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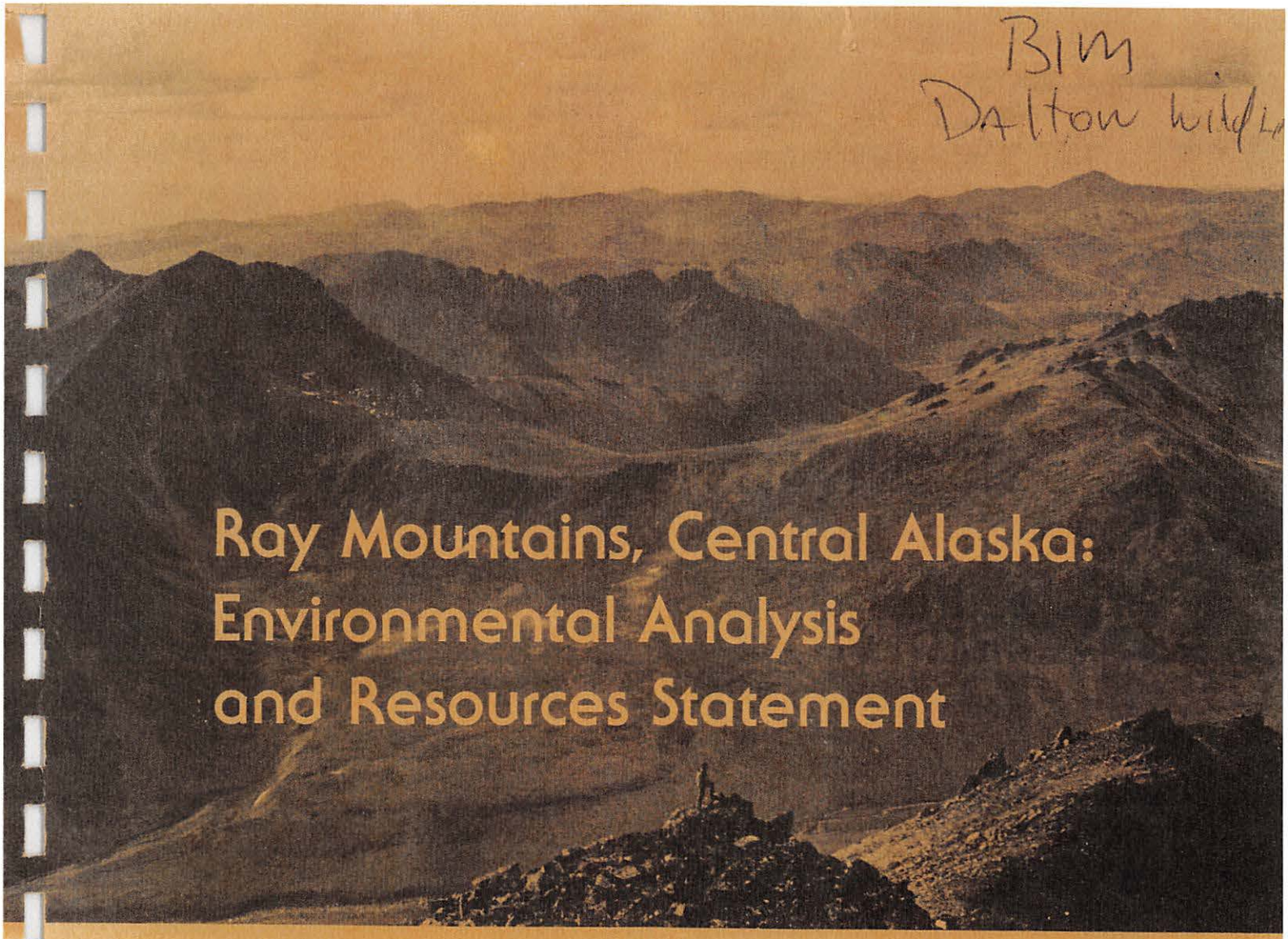

Ray Mountains, Central Alaska: Environmental Analysis and Resources Statement

N. Farquhar and J. Schubert, editors

MIDDLEBURY COLLEGE NORTHERN STUDIES PROGRAM

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Ned Farquhar and John Schubert, editors

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NORTHERN STUDIES PROGRAM
MIDDLEBURY COLLEGE
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Cover Photo: View west from Mt. Tozi toward Mt. Henry Eakin

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ABSTRACT

To the north of the central Yukon River lies a group of low mountain ranges that are one of the least known areas of the Alaskan interior. One of these ranges, the Ray Mountains, was chosen as the focus of this study. The objective was to compile a basic environmental inventory through the collection of data on the major biotic and abiotic components of the landscape and to synthesize these data for description of ecosystems, providing the basis for resource analysis in light of past, present, and future land use.

This work was planned and conducted by a research team of twelve participants supported primarily by the National Science Foundation's Student Originated Studies program. The fieldwork was accomplished during an eight week season from mid-June to mid-August of 1979. The project study team consisted of four research groups studying 1) geology, geomorphology, and soils; 2) floristics and vegetation; 3) mammals, birds, and insects; and 4) ecosystems and resources.

Fieldwork included quantitative and qualitative analysis in three areas of concentrated study. Two of these areas -- in Spooky Valley and lower Torment Creek -- were pictured in existing large-scale 1:5,000 near-infrared black and white aerial photography which became the basis for intensive study. The third area, in upper Torment Creek, was the site of concentrated ecosystems study. Upper elevation valley and rugged mountain environments of the Ray Mountains were well represented in Spooky Valley and upper Torment Creek, whereas lower Torment Creek was representative of lower elevation forested and rolling tundra environments.

Each study team also spent up to one-half of its field time observing, describing, and to a lesser extent sampling within other parts of the Ray Mountains, including environments similar to those within the areas of concentrated study as well as uncommon features such as hot springs.

Geologic studies focused on the complex geologic history of the area. The central and western portion of the range is dominated by a large granitic batholith, surrounded successively by gneisses and schists. Samples from the southeast portion of the range suggest a relation to ophiolite complexes of western and northern Alaska. Local late Pleistocene glaciation in the highest portions of the range formed classic glacial features including horns, arretes, cirques, U-shaped valleys, and moraines. Periglacial features are prominent throughout the range and include well developed solifluction lobes, altiplanation terraces, and a variety of frost-sorted features. Granite tors are conspicuous features at upper elevations.

Soil studies described the common morphological characteristics of nine soils subgroups that occur in the study area. Dominant upland soils include Pergelic Cryorthents and Lithic Cryorthents. Pergelic Cryochrepts and Pergelic Cryaquepts are the most extensive lowland soils. Significant associations of vegetation, topography, and soils were investigated in detailed study of several valley transects.

Investigation of the Ray Mountains vascular flora identified 227 plant species, of which 57 species were significant range extensions. The flora includes a mix of characteristically arctic, alpine, and boreal species.

The vegetation study team identified, classified, and described 30 vegetation types. The vegetation of the Ray Mountains is primarily alpine and low arctic tundra though boreal forest occurs at lower elevations along the periphery of the range. Dominant vegetation types observed were dwarf scrub - tussock-graminoid meadows, dwarf and medium scrubs, and alpine barrens. A small-scale (1:250,000) map showing the distribution of major vegetation types in the study area was derived from satellite (LANDSAT) imagery. Based on aerial photographs, three large-scale vegetation maps were constructed in two of the areas of concentrated study.

Zoologic studies included observation of large mammals and birds, trapping of small mammals, and collection of insects. The presence of 17 mammal species was documented. Range extensions were established for the singing vole, the pygmy shrew, and the Alaska marmot (preliminary identification). Observations confirmed the presence of a small herd of caribou probably restricted to the region of the Ray Mountains and the Kokrines Hills. Of the 55 bird species recorded in the study area, at least 39 were breeding. The presence of Upland Sandpipers and Golden-crowned Sparrows was significant, filling a gap in their previously known distribution within Alaska. In addition to species presence, habitat affinities and relative abundances were assessed for mammals and birds. Insect collection yielded 174 species.

Encompassing diverse landscapes, the Ray Mountains include a variety of subarctic tundra ecosystems surrounded at lower elevation by boreal forest ecosystems. Four ecosystems, useful for description and management, were recognized in the Ray Mountains: ALPINE BARREN, UPLAND TUNDRA, LOWLAND TUNDRA, and BOREAL FOREST. Resource studies revealed low economic values, and dominant natural values uncommon within central Alaska; a proposal is made to include parts of the area in the developing Alaska Ecological Reserves System and the US Natural Landmarks program, with continuing BLM management.

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PREFACE

As the Ray Mountains project reaches shore after many months at sea, it is the glad duty of the crew to recognize those who have helped keep it afloat. Many individuals and organizations have lent their support, and we can only hope to recognize a small number of them. Though the responsibility for this final report lies with the contributors and editors, the project study team thanks everyone, whether mentioned here or not, who has helped us along.

Dr. Max Ward, manager of the Student Originated Studies program of the National Science Foundation, has encouraged us from the project's beginning. Private sources, including the Explorers Club, have provided crucial support which enabled us to conduct our research. Our numerous advisors at Middlebury College, The Center for Northern Studies, the University of Alaska, the University of Northern Iowa, and the University of California, Santa Cruz, have been thoughtful and thorough with their attentions. The entire community of Middlebury College -- especially President Olin C. Robison, faculty, administrators, students, Science Center staff, and publications and computer personnel -- provided unlimited logistical, administrative, and technical support. Dr. Steven Rockefeller, Acting Dean of the College, was instrumental in finding our avenue of publication and guiding us along it. Ray Denney, Manager of the Middlebury College Press, was helpful and patient at every stage of a very long process. The Chemistry and Biology Departments kindly allowed our extended use of their facilities.

During the field season, our pilots at Alaska Central Air and Al Wright's Flying Service consistently furnished excellent and patient service. Jim Anderson provided wonderful hospitality when we were most in need. Dr. David Murray, Curator of the University of Alaska Herbarium, graciously arranged essential research and staging quarters for us. Dr. Steven B. Young of The Center for Northern Studies, a key advisor throughout the study, kindly permitted our use of the Center's field equipment.

And as our work drew to a close, some of the contributors were especially helpful in bringing the report together. Pam Matthews returned from California to invest herself in graphics production; Steve Brock, a darkroom magician, thoroughly upgraded our photographic material. Tom Smith was a continuous help throughout the spring and summer.

Our thanks to all who have contributed so much.

N.F. and J.S.
August 1980
Middlebury, Vermont

INTRODUCTION

John Schubert and Ned Farquhar

THE RAY MOUNTAINS PROJECT
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REFERENCES

NOTE

The reader is referred to the Vegetation chapter for definitions of physiographic and ecological terms used consistently throughout this volume. The ECOSYSTEMS referred to herein (in upper case lettering) are described in the Ecosystems chapter of this volume.

THE RAY MOUNTAINS PROJECT

This volume presents the results of the Ray Mountains project, an interdisciplinary environmental inventory of a previously little-studied mountain range in central Alaska (Photo 1).

Project History

Two factors dominated the conception and development of the Ray Mountains project. First, among scientists and land managers there was a recognized lack of basic knowledge of this major mountain range in central Alaska. Second, the project study team sought to conduct interdisciplinary fieldwork in a diverse environment not far from Fairbanks.

The project was conceived during the summer of 1978, when four students of the eventual project study team assisted with interior Alaskan field studies being conducted by The Center for Northern Studies of Wolcott, Vermont (Young et al. 1980, in press). Included in the fieldwork was a three-day excursion into the Kokrines Hills just southwest of the Ray Mountains, which yielded several interesting botanical finds (Kassler, this volume). Soon afterward, aerial reconnaissance of the Ray Mountains revealed an area similar to the Kokrines Hills but more dramatic; from the air we observed a range that included a central area of fairly high, rugged, barren terrain with extensive adjacent areas of rolling tundra, surrounded by typical interior Alaskan boreal forest and lowlands. In Fairbanks at the end of the summer, several scientists and land managers expressed interest in basic environmental research of the Ray Mountains.

Background work for a research proposal continued through the early fall at Middlebury College and the Center for Northern Studies in Vermont, and at the University of California, Santa Cruz (UCSC). The program announcement for the National Science Foundation's (NSF) Student Originated Studies program prompted the selection of more study team members, definition of the program of research, and preparation of the final proposal, which was submitted to NSF in November of 1978. Funding was announced in March of 1979; further monies became available from the Explorer's Club (New York), the UCSC Environmental Field Program, and other private sources. Final background work and preparations for field research continued, mainly in Vermont and Alaska, through mid-June, when the project study team left Fairbanks for the Ray Mountains.

Our program of field study was designed within the constraints of a limited budget, a single field season, and the nearly total independence of the group in the field.

Photo 1. View NW into the Ray Mountains to Mt. Tozi from near McCormick benchmark. Peripheral forest, rolling lowland tundra, and rugged high mountains were included in the study area.

Photo 2. View SSE into the lower Torment Creek valley from adjacent west slope. This section of the Torment Creek drainage, considered representative of the lower elevation tundra and forested portion of the range, was one of the project's three areas of concentrated study and the basecamp location.

The primary concern was to avoid overextension of the research team; thus the goals of the study were to examine closely several small areas of concentrated study in the Ray Mountains which were considered representative of larger areas, and for which large-scale imagery was available; and to observe and comment on larger areas of the Ray Mountains, with only limited sampling of these areas.

Once out of the field, the participants analyzed and described their results for inclusion in this final report of the Ray Mountains project. Funds granted by Middlebury College supported the publication of this volume and its distribution to libraries and individuals, primarily scientists, land managers, and educators, with interest in studies of the far northern environment.

Objectives

The project study team had three general objectives:

> First, to carry out the project safely and sensibly, for the benefit of the participants and other student groups which might later attempt independent research in Alaska.
>
> Second, in accordance with the tenets of the NSF funding program, to learn as much as possible about the students' individual fields of study, the process of interdisciplinary environmental field research, and the logistics of Alaskan fieldwork.
>
> Third, to gather, analyze, and distribute basic environmental information which would be valuable to Alaskan scientists and land managers interested in the Ray Mountains.

Maintaining an integrated approach to field study, data analysis, and documentation was an important element of the final objective. This was done to enhance the component studies, enable ecosystem and resource analysis (Schubert, this volume; Farquhar, this volume), and facilitate cross-referencing results of the chapters of this volume.

Study Team

The research presented in this volume was conducted by twelve students of the far north, most of whom had previously participated in Alaskan field expeditions and/or Northern Studies programs at the Center for Northern Studies and Middlebury College. Members of the project study team were solely responsible for the concept of the study, fund-raising

for it, and its organization, field research, and documentation.

From the beginning of the project the study team was divided into four informal research groups each with two or more component study teams. These groupings and their members were as follows:

Geology, Geomorphology, and Soils: Sarah Roeske, Lisa Senior, Richard Tarlov, and Thomas W. Smith.

Floristics and Vegetation: Trina Kassler, Steven Brock, and Ingrid Burke.

Mammals, Insects, and Birds: Bradford Armstrong, Libby Halpin, and Pam Matthews.

Ecosystems and Resources: John Schubert and Ned Farquhar.

Members of the project study team, in addition to performing their own research tasks, contributed to most phases of the project's planning, execution, and documentation. However, Ned Farquhar served as overall project director, with assistance from Trina Kassler. Steven Brock and Richard Tarlov coordinated photographic work. In the publication phase of the project Pam Matthews and Thomas W. Smith contributed heavily to production of the final report, especially graphics. Ned Farquhar and John Schubert served as editors.

Advisors to the project included Drs. Steven B. Young, Robert N. Starling, and Charles H. Racine of the Center for Northern Studies; Drs. Perry O. Hanson, III, and Robert R. Churchill of Middlebury College; Dr. James C. Walters of the University of Northern Iowa; Dr. David F. Murray of the University of Alaska; and Dr. Richard A. Cooley of the University of California, Santa Cruz. Other faculty, scientists, and individuals of these and other institutions and organizations also provided invaluable advice to the project study team.

Research Design

Presented here is a general description of the research design of the Ray Mountains project; details for each of the component studies are found in their respective chapters of this volume.

At the outset of the project the component study teams, in consultation with their other research group members, developed their own field research priorities based on the objectives of the project and the need for different types of

information about the various abiotic and biotic elements of the environment of the Ray Mountains. The participants then spent several months preparing for the field season, concentrating on literature review and aerial photography and satellite (LANDSAT) imagery review, and establishing contact with Alaskan scientists and land managers about research needs and appropriate methods. Once in Alaska, they made further contacts and continued refining their plans for field study. Aerial reconnaissance prior to entering the field provided an overview of the range, potential areas of concentrated study, and a probable location for the project's basecamp.

In the Ray Mountains all members of the project study team spent at least half of their field-time working in one or more of the three areas of concentrated study, selected as representative of the diverse environments of the Ray Mountains (Fig. 1). The basecamp for the field season (RMP site IIb) was located on lower Torment Creek in the northern foothills of the Ray Mountains (Photo 2). This site proved ideal because of its relative accessibility via float plane into the small lake 1485 approximately 10 km north of basecamp (Photo 3), its proximity to the flightline of US Forest Service large-scale imagery, its diversity of landforms and plant and animal life representative of the lower elevation environments of the range, and its proximity to upper elevation environments in the central Ray Mountains near Mt. Henry Eakin.

The entire project study team gained exposure to much of the Ray Mountains by participating in excursions to other parts of the range (Table 1; Fig. 1; Photo 4). At the beginning of the summer, half of the study team hiked from the Yukon River near the Moose and Roadhouse Creek outlets, across the Ray Mountains by Mt. Tozi and through Spooky Valley, to the basecamp in lower Torment Creek. Meanwhile another group flew into lake 1485, hiked to the basecamp, received several airdrops, constructed the basecamp, and became familiar with the Torment Creek area. The group which set up the basecamp hiked out of the Ray Mountains at the end of the summer, while the others flew out from lake 1485 to Fairbanks. Table 2, in conjunction with Fig. 1, presents the site numbering system by which all contributors to this volume identify locations in the study area.

Data reduction and analysis, further literature research, and writing for this volume were completed between September 1979 and July 1980. Post-field season work by the vegetation study team resulted in a vegetation classification system (Brock and Burke, this volume) easily adapted by the soils, floristics, mammals, birds, insects, and ecosystems study teams for landform association and habitat analysis. Such cooperation among all the component study teams in the field and after insured that results were presented in formats compatible for ecosystem and resource analysis.

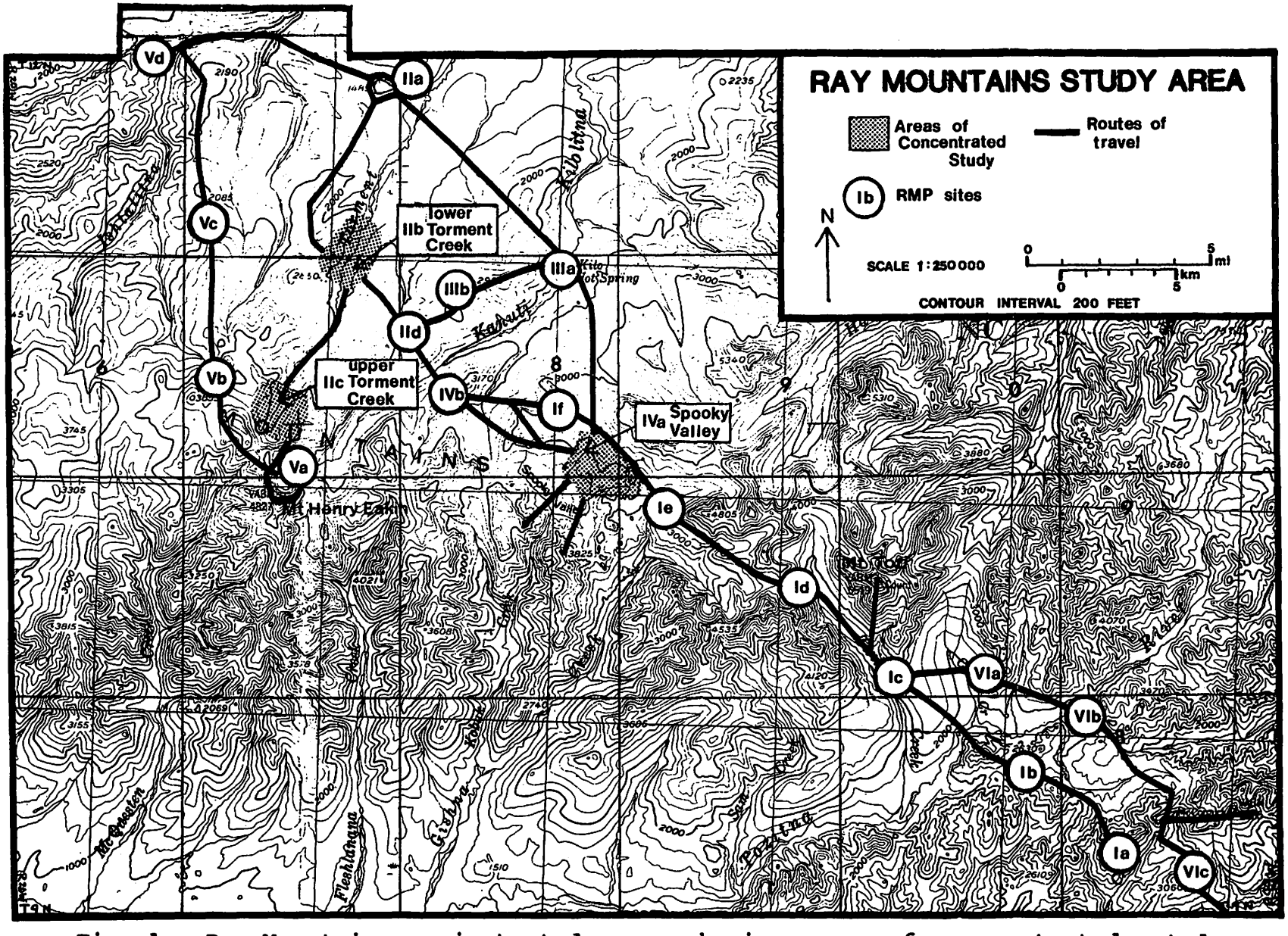

Fig. 1. Ray Mountains project study area showing areas of concentrated study, areas of less concentrated study along routes of travel, and camp locations (RMP sites). The travel routes shown are those hiked by parts, rarely the whole, of the Ray Mountains project study team.

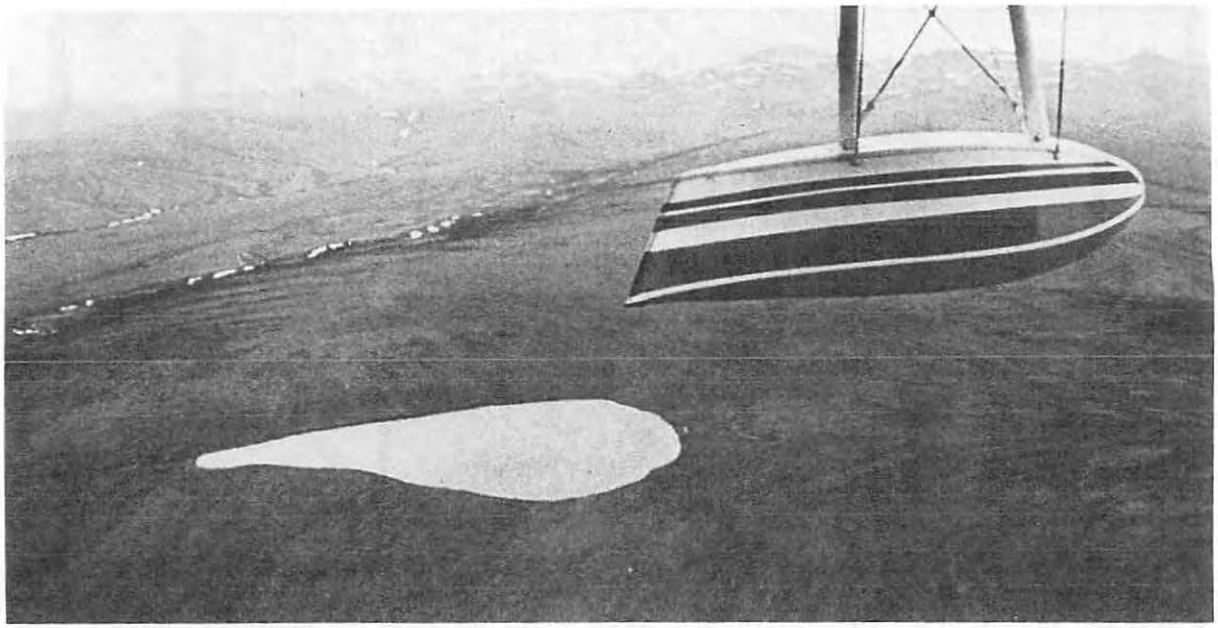

Photo 3. View south over lake 1485 and the lower Torment Creek valley toward the high mountains around Mt. Henry Eakin. The Torment Creek valley included two of the project's three areas of concentrated study.

Photo 4. View north over the broad valley 4 km west of McCormick benchmark. Excursions across the Ray Mountains to and from the Yukon River and to other locations permitted study of varied areas of the range.

Based on only a single summer's study, many of the results presented in this volume are descriptive, and as such can be considered only preliminary. We have presented the most complete discussion of the Ray Mountains' environment that we can, believing that the information will be useful to land managers and scientists.

All measurements in this volume are given in metric units only, with the exception of elevations from standard US Geological Survey (USGS) map contours, for which English and equivalent metric units are given. Except where noted otherwise, all maps included in this volume are adapted from USGS topographic quadrangles.

Table 1. Schedule of field studies away from basecamp. Limit of brackets, [], indicate dates of excursions; X's within brackets indicate two travel days; x's one day. Numbers within parentheses, (), denote number of participants in each excursion.

JUNE			JULY			AUGUST	
20	30	10	20	31	10	20	
[XXXX]	Group hikes into Ray Mountains (6)						
	[XXXX]	To Spooky Valley (6)					
		[XXXx]	To Kilo Hot Spring (4)				
To Upper Torment Creek (3-7) [XXXXx]							
To Mt. Henry Eakin and Ishtalitna R. (7) [XXXXx]							
To Kilo Hot Spring and Spooky Valley (12-6) [XXXXXx]							
			Group hikes out of Ray Mountains (6) [XXXX]				

Table 2. Ray Mountains project (RMP) sites (see Fig. 1). These sites, mostly camp locations, are where most collection, sampling, and observation occurred. They are referred to throughout this volume, sometimes with additional site numbers assigned by component study teams.

RMP site #	Location	Route/Area
Ia	near Moose (1)	
Ib	Tozitna R. trib. nr. McCormick	
Ic	lower Twilight Creek (Mt Tozi)	Hike in
Id	upper Twilight Creek	
Ie	upper Gishna Creek	
If	upper Spooky Valley	
IIa	lake 1485	
IIb	lower Torment Cr. (basecamp)	Torment Creek
IIc	upper Torment Creek	area
IId	ridge E of lwr. Torment Cr. (2)	
IIIa	Kilo Hot Spring	Kilo Hot
IIIb	ridge W of Kilo Hot Spring (2)	Spring area
IVa	Spooky Valley (upr. Kobuk Cr.)	Hike to
IVb	Kanuti Kilolitna R. trib.	Spooky Valley
Va	Mt. Henry Eakin tarn	
Vb	above upper Torment Cr.	Hike to
Vc	upper Ishtalitna Creek	Ishtalitna Cr.
Vd	lower Ishtalitna Creek	
VIa	Crash Creek	
VIb	Tozitna River	Hike out (3)
VIc	upper Moose Creek	

(1) US Geological Survey benchmark.
(2) RMP sites that were not camps.
(3) Additional camps same as hike in.

Fieldwork

Most of the Ray Mountains project study team spent approximately eight weeks in the study area between 20 June and 16 August 1979. During this time study was concentrated in three areas; additional data were gathered during excursions among these areas and to other parts of the range (Fig. 1). The data collection by each of the component study teams focused on determination of which species, communities, and physical features were present in the study area; the relative importance of each; and the habitat affinities or landform associations of each.

Areas of Concentrated Study

Areas of concentrated study were selected for their representativeness of widespread environments of the Ray Mountains. Within them, detailed sampling and description were generally concentrated within small areas approximately 25-200 hectares, according to the needs of the component study teams. Less detailed analysis was applied to larger nearby areas.

Lower Torment Creek (Photo 2-3). In lower Torment Creek near the field basecamp (RMP site IIb), detailed investigations were conducted throughout the summer by each of the component study teams. Sampling and description were concentrated within two photo areas 1 x 1.1 km (110 hectares) pictured in US Forest Service large-scale (1:5,000) near infra-red black and white aerial photographs.

Situated between 488-792 m (1600-2600 ft) and comprising a broad valley with rounded ridges, the lower Torment Creek area is representative of lower elevation environments of the north slope of the Ray Mountains. North-flowing Torment Creek and its small floodplain bisect the valley, underlain by schist bedrock. Ice-rich permafrost is deep or absent beneath the floodplain and continuous at 25-50 cm elsewhere. The area encompasses forest limit and treeline; the vegetation includes a variety of predominantly open evergreen and mixed boreal forest types on the lower floodplain of Torment Creek and adjacent steep west slope, tall and medium scrubs along the upper portion of the floodplain and at treeline, and tussock-graminoid meadows and dwarf scrub - tussock-graminoid meadows on the gentle slopes and ridgetops. The area is considered BOREAL FOREST and LOWLAND TUNDRA.

Upper Torment Creek (Photo 5). A camp (RMP site IIc) was maintained near the headwaters of Torment Creek from 22-30 July, primarily for coordinated ecosystem study (Schubert, this volume). Sampling and description were concentrated along a ridge-to-ridge transect roughly 50 x 3100 m. The upper Torment Creek watershed, situated between 702-1311 m (2300-4300ft) elevation and of small size (approximately 830

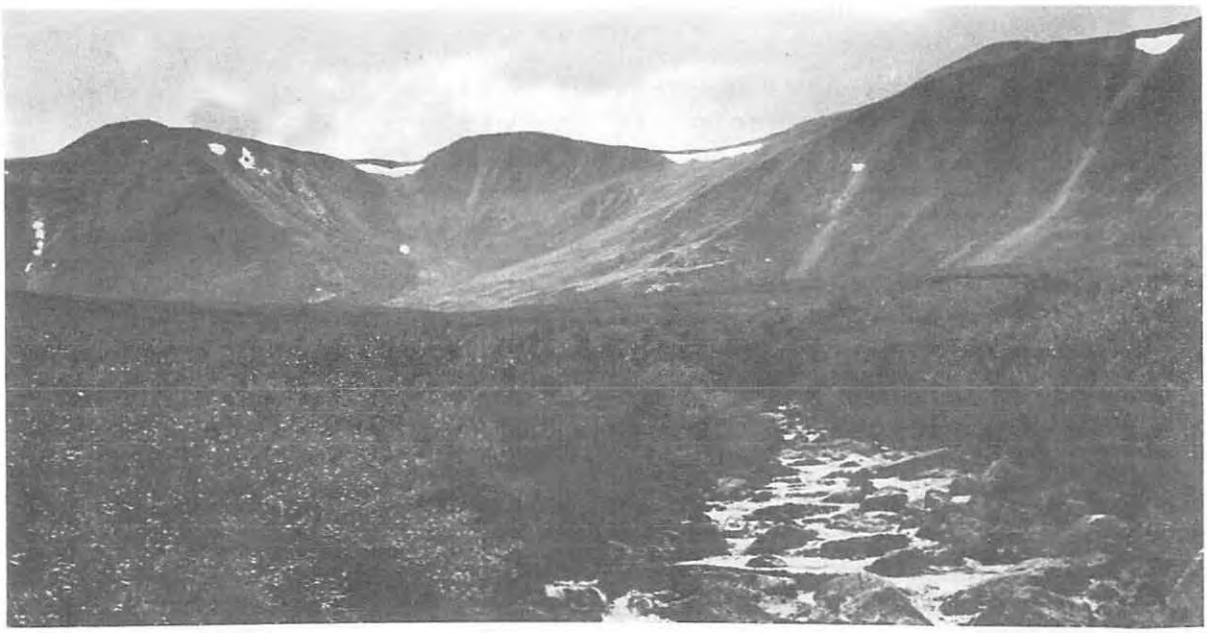

Photo 5. View south to the headwall of upper Torment Creek. Considered representative of the upper elevation tundra and barren portion of the range, this section of the Torment Creek drainage was one of the project's three areas of concentrated study.

Photo 6. View SW over Spooky Valley from the NE rim. This unusually broad, bowl-like valley, considered representative of the upper elevation tundra and barren portion of the range, was one of the project's three areas of concentrated study.

hectares) includes a variety of typical Ray Mountains upper elevation environments.

The area, underlain by granite and gneiss bedrock, is a narrow valley head with fairly steep east- and west-facing side slopes (5-15 degrees) and a steep north-facing headwall (10-40 degrees). Ice-rich permafrost is present at 50-75 cm only on the gentle lower valley side slopes; permafrost is below the bedrock surface elsewhere. The vegetation of the area, from valley bottom to ridgetop, generally grades from medium scrubs to dwarf and prostrate scrubs, to barrens. The area includes both UPLAND TUNDRA and ALPINE BARREN.

Spooky Valley (Photo 6). Detailed investigations of Spooky Valley (RMP site IVa) were carried out by component study teams from 7-11 July and 7-10 August. Sampling and description were concentrated in one photo area near the headwaters of the central fork of SSW-flowing Kobuk Creek.

Spooky Valley, elevation 701-1402 m (2300-4600 ft) is an unusually broad valley, representative of upper elevation Ray Mountains' environments. Underlain by granite bedrock, it is rimmed by rugged tor-studded ridges. The vegetation and ecosystems are similar to upper Torment Creek, described above.

Areas of Less Concentrated Study

Up to one-half of each component study team's field season was spent on excursions away from the areas of concentrated study to observe and describe, with less sampling, as wide a variety of Ray Mountains environments as possible (Table 1; Fig. 1; Photo 7). These excursions included the hikes in and out across the range passing by Mt. Tozi (Photo 8), and visits to Mt. Henry Eakin (Photo 9), the Ishtalitna Creek valley, and Kilo Hot Spring (Photo 10). The data gathered on these trips aided assessment of the areal extent of important species, vegetation types, soils, and other features of the range studied in more detail in the areas of concentrated study. Features uncommon in the range such as hot springs (RMP sites IIIa and Vd), recent wildfire sites (RMP sites IVb and Vd), and high mountain summits (RMP sites Ic and Va) were also visited during these excursions to assess the diversity of the range. To a lesser extent, aerial reconnaissance also provided useful overviews of the entire mountain range.

Photo 7. Data were collected along routes of travel in a variety of areas throughout the Ray Mountains.

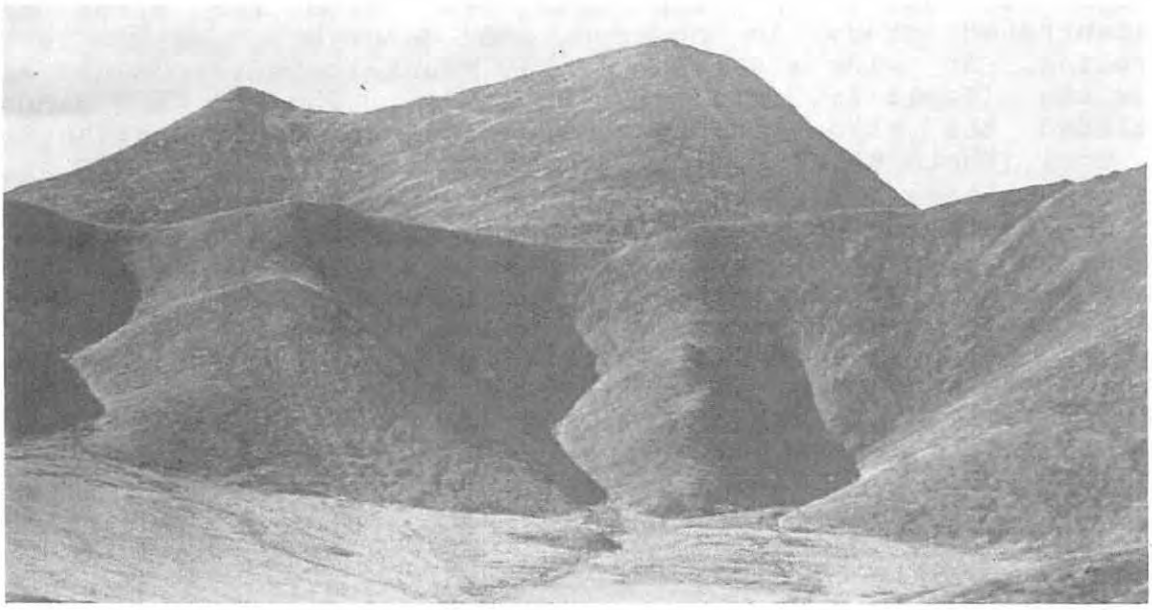

Photo 8. View NW to Mt. Tozi from Crash Creek. At 1682 m (5519 ft), Mt. Tozi is the highest peak in the range.

Photo 9. View south to Mt. Henry Eakin headwall. The classic cirque, tarn, arrete, and moraines are evidence of the late Pleistocene glaciation that occurred in the highest portions of the Ray Mountains.

Photo 10. Kilo Hot Spring outlet and adjacent eastern ridge. The Kilo area was among several areas of less concentrated study which parts of the study team visited.

OVERVIEW OF THE RAY MOUNTAINS ENVIRONMENT

The Ray Mountains (Fig. 1-2; Photo 1) are located in the heart of interior Alaska approximately 240 km northwest of Fairbanks and 80 km south of the Arctic Circle at 65 45′ N, 151 W. Lying between the Yukon and Koyukuk Rivers and considered to be delimited by the 1000 ft (305 m) contour, the range is roughly 40 x 120 km (approximately 4600 sq km) and trends nearly east to west. The terrain of the range is diverse, and though most of the area is between 457-1219 m (1500-4000 ft), several peaks exceed 1544 m (5000 ft). The highest peak in the Ray Mountains is Mt. Tozi (Photo 8) at 1682 m (5519 ft). The range is almost surrounded by the broad alluviated lowlands of the Tozitna, Melozitna, Kanuti, and Ray Rivers, which drain the south and southwest, west, north, and northeast portions of the range. The Ramparts of the Yukon River (Gordon and Shaine 1978) and the Rampart Trough (Wahrhaftig 1965) truncate the east and southeast ends of the range. The Ray Mountains are a physiographic and ecological island of diverse subarctic tundra ecosystems within the taiga that dominates central Alaska (Schubert, this volume). This Ray Mountains island includes roughly the contiguous area above treeline [generally near 610 m (2000 ft)], as well as the forested floodplains and their adjacent forested slopes that finger into the range. This area, approximately 3100 sq km, is clear on the US Geological Survey (USGS) 1:250,000 Tanana, Alaska Topographic Series green-shaded quadrangle (1976).

Previous Study

Prior to the Ray Mountains project the only known field studies in the range were those by the USGS in 1912-1913 (Eakin 1916) and 1970 (Yeend 1971; Chapman et al. 1975), and the the US Bureau of Land Management (BLM) in the spring of 1979 (Kato and Murray, pers. comm.). Other than Eakin's general comments on the biota of the Ray Mountains, these studies describe only the geology of the range. Several other authors have given brief descriptions of the Ray Mountains (for example, Wahrhaftig 1965; Gordon and Shaine 1978), but their descriptions appear to be based on earlier accounts and/or aerial reconnaissance.

Climate and Summary of Summer 1979 Weather

The Ray Mountains lie within a zone dominated by continental climate (Searby 1968, in Hartman and Johnson 1978) and experience long cold winters and short relatively mild summers, weather similar to that which prevails throughout much of interior Alaska (Eakin 1916). The mean annual temperature for the area is approximately -5 C (Hartman and

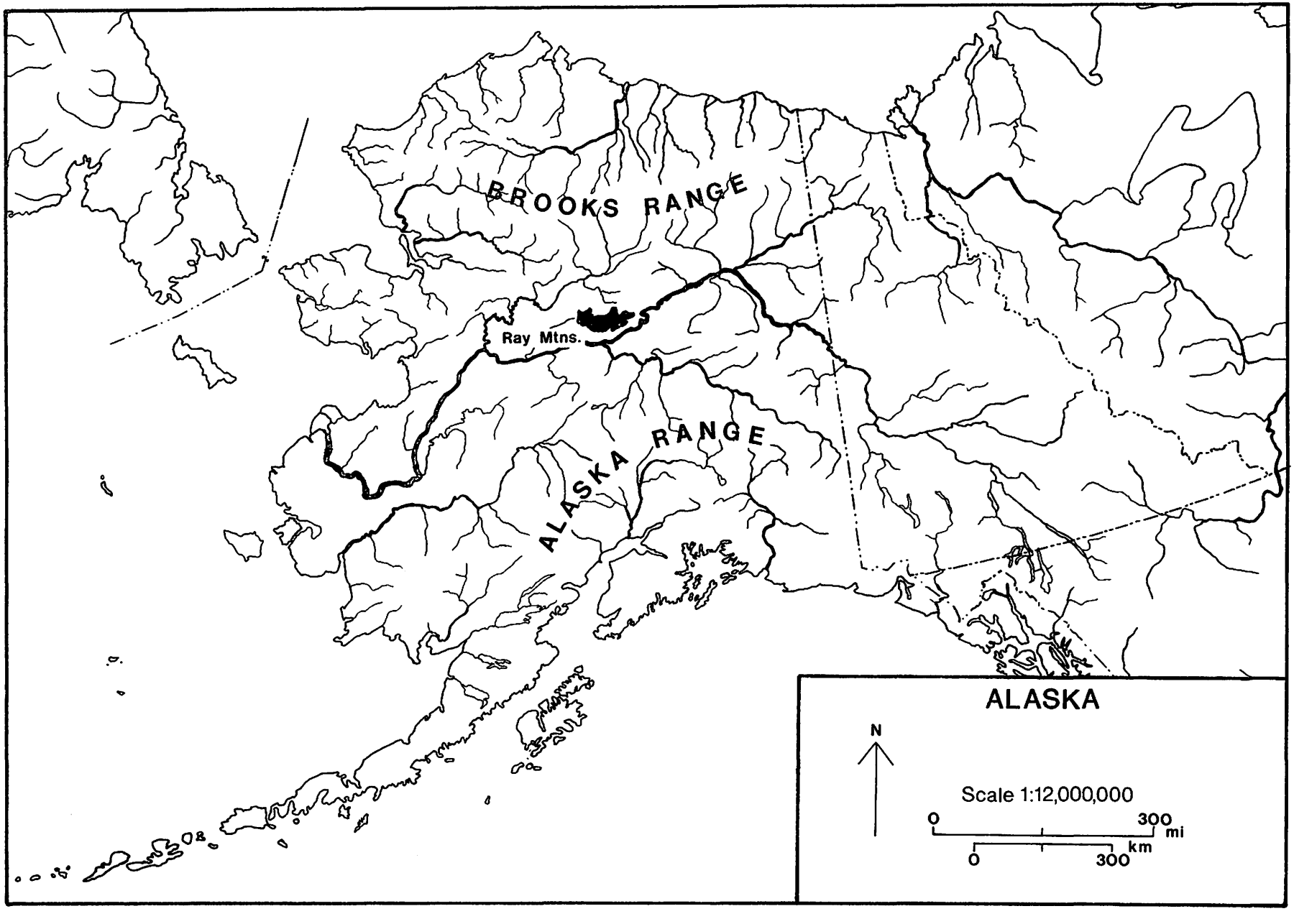

Fig. 2. The Ray Mountains are located in central Alaska approximately midway between the Brooks and Alaska Ranges.

Johnson 1978). The village of Rampart at 114 m elevation on the Yukon River is the nearest weather station; there, total precipitation averages 25 cm, including 125 cm of snow (Selkregg 1975). Summer high and low temperatures there average 22 and 3 C; winter high and low temperatures average -6 and -30 C (Selkregg 1975).

Statewide precipitation maps (Hartman and Johnson 1978) show that the higher portion of the Ray Mountains receives >51 cm of precipitation each year, which includes >254 cm of snowfall. Our fieldwork and extrapolation from Viereck (1973) indicate that snow probably covers the ground in the range from mid-October to mid- or late May.

Our weather observations from the Ray Mountains indicate that weather patterns for the range are changeable, and are variable within the range. A low temperature of -1.5 C was recorded on 7 July in lower Torment Creek (RMP site IIb), when new snow was visible in the higher peaks to the east. By mid-July temperatures rose considerably, and the rainy and overcast weather patterns of the previous three weeks ended; daily high temperatures in late July and early August often reached 30 C. Rain, which was not measured, was unpredictable from regular weather patterns. Before mid-July, rainstorms were blustery, cold, hard, and lengthy; later they became a less frequent, mostly afternoon phenomenon. Winds were usually mild (8-12 km/h) though a peak wind of around 90 km/h was estimated during a rainstorm in early July. Winds were predominantly from the southwest, though wind scour of ridges and trees indicates mostly northeasterly winter wind patterns. Rome (pers. comm.) reported that snow usually accumulates along valley floors after being blown from ridges by very strong winter winds.

Physiography

The Ray Mountains are situated between the Brooks and Alaska Ranges. This region between Alaska's two major mountain systems is the northernmost extension of the major North American physiographic division known as the Intermontane Plateaus; within Alaska this includes two subdivisions, the Western Alaska and Northern Plateaus physiographic provinces (Fenneman et al. 1946 in Wahrhaftig 1965). At the western end of the Northern Plateaus province lies the Kokrines-Hodzana Highlands physiographic section of which the Ray Mountains are the central part (Wahrhaftig 1965). The Highlands consist of rounded ridges rising to 610-1219 m (2000-4000 ft) with intervening alluviated valley floors; this rolling terrain is surmounted by three isolated areas of more rugged mountains of which the Ray Mountains are the central one. Nearly all the Kokrines-Hodzana Highlands physiographic section is surrounded by broad alluviated lowlands, as are the Ray Mountains on the more local scale

described above.

Bedrock and Surficial Geology

Although the number of bedrock types in the Ray Mountains is small, their structure and history are quite complex (Roeske and Senior, this volume). The high central and western portions of the range are massive granitic intrusions surrounded successively by gneisses and schists (Chapman et al. 1975; Eakin 1916). Deformed sediments of the Paleozoic era, the schists are the country rock into which the igneous granite was intruded during the Cretaceous period. The gneisses appear to be derived primarily from the intruded magma and show evidence of considerable shearing (Roeske and Senior, this volume). Significantly different from the rest of the range, the eastern portion is predominantly mafic and ultramafic rocks mostly of permian volcanic origin intermixed with marine sediments of the same age.

Almost the entire range is mantled with Quaternary and older surficial deposits (Eakin 1916; Chapman et al. 1975) which make actual bedrock outcrops scarce. The extraordinary abundance of colluvial and alluvial material is primarily due to the fracturing of bedrock by the active freeze-thaw cycles characteristic of subarctic periglacial climates. On steep slopes, most commonly at upper elevations, colluvium, from large boulders to fine scree, is present and usually actively moving downslope. On high ridges this material is usually more weathered, though only rarely enough to provide the gravelly substrate necessary for fellfield development. On gentler slopes the colluvium is covered with vegetation, considerably reducing the rate of downslope movement.

Important, but of less significance than the widespread colluvium, is the alluvial material found on the lower elevation floodplains of the larger streams (Chapman et al. 1975). Glacial till deposits, mostly moraines, are fairly common in the range, though mostly limited to the highest valleys where local glaciation was concentrated during the late Pleistocene (Yeend 1971).

Geomorphology

The diverse landscape of the Ray Mountains is primarily the result of three major forces acting on its various bedrock types: periglacial processes, stream erosion, and recent glaciation (Tarlov with others, this volume). Variation in the resistance of different bedrock types to weathering and erosion (predominantly periglacial and fluvial) has probably exerted the greatest influence on the gross morphology of the range. Where glaciation has scoured the resistant granite and gneiss bedrock of the high central part of the Ray Mountains,

the topography is very rugged. Where unglaciated, in the slightly lower elevation western part of the range, this same bedrock underlies more rolling terrain.

The rugged south slope and eastern portions of the range are dissected by deeply incised streams -- the south slope because of its resistant granite and gneiss bedrock, and the eastern portion of the range perhaps because of structural influences of its less resistant bedrock (Roeske, pers. comm.). In both of these areas there is generally an abrupt transition from the steep valley sides to nearly flat valley floors. The broad north slope of the Ray Mountains, underlain by less resistant schists, has a rolling landscape of smooth-topped ridges and gentle slopes merging into floodplain-floored valley bottoms where fluvial processes are active.

Tors, pinnacles of unjointed granite up to 30 m high, mark extensive upland areas of the range, usually near ridgelines. Though limited to the highest parts of the range around Mt. Tozi and Mt. Henry Eakin, late Pleistocene glaciers sculpted a rugged landscape of cirques, arretes, horns, and U-shaped valleys (Yeend 1971).

Periglacial Features

As mentioned in the discussion of surficial geology, periglacial mass wasting is a vitally important force in the Ray Mountains. Thus, a mantle of frost-shattered debris covers virtually every part of the range except the steepest glacially scoured cirque headwalls. Other periglacial processes have further worked this material into a variety of periglacial features characteristic of subarctic alpine environments. Solifluction occurs on gentle slopes at mid- to lower elevations where permafrost is present beneath insulating vegetation and fine-grained saturated surficial material. Lobes 0.5-10 m have developed in many areas, with larger lobes usually at higher elevations.

At higher elevations where vegetation is sparser and freeze-thaw cycles are more vigorous, numerous striking periglacial features such as altiplanation terraces, rock polygons, stone stripes, and other frost-sorted features are common (Eakin 1916; Wahrhaftig 1965). Nivation hollows are also common at upper elevations, though they are of minor areal extent.

Soils and Permafrost

The diverse periglacial landscape of the Ray Mountains has led to the development of a variety of soil types (Rieger et al. 1979; Smith, this volume). In Selkregg (1975) the

range is shown underlain by discontinuous permafrost, though Ferrians (1965, in Hartman and Johnson 1978) shows the range "generally underlain by continuous permafrost." In the high rugged portion of the range where frost-shattering of bedrock and downslope mass wasting are common, little or no soil is present. At upper elevations where rock material is more highly weathered and somewhat less active, Lithic Cryorthents (shallow coarse well drained soils) and Pergelic Cryorthents (deeper coarse well drained soils) predominate. In areas such as these, where substrate is well drained and insulating vegetation is sparse or absent, permafrost is seldom above the bedrock surface, though the mean annual temperature is <0 C (Rieger et al. 1979).

Pergelic Cryaquepts (fine-grained poorly drained gray-brown soils) and Pergelic Cryochrepts (coarse well drained brown soils) are common in alluviated valley bottoms and on adjacent gentle slopes, as well as on benches at upper elevations. These soils are fairly well insulated by continuous vegetation cover and a thin organic layer, and thus the active layer above ice-rich permafrost is shallow (30-75 cm). Permafrost is probably absent beneath the floodplains of the larger streams in the range. Though of limited extent a variety of other soils are also found in the range.

Flora and Vegetation

The flora of the Ray Mountains includes at least 227 vascular plant species which are a mix of arctic, alpine, and boreal species (Kassler, this volume).

The vegetation of the range includes at least 30 vegetation types of alpine and low arctic tundra and boreal forest (Brock and Burke, this volume). On low-elevation floodplains of major streams and their adjacent slopes, predominantly open evergreen, deciduous, and mixed forests are present. Treeline is most commonly near 610 m (2000 ft), but varies between 457-762 m (1500-2500 ft). At these elevations floodplain forests give way to tall willow or alder scrubs; at still higher elevations along drainageways medium willow scrubs dominate. Over the rolling lowlands of the range, tussock-graminoid meadows and dwarf scrub - tussock-graminoid meadows are dominant. In the higher valleys, dwarf scrubs are the most important vegetation types and in the highest portions of the range prostrate scrubs and barrens predominate.

Mammals, Birds, and Insects

At least 17 species of mammals inhabit the Ray Mountains (Armstrong and Halpin, this volume). Important species in the

upper areas of the range include Alaska marmot, arctic ground squirrel, grizzly bear, caribou, and ermine. Those important in the lower areas include moose, black bear, northern red-backed vole, and red squirrel.

At least 55 species of birds occur in the Ray Mountains, of which 39 are thought to breed in the range (Matthews, this volume). Important species in the higher areas of the range include the Water Pipit, Wheatear, Gray-crowned Rosy Finch, Lapland Longspur, Rock Ptarmigan, Golden Eagle, Least Sandpiper, American Golden Plover, Whimbrel, Long-tailed Jaeger, Marsh Hawk, and Gyrfalcon. Those species important in the lower areas include Savannah Sparrow, Tree Sparrow, White-crowned Sparrow, American Robin, Common Redpoll, Upland Sandpiper, Willow Ptarmigan, Boreal Chickadee, Wilson's Warbler, Yellow-rumped Warbler, Ruby-crowned Kinglet, and Dark-eyed Junco.

At least 174 insect species occur in the range (Halpin, this volume).

Ecosystems, Resources, and Human Use

The Ray Mountains encompass a diverse array of montane landscapes and include a variety of subarctic tundra ecosystems which are fringed at lower elevation by boreal forest ecosystems.

The central part of the Ray Mountains has remained virtually untouched by any human development, partly because economic values are very low. Most known uses of the study area have related to occasional scientific research, although a hot springs lease for limited commercial development has recently been issued to the only landusers in the study area, at Kilo Hot Spring.

Surrounding areas are among state and Native land selections, though the study area remains undesignated public land under BLM jurisdiction.

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GEOLOGY

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ABSTRACT

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- Regional Geologic Setting
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APPENDIX -- Descriptions of TrPv Unit

NOTE

The reader is referred to the Introduction of this volume for detailed descriptions of the project study area and the overall project research design. Also included there are descriptions of the project's three areas of concentrated study, with a map showing their locations and the locations of travel routes and Ray Mountains project sites (RMP sites Ia-VId) referred to in this chapter.

ABSTRACT

The geology of the Ray Mountains was investigated to provide reconnaissance descriptions and locally detailed descriptions of the bedrock geology. The area had been previously mapped on a preliminary basis at the scale of 1:250,000.

The country rock of the region is an Early Paleozoic metasediment, predominantly quartz-mica schist but including calcareous schist and cataclastic augen gneiss. Many of the samples collected contained large pebbles of quartz and feldspar, indicating the source of the original sediments was probably a nearby continental igneous and metamorphic complex. This rock experienced greenschist facies metamorphism and shallow level deformation in the Paleozic-Mesozoic.

The main body of the higher Ray Mountains is coarse-grained intrusives with compositions ranging from quartz-monzonite to granite. A K/Ar age for a sample from Mt. Tozi of 104 my indicates cooling during the Cretaceous. Similar plutons in central Alaska have been divided into two separate age groups, Cretaceous, and Late Eocene to Paleocene. The plutons in the Ray Mountains may also be divided into two distinct age groups since some have experienced regional deformation and others appear not to have. The margins of the Ray Mountains plutons which are deformed, have been brittly and thermally metamorphosed to augen gneiss and hornfels.

An ultramafic basalt-serpentinite-chert melange in the eastern portion of the range was dated as Pennsylvanian-Permian by radiolaria in the chert. A possible fault trending northeast forms the contact between the melange sequence and the schist-pluton terrane. Little deformation has occurred within the melange rocks but the varying rock types must have been sliced together to result in their present positions.

Two small and two medium-sized hot springs have been found associated with the granitic plutons. The larger ones have temperatures of 51 and 60 C. No economic mineral deposits have been found in the Ray Mountains.

INTRODUCTION

Little detailed information is available on the geology of the Ray Mountains, previous work having been solely reconnaissance. Prior to our study of the range the only geologic reports about the area were from two US Geological Survey (USGS) studies. Eakin, who led a party into the mountains by foot with packhorses in the summer of 1913, produced a fairly comprehensive report (1916) describing bedrock and surficial geology. Nearly 60 years later, Chapman and Yeend, with the use of helicopter support, continued studies of geology to produce a preliminary USGS geologic map of the Tanana quadrangle (Chapman et al. 1975) and an article on glacial geology in the range (Yeend 1971). Such is the extent of open literature dealing specifically with the Ray Mountains. Bureau of Land Management (BLM) geologists investigated the range for mineral potential in the spring of 1979.

Because the Ray Mountains consist mostly of large granitic batholiths, economic minerals associated with the intrusions might be expected. However, to date, no significant deposits have been found in the Ray Mountains (Eakin 1916; Murray, pers. comm.) although mining for tin has occurred in similar intrusive bodies of the region (Patton and Miller 1970). Also associated with the Ray Mountains granitic intrusions and other intrusions in the region are numerous small hot springs, located near the contact of the intrusions with the country rock. In Alaska, such hot springs are regarded as potential sources of geothermal energy (Forbes et al. 1975).

Objectives

The main objective of our study was to sample or describe all rock types observed to develop a more detailed and accurate geologic map of the Ray Mountains than is presently available as part of the USGS Tanana quadrangle reconnaissance geologic map (Chapman et al. 1975). Such study should assist with efforts to reconstruct the geologic past of interior Alaska.

Secondary objectives were to examine economic geologic resources of the range and generally provide geologic information useful to the other component study teams of the project.

Regional Geologic Setting

According to the geologic maps compiled by Chapman et al. (1975), and Patton et al. (1977) and those compiled for

the Yukon Regional Profile (Selkregg 1975), the granites of the Ray Mountains belong to a series of granitic plutons within the Kokrines-Hodzana Highlands (Wahrhaftig 1965) that trend NE-SW in central Alaska (Fig. 1). The Highlands are part of a larger structure, also trending NE-SW, called the Ruby geanticline (Payne 1955). The geanticline consists of Precambrian to Paleozoic sediments deformed during the Mesozoic, an era of metamorphism, deformation, and mountain building throughout Alaska. The granites that make up much of the present-day Ray Mountains intruded the Paleozoic metasediment country rock throughout the Mesozoic. A granite sample collected from Mt. Tozi has been potassium/argon dated as 104 my (Chapman, pers. comm.). Intrusions of similar age and composition outcrop in other areas of the Ruby geanticline.

The southeast portion of the Ray Mountains include mafic and ultramafic rocks, largely metadiabases and metabasalts, associated with marine sediments such as shale, limestone and chert, dated from fossil radiolaria as Permian in age (Chapman, pers. comm.). Thirty km to the northwest of the Ray Mountains lie other mafic and ultramafic rocks such as peridotites and layered gabbro which have been perceived as part of an ophiolite assemblage (Patton et al. 1977). Flanking the Ruby geanticline on the southeast is the Rampart ophiolite belt (Permian in age) and on the northwest the Yukon - Koyukuk ophiolite belt (150 my old?), both in supposed fault contact with the neighboring rocks. Mertie (1937) and Foster et al. (1979) noted that the Tintina Fault, which runs through east-central Alaska, has divided the Rampart region into two metamorphically different terranes. The rocks in the southeast portion of the Ray Mountains are thought to belong to the Rampart ophiolite belt, and have undergone less deformation than other rocks of the Rampart region to the south of the Tintina fault.

Interior Alaska is cut extensively by faults which separate and offset geologic terranes. The Tintina fault is recognized as the eastern extension of the Kaltag fault, a major fault running roughly parallel with the Yukon River across most of interior Alaska. The Kaltag fault cuts just south of the Ray Mountains, offsetting the Ruby geanticline as well as the ophiolite belts flanking the geanticline.

Previous Work

Eakin (1916) recognized at least two generations of granites in the Ray Mountains and areas west of the range. He referred to the granitic rocks that form most of the Ray Mountains as older granite, distinguishable by deformed margins and a somewhat composite nature. These older plutons were thought to have intruded Paleozoic schists during the Late Paleozoic or Early Mesozoic and to have been subjected to

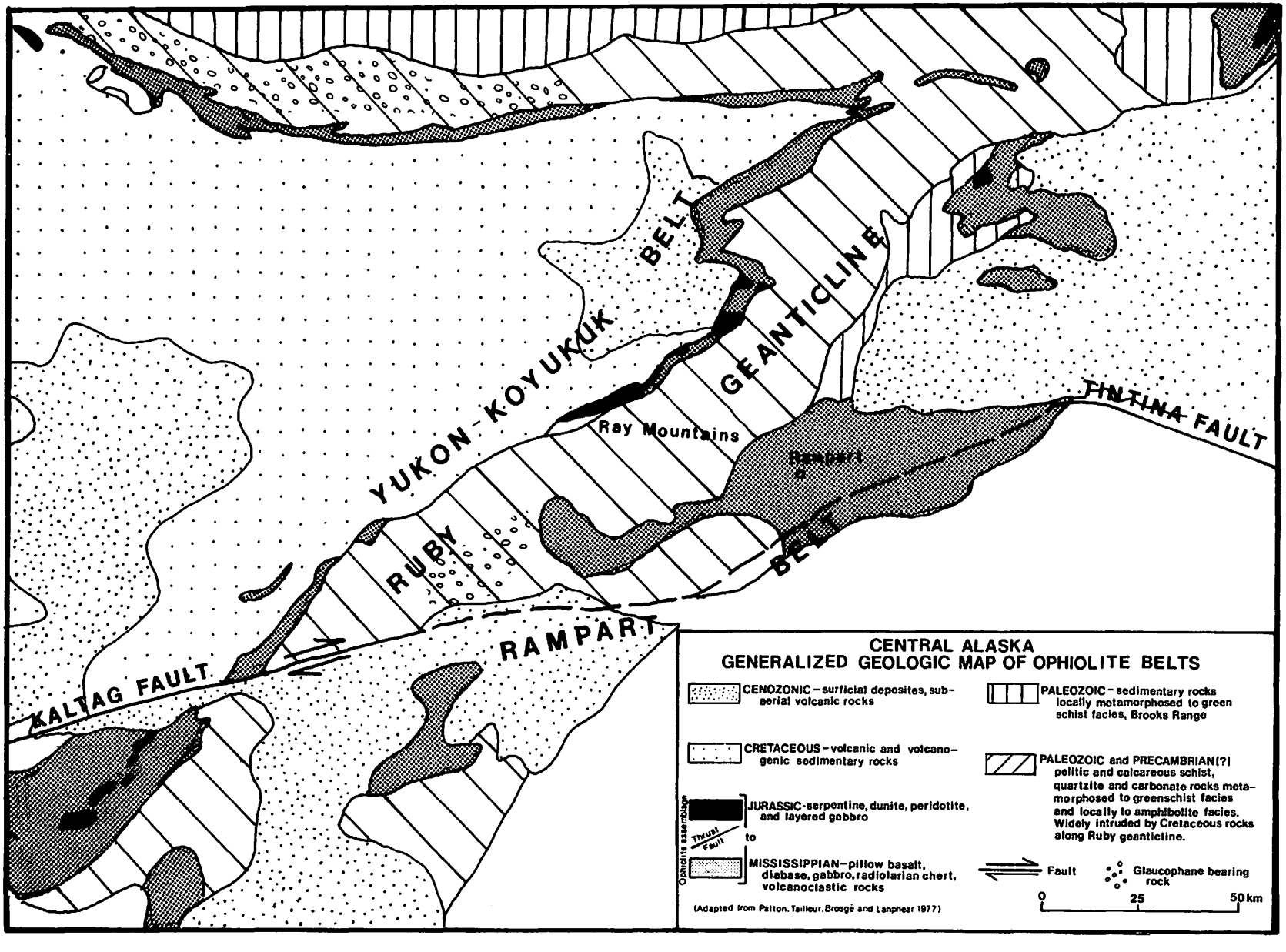

Fig. 1. Generalized geologic map of ophiolite belts in central Alaska.

regional stresses at that time. The younger granites, which Eakin mapped to the west of the Ray Mountains, lack deformed margins and cut rocks dated as young as Cretaceous in age. Granites of two ages have been noted southeast of the Ray Mountains in the Big Delta Quadrangle immediately east of Fairbanks (Foster et al. 1979), supporting the idea that intrusions occurred episodically in the same general region.

Granite from Mt. Tozi has been potassium-argon dated as 104 my, or Cretaceous (Chapman, pers. comm.). As Eakin (1916) noted, intrusive activity was probably continuous over a span of time, and granitic intrusions in the Ray Mountains could have continued from the Late Paleozoic through the Cretaceous. Thus some of the granite may be "old", recording regional deformation, and other granites "young", having emerged after deformation. Chapman et al. (1975) placed a Cretaceous age on all of the Ray Mountains granite, but did not discuss the significance of the gneissic character exhibited in the contact zone, peripheral to the granitic plutons. Some regional deformation seems to have been involved in the formation of the gneissic fabric of the zone of contact between the plutons and country rock, indicating the plutons were emplaced before deformation (Eakin 1916). Deformation in interior Alaska is thought to have occurred during the Mesozoic, although that deformation could conceivably have continued through the Cretaceous.

Although Eakin (1916) and Chapman et al. (1975) mapped and noted the greenstones, or TrPv unit (Fig. 2), southeast of the easternmost granitic pluton of the Ray Mountains, the tectonic relation of ultramafic, mafic, and chert sequence to the granitic plutons or the country rock was not discussed. Later work by Patton et al. (1977) suggests that the unit in question may be part of a dismembered ophiolite sequence.

METHODS

We studied in detail the upper Torment Creek (RMP site IIc) and Mt. Henry Eakin (RMP site Va) areas. There we focused on determining the origin of the gneissic contact zones between the granitic intrusions and the quartz-mica schist country rock of the region.

We also sampled in detail the volcanic and gabbroic suite of rocks in the southeast portion of the study area to examine its role in the tectonic evolution of the region.

Additional reconnaissance sampling and study of rocks were conducted during excursions to Spooky Valley (RMP site IVa), Kilo Hot Spring (RMP site IIIa), and the Ishtalitna Creek valley (RMP sites Vb-d), as well as along our

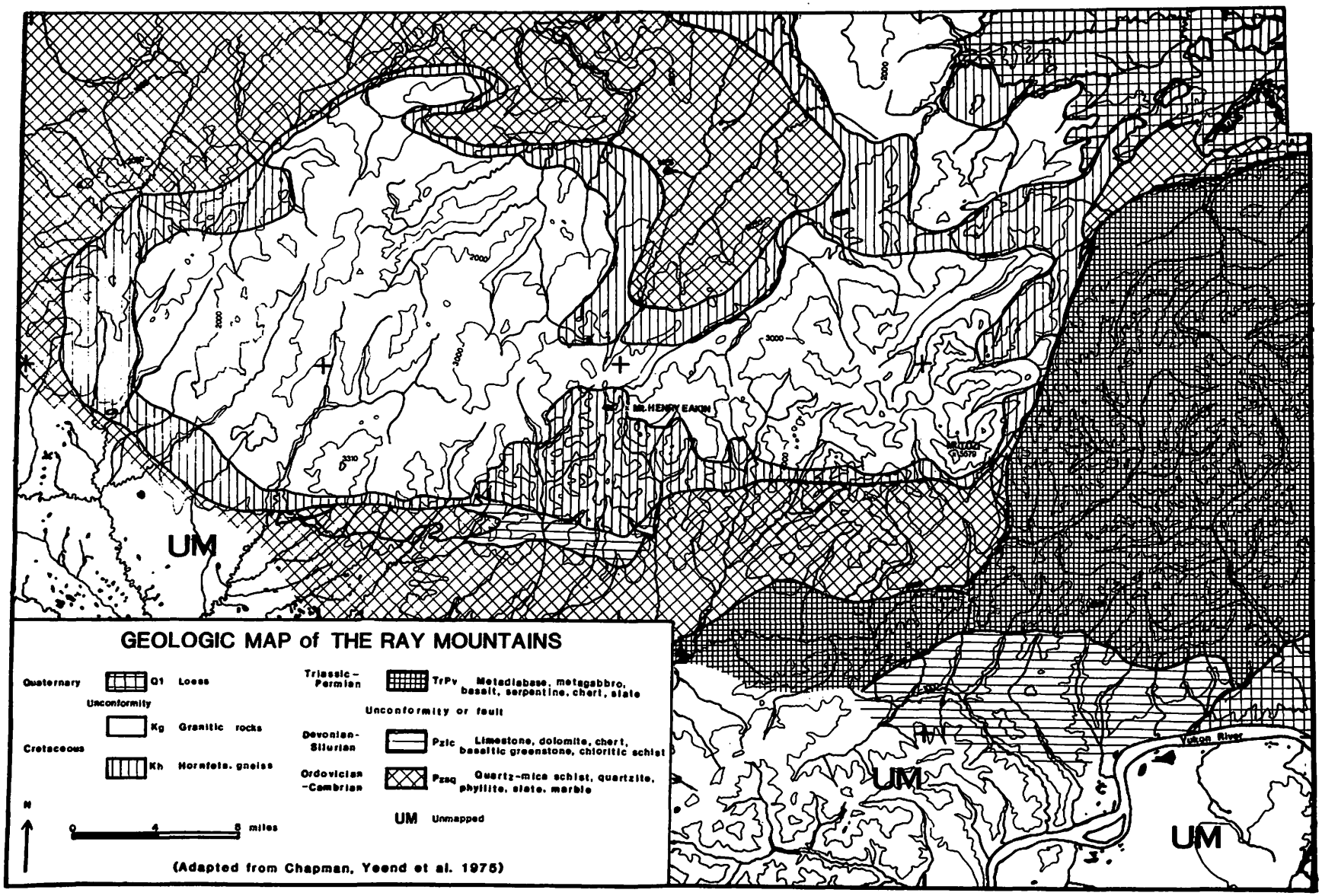

Fig. 2. Geologic map of the Ray Mountains.

hiking routes to and from the Yukon River (see Introduction, this volume.) The sample locations (sites) referred to in the text of this chapter are shown in Fig. 3-4.

Field data were augmented by analysis of 28 thin sections; literature review improved our knowledge of the geologic history of the region.

Determination of Map Contacts

Detailed geologic mapping in the Ray Mountains is difficult due to the scarcity of good outcrops. Soil and vegetation cover most of the bedrock at the lower elevations and in the higher mountains loose boulders and smaller debris, fractured from the bedrock by the intense frost action, mantle much of the bedrock. Solifluction is an ongoing process which moves rock fragments downslope as far as a mile. To minimize these problems, sampling was done mostly on ridge crests. On slopes we mapped the contact of a downslope unit at the location of loose boulders of that unit found farthest upslope. In the glaciated area of Mt. Henry Eakin (RMP site Va) we used a similar technique; because the glacier had flowed north from the cirque, we mapped the southern contact of granite where we saw granitic boulders farthest south.

Our most detailed sampling of the contact between the Kg and Kh units was done in the upper Torment Creek and Mt. Henry Eakin areas (Fig. 3). Samples from sites 28e1-28e5 were taken along a 200 m transect perpendicular to the contact, on a ten degree slope about 200 m below the ridgetop. These samples should reflect any trends in the bedrock of the ridge. However, all of these samples were loose rock and may have been transported by solifluction, and thus such a detailed study may not be indicative of the actual transitions which occur between the granite and the gneiss.

Anomalous samples leave some of the other mapped contacts open to question. In the upper Gishna Creek valley (RMP site Ie) an altered basalt sample from site 48 seems completely anomalous based on the present map (Fig. 4). Altered basalt samples also were collected at site 43, with schistose gneiss of the Kh unit. The unit to which these rocks are closest in composition are those in the TrPv unit, five miles east of this region.

Other problems exist in the determination of contacts. The contact between the Pzsq and Kh units is clearly gradational, with the differences in lithology and degree of metamorphism showing up clearly only in thin section. We placed the contact approximately where sample composition seemed closer to granite (high in K-feldspar), and where the degree of thermal metamorphism was greater than at site 2 or lake 1485 (RMP site IIa), both of which we considered

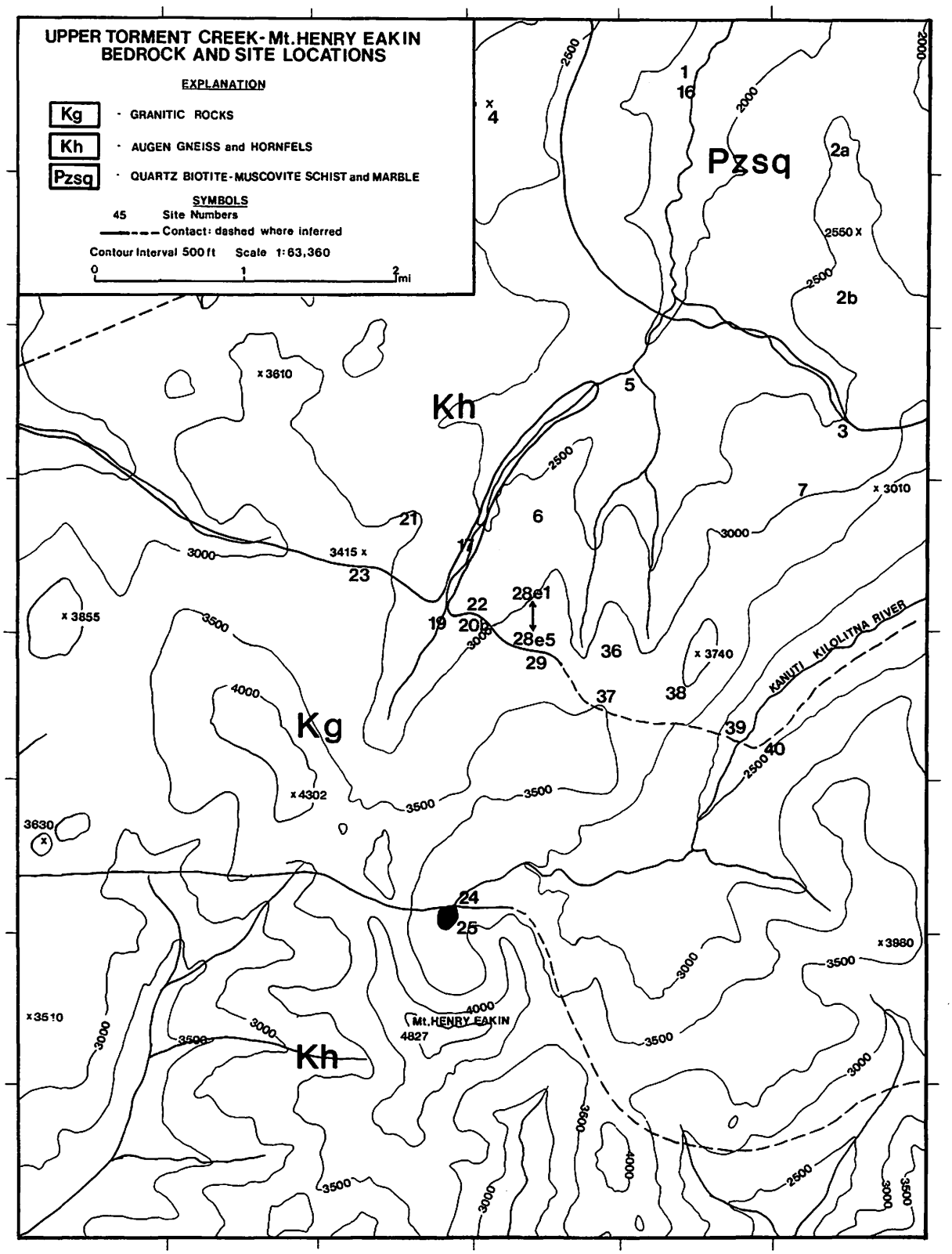

Fig. 3. Upper Torment Creek - Mt. Henry Eakin bedrock and site locations.

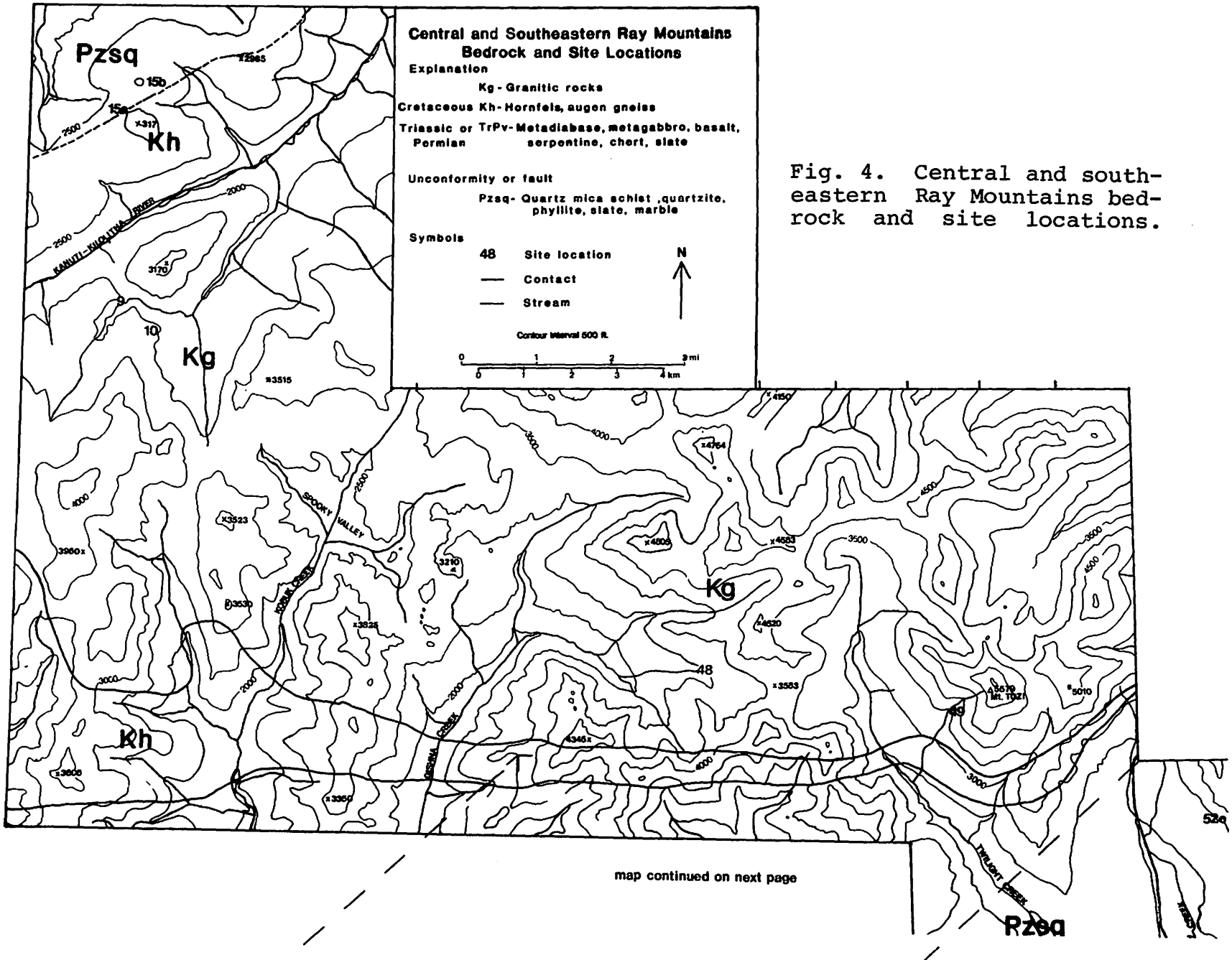

Fig. 4. Central and southeastern Ray Mountains bedrock and site locations.

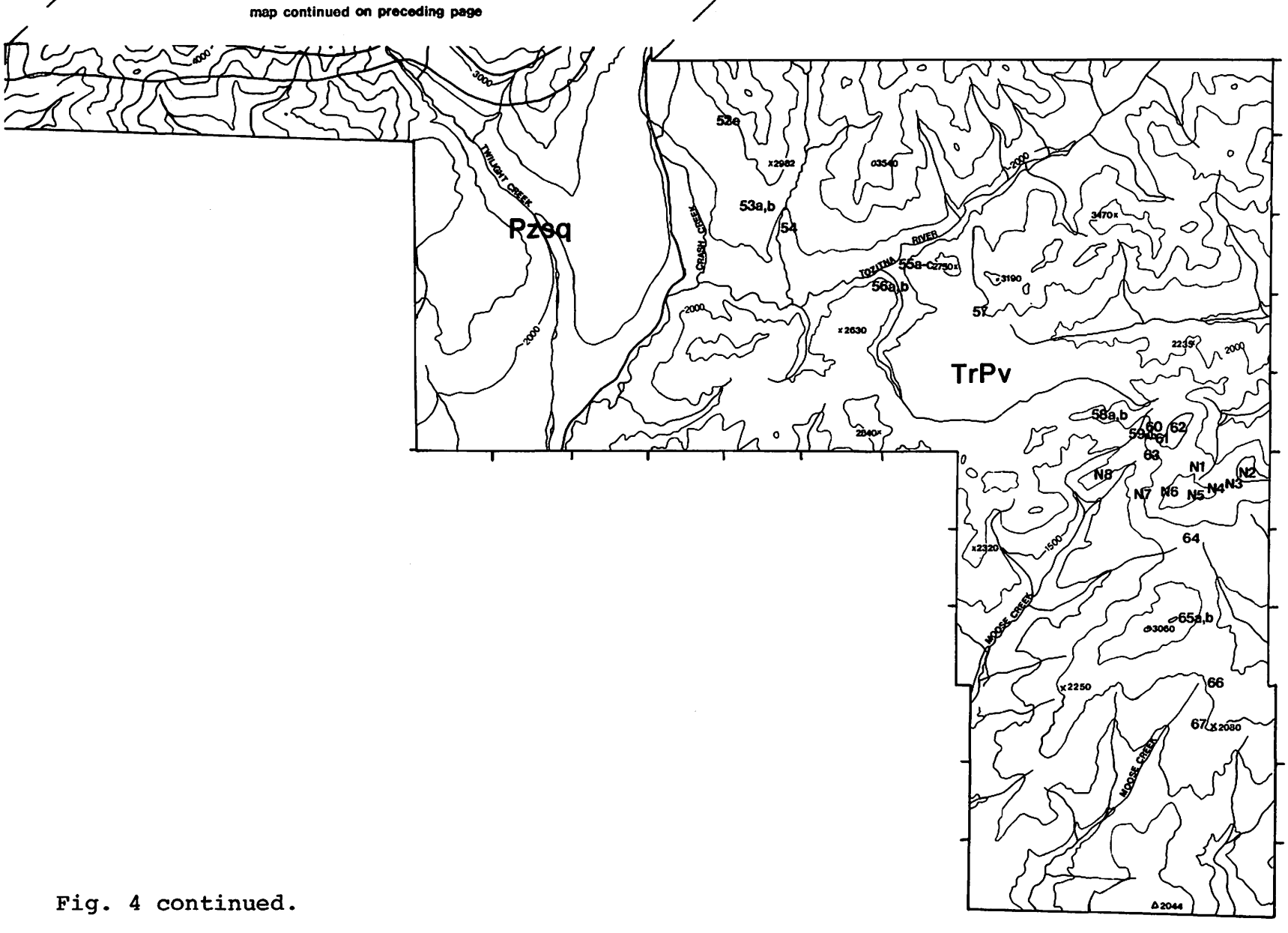

Fig. 4 continued.

typical Pzsq areas.

The contact between the Kh and Kg units is also gradational and should be mapped as a transition zone about 100 m wide.

RESULTS AND DISCUSSION

Bedrock Descriptions

The following descriptions, based on field descriptions and thin section analyses, cover the major lithologic units of the range. Most of the units are lithologically consistent within the study area. Only the TrPv unit has much variation within the area we mapped.

Granitic Rocks -- Kg Unit

The main body of the Ray Mountains is composed of plutonic rocks (Fig. 2). These are probably numerous closely related intrusions rather than a single intrusion. In this report the term "intrusions" refers to all of the granitic rock of the range.

Spooky Valley Area

The range in composition and grain size of plutonic rocks seen in Spooky Valley (RMP site IVa) and the upper Gishna Creek valley (RMP site Ie) is fairly representative of that of the main pluton east of the Kanuti Kilolitna River and of the plutonic rocks to the west in the vicinity of Ishtalitna Creek (RMP site Vc-d). Table 1 shows the range in composition of the granitic rocks in the Ray Mountains. The most common rock type is that of site 19, which is a coarse-grained biotite quartz monzonite, with equant to rounded smoky quartz 1-2 cm wide, rounded chalk white plagioclase approximately 1 cm wide, equant to tabular biotite from 0.5-2 cm wide, and prismatic to tabular pinkish-orange alkalic feldspar, commonly 1.5 x 2 cm. Prismatic porphyritic feldspars 2-6 cm long and 1-2 cm wide compose 10% of the rock in a given thin section, although usually these large phenocrysts are more scattered. The large feldspars and the generally very coarse texture are two of the most distinctive features of the granitic rock in this portion of the mountains. The main variations throughout the range are in the grain size and the amount of biotite (Table 1).

All of the samples from Spooky Valley and upper Gishna Creek were taken from tors, which are the remnants of the granitic bedrock left by preferential erosion along jointing planes (Photo 2). It was not clear whether the preferentially eroded bedrock is of the same composition as the tors.

Table 1. Mineralogic composition of granitic rocks. All percentages approximate from thin section analysis. Site locations are shown in Fig. 3-4.

Site 10:	Quartz	35%	Site 19:	Quartz	30%
	Oligoclase	10%		Plagioclase	5%
	Plagioclase	25%		K-feldspar	35%
	Biotite	30%		Biotite	15%
				Muscovite	8%
				Schorl	5%
Site 29:	Quartz	40%		Zircon	2%
	Plagioclase	25%			
	Perthite	25%			
	Biotite	7%			
	Muscovite	1%			
	Chlorite	2%			

Within the tors small dikes of finer-grained, slightly more mafic and quartz-rich rock commonly occur (Photo 1). These are often visible from a distance because they protrude 10-20 cm from the coarser, more felsic granite. The dikes are mostly 0.5-1 m in diameter, composed of fine-grained biotite quartz-monzonite. Most of the dikes have 30-40% biotite, compared to 10-20% in tors, though occasionally the tors have equally high percentages of biotite. Many of the dikes are extremely porphyritic with 6 cm prismatic feldspars composing up to 20% of the rock. The dikes show much more fracturing than the tors.

Many of the tors are inhomogeneous, although overall the granitic composition tends to be very similar. Within some of the quartz monzonite tors are discontinuous bands of biotite granodiorite 0.6-1 m long and 15 cm wide. The grain size is the same as the main body of the tor but these bands can be up to 50% biotite with plagioclase as the dominant feldspar.

Thin section analysis of samples from site 10 reveals that the fine-grained biotite quartz monzonite is extremely porphyritic. The texture is ophitic, with coarse-grained quartz, feldspar, and biotite phenocrysts surrounding their fine-grained equivalents. Fine-grained apatite crystals are extremely common, often within the biotite crystals. Only minimal alteration of the original minerals has occurred, mostly deuteric in the biotites and oligoclase.

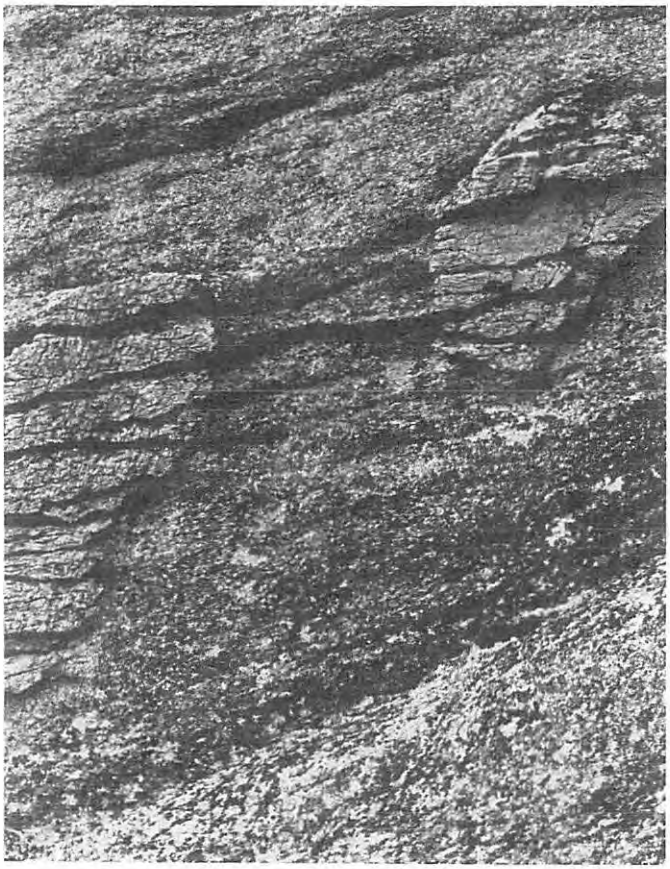

Photo 1. Apalitic dikes 0.5 m wide in quartz monzonite tors; Spooky Valley.

Photo 2. View from ridge SW of the Kanuti Kilolitna River. Granite tors, common throughout upper elevations in the Ray Mountains, commonly occur in linear trends along ridge crests.

Upper Torment Creek

At the headwaters of Torment Creek the granitic pluton becomes a narrow zone no more than 1.5 km wide (Fig. 3). Samples from the center of this area (site 41) are slightly more biotite rich than most of the samples from Spooky Valley. Some samples are biotite granite, with biotite quartz monzonite rarer than in Spooky Valley. The porphyritic feldspars commonly compose 20% of the rock. The alkalic feldspar is white and 0.5-1 cm wide in these rocks. Coarse phenocrysts of alkalic feldspar up to 3 cm long are very common in this area. In general these rocks are finer-grained, more porphyritic, and much whiter than the Spooky Valley granitic rocks.

Contact Granitic Rocks

We termed any rocks within 500 m of the contact of the pluton with the metamorphic terrane as contact granitic rocks. This contact is probably gradational and was never clearly seen in the study area. The contact granites show approximately the same mineralogic variations as the granitic rocks from sites further in the pluton, but many of these contact samples have a fabric. Similar to the biotite quartz monzonite samples around site 41, most of these samples vary in grain size from fine to coarse, and in color index from 5 to 40. Muscovite is fairly common in the granitic contact rocks around Mt. Henry Eakin and upper Torment Creek. Almost all of the samples within 100 m of the contact have some degree of fabric. Those rocks with a faint fabric have tabular to platy micas and the 4-6 cm feldspar phenocrysts show a slight preferred orientation. These samples are common around upper Torment Creek and Mt. Henry Eakin. A few rocks have a much stronger fabric seen as extremely elongated micas aligned strongly to a preferred orientation. In these rocks the micas and fine-grained crystals appear to flow around the quartz-feldspar phenocrysts so that the texture begins to resemble augen gneiss. This stronger fabric is less common but is seen throughout the contact region (sites 39, 23, 24 in the upper Torment Creek area, site 48 near Mt. Tozi, and the Ishtalitna Creek valley).

A few samples are gneissic, having a discontinuous laminated fabric, but they still retain a granitic mineralogy and porphyritic texture. Samples b and c from site 25 are from one rock near Mt. Henry Eakin, of which c is probably a xenolith. Sample b from site 25 has no fabric whereas sample c is gneissic with extremely elongated feldspars and biotites. Rocks showing similar mineral elongation and compositional layering outcrop at the northern edge of the western pluton, near Ishtalitna Creek.

Thin section analysis of two contact samples from upper Torment Creek (sites 19 and 29) show that the rocks are

strained. Many feldspar and quartz crystals are deformed and warped. In a thin section from site 19 the quartz and feldspar have sutured grain boundaries. A lesser amount of recrystallization occurs within the coarse grains of a sample from site 29. The original textures were coarse-grained hypidiomorphic with tabular biotite. The schorl is fine-grained, lath-like, and unusually common in the sample from site 29. Many of the plagioclases are strongly zoned. Perthite is the most common form of K-feldspar.

The other contact area studied is in the headwaters of Gishna Creek (site 48). The samples from here cover a range similar to those from both Spooky Valley and upper Torment Creek. The most common rocks are coarse-grained biotite granite to quartz monzonite with pinkish alkalic feldspar. Some have a slight fabric similar to samples from sites 40 and 20a, but in general they are coarser-grained than these samples.

Quartz-Mica Schist -- Pzsq Unit

A fine- to medium-grained poorly sorted quartz-mica schist is the predominant rock type around site 1 near basecamp (RMP site IIb), which is mapped as the Pzsq unit. The composition of the rock varies in the proportion of chlorite and muscovite to quartz and feldspar, ranging from 1:3 to 1:2. A few carbonate beds also occur. They are massive, dark, medium-grained graphitic calcite and dolomite, usually in beds no more than 3 m thick. A few samples from sites 1a-1e are medium-coarse grained hornblende diorites, probably small intrusions in the schist.

The composition of the schist on the south side of the mountains (site 49, RMP site Ic) is quite similar to samples from site 1. It is clear that the Pzsq unit was continuous in this region and has been intruded by the plutons. Thus the schist on the north side of the range is not distinct from the schist on the south side.

The schist commonly has discontinuous compositional layering with 3-5 mm thick bands of quartz and feldspar separated by 1-2 mm bands of chlorite and muscovite. The quartz is medium grained but most of the other minerals are extremely fine grained. Some of the feldspars appear to be fractured and sheared pebbles, often up to 1 cm long. Samples from site 2 (RMP site IId) have a fabric closer to a slaty cleavage, with layers no more than 1 mm thick. The trend from east to west (sites 2 to 4) appears to be an increase in the thickness and discreteness of the compositional layers, so that samples from sites 1e and 4 are gneissic schist.

Brittle shearing is the main style of deformation seen in the schist. Fine-grained muscovite crystals have been

strongly sheared and bent and quartz crystals have been warped. The compositional layers are often tightly folded on a local scale (2-5 cm amplitude). There is not enough outcrop to discern regional folding.

The schist experienced upper greenschist facies metamorphism, into the chlorite-muscovite zone. The original outlines of coarse pebbles still exist but the schist is almost completely recrystallized and the carbonate is completely recrystallized.

Fine-grained garnets occur in the quartz layers, parallel to the schistosity indicating that the highest grade of metamorphism occurred when the schistosity formed.

Gneiss and Hornfels -- Kh Unit

Field Description

The transition both structurally and lithologically from the Pzsq unit to the Kh unit is gradual; thus, defining the origin of samples must be somewhat arbitrary. We separated the two units by their degree of gneissic texture. Those rocks that are clearly gneissic and lack the flaky layering of the schist seen at site 1 belong to the Kh unit.

Nearer the granitic pluton the schist becomes coarser grained and the compositional layers more clearly defined and wider. Within 1 km of the pluton the rocks are schistose augen gneiss or less commonly hornfels. In the upper Torment Creek area the predominant rock type is augen gneiss with bands of quartz-feldspar 1 cm wide and bands of micas 2-5 mm wide.

At sites 4 and 5 near Torment Creek the rock is clearly more biotite rich, with 20-30% biotite and chlorite, and 70-80% quartz-feldspar. Quartz and feldspar begin to form as discrete elongate pods which gradually develop into very distinct augen surrounded by strongly lineated muscovite and chlorite layers (site 6).

Within 500 m of the contact between the granite and gneiss, the rock has a great deal of variation in the degree of recrystallization, of thermal metamorphism, and of cataclastic deformation. Most of the samples are still augen gneiss, but nearer the pluton the fabric is less clear and static recrystallization, particularly of hornblende, becomes increasingly common.

The outcrops at site 15 on the ridge between Torment Creek and the Kanuti Kilolitna River are unusual for this biotite-schist terrane because they are dolomitic marble. The marble is fine grained, but has bands of perfectly prismatic

medium-grained actinolite-tremolite. The marble is noticeably more resistant to weathering than the quartz-biotite schist on either side. The outcrop is approximately 10 x 100 m. Traces of similar rocks are found nearby at sites 15c, 3, and at site 49.

Thin Section Data

The thin sections from the rocks of the Kh unit vary in the degree of strain relative to the degree of recrystallization, with extremes of both processes seen. We could not find a correlation between the dominance of one process over another and the distance from the contact. Most of the samples have a strong cataclastic texture and a well-developed fabric. Brittle deformation and shearing have elongated the mica crystals, leaving clusters of quartz and feldspar in pods or augen. Most of the quartz and feldspar have recrystallized into fine grained cuspate crystals but a few original outlines of coarse crystals can be seen.

Samples from sites 28e1-28e5 are taken from a transect approaching the contact of the granitic pluton in upper Torment Creek. These samples vary only slightly in mineralogy but vary substantially in the degree of recrystallization (Table 2). Nearer the pluton the quartz and feldspars progress from fine-medium grained to medium-coarse grained, becoming more idiomorphic and less cuspate or indentate. The layers tend to differ in crystal size as well as composition, with medium-grained quartz and feldspar layers separated by fine grained muscovite and chlorite layers.

Some samples within a few hundred meters of the contact have statically recrystallized biotite and hornblende. These crystals show no fabric or strain (sites 28e2, 28e3, 28e4, and 20b). Site 15b is unusual in that its samples have mostly statically recrystallized hornblende and clinopyroxene, but it is over 1 km from the contact of the pluton.

Samples that do not have clear compositional layers tend to show a great deal of strain in the quartz and feldspar crystals (samples from sites 22 and 24 in upper Torment Creek). In these samples a small amount of recrystallization occurs within and on the margins of these warped crystals.

Two samples (from sites 3 and 9 in Torment Creek and RMP site IVb) are unusual in that they show no fabric. The quartz and feldspar crystals at site 3 have warping similar to those at site 24 but all of the recrystallization is static. Samples from site 9 appears to be almost completely recrystallized with hornblende and chlorite forming as fine grained laths on the margins of the coarse crystals. All of the samples have experienced at least lower greenschist facies metamorphism. The calcite sample from site 15 appears to have experienced higher grade metamorphism, possibly lower amphibolite facies.

Table 2. Mineralogic composition of quartz-mica schist and contact gneissic rocks. All percentages approximate from thin section analysis. Site locations are shown in Fig. 3-4.

Quartz-Mica Schist (Pzaq Unit)

Site 1:	Quartz	40%	Site 16:	Calcite	80%
	Plagioclase	20%		Chlorite	8%
	K-feldspar	5%		Graphite	12%
	Chlorite	10%			
	Garnet	5%			
	Muscovite	20%			

Contact Rocks (Kh unit)

Site 3:	Quartz	30%	Site 9:	Quartz	35%
	Plagioclase	5%		Albite	25%
	K-feldspar	30%		Chlorite	30%
	Perthite	5%		Biotite	9%
	Chlorite	13%		Prehnite	1%
	Epidote	10%		Muscovite	1%
	Hornblende	5%			
	Sphene	2%			
Site 15b:	Calcite	20%	Site 15a:	Calcite	20%
	Actinolite	30%		Tremolite	75%
	Clinopyroxene	20%		Feldspar	5%
	fine-grained mat	30%			
Site 20b:	Quartz	45%	Site 28e1:	Quartz	40%
	K-feldspar	30%		K-feldspar	30%
	Plagioclase	10%		Plagioclase	10%
	Biotite	12%		Muscovite	15%
	Chlorite	3%		Chlorite	2%
				Magnetite	2%
Site 28e2:	Quartz	23%		Sphene	2%
	K-feldspar	30%			
	Plagioclase	20%	Site 28e3:	Quartz	35%
	Biotite	10%		Plagioclase	25%
	Chlorite	15%		K-feldspar	20%
	Muscovite	5%		Biotite	5%
	Magnetite	2%		Chlorite	15%
				Hornblende	5%
				Magnetite	1%
Site 28e5:	Quartz	15%			
	Plagioclase	25%	Site 28e4:	Quartz	30%
	K-feldspar	20%		Plagioclase	30%
	Biotite	10%		K-feldspar	28%
	Chlorite	5%		Biotite	10%
	Opaque	10%		Chlorite	5%
	Epidote	5%		Opaque	2%
	Hornblende	3%		Muscovite	3%

(Table 2 is continued on the next page.)

Table 2 continued.

Site 22:	Quartz	15%	Site 24:	Quartz	15%
	Perthite	40%		Plagioclase	40%
	Plagioclase	30%		K-feldspar	25%
	Biotite	10%		Biotite	12%
	Chlorite	2%		Chlorite	5%
	Hornblende	2%		Hornblende	2%
	Zircon	1%		Sphene	1%

Basalt, Ultramafic Rocks, and Chert -- TrPv Unit

The rock types vary greatly in the southeast portion of the Ray Mountains (Table 3). However, they are so intimately intermixed that it was not possible to distinguish specific lithologies on the map. In this region, the rocks are simply mapped as TrPv. The main types observed include serpentinized peridotite, ultramafic cumulates, metadiabase and metagabbro, chert, and siltstone. The textures vary from quite fresh to almost completely altered. For a complete description of the rocks in this area see Appendix.

Certain lithologies did seem to occur in one area in the TrPv unit more commonly than in another. The highly serpentinized samples came from outcrops 3 km east of Crash Creek (RMP site VIa), which is the contact with the Kh unit. All of the samples within and north of the Tozitna River (sites 52-57) are mafic or ultramafic, ranging from basalts or gabbros to peridotites with varying degrees of alteration. Slickenside surfaces are very common on the metadiabase, metagabbro, and ultramafic rocks. Most of the gabbros and basalts contain greenschist facies minerals; chlorite, calcite, serpentine and quartz are the main metamorphic minerals.

The ultramafic rocks generally have very fresh mesocumulate textures with poikilitic orthopyroxene surrounding coarse grained olivine and medium grained clinopyroxene. Alteration can range from 10% to almost complete, seen mostly as secondary chlorite and serpentine forming pseudomorphically from the olivine and pyroxene. Most of the rocks have very fresh textures, with only a slight fabric defined by the secondary chlorite or serpentine.

The basalts and diabases commonly have sub-ophitic textures, with poikilitic orthopyroxenes surrounding euhedral laths of a fine-grained material termed paragarnet. These laths probably were originally feldspars which have since altered to a brown microcrystalline isotropic material. The term "rodingitized" best describes this alteration. Rodingite

Table 3. Mineralogic composition of samples from the TrPv unit. All percentages approximate from thin section analysis. Site locations are shown in Fig. 4.

Site 52e:	Augite	25%	Site 55a1:	Olivine	25%
	Paragarnet	50%		Enstatite	20%
	Enstatite	3%		Augite	25%
	Serpentine	20%		Serpentine	15%
	Actinolite	2%		Kaersutite	8%
				Opaque	7%
Site 55a2:	Clinopyroxene	15%			
	Orthopyroxene	10%	Site 48:	Plagioclase	20%
	Serpentine	25%		Serpentine	20%
	Septechlorite	20%		Calcite	20%
	Kaersutite	10%		Quartz	15%
	Tremolite	5%		Chlorite	10%
	Opaque	3%		Biotite	5%
	Biotite	2%		Magnetite	10%
Site 55b:	Serpentine	10%	Site N7:	Orthopyroxene	20%
	Paragarnet	50%		Chlorite	20%
	Clinopyroxene	20%		Paragarnet	50%
	Orthopyroxene	10%		Opaque	5%
Site 65:	Paragarnet	40%	Site 66b:	Orthopyroxene	40%
	Chlorite	10%		Clinopyroxene	20%
	Orthopyroxene	15%		Paragarnet	40%
	Serpentine	10%			
	Actinolite	5%	Site 64:	Chert	95%
	Quartz	10%		Radiolaria	5%
	Clinopyroxene	5%			
	Opaque	5%			

is mostly hydrogrossular or hydrogarnet, a low temperature form of garnet. Coleman (1977) suggests a possible reaction sequence for its formation:

3 Anorthite + Calcite + 2 H2O -> 4 Zoisite + 2 H+

4 Zoisite + 5 Calcite + 13 H2O -> 3 Hydrogarnet + 1.5 SiO2 + 10 H+

Commonly associated with the hydrogarnet are other low-grade minerals such as chlorite and tremolite-actinolite.

Hydrogarnet is defined by Coleman (1977) as fine grained but with distinguishable crystals. The TrPv samples have a brown cryptocrystalline material which does not appear to have developed into hydrogarnet. Honnorez (Honnorez and Kirst 1975) describes a very similar material in gabbro dredged from mid-Atlantic fracture zones. He sees it as a transition between plagioclase and hydrogrossular and calls it paragarnet. Plagioclases are being replaced by brown, fine-grained prehnite and paragarnet, the latter of indetermined composition but probably a mixture of several minerals. His descriptions apply very well to the brown cryptocrystalline material seen in samples from the Crash Creek and Tozitna River (RMP site VIb) valleys.

The sediments in the TrPv unit are commonly red, tan, and green chert and brown to grey mudstone. In general the sediments are more common south of site 59 although red chert does occur north of the Tozitna River. The bedrock in the vicinity of upper Moose Creek (RMP site VIc) is a mixture of cherts, siltstones, diabases, and slates, with sediments usually more common than igneous rocks. Almost all of the sediments are greatly fractured and crumbly, but they have preserved the original textures. Most of them have experienced little metamorphism.

The structure of the TrPv unit was not clear from field relationships. There is no clear pattern to the changes in lithology and often sediments and diabase will seem to be interlayered. The only clear relation of lithologies occurs between the ultramafic rocks and gabbros. All of the ultramafic outcrops have rodingitized gabbros adjacent to them.

At site 60 in upper Moose Creek two limbs of a fold can be seen approximately 0.7 m apart, and 100 m further south the same light grey chert has step folds, each one 0.5 m high, with numerous 1 cm crenulations.

Limestone and Chert -- Pzlc Unit

The unit mapped as Pzlc has approximately 10% altered diabase and gabbro, which is very similar to that at site 61, the TrPv terrane. The cherts and mudstones are also very similar to those found further north. Thin section analysis shows a slightly higher degree of shear. The chert has developed a weak to moderate fabric with 1% elongated micas. The rock is of zeolite facies, similar in the degree of metamorhpism to samples from sites 59 and 57. Most of the chert has distinct relict bedding.

This unit was only sampled in a very limited area, but in general it appears less sheared and deformed than the Pzsq unit to the north. The metamorphic facies is slightly lower but the mechanical fracturing and shearing in the Pzlc seems much less than in the Pzsq.

Local Geologic History

The geologic history of the Ray Mountains is complex. Slightly deformed Permian-Triassic mafics and cherts and Cretaceous granitic intrusions occur unconformably next to more highly deformed Paleozoic metasediments. The country rock (the Pzsq unit) associated regionally with what is termed the Ruby geanticline, is a quartz-mica schist which appears to have originally been a dirty, poorly sorted quartzite. The composition suggests a source area of immature rocks, possibly including greywackes and clays. A few limestone beds also occur in the Pzsq unit. This rock has undergone several deformations, mostly shallow level shearing and brittle folding.

The Pzlc unit south of the Ray Mountains generally contains much finer grained and better sorted sediment than the Pzsq unit and was probably deposited in a calm, low-energy environment. The structural history appears to have been similar, though, to the Pzsq unit, since both are low-grade metasediments with some fabric development.

The emplacement of the plutons may have covered a wide time span, possibly from the Late Paleozoic through the Cretaceous. The granites in the Ray Mountains are generally compositionally similar and probably formed by similar processes which operated through the Mesozoic. A possible criterion for distinguishing between the older and younger granites is that the former have deformed margins while the latter show no deformation (Eakin 1916). The younger have been dated by K/Ar as 103 my old (Mt. Tozi sample, Chapman, pers. comm.), although that age may have been reset metamorphically. No clear regional distribution of the young and older granites was visible in the Ray Mountains.

The transitional nature of the contact and the strong compositional similarity between the Kg and Kh units suggests that the extremely strained Kh unit is granitic rock which has been thermally and mechanically recrystallized. The lithologies have very similar proportions of feldspar and biotite and both have much less quartz than the Pzsq unit. The gneiss and schists of the Kh unit may have formed by two separate processes. A regional deformation that brittly folded and sheared the Pzsq unit appears to have brittly deformed the borders of the older granitic plutons, while the interiors remained undeformed. This might account for the wide bands of gneiss, mapped as Kh in the Ray Mountains, that grade compositionally and structurally into the Paleozoic quartz-mica schists. Metamorphism and deformation probably also occurred on a more local scale when the plutons intruded, but probably would not affect the rock much beyond several hundred meters of the contact with the pluton.

Which of these two deformation events accounts for most of the deformation seems to vary with distance from the pluton. Within 3.5 km of the pluton both may be seen, but beyond 3.5 km only the regional deformation is seen. Immediately next to the pluton it is not clear which deformation event is the dominant cause of the cataclastic and partially recrystallized texture. If the Kh unit fabric paralleled the Pzsq fabric one might suppose the Kh fabric formed by the same deformation event. However, there is not enough outcrop for positive determination on the north side of the Ray Mountains.

The emplacement of plutons adjacent to the crystallized ones might brittly deform the margins. Synchronous shallow level regional deformation may also have occurred. The probable sequence of events then is that early emplacements of the granitic rock cooled on the margins and crystallized completely. Flow features in these contact rocks probably originated with their emplacement. As the pluton cooled inward, the brittle and strained rock on their margins would be subject to later regional deformations but would act as a buffer for the interiors of the plutons.

The continuing emplacement of plutons probably thermally recrystallized the cooled margins of the earlier plutons. The heat aided recrystallization of the cataclastically deformed crystals, but also caused new minerals to form, predominantly Na-rich hornblende and epidote. This suite of metamorphic minerals is low grade, requiring temperatures below 400 C to form. However, the heat must have been high in places, because a sample from site 15, which was collected slightly over 1.5 km from the mapped contact, is a medium-grade rock. The tremolite-calcite-diopside suite requires temperatures above 500 C to form. It is very possible that an extension of the pluton just below the surface caused this facies to develop.

The presence of large amounts of biotite, large crystals, and two feldspars in the granitic rock suggests that the magma was fairly wet. The very alkalic nature also suggests fairly shallow level melting of continental material as the source area for the granitic rocks.

The TrPv unit's history is the most interesting and perplexing in the region. It has been described as part of the Rampart Group, which Brosge et al. (1969) suggest is Late Permian in age. We had radiolaria in cherts from Moose VABM (site 68) dated as Early to Mid-Pennsylvanian.

The time and method of emplacement of this unit are not certain. The linear drainages of Crash Creek and the Big Salt River may have formed along faults. The units to the west (Kg, Kh, Pzsq) seem sharply cut along this contact, unlike their irregular borders elsewhere in the region. Site 55 on the Tozitna River may also be on a fault. It is on the strike of a fault that has been mapped to the west which crosses the Tozitna River where it flows south (Chapman et al. 1975). LANDSAT imagery also suggests that a fault has controlled the river's course (Photo 3). The sharp cliffs on the south side of the river, dropping to the open, gentle hills on the north, also suggest a tectonic boundary. The rock types on either side of this possible fault do not differ enough to determine if there has been major movement. Samples in the Tozitna River of quartz breccia in a hematite matrix also suggest a fault zone in this area.

There are other indications of faulting and shearing in this terrane, both large and small scale. No original sequence of beds or layers is left; often five greatly different rock types occur within a few meters of each other. The slickenside surfaces, occasional shear zones, and generally fractured texture of the rocks suggest deformation restricted mostly to margins of rocks. Within the rocks themselves very little deformation has occurred. Thus, the TrPv unit has possibly emplaced, since the lithologies are not at all related to any others in the area.

This structural setting, combined with the lithologic sequence of ultramafic cumulates, rodingites, gabbros, basalts, serpentinites, diabases, and cherts suggests a possible ophiolite assemblage. However, the unit is too broken up and poorly exposed to allow for conclusive evidence for an ophiolite to be seen in the field. The ultramafic bodies north of this area near Sithylemenkat Lake have been identified as Triassic in age and have been suggested as ophiolites. These ophiolites in turn appear to be related to the broader distribution of ophiolites that occur north and west of the Ray Mountains (Patton and Miller 1970; Brosge et al. 1969). (see "Regional Geologic Setting", above, for a discussion of these ophiolites.)

Photo 3. Satellite (LANDSAT) view of the Ray Mountains. The dashed line indicates a possible fault contact in the eastern part of the range between the TrPv and Pzsq units.

Another possible explanation for the occurrence of ultramafic rocks would be a cumulate zone similar to the Duke Island peridotites (Irvine 1974). However, these ultramafics in southeast Alaska have a very different chemistry and structure than those in the Ray Mountains. The occurrence of the ultramafics with gabbros, diabases, serpentinites, and cherts and the probable tectonic emplacement of the sequence support the theory that the Ray Mountains TrPv unit is an ophiolite assemblage.

If the emplacement of the TrPv unit to its present place is tectonic, which seems most likely, then the linear contact between the Kh or Pzsq units and the TrPv unit along Crash Creek in the eastern section of the mountains may be interpreted as a fault. The line does trend northeast, parallel to faults associated with dismembered ophiolites west of the Ray Mountains (Patton and Miller 1970) and parallel to major structural trends in the area. If ophiolite emplacement occurred before the Cretaceous, faults associated with the transport of the oceanic material would have provided structural weaknesses along which subsequent granitic magma might have risen. If the intrusion occurred before the ophiolite emplacement then the fault that appears to run along Crash Creek, parallel to the contact between the Pzsq and TrPv units, could be the thrust fault along which the ophiolite was emplaced.

In conclusion, a generalized and hypothetical sequence of

events may be constructed to explain the present geology of the Ray Mountains in relation to their regional setting. Initially dirty quartzites and carbonates were deposited in Precambrian-Paleozoic basins occupying what is now central Alaska. Deformation and metamorphism of these sediments followed as part of the increased tectonic activity during the Late Paleozoic all over Alaska. Rifting in interior Alaska may have occurred, opening an ocean basin which was 600 km at its widest (Patton et al. 1977). Changes in plate motion would have then put a halt to rifting, giving rise to compressional forces which may have further deformed the Paleozoic metasediments, perhaps at this time creating the welt of metasediments termed the Ruby geanticline. Continued compression may have caused downwarping and subsequent melting of continental material resulting in pluton formation. Pluton emplacement would occur before deformation had ceased, accounting for deformation noted at margins of "older" granites of the Ray Mountains. Compression would eventually lead to ophiolite emplacement. Plutonic activity would have continued at least through the Cretaceous. Processes forming the granitic magmas would not change significantly as all the granitic plutons of the region seem roughly similar in composition. Erosion of granitic and ophiolitic bodies would follow. Crustal adjustments to stresses imposed by further plate motion would take place along major faults.

Economic Resources

Geothermal Potential

The Ray Mountains are part of a belt of granitic intrusions that occur in Alaska around the latitude of 60 to 65 degrees north. Related to these intrusions are numerous hot springs which usually occur on the contact of the pluton with the country rock or within a few miles of it.

In the vicinity of the Ray Mountains four such hot springs are known to exist. The hot springs on the Ray River, Kanuti Kilolitna River (Kilo Hot Spring, RMP site IIIa), Ishtalitna Creek (RMP site Vd), and McQuesten Creek are all on or within a few miles of the contact between the Kg and Kh units. Of these, only Kilo Hot Spring and Ray River Hot Spring are mapped on USGS topographic maps. We visited Kilo Hot Spring and the hot spring on Ishtalitna Creek.

Kilo Hot Spring is a series of springs seeping or flowing out of the ground on the east bank of the Kanuti Kilolitna River. There are two main sites, the smaller being approximately 75 m east of the river and the larger approximately 40 m east of the river. The smaller site has two main springs and numerous seeps which flow into a tributary of the Kanuti Kilolitna River. We recorded temperatures and flow estimates on 14-16 July. The two main

springs had flow rates of approximately of 2-4 liters per second and were 49 and 51 C 10 cm below the surface near their sources. The tributary stream was 9 C and had a flow rate of approximately 12-16 liters per second. The hot springs effluent mixes quickly with the cold water and did not raise the stream's temperature. These springs welled out into narrow channels which they followed 5 m and 2 m respectively before entering the tributary.

The main spring is approximately 150 m north-northwest (downriver) of the smaller springs. It is a series of seeps over a 20 m wide zone which collect at the base of the bank and flow into the same tributary as the smaller springs. Here the tributary is separated from the Kanuti-Kilolitna River by a 20 m wide gravel bar. The springs are 49 C at the top of the bank and 46 C at the base where they form a pool. The hot spring water mixes gradually with the tributary, forming pools of 40 C, 38 C, and finally a large pool, 5 x 12 m, of 31 C. The flow rate is difficult to gauge because the waters do not collect in one channel, but it appears to be about one-half the flow rate of the tributary, about 6-8 liters per second. The 31 C tributary flows into the 7 C Kanuti Kilolitna River approximately 50 m north of the main springs.

The Ishtalitna Creek hot springs are much smaller and were discovered only in May of 1979 by BLM geologists. They issue from a single site, a 3 x 3 m heap of granitic rubble. At the source the temperature was measured at 40 C. The spring flows in a 50 m stream only 0.2-0.6 m deep, paralleling the Ishtalitna Creek 20 m to the east. A meadow separates the two streams. The flow rate is slow, approximately equal to either of the two smaller springs at Kilo, 2 liters per second. A few pools exist, though only one is big enough to sit in. On the east side of Ishtalitna Creek, directly opposite the hot springs, is another spring, a trickle of water about 27 C.

Both Kilo Hot Spring and the Ishtalitna hot springs harbor thick growths of red, pink, and green algae and the rocks in the springs are coated with white mineral deposits. The Ishtalitna Creek hot spring has a slight sulfurous smell detectable 1 km downstream. The Kilo springs have no detectable smell.

Minerals

Metallic mineral resources of the Ray Mountains are negligible. We found no evidence of any sizeable mineral deposits, nor do mineral resource maps list any. This scarcity is rather unusual for central Alaska. Numerous rich placer deposits of gold and tin occur just south of the Yukon River near Rampart as well as to the east, where the geology is not substantially different.

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Some lignite samples have been reported along gravel bars in the Tozitna River. The only stones of potential use are the marbles seen at site 15, although the outcrop is extremely limited. Marble outcrops of an unknown extent have been reported on the south side of the mountains (Chapman, pers. comm.).

Suggestions for Further Research

The relation of the granitic plutons to the surrounding metamorphic terrane could be worked out in greater detail by further chemical analysis of the granite, gneiss and quartz-mica schist. Plutons of similar ages and compositions occur all across central Alaska and more work might suggest their source area, processes of formation, subsequent deformation and metamorphism, and their relation to Mesozoic tectonic activity elsewhere in Alaska.

Identification of the TrPv unit as part of an ophiolite would substantiate present speculation regarding the distribution of ophiolites in central Alaska and would provide an important key to the geologic understanding of the area. An age determination from the gabbros might indicate if the gabbro sequence is related to the nearby cherts of Permian age, and thus whether the TrPv unit in the Ray Mountains can be considered one unit. Ophiolites are thought to flank the Ruby geanticline, resting in fault contact on the schists of that structure. Detailed petrography, geochemistry, and mapping of all of these units is needed to determine their origin and history. Further investigation of the contacts between the geologically different terranes is essential to determine relative times of tectonic emplacement.

CONCLUSION

As more geologic information is gathered and analyzed, a clearer picture of the geologic history of central Alaska emerges, but questions remain how the different terranes relate to one another. Formations of distinctly different origin, dating from the Paleozoic through the Cretaceous, are found in the region of the Ray Mountains, indicating a tectonic arrangement and rearrangement of rocks throughout time.

The Paleozoic metasediments of the Ruby geanticline have been deformed by several regional events and intruded by granitic plutons from the Late Paleozoic through Mesozoic time. Cataclastic and static recrystallization have occurred along margins of some of the plutons in the region, indicating that regional stresses as well as local pressure and

temperature associated with pluton emplacement have acted upon the massive granitic bodies. Deformation along the margin of plutons may be related to events affecting Paleozoic sediments and probably took place no later than the Early Mesozoic, as some granites dated Cretaceous seem undeformed.

Rocks of the ultramafic-basalt-chert sequence (TrPv) lying in probable fault contact with the older Paleozoic schists of the Ruby geanticline show only mild fabric development, suggesting that these rocks were transported from areas unaffected by deformation or that the TrPv sequence post-dates the regional deformation. The TrPv rocks may define a dismembered ophiolite sequence as Patton et al. (1977) have suggested. The closing of an ocean basin resulting in obduction of oceanic crust onto the continental material might have occurred sometime during the Mesozoic as part of the series of orogenic events shaping the Cordillera system in western North America. The process of obduction would have imposed greater deformation on rocks of the continental margin than on the transported ophiolite assemblage. Some deformation and downwarping of the Paleozoic metasediments might have been associated with compressive stresses responsible for the closing of an ocean basin and eventual ophiolite obduction. Obduction would have occurred no earlier than the Permian, the age given to cherts in the TrPv unit.

The Ray Mountains granite, rich in K-spar, may have been derived from shallow melting of crustal rocks. The formation of granitic magma throughout the Mesozoic may have been the local response to stresses related to changes in plate motion or the result of downwarping and melting of continental material during compressional closing of an ocean basin to the west. The tectonic significance of Mesozoic plutonism in interior Alaska is yet to be determined.

ACKNOWLEDGMENTS

Our thanks go especially to Drs. Robert Chapman and Warren Yeend of the US Geological Survey for sharing with us their knowledge of the Ray Mountains. Dr. Chapman was kind enough to date a sample for us at Menlo Park. In Fairbanks, Dr. Florence Weber of USGS and Clyde Murray of the Bureau of Land Management also provided information on the Ray Mountains.

The professors of the Department of Geology at Middlebury College were very generous with their time, aiding us with the preparation for our work. Drs. William Glassley and Raymond Coish lent their experience with thin section analyses. Special thanks are due to Dr. Glassley for his editorial help.

APPENDIX

Descriptions of TrPv Unit

Site locations are shown in Fig. 3-4.

Field Descriptions

Site 52e. A cliff of metadiabase, metagabbros, and massive serpentinites cut by numerous veins of calcite, quartz, and asbestos. Dark feldspars are common in the metadiabases. Textures range from quite fresh (less than 20% alteration) to completely recrystallized to greenschist facies. Deformation is expressed as a slight warping of clinopyroxene crystals and flow texture in the serpentine.

Site 53a. Dark, dense, fine-grained serpentinite with slickenside surfaces.

Site 53b. Medium-grained diorite or quartz diorite with less than 20% alteration.

Site 54. Purple chert with layers of serpentine.

Site 55a. A series of cliffs above the south side of the Tozitna River, of which aprroximately 70% is fairly fresh pyroxenite. The remaining outcrop is more altered, probably a rodingitized gabbro. The pyroxenite samples have serpentine layers on slickenside surfaces. However, thin section analysis shows that the original texture is very fresh and generally the serpentine occurs only along fractures.

Site 55c. An aphanitic red rock found in the Tozitna drainage. Coarse, euhedral phenocrysts of quartz, up to 2 cm long, are in an iron-rich cement, probably hematite.

Site 56b. A metadiabase with 60% secondary minerals. The rock has no fabric.

Site 57. An outcrop approximately 20 m high and 100 m long. The outcrop base is black, serpentinized fine-grained peridotite, similar to 55a. Moving horizontally this layer gradually becomes a massive light grey serpentinite, then a metadiabase, and finally an aphanitic greenschist facies rock. Immediately above this outcrop is slightly sheared basalt. A loose sample on top of this outcrop is a grey-green mudstone with distinct laminations less than 1 mm wide that appear to be relict bedding. This rock has not been internally deformed at all.

Site 59a. A very clean, black slate.

Site 59b2. A completely altered aphanitic volcanic rock.

Site 59b3. Metadiabase with slickenside surfaces.

Site 60. Light grey chert to dark grey mudstone with occasional relict bedding, greatly fractured.

Site 61. Outcrops of dark and light green serpentinized gabbros.

Site 62. Grey chert and massive, slightly sheared serpentinite.

Site 63. A gabbroic hornblende-diorite with less than 30% alteration.

Site N1-8. These samples show a similar range to those described above with sedimentary rocks generally being more common. N2: Grey mudstone and metabasalt. N4-5: Metagabbro. N8: Grey, slightly metamorphosed mudstone and grey chert.

Site 64. Black chert with numerous quartz veins. About 5% of the sample was radiolaria which have been plucked from the thin section.

Site 66a. A light grey-green highly sheared slate.

Thin Section Descriptions

Site 55a1. Originally a medium-grained mesocumulate with euhedral, fine-medium grained olivine and clinopyroxene and medium-coarse grained poikilitic orthopyroxene. Brown medium-grained anhedral amphibole (kaersutite) forms reaction rims on some of the orthopyroxene crystals. The olivines are little altered, with only slight serpentine replacement.

Site 55a2. A mesocumulate very similar to 55a1 but with much more replacement of the original minerals. Medium-grained euhedral pyroxenes and fine-grained rounded septechlorite are surrounded by poikilitic coarse-grained serpentine and septechlorite. The fine-grained septechlorite appears to be pseudomorphic after olivine.

Site 55b. The pyroxenes are medium-grained with cuspate to indentate margins. Many of the pyroxenes contain completely euhedral fine-grained laths of paragarnet (for a discussion of the term paragarnet see the description of the TrPv unit). Some of the serpentine appears

pseudomorphic after olivine. The original texture was probably ophitic to sub-ophitic. The mineralogy is almost identical to the metagabbro at 52e but there is no fabric in this sample, whereas the other is strongly sheared.

Site 56a. Apahanitic, fine-grained serpentinite and chlorite mixed with epidote, greatly sheared.

Site 58a. A completely altered metadiabase to metagabbro with no fabric.

Site 58b. A slightly altered hornblende gabbro.

Site 59bl. A keratophyre, highly altered from a silica-rich volcanic rock. Calcite, chlorite, and quartz are the major secondary minerals. Very little texture can be made out due to cryptocrystalline alteration minerals.

Site N7. An extremely altered volcanic, probably originally a dacite. Fine-medium grained pyroxene phenocrysts are surrounded by microlitic brown cryptocrystalline material which appears to have been plagioclase.

Site 65. A sub-ophitic diabase which has lower greenschist facies alteration. All of the plagioclase is pseudomorphically altered to paragarnet. Opaques appear to be ilmenite exsolving to magnetite.

Site 66b. A metagabbro with medium-grained ophitic clinopyroxenes and orthopyroxenes that appear to have been euhedral. They are now cuspate to indentate, fairly well altered, enclosing fine-grained laths of paragarnet. A 5 mm thick vein of carbonate-quartz-chlorite cuts through the sample.

GEOMORPHOLOGY

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Middlebury College 1979

ABSTRACT

INTRODUCTION

METHODS

RESULTS AND DISCUSSION
- Physiographic Regions
- Processes and Features
  - Solifluction
  - Spooky Valley Massive Ground Ice
  - Cirques
  - Tors
  - Valley Asymmetry
  - Other Features
- Concentrated Study

ACKNOWLEDGMENTS

REFERENCES

NOTE

The reader is referred to the Introduction of this volume for detailed descriptions of the project study area and the overall project research design. Also included there are descriptions of the project's three areas of concentrated study, with a map showing their locations and the locations of travel routes and Ray Mountains project sites (RMP sites Ia-VId) referred to in this chapter. Physiographic and ecological terms used consistently throughout this volume are defined in the Vegetation chapter.

ABSTRACT

Major geomorphic processes in the Ray Mountains have included two late Pleistocene glaciations, stream action, and periglacial activities. In five physiographic regions of the range these processes have varied. Rugged glaciated areas, with classic features such as cirques and tarns, are found adjacent to gentle rolling areas which have been affected by periglacial processes. Solifluction and tor formation have been widespread through unforested parts of the range.

INTRODUCTION

Since the 1912-1913 geologic field expedition of Henry Eakin (1916), which included extensive geomorphic analysis, only one further geomorphic study has been conducted in the Ray Mountains. Yeend (1971) reported evidence of two late Pleistocene glaciations with glaciers up to 19.5 km long and 170 m thick in the upper central valleys of the range. His glacial mapping served as a partial basis for the study presented in this chapter.

The objectives of geomorphic study in the Ray Mountains were to compile a descriptive geomorphology of some periglacial features and to discuss processes as displayed by selected features. There is no intent to provide more than description and analysis of a few selected features and processes.

METHODS

Aerial reconnaissance, examination of aerial and satellite imagery, and field studies were the basis for description of geomorphic features and physiographic regions of the Ray Mountains. Field study included measurement, sketching, photography, and digging at selected specific sites. Physiographic regions have been defined from field observations and the interpretation of LANDSAT imagery and topographic maps.

Concentrated field study took place near the project basecamp in lower Torment Creek (RMP site IIb), at Mt. Henry Eakin (RMP site Va), along the eastern ridge of the upper Ishtalitna Creek valley (RMP sites Vb-d), and in Spoo

RESULTS AND DISCUSSION

The geomorphology of the range, as observed here, has been controlled by stream, glacial, and periglacial processes, which are described among "Features and Processes," below. Some detailed description and analysis is presented in the section entitled "Concentrated Study."

Physiographic Regions

The five physiographic regions of the Ray Mountains are shown in Fig. 1.

The North Slope region is the largest of the identified regions. It contains NNW trending asymmetrical valleys which are broadly cut and linked by an interconnecting ridge system. Valleys are up to 1.7 km wide (Kanuti River), but sometimes as constricted as 170 m (Ishtalitna Creek). The ridgetops are long and rounded, and some are benched altiplanation terraces. There has been no glaciation in the region. The northern fringes of the region include some of the fluvial plain which almost surrounds the Ray Mountains and is characteristic of the lower elevations of the Kokrines-Hodzana Highlands (Wahrhaftig 1965). Profile A in Fig. 2 is within this region.

The South Slope region, which we observed only from Mt. Henry Eakin and the Torment Creek headwall (RMP site Vb), appears to be a gently rolling interconnected ridge system with uniform ridgetop elevations.

The Western Highlands region contains evidence of some of the longest local glaciers in the Ray Mountains. The highest peak in this region, Mt. Henry Eakin [1471 m (4827 ft)], commands a view of the cirque and tarn on its north slope and the steeply dissected valleys to the south. Profile B in Fig. 2 shows some of the sharp relief in the Western Highlands. Also within this region, in Spooky Valley (RMP site IVa), are some of the range's finest examples of tors -- granitic erosional remnants which usually line ridgetops but occur in some valleys of the Ray Mountains. The Western Highlands have two major ridges: one is the north-south trending watershed ridge which divides the Ray Mountains; the second is a spur ridge which widens south, away from the divide, to create the bowl in which Spooky Valley lies.

The Central Dissected region is closely related to the Western Highlands, as the heaviest glaciation occurred in the region of Mt. Tozi, the Ray Mountains highest peak [1682 m

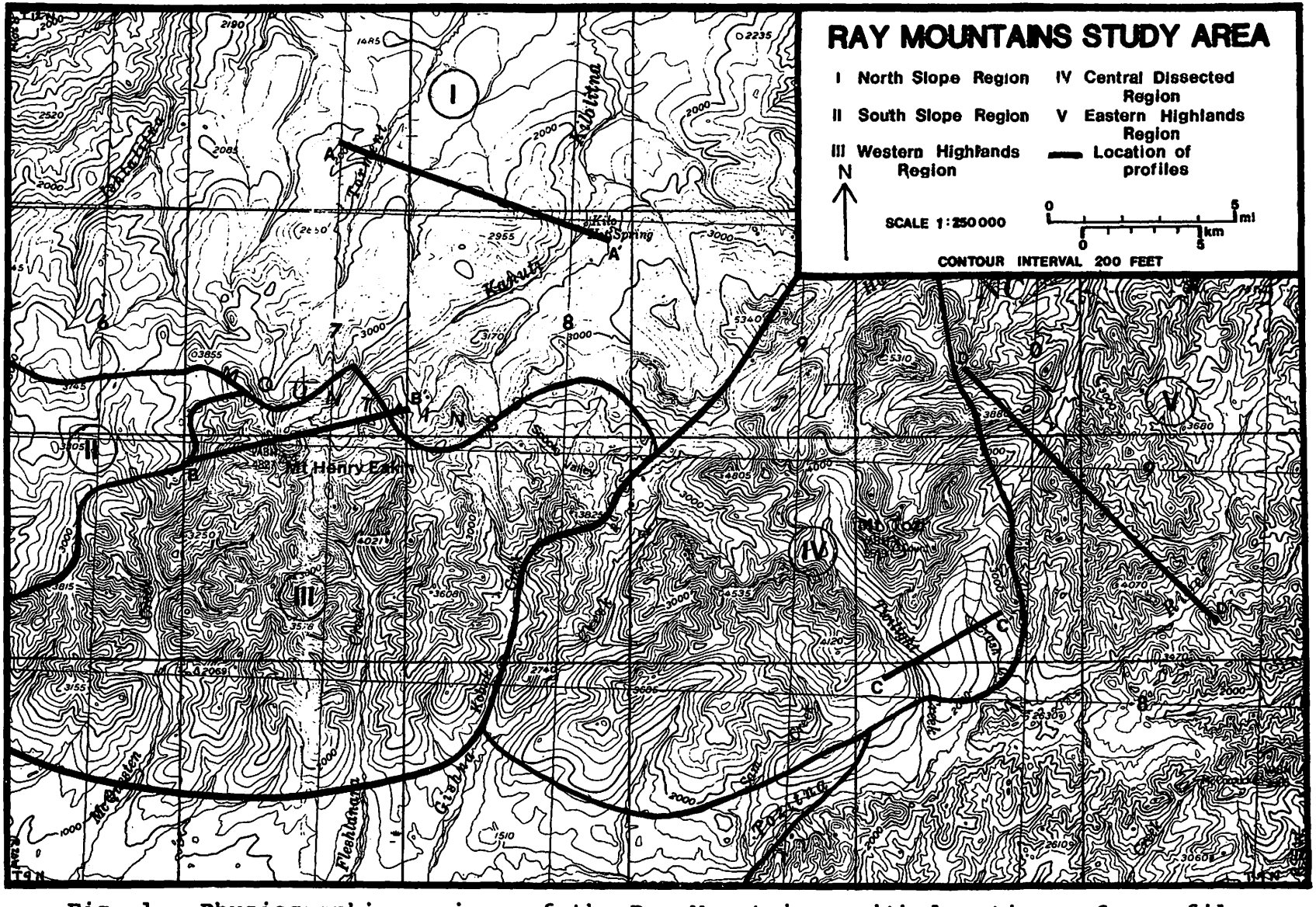
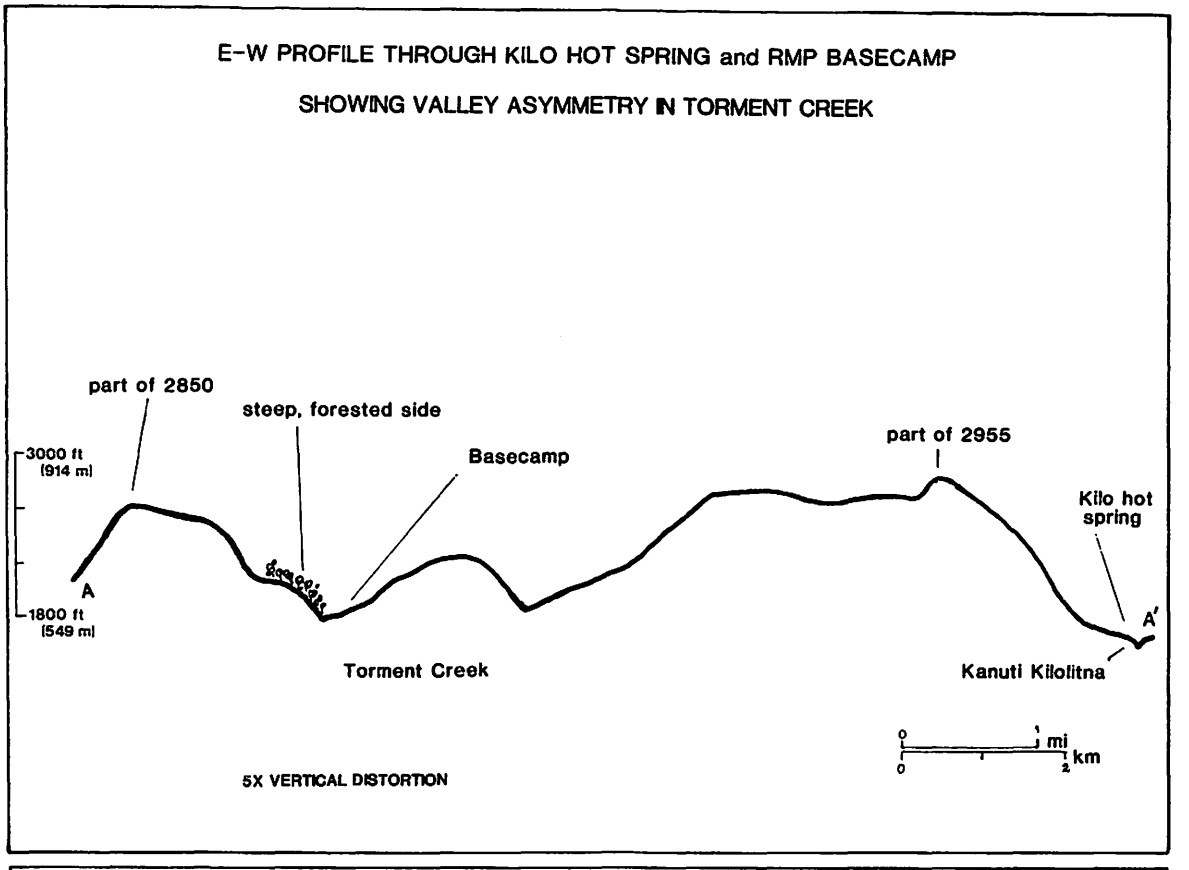


Fig. 1. Physiographic regions of the Ray Mountains, with locations of profiles shown in Fig. 2-3.



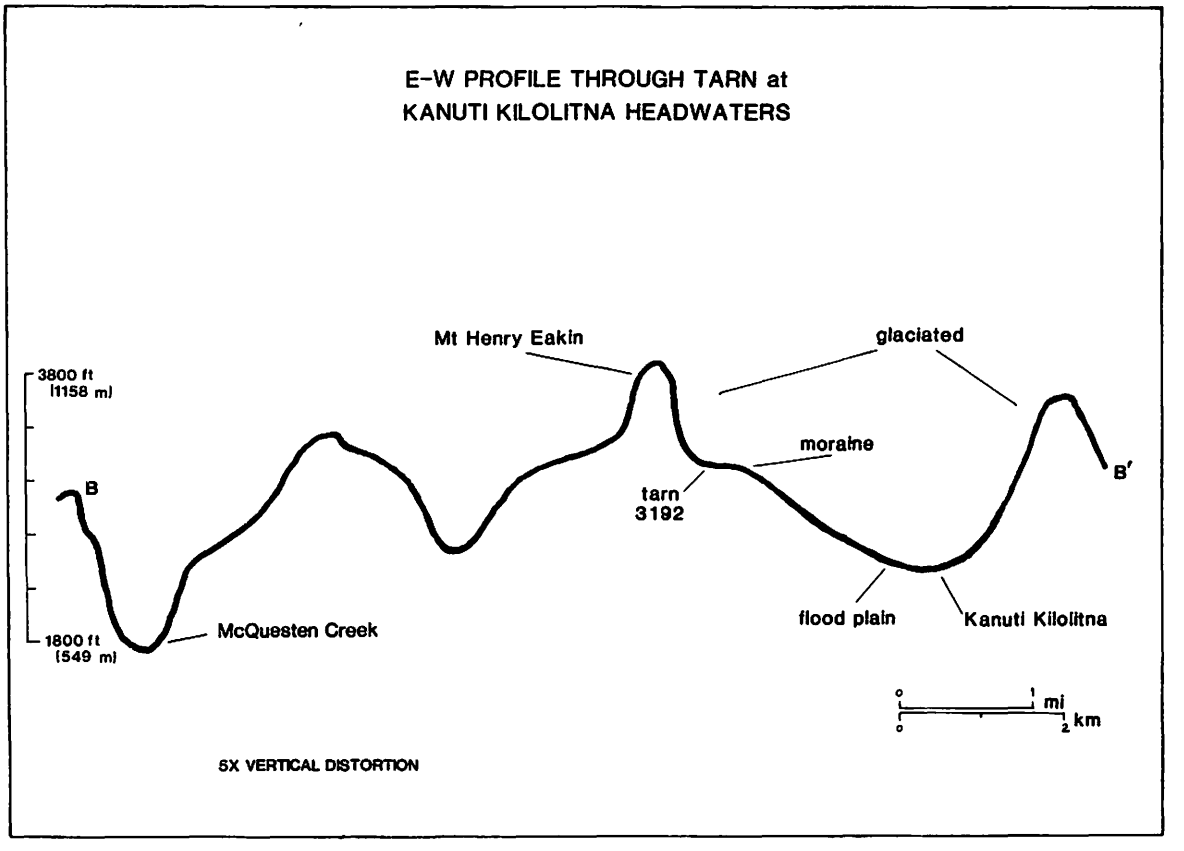


Fig. 2. Geomorphic profiles from the North Slope and Western Highlands Regions of the Ray Mountains. Locations of profiles are shown in Fig. 1.

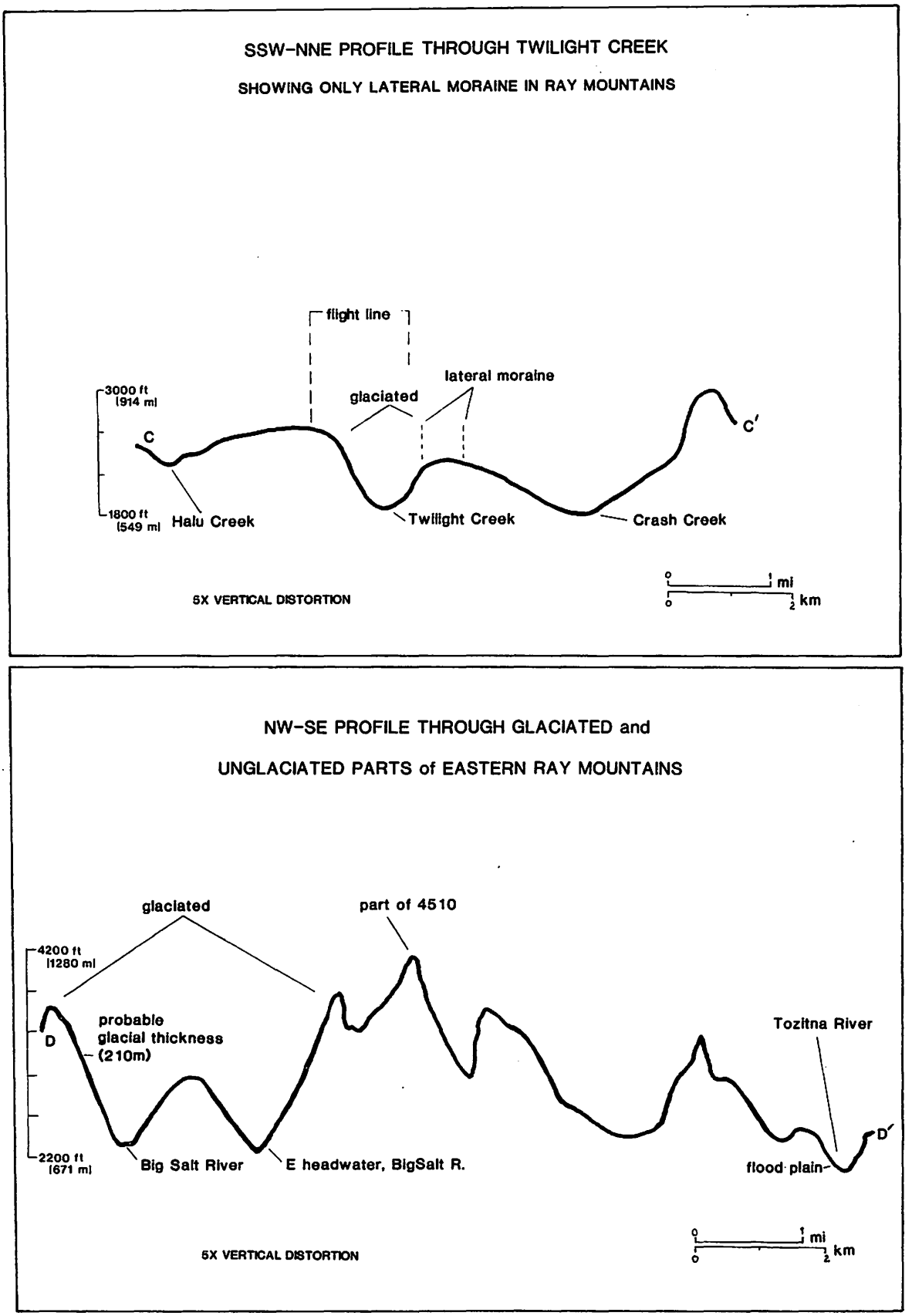


Fig. 3. Geomorphic profiles from the Central Dissected and Eastern Highlands Regions of the Ray Mountains. Locations of profiles are shown in Fig. 1.

(5519 ft)]. There is a concentration of short lineaments in the region, reflecting its dissection. Profile C in Fig. 3 shows glacial remnants in the Central Dissected region.

The Eastern Highlands are defined by the upper Tozitna and Big Salt River systems, which drain the eastern Ray Mountains. Profile D in Fig. 3 shows glaciated and unglaciated valleys and the overall slope toward the east.

Processes and Features

The following processes and features are considered significant in the Ray Mountains. Further description and mapping of a specific area are included in "Concentrated Study," below.

Solifluction

Solifluction lobes and terraces occur on most gentle unforested slopes (3-20 degrees) at lower and mid-elevations of the Ray Mountains. On these slopes, soil and vegetation cover are most well developed, and drainage is most likely to be impeded by permanently frozen ground. Solifluction lobes are 3-20 m wide, with 0.5-1.5 m scarps. Terraces are 15-25 m long with 1-3 m scarps, often occurring as many as ten to a 30-100 m slope, with upslope terraces typically overlaying the tail of downslope terraces. Slopes >20 degrees usually have sufficient drainage to prevent the formation of ice-rich permafrost, which underlies lobes and terraces. Upper elevation slopes >10 degrees usually have insufficient vegetation to provide insulation for what soil has developed; thus permafrost is below the bedrock surface. Our measurements of lobe and terrace sizes conform with measurements made in other areas of the subarctic (Ritter 1978).

All observed lobes and terraces were turf-banked, resulting from intense solifluction under the tundra vegetation mat. Terraces usually occur in a regular pattern [Spooky Valley (RMP site IVa), lower Torment Creek (RMP site IIb)] whereas lobes sometimes occur in erratic patterns on less regular terrain [mid-Torment Creek (near RMP site IIb)]. Smith (this volume) conducted transects for soils classification in several areas and found silty clay loams and silt loams (Pergelic Cryaquepts) beneath lobes and terraces. Solifluction was often associated with Moist Dwarf Scrub - Tussock-Graminoid Meadow vegetation (Brock and Burke, this volume).

Smith (this volume) provides more detailed description of the structure and composition of solifluction lobes and terraces in the Ray Mountains.

Although we observed no stone-banked lobes or terraces, we did observe a related feature. Block streams occur on 3-12 degree slopes [unlike the level block fields described by Washburn (1973)] and are 30-60 m wide and 200-300 m long. They are formed by frost heaving (Eakin 1916) of underlying bedrock, and frost wedging, creep, and lag (Washburn 1973). Block stream formation is favored by an absence of vegetation; the block streams we observed in upper Torment Creek (RMP site IIc), McQuesten Creek headwaters, and Ishtalitna Creek headwaters (RMP site Vb) were sharply bordered by graminoid meadow vegetation 1-2 m wide.

Spooky Valley Massive Ground Ice

In early July we observed a large ice mound (15 m across by 2 m high), covered with a fairly thick (0.5 m) mat of soil and vegetation (Photo 1-2). Through the mound were several deep (1-2 m) crevices up to 2 m wide. Pure blue ice, with a few pebbles, was up to 1.5 m thick where visible in the crevices. The ice in the crevices had been gully eroded, probably by rain and meltwater. Downslope of the blister there was continuous water flow, in deep and shallow rivulets, revealing a gravelly substrate in places.

In some of the crevices we found wet leaf litter from shrubs which grew on the mound; the leaves appeared to have fallen into the crevices the previous autumn. Moreover, where the vegetation mat had subsided to hang over the edge of a crevice, the stems of grasses and shrubs had re-oriented skyward. The combined signs probably indicate that the mound had been fairly stable in most places at least since the previous fall.

By early August the mound had collapsed to dimensions of 11 m across by 1.5 m high. The physical appearance of the mound was less obvious, though the vegetation mat had obviously been chopped up as the ice melted beneath it. Where the tundra mat had been uplifted, more ice was exposed. The ice was again fairly clear, with some air trapped in it; the top 30 cm included some roots and other organic matter.

The ice mound was at the base of a 5-15 degree SSW-facing slope approximately 200 m long and originating from a large (0.5-1 km long) granitic ridge outcrop. Around the mound was some wet, springy tundra which may have covered a sub-surface layer of contained water.

van Everdinger (1979) reported on frost mounds in the Northwest Territories. Somewhat larger than the Spooky Valley feature, his mounds developed in early winter from cold spring

water trapped between permafrost and seasonally frozen ground. He noted three conditions necessary for formation of frost mounds: 1) perennial discharge of low temperature groundwater; 2) presence of a low permeability layer near the ground surface, such as perenially frozen ground; and 3) a long winter with daily mean temperatures below 0 C.

Whether the water forming the Spooky Valley ice mound originates from a spring is undetermined. Presumably rain and meltwater from the adjacent slope could percolate through the tundra mat above the permafrost (up to 30 cm below). Such a process would probably be less likely to result in the formation of an ice feature during a single season, which was reported by Muller (1945), but even without the hydrostatic pressure, precooling, and steady flow of a cold spring, we believe that a frost mound could develop. I consider the Spooky Valley ice mound to be a "frost blister", similar to those reported by Muller (1945).

Another mound of smaller dimensions (4 m across by 1.5 m high), and with unidentified structure and origins, was found on a terrace of the eastern slope of upper Torment Creek (RMP site IIc). Because it issued a steady flow (300 cc/sec) of cold (5 C) water, we speculated that the mound might have been ice-cored, formed from the effluent of a cold spring.

Cirques

Nearly all of the glacial cirques in the Ray Mountains are found in the Central Dissected and Western Highlands physiographic regions. Mt. Henry Eakin, rising 530 m from the tarn on its north slope, is an excellent example of the glacial sculpting that formed the 25 well developed cirques in the Ray Mountains (Yeend 1971). Nivation cirques are also found throughout the Ray Mountains, for instance at the Torment Creek headwall (RMP site IIc), which rises 300 m at a 40 degree angle. (See photograph in the Introduction, this volume.)

In the glacial cirque at Mt. Henry Eakin (RMP site Va), the results of glacial sculpting are obvious. The cirque forms a small dog-leg, facing NNW near the highest point of glaciation and curving north toward the tarn. As the glacier receded or stabilized, it left across the valley a terminal moraine several hundred meters across. A cross-section of the cirque is shown in profile B of Fig. 2.

Geomorphic processes continue to shape the cirque at Mt. Henry Eakin. There is very little vegetation above the tarn, and during our brief period of observation we noted that mass wasting continues on the mountain's steep slopes. Gordon et al. (1978) reported that cirque formation can be accelerated by low frequency, high magnitude wasting, similar to what we

observed at Mt. Henry Eakin. The tremendous jointing on the north face of the mountain is especially subject to mass wasting on an infrequent but highly destructive scale, as indicated by the large boulders and scree in the cirque.

The nivation cirque in upper Torment Creek is steep, flat at the base, and northeast-facing. Like most nivation cirques, there is no moraine at its base. The basin at the bottom of the cirque is, however, fronted by a scarp which is part of a drift terrace, covered with scree composed of 3-30 cm fragments showing lichen growth. Elongate nivation hollows, which were snow-filled in June and part of July, though empty of snow by August, may be helping to form an altiplanation terrace at the upper Torment Creek headwall.

Tors

Many tors -- steep outcrops rising above eroded surrounding rock -- are found in the Ray Mountains (Photo 3). Several characteristics are common to those we observed.

Most tors occur on ridge spines or within about 100 m of the ridge crest. Most tors are composed of biotite quartz monzonite, although they range in composition from granite to granodiorite. Most have very long (0.5-2.5 cm) feldspar crystals and are jointed in several places. All joints within tors have identical orientation, but there seems to be no continuity in jointing among tors regardless of their proximity. Erodability seems controlled mostly by jointing patterns.

No tors were found in the metamorphic rock terrain abutting the granitic portion of the Ray Mountains. The highest concentration of tors occurs in Spooky Valley, where massive tors appear 1-3 km from the nearest ridgelines.

The weathering process which leads to tor formation is not fully understood. It is known that tors are erosional remnants formed when a portion of bedrock remains uneroded relative to the surrounding material. Many models for tor formation have been proposed. Usually tors are observed to form in massive igneous or metamorphic terrain with widely spaced joints. A two-stage process can be required: the first is a period of deep weathering, most likely under warm humid conditions; the second a period of regolith removal with frost fracturing (Embleton 1975).

Climatic changes may help account for tor formation in the Ray Mountains, but periglacial processes also appear significant. Freeze-thaw cycles are probably a major force; wind also appears to play an important role in the shaping of tors in the Ray Mountains. Although irrefutable proof that wind is capable of geomorphic shaping is not available (Ritter

1978), the power of winds, combined with the type of windblown matter, is such that it may historically have contributed to sculpting. The power of windblown snow in polishing rock surfaces has been documented, but the combinations of wind velocity, particle size, hardness, and height above ground may produce different degrees of abrasion. Sharp (1964) stated that maximum abrasion is related to a unique combination of velocity and size of windblown particles. The density of compacted snow particles carried by a strong wind could be sufficient to effect some geomorphic shaping of tors in the Ray Mountains. Ventifacts on the tors, and smooth avenues of wind abrasion around the bases and between crevasses, are testament to the power of wind-blown particles in shaping tors.

Lichen growth may also play a role in tor shaping. Light-colored biotite quartz monzonites would reflect more sunlight than dark lichen-covered rocks, and therefore heat more slowly and to lower extreme temperatures. Lichens, holding some moisture to the rock surface and presumably attaching themselves to irregularities in the rock surface, could protect the tors from some wind-blown erosion and could accelerate other erosional processes. In the Ray Mountains lichen growth was erratic, even on the surfaces of single tors.

Valley Asymmetry

Asymmetric valleys, in which one slope is steeper than the other, are common in the Ray Mountains. However, a periglacial explanation for the formation of asymmetric valleys is very difficult. Climatically determined asymmetry, for example, though very common at many latitudes, is the exception in polar regions (Washburn 1973).

The North Slope physiographic region of the Ray Mountains is the prime location of asymmetric valleys in the Ray Mountains. In the area of the basecamp on Torment Creek (RMP site IIb), solifluction is most developed on the more gradual, eastern slope. Whether solifluction may have been favored by the original degree of the slope is unknown; however, it appears that over time the soliflucted slope may have pushed the stream to where it has undercut the east-facing slope, which is steep and includes cliffs and rockfalls at stream level. In metamorphic or sedimentary terrain, and perhaps at the margins of granitic intrusions, bedding of the country rock can encourage valley asymmetry.

Asymmetric valleys seem to have no regular orientation; many types and angles of slope have been recorded. Washburn (1973) reviewed some explanations, which attribute asymmetry to solifluction and the influences of wind strength and direction and winter topography on slope development.

Photo 3. Tor outcrop in Spooky Valley.

Photo 4. Altiplanation terraces in the eastern Ray Mountains, near the headwaters of Moose Creek.

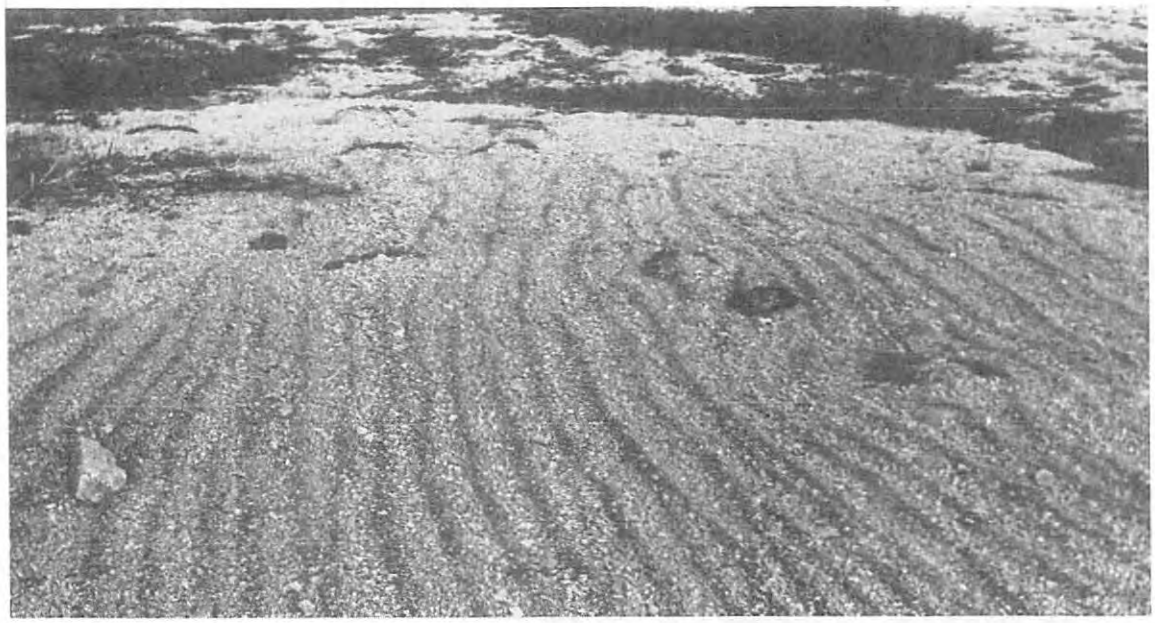
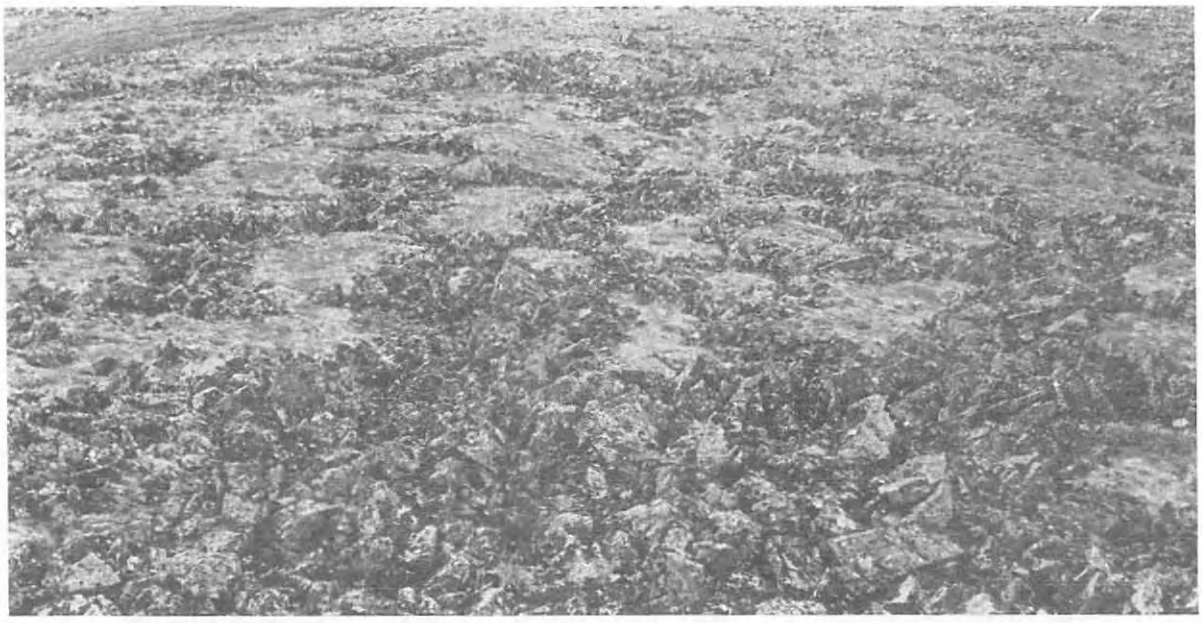


Photo 5 and 6. Frost action in the Ray Mountains has formed numerous periglacial features such as these stone stripes and rock polygons at higher elevations. These stone stripes were on a 5 degree slope; the rock polygons are 3 m in diameter.



Lithology and bedrock structure also affect slope morphology. In the lower Torment Creek valley, schist and gneiss occur in equal proportion on both slopes, indicating that rock type does not explain asymmetry there.

Other Features

The Ray Mountains have well developed examples of features which are regularly found under alpine and subarctic conditions. There is broad evidence of frost action throughout the region. Altiplanation terraces are common features of the Ray Mountains, particularly in the unglaciated highlands (Photo 4). Sorted stone circles, rock polygons, and stone stripes are also common at higher elevations where soil development and vegetative growth are limited (Photo 5-6).

Concentrated Study

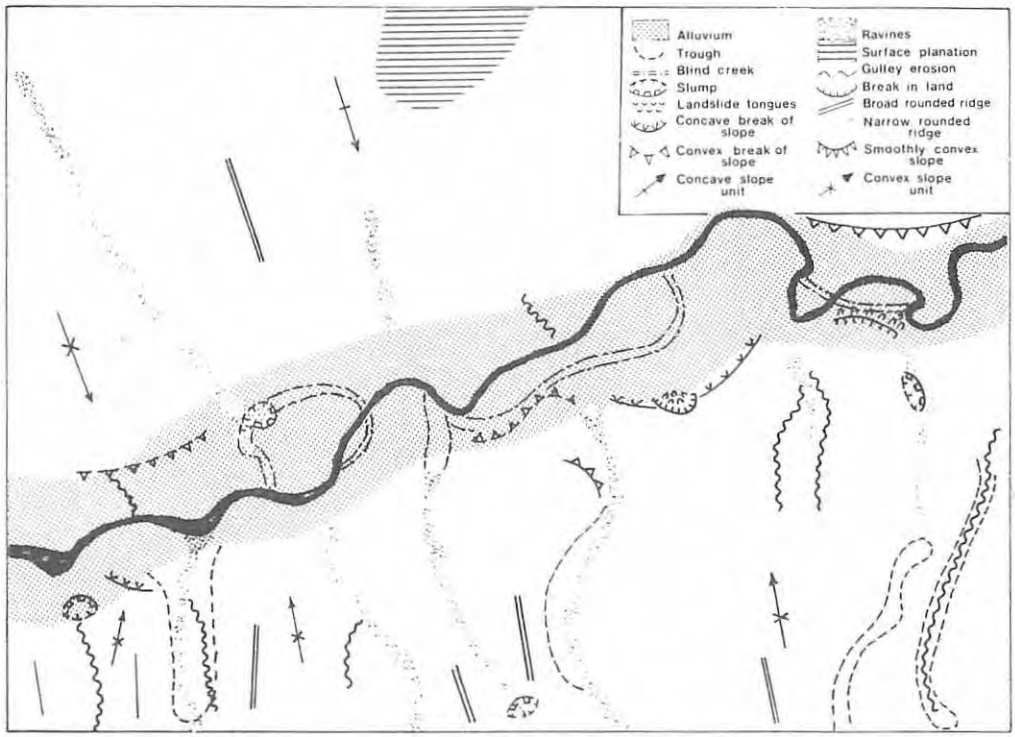
Torment Creek is a typical North Slope region drainage: a north-trending asymmetrical valley with headwaters in a nivation cirque. On the gradual slope on the lower elevation west-facing side of the valley is a good example of the solifluction slopes found throughout the Ray Mountains. The east-facing side is steeper with 18 m cliffs and rock slides, undercut slopes, and well drained forest.

Fig. 4 shows a reduction of a simple geomorphic map that was drawn from the lower Torment Creek valley large-scale black and white near infrared 1:5,000 aerial photo covering 1.5x1 km, which also served as the basis for some vegetation mapping (Brock and Burke, this volume). Used with a topographic map it yields a great deal more information about the terrain than a topographic map or aerial photo alone. For example, breaks in slope often indicate remnant stream boundaries; concavity reveals consistently large solifluction lobes and in other sites favorable conditions for solifluction terraces. Mapping of soil porosity and permeability would require a soils and surficial geology overlay and ground truthing, but would be very important for mapping water penetration and thus weathering (Cooke and Doornkamp 1974).

ACKNOWLEDGMENTS

Drs. Warren Yeend and Robert Chapman of the Alaska Branch of the US Geological Survey, Menlo Park, California, and Charles Herbert provided important information that focused this inquiry. Dr. Brewster Baldwin of the Middlebury College Geology Department provided valuable assistance throughout this study.

Fig. 4. Aerial photograph and photo-based geomorphological map of lower Torment Creek valley photo area. Former stream channels are clearly visible; course changes have resulted from landslides and flooding. Shallow (1-2 m) gullies are formed by surface runoff which may develop into deeper (3-16 m) ravines. Slumps are characteristic of ice-rich permafrost terrain.



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SOILS

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ABSTRACT

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- Objectives

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APPENDIX -- Representative Soil Profiles

NOTE

The reader is referred to the Introduction of this volume for detailed descriptions of the project study area and the overall project research design. Also included there are descriptions of the project's three areas of concentrated study, with a map showing their locations and the locations of travel routes and Ray Mountains project sites (RMP sites Ia-VId) referred to in this chapter. Physiographic and ecological terms used consistently throughout this volume are defined in the Vegetation chapter. Vegetation classification in this chapter follows that presented in the Vegetation chapter.

ABSTRACT

Investigation of the Ray Mountains' soils included detailed study in two sites representative of the range, and more general study elsewhere in the range. Soil morphologies were described, and samples were collected and subsequently analyzed for organic carbon, pH, texture, and carbonates. Study of the relation of soils to vegetation, topography, and bedrock was emphasized. Strong correlations between vegetation, slope, drainage, and soil texture were found in the areas of concentrated study. During the summer, nine soil subgroups were identified. Most extensive soils are Lithic Cryorthents, Pergelic Cryaquepts, and Pergelic Cryochrepts. Soils of less importance include Pergelic Cryorthents, Histic Pergelic Cryaquepts, Lithic Cryaquepts, Lithic Cryochrepts, Pergelic Cryumbrepts, and Pergelic Cryorthods.

INTRODUCTION

Literature Review

There is little information on the soils of and near the Ray Mountains. In an exploratory soil survey of Alaska, based on aerial reconnaissance, remote sensing data, and scattered fieldwork, Reiger et al. (1979) suggest that two associations of soil subgroups occur in the range. The Pergelic Cryaquept - Pergelic Cryochrept association typifies the broad mid-elevation valleys, rolling lowlands and lower elevation floodplains. This first association comprises Pergelic Cryaquepts (40%), Pergelic Cryochrepts (35%), Pergelic Cryorthents (15%), and Pergelic Cryorthods (5%), with minor components including Typic Cryochrepts and rough mountainous land. The rough mountainous land - Lithic Cryorthent association is dominant in the high central rugged mountains and upper elevation valleys and on mid-elevation ridges. This association is characterized by three soils: rough mountainous land (45%), Lithic Cryorthents (25%), and Pergelic Cryaquepts (10%). Minor soils in this association include Lithic Cryochrepts, Lithic Cryorthods, Pergelic Cryoborolls, Pergelic Cryorthods, Pergelic Cryumbrepts, Lithic Cryaquepts and Histic Pergelic Cryaquepts. Although they did not mention specific morphological characteristics of these subgroups, Rieger et al. (1979) reported generally the probable soil textures present in the Ray Mountains: poorly drained silt loams extending from the Yukon River to the high valleys of the range; shallow, wet, gravelly soils along the

upper northern slopes and lower slopes and narrow valleys; and stoney soils along the high ridges.

The Hughes, Alaska quadrangle (US Geological Survey 1:250,000) adjacent to and northwest of the Ray Mountains, was the site of a detailed soil survey conducted by Schoephorester and Wingard (1965). They reported some upland soils similar to several found in the Ray Mountains including Pergelic Cryaquepts, Histic Pergelic Cryaquepts, and Typic Cryaquepts.

Objectives

The objectives of this study were 1) to conduct detailed study of selected sites for information about the common associations of soils, vegetation, topography, and to a lesser extent, bedrock; 2) to sample widely for determination of the types and extent of soils in the Ray Mountains; and 3) to collect samples for further laboratory analysis.

METHODS

Much of the fieldwork for the soils analysis occurred in the project's three areas of concentrated study (see Introduction, this volume; Fig. 1, this chapter). Fieldwork in two areas of concentrated study allowed analysis of common associations of soils and landscape, and provided the basis for comparison with soils studied in less detail elsewhere in the Ray Mountains.

In areas of concentrated study, investigations of the relation among soils, vegetation, topography, and bedrock were conducted. Three soils transects were established (Fig. 1): two in lower Torment Creek, 200 m and 400 m north of the project basecamp (RMP site IIb), and another southwest of RMP site IVa in Spooky Valley. The three transects crossed through gradients of elevation, slope, vegetation, drainage and bedrock. Along each transect, soil pits were opened where landscape changed distinctly.

Further study in other areas of the Ray Mountains, yielded information about recurring combinations of soils, vegetation, topography, and bedrock. In these areas of less concentrated study, pits were opened over a broad area (Fig. 1) where conditions favored a variety of soils. A total of 67 pits was opened in areas of concentrated and less concentrated study during the summer.

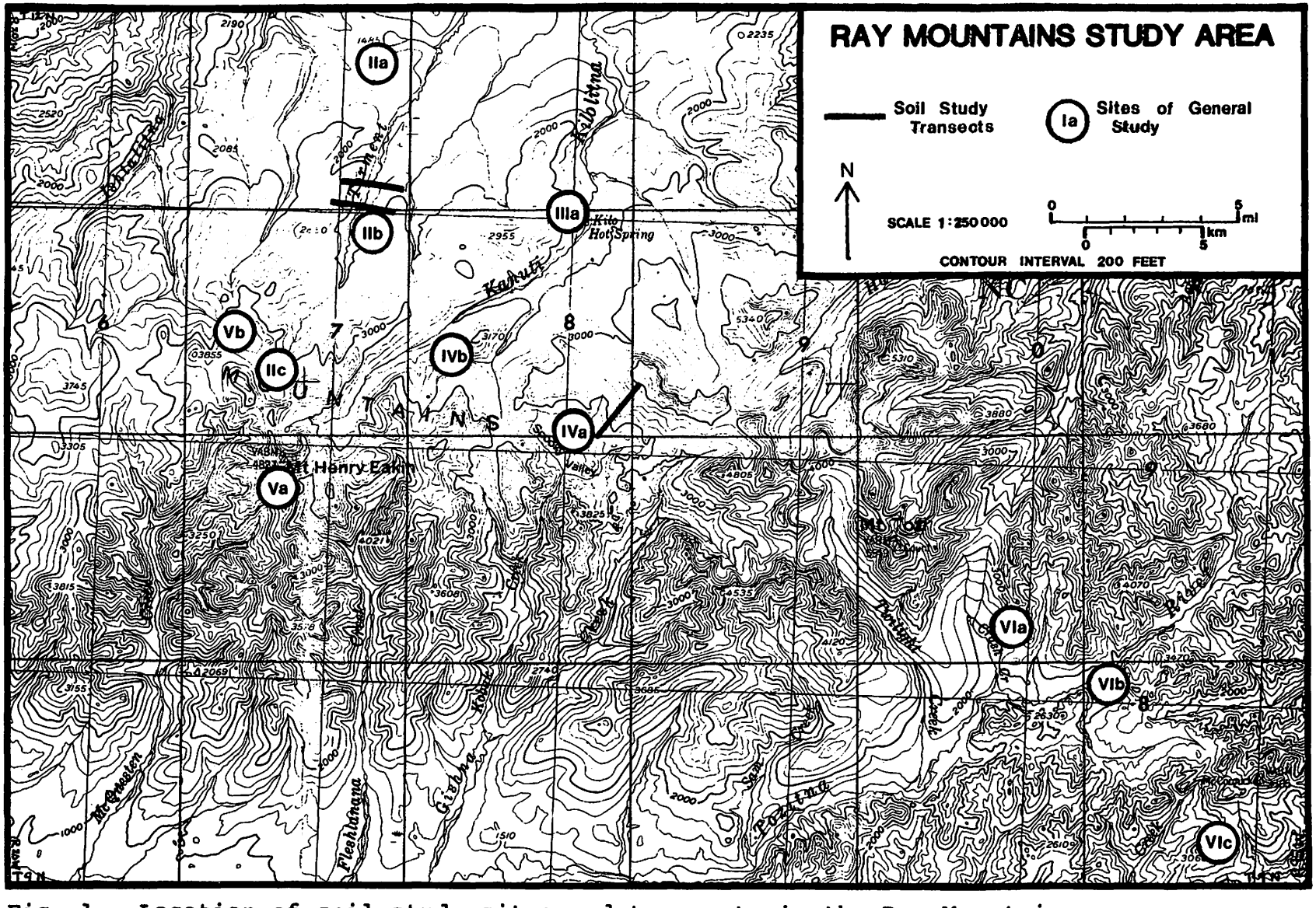

Fig. 1. Location of soil study sites and transects in the Ray Mountains.

Methods of data collection and analysis were similar in areas of concentrated and less concentrated study. Soil samples from these areas were analysed in the laboratory to confirm their subgroup classification according to the US Department of Agriculture (USDA) Soil Taxonomy (1978), which classifies soils by their morphologies. This hierarchical system has six levels: order, suborder, great group, subgroup, soil family, and soil series. The subgroup level of classification was used in this study for its field reliability.

Soil morphology descriptions and drainage estimates were made using the criteria of the USDA Soil Survey Manual (1962). Soil color was determined for moist soil samples according to standard Munsell color charts. Vegetation was classified according to Brock and Burke (this volume). At each pit, slope was measured with an Abney level, and elevation was estimated with a topographic map. Visual evidence of cryoturbation such as frost boils and sorted stone features was noted. Where possible a sample of the bedrock underlying a pit was collected for subsequent identification by the geology study team.

Samples collected for laboratory analysis were dried, crushed, and sieved through a 2 mm screen. The percent weight of material > 2 mm was determined. The fraction < 2 mm was used in all subsequent analyses. Physical and chemical analyses performed according to Jacobs et al. (1971) were as follows: soil texture was determined by the Bouyoucos method; pH was measured with a glass electrode from a 2:1 (soil:water) paste; organic carbon was determined by the ignition-loss method; and soils were checked for the presence of carbonates with a 10% HCl solution.

RESULTS AND DISCUSSION

Nine soil subgroups were found in the Ray Mountains (Table 1). Because large-scale soils mapping of the entire range was not attempted, the areal extent of these soil subgroups is not estimable. Instead, the dominance of particular soil subgroups was assessed on the basis of a previous study of Alaska that included the Ray Mountains (Reiger et al. 1979) and field observations made by this author.

Areas of Concentrated Study

Discussion of each area of concentrated study stresses the specific associations of soil texture and drainage, vegetation, slope, elevation, cryoturbation, and bedrock.

Table 1. Occurrence of soil subgroups at RMP sites studied.

Soil Subgroup	RMP Sites
Lithic Cryorthents	IIb-c; IVa-b; Va-b; VI
Pergelic Cryaquepts	IIa-c; III; IVa-b; Va; VIa-c
Pergelic Cryochrepts	IIa-b; IVa
Pergelic Cryorthents	IIa-c; IVa-b; Va-b
Histic Pergelic Cryaquepts	IIa-b; III; IVa-b; Va
Lithic Cryaquepts	IIb-c; IVa
Lithic Cryochrepts	IIc; IVa-b
Pergelic Cryumbrepts	IIb
Pergelic Cryorthods	IIb-c

Lower Torment Creek

The east and west slopes and floodplain of the lower Torment Creek valley are shown in a schematic profile (Fig. 2) based on a composite of two transects. In this area, particular associations of vegetation, topography, and soils are complexly interrelated, and are affected by climate.

Variability in drainage of the east slope soils is most closely related to the steepness of the slope and the occurrence of ice-cemented permafrost. Gradual slope (<5 degrees) and shallow, ice-cemented permafrost (<30 cm) contribute to poor soil drainage at the ridgetop because they impede runoff and percolation of water. The thick mat of Tussock-Graminoid Meadow vegetation, often with standing water between tussocks, may contribute to poor drainage by further obstructing surficial runoff and by insultating the permafrost layer. [Soil temperature studies made during the summer indicate that vegetation is a good insulator of frozen ground. Removal of vegetation in Tussock-Graminoid Meadow vegetation resulted in some thawing of the permafrost.]

On east slopes 8-15 degrees drainage is influenced by the microtopography of solifluction lobes (0.5-1.5 m scarps and 2-3 m tails) common on these slopes. Drainage can vary considerably within a lobe: at the tail, where permafrost is most shallow and slope near level, drainage is poor; drainage is best at the lobe scarp, where rapid runoff is favored by deeper permafrost and the steep slope (30-45 degrees).

The soil textures found on the east side of the valley are influenced by slope and drainage. Poorly drained clay loams occur at the ridgetop and silt loams beneath solifluction lobes. Silty clay loams occur at the foot of the east ridge, indicating that fines from the soils upslope are gradually being transported downhill.

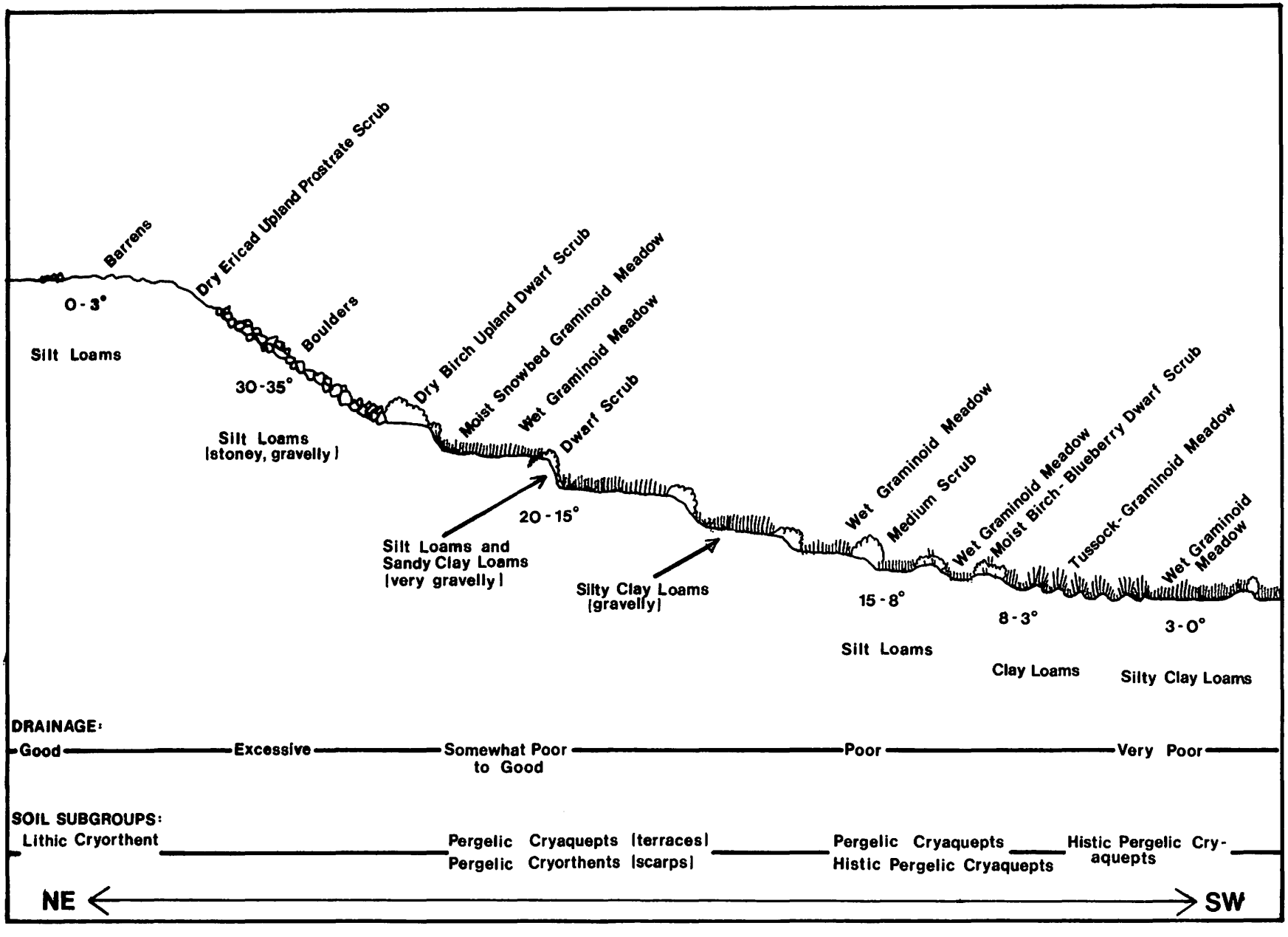

Fig. 3. Schematic profile (not to scale) of a SW-NE trending drainage in Spooky Valley showing vegetation, slope, soil texture, drainage, soil subgroups, and other features.

Vegetation of the east ridge is associated with poor drainage, gradual slope, and fine soil texture. Tussock-Graminoid Meadow occupies poorly drained soils in nearly flat areas. Dwarf Scrub - Graminoid Meadow and Dwarf Scrub - Tussock-Graminoid Meadow occur in areas with solifluction. On solifluction lobes, where slope allows slightly better drainage, more shrubs are present, and where drainage is impeded on lobe tails, Sphagnum moss cover increases. Soils covered with Tussock-Graminoid Meadow (downslope from the solifluction lobes) have drainage characteristics similar to those on the east ridgetop (5-8 degrees). Wet Graminoid Meadow and Wet Sphagnum Moss Meadow vegetation, underlain by poorly drained silty clay loams, occur at the foot of the east ridge slope. Pergelic Cryaquepts are the dominant soils on this poorly drained east side of the valley.

On the floodplain of lower Torment Creek there are areas of poor, moderate, and good drainage. They are generally associated with three vegetation types. 1) Dry White Spruce Floodplain Forest is present on very gravelly sandy loams and loamy sands, where adequate percolation of water and acid surface conditions (associated with decaying needle litter) promote podzolization of soils. A 2-5 cm albic (leached) layer and an iron-rich horizon are indicative of the Pergelic Cryorthods occurring there. Ice-cemented permafrost is undetectable at 100 cm. 2) Wet Black Spruce - Sphagnum Forests occur on poorly drained silt loams and sandy clays where permafrost is detectable at 60-70 cm. This vegetation is underlain by Pergelic Cryaquepts. 3) Ice-cemented permafrost is undetectable in moderately well drained and well drained loamy sands (Pergelic Cryochrepts and Pergelic Cryorthods) supporting Tall and Medium Scrub vegetation types.

At the foot of the west slope, colluvium covered thinly by loams and interspersed with shattered mica schist fragments underlies Tall and Medium Scrub vegetation. Slopes 18-25 degrees have well drained gravelly sandy clay loams which support Moist Paper Birch - White Spruce Forest. The gravel is shattered mica schist (3-15 cm long). Slopes 25-30 degrees have Moist Paper Birch Slope Forest on very gravelly loams. Moist White Spruce Slope Forest on sandy clay loams occurs on 10-15 degree slopes. Scattered Tall Scrub and Medium Scrub thickets occur on less steep slopes with silt loams. On the west ridgetop Tussock-Graminoid Meadow and Dwarf Scrub - Tussock-Graminoid Meadow are present on poorly drained silty clay loams. Bedrock is shallow there (25-45 cm). Several soil subgroups occur on the west slope (Fig. 2).

Spooky Valley

Although only one soil transect was established in Spooky Valley (RMP site IVa), supplementary data from adjacent areas

are considered in this discussion. Figure 3 is a schematic profile of the relation of soils to landscape in Spooky Valley; the transect runs NE-SW, from a well drained narrow ridge to a wet valley bottom.

Unvegetated silt loam soils, boulder fields, and tors occur on the ridge top; barren vegetation types, underlain by well drained silt loams (very gravelly Lithic Cryorthents) are common. Frost boils, sorted stone stripes, and rock polygons occur frequently here. On the steep slope below the ridgetop silt loams nearly devoid of vegetation occur. Scree and boulder slopes interrupt this sparse vegetation of Dry Ericad Upland Prostrate Scrub and Barren types.

Large solifluction terraces (3-6 m scarps; 15-25 m terraces) occur at the base of these steep slopes. Although most of the terraces are well saturated, the scarps are well drained. Stones and gravel (usually granitic) constitute 50% of the soil volume. The top edges of the scarps are often devoid of vegetation. The well drained silt loams and sandy clay loams (Pergelic Cryorthents) of the the scarps support Dwarf Scrub vegetation. Wet Graminoid Meadows and Moist Snowbed Graminoid Meadows occupy the terrace and scarp foot.

Below 700 m elevation solifluction lobes, rather than terraces, occur. Apparently poor drainage and fine textures of these soils saturating these soils (silty and clayey loams) contribute to the formation of smaller solifluction lobes interspersed with hummocky ground. Medium Scrub vegetation covers the 1.5-2 m scarps of these lobes. The hummocks have Wet Graminoid Meadow and Moist Birch - Blueberry Dwarf Scrub vegetation and are underlain by ice-rich permafrost below a 15-30 cm organic horizon. Wet Tussock-Graminoid Meadow vegetation is present on silty clay loams and silt loams downslope from the lobes. Permafrost, at 25-50 cm, is continuous below this vegetation and soil. In the valley bottom, Wet Graminoid Meadow vegetation is underlain by clay and silty clay loams, which are saturated year around by water. A complex of soil subgroups are associated with the vegetation of this transect (Fig. 3).

Soil Subgroup Accounts

This section catalogues the morphology, vegetation, and topography characteristic of the nine soil subgroups occurring in the areas studied. Subgroups are presented in estimated order of their importance in the Ray Mountains, with most extensive subgroups described first. A soil profile representative of each subgroup appears in the Appendix. Associations of soil subgroups and vegetation are listed in Table 2.

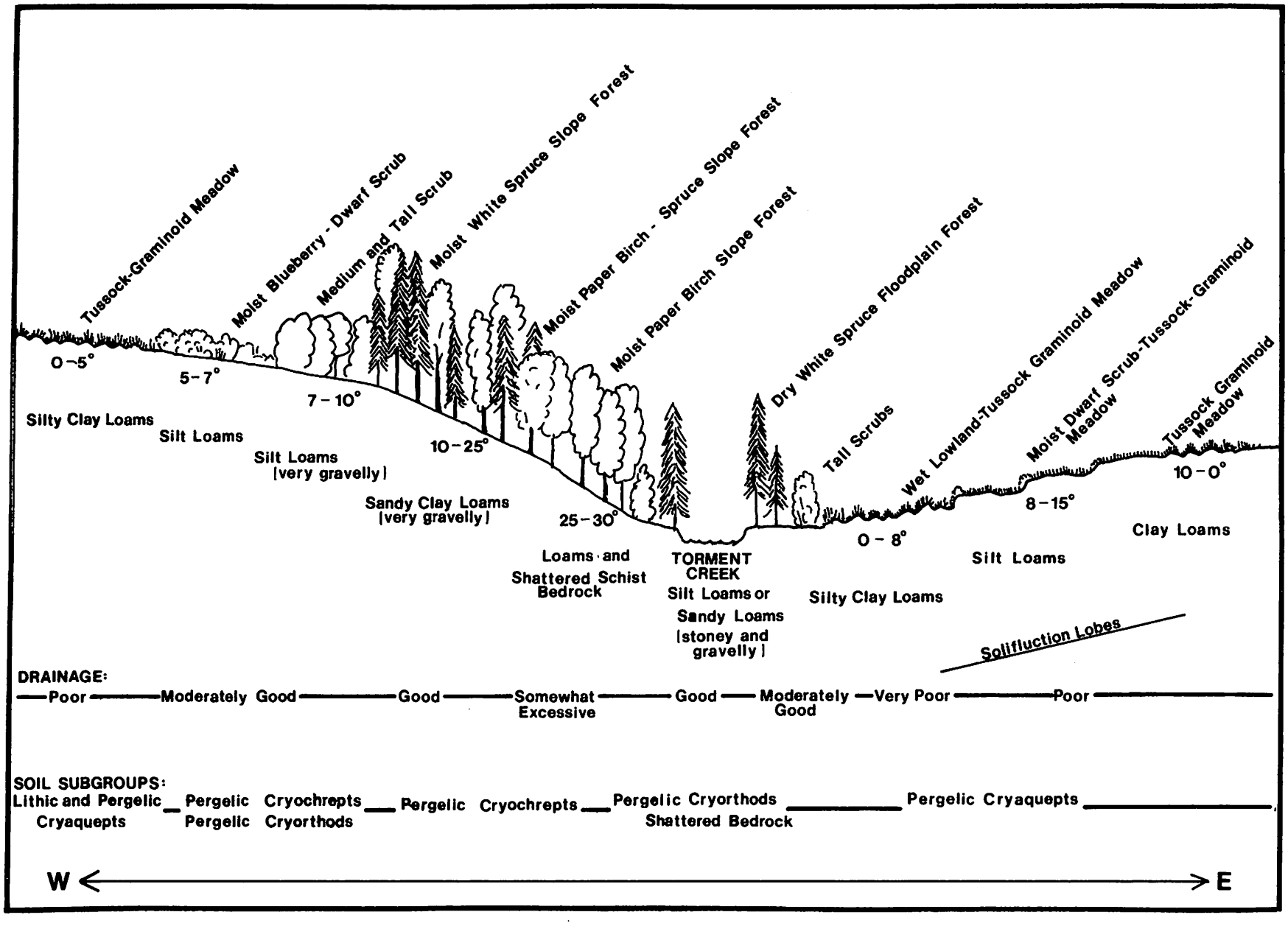

Fig. 2. Schematic profile (not to scale) of lower Torment Creek showing vegetation, slope, soil texture, drainage, soil subgroups, and other features.

Table 2. Geographic occurrence of associations of vegetation and soil subgroups in the study area; X -- common, R -- rare.

SOIL SUBGROUP	Moist White Spruce Slope Forest	Dry White Spruce Floodplain Forest	Moist White and Black Spruce Slope Forest	Wet Black Spruce-Sphagnum Forest	Moist Paper Birch Slope Forest	Dry Paper Birch Lichen Slope Forest	Moist Paper Birch-Spruce Slope Forest	Tall Scrubs	Medium Scrubs	Moist Birch - Blueberry Dwarf Scrub	Dry Birch Upland Dwarf Scrub	Dry Ericad Upland Prostrate Scrub	Moist Dwarf Scrub - Graminoid Meadow	Moist Dwarf Scrub - Tussock-Graminoid Meadow	Moist Tussock-Graminoid Meadow	Wet Lowland Tussock-Graminoid Meadow	Wet Graminoid Meadow	Moist Snowbed Graminoid Meadow	Moist Snowbed	Wet Sphagnum Forb Meadow	Dry Sphagnum Moss Meadow	Dry Upland Fellfield Barren	Dry Lichen Upland Rock Barren
Lithic Cryorthent											X	X								X		X	X
Pergelic Cryaquept			X					X	X				X	X	X	X			X				
Pergelic Cryochrept	X	X	X		X	X	X				X	X						X					X
Pergelic Cryorthent								X	X		X	X						X	X		X		X
Histic Pergelic Cryaquept														R	X	X			X				
Lithic Cryaquept										X				X	X	X							
Lithic Cryochrept										R	X	X						X				X	X
Pergelic Cryumbrept												X											
Pergelic Cryorthod		X																					

Lithic Cryorthents

These are the Cryorthents having a lithic contact within 50 cm of the soil surface. In the study area they occupy well drained ridgetops and steep slopes (>15 degrees) near RMP sites IIb-c, IVa-b, Va, and VI. Several vegetation types are associated with Lithic Cryorthents (Table 2), in particular Barrens vegetation types. All sites evidence periglacial activity, including frost boils and other frost-sorted features such as rock polygons and stone stripes. The organic and upper mineral horizons are medium to strongly acid, and become less acid in the lower horizons. Organic layers are usually less than 10 cm thick. Ice-cemented permafrost was not detectable in any of the Lithic Cryorthents examined. Most are coarsely textured (often very gravelly or stoney) and even after heavy rain drain, quickly and remain unsaturated. Lithic Cryorthents examined may have a pergelic temperature regime (mean annual soil temperature of 0 C).

Pergelic Cryaquepts

Occurring mostly in poorly and somewhat poorly drained areas, these soils are rare in the high, rugged central Ray Mountains, but common in the rest of the range (Photo 2). Buried horizons, bare ground, hummocky ground, and frost boils are common indicators of periglacial activities in these soils. Pergelic Cryaquepts generally have a thick wet organic layer over a strongly acid surface mineral horizon (5-10 cm). Below this horizon is a mottled, reduced (gleyed) very dark grayish brown layer. Mottling indicates fluctuating water conditions. Ice lenses and ice-cemented permafrost are common in this layer. Pergelic Cryaquepts were found in the widest variety of vegetation types (Table 2) and occurred at RMP sites IIa-c, IIIa-b, IVa-b, Va, and VIa-c.

Pergelic Cryochrepts

Pergelic Cryochrepts occur on well drained sites including slopes (especially from 10-30 degrees), floodplain bars, and narrow ridges. Most of those sampled have sandy loam or loamy sand textures. Frequently the organic layer is absent from the soil. Otherwise it is thin (3-5 cm) and moderately to strongly acid. The surface mineral horizon is very dark brown or black, weakly expressed, and interrupted by the underlying cambic horizon (dark brown to dark yellowish brown). This horizon rests on a very dark grayish brown to olive brown layer which is not ice-cemented at 100 cm. The Moist Paper Birch - Spruce Slope Forest is the predominant vegetation type associated with this soil, though in the uplands several vegetation types are associated (Table 2). Stone stripes, rock polygons, and stone nets are common on these soils in the high, central rugged mountains and upper

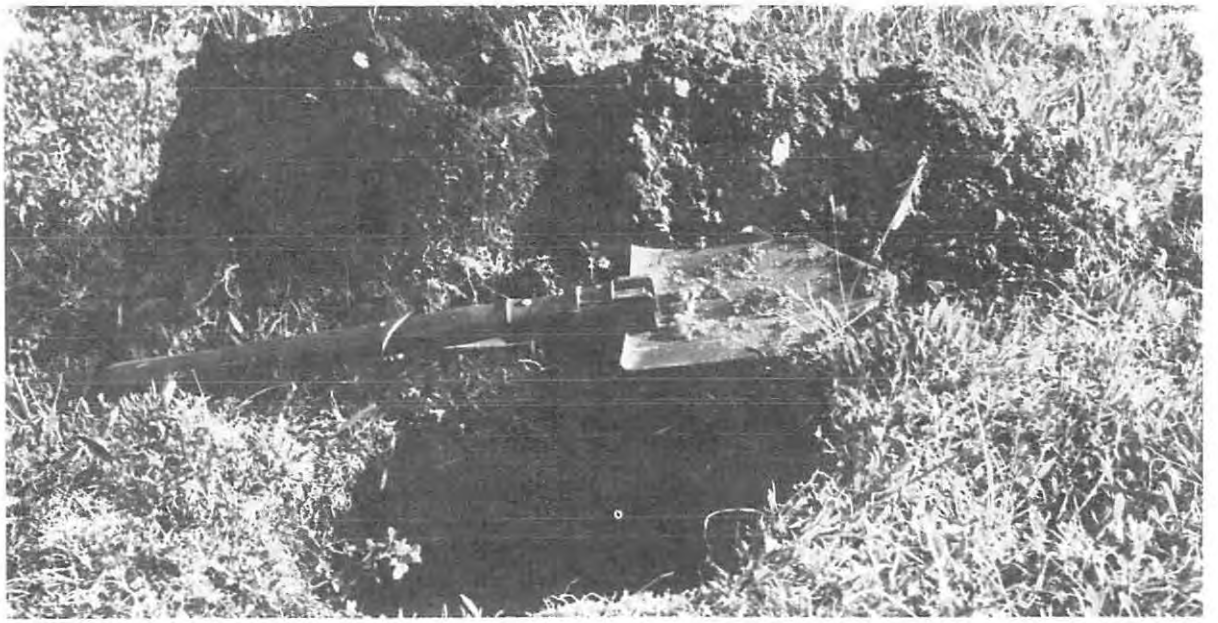

Photo 1. A Lithic Cryaquept (silt loam) overlain by Tussock-Graminoid vegetation near lower Torment Creek basecamp; note the thick over-turned organic layer and the very gravelly gleyed soil (from the C horizon).

Photo 2. A Pergelic Cryaquept (silty clay loam) overlain by Tussock-Graminoid vegetation near Crash Creek (RMP site VIa); note the thick layer of organic material underlain by thin A and B2 horizons, and the gleyed C horizon.

elevation ridges. Pergelic Cryochrepts were studied at sites IIa-b and IVa.

Pergelic Cryorthents

These Cryorthents, lacking a lithic contact within 50 cm of the soil surface, have a pergelic temperature regime. They are found on well drained ridges and on slopes > 15 degrees. Most are coarsely textured and very gravelly or stoney. Several vegetation types are associated with Pergelic Cryorthents (Table 2), among them Dry Birch Upland Dwarf Scrub and Dry Ericad Upland Prostrate Scrub. All organic and mineral horizons are strongly acid to very strongly acid. Surface horizons are usually thin and weakly expressed. Ice-cemented permafrost was not detected under these soils at depths to 1 m. There is strong evidence of frost action in these soils including rock polygons and stone stripes. Examples of Pergelic Cryorthents were studied near RMP sites IIIa-b, IVa-b, and Va-b.

Histic Pergelic Cryaquepts

These Cryaquepts are recognized by a histic surface horizon (organic layer 20-40 cm) and poor drainage. They occur along the floodplains and slopes less than 5 degrees in the upper elevation valleys, broad mid-elevation valleys, and rolling lowlands. Examples of Histic Pergelic Cryaquepts were studied near sites IIa-b, IIIa-b, IVa-b, and Va. Where the histic layer exceeds 40 cm these soils are considered as one of the Cryofibrists (occurring in one hectare of RMP site IVa). Most Histic Pergelic Cryaquepts evidence frost action in the form of hummocky ground and buried horizons. The vegetation associated with these soils is usually dominated by graminoids (Table 2) and includes Wet Graminoid Meadow, and occassionally, Wet Sphagnum Moss Meadow. These soils are moderately fine to medium textured and infrequently gravelly. All horizons are strongly acid, especially the histic horizon. These soils are probably wet year around.

Lithic Cryaquepts

Lithic Cryaquepts have a lithic contact within 50 cm of the soil surface. In the Ray Mountains Lithic Cryaquepts may have a mean annual soil temperature less than 0 C. They occur on poorly drained or somewhat poorly drained ridgetops in the high central rugged mountains, in the upper elevation valleys, and in many of the broad, mid-elevation valleys near rock outcrop (Photo 1). Lithic Cryaquepts often have unvegetated surfaces, buried surficial horizons, and frost boils. They are associated with Wet Graminoid Meadow, Moist Dwarf Scrub - Tussock-Graminoid Meadow, Moist Tussock- Graminoid

Meadow and Moist Dwarf Scrub - Graminoid Meadow (Table 2). Lithic Cryaquepts occurred near RMP sites IIb-c and IVa. Lithic Cryaquepts studied have gravelly, clayey silt loam textures. The organic horizons are usually < 5 cm. The surface mineral horizon may be thicker (5-10 cm), is black, and overlies a grey brown subsurface layer. Ice-cemented permafrost is occasionally found interspersed with shattered bedrock bits.

Lithic Cryochrepts

Lithic Cryochrepts have a lithic contact within 50 cm of the soil surface. Otherwise they are classified like Pergelic Cryochrepts. Found in the high, rugged central mountains, the upper elevation valleys, and on mid-elevation ridges, they are fequently bare and occur on slopes 15-30 degrees and on well drained narrow ridges (<50 meters). Some periglacial features occur with these soils, notably sorted stone stripes. Lithic Cryochrepts at the study sites often lack an ochric epipedon; in such cases a brown cambic horizon occurred at the soil surface. These soils are slightly acid to medium acid, though occasionally strongly acid. Most Lithic Cryochrepts are stoney or gravelly silt loams. Unlike Pergelic Cryochrepts they do not support forests. Vegetation types associated with these soils are Dry Birch Upland Dwarf Scrub, Moist Snowbed Graminoid Meadow, Dry Lichen Upland Rock Barren, and Dry Ericad Upland Prostrate Scrub (Table 2). These soils were studied at RMP sites IIc and IVa-b.

Pergelic Cryumbrepts

Pergelic Cryumbrepts have a pergelic temperature regime. They have an umbric epipedon; its characteristics include black color, base saturation < 50%, and thickness > 18 cm (unless underlain by a lithic contact). They are rare in the study area, confined to steep slopes and narrow ridges that are well drained or exceptionally well drained. They occupied several such spots in the lowlands. No examples were found in the uplands. Evidence of cryoturbation in these soils is rare. The umbric epipedon is strongly acid, on one occasion extremely acid. None were underlain by cambic (B2) horizons. All Pergelic Cryumbrepts found have silt loam textures. The vegetation types associated with these soils include Dry Birch Upland Dwarf Scrub (Table 2). They were studied at RMP site IIc.

Pergelic Cryorthods

Pergelic Cryorthods have significant accumulations of organic carbon, aluminum, and iron in a subsurface layer (spodic horizon). In the Ray Mountains, Pergelic Cryorthods

were uncommon, occurring under Dry White Spruce Floodplain Forest; no examples were found in the upland areas. A thin albic (leached) horizon is characteristic of the well drained Pergelic Cryorthods. Most examples are loams or sandy loams, and are strongly acid. All examples were studied at RMP site IIc.

Summary and Suggestions for Further Research

In two areas representative of the Ray Mountains, detailed study of the relationship among soils, vegetation, topography, and bedrock was conducted.

Drainage, slope, and soil texture influence the formation of particular vegetation types in lower Torment Creek. Gradual to moderate slopes have Tussock-Graminoid Meadow and Wet Graminoid Meadow vegetation underlain by poorly drained Pergelic Cryaquepts. Well drained Pergelic Cryochrepts and Pergelic Cryorthods occur beneath Moist Paper Birch - White Spruce Slope Forest and White Spruce Floodplain Forest on steeper slopes.

Ridges in Spooky Valley that have Barrens or Dry Upland Prostrate Scrub vegetation are associated with Lithic Cryorthents. Pergelic Cryaquepts and Histic Pergelic Cryaquepts occur on gradual slopes and in valleys with impeded drainage, and are frequently occupied by Wet Graminoid Meadow or Tussock-Graminoid Meadow vegetation. Hummocky ground is formed on the well saturated silty and clayey loams at the footslopes.

Solifluction lobes are common to slopes in Spooky Valley and in lower Torment Creek from 8-15 degree with poor drainage, ice-cemented permafrost, and Tussock-Graminoid Meadow vegetation. Solifluction terraces are significantly larger than lobes, and occur where slopes are steeper and soils more coarsely textured. Most terraces are associated with Moist Snowbed Graminoid Meadow vegetation.

General study throughout the range resulted in identification of nine soil subgroups. Lithic Cryorthents, Pergelic Cryaquepts, and Pergelic Cryochrepts were most extensive. Other less extensive soils include Pergelic Cryorthents, Histic Pergelic Cryaquepts, Lithic Cryaquepts, Lithic Cryochrepts, Pergelic Cryumbrepts, and Pergelic Cryorthods.

Pending the availability of large-scale aerial photography of the whole range, further study of landscape-soil associations could focus on detailed soils mapping. Such mapping could substantiate speculation about the extent of different soil subgroups.

AKNOWLEDGMENTS

Throughout this pedological study, I have been helped by the constructive advice and review of several people; to each of them I owe considerable thanks. I owe special thanks to Kevin Meyer (BLM, Anchorage) for his insights into field studies. Jim Walters (University of Northern Iowa) has aided this project with his helpful suggestions at its inception and critical review of this final report. Bob Churchill (Middlebury College) guided me through my initial research on arctic soils, and has been enthusiastic and indispensible in all areas from graphics to final review.

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APPENDIX

Representative Soil Profiles

Lithic Cryorthents

RMP site IIc: on the lip of a solifluction lobe.
Slope: 8-15 degrees Elevation: 900 m
Aspect: east
Vegetation: Dry Ericad Upland Prostrate Scrub

Depth cm	Horizon	Description
1-0	O	Original vegetation discernable in organic material.
0-4	A1	Dark brown (7.5YR 3/2); very gravelly silt loam; weak, fine granular; nonsticky, nonplastic; clear, smooth boundary; pH 5.7; few roots.
4-45	C	Dark brown (10YR 3/3); very gravelly silt loam; weak, fine crumb; abrupt, smooth boundary; pH 5.0;Bedrock at 46 cm.

Pergelic Cryaquepts

RMP site IIb: at the foot of the ridge west of Torment Creek
Slope: 0-3 degrees Elevation: 750 m
Vegetation: Wet Black Spruce - Sphagnum Forest

Depth cm	Horizon	Description
8-7	O1	Some lichens, Vaccinium spp. discernable.
7-0	O2	Black, wet.
0-6	A1	Black (10YR 2/1); silt loam; weak; very fine to fine crumb; nonsticky, nonplastic; abrupt wavy boundary; pH 4.0.
7-16	A2	Very dark grayish brown (10YR 3/2); silt loam;weak, fine crumb; nonsticky, nonplastic; abrupt, wavy;pH 4.9; gravelly.
17-20	B2	Brown (7.5YR 5/4); silt loam; massive, fine platy; slightly sticky, slightly plastic; clear, smooth boundary; pH 5.3.
20-22	B3	Dark grayish brown (2.5Y 4/2) mottled with dark brown (7.5YR 4/4); silty clay loam; massive, single grain; slightly sticky, slightly plastic; abrupt, wavy boundary; pH 5.5; 20% coarse schist fragments.
22-30	C	Olive gray (5Y 4/2); silty clay loam pit fills with water at this depth; sticky, slightly plastic; pH 6.0; ice-cemented permafrost at 30 cm (6/20/79).

Pergelic Cryochrepts

RMP site IIb: on ridge west of Torment Creek.
Slope: 18 degrees Elevation: 650 m
Aspect: east
Vegetation: Moist Paper Birch - Spruce Slope Forest

Depth cm	Horizon	Description
3-2	O1	Leaf and needle litter.
2-0	O2	Fine root material and other litter.
0-5	A	Black (7.5YR 2/1); silt loam; weak, granular; nonsticky, nonplastic; abrupt, wavy boundary; 5.6-6.0 pH.
5-7	B2	Grayish brown (10YR 5/2); silt loam; single grains; nonsticky, nonplastic; abrupt, wavy boundary; pH 6.1-6.5.
7-30	C	Dark yellowish brown (10YR 4/4); very gravelly loam; single grains; nonsticky, nonplastic; abrupt, smooth boundary; pH unknown.
30	IIC	Coarse schist fragments.

Pergelic Cryorthents

RMP site IVb: a well drained stream bank.
Slope: 5 degrees Elevation: 750 m
Aspect: WSW
Vegetation: Moist Snowbed Graminoid Meadow

Depth cm	Horizon	Description
1-0	O2	Slightly decayed vegetation.
0-3	A	Black (10YR 2/1); silt loam; massive; sightly sticky, slightly plastic; abrupt, wavy boundary; pH 4.5-5.0.
4-9	B2	Dark gray (5Y 4/1); silt loam; massive; nonsticky, nonplastic; abrupt, wavy boundary; pH 5.1-5.5.
9-38	B3	Olive brown (2.5Y 4/4); loamy sand; single grain; nonsticky, nonplastic; clear, smooth boundary; pH unknown.
38-65	C	Yellowish red (5YR 5/8); loamy silt; single grains nonsticky, nonplastic; pH unknown; stones at 65 cm.

Histic Pergelic Cryaquepts

RMP site IIa: about 75 m ENE of the east lakeshore.
Slope: 0 Elevation: 460 m
Vegetation: Wet Lowland Tussock-Graminoid Meadow

Depth cm	Horizon	Description
0-6	O1	Organic material--mosses, graminoids.
6-10	O2	Black (10YR 2/1) Well decayed, perhaps some charcoal in this layer.
10-18	03	Dark Brown (10YR 3/3); silt loam with >60% organic material; slightly sticky, slightly plastic; abrupt, wavy boundary; ph 5.1-5.5.
18-30	04	Dark brown (7.5YR 3/2); silt loam with 35% organic material; slightly sticky, non plastic; pH unknown; ice-cemented permafrost at 31 cm (July 18, 1979).

Lithic Cryaquepts

RMP site IIb: west ridgetop of lower Torment Creek.
Slope: 10 degrees Elevation: 780 m
Aspect: east
Vegetation: Moist Dwarf Scrub - Tussock Graminoid Meadow

Depth cm	Horizon	Description
8-3	O2	Partly decomposed vegetation.
3-0	O1	Black (5Y% 2.5/1); mostly decaying graminoids and mosses.
0-25	C	Very dark grayish brown (10YR 3/2); loam; massive structure; slightly sticky, nonplastic; mica grains in soil; clear, smooth boundary; pH 5.5-6.0; ice-cemented permafrost and mica schist bedrock at 25 cm (7/16/79).

Lithic Cryochrepts

RMP site IIc: a well drained ridge west of IIc.
Slope: 12 degrees Aspect: east Elevation: 1000 m
Vegetation: Dry Ericad Upland Prostrate Scrub

Depth cm	Horizon	Description
1-0	O1	Patchy organic layer.
0-3	A	Dark Brown (7.5YR 3/2); loam; single grains; nonsticky, nonplastic; abrupt, smooth boundary; ph 5.1-5.5.
3-10	B2	Yellowish brown (10YR 4/6); loam; single grains; nonsticky, nonplastic; abrupt, irregular boundary; pH 5.1-5.5.
10	IIC	Shattered gneiss bedrock.

Pergelic Cryumbrepts

RMP site IIb: on ridge west of Torment Creek.
Slope: 3 degrees Elevation: 800 m
Aspect: east (slight)
Vegetation: Moist Dwarf Scrub - Graminoid Meadow

Depth cm	Horizon	Description
5-0	O2	Well decayed root matter.
0-9	A1	Black (7.5YR 2/0); clayey silt loam; weak, fine crumb; slightly sticky, slightly plastic; clear, wavy boundary; pH 4.5.
9-18	A2	Dark Brown (7.5YR 3/4); silt loam; weak, fine crumb; sticky, slightly plastic; abrupt, irregular boundary; pH 4.5-5.0.
18	IIC	Very dark grayish brown (10YR 3/2); silt loam with 75% coarse gravel; weak-massive, slightly- or non-sticky, slightly plastic, pH unknown.

Pergelic Cryorthods

RMP site IIb: in the Torment Creek floodplain, 100 m south of basecamp.
Slope: 0 Aspect: south Elevation: 550 m
Vegetation: Dry White Spruce Floodplain Forest

Depth cm	Horizon	Description
1-0	01	Spruce needle litter.
0-7	A1	Dark Brown (7.5YR 3/2); silt loam; moderate, fine crumb; non-sticky, non-plastic; abrupt, smooth boundary; pH 4.5-5.0.
7-9	A2	Gray (7.5YR 5/0); silt loam; single grains, fine; non-sticky, non-plastic; abrupt, wavy boundary; pH 4.0-4.5.
9-22	B2	Dark reddish brown (5YR 3/3); loam; weak, fine crumb; non-plastic, non-sticky; abrupt, smooth boundary; pH 4.5-5.0.
22-55	B3	Dark brown (7.5YR 3/2); loamy sand; single grains to weak, fine crumb; non-sticky, nonplastic; abrupt, irregular boundary; pH 6.1-6.5.
55	IIC	Colluvium: stones and gravel.

FLORISTICS

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ABSTRACT

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APPENDIX -- Species Accounts

NOTE

The reader is referred to the Introduction of this volume for detailed descriptions of the project study area and the overall project research design. Also included there are descriptions of the project's three areas of concentrated study, with a map showing their locations and the locations of travel routes and Ray Mountains project sites (RMP sites Ia-VId) referred to in this chapter. Physiographic and ecological terms used consistently throughout this volume are defined in the Vegetation chapter, as are vegetation type names used in this chapter. The ECOSYSTEMS referred to herein (in upper case lettering) are described in the Ecosystems chapter of this volume.

ABSTRACT

A total of 227 vascular plant species was collected in the Ray Mountains. Fifty-seven of these species were found beyond their previously known ranges. Even taking into account species expected but not found, the Ray Mountains have 150 fewer species than the White Mountains, another interior Alaskan mountain range of similar size, climate, and glacial history. Differences in the geology of the two ranges may explain this discrepancy, though Alaska's recent glacial history and subsequent plant migrations may also be contributing factors. The Ray Mountains flora is most closely related to the Brooks Range subdivision of the Beringian arctic flora, although ties with the North American alpine flora also exist.

INTRODUCTION

The Ray Mountains are part of a large floristically unexplored region bordered approximately by the south slope of the Brooks Range to the north, the Yukon River to the south and east, and the base of the Seward Peninsula to the west (Hulten 1968). In fact, Hulten emphasized that the mountains within this region were among the few remaining areas in Alaska where the flora was still virtually unknown.

The floras of several other small groups of mountains in interior Alaska have been previously investigated. In 1926, A.E. Porsild collected in the Kokrines Hills, a range 125 km west of the Ray Mountains (Porsild 1939a-c). Across the Yukon River and to the east, the Sawtooth Mountains remain uncollected; but the White Mountains, which lie east of the Sawtooth Range, have been investigated by O. Gjaerevoll (1958, 1963, 1967).

Objectives

The primary objective of the floristic investigation was to collect and otherwise document as many vascular plant species growing in the Ray Mountains as possible. The second objective was to analyze the data collected to 1) identify species with range extensions, 2) compare the flora of the Ray Mountains to the floras of the White Mountains and the Kokrines Hills, and 3) determine the phytogeographical affinities of the Ray Mountains flora to the Beringian arctic flora and the North American alpine flora.

The Ray Mountains are equidistant between the Brooks Range to the north and the Alaska Range to the south. Which range the Ray Mountains shared more species with has been in question (Young, pers. comm.). While the Brooks Range flora is considered part of the Beringian arctic flora (Young 1978), which contains a large Asiatic element, the arctic-alpine flora of the Alaska Range is more heavily influenced by the North American alpine floras.

In 1978, S.B. Young and T. Kassler collected two unexpected ferns, Asplenium viride and Cryptogramma crispa var. sitchensis in the Kokrines Hills (unpublished data). The main populations of these two species in Alaska are located on the Pacific coast, and neither had been collected in northern interior Alaska (Hulten 1968). Collection of the two ferns in the Kokrines Hills area raised additional questions about the phytogeographical affinities of the unknown Ray Mountains flora.

METHODS

To maximize the number of species encountered, the investigation was divided equally between collection in the important vegetation types in the study area and collection in or around the rock outcrops, exposed ridgetops, late snowbeds, and hot springs that the study team visited. For two reasons, collection was concentrated in the vegetation types associated with these features. First, such isolated or restricted vegetation types tend to have more variation in species composition than widespread vegetation types (Murray, pers. comm.). Second, taxonomically problematic genera and families in Alaska also commonly occur in such restricted vegetation types. These include the genera Stellaria, Minuartia, Draba, and Potentilla, and the families Gramineae, Cyperaceae, and Compositae (Murray, pers. comm.). Some of the most common boreal species were simply noted rather than collected.

Collection sites

Plant collections were taken from nine sites within the study area (Fig. 1). The most extensive collecting occurred in the lower portion (BOREAL FOREST and LOWLAND TUNDRA) of the Torment Creek drainage (RMP site IIb) and in the UPLAND TUNDRA and ALPINE BARREN of Spooky Valley (RMP site IVa). Together, these areas provided a transect of the major ecosystems of the Ray Mountains (Schubert, this volume), which included most of the vegetation types identified in the range (Brock and Burke,

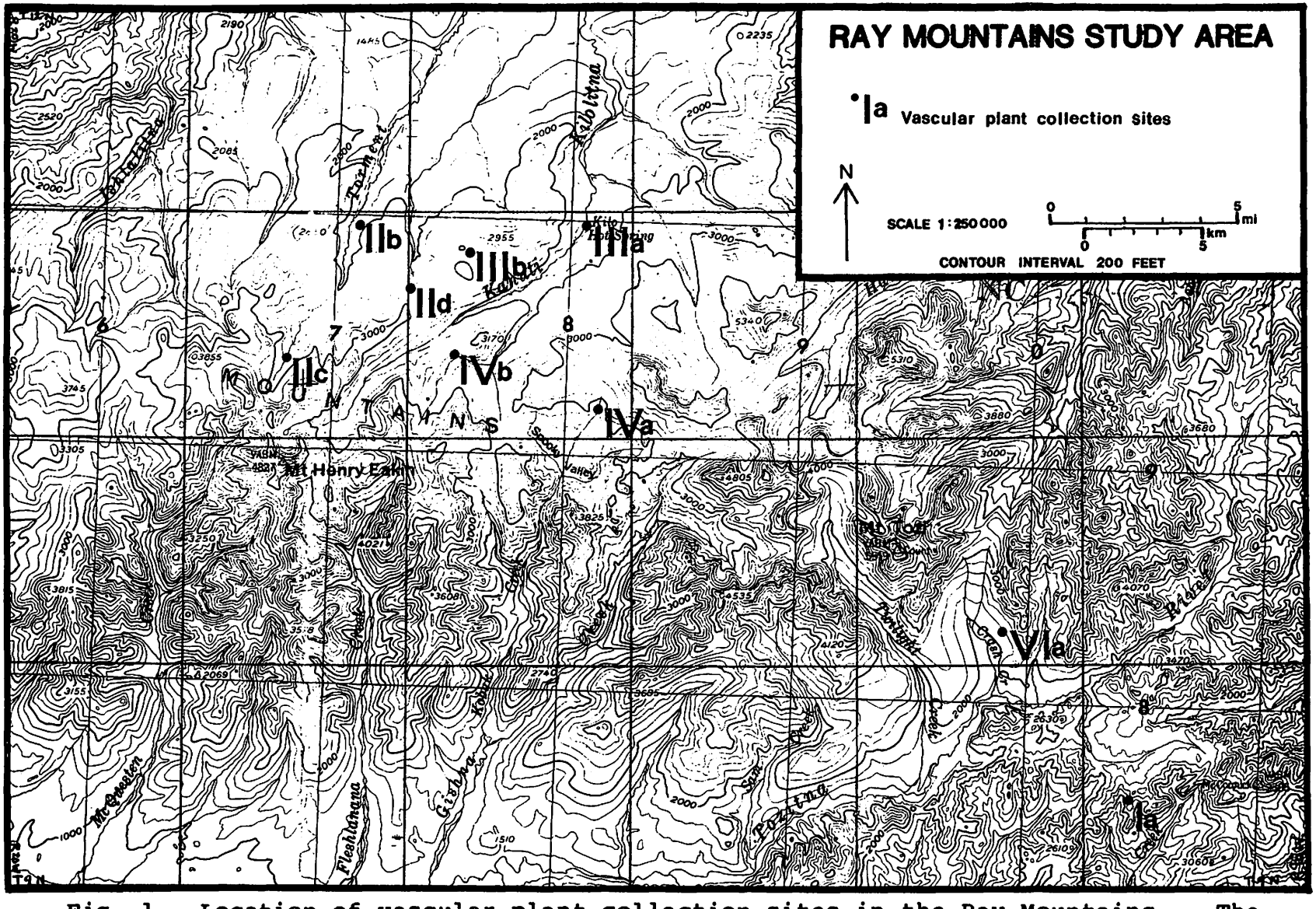

Fig. 1. Location of vascular plant collection sites in the Ray Mountains. The most extensive collections were made at RMP sites IIb and IVa, followed by IIc. Fairly large collections were made at IIIa, IId, IIIb, and Ia, and small collections at IVb and VIa. Additional collecting occurred during travel between sites and elsewhere.

this volume). To increase the value of the data for other study team members, collections at both sites were concentrated in vegetation mapping areas, although some collections were made elsewhere.

Sampling conducted in the upper Torment Creek area (RMP site IIc), another of the project's areas of concentrated study, also covered a wide range of vegetation types characteristic of the UPLAND TUNDRA and ALPINE BARREN ecosystems.

Although large collections were made at the following four sites, they were primarily restricted to one or two vegetation types. Collecting at Kilo Hot Spring (RMP site IIIa) was restricted to the area affected by the spring. The spring is located at treeline within a Dry White Spruce Floodplain Forest.

The first of two collection sites on the ridge northwest of the Kanuti Kilolitna River (RMP site IId) was a north-facing rocky slope supporting alternate patches of Dry Ericad Upland Prostrate Scrub grading into Barrens, and Moist Snowbed Meadows.

Collections at the second site on the ridge (RMP site IIIb) were focused on a small outcrop containing some calcareous rock types, and the surrounding Dry Upland Fellfield Barren underlain by granite.

The only large collection made in the eastern end of the range was taken from a small ridge northwest of Moose Creek (1.6 km NW of RMP site Ia) that supported a Dry Upland Fellfield Barren.

A small collection was taken from a site that had been burned 20-50 years ago, located southeast of the Kanuti Kilolitna River (RMP site IVb). The site consisted of an outcrop surrounded by Moist Birch-Blueberry Dwarf Scrub and Moist Dwarf Scrub - Tussock-Graminoid Meadow.

In addition to these collection sites, smaller collections were made by the author and other study team members during travel (see annotated list for acknowledgments). In some cases, other study team members made important collections, notably from a serpentine-rich outcrop in the Crash Creek drainage (RMP site VIa).

The entire collection has been divided into two sets that will be donated to the University of Alaska Herbarium (Fairbanks, Alaska), and the Center for Northern Studies Herbarium (Wolcott, Vermont).

Nomenclature in this chapter follows Hulten (1968, 1973) except for Salix spp. (Viereck and Little 1972) and Draba

spp. (Mulligan 1976). Unless intraspecific identification was certain, specimens were only keyed to the species level. Extensive use was made of specimens from the University of Alaska Herbarium for species identification. Dr. D.F. Murray kindly assisted in the verification of some difficult taxa.

Floristic investigations in the Ray Mountains were limited by two factors. First, substantial collecting could not begin until early July, after basecamp had been established; by this time most species were either in peak bloom or on the decline. Further disadvantages were imposed by the group's restricted mobility and the small capacity of the plant press carried on prolonged trips away from basecamp.

RESULTS AND DISCUSSION

In the following section, results are presented and evaluated for their representation of the complete Ray Mountains flora. Range extensions documented by the collections are identified and briefly discussed. The Ray Mountains flora is compared with the floras of the White Mountains and Kokrines Hills and a hypothesis explaining the relationship between the first two is presented. The discussion closes with an evaluation of the phytogeographical associations between the Ray Mountains flora and the Beringian arctic and North American floras.

Collections

During the summer of 1979, 430 vascular plant collections were made in the Ray Mountains. From these collections and additional field notes, a total of 227 species have been identified (see Appendix). Because of the research limitations discussed in Methods above, this collection does not represent the complete flora of the Ray Mountains. Hulten's (1968) distribution maps, supplemented by reports on the flora of the Kokrines Hills (Porsild 1939a-c) and the White Mountains (Gjaerevoll 1958; 1963; 1967), indicate about 50 species which might occur in the Ray Mountains although they were not found during this investigation (Table 1). All of these species have extensive ranges in interior Alaska. Most species expected but not found have habitats that were not widely sampled in the study area -- bogs, shorelines, and calcareous soil. Other missing species are normally widely dispersed or have early flowering periods and thus may have been overlooked. Although both Boykinia Richardsonii and Oxyria digyna, both expected, are conspicuous alpine plants, neither was observed.

Table 1. Species expected to grow in the Ray Mountains which were not found during the 1979 investigation. All have broad distributions in interior Alaska, and are known to occur in Kokrines Hills or the White Mountains, or both.

Lycopodium obscurum
Lycopodium clavatum
Selaginella selaginoides
Equisetum scirpoides
Equisetum palustre
Cystopteris montana
Sparganium hyperboreum
Potamogeton alpinus
Alopecurus aequalis
Poa lanata
Poa paucispicula
Arctophila fulva
Festuca brachyphylla
Bromus pumpellianus
Eriphorum Scheuchzeri
Carex chordorrhiza
Carex tenuiflora
Carex media
Carex capillaris
Carex membranacea
Luzula rufescens
Lloydia serotina
Platanthera obtusata
Salix hastata
Salix arbusculoides
Oxyria digyna
Stellaria longipes
Minuartia obtusiloba
Minuartia rubella
Melandrium apetalum
Anemone parviflora
Anemone Drummondii
Ranunculus Gmelini
Ranunculus lapponicus
Corydalis pauciflora
Descurainia sophioides
Drosera rotundifolia
Boykinia Richardsonii
Chrysosplenium tetrandrum
Parnassia Kotzbuei
Astragalus alpinus
Hippuris vulgaris

(Table 1 continued on next page.)

Table 1 continued.

Epilobium palustre
Chamaedaphne calyculata
Gentiana propinqua
Menyanthes trifoliata
Castilleja caudata
Pedicularis Kanei
Utricularia intermedia

In addition, the eastern part of the Ray Mountains may support other uncollected species. Ten species collected on the ridge north of Moose Creek (RMP site Ia) and in the Crash Creek drainage (RMP site VIa) were not encountered at the more heavily collected sites to the west. These species include Woodsia glabella, Carex podocarpa, Cerastium arvense, Stellaria monantha, Minuartia Rossi, Ranunculus pygmaeus, Smelowskia calycina, S. bronchialis, Saxifraga exilis, and Eritrichium aretioides. If we assume that between 25 and 50 possible additional species do occur, then the total estimated flora of the Ray Mountains may be between 250 and 275 species.

According to the range distribution maps in Hulten (1968), the ranges of 57 species were extended to include the Ray Mountains (Table 2). Though the Ray Mountains are included within the defined range distributions of many common species in Hulten (1968), no previous documentation existed for any plants in the Ray Mountains.

Some of the species with range extensions are important components in specific vegetation types found in the Ray Mountains. These species include Carex microchaeta, Salix reticulata, S. Chamissonis, Saxifraga Nelsoniana, Cassiope tetragona, Castilleja elegans, and Pedicularis capitata (see Brock and Burke, this volume). The majority of species whose range extensions have been documented grow in small populations in alpine habitats, or occur only around Kilo Hot Spring.

Floristic Comparisons with the White Mountains and Kokrines Hills.

Porsild (1939 a-c) reported 124 species from the Kokrines Hills. Hulten (1941-1950) cited an additional 32 species from Porsild's collection. In 1978, 32 species not mentioned by Porsild or Hulten were observed in the Kokrines Hills by S.B. Young and T. Kassler (unpublished data). Most of these

Table 2. Range extensions documented by plant collections made in the Ray Mountains in 1979.

Closes Gap in Range:

- Lycopodium selago L. subsp. appresum
- Woodsia ilvensis
- Calamagrostis inexpansa
- Eriophorum russeolum
- Trichophorum caespitosum
- Carex microchaeta
- Carex misandra
- Veratrum album
- Salix reticulata
- Salix Chamissonis
- Geocaulon lividum
- Stellaria monantha
- Stellaria laeta
- Cerastium arvense
- Minuartia Rossii
- Delphinium Chamissonis
- Ranunculus pygmaeus
- Saxifraga flagellaris
- Saxifraga bronchialis subsp. Funstonii
- Saxifraga Nelsoniana subsp.Nelsoniana
- Saxifraga exilis
- Saxifraga hieracifolia
- Saxifraga foliolosa
- Potentilla biflora
- Potentilla uniflora
- Oxytropis Mertensiana
- Oxytropis Scammaniana
- Cassiope tetragona
- Veronica Wormskjoldii
- Castilleja elegans
- Pedicularis Langsdorfii
- Pedicularis capitata
- Erigeron hyperboreus
- Senecio atropurpureus subsp. tomentosus
- Senecio resedifolius
- Saussurea viscida

Extends Range North:

- Athyrium filix-femina
- Gymnocarpium dryopteris
- Phalaris arundinacea
- Poa cf. laxiflora
- Glyceria striata
- Carex cf. practicola
- Arabis lyrata
- Sorbus scopulina

(Table 2 is continued on the next page.)

Table 2 continued.

Sibbaldia procumbens
Epilobium Hornemannii
Cicutia Douglasii
Heracleum lanatum
Gentiana algida

Extends Range South:
Luzula Wahlenbergii cf. subsp. Wahlenbergii
Smelowskia calycina
Geum glaciale

Extends Range West:
Betula occidentalis
Parrya nudicaulis
Senecio pauciflorus

Extends Range East:
Ranunculus glacialis
Oxytropis kokrinensis

species are common in interior Alaska. Thus a total of 188 plant species have been reported from the Kokrines Hills.

The available data show that the Ray Mountains flora is larger than the flora of the Kokrines Hills. The Kokrines Hills are smaller than the Ray Mountains and seem less ecologically diverse. They would therefore support fewer species. However, fewer than half of the species found in the Ray Mountains have also been recorded in the Kokrines Hills, which indicates that the current species list for the Kokrines Hills is probably incomplete.

Gjaerevoll (1958; 1963; 1967) recorded 384 species in the White Mountains. Hulten (1941-1950) attributed another 40 species to Gjaerevoll's collections, bringing the total number of species to 424. The flora of the White Mountains includes all but 33 of the species identified in the Ray Mountains, which suggests that the species list for the White Mountains is more nearly complete than that for the Kokrines Hills.

The White Mountains flora exceeds the estimated complete flora of the Ray Mountains by about 150 species, and the documented flora by 200. Both ecological and historical factors may be responsible for this disparity.

The Ray Mountains and the White Mountains have similar total areas, and the extent of alpine tundra habitat within them is roughly equivalent. Precipitation, snowfall, and mean

maximum and minimum temperatures are also similar (Selkregg 1975). Gjaerevoll (1958) noted the absence of lakes in the White Mountains in support of his conclusion that the mountains had remained unglaciated during the Pleistocene. The Ray Mountains also have very few lakes or tarns, though Yeend (1971) reported localized late Pleistocene glaciation in the Ray Mountains, noting 25 well developed cirques.

Though size, present climate, and, to some extent, glacial history may be similar in the two ranges, there are distinct differences in bedrock geology. The bedrock of the Ray Mountains is largely granite, gneiss, and schist, though the western part of the range includes outcrops of serpentine and other similar rock types, as well as calcareous rock types (Chapman et al. 1975). In contrast, the White Mountains are composed of granite, schist, sandstone, slate, limestone, dolomite, and various volcanics. The relative richness of the White Mountains flora may thus be explained in part by the area's more diverse geology and especially by the more widespread occurrence of two calcareous rock types (limestone and dolomite). The disparity between the flora of the White Mountains and the estimated total flora of the Ray Mountains may also be the result of historical factors; specifically, migratory access to the Ray Mountains may have been more restricted than access to the White Mountains.

Hulten's (1937) thesis that interior and western Alaska provided a refugium for arctic-alpine plant species during the late Wisconsin glaciation is contrary to accumulating evidence that suggests that warm summer temperatures and overall dry conditions precluded the widespread growth of arctic-alpine species in interior Alaska (see Hibbert, in press, for review). This evidence, combined with the fact that snowlines in interior Alaska were lower then than today (Pewe 1975), suggests that there was little remaining habitat for such species. Instead, many of the arctic-alpine species currently found in the interior mountains may have been restricted to the northern parts of Beringia and the land bridge (Young, in press), and have only recently migrated into the interior.

Many of the species found in the White Mountains, but not in the Ray Mountains, according to Hulten (1968) have a common pattern in their range distributions. This pattern traces a crescent through the Brooks Range, the mountains and uplands west of the Yukon Flats, and the Alaska Range (Fig. 2). Species with such ranges include Eriophorum angustifolium ssp. triste, E. callitrix, Kobresia myosuroides, K. simpliciuscula, Carex capitata, C. nardina, C. rupestris, C. stylosa, Draba caesia, Boykinia Richardsonii, Senecio yukonensis, Saxifraga oppositifolia, and Androsace septentrioalis. In each case the White Mountains population protrudes from the lower inside section of the crescent. This pattern suggests that the connecting migration channel between

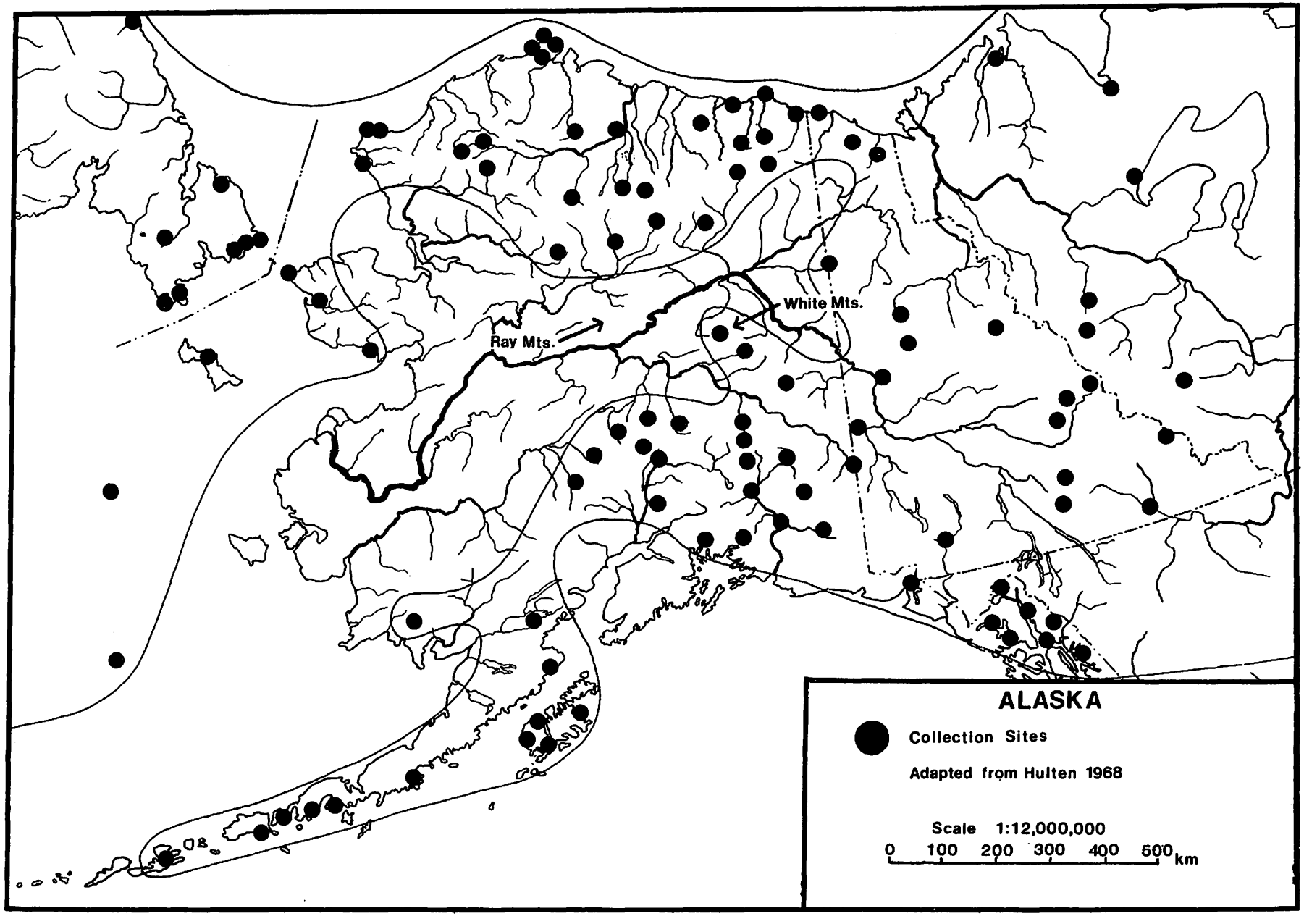

Fig. 2. Saxifraga oppositifolia exhibits the crescent-shaped distribution pattern characteristic of species found in the White Mountains but not in the Ray Mountains.

the Brooks Range and the Alaska Range is through the mountains and uplands east of the Yukon Flats, rather than through the Ray Mountains. However, at least some plant migration has occurred along the upland route extending through the Ray Mountains. Six species shown by Hulten (1968) to have two disjunct ranges, extending from the Brooks Range and the Alaska Range respectively, were collected in the Ray Mountains (Minuartia Rossii, Delphinium Chamissonis, Saxifraga bronchialis, Potentilla biflora, Pedicularis Langsdorfii, and P. Capitata). Salix Chamissonis also appears to have migrated through the Ray Mountains. The only known populations of the species south of the Brooks Range occur in the Ray Mountains and the White Mountains.

Thus, species have apparently migrated along both routes discussed above. However, the large number of species having only the crescent distribution (which are documented from the White Mountains but not the Ray Mountains) suggests that the migration route east of the Yukon Flats was more favorable and more widely followed. The difference in the size of the two floras could be the result of unequal use of the two migration routes.

The most obvious difference between the two routes is the relative continuity of the uplands. In the Ray Mountains, habitat for arctic-alpine species exists upward from several hundred feet below the 914 m (3000 ft) contour. The Ray Mountains are isolated from other uplands over 914 m in elevation (Fig. 3). In the uplands east of the Yukon Flats, the areas above 914 m are smaller, but they are much more numerous and less isolated. This network of uplands may therefore have been more favorable for migration than the Ray Mountains route.

It should be noted that this hypothesis is supported by the understanding that the Ray Mountains are an "ecological island" (Schubert, this volume). The reader is reminded that this hypothesis rests upon the assumption that the arctic-alpine plant species present in interior Alaska today were largely not present during the late Pleistocene glaciation. This assumption is not an established fact, but rather a new interpretation based on recent evidence.

In summary, factors causing the depauperacy of the Ray Mountains flora relative to the flora of the White Mountains may be historical as well as ecological. Of the ecological characteristics such as glaciation, climate, and geology, only the geology of the two ranges appears to differ significantly. The presence of more rock types in the White Mountains (including limestone and dolomite) may in part explain the rich flora of the range. The existence of another perhaps more widely used migration route east of the Yukon Flats indicates that post-Wisconsin migration into the Ray Mountains may have been limited.

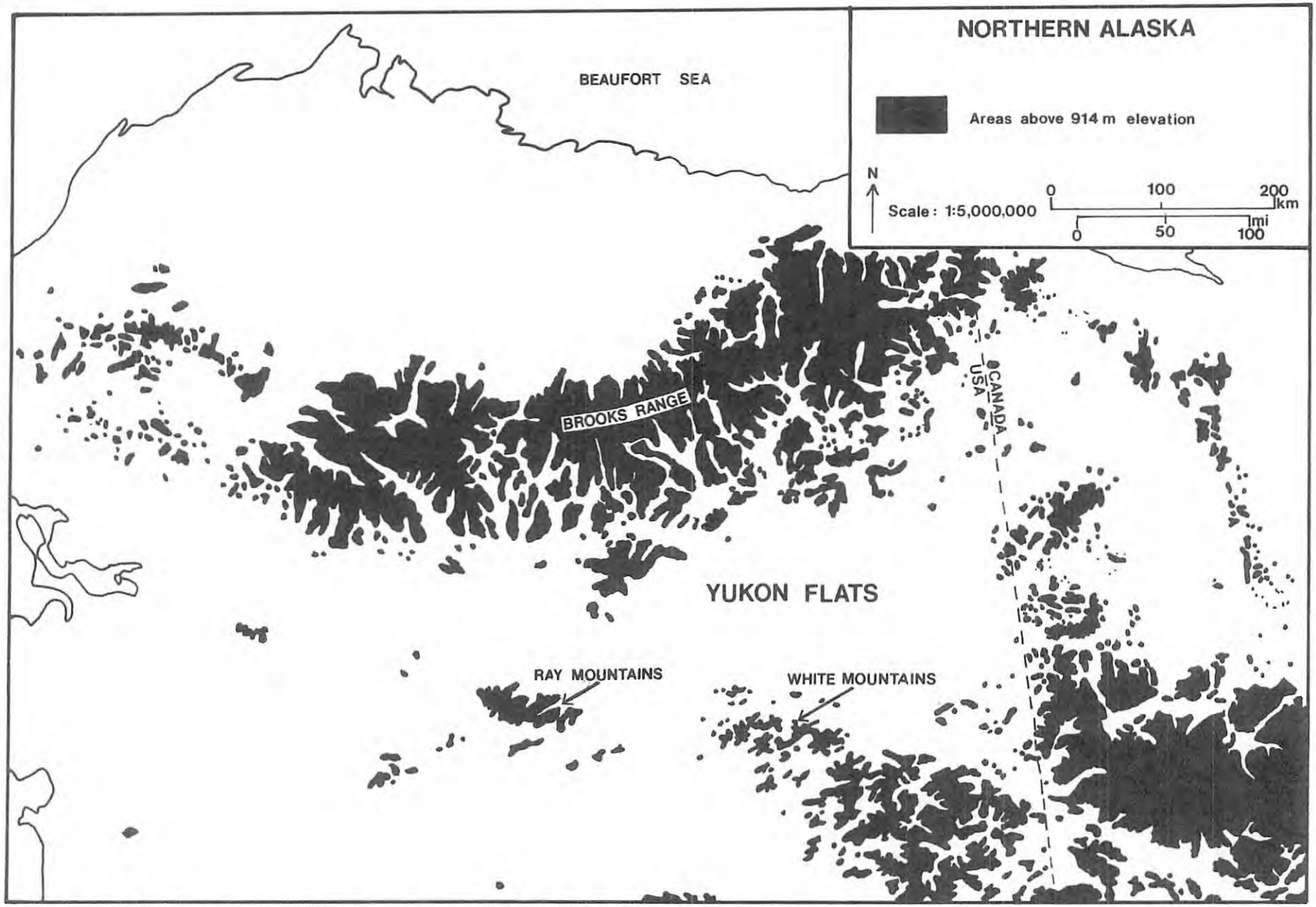

Fig. 3. The Ray Mountains are isolated from other areas over 914 m (3000 ft). Though more dissected, the high uplands to the east of the Yukon Flats are less isolated.

Table 3. Breakdown of the Ray Mountains flora into subgroups based on range distributions. Arctic-alpine species may be found below treeline as well, but their main distribution is above treeline. Brackets ([]) indicate total numbers for major categories.

Circumpolar Distributions	[99]
Arctic-Alpine	59
Boreal	40
North American Distributions	[41]
Arctic-Alpine	15
Boreal	26
Western North American Distributions	[22]
Arctic-Alpine	16
Boreal	6
Amphi-Beringian Distributions	[49]
Arctic-Alpine	44
Boreal	5
Asiatic Distributions	[17]
Arctic-Alpine	15
Boreal	2

Phytogeographical Analysis of the Flora

Following Gjaerevoll's (1967) treatment of the White Mountains flora, the flora of the Ray Mountains is divided into five phytogeographical groups (Table 3). Because many species do not fall clearly into one category, the numbers presented are only intended to indicate the size of the groups relative to one another. These groups may be used to determine the relationship of the Ray Mountains flora to the Beringian arctic flora on the one hand, and the North American flora on the other. (Gjaerevoll's (1967) category "Endemics of Northwestern America" is combined with his category "Western North American Distributions" here.)

The large number of arctic-alpine species with Amphi-Beringian, Western North American, or Asiatic distributions suggests that the Ray Mountains flora is closely related to the Beringian arctic flora described by Young (1978). The topography and location of the Ray Mountains are such that the flora should be more directly associated with the Br

to the Ray Mountains (Luzula Wahlenbergii ssp. Wahlenbergii, Veratrum album, Dianthus repens, Ranunculus glacialis, and Smelowskia calycina). Only two of the 13 species whose ranges have been extended north to include the Ray Mountains are alpine species. The other 11 are boreal species collected at Kilo Hot Spring.

The relatively large number of boreal species found in the Ray Mountains with North American distributions indicates that the boreal flora of the Ray Mountains is directly related to the North American boreal flora, which is not surprising. There are, however, no strong ties between the alpine floras of North America and the Ray Mountains flora. Thus, compared to the extent that the Alaska Range is influenced by North American alpine species, the flora of the Ray Mountains seems to be more closely associated with the Brooks Range flora than with the Alaska Range flora. The great number of species found in the Ray Mountains with circumpolar distributions say little about the phytogeographical associations of the range's flora because their demonstrated ability for postglacial recolonization complicates conjecture about their late Pleistocene distributions.

Suggestions for Further Research

Further botanical investigations in the Ray Mountains are needed for more complete documentation of the range's flora. Future collecting should begin in mid-May. More collections from boreal communities are essential; however, Dry Fellfield Upland Barren, Dry Ericad Upland Prostrate Scrub, and Moist Snowbed Meadow vegetation types at the eastern end of the range undoubtedly contain species not collected during the summer of 1979. A more complete species list will be useful in analysis of the hypothesis on the migration of arctic-alpine plant species in interior Alaska and the Yukon.

SUMMARY

Prior to this investigation, the flora of the Ray Mountains was unknown. To maximize the number of species encountered and the value of the data for other study teams, collecting was concentrated 1) in as many areas as possible of the vegetation types represented in vegetation maps (Brock and Burke, this volume); and 2) in and around rock outcrops, exposed ridgetops, late snowbeds, and Kilo Hot Spring.

227 vascular plant species were identified. 57 of these were range extensions. Another 25 to 50 species are expected to occur within the range though they were not found. Even including these expected species, the White Mountains, another

nearby mountain range of roughly similar size, climate, and glacial history, contain at least 150 more species than the Ray Mountains do. Both ecological and historical factors may be responsible for this difference; first, the geology of the White Mountains is much more varied, including widespread limestone and dolomite. Second, evidence was presented to show that of two possible migration routes used by alpine plants during post-glacial rebound in Alaska, the route through the Ray Mountains was the less well used. Therefore, it is suggested that some plants that have migrated into the White Mountains have not been able to migrate into the Ray Mountains.

The Ray Mountains flora was divided into five phytogeographic groups. Analysis of these groups and the range extensions suggests that the Ray Mountains flora is most closely associated with the Brooks Range subdivision of the Beringian arctic flora, although ties with the North American flora also exist. Future collecting should be concentrated in tree dominated vegetation types and in barren, prostrate scrub, and snowbed vegetation types at the eastern end of the range.

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APPENDIX

Vascular plant species found in the Ray Mountains during the 1979 investigation are listed below. The vegetation type (Brock and Burke, this volume) at each collection point is noted, along with RMP site number (Introduction, this volume) and collection number. For discussion of the relative importance of species in the vegetation types, see Brock and Burke (this volume). Nomenclature follows Hulten (1968, 1973) except Salix spp. (Viereck and Little 1972) and Draba spp. (Mulligan 1976). * denotes range extension.

LYCOPODIACEAE

* Lycopodium selago L. subsp. appressum (Desv.) Hult.
Common in rocky areas in UPLAND TUNDRA and ALPINE BARREN.

Vegetation type:			
Dry Lic. Upl. Rock Bar.	IVa	120
Dry Upl. Fellf. Barren	IVa	163

Lycopodium annotinum L.
Common in a variety of moist vegetation types above and below treeline.

Vegetation type:			
Mo. Wil. Drng. Med. Scr.	IIb	28
Moist Dwarf Scrub	IVa	161
Mo. Snowb. Gram. Mdw.	IIc	57

Lycopodium complanatum L.
Found only in the birch - white spruce forest adjacent to Kilo Hot Spring.

Vegetation type:		
Mo. Pap. Bir. Slope For.	IIIa	250

Lycopodium alpinum L.
Fairly common in well drained UPLAND TUNDRA vegetation types.

Vegetation type:		
Mo. Snowb. Gram. Mdw.	IVa	114

SELAGINELLACEAE

Selaginella sibirica (Milde) Hieron.
Found infrequently around tors in rocky soil or crevasses.

Vegetation type:		
Dry Lic. Upl. Rock Bar.	IVa	289

EQUISETACEAE

Equisetum variegatum Schleich.
Encountered along stream banks, gravel bars, and under riparian willow scrubs at a wide range of elevations.

Vegetation type:		
Mo. Wil. Fldp. Tall Scr.	IIb	27,325

Equisetum fluviatile L. ampl. Ehrh.
Found in scattered locations in drainageways and along streambanks.
Vegetation type: Wet Wil.-Ald. Drng. Tall Scr. IIb 307

Equisetum silvaticum L.
Common in Dry White Spruce Floodplain Forest and below.
Specimens not collected, but positive identification made at site IIb.

Equisetum arvense L.
Common in a wide variety of vegetation types including moist scrubs, snowbeds, and hot springs.
Vegetation type: Mo. Wil. Fldp. Tall Scr. IIa 26
Mo. Snowb. Gram. Mdw. IVa 59,60
Hot spring IIIa 227,246

POLYPODACEAE

* Athyrium filix-femina (L.) Roth
Abundant in moist places at Kilo Hot Spring.
Vegetation type: Hot spring IIIa 237

Cystopteris fragilis (L.) Bernh.
Found occasionally in crevasses of tors.
Vegetation type: Dry Lic. Upl. Rock Bar. IVa 131
IIIb 218,253

* Woodsia ilvensis (L.) R. Br.
Found only once in dry gravelly parts of the burned-over tor area.
Vegetation type: Dry Lic. Upl. Rock Bar. IVb 184

Woodsia glabella R. Br.
Found on one north-facing rocky slope.
Vegetation type: Dry Eric. Upl. Pros. Scr. Ia 286

Dryopteris fragrans (L.) Schott
Fairly abundant on south-facing cliffs and steep slopes at and below treeline.
Vegetation type: Mo. Ald. Slope Tall Scr. IIb 323
Dry Lic. Upl. Rock Bar. IVb 182

* Gymnocarpium dryopteris (L.) Newm.
Seen only in forest around Kilo Hot Spring.
Vegetation type: Mo. Pap. Bir. Slope For. IIIa 230,260,261

PINACEAE

Picea glauca (Moench) Voss
Occurs in all regions of study area below about 610 m (2000 ft).
The importance of this species in various vegetation communities, and the characteristic stature and age of the trees are discussed in the vegetation section (Brock and Burke, this volume).
Specimens not collected.

Picea mariana (Mill.) B. S. and P.
Also very common in the study area and discussed by Brock and Burke (this volume). The species occasionally became the dominant conifer at forest limit.
Specimens not collected.

CUPRESSACEAE

Juniperus communis L.
Observed infrequently on drier rocky slopes and streambanks above treeline. Individual plants are small and isolated.
Vegetation type: Mo. Bir.-Blue. Dw. Scr. IVa 165

GRAMINEAE

* Phalaris arundinacea L.
Found only at Kilo Hot Spring in dry soil. According to Hulten (1969), there have been only three other recordings of this species in Alaska.
Vegetation type: Hot spring IIIa 233

Hierochloe alpina (Sw.) Roem. and Schult.
Abundant through scrubs, meadows, and barrens of the UPLAND TUNDRA and ALPINE BARREN ecosystems.
Vegetation type:

Dry Bir. Upl. Dw. Scr.	IVa	102,152
Dry Eric. Upl. Pros. Scr.	IIc	344
Dry Upl. Fellf. Barren	IId	91
	IVa	143
Mo. Snowb. Gram. Mdw.	IVa	140
	IIc	47,337
	Ia	247
	IVb	186

Arctagrostis latifolia (R. Br.) Griseb.
Common both in lower elevation Dwarf Scrub - Tussock-Graminoid Meadows and in open white spruce forests. Found occasionally in Dry Upland Fellfield Barrens as well.

Vegetation type:			
Mo. Spr. Slope Pap. Bir. For.	IIb	309
Mo. Bir.-Blue. Dw. Scr.	IIb	312,315
Dw. Upl. Pros. Scrub	IIb	370

Agrostis scabra Willd.
Only seen at Kilo Hot Spring, where it grows in abundance along the banks of hot spring effluent.

Vegetation type:		
Hot spring	IIIa	231

* Calamagrostis inexpansa Gray
Common to abundant along streams in UPLAND TUNDRA; occasionally found in various vegetation types of LOWLAND TUNDRA ecosystems as well. This species has an extremely variable phenotype in the Ray Mountains. Some specimens were nearly impossible to distinguish from C. neglecta (Ehrh.) G. M. and S., and in fact, both species may be present.

Vegetation type:		
Mo. Wh. & Bl. Spr. Slope For.	IIb	425
Mo. Wil. Upl. Med. Scr.	IIc	351
Mo. Bir.-Blue. Dw. Scr.	IIb	313
Dry Bir. Upl. Dw. Scr.	IVa	122,173
Dry Lic. Upl. Rock Bar.	IVa	126,127

Calamagrostis purpurascens R. Br.
Encountered a few times in association with rock outcrops and tors.

Vegetation type:		
Mo. Ald. Slope Tall Scr.	IIb	322
Dry Upl. Fellf. Barren	Ia	71,291
Dry Lic. Upl. Rock Bar.	IIIb	207

Deschampsia caespitosa (L.) Beauv.
Collected once, inexact collection site information.

Vegetation type:		
Upland, Spooky Valley	IVa	402

Trisetum spicatum (L.) Richter.
Found only growing at and below treeline, usually along streambanks or on gravel bars.

Vegetation type:		
Mo. Wil. Fldp. Tall Scr.	IIb	317

Poa arctica R. Br.
Noted as quite common in Moist Willow Drainageway Medium Scrub, but not collected elsewhere.

Vegetation type:		
Mo. Wil. Drng. Med. Scr.	IIb	314

* Poa cf. laxiflora Buckl.
Only one small population was found near the Kilo Hot Spring effluent. Unfortunately, the specimens collected are immature. Hulten's (1968) description fits well, except that these specimens could not be considered retrorsely scabrous on the

culms or sheaths. The only other specimen collected in Alaska was at Cape Fox Springs (55 degrees N Lat.) at the southern tip of the panhandle.

Vegetation type:		
Hot spring	IIIa	380

Poa glauca M. Vahl
Present in some dry rocky places.

Vegetation type:		
Mo. Ald. Slope Tall Scr.	IIb	321,327
Dry Eric. Upl. Pros. Scr.	IIc	369
Dry Lic. Upl. Rock Bar.	IIIb	210
	IVb	185

* Glyceria striata (Lam.) Hitchc.
Found only at Kilo Hot Spring, where it grew near heated effluent.

Vegetation type:		
Hot spring	IIIa	226,228

Festuca altaica Trin.
Common in a wide variety of vegetation types in UPLAND TUNDRA.

Vegetation type:		
Mo. Wil. Upl. Med. Scr.	IIc	338
Dry Bir. Upl. Dw. Scr.	IVa	109,153
Mo. Snowb. Gram. Mdw.	IIc	356

Agropyron subsecundum (Link) Hitchc.
Collected from a shady area not directly affected by the hot springs

Vegetation type:		
Hot spring	IIIa	226,228

CYPERACEAE

Eriophorum angustifolium Honkc.
Common, though not abundant, in Wet Graminoid Meadows.

Vegetation type:		
Wet Graminoid Meadow	IVa	104,105,106
	IIc	341

* Eriophorum cf. russeolum E. Fries
Small stands occasionally found in poorly drained areas in UPLAND TUNDRA. Commonly forms matrix around frost heaves.

Vegetation type:		
Wet Graminoid Meadow	IIc	340,349

Eriophorum vaginatum L.
Common in all vegetation types with tussock-gramnoid species, and dominant in some Wet Tussock-Graminoid Meadows.

Vegetation type:		
Mo. Dw. Scr. - Gram. Mdw.	IVa	106
Mo. Dw. Scr. - Tus.-Gram. Mdw.	IIb	310
	IIc	46
Mo.Tus.-Gram. Mdw.	IIc	48

* Trichophorum caespitosum (L.) Hartm.
Common in hot spring seeps. Not found elsewhere.

Vegetation type:		
Hot spring.	IIIa	243

Carex scirpoidea Michx.
Found in dry vegetation types with gravelly soils, ALPINE BARREN.

Vegetation type			
Dry Eric. Upl. Pros. Scr.	IVa	45,63
Dry Upl. Fellf. Barren	IId	263
	Ia	292

* Carex cf. practicola Rydb.
Collected from shaded area near Kilo Hot Spring.
Not found elsewhere.

Vegetation type		
Hot spring	IIIa	229

Carex Lachenalii Schkuhr.
Co-dominant with Eriophorum russeolum in a few small pockets of Wet Graminoid Meadow, but not collected elsewhere.

Vegetation type		
Wet Graminoid Meadow	IIc	350

Carex curta Good, cf. Moore and Chater
Locally abundant in Kilo Hot Spring seepages, but not elsewhere.

Vegetation type		
Hot spring	IIIa	244

Carex Bigelowii Torr.
Very common throughout range. Although found often in snowbed vegetation types at higher elevations, it is one of the most important species in many types of tussock-graminoid meadows. Carex Bigelowii was frequently found to be the dominant tussock-forming species, rather than Eriophorum vaginatum. C. H. Racine reports a similar type of community from the Seward Peninsula (Racine 1974) and from Lake Clark (Racine and Young 1978).

Vegetation type		
Dry Bir. Upl. Dw. Scr.	IVa	166
Dry. Eric. Upl. Pros. Scr.	IIc	55,66
Mo. Snow. Forb Mdw.	IIc	354

Carex lugens Holm
Common near treeline in moist scrubs.

Vegetation type		
Mo. Wil. Upl. Med. Scr.	IIb	311

Carex elusinoides Turcz.
Occurs on gravel bars of larger streams. Quite common.

Vegetation type		
Mo. Wil. Fldp. Tall Scr.	IIb	324

Carex aquatilis Wahlenb.
Common in very wet pockets. Also present along streams and in Sphagnum spp. dominated areas at lower elevations.

Vegetation type		
Mo. Wil. Upl. Med. Scr.	IVa	353,431
Mo. Wil. Drng. Med. Scr.	IIb	19,20,24,25
Hot spring	IIIa	257

Carex podocarpa R. Br.
Collected only once, from late snowbed.
(Collected by J. Schubert).
Vegetation type: Mo. Snowb. Gram. Mdw. VIa 413

* Carex microchaeta Holm
Grows in a variety of vegetation types in the UPLAND TUNDRA ecosystem, but most abundant in moist snowbed meadows.

Vegetation type:			
	Dry Bir. Upl. Dw. Scr.	IVa	121
	Dry Eric. Upl. Pros. Scr.	IIc	343,430
	Mo. Tus.-Gram. Mdw.	IIc	62
	Mo. Snowb. Gram. Mdw.	IVa	139
	Dw. Upl. Frut. Lic. Mdw.	IIc	53

Carex rariflora (Wahlenb.) J. E. Sm.
Among the most important species ecologically in Wet Graminoid Meadows, although found in other vegetation types as well.

Vegetation type:			
	Wet Graminoid Meadow	IVa	97
	Mo. Snowb. Gram. Mdw.	IVa	394
	Mo. Snow. Forb Mdw.	IIc	347

* Carex misandra R. Br.
Found a few times in moist and wet graminoid meadows in the UPLAND TUNDRA ecosystem. Never common.
Vegetation type: Wet Graminoid Meadow IVa 174

Carex rotundata Wahlenb.
One of the more important species in Wet Graminoid Meadows, and occurs with less abundance in other UPLAND TUNDRA vegetation types as well.

Vegetation type:			
	Wet Graminoid Meadow	IVa	103,399,432
	Mo. Snowb. Gram. Mdw.	IVa	138

JUNCACEAE

Juncus castaneus Sm.
Found only in Kilo Hot Spring seepages. Probably occurs elsewhere as well.
Vegetation type: Hot springs IIIa 247

Juncus triglumis L.
Common in Wet Graminoid Meadow.
Vegetation type: Wet Graminoid Meadow IVa 98

Juncus biglumis L.
Collected in Wet Graminoid Meadow. Uncommon in area of study.
Vegetation type: Wet Graminoid Meadow IVa 113

* Luzula Wahlenbergii Rupr. cf. subsp. Wahlenbergii
Found once in Wet Graminoid Meadow. Uncommon.
Vegetation type: Wet Graminoid Meadow IVa 101

Luzula parviflora (Ehrh.) Desv.
Common along streambanks and gravel bars, both above and below treeline.
Vegetation type: Mo. Wil. Fldp. Tall Scr. IIb 318
Mo. Snowb. Gram. Mdw. IVa 346

Luzula arcuata (Wahlenb.) Sw.
Fairly common in moist snowbed meadows.
Vegetation type: Mo. Snowb. Gram. Mdw. IIc 359

Luzula cf. Kjellmaniana Miyabe and Kudo
Fairly common in a variety of dry vegetation types of the UPLAND TUNDRA ecosystem.
Vegetation type: Dry Eric. Upl. Pros. Scr. IIb 367
Dry Upl. Fellf. Barren IVa 387

Luzula confusa Lindeb.
Although common in fellfield where collected, not seen often in other barrens or elsewhere.
Vegetation type: Dry Upl. Fellf. Barren IId 262

LILIACEAE

Tofieldia coccinea Richards.
Common in dry rocky vegetation types in UPLAND TUNDRA.
Vegetation type: Dry Eric. Upl. Pros. Scr. IId 189
Dry Upl. Fellf. Barren IVa 135

Tofieldia pusilla (Michx.) Pers.
Not common within study area. Specimens keyed from treeline.
Specimens not collected.

Zygadenus elegans Pursh
Found only on calcareous outcrop.
Vegetation type: Dry Lic. Upl. Rock Bar. IIIb 211

* Veratrum album L. subsp. oxysepalum (Turcz.) Hult.
Scattered occurrence in moist snowbed meadows, often around tors. The majority of plants do not have flowering stalks. This species was also seen in the Kokrines Hills in 1978; however, it did not appear to be as common there as it is in the Ray Mountains.
Vegetation type: Mo. Snowb. Gram. Mdw. IVa 168

SALICACEAE

Populus balsamifera L.
Not abundant in the study area, except near Kilo Hot Spring in pure and mixed stands (Brock and Burke, this volume). Specimens not collected.

Populus tremuloides Michx.
Common in the vicinity of Kilo Hot Spring. Otherwise uncommon. Specimens not collected.

* Salix reticulata L.
Found in a variety of habitats, but most important in snowbed vegetation types of the UPLAND TUNDRA ecosystem.

Vegetation type:		
Mo. Snow. Forb Mdw.	IId	81

Salix phlebophylla Anderss.
Very common in all dry vegetation types in the UPLAND TUNDRA and ALPINE BARREN ecosystems.

Vegetation type:		
Dry Bir. Upl. Dw. Scr.	IVa	170
	IId	75

Salix arctica Pall.
Apparently uncommon in the area of interest. Both collections were made during travel in UPLAND TUNDRA ecosystems.

Vegetation type:		
unrecorded		
Specimens		21,87

Salix fuscescens Anderss.
Found in wet places in the LOWLAND TUNDRA ecosystem. Fairly common.

Vegetation type:		
Mo. Bir.-Blue. Dw. Scr.	IIb	3,4
Mo. Tus.-Gram. Mdw.	IIc	36

Salix glauca L.
Present both in riparian vegetation types and under drier conditions in frost-boil complexes where it becomes the dominant shrub.

Vegetation type:		
Mo. Wil. Upl. Med. Scr.	IIb	302
Dry Bir. Upl. Dw. Scr.	IIb	373
	IVa	88

Salix Barclayi Anderss.
Collected once. Apparently uncommon.

Vegetation type:		
Dry Wh. Spr. Fldp. For.	IIb	300

* Salix Chamissonis Anderss.
Common in a wide variety of moist vegetation types of the UPLAND TUNDRA ecosystem. Forms dense mats in flat snowbeds.

Vegetation type:		
Mo. Dw. Scr. - Gram. Mdw.	IIc	54
Mo. Snowb. Gram. Mdw.	IVa	107,178, 180,181

Salix alaxensis (Anderss.) Cov.
Usually forms the dominant species of willow along the larger streams below 610 m (2000 ft).
Vegetation type: Mo. Wil. Fldp. Tall Scr. IIb 9,10

Salix Bebbiana Sarg.
Collected once at treeline. Uncommon.
Vegetation type: Mo. Wil. Fldp. Tall Scr. IIb 299

Salix planifolia Purch. subsp. pulchra (Cham.) Argus
Above the elevational range of Salix alaxensis, this species is the dominant constituent in riparian scrub. It is also important in a variety of other vegetation types both above and below treeline.
Vegetation type: Wet Wil.-Ald. Drng. Tall Scr. IIb 11,12,301
Mo. Wil. Upl. Med. Scr. IVa 171,172
IIc 360,361
Mo. Dw. Scr. - Gram. Mdw. IIb 37

BETULACEAE

Betula nana L.
A very important species in UPLAND and LOWLAND TUNDRA. This species and S. glandulosa were hardly distinguishable in some cases.
Vegetation type: Mo. Pap. Bir. Slope For. IIb 434
Mo. Bir.-Blue. Dw. Scr. IIb 13

Betula glandulosa Michx.
Usually encountered at lower elevations than S. nana, particularly in ecotones.
Vegetation type: Mo. Pap. Bir. Slope For. IIb 435

* "Betula occidentalis Hook."
Common within the study area, particularly where B. glandulosa and B. papyrifera grow in close proximity. It seemed to be particularly abundant around Kilo Hot Spring.
Vegetation type: Mo. Pap. Bir. Slope For. IIb 371

Betula papyrifera Marsh.
Although very common within study area, this species rarely formed pure stands. It frequently mixes with spruce on slopes.
Vegetation type: Mo. Pap. Bir. Slope For. IIb 372

Alnus crispa (Ait.) Pursh
Abundant in most tall scrubs. Also commonly forms savanna.
Vegetation type: Wet Wil.-Ald. Drng. Tall Scr. IIb 5

SANTALACEAE

* Geocaulon lividum (Richards.) Fern.
Abundant in the vicinity of Kilo Hot Spring, but otherwise restricted to lower elevation boreal forests.
Specimens not collected.

POLYGONACEAE

Rumex acetosa L.
Found occasionally in wet places above treeline, and once on fellfield.
Vegetation type: Mo. Wil. Upl. Med. Scr. IIc 352
Dry Upl. Fellf. Barren Ia 285

Rumex arcticus Trautv.
Seen at one location only, though abundant there.
Vegetation type: Wet Sphag. Moss Mdw. IVa 85

Polygonum viviparum L.
Common in wet and moist meadows in the UPLAND TUNDRA ecosystem.
Vegetation type: Wet Graminoid Meadow IVa 175

Polygonum bistorta L.
Common in a number of different vegetation types of the LOWLAND and UPLAND TUNDRA ecosystems.
Vegetation type: Mo. Tus.-Gram. Mdw. IIb 1

Polygonum alaskanum (Small) Wight
Abundant in the burned area southeast of the Kanuti Kilolitna River, and the surrounding areas. Also seen around the cabins at Kilo Hot Spring.
Not encountered elsewhere.
Vegetation type: Mo. Bir.-Blue. Dw. Scr. IVb 86

PORTULACACEAE

Claytonia acutifolia Pall. subsp. graminifolia Hult.
Abundant in snowbed where collected. Not seen often.
Vegetation type: Mo. Snowb. Gram. Mdw. IVa 118

Claytonia sarmentosa C. A. Mey.
Patches occur in moist snowbed meadows.
Vegetation type: Mo. Snowb. Gram. Mdw. IId 203
Mo. Snowb. Forb Mdw. IIc 365

CARYOPHYLLACEAE

* Stellaria monantha Hult.
Collected in UPLAND TUNDRA ecosystem.
(Collected by R. Tarlov).
Vegetation type: unknown. VIa 410

* Stellaria laeta Richards.
Collected once, in fellfield.
Vegetation type: Dry Upl. Fellf. Barren IIb 377

Stellaria Edwardsii R. Br.
Commonly associated with upland scrubs.
Vegetation type: Mo. Wil. Upl. Med. Scr. IIc 358
Dry Bir. Upl. Dw. Scr. IVa 148

* Cerastium arvense L.
Collected from serpentine-rich outcrop. Not seen elsewhere.
(Collected by J. Schubert).
Vegetation type: Dry Lic. Upl. Rock Bar. VIa 420

Minuartia arctica (Stev.) Aschers. and Graebn.
Extremely common in Dry Upland Fellfield Barrens and Dry Ericad Prostrate Scrubs. A wide range of phenotypes were observed.
Vegetation type: Dry Eric. Upl. Pros. Scr. IId 82,92,198
Dry Upl. Fellf. Barren IVa 146,147
IIc 44
IId 384
Ia 188

* Minuartia Rossii (R. Br.) Graebn.
Found only at the eastern end of the range on one ridge.
Vegetation type: Dry Upl. Fellf. Barren Ia 296

Moehringia lateriflora (L.) Fenzl
Common in forests to treeline.
Vegetation type: Dry Wh. Spr. Fldp. For. IIb 329

Wilhelmsia physodes (Fisch.) McNeill
Abundant on gravel bars and in sandy places at treeline and below.
Vegetation type: Mo. Wil. Fldp. Tall Scr. IIb 305,319

Silene acaulis L.
Occurs occasionally in Dry Ericad Upland Prostrate Scrub and Dry Upland Fellfield Barren.
Vegetation type: Dry Eric. Upl. Pros. Scr. IId 95

Dianthus repens Willd.
Very common on dry ground around Kilo Hot Spring.
Also present in calcareous and serpentine-rich outcrops.
(Collected also by J. Schubert.)

Vegetation type:			
Hot spring	IIIa	223,224
Dry Upl. Fellf. Barren	Ia	67,294
	VIa	416

RANUNCULACEAE

Actaea rubra (Ait.) Willd.
Seen in the forests directly surrounding Kilo Hot Spring.

Vegetation type:		
Hot spring	IIIa	391

* Delphinium Chamissonis Pritz.
Apparently very sparsely distributed in Dry Ericad Upland Prostrate Scrub.

Vegetation type:		
Dry Eric. Upl. Pros. Scr.	IId	194,388

Delphinium glaucum S. Wats.
Common in spruce, birch and poplar forests around Kilo Hot Spring. Seen occasionally in other forests at lower elevations.
Specimens not collected.

Aconitum delphinifolium DC. subsp. delphinifolium
Very widely distributed throughout the study area, from forests to prostrate scrub.

Vegetation type:		
Dry Bir. Upl. Dw. Scr.	IVa	151
Dry Eric. Upl. Pros. Scr.	IId	76

Anemone Richardsonii Hook.
Usually present along streams in riparian scrub of all heights at a wide range of elevations.

Vegetation type:		
Mo. Wil. Fldp. Tall Scr.	IIb	15,31
Mo. Wil. Drng. Med. Scr.	IVa	124
Mo. Snow. Forb Mdw.	IId	209

Anemone narcissiflora L.
One of the most common perennials above treeline in the range. This species grows in a number of vegetation types, but is particularly abundant in snowbeds and along streams.

Vegetation type:		
Mo. Wil. Upl. Med. Scr.	Ia	66
Dry Bir. Upl. Dw. Scr.	IIc	42,43
Mo. Snowb. Gram. Mdw.	IId	197
Dry Lic. Upl. Rock Bar.	IVb	187

* Ranunculus glacialis L.
Found in most Wet Graminoid Meadows. Usually grows in shallow gravel-bottomed pools, or on wet moss. There is apparently a large disjunction between this population and surrounding populations which have only

been recorded from a couple of sites on the tip of the Seward Peninsula, and from two sites in interior Alaska.
Vegetation type: Wet Graminoid Meadow IVa 132

Ranunculus nivalis L.
Almost always present along streams above treeline and occasionally in snowbeds.
Vegetation type: Mo. Wil. Drng. Med. Scr. IVa 123
Mo. Snowb. Gram. Mdw. IId 208
Mo. Snow. Forb Mdw. IIc 362

* Ranunculus pygmaeus Wahlenb.
Collected from a snowbed at eastern end of range. Not seen elsewhere.
(Collected by J. Schubert.)
Vegetation type: Mo. Snowb. Gram. Mdw. VIa 405

PAPAVERACEAE

Papaver Macounii Greene
Occurs occasionally in rocky well drained portion of UPLAND TUNDRA.
Vegetation type: Dry Eric. Upl. Pros. Scr. IId 89

CRUCIFERAE

Cardamine bellidifolia L.
Grows in crevasses of tors and on nearby gravel in very shady areas. Common.
Vegetation type: Dry Lic. Upl. Rock Bar. IVa 142,403

Cardamine pratensis L.
Found once in snowbed, and also in the vicinity of Kilo Hot Spring.
(Collected by J. Schubert).
Vegetation type: Mo. Snowb. Gram. Mdw. VIa 412

Cardamine umbellata Greene
Found only around Kilo Hot Spring, where it was rare.
Vegetation type: Hot spring IIIa 378

Cardamine purpurea Cham. and Schlecht.
Well represented at collection site.
Not common in the rest of the study area.
Vegetation type: Dry Eric. Upl. Pros. Scr. IVa 83,190

Draba cana Rydberg.
Collected only on calcareous rock outcrop.
Vegetation type: Dry Lic. Upl. Rock Bar. IIIb 213

* Smelowskia calycina (Steph.) C. A. Mey
  This species was only seen once.
  Vegetation type: Dry Upl. Fellf. Barren Ia 282

* Arabis lyrata L.
  Found only near Kilo Hot Spring in shade of tall scrub.
  Vegetation type: Hot spring IIIa 239

Erysimum cheiranthoides L.
  Grows in dry soil around Kilo Hot Spring.
  Vegetation type: Hot spring IIIa 235

* Parrya nudicaulis (L.) Regel
  Scattered populations occur in snowbeds and other moist rocky vegetation types of the UPLAND TUNDRA ecosystem.
  Vegetation type: Dry Eric. Upl. Pros. Scr. IId 381
  Mo. Snowb. Gram. Mdw. IId 201

CRASSULACEAE

Sedum rosea (L.) Scop.
  Common in a variety of vegetation types, particularly along streams and in snowbeds.
  Vegetation type: Mo. Wil. Fldp. Tall Scr. IIb 14

SAXIFRAGACEAE

Saxifraga hirculus L.
  Fairly common in moist UPLAND TUNDRA vegetation types.
  Vegetation type: Mo. Dw. Scr. - Gram. Mdw. IIb 382
  Dry Eric. Upl. Pros. Scr. IIb 79

* Saxifraga flagellaris Willd.
  Fairly common at collection site, but rare elsewhere.
  Vegetation type: Dry Upl. Fellf. Barren Ia 284

* Saxifraga bronchialis L. subsp. Funstonii (Small) Hult.
  Abundant at the two collection sites, though not seen elsewhere. (Collected also by J. Schubert.)
  Vegetation type: Dry Upl. Fellf. Barren Ia 273
  VIa 417

Saxifraga tricuspidata Rottb.
  Found on steep dry slopes and on serpentine barrens. (Collected also by J. Schubert).
  Vegetation type: Mo. Ald. Slope Tall Scr. IIb 323
  Dry Upl. Fellf. Barren VIa 418

* Saxifraga Nelsoniana subsp. Nelsoniana
Frequently found along stream beds and other moist places in the UPLAND TUNDRA ecosystem, although plants are usually isolated. (Collected also by J. Schubert.)

Vegetation type:			
Dry Eric. Upl. Pros. Scr.	IId	93,192,204
Mo. Gram. Snowbed	IVa	376
	IIc	348
unknown	IIc	335

Saxifraga spicata D. Don.
Occurs only amongst tors. Often sterile.

Vegetation type:		
Mo. Snowb. Gram. Mdw.	IVa	129

* Saxifraga exilis Steph.
Collected only from Crash Creek. (Collected by R. Tarlov).

Vegetation type:		
unknown		404(RT)

Saxifraga reflexa Hook.
Grows in fellfield and around tors.

Vegetation type:		
Dry Eric. Upl. Pros. Scr.	IIc	333
Dry Upl. Fellf. Barren	Ia	295
Dry Lic. Upl. Rock Bar.	VIa	130
	IIIb	217,258

* Saxifraga hieracifolia Waldst. and Kit.
Found only once, in snowbed.

Vegetation type:		
Mo. Snowb. Gram. Mdw.	IId	200

* Saxifraga foliolosa R. Br.
Occasionally seen in Wet Graminoid Meadows on gravelly or mossy substrate. Patchy distribution.

Vegetation type:		
Wet Graminoid Meadow	IVa	112
	IIc	364

Parnassia palustris L.
Seen only along the effluent streams of Kilo Hot Spring, where it grows in dense stands.

Vegetation type:		
Hot spring	IIIa	225

ROSACEAE

Spiraea Beauverdiana Schneid
Common in a wide range of habitats from all but the most exposed tundra to many forest vegetation types.

Vegetation type:		
Mo. Wil. Drng. Med. Scr.	IIb	7,8

* Sorbus scopulina Greene
Occurs only in the vicinity of Kilo Hot Spring, where it is set back from the springs themselves.

Vegetation type:		
Hot spring	IIIa	249

Rubus chamaemorus L.
Very common in muskeg and LOWLAND TUNDRA, particularly in drainage lines and other wet areas. Specimens not collected.

Rubus arcticus L. subsp. arcticus
Most frequently found under moist drainageway and floodplain scrubs.
Vegetation type: Hot spring IIIa 240

Rubus idaeus L.
Seen only near Kilo Hot Spring.
Specimens not collected.

Potentilla palustris (L.) Scop.
Found in drainageways and other very wet places in LOWLAND TUNDRA.
Vegetation type: Wet Wil.-Ald. Drng. Tall Scr. IIb 17,308

Potentilla fruticosa L.
Occurs occasionally in white spruce and birch forests.
Vegetation type: Mo. Spr. Slope Pap. Bir. For. IIb 424

* Potentilla biflora Willd.
Only one population found, on granite-based fellfield.
Vegetation type: Dry Upl. Fellf. Barren IIIb 199

* Potentilla uniflora Ledeb.
Occasionally found on fellfield barrens and around tors.
Vegetation type: Dry Upl. Fellf. Barren IVa 128
Ia 278,293
Dry Lic. Upl. Rock Bar. IVb 183

Potentilla hyparctica Malte
Collected in snowbed. Uncommon.
Vegetation type: Mo. Snowb. Gram. Mdw. IVa 117,145

Potentilla nivea L.
Abundant on the calcareous outcrop where collected. Not seen elsewhere.
Vegetation type: Dry Lic. Upl. Rock Bar. IIIb 212

* Sibbaldia procumbens L.
Grows in moist dwarf scrub in the UPLAND TUNDRA ecosystem.
Vegetation type: Dry Bir. Upl. Dw. Scr. VIa 396

Geum macrophyllum Willd.
Seen at Kilo Hot Spring on dry soil.
Vegetation type: Hot spring IIIa 221,222

* Geum glaciale Adams
Common at collection site. Seen occasionally elsewhere in the same vegetation type.
Vegetation type: Dry Eric. Upl. Pros. Scr. IId 96,265

Dryas octopetala L.
Usually abundant in Dry Upland Fellfield Barrens and Dry Ericad Upland Prostrate Scrub; however, rarely dominant or co-dominant.

Vegetation type:			
Dry Bir. Upl. Dw. Scr.	IVa	134	
Dry Eric. Upl. Pros. Scr.	IId	160,167	
Dry Upl. Fellf. Barren	IIc	339	
	IIIb	254	
	Ia	283	

Dryas integrifolia M. Vahl.
Apparently rare in the area of interest.

Vegetation type:		
Dry Upl. Fellf. Barren	IIb	383

Rosa acicularis Lindl.
Common to 610 m (2000 ft), occasionally higher in riparian scrub.
Specimens not collected.

Lupinus arcticus S. Wats.
Surprisingly in Dry Ericad Upland Prostrate Scrub.

Vegetation type:		
Dry Eric. Upl. Pros. Scr.	IId	266,267
Dry Upl. Fellf. Barren	Ia	277

* Oxytropis Mertensiana Turcz.
Uncommon within study area.
Specimens collected by J. Dawe (pers. comm.).

* Oxytropis kokrinensis Pors.
This species' abundance was one of the most interesting discoveries of the summer. It has only been known from a handful of sites in the Brooks Range and Kokrines Hills. In both it was reported rare or uncommon. However, in the Ray Mountains O. kokrinensis is an important constituent of many Dry Upland Fellfield Barrens.
O. nigrescens (Pall) Fisch., a species which usually proliferates in the same fellfield habitat (Murray, pers. comm.), was not collected during the investigation.

Vegetation type:		
Dry Upl. Fellf. Barren	IVa	141
	IIIb	252

Oxytropis Maydelliana Trautv.
Scattered occurrence in Dry Ericad Upland Prostrate Scrub.

Vegetation type:		
Dry Eric. Upl. Pros. Scr.	IId	80

* Oxytropis Scammaniana Hult.
Found twice in prostrate scrub.

Vegetation type:		
Dry Eric. Upl. Pros. Scr.	IId	90

VIOLACEAE

Viola biflora L.
Very common in forests at lower elevations. Not present in forests at treeline.
Specimens not collected.

Viola epipsila Ledeb.
Common in snowbeds and along streambanks above and below treeline.
Vegetation type: Mo. Wil. Drng. Med. Scr. IIb 363

ELAEAGNACEAE

Shepherdia canadensis (L.) Nutt.
Very common in forests at lower elevations, but not present in forests at treeline.
Specimens not collected.

ONAGRACEAE

Epilobium angustifolium L.
Common in a wide variety of habitats from dry cliffs to Wet Sphagnum Moss Meadows. Occurs in large dense stands in clearings around cabins at Kilo Hot Spring.
Vegetation type: Mo. Ald. Slope Tall Scr. IIb 320
Wet Sphag. Moss Mdw. IIb 16

Epilobium latifolium L.
Scattered through tall scrub and bottomland forests, particularly along streams.
Vegetation type: Mo. Wil. Drng. Med. Scr. IIb 18

* Epilobium Hornemannii Rchb.
One of the dominant species around Kilo Hot Spring. Wide phenotypic variablility.
Vegetation type: Hot spring IIIa 232,268

UMBELLIFERAE

Bupleurum triradiatum Adams
Encountered only three times in study area.
Common in those locations.
(Collected also by J. Schubert).
Vegetation type: Dry Upl. Fellf. Barren Ia 72,280
VIa 414
Dry Lic. Upl. Rock Bar. IIIb 214

* Cicutia Douglasii DC. Coult. & Rose
Abundant around Kilo Hot Spring.
Vegetation type: Hot spring IIIa 234

Ligusticum mutellinoides (Crantz) Willar
Only two individuals of this species were encountered.
Vegetation type: Dry Eric. Upl. Pros. Scr. IId 94
Dry Upl. Fellf. Barren IVa 136

* Heracleum lanatum Michx.
Common around Kilo Hot Spring.
Specimens not collected.

CORNACEAE

Cornus canadensis L.
Common at lower elevations in forest; however, occurs at treeline near Kilo Hot Spring.
Specimens not collected.

PYROLACEAE

Pyrola asarifolia Michx.
Collected in Moist Paper Birch - Spruce Slope Forest near Kilo Hot Spring.
Vegetation type: Hot spring IIIa 265

Pyrola cf. grandiflora Radius
Only one individual of this species was collected.
Vegetation type: Mo. Dw. Scr. - Tus.-Gram. Mdw. IVb 395

Pyrola minor L.
Found growing in moss bed under riparian tall scrub.
Vegetation type: Mo. Wil. Fldp. Tall Scr. IIb 326

Pyrola secunda L.
Found in lower elevation forests, but not at treeline.
Specimens not collected.

Moneses uniflora (L.) Gray
Patchy distribution in moist spruce forest.
Vegetation type: Mo. Wh. Spr. Slope For. IIb 298

EMPETRACEAE

Empetrum nigrum L.
Fairly common in most of the vegetation types of the LOWLAND TUNDRA and BOREAL FOREST ecosystems.
Specimens not collected.

ERICACEAE

Ledum palustre L. subsp. decumbens (Ait.) Hult.
Very common in all types of dwarf and prostrate scrub communities.
Vegetation type: Mo. Dw. Scr. - Tus.-Gram. Mdw. IIa 2

Ledum palustre L. subsp. groenlandicum (Oeder) Hult.
Sparsely distributed in forests at treeline. More common at lower elevations.
Specimens not collected.

Rhododendron lapponicum (L.) Wahlenb.
Not found at treeline, although fairly common in spruce forests at lower elevations.
Vegetation type: Mo. Wh. & Bl. Spr. Slope For. Ia 433

Loiseleuria procumbens (L.) Desv.
Common in most vegetation types of ALPINE BARREN ecosystem.
Vegetation type: Dry Upl. Fellf. Barren IIc 41

* Cassiope tetragona (L.) D. Don
Very common in snowbeds, and other vegetation types of the ALPINE BARREN ecosystem excluding barrens.
Vegetation type: Mo. Snow. Forb Mdw. IIc 56

Andromeda polifolia L.
Abundant in meadows dominated or co-dominated by tussock-graminoids or Sphagnum spp.
Vegetation type: Wet Sphag. Moss Mdw. IIb 30

Arctostaphylos uva-ursi (L.) Spreng.
Not seen at treeline but common at lower elevations in mixed and deciduous slope forests.
Specimens not collected.

Arctostaphylos alpina (L.) Spreng.
Very important in fellfield communities.
Specimens not collected.

Arctostaphylos rubra (Rehd. and Wilson) Fern.
Not seen at collection sites but reported from the eastern of the range by J. Schubert and S. Roeske.
Specimens not collected.

Vaccinium vitis-idaea L.
Very common in a wide variety of vegetation types, particularly in UPLAND and LOWLAND TUNDRA and BOREAL FOREST.
Vegetation type: Wet Sphag. Moss Mdw. IIb 6

Vaccinium uliginosum L.
One of the most important species in UPLAND and LOWLAND TUNDRA and BOREAL FOREST ecosystems.
Vegetation type: Mo. Dw. Scr. - Gram. Mdw. IIc 34,35

Oxycoccus microcarpus Turcz.
Common in Sphagnum and tussock graminoid meadows, and also found in other vegetation types.
Specimens not collected.

DIAPENSIACEAE

Diapensia lapponica L.
Common in ALPINE BARREN vegetation types.
Vegetation type: Dry Upl. Fellf. Barren IIc 64

PRIMULACEAE

Dodecatheon frigidum Cham. and Schlecht.
A common species in snowbeds and along streams, at and above treeline.
Vegetation type: Mo. Upl. Med. Scr. IIc 40
Mo. Snowb. Gram. Mdw. IVa 158
IId 215

Trientalis europaea L.
Encountered only at Kilo Hot Spring in the shade of tall scrub.
Vegetation type: Hot spring IIIa 241

GENTIANACEAE

* Gentiana algida Pall.
Present in vegetation types of ALPINE BARREN. Bloomed in August.
Vegetation type: Dry Eric. Upl. Pros. Scr. IVa 400

Gentiana glauca Pall.
Found in moist graminoid meadows of all types.
Vegetation type: Mo. Wil. Fldp. Tall Scr. IIb 39
Moist Dwarf Scrub - Gram. Mdw. IVa 157

POLEMONIACEAE

Polemonium acutiflorum Willd.
Associated with dwarf to tall willow scrub, above and below treeline.
Vegetation type: Mo. Wil. Fldp. Tall Scr. IIb 38
Moist Dwarf Scrub - Gram. Mdw. IId 206

BORAGINACEAE

Eretrichium aretiodes (Cham.) DC.
Seen only at collection site.
Vegetation type: Dry Upl. Fellf. Barren Ia 271

Mertensia paniculata (Ait.) G. Don.
Common at treeline and below, in all floodplain vegetation types.
Vegetation type: Mo. Wil. Fldp. Tall Scr. IIb 32

LABIATAE

Mentha arvensis L.
Abundant along the effluent streams of Kilo Hot Spring.
Vegetation type: Hot spring IIIa 239

SCROPHULARIACEAE

* Veronica Wormskjoldii Roem. and Schult.
Found only at Kilo Hot Spring.
Vegetation type: Hot spring IIIa 219

Lagotis glauca Gaertn.
Occurs in scattered populations in snowbeds and scrub communities above treeline.
Vegetation type: Mo. Snowb. Gram. Mdw. IVa 115

* Castilleja elegans Malte
Usually well represented in large patches of Dry Upland Fellfield Barren.
Vegetation type: Dry Eric. Upl. Pros. Scr. IVa 162
Dry Upl. Fellf. Barren Ia 279,70

Pedicularis verticillata L.
Occasional in wet meadows or valley-bottom dwarf scrub communities.
Vegetation type: Moist Dwarf Scrub - Gram. Mdw. IIc 355
Wet Graminoid Meadow IVa 159

Pedicularis labradorica Wirsing
Very common in all types of tussock-graminoid meadows, and other LOWLAND TUNDRA vegetation types.
Specimens not collected.

* Pedicularis Langsdorfii Fisch.
An uncommon species found twice in Moist Dwarf Scrub - Graminoid Meadows.
Vegetation type: Moist Dwarf Scrub - Gram. Mdw. IIc 49
IId 205

Pedicularis sudetica Willd. subsp. interioides Hult.
Found in small concentrated populations in Wet Graminoid Meadows.
Vegetation type: Wet Graminoid Meadow IVa 167

* Pedicularis capitata Adams
Most common in moist graminoid dominated and co-dominated vegetation types and Moist Willow Upland Medium Scrub.
Vegetation type: Mo. Wil. Upl. Med. Scr. IVa 151
Wet Graminoid Meadow IVa 427
Moist Dwarf Scrub - Gram. Mdw. IId 193
Ia 287

Pedicularis Oederi M. Vahl
Uncommon. Collected from a snowbed.
Vegetation type: Mo. Snow. Forb Mdw. IVa 110

OROBANCHACEAE

Boschiniakia rossica (Cham. and Schlecht.) Fedtsch.
Fairly common, particularly in Moist Alder Scrub Savanna.
Specimens not collected.

LENTIBULARIACEAE

Pinguixula villosa L.
Common in tussock-graminoid and Sphagnum meadows.
Vegetation type: Mo. Tus.-Gram. Mdw. IIc 52
Wet Sphag. Moss Mdw. IIb 74

PLANTAGINACEAE

Plantago major L. var. major
Found on a gravel bar near Kilo Hot Spring.
Vegetation type: Hot spring IIIa 259

RUBIACEAE

Galium boreale L.
Common in meadows surrounding Kilo Hot Spring.
Also present at much lower elevations.
Specimens not collected.

Galium trifidum L.
Occurs along a short stretch of one of the effluent streams of Kilo Hot Spring.
Vegetation type: Hot spring IIIa 255

CAPRIFOLIACEAE

Viburnum edule (Michx.) Raf.
While important in lower elevation forests, also encountered near tors.
Specimens not collected.

Linnaea borealis L. subsp. americana (Forbes) Hult.
Common in moist deciduous forests and dry spruce forests. Found occasionally above treeline in dwarf scrub.
Vegetation type: Dry Bir. Upl. Dw. Scr. IVa 150

VALERIANACEAE

Valeriana capitata Pall.
Scattered individuals in tall, medium, and dwarf scrub communities at a wide range of elevations.
Vegetation type: Mo. Wil. Upl. Med. Scr. IIb 33
Mo. Dw. Scr. - Gram. Mdw. IVa 133,169

CAMPANULACEAE

Campanula lasiocarpa Cham.
Very common in Dry Upland Fellfield Barren.
Vegetation type: Dry Upl. Fellf. Barren IVa 402
IIIb 251

Campanula uniflora L.
Small populations found a couple of times in Dry Upland Fellfield Barren.
Vegetation type: Dry Upl. Fellf. Barren IId 191
IIIb 196

COMPOSITAE

Solidago multiradiata Ait.
Occasional specimens found on streambanks in UPLAND TUNDRA.
Vegetation type: Dry Bir. Upl. Dw. Scr. IVa 149,154
Dry Eric. Upl. Pros. Scr. IVa 401

Solidago canadensis L.
Found only at hot spring on dry ground.
Vegetation type: Hot spring IIIa 236,392

Aster sibiricus L.
Seen on serpentine-rich outcrop.
(Collected also by J. Schubert).
Vegetation type: Dry Upl. Fellf. Barren VIa 406,409

* Erigeron hyperboreus Greene
Associated with fellfield.
Vegetation type: Dry Upl. Fellf. Barren — IIIb 216; Ia 275

Erigeron acris L.
Found in eastern end of range.
(Collected by J. Schubert).
Vegetation type: unknown. — VIa 421

Antennaria Friesiana (Trautv.) Ekman
A very common constituent of prostrate scrub and fellfield barrens throughout the range.
Vegetation type: Dry Upl. Fellf. Barren — IIb 366; IVa 137,164; IIc 334; Ia 375

Bidens cernua L.
Restricted to the banks of one of the effluent streams of Kilo Hot Spring.
Vegetation type: Hot spring — IIIa 390

Achillea sibirica Ledeb.
Common around Kilo Hot Spring, but not seen elsewhere except well below treeline.
Vegetation type: Hot spring — IIIa 379

Artemisia Tilesii Ledeb.
Seen only in the clearings around the cabins near Kilo Hot Spring.
Specimens not collected.

Artemisia arctica Less.
Common in most dry vegetation types at a wide range of elevations, from Dry Upland Fellfield Barren to Dry White Spruce Floodplain Forest.
Vegetation type: Dry Eric. Upl. Pros. Scr. — IVa 155
Dry Upl. Fellf. Barren — VIa 415

Artemisia furcata Rieb.
Apparently quite widely distributed in barrens, though not common.
Vegetation type: Dry Upl. Fellf. Barren — IIc 330
Dry Lic. Upl. Rock Bar. — IIIb 269; Ia 69,290

Petasites frigidus (L.) Franch.
Common in vegetation types of LOWLAND TUNDRA.
Vegetation type: Mo. Wil. Drng. Med. Scr. — IIb 22,23

Arnica frigida C. A. Mey.
Common in most vegetation types of ALPINE BARREN except rock barrens. Very scattered at lower elevations.

Vegetation type:			
Dry Upl. Fellf. Barren	IIc	61
	Ia	68
Hot spring	IIIa	270

Senecio congestus (R. Br.) DC.
Collected in drainageway from lake 1485. Apparently uncommon.

Vegetation type:		
Wet Wil.-Ald. Drng. Tall Scr.	IIa	390

Senecio atropurpureus (Ledeb.) Fedtsch. subsp. frigidus (Richards.) Hult.
Quite common in scrubs of the UPLAND TUNDRA ecosystem.

Vegetation type:		
Dry Bir. Upl. Dw. Scr.	IIc	50
Dry Eric. Upl. Pros. Scr.	IId	202
Dry Upl. Fellf. Barren	IIc	332

* Senecio atropurpureus (Ledeb.) Fedtsch. subsp. tomentosus (Kjellm.) Hult.
Found in snowbeds. Less common than other subspecies.

Vegetation type:		
Mo. Snowb. Gram. Mdw.	IVa	116
	IIc	345

* Senecio resedifolius Less.
Patchy distributions occur in Moist Snowbed Graminoid Meadows. Found once on fellfield.

Vegetation type:		
Wet Graminoid Meadow	IVa	179
Mo. Snow. Gram. Mdw.	IVa	108,144,397
Dry Upl. Fellf. Barren	Ia	65

* Senecio pauciflorus Pursh
Well represented in dry soil near Kilo Hot Spring.

Vegetation type:		
Hot spring	IIIa	220

Senecio lugens Richards.
Found only once, on fellfield.

Vegetation type:		
Dry Upl. Fellf. Barren	IIa	272

Saussurea angustifolia Willd. DC.
Common in dwarf and prostrate scrub communities, as well as in tussock graminoid meadows and spruce slope forests.

Vegetation type:		
Mo. Tus.-Gram. Mdw.	IIc	51
Dry Eric. Upl. Pros. Scr.	IId	84

* Saussurea viscida Hult. var. yukonenesis (Pors.) Hult.
The few individual plants seen were restricted to fellfields.
(Collected also by J. Schubert.)

Vegetation type:		
Dry Upl. Fellf. Barren	IIc	331
	IId	426
	IVa	411

VEGETATION

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ABSTRACT

INTRODUCTION

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ACKNOWLEDGMENTS

REFERENCES

NOTE

The reader is referred to the Introduction of this volume for detailed descriptions of the project study area and the overall project research design. Also included there are descriptions of the project's three areas of concentrated study, with a map showing their locations and the locations of travel routes and Ray Mountains project sites (RMP sites Ia-VId) referred to in this chapter. The ECOSYSTEMS referred to herein (in upper case lettering) are described in the Ecosystems chapter of this volume.

ABSTRACT

The vegetation study team developed a hierarchial classification scheme for 30 different vegetation types identified in the Ray Mountains. The species composition, ecology, and geographical extent of each type were described. A small-scale (1:250,000) vegetation map based on satellite (LANDSAT) imagery was designed to show the distribution and areal extent of major vegetation types in the study area. Large-scale (1:5,000) vegetation maps of two areas representative of upland and lowland environments were constructed from aerial photographs and data gathered through detailed sampling.

The Ray Mountains include vegetation types characteristic of Alaskan alpine tundra, low arctic tundra, and boreal forest. The central upper elevation portion of the range is dominated by alpine rock - lichen barrens; the rolling lowland slopes are dominated by low arctic shrub - tussock tundra; and the lowest peripheral areas are forested.

INTRODUCTION

Lying near the northern limit of forest in interior Alaska, the Ray Mountains include diverse boreal forest and low arctic and alpine tundra vegetation types. Although the arctic tundra vegetation of Alaska has received considerable detailed analysis very little information is available on Alaskan alpine tundra and boreal forest (Dyrness and Viereck, 1979).

The main objective of this study was to describe the vegetation of the Ray Mountains for the scientific community, land managers, and the soil, floristics, fauna, and ecosystem study teams of this project. Because description at several levels of resolution was necessary to accomodate these diverse uses, a hierarchical scheme of vegetation classification was developed.

METHODS

The vegetation of the Ray Mountains was studied, classified, described, and mapped with the aid of aerial and ground reconnaissance, plot (releve) sampling, LANDSAT

satellite imagery, and 1:5,000 scale aerial photography.

Scientific and common plant nomenclature throughout this chapter and volume follows Hulten (1968) for all vascular plants except those in the genus Salix, which follows Viereck and Little (1972).

Preparation for Fieldwork

Black and white near - infrared aerial photographs (1:5,000, 1.0 X 1.2 km) depicting a northwest-southeast transect of the Ray Mountains were used to select sites for concentrated study. Aerial reconnaissance along this transect enabled us to choose two areas considered representative of the vegetation of the Ray Mountains. The Spooky Valley photo area is considered typical of the central upper elevation portions of the range, and the lower Torment Creek valley and ridge photo areas are considered characteristic of the rolling tussock tundra and lower elevation forested areas of the Ray Mountains.

Vegetation Sampling

Data for vegetation mapping and description were gathered through detailed vegetation sampling and description in areas of concentrated study, and less detailed sampling and description in areas of less concentrated study. Vegetation sampling techniques closely followed the methods developed by Walker et al. (1979, unpubl.) for use in Alaskan large-scale vegetation mapping. In brief, these methods were as follows. Sample sites (releves) within each unit were subjectively located in uniform vegetation, in most cases within an aerial photo map unit. Plot sizes ranged from 10 sq m in graminoid vegetation types to 100 sq m in forested areas, and were chosen to include an adequate representation of the vegetation. Releve information including site description, species present, and species percent cover estimates, was recorded on data forms designed by Walker et al. (1979). To assure adequate sampling, abbreviated releves were conducted in areas where time did not permit detailed sampling.

Small-scale Mapping (1:250,000)

A small-scale vegetation map was constructed by methods similar to those developed by Anderson (1976). His technique employs a winter black and white LANDSAT image to help determine plant stature, and a summer false color infared scene to help distinguish species composition. The images were first examined to differentiate spectral units, recognizable as different colors or gray shades. The colors or shades on the image were assumed to portray the different

reflective characters of vegetation types. Direct correlations between vegetation types and color classes were established with information collected in areas of detailed sampling. As suggested by Anderson (1976), these correlations were the basis for application of vegetation interpretation to other parts of the map area not visited.

Map construction followed several basic steps. First, major rivers and lakes, prominent landmarks, and the 610 m (2000 ft) contour were traced from the US Geological Survey (USGS) 1:250,000 Tanana Quadrangle (1976) topographic map onto two acetate transparancies. These transparencies were placed over both summer and winter LANDSAT scenes so that landmarks noted on the USGS map registered with those on the satellite images. Preliminary vegetation unit boundaries, recognizable as spectral units, were then traced from each image onto a transparency and their shade classes were coded. The two transparencies were superimposed and placed over the USGS topographic basemap. Final vegetation map unit boundaries that incorporated spectral data from both images, topographic information, and information collected in the field, were drawn and coded. Finally, the areal extent of each unit was computed with a dot grid.

Because problems were encountered in image interpretation, they are outlined here to provide a clear statement of the map's derivation and value. The fusion of the winter and summer spectral interpretations required averaging map unit boundaries and created many awkwardly shaped units not related to local topography. Thus, map unit boundaries were adjusted to assure consistency with clear topographical and ecological relations established in the field. Because of limited ground truthing, most of the map units were assigned vegetation codes on the basis of the few direct correlations between spectral units and vegetation types established in areas of detailed sampling; hence map unit identification was difficult and speculative in many areas. In addition, the winter scene shows severe shadows in the central high elevation regions of the range, because of an oblique sun angle. Thus, interpretation for those areas relied almost entirely on the summer scene.

Large-Scale Mapping (1:5,000)

Large-scale maps were constructed for three photo areas according to methods described by Walker et al. (1979). In brief, these methods were as follows. Preliminary map unit boundaries were outlined on the aerial photographs on the basis of differences in texture and shade. Photo areas were surveyed from a vantage point to identify and revise the vegetation unit boundaries. Sampling was conducted on each of the units within the photo areas. Releve information from all sites was summarized so that similar vegetation types could be

identified, grouped, and named. Then each vegetation unit identified on the aerial photograph was assigned a code for landform, microrelief, slope class, and vegetation type. This information was summarized on the master maps. Vegetation maps were constructed to show the distribution of different plant growth forms. Patterns on the vegetation maps represent different growth forms, and floristic codes in the map units correspond to the dominant species present.

RESULTS AND DISCUSSION

The classification scheme for the vegetation of the Ray Mountains is described and the physiographic and ecological terminology used throughout this report is defined. The 30 vegetation types found in the Ray Mountains are named and classified at three levels (Table 1). A general description of each level I vegetation type is followed by detailed descriptions of the species composition, structure, ecological characteristics, and geographic distribution of the 30 level III vegetation types. Following these descriptions, the equivalent plant communities recognized by Dyrness and Viereck (1979) are listed in Table 2. A small-scale (1:250,000) vegetation map showing the distribution of major vegetation types in the study area follows Table 2. The areal extents of these major types are given in Table 4. Finally, large-scale (1:5,000) vegetation maps of three photo areas are presented.

Classification Scheme

To construct a workable and consistent vegetation classification scheme for the Ray Mountains (Table 1), we defined a vegetation type as a visually recognizable homogeneous plant assemblage with characteristic species, usually associated with a well defined physiographic position. It is recognized that vegetation types are affected by diverse ecological factors and blend into one another along environmental gradients, with sometimes indistinct boundaries. The clarity of boundaries varies with the steepness of the environmental gradients between vegetation types.

Dyrness and Viereck (1979) have summarized Alaskan vegetation studies, and have proposed a "pure" classification system for the entire state, based solely on the characteristics of the vegetation. However, because vegetation is affected by landform and ecology, and because these factors aid in recognition of vegetation types, we have distinguished vegetation types on the basis of these additional criteria as well. To clarify the relation of the Ray Mountains vegetation types (as classified in this study) to other areas of Alaska, equivalent "plant communities"

recognized by Dyrness and Viereck (1979) are presented (Table 2).

The vegetation types of the Ray Mountains are classified and named on the basis of visual dominance (not percent cover), closely following Walker et al. (1979). The broadest (I) level classifies vegetation according to growth form, and breaks the vegetation into tree dominated units, shrub dominated units, shrub - herb co-dominated units, herb dominated units, bryoid dominated units, and barren units. Level I units are subdivided in a second level (II) by criteria which are applicable to specific growth forms: tree dominated units are subdivided into coniferous, deciduous, and mixed forests, shrub dominated units are subdivided into four height classes, co-dominated and herb dominated units are subdivided into tussock and non-tussock growth forms, and byroid dominated units are divided taxonomically.

A higher (III) level of classification, based on more detailed characteristics of the vegetation and its physiographic location, is used for detailed description of the vegetation types of the Ray Mountains. Though several of the vegetation types described at this level were sampled or observed in only a few sites, they are considered distinct vegetation types. All of the vegetation types in this level are named with a moisture category and growth form descriptor; where appropriate, dominant species and a physiographic or ecological modifier is included.

Vegetation types recognized in large-scale mapping are described at an even higher level of resolution than level III. These vegetation types are highly specific in their location and species composition, and might be considered a fourth level of classification.

Physiographic and Ecological Terminology

Physiographic and ecological modifiers (often used inconsistently in other reports) are defined for the Ray Mountains project in this chapter. Their use throughout the Ray Mountains project report is consistent with the following definitions.

Lowland is a general term for areas at lower elevations in the range, usually below 762 m (2500 ft) and with less than five degrees inclination.

Uplands are those areas in the central upper elevation portion of the range, above approximately 762 m (2500 ft).

Drainageways are small streams and moist depressions in slopes where draining water coalesces.

Floodplains are the flat alluvial areas along the lower courses of rivers and large streams in the range. They are prone to shifting channels and periodic flooding.

Slope, when unqualified, is a general term applied to slopes with an inclination greater than five degrees.

Fellfields are exposed areas with substrates of highly weathered rock fragments, usually less than 3 cm in diameter, and coarse soils. Vegetation includes widely scattered herbs, prostrate shrubs, and lichens. Fellfields are limited to scattered high elevation ridgetops in the range.

Rock outcrop refers to any exposed bedrock such as tors and cliffs.

Rock barrens are slopes or flat areas dominated (greater than 70%) by rocks of any size. Rock barrens include boulder fields, rock slopes, and talus slopes.

Savanna refers to vegetation types where visually dominant individuals of a taller growth form are scattered among a more prevalent growth form; for example, medium shrubs scattered within a dwarf scrub unit would be called a savanna medium scrub.

Vegetation complex refers to a vegetation type composed of smaller vegetation units too small to consider individual vegetation types. If the spatial arrangement of these smaller units is systematically determined by ecological factors such as periglacial processes like frost sorting or hummock formations, the overall vegetation type is considered a vegetation complex.

Vegetation mosaics are characterized by an apparently random distribution of component vegetation units, also too small to be considered separately. The subunits are usually slightly larger than those of the vegetation complexes. For small-scale mapping, spectral units that contain several shade classes which are too small to be mapped individually are also considered vegetation mosaics.

Treeline is a general term that refers to the zone of transition from forest to tundra.

Forest limit refers to the limit of trees with greater than five percent cover.

Table 1. Vegetation Types of the Ray Mountains.

Tree Dominated Units
- A. Evergreen Forest
  1. Moist White Spruce Slope Forest
  2. Dry White Spruce Floodplain Forest
  3. Moist White and Black Spruce Forest
  4. Wet Black Spruce - Sphagnum Forest
  5. Dry Black Spruce - Lichen Forest
- B. Deciduous Forest
  1. Moist Paper Birch Slope Forest
  2. Moist Balsam Poplar Floodplain Forest
  3. Dry Paper Birch - Lichen Slope Forest
- C. Mixed Forest
  1. Moist Paper Birch - Spruce Slope Forest
  2. Moist Balsam Poplar - Spruce Floodplain Forest

Shrub Dominated Units
- A. Tall Scrub (>2 m)
  1. Wet Willow - Alder Drainageway Tall Scrub
  2. Moist Willow Floodplain Tall Scrub
  3. Moist Alder Slope Tall Scrub
- B. Medium Scrub (0.5-2 m)
  1. Moist Willow Upland Medium Scrub
  2. Moist Willow Drainageway Medium Scrub
  3. Moist Alder Savanna Medium Scrub
- C. Dwarf Scrub (0.1-0.5 m)
  1. Moist Birch - Blueberry Dwarf Scrub
  2. Dry Birch Upland Dwarf Scrub
- D. Prostrate Scrub (<0.1 m)
  1. Dry Ericad Upland Prostrate Scrub

Shrub - Herb Co-dominated Units
- A. Dwarf Scrub - Graminoid Meadow
  1. Moist Dwarf Scrub - Graminoid Meadow
- B. Dwarf Scrub - Tussock-Graminoid Meadow
  1. Moist Dwarf Scrub - Tussock-Graminoid Meadow

Herb Dominated Units
- A. Tussock-Graminoid Meadow
  1. Moist Tussock-Graminoid Meadow
  2. Wet Lowland Tussock-Graminoid Meadow
- B. Graminoid Meadow
  1. Wet Graminoid Meadow
  2. Moist Snowbed Graminoid Meadow
- C. Forb Meadow
  1. Moist Snowbed Forb Meadow

Bryoid Dominated Units
- A. Moss Meadow
  1. Wet Sphagnum Moss Meadow
- B. Lichen Meadow
  1. Dry Upland Fruticose Lichen Meadow

Sparsely Vegetated Units (<30% cover)
- A. Barren
  1. Dry Upland Fellfield Barren
  2. Dry Lichen Upland Rock Barren

Description of Vegetation Types

The general descriptions here outline the vegetation types' dominant important species and structure, and their relative importance (percent cover) within the study area, based on the small-scale vegetation map (see Table 4). and the geographical distribution of the level I vegetation types of the Ray Mountains. Detailed descriptions of level III vegetation types are organized under three subheadings: SPECIES, ECOLOGY, and GEOGRAPHY. Under SPECIES, the major species in each layer (overstory, understory, and ground layer) are listed in approximate order of importance (percent cover). In ECOLOGY, the physiographic location, the variation within the vegetation type, and its position along the vegetation continuum are described. Where appropriate and available, additional information describing the elevation, exposure, slope, macrorelief and microrelief, cryoturbation, canopy cover, and tree age, height, and diameter at breast height (dbh) is included. Under GEOGRAPHY, the known occurrence in the Ray Mountains of the vegetation type is described and its relative importance is rated with subjective general abundance terms: abundant, common, uncommon, and rare.

Tree Dominated Units

Forests usually occur in the peripheral regions of the Ray Mountains at elevations below 610 m (2000 ft). They commonly develop along floodplains up to 600 m on adjacent slopes, and in poorly drained lowland tundra. Approximately 22% of the study area is forested (Table 4). Forests are predominantly open, usually with 5-60% canopy cover.

Three forest types were distinguished at the second level of classification: evergreen, deciduous, and mixed. These units were further subdivided on the basis of moisture, dominant tree species, understory composition, and physiographic position. Closed forests were not distinguished from open forests in the classification scheme for three reasons: very few stands of closed forest (60-100% canopy cover) were seen; the understories of closed forests visited were not significantly different from open stands of the same type; and closed forests graded into open stands with poorly defined boundaries.

Mixed forests dominated by white spruce (Picea glauca) and paper birch (Betula papyrifera) are considered the most important forest type in the Ray Mountains, covering approximately 14% of the study area, mostly in the Halu Creek area. White spruce slope and floodplain forests develop near most lowland river drainages in the range, but cover only 7% of the study area. Deciduous stands dominated by paper birch or balsam poplar (Populus balsamifera) are rare, occurring in small isolated patches. Though several small stands of aspen (Populus tremuloides) were seen in the Moose Creek area, they

were the only such stands seen in the range and were not sampled. Thus, they were not included in the classification scheme or described here.

A. Evergreen Forest

1. Moist White Spruce Slope Forest

SPECIES: White spruce is the dominant tree species in this vegetation type though paper birch was found in most stands sampled. Feltleaf willow (Salix alaxensis) and mountain alder (Alnus crispa) greater than 2 m in height form a tall shrub layer, but are scattered and rarely reach more than 10-15% cover. An extensive dwarf shrub layer that includes Betula nana, Ledum palustre ssp. decumbens, and Vaccinium vitis-idaea may reach up to 30% cover. In some areas the ground cover is dominated by Calamagrostis sp. and a feathermoss (Hylocomium splendens). Herb species sometimes include Epilobium angustifolium, Saussurea angustifolia, Polygonum bistorta, Rosa acicularis, and Equisetum arvense.

ECOLOGY: This vegetation type occurs on slopes above river floodplains and on other protected moist sites. Trees are usually 15-25 cm dbh and approximately 13-16 m tall. The forest's openness usually results in a well developed understory of dwarf shrubs and graminoids, and a ground layer of feathermoss. This forest type often grades into a mixed Moist Paper Birch-Spruce Slope Forest in areas where slope increases.

GEOGRAPHY: Moist White Spruce Slope Forests were observed on slopes above Torment Creek, Ishtalitna Creek, and the Kanuti Kilolitna River. This vegetation type is expected to occur on the slopes north of the Tozitna River, along McQuesten Creek, Fleshlanana Creek, Gishna Creek, and in the Halu Creek area. It is considered abundant, and is second in areal importance to Moist Paper Birch-Spruce Slope Forest.

2. Dry White Spruce Floodplain Forest (Photo 1-2)

SPECIES: White spruce is usually the only tree species in this vegetation type though occasional paper birch and black spruce (Picea mariana) do occur. A patchy shrub layer dominated by tall Salix alaxensis sometimes includes scattered medium height Salix planifolia ssp. pulchra. Dwarf and prostrate shrubs including alpine blueberry (Vaccinium uliginosum), V. vitis-idaea, Empetrum nigrum, Linnaea borealis, and Ledum palustre ssp. decumbens sometimes reaches 30% cover. The ground cover is composed of scattered herbs such as Aconitum delphinifolium, Epilobium angustifolium, Artemisia arctica ssp. arctica, and Calamagrostis sp. Patches of lichens usually include Cladonia spp., Cladina spp., and Cetraria spp.

Photo 1. View NE up the Tozitna River valley. To left, a Dry White Spruce Floodplain Forest; to right, a Moist Willow Floodplain Tall Scrub.

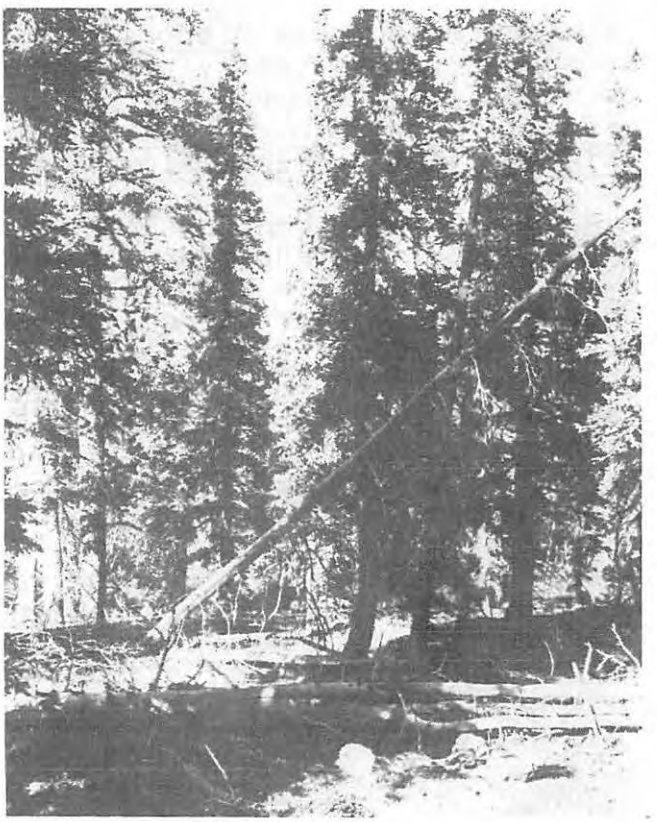


Photo 2. Dry White Spruce Floodplain Forest with typical open canopy and abundance of dead trees.

ECOLOGY: This forest type occurs along lowland river drainages. It reaches its greatest areal coverage in areas where meandering river courses have formed broad floodplains, but individual stands are small and localized. The trees are usually greater than 15 cm dbh and in some small areas closed canopies are formed. The understory varies greatly with openness of canopy, moisture, and proximity to the river. Lichens are most abundant in areas beneath an open canopy, dwarf shrubs tend to surround the spruce trunks, and tall shrubs dominate the understory near the river.

GEOGRAPHY: This forest type is common and characteristic of river drainages throughout the range. Stands of this type were sampled at lower Torment Creek, Kilo Hot Spring, and lower Ishtalitna Creek. They are expected to occur along McQuesten Creek, Fleshlanana Creek, Gishna Creek, Kobuk Creek, Sam Creek, and Halu Creek.

3. Moist White and Black Spruce Forest

SPECIES: White and black spruce trees co-dominate this forest type. Scattered medium height shrubs include Salix planifolia ssp. pulchra and occasional Alnus crispa. A dwarf and prostrate shrub layer usually includes Vaccinium uliginosum, V. vitis-idaea, Ledum palustre ssp. decumbens, Betula nana, and Empetrum nigrum. A mat of mosses such as Hylocomium splendens and Sphagnum spp. and lichens such as Cladonia spp., Cladina spp., and Cetraria spp. form a nearly continuous ground cover. Scattered herbs sometimes include Lycopodium annotinum, Petacites frigidus, Saussurea angustifolia, Equisetum arvense, Calamagrostis sp., and Carex Bigelowii.

ECOLOGY: This forest type develops on moist gentle slopes and flat areas next to river drainages. The substrate is wet, hummocky, and irregular. The trees are usually less than 15 cm dbh, 5-7 m tall, and under 60 years old. Viereck (1979) suggests that black spruce forests sometimes form the final successional stage on interior Alaskan river bars. However, the young age and small stature of these trees and the presence of nearby mature white spruce and mixed stands suggest that this vegetation type may be replaced by a Moist Paper Birch-White Spruce Slope Forest.

GEOGRAPHY: Moist White and Black Spruce Forests were observed in small isolated patches in the Torment Creek and Ishtalitna Creek areas, and are expected to occur along the Kanuti Kilolitna River, Halu Creek, and in protected moist sites next to the rivers draining the southern portion of the range. They are uncommon and not of significant areal extent.

4. Wet Black Spruce - Sphagnum Forest

SPECIES : Black spruce is the dominant tree species in this vegetation type, but occasional white spruce were found in most stands visited. Tall Salix alaxensis and medium height Salix planifolia ssp. pulchra may occur but are sparse and often entirely absent. The ground cover consists of a dense Sphagnum spp. mat and scattered dwarf and prostrate shrubs such as Ledum palustre ssp. decumbens, Vaccinium vitis-idaea, V. uliginosum, and Empetrum nigrum. Common herbs may include Rubus chamaemorus, Equisetum arvense, and Arctagrostis latifolia.

ECOLOGY: This typical muskeg is generally found in flat areas with poorly drained soils and a deep organic layer underlain by permafrost. The ground surface is wet and hummocky with small depressions and mounds. Canopy cover is open and uneven; trees are small and stunted with dead lower branches. This forest type usually grades into Moist White and Black Spruce Forest with an increase in slope, or into Dry White Spruce Floodplain Forest in better drained areas.

GEOGRAPHY: Muskegs occur in isolated pockets and are not widespread or common in the range. They reach their largest areal extent north of the Tozitna River and are expected to occur in patches along several other rivers draining the north slope of the range.

5. Dry Black Spruce - Lichen Forest

SPECIES: Black spruce dominates this vegetation type though occasional paper birch and aspen often occur. The understory consists of scattered dense patches of Betula nana surrounded by a lichen mat of Cladonia alpestris, C. gracilis, and C. rangiferina.

ECOLOGY: This classic lichen woodland usually develops on low knolls and ridges and on gentle well drained slopes. The black spruce are clumped, stunted, and frequently covered by lichens, predominantly Usnea spp. The stands are always open with tree cover often less than 25%. There is usually no shrub layer but always an extensive dry lichen mat. This forest type grades into Moist White Spruce Slope Forest in areas where moisture increases or slope decreases.

GEOGRAPHY: Lichen woodlands were observed on several low ridges above Ishtalitna Creek and on dry slopes north of Moose Creek. They are rare and expected to occur only in small isolated patches.

B. Deciduous Forest

1. Moist Paper Birch Slope Forest

SPECIES: Paper birch is the dominant tree species in this deciduous forest type though white spruce is often present. The shrub understory includes Betula nana, B. glandulosa, Alnus crispa, Vaccinium uliginosum, V. vitis-idaea, and Spiraea beauverdiana. The ground cover usually consists of herbs such as Equisetum arvense and Lycopodium annotinum, and mosses, predominantly Hylocomium splendens.

ECOLOGY: This deciduous forest occurs at lower elevations on steep (10-40 degrees) south and east-facing slopes above river drainages. Soils are deep, well drained, coarse, and often rocky. Stands are usually open with both single and multi-trunked trees greater than 15 cm dbh and up to 13 m tall. The understory is highly variable and seems to depend on the density of spruce trees present. In areas of greater spruce tree density, feathermoss is locally abundant. Pure stands of birch often grade into mixed stands of spruce and birch where slope and exposure decrease.

GEOGRAPHY: This vegetation type was seen on the west banks of Ishtalitna Creek and on some of the south-facing slopes north of the Tozitna River. Small stands were sampled on the west bank of Torment Creek next to basecamp. Although this vegetation type is not areally extensive, it is common and considered the most important deciduous forest type represented in the range. It is expected to occur on slopes south of the Tozitna River and in the Halu Creek area.

2. Moist Balsam Poplar Floodplain Forest

SPECIES: Balsam poplar is the dominant tree species in this vegetation type although scattered white spruce often occur. A tall shrub layer includes Salix alaxensis and Alnus crispa. Medium height shrubs such as Viburnum edule, Shepherdia canadensis, and Rosa acicularis occur beneath the tall shrub layer. An herbaceous ground cover may include Equisetum arvense, Epilobium angustifolium, Calamagrostis sp., Mertensia paniculata, and Aconitum delphinifolium.

ECOLOGY: Pure stands of balsam poplar are found in association with river terraces and floodplains. The trees are 30-40 cm dbh and 15-25 m in height, and usually form an open canopy above tall shrub, medium shrub, and herbaceous vegetation layers. Viereck (1979) considers balsam poplar stands an intermediate stage in the typical interior Alaskan riverbar succession that eventually gives way to a white spruce forest.

GEOGRAPHY: Significant stands of this type are rare and were

observed in only two sites within the study area. Both stands were next to hot springs, one along Ishtalitna Creek and the other at Kilo Hot Spring. It may occur on river terraces in the Tozitna River and Halu Creek.

3. Dry Paper Birch - Lichen Slope Forest

SPECIES: Paper birch is the principal tree species in this forest type. Scattered white spruce may occur but are sparse and not considered an important associate species. The only significant understory is a ground cover composed of fruticose lichens. Common lichen species belong to the genera Cladonia, Cladina, and Stereocaulon.

ECOLOGY: Paper birch - lichen woodlands were observed on steep and rocky south-facing slopes. Tree cover is usually less than 30% and the trees are frequently twisted and less than 8 m tall. The lichen mat may be poorly developed in some areas which is likely due to the increased cover of leaf and branch litter (Racine 1976).

GEOGRAPHY: This vegetation type was observed on the south-facing slopes north of Ishtalitna Creek. It may occur on similar slopes in the northern part of the range, but it is uncommon and considered to be of little areal importance.

C. Mixed Forest

1. Moist Paper Birch - Spruce Slope Forest

SPECIES: In this mixed forest type, white spruce is usually more abundant than paper birch. A tall shrub layer is formed by willows and scattered alders. Typical dwarf and prostrate shrubs include Empetrum nigrum, Vaccinium vitis-idaea, and Spiraea beauverdiana. Herbs such as Epilobium angustifolium, Cornus canadensis, Calamagrostis sp. and Linnaea borealis are unevenly distributed throughout this vegetation type. Frequently, feathermosses such as Hylocomium splendens have the highest ground cover of any understory species.

ECOLOGY: This forest type is best developed on south- and east-facing slopes above river drainages. Sites are usually well drained as a result of topography or coarse-textured substrate, and species composition and structure is highly variable. The spruce and birch tree layers are clearly stratified with the birch forming an open canopy beneath the spruce. Stands are usually open, though closed stands in this type are more common than in other forest types. The importance of paper birch usually increases in areas with better drainage and on steeper slopes. Pure stands of paper birch and white spruce blend in and out of this forest type.

GEOGRAPHY: This vegetation type is considered the most abundant forest type in the Ray Mountains, covering approximately 14% of the study area (Table 4). It was sampled at Ishtalitna Creek and Torment Creek, and is expected to occur near McQuesten Creek, Fleshlanana Creek, Gishna Creek, Moose Creek, and areas surrounding Halu Creek.

2. Moist Balsam Poplar - Spruce Floodplain Forest

SPECIES: In this mixed forest type, white spruce usually exceeds 12balsam poplar in2 number but not always in stature. In areas where balsam poplar is dominant, the ground cover contains herb species characteristic of pure balsam poplar stands. Such a typical herbaceous ground cover may include Calamagrostis sp., Mertensia paniculata, and Equisetum arvense. In stands where white spruce is dominant, feathermosses, Linnaea borealis, and Vaccinium vitis-idaea are more abundant. Tall alders are scattered throughout this forest type.

ECOLOGY: This vegetation type develops on flat areas near rivers or streams and probably represents a late stage in floodplain succession (Racine 1976). Trees are usually greater than 20 cm dbh and taller than 20 m. The understory and ground cover vary with the density and species of trees as this mixed forest type merges with pure stands of white spruce and isolated patches of balsam poplar dominated forests.

GEOGRAPHY: Mixed spruce - poplar forests are not widespread and are usually found in association with pure stands of balsam poplar near hot springs. They are of little areal significance and are considered uncommon in the Ray Mountains.

Shrub Dominated Units

Shrub dominated units occur in a variety of situations found throughout the range. They are most important in moist drainageway and riverside areas, and on upland slopes. They cover approximately 28% of the study area (Table 4).

Four classes of shrub dominated units are recognized at the second level of classification: tall scrub (>2 m); medium scrub (0.5-2 m); dwarf scrub (0.1-0.5 m); and prostrate scrub (<0.1 m). Different height classes commonly grade into one another. Though they form separate vegetation types, they are often composed of approximately the same species. Salix alaxensis, S. planifolia ssp. pulchra, and Alnus crispa are characteristic species of drainageway areas. Important dwarf and prostrate shrub species include Betula nana, Vaccinium uliginosum, Ledum palustre ssp. decumbens, Empetrum nigrum, Dryas octopetala, Salix phlebophylla, and S. reticulata.

Tall scrubs usually develop at lower elevations on rocky river banks and flat wet drainageways, but do not cover extensive areas. Medium scrubs are common at elevations below 1000 m. Dwarf scrubs often occur in association with graminoids, and their areal importance is represented chiefly in the large areal extent of the co-dominated Moist Dwarf Scrub - Tussock-Graminoid Meadow (Table 4). Prostrate scrubs occur predominantly on dry upland slopes and ridges. Although common in the range, they are not areally extensive.

A. Tall Scrub

1. Wet Willow - Alder Drainageway Tall Scrub

SPECIES: Willow species Salix planifolia ssp. pulchra and S. glauca usually dominate Alnus crispa in this vegetation type, but their relative densities vary considerably. Understory species commonly include Spiraea beauverdiana, Betula nana, Petacites frigidus, Equisetum arvense, Sphagnum spp., and Calamagrostis sp.

ECOLOGY: This vegetation type commonly occurs as a narrow strip along small streams and drainageways. It frequently grades into Moist Willow Drainageway Medium Scrub with poorly defined boundaries. There is usually a sharp boundary, however, between this scrub type and the Moist Dwarf Scrub - Tussock-Graminoid Meadow or Moist Birch - Blueberry Dwarf Scrub which usually occur adjacent to drainageways. The soils are usually better developed and more stable in this vegetation type than are those in Moist Willow Floodplain Tall Scrub. The understory varies with moisture, slope, canopy cover, and soil development. In areas of exposed muddy soil, there are frequently dense stands of pure Equisetum arvense and Calamagrostis sp.

GEOGRAPHY: This vegetation type was seen along most drainageways in LOWLAND TUNDRA ecosystems dominated by tussock-graminoid and dwarf scrub - tussock-graminoid vegetation. It is common, but it is not areally important in the Ray Mountains.

2. Moist Willow Floodplain Tall Scrub (Photo 1)

SPECIES: This vegetation type is dominated by Salix alaxensis. Beneath the tall willows, there are frequently dense patches of Vaccinium uliginosum with scattered Spiraea beauverdiana and medium height Alnus crispa and Salix planifolia ssp. pulchra. The ground cover includes various combinations of Calamagrostis sp., Equisetum arvense, Epilobium angustifolium, E. latifolium, and Hylocomium splendens.

ECOLOGY: This vegetation type develops on gravel bars, riverbanks, and rocky streamsides in the LOWLAND TUNDRA and BOREAL FOREST ecosystems. It is most extensive in areas where floodplain development is significant. Soils vary from rock, gravel, and sand to deeper organic soils further from the stream course. The understory and willow height vary with elevation, the density of shrubs, the frequency of flooding, and the amount of exposed rock, sand, and gravel. Higher concentrations of herb species occur in early succession sandy areas. Epilobium angustifolium is found in less stable and rocky areas; and abundant medium height shrubs develop in more open areas with more highly developed soils. This unit gives way to Moist Willow Streamside Medium Scrub at higher elevations and further from drainageways in more highly developed soils.

GEOGRAPHY: This vegetation type is found throughout the lower elevations of the range, but it is of little areal importance. It was studied in detail along Torment Creek, and seen along most of the river drainages that were visited. It is expected to occur in association with gravel bars throughout the range.

3. Moist Alder Slope Tall Scrub

SPECIES: Alnus crispa is the only tall shrub species in this vegetation type. Vaccinium uliginosum, Betula nana, Arctostaphylos alpina, Salix reticulata, Dryas octopetala, Carex Bigelowii, and fruticose lichen species are common in the understory.

ECOLOGY: This vegetation type develops on well drained slopes in LOWLAND TUNDRA and as an understory in the BOREAL FOREST ecosystem. It is frequently found at treeline, although dense stands are often associated with slopes above rivers. As exposure and elevation increase, the stands become more open. The understory is poorly developed in dense stands; in open stands the ground layer is more developed, and may have frost boil vegetation complexes. Moist Alder Savanna Medium Scrub intermixes with this vegetation type and is dominant at higher elevations.

GEOGRAPHY: Dry Alder Slope Tall Scrub was observed on slopes above major rivers such as Twilight Creek, Torment Creek, Gishna Creek, and Ishtalitna Creek. It is not of major areal significance, but is expected to occur on slopes just above treeline throughout the range.

B. Medium Scrub

1. Moist Willow Upland Medium Scrub

SPECIES: The dominant shrub species in this vegetation type

is Salix planifolia ssp. pulchra. Occasionally Alnus crispa is important. The understory is commonly composed of Betula glandulosa, B. nana, Vaccinium uliginosum, Arctostaphylos alpina, Salix reticulata, and Pedicularis capitata. Dryas octopetala, Diapensia lapponica, Saxifraga Nelsoniana, and several lichen species may occur in frost boil areas.

ECOLOGY: This vegetation type develops in the UPLAND and LOWLAND TUNDRA ecosystems. It often occurs near treeline on well drained slopes above river drainages. Frost boil vegetation complexes composed of dry prostrate shrubs, cushion plants, and lichens, are sometimes present in the ground layer. As elevation and exposure increase, this vegetation type grades into Dry Birch Upland Dwarf Scrub.

GEOGRAPHY: Although this is a common vegetation type in peripheral regions of the Ray Mountains, its occurrence is patchy. It was sampled above upper and lower Torment Creek and is expected to occur on slopes throughout the range.

2. Moist Willow Drainageway Medium Scrub

SPECIES: Salix planifolia ssp. pulchra and Alnus crispa are the major shrub species in this vegetation type. Characteristic understory species are Spiraea beauverdiana, Andromeda polifolia, Eriophorum angustifolium, Equisetum arvense, Pedicularis labradorica, Lycopodium annotinum, Rubus chamaemorus, and Sphagnum spp.

ECOLOGY: This vegetation type develops in association with drainageways throughout the UPLAND TUNDRA, LOWLAND TUNDRA and BOREAL FOREST ecosystems. Shrub height, density, and species vary with slope, moisture, and substrate. This medium scrub type grades into Moist Willow - Alder Drainageway Tall Scrub in flatter and wetter areas, and at lower elevations.

GEOGRAPHY: This vegetation type is common in valleys throughout the study area. It was most extensively sampled around Torment Creek and Ishtalitna Creek and is expected to occur in drainages throughout the range. It is considered the most important drainageway scrub vegetation type in the Ray Mountains.

3. Moist Alder Savanna Medium Scrub

SPECIES: This vegetation type is visually dominated by evenly scattered Alnus crispa, approximately 6 m apart. Understory species include those characteristic of Moist Tussock Graminoid Meadows and Moist Dwarf Shrub - Tussock-Graminoid Meadows.

ECOLOGY: This vegetation type develops on gentle slopes in

lowland tussock tundra. Except for the alders, this vegetation type is not distinct from tussock graminoid and dwarf scrub - tussock-graminoid tundra. Alders vary in abundance and seem to reach an elevational limit at 675 m, above which the understory alone becomes dominant (Moist Tussock-Graminoid Meadow).

GEOGRAPHY: Savannas are common in rolling tussock tundra regions of the range. They were observed at lake 1485, and on slopes above Torment Creek and Ishtalitna Creek. They are expected to occur on most north-facing lowland slopes in the range.

C. Dwarf Scrub

1. Moist Birch - Blueberry Dwarf Scrub

SPECIES: The dominant dwarf scrub species in this vegetation type are Betula nana and Vaccinium uliginosum. The understory includes scattered prostrate shrubs, herbs, and graminoids such as Andromeda polifolia, Empetrum nigrum, Rubus chamaemorus, Petacites frigidus, Pedicularis verticillata, Carex aquatilis, and Eriophorum angustifolium. The groundcover is dominated by a thick layer of Sphagnum spp. and feathermosses.

ECOLOGY: This vegetation type develops on moist gentle slopes and in wet flat areas near streams and drainageways in LOWLAND and UPLAND TUNDRA. The moss groundcover is moist to saturated. Alpine blueberry is usually dominant in the drier areas within this type. This vegetation type grades into a Moist Tussock-Graminoid Meadow in areas where slope increases and moisture decreases, or into a Wet Sphagnum Moss Meadow near wet impeded drainageways.

GEOGRAPHY: Although this vegetation type occurs in small patches or strips, it is common throughout the lower elevation rolling tussock tundra regions of the range and broader upper elevation valleys. It was observed alongside all of the major rivers and streams visited (Torment Creek, the Kanuti Kilolitna River, and Ishtalitna Creek) and probably occurs on slopes adjacent to streams throughout the range.

2. Dry Birch Upland Dwarf Scrub

SPECIES: Characteristic shrubs of this vegetation type are Betula nana, Vaccinium uliginosum, and Ledum palustre ssp. decumbens. Common understory species are Dryas octopetala, Diapensia lapponica, Loiseleuria procumbens, Salix phlebophylla, S. reticulata, Arnica frigida, Hierochloe alpina, and fruticose lichens.

ECOLOGY: This vegetation type occurs on dry, well drained and stable slopes in the UPLAND TUNDRA ecosystem. Betula nana forms dense mats between boulders that often constitute 30-40% of the groundcover. As exposure increases on slopes above 900 m the rock is more highly weathered, and the vegetation type typically grades into Dry Ericad Upland Prostrate Scrub. Dry Upland Dwarf Scrub grades into co-dominated Moist Dwarf Scrub - Tussock-Graminoid Meadows where the slope decreases to less than five degrees and moisture increases substantially.

GEOGRAPHY: This vegetation type common in the central high elevation regions of the range. It was studied in detail in Spooky Valley and upper Torment Creek, and is expected to occur on slopes above 610 m (2000 ft) in the central range.

D. Prostrate Scrub

1. Dry Ericad Upland Prostrate Scrub

SPECIES: Species commonly found in this vegetation type are Betula nana, Ledum palustre ssp. decumbens, Cassiope tetragona, Salix phlebophylla, Dryas octopetala, Diapensia lapponica, Loiseleuria procumbens, and Silene acaulis. Herb species sparsely scattered throughout this vegetation type include Lupinus arcticus, Minuartia arctica, Arnica frigida, Castelleja elegans, Saxifraga Nelsoniana, Campanula lasiocarpa, Hierochloe alpina, and Arctagrostis latifolia. Typical fruticose and crustose lichens are Cladina spp., Cladonia spp., Alectoria spp., Stereocaulon spp., and Rhizocarpon spp.

ECOLOGY: This vegetation type develops on ALPINE BARREN slopes above approximately 914 m (3000 ft). It commonly forms vegetation complexes with frost-sorted rock fragments, such as frost boils and stone stripes. Cushion plants and lichens occur in frost boil areas. As elevation and exposure increase, this vegetation type grades into Dry Upland Fellfield Barren or Dry Upland Fruticose Lichen Meadow.

GEOGRAPHY: Prostrate scrub is common in the central high elevation regions of the range. It was studied in detail in Spooky Valley, upper Torment Creek, and near Mt. Tozi and Mt. Henry Eakin.

Shrub-Herb Co-dominated Units

In transitional areas along an environmental gradient, two growth forms may intermix and become visually co-dominant. In areas between shrub dominated units and herb dominated units, visually co-dominated dwarf scrub - graminoid vegetation types are so extensive that they are classified as a separate unit at our first level of classification. They

cover approximately 16% of the study area (Table 4).

In LOWLAND TUNDRA, Moist Dwarf Scrub - Tussock-Graminoid Meadow usually lies on slopes between Moist Scrub Birch - Blueberry Dwarf Scrub and Moist Tussock-Graminoid Meadow. In UPLAND TUNDRA, Moist Dwarf Scrub - Graminoid Meadows are found in well drained areas between gentle and steep slopes.

A. Dwarf Scrub - Graminoid Meadow

1. Moist Dwarf Scrub - Graminoid Meadow (Photo 3)

SPECIES: In the dwarf shrub stratum, Betula nana and Vaccinium uliginosum are the dominant species. Common graminoids are Carex rotundata, C. rariflora, C. aquatilis, Eriophorum angustifolium, and Juncus triglumis. Other species may include Salix planifolia ssp. pulchra, Ledum palustre ssp. decumbens, Andromeda polifolia, Anemone narcissiflora, Pedicularis capitata, and Carex aquatilis.

ECOLOGY: This vegetation type develops on slopes near the upper limit of UPLAND TUNDRA. Hummocks and solifluction lobes sometimes found on these slopes may have wind-abraded tops with bare soil and the exposed roots and stems of dwarf shrubs. When hummucks are present, inter-hummock areas are wet with pockets of standing water beside which Sphagnum spp. and graminoid species grow. As moisture decreases, graminoids decrease in abundance and this vegetation type may grade into either a Moist Birch - Blueberry Dwarf Scrub or Dry Birch Upland Dwarf Scrub. As slope decreases, the Wet Graminoid Meadow becomes more dominant.

GEOGRAPHY: Moist Dwarf Scrub - Graminoid Meadows are most common in the higher elevation areas of the range. They were most extensively sampled in Spooky Valley, and probably occur wherever Wet Graminoid Meadows grade into slopes.

B. Dwarf Scrub - Tussock-Graminoid Meadow

1. Moist Dwarf Scrub - Tussock-Graminoid Meadow (Photo 6)

SPECIES: This vegetation type is visually co-dominated by tussock forming graminoids and dwarf shrubs; the cover of each is approximately equal. Carex Bigelowii is usually the dominant herbaceous species, though Eriophorum vaginatum is dominant in some areas. Dwarf and prostrate shrubs such as Ledum palustre ssp. decumbens, Betula nana, Vaccinium uliginosum, V. vitis-idaea, Empetrum nigrum, and Rubus chamaemorus occur in both the tussock and inter-tussock areas. Sphagnum spp. and lichens such as Cetraria cuculata, C. nivalis, and Cladina rangiferina commonly cover up to 40%

of the inter-tussock areas.

ECOLOGY: This vegetation type commonly develops on lower and middle slopes in LOWLAND TUNDRA, and in areas ecotonal between LOWLAND and UPLAND TUNDRA. It grades into areas dominated by tussock-graminoids and dwarf scrub, though not along a clear environmental gradient. Generally, the density of dwarf shrubs increases with an increase in slope. The density of mosses, Vaccinium uliginosum, and Rubus chamaemorus increases dramatically as ground moisture increases near small drainageways. In the wettest areas, this unit grades into a Wet Sphagnum Moss Meadow.

GEOGRAPHY: This vegetation type is the most abundant and widespread type in the range; it covers approximately 16% of the study area. It occurs in association with tussock-graminoid meadows throughout the rolling lowland regions of the range. It was studied in detail along Torment Creek and in areas surrounding lake 1485.

Herb Dominated Units

Herb dominated units are found throughout LOWLAND TUNDRA and occur in isolated pockets in UPLAND TUNDRA. They cover approximately 22% of the study area. They are dominated by graminoids or forbs, but usually include mosses, lichens, and dwarf and prostrate shrubs.

Three herb dominated units were distinguished at the second level of classification: Tussock-Graminoid Meadow; Graminoid Meadow; and Forb Meadow. These units were further subdivided into five vegetation types on the basis of moisture, species composition, and physiographic position.

Tussock-graminoid meadows occur throughout the range at elevations below 914 m (3000 ft). They are characteristic of gentle slopes (<5 degrees) in LOWLAND TUNDRA. Non-tussock wet graminoid meadows develop in flat poorly drained areas in UPLAND TUNDRA. They are typically found in valley bottoms, saddles between ridges, and other areas where drainage is impeded. Forb meadows are usually confined to small moist areas such as snowbeds and streambanks.

A. Tussock-Graminoid Meadow

1. Moist Tussock-Graminoid Meadow

SPECIES: Carex Bigelowii is the most important graminoid species in this vegetation type, though Eriophorum vaginatum dominates some areas. Many dwarf shrubs are intermixed, the most common of which are Betula nana, Ledum palustre ssp. decumbens, Vaccinium uliginosum, V. vitis-idaea, Salix

planifolia ssp. pulchra, Cassiope tetragona, and Empetrum nigrum. Scattered herbs such as Petacites frigidus, Pedicularis labradorica, and Polygonum bistorta are common but usually cover <5%. Lichens, predominantly Cetraria spp., are always present and may cover up to 40% in some areas.

ECOLOGY: This vegetation type develops predominantly on gentle solifluction slopes in LOWLAND TUNDRA. Solifluction lobes average 2 m in length and 0.6 m in height. Tussocks are usually 0.3 m tall, 0.15 m wide, and evenly spaced. Mosses are most dense at the moist bases of the solifluction lobes, and lichens are most important in flat areas where dwarf shrubs and mosses are less abundant. Dwarf shrubs vary in importance, but are most abundant on the fronts of the solifluction lobes and in drier or steeper areas. In areas where dwarf shrubs increase in density, this vegetation type grades into the co-dominated Moist Dwarf Scrub - Tussock-Graminoid Meadow.

GEOGRAPHY: This vegetation type is characteristic of the rolling lowland slopes that cover extensive areas north of the central upland regions. It is abundant below 914 m (3000 ft) throughout the range. Large expanses were sampled in the lower Torment Creek, lake 1485, and Ishtalitna River areas.

2. Wet Lowland Tussock-Graminoid Meadow

SPECIES: Though Eriophorum vaginatum is the dominant species in this vegetation type, Carex Bigelowii is common. Vaccinium uliginosum, Andromeda polifolia, and Petacites frigidus usually grow in drier areas and on the tops of well developed tussocks. Sphagnum spp. and Rubus chamaemorus develop in the inter-tussock hollows.

ECOLOGY: This vegetation type occurs in wet, flat LOWLAND TUNDRA and in depressions on ridgetops and saddles in UPLAND TUNDRA. Tussocks may reach 0.6 m in height and are separated by deep wet hollows which are often filled with water or saturated soft soils. This vegetation type grades into a Moist Tussock-Graminoid Meadow in areas where moisture decreases.

GEOGRAPHY: This vegetation type occurs in the same regions as Moist Tussock-Graminoid Meadows. It is not areally extensive, though it is particularly abundant in the flats on the northern border of the range where Torment Creek meets the Kilolitna River.

B. Graminoid Meadow

1. Wet Graminoid Meadow

SPECIES: Carex rotundata is the principal graminoid species in this wet vegetation type, though Eriophorum angustifolium occurs in areas more frequently immersed in standing water. Other common graminoid species include Carex rariflora, C. aquatilis, and Juncus triglumis. Carex Bigellowii is abundant in hummock areas. Forbs such as Dodecatheon frigidum, Aconitum delphinifolium, Ranunculus glacialis, and Pedicularis verticillata are sometimes present.

ECOLOGY: Wet Graminoid Meadows occur in valley bottoms and saddles between ridges in the UPLAND TUNDRA ecosystem. They may also develop in the drainage basins at the bases of snowbeds. These areas are flat and poorly drained, often with standing water covering up to 50% of the area. In areas with greater slope, the ground surface is more hummocky and wind-abraded. With a decrease in moisture, this vegetation type grades into the co-dominated Moist Dwarf Scrub - Graminoid Meadow.

GEOGRAPHY: Wet Graminoid Meadows are considered a common vegetation type in the Ray Mountains, but they are not areally extensive. They were sampled along Torment Creek and in the saddles between Mt. Tozi and Mt. Henry Eakin. They are expected to occur throughout the peripheral lowland regions and in flat areas where drainage is impeded.

2. Moist Snowbed Graminoid Meadow

SPECIES: The most common graminoid species in this vegetation type is Carex microchaeta. Important shrub species include Salix Chamissonis and Cassiope tetragona. Forbs such as Anemone narcissiflora, Aconitum delphinifolium, Dodecatheon frigidum, Sedum rosea, and Pedicularis capitata are scattered widely throughout this vegetation type.

ECOLOGY: These meadows develop in protected depressions at the bases of steep slopes such as streambanks, the fronts of large solifluction steps, and talus slopes. The late snowmelt in these areas provides additional moisture conducive to graminoid and forb development. Herbs dominate the ground cover in flat areas, but bare ground is more extensive on steeper slopes.

GEOGRAPHY: This vegetation type occurs in isolated patches in the central high elevation regions of the range. It was sampled at the base of Mt. Henry Eakin, in upper Torment Creek, and in Spooky Valley. It is considered rare, but it probably occurs in snowbeds scattered throughout the central high elevation regions of the range.

C. Forb Meadow

1. Moist Snowbed Forb Meadow

SPECIES: Species scattered throughout this vegetation type include Lupinus arcticus, Cassiope tetragona, Aconitum delphinifolium, Anemone narcissiflora, Dodecatheon frigidum, Calamagrostis inexpansa, Festuca altaica, and Campanula lasiocarpa.

ECOLOGY: This vegetation type develops on streambanks in LOWLAND TUNDRA and in rocky depressions in UPLAND TUNDRA. These areas are characterized by scattered boulders and weathered rock fragments. There is usually no shrub layer or groundcover and bare soil may cover up to 30% of the area. Herbs and graminoids are scattered throughout the vegetation type.

GEOGRAPHY: Forb meadows occur in small isolated patches in upland and lowland regions, and are considered rare in the Ray Mountains. They were sampled in Spooky Valley and in surrounding areas by streams in the UPLAND TUNDRA-ALPINE BARREN ecotone.

Bryoid Dominated Units

Bryoid dominated units are dominated by mosses or lichens. They cover little area and usually develop in well defined physiographic units. Wet Sphagnum Moss Meadows are found scattered throughout LOWLAND TUNDRA and rarely in UPLAND TUNDRA in flat areas where drainage is impeded. Dry Upland Fruticose Lichen Meadows occur on very exposed rocky ridges in ALPINE BARREN. Although bryoid dominated units are important vegetation types, they were not individually recognizable on the small-scale vegetation map, so their areal extent is not known.

A. Moss Meadow

1. Wet Sphagnum Moss Meadow

SPECIES: This vegetation type is dominated by Sphagnum spp. and usually includes patches of other mosses such as Hylocomium spp., Dicranum spp., and Polytrichum spp. Carex Bigelowii may form tussocks which are invaded by dwarf and prostrate shrubs such as Vaccinium uliginosum, V. vitis-idaea, Andromeda polifolia, Oxycoccus microcarpus, Ledum palustre ssp. decumbens, and herbs such as Pedicularis labradorica and Eriophorum vaginatum.

ECOLOGY: Moss meadows usually develop along drainageways and

in lowlying, poorly drained depressions. Large hummocks with standing water in the inter-hummock areas are sometimes present. The highest density of mosses occurs in the inter-hummock areas while dwarf shrubs dominate the hummock tops and sides. Typical shrub-tussock tundra commonly gives way to this vegetation type in flat and depressed areas where surface water is more abundant.

GEOGRAPHY: Moss meadows were observed in isolated patches near most river drainages and are expected to occur throughout lower elevation gently rolling slopes of the range in association with poorly drained areas. They were most extensively sampled 1.5 km north of basecamp adjacent to Torment Creek. Though common in the range, they are of minor areal extent.

B. Lichen Meadow

1. Dry Upland Fruticose Lichen Meadow

SPECIES: Fruticose lichens such as Cladonia spp., Cladina spp., Stereocaulon spp. and Alectoria spp. cover up to 40% of the ground surface in this vegetation type. Herbs and prostrate shrubs characteristic of Dry Ericad Upland Prostrate Scrub are scattered widely throughout the area.

ECOLOGY: This vegetation type occurs on exposed ridges in the ALPINE BARREN ecosystem. It often forms a complex composed of patches of lichens interspersed among large areas of rock. The substrate is composed of boulders and rock fragments, or bare soil in frost boil areas. This vegetation type may be a transition zone between Dry Ericad Upland Prostrate Scrub and Dry Upland Fellfield Barren.

GEOGRAPHY: Lichen meadows do not cover large areas, but they are present throughout the central high elevation regions of the range. They were observed and sampled in upper Torment Creek and on Mt. Henry Eakin. They are expected to occur in association with Dry Ericad Upland Prostrate Scrub and Dry Upland Fellfield Barren throughout the range.

Sparsely Vegetated Units

Sparsely vegetated units are characterized by a vegetation cover of less than 30%. These vegetation types develop mostly in ALPINE BARREN and are associated with harsh ridgetop environments, or active rock slopes. Bare soil and rock dominate the groundcover. Boulder fields and talus slopes, also classified as barrens, are located in patches throughout the ALPINE BARREN ecosystem. Vegetation units coded as Prostrate Scrub-Barren-Lichen mosaics cover 11% of the small-scale map area (Table 4).

A. Barren

1. Dry Upland Fellfield Barren

SPECIES: Fruticose lichen species dominate the vegetation cover. Scattered herbs and prostrate shrubs sometimes include Dryas octopetala, Diapensia lapponica, Loiseleuria procumbens, Minuartia arctica, Salix phlebophylla, Campanula lasiocarpa, Castelleja elegans, Arnica frigida, and Hierochloe alpina.

ECOLOGY: This typical fellfield vegetation type is found on highly exposed ridges throughout ALPINE BARREN. Poorly sorted stone nets and frost boils form as a result of cryoturbation. Herbs are scattered very widely, and often occur only in small protected depressions by large boulders. With decreased exposure or elevation, the vegetation may grade into a Dry Upland Fruticose Lichen Meadow or Dry Ericad Upland Prostrate Scrub.

GEOGRAPHY: Fellfield barrens cover limited areas on ridgetops throughout the central high elevation regions of the range. They were observed in Spooky Valley, on Mt. Tozi, and on Mt. Henry Eakin, and probably occur on most ridgetops above 1000 m. They are considered common in the study area.

2. Dry Lichen Upland Rock Barren (Photo 4)

SPECIES: Common lichen species of this vegetation type include Alectoria spp., Stereocaulon spp., and Rhizocarpon spp. Prostrate shrubs and herbs such as Diapensia lapponica, Loiseleuria procumbens, Dryas octopetala, and other species typical of the Dry Upland Fellfield Barren may be interspersed among the rocks.

ECOLOGY: This vegetation type occurs primarily on steep slopes with frost-shattered rock fragments ranging in size from 0.5-2 m. It usually forms a complex of lichen and rock. Crustose and foliose lichens grow on stable rocks, but other vegetation cover is sparse.

GEOGRAPHY: Rock Barrens are common on steep slopes and ridgetops throughout the central high elevation regions of the range. They were observed on Mt. Tozi and Mt. Henry Eakin, upper Torment Creek, and are considered characteristic of rocky alpine environments in the Ray Mountains.

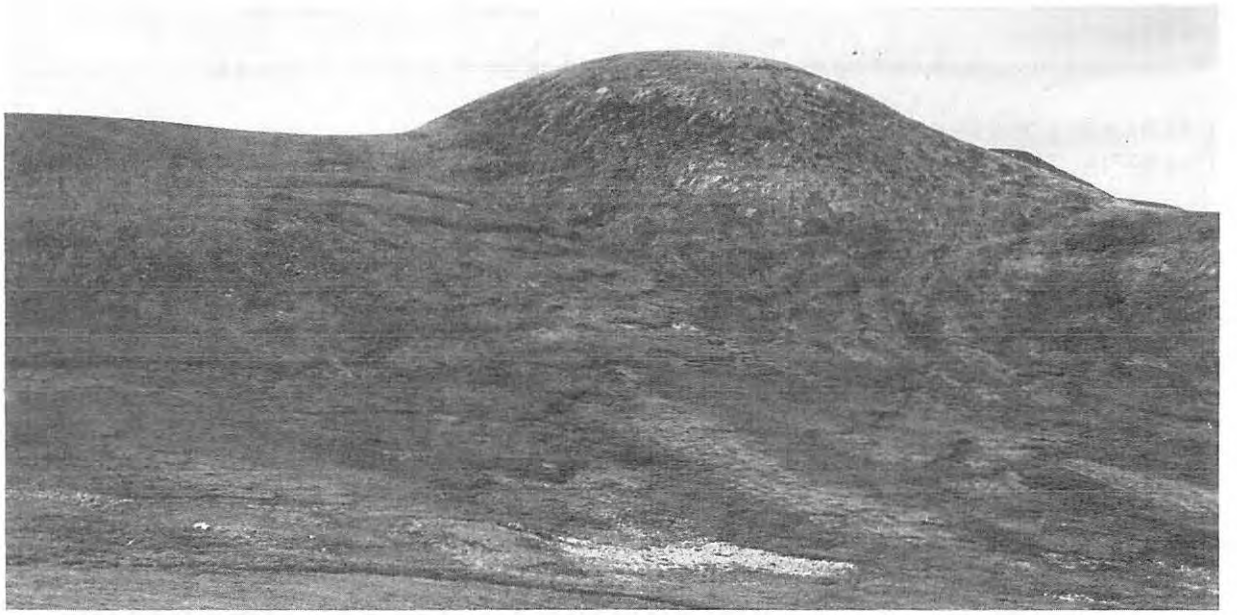


Photo 3. View of the WNW slope, upper Torment Creek valley, with mosaic of upper elevation vegetation types. Medium and dwarf scrubs dominate the lower slope; prostrate scrubs, barrens, and lichen meadows dominate the upper slope.

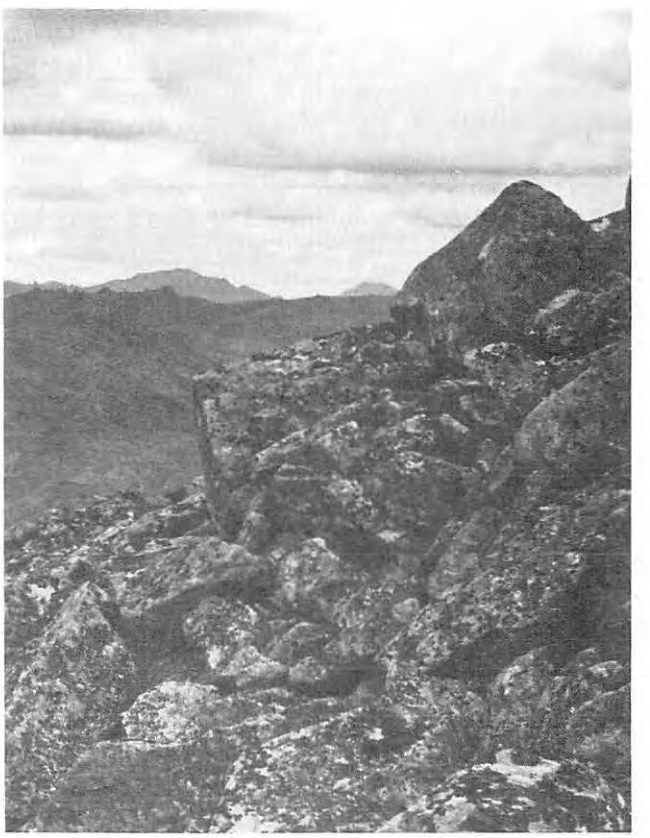


Photo 4. Dry Lichen Upland Rock Barren, common in the rugged higher mountains of the range.

Table 2. Level III vegetation types of the Ray Mountains and approximate equivalent level V plant communities recognized by Dyrness and Viereck (1979) in their proposed statewide classification.

/ separates species in different growth layers
- separates species in the same growth layer

Ray Mountains Level III Vegetation Types	Dyrness and Viereck Level V Plant Communities
Moist White Spruce Slope Forest	Picea glauca/feathermoss Picea glauca/Betula glandulosa/Hylocomium Picea glauca/Betula glandulosa/Sphagnum
Dry White Spruce Floodplain Forest	Picea glauca/Betula glandulosa/Cladonia Picea glauca/Viburnum edule/Equisetum edule Picea glauca/Linnaea borealis-Equisetum silvaticum
Moist White and Black Spruce Forest	Picea mariana-Picea glauca/feathermoss Picea mariana-Picea glauca/Betula glandulosa Picea mariana-Picea glauca/Betula glandulosa/feathermoss
Wet Black Spruce - Sphagnum Forest	Picea mariana/Sphagnum-Cladonia
Dry Black Spruce - Lichen Forest	Picea mariana/Cladonia
Moist Paper Birch Slope Forest	Betula papyrifera/Alnus crispa/Calamagrostis Betula papyrifera/Betula glandulosa/Hylocomium Betula papyrifera/Viburnum edule/Calamagrostis
Moist Balsam Poplar Floodplain Forest	Populus balsamifera/Salix-Alnus/Calamagrostis
Dry Paper Birch - Lichen Slope Forest	Betula papyrifera/Cladonia

Table 2. continued.

Ray Mountains Level III Vegetation Types	Dyrness and Viereck Level V Plant Communities
Moist Paper Birch - Spruce Slope Forest	Picea glauca-Betula papyrifera/ Alnus crispa/Calamagrostis canadensis Picea glauca-Betula papyrifera/ Calamagrostis-Hylocomium Picea glauca-Betula papyrifera/ Alnus crispa/Sphagnum
Moist Balsam Poplar - Spruce Floodplain Forest	Populus balsamifera-Picea glauca/ Alnus/Equisetum
Wet Willow - Alder Drainageway Tall Scrub	Alnus crispa-Salix lanata-S. glauca-S. planifolia/Ledum palustre-Carex Bigelowii/Sphagnum spp.
Moist Willow Floodplain Tall Scrub	Salix alaxensis-Salix glauca Salix alaxensis
Moist Alder Slope Tall Scrub	Alnus crispa/Calamagrostis canadensis
Moist Willow Upland Medium Scrub	Salix glauca-S. planifolia-S. lanata Alnus crispa-Salix planifolia/Carex Bigelowii
Moist Willow Drainageway Medium Scrub	Salix planifolia/Equisetum arvense Alnus crispa-Salix planifolia/Carex Bigelowii Alnus crispa-Salix lanata-S. glauca-S. planifolia/Ledum palustre-Carex Bigelowii/Sphagnum Alnus crispa-Salix planifolia/Carex Bigelowii
Moist Alder Savanna Medium Scrub	Alnus crispa/Vaccinium uliginosum-Ledum palustre-Betula nana-Carex Bigelowii/ Hylocomium splendens-Aulocomium palustre
Moist Birch - Blueberry Dwarf Scrub	Betula nana-Vaccinium spp.-Empetrum nigrum Betula nana-Ledum palustre-Vaccinium spp.

Table 2. continued.

Ray Mountains Level III Vegetation Type	Dyrness and Viereck Level V Plant Community
Dry Birch Upland Dwarf Scrub	Betula nana-Ledum palustre-Vaccinium spp.-Carex Bigelowii Betula nana-Ledum palustre-Vaccinium spp.-Empetrum nigrum-Arctostaphylos latifolia-Hierochloe alpina
Dry Ericad Upland Prostrate Scrub	Betula nana-Arctostaphylos alpina-Salix arctica-Dryas integrifolia Betula nana-Ledum palustre-Vaccinium vitis-idaea-Empetrum nigrum-Arctagrostis latifolia-Hierochloe alpina Vaccinium vitis-idaea-Salix phlebophylla-Arctostaphalos alpina Dryas integrifolia-Salix reticulata-Carex Bigelowii Cassiope tetragona
Moist Dwarf Scrub - Graminoid Meadow	Betula nana-Ledum palustre-Vaccinium spp.-Empetrum nigrum-Eriophorum vaginatum-Carex Bigelowii Eriophorum vaginatum-Betula nana-Ledum palustre-Vaccinium spp.-Carex Bigelowii Carex Bigelowii-Carex aquatilis-Betula nana Carex aquatilis-Salix planifolia
Moist Dwarf Scrub - Tussock-Graminoid Meadow	Betula nana-Ledum palustre-Vaccinium vitis-idaea-Carex spp.-Rubus chamaemorus/Sphagnum spp. Betula nana-Ledum palustre-Vaccinium spp.-Carex Bigelowii Eriophorum vaginatum-Betula nana-Ledum palustre-Vaccinium spp.-Carex Bigelowii Carex Bigelowii-Betula nana
Moist Tussock-Graminoid Meadow	Eriophorum vaginatum-Carex Bigelowii-Ledum palustre-Vaccinium vitis-idaea Eriophorum vaginatum-Betula nana-Ledum palustre-Vaccinium spp.-Carex Bigelowii Carex Bigelowii-Betula nana

Table 2. continued.

Ray Mountains Level III Vegetation Type	Dyrness and Viereck Level V Plant Community
Wet Lowland Tussock-Graminoid Meadow	Eriophorum vaginatum-Salix planifolia-Carex Bigelowii Betula nana-Ledum palustre-Vaccinium vitis-idaea-Carex spp.-Rubus chamaemorus/Sphagnum spp.
Wet Graminoid Meadow	Eriophorum vaginatum Carex aquatilis-Eriophorum vaginatum Carex aquatilis-Poa arctica
Moist Snowbed Graminoid Meadow	no level V equivalent
Moist Snowbed Forb Meadow	no level V equivalent
Wet Sphagnum Moss Meadow	Betula nana-Ledum palustre-Vaccinium spp.-Rubus chamaemorus-Sphagnum Betula nana-Ledum palustre-Vaccinium vitis-idaea-Carex spp.-Rubus chamaemorus/Sphagnum
Dry Upland Fruticose Lichen Meadow	Cladina spp.-Cetraria spp.-Stereocaulon sp.
Dry Upland Fellfield Barren	Dryas octopetala-Cassiope tetragona-Salix reticulata Dryas integrifolia-lichens Vaccinium vitis-idaea-Salix phlebophylla-Arctostaphylos alpina
Dry Lichen Upland Rock Barren	no level V equivalent

Small-Scale Vegetation Map of the Ray Mountains

According to Anderson et al. (1974), a vegetation map is a simplified picture of vegetation which can provide information for the mapping of climatic conditions, parent materials, soils, permafrost, wildlife habitat, agricultural potential, and recreational areas. Most importantly, a vegetation map serves as a visual inventory of the major vegetation types present in an area, and thus provides basic information against which future vegetation and environmental conditions can be compared and evaluated. A vegetation map is

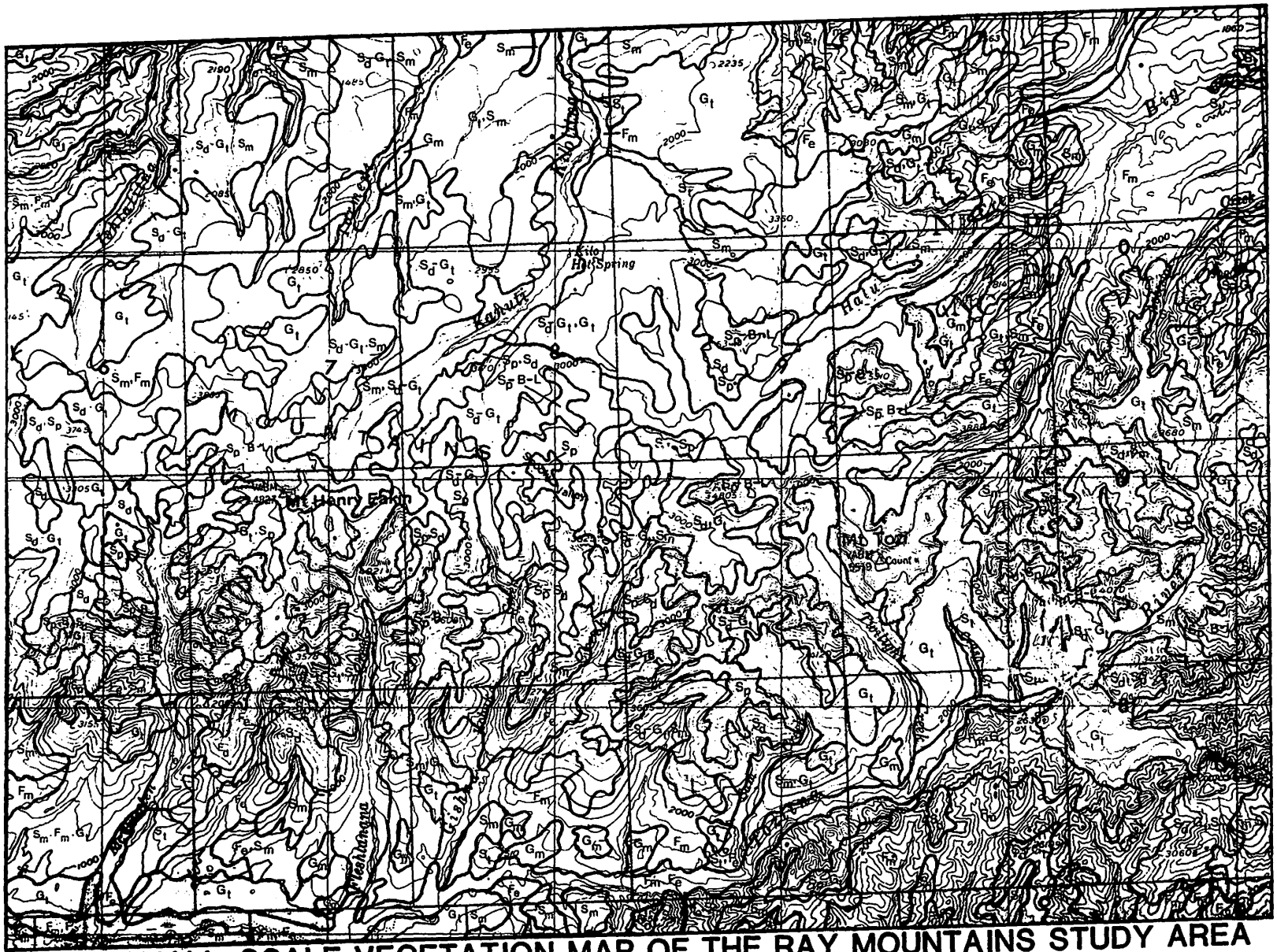


Fig. 1. SMALL-SCALE VEGETATION MAP OF THE RAY MOUNTAINS STUDY AREA

Table 3. Small-Scale Vegetation Map Key

Code	Vegetation Type
Fe	Evergreen Forest
Fd	Decidous Forest
Fm	Mixed Forest
St	Tall Scrub (>2m)
Sm	Medium Scrub (0.5m-2m)
Sd	Dwarf Scrub (0.1m-0.5m)
Sp	Prostrate Scrub (<.1m)
Sd-Gt	Dwarf Scrub - Tussock-Graminoid Meadow
Sd-Gm	Dwarf Scrub - Graminoid Meadow
Gt	Tussock-Graminoid Meadow
Sp-B-L	Prostrate Scrub-Barren-Lichen

Map units identify vegetation types named on the basis of dominant growth form. Hyphenated symbols designate mosaics which comprise separate map units too small to map individually, for instance, Sp-B-L refers to a mosaic composed of prostrate scrub, barren, and lichen vegetation types. In a series of symbols separated by commas, the symbol for the areally more important type is placed first, and the symbol for the vegetation type of secondary importance is placed second. For instance, Gt,Sm refers to an area dominated by tussock graminoids with scattered medium height shrubs.

Table 4. Areal extents in the study area of vegetation types recognized in the small-scale vegetation map.

Vegetation Type	Sq Km	Sq Mi	% Cover
Evergreen Forest (Fe)	153	55	7
Deciduous Forest (Fd)	19	7	1
Mixed Forest (Fm)	292	105	14
Tall Scrub (St)	31	11	2
Medium Scrub (Sm)	447	161	20
Dwarf Scrub (Sd)	67	24	3
Prostrate Scrub (Sp)	67	24	3
Dwarf Scrub - Tussock-Graminoid (Sd-Gt)	356	128	16
Tussock-Graminoid Meadow (Gt)	467	168	22
Graminoid Meadow (Gm)	22	8	1
Prostrate Scrub-Barren-Lichen (Sp-B-L)	230	83	11

a primary tool for land-use planning and management, and can be a guide to more thorough research in the future (Anderson et al. 1976).

Anderson (1976) and Racine (pers. comm.) have suggested that the extent of vegetation mapping and description in Alaska is inadequate to support planning and management decisions. For this reason, a vegetation map of the Ray Mountains was constructed with satellite (LANDSAT) imagery (Fig. 1; Table 3). Although the map is somewhat speculative, it provides useful general information on the distribution and areal extent of the major vegetation types of the Ray Mountains.

Previous vegetation maps that include the Ray Mountains are at a very small scale (1:2,500,000 or greater), or are coarse representations at larger scales. In 1963 Spetzman compiled a 1:2,500,000 scale Alaska vegetation map which has served as the basis of most subsequent small-scale vegetation maps of Alaska (Anderson et al. 1974). It shows the distribution of nine major vegetation types, three of which are shown in the Ray Mountains: Upland Spruce-Hardwood Forest, High-Brush, and Alpine Tundra. In 1967 Hutchison published a 1:5,000,000 Alaska forest map that shows Non-Forest for the central alpine areas of the Ray Mountains and Spruce-Hardwood Forest for the surrounding lowland areas. Viereck (in Viereck and Little 1972) published a 1:5,000,000 vegetation map of Alaska which is a condensation of Spetzman's (1963) map with some revisions based on the author's firsthand knowledge of Alaskan vegetation. Viereck's map shows Closed Spruce-Hardwood Forest, Alpine Tundra, and Treeless Bogs in the Ray Mountains study area. In 1973 the Federal - State Land Use Planning Commision for Alaska published a 1:2,500,000 map, Major Ecosystems of Alaska, which is essentially Spetzman's (1963) vegetation map with the incorporation of Viereck's and other minor revisions and which uses ecosystem oriented terminology. It maps the same three vegetation types in the Ray Mountains as Spetzman's (1963) map: Upland Spruce-Hardwood Forest, High Brush, and Alpine Tundra.

Although the small-scale vegetation map of the Ray Mountains provides useful information on vegetation distribution and areal extent, it should be considered preliminary. Further research is needed to revise and improve the map presented here for a more accurate representation of the vegetation in the Ray Mountains. Additional ground truthing in conjunction with examination of U-2 aerial photography could help verify map unit identification and evaluate map unit boundaries.

Large-Scale Vegetation Maps

Large scale (1:5,000) vegetation maps from three photo areas are presented here. Their locations are shown generally in Fig. 1 in the Introduction to this volume. Keys to map unit codes are in Table 5-7. A site description, aerial photograph, master map, vegetation map, and complete legend are included for each photo area.

Table 5. Key to denominators of master map codes (from Walker et al. 1979) The information in the master map is coded in the following manner:

Vegetation code

Landform, Microrelief class, Slope class

Landforms categories (first number):

1 Featureless or nonaligned hummocks
2 Aligned hummocks
3 Frost boils
4 Small ridge, hill, or kame
5 River or creek bluff
6 Closely spaced large rocks or talus
7 Scattered large rocks
8 Irregular microrelief
9 Solifluction lobes
10 Stream bottom with boulders
11 River bank
12 Talus or scree
13 Tor
14 Mud Flow
15 Drainage depression
16 Solifluction terrace
17 Solifluction lobe front
18 Braided stream course

Microrelief class (second number):

1 <25 cm
2 25-50 cm
3 >50 cm

Slope class (third number):

0 <2 degrees
1 2-5 degrees
2 5-30 degrees
3 >30 degrees

Table 6. Master map growth-form codes. These codes refer to the first part of the numerator of the master map fraction code, and represent the visually dominant plant growth-form.

Code	Growth-form
Tc	Trees (closed canopy, 60-100% crown canopy)
To	Trees (open canopy, 5-60% crown canopy)
St	Tall shrubs (>2 m tall)
Sm	Medium height shrubs (0.5-2 m tall)
Sd	Dwarf shrubs (0.1-0.5 m tall)
Sp	Prostrate shrubs (<0.1 m tall)
G	Single-shooted graminoids
Gt	Tussock-graminoids
A	Rooted aquatic herbs
H	Horsetails
M	Mosses
L	Lichens
B	Barren
Non-vegetation codes	
D	Disturbed
W	Water

Table 7. Master map vegetation codes for forested areas. The codes in forest areas consist of four parts: 1) the growth form code, either Tc or To, which denotes either closed or open canopy of trees, 2) a letter which denotes the dominant tree taxon or taxa, 3) a number representing the stature of the trees, and 4) the community code of the understory.

First symbol - growth-form code
- Tc - Closed canopy of trees
- To - Open canopy of trees

Second symbol - dominant tree taxon or taxa
- A - *Picea glauca*
- B - *Picea mariana*
- C - mixed *Picea glauca* and *P. mariana*
- D - *Betula papyrifera*
- E - *Betula papyrifera* and *Picea glauca*

Third symbol - size of trees
- 1 - Mature trees less than breast height (not krummholz)
- 2 - Trees <5 cm dbh
- 3 - Trees 5-15 cm dbh
- 4 - Trees <15 cm dbh
- 5 - Krummholz

Fourth symbol - community code of the understory
This number is given to the understory community when it is first described. If the understory code is missing, this means that the understory is either very mixed or undescribed.

Lower Torment Creek Valley

The lower Torment Creek valley (Photo 5) photo area (152 32' W and 65 50' N) is located approximately 1.5 km north of basecamp (RMP site IIb). North-flowing Torment Creek diagonally bisects the photo area into east and west-facing slopes. The area includes forest limit and treeline, and supports boreal forests, shrub thickets, and graminoid and moss meadows.

The east-facing slope is steep (approximately 10 degrees) and mostly forested. Deciduous forests dominated by paper birch cover the steepest parts of the slope, and grade into white spruce stands creating a mixed forest type with a highly variable understory. The understory composition is largely determined by the canopy cover and locally dominant tree species. In areas of high white spruce density, the ground layer is dominated by feathermoss. In areas where paper birch is dominant, a conspicuous litter layer inhibits the growth of feathermoss, and herbs such as Calamagrostis sp., Equisetum spp., and Epilobium spp. are abundant. Dwarf shrubs such as Betula nana, Ledum palustre spp. decumbens, and Vaccinium uliginosum are common and increase in areas of more open canopy cover (40% cover or less). Tall and medium height willows and alders are scattered throughout mixed, deciduous, and coniferous stands.

Tall willows dominate the flat rocky areas next to the river. The understory is usually composed of Alnus crispa, Spiraea beauverdiana, Ledum palustre spp. decumbens, and Vaccinium uliginosum. The ground surface is uneven with Sphagnum spp. interspersed among the rocks. Flat areas with well developed organic soils support Wet Sphagnum Moss Meadows. The ground surface is hummocky with standing water in some areas.

Open white spruce stands with highly variable understories develop on the riverbank. The spruce trees are mostly over 30 m tall, greater than 15 cm dbh, and over 100 years old. The ground cover consists mostly of lichens such as Cladina spp., Cladonia spp., and Cetraria spp., and forbs such as Epilobium angustifolium, Aconitum delphinifolium, and Delphinium glaucum.

Except for the drainageways and areas adjacent to the river, the west slope of the lower Torment Creek valley is dominated by Moist Tussock-Graminoid Meadows and Moist Dwarf Shrub - Tussock-Graminoid Meadows (Photo 6). This LOWLAND TUNDRA area is composed mostly of tussock forming Carex Bigelowii, dwarf shrubs such as Betula nana, Ledum palustre ssp. decumbens, and Vaccinium uliginosum, Sphagnum mosses, and lichens including Cetraria spp. and Cladina spp. Drai2nageways that form depressions in the surrounding tundra are dominated by medium height willows and alders.

Fig. 2. Lower Torment Creek valley aerial photograph, master map, and vegetation map.

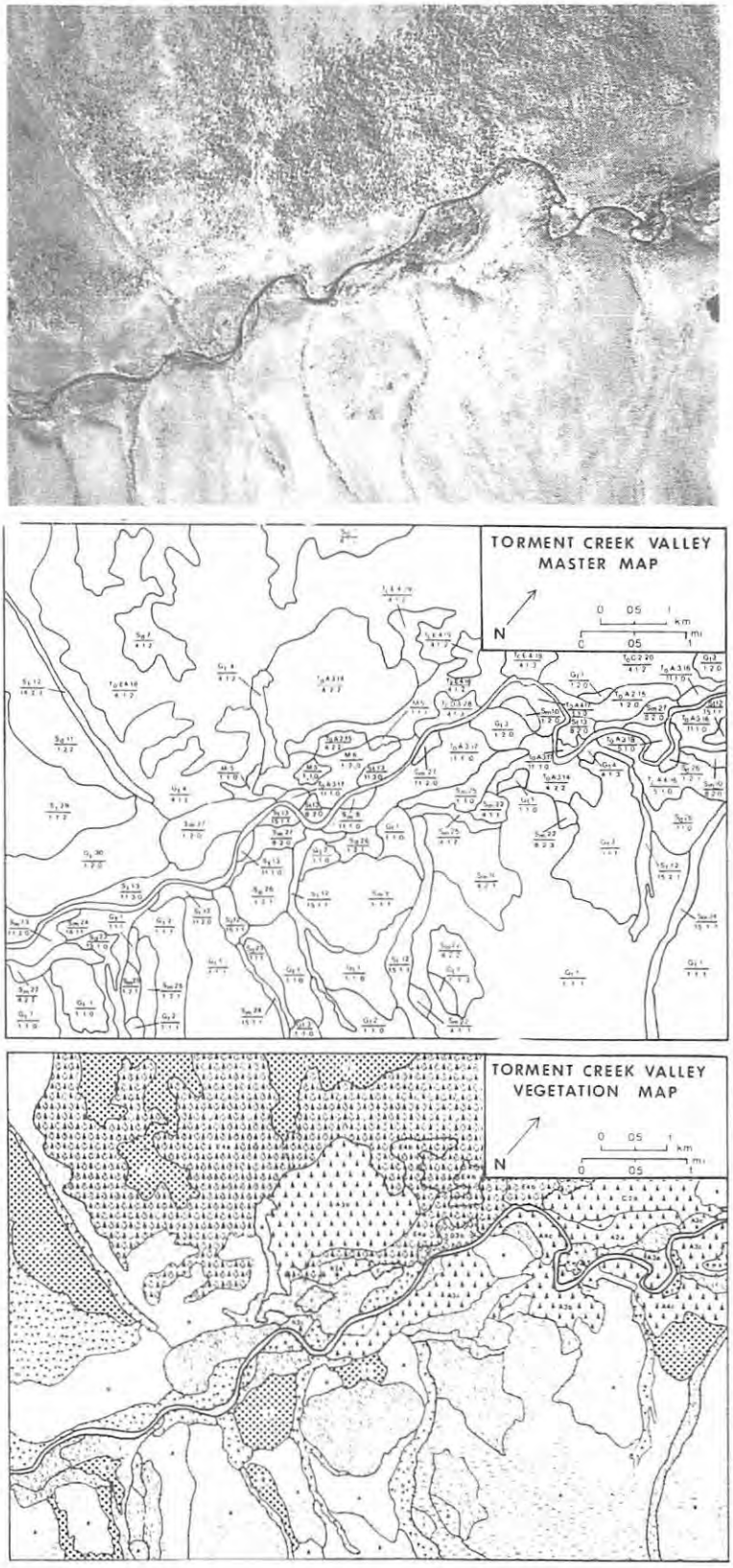


Table 8. Legend for lower Torment Creek valley vegetation map.

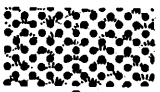
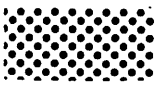
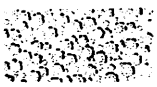
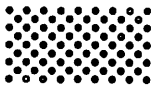
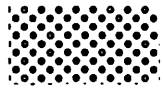
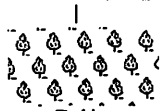
Master Map Vegetation Code	Vegetation Map Pattern and Floristic Code	Description
Gt 1	a	WET Carex Bigelowii - Cetraria spp. - Betula nana - Ledum palustre ssp. decumbens TUSSOCK GRAMINOID MEADOW
Gt 2	a	WET Carex Bigelowii - Eriophorum vaginatum - Cetraria ssp. - Betula nana - Alnus crispa - Vaccinium uliginosum TUSSOCK GRAMINOID MEADOW
Gt 3	a	MOIST Carex Bigelowii - Betula nana - Cetraria cuculata - Ledum palustre ssp. decumbens TUSSOCK GRAMINOID MEADOW
Sd-Gt 4	 e	MOIST Carex Bigelowii - Betula nana - Ledum palustre ssp. decumbens - Cetraria spp. - Cladina spp. - Vaccinium uliginosum DWARF SCRUB - TUSSOCK-GRAMINOID MEADOW
M 5	c	WET Sphagnum spp. - Ledum palustre ssp. decumbens - Vaccinium uliginosum - Cetraria spp. MOSS MEADOW
M 6	c	WET Sphagnum spp. - Betula nana - Vaccinium uliginosum - Arctagrostis latifolia MOSS MEADOW
Sd 7	 f	MOIST Betula nana - Vaccinium uliginosum - Arctostaphalos alpina - Ledum palustre ssp. decumbens - Salix reticulata - Carex Bigelowii UPLAND DWARF SCRUB
Sm 8	 l	MOIST Salix planifolia ssp. pulchra - Spiraea beauverdiana - Betula nana - Vaccinium uliginosum - Ledum palustre ssp. decumbens MEDIUM SCRUB
Sm 9	l	MOIST Salix planifolia ssp. pulchra - Betula nana - Vaccinium uliginosum - Petasites frigidus - Picea glauca MEDIUM SCRUB
Sm 10	l	WET Salix planifolia ssp. pulchra - Sphagnum spp. - Vaccinium uliginosum - Hylocomium splendens - Betula nana - Calamagrostis sp.MEDIUM SCRUB

Table 8. continued.

Sm 11	i	MOIST Betula spp. - Carex Bigelowii - Ledum palustre ssp. decumbens - Alnus crispa - Cetraria spp. UPLAND MEDIUM SCRUB
St 12	k	WET Salix alaxensis - Alnus crispa - Equisetum arvense - Spiraea beauverdiana - Sphagnum spp. TALL SCRUB
St 13	k	DRY Salix alaxensis - Vaccinium uliginosum - Spiraea beauverdiana - Hylocomium splendens FLOODPLAIN TALL SCRUB
ToA3,14	A3b	MOIST Picea glauca OPEN EVERGREEN FOREST Trees 5-15 cm dbh; understory Alnus crispa - Salix spp. - Ledum palustre ssp. decumbens - Hylocomium splendens
ToA2,15	A2a	MOIST Picea glauca OPEN EVERGREEN FOREST Trees <5 cm dbh; understory Betula spp. - Ledum palustre ssp. decumbens - Vaccinium uliginosum - Cetraria spp.
ToA4,16	A4c	MOIST Picea glauca OPEN EVERGREEN FOREST Trees >15 cm dbh; understory Hylocomium splendens - Cladina rangiferina - Sphagnum spp. - Vaccinium vitis-idaea - Empetrum nigrum
ToA4,17	A3c	MOIST Picea glauca OPEN EVERGREEN FOREST Trees >15 cm dbh; understory mixed
ToE4,18	E4a	MOIST Betula papyrifera - Picea glauca OPEN MIXED FOREST Trees >15 cm dbh; understory Betula spp. - Ledum palustre ssp. decumbens - Vaccinium uliginosum - Alnus crispa - Cetraria spp.
ToE4,19	E4b	MOIST Betula papyrifera - Picea spp. CLOSED MIXED FOREST Trees >15 cm dbh; understory Alnus crispa - Vaccinium uliginosum - Rosa acicularis

Table 8. continued.

ToC3,20	C3d	MOIST Picea glauca - P. mariana OPEN EVERGREEN FOREST Trees 5-15 cm dbh; understory Cladina spp. - Salix spp. - Ledum palustre ssp. decumbens - Vaccinium uliginosum - Betula nana
ToE4,21	E4a	MOIST Picea glauca - Betula papyrifera OPEN MIXED FOREST Trees >15 cm dbh; understory Betula spp. - Alnus crispa - Vaccinium uliginosum - Ledum palustre ssp. decumbens - Cladina spp.
Sm 22	I	MOIST Salix spp. - Alnus crispa - Ledum palustre ssp. decumbens - Carex Bigelowii - Betula nana MEDIUM SCRUB
Sd 23	 g	WET Vaccinium uliginosum - Betula nana - Ledum palustre ssp. decumbens - Shhanum spp. - Alnus crispa DWARF SCRUB
Sm 24	I	WET Salix spp. - Betula nana - Alnus crispa - Rubus chamaemorus - Equisetum arvense - Calamagrostis sp. MEDIUM SCRUB
Sd-Gt 26	 f	MOIST Betula nana - Carex Bigelowii - Ledum palustre ssp. decumbens - Vaccinium vitis-idaea - Cetraria spp. DWARF SCRUB TUSSOCK-GRAMINOID MEADOW
Sm 27	I	WET Salix spp. - Vaccinium uliginosum - Arctagrostis latifolia MEDIUM SCRUB
TcD4,28	 D4b	MOIST Betula papyrifera CLOSED DECIDUOUS FOREST Trees >15 cm dbh; understory Betula spp. - Alnus crispa - Linnaea borealis - Vaccinium vitis-idaea
St 29	j	MOIST Betula spp. - Alnus crispa - Salix spp. - Carex Bigelowii -Ledum palustre spp. decumbens - Picea glauca SLOPE TALL SCRUB
Gt 30	b	WET Eriophorum vaginatum - Carex Bigelowii - Sphagnum spp. - Rubus chamaemorus - Andromeda polifolia TUSSOCK GRAMINOID MEADOW

Lower Torment Creek Ridge

The lower Torment Creek Ridge photo area is located directly northwest of the Torment Creek Valley photo area. It extends northwest from the southeast-facing slope over the ridge, and down 92 m to the base of the adjacent valley.

Forest limit is reached at approximately 610 m (2000 ft), in the southern portion of the photo area. Thick stands of tall alder, alpine blueberry, and mixed dwarf shrubs become dominant beyond forest limit. As elevation continues to increase, the alder assumes a medium height growth form, and intermixes with Betula nana, Salix planifolia, Ledum palustre ssp. decumbens, and Arctostaphylos alpina. On the steep sections of the ridge, the ground is dry with evidence of cryoturbation. Frost boils are characterized by gravel on the surface, and typical dry fellfield species such as Dryas octopetala, Diapensia lapponica, Saxifraga spp., Loiseleuria procumbens, and Arnica frigida. Above 630 m and along the ridgetop are tussock-graminoid meadows similar to those on the lower northwest-facing slopes of lower Torment Creek valley. Co-dominant Carex Bigelowii and Eriophorum vaginatum intermix with lichen species and dwarf and prostrate shrubs. The north-facing slope of the ridge is similar to the northwest-facing slope of lower Torment Creek valley. It is predominantly a Moist Tussock-Graminoid Meadow with scattered medium height alders. The wet drainage at the base of the slope is dominated by tall alders and willows.

Fig. 3. Lower Torment Creek ridge aerial photo, master map, and vegetation map.

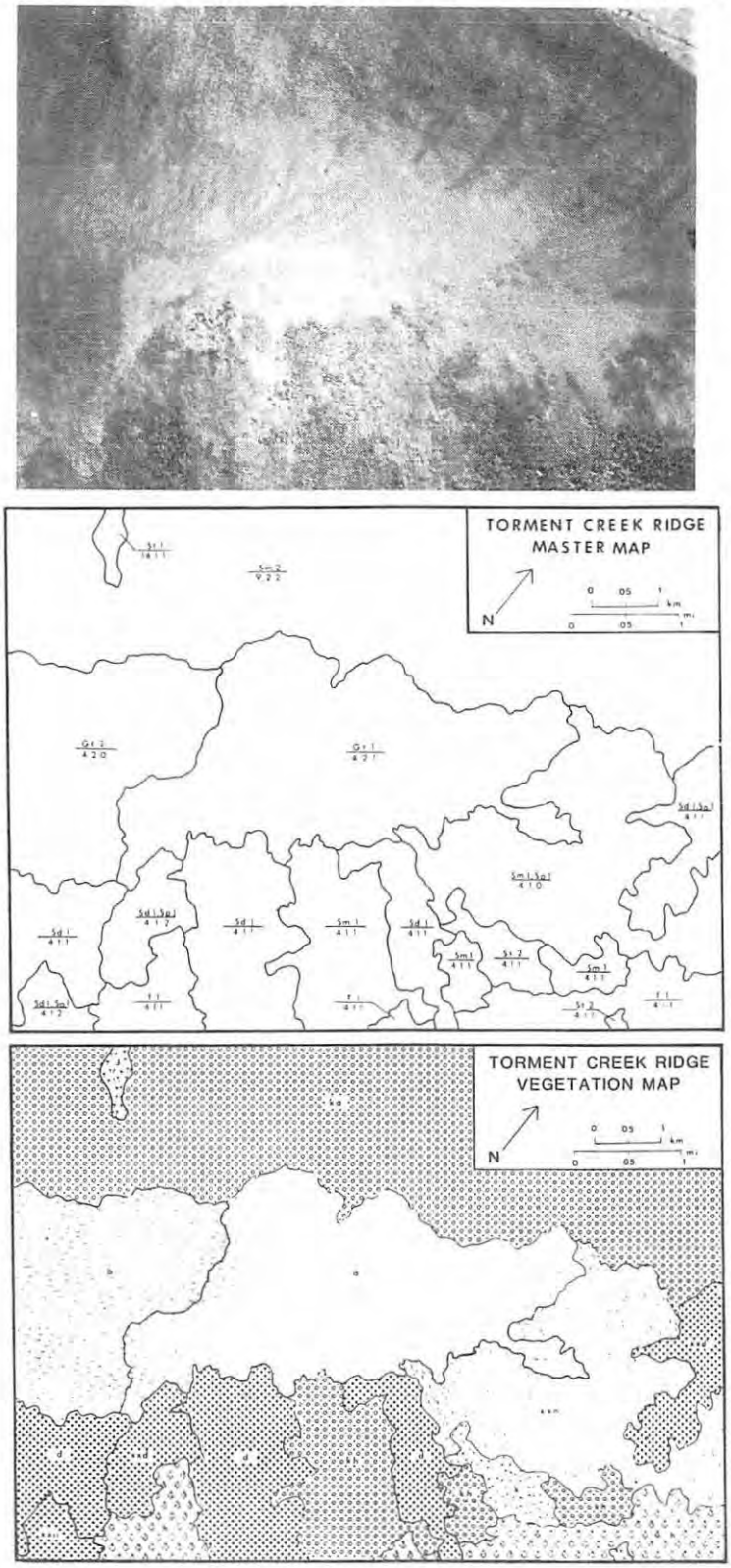


Table 9. Legend for lower Torment Creek ridge vegetation map.

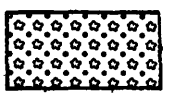
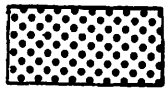
Master Map Vegetation Code	Vegetation Map Pattern and Floristics Code	Description
Tl	h	MOIST Betula occidentalis OPEN DECIDUOUS FOREST Trees <15 cm dbh Understory Alnus crispa - Betula glandulosa - Vaccinium uliginosum - Arctostaphylos alpina - lichen spp.
St 1	J	WET Salix alaxensis - Equisetum arvense - Lycopodium annotinum - Vaccinium uliginosum - Petacites frigiduus - Sphagnum spp. DRAINAGE TALL SCRUB
St 2	k	DRY Alnus crispa - Betula glandulosa - B. nana - Arctostaphylos alpina - Ledum palustre ssp. decumbens - Cetraria cuculata TALL SCRUB
Sm 1	 kh	DRY Alnus crispa - Betula glandulosa - B. nana - Arctostaphylos alpina - Ledum palustre ssp. decumbens - Cetraria cuculata SAVANNA MEDIUM SCRUB
Sm 2	ka	MOIST Alnus crispa - Carex Bigelowii - Eriophorum vaginatum - Vaccinium uliginosum - Cetraria cuculata - Cladina rangiferina SAVANNA MEDIUM SCRUB
Sm 1, Sp 1	xxn	FROST BOIL VEGETATION COMPLEX: a) Inter-frost boil areas: DRY Salix glauca - Carex Bigelowii- Betula nana - Vaccinium uliginosum- V. vitis-idaea MEDIUM SCRUB b) Frost boil areas: DRY Loiseleuria procumbens - Saussuria angustifolia - Diapensia lapponica - Salix phlebophylla - Stereocaulon spp. PROSTRATE SCRUB

Table 9. continued.

Sd 1	 d	DRY Betula nana - Vaccinium uliginosum - Empetrum nigrum - Arctostaphylos alpina - Cetraria cuculata DWARF SCRUB
Sd 1, Sp 1	xxd	FROST BOIL VEGETATION COMPLEX a) Inter-frost boil areas: DRY Betula nana - Vaccinium uliginosum - Empetrum nigrum - Arctostaphylos alpina - Cetraria spp. DWARF SCRUB b) Frost boil areas: DRY Loiseleuria procumbens - Saussurea angustifolia - Diapensia lapponica - Salix phlebophylla - Stereocaulon spp. PROSTRATE SCRUB
Gt 1	a	MOIST Carex Bigelowii - Vaccinium uliginosum - Ledum palustre ssp. decumbens - Empetrum nigrum - Cetraria spp. TUSSOCK-GRAMINOID MEADOW
Gt 2	b	WET Eriophorum vaginatum - Sphagnum spp. - Carex Bigelowii - Cassiope tetragona - Vaccinium uliginosum - Ledum palustre ssp. decumbens TUSSOCK-GRAMINOID MEADOW

Upper Spooky Valley

The upper Spooky Valley photo area is located near the headwaters of a central drainages of Kobuk Creek. The photo area extends from a ridge on the north side of the valley, south to within 62 m of the valley bottom. It encompasses terrain characteristic of the UPLAND TUNDRA and ALPINE BARREN ecosystems.

The saddle between ridges on the north side of the valley supports a Wet Graminoid Meadow. Large solifluction lobes (approximately 30 m long and 6 m high) have developed on the slopes above the saddle. Moist Graminoid Snowbed Meadows are at the bases of the lobes and Moist Dwarf Scrub - Tussock-Graminoid Meadows occur on the lobe tops.

The ridges adjacent to the saddle rise sharply to a peak of 1083 m. The tops of these ridges are Dry Upland Fellfield Barrens. The southern and western slopes of these ridges are steep for the top 100 m, and then lead gradually down to the valley. Dry Ericad Upland Prostrate Scrub occurs on the exposed slopes just below the barren ridges. At approximately 800 m this vegetation type grades down into the Dry Birch Upland Dwarf Scrub. Where the slope becomes very gradual and moisture increases, Wet Graminoid Meadow species intermix. The substrate becomes hummocky; graminoids occupy the wet flat areas at the bases of the hummocks, and dwarf shrubs occur on the sides and tops of the hummocks.

Fig. 4. Upper Spooky Valley aerial photo, master map, and vegetation map.

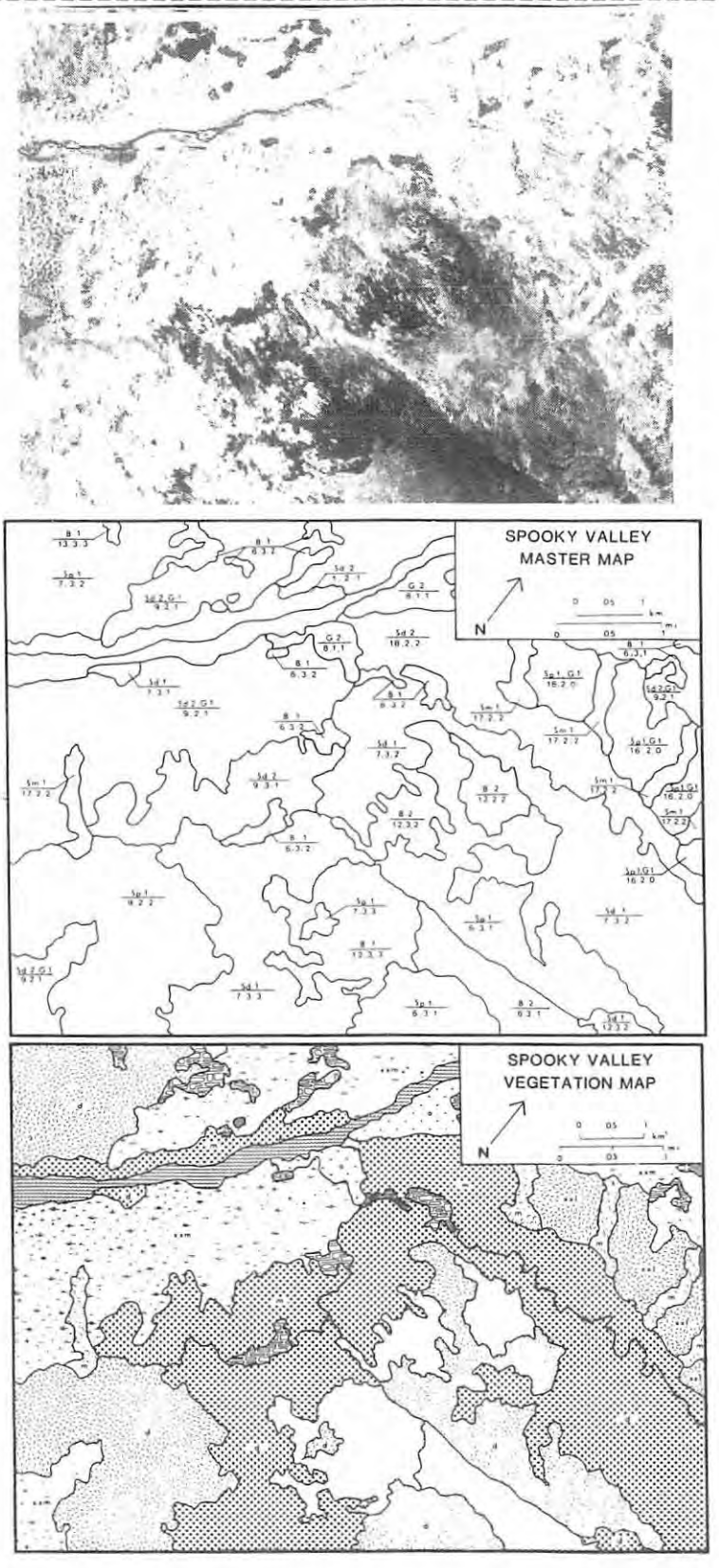


Table 10. Legend for upper Spooky Valley vegetation map.

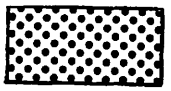
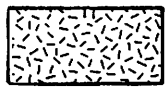
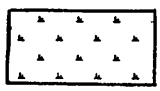
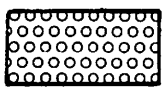
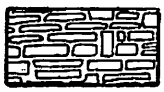
Master Map Vegetation Code	Vegetation Map Pattern and Floristics Code	Description
Sm 1	m	MOIST Salix Chamissonis - Betula nana - Cassiope tetragona - Vaccinium uliginosum - Carex microchaeta - Pedicularis captitata SNOWBED SCRUB
Sd 1	 d	TALUS SLOPE VEGETATION COMPLEX: a) inter-boulder areas: DRY Betula nana - Ledum palustre ssp. decumbens -Diapensia lapponica - Salix phlebophylla - crustose and fruticose lichens DWARF SCRUB b) boulders: DRY crustose lichen BOULDER BARREN
Sd 2	m	MOIST Salix Chamissonis - Betula nana - Vaccinium uliginosum - V. vitis-idaea - Carex rotundata - Sphagnum spp. DWARF SCRUB
Sd 2, G 1	xxm	HUMMOCK AND FROST BOIL VEGETATION COMPLEX: a) tops and sides of hummocks: Betula nana - Vaccinium uliginosum - Salix Chamissonis - V. vitis-idaea - Ledum palustre ssp. decumbens - Lupinus arcticus DWARF SCRUB b) depressions at bases of hummocks: WET Eriophorum angustifolium - Carex rotundata - Juncus triglumis - Sphagnum spp. GRAMINOID MEADOW c) frost boils: DRY Diapensia lapponica - Dryas octopetala - fruticose lichens BARREN

Table 10. continued.

Sp 1	 d	STONE STRIPE TALUS AND PROSTRATE SCRUB VEGETATION COMPLEX: a) inter-stone stripe areas: DRY Betula nana - Ledum palustre ssp. decumbens - Diapensia lapponica - Salix phlebophylla - crustose and fruticose lichens PROSTRATE SCRUB FELLFIELD b) stone stripe areas: DRY crustose lichen BOULDER BARREN
Sp 1, G 1	xxl	SOLIFLUCTION TERRACE FROST BOIL VEGETATION COMPLEX: a) inter-frost boil areas: WET Carex rotundata - Eriophorum angustifolium - Juncus triglumis - Sphagnum and other mosses GRAMINOID MEADOW b) frost boil areas: DRY Diapensia lapponica - Dryas octopetala - fruticose lichen spp. BARREN
G 2	 o	MOIST Carex microchaeta - Salix Chamissonis - Cassiope tetragona - Anemone narcissiflora - Pedicularis capitata SNOWBED GRAMINOID MEADOW
B 1		DRY crustose lichen spp. BOULDER BARREN
B 2		DRY crustose and fruticose lichen spp. UPLAND FELLFIELD BARREN

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The vegetation study team owes special thanks to several individuals whose help has been instrumental to the successful completion of this project. Skip Walker of the Institute of Arctic and Alpine Research (University of Colorado) introduced us to large-scale mapping based on aerial photographs, which became a major focus in the field. Chuck Racine guided us through vegetation mapping with satellite imagery, and offered advice and direction throughout the study. Steve Young of The Center for Northern Studies provided inspiration and understanding from the onset of the project. Randy Landgren of the Middlebury College Biology Department gave us valuable editorial advice. We are extremely grateful to Trina Kassler who gave her help and advice during the initial phases of the project, and to John Schubert who offered us his invaluable experience, guidance, and humor throughout the project. Finally, we thank Ned Farquhar, who made it all possible.

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ABSTRACT

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- Habitat Classification
- Small Mammals
- Large Mammals

RESULTS AND DISCUSSION
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ACKNOWLEDGMENTS

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APPENDIX -- Species Accounts

NOTE

The reader is referred to the Introduction of this volume for detailed descriptions of the project study area and the overall project research design. Also included there are descriptions of the project's three areas of concentrated study, with a map showing their locations and the locations of travel routes and Ray Mountains project sites (RMP sites Ia-VId) referred to in this chapter. Physiographic and ecological terms used consistently throughout the project report are defined in the Vegetation chapter of this volume. Habitat classification in this chapter correlates easily with the classification and detailed description of vegetation types also presented in the Vegetation chapter. The ECOSYSTEMS referred to herein (in upper case lettering) are described in the ecosystems chapter of this volume.

ABSTRACT

An inventory of the small and large mammal species of the Ray Mountains was compiled, with some investigations of the recorded species' relative abundances, distributions, associations, and habitat preferences.

Traps for small mammals were set in eight habitats, yielding 88 specimens of four species in 1466 trapnights. Of the four species, the northern red-backed vole was dominant, constituting 73% of the total yield. Range extensions were recorded for two small mammal species: the singing vole (Microtus miurus) and the pygmy shrew (Microsorex hoyi).

Sightings or sign were recorded for 13 species of large mammals. Grizzly bear (Ursos arctos) were common, but little evidence of other carnivores was seen. Caribou (Rangifer tarandus), part of the small herd endemic to the Ray Mountains and Kokrines Hills region, were the most conspicuous large mammal. Marmot (probably Marmota broweri) were common in the Upland Barrens; the Ray Mountains marmots are a previously undocumented population midway between populations of the two Alaskan species -- M. caligata and M. broweri. Positive species identification has not been completed.

INTRODUCTION

Prior to our investigation, no formal studies had been undertaken to determine the resident mammals of the Ray Mountains. The only historic reference to the mammals of the range is Eakin's (1916) observation of moose (Alces alces), caribou (Rangifer tarandus), grizzly bear (Ursos arctos), red fox (Vulpes vulpes), lynx (Lynx lynx), marten (Martes americanus), and ermine (Mustela erminea). Trappers and homesteaders in the region have observed four other species in or near the Ray Mountains: gray wolf (Canis lupus), beaver (Castor canadensis), muskrat (Ondatra zibethicus), and mink (Mustela vison) (Roberts, pers. comm.; Rome, pers. comm.). General information on the species likely to occur in the range is available from several regional studies (Melchior 1974; Gardner 1974; Selkregg 1975; Manville and Young 1965; Palmer 1954; Rausch 1953).

The major objectives of this investigation were 1) to determine the species of mammals present and their relative abundance in the Ray Mountains; 2) to determine habitat

affinities of large and small mammals; 3) to determine species associations in different habitats; and 4) to predict the distribution of species in the Ray Mountains.

METHODS

The means by which we collected and analyzed data for small and large mammals differed significantly; throughout this section and following ones, small and large mammals are described separately, except for habitat classification.

We have used the common and scientific nomenclature of Jones et al. (1973) with two exceptions: the singing vole is referred to as Microtus miurus rather than M. gregalis, and the common name northern red-backed vole is used instead of northern red-backed mouse. Both of these chosen names are more commonly used in Alaska than the alternatives.

Habitat Classification

Differentiation of habitats in the field followed Kessel (1979), Walker et al. (1979, unpubl.) and subjective estimates of habitat parameters such as soil moisture and percent cover of vegetation. Habitat terminology in this chapter is consistent with the vegetation types and descriptions of Brock and Burke (this volume), with mammal habitats corresponding to single or numerous Level III vegetation types within the identified habitats. Large mammals, in particular, are likely to utilize more than one vegetation type, and therefore have broader habitats. Small mammal habitats were determined strictly as those vegetation types in which specimens were trapped.

The names for habitats used here are intended to be descriptive of the vegetation types within them and usually corresponding to Level II of the vegetation classification of Brock and Burke (this volume).

Small Mammals

The definition of "small mammal" varies among authors, though the term generally refers to species weighing less than 2 kg (Bourliere 1975). Here we define small mammals as those insectivores and microtines for which traplines and grids were set.

Trapping was conducted between 7 July and 14 August at 24 locations including eight different habitats (Table 1). Because our basecamp at lower Torment Creek (RMP site IIb) was

near a variety of vegetation types, most of the trapnights were accumulated in that area.

We placed traps in semi-random grids and baited them with a mixture of peanut butter, rolled oats, sunflower seeds, and buckwheat groats. Trap sites were either single- or double-trapped, depending on the abundance of sign such as fecal deposits, evidence of foraging, and burrows. Traps set at various times on one day were checked and reset the next. Grids were normally established for three days, though grids 3 and 5 (RMP site IIb) were set for four days and grids 19 and 20 (RMP site IIb) for two days. Several pit traps were set to capture shrews, but these were not used consistently.

Between 7-19 July we used only Victor mouse traps. During this time grids 1 and 3-6 (RMP site IIb) were less random than later grids because fewer traps were available. As often as possible during this time we placed traps along runways and at the entrances to burrows. A grid pattern was maintained, though the distance between traps ranged from 5-12 m.

Grids 7-8 and 17-21 (RMP sites IIb-c), set between 20 July and 9 August, were more randomly organized. Six row by four column grids were established for grids 7-8 and six by three grids were established for grids 17-21. All grids were double-trapped with a random mix of Victor mouse traps and Museum Special traps.

In addition to grids we established traplines during excursions to Spooky Valley (RMP site IVa), upper Torment Creek (RMP site IIc), and Mt. Henry Eakin (RMP site Va), and during the hike out across the range (RMP sites VIa-c). Traplines consisted of 5-12 traps, usually set for a single night, though those in Spooky Valley and at the tarn below Mt. Henry Eakin were set for two nights. These traplines were placed in areas with abundant sign to determine species distributions and habitat affinities.

For each capture we recorded short descriptions of the surrounding microhabitat -- for example, "captured along Sphagnum runway near Carex and under dwarf Salix"; "captured at burrow beneath Picea glauca among spruce cone middens." Detailed vegetation and soil analyses were made for most trapping locations by members of other study groups; the reader is referred to Brock and Burke (this volume) and Smith (this volume) for detailed descriptions of vegetation and soils in the project's areas of concentrated study and most other trapping areas.

All captures were sexed, measured, weighed, and examined for ectoparasites. Skulls were saved and representative specimens of each species were prepared as study skins. Study

skins, skulls, and complete skeletons of two shrews, have been deposited at the Vertebrates Collection, University of Alaska Museum, Fairbanks.

Table 1. Small mammal trapping information. The grid numbers presented below are used throughout this chapter. Under "Method of Trapping," G = grid; T = trapline.

Grid Number/ RMP site	Location of grid or trapline	Date of Trapping	Method of Trapping
1/IIb	W slope above lower Torment Creek	7-10 July	G (a)
2/IVa	Spooky Valley	8-11 July	4 T's (b)
3/IIb	W slope above lower Torment Creek	10-13 July	G
4/IIb	W slope above lower Torment Creek	12-14 July	G
5/IIb	lower Torment Creek	14-18 July	G
6/IIb	lower Torment Creek	16-19 July	G
7/IIb	lower Torment Creek	20-23 July	G
8/IIb	lower Torment Creek	20-23 July	G
9/IIb	E ridge above lower Torment Creek	23-24 July	T
10/Va	tarn below Mt. Henry Eakin Eakin	23-25 July	T
11/Va	tarn below Mt. Henry Eakin	23-25 July	T
12/Vb	upper drainage of Ishtalitna Creek	25-26 July	T
13/IIc	upper Torment Creek	25-26 July	T
14/Vc	E ridge above Ishtalitna Creek	26-27 July	T
15/IIc	upper Torment Creek	26-27 July	T
16/IIc	upper Torment Creek	27-28 July	T
17/IIc	upper Torment Creek	25-28 July	G
18/IIc	upper Torment Creek	25-28 July	G
19/IIc	upper Torment Creek	28-30 July	G
20/IIc	upper Torment Creek	28-30 July	G
21/IIb	lower Torment Creek	6- 9 August	G
22/VIa	Crash Creek	11-12 August	T
23/VIb	Tozitna River	12-13 August	T
24/VIc	upper drainage of Moose Creek	13-14 August	T

Relative abundance of small mammals inhabiting lower Torment Creek (grids 1, 3-9, and 21) was determined according to methods presented by Caughley and Goddard (1972). When a trap is sprung, it is unavailable for further collection; therefore linear regression to determine relative abundance would be inaccurate. Thus frequency of captures per trap has been transformed to estimated number of catches per trap by the equation:

$$(1 - f) = e - x$$

where f = frequency of catches per trap (catch/trapnight); (1 - f) = proportion of traps empty; and x = density of animals caught per trap.

As traps might be set off by other animals and perhaps by heavy precipitation, estimates of relative abundance by the use of Caughley and Goddard's (1972) formula can be lower than the naturally occurring abundances.

A productivity status was assigned to habitats based on the relative abundance of small mammals within each. To assign productivity status to habitats, we assumed 1) that population densities did not change in any plot during the summer, although to the contrary Whitney (1976) reported that August was the month of highest microtine density during every summer in his study; and 2) that trapping was equally random on all grids. These limitations make our results a guide to future research rather than a statistically supported hypothesis.

Habitat preferences of small mammals were based on relative abundance of a given species within a particular habitat. Species associations were assessed, and by applying Dice's (1945) equation for the constant of association, CA, we tested for chance associations:

$$CA = hn/ab$$

where a = number of samples yielding species "A"; b = number of samples yielding species "B"; h = number of samples yielding both "A" and "B"; and n = total number of samples.

If CA = 1.0, two species are associated by chance alone. If CA > 1.0, the species are associated by factors other than chance. If CA < 1.0, the association between two species is less than chance would have it.

Large Mammals

All members of the project study team noted observations of large mammals. Sightings were recorded with available information on species, sex, number, location, habitat, and

direction of movement. Sign of large mammals, such as scat, bones, tracks, bear digs, game trails, and bark damage were also recorded, with notes on abundance and intensity of sign when possible. Several species were photographed.

Counts of sign and individual mammals observed in a particular habitat, and evaluation of literature describing species' habitat affinities, helped determine preferred habitats. The assigned habitats are approximate and become less reliable as the number of individuals and signs observed for a certain species decreases.

Relative abundance was assessed for large mammal species in relation to 1) occurrence throughout the study area, and 2) occurrence in preferred habitats. Abundance values were determined primarily by comparison of the conspicuousness of a given species (sighting and/or sign) in relation to other species present. Additionally, consideration was given to the energetic importance of a species; relative abundance values were upwardly adjusted for higher trophic level species occurring in lower numbers.

Terms used to indicate relative abundance of mammal species are similar to those used for bird species (Matthews, this volume). Abundance terms for within habitats are used as follows:

abundant -- species and/or sign observed repeatedly in appropriate habitat; optimum habitat heavily utilized and even marginal habitats occupied;
common -- species and/or sign observed frequently in optimum habitat but some areas of suitable habitat occupied sparsely or not all;
uncommon -- species and/or sign not often observed even in areas of presumed optimum habitat; large areas of suitable habitat occupied sparsely or not at all;
rare -- species occurs regularly in optimum habitat but only in very small numbers.

Abundance throughout the study area with no consideration for the availability of appropriate habitat is indicated as follows:

abundant -- species and/or sign observed repeatedly in large numbers;
common -- species and/or sign observed regularly but not in large numbers;
uncommon -- species and/or sign encountered infrequently;
rare -- no individuals sighted; observation of sign very limited.

Relative abundance observations are affected by limiting

factors such as the cyclic populations of some species, and behavioral characteristics such as nocturnality. Because quantifying the impact of these factors is difficult, the final assessment of these values remains subjective.

It is important to note several limitations inherent to our methods of studying both large and small mammals. First, many mammal populations experience cyclic population fluctuations, especially in northern ecosystems (Elton 1942). Because there is no evidence for spatial or temporal synchrony between conspecific populations or between populations of two different species (Pruitt 1966; Whitney 1976; Hutchinson 1978), we may not have collected or observed species in low population status. Reports of population highs elsewhere in interior Alaska may or may not be indicative of the status of a species' population in our study area, especially due to the "island" character of the Ray Mountains (Schubert, this volume). Second, we were unable to visit many areas of the range because our mobility was limited, and therefore some species may have been missed. Observation of forest-dwelling species was especially limited because we spent most of the field season in the tundra areas of the range.

RESULTS AND DISCUSSION

Seventeen species of mammals are known to occur in the Ray Mountains (Table 2). Five other species of which we found no evidence have been reported by homesteaders and trappers in and adjacent to the study area. According to Manville and Young (1965), six other species are expected to occur in the Ray Mountains, but no evidence of these species was found, nor were any references made to them by trappers or homesteaders. Species Accounts, with discussion of all of these mammal species found or expected in the Ray Mountains, are in the Appendix to this chapter.

Habitats

The habitat classification for this study (Table 3) represents an effort to integrate large and small mammal habitat descriptions in a single system, though approaches to habitat description differed. Habitats were described for small mammmal study by application of vegetation type names to trapping areas. For large mammals, habitat observations have been compiled so that patterns of habitat use have emerged. The classification of large mammal habitats dominates the classification system, easily encompassing the vegetation types trapped in small mammals study.

Small mammal trapping results (Table 4) and large mammal observations (see APPENDIX -- Species Accounts) are presented in the context of the habitats identified in Table 3.

Table 2. Known and expected mammal species of the Ray Mountains. Species in square brackets, [], were not confirmed by observation of sign or sighting of individuals during this study. Of these, * indicates presence predicted by Manville and Young (1965); ** indicates reported by homesteaders or trappers and predicted by Manville and Young.

INSECTIVORA
- Soricidae
  - Common Shrew (Sorex cinereus)
  - Pygmy Shrew (Microsorex hoyi)
  - [Arctic Shrew (Sorex arcticus)*]

LAGOMORPHA
- Leporidae
  - Snowshoe Hare (Lepus americanus)

RODENTIA
- Cricetidae
  - Northern Red-backed Vole (Clethrionomys rutilus)
  - Singing Vole (Microtus miurus)
  - [Tundra Vole (Microtus oeconomus)*]
  - [Brown Lemming (Lemmus sibiricus*]
  - [Muskrat (Ondatra zibethicus)**]
- Castoridae
  - Beaver (Castor canadensis)
- Sciuridae
  - Arctic Ground Squirrel (Spermophilus parryi)
  - Marmot (prob. Marmota broweri)
  - Red Squirrel (Tameasciurus hudsonicus)
- Erethizontidae
  - Porcupine (Erethizon dorsatum)

CARNIVORA
- Canidae
  - Gray Wolf (Canis lupus)
  - [Coyote (Canis latrans)*]
  - [Red Fox (Vulpes vulpes)**]
- Ursidae
  - Grizzly Bear (Ursos arctos)
  - Black Bear (Ursos americanus)
- Mustelidae
  - Ermine (Mustela erminea)
  - Wolverine (Gulo gulo)
  - [Least Weasel (Mustela nivalis)*]
  - [River Otter (Lontra canadensis)*]
  - [Marten (Martes americana)**]
  - [Mink (Mustela vison)**]
- Felidae
  - [Lynx (Lynx lynx)**]

ARTIODACTYLA
- Cervidae
  - Moose (Alces alces)
  - Caribou (Rangifer tarandus)

Table 3. Mammal habitats of the Ray Mountains. Small mammals habitats were defined by trapping results from vegetation types described by Brock and Burke (this volume). Large mammals habitats were defined by compilation and interpretation of field observations of large mammals. Numbers below precede habitats; letters precede vegetation types (Brock and Burke, this volume) within each identified habitat.

1. Evergreen Forest
   a. Moist White Spruce Slope Forest
   b. Dry White Spruce Floodplain Forest
   c. Moist White and Black Spruce Forest
   d. Wet Black Spruce - Sphagnum Forest
   e. Dry Black Spruce - Lichen Forest

2. Deciduous Forest
   a. Moist Paper Birch Slope Forest

3. Mixed Forest
   a. Moist Paper Birch - Spruce Slope Forest
   b. Moist Balsam Poplar - Spruce Floodplain Forest

4. Tall Willow - Alder Scrub
   a. Wet Willow - Alder Drainageway Tall Scrub
   b. Moist Willow Floodplain Tall Scrub
   c. Moist Alder Slope Tall Scrub

5. Lowland Tussock Meadow
   a. Moist Tussock-Graminoid Meadow

6. Medium Willow Drainageway Scrub
   a. Moist Willow Drainageway Medium Scrub

7. Dwarf Scrub - Graminoid Meadow
   a. Moist Birch - Blueberry Dwarf Scrub
   b. Moist Dwarf Scrub - Tussock-Graminoid Meadow

8. Upland Graminoid Meadow
   a. Wet Graminoid Meadow
   b. Moist Snowbed Graminoid Meadow

9. Upland Scrub
   a. Dry Birch Upland Dwarf Scrub
   b. Dry Ericad Upland Prostrate Scrub
   c. Moist Willow Upland Medium Scrub

10. Upland Barrens
   a. Dry Lichen Upland Rock Barren
   b. Dry Upland Fellfield Barren
   c. Dry Upland Fruticose Lichen Meadow

Small Mammals

Eight of ten Ray Mountains' habitats were trapped for small mammals with a total of 1466 trapnights yielding 88 captures. Four different species were collected (Table 4). The northern red-backed vole (Clethrionomys rutilus), was the dominant species in each grid area except grid 1, constituting 73% of the total yield. The presence of singing voles (Microtus muirus) and pygmy shrews (Microsorex hoyi) represented extensions of their previously known ranges.

All areas trapped showed signs of utilization by small mammals. However several sites, although relatively heavily trapped, yielded very few captures or none at all (Grids 3, 4, 13, 15-21; RMP sites IIb-c) despite ample evidence of burrow excavation. Grid 3 (RMP site IIb) yielded no specimens in 90 trapnights, and grids 17-20 (RMP site IIc) yielded a single specimen of both the northern red-backed vole and the singing vole in 412 trapnights. Grid 4 (RMP site IIb) yielded only two specimens of northern red-backed and singing vole. The low populations indicated by yields in these grids may result from 1) intense predation, as mustelid scat collected in the grid areas may suggest; 2) emigration out of these areas; 3) an early spring thaw followed by sub-freezing temperatures, which can lead to severe hypothermia in small mammals (Whitney 1977) and can occur in very localized areas (Young, pers. comm.); and 4) insufficient trapping pressure. However, the scarcity of small mammals in all grids of upper Torment Creek may reflect local variations in the species' population cycles.

Relative Abundance and Habitat Productivity

The northern red-backed vole was the most abundant small mammal in every grid trapping area except grid 1 (RMP site IIb), where the singing vole was equally abundant. Shrews, trapped in lower number, may be less susceptible to traps or may occur in fewer numbers in the habitats we trapped.

Habitat productivity was determined according to the methods in Caughley (1972), reviewed in Methods, above.

The Deciduous Forest (grid 7; RMP site IIb) proved to be the most productive habitat trapped (estimated density per trap = 0.16; see Table 5). This habitat provided deadfall, well-drained soil caused by steep slope, dense alder (Alnus crispa) and birch (Betula spp.) cover in the shrub layer, and a variety of monocots and dicots such as bog blueberry (Vaccinium uliginosum), dwarf Labrador tea (Ledum palustre ssp. decumbens), rose (Rosa acicularis), Carex spp., Calamagrostis spp., and Equisetum spp. (Brock and Burke, this volume). Dwarf Scrub - Graminoid Meadow (grid 6; RMP site

Table 4. Trapping results from Ray Mountains habitats, generally from lowest to highest elevation. Habitats are underlined, with total habitat yields in square brackets ([]).

Habitat: Vegetation Community(1)	Grid Number/ RMP site	Trap-nights	Species Total Cr (2)	Mm (3)	Sc (4)	Mh (5)	Total Yield
Evergreen Forest:		[308]	[12]	[4]			[17]
Mo. Wh. Spr. Sl. For.	3/IIb; 4/IIb	120	2	2	0	0	4
Dr. Wh. Spr. Fldp. For.	5/IIb; 23/VIb	188	10	2	0	1	13
Deciduous Forest:		[144]	[20]		[3]		[23]
Mo. Pa. Bir. Slo. For.	7/IIb	144	20	0	3	0	23
Mixed Forest:							
No traps set.							
Tall Alder - Willow Scrub:		[144]	[14]	[1]			[15]
Mo. Wil. Fldp. Tall Scr.	8/IIb	144	14	1	0	0	15
Lowland Tussock Meadow:		[144]					[0]
Mo. Tussock-Gram. Mdw.	21/IIb	144	0	0	0	0	0
Medium Willow Drainageway Scrub:		[84]	[2]	[1]			[3]
Mo. Wil. Drng. Med. Scr.	11/Va; 20/IIc	84	2	0	0	0	3
Dwarf Scrub - Graminoid Meadow:		[249]	[15]	[4]	[2]	[1]	[22]
Mo. Bir. Blue. Dw. Scr.	12/Vb; 15/IIc	17	1	1	0	0	2
Mo. Dw. Scr. Tus/Gram. Mdw.	6/IIb	80	7	0	2	1	10
Mo. Dw. Scr. Gram. Mdw.	10/Va; 16/IIc; 19/IIc; 22/VIa; 24/VIc	152	7	3	0	0	10
Upland Graminoid Meadow:		[115]		[1]			[1]
Wet Graminoid Meadow	18/IIc	108	0	0	0	0	0
Mo. Snowbed Gram. Mdw.	13/IIc	7	0	1	0	0	1
Upland Scrub:		[278]	[3]	[3]	[1]		[7]
Mo. Wil. Upland Med. Scr.	1/IIb	90	3	3	0	0	6
Dry Bir. Upland Dw. Scr.	2/IVa; 9/IIb; 14/Vc; 17/IIc	188	0	0	1	0	1
Upland Barrens:							
No traps set.							

(1) -- Habitats are shown in Table 3; vegetation types are from Brock and Burke (this volume).
(2) -- Clethrionomys rutilus.
(3) -- Microtus miurus.
(4) -- Sorex cinereus.
(5) -- Microsorex hoyi.

Table 5. Small mammals captures in eight Ray Mountains habitats of lower Torment Creek (grids 1, 3-9, 21; RMP site IIb), expressed as density of catch per trap according to formula reviewed in Methods, this chapter.

Habitat: Vegetation community (1)	SPECIES Cr (2)	Mm (3)	Sc (4)	Mh (5)
Evergreen Forest:				
Moist Wh. Spr. Slope Forest	0.02	0.02	0	0
Dry Wh. Spr. Fldplain For.	0.06	0.01	0	0.01
Deciduous Forest:				
Moist Pap. Bir. Slope For.	0.15	0	0.02	0
Tall Willow - Alder Scrub:				
Mo. Wil. Fldp. Tall Scrub	0.10	0	0.03	0
Lowland Tussock Meadow:				
Mo. Tus. - Gram. Meadow	0	0	0	0
Medium Willow Drainageway Scrub:				
Mo. Wil. Drng. Med. Scrub	0.03	0.01	0	0
Dwarf Scrub - Graminoid Meadow:				
Mo. Bir. - Blue. Dw. Scrub	0.06	0.06	0	0
Mo. Dw. Scr. - Gram. Mdw.	0.05	0.02	0	0
Upland Graminoid Meadow:				
Wet Graminoid Meadow	0	0	0	0
Moist Snowbed Gram. Mdw.	0	0.15	0	0
Upland Scrub:				
Dry Bir. Upland Dw. Scrub	0	0	0.01	0
Mo. Wil. Upland Med. Scrub	0.03	0.03	0	0

(1) -- Habitats are shown in Table 3; vegetation types are from Brock and Burke (this volume).
(2) -- Clethrionomys rutilus.
(3) -- Microtus miurus.
(4) -- Sorex cinereus.
(5) -- Microsorex hoyi.

Willow - Alder Scrub (grid 8) were the next most productive small mammal habitats (x = 0.13, 0.11). These habitats supported a less diverse flora than the habitat where grid 7 was set.

Species Associations

Species associations were determined according to the formula presented by Dice (1945), reviewed in Methods, above.

We found the following species associations:

Clethrionomus rutilus was associated with *Microtus miurus*, *Sorex cinereus*, and *Microsorex hoyi*.

M. miurus was associated with *C. rutilus* and *M. hoyi*.

S. cinereus was associated with *C. rutilus* and *M. hoyi*.

M. hoyi was associated with *C. rutilus*, *M. miurus*, and *S. cinereus*.

For the pair *C. rutilus* / *M. miurus*, CA = 1.50 if all trapping areas are considered, but CA = 1.0 if only those traplines and grids which yielded specimens are considered. The association between these two species will become clear with further research.

Large Mammals

We observed individuals or sign of 13 large mammal species during the field season (Table 6). According to the literature (Selkregg 1975; Manville and Young 1965; Rausch 1953) all of these species could have been predicted to occur in the study area with the exception of the marmot (probably Alaska marmot, *Marmota broweri*). We found the marmot to be common in the Upland Barrens in the higher elevations. Rausch (1953) describes two species of marmot in Alaska -- one occurring most commonly in the Alaska Range, the hoary marmot (*Marmota caligata*), and the other in the Brooks Range (*M. broweri*). He does not show marmot to occur in the region of the Ray Mountains (Fig. 1 and Photo 1, Appendix). We collected one marmot skull but species identification has not yet been confirmed. No specimens of *M. caligata* have been collected north of the Yukon River so we expect that Ray Mountains' species is *M. broweri*.

Table 6. Large mammal sightings and observation of sign.

SPECIES	SIGHTINGS (1)	SIGN (2)
Snowshoe Hare (Lepus Americanus)	0	1
Alaska Marmot [Marmota broweri (prob.)]	8	1
Arctic Ground Squirrel (Spermophilus parryi)	75-100	40
Red Squirrel (Tamiasciurus hudsonicus)	3	10
Beaver (Castor canadensis)	0	1
Porcupine (Erethizon dorsatum)	1	0
Gray Wolf (Canis lupus)	0	2
Black Bear (Ursos americanus)	3	4
Grizzly Bear (Ursos arctos)	15	37
Ermine (Mustela erminea)	15	0
Wolverine (Gulo gulo)	0	1
Moose (Alces alces)	4	12
Caribou (Rangifer tarandus)	78	25

(1) -- Sightings by all study team members throughout field season.
(2) -- J. Schubert's mammal sign count for late July - mid-August.

Although caribou were known previously to occur in the Ray Mountains, most reports indicated the area to be only wintering grounds for a small portion of the large Western Arctic Herd (Selkregg 1975; Hemming 1971). However, we observed caribou in the study area after mid-July. Our observations and recent aerial survey data from the Alaska Department of Fish and Game confirm recent suggestions (Davis 1978) that these caribou constitute a small herd independent of the Western Arctic Herd and endemic to the Ray Mountains region.

Habitat Preference

Large mammal habitat preferences in the Ray Mountains are summarized in Table 7. Primary, secondary, and tertiary habitat preferences were estimated when possible. Evergreen Forest and Medium Willow Drainageway Scrub appear to be the most heavily utilized habitats by large mammals. The only large mammal significantly to exploit the Dwarf Scrub - Graminoid Meadow habitat is the grizzly bear. This species was observed on several occasions foraging in areas of moist scrub along drainages with areas dominated by tussock meadows. Blueberry, an important element in the bear's diet, is the dominant or co-dominant plant species in both of the vegetation types included in the Dwarf Scrub - Graminoid Meadow (Brock and Burke, this volume). The sparsely vegetated Upland Barrens habitat is significantly utilized by only two species. It is considered primary habitat for the Alaska marmot, and secondary habitat for the arctic ground squirrel.

Relative abundance

Relative abundance values, as described in the Methods section of this chapter, are based primarily on the conspicuousness of a species relative to other species present. Table 6 indicates the number of individuals of each species sighted and presents an account of mammal sign over a period of one month. Relative abundance of the 13 large mammals species in both preferred habitats and throughout the entire study area are presented in Table 8. Although more than half of these species were commonly observed in their preferred habitats, only four species -- arctic ground squirrel, grizzly bear, ermine, and caribou -- were observed to be common over the entire range. Perhaps most surprising was the absence of snowshoe hare, which we expected to encounter frequently in the open forests and tall scrub habitats of the range.

Table 7. Large mammal habitat preferences. Primary, secondary, and tertiary (1,2,3) habitat utilization are indicated when possible. LO indicates limited observation.

SPECIES	H A B I T A T S									
	EF (1)	DF (2)	MF (3)	TW-AS (4)	LTM (5)	MWDS (6)	DS-GM (7)	UGM (8)	US (9)	UB (10)
Snowshoe Hare (Lepus americanus)	1	2	LO	3						
Alaska Marmot (prob. Marmota broweri)									2	1
Arctic Ground Squirrel (Spermophilus parryi)									1	2
Red Squirrel (Tamiasciurus hudsonicus)	1	2	LO							
Beaver (Castor canadensis)				1						
Porcupine (Erethizon dorsatum)	1	2	LO							
Black Bear (Ursos americanus)	1	2	LO	3						
Grizzly Bear (Ursos arctos)							2	1	3	
Ermine (Mustela erminea)								1	2	
Wolverine (Gulo gulo)	1		LO	2						
Moose (Alces alces)	2			1						
Caribou (Rangifer tarandus)								1	2	

[Gray Wolf (Canis lupus) is expected to occupy a wide variety of habitats throughout the range with habitat preference varying with changing prey density.]

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(1) - Evergreen Forest. (2) -- Deciduous Forest. (3) -- Mixed Forest. (4) -- Tall Willow - Alder Scrub. (5) -- Lowland Tussock Meadow. (6) -- Medium Willow Drainageway Scrub. (7) -- Dwarf Scrub - Graminoid Meadow. (8) -- Upland Graminoid Meadow. (9) -- Upland Scrub. (10) -- Upland Barrens.

Table 8. Relative abundance of large mammal species in preferred habitats and within the entire study area.

SPECIES	ABUNDANCE in preferred habitat	ABUNDANCE in study area
Snowshoe Hare (Lepus americanus)	Uncommon	Rare
Alaska Marmot (prob. Marmota broweri)	Common	Uncommon
Arctic Ground Squirrel (Spremophilus parryi)	Abundant	Abundant
Red Squirrel (Tamiasciurus hudsonicus)	Common	Uncommon
Beaver (Castor canadensis)	Rare	Rare
Porcupine (Erethizon dorsatum)	Rare--> Uncommon	Rare--> Uncommon
Gray Wolf (Canis lupus)	Uncommon	Uncommon
Black Bear (Ursos americanus)	Common	Uncommon
Grizzly Bear (Ursos arctos)	Common	Common
Ermine (Mustela erminea)	Common	Common
Wolverine (Gulo gulo)	Rare	Rare
Moose (Alces alces)	Common	Uncommon
Caribou (Rangifer tarandus)	Common	Common

Suggestions for Further Research

Further mammals research in the Ray Mountains should include studies 1) to confirm reports of sightings of species by others which we did not encounter; 2) to determine the species of marmot which inhabits the range; 3) to determine if the range is in fact the northwest limit of the pygmy shrew; and 4) to determine the origin and yearly movements of the caribou which utilize the range. Such studies will help to clarify the unique character of the habitats in the Ray Mountains with respect to the resident mammalian fauna.

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APPENDIX

Species Accounts

The following accounts include discussion of all species found or expected in the Ray Mountains. Habitats are written with the first letter in each word in upper case, such as Upland Barrens. Ecosystem names are in upper case lettering, as BOREAL FOREST.

INSECTIVORA

Soricidae

Common Shrew (Sorex cinereus). We collected six specimens of the common shrew of which five were caught in habitats with moist to wet substrate -- Deciduous Forest and Dwarf Scrub - Graminoid Meadow. Although we collected one in Upland Scrub (grid 17), a wet graminoid meadow bordered this grid. Moist habitats with some leaf litter provide a denser and more diverse array of insect species, favorable habitat for this shrew. Other studies (Hoffman 1971; Gardner 1974; Batzli 1975) have also found the common shrew to be primarily associated with wet habitats in high latitudes.

Pygmy Shrew (Microsorex hoyi). We collected two specimens of the pygmy shrew in the Ray Mountains, in wet Sphagnum microhabitats of Evergreen Forest and Dwarf Scrub - Graminoid Meadow. Data on this species are rather scarce, though Burt (1964) states that M. hoyi has a broad habitat preference for both wet and dry woodland and clearings, and for Sphagnum bogs. The pygmy shrew often appears to be a rare species, but may in fact be common in some areas of its range (Manville and Young 1965). To our knowledge the pygmy shrew has only been recorded once north of the Yukon River, in the Yukon Flats. The Ray Mountains are therefore the northwesternmost recorded limit of this species' distribution.

Arctic Shrew (Sorex arcticus). We expected the arctic shrew to inhabit the Ray Mountains but did not collect any specimens. The arctic shrew, in other parts of its range, is sympatric with S. cinereus, and probably is not competitively excluded from the Ray Mountains. Local habitats may not have been favorable to S. arcticus, or we may not have trapped as extensively as necessary to collect this shrew.

LAGOMORPHA

Leporidae

Snowshoe Hare (Lepus americanus). Though we did not observe the snowshoe hare in the Ray Mountains this summer, we found pellets on four occasions, three in open Evergreen Forest on the west slope above lower Torment Creek, and one on a boulder-lichen Upland Barren in Spooky Valley. Because 1980 is a predicted hare population high in the Alaskan interior (Gipson, pers. comm.), our observation is perplexing. The paucity of hare sign may be attributed to 1) insufficient study of preferred habitats, such as coniferous and mixed forests, swamps, and riverside thickets (Banfield 1974); 2) nonsynchronous cycles among populations in the Ray Mountains and other areas in the interior; and/or 3) a constant scarcity of hare in the Ray Mountains.

Based on the literature (Manville and Young 1965), we expect to find snowshoe hare in low elevation forested regions of the Ray Mountains. During periods of peak population density, hare populations may move beyond treeline along drainages where suitable cover and food resources are available. Pellets found in Upland Barrens possibly suggest an extreme case of exploitation of marginal habitats during population highs.

RODENTIA

Cricitidae

Northern Red-backed Vole (Clethrionomys rutilus). The northern red-backed vole was abundant and widespread, inhabiting all but Upland habitats. We usually found this vole in habitats affording dense cover in the shrub layer (grids 1,3-8). However, the species also occupied moist Medium Willow Drainageway Scrub where the cover provided by Betula nana is minimal (grid 11). These data support the varying reports of habitat utilization by the northern red-backed vole: Batzli (1975) stated that this vole inhabits well drained areas, while Palmer (1954) stated that it prefers open, damp forests and alpine conditions. The capture of northern red-backed voles at 50% of all sites trapped and 75% of sites yielding specimens suggests that the species is opportunistic, as reported by other sources (Krebs and Wingate 1976; Whitney 1976).

Our data also suggest that the northern red-backed vole population was in a high density phase of its cycle. This seems certain relative to our recorded trappings of other small mammal species in the Ray Mountains. However, because Whitney (1976) reports no evidence of cyclic fluctuations in red-backed vole populations near Fairbanks, we cannot be certain of the vole's population status.

The northern red-backed vole is considered important in

the BOREAL FOREST ecosystem of the Ray Mountains (Schubert, this volume).

Singing Vole (Microtus miurus). We collected the singing (or Alaska vole) in two grids and six traplines; it was the second most abundant small mammal collected (14% of all specimens). The species was primarily found in disturbed habitats such as streambanks, floodplains, and snowbed communities. Because the streambank and floodplain habitats are well drained, our findings support observations that the singing vole prefers well drained habitats (Bee and Hall 1956; Pitelka 1957; Gardner 1974; Palmer 1954).

Of the species he collected, Pruitt (1966) found that the singing vole was the microtine most tolerant of heavy snowfall and late snowmelt. This vole was the only species collected in the Upland Graminoid Meadow snowbed (grid 13). This species was also caught in well drained hummocks and Evergreen Forests on the west slope of lower Torment Creek. Burrows, litter piles, and/or extensive runways were almost exclusively associated with Salix spp. We caught 80% of the specimens under willows, supporting Pitelka's (1957) observation that the singing vole prefers willow for an understory.

Rausch's (1953) study located the singing vole in the Alaska and Brooks ranges and to the east along the Alaska-Yukon Territory border. This is the first account we have found of this vole in interior Alaska between the two major mountain ranges.

The singing vole is considered by some authors to be conspecific with the Siberian Microtus gregalis (Gardner 1974), and has been named as M. gregalis by Jones et al. (1973).

Tundra Vole (Microtus oeconomus). The tundra vole is an inhabitant of wet tundra areas (Melchior 1974). Though such habitat is present in the Ray Mountains, we collected no specimens of the vole. This vole may have been in a low phase of its population cycle in the Ray Mountains, or may have been competitively excluded from our study area by the northern red-backed vole and the singing vole; or, the Ray Mountains may not provide sufficient wet tundra habitat. Pruitt's (1966) study of the Kluane region showed that the tundra vole had a wider niche breadth than the northern red-backed vole, whereas Whitney (1976) found the reverse near Fairbanks.

Brown Lemming (Lemmus sibiricus). We did not collect any specimens of brown lemming. The brown lemming is primarily a coastal inhabitant which occasionally is found in the interior (Batzli 1975; Young, pers. comm.). The absence of this species in areas trapped probably reflects the lack of suitable lemming habitat in the range.

Muskrat (Ondatra zibethicus). The muskrat has been trapped near the mouth of the Ray River, 24-32 km east of the study area (Roberts, pers. comm.). However, we observed no

sign of this species during the summer. Muskrats inhabit lakes, swamps, rivers, and streams (Manville and Young 1965; Ernest 1978). The species requires considerable water depth for overwintering. Most drainages in the Ray Mountains are shallow and fast moving, with few areas for the construction of shelters. Thus the Ray Mountains probably do not supply suitable habitat for colonization by muskrat.

Castoridae

Beaver (Castor canadensis). The beaver has been trapped along the Ray River northeast of the range, at times heavily enough to cause depletion of the population (Roberts, pers. comm.). The only observed sign of beaver were a dam and lodge constructed from alder branches on Torment Creek at 640 m (2100 ft). A bed of fireweed and horsetail, typical early floodplain colonizers, indicated that the maximum water depth at this site could not have exceeded 1.2-1.5 m, perhaps too shallow for overwintering. Banfield (1974) found that in northern regions beavers must dam the water to a depth of 1.8-3 m to remain active under winter ice.

We expected beaver to occur along larger rivers and streams of the low elevation forested areas, and its range may extend beyond treeline along major rivers such as the Tozitna and Kanuti Kilolitna. However, in other regions of Alaska, flash floods seem to prevent the beaver from establishing permanent residence in such areas (Banfield 1974). The high possibility of flash floods in most drainages may therefore prevent the beaver from establishing a breeding population in the Ray Mountains.

Sciuridae

Arctic Ground Squirrel (Spermophilus parryi). Arctic ground squirrels (Photo 2) were abundant in Upland habitats of the range. The species was easily trapped at burrow entrances or along well worn runways between burrows in a colony. Four individuals were collected, two of which were prepared as museum specimens.

Arctic ground squirrels were observed in boulder and scree slopes, near rock outcrops and on fellfield ridges and occasionally sandy banks and ridges. These observations support Mayer's (1953) observation that arctic ground squirrels inhabit unvegetated well drained areas where permafrost is deep. Such conditions enable arctic ground squirrels to construct and maintain large burrows. larger colonies (10-25 ground squirrels) inhabited upland fellfields and lower rock slopes. Bear excavations of ground squirrel burrows on open ridges and slopes without rocks were more numerous than digs in rock slopes and rocky areas.

Arctic ground squirrels inhabit discontinuous patches of suitable habitat in the Ray Mountains; thus each colony seems to constitute a local population. Larger colonies inhabit the more continuous rock slopes such as the east ridge above Kilo

Hot Spring (RMP site IIIa). Immigration and emigration may be quite limited for isolated colonies. The arctic ground squirrel's broad diet -- including seeds, roots, stems, and leaves of monocots and dicots; insects; carrion; and trapped animals, even other ground squirrels (Batzli 1975; Gardner 1974; Mayer 1953) -- suggests that ground squirrels are adapted to sparsely vegetated habitats and a restricted home range.

Arctic ground squirrels were active during the day, withdrawing into their burrows in the evening. Despite continuous daylight, they responded as if there were a regular diurnal light rhythm. Mayer (1953) speculates that they respond to variation in light intensity.

Because arctic ground squirrels were the only small mammal found to occur in large numbers in the Ray Mountains, they almost surely form a crucial part of the food chain, providing food for most carnivores in the range. Schubert (this volume) considers them an important species in the ALPINE BARREN ecosystem of the Ray Mountains.

Alaska Marmot (Marmota broweri, preliminary identification). The Alaska marmot (Photo 1) was seen or heard on eight different occasions, always on steep boulder slopes above 914 m (3000 ft).

Two species of marmots occur in Alaska, M. broweri and M. caligata (Rausch 1953). Morphological differences in skull and external appearance led Rausch to postulate that marmots of the Brooks Range (now referred to as M. broweri) represent a distinct species from the hoary marmot (M. caligata) occurring south of the Yukon River. Before Rausch's work, there had been very little study of the fauna of interior Alaska north of the Yukon. Because at that time marmots were not thought to inhabit the area, they were not discussed in detail in his 1953 study. The Ray Mountains thus were an especially interesting study area for two reasons: 1) to confirm that marmots do inhabit the interior region north of the Yukon; and 2) to collect data on this previously unknown marmot population that lies between populations of two different species (Fig. 1).

A skull and detailed description of the coloration of the Ray Mountains marmot were given to the University of Alaska Museum for identification. However, confirmation of species type M. caligata or M. broweri was impossible because the museum had no M. broweri skulls for comparison. Preparation has been made to send the skull to Rausch for confirmation of species identity. Because no specimen of M. caligata has thus far been collected north of the Yukon, it is probable that the Ray Mountains marmot is M. broweri.

Marmots appeared to be restricted to steeper rock slopes in Upland habitats. We found no evidence of marmots on gently inclined rock slopes. Because marmots do not burrow as much as arctic ground squirrels, they require the shelter and protection provided by large boulders. Steeper rock slopes may also provide marmots with a better vantage point for

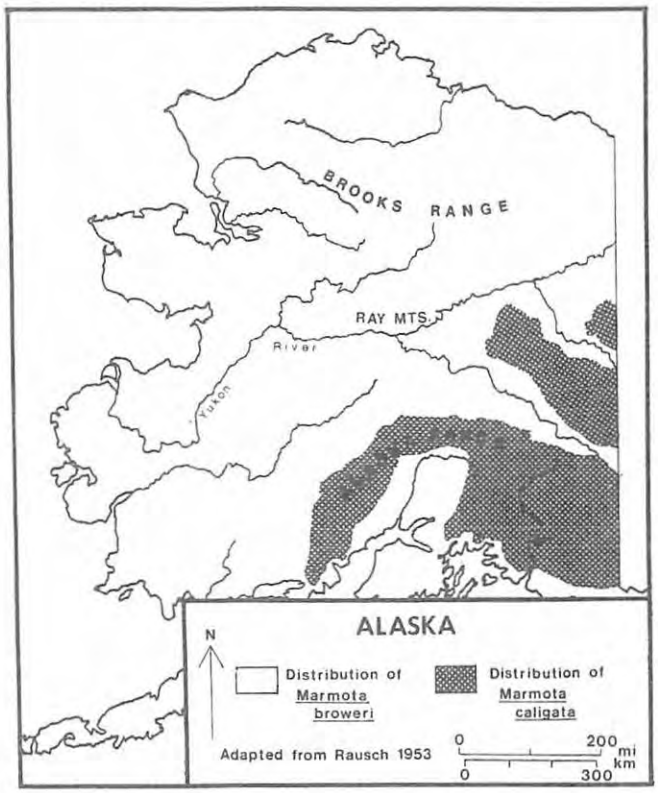

Fig. 1. Previously known distribution of marmot in Alaska.
Photo 1. Though they were not expected to occur in the Ray Mountains, marmots (probably Marmota broweri) were found to be common in alpine habitats.
Photo 2. Arctic ground squirrels (Spermophilus parryii) are common in upland habitats. They are probably an important prey species for grizzly bears and raptors.

viewing predators. Because vegetation is sparse on most of the rock slopes, marmots must travel to other habitats for food. One marmot was observed foraging in a dwarf scrub meadow several hundred meters from its den in a rock field.

Though exclusion was more commonly observed than sympatry, ground squirrels were sometimes observed to be closely associated with marmots. For example, in Spooky Valley (RMP site IVa) on a moderately steep boulder slope with 50% vegetation cover, arctic ground squirrels and marmots were both common and arctic ground squirrel burrows were located within a meter of a marmot den. In this habitat, niche parameters were broad enough to allow sympatry; areas of large boulders provided den sites for marmots and protection from predators for both species. The substrate beneath the vegetated portion of the slope was well drained because of the inclination of the slope, and thus supplied burrow sites for ground squirrels. The proximity of vegetation (graminoids and dwarf birch) allowed both species to forage successfully without travelling long distances. Marmots are considered an important mammal and an indicator species of the ALPINE BARREN ecosystem of the Ray Mountains (Schubert, this volume).

Red Squirrel (Tamiasciurus hudsonicus). Red squirrels inhabited the open floodplain Evergreen Forests along lower Torment Creek (RMP site IIb), the Tozitna River (RMP site VIb), and Ishtalitna Creek (RMP site Vd). None were trapped, but white spruce cone scale middens and established runways were conspicuous in the floodplain Evergreen Forest area surrounding grid 5, Ishtalitna Creek, and in the slope forests around upper Moose Creek (RMP sites VIc). Vocalizations were noted several times in the lower Torment Creek area, and individuals were seen on Ishtalitna Creek and along the Tozitna River. We encountered no red squirrel sign in the white spruce slope forests above lower Torment Creek.

Red squirrels forage primarily for white spruce seeds. In interior Alaska, white spruce seed crops are abundant only one out of every 10-11 years (Brink and Dean 1960). This seed crop variability can affect red squirrel populations in either of two general ways (Smith 1968): 1) a small diffuse population will be assured ample food even in low seed abundance years, or 2) a large population may maintain a wider diet. Our few observations of red squirrels, with observation of established runways and diffuse population in Evergreen Forests of the slopes and lower elevation floodplains, suggest that the Ray Mountains support small, stable populations of the red squirrel. Schubert (this volume) considers the red squirrel an important and indicator species of the Ray Mountains BOREAL FOREST ecosystem.

Erethizontidae

Porcupine (Erethizon dorsatum). One porcupine was observed, amidst the rock debris of a weathered tor on the east ridge above Ishtalitna Creek (RMP site Vc). Several

dwarf and paper birch surrounded the tor, but no sign of foraging activity was evident. We found fresh scat only in the immediate vicinity. The nearest spruce forest was along and above the floodplain of Ishtalitna Creek 1 km away.

Porcupine are most commonly found in deciduous and coniferous forests (Banfield 1974). In the Brooks Range this species is found along river drainages where alder-willow scrub occurs (Bee and Hall 1956). We suspect that the porcupine we encountered wandered up the dwarf birch covered slope from the floodplain forest.

In the Ray Mountains, this species should occur throughout Forest habitats and along rivers with higher elevation spruce stands. Porcupines may travel well above treeline in alder - willow thickets during the summer, but would be forced to move to lower spruce stands for food during the winter. (Banfield 1974; Bromley 1977).

CARNIVORA

Canidae

Gray Wolf (Canis lupus). The gray wolf was not sighted, though evidence of its presence included scat and several possible kills. One of the study team member N. Farquhar reported hearing wolves north of lake 1485 on one occasion. We found wolf scat in 11 locations, in five different habitats: closed and open Evergreen Forest, Upland Graminoid Meadow, Upland Scrub and Barrens, and along a well used game trail through Medium Willow Drainageway Scrub in Torment Creek (RMP site IIb). One of the scat specimens contained hair of moose or caribou. All scat were at least several months old.

As evidenced by the locations of scat, wolves may not prefer a specific habitat, but instead may exploit a variety of habitats depending on the availability of food. Bee and Hall (1956) report that wolves utilize all successional stages of vegetation and are seen frequently in association with dense populations of small birds and mammals. These observations indicate the importance of small prey in the diet of the wolf. As previously stated, populations of small mammals such as lemmings and snowshoe hare were very low or absent in the Ray Mountains, even where sign were observed. Though wolves often follow caribou to their wintering grounds, wolves become increasingly dependent on smaller mammals such as marmots, ground squirrels, and microtines for food (Murie 1944), and may occasionally kill a moose if caribou are scarce or absent from the wolves' foraging range.

We found evidence of three possible wolf kills. Two were scattered caribou leg bones with pieces of dried muscle still clinging to bone; one of these was 0.4 km south of lake 1485 (RMP site IIa) in Lowland Tussock Meadow, and the other was sighted in the southwest part of the range (near RMP site VIc) at 732 m (2400 ft) in a similar habitat. We also found a caribou skull next to Torment Creek 3 km north of basecamp;

it could indicate wolf predation though, it may also be attributed to bear predation or winter kill.

Because caribou are the most important food source for wolves, it is likely that the distribution of wolves in the Ray Mountains is linked to the distribution of caribou. Our study found caribou during summer to be most common in the upper elevations of the range, above 914 m (3000 ft). Because arctic ground squirrels and marmots were also most common at these elevations, we expect that the wolf's summer range extends through higher elevations of the Ray Mountains. For the winter, the caribou of the Ray Mountains probably move south of the range toward Tanana, while wintering Western Arctic Herd caribou sometimes move into the Kanuti Flats and the lower north slope of the Ray Mountains. In addition, ground squirrels and marmots hibernate during winter. Thus, because caribou and other important prey species are absent in winter, wolves probably disperse into the lower elevations of the range during the winter.

Although the Ray Mountains apparently include good wolf habitat, limited evidence of wolf indicates that this species is uncommon in the range.

Coyote (Canis latrans). According to Manville and Young (1965) the coyote's range extends into the Ray Mountains. However, it was not encountered this summer, nor were any references to the coyote made by trappers or homesteaders in or near the study area.

Red Fox (Vulpes vulpes). Eakin (1916) reported that red fox were numerous in the Ray Mountains in 1913. For years, trappers have caught red fox along the Ray River just northeast of the range (Roberts, pers. comm.); however, we found no evidence of red fox.

Red fox occur in a variety of habitats ranging from Forests to open tundra. However, this species most commonly inhabits open areas interspersed with better cover (Bee and Hall 1956). Red fox rely on hare and lemming as primary food resources (Elton 1942; Hutchinson 1978). We may not have observed red fox because of our limited study time in forested areas and the paucity of prey species. We expected the red fox to be distributed throughout the lower slopes and drainages of the range where the tundra is interrupted by patches of open forest and shrubby thickets.

Ursidae

Grizzly Bear (Ursus arctos). The grizzly bear (Photo 3-4) was common in the Ray Mountains. We frequently observed scat on ridgetops and on game trails along drainages. Fourteen individuals were sighted on eight different occasions, all above treeline. Four of these were sows and seven were cubs. We also observed two larger, solitary bears which were probably males. Both of these bears were almost

Photo 3 and 4. The grizzly bear (Ursus arctos) is the most conspicuous carnivore in the Ray Mountains; it often utilizes upland habitats where it forages for ground squirrels and berries.

completely yellow or white, contrasting with the darker pelage of the observed females. One other bear sighted, also alone, was of undetermined sex. All bears were observed between 1400 and 0500 hours.

We encountered bears in a number of different habitats, including Upland ridgetops and Lowland Tussock Meadow valleys. Such observed habitat seems related to the bear's diverse diet. We often found bears foraging in moist scrub vegetation types, usually next to rivers or streams dominated by willow and alder shrubs and commonly including blueberry and other dwarf shrubs. The contents of scat indicate that grizzly bears were subsisting primarily on plant material. Blueberries, which were abundant during the latter half of the summer, were found in most fresh bear scat during that time. One scat consisted almost entirely of yellow jackets. The abundance of bear-excavated arctic ground squirrel burrows on gradual slopes and ridges without a rocky substrate suggests that arctic ground squirrels represent a significant part of bears' diets. Although Bee and Hall (1956) report that bears excavate microtine burrows, evidence of such activity was observed only rarely in the Ray Mountains. Foraging for the abundant, larger ground squirrels would seem more efficient than for the microtines in the study area.

Several recent population studies on the grizzly bear in Alaska provide guidelines for a rough population estimate of this species in the study area. In the Canning River drainage on the northeast slope of the Brooks Range, considered high

quality bear habitat, Quimby (1974) estimated the density of bears to be one bear per 119 sq km. Dean's 1974 study in Mt. McKinley National Park showed bear density there to be much higher: one bear per 24-38 sq km. A rough estimate of the area above treeline in the Ray Mountains which we consider prime bear habitat, was calculated to be 2100 sq km. We therefore estimate the population at a minimum of 19 bears to a maximum range of 55-87 bears in the Ray Mountains. Although the Ray Mountains are almost equidistant between the Alaska and Brooks ranges, they are more closely related in physical and biotic characteristics to the northern range. Therefore, the population density of grizzly bears is likely to be closer to the lower estimate. The grizzly bear is considered an important mammal in the UPLAND TUNDRA ecosystem of the Ray Mountains (Schubert, this volume).

Black Bear (Ursus americanus). We sighted two solitary black bear in the Upland Graminoid Meadow just above diverse Forest habitats near the southwest edge of the range, near RMP site VIc on Moose Creek. We found no sign of black bear in the open tundra. We also found scat in the spruce - aspen forests near the McCormick and Moose USGS benchmarks, also at the east end of the range. All fresh scat contained blueberries.

In Alaska, the black bear is an inhabitant of forested regions, preferring open forest to densely timbered habitats. We expect this species to occur throughout the peripheral forests of the range, and in the forest-tundra ecotone. The ranges of the black bear and grizzly bear overlap in this ecotonal area. Schubert (this volume) considers the black bear important in the BOREAL FOREST

Mustelidae

Marten (Martes americana). The marten is primarily a forest inhabitant (Banfield 1974), and has been trapped near the Ray River (Roberts, pers. comm.). However, we found no evidence of this species in the forested areas we visited.

Ermine (Mustela erminea). Ermine were sighted on three different occasions, twice in upper Torment Creek (RMP site IIc) and once near lake 1485 (RMP site IIa). In upper Torment Creek we observed a solitary ermine in a Medium Willow Drainageway Scrub. The following day we sighted a group of seven ermine in dwarf Upland Scrub next to the willow thicket. Because weasels are known to travel in family groups (Banfield 1974), we assume that this group, consisting mostly of juveniles and accompanied by one or two larger individuals, was a family. We observed seven ermine at lake 1485 in a Medium Willow Drainageway Scrub. They were dispersed around a willow, underneath which were holes that appeared to enter their den. They all seemed to be the same size, so it is difficult to know whether or not they were a family group.

Ermine commonly occur in areas where there is relief.

morning. The nearest threatened resources were an inhabited mining cabin approximately 10 miles due west and native selected land approximately 15 miles to the southeast. Fuels were fairly continuous to the west, but broken by black spruce bogs and two rivers to the southeast. On the afternoon of the fifth day, the Tanana ~~Zone~~ Fire Management Officer recommended suppression action if prevention of a possible large fire was desirable. In absence of the Area Manager, Northwest Resource Area staff contacted the District Manager, who, without knowing the case history of this fire, ~~the District Manager~~ requested AFS to suppress it. . As previously stated, this decision was in effect until July 13, which placed all fires on BLM Public Lands, including 10 Limited Action fires, into Full Protection.

June 25 was the next most important day for fire starts: the Minto Fire (#8596). Although, it burnt mostly State land, it did include 54 acres of BLM Public Lands. Six Limited Action

	SLF	ELEV	QUAD	MAP	LOCATION
Ia	RDG	02300	TANA	C-2	13 0090N 0150W 029
Ib	RDG	02000	TANA	C-2	13 0090N 0160W 012
Ic	HIL	02200	TANA	C-2	13 0100N 0160W 032
Id	MTN	03100	TANA	C-3	13 0100N 0170W 023
Ie	MTN	02700	TANA	C-3	13 0100N 0170W 005
If	MTN	03200	TANA	D-3	13 0110N 0180W 026
IIa	MFH	01500	TANA	D-3	13 0120N 0190W 002
IIb	OSR	01800	TANA	D-3	13 0110N 0190W 002
IIc	MTN	02600	TANA	D-4	13 0110N 0190W 021
IId	RDG	02900	TANA	D-3	13 0110N 0180W 018
IIIa	OSR	01600	TANA	D-3	13 0110N 0180W 002
IIIb	RDG	02800	TANA	D-3	13 0110N 0180W 005
IVa	MTN	02800	TANA	C-~~3~~	13 0110N 0180W 036
IVb	RDG	02500	TANA	D-3	13 0110N 0180W 020
Va	GCR	03200	TANA	C-4	13 0110N 0190W 033 ~~034~~
Vb	MTN	02600	TANA	D-4	13 0110N 0190W 019
Vc	RDG	01900	TANA	D-4	13 0120N 0190W 030
Vd	OSR	01100	TANA	D-4	13 0120N 0200W 061
VIa	HIL	2100	TANA	C-2	13 0100N 0160W 035
VIb	OSR ~~HIL~~	1900 ~~2200~~	TANA	C-2	13 0090N 0150W 006
VIc	RDG	2300	TANA	C-2	13 0090N 0150W 027

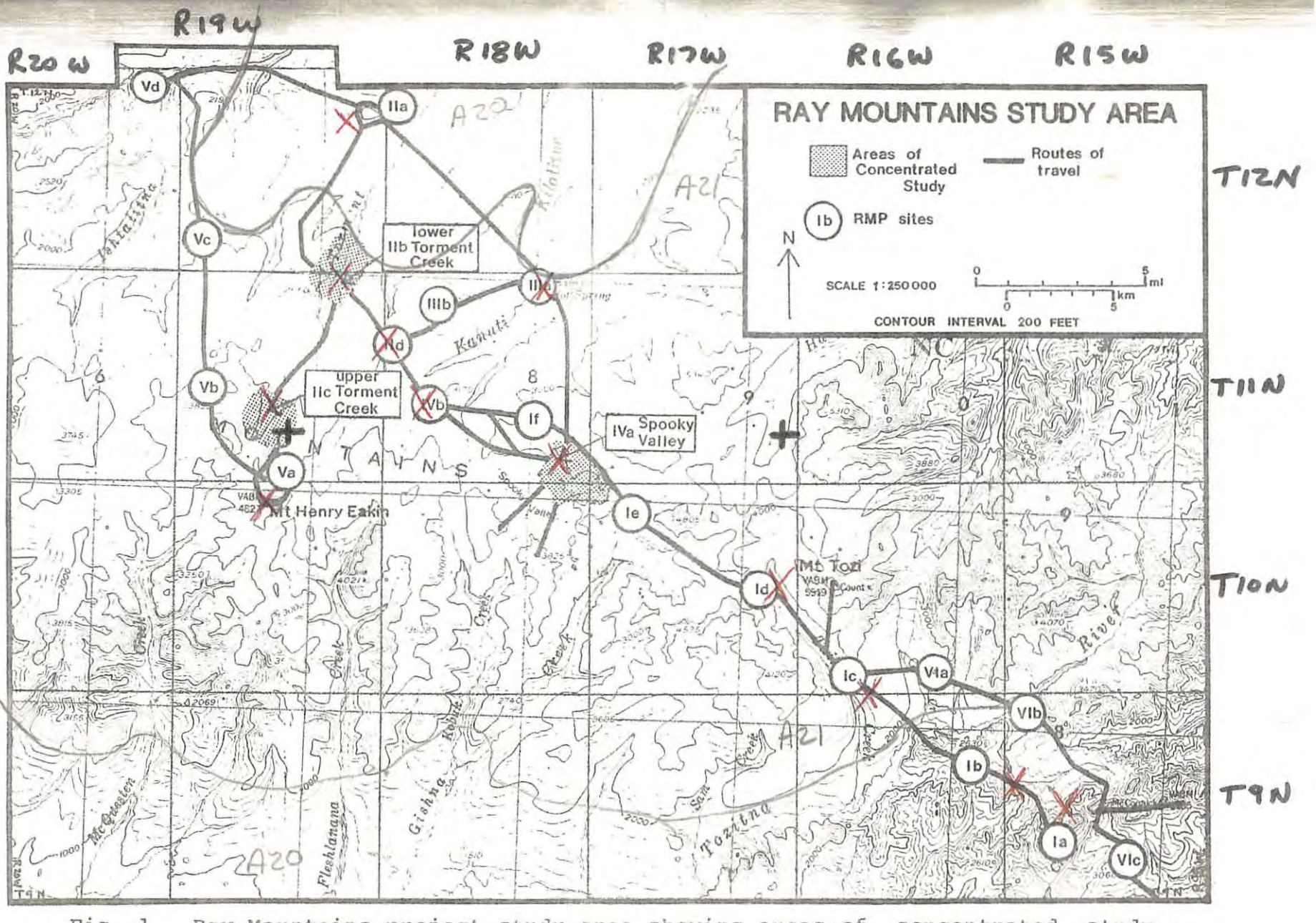

Fig. 1. Ray Mountains project study area showing areas of concentrated study, areas of less concentrated study along routes of travel, and camp locations (RMP sites). The travel routes shown are those hiked by parts, rarely the whole, of the Ray Mountains project study team.

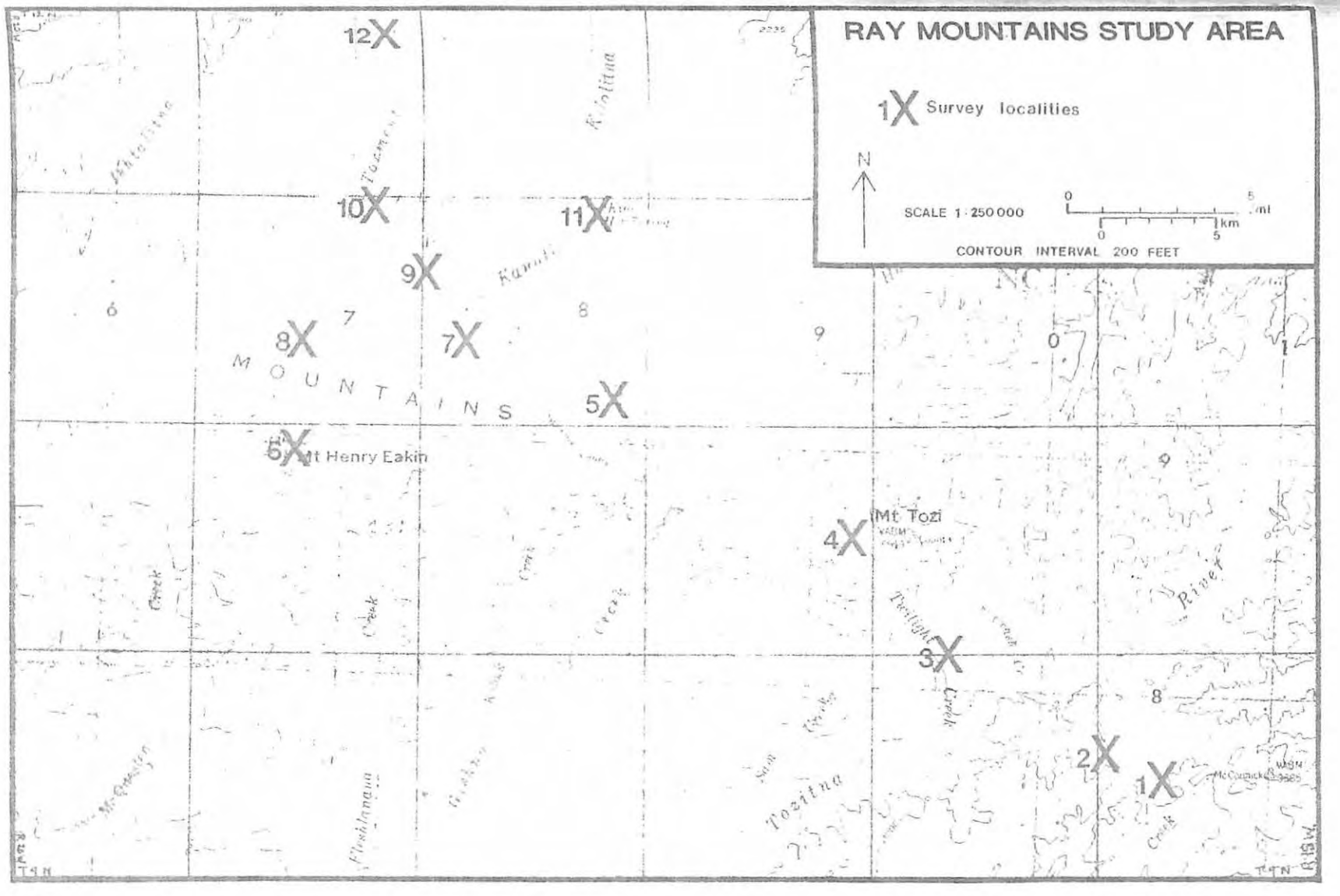

Fig. 2. Localities surveyed to determine bird species distribution in the study area (see Fig. 1).

They also frequent rockslides and streamsides, and rarely are found in damp or wet meadows of grasses and sedges (Bee and Hall 1956).

Ermine populations fluctuate in response to changes in the abundance of small mammals. In most cases, predator populations reach their peaks a year or two after the peak in prey numbers (Keith 1963). This may have been the case in upper Torment Creek; microtine holes were abundant in the Medium Willow Drainageway Scrub (grid 20) where weasels were observed, though results from trapping in this habitat indicated that microtines were very scarce (Table 4). This scarcity might reflect recent predator pressure exerted by weasels, resulting in the relative abundance of weasels this summer. Arctic ground squirrels are also important prey for weasels (Bee and Hall 1956). The weasel, with its long narrow body, atypical of most far northern species, is well suited for microtine and ground squirrel predation; its elongate shape permits it to enter the burrows of these species (Pianka 1978).

We expect ermine to be widely distributed in the Ray Mountains, occurring most commonly in streamside alder and willow thickets and in drier rocky areas where microtines and ground squirrels are most common. However, because of their population fluctuations, their abundance at a given locality would vary with time. Ermine are considered important in the UPLAND TUNDRA ecosystem of the Ray Mountains (Schubert, this volume).

Least Weasel (Mustela nivalis). The least weasel is the smallest carnivore in Alaska. Although Manville and Young (1965) include the Ray Mountains in this species' range, we did not find evidence of the least weasel. The presence of the least weasel may be difficult to confirm (Bishop, pers. comm.) as it occurs sparingly over its entire range (Manville and Young 1965). Therefore, we cannot be certain that the least weasel does not inhabit the Ray Mountains.

Mink (Mustela vison). Mink were not observed in the Ray Mountains though they have recently been trapped in the vicinity, (Roberts, pers. comm.). The mink is most commonly found in riparian communities where it can secure microtines, hares, muskrat, and fish (Banfield 1974). If mink inhabit the Ray Mountains, we would expect to find them in shrub thickets and forests at lower elevations.

Wolverine (Gulo gulo). A wolverine skull was found in a Tall Willow and Alder Scrub floodplain 1 km north of basecamp (RMP site IIb). Wolverine scat containing teeth and bones was discovered in a large natural den in an Upland Barren habitat in Spooky Valley. Wolverine inhabit forested areas and rock fields beyond treeline. They are omnivorous, consuming a wide variety of plants and small mammals, such as ground squirrels and microtines (Bee and Hall 1956). Because ground squirrels

and marmots commonly occur in rock fields, they are probably an important prey species to the wolverine in the upper elevations of the Ray Mountains. However, we expect wolverine to occur in the Ray Mountains in low numbers.

River Otter (Lontra canadensis). Although the range of the river otter reportedly extends into the Ray Mountains (Manville and Young 1965), no evidence of this species was observed, nor were any references to this species made by trappers or homesteaders near the study area.

Felidae

Lynx (Lynx lynx). This species is trapped northeast of the range near the Ray River (Roberts, pers. comm.). This species has also been sighted at Kilo Hot Spring (Rome, pers. comm.). We collected scat in an open Evergreen Forest in upper Moose Creek (RMP site VIc) near the Yukon River.

Lynx exhibit major population fluctuations, often associated with changes in abundance of snowshoe hare (Keith 1963; Odum 1971). Lynx may have been in a population low if snowshoe hare have been scarce in the past two to three years, as the scarcity of sign this summer suggests.

Lynx are primarily inhabitants of mature forests; however they may travel far north of the taiga after the decline of hares (Rausch 1953). In the Ray Mountains lynx may occur at low density throughout the range, being more common in forested regions.

ARTIODACTYLA

Cervidae

Moose (Alces alces). We recorded four single sightings of moose (Photo 6), three bulls and one of unknown sex. Three were sighted below 610 m (2000 ft) in or near open Evergreen Forests adjacent to rivers or streams. One other was observed in the central uplands of the range (near RMP site IVb) on a steep hill above Tall Willow - Alder Scrub. Sign was commonly observed in both the open Evergreen Forests and Tall Willow - Alder Scrub habitats at lower elevations of the range. Scat and racks were common in areas of open spruce forest and along game trails beside rivers and streams just beyond treeline. Game trails were also scattered through the Mixed Forests north of the Yukon River, which appeared to be heavily utilized by moose.

Eakin (1916) reported abundant moose in the vicinity of the Ray Mountains, especially in the Ray River basin and the adjacent headwaters of the Kanuti River.

Prime moose habitat consists of willow scrub communities (20-30 cm tall) at treeline and above, and in drier birch scrub communities at or below treeline (LeResche 1973). Young

(1978) proposes that moose are best adapted to "edge" areas, which are intermediate and often with unstable vegetation. This implies that moose should occur most commonly in recently disturbed areas with early succession vegetation. Moose are not resident in exposed alpine tundra and fellfields, but may cross these areas occasionally (Young 1978). Schubert (this volume) considers the moose important in the LOWLAND TUNDRA ecosystem of the range.

In the winter, moose mortality is directly related to snow depth; moose are generally found in taiga habitats where snow depth is less than in tundra (LeResche 1973). Thus, moose likely disperse from areas near or above treeline into the forests at lower elevations of the Ray Mountains during late fall, and they may move as far south as the Yukon River where alluvial willow communities are extensive.

Hunting pressure on moose in the Ray Mountains is minimal and limited to the more accessible areas along the Yukon and Ray Rivers (Wiehl, pers. comm.; Roberts, pers. comm.).

Caribou (Rangifer tarandus). Seventy-eight caribou (Photo 5) were sighted on 20 different occasions by study team members. Approximately 45% were cows, 3% calves, and 13% bulls, the remaining accounted for by juveniles or animals of unknown sex and age. Caribou were concentrated in the higher elevations from upper Torment Creek (RMP site IIb) to Mt. Tozi (RMP site Ic). None were seen prior to 8 July when we observed a solitary cow. On 17 July, a group of 8-15 caribou was seen from the air by our pilot. The remainder of the sightings occurred between 22 July and 10 August.

Larger groups of 10-20 individuals usually consisted of cows with calves and two or three bucks. Smaller groups usually included only cows with calves. Single sightings of caribou, usually a lone cow or juvenile, were common (55%). Caribou were most often observed in shrub dominated communities (Table 9). Of these, moist communities dominated by willow (Salix planifolia ssp. pulchra), appear to be preferred.

Most caribou which we observed were grazing. Generally, upon noticing us, bucks approached to within 30-40 m, circling us downwind to detect our scent. After scenting us, they departed rapidly. Calves and cows remained distant or immediately headed away. Most caribou seemed to be moving toward the west, often following well worn paths leading through mountain passes and across alpine meadows. Paths were noted at the headwaters of Torment Creek (RMP site IIc), above Spooky Valley (RMP site IVa), and near the headwaters of Twilight Creek (RMP site Id).

Although all sightings were in the higher elevations of the range in Upland habitats, caribou racks were common on the lower, more gradual slopes of the northern part of the range, which extend toward the Kanuti Flats. We observed no fresh sign of caribou in the lower elevations. Caribou are considered important in the UPLAND TUNDRA ecosystem of the

Photo 5. Caribou (Rangifer tarandus), part of the small herd endemic to the Ray Mountains - Kokrines Hills Region, are common in upland habitats.

Photo 6. Moose (Alces alces) are uncommon in the tundra habitats of the study area, though they are common in forest and ecotonal habitats at lower elevations.

Table 9. Caribou habitat-use observations. These habitats are according to vegetation types identified by Brock and Burke (this volume). Totals are shown in square brackets, [].

VEGETATION TYPE (Levels I and III)	CARIBOU SIGHTINGS (group and individual)
Shrub Dominated Units	[11]
Moist Willow Upland Medium Scrub	1
Moist Willow Drainageway Medium Scrub	4
Moist Alder Savannah Medium Scrub	1
Moist Birch - Blueberry Dwarf Scrub	2
Dry Ericad Upland Prostrate Scrub	3
Shrub-Herb Co-dominated Units	[4]
Moist Dwarf Scrub - Tussock-Graminoid Meadow	4
Herb Dominated Units	[3]
Moist Tussock-Graminoid Meadow	2
Moist Snowbed Graminoid Meadow	1
Sparsely Vegetated Units	[1]
Dry Upland Fellfield Barren	1
Other	[1]
Snowpatch	1
TOTAL SEPARATE SIGHTINGS	20

range (Schubert, this volume).

Based on the number of recorded sightings and variations within them, we estimate that 100-200 caribou were present in the Ray Mountains during our field season. The identity or origin of the herd is uncertain. Until recently caribou in the Ray Mountains were believed part of the Western Arctic Herd (WAH) (Valkenburg, pers. comm.). However, it has recently been proposed that the Ray Mountains caribou constitute a small herd independent of the WAH (Davis 1978; Bergstrand 1978; Fig. 2).

Mendenhall (1902) observed caribou on the Kanuti River north of the Ray Mountains. In the summer of 1913, Eakin (1916) noted that caribou were abundant in the uplands of the mountain range. In 1935, Murie (1944) reported a center of caribou abundance on the Dall River, 65 km) northeast of the range. People from the village of Tanana, directly south of the Ray Mountains, claim to have hunted caribou northeast of the village for years, finding them available at all times of the year. According to records of the Alaska Department of Fish and Game (ADF&G), in the 1940's there were some odd

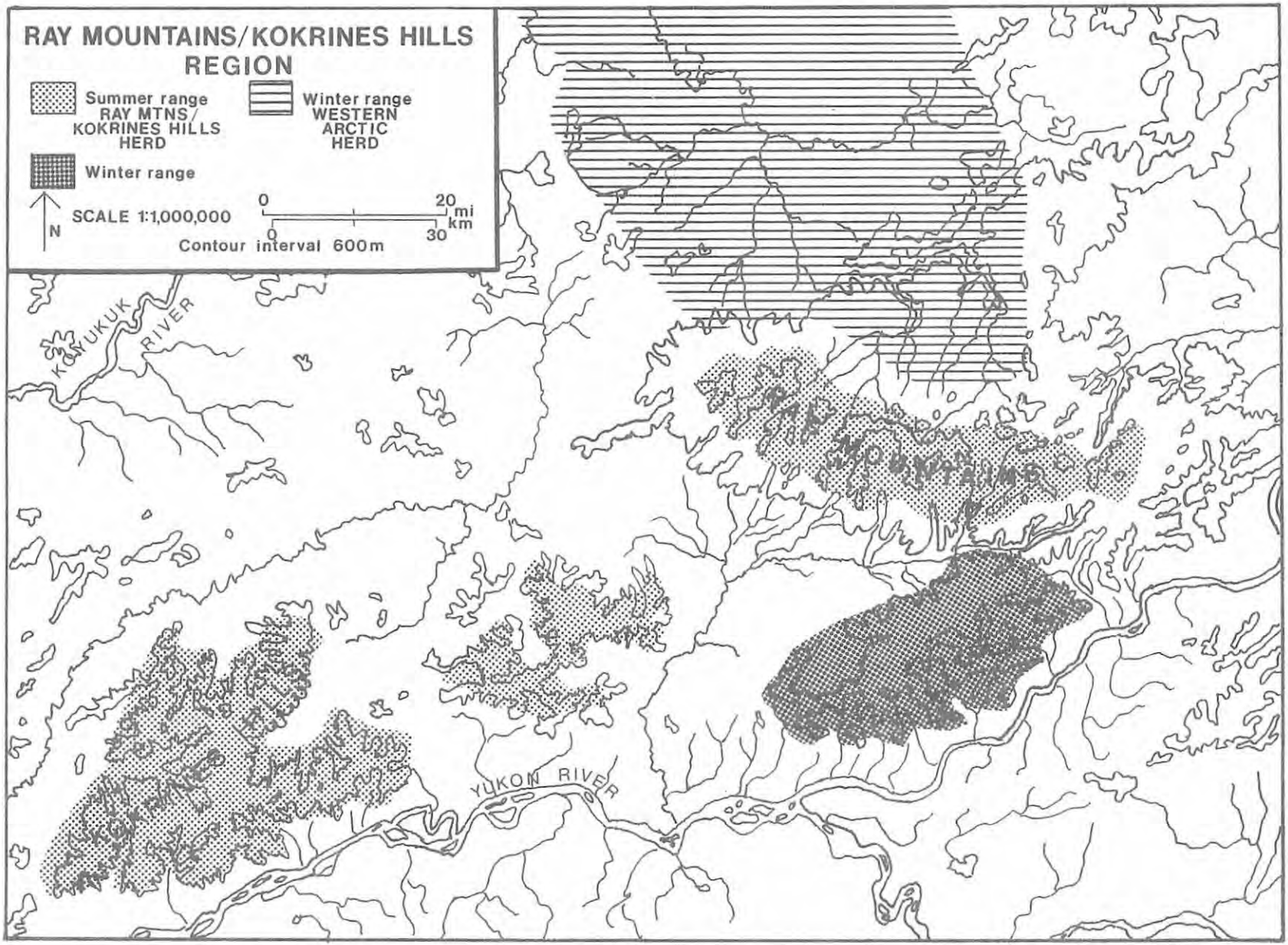

Fig. 2. Postulated winter and summer use by caribou in the Ray Mountains / Kokrines Hills region.

movements of caribou east out of the Ray Mountains and across the Yukon River in the springtime (Valkenburg, pers. comm.). Such movement has been observed more recently west of the study area (Roberts, pers. comm.). Since the 1940's, the area has been used by wintering WAH caribou. Most reports of the WAH in this region locate them on the north side of the Ray Mountains and in the southern Kanuti Flats. However, ADF&G reports that the WAH has used this area very little since 1973. In 1978-79 the fall movement of caribou from the central Brooks Range ceased, and no caribou were observed in the southern Kanuti Flats (Valkenburg, pers. comm.).

Recently, in efforts to establish the identity of the caribou in the Ray Mountains as a part of the larger WAH, ADF&G has flown several surveys in the Ray Mountains and over the Kokrines Hills to the west. In March 1977, 70 caribou were sighted in the hills north of Tanana, approximately 24 km south of the Ray Mountains. No caribou were seen north of the Tozitna River at this time (Davis 1978; Davis and Valkenburg 1978). At nearly the same time, caribou were spotted by other pilots in the Kanuti Flats near Old Dummy and Sithylemenkat Lakes, approximately 40 km north of the range (Valkenburg, pers. comm.). In August 1978 ADF&G conducted a thorough aerial survey over the Ray Mountains and Kokrines Hills; 62 caribou were observed, two-thirds of which were in the Kokrines Hills. The remainder were observed in the Ray Mountains west of Mt. Tozi (Valkenburg, pers. comm.).

Historic data, recent ADF&G information, and our data from the past summer indicate that caribou observed by our study team do not appear to belong to the large WAH, but probably constitute a smaller herd of calving caribou endemic to the Ray Mountains and Kokrines Hills region. Well worn trails through meadows and mountain passes of Ray Mountains Upland habitats indicate continuous use by caribou. Almost 70 years ago, Eakin (1916) observed significant numbers of caribou at a time when the WAH was small. The people of Tanana for years have been able to secure caribou year-round. Also, caribou and calves were observed in early to mid-July, indicating that these caribou were unlikely to belong to the WAH, which calves on the North Slope of the Brooks Range. Therefore, it is highly probable that these animals belong to a herd separate from the large migratory WAH.

Although this herd seems to be limited to a rather small area (Ray Mountains uplands and south toward Tanana and the Kokrines Hills), the herd appears to undergo short-distance seasonal elevational migration. Data from ADF&G's 1977 survey suggest that the herd apparently winters in the lower, more forested areas south of the mountains.

Our data indicate that caribou did not reach the uplands of the Ray Mountains until mid-July. These caribou appear to leave their wintering grounds south of the Ray Mountains sometime after March for suitable calving grounds, dispersing into the upper elevations of the Ray Mountains and probably the Kokrines Hills also. We have no information on the location of these calving grounds. The upland tundra provides

the caribou with abundant shrubs and, and stronger winds help mitigate harrassment by insects. We do not know when the caribou begin their southerly movement to the wintering grounds. Our field season ended in August, when caribou were still present.

The abundance of caribou antlers on the north slope of the Ray Mountains probably remains from recent wintering of parts of the WAH on the northern slopes of the Ray Mountains. These caribou probably moved south into this area from the Koyukuk drainage (Valkenburg, pers. comm.). Because adult male caribou shed their antlers in the fall during the rutting period, the presence of a large number of antlers on these northern slopes is not surprising. Lack of fresh caribou sign in this area may reflect the discontinued use of this area by the WAH in the recent past.

Thus, our data indicate that two different groups of caribou have utilized the Ray Mountains, but at different times of the year and at different locations in the range. A small calving herd of caribou endemic to the Ray Mountains and Kokrines Hills region utilizes the upper elevations of the Ray Mountains, west of Mt. Tozi, as summer range. Until recently, WAH caribou utilized the southern Kanuti Flats and the lower northern slopes of the Ray Mountains as wintering grounds.

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ABSTRACT

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- Biogeographic Considerations
- Summary and Suggestions for Further Research

ACKNOWLEDGMENTS

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NOTE

The reader is referred to the Introduction of this volume for detailed descriptions of the project study area and the overall project research design. Also included there are descriptions of the project's three areas of concentrated study, with a map showing their locations and the locations of travel routes and Ray Mountains project sites (RMP sites Ia-VId) referred to in this chapter. Physiographic and ecological terms used consistently throughout this volume are defined in the Vegetation chapter. Habitat classification in this chapter closely follows the classification and detailed description of vegetation types also presented in the Vegetation chapter. The ECOSYSTEMS referred to herein (in upper case lettering) are described in the Ecosystems chapter of this volume.

ABSTRACT

Fifty-five bird species were observed in the Ray Mountains; of these, 26 species breed and an additional 13 probably breed in the study area. Five species are presumed migrants, and 11 are of questionable status. These birds are distributed in the study area according to the growth form of the vegetation, but can also be grouped in recognizable zones roughly corresponding to elevation. Representative areas within these zones were studied in detail, and habitat profiles with associated bird communities are presented in this report. In addition, bird species of special interest are discussed, including 14 species that were expected to be present in the study area but were not observed.

The Ray Mountains avifauna shows many ecotonal characteristics, with species from both the Tundra and Taiga Biomes. Many of the species are strictly montane in their distribution in the north.

INTRODUCTION

Prior to the present study, no ornithological work had been conducted in the Ray Mountains, and almost nothing had been published on their avifauna. Henry Eakin (1916) mentioned the abundance and locations of Rock and Willow Ptarmigan, and alluded to the presence of a few species of large-bodied shorebirds. B. Kessel and D. Gibson (pers. comm.) briefly studied bird species along the Trans Alaska Pipeline Service (TAPS) haul road in 1977 and suggested that the Upland Sandpiper was probably a breeder in the Ray Mountains.

Because the Ray Mountains avifauna had been unknown, the primary objective of this study was to determine the bird species present and to evaluate their breeding status and abundance. Such information would add to the present knowledge of bird species distribution in Alaska. Other objectives were to determine bird habitat preferences and relative abundances within the major vegetation types and to evaluate bird distribution within the mountain range. These results were then compared with studies of the avifauna in other parts of Alaska.

METHODS

Field work for this study was conducted between 25 June and 16 August 1979. Information was gathered by observation in as many different habitat types as possible. Attempts to walk standard transects in the morning from 0300 to 0900 hrs and then again from 1700 to 2200 hrs, corresponding to the periods of highest avian activity in the north (D. Gibson, pers. comm.), were abandoned early in the summer because of bad weather and incompatible travel logistics. Instead, observations were recorded during the day as weather and group travel logistics permitted, and the areas studied covered varying amounts of distance. Data sheets were used for records of bird species, number, sex, time of observation, distance of the individual from the line of travel, habitat, behavior and activity, and other observations such as state of plumage or evidence of nesting. Every bird seen and identified during counts was recorded, except in areas near repeatedly used hiking routes or camp sites.

The bird species accounted here represent those encountered during a single season of one year within a narrow cross-section of the Ray Mountains. All travel was limited to excursions on foot under difficult conditions that hampered data collection. For this reason, and also because we arrived in the study area after most singing had ceased, conclusions on habitat preferences and relative densities were often not based on definitive breeding records, and breeding bird population estimates could not be made.

The Spooky Valley (RMP site IVa) and Torment Creek (RMP sites IIb-c) areas were chosen as areas of concentrated study for the Ray Mountains project (see Introduction, this volume). In these areas, special attention was paid to determination of the bird species associated with the vegetation types being analyzed by the vegetation study team. Many complete records of birds seen in these areas were kept, and routes walked early in the summer in Spooky Valley were repeated later in the summer to monitor avifaunal changes through the season.

Complete records were also kept in other habitat types not found within these areas of concentrated study.

Additional information was gathered on species or individuals of interest, on unusual behavior, and on phenological observations made when complete recording of observations was impossible. Also, valid sightings and descriptions by other members of the study team were recorded.

In this report, species have been listed phylogenetically following the American Ornithologists' Union checklist (1957) and its supplements (1973, 1976); these sources also provided scientific and common names.

Habitat Classification

Much of the habitat terminology in this chapter is based on the "level two" vegetation types identified by Brock and Burke (this volume). The occurrence of a bird species is influenced by the growth form of the vegetation more than by the particular plant species present (Kessel 1979). Because the level two vegetation types are based on growth form, these names were acceptable as habitat names, and were assigned according to the visually dominant growth form -- usually the tallest form of woody plant present in sufficient numbers to attract bird species typical of the habitat.

Kessel's (1979) avian habitat classification system was used for slight modifications of the vegetation scheme for bird habitat classification. Kessel's system includes topography and the type of physical substrate as important factors in avian habitat selection. Thus, three categories have been added to the habitat classification: Cliffs and Tors; Rivers, Streams, and Alluvial Bars; and Lakes and Shorelines.

Table 1 lists the names used to classify avian habitats; these appear in a format similar to that of the project's vegetation classification (Brock and Burke, this volume).

RESULTS AND DISCUSSION

Fifty-five bird species were observed during this investigation (Table 2). Of these species, positive breeding records, based on observation of nests with eggs or young or of fledglings, were established for 26, and probable breeding records, based on the observation of territorial pairs or of individuals carrying nest-building material, were assumed for an additional 13. Five species are presumed to be migrants, and an accurate evaluation of breeding status for 11 species could not be made. Of the 55 species recorded, the records for the Common Loon and the Belted Kingfisher were not personally verified.

Overall abundance (Table 2) has been assessed based on the frequency of occurrence of a species across the entire area without consideration of the availability of appropriate habitat. This rating is based on the total numbers of individuals seen throughout the summer, considered with the conspicuousness of the species and the amount of time spent in each area. Accordingly, the sighting of an inconspicuous

Table 1. Avian habitat units studied in the Ray Mountains. These names classify avian habitats and appear in a format similar to that of the vegetation chapter (Brock and Burke, this volume). The habitat names are followed by an asterisk (*).

I. Tree Dominated Units
   A. Evergreen Forest*
   B. Deciduous Forest*
   C. Mixed Forest*

II. Shrub Dominated Units
   A. Tall Scrub*
   B. Medium-height Scrubs - This unit has been subdivided into two categories following Kessel (1979).
      1. Medium Scrub* (1-2 m)
      2. Low Scrub* (0.5-1 m)
   C. Dwarf Scrub*
   D. Prostrate Scrub*

III. Shrub - Herb Co-dominated Units
   A. Dwarf Scrub - Tussock-Graminoid Meadow*

IV. Herb Dominated Units
   A. Tussock-Graminoid Meadow*
   B. Graminoid Meadows
      1. Wet Graminoid Meadow*

V. Vegetation Complexes
   A. Prostrate Scrub Hummocks - Wet Graminoid Meadow Complex* -- Both Wet Graminoid Meadow and Prostrate Scrub occur in this unit which is found in small areas of the Ray Mountains. The area exhibits patterns of raised hummocks covered with a moist Prostrate Scrub community; the low areas between hummocks support a Wet Graminoid community. This unit is considered a separate habitat because the microrelief seems to influence bird species composition.

VI. Sparsely Vegetated Units (<30% cover)
   A. Barrens
      1. Dry Upland Fellfield Barren*

Table 2. Species present, breeding status, and overall abundance in the Ray Mountains study area. B=breeder; b=probable breeder; m=migrant; ?=status unknown; A=abundant; C=common; U=uncommon; R=rare.

SPECIES	STATUS	ABUNDANCE
COMMON LOON - Gavia immer	?	R
MALLARD - Anas platyrhynchos	m	R
SCAUP - Aythya sp.	?	R
OLDSQUAW - Clangula hyemalis	B	U
SURF SCOTER - Melanitta perspicillata	b	U
SHARP-SHINNED HAWK - Accipiter striatus	b	U
ROUGH-LEGGED HAWK - Buteo lagopus	?	R
GOLDEN EAGLE - Aquila chrysaetos	?	R
MARSH HAWK - Circus cyaneus	b	U
GYRFALCON - Falco rusticolus	?	R
WILLOW PTARMIGAN - Lagopus lagopus	B	U
ROCK PTARMIGAN - Lagopus mutus	B	C
AMERICAN GOLDEN PLOVER - Pluvialis dominica	B	C
COMMON SNIPE - Gallinago gallinago	?	R
WHIMBREL - Numenius phaeopus	B	U
UPLAND SANDPIPER - Bartramia longicauda	B	U
SPOTTED SANDPIPER - Actitis macularia	B	U
WANDERING TATTLER - Heteroscelus incanus	B	U
LESSER YELLOWLEGS - Tringa flavipes	m	R
PECTORAL SANDPIPER - Calidris melanotos	b	U
LEAST SANDPIPER - Calidris minutilla	b	U
SEMIPALMATED SANDPIPER - Calidris pusilla	B	U
NORTHERN PHALAROPE - Phalaropus lobatus	m	R
LONG-TAILED JAEGER - Stercorarius longicaudus	b	C
MEW GULL - Larus canus	m	R
BELTED KINGFISHER - Megaceryle alcyon	?	R
SAY'S PHOEBE - Sayornis saya	B	U
ALDER FLYCATCHER - Empidonax alnorum	b	U
OLIVE-SIDED FLYCATCHER - Nuttallornis borealis	b	U
HORNED LARK - Eremophila alpestris	B	U
CLIFF SWALLOW - Petrochelidon pyrrhonota	B	U
GRAY JAY - Perisoreus canadensis	B	U
COMMON RAVEN - Corvus corax	?	U
GRAY-HEADED CHICKADEE - Parus cinctus	?	R
BOREAL CHICKADEE - Parus hunsonicus	b	C
AMERICAN ROBIN - Turdus migratorius	B	C
VARIED THRUSH - Ixoreus naevius	b	U
GRAY-CHEEKED THRUSH - Catharus minimus	B	U
WHEATEAR - Oenanthe oenanthe	B	C
RUBY-CROWNED KINGLET - Regulus calendula	B	U
WATER PIPIT - Anthus spinoletta	B	C
BOHEMIAN WAXWING - Bombycilla garrulus	?	R
NORTHERN SHRIKE - Lanuis excubitor	?	R
ORANGE-CROWNED WARBLER - Vermivora celata	b	R
YELLOW-RUMPED WARBLER - Dendroica coronata	b	U
WILSON'S WARBLER - Wilsonia pusilla	B	U
GRAY-CROWNED ROSY FINCH - Leucosticte tephrocotis	B	C
COMMON REDPOLL - Carduelis flammea	B	A
SAVANNAH SPARROW - Passerculus sandwichensis	B	A
DARK-EYED JUNCO - Junco hyemalis	B	U
TREE SPARROW - Spizella arborea	B	A
WHITE-CROWNED SPARROW - Zonotrichia leucophrys	B	A
GOLDEN-CROWNED SPARROW - Zonotrichia atricapilla	b	U
FOX SPARROW - Passerella iliaca	?	R
LAPLAND LONGSPUR - Calcarius lapponicus	B	A

species is considered to represent a larger number of birds than the sighting of a conspicuous species. For example, the observed number of Gray Jays was four times that of Alder Flycatchers, but because Gray Jays behave conspicuously, chances of seeing most individuals in an area are high, whereas the reverse is true for the flycatcher. Both species, therefore, are considered approximately equally abundant in the study area. Definitions of abundance terms are as follows.

Abundant: Region regularly hosts great numbers of the species.

Common: Region regularly hosts substantial numbers of the species.

Uncommon: Region regularly hosts small numbers of the species.

Rare: Region seems to host only occasional individuals of the species.

Some species listed in Table 2 are considered migrants in the Ray Mountains. This is a tentative classification based on the sighting of one or a few individuals toward the end of the field season. Because only one season was spent in the field, actual migration could not be verified.

Habitats

The affinities that the various bird species demonstrated for the habitats studied in the Ray Mountains are summarized in Table 3. Primary, secondary, and minor utilization are indicated. Counts of individual birds observed in a particular habitat, together with an evaluation of the factors limiting the occurrence of a given species, have been used to estimate the importance of a particular habitat to a bird species. The nesting area is usually the most important one for a breeding bird; however, nests for a given species were rarely located. When a nest was located, the habitat is listed as being of primary importance to that species. The location of a nest in one habitat does not exclude other habitats from being considered of primary importance if the species was seen in other habitats regularly or in large numbers. When no concrete evidence of nesting or of breeding was encountered, species have been assigned to the habitat unit(s) in which they were seen most frequently.

Avian habitat types are characterized below. Because these units represent artificial divisions of a continuum, there is not always a clear division of habitats, nor of associated bird species. However, in most cases, bird community boundaries follow these physiognomic boundaries;

Table 3. Avian habitat affinities, based primarily on sight records. XX=primary, X=secondary, o=minor utilization of the habitat.

	Evergreen Forest	Deciduous Forest	Mixed Forest	Tall Scrub	Medium Scrub	Low Scrub	Dwarf Scrub	Prostrate Scrub	Dwarf Scrub - Tussock-Graminoid Meadow	Tussock-Graminoid Meadow	Wet Graminoid Meadow	Prostrate Scrub Hummocks - Wet Graminoid Meadow Complex	Dry Upland Fellfield Barren	Dry Lichen Upland Rock Barren	Cliffs and Tors	Rivers, Streams, and Alluvial Bars	Lakes and Shorelines
Common Loon																	X
Mallard																	XX
Scaup																	XX
Oldsquaw																	XX
Surf Scoter																	XX
Sharp-shinned Hawk	X	o							X								
Rough-legged Hawk															XX		
Golden Eagle														o	XX		
Marsh Hawk							XX	X	XX	XX	X						
Gyrfalcon															XX		
Willow Ptarmigan				XX	X				XX								
Rock Ptarmigan							X	XX	o				X	X		o	
American Golden Plover								XX	X			X	XX				
Common Snipe																	X
Whimbrel									XX	X		XX					
Upland Sandpiper				XX					XX								
Spotted Sandpiper				o												XX	
Wandering Tattler																XX	
Lesser Yellowlegs																	X
Pectoral Sandpiper									X		XX						
Least Sandpiper											XX						X
Semipalmated Sandpiper							X				XX						
Northern Phalarope																	X
Long-tailed Jaeger								XX	XX	XX		X	X				
Mew Gull																	X
Belted Kingfisher																XX	
Say's Phoebe														X	XX		
Alder Flycatcher				XX													
Olive-sided Flycatcher	XX																
Horned Lark							X	XX					XX				

Table 3 continued.

	Evergreen Forest	Deciduous Forest	Mixed Forest	Tall Scrub	Medium Scrub	Low Scrub	Dwarf Scrub	Prostrate Scrub	Dwarf Scrub - Tussock-Graminoid Meadow	Tussock-Graminoid Meadow	Wet Graminoid Meadow	Prostrate Scrub Hummocks - Wet Graminoid Meadow Complex	Dry Upland Fellfield Barren	Dry Lichen Upland Rock Barren	Cliffs and Tors	Rivers, Streams, and Alluvial Bars	Lakes and Shorelines
Cliff Swallow							o								XX		
Gray Jay	XX	X	X										o		XX		
Common Raven																	
Gray-headed Chickadee	XX																
Boreal Chickadee	XX	X	X														
American Robin		XX	o	XX	XX	o	X								X		
Varied Thrush	XX			X													
Gray-cheeked Thrush		XX	o	XX													
Wheatear							XX	XX			X		X	X			
Ruby-crowned Kinglet	XX	X	XX														
Water Pipit					X		XX	XX	X				X	XX	X	X	
Bohemian Waxwing		XX															
Northern Shrike					X			X						o			
Orange-crowned Warbler		XX															
Yellow-rumped Warbler	XX	XX	XX														
Wilson's Warbler	X	XX		XX	XX												
Gray-crowned Rosy Finch							XX	XX						XX	XX		
Common Redpoll	X	X	X	XX	XX	X	X	o	X						o		
Savannah Sparrow	X				X	XX	X	o	XX								
Dark-eyed Junco	X		XX														
Tree Sparrow	X		X	X	XX	XX	X	o	X								
White-crowned Sparrow	XX		o	X	XX	XX	o										
Golden-crowned Sparrow					XX	X											
Fox Sparrow					XX												
Lapland Longspur					o				XX	XX	XX	XX	o				

for example, there is a clear distinction among species that inhabit Medium Scrub and Tall Scrub. In a few cases physiognomic boundaries may not separate distinct avian communities; for example, there is only a slight distinction between the bird species of Dwarf Scrub - Tussock-Graminoid Meadow and those of Tussock-Graminoid Meadow.

These habitat accounts are primarily descriptive; they are designed subjectively to portray the bird species associated with a particular habitat and to provide some information on the ways different species use a habitat. This discussion is based on a summation of all records of individuals seen in a given habitat during the summer, including counts taken outside areas of concentrated study and other miscellaneous notes. This discussion treats each habitat separately, and is not designed to compare the relative abundance of individuals from one habitat to another.

Evergreen Forest

Olive-sided Flycatchers, Gray Jays, Boreal Chickadees, Varied Thrushes, and Ruby-crowned Kinglets are typical of the open spruce forests and were also found in more closed forests. Yellow-rumped Warblers were found in open areas with scattered deciduous trees. This habitat is also used by Wilson's Warblers, Common Redpolls, Savannah Sparrows, Dark-eyed Juncos, Tree Sparrows, and White-crowned Sparrows, though these species are most common in the shrub understory. Sharp-shinned Hawks forage in this habitat.

Deciduous Forest

American Robins, Gray-cheeked Thrushes, and Wilson's Warblers were found most commonly in this habitat, along with Boreal Chickadees, Common Redpolls, Ruby-crowned Kinglets, and Gray Jays, which are usually associated with the scattered shrubs or conifers. Yellow-rumped Warblers and Orange-crowned Warblers were seen in Deciduous Forest carrying nesting material, though they occur in relatively low density.

Mixed Forest

Dark-eyed Juncos were the birds most commonly seen in this habitat. Ruby-crowned Kinglets, Boreal Chickadees, and Gray Jays were also commonly seen in the trees, along with the less common Yellow-rumped Warblers, Gray-cheeked Thrushes, and American Robins. The Common Redpoll, White-crowned and Tree Sparrows are associated with the scattered shrubs in this habitat.

Tall Scrub

American Robins, White-crowned Sparrows, Gray-cheeked Thrushes, and Wilson's Warblers were the most common birds seen in this habitat; Wilson's Warblers and American Robins follow this habitat to its highest elevation. White-crowned Sparrows frequently use the willows as lookout posts when flushed. Alder Flycatchers, Common Redpolls, and Tree Sparrows are also fairly common, although Alder Flycatchers are restricted to very dense patches.

Medium Scrub

White-crowned Sparrows, Tree Sparrows (Photo 1), Common Redpolls, and American Robins are abundant in the Medium Scrub habitat. Savannah Sparrows occur quite commonly where shrubs are scattered in open meadows. At higher elevations, Golden-crowned Sparrows also inhabit Medium Scrub areas. Willow Ptarmigan and Wilson's Warblers use this habitat when it is adjacent to water, but occur in relatively low numbers. Water Pipits, Lapland Longspurs, Upland Sandpipers and Northern Shrikes were sometimes seen on drier upland slopes where shrubs are scattered. Dense Medium Scrub seems to support the highest density of birds relative to other habitats.

Low Scrub

The bird associations in this habitat resemble those of Medium Scrub; Savannah Sparrows are the most common of the sparrows, followed in abundance by Tree Sparrows, White-crowned Sparrows, and Common Redpolls. American Robins and Golden-crowned Sparrows were also occasionally seen in this habitat. Willow Ptarmigan were found in Low Scrub near watercourses.

Dwarf Scrub

Dwarf Scrubs in the upper elevation valleys usually include boulders to varying extents -- often the occurrence of bird species was observed to be as strongly influenced by boulders as by shrubs.

The most abundant species in this habitat, Wheatears and Water Pipits, are associated with the boulders. Gray-crowned Rosy Finches and Horned Larks were also seen among boulders, but they are much less numerous. Savannah Sparrows were seen commonly at the edge of shrubs or in meadow patches between them. Common Redpolls, Tree Sparrows, White-crowned Sparrows, and American Robins use Dwarf Scrub less than the taller shrub classes. Marsh Hawks (Photo 2), Cliff Swallows, and Rock

Photo 1. Sparrows are among the most abundant birds in the Ray Mountains. They often nest in Medium and Low Scrub habitats, but can be found in any areas where shrubs occur.

Photo 2. Marsh Hawks (Circus cyaneus) are one of the most common predatory birds in the Ray Mountains. They nest in tundra and are frequently seen hunting over both upland and lowland tundra meadows.

Ptarmigan forage in this habitat.

Prostrate Scrub

The most common birds of Prostrate Scrub are Water Pipits, Wheatears, Rock Ptarmigan, Gray-crowned Rosy Finches, and Horned Larks. American Golden Plovers are common on exposed ridges of low elevation tundra where Prostrate Scrub occurs. Common Redpolls, Tree Sparrows, Savannah Sparrows, and Northern Shrikes were occasionally seen in this habitat. The Long-tailed Jaeger and Marsh Hawk forage over Prostrate Scrub.

Dwarf Scrub - Tussock-Graminoid Meadow

The Willow Ptarmigan, Whimbrel, Upland Sandpiper, Pectoral Sandpiper, and Savannah Sparrow commonly nest in tussock tundra. Lapland Longspurs are the most abundant species in this habitat but are restricted to the higher elevations. Marsh Hawks and Long-tailed Jaegers are most often seen foraging over these tundra expanses, and Marsh Hawks were observed nesting in this habitat. American Golden Plovers, Water Pipits, and Rock Ptarmigan sometimes forage in this habitat.

Tussock-Graminoid Meadow

This community was not extensively studied. It was found in fairly limited areas and did not seem to host a distinct avian community. Lapland Longspurs and Whimbrels were seen in Tussock-Graminoid Meadow. Marsh Hawks and Long-tailed Jaegers hunt there frequently.

Wet Graminoid Meadow

Least Sandpipers, Lapland Longspurs, and Pectoral Sandpipers nest in this habitat. Semipalmated Sandpipers nest where graminoid meadow mixes with drier rocky areas. Wheatears were seen hovering over these meadows often, and Cliff Swallows and Marsh Hawks use these as foraging areas.

Prostrate Scrub Hummocks - Wet Graminoid Meadow Complex

Lapland Longspurs are abundant nesters in this habitat. Whimbrels and American Golden Plovers use this habitat to feed young hatchlings during July, and Long-tailed Jaegers (Photo 3) forage here.

Dry Upland Fellfield Barren

Fellfields are used by Water Pipits, Horned Larks, Rock Ptarmigan, and Wheatears near the high rugged central portion of the range. American Golden Plovers were found on the small exposed fellfield areas in the rolling upland tundra.

Dry Lichen Upland Rock Barren

Gray-crowned Rosy Finches are by far the most abundant birds in this habitat; many individuals were seen at even the highest elevations of the range. Other birds occasionally seen on rock barrens included the Water Pipit, Rock Ptarmigan, and Wheatear.

Cliffs and Tors

These bedrock outcrops are important as potential nesting habitat for a number of birds, including the Cliff Swallow, Say's Phoebe, Common Raven, Golden Eagle, Gyrfalcon, Rough-legged Hawk, and sometimes the Water Pipit and Gray-crowned Rosy Finch. Where trees are absent, American Robins may use tor ledges for nest sites.

Rivers, Streams, and Alluvial Bars

Almost all streams encountered within the Ray Mountains are shallow. Away from the central mountains, however, many become deep enough potentially to support swimming birds.

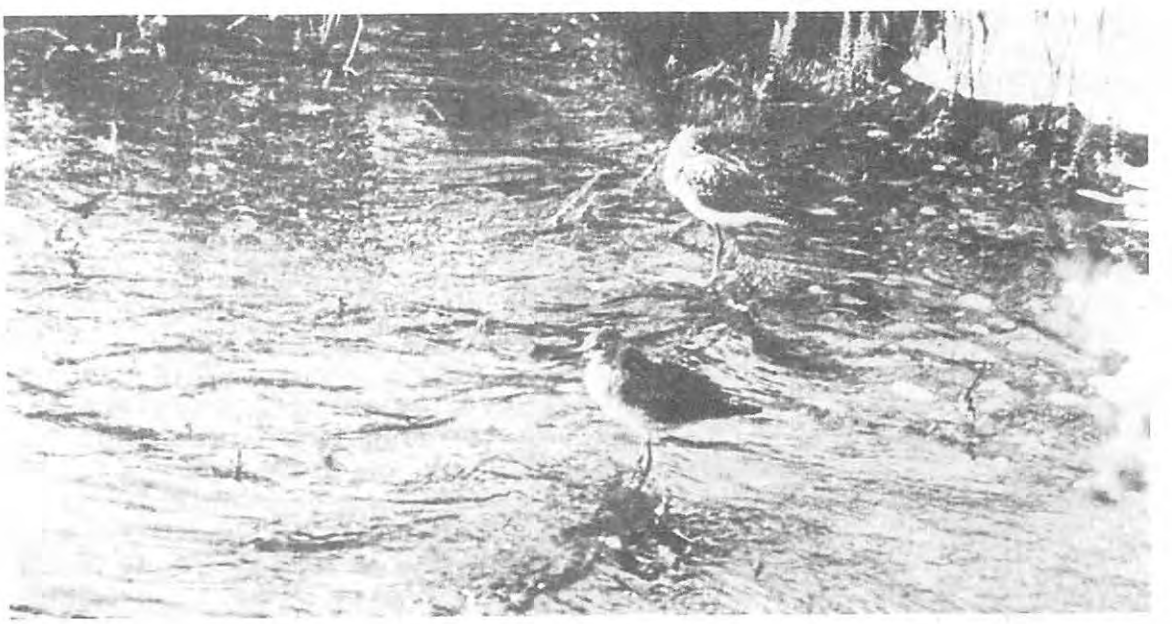
Alluvial bars are primary nesting habitats for Spotted Sandpipers and Wandering Tattlers. Water Pipits and Willow Ptarmigan were seen foraging at the water edge.

Lakes and Shorelines

Lake 1485 was the study area's only non-flowing body of water visited supporting a population of waterfowl. It is surrounded by a narrow strip of emergent vegetation in most places. Flocks of Surf Scoters and Oldsquaws were resident on this lake, and Scaups and possibly Common Loons seemed to be resident also. Particularly notable are the migratory species associated with this lake -- Lesser Yellowlegs (Photo 4), Mallards, a Mew Gull, and a large flock of Northern Phalaropes were observed in this area during their migration south.

Photo 3. Long-tailed Jaegers (Stercorarius longicaudus) are common in the Ray Mountains and frequently hunt over lowland tundra habitats. They are aggressive predators and frequently rob the nests of other tundra birds.

Photo 4. Lesser Yellowlegs (Tringa flavipes) are among the migratory species that stop over in the Ray Mountains. Like these, most migratory birds were seen at lake 1485.



Avifaunal Zonation

Figure 1 indicates species distribution throughout the study area. In general, sighting localities are listed following a 50 km southeast to northwest transect across the Ray Mountains (Fig. 2). This sequence incorporates the transitions in topography and communities through the Ray Mountains, starting near a forested area at treeline (1), continuing through rolling tundra lowlands (2, 3) into upper elevation tundra and central rugged mountain barrens (4 - 8), and back again through lowland tundra (9, 12) to the fingers of forest in the north that follow drainages into the higher country (10, 11).

As Fig. 1 illustrates, the distribution of birds can be grouped into somewhat recognizable zones based on elevation. Although each locality encompasses a variety of habitats, trends can be detected. Some species are restricted to lower elevation forests on the periphery of the study area, others to lower elevation tundra, and still others to the higher alpine areas within the central mountains. Some species are intermediate in nature, ranging over a wide variety of tundra habitats. Finally, some are found in all areas of the range excluding the highest peaks. These zones seem to correlate with the ecosystems recognized by Schubert (this volume).

Areas of Concentrated Study

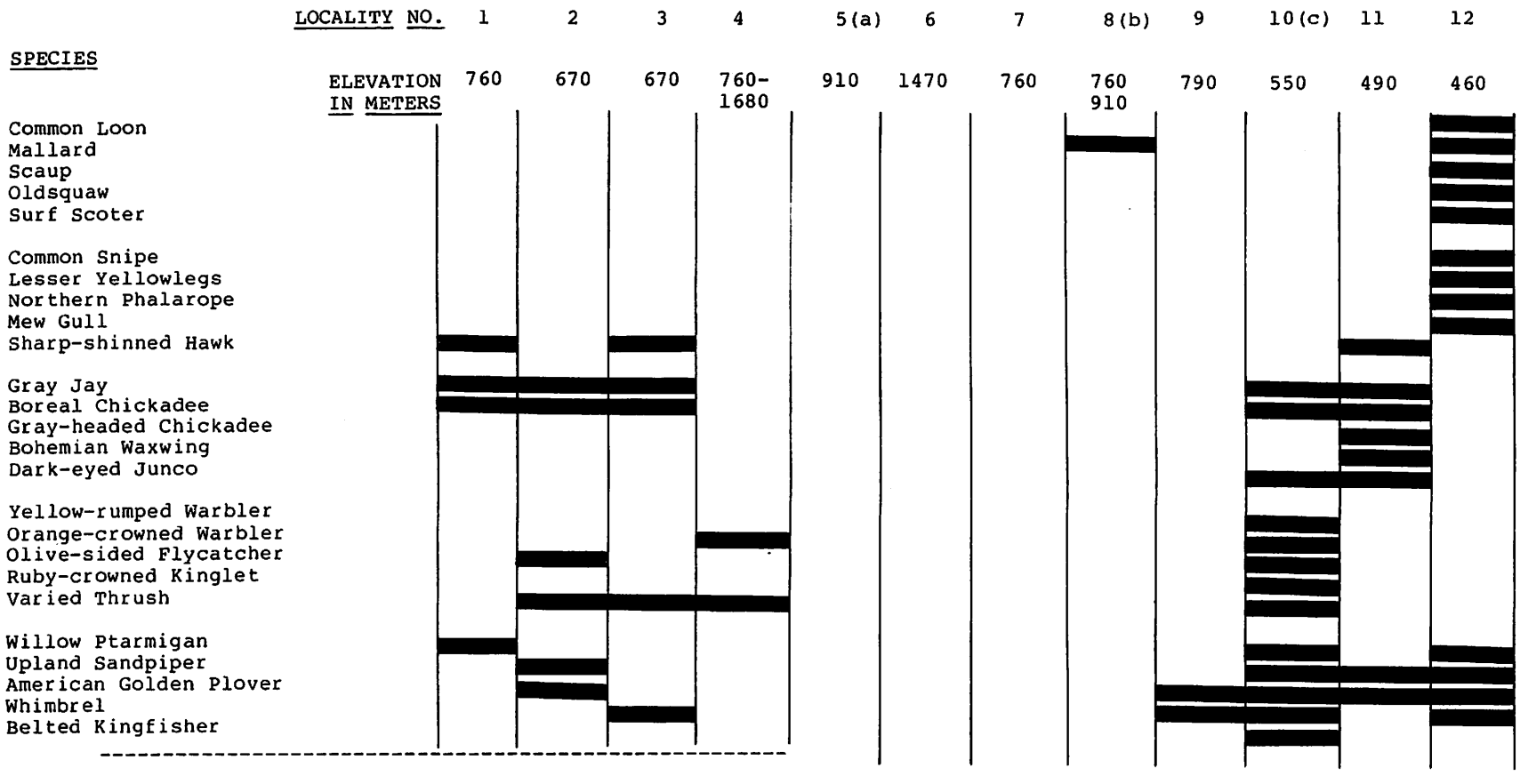
Although a large area was covered during the 1979 field season, most avian data collection occurred in three areas -- in Spooky Valley (RMP site IVa), in upper Torment Creek (RMP site IIc), and in lower Torment Creek (RMP site IIb), where many detailed counts were made. They are discussed in detail here as areas representative of the avifaunal zones presented above.

Spooky Valley

Spooky Valley is a broad upper elevation valley, surrounded on all sides by high rugged mountains. It includes a variety of upland tundra habitats, but is well above the limit of trees and of Tall Scrub areas.

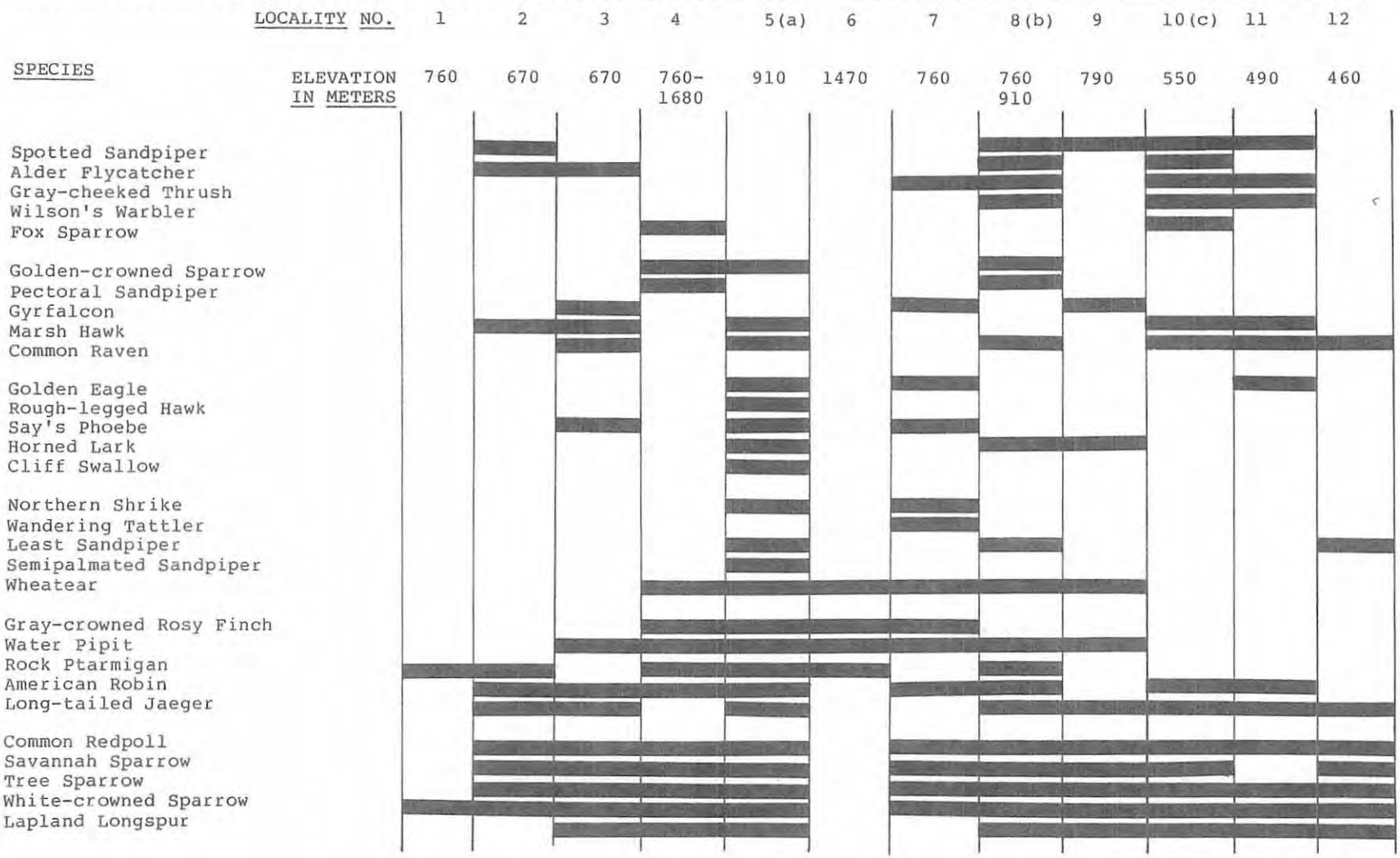
This area was visited on three separate occasions. The northeastern headwall was skirted on 29 June during the initial hike to basecamp. I returned to this valley for more detailed study between 7 and 11 July, when additional areas were explored. A final trip was made between 7 and 10 August, when much of the area studied during the second trip was reviewed to note any changes. The area most extensively studied for birds was between 792-1372 m (2600-4500 ft) elevation in the area east of the middle fork of Kobuk Creek.

Fig. 1. Avifaunal zonation in the Ray Mountains study area. Localities correspond to those shown in Fig. 2. The localities are arranged corresponding to a transect across the mountains from southeast to northwest. Solid line indicates presence of a species in the study area.



(a) -- see detailed profile of Spooky Valley (this chapter).
(b) -- see detailed profile of upper Torment Creek.
(c) -- see detailed profile of lower Torment Creek.

Fig. 1 continued



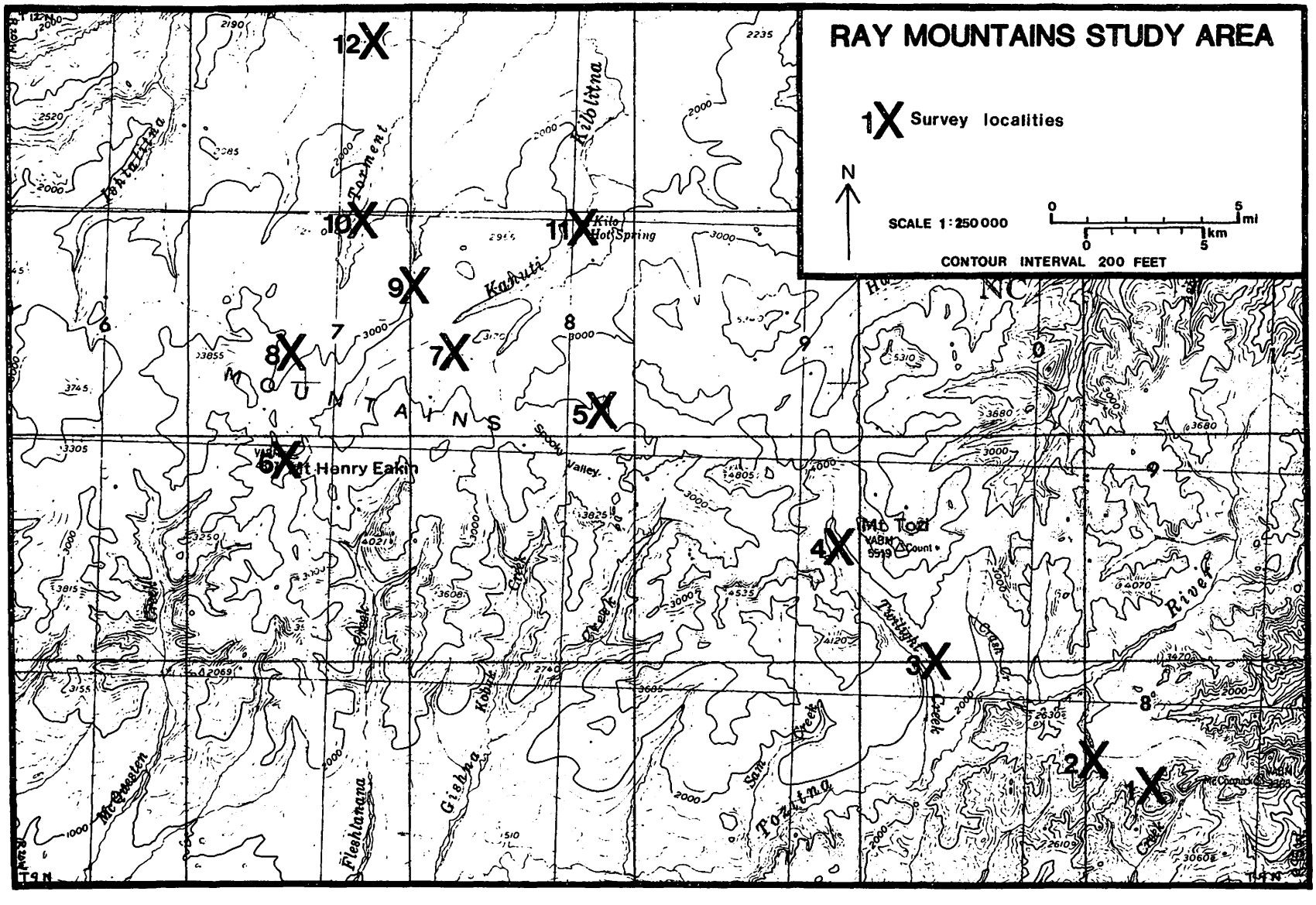


Fig. 2. Localities surveyed to determine bird species distribution in the study area (see Fig. 1).

Figure 3 depicts a schematic profile of the area's topography along with bird habitats and associated bird species, which are listed in descending order of relative abundance. Table 4 outlines the relative abundance calculations of species occurring in those habitats, based on transect data from both the July and the August trips. Relative abundance of a species is calculated as the number of individuals of that species divided by the total number of individuals in that habitat (Manuwal 1974).

For ornithological study, Spooky Valley presents an interesting mix of characteristics. Because it includes alpine areas, it harbors many typical alpine birds such as Rock Ptarmigan, Horned Larks, Wheatears, Water Pipits, Gray-crowned Rosy Finches, and Golden-crowned Sparrows. It is also a wide valley, and the gently sloping areas of tussock-shrub tundra and small shrub thickets attract the more universal tundra species such as Marsh Hawks, Long-tailed Jaegers, American Robins, Common Redpolls, Savannah Sparrows, and Lapland Longspurs. A fairly large Wet Graminoid Meadow found in Spooky Valley provides habitat for Least and Semipalmated Sandpipers. The many tors support bird species that require cliffs, namely Golden Eagles, Say's Phoebes, and Cliff Swallows.

Although many of these species were found in other parts of the Ray Mountains, nowhere else is there such a rich association of birds representing so many different physiognomic elements. Semipalmated Sandpipers and Cliff Swallows were found only in Spooky Valley, and the only Golden Eagles and Northern Shrikes seen during the study were in Spooky Valley or areas nearby.

The routes walked in early July were revisited during early August for observation of possible significant changes in the avifauna. As expected, bird numbers and species diversity had decreased in the valley, because many species had completed breeding and begun to migrate. Sparrows (most of them juveniles) dominated the avifauna to a greater extent, with many sparrow flocks beginning to form. No sandpipers, Say's Phoebes, male Wheatears, or Lapland Longspurs were seen during the August trip, and the number of Cliff Swallows had significantly decreased. Northern Shrikes were seen in August for the first time.

Upper Torment Creek

Upper Torment Creek (RMP site IIc) is alpine in nature; slopes are steep on three sides and support varying amounts of Dry Upland Prostrate Scrub or Dry Lichen Upland Rock Barren. Medium Scrub occurs only along drainageways, the predominant woody plant growth being Dwarf Scrub.

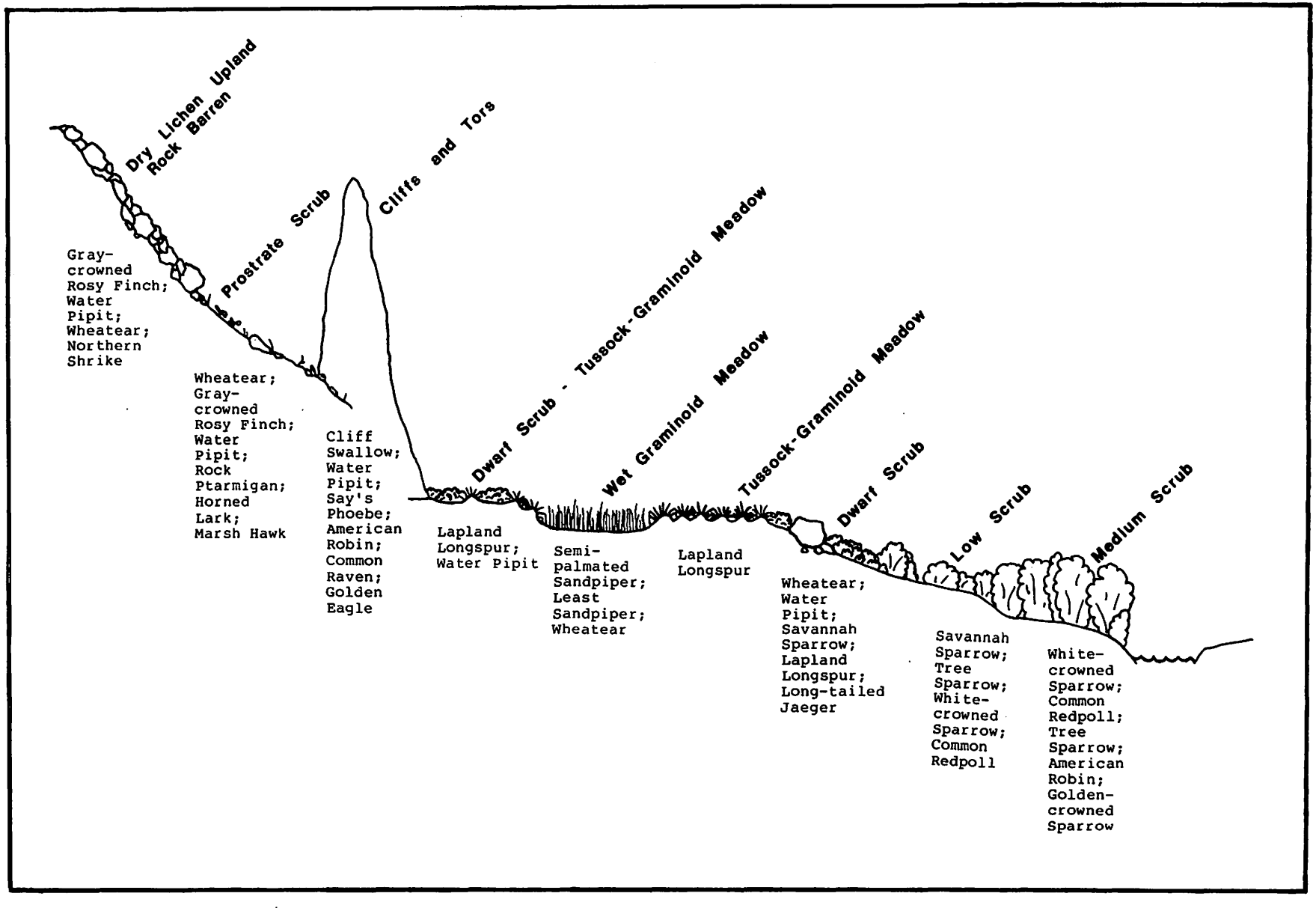


Fig. 3. Schematic profile of Spooky Valley showing topography, habitat types, and relative abundance of bird species in each habitat.

Table 4. Relative abundance (R) of bird species occurring in Spooky Valley (RMP site IVa), arranged by habitat.

HABITAT / species	(n) R	HABITAT / species	(n) R
MEDIUM SCRUB	(29)	DWARF SCRUB-TUSSOCK GRAMINOID MEADOW	(11)
White-crowned Sparrow	.448	Lapland Longspur	.545
Common Redpoll	.241	Water Pipit	.455
Tree Sparrow	.138		
American Robin	.103	TUSSOCK GRAMINOID MEADOW	(2)
Golden-crowned Sparrow	.069	Lapland Longspur	1.00
LOW SCRUB	(22)		
Savannah Sparrow	.545		
Tree Sparrow	.318	WET GRAMINOID MEADOW	(16)
White-crowned Sparrow	.091	Semipalmated Sandpiper	.438
Common Redpoll	.045	Least Sandpiper	.375
Cliff Swallow	+	Wheatear	.188
		Cliff Swallow	+
DWARF SCRUB	(47)		
Wheatear	.383	DRY LICHEN UPLAND ROCK BARREN	(18)
Water Pipit	.340	Gray-crowned Rosy Finch	.500
Savannah Sparrow	.234	Water Pipit	.222
Lapland Longspur	.021	Wheatear	.222
Long-tailed Jaeger	.021	Northern Shrike	.056
Cliff Swallow	+		
PROSTRATE SCRUB	(39)	CLIFFS AND TORS	(90)
Wheatear	.308	Cliff Swallow	.711
Gray-crowned Rosy Finch	.282	Water Pipit	.156
Water Pipit	.282	Say's Phoebe	.056
Rock Ptarmigan	.077	American Robin	.033
Horned Lark	.026	Common Raven	.022
Marsh Hawk	.026	Golden Eagle	.022

Study of the avifauna of this area was conducted from 24 - 30 July, fairly late in the season. Thus, no records were made of species of birds which may have inhabited this area earlier. This may be particularly important in the Wet Graminoid Meadow in the upper reaches of the valley.

Figure 4 depicts a schematic profile of the valley along with bird habitats present and associated bird species, which are listed in descending order of relative abundance. Table 5 outlines the relative abundance calculations of species occurring in those habitats. The data obtained nearby from Mt. Henry Eakin were used for the Dry Lichen Upland Rock Barren habitat.

Shrub density of Medium and Low Scrub habitats in upper Torment Creek varies considerably from drainages to more upland locations. Medium and low shrubs are very dense in mesic areas near running water, but were often sparse and within scattered graminoid patches on the drier uplands. This seems to affect bird species distribution. Although Tree Sparrows are the most common birds in Medium and Low Scrub both adjacent to drainages and on slopes, Savannah Sparrows are restricted to scrubs in upland situations, apparently requiring patches of open graminoid meadow. In contrast, White-crowned Sparrows are abundant in the dense drainageway scrubs, preferring them to the open slopes where these sparrows occur more rarely.

Some bird species were seen in the upper Torment Creek area in uncharacteristic habitats -- for example, a Lapland Longspur was seen on Dry Lichen Upland Rock Barren. This indicates that habitat affinities were beginning to break down, which often happens before migration.

Lower Torment Creek

This portion of the Torment Creek (RMP site IIb) drainage is between 503-671 m (1650-2200 ft) elevation and includes extensive areas of tussock-shrub tundra, some shrub thickets, and the uppermost extent of forest.

Because basecamp was located in the lower Torment Creek area, this area was studied intensively during the field season. Detailed observations were recorded in this area on 1-3, 18-23, and 30 July, and 5 August; miscellaneous notes were taken on 4-6, 12-14, 17, and 24 July and 1-4 and 6 August. The forest areas were not extensively studied; the first observations in the forest at Torment Creek were made fairly late in the season (18 July), and only three subsequent days were spent studying those habitats.

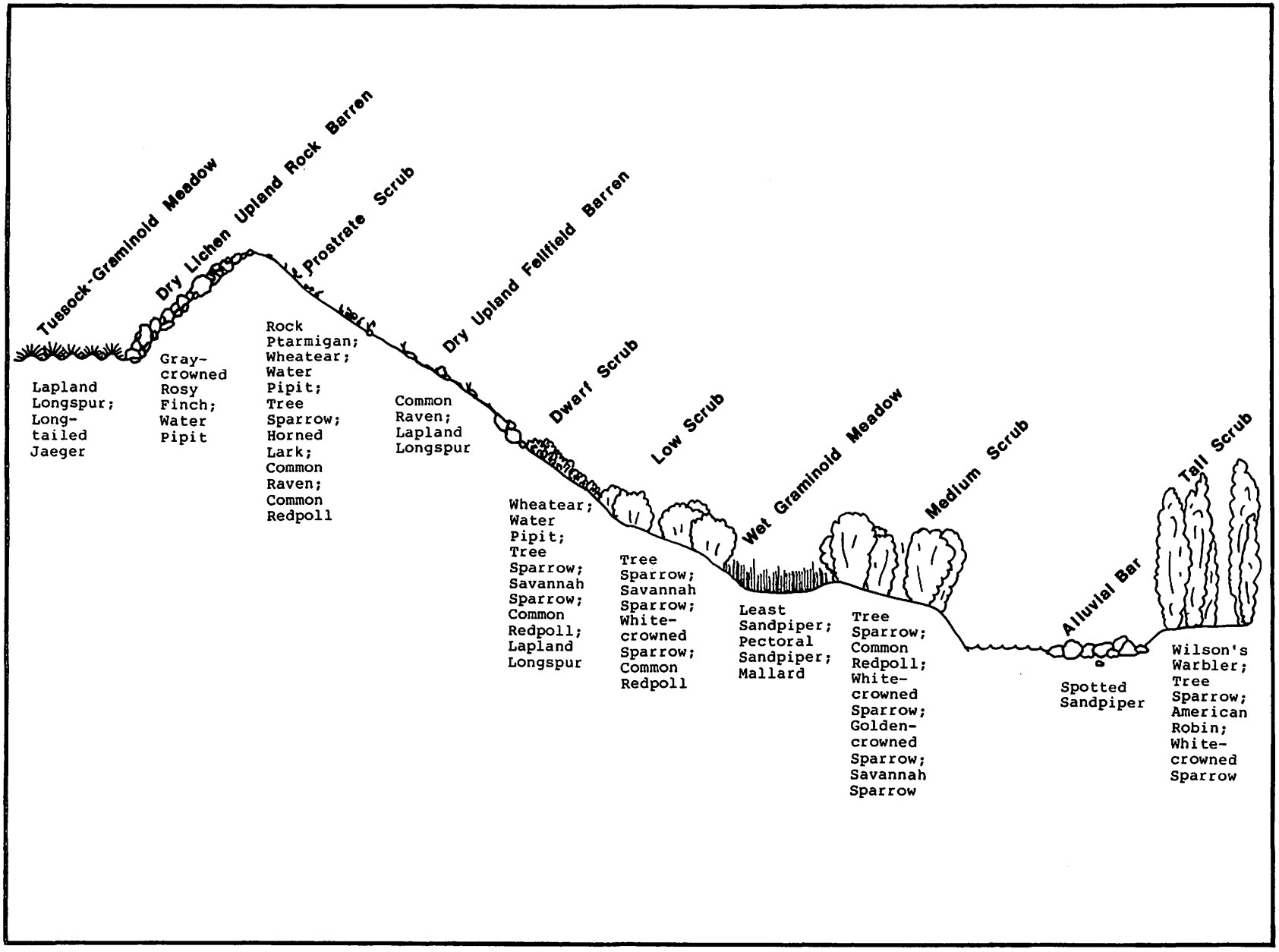


Fig. 4. Schematic profile of the upper Torment Creek area (including Mt. Henry Eakin) showing topography, habitat types, and relative abundance of bird species in each habitat.

Table 5. Relative abundance (R) of bird species in upper Torment Creek (RMP site IIc), arranged by habitat.

HABITAT / species	(n) R
TALL SCRUB	(12)
Wilson's Warbler	.417
Tree Sparrow	.333
American Robin	.167
White-crowned Sparrow	.083
MEDIUM SCRUB	(69)
Tree Sparrow	.464
Common Redpoll	.217
White-crowned Sparrow	.217
Golden-crowned Sparrow	.058
Savannah Sparrow	.043
LOW SCRUB	(86)
Tree Sparrow	.512
Savannah Sparrow	.319
White-crowned Sparrow	.151
Common Redpoll	.081
DWARF SCRUB	(13)
Wheatear	.231
Water Pipit	.231
Tree Sparrow	.154
Common Redpoll	.154
Savannah Sparrow	.154
Lapland Longspur	.077
PROSTRATE SCRUB	(59)
Rock Ptarmigan	.339
Wheatear	.254
Water Pipit	.237
Tree Sparrow	.068
Horned Lark	.051
Common Raven	.034
Common Redpoll	.017
TUSSOCK GRAMINOID MEADOW	(3)
Lapland Longspur	.667
Long-tailed Jaeger	.333
WET GRAMINOID MEADOW	(6)
Least Sandpiper	.500
Pectoral Sandpiper	.333
Mallard	.167
DRY UPLAND FELLFIELD BARREN	(2)
Lapland Longspur	.500
Common Raven	.500
DRY LICHEN UPLAND ROCK BARREN	(50)
Gray-Crowned Rosy Finch	.800
Water Pipit	.200
ALLUVIAL BAR	(1)
Spotted Sandpiper	1.00

A schematic profile of this drainage is depicted in Fig. 5. This figure outlines the habitat types within this area and the associated bird species listed in descending order of relative abundance. Table 6 shows the relative abundance indices for bird species in these habitats.

Study of the Torment Creek watershed and adjacent Mt. Henry Eakin provided a representative sampling of a cross-section of the spectrum of Ray Mountains habitats. In this watershed, the influence of elevation and habitat on the occurrence of bird species was observed. Birds that are restricted to the forest habitats or the surrounding dense shrub thickets are Olive-sided Flycatchers, Gray Jays, Boreal Chickadees, Varied Thrushes, Ruby-crowned Kinglets, Orange-crowned Warblers, Yellow-rumped Warblers, and Dark-eyed Juncos. Along with the ubiquitous sparrows, other species including American Robins, Gray-cheeked Thrushes, and Wilson's Warblers extended their range beyond the forest into the tundra areas; these were found well into the upper reaches of the watershed. Alder Flycatchers are restricted to very dense stands of Tall Scrub. Wilson's Warblers follow the Tall Scrub community to its highest elevation, and are present even in the sparsest and patchiest of this community near its upper limit. Gray-cheeked Thrushes follow the Tall Scrub habitat high up into the watershed also, but are no longer found where the tall shrubs thin out to less than "thickets."

The more universal tussock-shrub tundra species were found on the tundra slopes bordering Torment Creek. These birds include Willow Ptarmigan, American Golden Plovers, Whimbrels, Upland Sandpipers, Long-tailed Jaegers, Marsh Hawks, Lapland Longspurs, Common Redpolls, and Tree, White-crowned, and Savannah Sparrows.

The headwaters area supports characteristically alpine species such as Rock Ptarmigan, Horned Larks, Wheatears, Water Pipits, and Gray-crowned Rosy Finches.

Species of Interest

Raptors

The presence of raptors in the north depends on microtine rodent populations and availability of suitable nestsites. During the summer of 1979, trapping in the Ray Mountains showed that some tundra microtine populations were low in the portion of the study area above treeline (Armstrong and Halpin, this volume). For this reason, presumably, few raptors were observed and only scattered evidence of breeding was encountered.

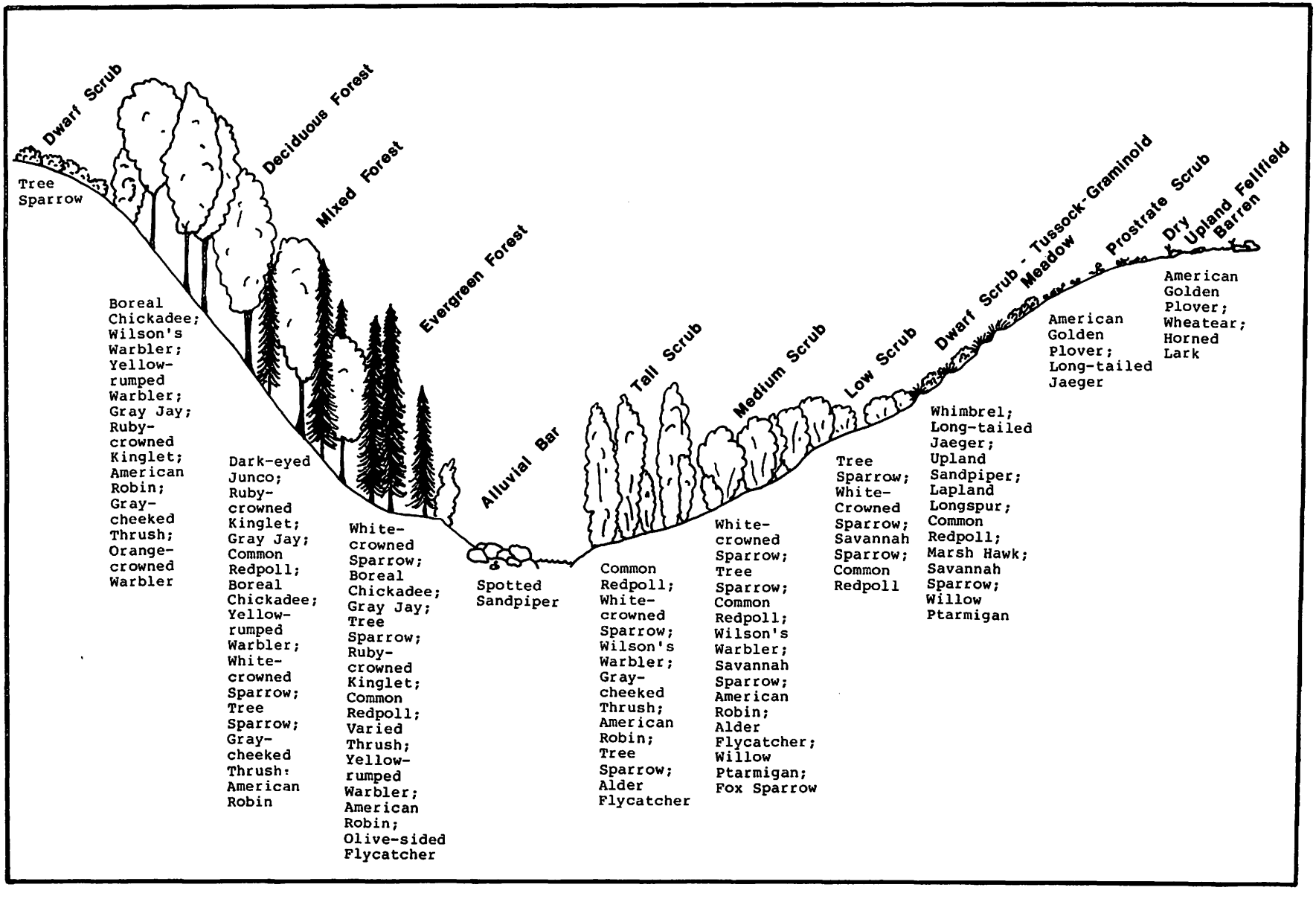


Fig. 5. Schematic profile of the lower Torment Creek area showing topography, habitat types, and relative abundance of bird species in each habitat.

Table 6. Relative abundance (R) of bird species occurring in lower Torment Creek (RMP site IIb), arranged by habitat.

HABITAT / species	(n) R
EVERGREEN FOREST	(104)
White-crowned Sparrow	.452
Boreal Chickadee	.154
Gray Jay	.096
Tree Sparrow	.087
Ruby-crowned Kinglet	.077
Common Redpoll	.048
Varied Thrush	.038
Yellow-rumped Warbler	.019
American Robin	.019
Olive-sided Flycatcher	.010
DECIDUOUS FOREST	(27)
Boreal Chickadee	.370
Wilson's Warbler	.259
Yellow-rumped Warbler	.148
Gray Jay	.074
Ruby-crowned Kinglet	.037
American Robin	.037
Gray-cheeked Thrush	.037
Orange-crowned Warbler	.037
MIXED FOREST	(63)
Dark-eyed Junco	.333
Ruby-crowned Kinglet	.159
Gray Jay	.159
Common Redpoll	.111
Boreal Chickadee	.095
Yellow-rumped Warbler	.048
White-crowned Sparrow	.032
Tree Sparrow	.032
Gray-cheeked Thrush	.016
American Robin	.016
TALL SCRUB	(64)
Common Redpoll	.219
White-crowned Sparrow	.172
Wilson's Warbler	.172
Gray-cheeked Thrush	.141
American Robin	.125
Tree Sparrow	.109
Alder Flycatcher	.063
MEDIUM SCRUB	(136)
White-crowned Sparrow	.500
Tree Sparrow	.243
Common Redpoll	.132
Wilson's Warbler	.044
Savannah Sparrow	.029
American Robin	.029
Alder Flycatcher	.007
Willow Ptarmigan	.007
Fox Sparrow	.007
LOW SCRUB	(20)
Tree Sparrow	.500
White-crowned Sparrow	.250
Savannah Sparrow	.200
Common Redpoll	.050
DWARF SCRUB	(3)
Tree Sparrow	1.00
PROSTRATE SCRUB	(11)
American Golden Plover	.636
Long-tailed Jaeger	.364
DWARF SCRUB-TUSSOCK GRAMINOID MEADOW	(30)
Whimbrel	.300
Long-tailed Jaeger	.200
Upland Sandpiper	.133
Lapland Longspur	.133
Common Redpoll	.100
Marsh Hawk	.067
Savannah Sparrow	.033
Willow Ptarmigan	.033
DRY UPLAND FELLFIELD BARREN	(7)
American Golden Plover	.571
Wheatear	.286
Horned Lark	.143
ALLUVIAL BAR	(4)
Spotted Sandpiper	1.00

Suitable raptor nesting habitat on cliffs and tors occurs extensively throughout the upland areas. One inactive nest was seen on a tor ledge near Spooky Valley, a find that may indicate at least a slightly greater breeding density of raptors during certain years.

The absence of Short-eared Owls may have been due to low tundra microtine populations within the study area.

Species of Biogeographic Interest

Upland Sandpiper. Bartramia longicauda.

In interior Alaska, this bird is an uncommon to fairly common breeder locally in the Wrangell Mountains, the Alaska Range, and the Brooks Range (Kessel and Gibson 1978). A few summer records (Kessel and Springer 1966) from the Yukon-Tanana Uplands suggest breeding, but no concrete evidence was established. The occurrence of breeding Upland Sandpipers in the Ray Mountains adds another breeding record for this species. It indicates that this bird does breed in smaller interior mountain ranges, not just in the major Alaskan mountain chains, and also increases the likelihood that this species is a breeder in the Yukon-Tanana Uplands.

Gray-crowned Rosy Finch. Leucosticte tephrocotis.

By coloration this population is probably part of the race (L. tephrocotis tephrocotis) that extends west into the Brooks Range and through the Yukon-Tanana Uplands (Gabrielson and Lincoln 1959; Johnson 1973) rather than the population found south of the Tanana River. According to Johnson (1973), this species occurs only sparingly west of Anaktuvuk Pass, and is restricted to the most rugged locations. Its occurrence in the Ray Mountains constitutes a southwestern range boundary for this race in interior Alaska north of the Yukon River.

Golden-crowned Sparrow. Zonotrichia atricapilla.

This bird is presently listed as a rare migrant in central Alaska and throughout the Brooks Range, and is considered a rare breeder or probable breeder in the major mountain systems, namely the Talkeetna Mountains, Alaska Range, and the south side of the Brooks Range into western Alaska (Kessel and Gibson 1978). The discovery that the Golden-crowned Sparrow is a probable breeder in the Ray Mountains extends the range of this species to a more central limit within interior Alaska.

Winter-resident Species

This study was conducted during the summer season only, and its findings include only the birds present during that season. Although some migrating species were observed, little is known about the importance of the Ray Mountains to birds

migrating to and from other points in Alaska during the spring and fall.

There are few bird species that over-winter in interior Alaska (Irving 1960). The species observed in the study area that may remain in residence during winter include the Gyrfalcon, Willow and Rock Ptarmigan, Common Raven, Gray Jay, Gray-headed Chickadee, Boreal Chickadee, Bohemian Waxwing, and Common Redpoll. Most of these birds probably move into lower elevation forests on the periphery of the mountains during the coldest months.

Species Expected But Not Seen

A few significant species of birds merit mention here because of their conspicuous absence from the Ray Mountains. The Ray Mountains are within the expected range of these species and also presumably host suitable habitats, yet the species were not seen in the study area. Whether these birds were in fact absent from the study area or whether they were simply overlooked is not known. The following distribution information has been compiled from Gabrielson and Lincoln (1959) and Kessel and Gibson (1978), along with the findings of Bee (1958), Campbell (1968), Dean (1974), Hines (1963), Irving (1960), Irving and Paneak (1954), Kessel and Cade (1958), Kessel and Gibson (1974), Kessel and Schaller (1960), Maher (1959), Manuwal (1974), and Williamson et al. (1966).

Red-breasted Merganser. Mergus serrator.

This bird is distributed throughout interior Alaska, especially along the length of the Yukon River and its major tributaries, and has been found near deep rivers or lakes throughout the Brooks Range. It is possible that this species is present along the deeper rivers in the Ray Mountains (for example the Tozitna and Kanuti-Kilolitna Rivers) but was not seen because of low densities.

Merlin. Falco columbarius.

This raptor is considered common throughout the Yukon River valley area. Its range is believed to extend into the Brooks Range, primarily following forest areas, despite its habit of hunting in open country.

Short-eared Owl. Asio flammeus.

This tundra bird can be found throughout the tundra areas of Alaska, especially from the Seward Peninsula and Cape Thompson areas, across the Brooks Range, to the Sheenjek River area. Surprisingly, none were seen in the tundra areas of the Ray Mountains, a situation that may be due in part to the relatively low populations of small tundra mammals in the area.

Northern Three-toed Woodpecker. Picoides tridactylus.

This woodpecker can usually be found with spruce forest in the mainland of Alaska, all the way to treeline; it is especially abundant in the Yukon valley. That this woodpecker was not seen within the Ray Mountains area is probably due to the study team's short time spent in forest habitats. N. Farquhar reported hearing the hollow tapping of a woodpecker, probably a Northern Three-toed Woodpecker, in bottomland mixed forest in the Ishtalitna Creek valley.

Dipper. Cinclus mexicanus.

Dippers are rarely seen in northern Alaska, probably due to their inconspicuous habits and low densities. Dippers could reside in the Ray Mountains, for the area is well within their range. Murie reported seeing overwintering Dippers in the neighboring Kokrines Hills (Gabrielson and Lincoln 1959), and Dippers occur regularly along the Yukon valley at least to treeline. Numerous clear running streams in the Ray Mountains would seem to provide optimal habitat.

Arctic Warbler. Phylloscopus borealis.

This Old World warbler is distributed throughout western Alaska, and it has been recorded as far east as Anaktuvuk Pass and the Colville River. Preferring shrub thickets within tussock-shrub tundra, it would find abundant suitable habitat in the study area. Chances are slim that it could have been overlooked had it indeed been present in the areas visited.

Yellow Warbler. Dendroica petechia.

The Ray Mountains may be outside the range of this warbler, but a record of this species from Bettles (Gabrielson and Lincoln 1959) indicates that they have been found in this vicinity.

Blackpoll Warbler. Dendroica striata.

This species was expected to be common in the Ray Mountains (S.B. Young and B. Kessel, pers. comm.), but was not found during our study. It is reportedly found throughout interior Alaska at least to treeline. Whether this species was at a low population level, or whether its habitat requirements are not present in the Ray Mountains, is unknown. The absence of Yellow Warblers, Blackpoll Warblers, Northern Waterthrushes, and Rusty Blackbirds within the area is interesting, because all these species are normally associated with dense tall shrub thickets. They may prefer denser thickets than those that occur in the Ray Mountains.

Northern Waterthrush. Seiurus noveboracensis.

This is another species that was not found in the Ray Mountains, even though it is expected in any wooded section of Alaska from treeline in the Brooks Range south into the interior.

Rusty Blackbird. Euphagus carolinus.
Although this is primarily a taiga species, it characteristically extends its range a bit beyond the spruce into peripheral tundra areas.

Pine Grosbeak. Pinicola enucleator.
The Ray Mountains are well within the range of this species. This species may have not been encountered because we spent little time in the denser forest areas.

White-winged Crossbill. Loxia leucoptera.
This bird is a resident of the forested regions south of the Brooks Range and, like the Pine Grosbeak, may have been missed because of the study team's limited time in forest areas.

Smith's Longspur. Calcarius pictus.
Although this species is uncommon west of Anaktuvuk Pass, it can be found as far west as Chandler Lake and the headwaters of the Noatak River, and is reportedly "not uncommon" in the nearby White Mountains (Blackwelder 1919).

Snow Bunting. Plectrophenax nivalis.
This bird probably would not have escaped notice if present in the Ray Mountains; its conspicuous color would have been spotted by study team members in appropriate habitats in the high central mountains. It is surprising, however, that Snow Buntings would not be present within the Ray Mountains, for they are found in the Alaska and Brooks Ranges and throughout the high mountains of the Yukon-Tanana Uplands, including Eagle Summit.

Biogeographical Considerations

The Ray Mountains lie in the Nearctic Region. Three major faunal elements, however, are represented in this mountain range, according to the system outlined by Fay and Cade (1959) and Kessel and Gibson (1974): 1) Panboreal, with birds that occur regularly in the arctic and north temperate zone of both Eurasia and North America; 2) North American, with birds having primary affinities to North America alone; and 3) Aleutican, with birds that differentiated in the Bering Sea region under the influences caused by the changing states of the Bering Land Bridge.

The Panboreal and North American elements are most strongly represented in the Ray Mountains. Many species found in the study area are common to both the New and Old Worlds or have close relatives in the Old World, including the Oldsquaw, Rough-legged Hawk, Golden Eagle, Gyrfalcon, Willow and Rock Ptarmigan, Whimbrel, Long-tailed Jaeger, Mew Gull, Common Raven, Gray-cheeked Thrush, Wheatear, Water Pipit, and Common Redpoll (Fay and Cade 1959; Manuwal 1974). The Wandering

Tattler, Pectoral Sandpiper, and Lapland Longspur were the only three species seen in the Ray Mountains that represent the Aleutican avifaunal element (Fay and Cade 1959; Kessel and Gibson 1974).

From an ecological viewpoint, the Ray Mountains are an upland tundra island surrounded by boreal forest. The avifauna, therefore, is one of a tundra region influenced by the relatively richer avifauna of the taiga. Table 7 lists the primary ecological affinities of the birds seen in the study area, based on their total breeding distributions in the north (Kessel and Cade 1958; Kessel and Gibson 1974; Manuwal 1974). Eleven of the 55 species sighted during this study were not included in this discussion because they were migrants or were of questionable status in the range.

The Ray Mountains avifauna shows many ecotonal characteristics. Of the 44 species considered, 14 (30%) show a primary affinity with the Taiga Biome (Table 7). Four of these taiga species were found above treeline. Seven species (16%), including the most abundant birds found in the study area, are species characterictic of sub-climax coniferous vegetation. These species are often found at the tundra-taiga interface. Roughly 40% of the species are tundra or alpine tundra (montane) birds, half of which are strictly montane species.

A comparison of the number of species found in the Ray Mountains with other areas in northern Alaska is shown in Table 8. The highest numbers of recorded species are from coastal areas or areas used as major migratory pathways. Compared to similar areas of the Brooks Range, the Ray Mountains show a comparable or slightly richer avifauna, probably owing to the influence of the taiga species.

Summary and Suggestions for Further Research

Fifty-five bird species were encountered in the Ray Mountains during this investigation. This count is incomplete; further study in the area will add more species to this list, especially during spring and fall migrations. More thorough study of the forest within the range will also supplement this list with the richer avifauna present in forest habitats.

The geographic position of the Ray Mountains makes them an interesting area -- not only are they one of the few upland areas within the boreal forest that dominates interior Alaska, but they are situated midway between Alaska's major mountain systems, the Brooks and Alaska Ranges.

As this study has shown, a few species found primarily

Table 7. Bird species occurring in the Ray Mountains (from mid-June to mid-August), arranged by ecological affinity.

TUNDRA	MONTANE	WIDESPREAD
Oldsquaw	Golden Eagle	Marsh Hawk
Rough-legged Hawk	Gyrfalcon	Spotted Sandpiper
Willow Ptarmigan	Rock Ptarmigan	Common Raven
American Golden Plover	Wandering Tattler	Say's Phoebe
Whimbrel	Horned Lark	American Robin
Semipalmated Sandpiper	Wheatear	Cliff Swallow
Long-tailed Jaeger	Water Pipit	
Golden-crowned Sparrow	Gray-crowned Rosy Finch	
Lapland Longspur		

TAIGA	TAIGA BIRDS FOUND ABOVE TREELINE IN RAY MOUNTAINS	TAIGA/TUNDRA INTERFACE
Surf Scoter	Surf Scoter	Upland Sandpiper
Sharp-shinned Hawk	Least Sandpiper	Gray-cheeked Thrush
Least Sandpiper	Alder Flycatcher	Common Redpoll
Alder Flycatcher	Wilson's Warbler	Savannah Sparrow
Olive-sided Flycatcher		Tree Sparrow
Gray Jay		White-crowned Sparrow
Boreal Chickadee		Fox Sparrow
Varied Thrush		
Ruby-crowned Kinglet		
Bohemian Waxwing		
Orange-crowned Warbler		
Yellow-rumped Warbler		
Wilson's Warbler		
Dark-eyed Junco		

SPECIES NOT INCLUDED IN CONSIDERATION
Common Loon
Mallard
Scaup
Common Snipe
Lesser Yellowlegs
Pectoral Sandpiper
Northern Phalarope
Mew Gull
Belted Kingfisher
Gray-headed Chickadee
Northern Shrike

Table 8. Number of bird species found in Ray Mountains and nearby areas.

Source	Area	No. of Species	Number Breeding
Matthews 1980	Ray Mountains	55	26
Bee 1958	Brooks Range	38	1
Campbell 1968	Chandler Lake	54	
Hines 1963	Upper Noatak River	83	
Irving & Paneak 1954	Howard Pass	48	18
Irving 1960	Anaktuvuk Pass	106	59
Kessel & Cade 1958	Colville River	87	52
Kessel & Gibson 1974	Chukchi-Imuruk	108	66
Kessel & Schaller 1960	Sheenjek	86	
Manuwal 1974	Noatak River	119	89

only in Alaska's major mountains chains were also found in the Ray Mountains. The presence of Upland Sandpipers, Gray-crowned Rosy Finches, and Golden-crowned Sparrows in the Ray Mountains fills a gap in the previously known distributions of these species within Alaska.

The Ray Mountains are very diverse, including BOREAL FOREST, LOWLAND TUNDRA, UPLAND TUNDRA, and ALPINE BARREN ecosystems within a few tens of kilometers. Thus species representative of each of these ecosystems are present, with birds typical of taiga, tundra, and montane habitats.

Within each of these ecosystems are many habitat types. The study area is primarily tundra and contains examples of different tundra habitats, from wet meadows to xeric fellfields. The Ray Mountains do not contain many lakes or extensive marshes, and therefore support far fewer waterfowl or marsh species than some other inland areas of Alaska. As a result, the Ray Mountains support a relatively higher proportion of birds that have a sporadic and limited distribution within interior Alaska, specifically montane species.

As an ecological island (Schubert, this volume), the Ray Mountains provide an ideal setting for ecological study. They are large enough to support populations of predatory birds which may experience yearly population cycles.

More extensive baseline data remain to be collected, including spring breeding bird densities and a more thorough raptor census.

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APPENDIX

Species Accounts

The following accounts include each species observed during the field season. They are primarily accounts of sightings and also include available information on habitat preference, breeding status, phenology, and abundance and distribution of species in the study area.

Abundance terms used in these accounts are of two types: abundance throughout the study area, and abundance within preferred habitats. Abundance within a preferred habitat is listed only when a species is considered common or abundant within that habitat.

Abundant: species repeatedly observed in this habitat with a great many occurring per unit area. Optimum habitat heavily utilized and even marginal habitats occupied.

Common: species observed on many trips, usually occurring in optimum habitat in large numbers, but some areas of suitable habitat occupied sparsely or not at all.

These abundance terms are influenced by the conspicuousness of a given species relative to other species using the same habitat. In addition, the energetic importance of a species is considered; species of a higher trophic level are considered more abundant than their absolute numbers indicate.

Common Loon. *Gavia immer*.

This bird was heard twice during the summer, by other members of the study team. R. Tarlov described this loon's call to me after hearing it at lake 1485 (RMP site IIa) on 13 July; it was later heard by S. Roeske, L. Halpin, I. Burke, and T. Kassler on 1 August, again at lake 1485.

Mallard. *Anas platyrhynchos*.

Mallards were present in the study area as migrants. One female was flushed from an open pond in upper Torment Creek (RMP site IIc) on 29 July; this female then flew down Torment Creek toward lake 1485. On 2 August, six females were seen on lake 1485.

Scaup. *Aythya marila* or *A. affinis*.

Two male scaups were seen on lake 1485 on 4 July. The inland location of the Ray Mountains and the small size of this lake suggest that these were Lesser Scaups, but exact determination of the species was impossible.

Oldsquaw. *Clangula hyemalis*.

This diving duck was uncommon in the study area, observed only at lake 1485. A flock of 10 Oldsquaws was observed on 4 July; on 2 August, two females with three young were observed.

Surf Scoter. Melanitta perspicillata.

This taiga bird was seen only at lake 1485. On 4 July, a flock of 20 males and one female was seen there. Twice in an hour, all the males took to the air simultaneously in a tight flock, circled, and landed on the lake again minutes later. In flight they maintained their tight flock formation and caused a loud air turbulence sound. Through all this, the female remained alone on the lake. On 2 August, the flock was still present, but neither an accurate count nor an accurate assessment of the sex ratio could be made.

Sharp-shinned Hawk. Accipiter striatus.

This accipiter was uncommon in the study area; five individuals were seen in four locations, always in the vicinity of a dense spruce forest though never actually within one. The first sighting was on 28 July, when B. Armstrong reported seeing a pair along the Ishtalitna River (RMP site Vd) in an area of Mixed Forest. He reported that they were both being defensive and that one dove at him. Another was seen on 11 August flying over the Kanuti Kilolitna River near Kilo Hot Springs (RMP ite IIIa). Two more individuals were reported by J. Schubert, one on 12 August flying over Dwarf Scrub - Tussock-Graminoid Meadow near Crash Creek (RMP site VIa) and another on 16 August flying over an open patch of Prostrate Scrub and Tussock-Graminoid Meadow near the forest at the headwaters of Moose Creek (RMP site VIc).

Marsh Hawk. Circus cyaneus.

This non-tundra bird was uncommon in the study area, although it was fairly widespread throughout the mountain range and was common in Dwarf Scrub - Tussock-Graminoid Meadow. It was the raptor most often seen in the study area, usually observed hunting over the broad expanses of rolling lowland tundra and in Spooky Valley (RMP site IVa). Ten individuals were seen during the field season, including both males and females. Only one pair was sighted. On 1 July, N. Farquhar reported being attacked near basecamp by a female Marsh Hawk which he suggests was protecting her nest. No nests or young were seen. From the distribution of sightings it appears that at least six pairs were encountered during the field season, if most observed individuals had mates.

Rough-legged Hawk. Buteo lagopus.

One individual of this species was seen on 10 August in Spooky Valley (RMP site IVa), the only sighting of this species during the summer. It flew from a tor, where it had been perched, down into the valley. The marmots nearby sounded alarm calls.

Golden Eagle. Aquila chrysaetos.

This eagle was rare in the study area; although there were five separate sightings, these may all have been of two individual birds. The first sighting, on 7 July, occurred when a Long-tailed Jaeger was seen circling, then diving,

toward a high tor on a ridge above Spooky Valley. As the jaeger approached the tor, a Golden Eagle, previously concealed among the rocks, opened its wings and glided off across the ridge. On 10 July, an eagle was seen at close range in Spooky Valley; from the amount of white coloration it retained it appeared to be about a two year old bird. On 11 July, L. Halpin, I. Burke, and T. Kassler reported seeing another eagle apparently being harassed by a Gyrfalcon near RMP site IVb. Although the first and third of these sightings were not at close range, and the birds could not be discerned as adults or immatures, I believe that these were all sightings of the same bird. The other sighting of a Golden Eagle was of another immature (third or fourth year) which exhibited considerably less white than the first individual. This bird was seen flying over Kilo Hot Spring (RMP site IIIa) on 15 July.

These two immatures may be outliers of a family of Golden Eagles inhabiting another area of the Ray Mountains. No evidence of nesting was encountered during the summer, although a large inactive raptor nest, which may have been a Golden Eagle's nest, was spotted through a spotting scope on a tor ledge near RMP site IVb.

Gyrfalcon. Falco rusticolis.

Gyrfalcons were rare in the Ray Mountains during this field season. One Gyrfalcon was seen in the vicinity of RMP site IVb on 11 and 12 July. On both days it was heard calling from a tor-lined ridge and was seen flying nearby. It was later seen by L. Halpin, I. Burke, and T. Kassler in this same area, where it reportedly was defensive toward a Golden Eagle. The search for an active nest in this area was unsuccessful.

On 11 August, L. Halpin reported that she saw a large falcon, which she believed was a Gyrfalcon, near Crash Creek (RMP site VIa). J. Schubert also reported hearing a raptor scream the same day.

Willow Ptarmigan. Lagopus lagopus.

This ptarmigan was uncommon in the study area, and was observed far less often than expected. Eakin (1916) reports seeing "countless numbers" of willow ptarmigan near the headwaters of the Kanuti River in 1913, yet our study team encountered no substantial numbers of this species or of ptarmigan in general. The largest group reported was of 15 individuals, seen on 18 July by T. Smith.

These birds preferred shrub thickets near watercourses and were common in Dwarf Scrub - Tussock-Graminoid Meadow. The first young ptarmigan was seen on 12 July by S. Brock, and another family with three young was seen on 14 July by B. Armstrong.

Rock Ptarmigan. Lagopus mutus.

Rock Ptarmigan were common in the study area and were found throughout upper elevation tundra areas. They were commonly found in association with rocky areas of high barren

ridges -- in Dwarf or Prostrate Scrub areas with a significant boulder component or on Dry Upland Fellfield or Dry Lichen Upland Rock Barrens. A few were observed on moister areas of Dwarf Scrub - Tussock-Graminoid Meadow. Even more commonly seen than the ptarmigan themselves were ptarmigan scat, which were found regularly on high rocky areas in the habitats described above. Most individuals were seen singly or in pairs, although two large broods, one of eight individuals (one adult, seven juveniles) and another of six individuals, were seen on 24 July by N. Farquhar and B. Armstrong.

Among the other indirect signs of the presence of this species were numerous carcasses, usually the remains of the legs and feet, found near RMP site IVb and near lake 1485. Some of these carcasses, however, may have been the remains of Willow Ptarmigan.

American Golden Plover. Pluvialis dominica.

This conspicuous tundra bird was widespread in the study area, and was found at all sites of its optimum habitat; that is, where the Prostrate Scrub cover of a gently sloping rolling tundra ridgetop was broken by a small area of Dry Upland Fellfield Barren. This particular mixture of features, however, was not always available, and pairs of birds were seen in Dwarf Scrub - Tussock-Graminoid Meadows and in moister hummock ridge meadows as well. They were not found within the upper elevation areas of the range, but were fairly common in the rolling tundra lowlands around the mountains.

These birds were always seen in pairs, and always appeared territorial and defensive. Within a semi-circle of 6.4 km radius east of basecamp (RMP site IIb), there were at least nine breeding pairs. One chick was seen with its parents on 12 July in a Prostrate Scrub Hummocks - Wet Graminoid Meadow Complex -- the only sighting of Golden Plovers in this habitat.

The last Golden Plover seen in the study area was sighted on 27 July along the Ishtalitna River (RMP site Vc) by B. Armstrong, who sensed that this bird was "on the move."

Common Snipe. Gallinago gallinago.

This bird was seen only once during the field season, on 2 August, when it was flushed from tall grasses near lake 1485 (RMP site IIa). Considering its wide distribution and abundance throughout interior Alaska, I was surprised that only one was observed in the study area. Some Common Snipes may have inhabited the marshes near the upper reaches of Torment Creek (RMP site IIc), but our late discovery of these marshes (28 July) may have prevented our observing them.

Whimbrel. Numenius phaeopus.

These large sandpipers were uncommon in the study area, although in the areas where they were found they were common. They seemed to be found in clusters, possibly indicating a restricted extent of optimal habitat in the Ray Mountains. Whimbrels were found exclusively in tussock and hummock areas

(Table 3), and it seemed that they were restricted to areas where the microrelief was sufficiently tall to conceal their presence. In two particular areas, Whimbrels were seen at an approximate density of 1 per 100 square meters; eight adults (four pairs) occurred in one area near Torment Creek (RMP site IIb) and six adults (three pairs) occurred in another area near lake 1485. Whimbrels are considered common in Dwarf Scrub - Tussock-Graminoid Meadow.

Two downy young attended by defensive parents were seen on 30 June on the ridge north of the Kanuti Kilolitna River (near RMP site IVb) and another fledgling was seen the same day near Torment Creek. No additional nests or young were seen, although defensive pairs and individuals were encountered through July. Many interactions between Whimbrels and Long-tailed Jaegers were witnessed during the summer, usually involving loud cries and a chase scene of some sort.

The last Whimbrel seen in the study area was observed by J. Schubert on 12 August near Crash Creek (RMP site VIa); this bird was far from its preferred habitat and was probably migrating. No Whimbrels were encountered on 1 and 4 August, when hikes were made through areas near lake 1485 where Whimbrels had previously been seen in high concentrations.

Upland Sandpiper. Bartramia longicauda.

This species was uncommon in the study area. Its preferred habitat was Dwarf Scrub - Tussock-Graminoid Meadow near treeline, where scattered tall shrubs or trees extended into tundra meadows. While common in this habitat, it was never found in tundra meadows very far from treeline or from this treeline scrub community. The first young were seen on 4 July, when two pairs of adults were seen with three young each. Each individual seen through the field season was very defensive, and often reacted by uttering cries of warning and by perching atop a nearby tree. One pair, observed near Kilo Hot Spring (RMP site IIIa) on 14 July, squeaked and feigned a broken wing, although no young were seen.

By 1 August, most of these birds had left, though two birds were seen on 2 August in valleybottoms near streams.

Spotted Sandpiper. Actitis macularia.

This non-tundra sandpiper was uncommon in the study area. It was always seen on alluvial rock bars along the streams that extend into the mountains, with the exception of one bird seen on 29 July near the tarn at the base of Mt. Henry Eakin (RMP site Va). Most sightings were of defensive pairs. Although no nests were found, the first downy juvenile was sighted on 19 July near basecamp (RMP site IIb). On 12 August, another juvenile was seen near Kilo Hot Spring (RMP site IIIa) although the two adults who had inhabited the same area previously were not seen. The last sighting of the season was of four individuals seen on 13 August along the Tozitna River (RMP site VIb).

It is estimated that four resident pairs inhabited an 11 km stretch of Torment Creek in the vicinity of basecamp.

Wandering Tattler. Heteroscelus incanus.

Two tattlers were seen during the summer -- one adult and its young. These birds were seen on a gravel bar on 11 July. The juvenile, with a downy head and body, was standing motionless in the water as the adult sounded a warning cry. Because these birds are inconspicuous, they probably occur more numerously than indicated here. They are considered uncommon in the study area.

Lesser Yellowlegs. Tringa flavipes.

Ten individuals of this species were seen, on 1 and 2 August, feeding along the shores of lake 1485. Since no Lesser Yellowlegs had been seen on previous visits to the lake, these birds may have been migrants stopping over in the Ray Mountains.

Pectoral Sandpiper. Calidris melanotos.

Pectoral Sandpipers were uncommon, found in only two localities. They were first seen on 28 June near upper Gishna Creek (RMP site Ie) in a very moist Dwarf Scrub - Tussock-Graminoid Meadow, where their alarm and territoriality indicated that they were breeding. They were then not seen again until 27 and 28 July, when two were seen in a Wet Graminoid Meadow in the upper Torment Creek area (RMP site IIc). These two birds appeared to be migrating; when they were flushed, they flew with a zig-zag motion until they could no longer be seen through the binoculars.

Least Sandpiper. Calidris minutilla.

These tiny sandpipers were uncommon in the study area, although in the few areas of Wet Graminoid Meadow that the area supported they were common. They were first seen on 8 July in Spooky Valley after nesting had occurred. There were many defensive pairs; each individual was seen either flying about calling defensively or performing a "wounded bird" routine. No young were seen at this time. On 29 July, an adult-sized fledged juvenile was seen in the upper Torment Creek area (RMP site IIc); the adults were beginning to adopt their faded winter plumage. On 1 August, an apparently migrating individual was seen along the shores of lake 1485. On our return trip to Spooky Valley (8 and 9 August), individuals of this species were no longer present.

Semipalmated Sandpiper. Calidris pusilla.

Semipalmated Sandpipers were uncommon in the study area; they were found only in Spooky Valley (Fig. 1) and occurred in very low densities. Five adults were seen; they were found primarily in Wet Graminoid Meadow, yet they seemed to prefer small patches of this habitat interspersed within drier Dwarf Scrub and boulder areas, rather than the extensive expanse of Wet Graminoid Meadow preferred by the Least Sandpiper. However, this species was found to occur in very close proximity to the Least Sandpipers in Spooky Valley.

Although no nests were discovered, two downy juveniles

with fairly well developed wing and tail feathers were seen on 9 July, while the adults were sounding warning calls and doing distraction displays. Another defensive pair was seen on 10 July. When a return visit was made to this area on 8 and 9 August, no sandpipers were seen.

Semipalmated Sandpipers do not normally breed this far inland (D. Gibson, pers. comm.), but they have been known to breed near Anaktuvuk Pass (Irving 1960). Although no specimens were taken, I maintain that these tiny gray-breasted peeps were Semipalmated rather than Baird's Sandpipers based on their size and shape, and also on color and amount of breast streaking.

Northern Phalarope. Phalaropus lobatus.

The only Northern Phalaropes present in the study area were definitely migrants. A flock of approximately 60 individuals arrived during the early morning of 16 August on lake 1485, where they remained throughout the morning despite the disturbance caused by two landings and take-offs of a Widgeon floatplane.

Long-tailed Jaeger. Stercorarius longicaudus.

These conspicuous birds were common and widely distributed in the study area; they were seen in every area visited during the summer, although the size of the population cannot be estimated because of probable repeated sightings of the same individuals. They are considered common in Dwarf Scrub - Tussock-Graminoid Meadow. Most sightings were of scattered individuals flying or hovering over expanses of open rolling tundra of various types. Some pairs were also sighted, several of which were defensive of nesting areas (R. Tarlov reported being attacked by diving jaegers near a tor near Torment Creek). No nests were found. Flocking had begun by 15 July, when a flock of 10 birds was seen. After this time, flocks of from three to five birds were seen regularly.

Mew Gull. Larus canus.

Although this is a common gull in interior Alaska, only one Mew Gull, definitely a migrant, was seen in the study area, on lake 1485 on 1 August.

Belted Kingfisher. Megaceryle alcyon.

One Belted Kingfisher was reported by another member of the study team (J. Schubert) on 20 July. It was heard uttering its loud, harsh, and rattling call while flying down Torment Creek just south of basecamp. I could not verify this record, but L. Halpin reported that she heard a kingfisher on the same day in the same vicinity.

Say's Phoebe. Sayornis saya.

This non-tundra flycatcher was uncommon in the study area, found only in the vicinity of rocky bluffs or tors, where it prefers to nest. Two nests were seen during the

summer. One nest that contained at least three young with well developed wing and tail feathers was seen in a tor crevice in Spooky Valley (RMP site IVa) on 8 July. Another nest was seen on 11 July near RMP site IVb in a rock crevice that was too high to allow viewing of the young. In both cases, the parents were actively bringing food to the young. In addition to these nest sightings, another pair of phoebes was seen on 6 August near RMP site IVb and another individual was seen on 12 August by J. Schubert near a serpentine outcrop area (RMP site VIa).

Alder Flycatcher. Empidonax alnorum.

This species was uncommon in the Ray Mountains, most likely because its preferred habitat of very dense Tall Scrub was scattered sparsely at lower elevations below 610m (2000 ft) along the streams that extend into the range. In relation to Tall Scrub habitat (both sparse and more dense), it was rare, although it occurred with some regularity in very thick, choked stands of tall willows.

Although only two individuals were seen, many more were heard. The first individuals were heard singing on 26 June just above treeline on the south slope of the mountains (near RMP site Ia). As we hiked across the range, a few more songs were heard near Twilight Creek (RMP site Ic) on 27 June, but no additional individuals were encountered until we neared treeline again on the north slope of the Ray Mountains, where two more calls were heard near basecamp (RMP site IIb). I estimate that from three to five breeding pairs inhabited a one kilometer stretch of Torment Creek in the vicinity of basecamp. Although little evidence of breeding was observed, these individuals remained very loyal to their specific willow patches from 30 June until at least 5 August, and sang regularly. One defensive (and very curious) pair was observed just south of basecamp on 21 July. This species was last seen on 12 August near Kilo Hot Spring (RMP site IIIa).

Olive-sided Flycatcher. Nuttallornis borealis.

This flycatcher was uncommon in the study area. Its song was occasionally heard from small patches of spruce that extend into the tundra areas along streams. Three males were heard singing vigorously on our first two days in the field (25 and 26 June), indicating territoriality and probable breeding. Two individuals could be heard often near basecamp uttering a single call. Both were heard as late as 23 July. No other evidence of nests or young was found.

Horned Lark. Eremophila alpestris.

This bird proved to be uncommon in the study area, even in its preferred habitats of high upland Dry Upland Fellfield Barren or upland areas of Dwarf or Prostrate Scrub with boulders or gravel. The first individual was seen on 6 July along the ridge north of the Kanuti Kilolitna River (RMP site IId), where later (6 August) a flock of eight individuals was seen. One individual was seen in Spooky Valley and a family

group, including two fully fledged juveniles, was seen in upper Torment Creek (RMP site IIc).

Cliff Swallow. Petrochelidon pyrrhonota.

Not being tundra birds, Cliff Swallows were uncommon in the Ray Mountains. They were found only in Spooky Valley, where a colony of 64 nests was present under a shallow rock overhang on the vertical face of a tor. Considering the number of potentially optimum nesting areas provided by the many tors and block faces present in the Ray Mountains, I was surprised to find Cliff Swallows at only this location.

Upon my return to this area on 8 August, swallows were still present in the valley, but their numbers were greatly reduced, and activity near the nesting area was almost nonexistent.

Gray Jay. Perisoreus canadensis.

These taiga jays are closely associated with forests, usually coniferous, and were therefore uncommon in the study area. They were, however, seen commonly in spruce forests outside the study area, and were also fairly common in areas of Mixed Forest with interspersed tall shrubs.

The Gray Jay is probably one of the few species that overwinters in the Ray Mountains. Any migration that does occur is probably very short, allowing the Gray Jay to be one of the area's earliest nesters. The first individual of this species seen was a fledged juvenile seen on 26 June among the spruce of the south side of the mountains (RMP site IIb). Many more adults were seen in the vicinity of basecamp and RMP site IIIa throughout the summer; these birds seemed to become much more boisterous and conspicuous as the summer progressed. They were still present in the area when we left.

Common Raven. Corvus corax.

These rather conspicuous birds occurred throughout the Ray Mountains, although they appeared to be much less common than had been expected. Only 12 raven sightings were recorded during the summer, and some sightings may have involved the same bird. One raven was seen on 18 July (by J. Schubert) and another on 1 August at lake 1485 (RMP site IIa) flying south toward upper Torment Creek (RMP site IIc), two ravens were seen on 23 July (by J. Schubert) and another on 28 July (by L. Halpin) in upper Torment Creek, and another bird was seen over basecamp on 4 August flying from the vicinity of upper Torment Creek toward lake 1485. There is reason to believe that all these sightings were of one raven, or one pair, which often flew from the headwaters of Torment Creek to lake 1485. Upper Torment Creek was the closest area where suitable nesting habitat of rock walls or tors was available. If in fact this was a single pair seen at various times, then possibly only four pairs may have been observed in the Ray Mountains -- the pair at upper Torment Creek, a pair seen near RMP site IIIa (seen on 11 and 12 August), a pair in Spooky Valley (seen on a tor on 8 August), and a pair near Crash

Creek (RMP site VIa) seen on 13 August by J. Schubert.

Although ravens were sometimes seen in pairs, there is some question as to whether these birds actually breed in the Ray Mountains, because the first sighting did not occur until quite late in the season (18 July). No nests or young were seen.

Gray-headed Chickadee. Parus cinctus.

A pair of small gray-capped and gray-flanked chickadees, without a trace of brown, were seen in a narrow strip of Evergreen Forest near Kilo Hot Spring on 15 July. These birds fit the description of the Gray-headed Chickadee given by Pough (1957), except that they were slightly smaller and had slightly sootier ear coverts. There was not a tint of buff anywhere on these birds. Whether these were Gray-headed Chickadees or juvenile Boreal Chickadees, they were different from the other chickadees seen.

Boreal Chickadee. Parus hudsonicus.

This chickadee was common in the study area, though it was found only in close proximity to Evergreen Forest, where it was also common. It was seen exclusively in flocks, sometimes in mixed flocks with Ruby-crowned Kinglets. Although it was also common in Mixed and Deciduous Forest, it was always found in association with spruce trees. Most individuals were recorded in the forests near basecamp, although significant numbers were seen in forests near the Tozitna River and also near Camp III. No nests or young were seen during the field season.

A sweet four or five note warbled song was heard from birds of this species on three separate occasions.

American Robin. Turdus migratorius.

Although robins are non-tundra birds, they are found throughout the study area. Robins were most numerous near the forested regions, where they were common in Medium and Tall Scrub and in Deciduous Forest understories, but they were also found occasionally among tors in Spooky Valley. They are considered common in the study area.

Although no nests were found, there were numerous sightings of adults carrying food, and later, sightings of young. Adults were seen carrying food in Spooky Valley and at RMP site IVb; juveniles were seen near basecamp and also near Kilo Hot Spring. On 30 July, a fully grown, spotted-breasted juvenile was seen noisily pursuing its parent, who had a beakful of food, in the upper Torment Creek area.

Robins were present in the Ray Mountains for the duration of the field season. The first one was seen on 25 June, the last one on 12 August at Kilo Hot Spring.

Varied Thrush. Ixoreus naevius.

This taiga bird was uncommon in the study area and was found only in low densities in Evergreen Forest. It was most numerous in the forest areas to the south of the mountains

which were more extensive and well developed than those visited north of the range. Most males were heard in the early summer in any sizeable spruce forest, although males were heard until 23 July. Two females were seen, each with a male.

Gray-cheeked Thrush. Catharus minimus.

Gray-cheeked Thrushes showed a scattered distribution over the study area, but were found to be common in Tall Scrub mixed with scattered Deciduous Forest. They were usually found along streams in the rolling lowland tundra, where the Tall Scrub community reached its greatest density, but the only nest found was high on a steep hillside of Prostrate Scrub. This nest was in a tall alder shrub near RMP site IVb; it was found on 11 July and contained three large half-downy young still being fed by the parents.

Wheatear. Oenanthe oenanthe.

Wheatears were common in the study area. They were considered abundant in areas of Dwarf Scrub and Prostrate Scrub, but were found only where boulders were also present. The absence of boulders from a habitat seemed to restrict the distribution of this species. Wheatears could also be seen occasionally on Dry Lichen Upland Rock Barrens and on tors, or hovering over Wet Graminoid Meadows. Many pairs were seen early in the field season, and the first fledglings were seen in Spooky Valley on 9 July. With the exception of one male seen by J. Schubert on 10 August, only females and juveniles were seen in the study area after 24 July. On 11 August, one female was seen near the summit of Mt. Tozi, the highest point in the Ray Mountains, at an elevation of 1682 m (5519 ft).

Ruby-crowned Kinglet. Regulus calendula.

This taiga bird was uncommon in the study area, though it was common in Evergreen and Mixed Forests north of basecamp. This species was always found in spruce trees, even when in a predominantly deciduous area. It was also seen in Medium Scrub areas near open forest. These birds were always seen in pairs or family groups between 18 and 23 July; two fledged young were seen with their parents on 19 and 22 July.

Water Pipit. Anthus spinoletta.

Water Pipits were common in the study area. Although their preferences varied, they were considered abundant in Dwarf and Prostrate Scrub (generally in those areas with scattered boulders) and common in Dry Lichen Upland Rock and Dry Upland Fellfield Barrens. Fledglings were seen commonly in Spooky Valley and in the upper Torment Creek area; the first family group was seen on 9 July, when a pair of adults was seen feeding its fledged juveniles. Distinct family groups (defensive parents, obligate fledglings) were seen as late as 28 July. Migratory flocking behavior was under way by 8 August.

Bohemian Waxwing. Bombycilla garrulus.

This bird was considered rare in the study area. Only two individuals were seen, flying over the forested area near RMP site IIIa on 17 July.

Northern Shrike. Lanius excubitor.

Northern Shrikes were first seen in the study area on 6 August, in an area that had been previously frequented by our study team. Two adults were seen on 6 August in Medium Scrub near RMP site IVb, another adult was seen on 8 August on a rock ridgetop at the northern edge of Spooky Valley, and a large juvenile was seen on a Prostrate Scrub ridge near the southern end of Spooky Valley. Because of the timing of these sightings, and also the frequency with which these areas had been visited without sign of these birds, I assume that these individuals were migrating through the Ray Mountains at the time.

Orange-crowned Warbler. Vermivora celata.

This taiga warbler was rare in the study area, where it was seen only twice in Evergreen and Deciduous Forest with dense tall shrubs. When it was seen on 27 June and 2 July, each individual was singing vigorously and flying from bush to bush defining a territory. No females or young were seen.

Yellow-rumped Warbler. Dendroica coronata.

This taiga warbler was uncommon in the study area. It was fairly common in Deciduous Forest and often preferred understory shrubs. This bird was first seen on 2 July, when two males were seen carrying food, and the first fledged juvenile was seen with two adults on 18 July near basecamp. The last sighting was on 23 July, the last day that forests near basecamp were studied.

Wilson's Warbler. Wilsonia pusilla.

Wilson's Warblers were uncommon in the study area, although in their habitats of Tall Scrub and Deciduous Forest they were common; they were also fairly common in Evergreen Forest. Closely associated with the occurrence of tall shrubs, they followed the Tall Scrub community to its limit in the upper stream headwaters.

There were many defensive males in the vicinity of basecamp, and one nest was found in a tall willow on 2 July. Although the contents of the nest could not be seen, a female bringing food to the nest indicated that eggs had hatched by this date. Another male Wilson's Warbler was seen in a different area (on 2 July) carrying food. Fledged juveniles were seen on 23 July. These warblers were still present in the study area on 12 August.

Gray-crowned Rosy Finch. Leucosticte tephrocotis.

Many rosy finches were seen during the summer, and although their distribution was limited to fairly high rocky areas, they were common in the study area. They were common

in their preferred habitats of Dry Lichen Upland Rock Barren and Prostrate Scrub, and were often seen on tors. The first Gray-crowned Rosy Finch was seen on 27 June in the vicinity of Mt. Tozi, and afterwards they were seen regularly near Mt. Tozi, Mt. Henry Eakin, throughout Spooky Valley, and near RMP site IVb.

A group of three fledged juveniles was observed on 9 July in Spooky Valley. These young, apparently impatient with hunger, would nearly attack a parent returning with food. These young were almost as large as the parents.

A hike to the top of Mt. Henry Eakin on 29 July revealed that these birds had begun flocking. One flock of eight, another of 12, and later a flock of 20 individuals were seen near the summit. This species was last seen on Mt. Tozi on 11 August by J. Schubert.

Common Redpoll. Carduelis flammea.

The Common Redpoll was abundant and widespread in the study area, being one of the most numerous birds seen in the Ray Mountains. It was found wherever there were shrubs of any height or density (it was abundant in Mixed Forest and Tall Scrub and common in Evergreen and Deciduous Forests and Tall and Dwarf Scrubs), and its characteristic call could be heard in many unlikely places. It was often identified only by call, because its habit of high flight often prohibited direct observation.

No nests were found; nesting had probably been completed by the time of our arrival in late June. Flocking had begun by 30 July; the largest flocks of about 25 to 40 individuals were seen on 11 and 12 August.

Savannah Sparrow. Passerculus sandwichensis.

Savannah Sparrows were abundant and widespread in the study area. They were at almost every area visited, most commonly seen in Low Scrub (where they were abundant) and in Medium and Dwarf Scrubs (where they were common). They were also frequently seen in Dwarf Scrub-Tussock Graminoid Meadow.

In some areas this species almost completely dominated the sparrow community; this was very apparent near lake 1485. This sparrow bred throughout the study area; although no nests were found, fledged juveniles became very numerous by the latter part of July. Flocking was under way by 8 August, when a very restless mixed flock of birds, including many Savannah Sparrows, was seen in Spooky Valley.

Dark-eyed Junco. Junco hyemalis.

Juncos were uncommon in the study area. They seemed to prefer Mixed Forests (where they were abundant), although they were always seen in conifers. They were first recorded on 5 July and were probably not recorded before that date because their singing had ceased before we arrived in the field. Throughout the summer these birds remained fairly quiet and inconspicuous, although one song was heard on 22 July. On this same day, I observed a feeding flock of nine, including

five large juveniles still being fed by the parents. Juncos were present in the study area late into the season; two were seen near Kilo Hot Spring on 13 August.

Tree Sparrow. Spizella arborea.

This sparrow was abundant and widely distributed in the study area. It was seen at almost every area visited. This bird is clearly a bird of shrub thickets; it was abundant in Medium and Low Scrub thickets, whether in the open or within forest openings, and it was common in Dwarf Scrub and Evergreen Forest.

The first fledgling was seen being fed by its parents on 9 July; from this time on, young Tree Sparrows became increasingly numerous. Flocking became apparent as early as 23 July and progressed until about 30 July, after which fewer individuals were seen. One Tree Sparrow nest was discovered very late in the season (on 4 August) by J. Schubert. An adult flushed from this nest was apparently incubating four eggs.

White-crowned Sparrow. Zonotrichia leucophrys.

White-crowned Sparrows were abundant and widespread in the study area. This sparrow was the most conspicuous and abundant bird in the range and was seen in every area visited. It was most predominant in the shrub thicket habitats; it was abundant in Medium Scrub and common in Tall and Low Scrubs. It was also frequently seen in areas of Evergreen Forest where medium height shrubs were a conspicuous component of the vegetation. It would frequently perch in nearby tall shrubs or trees when flushed, using these as lookout posts.

The first juvenile recorded was seen on 18 July, and by 23 July juveniles were the majority of the individuals seen. Flocking had begun by 8 August, when a flock was seen in Spooky Valley.

Golden-crowned Sparrow. Zonotrichia atricapilla.

This sparrow was uncommon in the study area and occurred at scattered locations at higher elevations. It preferred Low and Medium Scrub areas bordering high mountain streams. About 15 of these birds were heard singing between 27 and 29 June near RMP sites Id-f; these birds were probably breeding in this area though no nests were seen. After the end of June, singing rapidly diminished, though some singing was heard until 29 July. The birds were not seen during an August visit to a previously inhabited area in Spooky Valley.

Fox Sparrow. Passerella iliaca.

This sparrow was rare in the study area. A few were seen in a mixed Tall and Medium Scrub area on 27 June, and two individuals were seen in scattered Medium Scrub near basecamp on 2 July. These were the only occurrences of Fox Sparrows recorded in the Ray Mountains, and their breeding status there is unknown.

Lapland Longspur. Calcarius lapponicus.

This longspur was abundant and widespread in the study area, found throughout the tundra expanses. This species was found in a variety of habitats, all of which were open and mesic. It was abundant in Dwarf Scrub-Tussock Graminoid Meadow and common in Tussock Graminoid Meadow, though it was also found in Prostrate Scrub Hummock-Wet Graminoid Meadow Complex, Wet Graminoid Meadow, Medium Scrub savannah, and on drier Dry Upland Fellfield Barren.

Early in the field season, longspurs were observed singing vigorously and performing elaborate courtship displays (as described by Gabrielson and Lincoln 1959), while others had begun nesting and egg-laying. Many nests were found between 28 and 30 June, with usually from 3 to 5 eggs each, hidden within hollowed bowls in tussocks. Juveniles were seen often during July, and by 6 August flocking had begun. The largest flock, numbering about 40 individuals,

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NOTE

The reader is referred to the Introduction of this volume for detailed descriptions of the project study area and the overall project research design. Also included there are descriptions of the project's three areas of concentrated study, with a map showing their locations and the locations of travel routes and Ray Mountains project sites (RMP sites Ia-VId) referred to in this chapter. The ECOSYSTEMS referred to herein (in upper case lettering) are described in the Ecosystems chapter of this volume.

ABSTRACT

174 insect species in 13 orders were identified in the Ray Mountains. One order, Diptera, constituted approximately one-third of all insect species collected, although Lepidoptera, Coleoptera, Hymenoptera and Hemiptera were all well represented.

A comparison of the insect faunas of the predominantly alpine subarctic Ray Mountains and arctic Barrow, Alaska shows clear differences between these two tundra ecosystems. Insect species are more equally distributed among a greater number of orders in the Ray Mountains, indicating a greater species evenness than in the arctic tundra of Barrow. This greater species evenness likely results from the influx of taiga species into the Ray Mountains from the surrounding boreal forest.

Range extensions were recorded for ten species representing five different orders. Of particular interest was the finding of the second North American specimen of the Siberian moth Hyperborea czekanowskii 668 km inland from the first locality. This indicates that this species is clearly established in Alaska.

A new species of the arctiid moth Apantesis was collected. Only four other specimens of this species have been collected, all of which were found in Alaska. A tachinid Admontia, which is similar but not identical to A. washingtonae described from a single specimen found in New Hampshire, may also represent a new species.

INTRODUCTION

The status and distribution of Alaskan insects are poorly known. Although the state has been described as being of enormous ecological and biogeographical importance for entomological study (Mani 1968), because of its ruggedness and remoteness, efforts to inventory Alaska's insects have been limited.

Literature Review

Efforts to inventory the insects of Alaska began with the United States Polar Expedition of 1881-1883 (1885), which provided a small collection from arctic Alaska, and the Harriman Expedition of 1885 (Merriam 1904), which provided a

large collection from coastal Alaska. In the following years, studies in the Pribilof Islands (Preble 1923) and the Northern Insect Survey of 1947-48, a joint project of the US Departments of Agriculture and Defense, added additional collections (Freeman 1956). The Canadian Arctic Expedition of 1913-1918 and the Canadian Northern Insect Survey of 1947-1957 included sampling of Alaska, but were limited to the northern coastal region, the Alaska/Canada border, and the more populated areas of the state (Freeman 1956). In more recent years, insect collecting has occurred in northern Alaska (Gara and Holsten 1974; Gressitt and Yoshimot 1974; Bohnsack 1968; Watson et al. 1966; Hurd and Lundquist 1958; Weber 1950), in the Matanuska Valley, and near Fairbanks, Anchorage, and Juneau (Clarke, pers. comm.). However, reports from these studies are scattered, making attempts to catalog Alaskan insect species extremely difficult (Clarke; Hurd; Froeschner; pers. comms.).

The Alaska Lepidoptera Survey (ALS), which began in 1970, the first attempt to survey statewide a single insect order. Although Lepidoptera has been studied more extensively than any other order in the state, there remain several large regions, especially in interior Alaska, which have not yet been sampled (Philip, pers. comm.).

In conclusion, results from insect studies in Alaska (with the exception of the ALS) are generally poorly summarized and cover a relatively small portion of the state. Large areas of the state, especially in the interior, remain unsampled. As stated by Gressitt and Yoshimot (1974) "the study of Alaskan insects and their distribution is in an infant stage of development."

Study Area

The Ray Mountains are located in the heart of interior Alaska, and are inacessible. It is therefore not surprising that there has been no insect collecting in the study area. The geography of the range is an important factor influencing the insect fauna. The Ray Mountains are isolated subarctic, predominantly alpine, tundra surrounded by boreal forest. Although some species of alpine tundra insects have affinities with arctic forms, the alpine fauna may numerically be derived in large part from the surrounding boreal forest (MacLean 1975). For this reason I expected a greater variety of insect species in the Ray Mountains than in a similar area of arctic tundra. Also, because the range is isolated and biogeographically regarded as an island (Schubert, this volume), the possibility of finding new species or subspecies totally restricted to tundra habitats is increased.

Objective

The purpose of this study has been to provide a broad survey of the insects of the Ray Mountains, and in doing so to identify any endemic species or subspecies which might occur in the range. This information will help provide insight into the composition of the poorly known insect fauna of interior Alaska.

METHODS

Specimens were collected throughout the field season, though my collecting time was limited due to other research responsibilities. Terrestrial forms were collected with aerial nets, sweep nets, beating sheets, and pit traps. A lesser emphasis was placed on the collection of aquatic, soil-inhabiting, and parasitic insects. Specimens were collected at numerous localities in the range representing a wide variety of habitats, ranging from elevations of 457 m (1500 ft) to 1676 m (5500 ft) (Table 1). Included were ALPINE BARREN, UPLAND and LOWLAND TUNDRA, and BOREAL FOREST ecosystems. A list of the major and minor vegetation types in these ecosystems is presented by Schubert (this volume).

Order and family nomenclature follows Borror et al. (1976). Specimens were prepared and sent to specialists for genera and species identification (see specific acknowledgments in the Appendix). Because the insects were transported out of the field in backpacks, specimens of some of the more fragile families (e.g. members of Chironomidae and Culicidae) were too damaged for identification. Therefore, these insects are not accurately represented in the species list.

Upon completion of the project, insects will be donated to the Smithsonian Institution in Washington, D.C., for the US National Museum collection.

RESULTS AND DISCUSSION

Species Composition and Diversity

174 species (Appendix) in 13 orders (Table 2) were identified in the Ray Mountains study area. If efforts had been made to collect soil-inhabiting and parasitic insects, I would expect to find three additional orders -- Collembola, Mallophaga, and Anoplura, all of which appear to be widely distributed in tundra ecosystems (MacLean 1975).

Table 1. Insect collection localities.

LOCALITY	RMP SITE	AVERAGE ELEV.	ECOSYSTEM TYPE(S)	COLLECTING DATES
Lower Torment Cr.	IIb	580m	LOWLAND TUNDRA BOREAL FOREST	June 24-July 26; July 19-23; Aug.2-3
Upper Torment Cr.	IIc	854m	UPLAND TUNDRA ALPINE BARREN	July 24-30
Spooky Valley	IVa	763m	UPLAND TUNDRA ALPINE BARREN	July 8-11; Aug.8-9
Lake 1485	IIa	452m	LOWLAND TUNDRA	July 18; Aug.1
Kilo Hot Springs	IIIa	488m	BOREAL FOREST	Aug.4-7
Mt. Eakin Summit		1472m	ALPINE BARREN	July 29
Gishna Creek	Ie	885m	UPLAND TUNDRA	Aug.10
Twilight Creek	Ic	824m	UPLAND/LOWLAND TUNDRA ECOTONE	Aug.11
Mt. Tozi Summit		1683m	ALPINE BARREN	Aug.11
Crash Creek	VIa	580m	LOWLAND TUNDRA	Aug.12-13
Tozitna River	VIb	580m	BOREAL FOREST	Aug.14
Moose Cr. Hdwtrs.	VIc	610m	LOWLAND TUNDRA BOREAL FOREST	Aug.15

Table 2. Composition of the Ray Mountains insect fauna. Comparative data are shown for Barrow, Alaska. The Barrow values are recalculated from MacLean (1975), omitting Collembola, Mallophaga, and Anoplura (orders not collected in the Ray Mountains). Original Barrow data from Hurd (1958).

ORDER	# SPECIES	% OF ALL SPECIES	% OF ALL SPECIES (BARROW)
EPHEMEROPTERA	2	1.1	0
ODONATA	3	1.7	0
ORTHOPTERA	1	.1	0
PLECOPTERA	2	1.1	0
PSOCOPTERA	1	.1	0
HEMIPTERA	19	10.9	.6
HOMOPTERA	10	5.7	.6
NEUROPTERA	1	.1	0
COLEOPTERA	21	12.1	6.7
TRICHOPTERA	6	3.4	2.8
LEPIDOPTERA	31	17.8	4.5
DIPTERA	56	32.2	67.4
HYMENOPTERA	21	12.1	16.9
Total # Species	174	--	--

The relatively small number of orders and species represented in the Ray Mountains is characteristic of tundra ecosystems (MacLean 1975; Mani 1968; Downes 1965). However, this scarcity is not evenly distributed among all taxa, as indicated by the dominance of Diptera in the Ray Mountains insect fauna (Table 2). Hymenoptera, Hemiptera, and Lepidoptera are also well represented.

In a comparison of the insect faunas of subarctic tundra with arctic tundra, I would expect to find a greater variety of insects in the subarctic tundra due to the influx of taiga species. This can be seen in a comparison of the Ray Mountains insect fauna with the arctic insect fauna of Barrow, Alaska (Table 2). Of the 13 orders occurring in the Ray Mountains, only seven are known in Barrow, 85% of which are represented by two orders: Diptera and Hymenoptera. In general, the larger number of species and orders in the Ray Mountains indicates a greater species evenness than in the arctic tundra fauna of Barrow.

Range Extensions

Hemiptera

Acanthosomatidae: Elasmucha lateralis (Say). Lower Torment Creek (RMP site IIb), July 29, 1 male; Moose Creek headwaters (RMP site VIc), Aug. 15, 1 male, 1 female, 2 5th instar nymphs. This is the first record of this species in Alaska, although several apparently previously unreported specimens from Fairbanks are in the National Museum collection (Froeschner, pers. comm.).

Lygaeidae: Geocoris bullatus (Say). Moose Creek headwaters (RMP site VIc), Aug. 15, 1 female. This species is widely distributed in North America, and was previously cataloged only as far northwest as the Yukon in Canada (Froeschner, pers. comm.)

Nabidae: Dolichonabis americolimbatus (Carayon). Lake 1485 (RMP site IIa), Aug. 1, 1 male, 2 females, 1 nymph. This is a first record for Alaska, which partially fills the gap between the formerly known North American range and the disjunct occurrence in eastern Asia, as reported by Kerzhner (1969, Ent. Oboz., 47:848-863, for translation see Ent. Review, 47:521). A range of this sort suggests a natural migration eastward or westward through Beringia (Froeschner, pers. comm.).

Scutelleridae: Homaemus aeneifrons (Say). Lower Torment Creek (RMP site IIb), June 29, 1 female; July 29, 1 nymph. Absence of a male specimen prevents positive subspecies determination of these specimens, but they quite probably

represent western subspecies H. aeneifrons extensus (Walley) which was originally described from western North America from Northwest Territories, Canada, south to Colorado (Froeschner, pers. comm.)

Coleoptera

Carabidae: Pterostichus agonus (Horn). Lower Torment Creek (RMP site IIb) July 3, 1 specimen; Aug. 3, 1 specimen. The formerly known range extended west from Hudson Bay to Alaska, but included only coastal Alaska (Lindroth, 1961-1969). This is the first inland Alaska record for this species.

Trichoptera

Phryganeidae: Agrypnia deflata (Milne). Lake 1485 (RMP site IIa), 1 Aug., 2 females. The formerly known range of this species included Saskatchewan and the northern prairies of the United States (Wiggins 1977).

Leptoceridae: Triaenodes frontalis Banks. Lake 1485 (RMP site IIa), July 18, 1 male. This species was known previously to occur in Alberta, Ontario, and Saskatchewan and in the mountainous regions of Montana, Colorado, and Arizona (Manuel, pers.comm.).

Oecetis inconspicua (W.). Upper Torment Creek (RMP site IIc), July 25, 1 male. This species is widespread throughout the continent, but is rare in the Northwest. This species has been recorded in Alberta, Saskatchewan, British Columbia, Nova Scotia, and throughout much of the United States (Flint, pers. comm.; Ross 1944). There are no published records to date of this species in Alaska.

Lepidoptera

Arctiidae: Hyperborea czekanowskii. Lower Torment Creek (RMP site IIb), June 27, 1 male. This is the second North American specimen of this Siberian moth. This specimen was found 668 km inland from the first locality near Shishmaref which indicates that this species is clearly established in Alaska (Philip, pers. comm.)

Diptera

Tachinidae: Ceromasia borealis Brks. Moose Creek headwaters (RMP site VIc), Aug. 15, 1 male. This species is known from the Northwest Territories and Alberta (Stone et al. 1965).

New Species

Lepidoptera

Arctiidae: Apantesis sp. Near lake 1485 (RMP site IIa), 18 July, 1 male. This is the fourth specimen found of this undescribed species of moth. Two females were found in McKinley Park, Alaska, and one male in Yukon Territory (Ferguson, pers. comm.).

Diptera

Tachinidae: Admontia sp. Spooky Valley (RMP site IVa), July 9, 1 specimen. This species is very close to A. washingtonae (Coq.) described from Mt. Washington in New Hampshire, of which the US National Museum has only the holotype (Sabrosky, pers. comm.).

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APPENDIX

Species List

Species identifications and collection localities are listed below. RMP site numbers appear in brackets, { }, and species determination authority is preceded by "Det."

EPHEMEROPTERA
- Family Baetidae
  - *Baetis* sp. {IVa}
- Family Heptageniidae
  - Genus unknown {IIb}
    - Det. W.L. Peters*

ODONATA
- Family Coenagrionidae
  - *Lestes disjunctus* Selys {Ie, IIb, IIc, IIIa, IVa}
- Family Aeschnidae
  - *Aeschna juncea* (Linn.) {IIb}
  - *Aeschna eremita* Scudder {IIa}
    - Det. O.S. Flint**

ORTHOPTERA
- Family Acrididae
  - *Chorthippus curtipennis curtipennis* (Harris) {IVb, VIa, VIc}
    - Det. D.A. Nickle*

PLECOPTERA
- Family Chloroperlidae
  - *Alloperla* sp. {IIb}
- Family Capniidae
  - *Capnia* sp. {VIa}
    - Det. O.S. Flint**

PSOCOPTERA
- Family Psocidae
  - *Amphigerontia* prob. *bifasciata* (Latr.) {IIb}
    - Det. E.L. Mockford*

HEMIPTERA
- Family Saldidae
  - *Teloleuca bifasciata* (Thomson) {IIb}
- Family Miridae
  - *Trigonotylus ruficornis* (Geoffroy) {Ic}
  - *Plagiognathus obscurus* Uhler {IIb}

* -- Systematic Entomology Laboratory, US Department of Agriculture

** -- Department of Entomology, Smithsonian Institution

Plagiognathus obscurus Uhler {IIb}
Polymerus unifasciatus (Fabricius) {VIb}
Mecomma gilvipes (Stal) {IIIa}
Lygus columbiensis Knight {Ic, Mt. Tozi summit}
Calocoris fulvomaculatus (De Geer) {IIb, VIa}
Orthotylus katmai Knight {Ic}
Lygocoris contaminatus (Fallen) {IIa}
Lygus elisus Van Duzee {IIIa}
Lygus varius Kniight {Ic, VIc}
Teratocoris caricis Kirkaldy {Ic}
4 unidentified nymphs {IIIa}

Family Nabidae
Dolichonabis americolimbatus (Carayon) {IIa, IIb}

Family Lygaeidae
Geocoris bullatus (Say) {VIc}
Ligyrocoris sylvestris (Linn.) {IIIa}

Family Anthocoridae
Anthocoris melanocerus Reuter {IVa, VIb}

Family Acanthosomatidae
Elasmucha lateralis (Say) {IIb, VIc}

Family Scutelleridae
Homaemus aeneifrons extensus Walley {IIb}
Det. R.C. Froeschner**

HOMOPTERA

Family Cicadellidae
Draeculacephala angulifera (Walker) {IIa, IIb, VIa}
Scaphytopius sp. {Ic}
Idiocerus sp. {IIb}
Macrosteles (Sonronius) dahlbomi (Zett.) {IIIa}
Verdanus evansi (Ashmead) {Ic}
Typhlocybinae sp. {Ic}
Det. J.P. Kramer*

Family Psyllidae
Psylla sp. either galeaformis Patch or betulaenanae Ossiannilsson {IIb, IVa}
Det. D.R. Miller**

Family Aphididae
Cinara sp. {VIb}
Macrosiphum euphorbiae (Thomas) {VIc}
Dactynotus sp. {VIc}
Det. M.B. Stoetzel*

NEUROPTERA

Family Hemerobiidae
Hemerobius pacificus Banks {Ic}
Det. O.S. Flint**

COLEOPTERA

Family Carabidae
Pterostichus agonus (Horn) {IIb}
Agonum quinquepunatun (Horn) {IIb}
Diacheila polita (Falderman) {IIb}
Amara erratica (Duftschmidt) {IIIa}

Cymendis unicolor (Kirby) {IVa}
Notiophilus borealis (Harris) {IVa}
Bembidion mckinleyi (Fall) {VIb}
Det. T.L. Erwin**

Family Coccinellidae
Mulsantina hudsonica Casey {Mt. Tozi summmit}
Ceratomegilla ulkei Crotch {IIc}

Family Cantharidae
Cantharis sp. {IVa}
Det. R.D. Gordon*

Family Hydrophilidae
Enochrus diffusus (LeConte) {IIIa}
Det. P.J. Spangler**

Family Silphidae
Thanatophilus lapponicus (Herbst) {IIb}

Family Elateridae
Ctenicera ochreipennis (LeConte) {IIb, Mt. Tozi summit}

Family Cerambycidae
Monochamus scutellatus Say {IIb, IVa, Mt. Tozi summit}
Pachyta lamed (Linn.) {IIb}
Gnathacmaeops pratensis (Laich.) {IVa}
Det. T.J. Spilman*

Family Chrysomelidae
Goniotena nivosa (Suff.) {IIb}
Orsodacne atra (Ahrens) {IIIa}
Det. R. White*

Family Curculionidae
Lepyrus sp. {IIc}
Rhyncolus sp. {IIb}
Det. D.R. Whitehead*

Family Gyrinidae
Gyrinus minutus Fab. {IIa}
Det. L. Halpin, Dept. of Biology, Middlebury College

TRICHOPTERA

Family Phryganeidae
Agrypnia deflata (Milne) {IIa}

Family Brachycentridae
Brachycentrus americanus {VIb}

Family Leptoceridae
Triaenodes frontalis Banks {IIa}
Oecetis inconspicua (W.) {IIc}

Family Limnephilidae
Limnephilus sp. {III}
Det. O.S. Flint**
Onocosmoecus sp. {IIb}
Det. P. Wimmer, Dept. of Biology, Middlebury College

LEPIDOPTERA
- Family Geometridae
  - Campaea perlata {Mt. Henry Eakin summit}
- Family Arctiidae
  - Hyperborea czekanowskii {IIb}
  - Apantesis quenseli {near IIa}
  - Apantesis sp.
    Det. K.W. Philip, Institute of Arctic Biology, Univ. of Alaska, Fairbanks
- Family Noctuidae
  - Pseudospaelotis harruspica (Grote) {IIb}
  - Epipsiliamorpha alaskae (Grote) {IIIa}
    Det. D. Ferguson*
- Family Lycaenidae
  - Epidemia dorcas {Ie, IIb, VIa, VIc}
  - Lycaeides argyrognomon {VIa, VIc}
  - Vacciniina optilete {Ie, IIb, IVa, VIa}
- Family Pieridae
  - Pieris occidentalis {Ie}
  - Colias hecla {Ie}
  - Colias gigantea {IIa, IIb, IIc, VIa}
  - Colias philodice {Ie, IIIa, IVa}
  - Colias gigantea/philodice {VIa}
  - Colias palaeno {IIa, IIb, IVa, VIa}
- Family Papilionidae
  - Papilio machaon {IIb, IIc}
- Family Satyridae
  - Coenonympha kodiak {Ie, IIa, IIb, IIc, VIc}
  - Oeneis bore {IIb, IVa}
  - Oeneis jutta {IIb}
  - Erebia disa {IIb}
  - Erebia fasciata {IIb}
  - Erebia discoidalis {IIb}
  - Erebia youngi {IIb, IVa}
- Family Nymphalidae
  - Limenitis arthemis {IIb}
  - Nymphalis antiopa {IIb, VIa}
  - Polygonia gracilis {IIc, VIa, VIc}
  - Boloria napaea {Ie}
  - Boloria polaris {IIb, IVa}
  - Boloria chariclea {IIb}
  - Boloria chariclea/titania
  - Boloria eunomia {IIb}
    Det. K.W. Philip

DIPTERA
- Family Tipulidae
  - Dicranota prob. neomexicana (Alexander) {IIb}
- Family Mycetophilidae
  - Mycomya sp. {VIb}
  - Sciophila sp. {IVa}
  - Mycetophilidae sp. {VIc}
- Family Calliphoridae
  - Phaenicia sp. {IIb}
  - Francilia fuscipalpis {IIb}

Protocalliphora sp. {IIb}
Acronesia adlrichia (Shannon) {IIb}
Acronesia sp. {IVa}
Calliphora terraenorae Macquart {IIb}
Family Muscidae
Lispe cotidiana Snyder {IIa}
Quadrularia sp. {VIb}
Spilogona sp. {IVa}
Thricops sp. {IIc, IVa}
Hydrotaea scambus (Zett.) {IIb}
Coenosia sp. {VIa}
Pseudocoenosia solitaria (Zett.) {IIb}
Helina sp. {IVa}
Phaonia sp. {VIa}
Det. R.J. Gagne*
Family Agromyzidae
Liriomyza sp. {Ic}
Det. R.H. Foote*
Family Bibionidae
Bibio sp. {Ie, IIb}
Family Dolichopodidae
Dolichopus sp. {Ic, IIa, IIb, IIc}
Family Tabanidae
Hybomitra sexfasciata (Hine) {IIb}
Family Syrphidae
Ceilosia sp. {IIIa}
Melangyna lasiophthalma (Zett.) {IVa}
Megasyrphus laxus (Osten Sacken)
Syrphus torvus Osten Sacken {IIc, IVa}
Syrphus vitripennis Meigen {IIa, VIc}
Epistrophe grossulariae (Meigen) {IIc}
Metasyrphus lapponicus (Zett.) {IIIa}
Metasyrphus perplexus (Osburn) {IIa, IIb}
Metasyrphus sp. {IIIa}
Sphaerophoria philanthus (Meigen)
Family Anthomyidae
Hylemya spp. {Ic, IIb, IVa, VIa, VIb}
Pegomya sp. {IIa, IIIb, VIa, VIb}
Scatophaga furcata (Say) {IVa}
Choetosa sp. {IIa}
Cordilura picticorris Loew {IIa}
Det. F.C. Thompson*
Family Tachinidae
Nowickia sp. {IIb, IVa, VIa}
Linnaemya sp. {IIb, IIIa, IVa, VIa}
Admontia sp. near washingtonae (Coq.) {IVa}
Siphona sp. {IVa}
Psalidopteryx sp. {IIb}
Gonia sp. {IIb, VIa}
Ceromasia prob. borealis
Det. C.W. Sabrosky*
Family Chironomidae
Genus unknown {IIb, IVa}

Family Rhagionidae
Symphoromyia sp. {IVa}
Det. W.W. Wirth*
Family Lauxaniidae
Minettia lupulina (F.) {IIIa}
Family Dryomyzidae
Dryomyza bergi Steyskal {IIb}
Family Heleomyzidae
Suillia loewi (Garrett) {IIc}
Det. W.N. Mathis**
Family Culicidae
Aedes sp. near *communis* (De Geer) {VIb}
Aedes sp. near *nigripes* (Zett.) {IVa}
Aedes sp. {VIb}
Det. W.E. Bickley**

HYMENOPTERA
Family Torymidae
Torymus sp. {IIb}
Pseudotorymus sp. {IIIa}
Family Pteromalidae
Genus unknown {IVa}
Det. E.E. Grissell*
Family Alloxystidae
Alloxysta sp. {IVb}
Det. A.S. Menke*
Family Aphiidae
Lysiphlebus sp. {VIb}
Family Braconidae
Chorebus sp. {Ic}
Det. P.M. Marsh*
Family Tenthredinidae
Tenthredo sp. {IIb}
Pachynematus sp. {IIb}
Pristiphora sp. {VIa}
Family Siricidae
Urocerus gigas flavicornis (F.) {Mt. Eakin Summit}
Family Formicidae
Camponotus herculeanus (L.) {IIb}
Formica podzolica Francoeur {IIIa}
Formica neorufibarbis Emery {VIa, VIc}
Formica spp. {IIa, VIa}
Det. D.R. Smith*
Family Vespidae
Vespula vulgaris (L.) {IVa}
Dolichovespula arenaria (F.) {IIb}
Dolichovespula albida (Sladen) {IIb, IIc, IIIa, IVa, VIa}
Det. A.S. Menke*
Family Apidae
Bombus lucorum (L.) {Ie, IIb, IIc, IIIa, IVa}
Bombus sylvicola Kirby {Ic, IIb, IIc, IVa}
Megachile centuncularis (L.) {IIb}

ECOSYSTEMS

John Schubert
BA (Northern Studies)
Middlebury College 1980

ABSTRACT

INTRODUCTION
- Objectives
- The Ecosystem Concept and its Application to the Study

METHODS
- Ecosystem Delimitation
- Field Methods
  - Areas of Concentrated Study
  - Areas of Less Concentrated Study
- Data Analysis

RESULTS AND DISCUSSION
- Ecosystem Descriptions
  - ALPINE BARREN
  - UPLAND TUNDRA
  - LOWLAND TUNDRA
  - BOREAL FOREST
  - (For each ecosystem, physical, biotic, and natural disturbance characteristics are presented and their relationships discussed.)
- Ray Mountains as an Ecological Island

CONCLUSION

ACKNOWLEDGMENTS

REFERENCES

NOTE

The reader is referred to the Introduction of this volume for detailed descriptions of the project study area and the overall project research design. Also included there are descriptions of the project's three areas of concentrated study, with a map showing their locations and the locations of travel routes and Ray Mountains project sites (RMP sites Ia-VId) referred to in this chapter. Physiographic and ecological terms used consistently throughout this volume are defined in the Vegetation chapter. Vegetation classification in this chapter follows the classification and detailed description of vegetation types also presented in the Vegetation chapter.

ABSTRACT

Based on field study and analysis of the environmental data presented in the previous chapters of this volume, four ecosystem units have been recognized in central Alaska's Ray Mountains: ALPINE BARREN, UPLAND TUNDRA, LOWLAND TUNDRA, and BOREAL FOREST. Usually within predictable elevational zones, these ecosystems have characteristic vegetation types, animal species, and physical features. These characteristics of each ecosystem are presented here and their interrelations are discussed. A map showing the distribution of the ecosystems in the study area is also presented. This general ecosystem overview of the Ray Mountains should prove useful to Alaskan land managers for planning and land use decision-making that will affect the range.

INTRODUCTION

Prior to this study there had been no ecosystems research in the Ray Mountains. Though the range has been proposed for inclusion in the Alaska Ecological Reserve system [Underwood and Juday 1979; Underwood 1977; Federal - State Land Use Planning Commission for Alaska (FSLUPC) 1973a], there has been no detailed information about the ecosystems of the range. The very general statewide Major Ecosystems of Alaska map published by the FSLUPC (1973b) shows only two ecosystems in the Ray Mountains: Alpine Tundra and Upland Spruce-Hardwood Forest.

Objectives

The overall goal of this study has been to provide a general synthesis of the scientific studies of the Ray Mountains project to make them more useful in the resource analysis and management portion of the project. Work emphasized use of the ecosystem concept to understand relationships among the vegetation types, animal species, soils, and other physical features and processes present in the Ray Mountains, to achieve my primary objective of recognizing ecosystem units for description and mapping at a level of resolution useful to land managers.

A secondary objective has been to discuss the overall ecological character of the range.

The Ecosystem Concept and its Application to the Study

Although the ecosystem concept is one of the more elusive in ecological theory, when used in a definite sense to describe recognizable landscapes it can be an exceedingly useful conceptual tool for land management (Van Dyne 1969). The ecosystem concept enables synthesis of diverse information about a landscape into a concise comprehensible overview. Because it emphasizes the interrelatedness of the diverse biotic and physical elements of a landscape, ecosystem analysis can point out the effects of perturbations to a portion of the ecosystem.

Since its introduction by Tansley in 1935 (cited in Ricklefs 1979), the ecosystem concept has been defined in numerous ways. For this study the following composite definition is offered. The ecosystem "is the basic unit of ecology" including "organisms and their non-living environment, each interacting with and influencing the properties of the other." The concept is a broad one; "its main function in ecological thought is to emphasize interdependency and both casual and 'obligatory' relationships" (FSLUPC 1973b). It is the "interdependence of the physical and biological realms" that "is the basis of the ecosystem concept"; and thus the ecosystem is the most encompassing unit of ecology (Ricklefs 1979).

Adding energy flow and nutrient cycling to the defintion, Whittaker (1975) states that an ecosystem is a biological "community and its environment treated together as a functional system of complementary relationships, and transfers and circulation of energy and matter." It is the character of the physical and biotic environment, especially in relation to the flows of energy, water, and mineral nutrients among the physical environment and biological realm of producers (plants), consumers (insects, birds, and mammals), and decomposers (microorganisms) that is the focus of ecosystems analysis. Figure 1a-b schematically summarizes these relationships.

Rowe (1961) addressed the problems of ecosystems' scale and boundaries, calling an ecosystem a "topographic unit, a volume of land and air plus organic contents extended areally over a particular part of the earth's surface for a certain time, ... with boundaries fixed by definition." The concept of defined boundaries raises two related issues of ecosystem delineation. The first is the level of resolution at which a researcher chooses to study ecosystems. A photograph of earth from space (in which only two ecosystems can be differentiated, terrestrial and marine) and a low-altitude aerial photograph of a landscape (in which several homogeneous terrestrial ecosystems are recognizable) illustrate the broad variation in the "levels of homogeneity" (Hills 1976) or "levels of integration" (Rowe 1961) at which ecosystems study

Fig. 1a. Schematic diagram of the flow of energy through the ecosystem and the cycling of chemical nutrients within the ecosystem. The biological and physical realms, represented by organic and inorganic compounds, together constitute the ecosystem. (From Ricklefs 1979, by permission Chiron Press.)

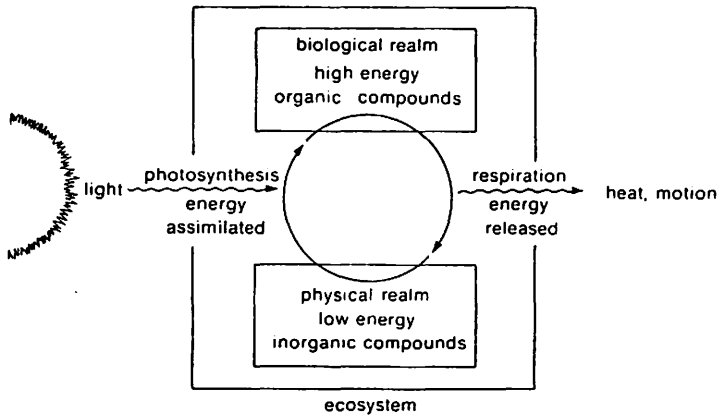
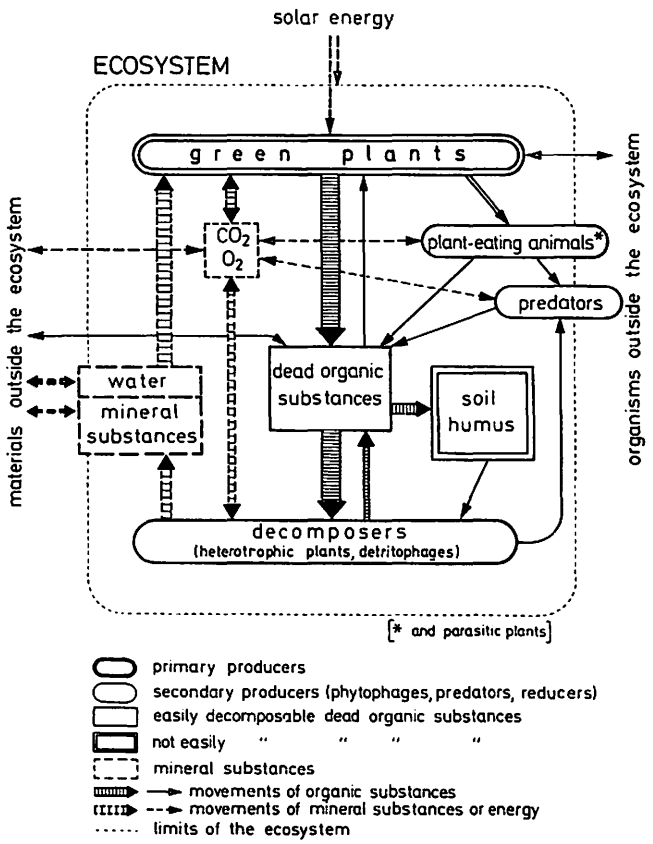


Fig. 1b. More detailed general scheme of an ecosystem. The individual components and processes may be of varying importance. (From Ellenberg 1971, by permission Springer-Verlag, Inc.)



can be conducted.

The second issue involves the decision of locating boundaries between ecosystems. Because ecosystems usually intergrade fairly continuously along environmental gradients (Whittaker 1975), any classification system distinguishing ecosystem types and their boundaries must be to some extent arbitrary. Just as the ecologist chooses the level of resolution at which to work, she chooses criteria on which a classification system and boundaries are based dependent on the use to which the system is to be put (Whittaker 1975; Hills 1976). Though these decisions are somewhat arbitrary, this in no way lessens the value of classification of ecosystems for purposes of description and management (Whittaker 1975).

The ecosystem concept has been applied widely in Alaska and throughout the north. Its most common use has been simply as a unifying conceptual framework into which diverse structural and functional studies of abiotic and biotic components and processes of the environment are fitted (see for example Bunnell et al. 1975; Brown et al., in prep.). Less frequently the concept has been used to describe landscape units with similar biotic and abiotic characteristics for purposes of land management (see for example National Petroleum Reserve for Alaska Task Force 1979; FSLUPC 1973b). This study emphasizes the latter approach, with the overall goal "to differentiate .. ecologically significant segments of the land surface" (Lacate 1969, in Hills 1976).

METHODS

Ecosystem analysis in the complete sense involves three elements: 1) recognition of ecosystem units; 2) description of their structure (composition); and 3) study, generally quantitative, of the functioning and interrelations of the abiotic and biotic components of the ecosystem (see for example Rosswall and Heal 1975; Bliss 1977). The ecosystem analysis in this study emphasizes the structural rather than the functional aspects, and hence provides only descriptive information about the biota and physical features of the ecosystems recognized in the Ray Mountains.

Because the ecosystem analysis of this study involved synthesis of data from the component scientific studies of the Ray Mountains project, in some ways its methods were the same as those of each of the other studies. Details of the methods and results of the other studies are found in their respective chapters of this volume.

In addition to working closely with the other members of the project both in the field and afterwards, I also conducted field research and data analysis of my own design. Described here are the overall methods of this study, with emphasis on those methods that I directed or carried out; only a general account of the others' methods is given.

Ecosystem Delimitation

The criteria that I used to recognize ecosystems gave primary consideration to vegetation physiognomy and elevation. Vegetation physiognomy was emphasized because of its recognized importance as a major determinant of animal habitat selection (Kessel 1979; Whittaker 1975) and because it was used as the basis for vegetation classification by the project's vegetation study team (Brock and Burke, this volume). Elevation was stressed because of the close relationship in subarctic mountains between decreasing elevation and increasing vegetation stature related to numerous environmental gradients. These gradients associated with decreasing elevation include increasing mean temperature, length of growing season, and soil development; and decreasing precipitation, wind speed, slope, substrate drainage, depth of active layer to ice-rich permafrost, and frost action.

The ecosystems classification developed for the Ray Mountains has been designed at a level of resolution to yield few units so that they were sufficiently distinct to be easily recognizable, and not beyond the limited scope of the study. Distinctions among ecosystems are based on characteristic groups of vegetation types, species, and physical features and processes. The boundaries between ecosystems were subjectively derived from discontinuities in physical and biotic gradients where possible.

Field Methods

Though most of the Ray Mountains project study team spent approximately eight weeks in the study area (see Introduction to this volume for detailed description of project research design), my fieldwork was conducted in one month, from 18 July to 16 August. Data collected, including that gathered by the other component study teams, included inventory of species, communities, and physical features present in the study area; their relative importance; and their habitat affinities or landform associations.

Areas of Concentrated Study

Upper Torment Creek

A camp was maintained near the headwaters of Torment Creek (RMP site IIc) between 22-30 July, primarily for coordinated ecosystem study. The upper Torment Creek watershed (Fig. 2), situated between 702-1312 m (2300-4300 ft) is small (approximately 8.3 sq km) and ideal for detailed ecosystems study. The drainage basin is typical of Ray Mountains upper-elevation valleys and thus is well suited for developing a basic understanding of the ecosystems of this portion of the range. The research there provided a foundation for extrapolation and correlation of data from other areas of the range studied in less detail.

A transect roughly 50 m wide and 3100 m long was established from ridge to ridge across the valley (Fig. 2) where seven researchers spent part or all of nine days collecting basic data. To a lesser extent, data were collected elsewhere within and near the watershed. Investigations included geologic mapping and description (S. Roeske and L. Senior); geomorphological description (J. Schubert); soil analysis (T. Smith and J. Schubert); vegetation description, sampling, and mapping (J. Schubert); plant collection (T. Kassler and J. Schubert); small mammal trapping and large mammal observation and recording of sign (L. Halpin and J. Schubert); transect and incidental observation of birds (P. Matthews and J. Schubert), and insect collection (L. Halpin).

Vegetation along the upper Torment Creek transect was sampled with the releve technique developed by Walker et al. (1979, unpubl.). Releve sites were chosen at six locations considered representative of the major vegetation types along the transect. Because there were no aerial photographs for the upper Torment Creek area, vegetation mapping was done freehand from high vantage points after sampling along the transect and extensive observation and description of vegetation.

In addition, in upper Torment Creek and throughout my field season, I maintained an extensive field journal for observations of weather, birds, and mammals; vegetation - environmental gradients; and a variety of correlations and ecological relationships. Likewise, I had numerous valuable conversations with project study team members to discuss correlations and relationships among ecosystem components.

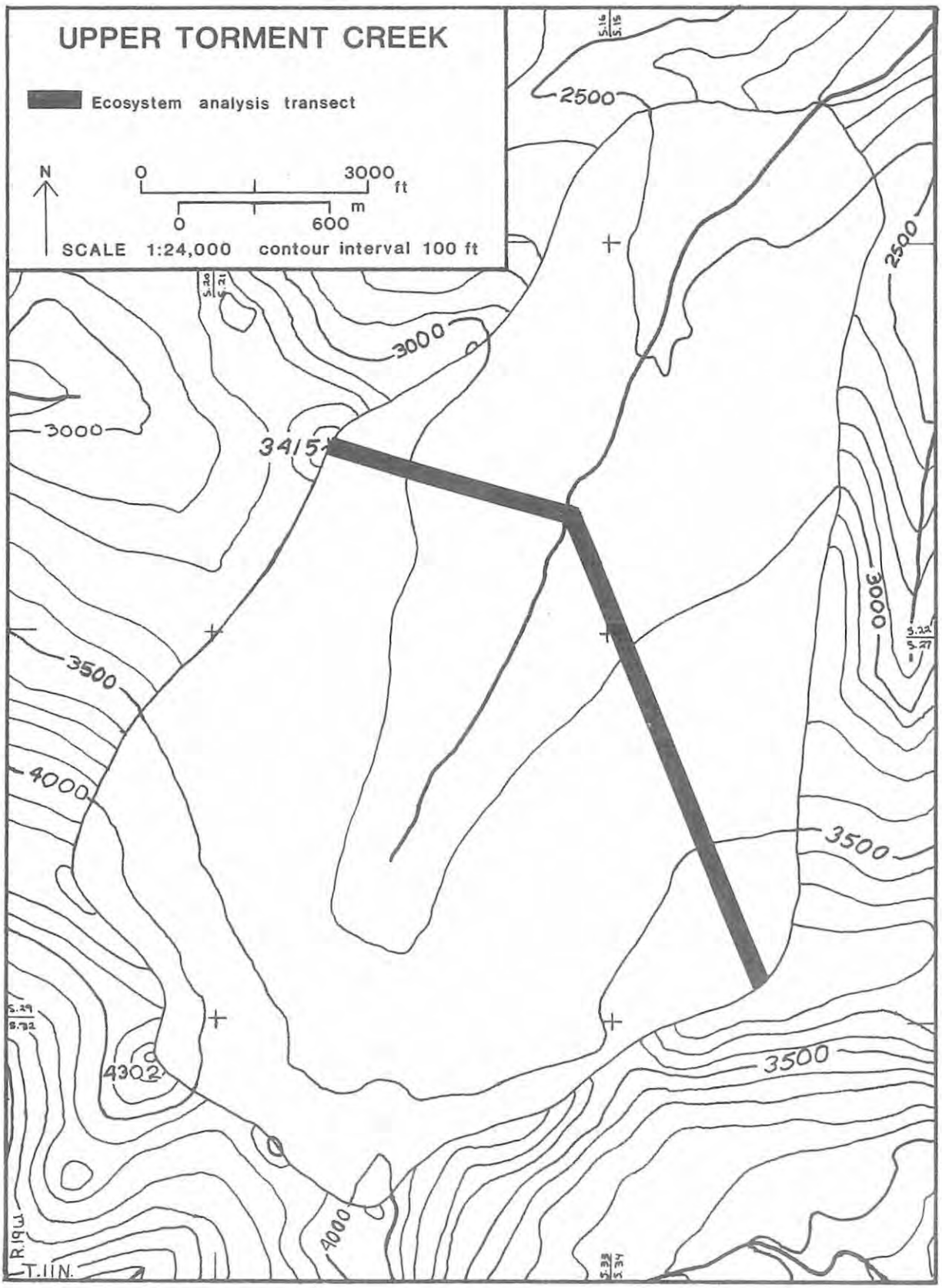


Fig. 2. The upper Torment Creek watershed was the site of detailed ecosystems study, particularly along a ridge to ridge transect.

Lower Torment Creek and Spooky Valley

In both lower Torment Creek near basecamp (RMP site IIb), and Spooky Valley along upper Kobuk Creek (RMP site IVa), fairly detailed investigations were carried out by each of the component study teams. Though the work in these areas was not coordinated specifically for ecosystem analysis, the multidisciplinary data gathered there was useful in my study. This was especially the case in lower Torment Creek which was representative of the lower elevations of the Ray Mountains.

Areas of Less Concentrated Study

Each study team spent up to one-half of the field season on excursions away from the areas of concentrated study to observe, describe, and to some extent sample a variety of areas in the Ray Mountains (see Table 1 and Fig. 1 in the Introduction, this volume). The data gathered on these trips were most useful for comparison with the areas which had been studied more rigorously and thus aided assessment of the areal extent of important species, vegetation types, soils, and other features, as well as ecosystems. Aerial reconnaissance also provided useful overviews of the entire mountain range.

Between 6-17 August, five others of the project study team and I hiked 61 km from basecamp, across the range to the Yukon River (see Fig. 1 in the Introduction, this volume). During this 12-day traverse of the Ray Mountains, studies included detailed observation and description, and some sampling, of geology (S. Roeske); geomorphology (R. Tarlov and J. Schubert); soils (T. Smith); vegetation, flora, and birds (J. Schubert); and mammals and insects (L. Halpin and others). With the understanding gained from the detailed work of the first part of the summer, I focused particular attention on delimitation and description of ecosystems, and on relationships among the ecosystems recognized.

Data Analysis

Before ecosystem data analysis could begin, the other study teams reduced and analyzed their data. The vegetation study team, through close work with other study teams, developed a vegetation classification system (Brock and Burke, this volume) useable, with only minor modifications, by the floristics, mammals, birds, insects, and soils study teams for habitat and landform association analysis. Cooperation with all these study teams insured that their results were presented in formats compatible for integration.

When the mammals, birds, and soils study teams had assessed habitat affinities and landform associations, and relative abundances, these data were used to make a matrix to

corroborate the ecosystem units I had recognized in the field. The matrix is essentially a "differentiated table" (Whittaker 1975) with important mammal and bird species and soil types arranged on the vertical axis, and the vegetation types used for habitat description arranged on the horizontal axis. Importance values (based on relative abundances and degree of habitat affinities) indicate the prominence of species and soil types in a given habitat. The vegetation types are arranged in the order they would occur along an idealized elevational gradient. The species and soil types are arranged to show groups that are important along different portions of the gradient. To emphasize the most important structural and functional elements of the ecosystems, only those species and soil types common or abundant in their preferred habitats were included in the matrix.

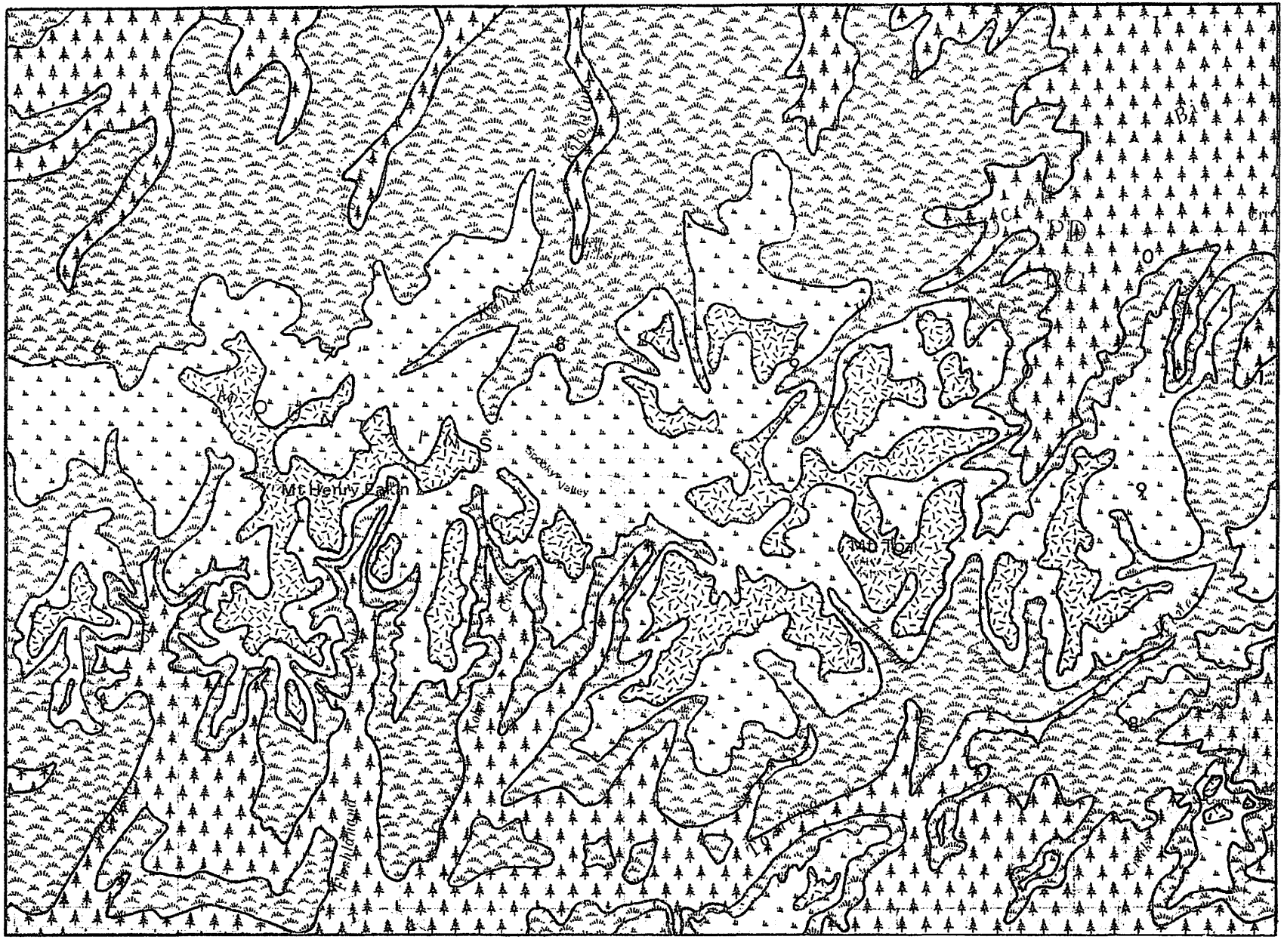
A map showing the ecosystem distributions in the study area was constructed from generalizations developed from field data and with use of the small-scale vegetation map developed by S. Brock (in Brock and Burke, this volume). Using a polar compensating planimeter, the areal extent of each of the ecosystems was calculated from the ecosystem map.

Scientific and common names in this chapter follow the authorities consulted by the component chapters of this volume: soils, Rieger et al. (1979); plants, Hulten (1968), except willows, Viereck and Little (1972); mammals, Jones et al. (1973) -- with minor exceptions (see Armstrong and Halpin, this volume), and birds, American Ornithologists' Union (1957, 1973, 1976).

RESULTS AND DISCUSSION

In this study four ecosystem units were recognized in the Ray Mountains. Occurring within usually predictable elevational zones, from highest to lowest in the range they are ALPINE BARREN, UPLAND TUNDRA, LOWLAND TUNDRA, and BOREAL FOREST. The map showing the ecosystems' distribution in the study area (Fig. 3) illustrates clearly this elevational zonation. The ecosystems have significant differences in physical, biotic, and disturbance characteristics of the environment, and are most easily recognized by characteristic vegetation types, animals, and physical features (Table 1).

Viewed at a higher level of resolution, each ecosystem is a mosaic of smaller, fairly discrete sub-units. The clearest mosaic is that of vegetation, with each ecosystem including at least two fairly distinct, areally important vegetation types and several less important ones. These vegetation types



PRELIMINARY ECOSYSTEMS MAP OF THE RAY MOUNTAINS

N

SCALE 1:250000

0 5 10 mi

0 5 10 km

CONTOUR INTERVAL 200 FEET

ALPINE BARREN

LOWLAND TUNDRA

UPLAND TUNDRA

BOREAL FOREST

Table 1. Principal physical and biotic characteristics of the ecosystems of the Ray Mountains; those shown between ecosystems are ecotonal or found in both ecosystems.

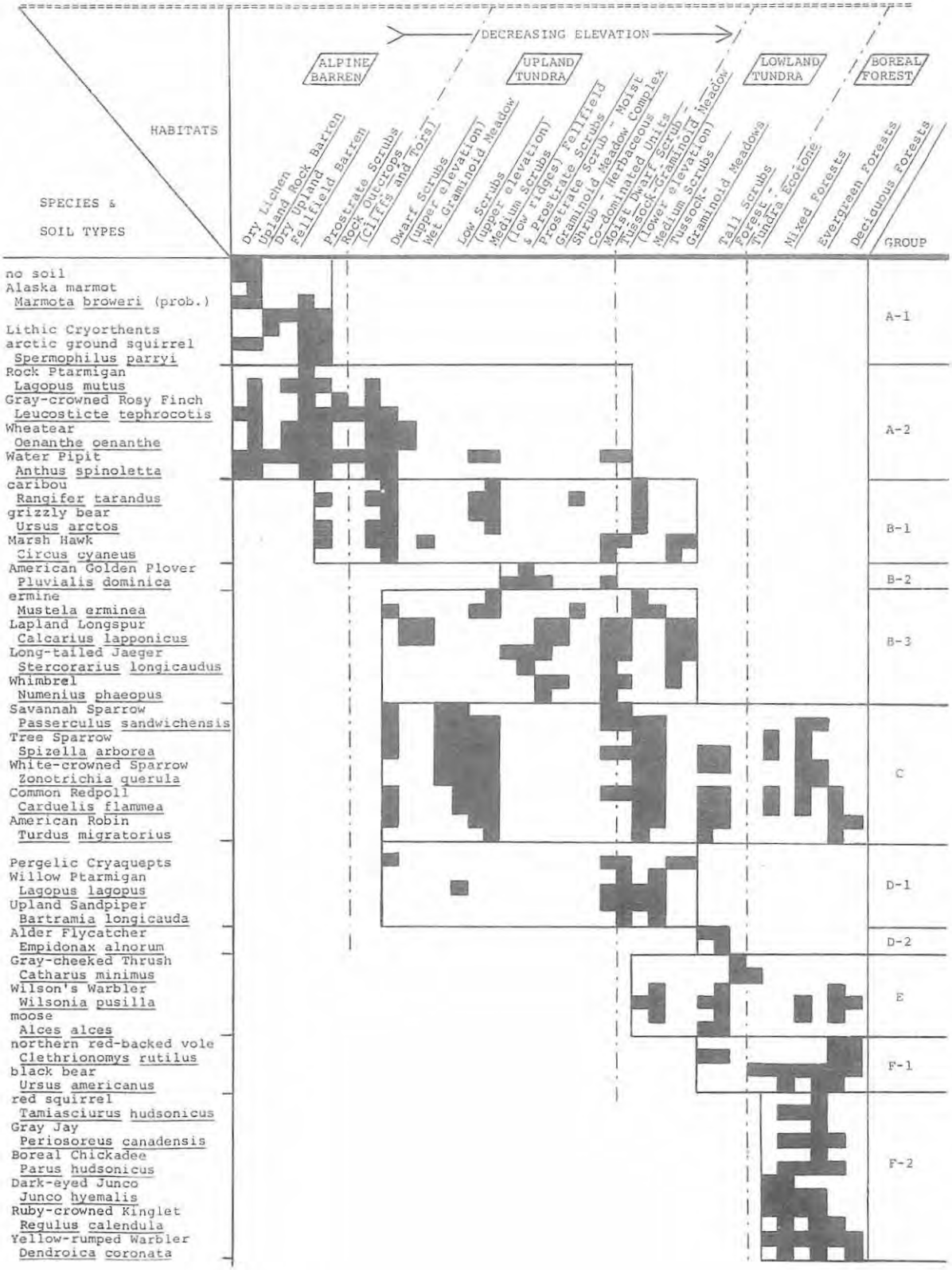
FEATURE	ECOSYSTEM			
	ALPINE BARREN	UPLAND TUNDRA	LOWLAND TUNDRA	BOREAL FOREST
Terrain	high central rugged mountains	upper elevation valleys and mid-elevation ridges	Broad mid-elevation valleys and rolling lowlands	lower elevation floodplains and adjacent slopes
Elevation	1683 m (5519 ft) to	1067 m (3500 ft) to	823 m (2700 ft) to	610 m (2000 ft)
Approximate areal extent in study area % of total	238 sq km (92 sq mi) 11 %	531 sq km (205 sq mi) 24 %	838 sq km (324 sq mi) 38 %	539 sq km (229 sq mi) 27 %
Geomorphic features	rock slopes, rock polygons, arretes, stone stripes, horns	altiplanation terraces, cirques, tors, nivation hollows U-shaped valleys	solifluction lobes	floodplains
Soils	no soil and Lithic Cryorthents	Pergelic Cryaquepts		Pergelic Cryochrepts and Pergelic Cryaquepts
Permafrost	dry and below bedrock	some ice-rich at moderate depth	75-50 cm ice-rich, near surface 29.5-19.7 in	deep or absent 90 cm
Vegetation types	Dry Lichen Upland Rock Barren, Dry Ericad Upland Prostrate Scrub	Moist Birch - Blueberry Dwarf Scrub, Moist Dwarf Scrub - Graminoid Meadow	Moist Tussock-Graminoid Meadow	Moist Paper Birch - Spruce Slope Forest, Moist White Spruce Slope Forest, Dry White Spruce Floodplain Forest
		Moist Dwarf Scrub - Tussock-Graminoid Meadow		
Mammals	arctic ground squirrel, Alaska marmot	caribou, grizzly bear, ermine	moose	black bear, northern red-backed mouse, red squirrel
Birds	Water Pipit, Wheatear, Gray-crowned Rosy Finch, Rock Ptarmigan	Lapland Longspur, Savannah Sparrow, Marsh Hawk, Long-tailed Jaeger, American Golden Plover	Common Redpoll, American Robin, White-crowned Sparrow, Wilson's Warbler, Willow Ptarmigan, Upland Sandpiper	Yellow-rumped Warbler, Ruby-crowned Kinglet, Dark-eyed Junco, Boreal Chickadee, Gray Jay
Natural disturbances	frost-shattering, mass wastage, wind scouring	minor animal excavation and wildfire	minor flooding and wildfire	wildfire and flooding
	cryoturbation			

within an ecosystem are generally closely related; their variation is due primarily to minor changes in slope, aspect, topographic position, and substrate. In anomalous environments unrelated vegetation types may be found within an ecosystem -- for example Wet "Lowland" Tussock-Graminoid Meadow, typically of the LOWLAND TUNDRA ecosystem, is sometimes found in high passes within the ALPINE BARREN ecosystem.

A differentiated ecosystem table (Fig. 4) corroborates the ecosystem units that I had recognized. The table indicates which mammals, birds, and soils are important along specific portions of the vegetation-elevation gradient and shows ten clearly discernible species-soils groups. Group A-1 includes birds, mammals, and soils that are important exclusively in ALPINE BARREN habitats; group A-2 includes those important in ALPINE BARREN primarily, but also important, though to a lesser extent, in UPLAND TUNDRA habitats. Group B-1 includes birds, mammals, and soils important primarily in UPLAND TUNDRA, but also in ALPINE BARREN and LOWLAND TUNDRA habitats; the single B-2 species is important exclusively in UPLAND TUNDRA; group B-3 includes birds, mammals, and soils important primarily in UPLAND TUNDRA, but also in LOWLAND TUNDRA habitats. Group C includes birds, mammals, and soils important in habitats of UPLAND TUNDRA, LOWLAND TUNDRA, and BOREAL FOREST. Group D-1 includes those important primarily in LOWLAND TUNDRA, but also in UPLAND TUNDRA habitats; the single D-2 species is important exclusively in LOWLAND TUNDRA. Group E includes birds, mammals, and soils of roughly equal importance in LOWLAND TUNDRA and BOREAL FOREST habitats. Group F-1 includes those important primarily in BOREAL FOREST, but also in LOWLAND TUNDRA habitats; and finally, group F-2 includes those birds, mammals, and soils important exclusively in BOREAL FOREST habitats.

The matrix (Fig. 4) shows the important constituent species and soils found in each ecosystem and the extent to which a species or soil is important in other ecosystems. (The matrix was not designed to show any minor occurrence of a species or soil in additional habitats.) The matrix also gives some indication of the distinctness of the ecosystems and the clarity of their boundaries. ALPINE BARREN and BOREAL FOREST have respectively four and six indicator characteristics (species or soils important in only one ecosystem and thus to some extent diagnostic of it). This suggests that these ecosystems are fairly discrete. On the other hand, UPLAND TUNDRA and LOWLAND TUNDRA each have only one indicator characteristic, therefore suggesting a less clear boundary between them along a more continuous gradient.

Fig. 4. Differentiated ecosystem table based on importance values for important birds, mammals, and soil types in their preferred or associated habitats. Assigned values for animals were based on relative abundance and habitat affinity: ■ =4=abundant in 1° habitat; ▟ =3=common in 1° habitat; ▬ =2=abundant in 2° habitat; ▪ =1=common in 2° habitat. Habitats are the vegetation types and variations used by the respective study teams for assessment of animal habitat affinities and soil landform associations. Vertical dashed lines indicate approximate boundaries between ecosystems along an idealized elevation - vegetation gradient. Darkened portion of squares was oriented to emphasize groups; see text for explanation of groups.



Ecosystem Descriptions

The following descriptions of the four ecosystems recognized in the Ray Mountains rely heavily on tabular presentation of the differentiating physical, biotic, and disturbance characteristics of each ecosystem. This table presentation approach has been used to present the information as concisely and clearly as possible. Included in the text is some discussion of the relationships among the different characteristics.

ALPINE BARREN

This ecosystem dominates the rugged central, highest portion of the Ray Mountains (Photo 1) and includes approximately 11% of the study area, mostly above 1067 m (3500 ft). Table 2-3 outline in detail the physical, biotic, and disturbance characteristics of the ALPINE BARREN ecosystem in the range.

The boundary of this ecosystem with UPLAND TUNDRA is generally quite distinct, often delimited clearly by a sharp slope gradient from steep (10-40 degrees inclination) to less steep (5-15 degrees inclination) at the base of high mountain peaks and ridges. This change in slope corresponds clearly with changes in substrate (from well-drained rock slopes and Lithic Cryorthents to less well-drained soils and poorly drained Pergelic Cryaquepts) and vegetation (from barrens and prostrate scrubs to dwarf scrubs), as well as other characteristics. The boundary may be less distinct along the more gradual gradients of rounded ridges at slightly lower elevations.

Resistant granite and gneiss bedrock form the backbone of the highest portion of the range. The resulting rigorous climate of ALPINE BARREN has significant effects on the structure and function of this ecosystem. Intense freeze-thaw cycles have worked on the bedrock to produce abundant frost-shattered material. Steep slopes (15-40 degrees inclination) are usually covered with such material, usually >0.5 m in diameter, which is actively moving downslope (Photo 1). This active movement and the extreme drainage of these rock slopes prevents any significant soil development. Thus, vegetation is very sparse, typically limited to crustose and foliose lichens on the rocks.

On less steep, more stable slopes (10-15 degrees inclination) and on exposed ridgetops, well-drained Lithic Cryorthent and Pergelic Cryorthent soils are present. These poorly developed soils are strongly influenced by cryoturbation that yields well developed periglacial features including altiplanation terraces, rock polygons, stone stripes, and sorted stone circles. Such inhospitable

Photo 1. The ALPINE BARREN ecosystem dominates the rugged, highest portion of the Ray Mountains. Frost-shattered rock slopes are common.

Photo 2. Severe winter winds and active freeze-thaw cycles limit vegetation development to prostrate scrubs, lichen meadows, and fellfield barrens in the ALPINE BARREN ecosystem. Periglacial features such as soil and stone stripes are common.

Table 2. Differentiating physical characteristics of the ALPINE BARREN ecosystem in the Ray Mountains.

PHYSIOGRAPHY: highest central portion of the range; rugged mountains usually with steep (10-40 degrees) slopes; ridges vary from ragged arretes to rounded

ELEVATION: highest point is Mount Tozi at 1683 m (5519 ft); lower limit varies from 1494-762 m (4900-2500 ft) -- lower on steep slopes and/or more exposed sites

CLIMATE: intense freeze-thaw cycles; coldest ecosystem in the range; high winds and therefore only local snow accumulation; area of greatest precipitaion (though best drained as well)

BEDROCK: predominantly granites; also gneisses, schists, and mafics and ultramafics

GEOMORPHIC PROCESSES & FEATURES:

Glacial -- extensive late Pleistocene alpine glaciation left cirques *, arretes *, and horns *

Periglacial -- intense freeze-thaw yields frost-shattered rock *, altiplanation terraces <, rock polygons *, stone stripes *, sorted stone circles *, and frost boils <,

Mass Wasting -- widespread downslope movement of frost-shattered material has formed extensive rock slopes *

Wind -- high velocity wind-blown snow contributes to sculpture of tors < (a common feature)

SOILS: none on rock slopes *, Lithic Cryorthents * and Pergelic Cryorthents < elsewhere; all dry and well drained

PERMAFROST: below bedrock surface *

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* designates a good indicator characteristic of this ecosystem
>(<) designates a characteristic also found in adjacent ecosystem upslope (downslope)
@ designates a feature with very limited distribution within the ecosystem

Table 3. Differentiating biotic and natural disturbance characteristics of the ALPINE BARREN ecosystem in the Ray Mountains. Vegetation types, animals, and disturbances are listed in approximate order of importance. Important vegetation types each covered more than approximately 15% of the ecosystem; less important ones covered less. Important animals were abundant or common in some portion of the ecosystem; less important ones were uncommon or rare.

Important Vegetation Types: Dry Lichen Upland Rock Barren * Dry Ericad Upland Prostrate Scrub <

Less Important Vegetation Types: Dry Upland Fruiticose Lichen Meadow *, Dry Upland Fellfield Barren <@, Wet "Lowland" Tussock-Graminoid Meadow <@

Important Mammals: arctic ground squirrel <, Alaska marmot *@

Less Important Mammals: caribou <, grizzly bear <

Important Birds: Water Pipit <, Wheatear <, Gray-crowned Rosy Finch <, Rock Ptarmigan <

Less Important Birds: Golden Eagle <@, Marsh Hawk <, Horned Lark <, Say's Phoebe <, Gyrfalcon <@, Golden-crowned Sparrow <

Important Natural Disturbances: cryoturbation <, mass wasting <, wind <

Less Important Natural Disturbances: animal excavation <

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* designates a good indicator species or vegetation type of this ecosystem.
>(<) designates a vegetation type, species, or disturbance also found in the adjacent ecosystem upslope (downslope).
@ desinates a species or vegetation type with very limited distribution within the ecosystem.

substrate, together with strong winds, limit vegetation to prostrate scrubs, lichen meadows, and fellfield barrens (Photo 2).

Not surprisingly, animal species are few in the ALPINE BARREN ecosystem (Table 3) and thus relationships among them are fairly simple. The two major mammal species, arctic ground squirrel and Alaska marmot, show clear adaptations to this rigorous environment. Both species make burrows in the rocky substrate to avoid predation in a habitat with little other cover. Both hibernate in their burrows, thus avoiding the difficult survival conditions of winter in the ALPINE BARREN ecosystem.

Bird species are also few (Table 3), but well adapted to this ecosystem. Most species migrate south for the winter and the only important year-round resident bird, the Rock Ptarmigan, shows highly developed cryptic coloration in both summer and winter.

UPLAND TUNDRA

This ecosystem covers approximately 24% of the study area and dominates upper elevation valleys (Photo 3) and mid-elevation ridges of the range, usually between 823-1067 m (2700-3500 ft). It extends higher on more gentle terrain; lower on steeper slopes. Table 4-5 outline in detail the physical, biotic, and disturbance characteristics of the UPLAND TUNDRA ecosystem in the Ray Mountains.

The boundary between this ecosystem and LOWLAND TUNDRA is not distinct. Environmental gradients between them are gradual, yielding a fairly broad transition, readily recognized by the dominant ecotonal vegetation type, Moist Dwarf Scrub - Tussock-Graminoid Meadow.

A factor that is responsible for the distinct character of UPLAND TUNDRA is the significant accumulation of winter's snow in the high valleys (much of it wind-blown from adjacent ALPINE BARREN) that lies late into spring and early summer. This snow, together with the intermediate slope (5-15 degrees inclination), intermediate drainage, and fairly active periglacial processes, undoubtedly influences the development of the dwarf scrub, dwarf scrub - graminoid meadow, and snowbed graminoid meadow vegetation characteristic of UPLAND TUNDRA (Photo 4).

This ecosystem supports primary habitat for two prominent Ray Mountains' mammal species, caribou and grizzly bear. UPLAND TUNDRA is also productive habitat for numerous bird species, mostly passerines, but also including large-bodied shorebirds and predatory birds (Table 5).

Photo 3. View of upper Torment Creek valley head. The UPLAND TUNDRA ecosystem dominates upper elevation valleys of the Ray Mountains and gives way to ALPINE BARREN on steep, higher elevation slopes. Large solifluction lobes are common.

Photo 4. Due to late lying snow in UPLAND TUNDRA valleys, Moist Snowbed Graminoid Meadow is a conspicuous vegetation type. Other common vegetation types include dwarf scrubs and dwarf scrub - graminoid meadows.

Table 4. Differentiating physical characteristics of the UPLAND TUNDRA ecosystem in the Ray Mountains.

PHYSIOGRAPHY: upper elevation valleybottoms and lower slopes, rounded mid-elevation ridges, and rolling uplands; slope generally 5-15 degrees

ELEVATION: upper limit varies from 762-1494 m (2500-4900 ft) -- higher on gentle slopes and/or protected sites; lower limit varies from 1037-610 m (3400-2000 ft) -- lower on steep slopes

CLIMATE: valleys are major snow accumulation areas (much of it wind blown) *

BEDROCK: predominantly granites; also gneisses, schists, and mafics and ultramafics

GEOMORPHIC PROCESSES & FEATURES:

Glacial -- fairly extensive late-Pleistocene alpine glaciation left numerous U-shaped valleys *, moraines <, and tarns *@

Periglacial -- fairly intensive freeze-thaw yields large * solifluction lobes <, altiplanation terraces >, and frost boils >

Mass Wasting -- some mudflows and slumps >@

Wind -- wind-blown snow contributes to sculpture of tors > (a common feature) and establishment of snowbeds

Other -- nivation hollows * (snowbeds) are common

SOILS: Pergelic Cryorthents > common on well drained sites; Pergelic Cryaquepts < common on poorly drained sites

PERMAFROST: at moderate depth (50-75 cm), some ice-rich

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* designates a good indicator characteristic of this ecosystem
>(<) designates a characteristic also found in adjacent ecosystem upslope (downslope)
@ designates a feature with very limited distribution within the ecosystem

Table 5. Differentiating biotic and natural disturbance characteristics of the UPLAND TUNDRA ecosystem in the Ray Mountains. Vegetation types, animals, and disturbances are listed in approximate order of importance. Important vegetation types each covered more than approximately 15% of the ecosystem; less important ones covered less. Important animals were abundant or common in some portion of the ecosystem; less important ones were uncommon or rare.

Important Vegetation Types: Moist Birch - Blueberry Dwarf Scrub * Moist Dwarf Scrub - Graminoid Meadow *

Less Important Vegetation Types: Moist Dwarf Scrub - Tussock-Graminoid Meadow <, Moist Willow Drainageway Medium Scrub <, Dry Birch Upland Dwarf Scrub *, Moist Willow Upland Medium Scrub *, Moist Snowbed Graminoid Meadow *, Wet Graminoid Meadow <@, Moist Snowbed Forb Meadow *@, Dry Ericad Upland Prostrate Scrub >@, Dry Upland Fellfield Barren >@, Wet Sphagnum Moss Meadow <@

Important Mammals: caribou ><, grizzly bear ><, ermine <

Less Important Mammals: arctic ground squirrel >, singing vole <, wolf <

Important Birds: Lapland Longspur <, Tree Sparrow <, Savannah Sparrow <, White-crowned Sparrow <, Common Redpoll <, Water Pipit >, Wheatear >, Marsh Hawk ><, Long-tailed Jaeger <, Gray-crowned Rosy Finch >, American Robin <

Less Important Birds: Rock Ptarmigan >, Least Sandpiper <@, Golden Eagle >, Willow Ptarmigan <, Say's Phoebe >, Pectoral Sandpiper <@, Gyrfalcon >@, American Golden Plover <, Horned Lark >, Semipalmated Sandpiper <@, Cliff Swallow @, Common Raven, Golden-crowned Sparrow >

Important Natural Disturbances: none

Less Important Natural Disturbances: animal excavation >, cryoturbation ><, wildfire <, wind >

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* designates a good indicator species or vegetation type of this ecosystem.
>(<) designates a vegetation type, species, or disturbance also found in the adjacent ecosystem upslope (downslope).
@ designates a species or vegetation type with very limited distribution within the ecosystem.

LOWLAND TUNDRA

This ecosystem covers approximately 38% of the study area and dominates broad mid-elevation valleys and ridges and rolling lowlands of the range (Photo 5-6). It usually occurs between 610-823 m (2000-2700 ft), but extends higher on more gentle terrain. Table 6-7 outline in detail the physical, biotic, and disturbance characteristics of the LOWLAND TUNDRA ecosystem in the Ray Mountains.

The boundary between this ecosystem and BOREAL FOREST is clearly defined by forest limit; the forest-tundra ecotone is only a narrow band in the Ray Mountains. The boundary occurs at lower elevations where poorly drained rolling to flat terrain gives way to well-drained floodplains and adjacent slopes 5-15 degrees inclination.

Less resistant schist bedrock underlies most of this portion of the range and has been eroded to form the rolling landscape of the LOWLAND TUNDRA ecosystem. This soft bedrock has also yielded well-developed soils that in the moderate climate of this ecosystem support lush tundra vegetation, predominantly tussock-graminoid meadows and dwarf scrub - tussock-graminoid meadows. Medium to tall willow scrubs are important along streams and drainageways. Ice-rich permafrost is at shallow depth (25-40 cm) and is responsible for moist to wet Pergelic Cryaquept soils. These factors together with the continuous vegetation cover and moderate freeze-thaw cycles in this portion of the range yield well-developed solifluction lobes on gentle slopes.

Moose are the only important large mammal in this ecosystem and are most commonly found in the tall scrubs near treeline. Several other mammals utilize LOWLAND TUNDRA habitats to some extent (Table 7). This ecosystem is very productive for birds including a mix of passerine species, large-bodied shorebirds, and predatory birds.

Photo 5. View from ridge west of lower Torment Creek to upper Torment Creek and Mt. Henry Eakin. The LOWLAND TUNDRA ecosystem dominates broad mid-elevation ridges of the Ray Mountains and gives way to UPLAND TUNDRA and ALPINE BARREN at higher elevations.

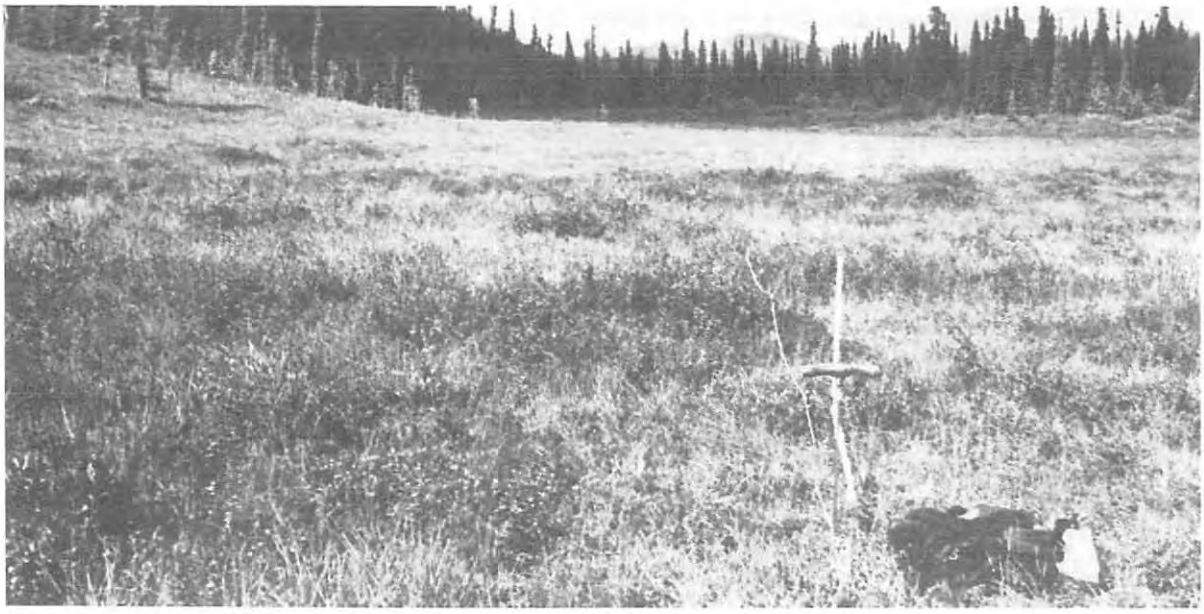

Photo 6. Wet LOWLAND TUNDRA dominates broad mid-elevation valley floors and gives way to BOREAL FOREST at lower elevations.

Table 6. Differentiating physical characteristics of the LOWLAND TUNDRA ecosystem in the Ray Mountains.

PHYSIOGRAPHY: lower elevation valleys and broad ridges, rolling lowlands, and poorly drained lowland flats below treeline; slope generally 0-5 degrees

ELEVATION: upper limit varies from 610-1037 m (2000-3400 ft) -- higher on gentle terrain; lower limit varies from 762-305 m (2500-1000 ft) -- higher on broad ridges above forested slopes, lower on rolling lowlands and poorly drained lowland flats

CLIMATE: intermediate in all respects

BEDROCK: predominantly schist; also gneisses, mafics and ultramafics, and granites

GEOMORPHIC PROCESSES & FEATURES:

Glacial -- late Pleistocene valley glaciers reached a few LOWLAND TUNDRA valleys leaving moraines >@

Periglacial -- moderate freeze-thaw yields abundant small solifluction lobes > on slopes; frost boils >@ present

Mass Wasting -- minor slumping along streambanks @

Fluvial -- minor shifting channels and floodplain development <@

SOILS: Pergelic Cryaquepts >< and Histic Pergelic Cryaquepts * common

PERMAFROST: except along streams, shallow active layer (25-50 cm) above ice-rich frozen ground

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* designates a good indicator characteristic of this ecosystem
>(<) designates a characteristic also found in adjacent ecosystem upslope (downslope)
@ designates a feature with very limited distribution within the ecosystem

Table 7. Differentiating biotic and natural disturbance characteristics of the LOWLAND TUNDRA ecosystem in the Ray Mountains. Vegetation types, animals, and disturbances are listed in approximate order of importance. Important vegetation types each covered more than approximately 15% of the ecosystem; less important ones covered less. Important animals were abundant or common in some portion of the ecosystem; less important ones were uncommon or rare.

Important Vegetation Types: Moist Tussock-Graminoid Meadow *, Moist Dwarf Scrub - Tussock-Graminoid Meadow >

Less Important Vegetation Types: Moist Willow Drainageway Medium Scrub >, Moist Alder Savanna Medium Scrub *, Wet Lowland Tussock-Graminoid Meadow *, Wet Willow - Alder Drainageway Tall Scrub *, Moist Willow Floodplain Tall Scrub <, Moist Alder Slope Tall Scrub *, Wet Graminoid Meadow >@, Wet Sphagnum Moss Meadow >@

Important Mammals: moose <

Less Important Mammals: ermine >, northern red-backed vole <, caribou >, grizzly bear >, black bear <, wolf >, singing vole ><, snowshoe hare <, wolverine <, masked shrew <

Important Birds: Common Redpoll ><, Tree Sparrow ><, American Robin ><, White-crowned Sparrow ><, Wilson's Warbler <, Lapland Longspur >, Long-tailed Jaeger >, Marsh Hawk >, Willow Ptarmigan >, Whimbrel *, Upland Sandpiper *, Savannah Sparrow ><

Less Important Birds: Alder Flycatcher *, Least Sandpiper >@, American Golden Plover >, Gray-cheeked Thrush <, Pectoral Sandpiper >@, Sharp-shinned Hawk <@, Semipalmated Sandpiper @>, Varied Thrush <

Important Natural Disturbances: none

Less Important Natural Disturbances: cryoturbation >, wildfire ><, flooding <

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* designates a good indicator species or vegetation type of this ecosystem.
>(<) designates a vegetation type, species, or disturbance also found in the adjacent ecosystem upslope (downslope).
@ designates a species or vegetation type with very limited distribution within the ecosystem.

BOREAL FOREST

This ecosystem covers approximately 27% of the study area and dominates lower elevation floodplains and some adjacent slopes in the range, usually to about 610 m (2000 ft) (Photo 6-7). BOREAL FOREST extends higher on the slopes adjacent to floodplains and not as high where floodplains give way to rolling lowlands. On large lowland flats below treeline it may give way to wet LOWLAND TUNDRA. Table 8-9 outline in detail the physical, biotic, and disturbance characteristics of the BOREAL FOREST ecosystem in the Ray Mountains.

This ecosystem is, of course, clearly distinguished from the higher elevation tundra ecosystems by the presence of predominantly open mixed, evergreen, and deciduous forests. The structure of these forests is strongly influenced by two natural disturbances, flooding and wildfire. Shifting channels and floodplain development due to flooding are common along the lower portions of the major streams in the range and are an important natural disturbance that maintains early succession forb meadows and tall scrubs (Bliss and Cantlon 1957), and diverse patchy even-aged forests (Viereck 1975; Photo 7).

Wildfire is likely an even greater disturbance force in this ecosystem, significantly affecting BOREAL FOREST succession patterns. Eakin (1916) reported tremendous forest fires in the vicinity of the range during the summer of 1913, and it is well known that wildfire is common throughout interior Alaska (Viereck 1973). A very recently (1978?) burned forest area was visited in the Ishtalitna Creek valley (RMP site Vd) by members of the project study team. Charcoal was found in soil samples from several forest sites in lower Torment Creek valley (RMP site IIb) by T. Smith (pers. comm.) and the litter of firefighting crews was found in several locations (Farquhar, this volume).

The maintenance of early succession vegetation by flooding and wildfire is important to the BOREAL FOREST ecosystem's ability to support several animal species, most notably, moose. This ecosystem has a fairly distinct and diverse fauna including black bear, northern red-backed vole, red sqirrel, Boreal Chickadee, and several other passerine bird species (Table 9).

Table 8. Differentiating physical characteristics of the BOREAL FOREST ecosystem in the Ray Mountains.

PHYSIOGRAPHY: major lower elevation floodplains and adjacent slopes (usually 5-15 degrees)

ELEVATION: upper limit (forest limit) varies from 305-762 m (1000-2500 ft) -- lower adjacent to rolling lowlands and poorly drained lowland flats; higher on slopes adjacent to forested floodplains

CLIMATE: warmest ecosystem in the range; least precipitation

BEDROCK: predominantly schists; also mafics and ultramafics, gneisses, granites

GEOMORPHIC PROCESSES & FEATURES:

Glacial -- none

Periglacial -- minor

Fluvial -- shifting channels and floodplain development significant along major streams

SOILS: Pergelic Cryochrepts * common steep slopes; Pergelic Cryaquepts > common on poorly drained sites; Pergelic Cryorthods common on well drained floodplains

PERMAFROST: deep (>90 cm) on slopes; likely absent on floodplains

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* designates a good indicator characteristic of this ecosystem
>(<) designates a characteristic also found in adjacent ecosystem upslope (downslope)
@ designates a feature with very limited distribution within the ecosystem

Table 9. Differentiating biotic and natural disturbance characteristics of the BOREAL FOREST ecosystem in the Ray Mountains. Vegetation types, animals, and disturbances are listed in approximate order of importance. Important vegetation types each covered more than approximately 15% of the ecosystem; less important ones covered less. Important animals were abundant or common in some portion of the ecosystem; less important ones were uncommon or rare.

Important Vegetation Types: Moist Paper Birch - Spruce Slope Forest *, Moist White Spruce Slope Forest *, Dry White Spruce Floodplain Forest *

Less Important Vegetation Types: Moist Willow Floodplain Tall Scrub >, Moist Paper Birch Slope Forest *, Moist Balsam Poplar Floodplain Forest *, Moist White and Black Spruce Slope Forest *, Moist Balsam Poplar - Spruce Floodplain Forest *, Dry Paper Birch - Lichen Slope Forest *@, Dry Black Spruce - Lichen Forest *@, Wet Black Spruce - Sphagnum Forest *@

Important Mammals: black bear >, northern red-backed vole >, red squirrel *

Less Important Mammals: moose >, snowshoe hare >, singing vole >, porcupine, wolverine >, masked shrew >, beaver

Important Birds: Yellow-rumped Warbler *, Ruby-crowned Kinglet *, Dark-eyed Junco *, Common Redpoll >, Boreal Chickadee *, Gray Jay *, Wilson's Warbler >, White-crowned Sparrow >, Tree Sparrow >

Less Important Birds: American Robin >, Savannah Sparrow >, Sharp-shinned Hawk >, Olive-sided Flycatcher *, Varied Thrush >, Gray-cheeked Thrush >

Important Natural Disturbances: wildfire >

Less Important Natural Disturbances: flooding >

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* designates a good indicator species or vegetation type of this ecosystem.
>(<) designates a vegetation type, species, or disturbance also found in the adjacent ecosystem upslope (downslope).
@ designates a species or vegetation type with very limited distribution within the ecosystem.

Photo 7. View NE up the Tozitna River valley. The BOREAL FOREST ecosystem follows floodplains into the lower elevations of the Ray Mountains. Dry White Spruce Floodplain Forest is the characteristic vegetation type.

Ray Mountains as an Ecological Island

The results of this volume together with other statewide and regional environmental studies (Hartman and Johnson 1978; Selkregg 1975; Wahrhaftig 1965; Viereck 1971; FSLUPC 1973b) indicate that the Ray Mountains are an ecologically diverse mountain range, significantly different from the lower elevation landscape that surrounds them. Conspicuous in central Alaska as the largest contiguous area above treeline, the Ray Mountains are an ecological "island" of subarctic tundra fringed by the taiga (Viereck 1973, 1975) which is dominant in central and interior Alaska (Fig. 5). I define such a Ray Mountains island to include the area above treeline [generally near 610 m (2000 ft)], as well as the forested floodplains and their adjacent forested slopes that finger into the range. The following section summarizes information supporting these generalizations and presents background on other aspects of the ecological character of the range.

Physiographically, the Ray Mountains are surrounded by lowland alluvial flats of the Tozitna, Melozitna, Kanuti Kilolitna, and Ray Rivers and the low elevation valley of the Yukon River. In a larger regional context, the more extensive lowland alluvial flats of the lower Tanana, Kantishna, Nowitna, Koyukuk, Kanuti, and upper Yukon Rivers isolate the uplands of the Ray Mountains and adjacent Kokrines Hills and Hodzana Highlands. The only upland connection higher than

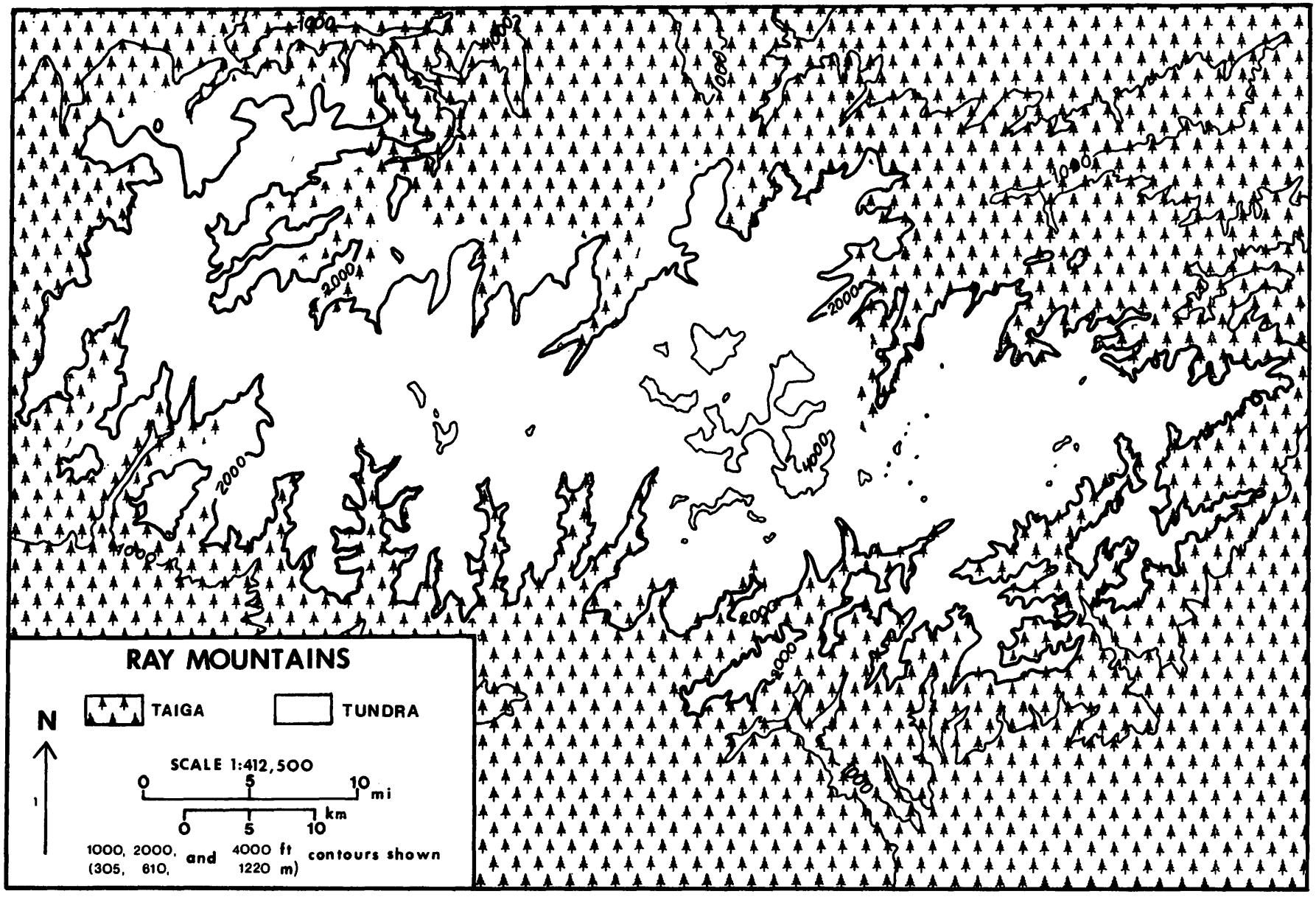

Fig. 5. The Ray Mountains as a physiographic and ecological island. The range is a distinct "island" of mountainous terrain above 2000 ft (610 m) supporting diverse subarctic tundra ecosystems and is surrounded by lowlands below 1000 ft (305 m) supporting taiga ecosystems.

300 m between the Ray Mountains and another major mountainous area is through the Hodzana Highlands to the Brooks Range.

The physical environment of the Ray Mountains is considerably different than that of the surrounding region. Due to orographic effects, the range receives almost twice as much precipitation, both as rain and snow, as the surrounding area (Hartman and Johnson 1978), and because of its higher elevation (Haugen and Brown 1978), the range has a lower mean annual temperature (Hartman and Johnson 1978). Rome (pers. comm.) reports that the range experiences unusually severe winter winds.

The Ray Mountains are underlain by a variety of bedrock types (Chapman et al. 1975; Roeske and Senior, this volume) that have yielded a diverse array of landforms (Tarlov with others, this volume) such as rugged high peaks, U-shaped upper elevation valleys, rolling uplands and lowlands, and broad alluviated lower elevation valleys. The rugged upper elevation portion of the range experienced late Pleistocene glaciation, a phenomenon which otherwise was very limited within interior Alaska (Yeend 1971). All these physical factors combine to yield a landscape with soils and well developed periglacial features characteristic of a subarctic mountain landscape (Smith, this volume; Eakin 1916; Tarlov with others, this volume).

The biota of the Ray Mountains is strongly influenced by the physical environment and thus is also significantly different from the biota of the surrounding region. In contrast to the dominant taiga of central Alaska, the Ray Mountains are an extensive area supporting a wide variety of alpine and low arctic tundra vegetation types, as well as some boreal forest types in the periphery of the range (Brock and Burke, this volume). The range's diversity of vegetation types probably results from a variety of factors, perhaps the more important of which are the range's diversity of landforms and large area, combined with its ecotonal situation near the northern latitudinal limit of forest.

These same factors, especially the large extent of diverse tundra, are probably responsible for the rich fauna and flora of the Ray Mountains (Matthews, this volume; Halpin, this volume; Armstrong and Halpin, this volume; Kassler, this volume). The flora of the range, though not exceptionally diverse, includes arctic and alpine species, as well as some boreal species (Kassler, this volume). Fifty-seven of the 227 species documented in the range were extensions beyond their previously recorded ranges. Except for the extensions that were associated with Kilo Hot Spring (RMP site IIIa), most were disjuncts collected from isolated alpine tundra habitats.

The diverse and fairly extensive tundra habitats of the

Ray Mountains support a vertebrate fauna dominated by characteristic tundra species such as grizzly bear, caribou, Alaska marmot (preliminary identification), arctic ground squirrel, ermine, Long-tailed Jaeger, Marsh Hawk, Rock Ptarmigan, American Golden Plover, Whimbrel, Water Pipit, Wheatear, Gray-crowned Rosy Finch, and several other passerine bird species. The fauna is enriched by taiga species including moose, black bear, red squirrel, northern red-backed vole, Boreal Chickadee, Dark-eyed Junco, Gray Jay, and several other passerine bird species. The caribou of the range are part of a small herd restricted to the Ray Mountains - Kokrines Hills area; the Alaska marmots are a population isolated from their previously known range in the Brooks Range; and the singing voles, uncommon in the range, are an isolated population between the Brooks and Alaska Ranges. The insect fauna of the range is also predominantly tundra species, enriched by taiga species (Halpin, this volume). Of the 174 insect species collected in the range, ten are range extensions and two are possibly new species.

Thus, the data from our study indicate that the Ray Mountains are a physiographically discrete mountain range with physical environmental characteristics considerably different than the surrounding terrain. The dominant alpine and low arctic tundra of the range is diverse, and very different from the taiga that dominates central Alaska. The biotic richness of the Ray Mountains is probably the result of the range's large area of varied tundra habitats with peripheral taiga habitats. Because the Ray Mountains tundra "island" is sufficiently large and diverse, it supports several isolated populations of tundra species apparently not found elsewhere in central Alaska.

Overall, the range is an island of diverse tundra ecosystems within the taiga ecosystems that dominate central and interior Alaska.

CONCLUSION

In recent years natural scientists have visited numerous little- or unstudied areas in Alaska to conduct multi-disciplinary environmental surveys (see for example Wilimovsky and Wolfe 1966; Young 1974; and Melchior 1979). These surveys provide basic environmental data, primarily for use by land managers and others for planning and decision-making regarding future uses of these areas. Though the component studies of these projects have yielded valuable information, the overall projects have rarely been integrated to present clear overviews of the environment of these areas -- overviews that would be readily understandable and useful to land managers.

The results of this study indicate that it is possible to take the basic data of an environmental survey and use the ecosystem concept for integrating the data from the component studies. For a basic study such as this one, synthesis was possible only with recognition of a small number of ecosystem units and coordinated data collection and presentation by component study teams.

For two reasons, the concise overview of the Ray Mountains environment provided by this study can be useful to land managers. First, from this single report they can quickly gain an understanding of the major biotic, physical, and natural disturbance features that are present in any portion of the range. If management plans exist for specific features -- such as caribou or grizzly bear habitat, wildfire, or ice-rich permafrost -- this report guides them to the areas of interest.

Second, and more important, this chapter indicates some interrelations within and among the ecosystems of the Ray Mountains. Overlapping and related features, perhaps with specific management considerations, are indicated. This aspect of a descriptive ecosystem analysis points out generally to a manager that if an action is taken affecting a specific feature of an ecosystem (for example, permafrost disturbance in LOWLAND TUNDRA or caribou hunting in UPLAND TUNDRA), effects on other features within the ecosystem can be expected.

Though this study is limited in these respects, it should serve to guide land managers' decision-making regarding appropriate uses of the Ray Mountains. I hope also that it may help to direct future, more detailed ecosystems research in the range that will more clearly direct management.

ACKNOWLEDGMENTS

I owe unbounded thanks to all the members of the Ray Mountains project study team; without their co-operation, assistance, data, and patience, this synthesis of our work would have been impossible. I am also grateful to Dr. Charles H. Racine, formerly of The Center for Northern Studies, for crucial guidance throughout the writing stage of this project.

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RESOURCES AND MANAGEMENT STATEMENT

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ABSTRACT

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- Objectives
- Interior Alaska
- The Ray Mountains
- Planning Guidelines

METHODS

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SUMMARY

ACKNOWLEDGMENTS

REFERENCES

NOTE

The reader is referred to the Introduction of this volume for detailed descriptions of the project study area and the overall project research design. Also included there are descriptions of the project's three areas of concentrated study, with a map showing their locations and the locations of travel routes and Ray Mountains project sites (RMP sites Ia-VId) referred to in this chapter. Physiographic and ecological terms used consistently throughout this volume are defined in the Vegetation chapter. The ECOSYSTEMS referred to herein (in upper case lettering) are described in the ecosystems chapter of this volume.

ABSTRACT

The Ray Mountains, as described in earlier chapters of this volume, are an ecological "island" of tundra in interior Alaska's dominant boreal forest. Though the central part of the mountain range has been virtually undisturbed and will remain under the jurisdiction of the US Bureau of Land Management (BLM), adjacent areas have been among state and Native land selections which may become subject to development or disposal to private owners. In addition, proposed transportation corridors could surround the Ray Mountains.

Natural systems continue to function without interference in the Ray Mountains partly because few resources have been considered developable. In planning for the Ray Mountains, land managers will have to consider the dominance of natural values and schedule human activities accordingly.

The Ray Mountains' special environmental characteristics and the absence of resource conflicts combine to suit most of the area for designation in the Alaska Ecological Reserves System now under development. Such a designation will provide a study area for research into the workings of the subarctic environment, from lowland forest through tundra and alpine barrens, and will provide an ideal beginning for BLM participation in the Ecological Reserves program.

INTRODUCTION

In the past decade the federal government, the state of Alaska, and the private Native corporations of Alaska have been embroiled in jurisdictional controversy involving hundreds of millions of acres of Alaska and some of the nation's most valuable resources, as diverse as oil, minerals, wildlife habitat, and wilderness. State, federal conservation, and Native land designations will account for most land ownership and management in Alaska; and fewer than 0.4 million of Alaska's 1.5 million sq km are expected to remain undesignated national resources lands under the jurisdiction of the Bureau of Land Management (BLM) in the US Department of the Interior. The Ray Mountains are likely to be among these undesignated public lands.

Objectives

The first objective of this study was to use the information presented in the chapters of this volume as the basis for an interdisciplinary assessment of resource values in the study area. The second objective was to provide management guidelines and proposals for land managers and scientists who have interest in the Ray Mountains. The study has been limited by several factors (see Introduction, this volume), but it provides impetus for further work in the Ray Mountains in accordance with the planning process that BLM will conduct on federal lands throughout Alaska.

Interior Alaska

Inaccessibility and a poor resource base have been major deterrents to sustained development of interior Alaskan resources. Past interest in mineral and fur resources has diminished; modern transportation and communication systems have pushed Alaska's "development frontier" (Armstrong et al. 1978) to other parts of the state -- notably southcentral and southeast Alaska and the North Slope, comparatively resource-rich areas. Thus the Yukon planning district defined by the Federal-State Land Use Planning Commission for Alaska (FSLUPC) (at 0.5 million sq km almost twice the size of any other Alaskan planning unit) includes none of Alaska's major oil or mineral development, recreation areas, or timber or fisheries harvest areas, which can be found in each of the other five planning areas (FSLUPC 1975). The economic value of interior Alaskan resources is generally recognized as low; even maximum development scenarios for large parts of the interior would result in low employment and materials production (Alves 1978).

However, wildlife productivity in some parts of interior Alaska is high, and because of waterfowl migration is valuable to other parts of North America and to Asia. The US Fish and Wildlife Service has noted that the Yukon Flats, east of the Ray Mountains, are among the most waterfowl productive areas in North America [US Department of the Interior (USDI) 1974].

Research and planning efforts in interior Alaska have been isolated. Some continuing research is carried on in the interior, mostly associated with the pipeline corridor separating the Ray Mountains and the Yukon Flats. The pipeline and haul road corridor is the only area of federal land in interior Alaska for which a BLM management plan has been prepared (Borecki, pers. comm.). Other planning documents have been interest-oriented, usually toward some sort of resource development or conservation. [See for example the environmental impact statements prepared for federal conservation proposals throughout Alaska (USDI 1974); documents associated with the Rampart Canyon hydro-electric

proposal, culminating in US Senate Doc 96-7 (1979); borough government proposals for the Yukon Flats region (Darbyshire and Associates 1979); and the planning efforts directed toward forest and land management in the upper Yukon River corridor (Alaska Extension Service for US Forest Service 1978)]. Most planning efforts in interior Alaska have necessarily been quite general and speculative because they rely on a weak data base.

The Ray Mountains

The public land which includes the Ray Mountains is the largest block of undesignated public land within BLM's Yukon Resource Area (Borecki, pers. comm.). Although state and Native land selections practically surround the Ray Mountains (see "Planning Guidelines," below), there have been no land claims within the study area. The few mining claims have lapsed and the only leasing activity involves the area around Kilo Hot Spring, where homesteading and land settlement have occurred and hot springs leases have recently been approved by BLM.

The Ray Mountains have historically been ignored by the region's indigenous populations of Koyukon Athapascan Indians. The Koyukon people regularly travelled between the Koyukuk and Yukon Rivers along trails west and north of the Ray Mountains, but seldom entered the mountains; for their low productivity, rugged environment, and inaccessibility, the Ray Mountains were avoided (Harwood, pers. comm.). In the only known paleocultural studies within the Ray Mountains, BLM's archaeological review of the Kilo Hot Spring area revealed no cultural values there.

It is likely that during the early gold rush near Rampart Village, across the Yukon River from the Ray Mountains, minerals prospectors explored the Ray Mountains. Since then most of the limited interest in the area has been scientific, though trappers have used the area (Roberts, pers. comm.). The 1912-1913 geologic field expedition led by Henry Eakin of the US Geological Survey (USGS) confirmed the absence of marketable minerals while mapping and describing the central part of the range (Eakin 1916). The only other researchers who have visited and published on any aspect of the environment of the Ray Mountains are Chapman and Yeend, also of USGS (Yeend 1971; Chapman et al. 1975).

Other scientists have however been interested in the region. Hulten (1968) mentioned that the flora of the montane areas north of the central Yukon River has remained uncollected (see Kassler, this volume); Murray (pers. comm.) emphasized the potential importance of collections from the Ray Mountains. Stenmark (pers. comm.) pointed out that the area is little known and that any information gathered there

will broaden the knowledge of central Alaska.

Without detailed on-the-ground studies, several general resource reports and proposals have included the Ray Mountains among areas of interest, exclusively for natural values. In its initial resource studies of Alaska, FSLUPC indicated that the Ray Mountains were the largest block of good-to-high quality scenic and primitive area within the central Yukon planning district, and one of several natural areas listed under "preservation opportunities" (FSLUPC 1975). Gordon and Shaine (1978) included the Ray Mountains among their areas designated as "outstanding or representative visual units and scenic complexes." Their report noted the "oddly shaped rocky crags and tors," springs, and local glaciation of the Ray Mountains (see Tarlov with others, this volume). Underwood and Juday (1979) included the Ray Mountains among Alaskan areas suitable for designation in the Alaska Ecological Reserves System, presently under development; Juday (pers. comm.) considers the area ideal for baseline research of natural ecosystems in interior Alaska. Stenmark and Hall (1979), in the "primitive lands evaluation" of their Alaska wilderness report, recognized the "good" qualities of the Ray Mountains and recommended most of the range for further study of wilderness potential, perhaps leading to designation of the area within the National Wilderness Preservation System. Young et al. (1980, in press) listed a large part of the Ray Mountains among interior and western Alaska sites recommended as potential National Natural Landmarks, designated by the Natural Landmarks Program of the Heritage Conservation and Recreation Service, USDI to preserve "nationally significant" geologic and ecologic features. The Rampart section of the Yukon River, just south and east of the Ray Mountains, is being considered by the US Congress for National Wild and Scenic River designation.

Planning Guidelines

Because the study area is entirely under federal jurisdiction, it will be managed according to guidelines in a diverse group of federal laws and regulations. State and Native interests on federal lands have been partially protected by legislation such as the Statehood Act of 1959 and the Alaska Native Claims Settlement Act of 1971, both of which also accorded large grants (totalling about 150 million acres) of federal land to Alaskan interests. Proposed conservation legislation presently before the US Congress could provide statutory direction for federal policies toward subsistence hunting, transportation and utility corridor planning, access, and further conservation uses for public lands. Until the legislation is decided upon, some aspects of planning for Alaskan federal lands will remain speculative.

However, there are existing standards for planning on

federal public lands. The controlling statute is the Federal Land Policy and Management Act of 1976 (FLPMA), in accordance with which BLM has devised regulations [43 Code of Federal Regulations (CFR) Part 1600] for the planning process. The regulations require Resource Management Plans, with regular updates and revisions, for "resource areas" under BLM management. According to the regulations, an interdisciplinary team constructs and criticizes the plan and submits it to public review.

There is special emphasis, in FLPMA and in BLM's planning regulations, on appropriate protection of Areas of Critical Environmental Concern (ACEC), which must meet four criteria to receive protection: relevance, importance, criticalness, and protectability. Among the considerations in ACEC planning, according to proposed guidelines (Federal Register, Volume 44 Number 110: 32590-32602), are historic, cultural, scenic, and fish and wildlife values and resources; natural systems or processes; and natural hazards. FLPMA gives management priority to ACEC's, although ACEC's are considered within BLM's multiple use and sustained yield planning framework and remain undeveloped only when development would conflict with the purposes of ACEC designation. (Final regulations are due in July 1980 after this volume has gone to press.)

FLPMA also mandated thorough review of BLM holdings for lands with potential for inclusion in the National Wilderness Preservation System. The review process is proceeding according to a 20-year review required by FLPMA. The leasing of mineral hot springs is also important within the Ray Mountains, and is guided by the Executive Order of April 1926 reserving mineral hot springs for public benefits.

Private (primarily Native) and state lands adjacent to the Ray Mountains will be managed according to other guidelines. The use of these lands could affect the federal land in the Ray Mountains, especially if the state or Native corporations choose to release lands for private ownership or to develop resources within them.

State land selections south of the Ray River and north and west of the Yukon River (that is, generally east of the study area) amount to about 12 townships, or about 121,400 hectares [Alaska Department of Natural Resources (Alaska DNR) 1978; Mielke, pers. comm.]. In choosing the larger parcel of land that includes this acreage near the Ray Mountains, the state cited the "mixture of high resource values throughout the area, in addition to its accessibility." Specifically, the state recognized the "agricultural and settlement capabilities" of this land, and its "mineral, recreational and wildlife resource values" (Alaska DNR 1978). Bennett (pers. comm.) cited its "obvious value," with access to the Yukon River, natural beauty, and potential for disposal. Unless a borough government is formed for the Yukon Flats

area, including most or all of these state lands, they will remain under the authority of the Director of the Division of Lands, in the Alaska DNR.

Native land selections around the Ray Mountains have been made by individuals, village corporations, and the regional corporation, Doyon, Inc. Some of the selections conflict with (and probably will supersede) the state's selections. Individual and village selections are likely to remain largely undeveloped (Lincoln, pers. comm.). Planning for development on Doyon, Inc., holdings will be "target-oriented" for specific development projects (Williams, pers. comm.). Haynes (1975), who has been employed by Doyon, Inc., noted the relatively bold development planning among Alaska's regional Native corporations.

METHODS

This study has been conducted in several stages. First, it has involved literature review and contact with individuals and staff of organizations having interest in the Ray Mountains and in resource planning throughout Alaska. Fieldwork included evaluation of resources, by aerial and surface observation of most parts of the study area. The final stage has been the evaluation of the research conducted by other members of the study team, resulting in a working knowledge of the Ray Mountains environment. This synthesis has allowed relative assessments of resource values in the study area, and has provided the basis for management recommendations and mapping.

RESULTS AND DISCUSSION

Significant resources of the Ray Mountains are discussed in two sections: natural values and economic values, terms which are applied for the reader's benefit rather than to imply incompatible resource values. These resource assessments provide the basis for the management statement, divided into guidelines and proposals, which follows.

Resources

Partly because natural (as opposed to economic, or developable) resources are so dominant in the Ray Mountains, there has been very little human activity in the study area. The factors listed below as natural and economic values are significant in that they are inherent resource values or are able to affect human activity in the Ray Mountains.

Natural Values

Like many other areas in Alaska, the Ray Mountains have retained their natural character; natural systems have functioned mostly without human interference. Few other areas in Alaska, however, have the compact diversity of natural features present in the Ray Mountains, particularly with negligible development conflicts.

Physical features and processes

Location. Near the geographic center of the Alaskan mainland, the Ray Mountains are about midway between two major Alaskan mountain ranges, the Brooks and Alaska Ranges.

Access (Photo 1). The Ray Mountains are only 60 km west of the intersection of central Alaska's two major transportation corridors: the Yukon River and the Trans Alaska oil pipeline (TAPS) and haul road. This sort of intersection is a "favoured location" for future settlement and development (Jackman 1973). The proposed development of a Nenana-Kobuk railway, which would traverse the western foothills of the Ray Mountains, and the potential feeder road from Sithylemenkat Lake (for development of Doyon, Inc. mineral holdings) to the haul road would surround the Ray Mountains with four major transportation corridors. Lake 1485 in the Ray Mountains is air accessible; during winter other areas are accessible by ski plane. Otherwise there are no adequate landing areas for fixed-wing aircraft, though an airstrip has been proposed in connection with the hot springs development at Kilo Hot Spring (Rome and Waidtlow 1979; see Geothermal, below). Fig. 1 shows how three access points [lake 1485, the Kilo airstrip (proposed), and the Yukon River] help create three access-influenced management zones in the study area.

Environment. More exposed than most of central Alaska, the Ray Mountains experience extremely harsh winters (Rome, pers. comm.) and may have weather patterns somewhat distinct from those that prevail through central Alaska. Annual precipitation in the Ray Mountains is about twice as high as in the immediate vicinity (Hartman and Johnson 1978).

Physiography. Within a compact area, the Ray Mountains show a remarkable diversity of topographic features. Diverse geomorphic processes have formed a broad spectrum of glacial, periglacial, and alpine landforms. The glaciated high peaks, with classic glacial features such as the cirque and tarn at Mt. Henry Eakin (RMP site Va), are near unglaciated rolling lowlands. The tors in Spooky Valley (RMP site IVa) are further evidence of active geomorphic processes. (For more

Photo 1. The Yukon River is an existing transportation corridor near the Ray Mountains. The Yukon River crossing of the TAPS Haul Road is just 60 km east of the central Ray Mountains.

thorough review of landforms, see Tarlov with others, this volume.)

Watershed. The waterways in the study area are unnavigable and are subject to great seasonal changes in volume. We visited three bodies of standing water: lake 1485 (RMP site IIa), the tarn below Mt. Henry Eakin (RMP site Va), and a small pond southeast of Kilo Hot Spring near the north end of Spooky Valley. The scarcity of muskeg, bogs, lakes, and ponds indicates that the Ray Mountains are well drained. A significant feature is the occurrence of hot springs near the margins of granitic plutons in the study area; Kilo Hot Spring (RMP site IIIa) is most notable because of its temperature, flow rates, location, and numerous outlets, though it probably is not exceptional relative to other hot springs in interior Alaska. (See Roeske and Senior, this volume.)

Earth processes. Within the Ray Mountains are classic examples of continuing earth processes, such as nivation and solifluction, as well as the examples of historic glacial processes described above. We saw a well developed example of ground ice in Spooky Valley (see Tarlov with others, this volume). Tarlov with others, and Smith (this volume) studied the solifluction which occurs throughout the Ray Mountains.

In addition, flooding occurs along streams and rivers within the Ray Mountains, maintaining early successional communities in many valley bottoms. Fire, according to soil samples (Smith, this volume) and floristic and ecosystem analysis (Kassler, this volume; Schubert, this volume), is a factor in the development of vegetation communities within the Ray Mountains. Firefighting litter in several places (RMP sites IVb, IIb, and Vd) indicates that some fires in the Ray Mountains have been contained or put out.

Biotic features

Ecological island. The Ray Mountains are an ecological island in central Alaska's dominant boreal forest (Schubert, this volume). The range provides habitat for numerous isolated plant and animal species which otherwise might not be found in central Alaska. This is indicated by the significant range extensions of disjunct species recorded by Kassler (this volume), Armstrong and Halpin (this volume), and Halpin (this volume). (See Ecological character under "Special features and areas," below.) Ecologically significant areas, as observed in the field study, are included in Fig. 1.

Ecosystems. Schubert (this volume) documents four ecosystems in the Ray Mountains. Including boreal forest and low arctic and alpine tundra types, the ecosystems of the range combine to create a well developed boreal forest - tundra interface, with a biota uncommonly rich for central Alaska. Though none of these ecosystems is individually unique or exceptional, together they occur in a compact continuum unusual in Alaska. They are especially sensitive to disturbance because they are areally limited and lack the rebound capacities of similar, more extensive ecosystems in other parts of Alaska. Disjunct mammal and plant species which occur in the Ray Mountains depend on maintenance of these diverse ecosystems.

Ecotones. Providing "edge" habitat for many species (Schubert, pers. comm.), ecotones between ecosystems are utilized by a large number of the species and individuals recorded in the Ray Mountains (personal observation). Moose and black bear, for instance, prefer the BOREAL FOREST - LOWLAND TUNDRA ecotones, whereas grizzly bear were often observed near UPLAND TUNDRA - ALPINE BARREN ecotones. In these transitional areas the ecological diversity of the Ray Mountains is intensified because many habitats (Armstrong and Halpin, this volume) and vegetation types (Brock and Burke, this volume) are represented. Ecotones in themselves are a significant resource deserving special management attention because of the high species diversity within them.

Flora and vegetation. The flora of the Ray Mountains is not exceptionally rich, though numerous uncommon species are found (Kassler, this volume). The diversity of vegetation

types, however, supports a large number of mammal and bird species generally not found in central Alaska. Under natural circumstances these vegetation types adapt to harsh climatic conditions, geomorphic processes such as solifluction, flooding, and permafrost, and periodic wildfire. For various reasons, such as composition of cover and substrate, slope, and exposure (Webber and Ives 1978), some vegetation types are more sensitive to damage from human activities than others.

Wildlife. Some areas of the Ray Mountains are more significant than others as wildlife habitat. Three types are particularly important: 1) ecotones between ecosystems, because of their diverse characteristics supporting many species; 2) game trails, because of large mammal species' regular movements and migration; and 3) special habitats, such as Spooky Valley, which for various reasons are preferred habitats. The significant areas shown in Fig. 1 include some areas of critical wildlife habitat in the Ray Mountains, as drawn from the findings of Armstrong and Halpin (this volume), Matthews (this volume), and Schubert (this volume), and my personal observations. Among the species that seem particularly important ecologically are caribou and grizzly bear. Other disjunct populations (such as the Alaska marmot and the pygmy shrew) are also significant. Maintenance of habitat is essential to the mammals' continued use of the Ray Mountains, particularly because most have relatively small populations in the Ray Mountains (Armstrong and Halpin, this volume).

Economic Values

Energy and minerals. Although the Yukon Flats basin, with "high" potential for developable oil and gas (Selkregg 1975), is near the Ray Mountains, there have been no indications of developable hydrocarbon resources in the Ray Mountains. Other energy potentials, such as geothermal (discussed below) and hydroelectric, are low. The Alaska Power Administration's inventory of potential hydro sites in Alaska includes none within or near the Ray Mountains, except for the huge Rampart Canyon Dam proposal (US Senate 1979), which has been dismissed as a possibility because of its size, cost, environmental expense, and distance from power markets (Mohn, pers. comm.). Though the Rampart District, generally southeast of the study area along the Yukon River, has produced 90,000 ounces of gold -- mostly before 1920 (Todd 1978) -- there have been no discoveries of recoverable minerals in the study area (Eakin 1916; Roeske and Senior, this volume). The eastern Ray Mountains have mineralized areas that have been selected among state and Native land claims. In addition, mineral development is likely to occur about 40 km north of the central Ray Mountains on Doyon, Inc., holdings near Sithylemenkat Lake.

Agriculture and grazing. The Agricultural Station at the village of Rampart closed in 1925 after almost three decades of operation; Lewis et al. (1978) characterized it as "one of the most successful (agricultural stations) in Alaska." However it is doubtful that soil and ground ice conditions in the Ray Mountains would allow general agricultural development. Some greenhouse agriculture could be associated with hot springs in the Ray Mountains, and was proposed by Rome and Waidtlow (1979) in their application to BLM for a mineral hot springs lease at Kilo Hot Spring. Reindeer grazing [reported by Orth (1971) to have occurred in Spooky Valley in the 1920's] could occur in parts of the Ray Mountains, though it would conflict with natural uses and with other development. The economic viability of reindeer grazing, except where it has occurred in parts of northwestern Alaska, remains highly questionable, especially in very remote areas.

Timber. Almost 80% of interior Alaska's forestland, which is not continuous, is considered noncommercial (Neiland and Viereck 1977), with long regeneration cycles and an absence of marketing and production infrastructures. Although the BOREAL FOREST ecosystem in the fringe areas of the Ray Mountains has good standing timber for very limited, local uses (such as the cabin construction at Kilo Hot Spring by Rome, Waidtlow, and Kendall), the timber harvest potential even for forested areas of the Ray Mountains is virtually nonexistent.

Fur and fisheries. Some sporadic trapping continues to occur in areas around the Ray Mountains (Rome, pers. comm.; Roberts, pers. comm.), although trapping harvest is low. Fur harvest in interior Alaska is limited; Armstrong et al. (1978) indicated that land mammals account for only one-quarter of Alaska's total fur industry. Fur harvest has no potential for development in the Ray Mountains, judging from the results of the Ray Mountains mammals study of Armstrong and Halpin (this volume). Fisheries production throughout interior Alaska is very low; Bergstrand (1978) showed that in 1976 only 11% of fisheries production on the US portion of the Yukon River occurred upriver of the old village of Kokrines. There is no potential for fisheries production in the Ray Mountains.

Geothermal (Photo 2-3). Though there is little potential for large scale geothermal development in the Ray Mountains (Kato, pers. comm.), hot springs in McQuesten and Ishtalitna Creek are likely to attract future development and recreational interests, in addition to those already established around Kilo Hot Spring. Rome and Waidtlow (1979) have received BLM approval for a hot springs lease at Kilo, where they are constructing a wilderness cabin complex. Their lease application proposed primitive cabins for up to 15 visitors. Facilities will eventually include a geothermal greenhouse. The proprietors have applied for BLM approval for

Photo 2. Local geothermal potential of Ray Mountains' hot springs is indicated by the presence of radiators at lake 1485, 10 km from both Kilo and Ishtalitna Hot Springs.

Photo 3. A hot springs lease has been issued to applicants who plan a small wilderness lodging complex at Kilo Hot Spring. The proprietors also have asked for permission to build a small airstrip nearby.

an airstrip (1000′ by 30′) about 1 km downstream (see Transportation, below). So far, cabin and trail construction have been carefully performed, and the hot springs have been left in their original condition except for some piping. There is relatively great potential for recreational growth and some research, perhaps even limited agriculture, at other hot springs in the Ray Mountains.

Transportation and communication. Stenmark (pers. comm.) believes that resource development would be the only reason for transportation development in the Ray Mountains. Current development at Kilo Hot Spring, supporting Stenmark's statement, includes proposals for a 1000′ by 30′ airstrip (Rome and Waidtlow 1979). The proposal has been approved by the Federal Aviation Administration, though BLM approval is still required. If the airstrip is used by recreationists, especially hunters and hikers, the Ray Mountains could experience unprecedented, perhaps damaging, use. (See Recreation, below.) High altitude air traffic is presently fairly common above the Ray Mountains, but an airstrip will create conditions for what Klein (1972) called "accidental and intentional harassment" of wildlife from the air. Existing and potential transportation corridors in interior Alaska could have major impacts on the Ray Mountains as well, though present use of the Yukon River corridor is way below the level of the early 20th century (Todd and Alves 1978). The TAPS haul road, 60 km east, presents continuous possibilities of human incursion into the eastern Ray Mountains. Jackman (1973) has outlined some of the possible results from transportation developments in wilderness areas. He emphasized that crossroads and junctions of transport corridors are prime locations for human settlement, placing new demands on the surrounding environment. Such a crossroads already exists east of the Ray Mountains, where the TAPS Haul Road crosses the Yukon River, and both Roberts (pers. comm.) and Lincoln (pers. comm.) believe that the corridors have introduced poorly controlled, degrading influences into the region. They cited hunters and other recreationists, some of whom are not concerned with the long-term results of their actions, as new and sometimes undesirable influences near the TAPS haul road corridor.

Human settlement. Settlement potentials, especially for second and recreational homes, are fairly high on the state and Native landholdings in the eastern Ray Mountains (Bennett, pers. comm.). However, they are extremely low in the Ray Mountains because federal law (FLPMA) now prohibits the disposal of national resource lands. The only existing settlement in the study area has been in the vicinity of Kilo Hot Spring, though there are a number of cabins in the lower Tozitna River valley, outside of the study area. A cabin in lower Torment Creek, occupied for part of one winter by a reclusive resident (Kato, pers. comm.), has fallen into disrepair.

Recreation. Elsewhere than Kilo Hot Spring, recreational uses of the Ray Mountains have been limited to sporadic sport hunting and fishing, and some hiking. Two sport hunting guides, Joe Want and Berndt Gaedeke, are reported to have guided in and north of the Ray Mountains (Rome, pers. comm.). Klein (1972) noted that the grizzly bear is the "basis of a highly competitive (sport hunt) guiding industry" in northern areas. There is potential for growing recreational use of the Ray Mountains, associated with the Kilo Hot Spring development and with settlement of state and Native holdings in the eastern Ray Mountains.

Research. Previous research in the Ray Mountains has been reviewed above and in the Introduction to this volume. Future research uses could increase in the Ray Mountains if the area is designated as an Alaska Ecological Reserve (Underwood and Juday 1979). Further research will require BLM management and participation. (See "Research needs," in Management Statement below.)

Borough government. Borough government for the Yukon Flats area, including the town of Rampart, has been proposed in part to encourage resource development in the region (Darbyshire and Associates 1979). However, borough government is unlikely to spur resource development in the Ray Mountains (Stenmark, pers. comm.), though it could help create more positive conditions for public services (such as transportation infrastructures) that encourage some resource development (Council on Environmental Quality 1976).

Management Statement

Until now there has been no concern for management of the resources of the Ray Mountains. Such planning as has occurred -- for development proposals at Kilo Hot Spring -- has been in reaction to the specific development possibilities at Kilo, rather than in anticipation of future demands on the Ray Mountains. The potential for disposal of state and Native lands and continued transportation development around the Ray Mountains, and for growing recreational and research demands within the Ray Mountains, creates a special need for planning for undesignated public lands in the region.

The following management statement is divided into three sections: 1) identification of areas which constitute management units; 2) guidelines for management of special resources and areas and human activities; and 3) proposals for land and resource management.

Management Areas

The Ray Mountains are naturally divided into three general zones (Photo 4-5; Fig. 1) which are influenced by physiography and by access routes within and into the range. The first zone extends south from lake 1485 through Torment Creek and Mt. Henry Eakin to the McQuesten Creek drainage on the south slope. The second, including Spooky Valley, is dominated by the Kilo Hot Spring development; it would be especially affected by the proposed airstrip at Kilo (Rome and Waidtlow 1979). The third zone could also be affected by the Kilo development, although an equal consideration for this area is the presence of state- and Native-owned adjacent lands.

These three zones have diverse characteristics which should be considered by land managers. They are discussed in the key to Fig. 1 and throughout the text of this chapter.

Management Guidelines

Certain resources and areas of the Ray Mountains, discussed below, deserve special management attention. In addition, planning for the Ray Mountains should include consideration of suitable and inappropriate human activities, also discussed below.

Special resources and areas

Ecological character. Throughout this volume, the Ray Mountains have been referred to as an ecological "island" in the dominant boreal forest of central Alaska. Though the Ray Mountains ecosystems are individually not uncommon for a subarctic mountain range, the topography and location of the Ray Mountains have made the range ecologically very diverse and therefore suitable for plant, insect, and mammal species which might not otherwise be found in central Alaska. For instance, Kassler (this volume) documents 57 significant range extensions within the Ray Mountains flora; Armstrong and Halpin (this volume) report range extensions of several mammals; and Halpin (this volume) reports ten range extensions for insects, including two possible new species. The Ray Mountains' "island" character distinguishes them ecologically from the surrounding country and should attract special management attention to them; FLPMA requires special management and sometimes protection of ecologically significant areas. Much of the range should be given special management classification (Fig. 2), and special management plans should be designed. According to proposed guidelines, described above, ACEC designation can be made even where there is no existing Resource Management Plan. In the planning process for the Ray Mountains, scientists and administrators who have been involved in the management of other research

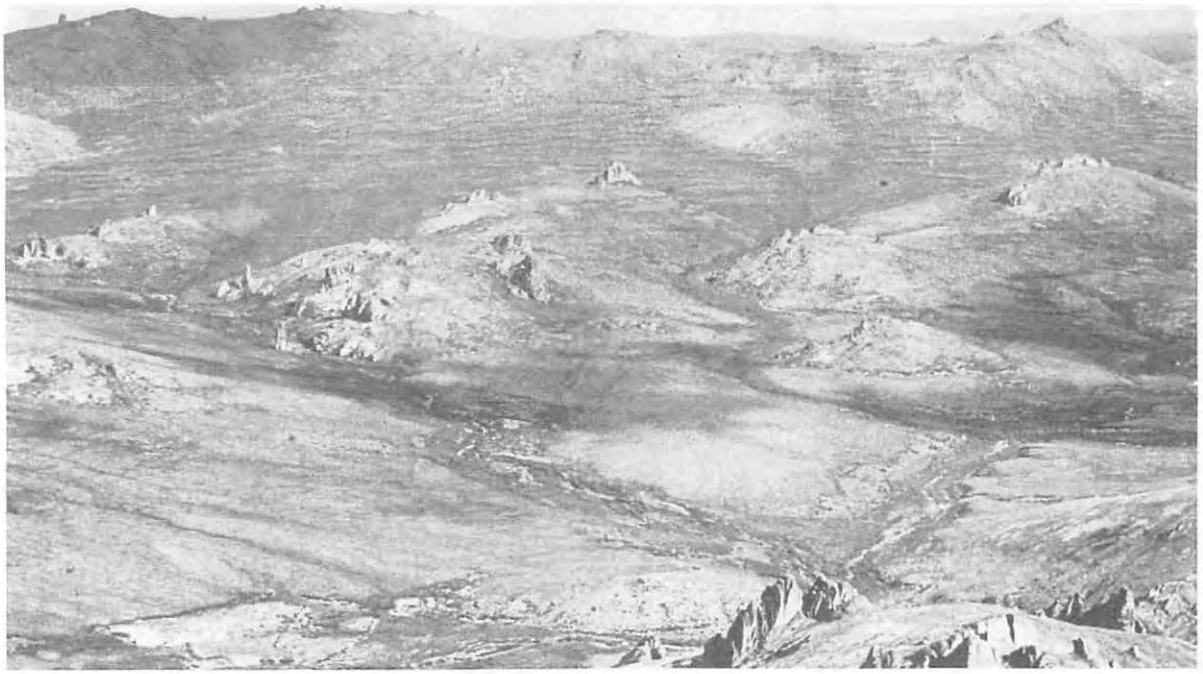

Photo 4 and 5. There are three major management zones in the Ray Mountains, each dominated by major features and by existing or proposed access potential. The first zone, the Torment Creek / Eakin unit, is shown in Photo 3 of the Introduction (this volume). The second is the Spooky Valley unit (above), which includes Kilo Hot Spring, the only site of existing development in the Ray Mountains. The third zone, the Tozi unit, is influenced by its proximity to the Yukon River and lands selected by the State of Alaska and Native interests.

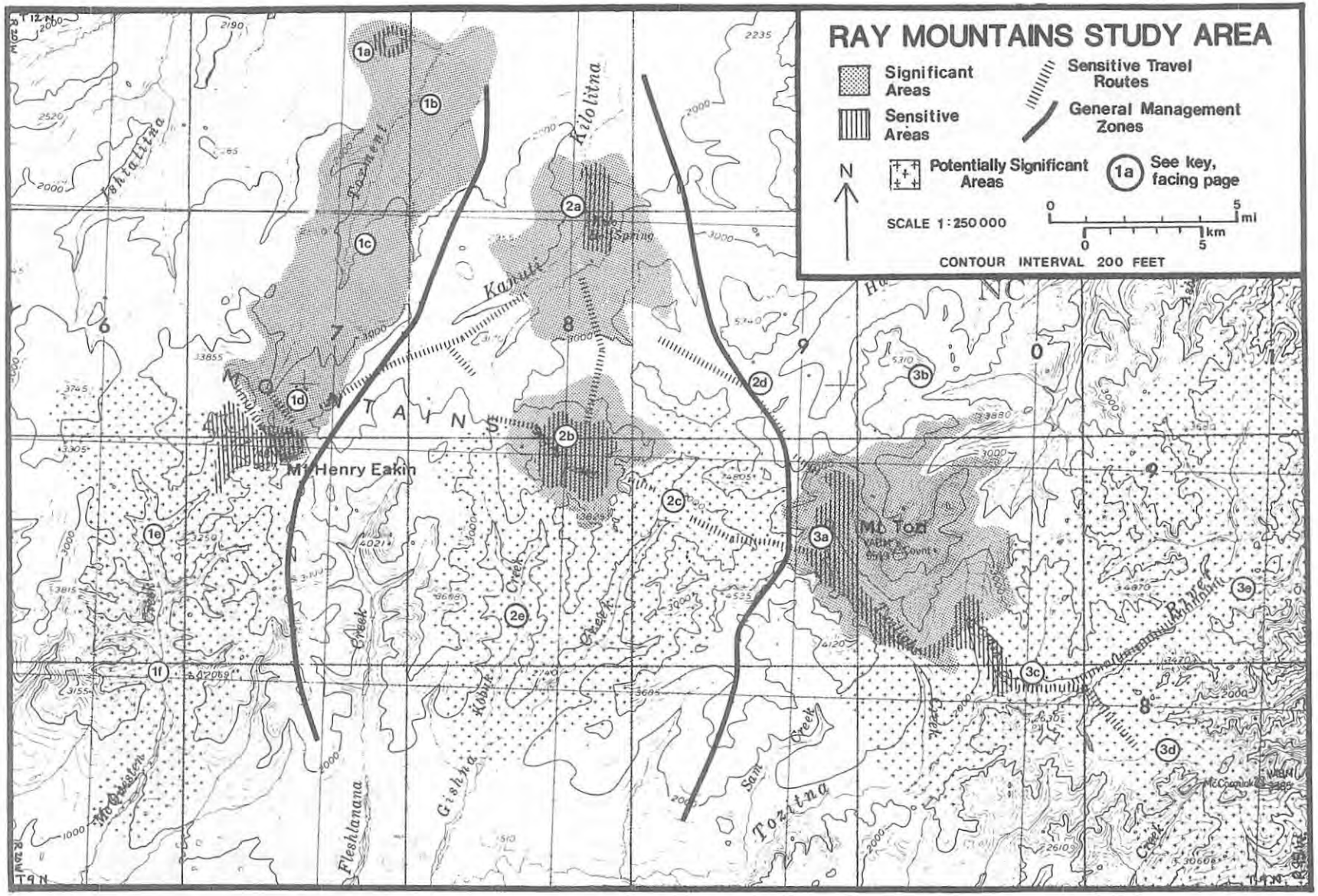

Fig. 1. Management zones and significant areas of the Ray Mountains.

KEY
Fig. 1. General management zones and features of the Ray Mountains.

The Ray Mountains have natural characteristics that divide the range into three basic management units, each dominated by one or two features and having or likely to have independent access pressures.

The first area, the Torment/Eakin unit (1a-f), includes the environmental continuum described among "Special features and areas," below. On the south slope the McQuesten Creek drainage appears to be an example of a highly dissected south-facing valley of the Ray Mountains. The Ishtalitna drainage is also considered within this unit. Access to the Torment/Eakin unit can be from lake 1485 or from the proposed airstrip at Kilo Hot Spring.

The second area, the Spooky Valley unit (2a-e), includes Kilo Hot Spring and portions of the lower Kanuti Kilolitna River, as well as two major south slope drainages, Kobuk and Gishna Creeks. Presently it is accessible from lake 1485 and from the Yukon River via the major pass between upper Twilight and Gishna Creeks; the proposed airstrip at Kilo would make the unit much more accessible.

The third area, the Tozi unit (3a-e), is most influenced by its proximity to the Yukon River and the adjacent state and Native land selections. It includes the highest peaks in the Ray Mountains; some lowlands and passes will be especially prone to damage because they are among the very few areas where human use will be concentrated in this unit.

Key to Map Sites

Torment/Eakin unit

1a - lake 1485 is a present access point for the unit. Will support only limited use. Camping area presently established near drainage outlet, east end of lake.

1b - This area of the Torment Creek floodplain is the BOREAL FOREST part of the Torment/Eakin continuum.

1c - Lower Torment Creek is the transition zone from BOREAL FOREST to LOWLAND TUNDRA. Our basecamp established here is near the ecotone.

1d - Upper Torment Creek and Mt. Henry Eakin are UPLAND TUNDRA and ALPINE BARREN areas at the highest point of the environmental continuum. Likely to receive a large part of future use.

(Key is continued on next page.)

1e - The headwaters of McQuesten Creek are highly dissected and probably exemplary of upland south slope environments. Could fit well into the environmental continuum.
1f - Hot springs have been reported in the McQuesten Creek drainage (Kato, pers. comm.). Would add an important element to the proposed research continuum.

Spooky Valley unit

2a - Kilo Hot Spring is a potential access point for the central Ray Mountains and is already the most developed site in the study area.
2b - Spooky Valley is a productive and scenic area which, though sensitive, will be a primary target for recreationists from both Kilo Hot Spring and any state and Native lands which are released for private or public use. Requires special management attention.
2c/d - Upland areas between Kilo/Spooky Valley and the eastern high peaks will have to support the foot traffic from recreationists drawn to Kilo.
2e - Kobuk and Gishna Creeks are scenic south slope drainages deserving research.

Tozi unit

3a - The passes and valley floors near Mt. Tozi are sensitive areas which will be among the first to receive use.
3b - The eastern high peaks region is probably rugged enough that it will support the limited use to which it will be subjected, but it deserves further research in the near term.
3c - The lowlands between Mt. Tozi and the eastern state and Native land selections will receive early use.
3d - The McCormick area is scenic and will be one access corridor to Mt. Tozi.
3e - The upper Tozitna appears to be a natural corridor to the east. Deserves special research and management attention.

areas in Alaska should be consulted. A primary concern is the provision for suitable short-term management that protects the Ray Mountains' limited environmental reservoirs.

Environmental continuum. The compactness of the environmental continuum from BOREAL FOREST ecosystems through unglaciated LOWLAND TUNDRA to glaciated and unglaciated UPLAND TUNDRA and ALPINE BARREN provides special quality to the Ray Mountains as a management unit. The Torment Creek area, where our study was based, featured a remarkable diversity in ecosystems and physiography within just a 20 km transect of the north slope of the Ray Mountains, from lake 1485 to Mt. Henry Eakin (RMP sites IIa-c, Va). This continuum provides excellent opportunities for research and education, without the resource conflicts often present in other areas of Alaska. It is far enough from nonfederal lands that it is protected from most "adjacent lands" pressures (Shands 1979); proper management will allow continued research of the natural environment of the diverse subarctic ecosystems which occur along this continuum. The adjacent south slope drainage, McQuesten Creek, includes potentially interesting research areas as well, such as the hot springs reported there by Kato (pers. comm.). Inclusion of this south slope drainage would complete the environmental continuum which begins at lake 1485. (See Fig. 1.)

Hot springs. Within the Ray Mountains are several known hot springs [Kilo, Ishtalitna Creek, and McQuesten Creek (Kato, pers. comm.)] which are among those that form a geothermal belt across Alaska at the latitude of the Ray Mountains. Although there is little reason to expect that these hot springs are unique, their floras should be studied carefully for plant species composition (Murray, pers. comm.). In addition, a comprehensive hot springs plan should clarify acceptable uses and management of the hot springs in the Ray Mountains, as well as geothermal energy potential of the springs.

Wilderness character. Uses of the Ray Mountains have been few, leaving the range in basically unaltered condition. Although many areas of Alaska remain in such a wilderness condition, the Ray Mountains are exceptional: they are a centrally located mountain range which has attracted little development attention or state or Native land selections, and conservation proposals, though numerous, have received little attention. Although designation into the National Wilderness Preservation System may be found to interfere with other uses of the area (see Management Proposals, below), the Ray Mountains should be studied for Wilderness potential according to the terms of FLPMA.

Other features. Some features, such as ecotones and areas of geomorphic significance, also deserve special management attention. Though some of the special features are

included among those listed below, our study has been insufficient to identify more than a few of the special areas and features of the Ray Mountains. Table 1 lists some special areas of the Ray Mountains and indicates some of their qualities. Particularly significant areas are noted in the paragraphs below.

Spooky Valley (RMP site IVa). Its tors and erratic landforms, set in a broad bowl-like valley, contribute to Spooky Valley's impressive natural character. A southern spur ridge of the Ray Mountains north-south divide separates the valley from the Tozitna River valley. Through a deep cut in this steep, sharp spur ridge, Kobuk Creek drains the whole Spooky Valley watershed. Further natural values help distinguish Spooky Valley from other parts of the Ray Mountains: Armstrong and Halpin (this volume) and Matthews (this volume) documented an especially diverse and plentiful fauna in Spooky Valley; Kassler (this volume) made significant floristic collections there. Spooky Valley, for its natural character and its sensitivity to disturbance, should be managed by a special area plan that limits human activity and concentrates use in areas of lowest sensitivity. (See Fig. 1.)

Kilo Hot Spring (RMP site IIIa). At Kilo are the largest hot springs found in the Ray Mountains. Around them occur numerous plant species not found elsewhere in the study area (see Kassler, this volume). BLM has granted a 20-year hot springs lease to Rome and Waidtlow (1979). Their proposal to construct an airstrip has been approved by the Federal Aviation Administration and is still under BLM's consideration. Use of the area, especially the proposed airstrip, must be carefully monitored, particularly in spring and summer, when there is the potential for damage to trails and for interference with wildlife. (See Fig. 1.)

Mt. Tozi. The highest mountain in the range, Mt. Tozi is among the glaciated peaks of the central Ray Mountains. Its rugged slopes can absorb a great deal of use; however, the sensitive areas around the mountain should be managed carefully to prevent degradation. The pass below Mt. Tozi, between upper Gishna and upper Twilight Creeks, is the major route between the eastern and central Ray Mountains; it will be very sensitive to disturbance as uses of the Ray Mountains increase. (See Fig. 1.)

Mt. Henry Eakin (RMP site Va). The classic glacial cirque and tarn below Mt. Henry Eakin are the upper limit of the environmental continuum starting at lake 1485 some 20 km north. This area, with good research opportunities and perhaps the most dramatic scenery in the Ray Mountains, should be managed for the protection and research of natural systems. (See Fig. 1.)

Table 1. Some special areas of the Ray Mountains. This table is constructed for the use of land managers evaluating specific features and areas of the Ray Mountains, and includes only areas visited in this study. Abbreviations for ecosystems (Schubert, this volume) are AB (ALPINE BARREN), UT (UPLAND TUNDRA), LT (LOWLAND TUNDRA), and BF (BOREAL FOREST).

Site RMP Site	Ecological character	Scenic description [photo] (1)	Development potential	Other factors
Gishna Cr. (upper) RMP Ie	UT, game trail	Broad valley, steep sides	None found	Major pass betw. ctrl and east'n Ray Mtns
Henry Eakin, Mt. RMP Va	AB/UT, glaciation, cirque tarn, continuum (2)	Excellent panorama of Ray Mtns north slope [see Intro]	None found	Access fr. lake 1485 (3)
Ishtalitna Cr. (upper) RMP Vb	UT	Ridge tors and outcrops in rolling tundra terrain	None found	
Ishtalitna Cr. (lower) RMP Vd	BF/LT, burn site	Steep slopes, braided stream, river confluence	Geothermal, settlement, recreation	Hot springs
Kanuti Kilo R. (upper)	AB/UT, moraine, tarn, game trails	Steep-sided dog-leg valley unusual in Ray Mtns	None found	
Kanuti Kilo R. (lower) RMP IIIa	BF/UT, game trails	Outcrop ridges, forested floodplain	See Kilo HS, airstrip	Access fr. Spooky Valley
Kilo Hot Spring RMP IIIa	BF, game trails	Uncommon poplar forests and lush graminoid meadow [see Intro and Photo 3]	Recreation, lodging, airstrip	Access fr. Spooky Valley and lake 1485
lake 1485 (3) RMP IIa	LT, slow drainage, continuum	Rolling tundra, [see Intro]	Access point for central Ray Mtns	

(Table 1 is continued on next page.)

Table 1 continued.

McCormick (4)	BF/UT, ridge outcrop	Deeply cut BF east, rolling LT west	Land disposal	Access fr. Yukon R. & nonfederal lands
Moose (4)	BF/LT, ridge outcrop	Excellent view to Mt. Tozi and Yukon R.	None found	Access fr. Yukon R. & nonfederal lands
Moose Cr. (upper) RMP VIc	BF/LT	Irregular steep slopes, rolling country	None found	Access fr. Yukon R.& nonfederal lands
Spooky Valley RMP IVa	UT/AB, grizzly bear and caribou habitat	Tors, bowl-like valley, frost blister, knife-edge ridges, irregular landforms [see Intro and Photo 4]	Recreation	
Torment Cr. (lower) RMP IIb	BF/LT, game trails, continuum	Gentle mid-elev. valley [see Intro]	None found	Access fr. lake 1485
Torment Cr. (upper) RMP IIc	UT/AB, game trails, continuum	Steep headwall [see Intro]	None found	Access fr. lake 1485
Tozi, Mt.	UT/AB, Ray Mtns highest point, glaciation	Excellent view to Ray Mtns high peaks, Yukon R., glaciated and unglaciated areas [see Intro and Photo 5]	None found	
Tozitna R. (upper) RMP VIb	BF/LT/UT	Forested bluffs and floodplain, braided river, rolling tundra	None found	
Twilight Cr. (upper) RMP Id	UT/AB, glaciation	Steep valleys, high peaks and ridges	None found	

(1) -- Some photographs are found in the Introduction to this volume.
(2) -- The continuum is discussed in "Special resources and areas," this chapter, and is shown in Fig. 1.
(3) -- "lake 1485" is the unofficial USGS map designation for this lake.
(4) -- USGS Benchmark.

Human activities

Resource development. The only potentials for resource development in the study area are those associated with hot springs, research, and recreation. Disposal of state and Native lands around the Ray Mountains would increase recreational pressures, and transportation development will continue to present possibilities of further human pressures on the Ray Mountains. Although BLM is unlikely to be able to control outside pressures, it should work toward a cooperative management arrangement with adjacent land managers, so that appropriate human uses will be defined and properly managed.

Transportation development. Further transportation development, as proposed for the corridors west and north of the Ray Mountains (see Transportation and communications, above), would effectively box in the range. Use of transportation corridors must be carefully managed to prevent degradation of surrounding areas and inappropriate human activities within the Ray Mountains. Access via the proposed Kilo airstrip should be carefully managed to prevent degradation of nearby critical areas.

Recreation. A major thrust of the development at Kilo Hot Spring is recreational. If localized, it will prove manageable; however, dispersed recreational activities, from sport hunting to wilderness backpacking, will have visible impacts on the Ray Mountains environment. Initially, prime areas will be degraded and some wildlife populations will be harvested or harassed. Recreation planning will help prevent damaging use. (See Fig. 1.)

Research. The Ray Mountains are ideally suited for research management: they are small, accessible to scientists in central Alaska, diverse, and virtually devoid of economic resources. Research designation will protect prime areas and features of the Ray Mountains, provide a high-quality research site for government and academic interests, and return important information on the workings of subarctic ecosystems (see Management Proposals, below). Research will provide land managers with information necessary for proper management of the Ray Mountains and similarly sensitive areas throughout Alaska.

Management Proposals

The preceding sections have identified resources of the Ray Mountains, with guidelines for management of some significant areas and resources. The following section provides management proposals which will implement some of the guidelines recommended above.

Research needs

The need for research into northern ecosystems has become more clear in the past decade, as resource demands on Alaska's North Slope created a need for efficient and sound means of removing and transporting huge amounts of crude oil. Although Wonders (1976) has stated that northern resource development occurs at dimensions which can cause "immense impact" and "ecological destruction," the demands for northern resources will continue to grow. Without adequate knowledge of the environment, planners will be unable to schedule and guide future development in a sensible fashion.

Britton (1971) cited the need for long-range research in northern areas before development occurs. Reed (1970) pointed out that appropriate research, by protecting the environment and reducing valid objections to insensitive development, could help minimize the impacts of development. Klein (1971, 1972) and Clarke (1976) have reported some of the sensitivities of northern wildlife to development, and Theberge (1976) has recommended research "imperatives" for a better understanding of how wildlife responds to development.

In Alaska there has been continuing interest in the development of an Ecological Reserves System for almost a decade (FSLUPC 1979). The Alaska system will include Reserves for baseline environmental studies and for studies of disturbed areas as well, in a variety of sites on public and private land (Underwood and Juday 1979). Many Reserves will likely be within conservation areas recently created by federal action on federal lands; however, some other areas will be added to the system.

The Federal Committee on Ecological Reserves (FCER) has reported some of the purposes and management priorities for Ecological Reserves, which have been designated on private, state, and federal lands in most states (FCER 1977). Humke et al. (1975) surveyed the need for preservation of genetic pools and natural areas in ecological preserves nationwide.

Ecological Reserve proposal

The previous chapters of this volume have indicated that the Ray Mountains are an ecological island. Resource assessment has shown the dominance of natural, as opposed to economic, values in the range. By depicting areas of the Ray Mountains which are suited to various management designations, Fig. 2 summarizes these ecological and resource findings.

The major finding of this study is that Ecological Reserve status, as proposed in Underwood and Juday (1979), is appropriate for large parts of the Ray Mountains. (See Research and Ecological character in Management Guidelines, above.)

Management of the Ecological Reserve should incorporate several major points:

1. Maintenance of natural systems. Damaging human activities should be minimized so that natural systems continue to operate unhindered. Included among potentially damaging activities are sport hunting and other forms of wilderness recreation, transportation development (including use of the proposed airstrip at Kilo Hot Spring), leasing of other hot springs, and improperly managed research. Natural processes such as flooding and wildfire should continue without interference except where they endanger adjacent lands and must be controlled on federal lands.

2. Cooperative management of the planning unit. Consideration must be given to owners of adjacent lands, so that there is a mutual understanding of the objectives and operation of the Ray Mountains Ecological Reserve. Toward this end BLM should create an advisory management panel, including adjacent landowners as well as scientists and land managers, which will provide management insights for recreation, research, and transportation planning.

3. Interdisciplinary baseline research. In cooperation with the coordinators and council of the Alaska Ecological Reserves System, planners should design a research schedule for the Ray Mountains and initiate BLM baseline studies. BLM's recent FLPMA mandate to conduct scientific research on federal lands -- especially critical areas -- will be well served by a continuing research program in a central, subarctic mountain range.

Negative impacts of the Ecological Reserve designation will be few. Because the only present documented regular use of the Ray Mountains is at Kilo, where Rome (pers. comm.) has verbally expressed his support for Ecological Reserve designation, no existing users will be affected. The paucity of developable resources in the area should indicate that Ecological Reserve designation will not affect the area's development potential.

Some significant benefits would include the results of scientific research which might be applicable to other areas of Alaska facing development, the maintenance of natural systems in the area, and an ideal initiation for BLM's membership in the Alaska Ecological Reserves System.

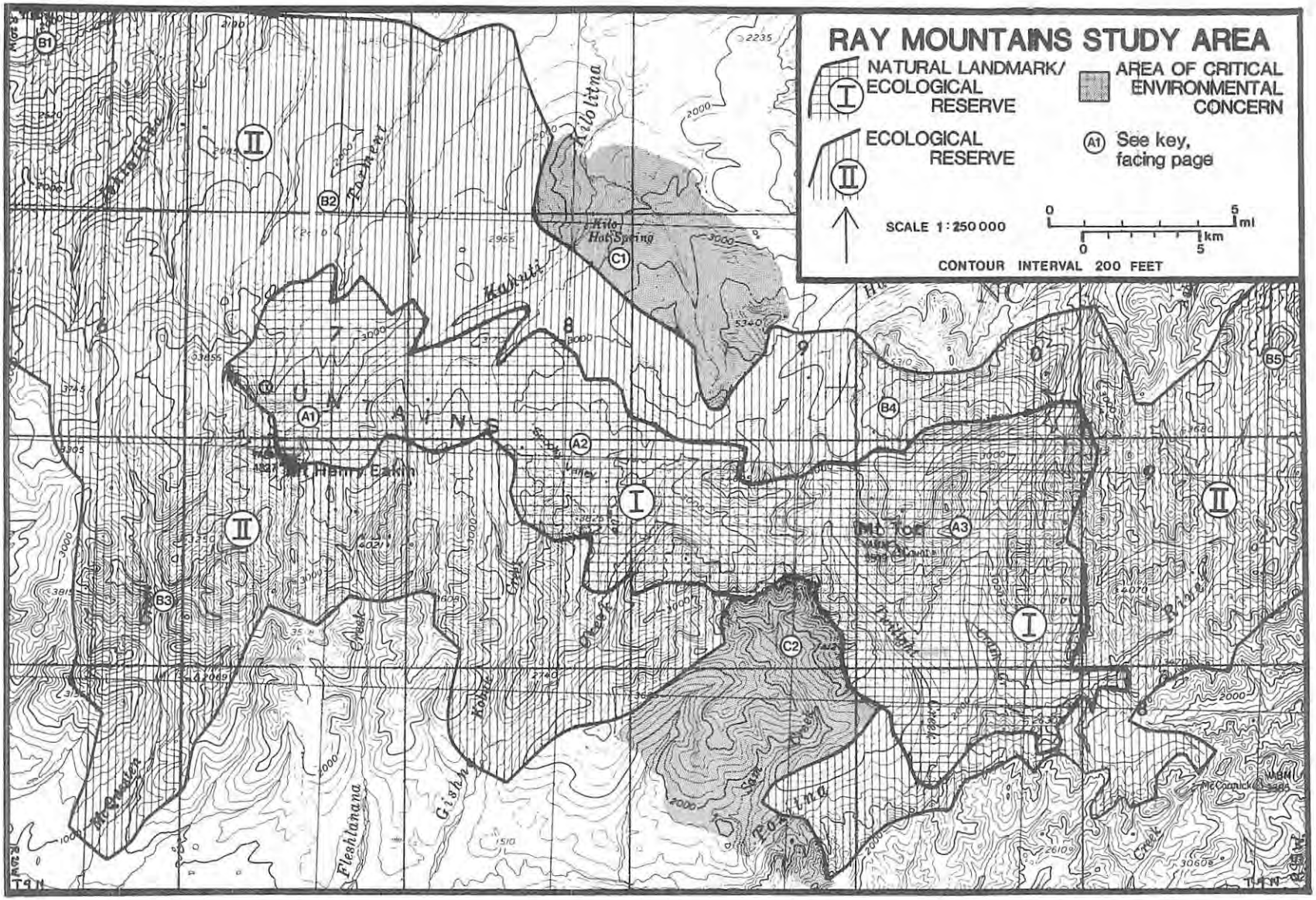

Fig. 2. Proposed management designations.

KEY
Fig. 2. Proposed management designations.

The natural characteristics of the Ray Mountains, combined with a lack of economic resources, suit much of the area for designation into special management systems. The central part of the range, including Mt. Henry Eakin, Spooky Valley, and Mt. Tozi, is recommended as a core Natural Landmark/Ecological Reserve (A1-3). Much of the surrounding country (B1-5) should be included within the Ray Mountains Ecological Reserve, though not within the Natural Landmark. Two adjacent areas (C1-2), which are not judged suitable for Natural Landmark or Ecological Reserve designation, should be classified by BLM as Areas of Critical Environmental Concern (ACEC).

Key to map sites

I Ray Mountains Natural Landmark/Ecologial Reserve

A1 - The area around Mt. Henry Eakin shows classic glacial and periglacial features which justify Natural Landmark classification.
A2 - Spooky Valley is ecologically and geologically singular, befitting Natural Landmark classification.
A3 - The Mt. Tozi area is the third part of Natural Landmark/Ecological Reserve core region. It has glacial and ecological features among the finest in the Ray Mountains.

II Ray Mountains Ecological Reserve

B1 - The Ishtalitna drainage includes hot springs, LOWLAND and UPLAND TUNDRA, and BOREAL FOREST that should be included in the Ecological Reserve for further research.
B2/3 - The Torment/Eakin continuum provides a compact and diverse research corridor.
B4 - Some of the eastern high peaks region should be included within the Ecological Reserve, for further research and comparison with the less highly dissected areas of the Ray Mountains.

(Key is continued on next page.)

B5 - The upper Tozitna River valley is the broad watershed of the Ray Mountains major drainage. It deserves further research if no conflicting values are found.

Areas of Critical Environmental Concern (ACEC)

C1 - The Kilo area is not suited for designation into the Ray Mountains Ecological Reserve because of the development there, which could set a improper standard for management of other parts of the Reserve. However, its ecological significance warrants classification as an Area of Critical Environmental Concern.

C2 - Sam Creek was not studied, but its proximity to critical areas within the proposed Ray Mountains Natural Landmark/Ecological Reserve creates a need for special management of the watershed.

Natural Landmark/ACEC proposal

The core area of the Ray Mountains, within the proposed Ecological Reserve, is ideal for inclusion in the US Natural Landmarks program, as indicated by Young et al. (1980, in press). The program, without changing land jurisdiction, protects ecologic and geologic natural features nationwide.

There are several factors favoring inclusion of this core area in the Natural Landmarks program. The previous chapters of this volume have identified valuable ecologic characteristics of the study area; geologic features such as tors, hot springs, and well developed glacial and periglacial features are especially significant in the proposed Natural Landmark (Fig. 2).

Like the proposed Ecological Reserve designation, Natural Landmark status would not interfere with existing uses of the Ray Mountains, and because of the region's paucity of economic resources it is doubtful that any future development will be impeded.

Two sensitive areas which are not included in the Ecological Reserve proposal are recommended for Area of Critical Environmental Concern (ACEC) status. The first area, surrounding Kilo Hot Spring, is endowed with natural characteristics befitting the Ecological Reserve and Natural Landmark programs, but development at Kilo has reached the stage that inclusion of the area might set an inappropriate standard for allowable human activity within the Ray Mountains

Ecological Reserve. The Kilo ACEC should be managed especially carefully, with consideration for the factors mentioned in the "Kilo Hot Spring" paragraph above and in the key for Fig. 2.

The second area is south of Twilight Creek near Mt. Tozi. Although further research may prove otherwise, the area does not appear to have extremely high natural values suited to the Ecological Reserve and Natural Landmark programs, but its proximity to critical proposed units of these programs creates a need for careful management of the area.

SUMMARY

The Ray Mountains have experienced few uses and have little potential for future development. The ecological character of the range, combined with other features such as location and land ownership, suit the area to designation within the Alaska Ecological Reserves System now under development. Management of the Ray Mountains Ecological Reserve should be cooperative, with an advisory panel of adjacent landowners and scientists providing advice to BLM land managers.

Further resource analysis may show that the Ray Mountains are appropriate for other management designations such as Wilderness. No recommendations are made for other designations because they will require further BLM investigation.

Baseline research which should be conducted in the Ray Mountains should complete the environmental analysis begun by this project. Further research should begin to provide data that will be useful to development planners in other areas of Alaska.

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