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Vegetation and Soils of an Alpine Range in the Absaroka Mountains, Wyoming

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Abstract

Alpine vegetation on Carter Mountain in the Absaroka Range of northwestern Wyoming was classified into eight community types. Community type differences are due mainly to shifts in the standing crop and constancy of a few species. Floristic differences among community-types are not marked, and very few species are confined to a single community type. Soils associated with each community type were classified to soil subgroup level. No consistent relationships were found between the vegetation and soil classifications. Exposure to prevailing wind, elevation, soil particle size distribution, available water content, and snow accumulation were statistically significant environmental factors determining community type distribution.

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INTRODUCTION

Of the five major mountain ranges in northwestern Wyoming (Absaroka, Beartooth, Gros Ventre, Teton, Wind River), only the Absaroka Range is of volcanic origin. The highly dissected Absaroka Plateau covers an area approximately 80 by 130 km, much of which exceeds 3000 m elevation. Consequently, alpine vegetation is widely distributed. Access to the alpine zone is limited by the steep and rugged terrain below it and by the loosely consolidated, easily disturbed volcanic material which makes travel difficult and sometimes dangerous. Large portions of the mountains are in wilderness, which further limits easy access.

Only a very limited amount of scientific information is available on the alpine vegetation of the Absaroka Range, although the alpine vegetation and soils of the nonvolcanic Beartooth Plateau immediately to the north have been studied (Johnson and Billings 1962, Nimlos and McConnell 1962).

Strasia et al. (1970) studied the influence of grazing by domestic sheep on the alpine vegetation at Carter Mountain on the eastern edge of the Absaroka Range. They provided some information on taxa composition and coverage, and on selection and utilization of alpine plants as forage by sheep. In general, their work was oriented toward range management rather than ecology. However, the study indicated a need for more detailed information on the vegetation and soils of Carter Mountain and in, part, was responsible for the initiation of this study.

Study objectives were: (1) to determine taxa composition and aboveground production of the alpine vegetation on Carter Mountain; (2) to develop a phytosociological classification of the vegetation; (3) to classify the alpine soils according to the current system of soil taxonomy; (4) to examine the relationship between the vegetation and soil classifications; (5) to determine the environmental factors that may influence plant distribution.

In addition to the scientific aspects, there was a practical need for such information. The alpine zone on Carter Mountain is almost entirely within the Shoshone National Forest. It provides summer and early fall range for domestic sheep and for many kinds of wildlife. Classification of the vegetation and soils provides a framework for land use planning. It is essential for proper, long-term, range management on this Federally controlled range.

STUDY AREA

Carter Mountain is a long (ca. 32 km) northeast-southwest trending ridge on the eastern edge of the Absaroka Range. Along the northwestern side, it is an almost unbroken line of vertical cliffs and steep talus slopes of rounded, loose rocks. The southeastern side of the mountain is much less steep and rugged. The horizontal distance from the crest of the main ridge to the lower edge of the alpine zone varies from 2 to 5 km.

The alpine zone on Carter Mountain begins at about 3000 m elevation and extends to the crest (ca. 3750 m). Isolated groves of *Picea engelmannii*[2] and *Abies lasiocarpa* and some scattered *Pinus flexilis*, are present on the southeastern slope. These groves are composed of erect trees and are confined to steep mesic slopes along watercourses.

On ridges and other convex topography interspersed between the *Picea-Abies* groves is a shrub-grass vegetation where *Artemisia tridentata* dominates the shrub stratum. In places, this high elevation extension of the Great Basin sagebrush-type abuts almost directly upon true alpine vegetation. *Hesperochloa kingii* is a conspicuous member of the herb stratum in this vegetation. Usually, the transition between alpine and Great Basin shrub extends over 150 to 200 m of elevation.

The rim and the talus slopes along the northwestern side of the mountain abruptly delineate the boundary between the alpine zone and coniferous subalpine forest below. There is an almost complete absence of the coniferous krummholz that often characterizes the alpine-subalpine transition in other areas of the Rocky Mountains.

The volcanic substrate of Carter Mountain is of late Eocene and Oligocene origin. The base of the mountain is basalt and breccia. The upper part has been identified only as basic breccia on the Wyoming geologic map (Love et al. 1955). This breccia is a mass of cinders, ash, tuff, basalt, pumice, conglomerate, and other pyroclastic material.

The soils on Carter Mountain are derived from this heterogenous mixture of volcanic materials. Below the zone of maximum weathering the rock fragments are a partially cemented mass; within the upper 1–3 m the rock is more fragmented, and cementation into a continuous body is weak or absent. This relatively unconsolidated rock mass is considered to be a fragmental substratum (IIC horizon) rather than a lithic contact.

Examples of both active and inactive cryopedogenic processes can be observed. The fragmented substratum promotes good to excessive drainage conditions, and indications of restricted drainage such as gleyed or mottled subsoils were not present.

[2]Taxa identifications were checked by the Rocky Mountain Herbarium, University of Wyoming, Laramie. Voucher specimens are on file there and at the Forest, Range and Watershed Laboratory, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Laramie, Wyo.

There are no long-term weather records from the study area. From observations made during the study, the general climate is believed to be similar to that of other alpine areas in the Rocky Mountain region. Winds are predominantly northwesterly and strong (20–30 km/h) throughout the year. Summer temperature data that might be extrapolated to Carter Mountain were collected by Johnson and Billings (1962) on the Beartooth Plateau about 80 km to the north. There, the mean July air temperature ranged from 7° to –9° C.

The precipitation map of the state of Wyoming (Wyoming Water Planning Program, n.d.) indicates Carter Mountain lies between the 30- and 50-cm isohytes. Actual precipitation may vary greatly from that indicated on the maps. Summer thundershowers are common, with precipitation often in the form of hail or snow. Relatively heavy snowfall may occur in late August or early September. Aerial photographs taken in winter show ridges and other sites exposed to the wind to be free of snow, while deep accumulations of snow occur in watercourses, on lee slopes, and in local sheltered areas. This snow may remain until late July or early August.

The study area had been grazed by domestic sheep for many years. Wapiti (*Cervus canadensis*), mule deer (*Odocoileus hemionus*), and somewhat suprisingly in the alpine zone, pronghorn antelope (*Antilocapra americana*) were often seen during the study. Bighorn sheep (*Ovis canadensis*) were also present on Carter Mountain. Small herbivorous mammals included pika (*Pika pika*) and marmot (*Marmota flaviventris*). Pocket gophers (*Thomomys* spp.), voles (*Microtus* spp.), and other microtines were not common.

Except for activities associated with domestic sheep grazing, human influence has been limited. The area is traversed by a road only barely passable by four-wheel drive vehicles in late summer and early fall. Hunters use the area in the fall, but summer recreational use is nonexistent. Oil exploration had been carried out on Carter Mountain in the past, but there had been no activity for several years prior to sampling.

METHODS

FIELD PROCEDURES

The study sites were at the headwaters of Little Rose Creek, Rose Creek, and Meeteetse Creek in Sections 7, 8, 17, 18, 19, 20; T49N; R103W; 6th Principal Meridian, Wyoming. Within the study area 29 randomly located stands were sampled during the period July 18 to August 3, 1969. Each stand was 5 by 5 m. All of the sampled stands had been grazed by domestic sheep for many years prior to sampling.

Within a stand, a systematically located sample of 20 quadrats, each 0.3 by 0.3 m, was used to estimate aboveground standing crop. Aboveground herbage of vascular plants was clipped to a 1-cm stubble height, separated by taxon, and placed in plastic bags. Oven-dry weights (24 h at 105° C) were determined to the nearest 0.1 g.

A soil pedon in each stand was described to Soil Conservation Service standards (USDA Soil Conservation Service 1975). Samples of at least 100 g of soil were collected from each horizon for laboratory analyses. The analytical techniques and standards given in *Soil Taxonomy* (USDA Soil Conservation Service 1975) were followed.

The following site features were recorded: elevation (meters); slope aspect (degrees from true North); slope gradient (percent); position on slope from nearest ridgeline (top, upper 1/3, mid 1/3, lower 1/3, base); estimated depth and duration of snow accumulation; exposure to wind (lee, windward).

DATA ANALYSIS

A correlation matrix was made from the taxa that averaged at least 0.9 g/m² of aboveground standing crop. The 20 taxa with the highest variance or a significant ($p = 0.1$) covariance were selected for principal component analysis (van Groenewoud 1965). Principal components were derived from a Q-type analysis, which expresses interstand relationships.

The first three principal components were used as the basis for a three-dimensional ordination of the stands. Stands were ordinated in three-dimensional space by graphical plotting and were grouped on the basis of their proximity in the three-dimensional space. The groups were defined primarily on taxa composition and aboveground standing crop. Average aboveground standing crop was calculated for each taxon by using the total number of stands within a group as the divisor. Soil and site attributes were summarized in the same manner.

Sorensen's coefficient (Sorensen 1948) was used to determine the similarity of the groups of stands established by the ordination. The initial matrix of similarity was based on the standing crop of the 20 taxa used in the ordination. The weighted pair-group method (Sokal and Sneath 1963) was used to classify the stand groups and to show intergroup relationships. To test the adequacy of the use of only 20 taxa to establish stand groups, the similarity and cluster analyses were repeated with all of the 60 taxa encountered in sampling.

Soil scientists of the Soil Conservation Service classified the soils to the Soil Subgroup level by the methods described in *Soil Taxonomy* (USDA Soil Conservation Service 1975).

The method of van Groenewoud (1965) was used to examine the first three principal components in an ecological context. Site and soil attributes were individually plotted against the corresponding eigenvalue of the stand on each of the first three principal components. The resulting scatter diagram was visually examined for an evident relationship. If this was found a line was fitted to the scatter of points. Simple correlation coefficients were calculated when a straight-line relationship was present.

SOIL CLASSIFICATION AND MORPHOLOGY

Although no data were available on soil temperature from Carter Mountain, it was assumed the temperature regime was similar to other alpine sites in the Rocky Mountain region. The soils described were assumed cold enough to be placed in the "Cryo" great group soil category (soils with a mean annual temperature in the range 0–8° C) and in the Pergelic soil subgroup (mean annual soil temperature 0° C).

Data on bulk density could only be estimated, because of the large amount of coarse fragments present and the lack of discrete peds. Consequently, only the physical and chemical attributes of cation exchange capacity, exchange acidity, water retention at 15 bars, and clay content were used to substantiate placement of some of the pedons in an Andic subgroup.

The pedons from the 29 stands represented three soil orders: Entisols—soils with little or no evidence of pedogenic development; Inceptisols—soils with altered horizons that have lost bases and aluminum, but that retain some weatherable minerals; Mollisols—soils with dark-colored, base-rich surface horizons, and subsurface horizons with variable degrees of pedogenic development.

The three soil orders were further subdivided into seven soil subgroups. Brief description of these follow. More complete information on the morphology of these subgroups is given in appendix 1.

Pergelic Cryorthent, fragmental, mixed (2 of 29 pedons).—These were shallow soils with little pedogenic development. An ochric epipedon (a thin, light-colored surface horizon, low in organic matter) rested directly on a fragmental substratum (IIC horizon).

Pergelic Cryochrept, coarse-loamy over fragmental, mixed (2 of 29 pedons).—These soils had some pedogenic development, but without mineral accumulation or extreme weathering. A cambic horizon, (an altered, non-illuvial, subsoil horizon with texture finer than loamy fine sand) occurred immediately below the diagnostic ochric epipedon.

Andic Entic Pergelic Cryumbrept, loamy-skeletal over fragmental, mixed (6 of 29 pedons).—These soils had an umbric epipedon (a dark-colored surface horizon with base saturation below 50%) resting directly on a fragmental substratum. The term Entic indicates poor pedogenic development; Andic indicates 60% or more (by weight) of the soil is vitric volcanic ash, or other pyroclastic materials.

Andic Pergelic Cryochrept, loamy-skeletal over fragmental, mixed (1 of 29 pedons).—This subgroup was similar to the Pergelic Cryochrept subgroup except for a low, 15-bar clay-to-water retention ratio, which placed it in the Andic subgroup.

Andic Pergelic Cryumbrept (8 of 29 pedons).—These soils had well-developed, often subdivided cambic horizons underlying relatively thick umbric epipedons. The surface horizon rested directly on a fragmental substratum (IIC horizon).

Andic Pergelic Cryoboroll, fragmental, mixed (3 of 29 pedons).—This subgroup was characterized by the presence of a shallow mollic epipedon resting directly on a fragmental substratum. A mollic epipedon is a relatively thick, dark-colored, mineral surface horizon with base saturation higher than 50% and a relatively high organic carbon content. Two of the pedons had mollic epipedons less than the required 18 cm thickness, but as all other requirements were met they were considered to be true mollic epipedons.

Andic Pergelic Cryoboroll, loamy-skeletal, mixed (7 of 29 pedons).—In this subgroup all mollic epipedons met the required 18 cm thickness. Cambic horizons were present in six of the seven pedons.

VEGETATION

FLORISTICS AND PRODUCTION

Sixty vascular plant taxa were found on the 29 sample stands (appendix 2). Forb taxa were much more common than gramineous taxa. Two categories of forbs were present: erect forbs (38 taxa) and cushion plant forbs (8 taxa). The prostrate shrub *Salix recticulata* was the only woody plant present. It was included in the erect forb category. Grasses (9 taxa) were more common than graminoids (sedges and woodrush—5 taxa). Lichens and bryoids were not sampled.

As is generally the rule in alpine vegetation, while many taxa were present, most of the aboveground standing crop was produced by relatively few taxa. Nineteen taxa (8 erect forbs, 7 cushion plant forbs, 2 grasses, and 2 sedges) produced 84% of the average total standing crop of 107.6 g/m².

Four genera produced 54% of the average total standing crop. The most productive genus was *Trifolium* (3 species), which produced 18% of the average total standing crop. One species (*Geum rossii*) produced 15% of the average total standing crop. This species is widely distributed in the alpine zone of the North American cordillera. On the study area it was the most abundant and conspicuous plant throughout the growing season. Other genera that produced a large portion of aboveground standing crop were *Phlox* 12% and *Poa* 9%.

PHYTOSOCIOLOGY

Ordination

The first three principal components accounted for 32%, 17%, and 13%, respectively, of the total variation in taxa composition and standing crop biomass; the other 26 components accounted for the remaining 38% of the variation (table 1). Three-dimensional or-

Table 1.—Eigenvectors and eigenvalues of the first three principal component axes of the 29-stand matrix.

Stand	Axes 1	2	3
	---------- eigenvectors for plots ----------		
16	-0.15527	-0.30227	-0.18831
19	0.05138	-0.40368	0.00316
15	0.01433	-0.38171	0.09341
14	-0.03321	-0.25253	0.12229
30	0.05535	-0.28129	-0.12325
40	0.04995	-0.24710	-0.25467
20	0.02113	-0.20075	-0.11274
18	0.06138	-0.25967	-0.13644
11	0.00095	-0.00841	0.00841
10	0.00066	-0.08534	-0.23043
28	0.07116	-0.05542	-0.36007
29	0.09450	-0.00754	-0.39689
36	0.25856	-0.12950	0.14946
23	0.18987	-0.18725	0.17393
12	0.11114	-0.18612	0.27301
17	0.24502	-0.09234	0.23897
21	0.24611	-0.13048	-0.20819
22	0.26222	-0.01621	-0.24893
38	0.22036	0.03545	-0.17735
27	0.22841	0.11560	-0.17014
31	0.14386	0.09704	-0.10694
35	0.28779	-0.02856	-0.05186
25	0.29424	0.02130	0.20941
38	0.22036	0.03545	-0.17735
26	0.30005	0.10045	-0.01125
37	0.28183	0.16145	0.07567
39	0.23628	0.17615	0.09722
24	0.20228	0.19876	0.11376
32	0.06321	0.08442	0.14539
Eigenvalues	9.31255	5.03224	3.52761
Cumulative variation (%)	32.11	49.48	61.63

dination segregated the 29 stands into eight groups (fig. 1). The third vector was particularly effective in separating stands that appeared to be in close proximity on the two-dimensional, vector 1:vector 2 ordination plane. Six multiple-stand groups, one two-stand group, and one single-stand group were delimited.

Eleven of the 60 taxa had relatively high average aboveground standing crop and 100% constancy in one or more groups; they will be referred to as characteristic taxa. "Characteristic" has been used in preference to "dominant" because it does not imply these taxa exert any control over the other taxa present. Nine characteristic taxa had been used in the ordination: *Geum rossii*, *Poa* spp., *Trifolium dasyphyllum*, *T. nanum*, *T. parryi*, *Phlox pulvinata*, *P. multiflora*, *Lupinus greenii*, and *Artemisia scopulorum*. Two taxa, *Antennaria rosea*, and *Erigeron compositus*, which had not been used in the ordination, were used as characteristic taxa in two groups because of high standing crop and constancy. None of the characteristic taxa was confined to a single group, and many were present at low constancy or standing crop in all groups.

The eight classes were defined by the following combinations of characteristic taxa:

Characteristic taxa	**Acronym**
Geum rossii-Trifolium parryi	Gero-Trpa
Geum rossii-Trifolium nanum	Gero-Trna
Trifolium dasyphyllum-Geum rossii	Trda-Gero
Lupinus greenii-Poa spp.	Lugr-Poa
Phlox pulvinata-Trifolium dasyphyllum	Phpu-Trda
Antennaria rosea-Artemisia scopulorum	Anro-Arsc
Phlox multiflora-Trifolium nanum	Phmu-Trna
Erigeron compositus-Poa spp.	Erco-Poa

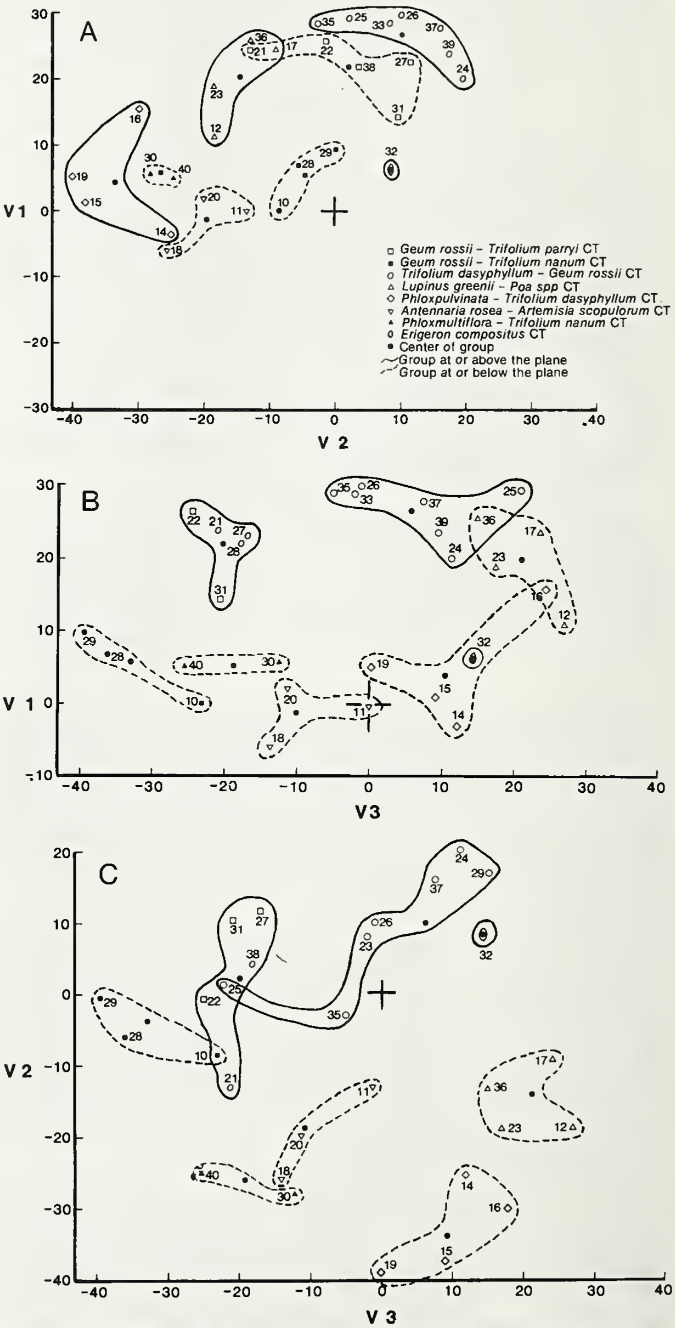

Figure 1.—Ordination of 29 stands of alpine vegetation on (A) the first (V1) and second (V2) principal components; (B) the first (V1) and third (V3) principal components; (C) the second (V2) and third (V3) principal components.

The first taxon listed produced the greatest average aboveground standing crop. *Poa* spp. represents at least three different species—*P. alpina*, *P. pattersonii*, and *P. rupicola*. These usually were present without flowers and could not be identified separately. Consequently, it was overrepresented in comparison to the other characteristic taxa that represent single species. It was never the most productive taxon.

Hereafter, the term community type will be used for the groups of stands defined by the ordination. A community type is a purely abstract phytosociological classification unit and must be distinguished from an actual stand of vegetation (Whittaker 1978). A stand is a real entity, in the sense that it actually exists. A community type, or any other type of classification unit (e.g., species), is a conceptual entity, with its descriptive characteristics derived from the measurable characteristics of the stands from which it was developed.

Because the eight community types distinguished on Carter Mountain have been defined on the basis of shared multiple characteristics considered concurrently, they are considered to be polythetically developed (Sokal and Sneath 1963). Consequently, a sample stand that "belongs" to a given community type need not possess all of the characteristics used to define it, and no single characteristic is either essential or sufficient for inclusion in a community type.

Narrative descriptions of the important modal vegetation features and associated major soil and site attributes of the community types are given below. Summaries of data on which the descriptions are based are presented in appendix 2 (vegetation) and appendix 3 (site-soil). In the narrative, values for standing crop have been rounded to the nearest whole gram. To describe soils, the following conventions were used: Surface soil refers to the epipedons (mollic umbric, ochric) and subsoil to the subsurface horizon (cambic) or to the IIC horizon.

Geum rossii-*Trifolium parryi* community type (5 stands)

Structure.—A dense, generally continuous plant cover composed mainly of forbs was present in the stands representing this community type. The tallest taxon, *Geum rossii*, usually did not exceed 30 cm in height and had a clumped distribution. The clumps were roughly oblong, with the long axis parallel to the slope contour. Most associated taxa had an erect growth form. Cushion plants (plants with a compact, prostrate, caespitose growth form) were a minor component of the vegetation; grasses and graminoids were relatively abundant.

Composition.—Average aboveground standing crop was 103 g/m². *Geum rossii*, 21% of standing crop, and *Trifolium parryi*, 15%, were characteristic species. This was the only community type where *Trifolium parryi* was abundant; *Salix reticulata* was essentially restricted to this community. Important subordinate taxa were *Artemisia scopulorum*, *Polygonum bistortoides*, *Phlox multiflora*, *Poa* spp., *Deschampsia caespitosa*, and *Carex ebenea*. The last two taxa had low constancy. This community type may be the Absaroka analog of the "Parry's clover meadow stand-type" described by Marr (1961) on Niwot Ridge in the Colorado Front Range.

Site.—The stands of this community type were present on steep lower slopes that were generally protected from strong winds. These were areas of snow accumulation, and small solifluction terraces were a characteristic feature of the landscape. These were the most mesic sites occupied by *Geum rossii*.

Soils.—Two of the five pedons were classified as Cryochrepts and two as Crumbrepts; the other was placed in the Cryoboroll subgroup. All pedons had deep sola, which were quite variable in stone content. Soil texture was sandy loam throughout. The soils were medium acid in the surface and only slightly less acidic in the subsoil. Available water ranged from 4.3% to 13.8% in the surface horizons and from 6.7% to 10.5% in the subsoil horizons.

Geum rossii-*Trifolium nanum* community type (7 stands)

Structure.—A somewhat open plant cover characterized by well-distributed, caespitose, clumps of *Geum rossii* that generally did not exceed 25 cm in height, was present in the stands. The ground layer was a mixture of erect forbs and cushion plant species, with the latter the more abundant group.

Composition.—*Geum rossii* contributed 35% of the average total standing crop of 101 g/m². The most abundant species in the ground layer was the prostrate legume *Trifolium nanum*, which produced 23% of standing crop. Other well-distributed, but less productive, taxa were *Poa* spp., *Phlox multiflora*, *Sedum lanceolatum*, *Cerastium arvense*, *Lomatium montanum*, *Besseya cinera*, and *Polygonum bistortoides*. Forbs produced 90% of the total standing crop. The closest analog of this community type would be the *Geum* turf of Johnson and Billings (1962) on the Beartooth Plateau.

Site.—Stands were located on moderately steep terrain. All were on windward exposures on the upper and middle portions of the slope. There was no evidence of snow accumulation, and only intermittent snow cover may occur during the winter. Rubble, gravel pavement, and bare soil were exposed on approximately half of the ground surface.

Soils.—The seven pedons were classified as Cryumbrepts (3), Cryochrept (1), Cryoborolls (2), and Cryorthents (1). Sola were stoney and, in general, shallow with sandy loam texture. Surface horizons were acidic. The subsurface horizons had reaction values as low as pH 4.9, the most acidic values recorded. Percentage available water ranged from an average of 6.7% in the surface to 6.9% in the subsoil.

Trifolium dasyphyllum-*Geum rossii* community type (4 stands)

Structure.—An open mosaic of cushion plants interspersed with somewhat depauperate and caespitose *Geum rossii* characterized this community type. Plants rarely exceeded 20 cm in height in any of the stands.

Composition.—*Trifolium dasyphyllum* produced 20% of the standing crop of 134 g/m² in this community type, while *Geum rossii* produced 15%. Important subordinate taxa were *Phlox multiflora*, *Sedum lanceolatum*, *Poa* spp., *Carex obtusata*, *Oxytropis parryi*, *Lomatium montanum*, and *Arenaria congesta*. All of these taxa had 100% constancy, but low average standing crop. Cushion plants constituted 51% of the total standing crop. *Trifolium nanum* occurred only at low constancy and had a low standing crop in the *Trifolium dasyphyllum-Geum rossii* community type.

Site.—Included stands were present on the middle and upper portions of windward slopes of moderate steepness. The ground surface was at least 50% rubble, gravel pavement, and bare soil. These were the least mesic sites for *Geum rossii*.

Soils.—The pedons were classified as Cryumbrepts (2) and Cryoborolls (2) and were well developed, with cambic horizons present in three of the four profiles. Sola were shallow to moderately deep and sandy in the surface horizons. The surface horizons were the shallowest of those described. Available water in the surface soil averaged 6.6% and in the subsoil 7.9%. Soil reaction was slightly acidic throughout the sola with some values in the neutral range.

Lupinus greenii-Poa spp. community type (3 stands)

Structure.—A dense, two-layered plant cover, characterized by a single taxon of erect growth form (*Lupinus greenii*), which may reach 40 cm height, was present in the stands of this community type. The lower layer was predominantly erect forbs; cushion plants were only moderately abundant.

Composition.—The major identifying characteristic was the abundance of *Lupinus greenii*. This species provided 24% of the average standing crop of 113 g/m². The erect stems of *Lupinus greenii* trap blowing snow even during minor summertime snowstorms. Snow may reach considerable depths and remain after it has disappeared from surrounding areas. Stands of the *Lupinus greenii-Poa* spp. community type were the first to be covered by snow in the fall and may have some snow cover until relatively late in the growing season. Thus, the growth form of the dominant species may enhance the moisture regime of the site. Subordinate forbs were *Phlox multiflora*, *Geum rossii*, *Artemisia scopulorum*, *Solidago ciliosa*, *Antennaria rosea*, and *Arenaria congesta*. This and the *Geum rossii-Trifolium parryi* community type are the only ones where *Trifolium parryi* was present. Here it contributed less than 4% of the total standing crop. Forbs as a group contributed 80% of the total standing crop. Grasses contributed 18% of the average standing crop, with *Poa* spp. the major taxa. Graminoids constitued only 2% of the standing crop.

Site.—The stands of this community type were present on the middle portion of steep lee slopes where snow may persist until midsummer.

Soils.—All pedons were classified as Cryumbrepts. The average thickness of the sola was 110 cm, which was the greatest depth recorded. Surface stoniness was in the range 5-25%, the least stoney of the soils examined. The pH values were strongly acid in the surface horizons, but only moderately acid in the subsoil. Available moisture was 7.3% in the surface horizons and 10.4% in the subsoil.

Phlox pulvinata-Trifolium dasyphyllum community type (4 stands)

Structure.—A moderately dense, single-tier, plant cover of prostrate, caespitose forbs and depauperate graminoids, usually not over 20 cm in height, was present in the stands placed in this community type.

Composition.—The average aboveground standing crop was 142 g/m²—the highest of all the community types studied. *Phlox pulvinata*, which was present at low constancy and standing crop in many of the other communities, was the most characteristic taxon. Although it is a cushion plant, it produced over 100 g/m² of standing crop on one of the sites and produced an average of 26% of the standing crop for the community type. The other characteristic taxon, *Trifolium dasyphyllum*, averaged 22 g/m² and had more consistent production in all stands than *Phlox pulvinata*. *Artemisia scopulorum*, *Lomatium montanum*, *Oxytropis parryi*, *Phlox multiflora*, and *Arenaria congesta* were other common forb species. *Geum rossii* produced less than 1% of the total standing crop and was sparsely distributed. Grasses and graminoids were more productive in this plant community than in any of the others. Together they produced 28% of the standing crop. *Poa* spp., *Koeleria cristata*, *Carex elynoides*, and *C. obtusata* were the major taxa.

Site.—All stands occurred on the lee side of ridgetops on moderately steep slopes. There was a considerable amount of exposed surface rock, but gravel pavement and bare soil surfaces were not as common as in some of the other previously described community types.

Soils.—Three of the four pedons were classified as Cryoborolls; one as a Cryumbrept. All had cambic horizons. Soils were moderately deep, very stoney throughout the sola and had sandy loam to loamy texture. Average soil reaction values were in the range pH 6.0-6.6. Mean available water in the surface was 4.0%. This was lowest of all described soils.

Antennaria rosea-Artemisia scopulorum community type (3 stands)

Structure.—A single-tier plant cover composed of a scattered mixture of forbs, graminoids, and cushion plants usually not over 20 cm high was present.

Composition.—Taxa that occurred only as subordinates in other community types were characteristic. With the exception of *Phlox pulvinata*, taxa characteristic of other community types were either absent or poorly represented. Erect forbs were more productive than the cushion plant forbs. *Antennaria rosea* and *Artemisia scopulorum* produced 25% of the average standing crop of 139 g/m². *Phlox pulvinata* contributed 10% of the total standing crop. Other common forbs were *Achillea lanulosa*, *Oxytropis parryi*, *Cerastium arvense*, and *Lomatium montanum*. *Trifolium dasyphyllum*, *Arenaria congesta*, and *Sedum lanceolatum* were cushion plants with high constancy, but low standing crop. About 24% of the average standing crop was composed of grasses and graminoids. *Poa* spp., *Koeleria cristata*, *Festuca rubra*, and *Carex elynoides* are the most abundant taxa.

Site.—The stands in this community type were present on the lower portion of protected, relatively steep slopes. Snow accumulation on these sites was estimated to be moderate.

Soils.—Two of the soils were classified as Cryumbrepts and the other as a Cryoboroll. Sola were deep and slightly acid in both the surface and subsurface soil. Surface stoniness was variable. The clay content of the surface horizons of these soils averaged 21%. This was greater than that of the soils from the other community types. The subsoil clay content was similar to that of the other pedons. The percentage moisture held at the wilting point was the highest of all the soil groups. However, percentage available water was only moderate.

***Phlox multiflora-Trifolium nanum* community type (1 stand)**

Structure.—The vegetation was a single layer of sparsely distributed cushion plants and depauperate forbs and graminoids.

Composition.—*Phlox multiflora*, *Trifolium nanum*, *Eritrichium nanum* var. *elongatum*, and *Festuca ovina* were the major species. Together these four species provided 80% of the average total standing crop of 63 g/m^2. Only eight other taxa were present.

Site.—The single stand representative of this community type was present on the upper portion of the windward side of an exposed slope of moderate steepness. This was an area of very low snow accumulation.

Soil.—The pedon was shallow (15 cm), with 80% stones. Soil reaction was slightly acid in the only horizon present. The epipedon was dark enough and contained sufficient organic carbon to be considered mollic. It was not sufficiently thick to fit this classification fully and the term "minimal-Cryoboroll" is probably appropriate.

***Erigeron compositus-Poa* spp. community type (2 stands)**

Structure.—A very sparsely distributed vegetation of depauperate forbs and grasses was present. Maximum height of plants rarely exceeded 10 cm.

Composition.—The most abundant species was *Erigeron compositus*, which produced 35% of the aboveground standing crop of 25.9 g/m^2. The only other taxa with 100% constancy were *Lomatium montanum*, and the grasses *Poa* spp. and *Agropyron scribneri*. These two grass taxa, plus *Koeleria cristata*, produced 30% of the average standing crop. The very sparse, scattered distribution of the plants, the low number of taxa present, and the low productivity made it difficult to distinguish a true characteristic taxon.

Site.—This community type was found on very stoney areas on the middle portion of lee slopes.

Soils.—The two pedons were classified as a Cryorthent and a Cryogboroll. Both were poorly developed, without cambic horizons. Pedons were shallow, rocky, and sandy, with slightly acidic reaction. Percentage available water was relatively high in the surface horizon.

Classification

There is a large degree of floristic similarity between the alpine community types on Carter Mountain. Differences are due mainly to shifts in the standing crop and constancy of a few species rather than distinctly different floristic composition. Very few species are confined to a given community type and, as had been found elsewhere, while many species may be present, the bulk of the standing crop is contributed by relatively few species (Scott and Billings 1964).

Because of their floristic similarity, it is possible the community types represent successional seres. However, the applicability of the classic concepts of climax and succession to the alpine zone has been questioned (Churchill and Hansen 1958, Billings and Mooney 1959). On Carter Mountain the vegetation has had a long history of domestic sheep grazing, which has influenced the present floristic composition. It would be considered "disturbed" and successional relationships would be obscured. It appears best to consider the community types on the basis of what they are at the time the stands are sampled, not what they might, or should, become.

Perennial forbs are the dominant life-form in all of the community types. With the possible exception of *Lupinus greenii*, all of the indicator taxa commonly occur throughout the alpine zone in the central and northern Rocky Mountains. The vegetation reflects the generally dry nature of the entire study area, caused by the porous nature of the geological substratum and the steep slope gradients. The situation on Carter Mountain is representative of much of the volcanic portion of the Absaroka Range. Flat or concave sites where hydrophytic vegetation might develop are very limited and the wet meadow or low shrub vegetation of other Rocky Mountain alpine areas is absent.

Although most of the community types had generally comparable taxa composition, similarity analysis indicated they were rather dissimilar. When similarity coefficients were calculated using only the 20 taxa also used for ordination, the maximum similarity coefficient between two community types was 52.4%. Only 3 (of 28) similarity coefficients were greater than 50% and most (21 of 28) were less than 40% (table 2). The minimum similarity coefficient was 9.9%.

Similarity coefficients calculated with all 60 taxa were only slightly different (table 3). The overall effect of adding 40 taxa was a very slight reduction in the levels of most of the similarity coefficients. However, the levels of both the maximum and minimum similarity coefficients were slightly increased. The increase in the maximum coefficients was accompanied by a change in the relationships between the three

Table 2.—Matrix of similarity between eight alpine community-types based on 20 taxa.

	Gero-Trpa	Gero-Trna	Trda-Gero	Lugr-Poa	Phpu-Trda	Anro-Arsc	Phmu-Trna	Erco-Poa
Gero-Trpa	*	52.4	45.0	43.1	23.7	37.7	19.2	16.3
Gero-Trna		*	50.2	29.3	14.2	29.3	37.9	18.5
Trda-Gero			*	38.2	44.6	44.5	33.5	16.6
Lugr-Poa				*	38.2	39.2	22.1	14.7
Phpu-Trda					*	44.5	33.5	16.6
Anro-Arsc						*	9.9	11.2
Phum-Trna							*	24.5
Erco-Poa								*

Table 3.—Matrix of similarity between eight alpine community-types based on 60 taxa.

	Gero-Trpa	Gero-Trna	Trda-Gero	Lugr-Poa	Phpu-Trda	Anro-Arsc	Phmu-Trna	Erco-Poa
Gero-Trpa	*	47.1	39.7	41.0	22.6	32.3	16.5	11.8
Gero-Trna		*	53.9	29.3	15.9	30.6	35.5	20.1
Trda-Gero			*	36.0	44.0	41.4	30.5	19.7
Lugr-Poa				*	27.0	44.4	19.7	13.6
Phpu-Trda					*	47.8	30.6	11.5
Anro-Arsc						*	16.0	19.4
Phmu-Trna							*	17.1
Erco-Poa								*

community types where *Geum rossii* was a characteristic taxon. No such change occurred at the minimum level.

Cluster analysis further clarified the relationships between community types and allowed them to be classified at several levels (fig. 2). The associations between community types were very much alike for both the 20-taxa and 60-taxa cluster analyses. The most significant change in association was the replacement of the *Geum rossii-Trifolium parryii* community type by the *Trifolium dasyphyllum-Geum rossii* community type as the closest associate of the *Geum rossii-Trifolium nanum* community type. The increased number of taxa also eliminated the very low similarity pairing of the *Phlox multiflora-Trifolium nanum* community type and the *Erigeron compositus-Poa* spp. community type. The latter was the least alike of all community types for the 20-taxa and 60-taxa cluster analyses, and the arrangement of the 60-taxa cluster analysis is preferable.

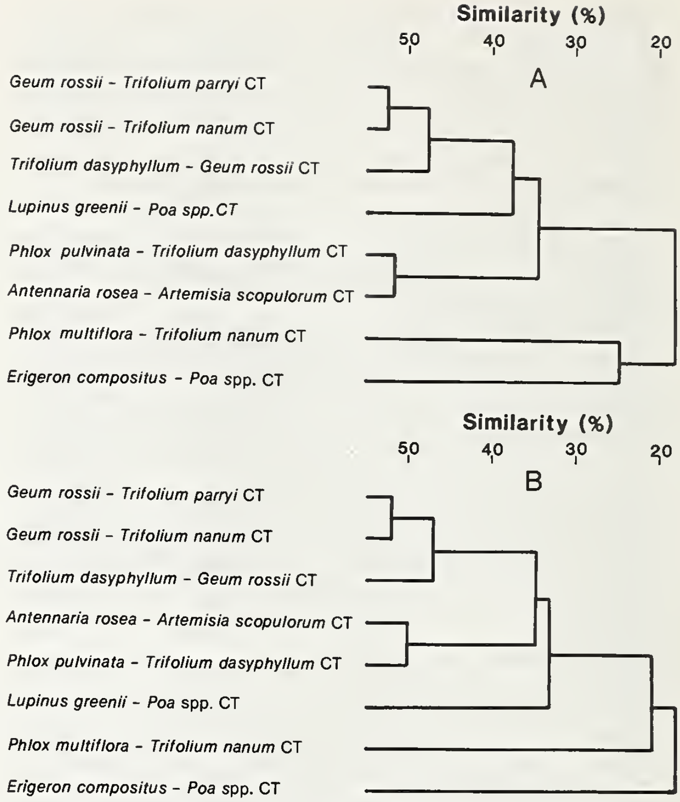

Figure 2.—Dendrogram of similarity between eight alpine community-types based on (A) 20 taxa, and (B) 60 taxa.

The slightly different associations between community types had no effect on the classification of the community types into higher order clusters at several levels of increasing simplicity. At the first level of agglomeration five clusters can be defined. Applying the same nomenclatural procedure used for the designation of community types, these five clusters are:

Geum rossii-Trifolium spp.
Lupinus greenii-Poa spp.
Phlox pulvinata-Artemisia scopulorum
Phlox multiflora-Trifolum nanum
Erigeron compositus-Poa spp.

The next logical agglomeration combines the *Lupinus greenii-Poa* spp. community type with the *Geum rossii-Trifolium* spp. cluster. The other clusters remain unchanged. Thus, agglomeration provides four clusters with the standing crop of *Geum rossii* as the key descriptive attribute. *Geum rossii* is abundant in the first cluster at this level with an average standing crop of 23.7 g/m². Its standing crop falls to only 1.1 g/m² in the second cluster, and it is absent from the last two clusters. A final agglomeration can be made by combining both lower order clusters containing *Geum rossii*, which allows a "*Geum*:No-*Geum*" separation to be made on the 20-taxa cluster analysis, but not on the 60-taxa cluster analysis where two community types without *Geum rossii* will be present. These latter represent only about 10% of the stands.

There is little reason to proceed beyond the first agglomeration. First, because the levels of similarity at which further agglomerations are made are below 35% and consequently the vegetation types are quite internally diverse. More importantly, the five-cluster agglomeration provides a set of utilitarian subdivisions of the vegetation. Stands representative of the five vegetation units are readily identified in the field and may be detected and delineated on aerial photographs. Thus, the vegetation units at this level can serve as the basis for vegetation mapping units and as rangeland inventory units at the management level. For other management or research purposes, such as studies of forage nutrition, productivity or utilization, the information that finer variations (community types) are present will be useful.

The eight community types also may be grouped into four physiognomic types:

Turf plant-type
- *Geum rossii-Trifolium parryi* community type
- *Geum rossii-Trifolium nanum* community type
- *Trifolium dasyphyllum-Geum rossii* community type

Herb meadow-type
- *Lupinus greenii-Poa* spp. community type

Cushion plant-type
- *Phlox pulvinata-Trifolium dasyphyllum* community type
- *Antennarria rosea-Artemisia scopulorum* community type
- *Phlox multiflora-Trifolium nanum* community type

Scree plant-type
- *Erigeron compositus-Poa* spp. community type

The *Erigeron compositus-Poa* spp. community type has been called a scree plant-type because the ground surface is characterized by loose, cobblestone-shaped rocks rather than the more angular and somewhat imbedded rocks usually associated with fellfields.

VEGETATION-SOIL RELATIONSHIPS

There were no close relationships between the classification of vegetation into community types (or higher order classification units) and the classification of soils. Soil with dark-colored surface horizons (umbric or mollic epipedons) and relatively well-developed subsurface horizons (usually a cambic horizon) occurred on 26 of the 29 stands sampled. The dark-colored, organic-rich epipedons are a direct contribution of the vegetation to soil morphology and they are present on almost all of the sites where the vegetation was sufficient to allow a significant amount of litter and roots to accumulate and decompose.

The distinction between the two types of epipedons is based on many factors, the most important being the thickness of the epipedon, organic content, and the prevalence of bivalent cations. An umbric epipedon does not have high bivalent cation saturation and may be simply described as an acidic mollic epipedon. The kind of epipedon present is very important in the classification of the soils on Carter Mountain, but the presence of a certain kind of epipedon did not seem to be related to the vegetation classification. There is no sound biological reason why two abstraction systems (classifications), each based on a set of different attributes, should coincide. This does not imply vegetation and soil are unrelated. It does mean the relationship is a functional one and cannot be expressed by comparisons between classifications.

This may be particularly true when the classification processes are opposites. The soils were classified by logical division for the purpose of identifying a soil individual (Great Group, Soil Series, etc.) The vegetation on Carter Mountain was classified by an agglomerative process which had as its endpoint the development of the vegetation groups which have been called community types.

ENVIRONMENTAL RELATIONSHIPS

Plant-environment relationships are considered more important in the alpine than inter- or intraspecies relationships, and the vegetation is regarded as a complex mosaic of community types arranged along environmental gradients (Billings and Mooney 1968). Topographic site, degree, and duration of snow cover and exposure to wind are the major environmental influences. Their combined effect is basically a gradient of available moisture and temperature.

The sample stands of alpine vegetation on Carter Mountain were grouped by their relationships to the first three principal components. These were based on taxa composition and biomass. According to van Groenewoud (1965) each of the principal components also may indirectly represent a compound variable of several environmental factors. The significantly correlated site and soil factors are given in table 4.

The first principal component may be interpreted as a combination of elevation and exposure to wind plus soil factors associated with particle size distribution in the solum. Elevation was the most significant variable on the first principal component. It is in itself a compound variable, but is often expressed in terms of its effect on temperature. The 440-m change in elevation between the highest and lowest sites could be interpreted as an average difference of 2.4° C in mean air temperature over the range in site elevations. In areas where the average growing season temperature is close to the freezing point, this difference might be critical for some species. The effects of wind in the alpine are well known (Billings and Mooney 1968), and exposure to wind was the second most highly correlated site factor on the first principal component.

The clay content of the solum was the most significant soil attribute on the first principal component. Clay content decreased with increasing elevation, while sand content increased. The greater proportion of sand might be caused by increased potential for wind erosion of the soil fines at higher elevations or by illuviation. Several of the other significant soil factors are those often associated with the clay fraction, e.g., cation exchange capacity, percent of water at 15 bars tension (wilting point), and the K^+ and Mg^+ levels.

Table 4.—Correlation and statistical significance of site and soil attributes on the first three principal components.

	Principal components[1]		
	V1	V2	V3
Significant[2] site attributes			
Elevation	0.66**	0.43*	
Exposure to wind	-0.51*	-0.51*	-0.55*
Position on slope		0.44*	-0.62**
Slope angle			-0.62
Snow accumulation			-0.80**
Significant[3] soil attributes			
Sand content	0.44*		
Clay content	-0.61**		
Silt content		-0.40*	
Coarse fragment (+2 mm) content			0.45*
Water content (15 bars)	-0.48*		
Available water		0.45*	
Soil reaction		-0.49*	0.38*
Cation exchange capacity	-0.57*		
Potassium content	-0.51*		
Magnesium content	-0.38*		

[1]** *Significant at* α *= 0.01; * significant at* α *= 0.05.*
[2]*Nonsignificant site attributes: slope aspect.*
[3]*Nonsignificant soil attributes: solum depth; organic matter content; water content (1/3 bar); Kjeldahl nitrogen; phosphorus content; calcium content; sodium content; base saturation; ferricoxide content.*

The exposure to wind and elevation were again significant site attributes on the second principal component, as was the position of the stand on the slope relative to the ridgeline. Exposure to wind was indirectly related to elevation, while position on slope was directly related.

Three soil factors were significant on the second principal component: the silt fraction and the percentage of water available between 1/3 and 15 bars tension, and soil reaction (pH). The percentage of available water was the most significant of all factors on the second principal component. This can be interpreted as an index of the ability of the soil to hold water and to supply it to the plants. This ability is related to the textural composition of the soil where, of the three textural classes, the silt fraction may represent a "happy medium" where there is sufficient porosity to hold water, but water is not held so tightly it is unavailable (which may occur in the clay fraction) or so loosely it is lost through percolation (as in the sand fraction). The importance of soil reaction (pH) to alpine plants is unknown. Extremely acidic or basic pH can influence the availability of mineral ions in the soil, but the pH ranges in the Carter Mountain soils were not extreme enough to materially influence ion uptake.

The most important factor on the third principal component is snow accumulation. Three habitat factors associated with snow accumulation—position on slope, slope angle, and exposure to wind—are also significant. The only soil factors to be significantly related are the coarse fragment (+2 mm) content of the solum and soil pH.

A statistically significant correlation between a site or soil factor and the eigenvalues of the principal components does not imply a cause and effect relationship, but merely indicates the possibility of relationships between many different environmental factors and the distribution of alpine species and, consequently, alpine plant communities.

That several factors were significant in a given principal component may be interpreted to mean plant distribution is controlled by a combination of several factors and not by a single factor. The significance of such factors as elevation, exposure to wind, snow accumulation, and the availability of soil water have been recognized by alpine ecologists as controlling influences in the distribution of alpine plants. The influence of factors such as snow accumulation on plant species may be empirically deduced. However, the influence of factors such as soil texture, cation exchange capacity, soil reaction, or the level of particular soil cations cannot be fully explained without considerable knowledge of the autecological requirements of the individual species, and this knowledge is not yet available for any of the species.

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APPENDIX 1. Morphology of typical soil subgroups from the alpine zone, Carter Mountain, Wyoming.

Soil subgroup	Horizon	Depth (cm)	Color (Munsell)	Texture; Coarse fragments	Structure consistency	Reaction (pH)	Boundary
Pergelic Cryorthent, fragmental, mixed (2 of 29 pedons)	A1	0–10	10YR5/2 dry 10YR3/2 moist	Sandy loam; 40% gravel gravel, cobble, stones	Strong, fine crumb and granular; soft, friable, nonsticky, nonplastic	6.1	Broken, irregular
	IIC	10+		Fragmented volcanic breccia, tuff, ash			
Pergelic Cryochrept, coarse-loamy over fragmental, mixed (2 of 29 pedons)	A1	0–10	2.5YR6/2 dry 2.5YR4/2 moist	Sandy loam; 20–35% angular and rounded stones	Weak, fine crumb; soft, soft, very friable non-sticky, nonplastic	6.3	Clear, wavy
	B2	10–74	2.5YR6/3 dry 2.5YR4/3 moist	Gravelly, sandy loam	Weak, fine crumb; soft, very friable, nonsticky, nonplastic	6.3	Abrupt, wavy
	11C	74+		Fragmented volcanic breccia			
Andic Pergelic Cryochrept, loamy-skeletal over frag-mental, mixed (1 of 29 pedons)	A1	0–8	10YR6/2 dry 10YR4/2 moist	Channery, sandy loam; 15–20% angular frag-ments of volcanic breccia, tuff	Weak, fine crumb; soft, very friable, nonsticky, nonplastic	5.6	Abrupt, wavy
	B21	8–18	10YR6/4 dry 10YR4/3 moist	Very channery loam; 50–60% angular frag-ments 3–15 cm long	Weak, fine crumb; soft, very friable, nonsticky, nonplastic	5.7	Abrupt, Wavy
	B22	18–33	10YR7/3 dry 10YR5/3 moist	Very channery loam; 50–60% angular frag-ments 3–15 cm long	Weak, fine crumb; soft, very friable nonsticky, nonplastic	5.7	Diffuse, irregular
	B23 IIC	66+		Fragmented volcanic breccia			
Andic Entic Pergelic Cryumbrept, loamy-skeletal over frag-mental, mixed (6 of 29 pedons)	A11	0–8	10YR5/2 dry 10YR3/2 moist	Sandy loam; 50% stones	Strong, fine crumb; soft very friable, nonsticky, nonplastic	6.6	Gradual, smooth
	A12	8–33	10YR5/3 dry 10YR3/2 moist	Sandy loam; 50% stones	Strong, fine crumb; soft, very friable nonsticky, nonplastic	6.4	Broken, wavy
	IIC	33+		Fragmented, volcanic breccia, tuff, large stones with open interstices			
Andic Pergelic Cryumbrept (8 of 29 pedons)	A11	0–8	10YR5/3 dry 10YR3/3 moist	Fine, sandy loam	Weak, very fine crumb; soft very friable nonsticky, nonplastic	5.2	Clear, wavy
	A12	8–18	10YR5/3 dry 10YR3/3	Fine sandy loam; 5–15% coarse sub-rounded and angular fragments	Weak, very fine crumb; soft, very friable	5.2	Clear, wavy
	B21	18–48	10YR6/3 dry 10YR4/3 moist	Sandy loam; 15–25% coarse subrounded and angular fragments	Weak, medium, and fine subangular blocky; soft, very friable, nonsticky, nonplastic	5.8	Diffuse, irregular
	B22	48–102	10YR6/3 dry 10YR4/3 moist	Very channery, sandy loam; 65–80% channery 3–15 cm long	Structureless; soft, very friable, nonsticky, non-plastic	6.2	Diffuse, irregular
	IIC	102+		Fragmented volcanic breccia			

APPENDIX 1.—Continued

Soil subgroup	Horizon	Depth (cm)	Color (Munsell)	Texture; Coarse fragments	Structure consistency	Reaction (pH)	Boundary
Andic Pergelic Cryoboroll, fragmental, mixed	A1	0–15	10YR5/3 dry 10YR3/3 moist	Gravelly, sandy loam; 60–70% rounded and angular volcanic conglomerate cemented by tuff	Weak, very fine crumb; loose when dry and moist, nonsticky, nonplastic	6.2	Diffuse, irregular
	IIC	15+		Fragmented volcanic breccia			
Andic Pergelic Cryoboroll, loamy-skeletal, mixed (7 of 29 pedons)	A11	0–8	10YR5/2 dry 10YR3/2 moist	Sandy loam; 60% stones	Strong, fine crumb; soft, very friable, nonsticky, nonplastic	6.6	Gradual, smooth
	A12	8–36	10YR5/3 dry 10YR4/3 moist	Sandy loam; 60% stones	Strong, fine crumb; soft, very friable	6.6	Gradual, wavy
	B2	36–71	10YR5/3 dry 10YR4/3 moist	Sandy loam; 60% stones	Weak, fine subangular blocky; slightly hard, very friable, nonsticky, nonplastic	6.4	Gradual, wavy
	C	71+	10YR5/3 dry 10YR4/3 moist	Sandy loam; 80% stones	Massive; slightly hard, very friable, nonsticky, nonplastic	6.2	

APPENDIX 2

APPENDIX 2. Average standing crop (SC) in grams per square meter, dry weight, percentage composition by weight (CW), and percentage constancy (CT) for taxa in eight community types of the alpine zone, Carter Mountain, Wyoming.

Taxa[1]	Geum rossii-Trifolium parryi (n = 5)			Geum rossii-Trifolium nonum (n = 7)			Trifolium dasyphyllum-Geum rossii (n = 4)			Lupinus greennii-Poa spp. (n = 3)			Phlox pulvinata-Trifolium dasyphyllum (n = 4)			Antennaria roseo-Artemisia scopulorum (n = 3)			Phlox multiflora-Trifolium nonum (n = 1)			Erigeron campasitus-Poa spp. (n = 2)			All community types (n = 29)		
	SC	CW	CT	SC	CW	CT	SC	CW	CT	SC	CW	CT	SC	CW	CT	SC	CW	CT	SC	CW	CT	SC	CW	CT	SC	CW	CT
Eract forbs																											
*Gaum rossii	21.6	21	100[2]	35.1	35	100	20.2	15	100	5.0	4	100	0.6	X	50	1.7	1	33							16.4	15	72
*Trifolium parryi	14.9	15	100							3.7	3	100													2.8	3	21
*Lupinus greani	1.1	1	40	1.1	1	28	3.3	3	50	27.6	24	100				2.5	2	67							4.4	4	38
*Lomatium montanum				1.5	2	86	2.4	2	100	0.1	X	33	6.9	5	100	1.5	1	100	1.9	4	N[5]	1.1	6	100	1.9	2	69
*Artemisia scopulorum	8.0	8	100	1.8	2	71	2.2	2	50	4.7	4	100	8.6	6	100	14.1	12	100							5.3	5	69
*Polygonum bistortoides	2.7	3	100	2.9	3	71	1.2	1	50	3.5	3	100	T	X	50	2.2	2	67							1.9	2	66
*Oxytropis parryi				0.1	X	14	2.5	2	100	2.7	2	33	5.3	4	100	4.6	4	100							1.9	2	49
*Cerastium arvense	0.7	1	80	2.0	2	86	0.6	X	100	4.1	4	100	0.2	X	75	3.5	3	100	0.6	1	N	0.3	2	50	1.5	1	83
*Solidago ciliosa	1.5	2	40	T	X	14	0.5	X	50	6.6	6	33	T	X	25	1.7	1	33				T	X	50	1.2	1	31
Potentilla divarsifolia	1.3	2	60	1.0	1	71	0.5	X	50	1.7	2	67				1.3	2	67							2.1	2	59
Erigaron compositus	T[3]	X[4]	20	0.6	1	28	3.4	3	25				0.4	X	25	1.0	X	67				6.8	35	100	1.2	1	28
Polemonium viscosum	0.3	X	20	0.7	1	71	T	X	25	1.4	1	67				0.2	X	33							0.4	X	38
Myosotis alpastris	0.5	X	80	0.6	X	57	1.3	1	25	1.3	1	100	0.3	X	50	0.8	X	67							0.6	X	62
Achillea lanulosa	0.3	X	40	0.3	X	14	0.2	X	50	1.0	1	100				2.8	3	100				1.3	7	50	0.6	X	41
Besseya cinera	0.3	X	80	1.0	1	86	0.7	X	25	T	X	67	T	X	25	1.7	1	67	1.6	3	N				0.6	X	62
Agoseris glauca	0.6	1	20	0.2	X	28	0.5	X	50	1.5	1	67	T	X	25	0.4	X	33							0.4	X	35
Erigeron simplex	0.9	1	40	0.1	X	43	0.3	X	25	2.6	2	67	0.2	x	25	2.6	2	67	1.1	2	N				0.7	X	38
Potantilla plattenensis				0.7	1	43	0.5	X	25				0.4	X	25	0.2	X	33				0.7	4	50	0.4	X	35
Senecio fremontii				T	X	14				0.7	1	67	T	X	25	0.9	X	33							0.3	X	28
Mertensia alpina	0.7	1	60	0.3	X	57	0.5	X	25																0.2	X	31
Saxifraga rhombidea	0.5	X	80	0.4	X	28				T	X	33				0.2	X	33							0.2	X	24
Epilobium alpinum	0.1	X	20	0.2	X	28	0.2	X	50	T	X	33	0.1	X	25	T	X	33							0.1	X	28
Salix reticulata	4.1	4	20										0.1	X	25										0.7	X	3
Castilleja rhexifolia	T	X	20							T	X	67													T	X	11
Castilleja pulchella													T	X	25	0.2	X	33							T	X	7
Pedicularis groenlandica																T	X	33							T	X	3
Padicularis parryi							1.2	X	25							T	X	33							0.1	X	7
Crepis nana	1.2	2	20													1.7	1	33							0.1	X	10
Collomia linaaris				T	X	14																			T	X	3
Penstemon procerus																T	X	33							T	X	3
Dodecatheon conjugens	T	X	20							T	X	33				0.2	X	67							T	X	10
Delphinium nelsoni	0.1	X	20							T	X	33													T	X	7
Astragalus alpinus																0.1	X	33							T	X	3
Arnica fulgens																0.2	X	33							T	X	3
Lewisia pygmaea	T	X	20																						T	X	3
Cirsium polyphyllum							T	X	25				T	X	25										T	X	7
Draba auraa	T	X	20																						T	X	3
Ranunculus sp.	T	X	20																						T	X	3
Standing crop:	61.7	60		50.9	51		42.3	31		68.5	61		23.1	16		46.5	42		5.2	10		10.2	52		46.6	43	
Cushion plant forbs																											
*Trifolium dasyphyllum				2.5	3	28	26.1	20	100				32.5	22	100	4.0	4	100				0.1	X	50	9.7	9	56
*Trifolium nanum	3.6	4	20	23.3	23	100	4.4	3	50	0.9	X	67							11.4	23	N				6.4	6	31
*Phlox pulvinata	0.1	X	40	0.4	X	28	3.6	3	75	0.3	X	33	38.0	26	100	11.3	10	100							7.1	7	56
*Phlox multiflora	2.2	2	80	5.8	6	100	13.2	10	100	8.4	7	100	2.4	2	100	1.8	2	67	14.0	28	N				5.4	5	83
*Arenaria congesta	0.9	1	40	1.4	1	43	4.3	3	100	6.6	6	67	1.6	1	100	0.5	X	100				1.1	6	50	2.1	2	59
*Sedum lanceolatum	0.9	1	80	4.5	5	71	10.9	8	100	0.7	X	67	0.2	X	50	4.4	4	100				2.1	11	50	3.5	3	72
Antennaria rosea	0.5	X	20				2.0	2	75	4.6	4	100	2.7	3	75	14.8	13	100							2.3	2	41
Eritrichium elongatum	T	X	20	1.6	2	57	2.1	2	75				1.1	1	50	1.7	1	67	8.2	16	N				1.3	1	41
Standing crop:	8.3	8		39.5	39		66.6	51		21.5	19		78.5	56		38.5	34		32.6	66		3.3	17		38.0	35	
Grassas																											
*Poa spp.	11.3	11	100	4.3	4	100	6.8	5	100	15.7	14	100	22.2	15	100	9.2	8	100	3.7	7	N	4.4	22	100	9.9	9	100
*Koeleria cristata	0.3	X	20	0.2	X	57	3.3	3	50	2.0	2	33	6.0	4	100	5.2	5	100				0.9	5	50	2.2	2	59
*Festuca rubra	0.8	1	40	0.1	X	28	4.1	3	75				1.5	1	75	5.3	5	100							1.5	1	41
Agropyron scribneri				1.3	1	57	2.3	2	75	0.4	X	33	0.4	X	50	0.8	X	33	0.9	2	N	0.9	5	100	1.2	1	45
Daschampsia caespitosa	4.1	4	40	0.8	1	57				1.2	1	67													0.8	1	14
Festuca ovina	0.8	1	40							0.6	X	67							7.7	15	N				0.5	X	38
Agropyron trachycaulum				0.3	X	57	0.6	X	25				0.2	X	50										0.4	X	14
Trisetum spicatum	T	X	20				T	X	25	1.0	1	67													0.2	X	24
Hasperochloa kingii	T	X	20																						0.1	X	7
Standing crop:	17.4	17		7.0	7		17.1	13		20.9	18		30.2	21		20.5	18		12.3	24		6.2	32		16.8	16	
Graminoids																											
*Carex albonigra	3.2	3	60	2.6	3	57	0.1	X	25							0.5	X	33							1.2	1	31
*Carex elynoides				0.1	X	14	1.0	1	50	T	X	33	7.9	6	100	5.4	5	33							0.9	1	28
Carex ebenea	10.3	10	60							1.4	1	33													2.0	2	17
Carex obtusata	1.7	X	40	0.4	X	43	6.3	5	75	T	X	33	1.9	1	100	0.5	X	33	0.2	X	N				1.9	2	45
Luzula spicata	0.2	2	80	0.3	X	57	0.2		75	0.5	X	67				0.2	X	33							0.2	X	48
Standing crop:	15.4	15		3.4	3		7.6	6		2.0	2		9.8	7		6.6	6		0.2	X		.0			6.2	6	
Standing crop: All forb taxa	70.0	68		90.4	90		108.9	82		90.0	80		101.6	72		85.0	76		37.8	76		13.5	68		84.6	78	
Standing crop: Grass and graminoid taxa	32.8	32		10.4	10		24.7	18		22.9	20		40.1	28		27.1	24		12.5	24		6.2	32		23.0	22	
TOTAL STANDING CROP	102.8			100.8			133.6			112.9			141.7			112.1			50.3			19.7			107.6		

[1]Asterisk indicates taxa utilized in principal component analyses.
[2]Underlining indicates characteristic taxa for each plant community type.
[3]T: Less than 0.1 g/m^2; a value of 0.05 g/m^2 was used in calculation of totals.
[4]X: Less than 1% composition.
[5]N: Not calculated, only 1 sample.

APPENDIX 3. Major[1] habitat features and average soil properties of eight alpine community types, Carter Mountain, Wyoming.

Significant attributes	Horizon[2]	PLANT COMMUNITIES *Geum rossii-Trifolium parryi* (n = 5)	*Geum rossii-Trifolium nanum* (n = 7)	*Trifolium dasyphyllum Geum rossii* (n = 4)	*Lupinus greenii-Poa spp* (n = 3)	*Phlox pulvinata-Trifolium dasyphyllum* (n = 4)	*Antennaria rosea-Artemisia scopulorum* (n = 3)	*Phlox multiflora Trifolium nanum* (n = 1)	*Erigeron Erigeron compositus Poa spp.* (n = 2)
Habitat features									
Elevation (meters)		3235	3345	3345	3235	3220	3170	3225	3255
Slope aspect		All	North, west, east	South, east	East, west	South, east north	South, east	West	South, east
Slope angle (%)		40	32	28	50	32	44	38	47
Position on slope		Lower ⅓	Mid and upper⅔	Mid and upper ⅔	Mid ⅓	Ridgetop	Lower ⅓	Upper ⅓	Mid ⅓
Exposure to prevailing wind		Lee	Windward	Windward	Lee	Lee	Lee	Windward	Lee
Snow accumulation		Deep	Shallow	Shallow	Deep	Shallow	Moderate	Shallow	Moderate
Snow duration		Long	Short	Short	Long	Short	Moderate	Short	Moderate
Soil properties									
Coarse fragments 2 mm (%)	Surface	22	43	37	13	61	34	80	60
	Subsoil	52	68	35	50	70	47		
Sands 2 mm; 0.02 mm (%)	Surface	60	54	62	56	59	52	52	67
	Subsoil	56	63	59	55	60	51		
Silts 0.02mm; 0.002mm (%)	Surface	29	27	25	29	26	27	36	21
	Subsoil	31	28	23	24	28	26		
Clays 0.002 mm (%)	Surface	12	10	14	14	14	21	12	13
	Subsoil	13	10	13	22	12	23		
Water available ⅓ to 15 bar (%)	Surface	9.0	6.7	6.6	7.3	4.0	6.3	8.5	6.8
	Subsoil	9.0	6.9	7.9	10.4	7.4	9.7		
Water retained at 15 bar (%)	Surface	13.5	11.4	12.0	13.4	13.3	14.9	16.4	9.3
	Subsoil	11.6	9.6	12.8	11.0	14.2	16.3		
Cation exchange capacity (meq/100 g)	Surface	22.2	18.1	19.6	19.0	21.2	25.3	14.1	20.8
	Subsoil	20.0	17.5	24.8	20.0	27.8	28.0		
Soil reaction (pH)	Surface	5.6[3]	5.9	5.9	5.1	6.4	6.3	6.4	6.2
	Subsoil	6.1	5.7	6.3	6.1	6.4	6.1		
Potassium content (meq/100 g)	Surface	0.45	0.37	0.45	0.69	0.63	0.64	0.75	0.24
	Subsoil	0.34	0.16	0.20	0.41	0.45	0.58		
Magnesium (meq/100 g)	Surface	5.3	4.3	5.1	3.4	5.4	4.4	8.0	5.1
	Subsoil	4.8	2.8	5.6	4.9	6.0	5.6		

[1]Statistically significant at = 0.05 on the first three eigenvectors derived from principal component analysis.
[2]Diagnostic epipedon (i.e., A1 horizon). Cambic horizon (i.e., B2 horizon).
[3]Median value.

APPENDIX 4. Alphabetical list of scientific and common names of plants.[1]

Trees and Shrub (non-alpine taxa)

Abies lasiocarpa (Hook.) Nutt.	subalpine fir
Picea engelmannii Parry ex Engelm.	Engelmann spruce
Pinus flexilis James	limber pine
Artemisia tridentata Nutt.	big sagebrush

Erect Forbs

Achillea lanulosa Nutt.	western yarrow
Agoseris glauca (Pursh) Raf.	pale agoseris
Arnica fulgens Pursh	orange arnica
Artemisia scopulorum A. Gray	alpine sagewort
Astragalus alpinus L.	alpine milkvetch
Besseya cinera (Raf.) Penn.	Wyoming kittentails
Castilleja pulchella Rydb.	indianpaintbrush
Castilleja rhexifolia Rydb.	splitleaf indianpaintbrush
Cerastium arvense L.	starry cerastium
Cirsium polyphyllum (Rydb.) Petr.	thistle
Collomia linearis Nutt.	narrowleaf collomia
Crepis nana Richards.	tiny hawksbeard
Delphinium nelsonii Greene	Nelson larkspur
Dodecatheon conjugens Greene	sailorscap shootingstar
Draba aurea M. Vahl.	golden draba
Epilobium, alpinum L.	alpine willowherb
Erigeron compositus Pursh	fernleaf fleabane
Erigeron simplex Greene	oneflower fleabane
Geum rossii (R. Br.) Ser.	alpine avens
Lewisia pygmaea (A. Gray) Robins.	dwarf Lewisia
Lomatium montanum C. & R.	mountain lomatium
Lupinus greenii A. Nels.	Green lupine
Mertensia alpina (Torr.) G. Don	alpine bluebells
Myosotis alpestris Schmidt.	alpine forgetmenot
Oxytropis parryi A. Gray	Parry loco
Pedicularia groenlandica Retz.	elephanthead lousewort
Pedicularis parryi A. Gray	Parry lousewort
Penstemon procerus Dougl. ex Graham	littleflower penstemon
Polemonium viscosum Nutt.	sticky polemonium
Polygonum bistortoides Pursh	americanbistort knotweed
Potentilla diversifolia Lehm.	blueleaf cinquefoil
Potentilla plattenensis Nutt. ex T. & G.	Platte cinquefoil
Ranunculus sp. L.	buttercup
Salix reticulata L.	netleaf willow
Saxaifraga rhombidea Greene	diamondleaf saxifrage
Senecio fremontii T. & G.	Fremont groundsel
Solidago ciliosa Greene	hairy goldenrod
Trifolium parryi A. Gray	Parry clover

APPENDIX 4. Alphabetical list of scientific and common names of plants.[1]

Cushion Plant Forbs	
Antennaria rosea Greene	rose pussytoes
Arenaria congesta Nutt. ex T. & G.	ballhead sandwort
Eritrichium elongatum (Rydb.) Wright	falseap lineforgetmenot
Phlox multiflora A. Nels.	flowery phlox
Phlox pulvinata (Wherry) Cronquist	cushion phlox
Trifolium dasyphyllum T. &. G.	whiproot clover
Trifolium nanum Torr.	dwarf clover
Sedum lanceolatum Torr.	yellow stonecrop
Grasses	
Agropyron scribneri Vasey	Scribner wheatgrass
Agropyron trachycaulum (Link) Malte	slender wheatgrass
Deschampsia caespitosa (L.) Beauv.	tufted hairgrass
Festuca ovina L.	sheep fescue
Festuca rubra L.	red fescue
Hesperochloa kingii (S. Wats.) Rydb.	King spikefescue
Koeleria cristata (L.) Pers.	prairie junegrass
Poa spp. L.	bluegrass
Poa alpina L.	alpine bluegrass
Poa pattersonii Vasey	Patterson bluegrass
Poa rupicola Nash ex Rydb.	timberline bluegrass
Trisetum spicatum (L.) Richt.	spike trisetum
Graminoids	
Carex albonigra Mack.	blackandwhitescaled sedge
Carex ebenea Rydb.	ebony sedge
Carex elynoides Lilj.	blackroot sedge
Carex obtusata Mackenzie	obtuse sedge
Luzula spicata (L.) DC.	spike woodrush

[1]*Common names follow Beetle (1970).*

Thilenius, John R., and Dixie R. Smith. 1985. Vegetation and soils of an alpine range in the Absaroka Mountains, Wyoming. USDA Forest Service General Technical Report RM-121, 18 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Alpine vegetation was classified into eight community types, described in this report. Soils associated with each community type were classified to soil subgroup level. Environmental factors related to community type distribution were determined.

Keywords: Alpine vegetation, alpine soils, vegetation classification, Carter Mountain

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