the surface (0-5 cm) spoil samples. The samples were washed and estimates made of the volume percentages of coal, sandstone, siltstone and shale (together), clinker, and miscellaneous other rock types.

Principal Component Analysis

Principal component analysis (PCA) was used as a means of synthesizing the vegetation data, with the aim of detecting relationships among plant species, communities, and topographic and edaphic environmental factors. PCA is an indirect ordination technique (Whittaker 1967), and as such is particularly useful when environmental gradients are unclear. Of the many ordination methods available, PCA was used because it is objective and expresses the relative amount of variance accounted for by each axis. Details of the mathematics of PCA may be found in Pielou (1977) or Orloci (1973).

Four separate PCA's were run, using untransformed and transformed data from each of the two intensive study sites. The untransformed data consisted of species cover percentages. These were coded and transformed using $\log_{10}$ (100000 a + 1), where a is a species cover percentage. The transformation raises the smallest non-zero cover value to one, and has the effect of reducing quantitative differences among species.

The analyses were conducted using the CLUSTAN 1C program package (Wishart 1978) on the University of Alberta Amdahl 470/V-7 computer. To accomodate program dimensioning restrictions, all species present in only one stand were dropped from the data sets. Rare species usually contribute little quantitative information and deleting them has been found by Austin and Greig-Smith (1968) to have little effect on ordinations using quantitative data.

Two-dimensional ordinations were constructed for each study site, using the first and second principal components as the x and y axes, respectively. To identify environmental factors which may be influencing stand composition, all topographic and edaphic variables were plotted on the ordinations. The edaphic variables were also subjected to Spearman rank-order correlation analysis (Daniel 1978) with the first two principal components.

The responses of total plant cover, species richness, and selected species (those with >15% stand presence) were examined by 1) plotting their values on the ordinations, and 2) subjecting them to rank-order correlation analysis with all edaphic variables.

Community Classification

In order to describe and compare the vegetation of the two Mountain Park study sites, stands were classified into community types (ct's), *i.e.* plant assemblages with similar composition, physiognomy, and habitat.

The ct's were given binomial names using, where possible, two dominant, character species, *i.e.* relatively abundant species which show a distinct maximum concentration (quantitatively and by presence) in a ct (Mueller-Dombois and Ellenberg 1974). If no character species [illegible]ant then the first species in the name was the leading [illegible]nd the second was the most abundant character species. If [illegible]e no character species then two species whose distributions overlapped only in the ct under consideration were used.

Classification was accomplished with the aid of cluster analysis, a numerical procedure which sorts individuals into groups based on some similarity criterion. Ward (1963) describes a clustering procedure which minimizes the 'loss of information' which occurs when individuals are formed into groups. His method, which is of the SAHN type described by Sneath and Sokal (1973), *i.e.* sequential, agglomerative, hierarchic, and non-overlapping, was used in this study.

Cluster analysis was performed on all stands using species cover (quantitative) data and, in a separate run, on all stands using species presence-absence (qualitative) data. The analyses were conducted using the CLUSTAN 1C program (Wishart 1978) on the University of Alberta Amdahl 470/V-7 computer. The resulting hierarchies were plotted as dendrograms.

Transect Studies

Separate Friedman tests (analysis of variance by ranks; Daniel 1978) were conducted to determine the effects of slope position on total plant cover and species richness at each study site. The significance of differences in cover and richness among the slope positions was determined using the multiple-comparison procedure recommended by Daniel (1978) for use with the Friedman test. The significance of differences in cover and richness between the study sites at a given slope position was determined using the Wilcoxon two-sample test (Sokal and Rohlf 1969).

To evaluate and compare the responses of individual species to slope position, species quadrat frequencies were calculated for each position.

RESULTS

Floristic Survey

A total of 245 species representing 40 families of vascular plants were found on the six abandoned minesites (Appendix 2). Mountain Park West Mine is the richest site with 141 species and Nordegg the poorest with 94 species.

The largest plant families are: Compositae (43 species), Gramineae (35), Leguminosae (24), Rosaceae (19), Cyperaceae (19), Cruciferae (16), and Salicaceae (14). Genera with more than five species include: *Carex* (19 species), *Salix* (12), *Poa* (9), *Potentilla* (8), *Astragalus* (7), and *Agropyron* (6).

Twenty-one species were common to all six sites: *Achillea millefolium, Agropyron trachycaulum, Agrostis scabra, Aster sibiricus, Epilobium angustifolium, Festuca rubra, F. saximontana, Fragaria virginiana, Gentianella amarella, Poa alpina, P. interior, P. palustris, P. pratensis, Populus balsamifera, Potentilla norvegica, Solidago decumbens, S. multiradiata, Taraxacum officinale, Trifolium pratense, T. repens,* and *Trisetum spicatum.*

The total minesite flora (245 species) consists of 206 native and 39 introduced species (Appendix 2). Introduced species were found to be more numerous at the lower elevation study sites (Mercoal and Sterco-Coal Valley), and at sites which are (or were) in close proximity to villages (Mercoal, Sterco-Coal Valley, and Mountain Park Townsite; Table 3). The Mountain Park West Mine, Cadomin, and Nordegg study sites have always been more removed from human settlements and have substantially

Table 3. Numbers (and percentages) of native and introduced species in the six abandoned minesite floras.

Study Site	Native species No. (%)[1]	Introduced species No. (%)[1]
Mountain Park West Mine (el. 1810 m)	132(94)	9(6)
Mountain Park Townsite (el. 1780 m)	89(83)	18(17)
Cadomin (el. 1675 m)	103(92)	9(8)
Nordegg (el. 1500-1600 m)	85(90)	9(10)
Sterco-Coal Valley (el. 1408 m)	85(79)	22(21)
Mercoal (el. 1343 m)	65(68)	31(32)

[1] Percentage of the total number of species found at the study site.

fewer introduced species.

Floristic similarity among the six minesites ranged from 32 to 68%, indicating that the floras are neither highly similar nor highly dissimilar to one another (Table 4). The highest similarity was between Mountain Park West Mine and Cadomin (68%), and the lowest between Mountain Park West Mine and Mercoal (32%).

The coefficients of community were negatively correlated with differences in elevation between the sites ($r_S = -0.77$; $P < 0.001$), *i.e.* floristic similarity between the sites generally increased with proximity in elevation.

The remainder of this section compares in greater detail the floras of the two intensive study sites.

The Mountain Park West Mine flora is substantially richer than the Townsite flora (141 species compared to 107, respectively). Furthermore, considering the close proximity of these two sites (1.2 km apart and differing only 30 m in elevation), their floras are significantly dissimilar (57% similarity).

The largest plant families are Compositae, Gramineae, Leguminosae, Rosaceae, and Cyperaceae at the West Mine, and Gramineae, Compositae, Leguminosae, Rosaceae, and Cruciferae at the Townsite (Table 5). Families which are substantially richer at the West Mine include Compositae, Scrophulariaceae, Cyperaceae, and Leguminosae. The Townsite flora is richer in Cruciferae.

The alpine flora of the Mountain Park area has been studied by Packer and Vitt (1974), Mortimer (1978), and See (1978) and is well known. A composite alpine vascular flora (200 species), taken from the last two studies, was compared with the two minesite

Table 4. Comparison of vascular plant floras among the six abandoned minesites using Sørensen's coefficient of community.

Study Sites		1	2	3	4	5	6
Mountain Park West Mine (el. 1810 m)	1	--	57	68	52	44	32
Mountain Park Townsite (el. 1780 m)	2	57	--	59	54	54	49
Cadomin (el. 1675 m)	3	68	59	--	64	52	41
Nordegg (el. 1500-1600 m)	4	52	54	64	--	59	45
Sterco-Coal Valley (el. 1408 m)	5	44	54	52	59	--	60
Mercoal (el. 1343 m)	6	32	49	41	45	60	--
Average Coefficient		51	55	57	55	54	45

Table 5. Species distribution among vascular plant families for the Mountain Park West Mine and Townsite floras.

Family	West Mine No. of species (%)[1]	Townsite No. of species (%)[1]
Ophioglossaceae	1 (1)	1 (1)
Equisetaceae	2 (1)	0 (0)
Pinaceae	4 (3)	2 (2)
Gramineae	20 (14)	23 (21)
Cyperaceae	13 (9)	7 (7)
Juncaceae	2 (1)	0 (0)
Orchidaceae	1 (1)	0 (0)
Salicaceae	5 (4)	4 (4)
Betulaceae	1 (1)	0 (0)
Polygonaceae	4 (3)	4 (4)
Caryophyllaceae	6 (4)	3 (3)
Ranunculaceae	2 (1)	3 (3)
Papaveraceae	0 (0)	1 (1)
Cruciferae	5 (4)	9 (8)
Crassulaceae	1 (1)	0 (0)
Saxifragaceae	2 (1)	0 (0)
Rosaceae	13 (9)	12 (11)
Leguminosae	16 (11)	12 (11)
Onagraceae	2 (1)	1 (1)
Umbelliferae	2 (1)	0 (0)
Ericaceae	1 (1)	1 (1)
Primulaceae	2 (1)	1 (1)
Gentianaceae	2 (1)	1 (1)
Polemoniaceae	0 (0)	1 (1)
Hydrophyllaceae	1 (1)	1 (1)
Boraginaceae	1 (1)	1 (1)
Labiatae	0 (0)	1 (1)
Scrophulariaceae	7 (5)	1 (1)
Plantaginaceae	0 (0)	1 (1)
Rubiaceae	0 (0)	1 (1)
Campanulaceae	0 (0)	1 (1)
Compositae	25 (18)	14 (13)
Total Species	141	107
Total Families	26	25

[1]Percentage of the total number of species found at the study site.

floras using Sørensen's coefficient of community. Similarities of 48% and 31% were obtained for the West Mine and Townsite, respectively. Thus, plants adapted to alpine environments form a large proportion of both minesite (subalpine) floras, but a substantially higher proportion of the West Mine flora. Appendix 2 lists the minesite species found in alpine study sites by Mortimer (1978) and/or See (1978).

Intensive Study

Meteorological Observations

Precipitation

Monthly precipitation totals were very similar for the two Mountain Park study sites during the summer of 1976 (Fig. 3). Total summer precipitation (June through August) was 223 mm at the Townsite and 211 mm at the West Mine.

The spoil-heaps at both sites were nearly snow-free by May 13; only hollows and N-facing slopes were still covered. Snow fell several times during the summer but melted on impact, or soon after, and did not contribute significantly to the summer precipitation totals.

The monthly totals for the Grave Flats Lookout, 19 km to the east and 280 m higher in elevation, were similar to those for the study sites in 1976 (Fig. 3). Also, the climate maps of Powell and MacIver (1976) indicate that the Mountain Park area and the Grave Flats Lookout have the same total summer precipitation. Thus, the 30-year monthly precipitation normals for Grave Flats (Fig. 3) may be similar to long-term monthly averages for Mountain Park.

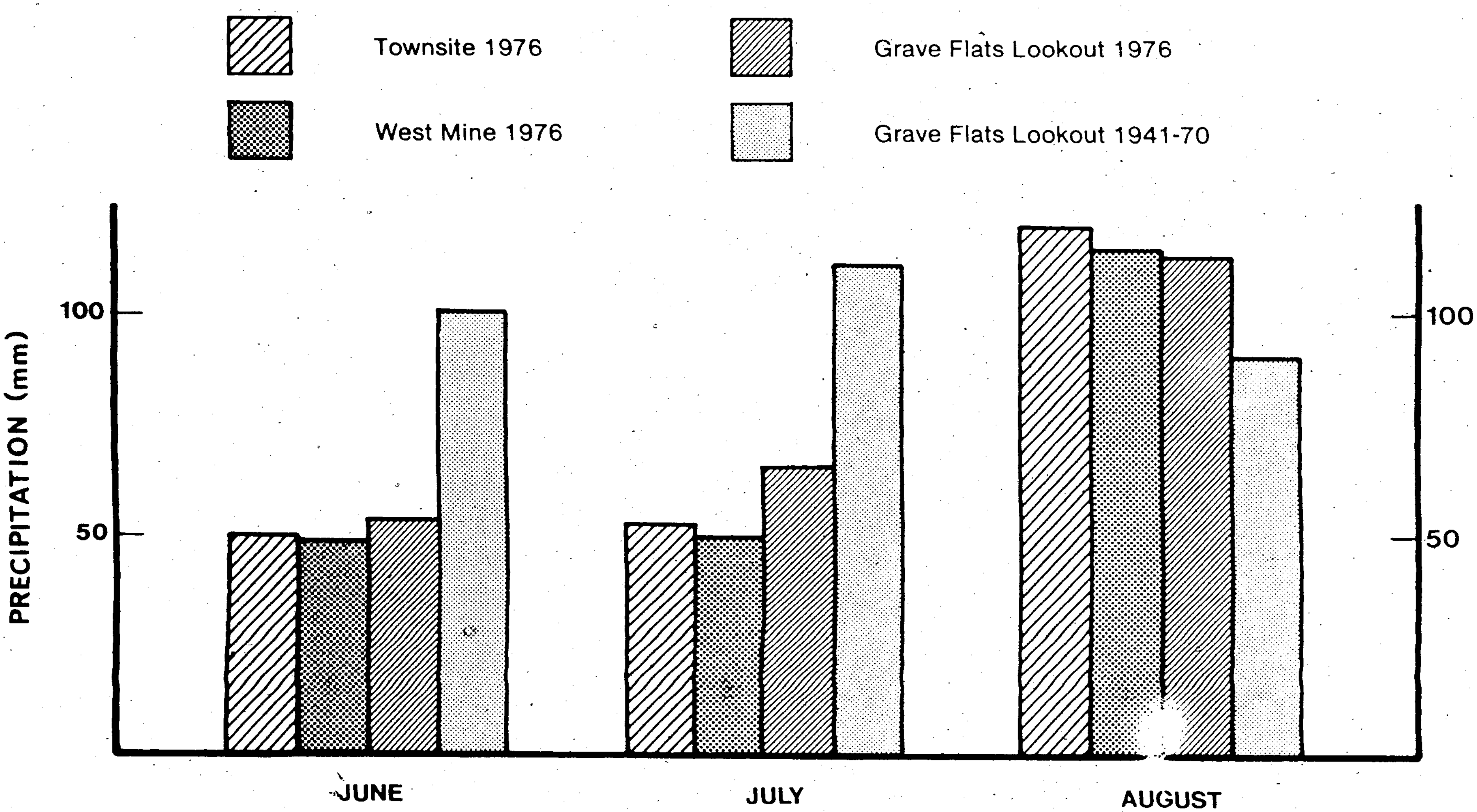


Figure 3. Summer (1976) monthly precipitation totals for the Mountain Park Townsite and West Mine study sites and the Grave Flats Lookout (Alberta Forest Service unpublished), and 30-year (1941-70) calculated normals for Grave Flats (Canada Atmospheric Environment Service 1975).

Air Temperature

Summer weekly max-min air temperatures at 30 cm above-ground were very similar for the two sites (Fig. 4). Weekly minima were at or below 0°C for most of the summer at both sites. The lowest temperatures recorded during the summer were -7°C at the Townsite and -5°C at the West Mine. The highest temperatures were 27°C at the Townsite and 31°C at the West Mine.

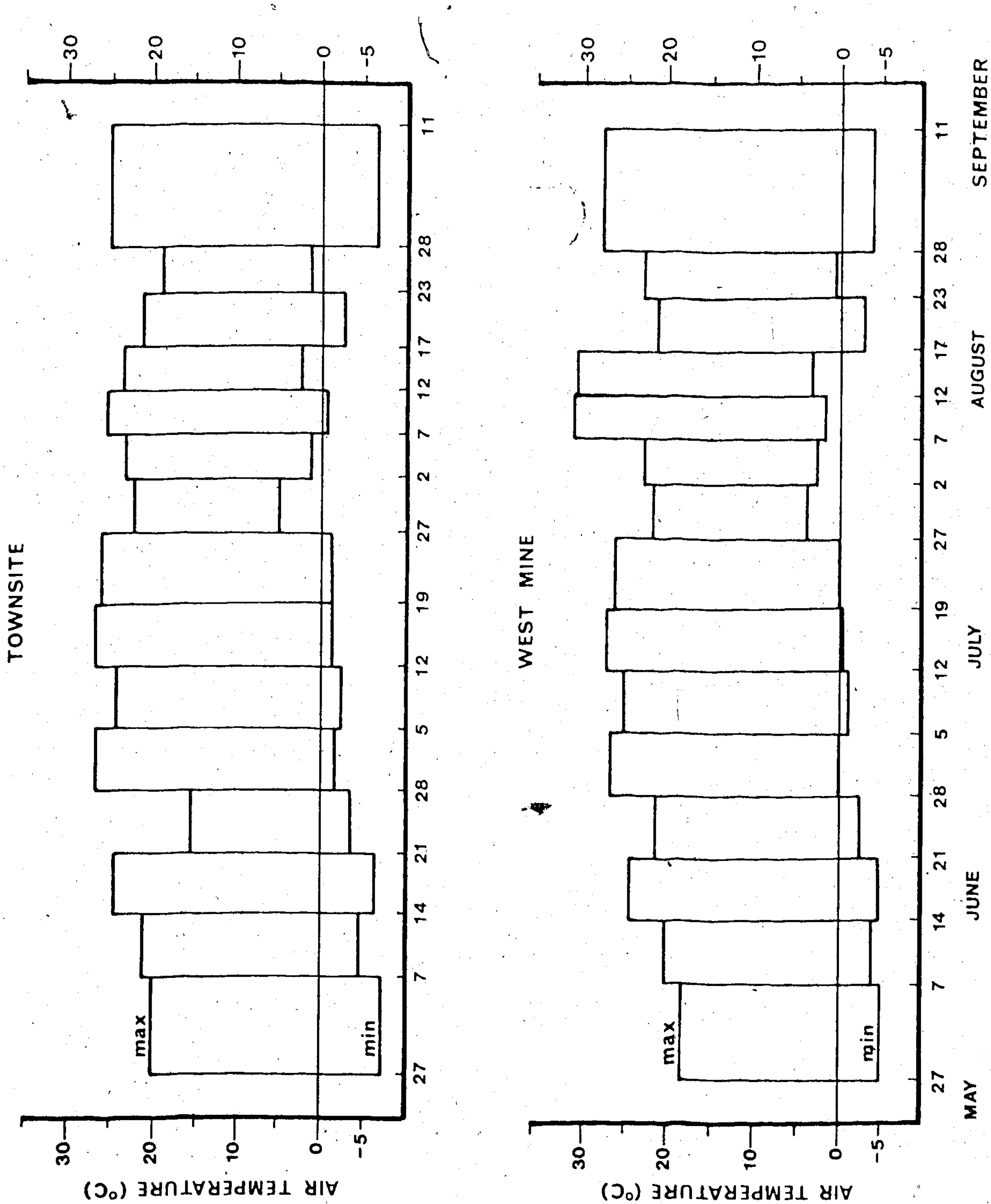
Wind

After one year of exposure, moderate winter abrasion was noted on the SW sides of the painted dowels installed at the Townsite, and on the W sides of those at the West Mine; thus indicating the direction of the prevailing winds. No difference was detected in the amount of abrasion at the two sites.

Trees adjacent to the minesites exhibit asymmetrical growth with branches flagging away from the prevailing winds. The annual growth rings of such trees show a marked eccentricity, with the pith closest to the windward side of the tree. On the minesites themselves, trees and shrubs are often stunted and occur mostly in protected areas. New stem growth extending above the protected zone in summer is often killed during winter by desiccation and/or abrasion.

Plants growing on the minesites sometimes have their root systems exposed due to wind scouring of spoil materials from around their bases. This is particularly common in exposed areas on the West Mine.

Root (1976) found that year round, persistent high winds on the Cadomin strip mine (east), *ca.* 10 km N of the Mountain Park study sites, act to increase potential evapotranspiration, inhibit seed


TOWNSITE
WEST MINE
AIR TEMPERATURE (°C)
max
min
30
20
10
0
-5
27
7
14
21
28
5
12
19
27
2
7
12
17
23
28
11
MAY
JUNE
JULY
AUGUST
SEPTEMBER

lodgement, remove fine spoil particles, mechanically damage plants, and remove protective snow cover. He concluded that wind is a major factor inhibiting plant growth on the Cadomin minesite. Observations made in the present study suggest that wind has similar ecological importance on the Mountain Park minesites.

Spoils

Results of the spoil analyses are summarized in Table 6.

The majority of spoils at both sites are coarse textured and structureless, consisting of rock fragments and loose, single grains. Spoils with higher clay contents (predominantly at the West Mine) are more coherent and have massive structure. There is no visible horizon development at either site.

At the Townsite coal is the dominant parent rock, siltstone and shale are abundant, and sandstone is relatively scarce. In contrast, siltstone and shale are predominant at the West Mine, sandstone is second, and coal is rare.

Fine earth contents range from very low (<20%) to relatively high at both sites, but are generally higher at the West Mine. Fine earth contents of <20% have been considered a probable limiting factor to plant survival on surface-mined land (Bramble and Ashley 1955). Surface spoils at both sites have higher fine earth contents than those deeper in the profile, probably due to higher physical weathering rates.

Using the textural classification of the United States Department of Agriculture (Soil Survey Staff 1960), spoil textures are predominantly loamy sands and sandy loams at the Townsite, and loamy sands, sandy loams, and sandy clay loams at the West Mine. The Townsite spoils

Table 6. Some chemical and physical properties of spoil materials collected in stands at the Mountain Park Townsite and West Mine study sites. Spoil properties were compared between the two sites using the Wilcoxon two-sample test.

Spoil Property	Depth (cm)	Townsite (N = 15)		West Mine (N = 19)		Significance of Wilcoxon Test
		$\bar{x}$	Range	$\bar{x}$	Range	
pH	0-5	7.0	5.6-7.8	7.7	6.5-8.4	**
	13-18	6.4	4.6-7.9	7.6	6.6-8.5	***
	25-30	6.2	4.9-8.1	7.5	6.4-8.6	***
Available Plant Nutrients (ppm)						
NH_4-N	0-5	2.0	0.2-3.7	0.4	0.0-2.2	***
NO_3-N	0-5	1.3	0.0-2.7	0.2	0.0-1.1	***
P	0-18	3.6	0.5-11.0	0.8	0.0-3.0	***
K	0-18	74	33-157	76	29-103	NS
Total Exchange Capacity (m.e. 100 g^{-1} whole soil)	0-18	4.4	2.5-8.0	5.9	2.6-11.3	*
Exchangeable Cations (m.e. 100 g^{-1} whole soil)						
Ca	0-18	4.0	1.5-12.3	6.8	3.1-11.1	***
Mg	0-18	1.0	0.6-1.5	1.9	0.8-3.3	***
Na	0-18	0.4	0.1-1.4	0.2	0.0-0.9	**
K	0-18	0.2	0.1-0.2	0.2	0.1-0.9	NS
Electrical Conductivity (mmhos cm^{-1})	0-18	0.2	0.2-0.4	0.3	0.2-0.5	*
Fine Earth Content (% <2 mm)	0-5	50	25-77	53	38-72	NS
	13-18	39	21-51	46	17-77	*
	25-30	34	15-49	45	13-90	*
Coal Rock Content (% of >2 mm)	0-5	67	8-100	6	0-34	***
Sandstone Rock Content (% of >2 mm)	0-5	2	0-15	19	1-80	***

Table 6. Cont'd.

Spoil Property	Depth (cm)	Townsite (N = 15) $\bar{x}$	Townsite (N = 15) Range	West Mine (N = 19) $\bar{x}$	West Mine (N = 19) Range	Significance of Wilcoxon Test
Siltstone and Shale Rock Content (% of >2 mm)	0-5	30	0-87	75	20-99	***
Available Water Holding Capacity (%)	0-5	2.9	1.4-4.3	3.0	1.3-5.7	NS
	13-18	2.9	1.1-6.2	2.9	0.9-6.3	NS
Particle Size Distribution (%)						
Sand (0.05-2.00 mm)	0-5	80	64-97	69	52-88	***
	13-18	81	59-90	70	47-86	***
	25-30	82	65-93	69	39-86	*
Silt (0.002-0.05 mm)	0-5	8	3-11	13	5-22	***
	13-18	8	5-14	12	5-25	*
	25-30	9	4-19	14	6-37	*
Clay (<0.002 mm)	0-5	12	0-29	19	4-27	**
	13-18	10	3-29	18	10-34	***
	25-30	9	3-18	17	6-28	**

*Differences between the sites are significant at $P \leq 0.05$.
**Differences between the sites are significant at $P \leq 0.01$.
***Differences between the sites are significant at $P \leq 0.001$.
NS: Differences between the sites are not significant ($P > 0.05$).

are generally sandier than the West Mine spoils.

Available water holding capacity (a.w.h.c.) is variable at both sites. Some spoils have very low a.w.h.c. (<2%), probably due to the sandy textures and low fine earth contents. No significant differences in a.w.h.c. were found between the sites.

Spoils pHs range from strongly acid to moderately alkaline at the Townsite (4.6-8.1) and from slightly acid to strongly alkaline at the West Mine (6.4-8.6). At all depths sampled, pHs were significantly higher at the West Mine.

Electrical conductivity levels are low (<2 mmhos cm^{-1}) at both sites, indicating non-saline conditions. Conductivity levels of <2 mmhos cm^{-1} are considered to have a negligible effect on the yields of most agricultural plants (Richards 1954).

The spoils at both sites vary in total exchange capacity, which is the sum total of exchangeable cations (expressed in milligram equivalents) that a soil can adsorb (Brady 1974). Total exchange capacity is very low in some spoils at both sites, probably due to the coarse textures and low fine earth contents. Total exchange capacity and the levels of exchangeable calcium, magnesium, and sodium are, on the average, higher at the West Mine than Townsite.

The Soils Branch of Alberta Agriculture in Edmonton considers the following available plant nutrient levels to be low for the growth of most agricultural plants (Alberta Department of Agriculture 1976); nitrogen (NO_3-N) <10 ppm, phosphorus (P) <12.5 ppm, and potassium (K) <75 ppm. Using these guidelines, the available nitrogen and phosphorus levels are low in the spoils at both sites; but are higher at the Townsite than West Mine. Potassium levels ranged from low to medium at both sites, and did not differ significantly between the sites.

It should be pointed out that the soil fertility tests employed by the provincial laboratory were designed to be used on agronomic soils and may not produce valid results when used on mine spoils. Results of soil fertility tests should be interpreted with caution until the relation between soil tests and plant growth on spoils has been determined (Berg 1969).

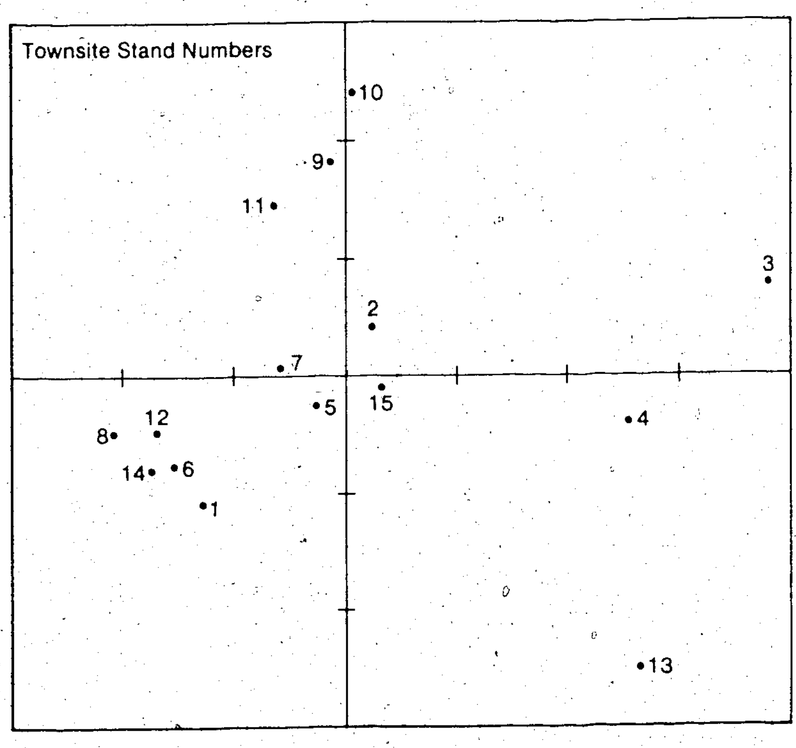
Principal Component Analysis

The ordinations based on untransformed species cover data had many stands clustered tightly together and were ecologically uninterpretable. In contrast, the log transformed cover data produced ecologically meaningful ordinations with far less clustering. Gauch *et al.* (1977) found that PCA ordinations are often improved by data transformations which reduce the effects of dominant species. They show that such treatments extend the range of beta diversities (degree of floristic difference among stands) which may be ordinated without severe distortion.

Only the ordinations derived from log transformed data are used in this thesis. The first two principal components respectively accounted for 31% and 15% of the variance in the Townsite vegetation data, and for 41% and 10% in the West Mine data. Locations of the stands on the ordinations are shown in Fig. 5.

Mountain Park Townsite

Correlation with Environmental Factors. Of the measured edaphic variables, fine earth content was most strongly correlated with both the first and second axes (Table 7). The first axis was also



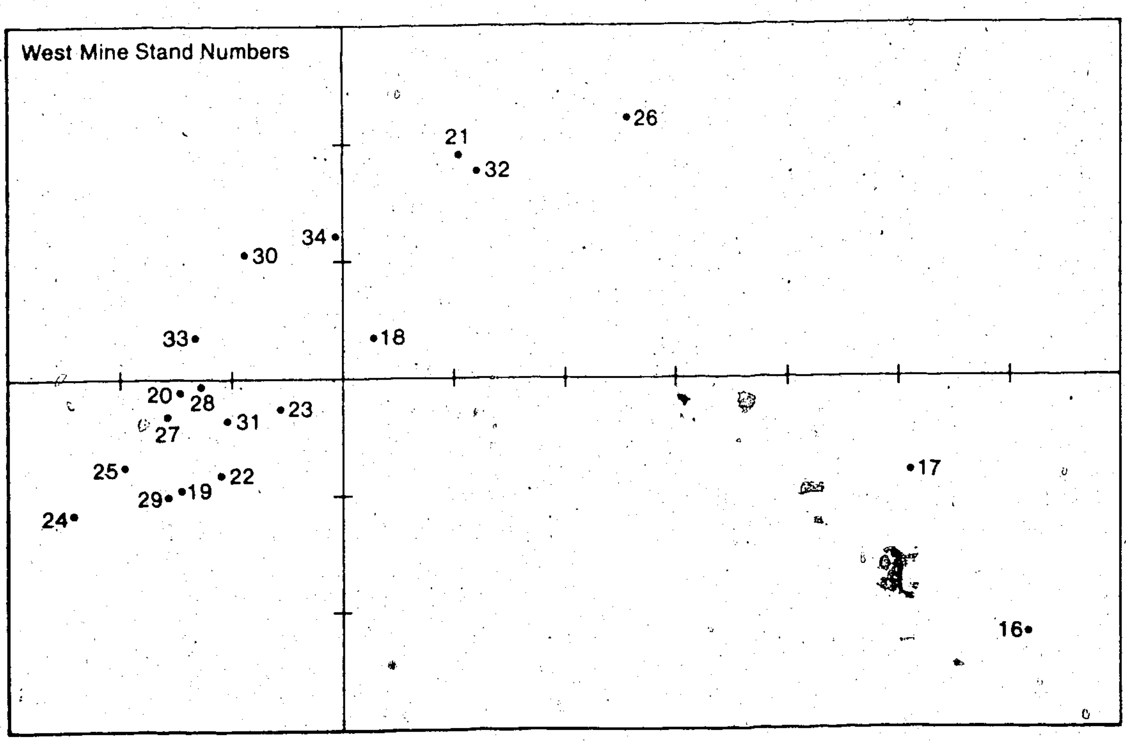


Figure 5. Stand locations on the Mountain Park Townsite and West Mine ordinations. The first and second principal components were used as X and Y axes, respectively.

Table 7. Spearman rank-order correlations (r_s) between the first and second principal components, derived from PCA of the Mountain Park Townsite vegetation data, and selected edaphic variables (N = 15).

Edaphic Variable	Depth (cm)	Principal Components 1	2
Fine Earth Content (% <2 mm)	0-5	0.62**	0.63**
	13-18	0.43	0.79**
	25-30	0.76**	0.59**
Sand Content (%)	0-5	-0.31	0.00
	13-18	-0.35	-0.03
Silt Content (%)	0-5	0.38	0.29
	13-18	0.40	0.13
Clay Content (%)	0-5	0.30	0.04
	13-18	0.03	-0.06
Available Water Holding Capacity (%)	0-5	0.72**	0.61**
	13-18	0.72**	0.38
Total Exchange Capacity (m.e. 100 g^{-1} whole soil)	0-18	0.68**	0.29
pH	0-5	-0.39	0.13
	13-18	-0.44*	0.08
Electrical Conductivity (mmhos cm^{-1})	0-18	-0.50*	-0.03
Available P (ppm)	0-18	0.60**	0.37
Available K (ppm)	0-18	0.10	-0.48*
Exchangeable Ca (m.e. 100 g^{-1} whole soil)	0-18	0.02	0.40
Exchangeable Mg (m.e. 100 g^{-1} whole soil)	0-18	0.31	-0.14
Exchangeable Na (m.e. 100 g^{-1} whole soil)	0-18	-0.34	0.02
Exchangeable K (m.e. 100 g^{-1} whole soil)	0-18	0.60**	0.35
Coal Content (% of >2 mm)	0-5	0.25	0.46*
Sandstone Content (% of >2 mm)	0-5	-0.12	-0.12
Siltstone and Shale Content (% of >2 mm)	0-5	-0.32	-0.50

*Significant at $P \leq 0.05$.

**Significant at $P \leq 0.01$.

strongly correlated with available water holding capacity, total exchange capacity, available phosphorus, and exchangeable potassium; and the second axis with available water holding capacity. Of the topographic variables only slope aspect showed strong patterning on the ordination (Fig. 6).

Thus, both axes correspond to complex topographic and edaphic gradients. From left to right the first axis ranges from relatively xeric conditions in spoils with low water holding and total exchange capacities, predominantly on W-facing slopes, to more mesic conditions with higher water holding and total exchange capacities on flat ground. The second axis distinguishes the stands on N-facing slopes, where conditions are also relatively mesic (Fig. 6).

The results suggest possible interactions between aspect and edaphic variables. This may be due to the prevailing southwesterly winds which deposit fine-grained particles (mostly coal fines) on the northerly slopes. Surface (0-5 cm) fine earth contents tend to be higher in spoils on the N-facing slopes and lower in spoils on the unprotected W-facing slopes.

Response Patterns of Species and Community Attributes. Total plant cover and species richness are plotted on the ordination in Fig. 7. The results suggest that only a few species are able to survive in the coarser, more xeric spoils (on the left). Total plant cover and species richness increased substantially in spoils with higher fine earth contents (up and to the right on the ordination).

The responses of species to the environmental gradients were grouped into five major response pattern types. Representative species of each group were chosen to illustrate the patterns.

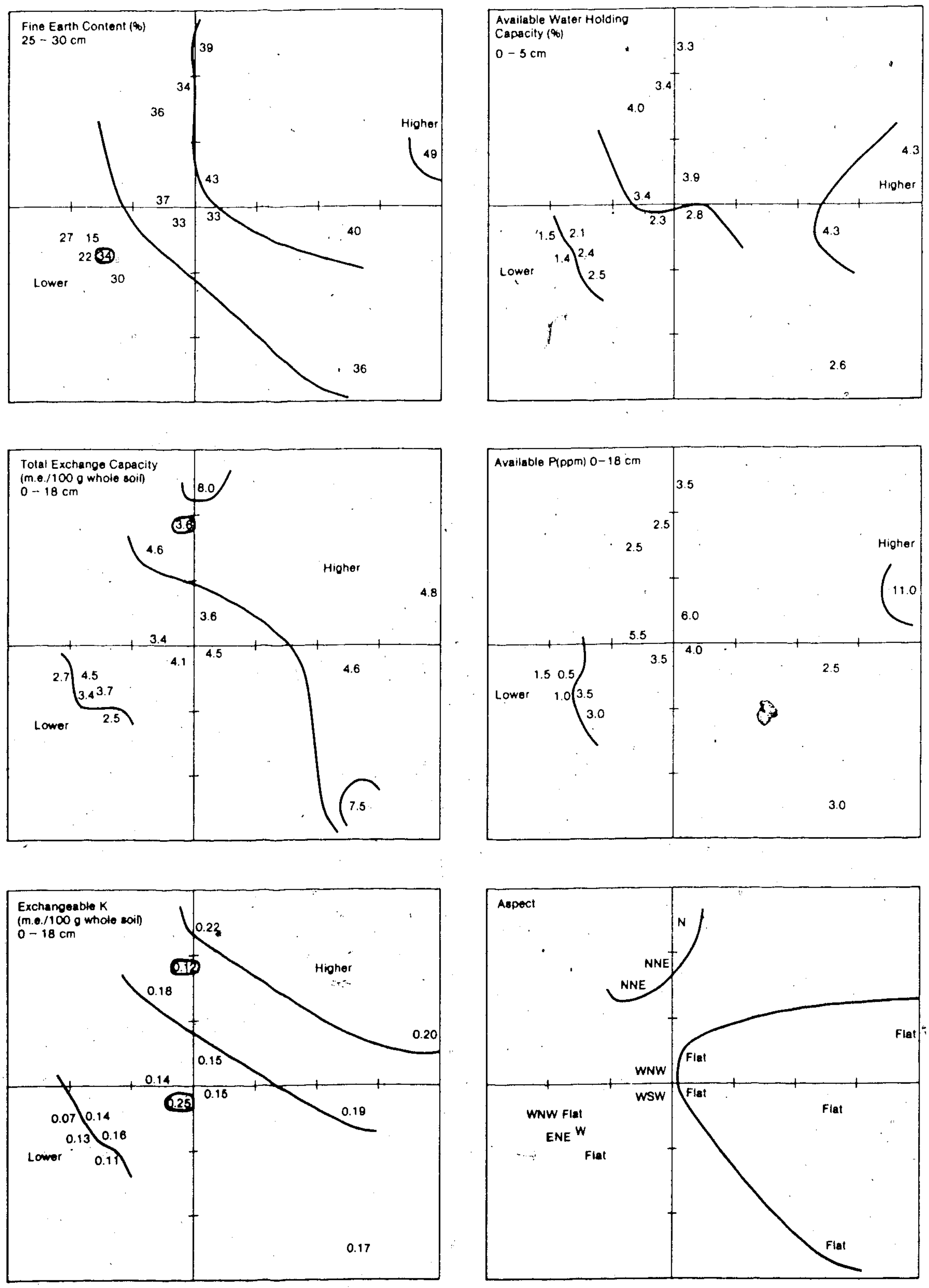


Figure 6. Patterns of selected environmental variables on the Mountain Park Townsite ordination.

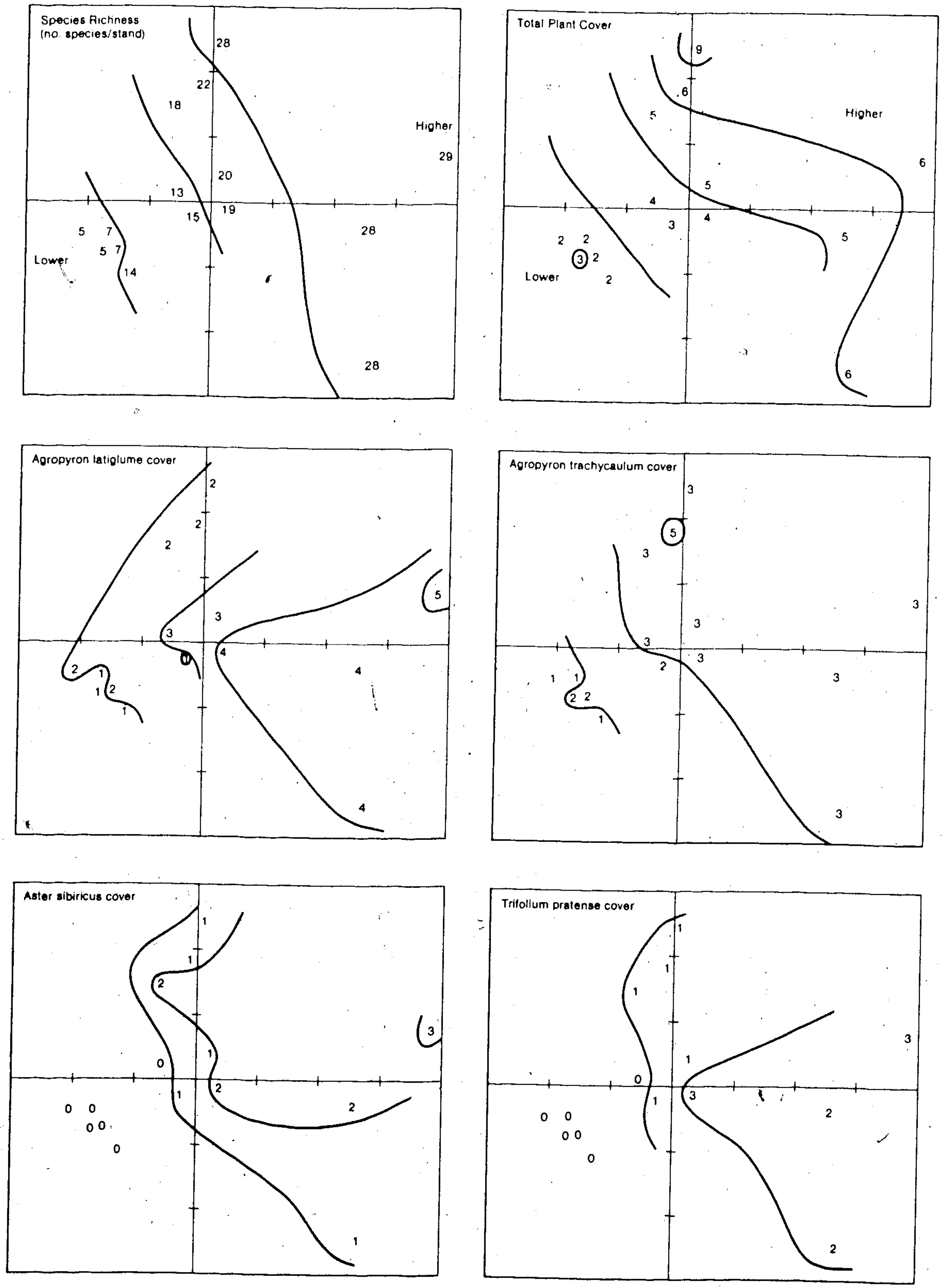


Figure 7. Response patterns of community attributes and selected species on the Mountain Park Townsite ordination. A numerical scale was used to represent percent cover: 0 = absent; 1 = <0.01% cover and/or present but not sampled; 2 = 0.01-0.09%; 3 = 0.10-0.99%; 4 = 1.00-1.99%; 5 = 2.00-3.99%; 6 = 4.00-6.99%; 9 = 13.00-15.99%.

1) Ubiquitous species (common, with wide ecological amplitude): *Agropyron latiglume*, *A. trachycaulum* (Fig. 7); *Festuca saximontana*, *Poa alpina*, *P. interior*, *Potentilla bipinnatifida*, *Potentilla norvegica*, and *Taraxacum officinale*. Species of this group have high stand presences (60-100%). Although widely distributed, they increase in abundance with spoil fine earth content.

2) Common species, but absent from spoils of relatively low fine earth content: *Aster sibiricus*, *Trifolium pratense* (Fig. 7); *Achillea millefolium*, *Agropyron repens*, *Astragalus vexilliflexus*, *Hordeum jubatum*, *Phacelia sericea*, *Poa pratensis*, *Potentilla fruticosa*, and *Solidago multiradiata*. Stand presence is variable, ranging from 33% to 73%.

3) Species restricted to spoils of relatively high fine earth content on level ground: *Fragaria virginiana*, *Oxytropis splendens* (Fig. 8); *Astragalus alpinus*, *Draba aurea*, *Oxytropis deflexa*, and *Senecio canus*. Stand presence is low, ranging from 20 to 27%.

4) Species restricted to the central portion of the environmental gradients: *Artemisia borealis* (Fig. 8).

5) Species restricted to N-facing slopes: *Epilobium angustifolium*, *Galeopsis tetrahit*, *Salix galuca* (Fig. 8); and *Festuca rubra*. Surface spoils on the northern slopes consist predominantly of aeolian deposited coal fines, and conditions are relatively mesic. Although not restricted to N-facing slopes, *F. rubra* is more common and abundant on them, and so is included here.

6) Species with scattered distributions: *Ranunculus acris*, *Rumex mexicanus*, and *Trisetum spicatum*. These species have ecologically

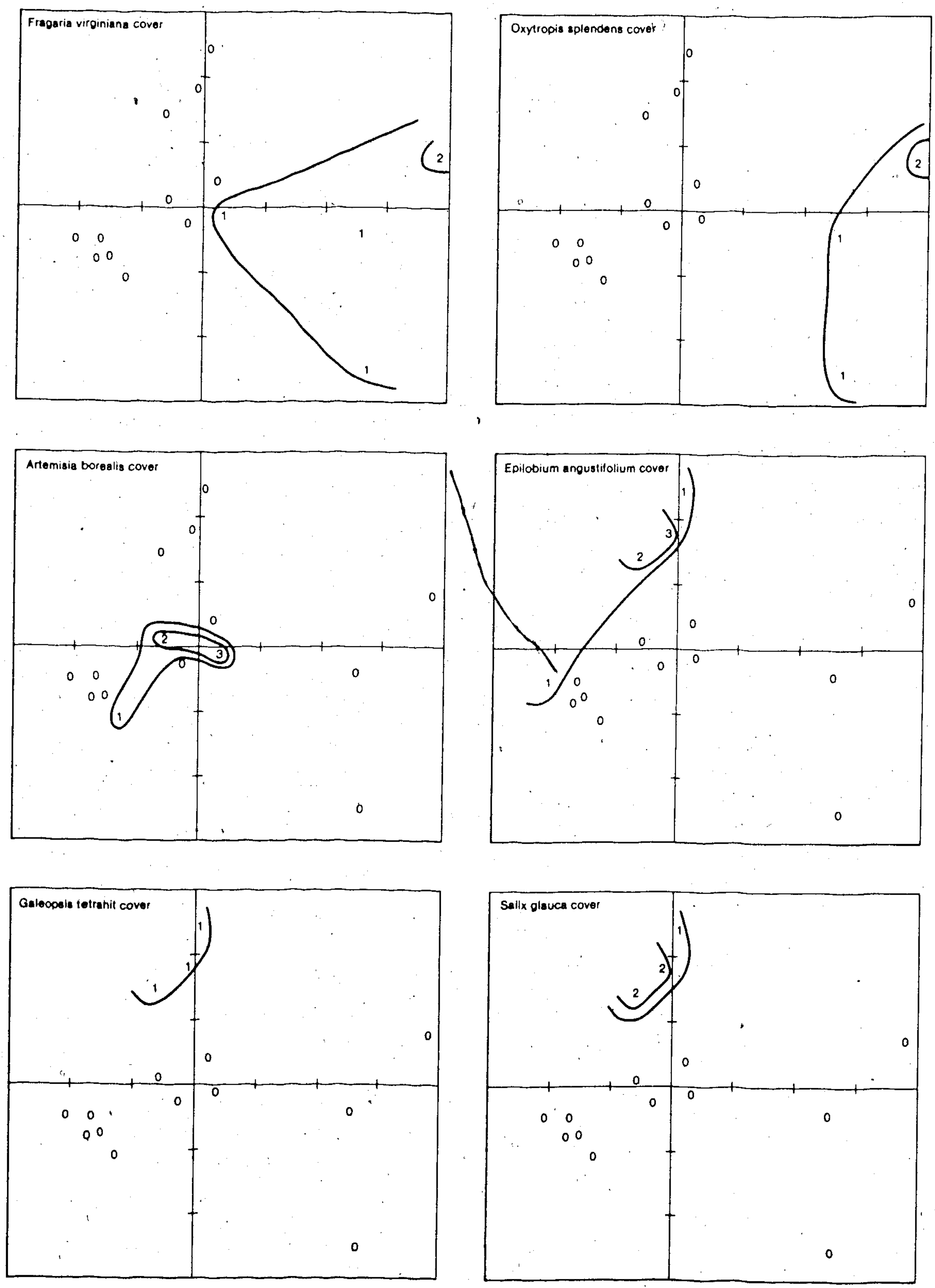


Figure 8. Species response patterns on the Mountain Park Townsite ordination. A numerical scale was used to represent percent cover: 0 = absent; 1 = <0.01% cover and/or present but not sampled; 2 = 0.01-0.09%; 3 = 0.10-0.99%.

uninterpretable distributions.

Results of the correlation analysis support the ordination findings (Table 8). Total plant cover, species richness, and most species are significantly correlated with fine earth content, available water holding capacity, total exchange capacity, and other edaphic variables. These results suggest strong edaphic control of species distributions, species abundances, and, hence, community development.

Mountain Park West Mine

Correlation with Environmental Factors. The first axis was correlated with several edaphic variables but most strongly with clay content, silt content, and sand content (Table 9; Fig. 9). The topographic variables showed no clear patterns when plotted on the ordination. Thus, the first axis corresponds to a spoil texture gradient. It ranges from relatively xeric, coarse textured spoils with high pHs on the left, to more mesic, fine textured spoils with neutral pHs on the right.

The second axis was uncorrelated with topographic variables and only weakly correlated with edaphic variables (Table 9). Little confidence can be placed in any topographic or edaphic interpretation of this axis.

Response Patterns of Species and Community Attributes. Total plant cover and species richness are very low in the coarser textured spoils (Fig. 10). Both increased from left to right on the ordination field, *i.e.* are higher in finer textured spoils.

Species response patterns were divided into six groups.
1) Ubiquitous species: *Agropyron latiglume, Artemisia borealis* (Fig. 10); *Achillea millefolium, Agropyron trachycaulum, Deschampsia caespitosa,*

Table 8. Significant Spearman rank-order correlations (P ≤ 0.05) between plant variables and selected edaphic variables using Mountain Park Townsite stand data (N = 15). Species are grouped according to their distribution patterns on the PCA ordination (*see* p. 42).

Plant Variables	Fine Earth Content (% <2 mm)		Sand Content (%)		Clay Content (%)		A.W.H.C. (%)[1]		T.E.C.[2]	Available P (ppm)	pH
	0-5 cm	25-30 cm	13-18 cm	25-30 cm	0-5 cm	13-18 cm	0-5 cm	13-18 cm	0-18 cm	0-18 cm	0-5 cm
Community Attributes											
Total Plant Cover	++[3]	++	.	.	.	.	++	++	++	.	.
Species Richness	++	++	.	.	.	.	++	++	++	+	.
Species Group 1											
Agropyron latiglume	+	++	.	.	.	.	++	.	+	+	.
Agropyron trachycaulum	++	++	.	.	.	.	++	+	.	.	.
Festuca saximontana	+	+	.	.	.	-	++	.	.	++	-
Poa alpina	++	++	.	.	.	.	++	.	.	+	.
Poa interior	.	++	-	.	.	.	++	++	.	.	-
Potentilla bipinnatifida	+	.	.	.	+	.	.	+	++	.	.
Potentilla norvegica	.	+	.	.	.	.	+	+	.	+	--
Taraxacum officinale	.	.	-	.	.	.	.	++	.	.	.
Species Group 2											
Achillea millefolium	++	++	.	.	.	.	++	++	+	+	.
Agropyron repens	.	.	.	.	.	.	.	.	+	.	.
Aster sibiricus	++	++	.	.	.	.	++	.	++	.	.
Astragalus vexilliflexus	.	+	.	.	.	.	+	.	++	.	.
Hordeum jubatum	.	+	.	.	.	.	.	+	.	+	.
Phacelia sericea	.	++	-	.	.	.	++	+	+	+	.
Poa pratensis	.	+	-	.	.	.	.	+	.	+	--
Potentilla fruticosa	.	.	--	.	.	.	.	+	+	.	.
Solidago multiradiata	.	.	-	.	.	.	.	++	.	.	-
Trifolium pratense	++	+	.	.	.	.	+	+	++	.	.
Species Group 3											
Astragalus alpinus	+	+	.	.	.	.	+	.	++	.	.
Draba aurea	.	++	.	-	.	.	.	++	.	+	.
Fragaria virginiana	.	.	.	.	.	.	.	.	++	.	.
Oxytropis deflexa	+	.	.	.	.	.	.	.	+	.	.
Oxytropis splendens	.	+	.	.	.	.	+	.	+	.	.
Senecio canus	.	+	-	.	.	.	.	.	+	.	.
Species Group 4											
Artemisia borealis	.	.	.	.	.	.	.	.	.	.	.
Species Group 5											
Epilobium angustifolium	.	.	.	.	.	.	.	.	.	.	+
Festuca rubra	++	.	.	.	.	.	.	.	+	.	.
Galeopsis tetrahit	+	.	.	.	.	.	.	.	.	.	.
Salix glauca	+	.	.	.	.	.	.	.	.	.	.
Species Group 6											
Ranunculus acris	.	.	.	.	.	.	.	+	.	.	.
Rumex mexicanus	.	.	.	.	.	+	.	.	++	.	.
Trisetum spicatum	.	.	.	+	.	.	.	.	.	.	.

[1] Available water holding capacity.

[2] Total exchange capacity (m.e. $100\ g^{-1}$ whole soil).

[3] +, -, and ++, -- correspond to significant positive and negative correlations at P ≤ 0.05 and P ≤ 0.01, respectively.

Table 9. Spearman rank-order correlations (r_s) between the first and second principal components, derived from PCA of the Mountain Park West Mine vegetation data, and selected edaphic variables (N = 19).

Edaphic Variable	Depth (cm)	Principal Components 1	2
Fine Earth Content (% <2 mm)	0-5	0.25	0.08
	13-18	0.00	-0.50*
Sand Content (%)	0-5	-0.58**	-0.20
	13-18	-0.59**	-0.14
Silt Content (%)	0-5	0.59**	0.13
	13-18	0.45*	0.20
Clay Content (%)	0-5	0.44*	0.28
	13-18	0.64**	0.11
Available Water Holding Capacity (%)	0-5	0.49*	0.20
	13-18	0.36	-0.06
Total Exchange Capacity (m.e. 100 g^{-1} whole soil)	0-18	0.46*	-0.17
pH	0-5	-0.55**	-0.21
	13-18	-0.43*	0.00
Electrical Conductivity (mmhos cm^{-1})	0-18	-0.50*	0.01
Available P (ppm)	0-18	0.56**	0.02
Available K (ppm)	0-18	0.32	-0.03
Exchangeable Ca (m.e. 100 g^{-1} whole soil)	0-18	0.15	-0.33
Exchangeable Mg (m.e. 100 g^{-1} whole soil)	0-18	-0.06	-0.40*
Exchangeable Na (m.e. 100 g^{-1} whole soil)	0-18	0.23	-0.48*
Exchangeable K (m.e. 100 g^{-1} whole soil)	0-18	0.28	-0.29
Coal Content (% >2 mm)	0-5	0.15	0.46*
Sandstone Content (% >2 mm)	0-5	0.28	0.07
Siltstone and Shale Content (% >2 mm)	0-5	-0.31	-0.17

* Significant at $P \leq 0.05$.

** Significant at $P \leq 0.01$.

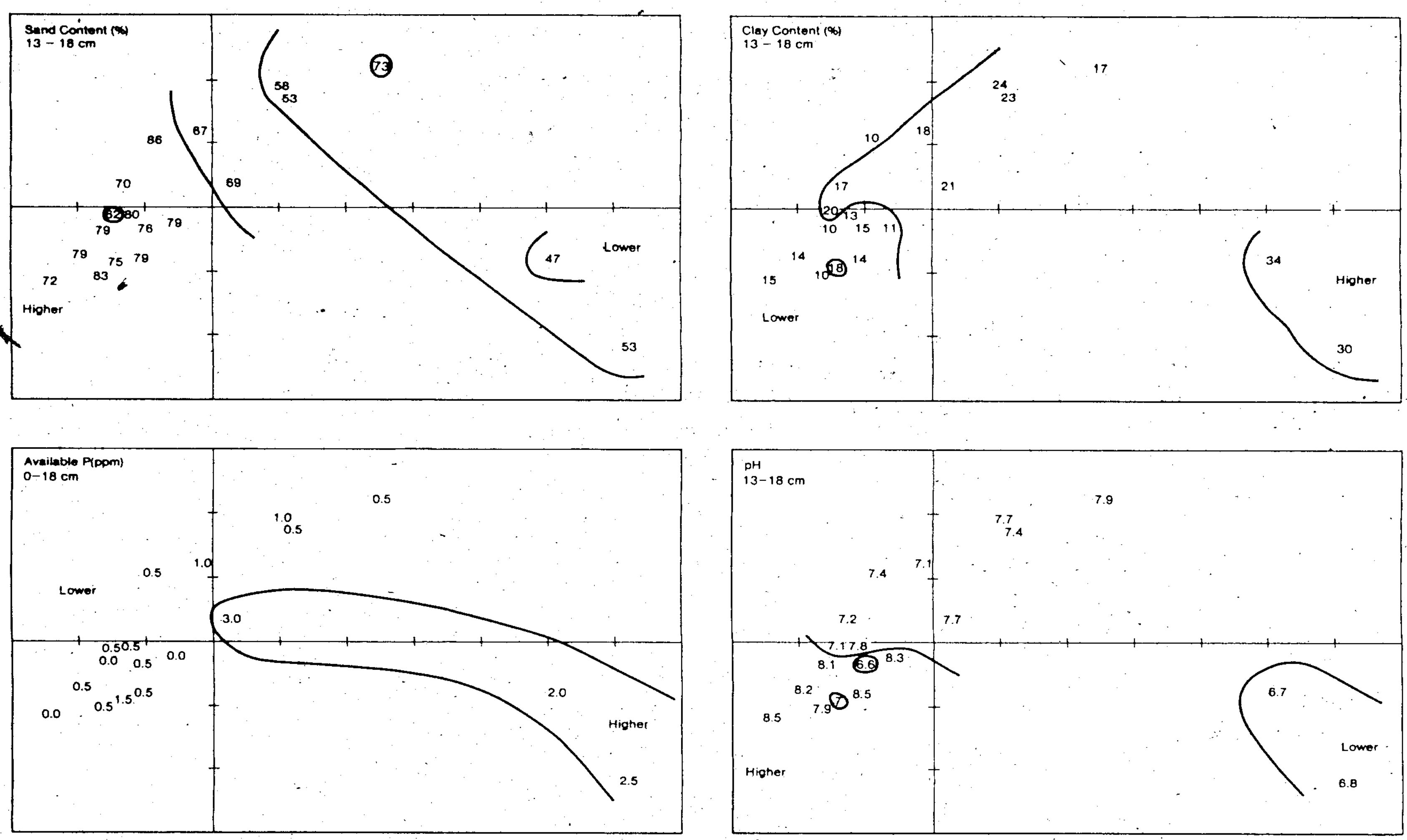


Figure 9. Patterns of selected edaphic variables on the Mountain Park West Mine ordination.

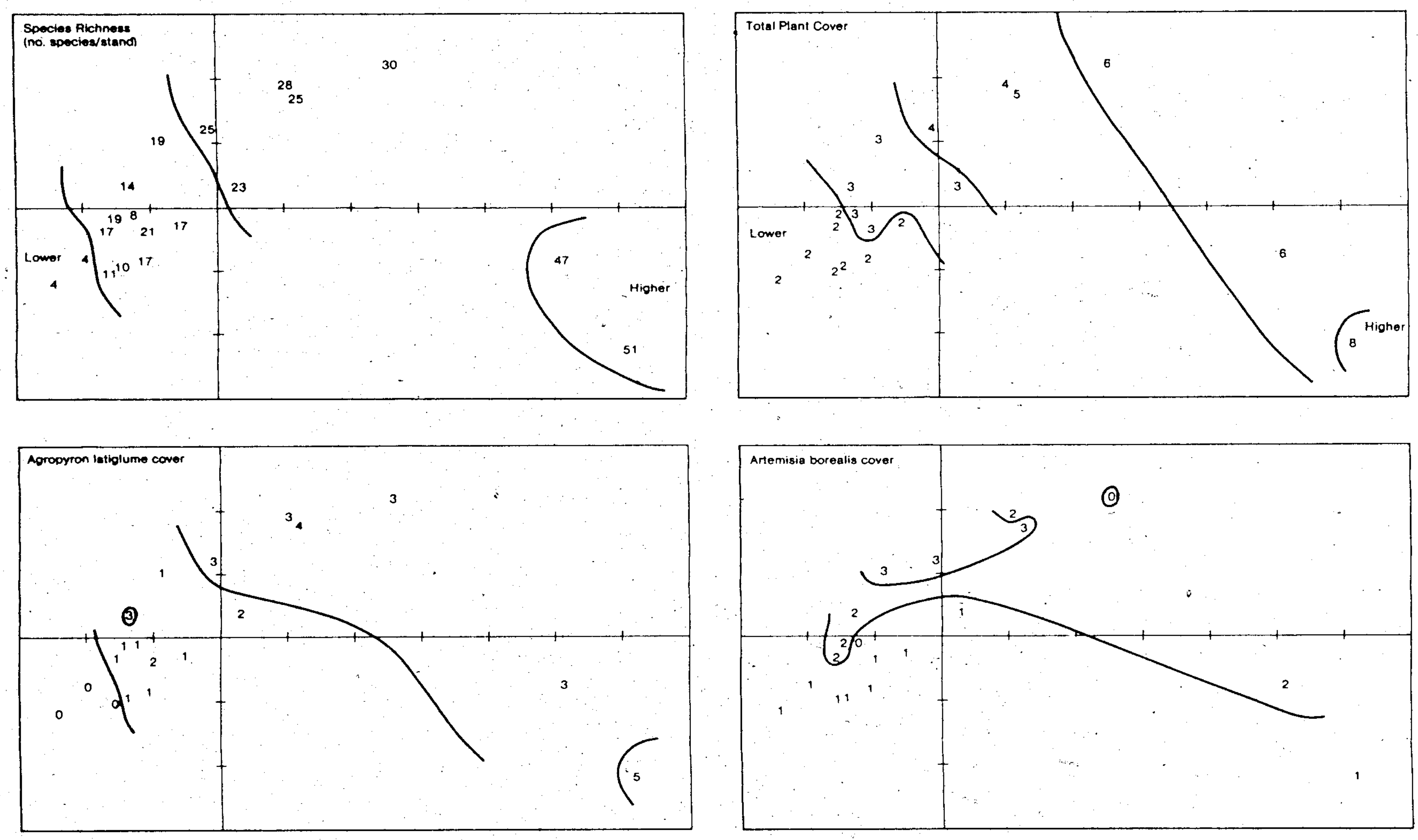


Figure 10. Response patterns of community attributes and selected species on the Mountain Park West Mine ordination. A numerical scale was used to represent percent cover: 0 = absent; 1 = <0.01% cover and/or present but not sampled; 2 = 0.01-0.09%; 3 = 0.10-0.99%; 4 = 1.00-1.99%; 5 = 2.00-3.99%; 6 = 4.00-6.99%; 8 = 10.00-12.99%.

Festuca baffinensis, *Hedysarum alpinum*, *Poa alpina*, *P. interior*, *P. secunda*, and *Trisetum spicatum*. They range in presence from 58% to 90% and have wide amplitudes on the edaphic gradient. Most species increase in abundance from left to right along the gradient. A notable exception is *Artemisia borealis* which is more abundant near the center of the gradient.

2) Common species, but absent from the coarser textured spoils: *Festuca saximontana*, *Oxytropis deflexa* (Fig. 11); *Astragalus alpinus*, *Aster sibiricus*, *Cerastium beeringianum*, *Epilobium angustifolium*, *Mertensia paniculata*, *Solidago multiradiata*, and *Taraxacum officinale*. Species stand presences range from 26 to 58%.

3) Species restricted to the finer textured spoils: *Arenaria rubella*, *Gentianella amarella* (Fig. 11); *Agoseris glauca*, *Botrychium lunaria*, *Draba aurea*, *Elymus innovatus*, *Erigeron trifidus*, *Solidago decumbens*, and *Trifolium pratense*. Stand presences are relatively low; ranging from 16% to 32%. These species occur only in the most mesic stands.

4) Species restricted to, or more abundant in the coarser textured spoils: *Crepis nana*, *Eriogonum androsaceum* (Fig. 12); and *Epilobium latifolium*. They range in presence from 26% to 84%. *Epilobium* and *Eriogonum* have rather narrow amplitudes, whereas *Crepis* is widely distributed. These species are probably more xerophytic than those of other groups.

5) Species restricted to the central portion of the edaphic gradient: *Astragalus aboriginum*, *A. vexilliflexus* (Fig. 12); *Crepis elegans*, and *Draba oligosperma*. They have relatively low stand presences; ranging [illegible] and narrow amplitudes on the edaphic gradient.

[illegible]ttered distributions: *Equisetum arvense*, *Fragaria*

[illegible]

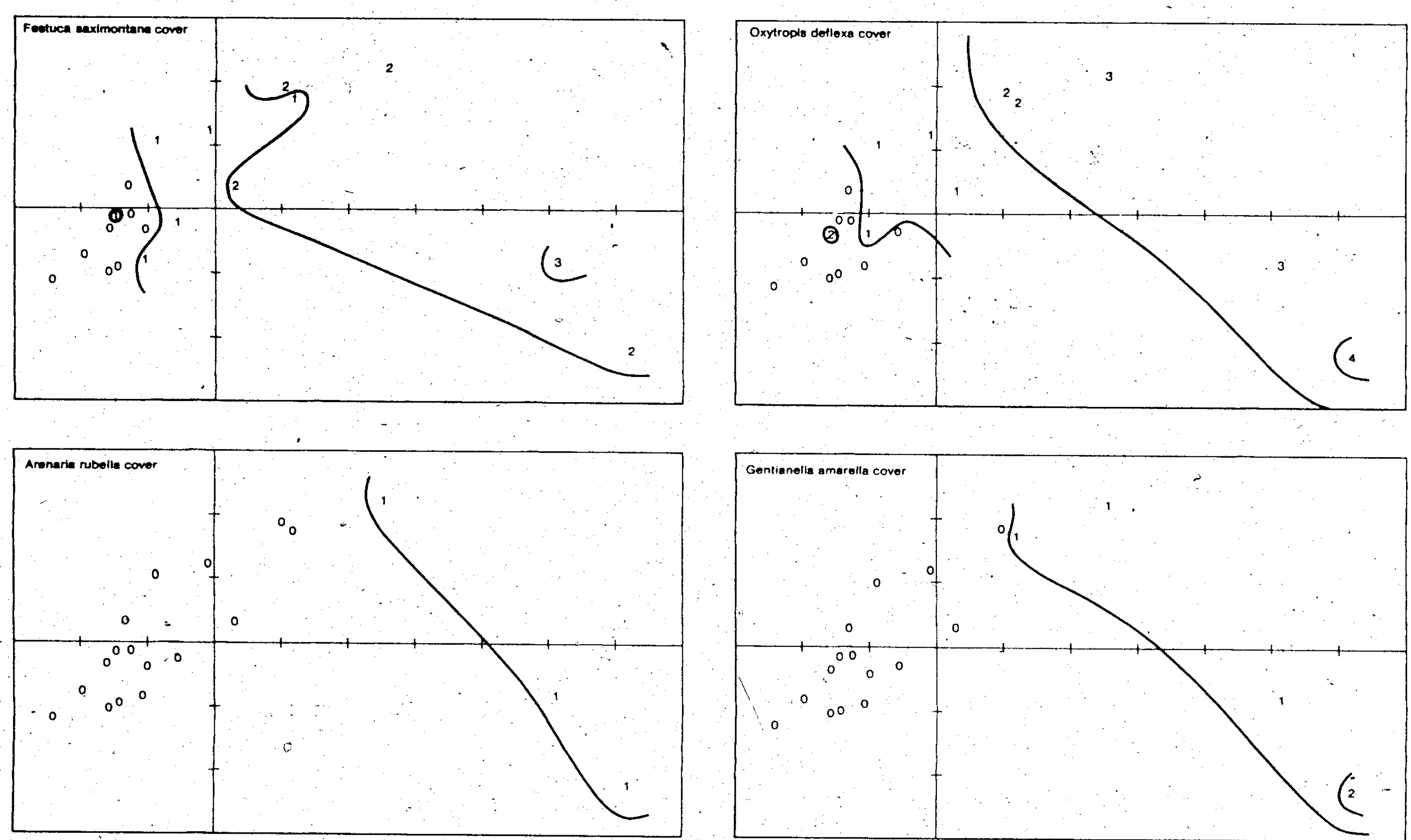


Figure 11. Species response patterns on the Mountain Park West Mine ordination. A numerical scale was used to represent percent cover: 0 = absent; 1 = <0.01% cover and/or present but not sampled; 2 = 0.01-0.09%; 3 = 0.10-0.99%; 4 = 1.00-1.99%.

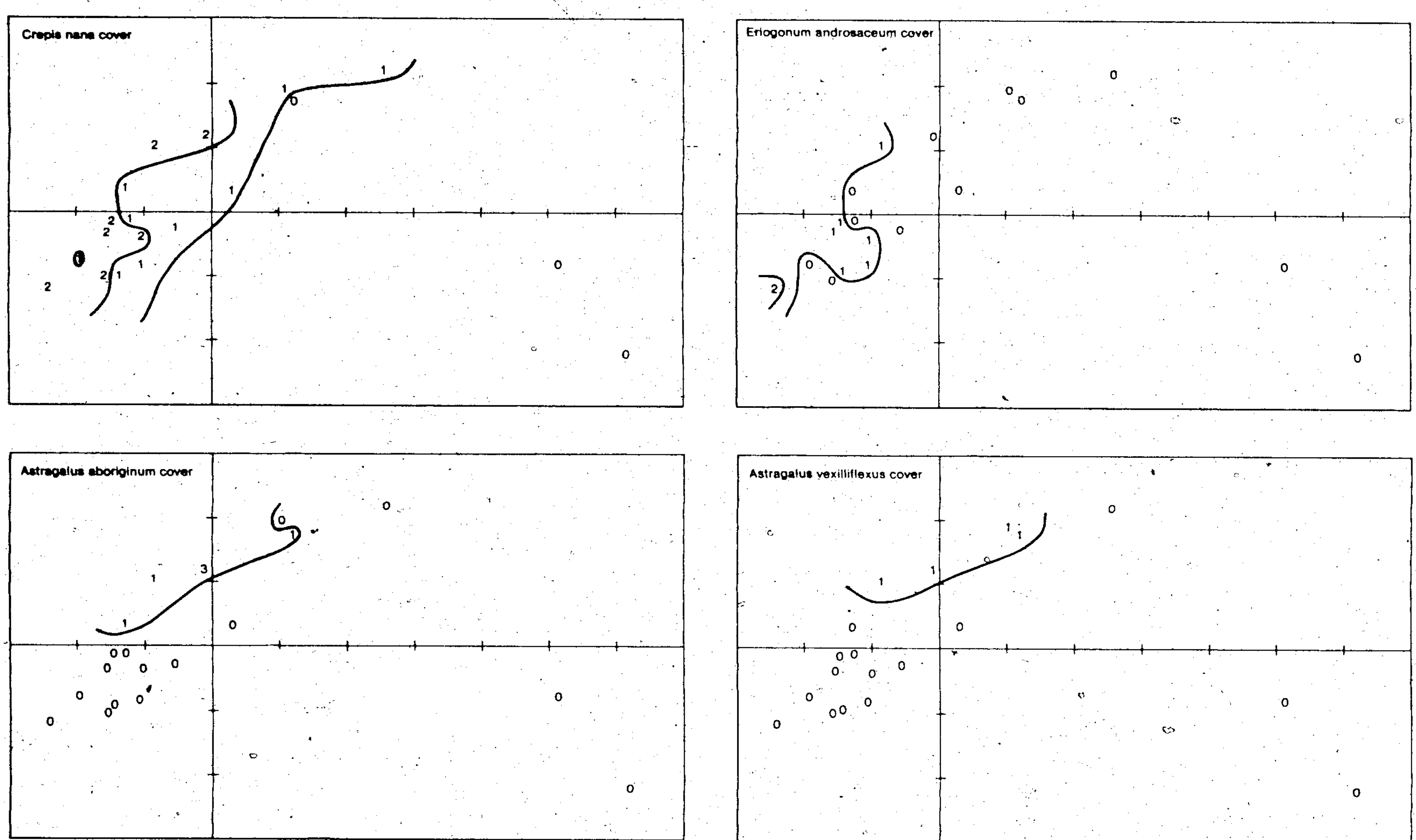


Figure 12. Species response patterns on the Mountain Park West Mine ordination. A numerical scale was used to represent percent cover: 0 = absent; 1 = <0.01% cover and/or present but not sampled; 2 = 0.01-0.09%; 3 = 0.10-0.99%.

virginiana, Phleum alpinum, Salix glauca, and *Stellaria longipes. Equisetum* is more abundant in the finer textured spoils. The remaining species showed no clear patterns on the ordination.

The community and species attributes were subjected to correlation analysis with all edaphic variables (Table 10). The results support the ordination findings. Total plant cover, species richness, and most species were correlated with silt content, clay content, available water holding capacity, total exchange capacity, available phosphorus, and other edaphic variables. *Crepis nana* and *Epilobium latifolium* were more abundant in the coarser textured spoils and were the only species positively correlated with sand content.

The results suggest that edaphic factors play a major role in controlling plant distribution on the west minesite.

Comparison of the Mountain Park Townsite and West Mine Ordination Results

On both study sites, total plant cover and species richness range from very low in the coarser, more xeric spoils, to higher in finer, more mesic spoils. While the range of total cover is similar on the two sites, that of species richness is much wider at the West Mine, due to the large number of species in stands 16 and 17. These stands have the finest textured spoils and most mesic conditions of stands at either site.

Some species showed similar response patterns on the two ordinations: *Agropyron latiglume, A. trachycaulum, Poa alpina,* and *P. interior* are ubiquitous at both sites; *Aster sibiricus* and *Solidago multiradiata* are common, but absent from the coarser, more xeric spoils at both sites; and *Draba aurea* is restricted to the more mesic spoils

Table 10. Significant Spearman rank-order correlations ($P \le 0.05$) between plant variables and selected edaphic variables using Mountain Park West Mine stand data ($N = 19$). Species are grouped according to their distribution patterns on the PCA ordination (see p. 47).

Plant Variables	Fine Earth Content (% < 2 mm) 0-5 cm	Fine Earth Content (% < 2 mm) 25-30 cm	Sand Content (%) 0-5 cm	Sand Content (%) 13-18 cm	Clay Content (%) 0-5 cm	Clay Content (%) 13-18 cm	A.W.H.C. (%)[1] 0-5 cm	A.W.H.C. (%)[1] 13-18 cm	T.E.C.[2] 0-18 cm	Available P (ppm) 0-18 cm	pH 0-5 cm
Community Attributes											
Total Plant Cover	.	.	-[3]	--	.	++	++	++	++	+	--
Species Richness	.	.	-	--	.	++	+	.	++	++	--
Species Group 1											
Achillea millefolium	.	.	-	-	.	+	+	.	.	+	-
Agropyron latiglume	.	.	--	--	+	++	++	+	+	+	--
Agropyron trachycaulum	.	+	.	.	.	.	.	.	.	.	-
Artemisia borealis	.	.	.	.	.	.	+	.	+	.	.
Deschampsia caespitosa	.	.	-	.	+	.	.	.	.	+	.
Festuca baffinensis	.	.	-	--	.	++	+	+	++	++	--
Hedysarum alpinum	+	.	-	-	+	+	.	.	.	+	.
Poa alpina	.	.	--	--	+	++	+	.	+	++	--
Poa interior	.	.	--	--	.	++	++	++	++	+	--
Poa secunda	.	.	--	--	++	++	++	+	+	++	-
Trisetum spicatum	.	.	--	--	++	++	+	.	.	+	.
Species Group 2											
Astragalus alpinus	.	.	--	--	++	++	.	.	.	+	.
Aster sibiricus	.	.	.	--	.	++	+	.	+	++	-
Cerastium beeringianum	.	.	.	--	.	++	+	+	++	+	--
Epilobium angustifolium	.	.	-	--	.	++	+	++	++	+	-
Festuca saximontana	.	.	--	--	++	++	.	.	.	++	.
Mertensia paniculata	.	.	.	-	.	+	+	.	+	++	--
Oxytropis deflexa	.	.	--	--	+	++	+	.	.	+	-
Solidago multiradiata	.	.	-	-	+	+	.	.	.	+	.
Taraxacum officinale	.	.	-	-	+	+	++	+	+	.	-
Species Group 3											
Agoseris glauca	.	.	--	--	+	++	++	++	++	+	-
Arenaria rubella	.	+	-	-	+	+	++	+	+	.	.
Botrychium lunaria	.	.	--	--	++	++	++	++	+	+	.
Draba aurea	.	.	--	--	+	++	++	++	++	+	.
Elymus innovatus	.	+	-	-	+	+	++	+	+	+	.
Erigeron trifidus	.	.	.	-	.	+	.	+	.	.	.
Gentianella amarella	+	+	--	--	+	++	++	++	++	.	.
Solidago decumbens	.	.	--	--	+	++	+	+	.	+	.
Trifolium pratense	.	.	--	.	++	.	++	+	.	.	.
Species Group 4											
Crepis nana	.	.	+	+	.	-	.	-	.	-	.
Epilobium latifolium	.	.	+	.	.	.	.	.	.	-	.
Eriogonum androsaceum	.	.	.	.	.	.	.	.	.	.	.
Species Group 5											
Astragalus aboriginum	.	.	.	.	.	.	+	.	+	.	-
Astragalus vexilliflexus	.	.	.	.	.	.	.	.	.	.	.
Crepis elegans	.	.	.	.	.	.	.	.	.	.	.
Draba oligosperma	-	--	-	.	+	+	.	.	-	.	.
Species Group 6											
Equisetum arvense	.	.	.	.	.	.	.	.	+	+	.
Fragaria virginiana	.	.	.	.	.	.	.	.	.	++	.
Phleum alpinum	.	.	-	.	.	.	+	.	.	.	.
Salix glauca	-	.	.	.	.	.	.	.	+	.	-
Stellaria longipes	.	.	.	.	.	.	.	.	.	.	.

[1]Available water holding capacity.

[2]Total exchange capacity (m.e. 100 g^{-1} whole soil).

[3]+, -, and ++, -- correspond to significant positive and negative correlations at $P < 0.05$ and $P \le 0.01$, respectively.

at both sites. Many species, however, showed very different response patterns on the two ordinations: *Potentilla bipinnatifida* and *P. norvegica* are ubiquitous at the Townsite but rare and absent, respectively, at the West Mine; *Deschampsia caespitosa, Festuca baffinensis, Hedysarum alpinum,* and *Poa secunda* are ubiquitous at the West Mine but rare or absent at the Townsite; *Artemisia borealis* is ubiquitous at the West Mine but restricted to the central portion of the environmental gradient at the Townsite; *Epilobium angustifolium* is common at the West Mine but occurs only on N-facing slopes at the Townsite; and *Astragalus vexilliflexus* is common at the Townsite but restricted to the central portion of the environmental gradient at the West Mine. These results probably reflect floristic and/or environmental differences between the two sites.

Species restricted to the extremes of the environmental gradient on the West Mine ordination are rare or absent at the Townsite. This suggests that the West Mine has a wider range of habitats than the Townsite. For example, *Agoseris glauca, Arenaria rubella, Botrychium lunaria, Elymus innovatus, Erigeron trifidus, Gentianella amarella,* and *Solidago decumbens* occur only in the finer textured, more mesic spoils at the West Mine, but are rare or absent at the Townsite. Similarly, *Crepis nana, Epilobium latifolium,* and *Eriogonum androsaceum* are restricted to or, in the case of *Crepis*, more abundant in the coarser textured, more xeric spoils at the West Mine, but are absent entirely at the Townsite.

Community Classification

Cluster Analysis

The cluster dendrogram based on species presence-absence (qualitative) data is a useful and ecologically interpretable representation of stand relationships (Fig. 13). It cleanly separates the Townsite from the West Mine stands, thus illustrating their floristic differences.

In contrast, the dendrogram derived from species cover (quantitative) data is a poor representation of stand ecological relationships and, thus, was of little use in community classification. Its poor performance may be because Euclidean distance, which was the similarity index used in cluster analysis to compare stands, squares the species importance values (*see* Sneath and Sokal 1973 for euclidean distance formula). This emphasizes the more abundant species, which in this study tend to be widely distributed and less ecologically distinguishing.

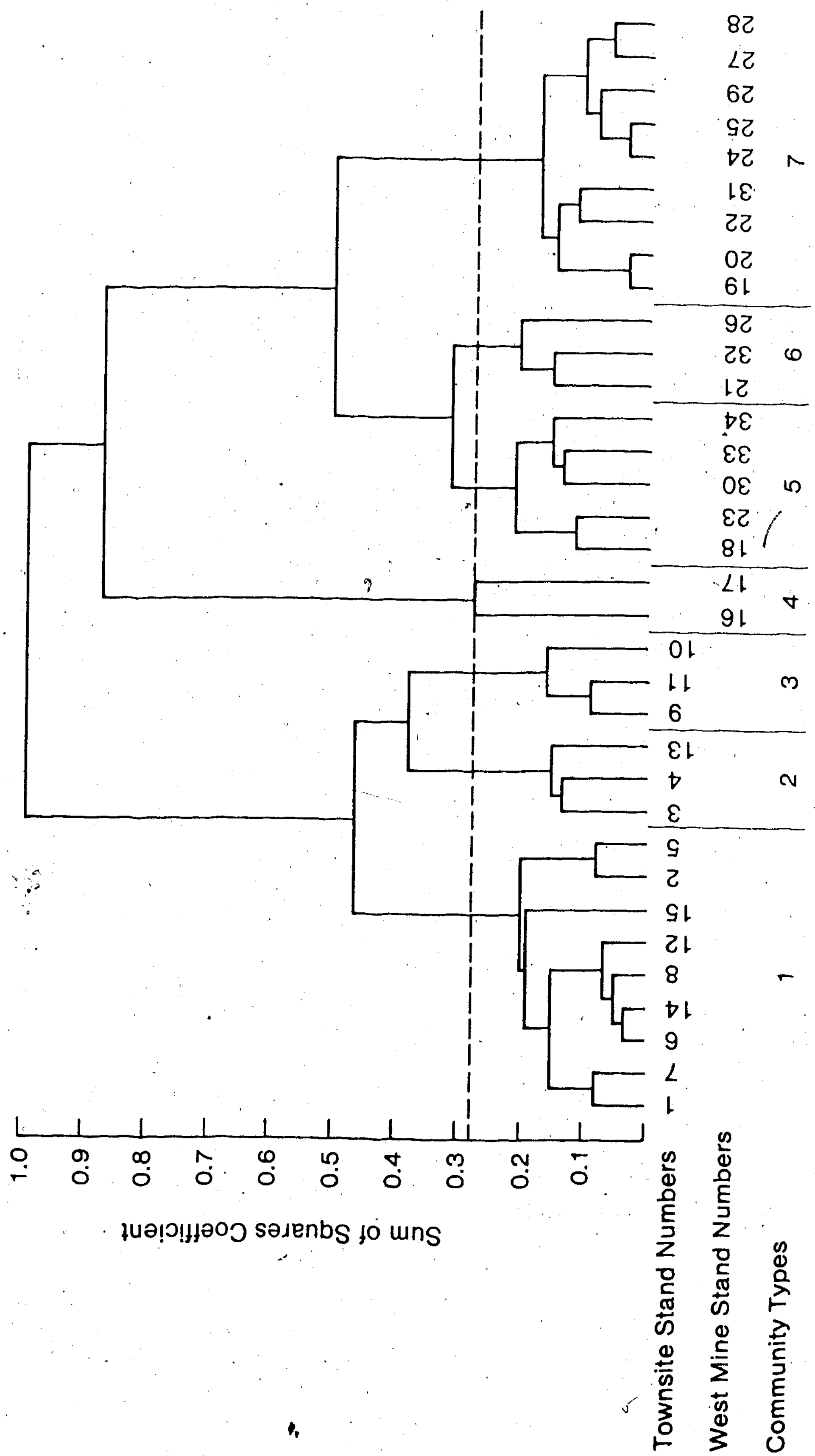
Using the qualitative dendrogram, PCA results, and field observations, seven plant community types (ct's) were recognized: three at the Townsite and four at the West Mine (Fig. 13). These are shown plotted on the PCA ordinations in Fig. 14.

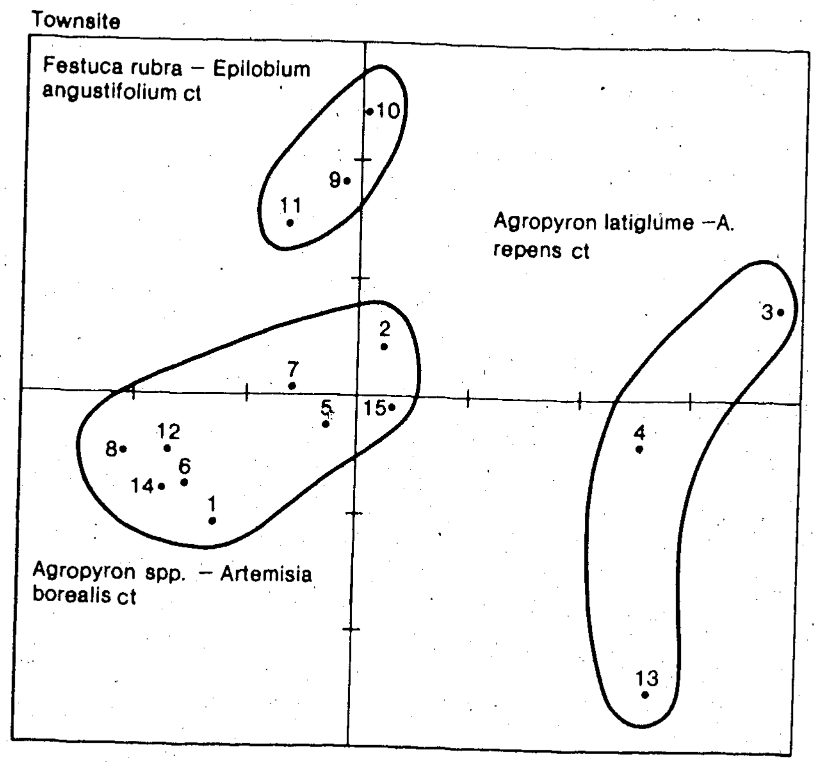
Description of Plant Communities

The vegetation of both sites consists of sparse, mostly herbaceous plant communities dominated by perennial grasses and forbs. Total plant cover is low (usually <15%) and isolated plants are common. Trees are rare, occur in protected areas, and often display stunted growth-forms. Shrubs are more common but contribute little to the total plant cover. Bryophytes occur in mesic, protected microsites, *e.g.*, between and under rocks or where vascular cover is high, but achieve little cover. Foliose lichens occur in the most mesic areas on the West Mine, but have very low cover. Fruticose and crustose lichens are lacking entirely.

Figure 13. Cluster dendrogram derived from Ward's (1963) method of cluster analysis applied to qualitative vegetation data from the Mountain Park Townsite and West Mine study sites. The vertical scale is a coefficient which is twice the increase in the error sum of squares caused by fusion at that level. Seven community types were recognized:

1. *Agropyron* spp. - *Artemisia borealis*
2. *Agropyron latiglume* - *A. repens*
3. *Festuca rubra* - *Epilobium angustifolium*
4. *Equisetum arvense* - *Potentilla fruticosa*
5. *Agropyron latiglume* - *Crepis elegans*
6. *Agoseris glauca* - *Crepis nana*
7. *Crepis nana* - *Eriogonum androsaceum*


Sum of Squares Coefficient
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Townsite Stand Numbers
1 7 9 14 8 12 15 2 5 3 4 13 9 11 10
West Mine Stand Numbers
16 17 18 23 30 33 34 21 32 26 19 20 22 31 24 25 29 27 28
Community Types
1 2 3 4 5 6 7



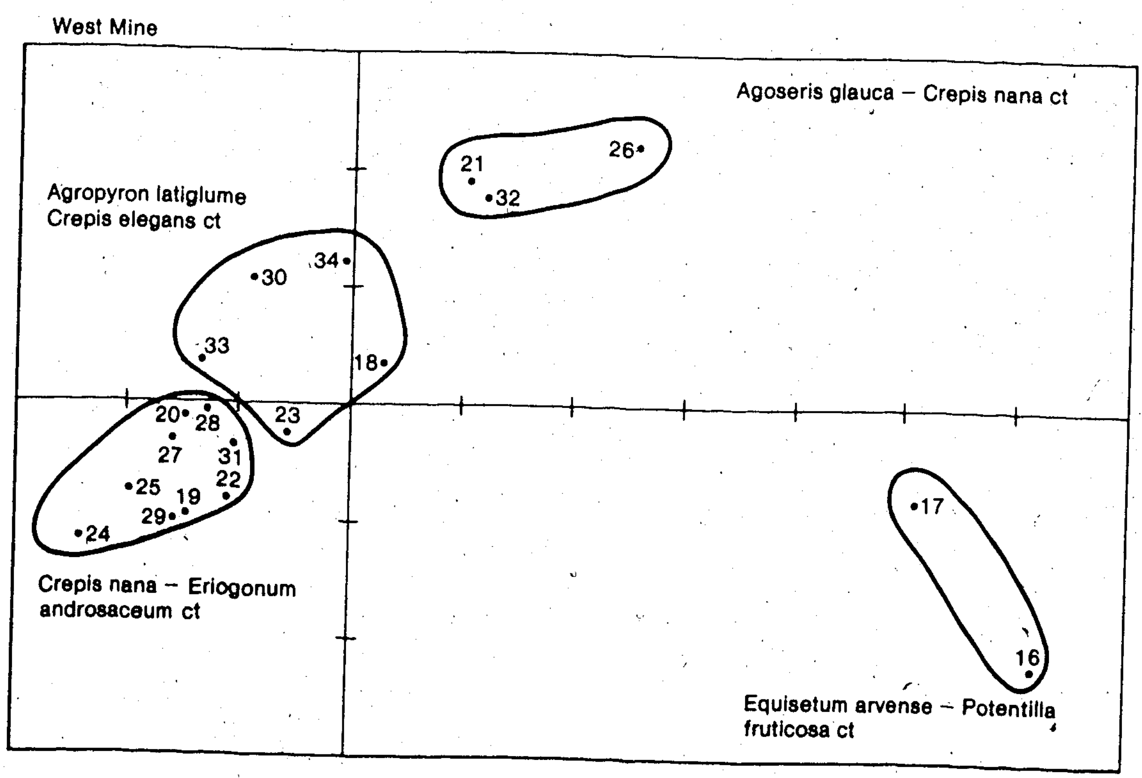


Figure 14. Stand locations and community types on the Mountain Park Townsite and West Mine PCA ordinations.

Mountain Park Townsite Communities (Table 11, *see* attached packet). 1) *Festuca rubra* - *Epilobium angustifolium* community type (stands 9, 10, 11), occurs at the northern end of the minesite on N- and NNE-facing slopes, where protected from the prevailing southwesterly winds. Surface spoils consist predominantly of aeolian deposited coal fines (especially in stands 9 and 11) with relatively high fine earth content.

Festuca rubra is dominant in most stands. *Agropyron trachycaulum* is usually second in abundance but achieves dominance in stand 9. Other relatively abundant species are *Epilobium angustifolium*, *Taraxacum officinale* and *Achillea millefolium*. Several character species distinguish this ct, including *Epilobium angustifolium*, *Taraxacum officinale*, *Salix glauca*, and *Galeopsis tetrahit*.

Total plant cover is higher than in other Townsite ct's ($\bar{x}$ = 7.0%). Average species richness is also relatively high at 23.

2) *Agropyron latiglume* - *A. repens* community type (stands 3, 4, 13)

This ct occurs on level to slightly undulating ground near the center of the minesite. Average fine earth content of its spoils is second highest of the Townsite ct's.

Agropyron latiglume is dominant in all stands and achieves maximum cover in this ct. Other relatively abundant species are *Poa pratensis*, *Agropyron trachycaulum*, *Potentilla norvegica*, and *P. bipinnatifida*. A number of species have diagnostic value, including *Agropyron repens*, *Astragalus vexilliflexus*, *Fragaria virginiana*, *Oxytropis deflexa*, *O. splendens*, and *Senecio canus*.

This ct has the highest species richness ($\bar{x}$ = 28) and the second highest total plant cover ($\bar{x}$ = 4.9%) of the Townsite ct's.

3) *Agropyron* spp. - *Artemisia borealis* community type (stands 1, 2, 5, 6, 7, 8, 12, 14, 15)

This is the most common and widely distributed ct at the Townsite; occurring on level ground and W- and E-facing slopes. The spoils generally have lower fine earth content, available water holding capacity, and total exchange capacity than those in other Townsite ct's.

Agropyron latiglume and *A. trachycaulum* are usually co-dominant. *Taraxacum officinale* is also relatively abundant, achieving dominance in stands 5 and 14.

This ct has the lowest total plant cover ($\bar{x}$ = 0.64%) and species richness ($\bar{x}$ = 12) of any Townsite ct. Furthermore, there are no character species. Species of common occurrence here are common and often more abundant in other ct's, and thus of little diagnostic value. *Artemisia borealis* occurs exclusively in this ct, but in only three of the nine stands.

Mountain Park West Mine communities (Table 12, *see* attached packet).

1) *Equisetum arvense* - *Potentilla fruticosa* community type (stands 16, 17)

This ct is restricted to one small spoil-heap at the NW end of the minesite. It is the most mesic ct of both sites. In general, the spoils have finer textures and higher water holding and total exchange capacities than those in other ct's.

It is further distinguished by having the highest total plant cover ($\bar{x}$ = 8.2%) and species richness ($\bar{x}$ = 49) of the ct's of both study sites. The dominant species are *Equisetum arvense* and *Agropyron latiglume*. *Equisetum* is uniformly distributed and forms the matrix of the community. There are many character species, including *Androsace septentrionalis*, *Arenaria rubella*, *Elymus innovatus*, *Equisetum arvense*, *Oxytropsis splendens*, *Phleum alpinum*, *Potentilla fruticosa*, and *Rumex alpestris*.

Shrubs and bryophytes attain their greatest abundance in this ct, but still contribute little to its total cover. Lichens, represented by *Peltigera* spp., occur only in this ct and thus are of diagnostic value.

2) *Agoseris glauca* - *Crepis nana* community type (stands 21, 26, 32)

This ct is not extensive, but occurs locally on level ground in several areas on the minesite. The spoils are relatively fine textured. *Agropyron latiglume* is dominant in all stands. Other abundant species are *Agoseris glauca*, *Poa interior*, *Achillea millefolium*, *Oxytropis deflexa*, and *Hedysarum alpinum*.

This ct has no character species of its own, but is distinguished from the *Equisetum-Potentilla* ct by the presence of *Crepis nana* and absence of *Equisetum arvense*, and from the remaining West Mine ct's by the presence of *Agoseris glauca* and *Botrychium lunaria*.

3) *Agropyron latiglume* - *Crepis elegans* community type (stands 18, 23, 30, 33, 34)

A common ct on N, S, and E-facing slopes. The spoils are relatively coarse textured. Total plant cover ($\bar{x}$ = 0.54%) and species richness ($\bar{x}$ = 20) are low compared to most other West Mine ct's.

Dominance varies and is unrelated to slope aspect. *Agropyron latiglume* has the highest average cover and *Artemisia borealis* is second. *Agropyron trachycaulum*, *Poa alpina*, *Achillea millefolium*, and *Crepis nana* are occasionally relatively abundant. *Crepis elegans* and

Astragalus aboriginum are character species, but do not have high community presence and thus are only of moderate diagnostic value.

4) *Crepis nana - Eriogonum androsaceum* community type (stands 19, 20, 22, 24, 25, 27, 28, 29, 31)

This is the most extensive West Mine ct; occupying large areas on level ground and N, W, and E-facing slopes. Spoil textures are generally sandier, and water holding and total exchange capacities lower than in other West Mine ct's.

Total plant cover ($\bar{x}$ = 0.08%) and species richness ($\bar{x}$ = 10) are the lowest of the ct's at both sites.

Although dominance varies, *Crepis nana* is consistently abundant and *Artemisia borealis, Agropyron trachycaulum,* and *Hedysarum alpinum* are frequently abundant. *Eriogonum androsaceum* and *Epilobium latifolium* are character species, but have moderate diagnostic value because their presence is low.

Transect Study

Slopes sampled at the Townsite ranged in length from 8 to 39 m, had predominantly western and northern exposures, and ranged in mid-slope angle from 27 to 35°. Those sampled at the West Mine varied in length from 7 to 46 m, had mostly northern and eastern exposures, and ranged in mid-slope angle from 22 to 35°.

Effects of Slope Position

Species richness and total plant cover varied significantly with slope position on both study sites (Table 13) and were greatest at the slope base position (Tables 14 and 15). At the Townsite, the top and lower-slope positions were richer than the upper-slope, and had

Table 13. Results of Friedman's analyses of variance by ranks, which test the effects of slope position on species richness and total plant cover using Mountain Park Townsite and West Mine transect data.

Data	Friedman's Test Statistic
Townsite	
Species Richness (no. species 4 m^{-2})	56.4***
Total Plant Cover (%)	62.8***
West Mine	
Species Richness (no. species 4 m^{-2})	56.5***
Total Plant Cover (%)	57.9***

***The effects of slope position are significant at $P < 0.005$.

Table 14. Effects of slope position on species richness at the Mountain Park Townsite and West Mine. The Wilcoxon two-sample test was used to test for significant differences between the study sites.

Slope Position	Median No. Species 4 m^{-2}		Significance of Wilcoxon Test
	Townsite	West Mine	
Top	4+ b++	4 bc	NS
Crest	1 bc	2 c	NS
Upper-slope	0 c	3 bc	**
Mid-slope	0 bc	4 bc	**
Lower-slope	3 b	4 b	NS
Base	9 a	12 a	**

+Each median is based on a sample size of 21.

++Medians followed by the same letter within a column are not significantly different at the 5% confidence level, according to the multiple-comparison procedure recommended by Daniel (1978) for use with the Friedman's test.

**Differences between the study sites are significant at $P \leq 0.01$.

NS: Differences between the study sites are not significant ($P > 0.05$).

Table 15. Effects of slope position on total plant cover at the Mountain Park Townsite and West Mine. The Wilcoxon two-sample test was used to test for significant differences between the study sites.

Slope Position	Median Total Plant Cover (%) Townsite	West Mine	Significance of Wilcoxon Test
Top	2.1+ b++	0.6 bc	NS
Crest	0.1 c	0.2 c	NS
Upper-slope	0.0 c	0.2 c	*
Mid-slope	0.0 c	0.2 bc	*
Lower-slope	0.9 b	0.8 b	NS
Base	8.4 a	7.2 a	NS

+Each median is based on a sample size of 21.

++Medians followed by the same letter within a column are not significantly different at the 5% confidence level, according to the multiple-comparison procedure recommended by Daniel (1978) for use with the Friedman's test.

*Differences between the sites are significant at $P \leq 0.05$.

NS: Differences between the study sites are not significant ($P > 0.05$).

higher cover than the upper-slope, mid-slope, and crest positions. At the West Mine, the lower-slope position was richer than the crest, and had higher cover than the crest and upper-slope positions. Thus, at both sites, total cover and species richness were highest at the slope base, and lowest at the upper-slope, mid-slope, and/or crest positions.

Species varied in their response to slope position (Figs. 15 and 16). Some showed wide ecological amplitude by occurring at all six slope positions, including: at the Townsite, *Agropyron latiglume, A. trachycaulum, Poa pratensis,* and *Taraxacum officinale*; at the West Mine, *Achillea millefolium, Agoseris glauca, Agropyron latiglume, A. trachycaulum, Artemisia borealis, Astragalus alpinus, Crepis nana, Festuca baffinensis, F. saximontana, Hedysarum alpinum, Oxytropis deflexa, Poa alpina, P. interior, P. secunda, Solidago multiradiata, Taraxacum officinale,* and *Trisetum spicatum.*

Other species were more restricted in distribution. For example, several species occurred only at the relatively mesic and protected lower-slope and/or base positions. These are: *Draba aurea, Oxytropis deflexa, Solidago multiradiata,* and *Trifolium hybridum* at the Townsite (Fig. 15); *Astragalus eucosmus, Castilleja occidentalis, Phleum alpinum,* and *Trifolium hybridum* at the West Mine (Fig. 16); and most of the rare species at both sites.

Although species differed in ecological amplitude, most showed similar response to changes in slope position. The majority of species at both sites occurred most frequently at the slope base position, and less (often least) frequently at the crest, upper-slope, and/or mid-slope positions (Figs. 15 and 16). Notable exceptions were *Potentilla norvegica* and *Hordeum jubatum* at the Townsite, which occurred

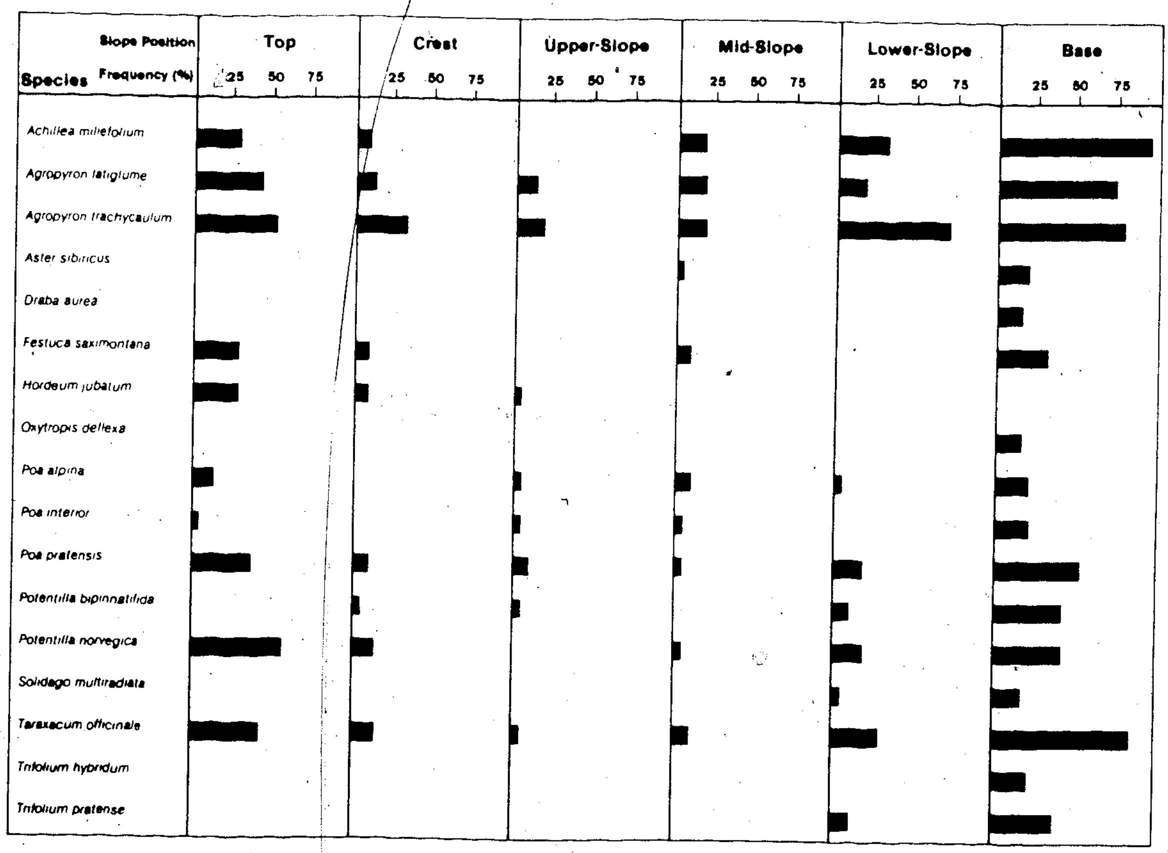


Figure 15. Species frequencies (%) at each of six major slope positions on the Mountain Park Townsite (N = 21 for each position). Species occurring in >15% of all quadrats and/or in >15% of quadrats at any one slope position are included.

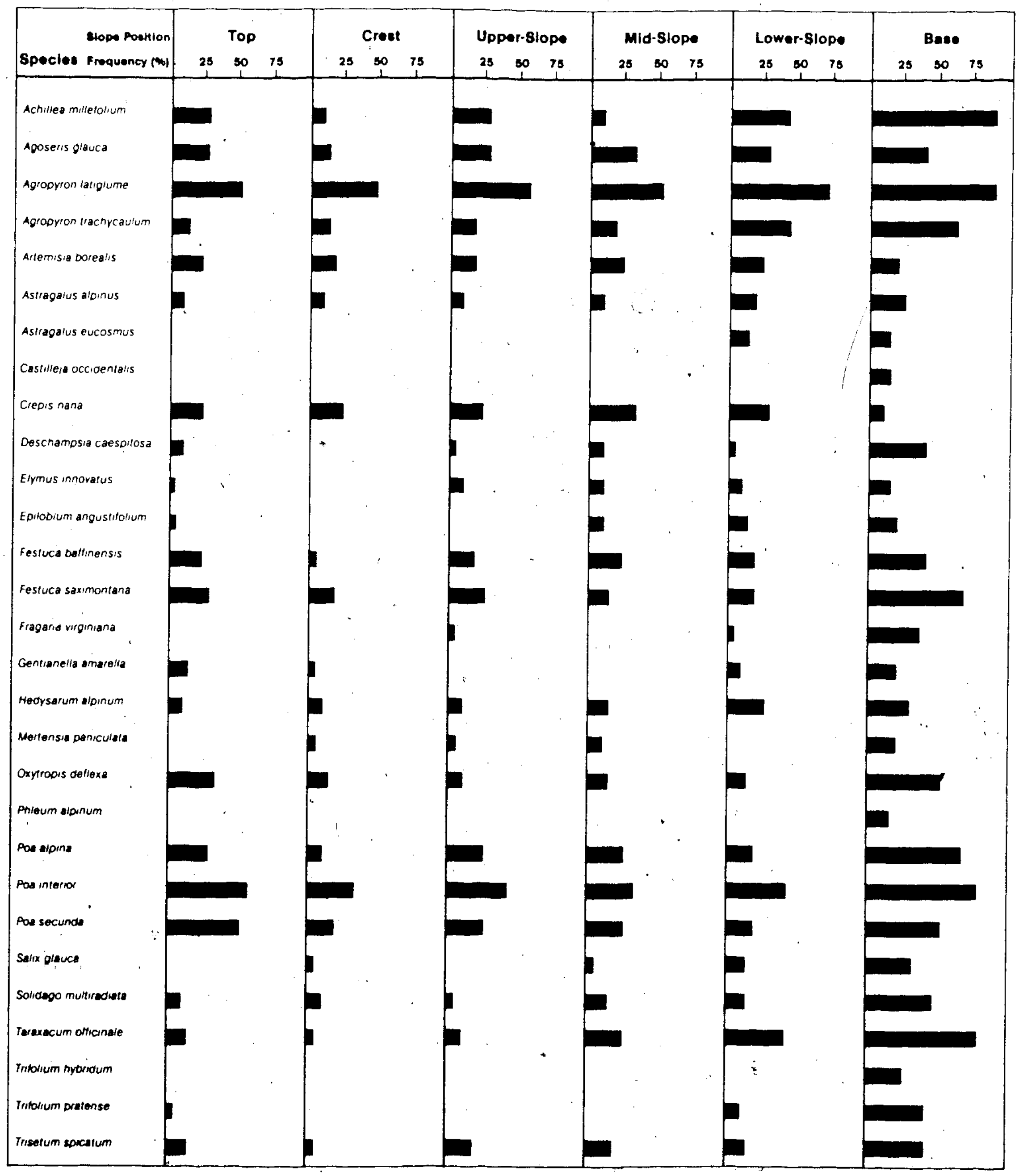


Figure 16. Species frequencies (%) at each of six major slope positions on the Mountain Park West Mine (N = 21 for each position). Species occurring in >15% of all quadrats and/or in >15% of quadrats at any one slope position are included.

more frequently at the top position, and *Crepis nana* and *Artemisia borealis* at the West Mine, which showed little preference for any slope position.

The results suggest strong environmental control of species richness, total plant cover, and species abundances on slopes at both study sites. Conditions for plant survival appear to be most favorable at the slope base position, and least favorable at the upper-slope, mid-slope, and crest positions.

Comparison of the Mountain Park Townsite and West Mine Transect Results

A total of 82 species occurred in transects at the West Mine, compared to only 49 at the Townsite. Since the amount of area sampled on the two sites was the same (504 m^2), this suggests that the West Mine is floristically richer on slopes.

The West Mine is significantly richer in species at the upper-slope, mid-slope, and base positions (Table 14), and has significantly higher total plant cover at the upper- and mid-slope positions than the Townsite (Table 15).

Of the 11 non-rare species which occurred at both sites in the transect study, six had substantially higher frequency (overall) at the West Mine, including: *Agropyron latiglume* (61 vs. 30%), *Festuca saximontana* (28 vs. 13%), *Oxytropis deflexa* (23 vs. 2%), *Poa alpina* (28 vs. 9%), *P. interior* (47 vs 6%), and *Solidago multiradiata* (16 vs. 3%). Only *Agropyron trachycaulum* occurred more frequently at the Townsite (28 vs. 45%). The remaining four species differed little in frequency between the two sites: *Achillea millefolium* (33 vs. 30%), *Taraxacum officinale* (27 vs. 30%), *Trifolium hybridum* (4 vs. 3%) and *T. pratense* (9 vs. 7%).

Four of the 11 common species showed the same distribution pattern on slopes at the West Mine as at the Townsite: *Agropyron latiglume*, *A. trachycaulum*, and *Taraxacum officinale* occurred at all six slope positions at both sites, and *Trifolium hybridum* occurred only at the base position at both sites. In varying degrees, the seven remaining common species were more restricted in distribution at the Townsite than West Mine. Most notably, *Oxytropis deflexa* and *Solidago multiradiata* occurred at all six positions at the West Mine, but were restricted to the base, and lower-slope and base positions, respectively, at the Townsite (Figs. 15 and 16).

The results suggest that conditions for plant survival on slopes are more favorable at the West Mine than Townsite, particularly at the upper- and mid-slope positions. This could be because spoils at the West Mine are, on the average, finer textured, more consolidated, and more stable on slopes (personal observation) than those at the Townsite.

DISCUSSION AND CONCLUSIONS

Floristic Survey

A total of 245 vascular plant species were found on coal spoils at six abandoned minesites in Alberta's Eastern Slopes. The largest plant families were Compositae (43 species) and Gramineae (35 species). The predominance of these two families on mined lands has also been noted by Brierly (1956), Wali and Freeman (1973), Alvarez *et al.* (1974), Glenn-Lewin (1979), and Jonescu (1979).

Floristic similarity of the six minesites to one another ranged from 32 to 68%, indicating that the floras are neither highly similar nor highly dissimilar (*see* Table 4, p. 29). Of the total flora (245 species), 67 species were found on four or more of the sites, and 77 species were found on only one site. Of the latter group, Mountain Park West Mine had the most species (29), and Nordegg the fewest (6). Thus there is a regional flora common to many or all of the sites, but each minesite also has a degree of floristic individuality.

Introduced species were most numerous on minesites which are (or were) in close proximity to human settlements (*i.e.* Mercoal, Sterco--Coal Valley, and Mountain Park Townsite). Some species may have been introduced via feed for horses or other domestic animals. Other species may have escaped from gardens, which are known to have been common in mining settlements in this region (Ross 1974).

Root (1976) found 36 vascular plant taxa on the Cadomin strip mine in 1972. In the present study, 112 vascular species were found on the Cadomin site in 1975 and 1976. No other published species lists have been found for minesites in the Eastern Slopes of Alberta.

Vegetation

After *ca.* 26 years of abandonment the natural vegetation on the two Mountain Park minesites consists of sparse, mostly herbaceous plant communities dominated by perennial grasses and forbs. Total plant cover is very low (usually <15%). Seven community types (ct's) were recognized, based largely on floristic criteria.

No previous descriptions of natural vegetation on mined land have been found for the Eastern Slopes of Alberta. Root (1976) recognized general ct's on the Cadomin strip mine, but offered no species lists or descriptions for them. Thus the similarity of the Mountain Park ct's with those on mined lands elsewhere in the foothills and mountains of Alberta is unknown.

In the only other study of mined land vegetation in Alberta, Schumacher *et al.* (1977) investigated general successional patterns on coal spoils in the aspen parkland region. They recognized five stages in a succession leading to a young aspen parkland community in *ca.* 50 years: 1) forb stage, dominated by a variety of forbs, especially *Melilotus* sp. (1-4 years); 2) early grassland-weed stage, with numerous weedy species and *Hordeum jubatum* (5-20 years); 3) early grassland stage, dominated by *Bromus inermis* (20-30 years); 4) grassland stage, with *Bromus* grassland being invaded by *Poa* spp., *Agropyron* sp., and *Festuca scabrella* (30-50 years); 5) early aspen parkland stage, with *Populus tremuloides* groves and *Festuca scabrella* grassland (50+ years).

It is evident that succession on spoil materials progresses much faster in the aspen parkland than in the subalpine at Mountain Park, and that the dominant species are different.

Workers elsewhere in western North America have generally not characterized mined land vegetation by community classification and description, as was done in this study. Thus, comparison between areas is difficult. Nonetheless, based on subjective comparisons, mined land plant communities elsewhere in western Canada and western U.S.A. (Leisman 1957, Wali and Freeman 1973, Alvarez *et al.* 1974, Errington 1975, Taylor 1976, Glenn-Lewin 1979, Jonescu 1979, Sindelar 1979) have low floristic similarity with those at Mountain Park. This reflects regional floristic and environmental differences.

The minesite plant communities at Mountain Park did not change noticeably in species composition or structure over the two-year term of this study. Nonetheless, they probably represent early stages in a primary succession, which is the process of community change that begins on substrates that had never before supported any vegetation (Mueller-Dombois and Ellenberg 1974). The general sparseness of the plants and low total plant cover suggest that, thus far, succession has proceeded predominantly by species invasion and enrichment. Significant community changes due to plant interactions, *i.e.* autogenic succession, have probably not yet occurred.

There have been few studies of primary succession in Canada's Rocky Mountains. The most significant efforts have been on morainic materials in the main ranges, near Mt. Robson on the Alberta-British Columbia border (Cooper 1916, Heusser 1956, Tisdale *et al.* 1966). Pioneer communities described in these studies, however, have low similarity with the minesite communities at Mountain Park. Grasses, for example, are important and often predominant at Mountain Park, but have relatively low importance on the Mt. Robson moraines. Conversely, dwarf-shrubs are important in early successional communities at Mt. Robson, particularly *Dryas octopetala*, *D. drummondii*, and *Arctostaphylos rubra* (Cooper 1916, Heusser 1956), but they are rare or absent at Mountain Park.

Agropyron latiglume is a dominant species in five of the seven ct's described at Mountain Park. Although its range is not fully known (Hultén 1968), *A. latiglume* is widely distributed in the North American arctic, where it is common on well drained, alluvial, calcareous, sandy or clay soils of the Paleozoic series (Porsild 1973). In Alberta *A. latiglume* is restricted to the Rocky Mountains (*pers. comm.* J. G. Packer, Department of Botany, University of Alberta), where it occurs often in alpine plant communities (Ogilvie 1969, Kuchar 1975, Mortimer 1978, Hrapko and LaRoi 1978). It is relatively rare in the undisturbed alpine zone on Prospect Mountain (Mortimer 1978), *ca.* 8 km W of Mountain Park, but frequent on roadsides and other disturbed sites in the alpine and subalpine zones around Mountain Park (personal observation). No previous mention of *Agropyron latiglume* as a community dominant in Alberta has been found.

Environmental Considerations

Total plant cover, species richness, species abundances, and community patterns are correlated with edaphic factors on both intensive study sites. Of the variables measured, correlations were highest with fine earth content on the Townsite and with clay content on the West Mine. Thus, variation in physical spoil properties appears to strongly influence plant distribution on both study sites.

Relationships between plant distribution and edaphic variability are commonly reported in studies of natural revegetation on mined land. Schumacher *et al.* (1977) indicate that salinity can be a major limiting factor to natural revegetation of coal spoils in central Alberta, especially when combined with fine textures and/or poor drainage. Errington (1975) suggests that coarse textures and, in limited areas, low pHs, inhibit natural revegetation of mine spoils in the West Kootenay Mountains of British Columbia. Taylor (1976) reports that low levels of available plant nutrients, drought, and soil acidity with associated metal toxicity, are the major factors inhibiting natural revegetation of gold mine tailings in the Northwest Territories.

Farther south, Sindelar (1975) observed that high silt and clay content was correlated with relatively rapid plant succession on coal mine spoils in Montana. Alvarez *et al.* (1974) report that, of the variables they measured, spoil temperature and texture, and phosphorus and calcium levels were most important in controlling plant distribution on mine dumps in Utah. Glenn-Lewin (1979) related plant distribution patterns to variability in substrate acidity on coal spoils in SE Iowa. He found that plant cover and species richness were lowest on acid substrates and highest on non-acid substrates.

Studies in eastern North America and Great Britain also show correlations between plant distribution and edaphic factors on mined lands (notably: Croxton 1928, Bramble and Ashley 1955, Brierly 1956, Byrnes and Miller 1969, Cornwall 1971, Hogan *et al.* 1977, Kimber *et al.* 1978, Tasker and Chadwick 1978). In fact, few studies of natural mined land vegetation were found anywhere that did not mention the variability of the spoils, and the associated variability in vegetation.

Slope position strongly influences plant distribution on both intensive study sites. Total plant cover, species richness, and the abundance of most species (as measured by frequency) are highest at the slope base and lowest at the upper-slope, mid-slope, and/or crest positions.

Since no environmental measurements were made on the slopes, the cause(s) of these distribution patterns are unknown. Observations suggest, however, that the slope base is more mesic and less exposed to wind than the other positions. Stability of the spoils is higher at the base and lowest at the upper-slope and mid-slope positions. Also, on some slopes, fine spoil materials accumulate at the lower-slope and base positions via downslope movement and/or aeolian deposition. Other factors not observed, but which may be important, include snow distribution patterns, seed accumulation at the base and lower slopes, and downslope movement of water soluble nutrients.

Studies of natural mined land vegetation made elsewhere also cite the importance of slope position. Root (1976) observed that plants on spoil piles at the Cadomin strip mine occur more frequently at the slope base position. Jonescu (1979) showed that the natural vegetation on ridge slopes differs substantially from that in interridge areas (valleys between the ridges) on strip mined lands in SE Saskatchewan. She found that interridge areas have greater spoil stability than the ridge slopes and, in mesic sites, have richer and more successionally advanced plant communities. Errington (1975) reports a significant negative correlation between total plant cover and distance from the slope base on mine waste slopes in British Columbia. He suggests that this may be due to greater moisture availability at the lower slope positions. On surface mined land with "ridge-trough" topography in Indiana, Byrnes and Miller (1969) found that plant cover was higher in the troughs than on ridges or slopes. This was correlated with higher soil content (<2mm) of the spoils in the troughs. Hall (1957) and Molyneux (1963) note that natural vegetation is often concentrated on the lower slopes of coal spoil heaps in England.

Comparison of the Intensive Study Sites

The floras of the two Mountain Park minesites are significantly dissimilar (57% similarity). Also, none of the seven community types described for these sites occurs on both sites, *i.e.* they have no communities in common. Thus, they differ significantly in species composition at both the plant community and site levels.

Factors that influence "why plants grow where they do' may be grouped into five general categories (Billing 1952); 1) geographic (includes topographic); 2) biotic; 3) climatic; 4) edaphic; and 5) pyric. Differences between the two sites in any one of these factors may suggest reasons for their low floristic similarity.

Geographic Factors

The two sites are 1.2 km distant from one another, differ *ca.* 30 m in elevation, and have been abandoned for the same length of time (*ca.* 26 years when sampled in 1976). The West Mine is larger in area than the Townsite (34 vs 15 ha), which may partially explain why its flora is richer (141 vs 107 species).

The spoil-heaps at both sites are generally flat-topped with steep banks. Slopes at the Townsite have predominantly northern and western exposures. Those at the West Mine have mostly northern and eastern exposures. The ranges of slope lengths and of slope angles are similar on the two sites.

Little difference was noted in the amount of erosion on the two sites. Wind erosion of surface spoil particles occurs at both sites. There was little evidence of significant erosion by water at either site, probably due to high infiltration rates caused by the coarse textures and low fine earth contents of the spoils.

Results of the transect study suggest that there are some areas on the West Mine where the stability of spoil materials on slopes is greater than at the Townsite. This is most pronounced at the upper- and mid-slope positions. The difference is probably due to finer-textured, more consolidated spoils in these areas on the West Mine.

Thus, with the exceptions of size and, in limited areas, slope stability, the two sites differed little 'geographically' (*sensu* Billings 1952).

Biotic Factors

The sparseness of the plant communities suggested that plant-plant interactions were low at both sites. Also, no obvious differences were observed in plant-animal interactions at the two sites. The only mammals seen on the minesites were golden mantle ground squirrels (*Spermophilus lateralis*), and they were common on both sites.

Some differences were noted in the vegetation and floras immediately surrounding the two sites, which could influence the accessibility of some species to them. For example, immediately north of the West Mine is a wet sedge meadow community, rich in species of the genus *Carex*. Close proximity to this community could explain the high number of carices on the West Mine relative to the Townsite (13 vs 7 species). Also, the West Mine is geographically closer to alpine vegetation than is the Townsite, which could wholly or partially account for the greater alpine affinity of the West Mine flora. As a final example, the Townsite was adjacent to the village of Mountain Park when the mines were in operation. Close proximity to the gardens and animals associated with human settlements may explain the higher number of introduced species at the Townsite (17 species) compared to the more remote West Mine (6 species).

Climatic Factors

The two sites differed very little in monthly precipitation totals, weekly max-min air temperatures, and the amount of winter wind abrasion of wooden stakes exposed on the minesites for one year. Wind scouring of spoil materials from around the bases of plants was more common at the West Mine, suggesting that this site is more exposed to winds than the Townsite.

Although no micro-climatic measurements were made in this study, spoil surface temperatures are expected to be higher at the Townsite due to the higher coal content and, thus, lower albedo of its spoils. However, the degree or importance of any temperature differences between the sites is unknown.

While more intensive meteorological study is needed to fully characterize and compare the climates of the two sites, these general observations revealed no major climatic differences between them.

Edaphic Factors

Spoils at the two sites differ substantially in parent rock type and in a number of physical and chemical properties. At the Townsite, coal is the predominant parent rock, whereas siltstone and shale are dominant at the West Mine. Spoils at the West Mine, on the average, have higher fine earth content, finer texture, higher pH, higher total exchange capacity, and lower available nitrogen and phosphorus levels, than those at the Townsite.

Pyric Factors

Although some of the coal dominated spoil heaps at the Townsite have been burning internally for years, there is no evidence of any previous surface fires at either site. An extensive fire in 1913, however, burned the areas surrounding both minesites. Fire has probably had little effect on the study site floras, except indirectly as it influenced species composition of the surrounding vegetation.

Integration

Any or all of the factors discussed above may contribute to the observed differences in floras and plant communities at the two study sites. However, the strongest differences between the sites were in 1) edaphic factors, 2) floras of the surrounding areas, and 3) size of the minesites, suggesting that these factors are most important.

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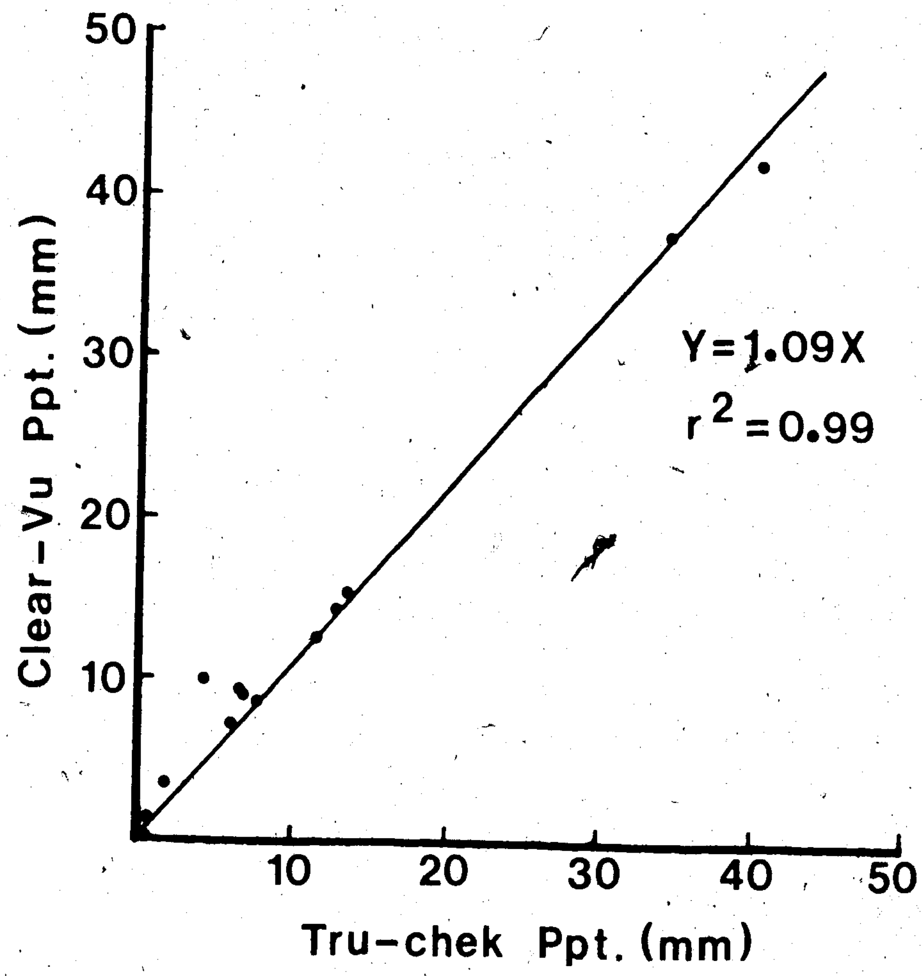

Appendix 1. Precipitation received by a Taylor Clear-Vu Rain gauge as a function of that received by a Tru-chek rain gauge. The regression line was made to intersect the origin (Steel and Torrie 1960).

The instruments were mounted on wooden stakes, with the orifices 30 cm above ground level, and placed within 2 m of one another. The data were collected at the Mountain Park and Sterco-Coal Valley study sites between May 13 and September 11, 1976. The Tru-chek values are averages of readings taken from two or three gauges.

The Clear-Vu gauge has a round orifice (*ca.* 28 cm diameter) and consistently received more precipitation than the wedge-type Tru-chek gauge (square orifice). The difference may be due to the lower surface area and thus reduced air turbulence offered by the round orifice.

APPENDIX 2. List of vascular plant species found on coal spoils at six abandoned minesites in the Rocky Mountain Foothills of west-central Alberta. Species marked by an asterisk (*) were also found by Mortimer (1978) and/or See (1978) in the alpine zone near Mountain Park, Alberta.

	Introduced (I) or Native (N)	Minesites					
		Mountain Park West Mine	Mountain Park Townsite	Cadomin	Nordegg	Sterco, Coal Valley	Mercoal
OPHIOGLOSSACEAE							
Botrychium lunaria (L.) Sw.*	N	x	x	x	x	x	
EQUISETACEAE							
Equisetum arvense L.*	N	x		x	x	x	x
Equisetum scirpoides Michx.*	N	x		x	x		x
Equisetum sylvaticum L.	N					x	
PINACEAE							
Abies lasiocarpa (Hook.) Nutt.*	N	x		x	x		
Juniperus communis L.*	N	x		x	x	x	
Picea engelmannii Parry*	N	x	x	x	x		
Pinus contorta London var. *latifolia* Engelm.	N	x	x	x	x	x	
JUNCAGINACEAE							
Triglochin palustris L.	N						x
GRAMINEAE							
Agropyron elongatum (Host) Beauv.	I				x		
Agropyron latiglume (Scribn. & Smith) Rydb.*	N	x	x	x		x	x
Agropyron pectiniforme Roem. & Schult.	I				x		x
Agropyron repens (L.) Beauv.	I		x		x	x	x
Agropyron subsecundum (Link) Hitchc.	N			x	x	x	x
Agropyron trachycaulum (Link) Malte	N	x	x	x	x	x	x
Agrostis palustris Huds.	I						x
Agrostis scabra Willd.	N	x	x	x	x	x	x
Bromus inermis Leyss.	I		x	x	x	x	x
Bromus pumpellianus Scribn.*	N	x	x			x	
Calamagrostis canadensis (Michx.) Beauv.	N					x	
Calamagrostis inexpansa A. Gray	N			x		x	x
Calamagrostis neglecta (Ehrh.) Gaertn.	N		x				
Calamagrostis purpurascens R. Br.*	N	x			x		
Deschampsia caespitosa (L.) Beauv.*	N	x	x	x		x	x
Elymus innovatus Beal*	N	x	x	x	x	x	
Elymus junceus Fisch.	I						x
Festuca baffinensis Polunin*	N	x	x	x	x		
Festuca rubra L.	N	x	x	x	x	x	x
Festuca saximontana Rydb.	N	x	x	x	x	x	x
Hierochloe odorata (L.) Beauv.	N		x		x		x
Hordeum jubatum L.	N		x	x	x	x	x
Phleum alpinum L.*	N	x	x	x	x		
Phleum pratense L.	I		x	x	x	x	x
Poa alpina L.*	N	x	x	x	x	x	x
Poa arctica R. Br.*	N	x		x		x	
Poa compressa L.	I		x			x	x
Poa glauca Vahl	N	x		x	x	x	
Poa interior Rydb.	N	x	x	x	x	x	x
Poa palustris L.	N	x	x	x	x	x	x
Poa pattersonii Vasey*	N	x			x		
Poa pratensis L.*	N	x	x	x	x	x	x
Poa secunda Presl	N	x	x		x		
Puccinellia nuttalliana (Schult.) Hitchc.	N					x	
Trisetum spicatum (L.) Richt.*	N	x	x	x	x	x	x
CYPERACEAE							
Carex aenea Fern.	N		x				x
Carex albo-nigra Mack.	N	x					
Carex aperta Boott	N	x					
Carex atrosquama Mack.*	N	x	x				
Carex babbii Olney	N						x
Carex bigelowii Torr.	N	x					
Carex crawfordii Fern.	N		x				x
Carex festivella Mack.*	N	x	x	x			
Carex foenea Willd.	N	x	x	x		x	x
Carex houghtonii Torr.	N					x	
Carex limnophila F.J. Hermann	N	x					
Carex media R. Br.	N	x					
Carex nardina Fries*	N	x					
Carex obtusata Lilj.	N	x		x			
Carex phaeocephala Piper*	N	x	x	x	x		
Carex podocarpa R. Br.	N	x					
Carex praegracilis W. Boott	N		x				x
Carex richardsonii R. Br.	N				x		
Carex rostrata Stokes	N	x				x	

APPENDIX 2. Cont'd.

	Introduced (I) or Native (N)[1]	Minesites: Mountain Park West Mine	Mountain Park Townsite	Cadomin	Nordegg	Sterco, Coal Valley	Mercoal
JUNCACEAE							
Juncus drummondii E. Meyer*	N	x		x			
Luzula wahlenbergii Rupr.	N	x					
LILIACEAE							
Zygadenus elegans Pursh*	N			x			
IRIDACEAE							
Sisyrinchium montanum Greene	N				x	x	x
ORCHIDACEAE							
Habenaria hyperborea (L.) R. Br.	N				x	x	
Habenaria viridis (L.) R. Br. var. *bracteata* (Muhl.) A. Gray*	N	x					
SALICACEAE							
Populus balsamifera L.	N	x	x	x	x	x	x
Populus tremuloides Michx.	N		x		x	x	x
Salix alaxensis (Anderss.) Coville*	N			x			
Salix arbusculoides Anderss.*	N				x	x	
Salix barklayi Anderss.	N					x	x
Salix barrattiana Hook.*	N	x	x				
Salix bebbiana Sarg.	N				x	x	x
Salix discolor Muhl.	N						x
Salix drummondiana Barratt*	N			x	x	x	x
Salix glauca L.*	N	x	x	x	x	x	
Salix myrtillifolia Anderss.	N				x	x	x
Salix nivalis Hook.*	N	x					
Salix planifolia Pursh	N	x				x	
Salix scouleriana Barratt	N			x	x	x	
BETULACEAE							
Alnus crispa (Ait.) Pursh	N			x			
Betula glandulosa Michx.*	N	x		x			
Corylus cornuta Marsh.	N						x
POLYGONACEAE							
Eriogonum androsaceum Benth.*	N	x					
Polygonum aviculare L.	I						x
Polygonum viviparum L.*	N	x					
Rumex acetosella L.	I	x	x			x	x
Rumex alpestris (Scop.) Löve*	I	x	x				
Rumex mexicanus Meisn.	N		x	x		x	x
Rumex occidentalis S. Wats. var. *fenestratus* (Greene) Le Page	N					x	x
CHENOPODIACEAE							
Chenopodium album L.	I						x
CARYOPHYLLACEAE							
Arenaria dawsonensis Britt.	N				x	x	x
Arenaria rubella (Wahlenb.) J.E. Sm.*	N	x	x		x	x	
Cerastium arvense L.	N		x				
Cerastium beeringianum Cham. & Schlect.*	N	x	x	x			
Cerastium vulgatum L. var. *hirsutum* Fries	I						x
Silene acaulis L. var. *exscapa* (All.) DC.*	N	x					
Stellaria crassifolia Ehrh.	N	x					
Stellaria longipes Goldie	N	x			x	x	
Stellaria monantha Hultén*	N	x				x	
RANUNCULACEAE							
Aconitum delphinifolium DC.*	N						
Anemone multifida Poir.*	N		x	x	x		
Delphinium glaucum S. Wats.*	N		x	x	x		
Ranunculus acris L.	I		x	x		x	x
Ranunculus cymbalaria Pursh	N						x
Thalictrum venulosum Trel.	N						x
PAPAVERACEAE							
Papaver nudicaule L.	I		x				
FUMARIACEAE							
Corydalis aurea Willd.	N					x	

APPENDIX 2. Cont'd.

	Introduced (I) or Native (N)	Minesites: Mountain Park West Mine	Mountain Park Townsite	Cadomin	Nordegg	Sterco, Coal Valley	Mercoal
CRUCIFERAE							
Arabis divaricarpa A. Nels.	N				x		
Arabis drummondii A. Gray*	N	x	x	x	x	x	
Arabis hirsuta (L.) Scop.	N				x	x	
Arabis lyrata L.	N		x			x	
Conringia orientalis (L.) Dum.	I					x	
Descurainia richardsonii (Sweet) O.E. Schulz	N		x			x	x
Descurainia sophia (L.) Webb	I		x				
Draba aurea Vahl*	N	x	x	x			
Draba lanceolata Royle	N	x					
Draba oligosperma Hook.*	N	x					
Erucastrum gallicum (Willd.) Schulz	I						x
Erysimum cheiranthoides L.	I		x			x	x
Erysimum inconspicuum (S. Wats.) MacM.	N				x	x	
Lepidium ramosissimum A. Nels.	N		x			x	x
Smelowskia calycina (Stephán) C.A. Mey.* var. *americana* (Rydb.) Drury & Rollins	N	x	x	x			
Thlaspi arvense L.	I		x			x	x
CRASSULACEAE							
Sedum stenopetalum Pursh*	N	x					
SAXIFRAGACEAE							
Parnassia montanensis Fern. & Rydb.	N	x		x			x
Ribes oxyacanthoides L.*	N				x	x	
Saxifraga tricuspidata Rottb.*	N	x					
ROSACEAE							
Dryas drummondii Richards.	N	x		x	x		
Dryas integrifolia M. Vahl*	N	x		x			
Dryas octopetala L.*	N	x		x			
Fragaria virginiana Duchesne*	N	x	x	x	x	x	x
Geum allepicum Jacq. var. *strictum* (Ait.) Fern.	N						x
Geum macrophyllum Willd.	N	x					
Geum triflorum Pursh	N						x
Potentilla anserina L.	N		x			x	
Potentilla bipinnatifida Dougl. ex Hook.	N						x
Potentilla bipinnatifida Dougl. ex Hook. var. *glabrata*	N	x	x				x
Potentilla diversifolia Lehm.*	N	x	x	x			
Potentilla fruticosa L.*	N	x	x	x	x		
Potentilla gracilis Dougl.*	N	x	x	x			
Potentilla nivea L.*	N	x	x	x			
Potentilla norvegica L.	N	x	x	x	x	x	x
Potentilla pensylvanica L.	N	x	x	x	x		x
Rosa acicularis Lindl.	N		x	x	x		
Rosa woodsii Lindl.	N			x	x	x	
Rubus acaulis Michx.	N	x	x				
Rubus strigosus Michx.	N		x	x	x	x	x
LEGUMINOSAE							
Astragalus aboriginum Richards.*	N	x		x			
Astragalus alpinus L.*	N	x	x	x	x		
Astragalus eucosmus Robins.	N	x		x			
Astragalus flexuosus Dougl.	N		x				
Astragalus frigidus (L.) A. Gray var. *americanus* (Hook.) S. Wats.	N	x		x	x		
Astragalus striatus Nutt.	N	x		x	x		
Astragalus vexilliflexus Sheld.*	N	x	x	x			
Hedysarum alpinum L.*	N	x	x	x	x		
Hedysarum mackenzii Richards.*	N	x		x	x		
Hedysarum sulphurescens Rydb.	N				x		
Lathyrus ochroleucus Hook.	N				x		
Melilotus alba Desr.	I					x	x
Melilotus officinalis (L.) Lam.	I					x	x
Oxytropis campestris (L.) DC.*	N	x	x	x	x	x	
Oxytropis deflexa (Pall.) DC.	N	x	x	x	x	x	
Oxytropis podocarpa A. Gray*	N	x					
Oxytropis sericea Nutt. var. *spicata* (Hook.) Barneby	N	x		x	x		
Oxytropis splendens Dougl.*	N	x	x		x		
Trifolium agrarium L.	I						x
Trifolium hybridum L.	I	x	x	x		x	x
Trifolium pratense L.	I	x	x	x	x	x	x
Trifolium repens L.	I	x	x	x	x	x	x
Vicia americana Muhl.	N		x				
Vicia cracca L.	I		x			x	
VIOLACEAE							
Viola adunca J.E. Smith	N					x	

APPENDIX 2. Cont'd

	Introduced (I) or Native (N)	Minesites: Mountain Park West Mine	Mountain Park Townsite	Cadomin	Nordegg	Sterco, Coal Valley	Mercoal
ELAEAGNACEAE							
Shepherdia canadensis (L.) Nutt.	N			x	x		
ONAGRACEAE							
Epilobium angustifolium L.*	N	x	x	x	x	x	x
Epilobium latifolium L.*	N	x		x	x	x	x
UMBELLIFERAE							
Carum carvi L.	I	x		x	x		
Heracleum lanatum Michx.*	N	x		x			x
ERICACEAE							
Arctostaphylos uva-ursi (L.) Spreng.*	N	x	x	x	x	x	
PRIMULACEAE							
Androsace chamaejasme Host*	N	x		x			
Androsace septentrionalis L.*	N	x	x				
GENTIANACEAE							
Gentiana prostrata Haenke var. *americana* Engelm.*	N	x					
Gentianella amarella (L.) Börner ssp. *acuta* (Michx.) J.M. Gillett*	N	x	x	x	x	x	x
POLEMONIACEAE							
Collomia linearis Nutt.	N		x		x	x	x
HYDROPHYLLACEAE							
Phacelia franklinii (R. Br.) A. Gray	N					x	
Phacelia sericea (Graham) A. Gray*	N	x	x				
BORAGINACEAE							
Lappula echinata Gilib.	I						
Mertensia paniculata (Ait.) G. Don*	N	x	x	x	x	x	x
LABIATAE							
Galeopsis tetrahit L.	I		x			x	
SCROPHULARIACEAE							
Castilleja miniata Dougl.*	N	x		x		x	
Castilleja occidentalis Torr.*	N	x		x			
Euphrasia disjuncta Fern. & Wieg.*	N	x					
Linaria vulgaris Hill	I	x					
Penstemon procerus Dougl.	N	x	x			x	
Rhinanthus crista-galli L.*	I	x		x			
Veronica alpina L. var. *unalaschcensis* C. & S.*	N	x					
PLANTAGINACEAE							
Plantago major L.	I		x				x
RUBIACEAE							
Galium boreale L.	N		x	x			
CAPRIFOLIACEAE							
Sambucus pubens Michx.	N			x			
CAMPANULACEAE							
Campanula rotundifolia L.*	N		x	x		x	
COMPOSITAE							
Achillea millefolium L.*	N	x	x	x	x	x	x
Agoseris aurantiaca (Hook.) Greene	N			x			
Agoseris glauca (Pursh) Raf.	N	x	x	x			
Antennaria lanata (Hook.) Greene*	N	x				x	
Antennaria neglecta Greene	N	x		x			
Antennaria nitida Greene	N	x				x	
Antennaria rosea Greene	N	x				x	
Arnica alpina (L.) Olin*	N	x					
Arnica chamissonis Less.	N		x				
Arnica cordifolia Hook.*	N	x	x	x	x		
Arnica lonchophylla Greene	N	x		x			
Artemisia biennis Willd.	I						
Artemisia borealis Pall.	N	x	x				x
Artemisia norvegica Fries*	N	x		x			x
Aster alpinus L.*	N		x				
Aster ciliolatus Lindl.	N				x	x	x
Aster conspicuus Lindl.	N				x		
Aster laevis L. var. *geyeri* A. Gray	N				x	x	
Aster sibiricus L.*	N	x	x	x	x	x	x

APPENDIX 2. Cont'd.

	Introduced (I) or Native (N)	Minesites					
		Mountain Park West Mine	Mountain Park Townsite	Cadomin	Nordegg	Sterco, Coal Valley	Mercoal
COMPOSITAE Cont'd.							
Chrysanthemum leucanthemum L.	I					x	x
Cirsium arvense (L.) Scop.	I					x	x
Cirsium hookerianum Nutt.	N			x			
Crepis elegans Hook.	N	x		x	x	x	
Crepis nana Richards.*	N	x		x		x	
Crepis runcinata (James) T. & G.	N						x
Erigeron acris L.	N	x		x	x	x	x
Erigeron lonchophyllus Hook.	N						x
Erigeron trifidus Hook.	N	x	x	x			
Haplopappus lyallii A. Gray	N			x			
Hieracium umbellatum L.	N			x		x	
Matricaria matricarioides (Less.) Porter	I						x
Saussurea densa (Hook.) Rydb.*	N	x					
Senecio canus Hook.*	N	x	x	x	x		
Senecio cymbalarioides Nutt.	N			x			x
Senecio indecorus Greene	N	x	x			x	
Senecio lugens Richards.*	N	x	x				
Senecio pauciflorus Pursh	N	x					x
Solidago decumbens Greene	N	x	x	x	x	x	x
Solidago lepida DC.	N					x	x
Solidago multiradiata Ait.*	N	x	x	x	x	x	x
Sonchus uliginosus Bieb.	I					x	x
Taraxacum ceratophorum (Ledeb.) DC.*	N	x					
Taraxacum officinale Weber	I	x	x	x	x	x	x
	Total number of species	141	107	112	94	107	96

[1]Source: Scoggan (1978).

Table 11. Selected site and community attributes of stands at the Mountain Park Townsite. Cover values are percentages with dash (–) indicating absenc
the species was present in the stand but not sampled. Species present in < 15% of all stands are listed at the bottom as rare species.

Community Type	Festuca rubra – Epilobium angustifolium			Agropyron latiglume Agropyron repens			Agropyron s			
Stand No.	10	11	9	13	4	3	5	2	15	12
Stand Size (m^2_1)	160	374	402	339	386	374	152	456	405	335
No. Quadrats	27	30	45	20	15	40	0	28	15	0
Slope ( )	33	33	33	0	0	0	31	0	0	0
Aspect	N	NNE	NNE	Flat	Flat	Flat	WSW	Flat	Flat	Flat
Fine Earth Content (% < 2 mm)										
0 – 5 cm	53	77	60	49	54	57	45	53	60	43
25 – 30 cm	39	36	34	36	40	49	33	43	33	15
Sand Content (%)										
0 – 5 cm	77	85	83	78	64	84	79	77	84	66
13 – 18 cm	59	86	89	77	69	84	77	83	90	86
Available Water Holding Capacity (%), 0 – 5 cm	3.26	4.00	3.38	2.58	4.31	4.26	2.30	3.89	2.75	2.05
pH										
0 – 5 cm	7.3	7.4	7.2	7.0	5.6	6.9	7.2	6.4	7.4	7.2
13 – 18 cm	6.6	7.4	7.1	5.8	4.6	6.8	6.1	5.0	7.4	6.2
Total Exchange Capacity (m.e. 100 g^{-1} whole soil), 0–18 cm	8.0	4.6	3.6	7.5	4.6	4.8	4.1	3.6	4.5	4.5
Available P (ppm), 0 – 18 cm	3.5	2.5	2.5	3.0	2.5	11.0	3.5	6.0	4.0	0.5
No. Vascular Species	28	18	22	28	28	29	15	20	19	7
Total Plant Cover (%)	14.4	2.7	4.0	5.7	2.6	6.4	0.25	2.0	2.0	0.02
Bryophyte Cover (%)	0.04	0.005	+	+	–	0.005	–	–	0.005	–
Lichen Cover (%)	–	–	–	–	–	–	–	–	–	–
Vascular Species Cover (%)										
Shrubs										
Salix glauca	+	0.04	0.01	–	–	–	–	–	–	–
Potentilla fruticosa	+	–	–	–	+	+	0.01	–	–	–
Graminoids										
Festuca rubra	14.0	1.8	0.1	–	0.01	–	–	–	0.1	0.009
Hordeum jubatum	+	–	+	0.002	–	0.01	+	0.04	–	–
Agropyron latiglume	0.01	0.04	0.02	1.4	1.2	2.4	+	0.6	1.1	0.002
Agropyron trachycaulum	0.2	0.5	3.2	0.3	0.2	0.5	0.07	0.3	0.3	0.003
Poa interior	0.01	+	+	+	0.01	0.02	+	0.01	–	+
Poa alpina	0.02	+	0.03	–	0.008	0.002	–	0.03	0.005	–
Festuca saximontana	–	0.002	0.007	0.001	0.009	0.01	+	0.07	0.03	–
Poa pratensis	–	–	+	1.4	0.04	0.6	0.02	0.6	–	–
Agropyron repens	–	–	–	0.2	0.08	0.4	–	–	0.002	–
Trisetum spicatum	–	–	+	–	0.02	–	–	–	0.009	–
Forbs										
Galeopsis tetrahit	0.005	0.003	+	–	–	–	–	–	–	–
Rumex mexicanus	+	+	–	0.005	–	–	–	–	–	–
Ranunculus acris	+	–	+	–	–	0.01	–	–	–	–
Epilobium angustifolium	0.006	0.07	0.3	–	–	–	–	–	–	–
Draba aurea	0.01	–	–	–	–	+	–	+	–	–
Astragalus alpinus	0.006	–	–	–	+	0.04	–	–	0.001	–
Astragalus vexilliflexus	–	+	–	0.04	0.03	0.01	–	–	–	–
Senecio canus	–	–	–	0.02	0.01	0.002	–	–	–	–
Oxytropis splendens	–	–	–	+	0.004	0.03	–	–	–	–
Fragaria virginiana	–	–	–	0.09	+	0.1	–	–	+	–
Oxytropis deflexa	–	–	–	+	0.06	0.02	–	–	0.08	–
Trifolium pratense	+	+	+	0.01	0.07	0.7	0.006	+	0.1	–
Aster sibiricus	+	0.04	+	+	0.03	0.2	0.005	+	0.01	–
Phacelia sericea	0.09	+	–	+	0.003	0.07	–	0.006	–	–

nds at the Mountain Park townsite. Cover values are
ampled. Species present in < 15% of all stands are listed at the bottom as rare species.

ubra – Epilobium lium		Agropyron latiglume Agropyron repens			Agropyron spp. – Artemisia borealis								
11	9	13	4	3	5	2	15	12	8	14	6	7	1
374	402	339	386	374	152	456	405	335	507	85	227	178	374
30	45	20	15	40	0	28	15	0	0	0	0	0	0
33	33	0	0	0	31	0	0	0	33	37	10	33	0
NNE	NNE	Flat	Flat	Flat	WSW	Flat	Flat	Flat	WNW	ENE	W	WNW	Flat
77	60	49	54	57	45	53	60	43	25	46	48	45	40
36	34	36	40	49	33	43	33	15	27	22	34	37	30
85	83	78	64	84	79	77	84	66	87	97	78	82	83
86	89	77	69	84	77	83	90	86	85	88	81	77	88
4.00	3.38	2.58	4.31	4.26	2.30	3.89	2.75	2.05	1.50	1.41	2.43	3.42	2.50
7.4	7.2	7.0	5.6	6.9	7.2	6.4	7.4	7.2	7.7	7.8	6.8	6.5	6.2
7.4	7.1	5.8	4.6	6.8	6.1	5.0	7.4	6.2	7.7	7.9	7.4	5.6	4.7
4.6	3.6	7.5	4.6	4.8	4.1	3.6	4.5	4.5	2.7	3.4	3.7	3.4	2.5
2.5	2.5	3.0	2.5	11.0	3.5	6.0	4.0	0.5	1.5	1.0	3.5	5.5	3.0
18	22	28	28	29	15	20	19	7	5	5	7	13	14
2.7	4.0	5.7	2.6	6.4	0.25	2.0	2.0	0.02	0.04	0.11	0.07	1.2	0.05
0.005	+	+	–	0.005	–	–	0.005	–	–	–	–	–	–
–	–	–	–	–	–	–	–	–	–	–	–	–	–
0.04	0.01	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	+	+	0.01	–	–	–	–	–	–	–	–
1.8	0.1	–	0.01	–	–	–	0.1	0.009	–	–	–	–	–
–	+	0.002	–	0.01	+	0.04	–	–	+	–	–	0.002	–
0.04	0.02	1.4	1.2	2.4	+	0.6	1.1	0.002	0.02	+	0.04	0.2	0.008
0.5	3.2	0.3	0.2	0.5	0.07	0.3	0.3	0.003	0.008	0.05	0.01	0.3	0.008
+	+	+	0.01	0.02	+	0.01	–	+	–	–	–	0.002	+
+	0.03	–	0.008	0.002	–	0.03	0.005	–	–	–	+	0.002	+
0.002	0.007	0.001	0.009	0.01	+	0.07	0.03	–	+	0.001	0.002	0.007	0.004
–	+	1.4	0.04	0.6	0.02	0.6	–	–	–	–	–	–	0.004
–	–	0.2	0.08	0.4	–	–	0.002	–	–	0.01	–	–	–
–	+	–	0.02	–	–	–	0.009	–	–	–	–	–	0.002
0.003	+	–	–	–	–	–	–	–	–	–	–	–	–
+	–	0.005	–	–	–	–	–	–	–	–	–	–	–
–	+	–	–	0.01	–	–	–	–	–	–	–	–	–
0.07	0.3	–	+	–	–	–	–	–	0.007	–	–	–	–
–	–	–	–	+	–	+	–	–	–	–	–	–	–
–	–	–	+	0.04	–	–	0.001	–	–	–	–	–	–
+	–	0.04	0.03	0.01	–	–	–	–	–	–	–	–	–
–	–	0.02	0.01	0.002	–	–	–	–	–	–	–	–	–
–	–	+	0.004	0.03	–	–	–	–	–	–	–	–	–
–	–	0.09	+	0.1	–	–	+	–	–	–	–	–	–
–	–	+	0.06	0.02	–	–	0.08	–	–	–	–	–	–
+	+	0.01	0.07	0.7	0.006	+	0.1	–	–	–	–	–	–
0.04	+	+	0.03	0.2	0.005	+	0.01	–	–	–	–	–	–
+	–	+	0.003	0.07	–	0.006	–	–	–	–	–	0.07	–
+	+	0.3	0.3	0.1	0.003	+	0.1	0.001	–	–	+	–	–

25 – 30 cm	39	36	34	36	40	49	33	43	33	15
Sand Content (%)										
0 – 5 cm	77	85	83	78	64	84	79	77	84	66
13 – 18 cm	59	86	89	77	69	84	77	83	90	86
Available Water Holding Capacity (%), 0 – 5 cm	3.26	4.00	3.38	2.58	4.31	4.26	2.30	3.89	2.75	2.05
pH										
0 – 5 cm	7.3	7.4	7.2	7.0	5.6	6.9	7.2	6.4	7.4	7.2
13 – 18 cm	6.6	7.4	7.1	5.8	4.6	6.8	6.1	5.0	7.4	6.2
Total Exchange Capacity (m.e. 100 g^{-1} whole soil), 0–18 cm	8.0	4.6	3.6	7.5	4.6	4.8	4.1	3.6	4.5	4.5
Available P (ppm), 0 – 18 cm	3.5	2.5	2.5	3.0	2.5	11.0	3.5	6.0	4.0	0.5
No. Vascular Species	28	18	22	28	28	29	15	20	19	7
Total Plant Cover (%)	14.4	2.7	4.0	5.7	2.6	6.4	0.25	2.0	2.0	0.02
Bryophyte Cover (%)	0.04	0.005	+	+	–	0.005	–	–	0.005	–
Lichen Cover (%)	–	–	–	–	–	–	–	–	–	–
Vascular Species Cover (%)										
Shrubs										
Salix glauca	+	0.04	0.01	–	–	–	–	–	–	–
Potentilla fruticosa	+	–	–	–	+	+	0.01	–	–	–
Graminoids										
Festuca rubra	14.0	1.8	0.1	–	0.01	–	–	–	0.1	0.009
Hordeum jubatum	+	–	+	0.002	–	0.01	+	0.04	–	–
Agropyron latiglume	0.01	0.04	0.02	1.4	1.2	2.4	+	0.6	1.1	0.002
Agropyron trachycaulum	0.2	0.5	3.2	0.3	0.2	0.5	0.07	0.3	0.3	0.003
Poa interior	0.01	+	+	+	0.01	0.02	+	0.01	–	+
Poa alpina	0.02	+	0.03	–	0.008	0.002	–	0.03	0.005	–
Festuca saximontana	–	0.002	0.007	0.001	0.009	0.01	+	0.07	0.03	–
Poa pratensis	–	–	+	1.4	0.04	0.6	0.02	0.6	–	–
Agropyron repens	–	–	–	0.2	0.08	0.4	–	–	0.002	–
Trisetum spicatum	–	–	+	–	0.02	–	–	–	0.009	–
Forbs										
Galeopsis tetrahit	0.005	0.003	+	–	–	–	–	–	–	–
Rumex mexicanus	+	+	–	0.005	–	–	–	–	–	–
Ranunculus acris	+	–	+	–	–	0.01	–	–	–	–
Epilobium angustifolium	0.006	0.07	0.3	–	–	–	–	–	–	–
Draba aurea	0.01	–	–	–	–	+	–	+	–	–
Astragalus alpinus	0.006	–	–	–	+	0.04	–	–	0.001	–
Astragalus vexilliflexus	–	+	–	0.04	0.03	0.01	–	–	–	–
Senecio canus	–	–	–	0.02	0.01	0.002	–	–	–	–
Oxytropis splendens	–	–	–	+	0.004	0.03	–	–	–	–
Fragaria virginiana	–	–	–	0.09	+	0.1	–	–	+	–
Oxytropis deflexa	–	–	–	+	0.06	0.02	–	–	0.08	–
Trifolium pratense	+	+	+	0.01	0.07	0.7	0.006	+	0.1	–
Aster sibiricus	+	0.04	+	+	0.03	0.2	0.005	+	0.01	–
Phacelia sericea	0.09	+	–	+	0.003	0.07	–	0.006	–	–
Potentilla bipinnatifida	+	+	+	0.3	0.3	0.1	0.003	+	0.1	0.001
Solidago multiradiata	–	–	+	0.03	0.008	+	0.002	0.001	–	–
Achillea millefolium	0.03	0.08	0.08	0.3	0.07	0.1	0.02	0.1	0.003	–
Potentilla norvegica	0.001	+	0.003	0.5	0.1	0.3	0.03	0.2	0.008	0.002
Taraxacum officinale	0.1	+	0.2	0.8	0.03	0.03	0.08	0.08	+	0.005
Artemisia borealis	–	–	–	–	–	–	–	–	0.1	–

[1] Stands for which preliminary estimates of total plant cover were less than 1% were inventoried, i.e. quadrats were not used.

Rare species. Shrubs : Stand 4 Rubus strigosus. Graminoids : Stand 9 Poa compressa, Poa palustris; Stand 13 Phleum alpinum ; Stand 5 Bromus
Stand 7 Bromus inermis, Carex festivella ; Stand 1 Carex foenea, Poa secunda Forbs : Stand 10 Agoseris glauca, Descurainia richardsonii, Erige
ramosissimum, Mertensia paniculata, Senecio lugens ; Stand 13 Collomia linearis, Lepidium ramosissimum, Plantago major, Rumex alpestris, Thlaspi
Rumex alpestris, Vicia cracca ; Stand 3 Agoseris glauca, Arnica chamissonis, Trifolium repens ; Stand 2 Androsace septentrionalis, Arabis lyrata ; Sta
calycina ; Stand 1 Thlaspi arvense.

36	34	36	40	49	33	43	33	15	27	22	34	37	36
85	83	78	64	84	79	77	84	66	87	97	78	82	83
86	89	77	69	84	77	83	90	86	85	88	81	77	88
4.00	3.38	2.58	4.31	4.26	2.30	3.89	2.75	2.05	1.50	1.41	2.43	3.42	2.50
7.4	7.2	7.0	5.6	6.9	7.2	6.4	7.4	7.2	7.7	7.8	6.8	6.5	6.2
7.4	7.1	5.8	4.6	6.8	6.1	5.0	7.4	6.2	7.7	7.9	7.4	5.6	4.7
4.6	3.6	7.5	4.6	4.8	4.1	3.6	4.5	4.5	2.7	3.4	3.7	3.4	2.5
2.5	2.5	3.0	2.5	11.0	3.5	6.0	4.0	0.5	1.5	1.0	3.5	5.5	3.0
18	22	28	28	29	15	20	19	7	5	5	7	13	14
2.7	4.0	5.7	2.6	6.4	0.25	2.0	2.0	0.02	0.04	0.11	0.07	1.2	0.05
0.005	+	+	–	0.005	–	–	0.005	–	–	–	–	–	–
–	–	–	–	–	–	–	–	–	–	–	–	–	–
0.04	0.01	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	+	+	0.01	–	–	–	–	–	–	–	–
1.8	0.1	–	0.01	–	–	–	0.1	0.009	–	–	–	–	–
–	+	0.002	–	0.01	+	0.04	–	–	+	–	–	0.002	–
0.04	0.02	1.4	1.2	2.4	+	0.6	1.1	0.002	0.02	+	0.04	0.2	0.008
0.5	3.2	0.3	0.2	0.5	0.07	0.3	0.3	0.003	0.008	0.05	0.01	0.3	0.008
+	+	+	0.01	0.02	+	0.01	–	+	–	–	–	0.002	+
+	0.03	–	0.008	0.002	–	0.03	0.005	–	–	–	+	0.002	+
0.002	0.007	0.001	0.009	0.01	+	0.07	0.03	–	+	0.001	0.002	0.007	0.004
–	+	1.4	0.04	0.6	0.02	0.6	–	–	–	–	–	–	0.004
–	–	0.2	0.08	0.4	–	–	0.002	–	–	0.01	–	–	–
–	+	–	0.02	–	–	–	0.009	–	–	–	–	–	0.002
0.003	+	–	–	–	–	–	–	–	–	–	–	–	–
+	–	0.005	–	–	–	–	–	–	–	–	–	–	–
–	+	–	–	0.01	–	–	–	–	–	–	–	–	–
0.07	0.3	–	–	–	–	–	–	–	0.007	–	–	–	–
–	–	–	–	+	–	+	–	–	–	–	–	–	–
–	–	–	+	0.04	–	–	0.001	–	–	–	–	–	–
+	–	0.04	0.03	0.01	–	–	–	–	–	–	–	–	–
–	–	0.02	0.01	0.002	–	–	–	–	–	–	–	–	–
–	–	+	0.004	0.03	–	–	–	–	–	–	–	–	–
–	–	0.09	+	0.1	–	–	+	–	–	–	–	–	–
–	–	+	0.06	0.02	–	–	0.08	–	–	–	–	–	–
+	+	0.01	0.07	0.7	0.006	+	0.1	–	–	–	–	–	–
0.04	+	+	0.03	0.2	0.005	+	0.01	–	–	–	–	–	–
+	–	+	0.003	0.07	–	0.006	–	–	–	–	–	0.07	–
+	+	0.3	0.3	0.1	0.003	+	0.1	0.001	–	–	+	–	–
–	+	0.03	0.008	+	0.002	0.001	–	–	–	–	+	–	–
0.08	0.08	0.3	0.07	0.1	0.02	0.1	0.003	–	–	–	–	0.06	+
+	0.003	0.5	0.1	0.3	0.03	0.2	0.008	0.002	–	–	–	0.003	0.01
+	0.2	0.8	0.03	0.03	0.08	0.08	+	0.005	–	0.05	0.01	0.1	0.003
–	–	–	–	–	–	–	0.1	–	–	–	–	0.09	0.002

cover were less than 1% were inventoried, i.e. quadrats were not used.

Graminoids : Stand 9 Poa compressa, Poa palustris; Stand 13 Phleum alpinum ; Stand 5 Bromus pumpellianus; Stand 2 Carex aenea, Poa palustris ; l Carex foenea, Poa secunda Forbs : Stand 10 Agoseris glauca, Descurainia richardsonii, Erigeron trifidus, Hedysarum alpinum, Lepidium ns ; Stand 13 Collomia linearis, Lepidium ramosissimum, Plantago major, Rumex alpestris, Thlaspi arvense ; Stand 4 Erigeron trifidus, auca, Arnica chamissonis, Trifolium repens ; Stand 2 Androsace septentrionalis, Arabis lyrata ; Stand 15 Botrychium lunaria, Smelowskia

Table 12. Selected site and community attributes of stands at the Mountain Park West Mine. Cover values are percentages with dash (–) indicating absence, and cross (+) in in the stand but not sampled. Species present in < 15% of all stands are listed at the bottom as rare species.

Community Type	Equisetum arvense Potentilla fruiticosa		Agoseris glauca Crepis nana			Agropyron latiglume – Crepis elegans					C		
Stand No.	16	17	26	32	21	18	23	34	30	33	20	22	31
Stand Size (m^2)	275	263	234	266	234	209	373	248	461	166	157	319	45
No. Quadrats[1]	15	18	15	18	16	0	0	19	0	30	0	0	[illegible]
Slope (°)	0	30	0	0	0	30	33	34	32	27	0	35	3
Aspect	Flat	NNE	Flat	Flat	Flat	N	ESE	NNW	ENE	S	Flat	ENE	N
Fine Earth Content (% < 2 mm)													
0 – 5 cm	48	67	65	62	46	39	58	44	72	47	46	66	3
25 – 30 cm	68	56	59	41	28	13	35	48	37	51	26	62	2
Sand Content (%)													
0 – 5 cm	52	62	62	54	60	64	66	72	78	80	55	80	7
13 – 18 cm	53	47	73	53	58	69	79	67	85	70	62	79	7
Available Water Holding Capacity (%), 0 – 5 cm	4.42	5.20	4.22	5.72	2.46	1.33	2.54	3.60	2.99	3.19	3.14	2.50	2.1
pH													
0 – 5 cm	7.0	7.0	7.8	7.5	8.0	7.8	8.3	6.8	7.0	7.3	8.2	8.4	6.5
13 – 18 cm	6.8	6.7	7.9	7.4	7.7	7.7	8.3	7.1	7.4	7.2	7.1	8.5	6.6
Total Exchange Capacity (m.e. 100 g^{-1} whole soil), 0–18 cm	10.5	11.3	4.8	8.4	4.8	3.0	4.4	7.5	5.6	6.8	3.2	6.4	6.9
Available P (ppm), 0 – 18 cm	2.5	2.0	0.5	0.5	1.0	3.0	0.0	1.0	0.5	0.5	0.5	0.5	0.5
No. Vascular Species	51	47	30	26	28	24	17	24	19	13	10	17	2
Total Plant Cover (%)	10.4	5.9	5.4	2.4	1.1	0.14	0.05	1.6	0.32	0.34	0.09	0.06	0.1
Bryophyte Cover (%)	0.2	0.8	–	–	0.09	–	–	–	–	–	–	–	–
Lichen Cover (%)	0.03	0.1	–	–	–	–	–	–	–	–	–	–	–
Vascular Species Cover (%)													
Shrubs													
Salix glauca	0.06	–	–	–	–	–	–	+	–	–	–	–	0.0
Graminoids													
Elymus innovatus	0.03	0.02	0.002	–	–	–	–	–	–	–	–	–	–
Phleum alpinum	0.003	0.003	–	–	–	–	+	–	–	–	–	–	–
Festuca saximontana	0.04	0.1	0.05	0.002	0.02	0.01	0.008	0.003	+	–	0.002	0.001	–
Poa secunda	0.2	0.07	0.03	0.09	0.005	+	+	0.004	+	–	0.005	–	+
Festuca baffinensis	0.02	0.03	0.002	0.008	0.005	0.01	–	0.1	–	+	–	0.002	+
Deschampsia caespitosa	0.07	0.3	0.7	–	0.03	0.03	0.02	–	0.002	–	–	0.03	–
Trisetum spicatum	0.04	0.03	+	0.007	0.05	0.05	0.003	0.002	–	–	0.006	+	+
Poa alpina	0.1	0.08	0.004	0.005	0.02	0.02	0.003	0.02	0.003	–	–	0.002	0.0
Agropyron latiglume	2.0	0.5	1.0	1.1	0.4	0.02	0.009	0.8	0.008	0.3	0.004	0.003	0.0
Poa interior	0.3	0.1	0.1	0.1	0.2	–	+	0.02	0.003	0.002	+	–	0.0
Agropyron trachycaulum	0.1	0.2	0.7	–	0.005	–	–	0.1	0.02	0.01	–	0.004	0.0
Forbs													
Arenaria rubella	0.002	0.001	0.003	–	–	–	–	–	–	–	–	–	–
Gentianella amarella	0.04	0.008	0.002	+	–	–	–	–	–	–	–	–	–
Trifolium pratense	+	–	0.03	0.001	–	–	–	–	–	–	–	–	–
Solidago decumbens	0.09	0.003	+	–	0.02	–	–	–	–	–	–	–	–
Botrychium lunaria	0.002	0.002	0.002	+	+	–	–	–	–	–	–	–	–
Draba aurea	0.009	+	–	+	+	–	–	–	–	–	–	–	–
Erigeron trifidus	0.1	–	+	0.008	–	–	–	–	–	–	–	–	–
Astragalus alpinus	0.9	0.02	0.07	+	+	0.007	0.002	–	–	–	–	–	–
Agoseris glauca	0.7	0.09	0.4	0.4	0.003	–	–	0.001	–	–	–	–	–
Stellaria longipes	–	+	–	–	–	+	+	–	–	–	–	–	–
Mertensia paniculata	0.01	0.008	0.003	–	–	0.001	–	0.004	+	–	–	–	–
Cerastium beeringianum	0.001	0.03	–	+	–	–	–	0.01	–	–	–	–	0.0
Aster sibiricus	0.02	0.03	0.004	–	–	+	–	+	–	+	–	–	–
Taraxacum officinale	0.3	0.07	0.3	0.04	–	+	0.008	+	+	+	–	–	–
Epilobium angustifolium	0.05	0.06	–	0.004	0.002	–	–	0.002	–	–	–	–	–
Solidago multiradiata	0.08	0.05	0.1	0.04	+	+	–	–	+	–	–	–	–
Astragalus vexilliflexus	–	–	–	+	+	–	–	+	0.002	–	–	–	–
Fragaria virginiana	0.004	0.05	–	–	–	0.002	+	–	–	–	–	+	+
Oxytropis deflexa	1.7	0.8	0.7	0.02	0.04	0.002	–	+	0.002	–	–	–	+
Achillea millefolium	0.01	0.06	0.8	0.02	0.1	0.004	0.001	0.006	0.02	0.001	–	+	+
Hedysarum alpinum	0.7	1.0	0.3	0.004	0.1	–	–	–	0.004	–	0.03	0.001	0.0
Draba oligosperma	–	–	–	–	0.02	+	–	–	–	–	+	–	–
Astragalus aboriginum	–	–	–	0.006	–	–	–	0.1	+	+	–	–	–
Artemisia borealis	+	0.05	–	0.6	0.02	+	0.002	0.3	0.2	0.05	0.02	0.002	0.0
Crepis elegans	–	–	–	–	–	+	+	–	0.002	0.007	–	–	0.0

at the Mountain Park West Mine. Cover values are percentages with dash (−) indicating absence, and cross (+) indicating < 0.001% cover, and/or that the species was present
< 15% of all stands are listed at the bottom as rare species.

Agoseris glauca – Crepis nana			Agropyron latiglume – Crepis elegans					Crepis nana – Eriogonum androsaceum								
26	32	21	18	23	34	30	33	20	22	31	19	27	28	25	29	24
234	266	234	209	373	248	461	166	157	319	456	278	316	130	228	317	233
15	18	16	0	0	19	0	30	0	0	0	0	0	0	0	0	0
0	0	0	30	33	34	32	27	0	35	37	31	0	33	38	35	0
Flat	Flat	Flat	N	ESE	NNW	ENE	S	Flat	ENE	N	NNW	Flat	WSW	NNW	N	Flat
65	62	46	39	58	44	72	47	46	66	38	56	55	59	40	39	56
59	41	28	13	35	48	37	51	26	62	20	42	90	40	38	35	60
62	54	60	64	66	72	78	80	55	80	78	73	[illegible]	73	75	88	68
73	53	58	69	79	67	85	70	62	79	76	75	79	80	79	83	72
4.22	5.72	2.46	1.33	2.54	3.60	2.99	3.19	3.14	2.50	2.18	2.01	3.09	2.31	1.76	1.54	3.00
7.8	7.5	8.0	7.8	8.3	6.8	7.0	7.3	8.2	8.4	6.5	7.7	8.1	8.0	8.3	8.0	8.4
7.9	7.4	7.7	7.7	8.3	7.1	7.4	7.2	7.1	8.5	6.6	7.0	8.1	7.8	8.2	7.9	8.5
4.8	8.4	4.8	3.0	4.4	7.5	5.6	6.8	3.2	6.4	6.9	5.9	4.3	4.4	2.6	4.5	6.8
0.5	0.5	1.0	3.0	0.0	1.0	0.5	0.5	0.5	0.5	0.5	1.5	0.0	0.5	0.5	0.5	0.0
30	26	28	24	17	24	19	13	10	17	20	10	9	8	4	10	4
5.4	2.4	1.1	0.14	0.05	1.6	0.32	0.34	0.09	0.06	0.19	0.03	0.06	0.11	0.03	0.06	0.08
−	−	0.09	−	−	−	−	−	−	−	−	−	−	−	−	−	−
−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
−	−	−	−	−	+	−	−	−	−	0.05	−	−	−	−	+	−
0.002	−	[illegible]	−	−	−	−	−	−	−	−	−	−	−	−	−	−
−	−	−	−	+	−	−	−	−	−	−	−	−	−	−	[illegible]	−
0.05	0.002	0.02	0.01	0.008	0.003	+	−	0.002	0.001	−	−	−	−	−	−	−
0.03	0.09	0.005	+	+	0.004	+	−	0.005	−	+	+	−	−	−	−	−
0.002	0.008	0.005	0.01	−	0.1	−	+	−	0.002	+	−	−	+	−	−	−
0.7	−	0.03	0.03	0.02	−	0.002	−	−	0.03	−	−	−	−	0.003	−	−
+	0.007	0.05	0.05	0.003	0.002	−	−	0.006	+	+	+	+	−	−	−	−
0.004	0.005	0.02	0.02	0.003	0.02	0.003	−	−	0.002	0.003	−	0.002	+	−	−	−
1.0	1.1	0.4	0.02	0.009	0.8	0.008	0.3	0.004	0.003	0.01	0.001	0.004	0.003	−	−	−
0.1	0.1	0.2	−	+	0.02	0.003	0.002	+	−	0.001	+	−	0.001	−	+	−
0.7	−	0.005	−	−	0.1	0.02	0.01	−	0.004	0.002	−	0.002	0.05	0.01	+	−
0.003	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
0.002	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
0.03	0.001	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
+	−	0.02	−	−	−	−	−	−	−	−	−	−	−	−	−	−
0.002	+	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−
−	+	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−
+	0.008	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
0.07	+	+	0.007	0.002	−	−	−	−	−	−	−	−	−	−	−	−
0.4	0.4	0.003	−	−	0.001	−	−	−	−	−	−	−	−	−	−	−
−	−	−	+	+	−	−	−	−	−	[illegible]	−	−	−	−	−	−
0.003	−	−	0.001	−	0.004	+	−	−	−	−	−	−	−	−	−	−
−	+	−	−	−	0.01	−	−	−	−	0.02	−	−	−	−	−	−
0.004	−	−	+	−	+	−	+	−	−	−	−	−	−	−	−	−
0.3	0.04	−	+	0.008	+	+	+	−	−	−	−	−	−	−	−	−
−	0.004	0.002	−	−	0.002	−	−	−	−	−	−	−	−	−	+	−
0.1	0.04	+	+	−	−	+	−	−	−	−	−	−	−	−	+	−
−	+	+	−	−	+	0.002	−	−	−	−	−	−	−	−	−	−
−	−	−	0.002	+	−	−	−	−	+	+	0.005	−	−	−	−	−
0.7	0.02	0.04	0.002	−	+	0.002	−	−	−	+	−	0.01	−	−	−	−
0.8	0.02	0.1	0.004	0.001	0.006	0.02	0.001	−	+	+	−	+	+	−	+	−
0.3	0.004	0.1	−	−	−	0.004	−	0.03	0.001	0.002	0.006	−	0.05	−	−	−
−	−	0.02	+	−	−	−	−	+	−	−	−	−	−	−	−	−
−	0.006	−	−	−	0.1	+	+	−	−	−	−	−	−	−	−	−
−	0.6	0.02	+	0.002	0.3	0.2	0.05	0.02	0.002	0.006	0.004	0.02	−	+	0.003	0.007
−	−	−	+	+	−	0.002	0.007	−	−	0.007	−	−	−	−	−	−
−	−	−	−	−	−	−	−	−	0.001	−	0.004	−	−	−	0.04	−
0.001	−	0.007	+	+	0.02	0.03	+	0.02	0.006	0.08	0.004	0.01	+	0.009	0.02	0.05

Fine Earth Content (% < 2 mm)													
0 – 5 cm	48	67	65	62	46	39	58	44	72	47	46	66	38
25 – 30 cm	68	56	59	41	28	13	35	48	37	51	26	62	20
Sand Content (%)													
0 – 5 cm	52	62	62	54	60	64	66	72	78	80	55	80	78
13 – 18 cm	53	47	73	53	58	69	79	67	85	70	62	79	76
Available Water Holding Capacity (%), 0 – 5 cm	4.42	5.20	4.22	5.72	2.46	1.33	2.54	3.60	2.99	3.19	3.14	2.50	2.18
pH													
0 – 5 cm	7.0	7.0	7.8	7.5	8.0	7.8	8.3	6.8	7.0	7.3	8.2	8.4	6.5
13 – 18 cm	6.8	6.7	7.9	7.4	7.7	7.7	8.3	7.1	7.4	7.2	7.1	8.5	6.6
Total Exchange Capacity (m.e. 100 g[1] whole soil), 0 – 18 cm	10.5	11.3	4.8	8.4	4.8	3.0	4.4	7.5	5.6	6.8	3.2	6.4	6.9
Available P (ppm), 0 – 18 cm	2.5	2.0	0.5	0.5	1.0	3.0	0.0	1.0	0.5	0.5	0.5	0.5	0.5
No. Vascular Species	51	47	30	26	28	24	17	24	19	13	10	17	20
Total Plant Cover (%)	10.4	5.9	5.4	2.4	1.1	0.14	0.05	1.6	0.32	0.34	0.09	0.06	0.19
Bryophyte Cover (%)	0.2	0.8	–	–	0.09	–	–	–	–	–	–	–	–
Lichen Cover (%)	0.03	0.1	–	–	–	–	–	–	–	–	–	–	–
Vascular Species Cover (%)													
Shrubs													
Salix glauca	0.06	–	–	–	–	–	–	+	–	–	–	–	0.05
Graminoids													
Elymus innovatus	0.03	0.02	0.002	–	–	–	–	–	–	–	–	–	–
Phleum alpinum	0.003	0.003	–	–	–	–	+	–	–	–	–	–	–
Festuca saximontana	0.04	0.1	0.05	0.002	0.02	0.01	0.008	0.003	+	–	0.002	0.001	–
Poa secunda	0.2	0.07	0.03	0.09	0.005	+	+	0.004	+	–	0.005	–	+
Festuca baffinensis	0.02	0.03	0.002	0.008	0.005	0.01	–	0.1	–	+	–	0.002	+
Deschampsia caespitosa	0.07	0.3	0.7	–	0.03	0.03	0.02	–	0.002	–	–	0.03	–
Trisetum spicatum	0.04	0.03	+	0.007	0.05	0.05	0.003	0.002	–	–	0.006	+	+
Poa alpina	0.1	0.08	0.004	0.005	0.02	0.02	0.003	0.02	0.003	–	–	0.002	0.003
Agropyron latiglume	2.0	0.5	1.0	1.1	0.4	0.02	0.009	0.8	0.008	0.3	0.004	0.003	0.01
Poa interior	0.3	0.1	0.1	0.1	0.2	–	+	0.02	0.003	0.002	+	–	0.001
Agropyron trachycaulum	0.1	0.2	0.7	–	0.005	–	–	0.1	0.02	0.01	–	0.004	0.002
Forbs													
Arenaria rubella	0.002	0.001	0.003	–	–	–	–	–	–	–	–	–	–
Gentianella amarella	0.04	0.008	0.002	+	–	–	–	–	–	–	–	–	–
Trifolium pratense	+	–	0.03	0.001	–	–	–	–	–	–	–	–	–
Solidago decumbens	0.09	0.003	+	–	0.02	–	–	–	–	–	–	–	–
Botrychium lunaria	0.002	0.002	0.002	+	+	–	–	–	–	–	–	–	–
Draba aurea	0.009	+	–	+	+	–	–	–	–	–	–	–	–
Erigeron trifidus	0.1	–	+	0.008	–	–	–	–	–	–	–	–	–
Astragalus alpinus	0.9	0.02	0.07	+	+	0.007	0.002	–	–	–	–	–	–
Agoseris glauca	0.7	0.09	0.4	0.4	0.003	–	–	0.001	–	–	–	–	–
Stellaria longipes	–	+	–	–	–	+	+	–	–	–	–	–	–
Mertensia paniculata	0.01	0.008	0.003	–	–	0.001	–	0.004	+	–	–	–	–
Cerastium beeringianum	0.001	0.03	–	+	–	–	–	0.01	–	–	–	–	0.02
Aster sibiricus	0.02	0.03	0.004	–	–	+	–	+	–	+	–	–	–
Taraxacum officinale	0.3	0.07	0.3	0.04	–	+	0.008	+	+	+	–	–	–
Epilobium angustifolium	0.05	0.06	–	0.004	0.002	–	–	0.002	–	–	–	–	–
Solidago multiradiata	0.08	0.05	0.1	0.04	+	+	–	–	+	–	–	–	–
Astragalus vexilliflexus	–	–	–	+	+	–	–	+	0.002	–	–	–	–
Fragaria virginiana	0.004	0.05	–	–	–	0.002	+	–	–	–	–	+	+
Oxytropis deflexa	1.7	0.8	0.7	0.02	0.04	0.002	–	+	0.002	–	–	–	+
Achillea millefolium	0.01	0.06	0.8	0.02	0.1	0.004	0.001	0.006	0.02	0.001	–	+	+
Hedysarum alpinum	0.7	1.0	0.3	0.004	0.1	–	–	–	0.004	–	0.03	0.001	0.002
Draba oligosperma	–	–	–	–	0.02	+	–	–	–	–	+	–	–
Astragalus aboriginum	–	–	–	0.006	–	–	–	0.1	+	+	–	–	–
Artemisia borealis	+	0.05	–	0.6	0.02	+	0.002	0.3	0.2	0.05	0.02	0.002	0.006
Crepis elegans	–	–	–	–	–	+	+	–	0.002	0.007	–	–	0.007
Equisetum arvense	1.6	1.0	–	–	–	–	–	–	–	–	–	0.001	–
Crepis nana	–	–	0.001	–	0.007	+	+	0.02	0.03	+	0.02	0.006	0.08
Epilobium latifolium	–	–	–	–	–	–	+	–	–	–	–	+	0.002
Eriogonum androsaceum	–	–	–	–	–	–	–	–	0.009	–	+	0.001	+

[1]Stands for which preliminary estimates of total plant cover were less than 1% were inventoried, i.e. quadrats were not used.

Rare Species. Trees : Stand 17 Picea glauca/engelmanii, Populus balsamifera ; Stand 18 Picea glauca/engelmanii. Shrubs : Stand 16 Potentilla fruticosa ; Stand 17 Pote Dryas integrifolia. Graminoids : Stand 16 Agrostis scabra, Carex media, Carex obtusata ; Stand 18 Poa palustris ; Stand 33 Poa glauca ; Stand 22 Bromus pumpellianus ; Star Forbs : Stand 16 Androsace septentrionalis, Antennaria nitida, Gentiana prostrata, Oxytropis splendens, Polygonum viviparum, Potentilla bipinnatifida, Potentilla gracilis, Rub monantha, Trifolium hybridum, Trifolium repens ; Stand 17 Androsace septentrionalis, Antennaria rosea, Arnica cordifolia, Artemisia norvegica, Oxytropis splendens, P crista-galli, Rumex acetosella, Rumex alpestris, Senecio lugens ; Stand 26 Astragalus striatus, Carum carvii, Castilleja miniata, Rhinanthus crista-galli ; Stand 32 Smelowski striatus, Potentilla diversifolia, Senecio canus, Senecio indecorus ; Stand 16 Phacelia sericea, Polygonum viviparum ; Stand 34 Astragalus eucosmus, Oxytropis campestris, Pl Stand 22 Antennaria rosea ; Stand 31 Oxytropis sericea.

7	65	62	46	39	58	44	72	47	46	66	38	56	55	59	40	39	56
6	59	41	28	13	35	48	37	51	26	62	20	42	90	40	38	35	60
2	62	54	60	64	66	72	78	80	55	80	78	73	71	73	75	88	68
7	73	53	58	69	79	67	85	70	62	79	76	75	79	80	79	83	72
0	4.22	5.72	2.46	1.33	2.54	3.60	2.99	3.19	3.14	2.50	2.18	2.01	3.09	2.31	1.76	1.54	3.00
	7.8	7.5	8.0	7.8	8.3	6.8	7.0	7.3	8.2	8.4	6.5	7.7	8.1	8.0	8.3	8.0	8.4
	7.9	7.4	7.7	7.7	8.3	7.1	7.4	7.2	7.1	8.5	6.6	7.0	8.1	7.8	8.2	7.9	8.5
3	4.8	8.4	4.8	3.0	4.4	7.5	5.6	6.8	3.2	6.4	6.9	5.9	4.3	4.4	2.6	4.5	6.8
	0.5	0.5	1.0	3.0	0.0	1.0	0.5	0.5	0.5	0.5	0.5	1.5	0.0	0.5	0.5	0.5	0.0
	30	26	28	24	17	24	19	13	10	17	20	10	9	8	4	10	4
	5.4	2.4	1.1	0.14	0.05	1.6	0.32	0.34	0.09	0.06	0.19	0.03	0.06	0.11	0.03	0.06	0.08
	–	–	0.09	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	–	–	–	–	–	+	–	–	–	–	0.05	–	–	–	–	+	–
2	0.002	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
03	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–
	0.05	0.002	0.02	0.01	0.008	0.003	+	–	0.002	0.001	–	–	–	–	–	–	–
	0.03	0.09	0.005	+	+	0.004	+	–	0.005	–	+	+	–	–	–	–	–
3	0.002	0.008	0.005	0.01	–	0.1	–	+	–	0.002	+	–	–	+	–	–	–
	0.7	–	0.03	0.03	0.02	–	0.002	–	–	0.03	–	–	–	–	0.003	–	–
3	+	0.007	0.05	0.05	0.003	0.002	–	–	0.006	+	+	+	+	–	–	–	–
3	0.004	0.005	0.02	0.02	0.003	0.02	0.003	–	–	0.002	0.003	–	0.002	+	–	–	–
	1.0	1.1	0.4	0.02	0.009	0.8	0.008	0.3	0.004	0.003	0.01	0.001	0.004	0.003	–	–	–
	0.1	0.1	0.2	–	+	0.02	0.003	0.002	+	–	0.001	+	+	0.001	–	+	–
	0.7	–	0.005	–	–	0.1	0.02	0.01	–	0.004	0.002	–	0.002	0.05	0.01	+	–
01	0.003	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
08	0.002	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	0.03	0.001	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
03	+	–	0.02	–	–	–	–	–	–	–	–	–	–	–	–	–	–
02	0.002	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	–	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	+	0.008	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	0.07	+	+	0.007	0.002	–	–	–	–	–	–	–	–	–	–	–	–
	0.4	0.4	0.003	–	–	0.001	–	–	–	–	–	–	–	–	–	–	–
	–	–	–	+	+	–	–	–	–	–	–	–	–	–	–	–	–
08	0.003	–	–	0.001	–	0.004	+	–	–	–	–	–	–	–	–	–	–
	–	+	–	–	–	0.01	–	–	–	–	0.02	–	–	–	–	–	–
	0.004	–	–	+	–	+	–	+	–	–	–	–	–	–	–	–	–
	0.3	0.04	–	+	0.008	+	+	+	–	–	–	–	–	–	–	–	–
		0.004	0.002	–	–	0.002	–	–	–	–	–	–	–	–	–	+	–
	0.1	0.04	+	+	–	–	+	–	–	–	–	–	–	–	–	+	–
	–	+	+	–	–	+	0.002	–	–	–	–	–	–	–	–	–	–
	–	–	–	0.002	+	–	–	–	–	+	+	0.005	–	–	–	–	–
	0.7	0.02	0.04	0.002	–	+	0.002	–	–	–	+	–	0.01	–	–	–	–
	0.8	0.02	0.1	0.004	0.001	0.006	0.02	0.001	–	+	+	–	+	+	–	+	–
	0.3	0.004	0.1	–	–	–	0.004	–	0.03	0.001	0.002	0.006	–	0.05	–	–	–
	–	–	0.02	+	–	–	–	–	+	–	–	–	–	–	–	–	–
	–	0.006	–	–	–	0.1	+	+	–	–	–	–	–	–	–	–	–
	–	0.6	0.02	+	0.002	0.3	0.2	0.05	0.02	0.002	0.006	0.004	0.02	–	+	0.003	0.007
	–	–	–	+	+	–	0.002	0.007	–	–	0.007	–	–	–	–	–	–
	–	–	–	–	–	–	–	–	–	0.001	–	0.004	–	–	–	0.04	–
	0.001	–	0.007	+	+	0.02	0.03	+	0.02	0.006	0.08	0.004	0.01	+	0.009	0.02	0.05
	–	–	–	–	+	–	–	–	–	+	0.002	–	–	–	–	+	+
	–	–	–	–	–	–	0.009	–	+	0.001	+	0.001	+	–	–	–	0.02

cover were less than 1% were inventoried, i.e. quadrats were not used.

anii, Populus balsamifera ; Stand 18 Picea glauca/engelmanii. Shrubs : Stand 16 Potentilla fruticosa ; Stand 17 Potentilla fruticosa, Arctostaphylos uva-ursi, abra, Carex media, Carex obtusata ; Stand 18 Poa palustris ; Stand 33 Poa glauca ; Stand 22 Bromus pumpellianus ; Stand 31 Poa arctica.

ria nitida, Gentiana prostrata, Oxytropis splendens, Polygonum viviparum, Potentilla bipinnatifida, Potentilla gracilis, Rubus acaulis, Rumex alpestris, Smelowskia calycina, Stellaria and 17 Androsace septentrionalis, Antennaria rosea, Arnica cordifolia, Artemisia norvegica, Oxytropis splendens, Parnassia montanensis, Potentilla diversifolia, Rhinanthus cio lugens ; Stand 26 Astragalus striatus, Carum carvii, Castilleja miniata, Rhinanthus crista-galli ; Stand 32 Smelowskia calycina, Taraxccum ceratophorum ; Stand 21 Astragalus o indecorus ; Stand 18 Phacelia sericea, Polygonum viviparum ; Stand 34 Astragalus eucosmus, Oxytropis campestris, Phacelia sericea ; Stand 33 Taraxacum ceratophorum ; Stand cea.