PLANT COVER TYPES OF THE UPPER BEAR RIVER DRAINAGE, UTAH

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by

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A thesis submitted to the faculty of the
University of Utah in partial fulfillment of the requirements
for the degree of

Master of Science

Geography

Department of Geography

University of Utah

August 1973

This thesis for the

Master of Science Degree

by

John Adrianus van Balen

was approved

July 1973

[redacted]

Chairman, Supervisory Committee

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Dean of the Graduate School

ACKNOWLEDGMENTS

The writer is indebted to Dr. D. R. Currey of the University of Utah Geography Department, who spent many long hours guiding the author during the writing of this thesis. Dr. Currey provided many helpful suggestions in the compilation of the plant cover type maps.

Dr. R. M. McCoy made many valuable suggestions and encouraged the author during the earlier part of the writing.

A special thanks goes to Dr. K. T. Harper, who offered valuable suggestions and stimulating discussions in the field of biogeography. Special thanks also to J. Nelson for reading and discussing some of my earlier drafts, and to A. L. Beary, who helped in the fieldwork.

Special appreciation goes to my parents, for their understanding and moral support during the course of the author's graduate work.

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ABSTRACT

The primary objective of this thesis is the cartographic representation of the dominant plant cover types, and a spatial interpretation of the zonal community types, within the upper Bear River drainage. The upper Bear River drainage is located within the western section of the Uinta Mountains, Utah.

Two maps, titled "Plant Cover Types, Hayden Fork," and "Plant Cover Types, upper Bear River," were compiled. The two maps were prepared from data derived from field work, aerial photographs at a nominal scale of 1:15,840, and a photo-mosaic. Four broad steps were carried out in the preparation of the maps: (1) reconnaissance of the vegetation units to be mapped; (2) analysis and interpretation of the plant types from aerial photographs; (3) ground checking, which consisted of using transects and quadrats in determining plant cover frequency, transition belts, and boundaries; and (4) construction of the maps through the process of expansion and reduction by porportional squares.

Six zonal community types were recognized in the upper Bear River drainage; krummholz, one of the cover types included, is a physiognomic type. Altitudinal distribution of the six zonal cover types are: (1) sagebrush from the Wyoming Basin to 9,800 feet, (2) quaking aspen to an upper altitudinal limit of 9,200 feet, (3) lodgepole pine from 8,000 to 9,600 feet, (4) spruce-fir from 9,600 to 11,000 feet, (5) krummholz from 10,400 to 11,600 feet, and (6) alpine

tundra from 10,600 feet upward. Under optimum conditions timberline was found to be 11,000 feet and mean timberline in the study area was determined to be 10,500 feet. The upper limits of krummholz was observed at 11,600 feet. Lodgepole pine was not found to be a component of krummholz, nor were cones found on any of the krummholz stands.

CHAPTER I

INTRODUCTION

Purpose of Study

The objective of this thesis is to represent cartographically the dominant plant cover types of the upper Bear River and Hayden Fork drainage, on the north slope of the Western Uinta Mountains, Utah. This is done on two maps (plates 1 and 2), from which a spatial interpretation of vegetation zones is made. A special emphasis on locating the upper limits of the vegetation zones is undertaken.

Location

The study area extends from the Utah-Wyoming state line southward to Bald Mountain, Utah. This area, which is roughly rectangular, with a width of four miles and a length of 24 miles, covers approximately 88 square miles, and approximates the upper drainage system of the Bear River and its tributary, the Hayden Fork. Access is gained through State Highway 150, a paved road that traverses the center of the map area. Figure 1 shows the location of the thesis area in relation to surrounding regions. The study area appears to be representative of the vegetation zones found on the north slope of the Western Uinta Mountains.

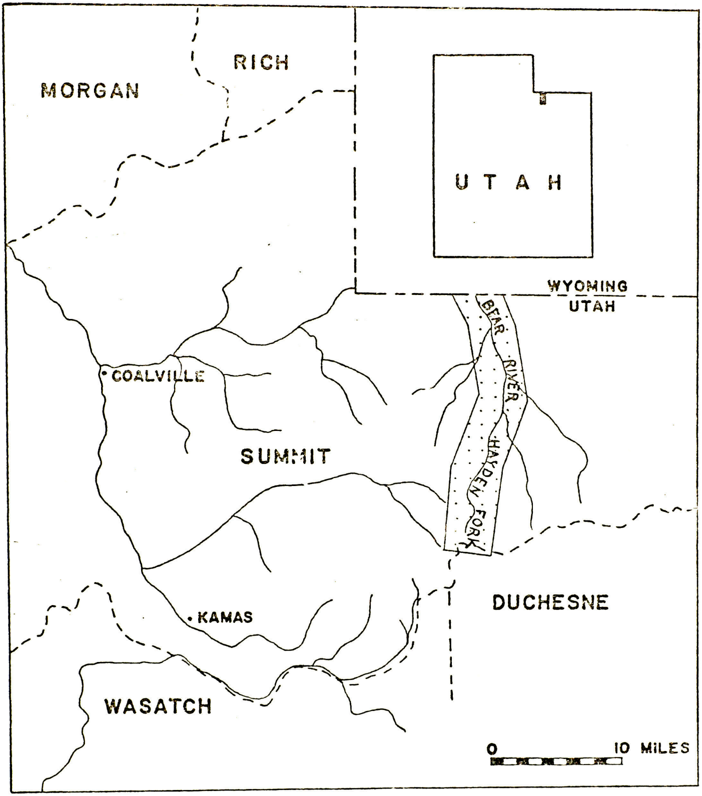

FIGURE I. INDEX MAP OF THE THESIS AREA
UPPER BEAR RIVER DRAINAGE

Regional Environment of the Study Area

On a topographic basis, the Uinta Mountains can be divided into two sections, the Western and Eastern Uinta Mountains. The name "High Uintas" is frequently used in reference to the Western Uinta Mountains. A low divide occupied by Cart and Brush Creeks marks the division between the two topographic sections of the Uinta Mountains (Hansen, 1969, p. 13). The geology of the Eastern Uinta Mountains is more complex structurally than that of the Western Uinta Mountains, but the high summits typical of the western section of the range are lacking in the Eastern Uinta Mountains.

The geology of the Uinta Mountains has been described and commented on by many geologists. Three Territorial Surveys, conducted by F. V. Hayden (1871), J. W. Powell (1876), and S. F. Emmons (1877), were made of the Uinta Mountains. The structural geology of the Uintas was described by J. D. Forrester (1937). W. H. Bradley (1936) treated the geomorphology of the north flank of the range, and W. W. Atwood (1909) described the glaciation that sculptured the range. Recent geologic work completed in the Uinta Mountains is summarized by Lindsay (1969).

The Uinta Mountains were formed through an arching of the earth's crust, forming an east-west trending anticlinal fold. The structural uplift that formed this range took place during Late Cretaceous time. The oldest Precambrian strata in the range, the Red Creek Quartzite, are found in Daggett county, Utah. Younger Precambrian strata, called the Uinta Mountain Group, form the heart of the range and are exposed on Hayden Peak and Bald Mountain. Along the flanks of the range "are Paleozoic and Mesozoic sedimentary rocks reaching as high as Upper Cretaceous in age. Filling the flanking basins and lapping up on the borders of the range are lower Tertiary, mostly Eocene, lacustrine and fluviatile sediments (Lindsay, 1969, p. 5). The Bear River piedmont glacier largely removed the Phanerozoic strata that had covered the Precambrian metamorphic rocks. Quaternary ground moraine and fluviatile sediments now cover the valley floors of the study area; due to their late Pleistocene age, many of these deposits are little eroded and quite conspicuous. Precambrian and Cambrian quartzite formations are well exposed at higher altitudes.

The rugged topography of the study area has been created largely by the action of Pleistocene glaciers and streams. The study area has a maxiumum relief of 4,578 feet, ranging from Hayden Peak, with an altitude of 12,478 feet, to an altitude of 7,900 feet at the Utah-Wyoming state line. Features formed through glacial action, as shown in figure 2, dominate the landscape. U-shaped valleys, cirque basins, mounuments, and aretes are common features in he upper elevations. Talus slopes are typical of the over-steepened cirque walls in the area. Rockfalls and rock slides are the most common forms of mass-wasting in the area. Lateral, terminal, and gound moraines dominate the upper cirque valleys; outwash deposits are found at lower elevations. Numerous bogs, meadows, lakes, and ponds attest to the hummocky nature of the area, and the unadjusted stream habits of the Bear River drainage.

The Western Uinta Mountains, due to its high peaks and its location athwart eastward moving storm tracks, is a region of abundant moisture. This moisture feeds four major rivers that head within the

Figure 2.--Naturalist Basin, a large confluent cirque, with Hayden Peak near center of photograph.

upper reaches of the thesis area. The Bear, Weber, and Provo rivers drain to the Great Basin; the Duchesne River drains into the Colorado River Basin. These rivers provide needed irrigation and culinary water for northern Utah.

Middle latitude cyclones and the orographic uplift that occurs as storm tracks pass over the mountains furnish the greater part of the moisture that falls in the area. In August and September, moist air masses arrive from the Gulf of Mexico; this moisture, subject to high evaporation losses, is usually not effective for plant growth. Although climatological data for the area are scarce, precipitation storage gauges are found at Hayden Fork (9,400 ft) and Burts-Miller Ranch (7,900 ft). Hayden Fork receives on the average 39 inches of precipitation annually, and Burts-Miller Ranch 22 inches of precipitation (Water supply, 1970, p. 14). The Western Uinta Mountains, a Dc climate region, according to the Koppen classification, is characterized by a cool short summer with less than 4 months over 50 F. A wide diurnal temperature range occurs between day and night.

The soils of the area can be classified under the broad category of the upland forest soil group (Wilde, 1958). Except for alpine sward soils in meadows near timberline, mature soils are largely lacking in cirque valleys and alpine tundra areas. Mountain podzols are found beneath the pine and spruce-fir forests; on steep slopes this soil type may be missing. Alluvial azonal soils derived from glacial outwash are found toward the Utah-Wyoming state line. On some sites willow thickets are found growing on intrazonal bog soils.

Previous Ecological Studies

Previous ecological studies done within the Western Uinta Mountains are few and far between. None of the studies treats the Uinta's vegetation in purely spatial terms. Pammel (1903) made some of the earliest observations on plant distributions in the Uinta Mountains. Some unsual floristic features that occur near Beaver Creek were noted by Cottam (1930). Svihla (1932) presented a paper on the distribution of mammals on the north slope, with some notes on plant distributions. The alpine biotic communties of the western Uinta Mountains were discussed by Hayward in two separate papers (1945 and 1952). Graham (1937) sketched out the vegetation zones of the Uinta Basin and the south slope of the Uinta Mountains. In their development of the zonal concept, Merriam (1898) and Daubenmire (1943), who treated western North America as whole, exerted a noteworthy influence on biogeographical research. A recent and important work on the vegetation and pedology of the Uinta Mountains has been done by Lewis (1970).

Dominant Woody Plants of the Study Area

Four tree species comprise the dominant cover types within the Western Uinta Mountains. One, *Populus tremuloides*, is deciduous, and three, *Abies lasiocarpa*, *Pinus contorta*, and *Picea engelmannii*, are coniferous. Other tree species that occur, but do not comprise a dominant cover type, include *Pseudotsuga menziesii* var. *glauca*, *Abies concolor*, *Picea pungens*, and *Populus angustifolia*. Small shrubs such as *Amelanchier spp.*, *Prunus virginiana*, *Arctostaphylos uva-ursi*, *Rosa fendleri*, and *Symphoricarpos orephilus* are present. *Artemisia tridentata* is a frequent shrub throughout the thesis area.

Morphology of Dominant Tree Species

The willows (*Salix*) are well represented within the thesis area. In habit they vary from erect bushes within the lower altitudes of the area to twisted, creeping shrubs in the upper altitudes. If all willow species were classified within the thesis area, they would probably comprise the most abundant shrub genus present. Willows are important in providing summer and winter forage for many game animals.

Lodgepole pine (*Pinus contorta*) is a medium size evergreen, reaching from 20 to 75 feet tall. The needles are two in a bundle, with a sheath at the base; needles are 1 to 2.25 inches long. The cones of this tree point outward, and can remain closed for many years. The bark is thin and scaly, and ranges in color from gray to dark brown. It is an important lumber tree in the area and is used for knotty pine veneer and for poles.

Subalpine fir (*Abies lasiocarpa*) is the smallest of the true firs within tho western United States. Subalpine fir is the most widely distributed fir in North America. Although it is considered an inferior lumber tree, in future years it may become an important species in the pulp wood industry. The general description of this species is that of an evergreen from 20 to 60 feet tall. Needles are 0.75 to 1.5 inches long, flat, dark blue-green, and are very crowed and spreading on the branches. The dark purple cones are found on the highest branches and point straight up. The smooth bark is ash-gray in color.

Engelmann spruce (Picea engelmannii) grows in a climatic zone that can be characterized as cold and humid. It is an important lumber tree in Utah and is noted for its strength and light weight. Engelmann spruce is the largest of the coniferous species within the thesis area. This species sometimes reaches a height of 100 feet. However, at timberline, it sometimes occurs as a prostrate shrub. The needles are blue-green, four angled, 1 to 1.25 inches long, blunt to acute tipped, and slightly curving. The bark is cinnamon-red to purple brown in color. This tree species has a narrow, pyramidal, scraggly appearance.

Quaking aspen (Populus tremuloides) is the most widely distributed tree species in North America. Quaking aspen grows on a great variety of soils and terrains and is typically found growing on old burns in the thesis area. Aspen is a small to medium size tree, 15 to 40 feet tall. Its leaves are nearly round, with small rounded teeth toward the apex of the leaf. Leaves turn bright yellow in the fall. Bark is whitish or slightly greenish; older trees have black knotty scars. Quaking aspen is a valuable humus former. The vegetation associated with this species is more diverse than that of any other plant zone in the area.

Morphology of the Dominant Shrub Species

Common sagebrush (Artemisia tridentata) is a shrub with a woody twisted trunk and gray-green foliage. The shrub ranges in height from 1 to 4 feet. The leaves are notched at the ends and are about 0.75 inches long. The bark of this species is grayish-brown and shreds quite readily. This species is very abundant in the study area:

local soil conservationist attribute its abundance to overgrazing by sheep and cattle.

Nonwoody Flora

The flowering plants identified within the study area are listed in the appendix. The plants listed within the appendix are arranged according to family and the dominant cover type within which the species was first identified. No sampling method was used in the compilation of the flowering species list. Extensive flora lists of the Uinta alpine can be found within Hayward's (1952), and Lewis's (1970) works.

CHAPTER II

METHODS

History of Stand Mapping

The history of stand mapping and general vegetation mapping has evolved a great deal since 1920, when a stand was first hand sketched from a airplane above Quebec, Canada (Wilson, 1920). Since then, aerial photographs have been repeately used for compilation of vegetation maps. Sisam (1947) and Kuchler (1967) give historical summary and bibliography of vegetation mapping

Steps in Vegetation Mapping

Four steps are generally involved in the collection of data and in the preparation of plant cover maps from aerial photographs: (1) reconnaissance, (2) photographic analysis, (3) ground checking, and (4) construction of the map. One or two of these steps may sometimes be omitted, or combined with other activities, such as studies of sample plots in the field (Spurr, 1948, p. 275). Four broad steps in vegetation mapping are described by Kuchler (1967): (1) laboratory activities, which include library research of available literature of the vegetation area, acquisition of aerial photographs, and the drawing of type boundaries on aerial photographs: (2) field work, consisting of preliminary reconnaissance, and analyzing the flora in the field and recording the observations on a phytocenological record; (3) second phase of laboratory activity, consisting of analyzing field notes and preparation of the vase vegetation map; and (4) preparation of the final vegetation map, based on the classification system selected (i.e., plant cover types or Raunkiaer plant life form) and the purpose of the map. Kuchler's method is vastly different from Spurr's method. Spurr's (1948) methods are based on silvicultural needs, such as measuring the total cover of an area based on crown diameters and estimating the total volume of suitable commerical timber within a certain stand and conveying the data on a stand map. Kuchler is concerned with the total applicability of his vegetation maps, which could range from floristic analysis to inventorying wildlife habitats.

Selection of Aerial Photographs

For this thesis, data gathering for the compilation of the plant cover type maps was initated by the acquisition of aerial photographs, at a nominal scale of 1:15,840. The aerial photographs used for compilation of the maps were taken by the U.S. Forest Service in the summer of 1969. In the selection of suitable aerial photographs for use in vegetation mapping, the time of year that the photographs were taken should play an important role. Summer photographs show the greatest contrast among vegetation species. If photographs are taken too late in the year some of the deciduous tree species may have lost their leaves; a typical example is aspen. Small stands of deciduous trees may be lost since one may miss their shadows, a key to photographic identification of species, if foliage is missing.

Reconnaissance

Field work was started in May, 1972, with a preliminary automobile reconnaissance of the area. This was done to familarize the author with vegetation types in the field and to correlate them with the aerial photographs. Ground photographs of various landscape features were taken to familarize the author and to relate them to the aerial at a latter time. A careful field study of certain vegetation types was made particularly of sagebrush and natural meadows, which in the upper elevations appeared similar in stereoscopic appearance.

Visual observations made from an autombile can be a helpful method of speeding up field work and correlating photographs with contour maps. Where the road systems were found to be suitable, secondary autombile reconnaissance was carried out for the express purpose of determining upper and lower limits of certain species. It is a relatively easy exercise to relate visual observations of diagnostic species and their spatial limits to mileage readings taken from an odometer, and then to transcribe the data to a contour map. In this way, for example, the lower limits of the Spruce-Fir Zone were ascertained from odometer readings and transcrived to a base map. The greatest use of the automobile can be accomplished during the dry summer months, when roads are most passible.

Photographic Analysis

The problem of stereoscopic identification of tree species within the thesis area is miminized by the fact that the flora is relatively simple, compared to those of other forested regions in the United

States. Shape and size characteristics of the various tree and shrub species, as well as their tones and textures, are distinct indicators of their identity. Table 1 is a summary and guide to the stereoscopic identification of the dominant plant cover types within the upper Bear River drainage. Aerial photographs at the 1:15,840 scale are useful in synthesizing larger areas of vegetation and identifing broad cover classes. However, upper altitudinal shrubs, such as willows and scattered sagebrush, found above 9,000, were difficult to identify from the aerial photographs at that scale. Spurr (1960) recommends aerial photographs at scales of 1:2000 to 1:5000 for proper identification of elementary growth forms, such as tree, shrub, and vine. However, the cost of mapping a large area by use of such large scale photographs would be virtually prohibitive.

Identification of individual coniferous species from aerial photographs is especially difficult, since their morphologic appearance is not vastly different from one species to another. Extensive type testing has been carried out by the California Forest and Range Expermental stations, but their success has not been great, except in determing the lumbering suitablity of various forest stands (Spurr, 1948). Through infared photography and other modern photogrammetric techniques it may become possible in future years to identify various tree species. Color ground photographs taken with a single-lens reflex camera proved useful in identifing and delimiting the Spruce-Fir Zone.

Vegetation Boundaries

Through photo interpretation it is possible in many cases to determine vegetation boundaries directly from aerial photographs. In

TABLE 1.--Key to aerial photographs within the upper Bear River drainage, Uinta Mountains, Utah

--summer key--

Vegetation type	Tone	Texture	Stereoscopic image
Spruce-fir	Dark gray	Compact matrix stippled	Tappered crowns and slender
Lodgepole pine	Medium gray	Fainly stippled	Rounded crown
Aspen	Medium to light gray	Smooth surface and fluffy	Crown surface diffuse, merges with other trees
Sagebrush	Light gray, medium gray in depressions	Stippled gray to smooth light gray and fluffy	Diffuse to stippled; stippled areas individual plants slightly raised
Tundra type	Very light gray, sometimes diffuse	Smooth rill-like surface; vegetated areas diffuse to gray stippled	Vegetated area diffuse to gray stippled; angular surface

TABLE 1.--Continued

Vegetation type	Tone	Texture	Stereoscopic image
Willows	Medium gray to dark gray	Ridged to fluffy surface	Uniform low height; crown surface merges with other shrubs
Irrigated pasture	Diffuse medium gray	Smooth surface, rolling in places; compact with little depth	Distinct boundaries; parallel pattern of drainage ways; smooth surface
Meadows wet and dry	Moist areas diffuse dark gray; dry areas light tone	Compact; fluffy texture in places	Smooth to rolling surface; diffuse boundaries merge with other vegetation
Krummholz	Dark gray to black	Darkly stippled to compact matrix	Sharp boundaries; dense shrubby, uniform height

Source: Compiled by the author.

this thesis a vegetation boundary is defined as a line between two vegetation types. Tonal contrasts are sufficient to differentiate many cover types, including wet and dry meadows, aspen stands, alpine tundra areas, and willows. Figure 3 shows a sharp vegetation boundary between two vegetation types, in this case, aspen and lodgepole pine. Sharp vegetation boundaries may be caused by edaphic factors, topography, climatic or, in the case of the vegetation types present on figure 3, a former burn area.

Prior to going into the field, all vegetation boundaries should be drawn on the aerial photographs, if possible. "Experience has shown that boundaries are hard to establish while in the field" (Kuchler, 1967, p. 267). My own field work experience has shown that one can easily walk through an area of the Spruce-Fir Zone into the Lodgepole Pine Zone with a minimum of noticeable type change. In other field areas, however, type changes are easily locateable within a few feet.

Stereoscopic Appearance of the Dominant Plant Cover Types

Sagebrush (<u>Artemisia tridentata</u>) may be identified as light to medium-gray tones on the aerial photographs. Stereoscopically, the individual plants appear as low diffuse shrubs; in dense stands individuals appear to blend into each other. The term "diffuse" in this thesis means spreading out and blending with surrounding plants or features. Within slight depressions and gullies, sagebrush appears as dark gray rivulets. On flat surfaces, as is shown in figure 4, individual clumps of sagebrush appear as dark stipples raised above

Figure 3--An extensive cover of aspen occuring at an altitude of 8,400 feet, East Fork of the Bear River. Symbols identify aspen (A), which has a light gray tone, and lodgepole pine (L), medium gray tone.

the surrounding surface. Where sagebrush is less frequent, as in the upper altitudes, these dark stipples are useful indicators of sagebrush location.

As shown in figure 4, sagebrush occupies the outwash channels of the West Fork of the Bear River. The black circular object on the photograph is a pond; the diffuse light gray tone about the fringes of the pond is a natural meadow. Aspen can be identified by its medium-gray diffuse canopy. In ths photograph, lodgepole pine and subalpine fir occupy the east-facing slopes. Willows occupy the West Fork stream channel and appear as flat dark gray areas.

Aspen (Populus tremuloides) is one of the easier tree species to identify from aerial photographs within the thesis area. Aspen has a medium to light gray tone, as can ve seen by referring to figure 3. Symbol "A" on the photograph identifies aspen. Stereoscopically, aspen has a crown surface that is rounded and diffuse; in dense stands the crown surfaces merge with other trees. Crown images appear smooth to fluffy and where the terrain is rolling a wave-like pattern may occur on the canopy surface.

Figure 5 is an aerial photograph of the plant cover types found about Lily Lake, near the East Fork of the Bear River. Symbol "W" on the photograph identifies a willow (Salix spp.) complex directly south of Lily Lake. Stereoscopically, the willows can be identified by their uniform low height, with crown surfaces merging. Extensive stands of Salix have a ridged to fluffy appearance. Tones range from medium gray to dark gray. Moist sites form the typical habitat for Salix and can be used as a key indicator for locating these species from aerial photographs.

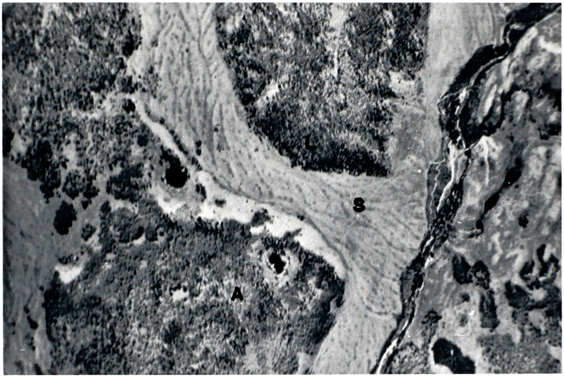

Figure 4.--West Fork of the Bear River, at an altitude of 8,200 feet. Sagebrush (S) occupies the outwash channels. Aspen (A) and lodgepole pine (L) occupy the upper slopes.

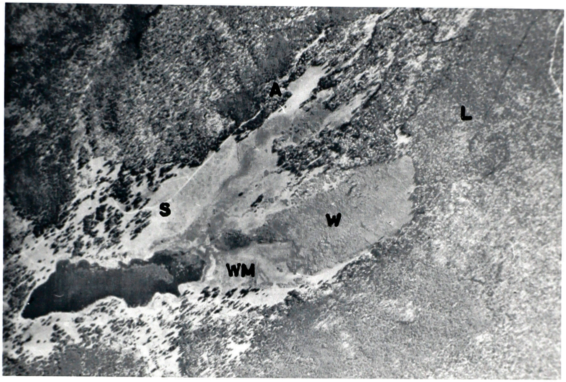

Figure 5.--Lily Lake, near the East Fork of the Bear River, at an altitude of 8,900 feet. Symbols identify aspen (A), willows (W), lodgepole pine (L), sagebrush (S), and wet meadows (WM).

Lodgepole pine (*Pinus contorta*) has a slightly ragged and rounded crown in stereoscopic image. In extensive stands *P. contorta* has a medium gray tone. Symbol "L" on figure 5 identifies lodgepole pine. In mixed conifer stands lodgepole pine is a difficult species to identify. In the thesis area it usually occurs as a smaller individual in association with Engelmann spruce. Subalpine fir is frequently the same height as lodgepole pine. In upper altitudes of the thesis area lodgepole pine stands are typically more open than the surrounding spruce-fir stands, which have a typically closed canopy. Relating closed canopies on aerial photographs to spruce-fir, and open stands to lodgepole pine, is a helpful fact in delimiting the two cover types.

Wet meadows, identified by the symbol "WM" on figure 5, can be characterized stereoscopically as dark gray diffuse areas; dry meadows have light gray tones. Differences of exposure, site, and slope angle have an effect on the appearance and texture of the aerial photographic image. Dark tones many times are typical of moist sites.

The spruce-fir association, composed of Engelmann spruce and subalpine fir, is characterized by dark gray tones and tappered crowns. The crowns of these two species have a typically ragged appearance. *Picea engelmannii* usually occupies the upper story within the *Picea-Abies* association. The mature *Picea* individuals are usually broader of canopy and greater of height than the mature *Abies* speciemens. The height difference can be a useful fact in determining the individual species from aerial photographs. The position of occupance, or spatial distribution, of a species may be helpful in determining what type of tree species one is trying to identify. For example, Engelmann spruce occupies a relatively high zone; only its close associate, subalpine fir, is found at comparable elevations and then only sparsely.

Krummholz can be identified stereoscopically by its dark gray tones and dense matrix. Individual shrubs appear as dark gray stipples on a light background. This cover type has a shrubby uniform height and in many areas sharp boundaries. High ridges and steep slopes are typical locations for krummholz.

Alpine tundra stands cover a large area within the Uinta Mountains. They are characterized stereoscopically by very light gray tones, due to the reflection light from bare rock surfaces. Areas in the alpine tundra that appear diffuse medium gray on the aerial photographs are usually moist sites or dense vegetation. Extensive areas of alpine tundra are covered with fèlsenmeer and talus; this terrain has an angular stereoscopic image.

Other Photogrammetric Techniques

In addition to field use of aerial photographs, interpretive ability can be increased by the use of photographs taken of known terrain features. Stereograms are of particular value as they present a record of ground conditions as they occur in the field. Photographs for stereograms should be taken from a stable position, preferably a tripod. To attain a good stereoscopic image, a 2.00 inch separation between photographs is recommended by Spurr (1948, p. 176). A single-lens reflex camera with a 55mm lens and Kodacolor X film furnished excellent resolution of tree species. Vegetation on color photographs usually shows the following color scheme: aspen, light-green, turning yellow-green in fall; spruce-fir, brown-green; lodgepole pine, blue-green; meadows diffuse yellow-green; and willows, dark-green, turning golden in fall. Stereograms were found useful in identifing and delimiting the Spruce-Fir-Lodgepole Pine Transition Zone.

It is my opinion that color aerial photographs are vastly superior to the conventional black-and-white prints. In the interpretation of a tree species from black-and white aerial photographs the interpreter must be familiar with the morphological features of the tree as well as being familar with the gray tone of the individual species. On color prints the interpreter can associate color with the tree species, together with the assiciation of morphology and tree species, making for an easier task in tree identification.

Ground Checking

Ground checking and the floristic analysis of an area are synonymous terms in ths paper. Analysis of floristic morphology consists of determining species frequency, abundance, and listing of species present. Floristic analysis was carried out in the field for the express purpose of determining the plant cover types wherever photographic interpretation proved impossible or difficult.

Floristic morphology can be recorded on a species presence chart, as shown in table 2, and can also be recorded in a notebook. The floristic morphology chart should record location of sample transects quadrats and should be able to relate the collected data to base maps or aerial photographs for later use. The four major tree species comprising the dominant plant cover types in the thesis area are listed on table 2; other tree species can be recorded as supplementary data elsewhere on the table. Only two dominant shrub forms, Juniperus

TABLE 2.--Floristic morphology chart for recording dominant plant cover types, upper Bear River drainage, Utah

Floristic Analysis

Stand sample number__________________ Aerial photograph number____

Location on map______________________

Type and size of stand sample__________

Trees	Number of individuals per sample	Percent
Pinus contorta		
Populus tremuloides		
Abies lasiocarpa		
Picea engelmannii		
Shrubs		
Artemisia tridentata		
Juniperus communis		

Structural Analysis

Height

Diameter

Source: Compiled by the author.

communis and Artemisia tridentata, are recorded on the table. Some structural characteristics, such as height and diameters of tree species, were recorded; however, structural characteristics of the stands were not symbolized on the final maps (plates 1 and 2) except for krummholz, which is a physiognomic type.

Throughout the thesis area, quadrats and transects were taken to determine species composition. The line transect was found to be the most useful and speediest method of determining species frequency and in determining boundaries between vegetation types. Vegetation boundaries can be ascertained by one tree species' variation from one area to another; for example the boundary line separating the Spruce-Fir Zone from the Lodgepole Pine Zone can be determined by a frequency count, the boundary being drawn where lodgepole pine accounts for less than 40 percent of the stand volume. This is an especially useful concept in the Uinta Mountains, where floristic composition among tree species is slight and zones are sometimes based only on one tree species, for example, lodgepole pine. Due to the altitudinal zonation of vegetation within the thesis area, the vegetation naturally occurs as successional stages as one proceeds up the mountain mass. This is a helpful factor when plotting transects and quadrats to determine environmental limits of various plant species. Running transects down slope is the easiest method of determining boundaries between cover types.

Time and Equipment Saving Procedures

Some of the following methods are time and equipment saving procedures that proved helpful in the thesis work. In laying out a line transect, it is a simpler and less physically exerting task to run the transect down slope than up slope. A compass should be used to maintain directional orientation. This is a vital tool where there is rugged terrain and dense vegetation, which cause one to stray and lose direction. A hundred-foot tape was found most versatile for use in the field; however, it is easier to maintain direction with a shorter tape. Whenever possible, two or more field assistants should be used for carrying equipment, correctly orienting transects, and recording data. When one is sampling the macro-vegetation complex of an area, slopes bordering streamsides should be avoided. This is because riparian micro-environmental factors, both climatic and edaphic, cause species to extend to low or high altitudes in stream valleys.

Due to frequent rain, which is so common in the Western Uinta Mountains, it was found necessary to cover the aerial photographs with self-adhesive clear plastic sheets. Dimensional changes caused by moisture and by temperature changes are minimized when plastic cover sheets are used to cover the aerial photographs. A grease pencil is useful in making notes because corrections can easily be made on plastic material. When not in use, the aerial photographs should be stored securely to prevent curling of the prints. In so far as possible, field work near streams and rivers should be avoided during early spring, because high water and saturated ground greatly inhabit travel.

Basis for Classification of Plant Cover Types

Various researchers have identified and named the plant zones within the Uinta Mountains and its environs. Svihla (1932) briefly discussed the vegetation zones of the north slope of the Uinta Mountains in relationship to faunal distribution. She identified cedar-pinyon (actually pinyon-juniper), sagebrush, pine, spruce-fir, and alpine zones.

The concept expressed by the term "vegetation zone" is basically an artificial concept. Rather, vegetation should be considered as a mosaic, with similar vegetation types occupying similar environmental sites.

The classification of the vegetation and consequent mapping of the thesis area is based on the dominant cover types, called zonal community types, as shown in table 3. The determination of plant cover types is vased on the quantitiative analysis of the floristic morphology of an area.

Construction of Plates 1 and 2

Two maps were compiled of the plant cover types found within the thesis area. The maps are titled "Plant Cover Types, Hayden Fork," and Plant Cover Types, upper Bear River." Each map covers a length of approximately twelve miles and an width of approximately two miles on either side of Utah State Highway 150.

Transfer of detail from the individual aerial photographs to a base comprised of U. S. Forest Service contour maps, scale 1:24,000, was accomplished through the process of expansion and reduction by porportional squares. Clear mylar was overlayed on the contour map base, and was used to transcribe detail from the aerial photographs. A grid system was placed on the aerial photographs; a four-inch square grid was found easiest to work with. This grid was then tied to control

TABLE 3-- Zonal community types with successional stages that are recognized in the upper Bear River drainage, Utah

Zonal community type	Upper altitudianl limits (feet)	Subclimax or climax	Successional stages
Sagebrush (*Artemisia tridentata*)	9,800	Climax	Aspen
Aspen (*Populus tremuloides*)	9,200	Subclimax Climax	Lodgepole pine
Lodgepole pine (*Pinus contorta*)	9,600	Climax	Aspen Burn grassland
Spruce-Fir (*Picea engelmannii*-*Abies lasiocarpa*)	11,000	Climax	Aspen Burn grassland lodgepole pine
Alpine tundra (*Kobresia myosuroides*-*Carex elynoides**)	12,478 Hayden Peak	Climax	Forbs *Geum rossii* Geum-Sedge

*after Lewis, 1970

Physiognomic type	Upper and lower altitudinal limits (feet)
Krummholz (*Picea engelmannii*-*Abies lasiocarpa*)	10,400-11,600

Source: Compiled by the author

points. Cultural control points usually consisted of roads, road intersections, buildings, irrigation ditches, campgrounds, or fence lines. Physical control points consisted of lakes, ponds, streams, and distinctive river features such as ox bows. In the upper altitudes, good control points consisted of cliffs, felsenmeer fields, prominent peaks and ridges, and other sharp changes in slope angle. Physical control points can easily be found on contour maps by map interpretation. The photographic image was than reduced to fit into a proper pattern on the contour base. At many places in the study area the vegetation follows certain environmental gradients that proved helpful in plotting the vegetation on the contour map.

Distortion of Aerial Photographs

In areas of great vertical relief the individual aeril photograph displays distortion in scale. Parallactic displacement is at a minimum near the center of the photograph. Whenever possible, for correct transfer of detail from aerial photographs to a base map, detail should be transfered from the center of the aerial photographs.

A photo-mosiac obtained from Olympus Aerial Surveys, by Dr. Donald Currey of the Geography Department, was very valuable for correlating vegetation features within the upper altitudinal reaches of the thesis area. Although the mosaic was not accurate at all points, especially in regions of extreme relief, it was helpful in plotting upper tree line.

Cartographic Symbolization

No minimum unit size was set for the representation of vegetation types; rather, an arbitary system was devised, based on the opinion of the author. For example, where vegetation units occurred in linear patterns, and the representation of the vegetation unit was important, the width of the vegetation pattern was exaggerated. Some vegetation units, although beyond minimal reproduction size, were included due to the utility of cartographic symbolization. The cartographic representation of krummholz is irregular black patterns; because of this pattern krummholz in units smaller than comparable units of other vegetation can be easily portrayed.

Black and White Representation of Vegetation

Use of black and white cartographic representation of vegetation limits the versatility and the amount of data that can be symbolized on a map. Use of color on maps greatly increases the amount of representation possible. However, the cost of printing a map is increased many times if color is used. The use of screening methods to tone out certain features may increase the versatility of the black and white map. Limited use of place names, and using vegetation types to represent drainage patterns rather than cartographically symbolizing rivers and streams limits the cluttering that normally occurs on the black and white map.

CHAPTER III

PLANT COVER TYPES

The following is a discussion of the plant cover types occurring within the upper Bear River and Hayden Fork drainage. The cover types are discussed in ascending order of occurrence, from the Sagebrush Zone to the Alpine Tundra Zone. Intrazonal plant cover types, such as the willow and meadow complexes, will be discussed as they occur within the zonal belts.

Figure 6 is a diagrammatic transect across the north slope of the Uinta Mountains, representing the altitudinal zonation of vegetation on a north-south axis.

Sagebrush Zone

The Sagebrush (*Artemisia tridentata*) Zone dominates a large part of the thesis area. Sagebrush, a species intruding from the Green River Basin, attains an upper altitudinal limit of 10,200 feet within the thesis area. In the upper elevations *A. tridentata* prefers the rocky or gravelly slopes of well-drained ridges. At its upper limits the species is suppressed due to more competitive grasses, as well as to climatological and edaphic factors. In the lower elevations *A. tridentata* prefers the former outwash channels of the Bear River and its tributaries. The densest stands of sagebrush are found growing on permeable Quaternary alluvial deposits. In some areas this

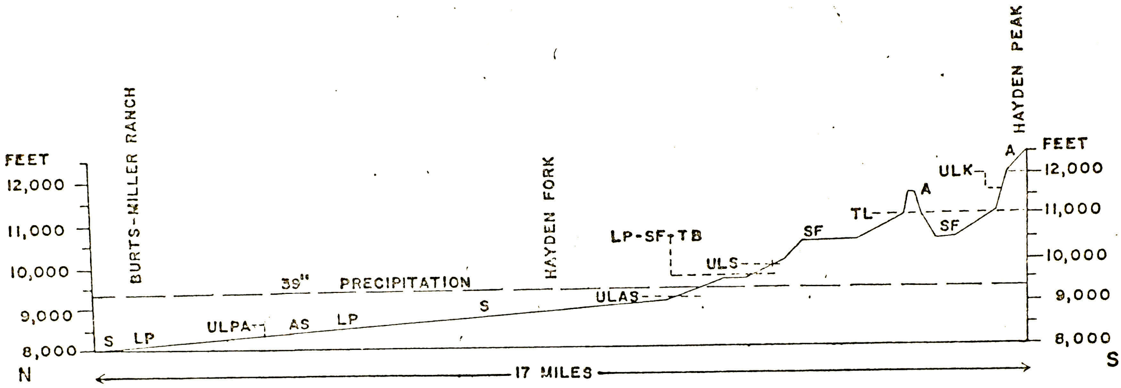

Figure 6.--Diagrammatic transect across the north slope of the Uinta Mountains, from Hayden Paark to Burts-Miller Ranch, illustrating the altitudianl zoning of the vegetation. Alpine tundra (A); upper limit krummholz (ULK); timberline (TL); spruce-fir forest (SF); upper limits sagebrush (ULS); lodgepole pine-spruce-fir transition boundary (LP-SF-TB); upper limits aspen (UPLAS); sagebrush (S); lodgepole pine forest (LP); aspen (AS); upper limit narrowleaf cottonwood (ULPA).

brush is so dense that walking through it is difficult.

Graham (1937) refers to the Sagebrush Zone that occurs within the Uinta Mountains as the Shrub-Montane Zone. He lists the following shrub species occurring with *Artemisia tridentata*.

Amelanchier pallida
Cercocarpus montanus
Purshia tridentata

In this study, the following shrub species were identified within the Sagebrush Zone.

Amelanchier anifolia
Juniperus communis
Symphoricarpos oreophilus

and the following non-woody species were observed with *A. tridentata*.

Pholox longifolia	*Sedum stenopetallum*
Vicia americana	*Solidage decumbens*
Iliamna rivularis	*Cirsium foliosum*
Calochortus nuttalli	*Astragalus purshii*
Fritillaria atropurpurea	*Gutierrezia sarothrae*

At lower altitudes in the study area the Sagebrush Zone is intensely grazed by sheep and cattle. Large areas of this zone have been reclaimed and turned into irrigated pasture. Near the Bear River Guard Station, sagebrush flats are commonly used as snowmobile recreation sites.

Below 8,200 feet, floodplains appear on aerial photographs as a jumbled mosaic of trees and shrubs. *Salix* occurs with the greatest frequency. Tree species such as *Populus angustifolia* occur less frequently in floodplains and drop entirely out of the vegetation mosaic above 8,200 feet. Flood plains bordering stream channels support *Populus tremuloides*, *Symphoricarpos oreophilus*, and *Amelanchier anifolia*. On dry ridges bordering the stream channels *Juniperus communis* is sometimes found. Occasionally, *Picea engelmannii* and

Abies lasiocarpa are found bordering stream channels. Above 8,200 feet, willow complexes increasingly dominate areas bordering stream channels and on occasions completely obstruct flowing channels. Hayward (1952) identified the following Salix species growing in the Western Uinta Mountains.

Salix cascadensis
Salix petrophila
Salix saximontana

Salix forms a valuable habitat for Utah's largest moose herd and also provides valuable cover for various bird species.

Aspen Zone

The Aspen (*Populus tremuloides*) Zone generally occurs above the Sagebrush Zone and is commonly associated with lodgepole pine on burned areas, but usually occurs at lower altitudes than *Pinus contorta*. The common upper limit of *P. tremuloides* is 9,200 feet; however, on some sites aspen occurs at higher elevations. For example, aspen occupies a slide area at an elevation of 9,700 feet, in association with *Abies lasiocarpa*, on Kletting Peak. *P. tremuloides* is capable of growing on a variety of sites; even unstable talus slopes sometimes provided suitable habitat for this species. At upper altitudes aspen growth form is usually gnarled and shrubby.

As shown in figure 7, the herbaceous understory below aspen is floristically rich. This is probably due to the high nutrient content derived from fallen aspen leaves, branches, and other organic debris recycled from aspen stands. Graham (1937) describes the vegetation of the Aspen Zone as being the most luxuriant of any of the zones occuring within the Uinta Basin or on the south slope of the Uinta.

Figure 7.--A stand of P. tremuloides, with a dense herbaceous understory. Near Lily Lake, Uinta Mountains, at an altitude of 8,800 feet.

Graham further states that aspen forms a permanent zone on the south slope and does not represent a transitional stage in the vegetation mosaic. Cronquist et al. (1972) do not recognize an exclusive Aspen Zone as such, but rather refer to an Aspen-Lodgepole Pine Zone as occurring within the Uinta Mountains. In much of the thesis area, aspen and lodgepole pine occur as close associates; however, I feel that where-ever this association occurs, it is but a successional stage and that aspen will eventually be suppressed by lodgepole pine. It is my studied opinion that _P. tremuloides_ on some sites forms a climax species, and that on the north slope of the Uinta Mountains its bioclimatological zone lies at an optimum altitude of 8,200 feet. Subalpine fir, is the commonest conifer that occurs within the aspen climax.

Other tree species associated with aspen at lower elevations of the thesis area include _Abies lasiocarpa_ and _Prunus virginiana_, the latter occurring as a small tree. In one locality, at an elevation of 8,400 feet, _P. virginiana_ forms a dense secondary understory below aspen.

As shown in table 4, average diameters of aspen are usually small in the study area. Very large aspen are not common in the area; one of the larger trees measured had a diameter of 28.5 inches.

The following secondary species are associated with aspen in the thesis area.

Artemisia tridentata
Aster adscendens
Aster foliaceus
Campanula rotundifolia
Cerastium arvense
Geranium fremontii
Gilia aggregata
Lathyrus pauciflorus
Lupinus aduncus
Penstemon spp.

TABLE 4.--Mean bole diameters and crown heights of _Populus tremuloides_, taken from eight 0.01-acre sample quadrats, altitude 8,200 feet, north-west of the Bear River

Quadrat	1	2	3	4	5	6	7	8
Height (feet)	30	18	25	15	40	24	20	25
Diameter (inches)	6.2	3.1	4.6	3.1	6.4	3.7	2.8	4.2

Source: compiled by the author

A prevernal type of aspen occurs within the thesis area; this race is typified by its early leafing habit, its yellow-green bole, and its longer retention of leaves into the fall.

Lodgepole Pine Zone

Lodgepole pine (_Pinus contorta_), formerly named _Pinus murrayana_, forms an extensive forest in much of the area. The upper altitudinal limit of the individual lodgepole pine within the thesis area is approximately 10,600 feet, in the Spruce-Fir Zone. Lodgepole pine was not observed as a component of the krummholz. In the Rocky Mountains of Colorado, _P. contorta_ forms dense forest between the elevations of 8,000 and 9,000 feet. Within the study area the transition between the Spruce-Fir Zone and the Lodgepole Pine Zone occurs at approximately 9,600 feet. The lower limit of the species was observed at 8,000 feet; however, it may occur at lower altitudes in other areas of the Uinta Mountains.

Inversions of vegetation occur within the area, with lodgepole pine intruding into higher altitudes along the shoulders of mountain masses, such as Hayden Peak, and with subalpine fir and Engelmann spruce inverting downward along moist stream channels. Due to anthropogenic activities, inversion are not well pronounced within the thesis area. For example, the successive effects of lumbering, burning, and grazing have converted the area surrounding Sulphur Creek Campground, formerly under spruce-fir, into burn grasslands and lodgepole pine stands. The present vegetation completely masks the former extent of spruce-fir downward along Hayden Fork. A fine example of a plagioclimax can be seen near Gold Hill and Moffit Peak, where an extensive stand of lodgepole pine has been removed through lumbering and fire, and has been replaced by aspen and burn grassland. Successive fires and grazing primarily by sheep have sustained the present non-climax plant communities.

Within the thesis area, overstocking of lodgepole pine appears to be a common phenomenon wherever burns have occurred. A striking example of overstocking was recorded when 23 trees with an average diameter of 2.5 inches and a height of 12 feet were counted within a 40-square foot quadrat.

Mountain pine beetle (Dendroctonus monticolae) has caused intensive damage and destroyed many trees within the upper Bear River area. Dwarf mistletoe (Arceuthobium americanum) on the north slope of the Uinta Mountains, during recent years has infected a great number of trees.

The oldest lodgepole pine cored within the thesis area was dated at 112 years; this tree had a 16-inch diameter. Burns and lumbering activities within the area have kept the lodgepole pine stands at a relatively young age. Bole sizes are small, as reflected in table 5.

The flora of the Lodgepole Pine Zone is typically poor due to the closed crown cover that produces a micro-climatological effect that inhibits plant growth. The following species were found growing within the Lodgepole Pine Zone.

Arctostaphylos uva-ursi
Arnica cordifolia
Castilleja spp.
Geranium richardsoni
Juniperus communis
Phacelia sericea
Pseudocymoterus montanus
Pterospora andromedea
Vaccinium scoparium
Vaccinium scoparium
Viola adunca

Within the Lodgepole Pine Zone, Rocky Mountain Douglas-Fir (*Pseudotsuga Menziessii* var. *glauca*) occurs only rarely within the study area. The upper limit of this species was recorded by altimeter at 8,750 feet. Other tree species occurring within the Lodgepole Pine Zone include *Abies lasiocarpa*, *Populus tremuloides* and *Picea engelmannii*.

TABLE 5--Mean bole diameters and crown heights of *Pinus contorta* taken from eight 0.01-acre sample quadrats, altitude 8,800 feet, East Fork of the Bear River

Quadrat	1	2	3	4	5	6	7	8
Height (feet)	43	50	45	40	70	56	65	45
Diameter (inches)	3.1	8.8	5.6	5.0	21.	6.1	5.6	6.7

Source: Compiled by the author

Spruce-Fir Zone

The Spruce-Fir (*Picea engelmannii-Abies lasiocarpa*) Zone occurs between the altitudinal limits of 9,400 feet and a mean timberline of

10,500 feet. Where the gangplank effect of vegetation occurs timberline extends to 11,000 feet. The gangplank effect can be defined as extensions of vegetation into upper altitudes, in an attempt to establish its upper limit. This extension upward of vegetation can be caused by edaphic or topographic factors, such as slope angles merging gently into the mass of the mountain. Faulting may also cause a depression in which vegetation moves upslope. This is similar to the effect of inversions described by Daubenmire (1943); however, in the gangplank effect vegetation is seeking its ultimate natural limit by following upward a topographic feature or an edaphic type.

Timberline in the study area is a ragged and disjunct line, the uneveness of which is due to talus slopes, slides, and expanses of exposed bedrock that inhibit tree growth. Graham (1937, p. 79) states that subalpine fir often becomes the commoner timberline species and frequently extends to a higher altitude than Engelmann spruce. Timberline is usually higher on south-facing slopes than on north-facing slopes. In some places within the study area the difference is as great as 200 feet.

In many places in the Spruce-Fir Zone herbaceous undercover is absent due to the shade produced by the dense canopy. The following understory species were identified within this zone.

<u>Arctostaphylos uva-ursi</u>
<u>Claytonia lanceolata</u>
<u>Epilobium angustifolium</u>
<u>Erythronium grandiflorum</u>
<u>Lewisia pygmacea</u>
<u>Mimulus lewisii</u>
<u>Pedicularis racemosa</u>
<u>Penstemon whippleanus</u>
<u>Pterospora andromedea</u>
<u>Rosa fendleri</u>

Another tree species commonly found throughout this zone is lodgepole pine. Although never occurring frequently, <u>P. contorta</u> trees do attain large sizes. Mean data derived from some typical transects to determine species composition are shown in table 6. As the table indicates, lodgepole pine occurs less frequently above an altitude of 9,800 feet.

TABLE 6.--Some typical transects taken to determine species frequency, expressed in percent, within the Spruce-Fir Zone

Transect	1	2	3	4	5	6
Elevation (feet)	9400	9600	9800	10200	10100	10200
P. contorta	16.7	40.0	20.5	19.1	3.8	28.6
A. lasiocarpa	16.8	33.3	14.0	50.3	48.7	30.9
P. engelmannii	66.5	26.7	65.6	30.6	47.5	40.5

Source: Compiled by the author

In many transects subalpine fir produced more individuals in a frequency count. Subalpine fir seldom dominated the canopy, but rather comprised the tree understory below the taller Engelmann spruce. Subalpine fir tolerates a wide range of environmental conditions, ranging from minimum soil, relatively moist sites, to old burns and steep slopes. Subalpine fir appears to be a fire-induced species in some areas. The high frequency rate of this species in tree counts could indicate the former presence of a fire. Some burns were noted within the elevation range of 9,000 to 9,800 feet. However, no burns were noted above 9,800 feet, where more humid conditions have no doubt helped to maintain the dominance of Engelmann spruce by reducing the frequency of fire.

Tree heights and diameters are on the average larger within the Spruce-Fir Zone than in the Lodgepole Pine Zone. By comparing table 5 with tables 7 and 8, one can easily note this difference.

TABLE 7--Mean bole diameters and crown heights of *Picea engelmannii* taken from eight 100-foot transects at an elevation of 10,200 feet

Transect	1	2	3	4	5	6	7	8
Height (feet)	90	40	50	30	50	45	70	40
Diameter (inches)	32.6	10.6	10.3	7.2	11.2	10.9	20.4	8.1

Source: Compiled by the author

TABLE 8--Mean bole diameters and crown heights of *Abies lasiocarpa* taken from eight 100-foot transects at an elevation of 10,200 feet

Transect	1	2	3	4	5	6	7	8
Height (feet)	60	12	20	20	25	40	35	30
Diameter (inches)	10.4	3.2	4.3	3.7	7.4	9.1	9.1	8.9

Source: Compiled by the author

Throughout the Spruce-Fir Zone meadows and lakes are a common occurrence. Generally there are two types of lakes present within the area, rock basin lakes and lakes formed behind moraines. All these lakes and ponds are remnants of past glacial action and are in various stages of gradual filling, either by silting or by vegetative accretion action. Two plants typical of these ponds and lakes are *Isoetes bolanderi* and *Nuphar polysepalum*. Other conspicuous plants that form the main flora about these lakes and ponds belong to the genera *Sphagnum*, *Kalmia*, *Ledum*, and *Vaccinium*. A successional study of bog formation was carried out at Lily Lake, in the Uinta Mountains, by Christensen and Harrison (1960).

Wet meadows and dry meadows, common in the area, are both the result of advanced stages of lake and pond filling, fire, edaphic onditions, and various other factors that have caused openings within the forest stand. Island-like patches of spruce and fir, occupying areas of morainal drift and rock outcrops that are better drained than the surrounding meadow, are numerous in some wet meadows. The Weber River drainage, below Pass Lake, has many fine examples of island-parks. As shown in figure 8 island-parks can also be seen below Reids Peak.

Herbaceous undercover is usually poor beneath the spruce-fir stands; typically, the most abundant flora is found within openings. The following plants are among those occuring within wet meadows and dry meadows.

Aconitum columbianum
Caltha leptosepala
Dedecatheon pauciflorum
Erysimum capitatum
Galium boreale
Gentiana fremontii
Mimulus guttatus
Mimulus lewisii
Nuphar variegata
Potentilla fruticosa
Pedicularis groenlandica
Swertia perennis

Krummholz Cover Type

The transition between the Spruce-Fir Zone and the Alpine Tundra Zone is recognizable by the character of stunted and prostrate tree forms called krummholz. As early as 1909, C. H. Shaw was elucidating on the causes of krummholz. He concluded that timberlines, as characterized by krummholz, are caused by wind and snow. There are many factors behind the cause of krummholz, including low temperatures of the wind and its associated drying effect. Griggs (1938) concluded that wind was the controlling factor of krummholz formation. That

Figure 8.--Upper altitudinal meadow at 10,600 feet. Spruce-fir occupying better drained ridges and rock outcrops within meadow.

wind has an effect on the prostrate habit of krummholz is strongly suggested by the clipped and dead branches above the prostrate krummholz clumps. A clump of krummholz, in this case *Picea engelmannii* migrating across a spur of Bald Mountain, is shown in figure 9.

Cones were not observed on any of the krummholz stands visited. This cover type is propagated by seeds blown up from below or by vegetative processes. The krummholz of the area appears to have a uniform, neatly pruned height. Dead shoots are usually visible above the main mass of the shrub, indicating seasons past that were more favorable for upward growth. Krummholz occurs as low as 10,400 feet and as high as 11,600 feet in the study area.

Alpine Tundra Zone

Alpine Tundra Zone, titled felsenmeer and talus on the accompanying maps, ranges in altitude from 12,478 feet, the summit of Hayden Peak, to a low of about 10,600 feet within the thesis area. The lower elevational ranges of the alpine tundra usually occur on talus slopes. As can be seen in figure 10, the alpine tundra is characterized by extensive fell fields. Geologically the upper altitudes are composed entirely of Precambrian quartzites and the terrain consists of angular blocks of frost-shattered rock. The soil, if any, is found in isolated pockets and crevices between the rocks. The following are some of the non-woody plants occuring within the alpine tundra.

Aquilegia coerulea
Arnica foliosa
Erigeron leiomerus
Ivesia gordonii
Mertensia ciliata
Oxyria digyna
Polemonium viscosum
Primula parryi

Figure 9.--Migrating krummholz at an altitude of 11,200 feet, moving in a north-eastern direction. Note the dead branches left in the shrub's wake.

Figure 10.--Felsenmeer field, which is easily accessible by trail, can be seen on Bald Mountain. Within protected sites cushion plants such as Silene acaulis grow.

Many factors influence plant growth within the alpine regions. Some of these include frost and its effect on rooting habit of plants, wind, rain, solar radiation, sudden changes of air temperatures, and the abrasive effects of blowing snow and avalanches. Plant growth is usually stunted and plant structures exposed above sheltered areas are sometimes tattered and broken, reflecting the effect of high winds and beating rains. Micro-relief is responsible for small pockets of subalpine and lower montane plants growing within the felsenmeer fields. Talus slopes frequently have multi-colored lichens growing on the rocks. The unstable nature of talus for the most part precludes establishment of higher plants. Mosses are not frequent within the fell fields. The high mountain peaks are usually entirely bare of vegetation except for crustose lichens. Hayward (1945 and 1952) and Lewis (1970) furnish detailed information on the Alpine Tundra Zone.

CHAPTER IV

SUMMARY AND CONCLUSIONS

Briefly stated, this thesis on plant cover types of the upper Bear River and Hayden Fork drainage is centered about two dominant plant cover type maps. The two maps were prepared from data derived from aerial photographs, field study and a photo-mosaic. Automobile and foot reconnaissance were made of the area mapped. Transects and quadrats were taken to determine species composition in order to elucidate on cover abundance and draw vegetation boundaries between plant types. The line transect was found the most useful in determining transition zones and vegetation boundaries.

Shape and size characteristics as well as tones and textures are important indicators for stereoscopic identification of various cover types. Stereograms were also found useful in identifying boundaries between various plant types.

The cover types in the lower elevational areas are greatly affected by the activities induced by man. Extensive areas of forest have been burned, logged by the timber industry, drained for pasture, grazed by sheep and cattle, and just recently affected by the recreation boom.

A variety of edaphic, topographical, and climatic factors control the distribution of plant cover types within the upper Bear River drainage. Altitudianl distribution of priniciple cover types are: (1) sagebrush from the Wyoming Basin to 9,800 feet, (2) quaking aspen to an upper altitudinal limit of 9,200 feet, (3) lodgepole pine from 8,000 to 9,600 feet, (4) spruce-fir from 9,600 to 11,000 feet, (5) krummholz from 10,400 to 11,600 feet, (6) alpine tundra from 10,600 feet upward.

Rocky Mountain Douglas fir, Colorado blue spruce and narrow-leaf cottonwood are other tree species that occur but do not comprise a dominant cover type. Lodgepole pine does occur within the *Picea-Abies* Zone above 9,600 feet, but never comprised more than 40 percent of the total tree counts in line transects taken. Engelmann spruce dominates the canopy within the *Picea-Abies* association, however, subalpine fir is predominant as seedlings and as young trees.

Krummholz, recognized as a distinct cover type within this paper, is composed of Engelmann spruce and subalpine fir. Lodgepole pine was not found to be a component of krummholz within the thesis area. In the Appendix, 75 flowering plants collected throughout the thesis area are listed. The richest herbaceous understory occurs under aspen stands and openings within the forest stand.

Future research in this mountain area could find fertile ground in bioclimatological and edaphic studies. In-depth mapping projects based on Pleistocene and Holocene terraces may prove useful in correlating glacial chronologies. A concise study based on man's activities about lakes, streams, and trails in the area would prove helpful in assessing the recreational impact and providing guidelines on pollution controls. It is my opinion that future generations will never lack in finding some aspect to study in this area.

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APPENDIX

FLOWERING PLANTS IDENTIFIED WITHIN THE STUDY AREA THE NUMBER FOLLOWING THE SPECIES NAME IDENTIFIES THE PLANT ASSOCIATION WITHIN WHICH THE SPECIES OCCURS

Plant Associations	
Pinus contorta...1	*Picea engelmannii-Abies lasiocarpa*...4
Populus tremuloides...2	*Artemisia tridentata*...5
Wet-dry meadow complex...3	Alpine tundra...6

BERBERIDACEAE

Berberis repens...1

BORAGINACEA

Mertensia ciliata...6
Myosotis alpestris...2

CAPRIFOLIACEAE

Symphoricarpos oreophilus...2

CARYOPHYLLACEAE

Cerastium beeringianum...4
Silene acaulis...6

COMPOSITAE

Antennaria rosea...6
Arnica cordifolia...1
Aster foliaceus...2
Aster fulgens...2
Cirsium foliosum...5
Erigeron leiomerus...6
Gutierrezia sarothrae...5
Senecio canus...4
Solidago canadensis...5

CRUCIFERAE

Erysimum capitatum...3

APPENDIX--Continued

ERICACEAE

Arctostaphylos uva-ursi...1
Kalmia polifolia...3
Vaccinium scoparium...4

GENTIANACEAE

Gentiana affinis...3
Gentiana calycosa...3
Gentiana fremontii...3
Swertia perennis...3

GERANIACEAE

Geranium fremontii...2
Geranium richardsoni...1

HYDROPHYLLACEAE

Phacelia sercea...1

ISOETACEAE

Isoetes bolanderi

LABIATAE

Mentha arvensis...2

LEGUMINOSAE

Astragalus miser...5
Astragalus purshii...5
Lathyrus pauciflorus...2
Lupinus aduncus...2
Thermopsis montana...2
Vicia americana...5

LILIACEAE

Allium acuminatum...5
Calochortus nuttallii...5
Erythronium grandiflorum...4
Fritillaria atropurpurea...5
Veratrum californicum...4
Zigadenus elegans...3

NYMPHAEACEA

Nuphar polysepalum...3
Nuphar variegata...3

ONAGRACEAE

Epilobium angustifolium...4

ORCHIDACEAE

Spiranthes romanzoffiana...3

POLEMONIACEAE

Gilia aggregata...2
Pholox longifolia...5
Polemonium viscosum...6

POLYGONACEAE

Oxyria digyna...6
Polygonum bistoides...6

PYROLACEAE

Pterospora andromedea...1

RANUNCULACEAE

Aconitum columbianum...3
Aquilegia coerulea...3
Caltha leptosepala...3
Delphinium occidentale...2
Ranunculus jovis...3

ROSACEAE

Amelanchier anifolia...2
Fragaria vesca...2
Ivesia gordonii...6
Potentilla fruticosa...3
Potentilla glandulosa...3

SAXIFRAGACEA

Parnassia fimbriata...3

SCROPHULARIACEAE

Castilleja rhexifolia...1
Mimulus guttatus...3
Mimulus lewisii...3
Pedicularis groenlandica...3
Pedicularis racemosa...3
Penstemon humilus...2
Penstemon whippleanus...4

UMBELLIFERAE

Ligusticum porteri...2

VIOLACEAE

Viola adunca...1
Viola canadensis...3
Viola nuttallii...1