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Alaska Research Natural Areas. 2: Limestone Jags

Glenn Patrick Juday

White Mountains National
Recreation Area

Bureau of Land Management
U.S. Department of the Interior

Study and documentation of Limestone Jags Research Natural Area was supported by the Bureau of Land Management, USDA Forest Service, and the University of Alaska Fairbanks.

About the cover: A large limestone pinnacle with Windy Arch on the top is depicted in the foreground. The slopes in front of Windy Arch support a few fire-remnant trees. Behind Windy Arch are the Fossil Creek lowlands with mature white spruce forest to the right and a pocket of black spruce permafrost to the left. An aufeis zone shows along Fossil Creek in the right background. A lady's slipper orchid (*Cypripedium guttatum*) and dryas (*Dryas octopetala*), species typical of limestone habitats, are depicted in the inset.

Author

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Foreword

The concept of establishing natural areas for education and scientific research is not new. As early as 1917 in the United States, the Ecological Society of America set up the Committee on the Preservation of Natural Conditions and published its findings in 1926. Other professional societies—Society of American Foresters, the Society of Range Management, and the Soil Conservation Society of America—proposed programs to identify and set aside areas where natural forest, range, and soil conditions could be preserved and studied.

The name Research Natural Area (RNA) was adopted and, in 1966, the Secretaries of Agriculture and the Interior formed the Federal Committee on Research Natural Areas to inventory research sites established on Federal land and to coordinate their programs. A 1968 directory from the Federal committee listed 336 RNA's nationwide, of which 13 were in Alaska.

By 1969, the International Biome Program (IBP) was active across the United States, and a tundra biome team was headquartered at the University of Alaska. The IBP proposed the establishment of an ecological reserves system for Alaska—"field sites uniquely suited for natural research and education. All identified sites...to illustrate one or more ecological phenomena particularly well." Called Research Natural Areas in the United States, such areas are still called Ecological Reserves in Canada and other parts of the world.

In 1973, the Joint Federal-State Land Use Planning Commission for Alaska assumed the role of lead agency in establishing Research Natural Areas and provided badly needed funds and staff support. By fall 1976, a resource planning team of the commission had prepared a comprehensive plan for establishment and management of the RNA's. A total of 222 sites, representing a wide range of physiographic regions and planning areas in the State, were recommended.

In 1976, the commission formed the Ecological Reserves Council to represent Federal, State, and private agencies. It also entered into a contract with the University of Alaska to assist in carrying out the Council's recommendations.

Present members of the Ecological Reserves Council are:

U.S. Department of the Interior:
- Bureau of Land Management
- Fish and Wildlife Service
- National Park Service

U.S. Department of Commerce:
- National Marine Fisheries Service

Alaska Department of Fish and Game
Alaska Federation of Natives
University of Alaska Fairbanks

U.S. Department of Agriculture, Forest Service:
- Alaska Region
- Pacific Northwest Research Station

A management-coordinator position for gathering on-the-ground data for the Research Natural Areas in Alaska has been filled since 1978 by Dr. Glenn Juday—originally under the planning commission, then by contract between the University of Alaska and the USDA Forest Service.

In 1985, the Ecological Reserves Council proposed to the Director of the Forest Service's Pacific Northwest Research Station that the reports for the Research Natural Areas be published formally by the Station. The Station agreed to publish them in the General Technical Report series; the first was "Alaska Research Natural Area: 1. Mount Prindle."

KENNETH H. WRIGHT (Retired)
USDA Forest Service

Abstract

Juday, Glenn Patrick. 1989. Alaska Research Natural Areas. 2: Limestone Jags. Gen. Tech. Rep. PNW-GTR-237. Portland OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 58 p.

The 2083-hectare Limestone Jags Research Natural Area in the White Mountains National Recreation Area of central Alaska contains old limestone terrain features—caves, natural bridges, disappearing streams, and cold springs in a subarctic setting. A limestone dissolution joint-type cave in the area is one of the largest reported in high-latitude North America. A Silurian limestone and an Ordovician volcanic and sedimentary sequence are in disconformable contact in the Research Natural Area (RNA); the limited stratigraphic break between the two units is evidence of a major drop in sea level caused by ancient glaciation. The tilted and faulted rocks within and near the RNA have been interpreted to illustrate the process by which Alaska was accreted to the geologic core of North America. A wind gap in the area marks a former stream channel through the White Mountains that was stranded after Fossil Creek captured the drainage through headward erosion. Groundwater released during the winter into Fossil Creek freezes into thick accumulations of aufeis.

Limestone Jags RNA contains a rich diversity of habitats for vascular plants; the 303 species collected in the area represent nearly one-fourth of the flora of Alaska. Open, rocky limestone habitats support several plant species disjunct from the Rocky Mountains. A collection of the plant *Draba fladnizensis* in the RNA represents a marginal range extension from its previously known Alaska distribution. The only collection of the arctic moss *Andreaeobryum macrosporum* Steere & B. Murray south of the Brooks Range in Alaska is from the RNA. Alpine plant communities on basaltic rock in the RNA are especially lush and rich in lichens. An unusual form of open-canopied white spruce parkland occurs on dry limestone uplands. A closed-canopy, old-growth white spruce forest occupies productive bottomland sites of Fossil Creek. South-facing basalt slopes support a young paper birch and white spruce mixed forest that originated after a wildfire in the 1950's.

The RNA includes important alpine habitat of the resident White Mountain caribou herd; it was part of the traditional calving area of the migratory Steese-Fortymile caribou herd until the early 1960's. Vertical limestone cliffs and pinnacles in the RNA provide escape terrain for an isolated population of Dall sheep and perching sites for raptors, including golden eagle and peregrine falcon. Rocky overhangs and abundant talus on steep limestone slopes of the RNA provide excellent escape terrain for the hoary marmot. A relatively uncommon songbird, the Townsend's solitaire, is found in the RNA.

Keywords: Alaska, aufeis, basalt, caribou, cave, cold spring, Dall sheep, disconformity, ecosystems, hoary marmot, limestone, Natural Areas (Research), natural bridge, old-growth forest, Research Natural Area, scientific reserves, Townsend's solitaire, windgap.

Contents

Introduction

Limestone Jags is an area of the White Mountains National Recreation Area in central Alaska with classic karst terrain features in a subarctic setting (Juday 1983b). An early prospector, looking at the gleaming white exposures of several sharply dissected limestone pinnacles along a fault, called the area the "high jags" (Weber 1988). The name Limestone Jags was chosen as the best description of the area consistent with this local tradition. In this report, "White Mountains" refers to the entire mountainous region of the White Mountains National Recreation Area (WMNRA); "Fossil Creek Ridge," to the limestone mountain system trending northeast to southwest through the WMNRA.

The WMNRA, established by the Alaska National Interest Lands Conservation Act (ANILCA) of 1980, is managed by the Bureau of Land Management, U.S. Department of the Interior (1150 University Avenue, Fairbanks, AK 99709). Section 1312 of ANILCA recognizes the scientific values of the WMNRA and requires their protection. In the late 1970's, the entire Fossil Creek Ridge limestone section of the WMNRA was nominated as a National Natural Landmark (Young and Walters 1982). Juday and others (1982) developed a list of natural features of scientific interest as part of a resource inventory for the WMNRA. This list was the basis for the nomination of three Research Natural Areas (RNA's). The draft land and resource management plan for the WMNRA proposed a 2083-ha Limestone Jags RNA in 1983 (Bureau of Land Management 1984). After public review and comment, Limestone Jags RNA was established by a revised plan adopted in 1986.

The WMNRA plan established a large primitive recreation management zone surrounding the RNA. This zone encompasses essentially all the mountainous land north and east of Beaver Creek and includes about 47 percent of the WMNRA. It contains important caribou and Dall sheep habitat, special limestone features, and restricted plant habitats. It will be kept free of management disturbances, except for development of valid existing mineral claims, recreational trails and shelters, and prescribed fires. The WMNRA plan also approved the use of two cross-country trails near the RNA and the location of a new public-use recreation cabin near Fossil Creek; the cabin was constructed in 1985. The Beaver Creek National Wild and Scenic River corridor is within 2 km of the southern boundary of the RNA.

The principal historical use of the Limestone Jags RNA has been botanical and geologic study, caribou hunting, trapping, recreation, and mineral prospecting. Prindle (1913) and Mertie (1917) began geologic study and prospecting in the early 1900's. Field geologic studies were carried out in the late 1950's and early 1960's (Church and Durfee 1961). The work of Weber and Chapman in the area in the 1960's led to the first bedrock geology map of the quadrangle (Chapman and others 1971). In the 1950's and early 1960's, a Norwegian botanist, Gjaerevoll (1958, 1963, 1967), conducted the first taxonomic work on the special limestone habitats in this part of Alaska. Skarland conducted a brief reconnaissance trip into the area to locate caves and archeological sites in 1955 (Skarland and Libby 1955). The 1982 field documentation of the RNA resulted in the discovery of one of the largest caves in Alaska, new plant collections, and the establishment of permanent plots in forest and tundra. The Bureau of Land Management has been conducting studies of habitat use of the area by Dall sheep and caribou since 1982. The U.S. Geological Survey evaluated the geology and mineral resources of the WMNRA in 1986 and 1987. The remains of an old cabin indicates some early use, but hunting and winter recreation in the RNA are relatively recent developments. The number of recreational visits to the RNA is low.

The Limestone Jags RNA is managed by the Steese-White Mountains District of the Bureau of Land Management; district headquarters is in Fairbanks, Alaska. The approximate center of the RNA lies at 65°32′ N., 147°30′ W. (fig. 1). The location of Limestone Jags RNA within the public land survey system is shown in figure 2. Elevations within the RNA range from 490 to 1211 m (fig. 3).

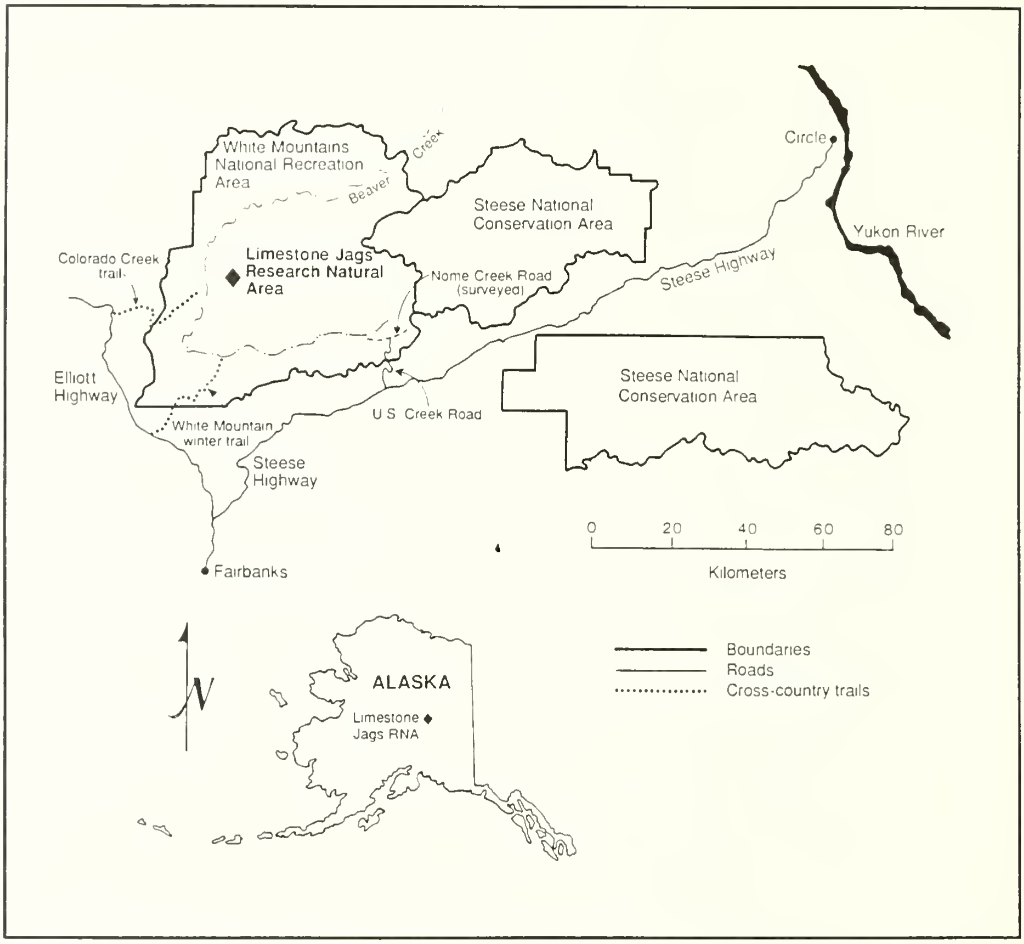

Figure 1—Location of Limestone Jags Research Natural Area.

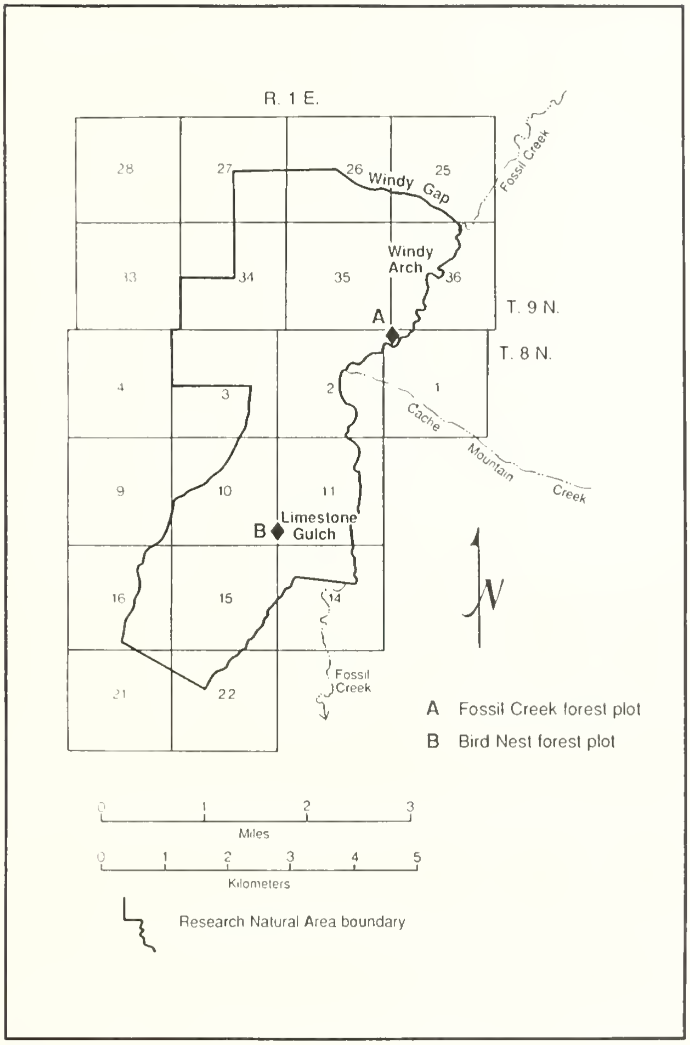

Figure 2—Boundary of Limestone Jags Research Natural Area within the public land survey grid, Fairbanks Meridian.

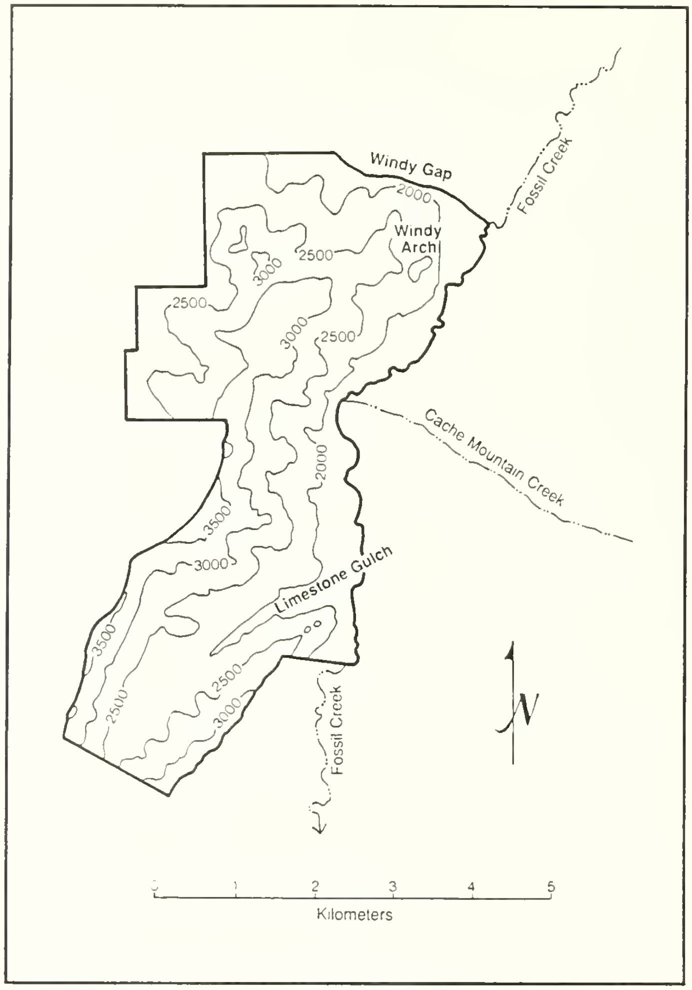

Figure 3—Topography of Limestone Jags Research Natural Area (contours in feet).

Access and Accommodations

Parking, Roads, and Rights-of-Way

There is no road access to Limestone Jags RNA. Visitors can reach the area by aircraft, snow machine, or a combination of river and cross-country travel. Air access to Limestone Jags is relatively good. Fairbanks International Airport is only 100 km south of the RNA (fig. 1). Helicopter access to Limestone Jags RNA is excellent; there are many open terraces, meadows, and bare rock landing places in and near the RNA (fig. 4). Skiplanes can usually land near Limestone Jags in the winter. Floatplanes can operate throughout the warm season at the confluence of Beaver Creek and Victoria Creek, about 60 river km downstream from the RNA; however, floatplanes can land on the middle reaches of Beaver Creek (within 5 km of the RNA) only during high water stages.

Snowmobiles can reach the RNA by the Colorado Creek trail or the White Mountain winter trail. The trailhead for both trails is on the Elliott Highway northwest of Fairbanks (fig. 5). The Colorado Creek trail begins near the Tolovana River about 90 km north of Fairbanks and extends east to Beaver Creek. Limestone Jags RNA can be reached from there by continuing east on an unimproved winter route along Windy Creek to the northern border of the RNA (fig. 6). Beaver Creek can usually be crossed in the winter, but visitors must often contend with open water channels. Winter visitors should inquire about local snow and ice conditions at the Bureau of Land Management district office.

Figure 4—Limestone ledges and openings provide helicopter landing sites at Limestone Jags Research Natural Area.

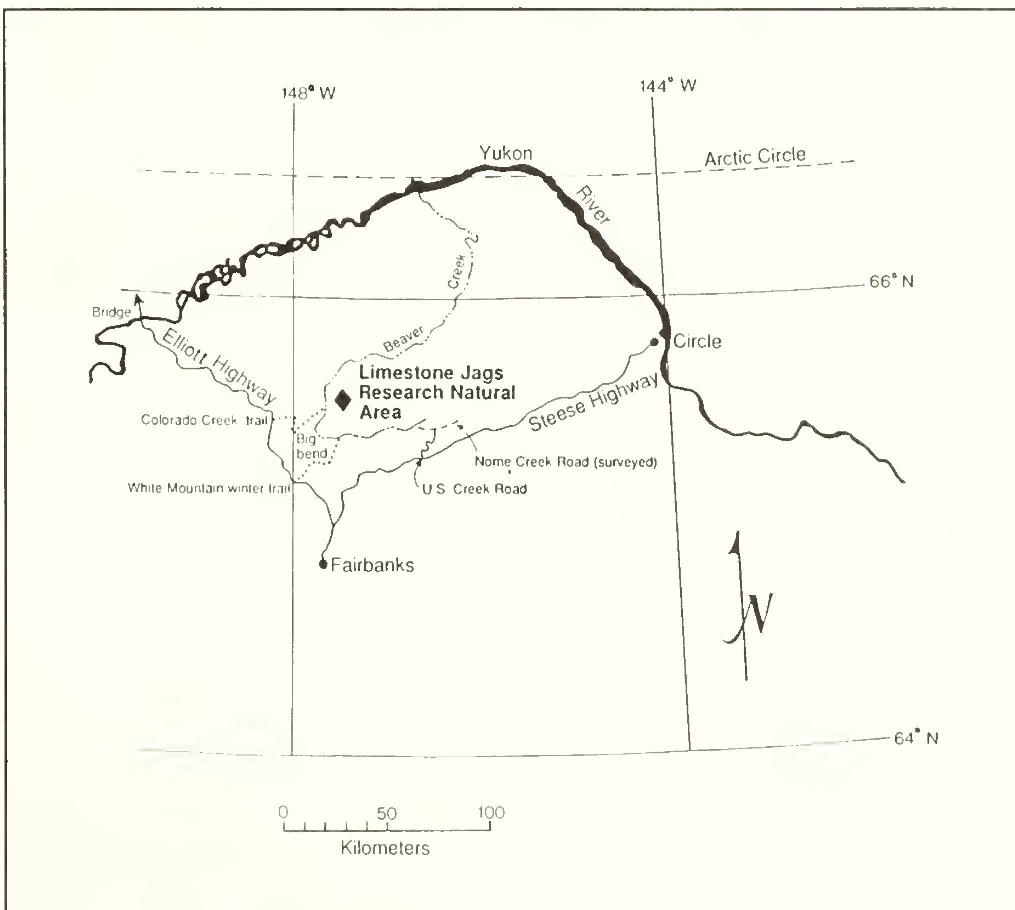

Figure 5—Road and trail access routes to Limestone Jags Research Natural Area.

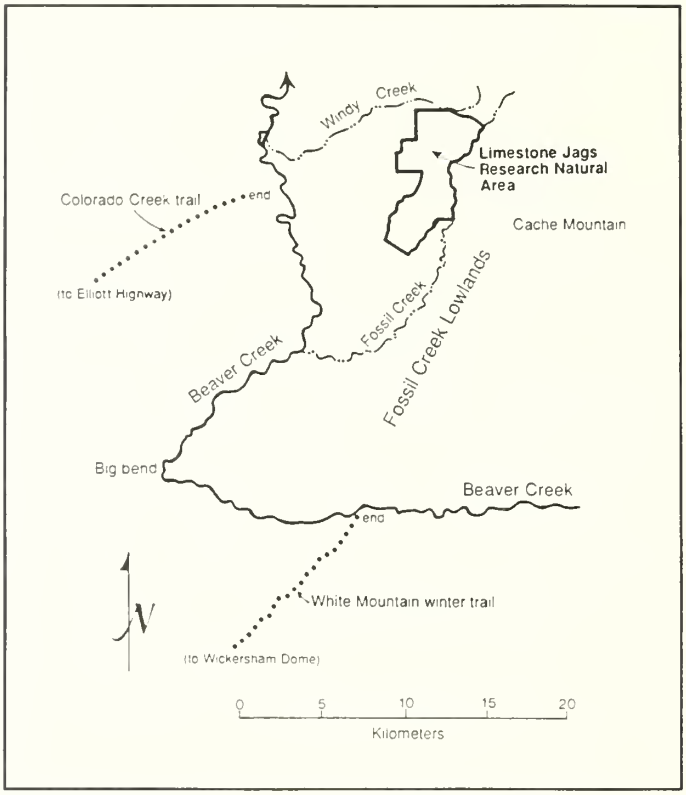

Figure 6—Cross-country travel routes to Limestone Jags Research Natural Area from the end of the White Mountain winter trail and the Colorado Creek trail.

The Elliott Highway trailhead for the White Mountain winter trail is about 50 km north of Fairbanks (fig. 5). The trail passes through the southwest portion of the WMNRA and east of the "big bend" section of Beaver Creek (fig. 6). Visitors can continue from there either west and north on the frozen surface of Beaver Creek to Windy Creek and the RNA, or northeast along the Fossil Creek lowlands to the RNA (fig. 6).

Another way to reach the RNA is a combination of boating down Beaver Creek and cross-country hiking. The U.S. Creek Road, a medium-standard public road, provides access to Nome Creek, a tributary of Beaver Creek (figs. 5 and 7). Nome Creek is narrow and shallow at the end of the U.S. Creek Road, making it difficult to move a boat onto Beaver Creek. The WMNRA land-use plan approved an extension and improvement of the road to the navigable lowermost section of Nome Creek. A centerline survey for the new road was completed in the summer of 1987. The new section of Nome Creek road will end at a campground and boat launch about 24 km southeast of the RNA (fig. 7). Boaters can float from there to within 5 km of the RNA. The first half of the cross-country hike from Beaver Creek to the RNA is across difficult lowland tussock tundra; the second half is across easier rocky and alpine terrain.

No road-accessible, take-out point for boats is available on Beaver Creek downstream from the RNA. Boats must return upstream to the launching point on Nome Creek, be airlifted out, or float several hundred kilometers down Beaver Creek and the Yukon River to the bridge at the end of Elliott Highway (fig. 1).

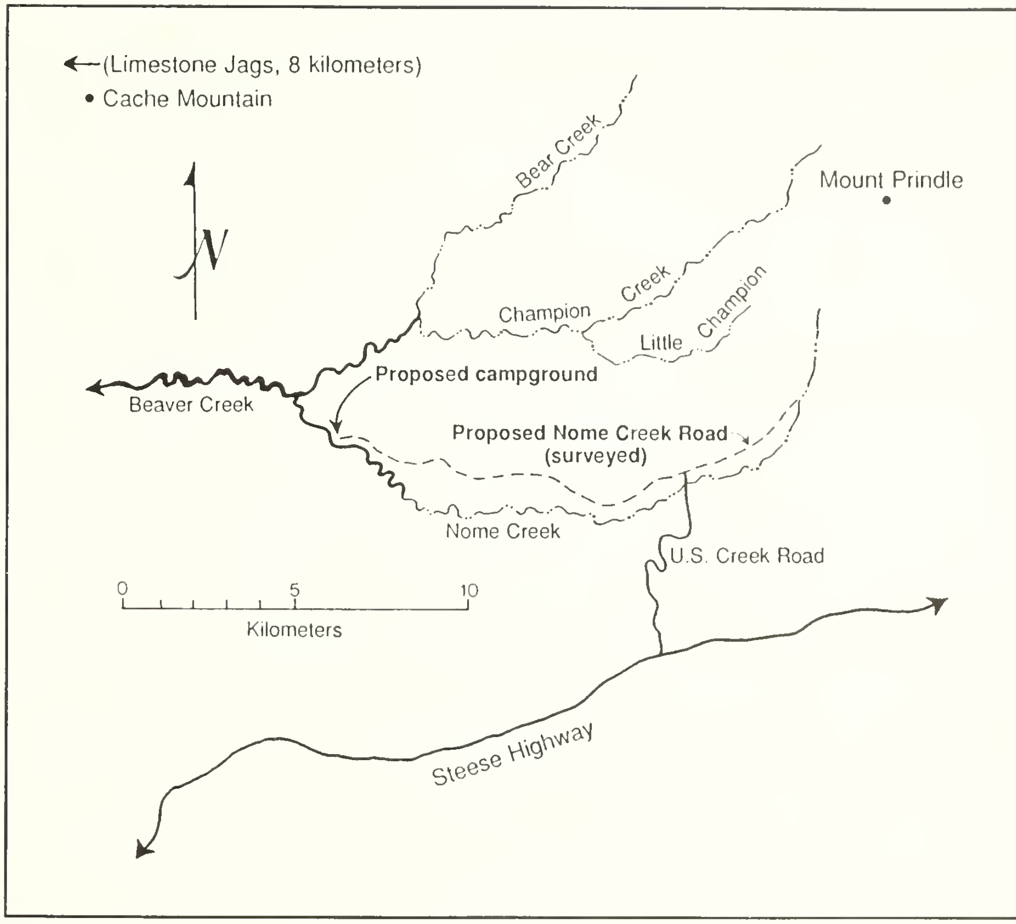

Figure 7—Access for boats to upper Beaver Creek from U.S. Creek Road and proposed Nome Creek Road.

Structures and Trails

No standing structures are currently in the RNA. The remains of an old trapper's cabin stand along Fossil Creek within the RNA. The Bureau of Land Management constructed a public-use recreation cabin (Windy Gap cabin) east of Fossil Creek near the border of the RNA in the summer of 1985. Windy Gap cabin is equipped with bunks, a sleeping loft, wood-heating stove, cookstove, and lantern. The cabin is used mostly in the winter. It was built at a distance from Fossil Creek because repeated overflows of water in the winter refreeze and cause the buildup of a large aufeis area on the bottomland (fig. 8). Aufeis can come within 2 m of the cabin.

Summer use of Windy Gap cabin is allowed but not encouraged. Summer access is difficult because only informal trails cross the tussock tundra bottomlands. Constructing trails on ice-rich permafrost areas of the bottomlands or even regular hiking across such terrain causes thawing, ground degradation, and vegetation damage.

Most visitors to the cabin and the surrounding area are attracted by the remote, primitive environment. Bureau of Land Management policy is to maintain the primitive character of the area, especially because the wildlife are sensitive to human disturbance during breeding and migration.

Figure 8—Aufeis buildup (broad section of flood plain behind and right of Windy Arch) on Fossil Creek near Windy Gap cabin. Light snow-covered area with no tree canopy behind and left of Windy Arch is black spruce permafrost bottomland, March 1986.

The construction of new trails approved in the WMNRA plan needs additional study and consultation to avoid damaging sensitive features in the RNA. Within the RNA are excellent game trails on the floor of Limestone Gulch and a few stretches of good moose trails along the Fossil Creek bottomland. The dry beds of the disappearing stream in Limestone Gulch and the disappearing portions of Fossil Creek are good hiking routes. The rocky, poorly vegetated alpine zone in the WMNRA is excellent hiking terrain.

Reasons for Establishing the Research Natural Area

The criteria for selecting RNAs in Alaska are called type needs (Juday 1983a, Underwood and Juday 1979). Type needs are plant communities, rare plants, geologic features, and animal species that are characteristic of a given region and are needed to make a complete and representative system of RNA's. The RNA type-needs list for the WMNRA is described by Juday and others (1982). For animal species, the presence of a target species in some particular setting or habitat defines the type need. The type-need features within an RNA are the basis for management actions.

Table 1 is a list of the diverse type needs found in Limestone Jags RNA; 8 geologic features, 11 plant communities, and 3 animal species. No BLM-listed "sensitive" plant species were verified as growing in the area, although additional collections are needed to complete the flora of the RNA. A new location for the moss *Andreaeobryum macrosporum* Steere & B. Murray was discovered during the site investigation for this report.

Table 1—Natural feature types needs used in the selection of the Limestone Jags Research Natural Area

Type need	Comments and definition
Geologic features:	
Caves	Limestone dissolution-joint type and overhang shelter type
Limestone exposures	Calcium carbonate with low vegetation cover and unstable talus, stable summits or ledges, and pinnacles
Cliffs	Elongate steep rock faces that generate updrafts for soaring birds, serve as escape terrain, or provide secure ledge habitat
Emergent cold springs	Mineral-rich water emerging from limestone that supports aquatic mosses and green algae
Red soil	Intensively weathered soil or paleosoil with a reddish or reddish-brown hue
Underground stream	Sections of 2d or 3d order (or higher) stream through limestone terrain; "swallow holes" dry stream beds, and persistent or emergent pools
Fossils[a]	Limestone coral reef organisms
Faultline features	Sharp contact of bedrock units with evidence of displacement
Animal species:	
Mammals—	
Dall sheep	Presence of isolated Yukon-Tanana upland population in early spring and summer foraging habitat with good escape terrain
Hoary marmot	Presence in typical alpine habitat with ledges, overhangs, and crevices in large rubble talus as escape terrain
Bird	
Peregrine falcon	Nests in habitat with cliffs for soaring updrafts and numerous isolated perches

See footnotes at end of table.

Table 1—Natural feature types needs used in the selection of the Limestone Jags Research Natural Area (continued)

Type need	Comments and definition
Plant communities:	
Forest—	
Moist white spruce slope forest	*Picea glauca*/feathermoss and *Picea glauca*/*Linnaea borealis*-*Equisetum sylvaticum*[b]
Wet black spruce-sphagnum forest[a]	Black spruce open needleleaf forest (includes several level V communities)[b]
Moist balsam poplar flood-plain forest[a]	Balsam poplar closed broadleaf forest (includes more than one level V community)[b]
Moist balsam poplar-spruce flood-plain forest[a]	*Populus balsamifera*-*Picea glauca*/*Alnus*/*Equisetum*[b]
Shrubs—	
Wet willow-alder drainageway tall shrub	Alder-willow closed tall shrub[b]
Moist willow flood-plain tall shrub[a]	Willow closed tall shrub (includes *Salix alaxensis* and other level V communities)[b]
Moist alder slope tall shrub	Alder-willow closed tall shrub[b]
Herbs—	
Snowbed herb-graminoid meadow	Alpine herb-sedge (snowbed)[b]
Lowland tussock meadow	Tussock tundra (includes *Eriophorum vaginatum* level V community)[b]
Barren and lichen—	
Foliose lichen	Foliose and fruticose lichen[b]
Crustose lichen rocks	Crustose lichen[b]

[a] Type need listed is only marginally represented in Limestone Jags Research Natural Area.

[b] Nearest unit of Alaska vegetation classification system of Viereck and others (1986).

The main features of geologic interest at Limestone Jags are karst (limestone dissolution) features in a very unusual subarctic setting. When limestone is dissolved by naturally acidic groundwater, caves, underground streams, natural bridges or arches, and emergent cold springs are produced (Strahler 1981). These features are rare at high latitudes, however, because the slow chemical reaction rates of dry subarctic soils severely restrict the rate at which they are formed (Jennings 1983). Even where karst features have formed in northern regions, repeated glaciations have usually destroyed them. Examples of caves, disappearing streams, springs, and a large natural bridge can be found in Limestone Jags RNA. Limestone pinnacles in the RNA resemble tower karst that was described for the first time in the far north at Nahanni National Park in the Northwest Territories, Canada (Brook and Ford 1978).

The Tolovana Limestone in the RNA formed in tropical ocean waters southeast of the current location of the RNA. According to a recent interpretation, the geologic terranes of the area were transported north until they collided with the growing edge of North America (Churkin and others 1982). In this interpretation, the sharp contact zone between basalt and limestone in the RNA is a suture zone that illustrates how Alaska was accreted to the geologic core of North America. This theory has been criticized for relying too readily on "suspect" terranes (Hudson 1987). Details of the geology of the RNA bear directly on this important debate. A wind gap (Windy Gap) along the northern boundary of the RNA marks a former stream channel or water gap through the White Mountains. The water gap became a wind gap after the modern Fossil Creek captured the Windy Creek stream drainage through headward erosion, leaving the gap through the mountains without the stream that formed it. Unlike many high-elevation mountain ridges and summits in the Yukon-Tanana uplands, the central and southern portions of Fossil Creek Ridge do not appear to have been glaciated during the Pleistocene. As a result, the landforms of the RNA have been shaped over long periods.

The presence of limestone in the RNA produces some hydrologic responses unusual for interior Alaska. The tilted limestone bedrock layers of Fossil Creek Ridge absorb most surface precipitation and feed it into a zone of mineral-rich cold springs at the base of the ridge. An upwelling groundwater zone outside the RNA feeds directly into Beaver Creek, causing open channels in winter ice. Along the eastern edge of the RNA, Fossil Creek disappears (flows underground in porous limestone) in several sections at all but high water stages. Within the RNA, winter overflow from springs causes a large buildup of aufeis in tributary stream channels.

A sparse dryas tundra occupies the higher elevations of the RNA on limestone substrates. In contrast, a lush lichen-herb-dryas tundra covers higher elevations on basalt. Well-developed, old-growth white spruce forests grow on the more productive sites of the Fossil Creek bottomlands and on exposed south-facing slopes in Limestone Gulch. An alder shrub transition is between forest and tundra on basalt slopes. Permafrost-dominated black spruce muskeg and tussock tundra occupy the valley along Fossil Creek. The forests on south exposures in the northeast part of the RNA were burned between 1953 and 1956. The burned area is now occupied by a young willow-alder and birch-white spruce thicket.

Dall sheep and caribou occur seasonally in Limestone Jags RNA. They graze on the tundra of Fossil Creek Ridge in the fall, winter, and spring, but leave the area in the summer because of lack of forage. The population of Dall sheep in the White Mountains is isolated from populations inhabiting large, contiguous areas of better habitat in the Alaska Range and Brooks Range. Although some genetic interchange with the larger populations probably occurs, the western Yukon-Tanana upland Dall sheep are affected by reproductive isolation. Well-developed trails in lower elevations indicate that bear and moose have occupied the RNA for many years.

Two typical alpine tundra small mammals are found in the RNA. The hoary marmot and collared pika harvest alpine grasses and forbs and find refuge from predators among the numerous rock ledges, overhangs, and talus slopes in the RNA. American peregrine falcons, which are classified by the State and Federal governments as threatened, nest in the RNA and use cliffs and pinnacles as perching sites. The uncommon Townsend's solitaire was sighted in rocky limestone tundra; the northern shrike, in a lowland forest opening.

Environment

Climate

There are no meteorological stations in the Beaver Creek watershed. National Weather Service data for Fairbanks, the nearest first-order reporting station, are not representative of Limestone Jags RNA because of distance and differences in topography and elevation. Meteorological data are available from several sites in the Caribou-Poker Creeks research watershed 40 km south of the RNA, a location representative of the Yukon-Tanana uplands.

Limestone Jags RNA has a continental climate, characterized by large diurnal and annual temperature variations and low humidity. Temperatures are below freezing in the RNA from 270 to 300 days a year. Because Limestone Jags RNA is near the Arctic Circle, low sun angles interact with topographic relief to cause predictable patterns of shadows (fig. 9). Extreme contrasts in microclimate over short distances are due to slope aspect and blockage of sun by surrounding topography. North-facing slopes are dominated by permafrost and retain snow patches into the early summer, whereas nearby south-facing slopes are free of permafrost at low elevations. Temperature inversions are common over the Fossil Creek lowlands, causing pockets of permafrost.

Santeford (1976) estimated precipitation at high elevations in the Yukon-Tanana upland by measuring hydrological response of the Chena River at Fairbanks. The average precipitation across the upland was more than twice the mean at Fairbanks. By this method, an annual precipitation of at least 50 cm can be inferred in the RNA. Terrain-induced convection is common in the summer, often resulting in brief rain showers over the RNA. A comparison of precipitation patterns in the hills and mountains of the Yukon-Tanana upland with data from the Fairbanks airport reveals that the uplands are subject to longer periods of heavy precipitation (Haugen and others 1982).

Figure 9—Late winter shadows on basalt summit, Limestone Jags Research Natural Area, March 1987. The winter snowpack at the highest elevations has been removed by wind and solar warming of the ridgetop and spur slope that are free from shadows.

Snow-course surveys in terrain similar to that in Limestone Jags RNA suggest an annual snowfall of about 130 cm. Winter precipitation generally increases with elevation, although wind locally rearranges snow into bare deflation patches and deep snowdrifts (fig. 10). Snow begins accumulating in the high elevations between September 1 and October 1. Low elevations in the RNA generally remain free of snow until early October. Snow cover disappears from the lowlands of the RNA in the last week of April or the 1st week of May, about a week later than at Fairbanks. The snowpack at higher elevations is generally gone by the end of the 1st week in June, although patches persist in shaded pockets at the highest elevations in the RNA for several more weeks. Plant growth begins early on alpine tundra areas that have been blown free of snow in the winter; these areas are heavily used by Dall sheep and caribou.

Geology

Juday (1987), using the Limestone Jags RNA as an example, describes the importance of geological features in Alaska RNA proposals. Scientific and educational values of bedrock structure, special karst features, and the influence of geology on plant and animal habitat at Limestone Jags RNA are all significant.

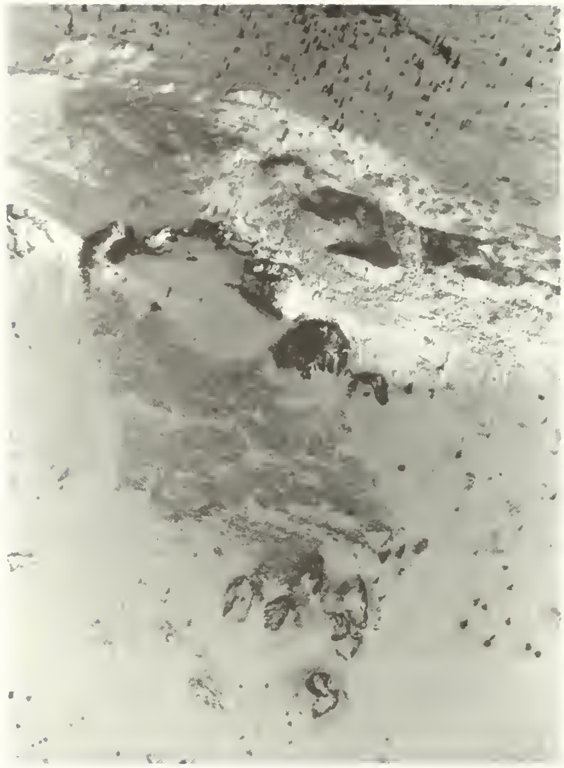

Figure 10—Snow deflation (wind removal) and snowdrift around a limestone pinnacle in Limestone Jags Research Natural Area, March 1987.

Bedrock geology—Two principal bedrock types are found in the RNA (fig. 11). The Tolovana Limestone is a relatively homogeneous microcrystalline chemical or partly biochemical calcium carbonate precipitate (Church and Durfee 1961). It is thickly bedded and massive, fractured, and veined by quartz and calcite. Tolovana Limestone exposures in the RNA are Silurian in age (Blodgett and others 1987) and were probably deposited in shallow, stable marine waters. The Tolovana Limestone lacks terrigenous (land-derived) sediment and is nearly pure calcium carbonate. Fossils are uncommon, except for a section about 20 m thick at the contact with the Fossil Creek Volcanics. Fossils present include Silurian corals and brachiopods (Chapman and others 1971, Church and Durfee 1961).

An Ordovician basalt, agglomerate, and conglomerate sequence (Blodgett and others 1987), known as the Fossil Creek Volcanics (Mertie 1937), makes up the other major bedrock unit in the RNA (fig. 11). The bedrock in the Fossil Creek Ridge area has been only very weakly metamorphosed.

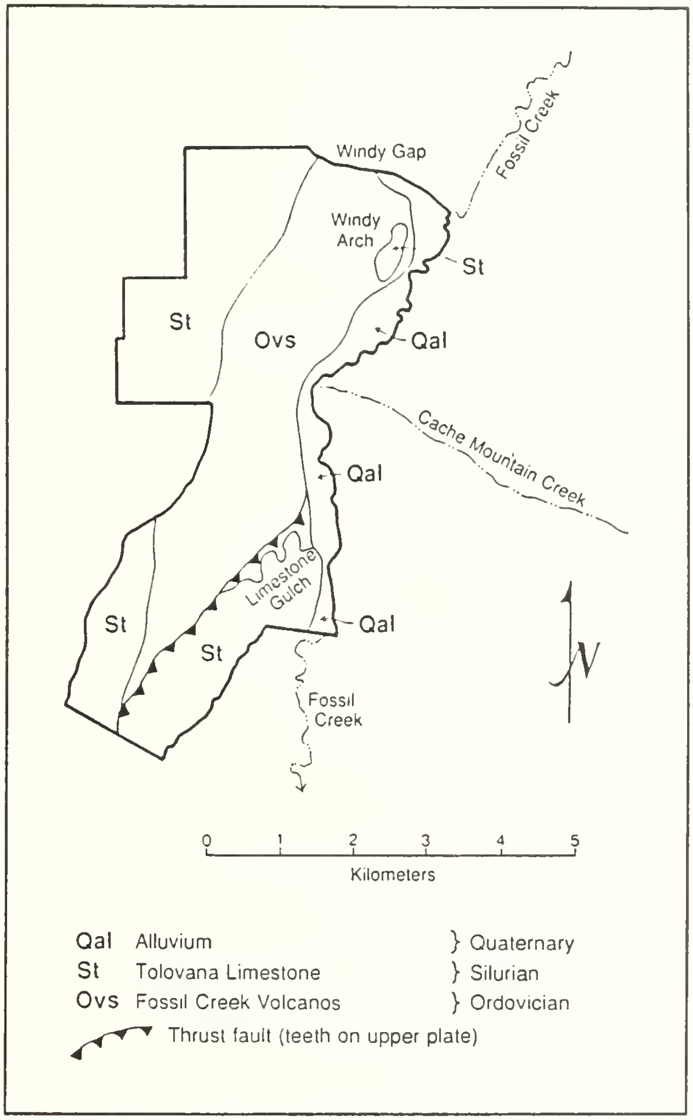

Figure 11—Surface geology of Limestone Jags Research Natural Area; adapted from Wheeler and others (1987) and Chapman and others (1971).

Chapman and others (1971) divide the Fossil Creek Volcanics into a lower sedimentary unit and an upper volcanic unit. Wheeler and others (1987) describe the composition of the lower half as:

> (1) thinly interbedded calcareous dark-gray slate to light-gray slaty phyllite and black tuffaceous shale, (2) gray to black calcareous and siliceous siltstone, (3) medium-gray sandy platy limestone, (4) black and gray banded silty chert, and (5) minor intercalations of basalt flows, pillow lavas, and gabbroic sills.

Chapman and others (1971) describe the upper 10 to 70 m of the volcanic sequence as:

> Volcanic conglomerate, dark greenish-gray, with rounded pebbles, cobbles, and boulders, composed chiefly of basaltic rocks with minor amounts of quartzite, slate, chert, and granitic rocks in a volcanic graywacke matrix; some limy tuff, light to medium grayish green; and a tuffaceous sandy limestone or calcareous sandy tuff, light to medium reddish-brown, yellowish-brown, medium brown, and grayish-green — abundantly fossiliferous in some places.

Wheeler and others (1987) describe the basalt within the Fossil Creek Volcanics and conclude that the clasts in the conglomerate and agglomerate of the upper portion are lahar and debris flow deposits from a continental source area.

Churkin and others (1982) describe the mosaic of allochthonous (formed elsewhere and moved in) terranes in east-central Alaska. They recognize a White Mountains Terrane that:

> apparently collided with and accreted to North America and Eurasia. ...The White Mountains terrane forms two narrow bands within the Beaver Creek suture zone in the Livengood quadrangle and the western part of the Circle quadrangle. ...This terrane...comprises an Ordovician siliceous sedimentary sequence rich in basaltic submarine flows, tuff, and breccia that grades upward into a Silurian...carbonate bank deposit... .

Their interpretations suggest the following scenario. The Fossil Creek Volcanics originated in a volcanic zone south of the current position of the RNA. The volcanos erupted at least partially underwater. Submerged volcanic reefs supported the formation of a shallow water limestone deposit. Northward motion of the Pacific plate delivered these geologic units to the accreting margin of the North American continent and pressed them together. Additional volcanic eruptions took place after the reefs were joined to the continent. Several significant geologic structural features of the area are consistent with this scenario: weak metamorphism of the rocks; vertical tilt of the Tolovana Limestone, a northeast-southwest axis of alignment of the contact zone among bedrock types, and the presence of thrust faults. Geologic terranes, by definition, must be bounded by thrust faults. Wheeler and others (1987), however, interpret the southern margin of the White Mountain terrane in the RNA as simply an unconformity (buried erosion surface), not a tectonic feature. This is a major problem for the migrating-terrane view, which calls for it to be modified or rejected in this case.

Blodgett and others (1987) describe a disconformity (a break in the continuity through time of undeformed sedimentary rock layers) between the Fossil Creek Volcanics and the overlying Tolovana Limestone. This disconformity matches a significant shallow-water gap in the geologic record around the world. They note,

> This stratigraphic gap, usually represented by an unconformity separating Upper Ordovician and Lower Silurian strata, is thought to have been caused by a major sea-level drop accompanying the late Ordovician glaciation in Gondwanaland. ...This is the first time that this...hiatus has been recognized in Alaska.

Figure 12—Tower karst feature (also called a pinnacle or "jag") in Limestone Jags Research Natural Area.

Karst geology—Corbel (1959) calculates a rate of surface lowering through dissolution (karst erosion) for the Tanana River basin in interior Alaska of 40 mm/1,000 yr, a high value especially for a dry, cold-climate region. Corbel's thesis that high latitudes often have higher rates of karst erosion than low latitudes is controversial.

Juday (1983b) describes many of the classic karst or limestone country features in the Limestone Jags RNA and their subarctic setting. These include caves, a natural arch, disappearing streams, and emergent cold springs. Brook and Ford (1978) describe the development of limestone towers in Nahanni National Park (61° to 62° N). Their work demonstrates that tower karst features are not restricted to the humid tropics as was widely believed. The pinnacles and jags of Limestone Jags RNA may represent tower karst (fig. 12).

The two best-developed caves discovered in the RNA to date are on the east-facing slope above Fossil Creek at the mouth of Limestone Gulch. Several rock shelters and overhangs are also in the RNA. The upper cave is called Icedam Cave because of a persistent snowdrift at the opening that obstructs its drainage (fig. 13). Icedam Cave is a joint-dissolution cave, with a narrow opening on a ledge or shelf about 30 m above Fossil Creek. The triangular cave opening is about 1 m tall. The ice obstruction persists until late summer and produces a water and ice pool over most of the cave floor (fig. 14).

Figure 13—Ice dam at the mouth of Icedam Cave in Limestone Jags Research Natural Area, June 1987.

Figure 14—Ice and water pool on the floor of Icedam Cave, June 1987.

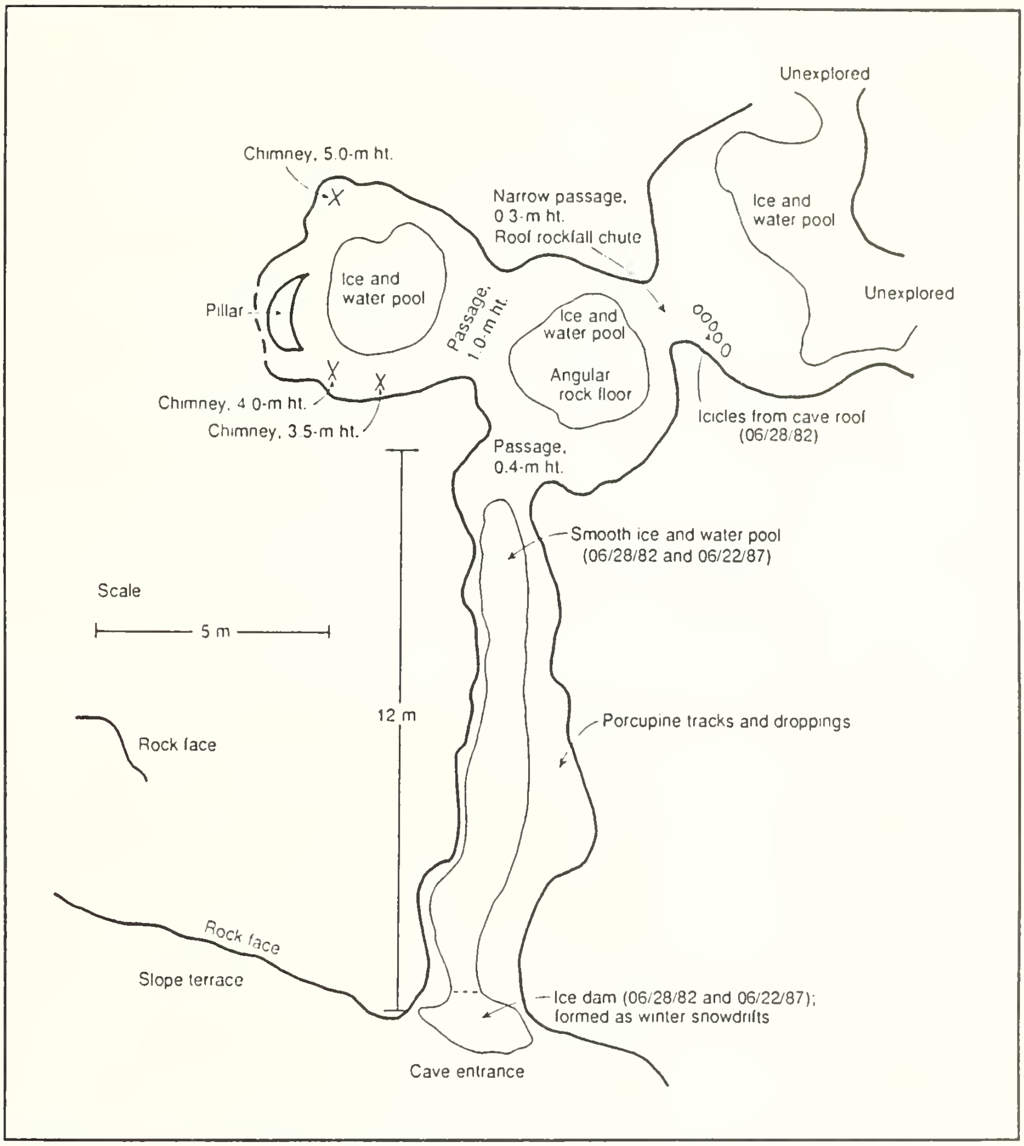

Figure 15—Features and dimensions of Icedam Cave.

Figure 15 is a map of the interior features of Icedam Cave. About 20 m of Icedam Cave have been explored. The first part of the passageway is about 1 to 1.5 m tall and contains porcupine tracks and droppings. A passage that extends about 12 m from the entrance opens into a circular chamber. A rockfall chute on the right rear of the first chamber constricts the cave to a passage only 30 cm tall (figs. 15 and 16). A large second chamber on the interior side of this passage was not fully explored.

Another passage on the left rear of the first chamber leads to the third and tallest chamber (fig. 17). Three chimneys extend up from the roof of the third (tall) chamber, and the far wall is a pillar. Plant fragments and bits of soil beneath the tallest chimney indicate a connection to the surface.

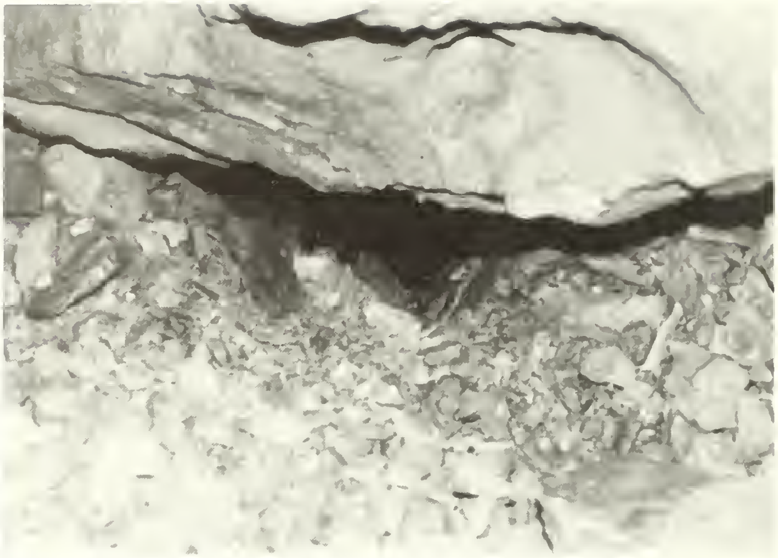

Figure 16—Rockfall constricting a passage from the first chamber to the second chamber of Icedam Cave. A large joint in the limestone above makes an active rockfall chute at this passage.

Figure 17—Tallest chamber in Icedam Cave. Author, pictured here, is 1.85 m tall; height of chamber here is about 3 m.

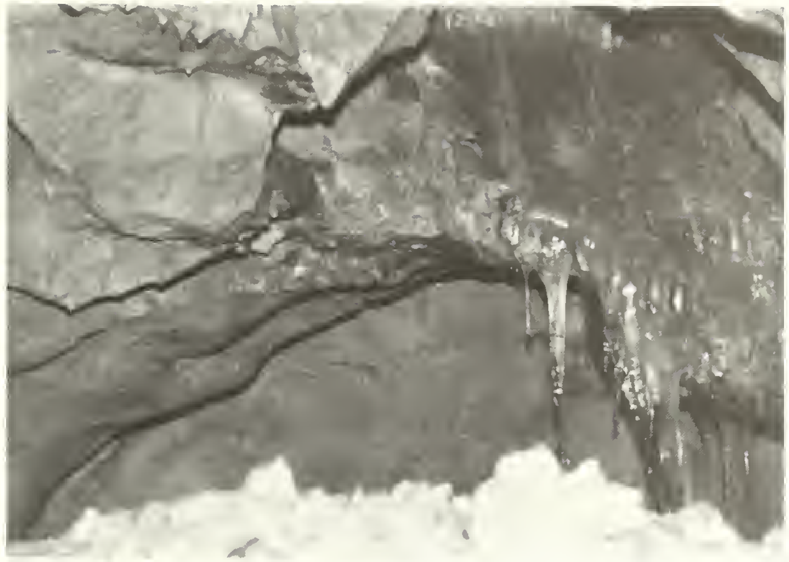

Figure 18—Icicles on the roof of Icedam Cave, June 1987.

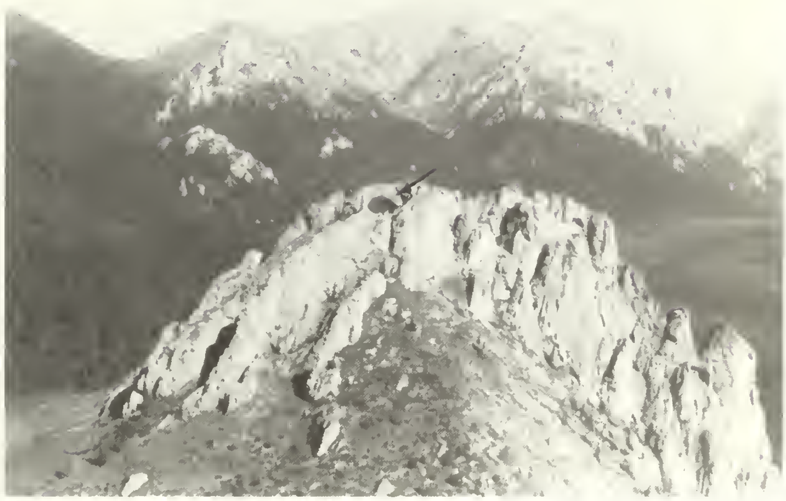

Figure 19—Windy Arch at the top of a limestone pinnacle.

Icicles hang from the chamber roof of Icedam Cave in the spring and early summer (fig. 18). Dissolved limestone is on the wet lower surfaces and rocks in the cave, but the walls and recent roof rockfalls are made up of much sharp angular rock. The debris cone at the entrance is similar to sites that have yielded remains from ancient predator kills (Guthrie 1988).

Windy Arch stands on a tower or pinnacle about 150 m above Windy Gap near the northern end of the RNA (fig. 19). Windy Arch is the largest known natural bridge on Fossil Creek Ridge. The span of the arch is about 10 m; the bridge is 3 to 4 m thick (fig. 20). Other natural bridges occur along Fossil Creek Ridge, but most are small

Figure 20—Supports and span at Windy Arch, June 1987.

Figure 21—Circular, undrained sinkhole in lower Limestone Gulch. Most sinkholes in Limestone Jags Research Natural Area are covered with a thick mat of soil humus, lichens, and moss. Rifle bolt is level with ground surface; butt of rifle stock is resting on the bottom of the sinkhole.

(1 to 2 m in diameter), ground-level holes through towers. Skarland and Libby (1955) describe a thick natural bridge just south of Limestone Jags RNA. They also discovered several shallow caves or overhangs in the same area that were extensively used by Dall sheep and porcupines.

Small, sinkholelike features (circular, undrained depressions), often covered with moss and lichens, occur on benches near the lower portion of the dry streambed that drains Limestone Gulch (fig. 21). Permafrost is present in the vicinity, potentially restricting the dissolution process that makes sinkholes.

Windy Gap is on the northern border of the RNA (fig. 3). Windy Gap is a wind gap, the remnant of a stream gap through the mountains that no longer carries the stream that formed it. The lower section of Fossil Creek pirated the ancestral Windy Creek drainage and routed it south around the gap instead of west through the mountains (fig. 6).

Figure 22—Limestone Gulch, March 1987. Despite a considerable drainage area, Limestone Gulch does not support a live (surface) stream course.

Figure 23—Emergent pool of cold spring. Pool is lined with a lush growth of mosses and leafy liverworts above the water level and aquatic mosses and green algae below.

Fossil Creek and the stream at Limestone Gulch are disappearing streams, typical of karst regions. Limestone Gulch is a sharp V-shaped valley (fig. 22); the stream at the bottom of the gulch flows at the surface only during flash floods. Water can often be heard flowing in the rocks beneath the surface of the gulch. Fossil Creek disappears underground in places along its course, depending on water stage, length of time since rain, and shifting morphology of the river channel. Mineral-rich, cold springs emerge in the RNA where subsurface waterflow encounters an impervious layer. Cold springs in the Fossil Creek Ridge area are surrounded with lush mats of mosses, aquatic algae, and liverworts (fig. 23).

Pleistocene geology—The Fossil Creek Ridge area mainly escaped Pleistocene glaciation. The highest elevations of the north block of the ridge (from Windy Gap northward) may have supported some glaciers and rock glaciers. Cache Mountain, a granitic pluton 10 km east of Limestone Gulch, shows clear evidence of glaciation (cirques and U-shaped valleys). Granitic boulders on the slopes above Fossil Creek in the east-central portion of the RNA probably represent glacial erratics from Cache Mountain that were deposited by early Pleistocene glaciation (Weber 1988).

A low cave near Fossil Creek is an undercut cliff, with a wide opening, deep roof-rockfall piles, and a few small chambers in the rear. It resembles shelters used by early humans in many parts of the world (Ford and Cullingford 1976). The remoteness of the White Mountains and the general lack of steady or abundant subsistence resources either now or in the past, however, do not favor the finding of early human artifacts. Looking for caves of possible anthropological significance, Skarland and Libby (1955) investigated a few areas near Fossil Creek. They apparently did not find the lower cave but did locate a higher, similarly shallow cave or rock shelter; they did not think it was anthropologically significant. They also found a deeper cave with a small opening north of the RNA. They noted signs of Dall sheep, porcupine, and ptarmigan but found no evidence of human use in the deeper cave.

Soils

The topography of Limestone Jags RNA includes rough and mountainous terrain, with areas of barren limestone exhibiting poor soil development (fig. 24). Steep-to-vertical limestone slopes in the RNA undergo extensive rock shattering and fragmentation. The lower south-facing slopes in Limestone Gulch are a thick accumulation of limestone talus. Rockfall is still active in that area (fig. 25).

No intensive soil surveys have been carried out in Limestone Jags RNA. Most upland soils in the RNA are Lithic Cryorthents derived from limestone or basalt and are very gravelly, well drained, and shallow over bedrock. They support sparse alpine vegetation. Mean annual temperatures are below freezing, but ice-rich permafrost rarely develops above bedrock. Soils on basalt are considerably better developed than on limestone and typically have larger amounts of clay.

The soils of valley bottoms, benches, and lower slopes are typically very gravelly, poorly drained Pergelic Cryaquepts in well-sorted alluvium. The abundant coarse fraction is due to the proximity of headwaters and steep mountain slopes. Granitic parent materials from Cache Mountain, just east of the RNA, make up part of the bedload of Fossil Creek. Older terrace surfaces in the bottomland are rich in peat and underlain by permafrost. Ice-rich permafrost occurs at depths of 30 to 60 cm during the growing season, causing the soils to be wet or ponded. Soils deposited more recently near Fossil Creek have deeper active layers or are free of permafrost as is indicated by the presence of large white spruce trees. Seasonal frost was present at a depth of 20 cm in the mineral horizon in late June 1982 at the Fossil Creek forest reference plot, a mature white spruce stand within 30 m of Fossil Creek.

Steep, south-facing lower slopes include areas of very gravelly Typic Cryochrepts, which are well-drained soils with brown cambic horizons. Loamy Aeric Cryaquepts occur in deep silty deposits on south toe slopes and along banks of large streams. These soils support spruce forests as tall as 25 m.

Figure 24—Bare rock patches and ridges with poor soil development in Limestone Jags Research Natural Area.

Figure 25—Rockfall chutes extend from the ridge to the floor of Limestone Gulch. Areas of tree destruction can be seen at the base of this slope. Zone of sharp contact between basalt (tree-covered) and limestone (treeless) can be seen on the right horizon, March 1986.

The soils of north-facing slopes in Limestone Gulch are either underlain by permafrost or have very late-season frozen zones. North slope soils consist of nearly barren limestone rubble; north-facing slopes in the RNA often support snowbanks or ice crusts that persist into the early summer. Limestone-derived soils below treeline are generally shallow, well-drained or excessively well-drained mixtures of limestone colluvium and humic mat.

Figure 26—Excavation for soil sample in red soil on steep south-facing talus slope above Limestone Gulch.

Table 2—Properties of red soil found at Limestone Jags Research Natural Area[a]

Soil characteristic	Value	Unit
Total N	1.212	Percent
Organic N	7.04	Percent
pH	8.5	
Exchange capacity	14.32	Milliequivalent per 100 grams
Exchangeable bases:		
Ca	33.924	Milliequivalent per 100 grams
Mg	.213	Milliequivalent per 100 grams
Mn	.014	Milliequivalent per 100 grams
Fe	0	
K	.043	Milliequivalent per 100 grams

[a] Values from Juday (1987).

Soils with a red hue are the result of intense weathering processes that oxidize iron and aluminum compounds. Red soils are rare at high latitudes because (1) widespread glaciation and other processes have generally rejuvenated northern soils; and (2) the low chemical reaction rate in frozen or cold, dry soils limits the intensity of weathering. The northern slopes above Limestone Gulch contain exposures of a fine-textured (clay-loam and loam), reddish-brown soil within limestone talus rubble (fig. 26). Table 2 gives some characteristics of the red soil. The red soils appear to correspond to exposures of a maroon lime mudstone in the basal layer of the Tolovana Limestone.

Biota

Vegetation

Flora—Table 3 is a list of herbarium voucher specimens of vascular plants collected in Limestone Jags in early July 1982 as part of the site documentation effort for the RNA. All specimens were collected from the limestone-basalt contact area north of Limestone Gulch (fig. 25). The collection of *Draba fladnizensis* in the RNA represents an extension many kilometers north and west in the Yukon-Tanana upland beyond the range given by Hultén (1968). *Douglasia arctica* was previously reported from the White Mountains, but its total range is restricted to three locations: northernmost Yukon Territory, Canada, the Chugach Mountains of south-central Alaska, and the central Yukon-Tanana uplands (Hultén 1968).

The moss *Andreaeobryum macrosporum* Steere & B. Murray, a species only recently described (Steere and Murray 1976), was collected in Limestone Jags RNA in 1982. It was previously thought to be restricted to the Arctic in northwest North America and is nearly always found on wet limestone (Murray, in press). The Limestone Jags RNA collection is the first outside the Brooks Range in Alaska. Persson and Gjaerevoll (1957) collected an unexpected central European moss, *Encalypta longicolla* Bruch., on the limestone of Fossil Creek Ridge in or near the RNA.

Table 4 is a list of 303 vascular plant species known to grow in Limestone Jags RNA or in similar habitat nearby in the White Mountains. Gjaerevoll (1958, 1963, 1967) and Persson and Gjaerevoll (1957) made extensive plant collections in the Beaver Creek and Fossil Creek lowlands and on Fossil Creek Ridge. They produced a nearly complete flora of the region and reported several species new to Alaska or new to the interior of the State. Gjaerevoll (1958) proposed a new species of grass, *Poa porsildii* Gjaerevoll, that is probably an endemic species of unglaciated mountains in central Alaska and Yukon Territory (Porsild 1974).

In the spring and early summer, alpine tundra in the RNA is rich in plant species that have large or attractive flowers. The following species were prominent on limestone tundra on the ridge north of Limestone Gulch in late June 1982: *Anemone drummondii*, *A. narcissiflora*, *Arctostaphylos rubra*, *Astragalus umbellatus*, *Cassiope tetragona*, *Dryas integrifolia*, *Eritrichium aretioides*, *Lloydia serotina*, *Loiseleuria procumbens*, *Papaver macounii*, *Parrya nudicaulis*, *Pedicularis kanei*, *P. oederi*, *Saxifraga oppositifolia*, *Silene acaulis*, and *Zygadenus elegans*. Basalt tundra near the contact with limestone in the same area supported the following species in flower: *Draba lactea*, *Phlox sibirica*, *Potentilla hyparctica*, *Saxifraga tricuspidata*, *Sedum rosea*, and *Valeriana capitata*.

Gjaerevoll (1967) notes that the unglaciated mountains of central Alaska, especially the White Mountains, are relatively rich in plant species, many of them poorly understood. The great diversity of plants in the White Mountains is probably due to (1) a diversity of distinct habitats, especially limestones, granites, alpine snowbanks, talus, low-elevation forest, and large river flood plains; and (2) old unglaciated mountain terrain. The 303 species listed in table 4 represent about one-fourth of the flora of Alaska. Plants with an affinity for calcareous substrates are well represented in the Limestone Jags flora (table 4, fig. 27).

Table 3—Herbarium voucher specimens of plants collected in Limestone Jags Research Natural Area[a]

Collection number	Species
DM8500	*Castilleja hyperborea* Pennell
DM8501	*Pedicularis verticillata* L.
DM8502	*Podistera macounii* (Coult. & Rose) Math. & Const.
DM8503	*Antennaria friesiana* (Trautv.) Ekman
DM8504 and DM8518	*Minuartia arctica* (Stev.) Aschers. & Graebn.
DM8505	*Douglasia arctica* Hook.
DM8506	*Eritrichium aretioides* (Cham.) D.C.
DM8507	*Carex glacialis* Mack.
DM8508	*Oxytropis jordalii* Pors.
DM8509	*Hedysarum mackenzii* Richards.
DM8510	*Artemisia furcata* Bieb.
DM8511	*Rumex acetosa* L. ssp. *alpestris* (Scop.) Love
DM8512	*Lagotis glauca* Gaertn.
DM8513	*Salix brachycarpa* Nutt. ssp. *niphoclada* (Rydb.) Argus
DM8514	*Erigeron hyperboreus* Greene
DM8515 (range extension)	*Draba fladnizensis* Wulf.
DM8516	*Potentilla hookeriana* Lehm.
DM8519	*Carex petricosa* Dew.
DM8520	*Carex nardina* E. Fries
DM8521	*Hedysarum alpinum* L. ssp. *americanum* (Michx.) Fedtsch
DM8523	*Minuartia stricta* (Sw.) Hiern

[a] Collected by David Murray, July 1, 1982; voucher specimens preserved in the University of Alaska Herbarium, Fairbanks, Alaska. Scientific names follow Hultén (1968).

Table 4—Vascular plants collected or observed in Limestone Jags Research Natural Area or immediate vicinity[a]

Family and species	Habitat, abundance, and distribution notes
Ophioglossaceae:	
Botrychium boreale (E. Fries) Milde	Relatively uncommon species
Botrychium lunaria (L.) Sw.	
Athyriaceae:	
Cystopteris fragilis (L.) Bernh.	Rock and montane species
Cystopteris montana (Lam.) Bernh.	Moist calcareous and forest species
Woodsia alpina (Bolton) S.F. Gray	Calcareous species
Woodsia glabella R. Br.	Calcareous species
Aspidiaceae:	
Dryopteris fragrans (L.) Schott	
Equisetaceae:	
Equisetum arvense L.	
Equisetum fluviatile L. ampl. Ehrh.	Low elevations of RNA
Equisetum scirpoides Michx.	
Equisetum variegatum Schleich.	
Lycopodiaceae:	
Lycopodium annotinum L.	
Selaginellaceae:	
Selaginella selaginoides (L.) Link	Especially in calcareous soil
Selaginella sibirica (Milde) Hieron.	Basalt alpine transect
Pinaceae:	
Juniperus communis L.	Limestone[b]
Picea glauca (Moench) Voss	Fossil Creek forest plot
Picea mariana (Mill.) Britt., Sterns & Pogg.	Near Fossil Creek plot
Gramineae:	
Agropyron boreale (Turcz.) Drobov	
Agrostis borealis Hartm.	
Agrostis scabra Willd.	
Alopecurus aequalis Sobol.	
Arctagrostis latifolia (R. Br.) Griseb.	
Arctophila fulva (Trin.) Anderss.	
Bromus pumpellianus Scribn.	
Calamagrostis canadensis (Michx.) Beauv.	Field notes
Calamagrostis purpurascens R. Br.	
Deschampsia caespitosa (L.) Beauv.	
Festuca altaica Trin.	
Festuca brachyphylla Schult.	Basalt alpine transect
Festuca rubra L.	
Festuca saximontana Rydb.	Rocky Mountain and boreal species
Festuca vivipara (L.) Sm.	
Hierochloe alpina (Sw.) Roem. & Schult.	Basalt alpine transect
Hierochloe odorata (L.) Wahlenb.	
Poa alpigena (E. Fries) Lindm.	
Poa arctica R. Br.	
Poa glauca M. Vahl	
Poa lanata Scribn. & Merr.	
Poa paucispicula Scribn. & Merr.	Common near snowbeds
Poa porsildii Gjaerevoll	Common near snowbeds
Trisetum sibiricum Rupr.	Restricted range in Alaska

See footnotes at end of table.

Table 4—Vascular plants collected or observed in Limestone Jags Research Natural Area or immediate vicinity[a] (continued)

Family and species	Habitat, abundance, and distribution notes
Trisetum spicatum (L.) Richter	
Cyperaceae:	
Carex aquatilis Wahlenb.	
Carex brunnescens (Pers.) Poir.	
Carex canescens L.	
Carex capillaris L.	
Carex capitata L.	
Carex diandra Schrank.	
Carex eleusinoides Turcz.	Abundant along Fossil Creek
Carex franklinii Boott	Calcareous species, described in Rocky Mountains; few collections in Alaska
Carex glacialis Mack.	DM 8507
Carex lachenalii Schkuhr	Snowbed species
Carex limosa L.	
Carex loliacea L.	
Carex lugens Holm	
Carex media R. Br.	
Carex membranacea Hook.	Calcareous wet places
Carex microchaeta Holm	Basalt alpine transect
Carex misandra R. Br.	
Carex nardina E. Fries	DM 8520
Carex petricosa Dew.	DM 8519
Carex podocarpa C. B. Clarke	
Carex rariflora (Wahlenb.) J.E.Sm.	
Carex rotundata Wahlenb.	
Carex rupestris All.	Dry sites
Carex scirpoidea Michx.	Limestone alpine transect
Carex supina Willd. (Steud.) Hult.	Dry sites
Carex tenuiflora Wahlenb.	
Carex vaginata Tausch	
Eriophorum angustifolium Honck.	Field notes
Eriophorum brachyantherum Trautv. & Mey.	
Eriophorum vaginatum L.	Field notes
Kobresia myosuroides (Vill.) Fiori & Paol.	
Kobresia sibirica Turcz.	Alkaline wet places
Kobresia simpliciuscula (Wahlenb.) Mack.	
Juncaceae:	
Juncus biglumis L.	
Juncus castaneus Sm.	
Juncus tenuis Willd.	Few collections in Alaska
Juncus triglumis L.	
Luzula arctica Blytt	
Luzula tundricola Gorodk.	Basalt alpine transect
Liliaceae:	
Lloydia serotina (L.) Rchb.	Limestone,[b] limestone alpine transect
Tofieldia coccinea Richards.	Limestone alpine transect
Tofieldia pusilla (Michx.) Pers.	
Zygadenus elegans Pursh	Limestone[b]
Orchidaceae:	
Amerorchis rotundifolia (Banks) Hult.	
Corallorhiza trifida Chatelain	
Cypripedium guttatum Sw.	Calcareous species

See footnotes at end of table.

Table 4—Vascular plants collected or observed in Limestone Jags Research Natural Area or immediate vicinity[a] (continued)

Family and species	Habitat, abundance, and distribution notes
Cypripedium passerinum Richards.	
Goodyera repens (L.) R. Br. var. *ophioides* Fern.	
Platanthera obtusata (Pursh) Lindl.	Calcareous species
Spiranthes romanzoffiana Cham.	
Salicaceae:	
Populus balsamifera L.	Fossil Creek plot
Populus tremuloides Michx.	Field notes
Salix alaxensis (Anderss.) Cov.	Field notes
Salix arbusculoides Anderss.	
Salix arctica Pall.	Basalt alpine transect
Salix chamissonis Anderss.	Disjunct from Brooks Range
Salix glauca L.	
Salix hastata L.	
Salix myrtillifolia Anders.	
Salix brachycarpa Nutt. ssp. *niphoclada* (Rydb.) Argus[c]	DM 8513
Salix phlebophylla Anderss.	Basalt alpine transect
Salix polaris Wahlenb.	
Salix pulchra Cham.	
Salix reticulata L.	Field notes
Salix rotundifolia Trautv.	
Betulaceae:	
Betula glandulosa Michx.	Field notes
Betula occidentalis Hook.	
Betula papyrifera Marsh.	Forest plots
Alnus crispa (Ait.) Pursh	Forest plots
Santalaceae:	
Geocaulon lividum (Richards.) Fern.	Field notes
Polygonaceae:	
Oxyria digyna (L.) Hill	
Polygonum alaskanum (Small) Wight	
Polygonum bistorta L.	
Polygonum viviparum L.	Limestone alpine transect
Rumex acetosa L. ssp. *alpestris* (Scop.) Love	DM 8511
Rumex arcticus Trautv.	
Portulacaceae:	
Claytonia sarmentosa C. A. Mey.	Talus and snowbed species
Caryophyllaceae:	
Cerastium beeringianum Cham. & Schlecht.	
Cerastium jenisejense Hult.	Disjunct in White Mountains
Cerastium maximum L.	
Melandrium apetalum (L.) Fenzl	
Melandrium taylorae (Robins.) Tolm.	
Minuartia arctica (Stev.) Aschers. & Graebn.	DM 8504 and DM 8518, limestone and basalt transects
Minuartia dawsonensis (Britt.) Mattf.	
Minuartia macrocarpa (Pursh) Ostenf.	Talus species
Minuartia obtusiloba (Rydb.) House	
Minuartia rubella (Wahlenb.) Graebn.	Calcareous species

See footnotes at end of table.

Table 4—Vascular plants collected or observed in Limestone Jags Research Natural Area or immediate vicinity[a] (continued)

Family and species	Habitat, abundance, and distribution notes
Minuartia stricta (Sw.) Hiern	DM 8523
Minuartia yukonensis Hult.	Dry talus species
Moehringia lateriflora (L.) Fenzl	
Silene acaulis L.	Limestone,[b] limestone alpine transect
Silene repens Patrin	
Stellaria calycantha (Ledeb.) Bong.	Possible, edge of range
Stellaria laeta Richards.	Basalt alpine transect
Stellaria longipes Goldie	
Stellaria monantha Hult.	Possible, edge of range
Wilhelmsia physodes (Fisch.) McNeill	Sandy gravel bars
Ranunculaceae:	
Aconitum delphinifolium DC.	Field notes
Anemone drummondii S. Wats.	Limestone,[b] limestone alpine transect
Anemone narcissiflora L.	Limestone,[b] limestone and basalt transects
Anemone parviflora Michx.	
Anemone richardsonii Hook.	
Delphinium brachycentrum Ledeb.	
Delphinium glaucum S. Wats.	
Ranunculus gmelinii DC.	Aquatic species
Ranunculus hyperboreus Rottb.	Limestone alpine transect
Ranunculus lapponicus L.	
Ranunculus nivalis L.	
Ranunculus reptans L.	
Thalictrum alpinum L.	Limestone and basalt transects
Thalictrum sparsiflorum Turcz.	
Papaveraceae:	
Papaver macounii Greene	Limestone[b]
Fumariaceae:	
Corydalis pauciflora (Steph.) Pers.	
Cruciferae:	
Arabis hirsuta (L.) Scop.	
Arabis lyrata L.	Talus species
Braya humilis (C.A. Mey.) Robins.	
Cardamine pratensis L.	
Cardamine purpurea Cham. & Schlecht.	Limestone alpine transect
Draba caesia Adams	
Draba fladnizensis Wulf.	DM 8515, range extension
Draba hirta L.	Stony soil in mountains
Draba lactea Adams	Basalt[b]
Draba lanceolata Royle	Stony soil in mountains
Draba macrocarpa Adams	
Lesquerella arctica (Wormskj.) S. Wats.	
Parrya nudicaulis (L.) Regel	Limestone[b]
Rorippa hispida (Desv.) Britt. var. *barbareaefolia* (DC.) Hult.	
Crassulaceae:	
Sedum rosea (L.) Scop.	Basalt[c]
Saxifragaceae:	
Boykinia richardsonii (Hook.) Gray	
Chrysosplenium tetrandrum (Lund) T. Fries	
Chrysosplenium wrightii Fr. & Sav.	

See footnotes at end of table.

Table 4—Vascular plants collected or observed in Limestone Jags Research Natural Area or immediate vicinity[a] (continued)

Family and species	Habitat, abundance, and distribution notes
Parnassia kotzebuei Cham. & Schlecht.	
Parnassia palustris L.	
Saxifraga exilis Steph.	
Saxifraga foliolosa R. Br.	Edge of range
Saxifraga hieracifolia Waldst. & Kit.	
Saxifraga hirculus L.	
Saxifraga oppositifolia L.	Limestone,[b] limestone alpine transect
Saxifraga punctata L.	
Saxifraga reflexa Hook.	Basalt alpine transect
Saxifraga spicata D. Don	
Saxifraga tricuspidata Rottb.	Basalt[b]
Rosaceae:	
Dryas integrifolia M. Vahl	Limestone[b]
Dryas octopetala L. ssp. *alaskensis* (Pors.) Hult.	Limestone alpine transect
Dryas octopetala L. ssp. *octopetala*	Limestone and basalt transects
Potentilla biflora Willd.	
Potentilla fruticosa L.	
Potentilla hookeriana Lehm.	DM 8516
Potentilla hyparctica Malte	Basalt[b]
Potentilla palustris (L.) Scop.	
Potentilla uniflora Ledeb.	
Ribes triste Pall.	
Rosa acicularis Lindl.	Fossil Creek plot
Rubus arcticus L.	
Rubus chamaemorus L.	Field notes
Spiraea beauverdiana Schneid.	
Leguminosae:	
Astragalus aboriginum Richards.	
Astragalus alpinus L.	
Astragalus umbellatus Bunge	Limestone,[b] limestone alpine transect
Hedysarum alpinum L. ssp. *americanum* (Michx.) Fedtsch	DM 8521
Hedysarum mackenzii Richards.	DM 8509
Lupinus arcticus S. Wats.	Basalt alpine transect
Oxytropis jordalii Pors.	DM 8508
Oxytropis maydelliana Trautv.	
Oxytropis nigrescens (Pall.) Fisch.	
Oxytropis scammaniana Hult.	Basalt alpine transect
Oxytropis viscida Nutt.	
Violaceae:	
Viola biflora L.	
Elaeagnaceae:	
Shepherdia canadensis (L.) Nutt.	
Onagraceae:	
Epilobium angustifolium L.	Field notes
Epilobium latifolium (L.)	
Epilobium palustre L.	
Umbelliferae:	
Bupleurum triradiatum Adams	
Cnidium cnidiifolium (Turcz.) Schischk.	
Ligusticum mutellinoides (Crantz) Willar	

See footnotes at end of table.

Table 4—Vascular plants collected or observed in Limestone Jags Research Natural Area or immediate vicinity[a] (continued)

Family and species	Habitat, abundance, and distribution notes
Cornaceae:	
Cornus canadensis L.	Fossil Creek plot
Pyrolaceae:	
Pyrola grandiflora Radius	
Pyrola secunda L.	
Ericaceae:	
Andromeda polifolia L.	
Arctostaphylos alpina (L.) Spreng.	
Arctostaphylos rubra (Rehd. & Wilson) Fern.	Limestone[b]
Arctostaphylos uva-ursi (L.) Spreng.	
Cassiope tetragona (L.) D. Don.	Limestone,[b] limestone alpine transect
Diapensia lapponica L.	Field notes
Empetrum nigrum L.	Field notes[c]
Ledum decumbens Ait.	Field notes[c]
Ledum groenlandicum Oeder	Field notes
Loiseleuria procumbens (L.) Desv.	Limestone[c]
Rhododendron lapponicum (L.) Wahlenb.	Field notes
Vaccinium uliginosum L.	Limestone alpine transect
Vaccinium vitis-idaea L.	Limestone alpine transect
Primulaceae:	
Androsace chamaejasme Host	Limestone alpine transect
Androsace septentrionalis L.	
Dodecatheon frigidum Cham. & Schlecht.	
Douglasia arctica Hook.	DM 8505, uncommon species
Gentianaceae:	
Gentiana propinqua Richards.	
Gentiana prostrata Haenke	
Lomatogonium rotatum (L.) E. Fries	
Polemoniaceae:	
Phlox sibirica L. ssp. *richardsonii* (Hook.) Hult.	
Phlox sibirica L.	Basalt,[b] calcareous species
Polemonium acutiflorum Willd.	
Polemonium boreale Adams	Disjunct in White Mountains
Boraginaceae:	
Eritrichium aretioides Cham. D.C.	DM 8506, limestone,[b] limestone alpine transect
Eritrichium splendens Kearney	
Mertensia paniculata (Ait.) G. Don.	Field notes
Scrophulariaceae:	
Castilleja caudata (Pennell) Rebr.	Basalt alpine transect
Castilleja hyperborea Pennell	DM 8500, basalt alpine transect
Lagotis glauca Gaertn.	DM 8512
Pedicularis capitata Adams	Possible, edge of range
Pedicularis kanei Durand	Limestone,[b] limestone and basalt transects
Pedicularis langsdorffii Fisch.	
Pedicularis oederi M. Vahl	Limestone[b]
Pedicularis sudetica Willd.	
Pedicularis verticillata L.	DM 8501
Synthyris borealis Pennell	Basalt alpine transect

See footnotes at end of table.

Table 4—Vascular plants collected or observed in Limestone Jags Research Natural Area or immediate vicinity[a] (continued)

Family and species	Habitat, abundance, and distribution notes
Lentibulariaceae:	
Pinguicula villosa L.	
Pinguicula vulgaris L.	Calcareous species
Rubiaceae:	
Galium boreale L.	Field notes
Galium trifidum L.	Field notes
Galium triflorum Michx.	Field notes
Adoxaceae:	
Adoxa moschatellina L.	Calcareous species
Caprifoliaceae:	
Linnaea borealis L.	
Viburnum edule (Michx.) Raf.	Field notes
Valerianaceae:	
Valeriana capitata Pall.	Basalt[b]
Campanulaceae:	
Campanula aurita Greene	Endemic of central Alaska and northwestern Canada, calcareous species
Campanula lasiocarpa Cham.	
Campanula uniflora L.	
Compositae:	
Achillea borealis Bong.	
Achillea sibirica Ledeb.	
Antennaria friesiana (Trautv.) Ekman	DM 8503, basalt alpine transect
Arnica alpina (L.) Olin	
Arnica frigida C.A. Mey.	Basalt alpine transect
Arnica lessingii Greene	
Artemisia alaskana Rydb.	Possible, edge of range
Artemisia arctica Less.	Basalt alpine transect
Artemisia borealis Pall.	
Artemisia frigida Willd.	Possible, edge of range
Artemisia furcata Bieb.	DM 8510, limestone alpine transect disjunct in White Mountains
Artemisia tilesii Ledeb.	
Aster sibiricus L.	Field notes
Chrysanthemum integrifolium Richards.	Endemic of northern Alaska and far north of Canada
Crepis elegans Hook.	
Erigeron acris L. ssp. *politus* (E. Fries) Schinz & Keller	
Erigeron hyperboreus Greene	DM 8514, disjunct in White Mountains
Erigeron lonchophyllus Hook.	Sand and gravel bars of Fossil Creek
Erigeron purpuratus Greene	Sand and gravel bars of Fossil Creek
Petasites frigidus (L.) Franch	
Petasites hyperboreus Rydb.	
Saussurea angustifolia (Willd.) DC.	
Saussurea viscida Hult.	
Senecio atropurpureus (Ledeb.) Fedtsch.	
Senecio congestus (R. Br.) DC.	River gravel bars
Senecio ogotorukensis Packer	*Senecio conterminus* Greenm.[d]
Senecio fuscatus (Jord. & Fourr.) Hayek	
Senecio lugens Richards.	
Senecio resedifolius Less.	

See footnotes at end of table.

Table 4—Vascular plants collected or observed in Limestone Jags Research Natural Area or immediate vicinity[a] (continued)

Family and species	Habitat, abundance, and distribution notes
Senecio yukonensis Pors.	Endemic of Yukon Territory and northern Alaska
Solidago multiradiata Ait.	Basalt alpine transect
Taraxacum ceratophorum (Ledeb.) DC.	
Taraxacum lacerum Greene	
Taraxacum phymatocarpum J. Vahl	Disjunct in White Mountains

[a] Unless otherwise noted, species listed were collected by Gjaerevoll (1958, 1963, 1967) within Limestone Jags RNA or on nearby limestone habitat of Fossil Creek Ridge or alluvial habitat of Fossil Creek.

[b] Species observed and identified by G. Juday and Dale Taylor (Bureau of Land Management) on limestone or basalt as noted.

[c] Taxonomy follows Viereck and Little (1972).

[d] Treated as *Senecio conterminus* Greenm. in Hultén (1968).

Figure 27—*Cypripedium guttatum*, the lady's slipper orchid, is favored by the calcareous habitats in Limestone Jags Research Natural Area. *Dryas octopetala* and lichens shown here achieve dense ground cover on stable limestone habitats.

Plant communities—Figure 28 is a vegetation cover map of Limestone Jags RNA. The most extensive unit mapped is barren limestone. Many of the talus and calcareous species are restricted to or are most common in this habitat. Basalt tundra, limestone dryas tundra, and undifferentiated alpine tundra cover 34 percent of the RNA. All forest types occupy about 39 percent of the RNA and an open white spruce woodland on limestone occupies about 9 percent. Open white spruce woodland is relatively uncommon in Alaska, reflecting the scarcity of mature, stable limestone sites in the interior Alaska forest zone. An alpine tundra woodland is found between basalt tundra and closed canopy forest (fig. 29). Black spruce on permafrost covers about 4 percent of the RNA, mainly in a cold air inversion basin along Fossil Creek and on shaded lower slopes in Limestone Gulch (figs. 8 and 28).

Table 5 presents data from two permanently marked vegetation transects on an alpine basalt and limestone tundra (fig. 30). The basalt transect has greater species cover, less rock exposure, and a greater number of species (especially lichens) than the limestone. The limestone tundra appears to be a *Dryas octopetala-Carex scirpoidea-Cetraria nivalis* community type. The basalt tundra is a *Dryas octopetala-Carex microchaeta-Lobaria linita* community. The steepest and driest south-facing limestone slopes just below the transect support isolated *Juniperus communis* shrubs.

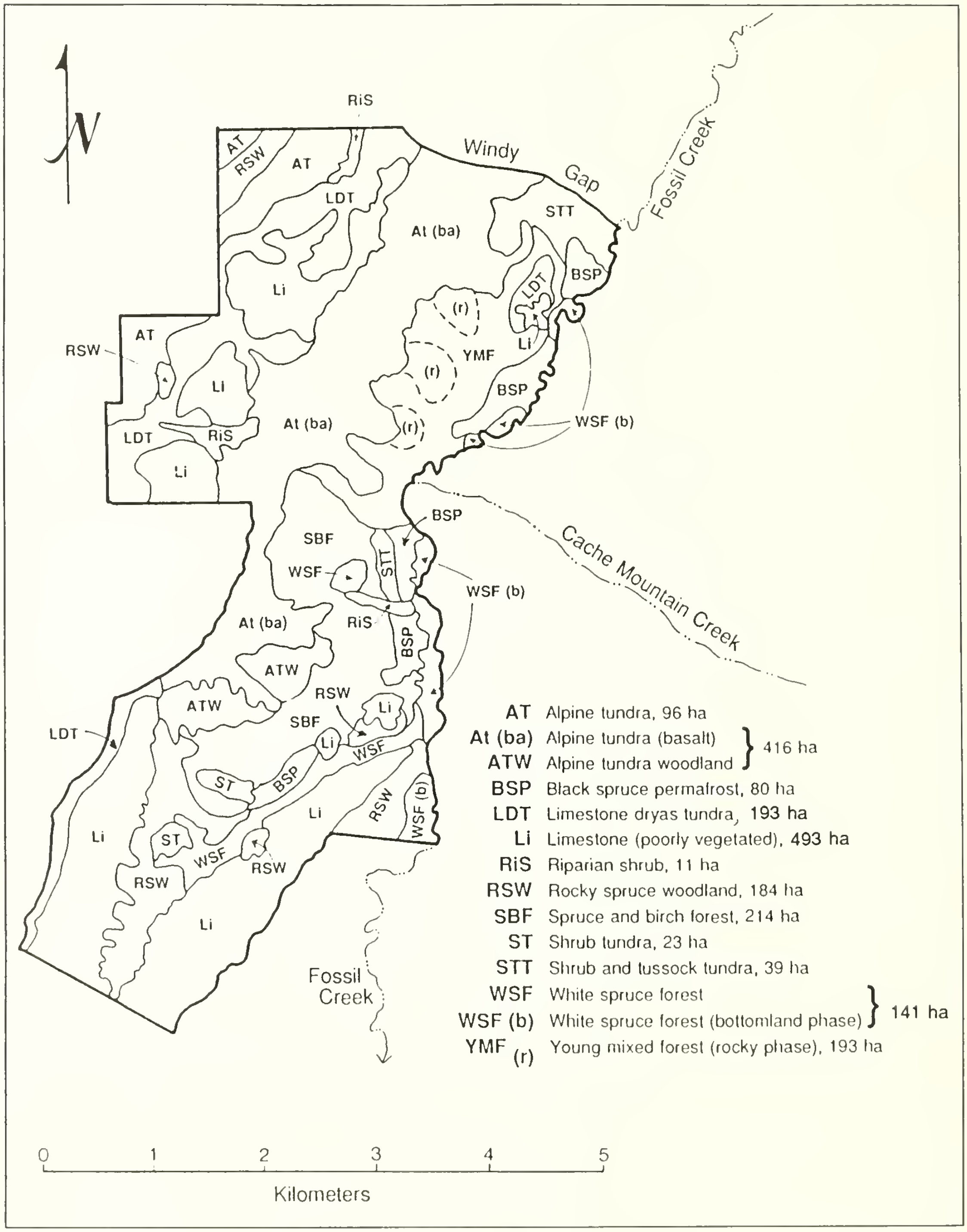

Figure 28—Vegetation cover types for Limestone Jags Research Natural Area; total area, 2083 ha.

Figure 29—Alpine tundra woodland on basalt slopes.

Table 5—Average canopy cover and constancy of plants on nearby level limestone and basalt summits in Limestone Jags Research Natural Area, June 1982[a]

Species	Limestone[b] Average cover	Limestone[b] Constancy	Basalt[c] Average cover	Basalt[c] Constancy
		Percent		
Vascular plants:				
Dryas octopetala	30.80 (± 22.1)	100	57.25 (± 19.6)	100
Carex scirpoidea	7.50 (± 7.6)	95		
Polygonum viviparum	1.70 (± 2.5)	90		
Thalictrum alpinum	1.40 (± 1.6)	80	.05 (± .2)	5
Tofieldia coccinea	1.40 (± 2.5)	55		
Eritrichium aretioides	1.25 (± 2.0)	45		
Pedicularis kanei	1.15 (± 2.0)	35	.25 (± 1.1)	5
Lloydia serotina	.60 (± .5)	60		
Astragalus umbellatus	.60 (± 1.9)	20		
Ranunculus hyperboreus	.50 (± .5)	50		
Anemone drummondii	.45 (± 1.1)	25		
Androsace chamaejasme	.40 (± .5)	40		
Silene acaulis	.35 (± 1.1)	15		
Anemone narcissiflora	.25 (± 1.1)	5	.35 (± .5)	35
Cassiope tetragona	.10 (± .3)	10		
Vaccinium uliginosum	.10 (± .3)	10		
Minuartia arctica	.05 (± .2)	5	.05 (± .2)	5
Vaccinium vitis-idaea	.05 (± .2)	5		
Saxifraga oppositifolia	.05 (± .2)	5		
Carex microchaeta			2.95 (± 2.7)	90
Lupinus arctica			2.55 (± 5.1)	50
Salix arctica			4.67 (± 5.4)	30
Arnica frigida			1.00 (± 1.8)	40
Synthyris borealis			.95 (± 1.5)	55
Festuca brachyphylla			.90 (± .3)	90
Artemisia arctica			.55 (± 2.2)	10
Antennaria friesiana			.40 (± 1.1)	20
Podistera macounii			.35 (± 1.1)	15
Castilleja caudata			.30 (± 1.1)	10
Stellaria laeta			.25 (± .4)	25
Solidago multiradiata			.25 (± .4)	25
Castilleja hyperborea			.25 (± 1.1)	5
Oxytropis scamaniana			.25 (± 1.1)	5
Salix phlebophylla			.25 (± 1.1)	5
Selaginella sibirica			.15 (± .4)	15
Saxifraga reflexa			.15 (± .4)	15
Hierochloe alpina			.10 (± .3)	10
Luzula tundricola			.10 (± .3)	10
Poa spp.			.10 (± .3)	10
Mosses	3.55 (± 4.9)	90	8.05 (± 5.6)	100
Lichens:[d]				
Cetraria nivalis (L.) Ach.	10.10 (± 6.7)	95	6.40 (± 9.6)	85
Thamnolia spp.	6.85 (± 6.1)	100	2.30 (± 3.3)	100
Alectoria ochroleuca (Hoffm.) Mass.	4.50 (± 4.7)	80	1.10 (± 2.4)	60
Cetraria laeviegata Rass.	3.60 (± 3.8)	85	4.95 (± 5.3)	70
Cetraria tilesii Ach.	1.90 (± 1.9)	90		
Asahinea spp.	1.50 (± 2.7)	45		
Dactylina arctica (Hook.) Nyl.	1.45 (± 1.8)	65	1.15 (± 2.6)	30
Lobaria linita (Ach.) Rabh.			13.10 (± 10.9)	95
Cetraria cuculata (Bell.) Ash			4.60 (± 4.3)	95
Stereocaulon spp.			4.51 (± 4.6)	75
Cornicularia divergens Ach.			1.80 (± 1.9)	80
Cetraria hepatizon (Ach.) Vain.			.55 (± 4.4)	15
Cladonia carneola (Fr.) Fr.			.50 (± .5)	50
Cladonia coxifera (L.) Willd.			.10 (± .3)	10

[a] Values calculated from 20 plots of 2 by 5 decimeters at 1-m spacing; values are average (plus or minus standard deviation).

[b] Limestone transect data taken June 24, 1982; average extent of bare rock 27.1 percent, 95-percent constancy.

[c] Basalt data taken June 26, 1982; average extent of bare rock 3.8 percent, 40-percent constancy.

[d] Nomenclature of lichens follows Hale (1969)

Figure 30—Beginning of limestone alpine tundra transect.

Table 6 presents ages of trees at various locations in the RNA. Trees in the north-east portion of the RNA around Windy Arch probably originated from a fire in 1953 or 1954. Table 7 gives stocking levels and average diameters of trees for regeneration in the burned area. Paper birch has generally overtopped white spruce and is more densely stocked in the burned area, but white spruce is well established and was already larger in diameter in 1982.

Trees as old as 235 years grow in the Fossil Creek bottomland (fig. 31). Dominant trees in the forest of Limestone Gulch are generally 100 to 200 years old. Juday and Taylor (1982) compared the structure of old-growth white spruce forests on the Fossil Creek bottomland (Fossil Creek plot) and the valley floor of Limestone Gulch (Bird Nest plot). Both plots were marked to allow relocation; maps of tree stems in the plots were produced as part of the RNA site documentation and are available from the Bureau of Land Management District Office in Fairbanks.

Table 6—Increment core data for trees at Limestone Jags Research Natural Area, June 1982

Sample location	Species	D.b.h.	Minimum age in 1982	Date of first measureable ring	Tree height
		cm	*years*	*date*	*m*
Burned area:					
Windy Arch, below burn	Alder	4.0	16	1966	3.3
Southwest corner of burn	White spruce	2.0	18	1964	2.4
Southwest corner of burn	White spruce	2.5	24	1958	4.6
Southwest corner of burn	White spruce	2.5	17	1965	4.6
Southwest corner of burn	White spruce	2.0	19	1963	3.7
Southwest corner of burn	White spruce	1.5	20	1962	6.1
Windy Arch, burn level	White spruce	2.5	27	1955	3.7
Windy Arch, below arch	White spruce	2.5	29	1953	3.7
Bottomland forest:					
Fossil Creek plot 1	White spruce	38.5	233	1749	
Fossil Creek plot 3	White spruce	35.0	154	1828	
Fossil Creek near plot	White spruce	18.0	236	1746	
Limestone Gulch:					
Bird Nest	White spruce	30.0	129	1853	
Bird Nest	White spruce	33.5	190	1792	
Bird Nest	White spruce	23.0	180	1802	
Below alpine plot	Black spruce	3.0	73	1909	5.5
Below alpine plot	Black spruce	5.0	113	1869	
Marmot hump	White spruce	32.0	120	1862	
Marmot hump upper extension	White spruce	6.5	50	1931	3.7
Disappearing stream	White spruce	[a]	211	1771	

[a] Accurate measurement of d.b.h. not possible.

Table 7—Structure of regenerating forest of burned area in northeast portion of Limestone Jags Research Natural Area, June 1982[a]

Species	Stocking density	Basal diameter (unweighted)
	Number per hectare	*Centimeters*
White spruce	1560 (±1890)	4.7 (±4.97)
Paper birch	9160 (±6771)	3.4 (±0.88)
Green alder	2920 (±3671)	3.9 (±1.05)

[a] Data from 10 plots of 1/400 hectare (5 by 5 m) each along a 50-meter transect. Values are means, plus or minus standard deviation.

Figure 31—Tall trees near the Fossil Creek forest plot.

The Bird Nest plot at Limestone Gulch supports less basal area and more white spruce trees of smaller diameter (table 8): the trees are shorter than trees in the Fossil Creek plot (fig. 32, A and B; table 9). Table 9 demonstrates that white spruce in the Fossil Creek plot are generally taller than those at Bird Nest, although the height-diameter ratios are similar. White spruce trees at Fossil Creek compete strongly for canopy light. Apparently, the white spruce canopy on limestone sites does not fully close, even at maturity (fig. 33). The diameter distribution of white spruce in the two plots is shown in figure 34.

Diameters of spruce in both stands appear to be normally distributed, but the richer, deeper soils of the Fossil Creek bottomland are more productive and support larger trees. The Bird Nest site does not appear to be susceptible to permafrost formation as is the site at Fossil Creek. Soils derived from limestone at Bird Nest remain well drained and generally free of thick insulating layers of moss, even under an old-growth canopy.

Table 8—Structural attributes of old-growth forest reference plots in Limestone Jags Research Natural Area, July 1982

Plot name and species[a]	Total trees	Mean d.b.h.[b]	Total basal area	
			Live trees	Dead trees
	Number	*Centimeters*	*Square meters per hectare*	
Bird Nest:				
White spruce	67	18.1± 7.9	33.0	6.6
Alder	44	3.4± 1.1	.7	—
Fossil Creek:				
White spruce	40	27.6± 9.0	42.3	7.1
Balsam poplar	1	24.0	.7	0

[a] Each plot is 25 by 25 meters (1/16 hectare).

[b] Plus or minus standard deviation.

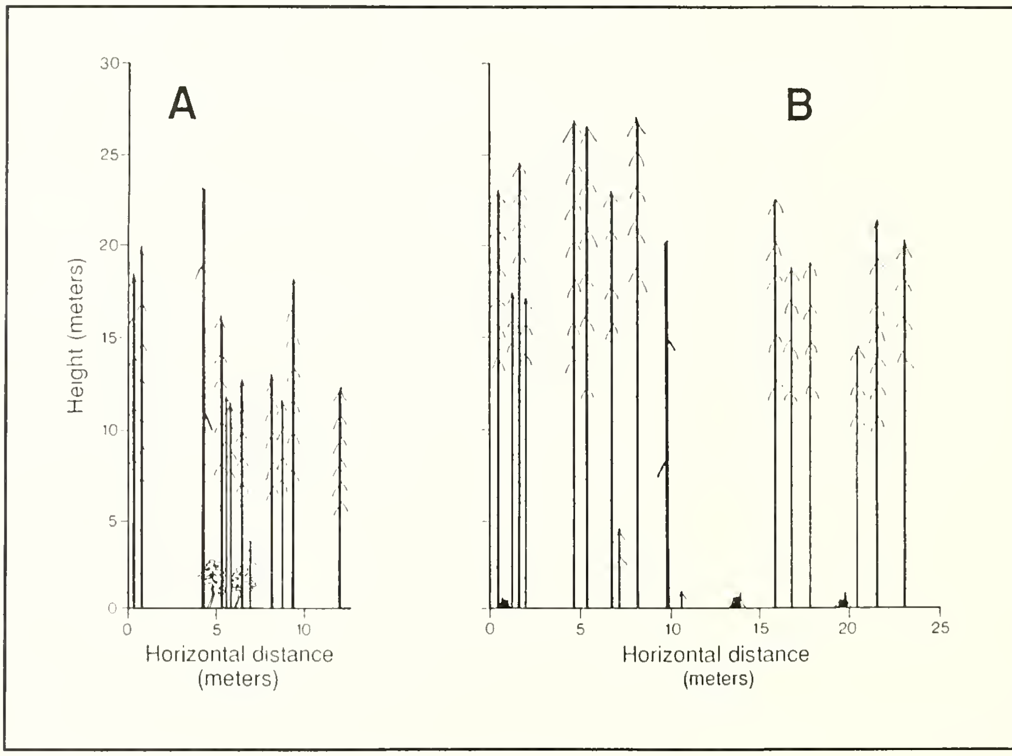

Figure 32—Height profile (height and canopy shape of all trees in a strip 10 m wide and 25 m long): **(A)** Bird Nest forest plot; **(B)** Fossil Creek forest plot.

Table 9—Relation of height to diameter, old-growth white spruce at Bird Nest and Fossil Creek forest plots, Limestone Jags Research Natural Area, July 1982

Plot name	D.b.h.	Height	Age	Height-d.b.h. ratio[a]
	Centimeters	*Meters*	*Years*	
Bird Nest	33.5	18.35	163	0.55
	30.5	19.96		.65
	30.0	16.03	146	.53
	16.5	11.61		.70
	15.5	11.49		.74
	17.5	13.02		.74
	13.5	11.60		.86
	17.0	12.91		.76
	4.5	3.5		.78
	16.5	12.36		.75
	25.0	18.00	165	.72
Mean		13.53		.71
Standard deviation		4.53		.10
Fossil Creek	26.5	22.95		.87
	29.5	17.51		.59
	18.0	17.23		.96
	25.0	24.51		.98
	37.5	27.04		.72
	38.5	26.60	231	.69
	4.5	5.50		1.22
	37.0	22.95		.62
	38.5	27.04	210+	.70
	29.0	22.58		.78
	22.0	18.78		.85
	30.0	19.11		.64
	17.5	14.59		.83
	38.0	21.13		.56
	29.0	20.25		.70
Mean		20.52		.78
Standard deviation		5.61		.18

[a] Height-d.b.h. calculated as meters per centimeter.

Figure 33—View up through open canopy at Bird Nest forest plot, June 1982.

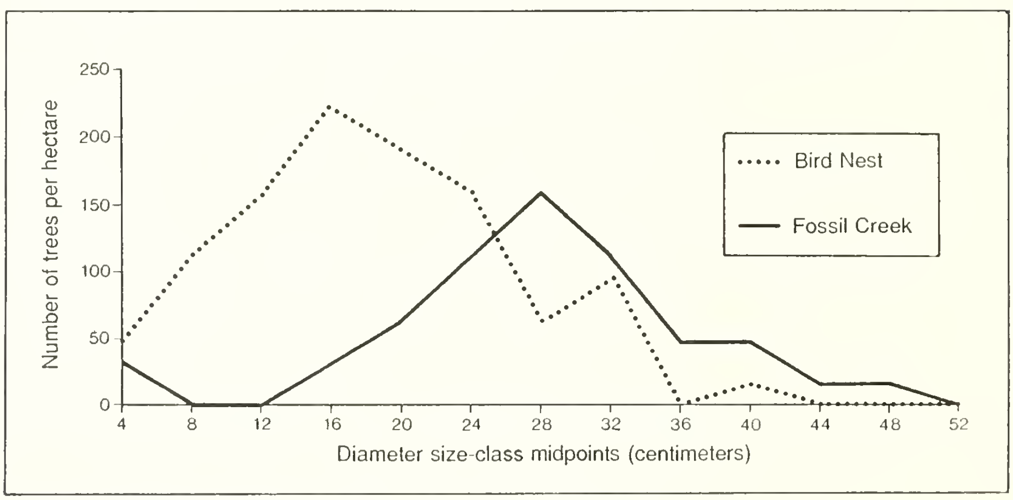

Figure 34—Diameter size-class distribution for white spruce on Bird Nest and Fossil Creek forest plots.

Fauna

Distribution records and maps indicate that 203 birds and 45 mammals may be found in the White Mountains (Armstrong 1983, Gabrielson and Lincoln 1959, Hall 1981). In the short time the Limestone Jags RNA was explored, however, only a few of the total possible species were observed.

Birds—Table 10 is a checklist of birds for Limestone Jags RNA. The abundance and diversity of birds, especially passerines (songbirds), is low on Fossil Creek Ridge. A transect covering about 5 ha (1100 m long by 45 m wide) of white spruce forest on limestone at the Bird Nest plot, observed from 10:00 a.m. to noon in late June 1982, resulted in no bird sightings. A principal cause is the lack of surface water on excessively well-drained limestone. Aquatic birds are restricted to Beaver Creek and to permanent pools provided by beaver dams along Fossil Creek. The common goldeneye was the only aquatic species observed, but a systematic search for aquatic birds was not made.

The Townsend's solitaire, a songbird uncommon in Alaska (Armstrong 1983, U.S. Department of Agriculture 1979), was sighted in the RNA on the narrow ridge north of the limestone alpine transect. Townsend's solitaires usually nest above timberline, often choosing crevices in overhangs (Gabrielson and Lincoln 1959). Limestone portions of the RNA contain abundant nesting sites such as overhangs and isolated pinnacles with fissures and crevices. Townsend's solitares are insectivorous (Gabrielson and Lincoln 1959); when they were seen in the RNA, they were feeding in flight on insects caught in an eddy of air on the lee of the narrow limestone ridge above Limestone Gulch. Violet-green swallows were also seen feeding on the same group of insects. Water pipits were seen in nearby alpine tundra.

Swainson's thrush, slate-colored junco, and ruby-crowned kinglet were observed in vegetation along creeks and streams in the northern portion of the RNA. The gray jay, Wilson's warbler, ruby-crowned kinglet, an unidentified woodpecker sign (probably hairy woodpecker), and droppings of grouse/ptarmigan were seen in white spruce forests. Although signs of ptarmigan or other grouse were observed frequently, the birds were not seen. Robins, ravens, and dark-eyed juncos were seen in forest edge habitat. White-crowned sparrows, gray jays, and grouse or ptarmigan droppings were observed in the burned area of shrub/young forest. A northern shrike was seen in the burned area near Windy Arch. Two peregrine falcons were observed on two occasions, and a golden eagle was observed once. At least two raptor nests are in the RNA, and two others are reported close by (Bureau of Land Management 1984).

Table 10—Checklist of birds known to occur or that may occur in the Limestone Jags Research Natural Area[a]

Order and common name	Scientific name	Comments
Anseriformes:		
Common goldeneye	*Bucephala clangula*	On beaverpond, Fossil Creek
Mallard	*Anas platyrhynchos*	Probable migrant, Fossil Creek
Green-winged teal	*Anas crecca*	Probable migrant, Fossil Creek
Greater scaup	*Aythya marila*	Probable migrant, Fossil Creek
Lesser scaup	*Aythya affinis*	Probable migrant, Fossil Creek
Falconiformes:		
Red-tailed hawk	*Buteo jamaicensis*	
Rough-legged hawk	*Buteo lagopus*	
Golden eagle	*Aquila chrysaetos*	Seen in RNA
Marsh hawk	*Circus cyaneus*	
Gyrfalcon	*Falco rusticolus*	
Peregrine falcon	*Falco peregrinus anatum*	Nest in RNA
Galliformes:		
Spruce grouse	*Canachites canadensis*	Heard in RNA
Willow ptarmigan	*Lagopus lagopus*	
Rock ptarmigan	*Lagopus mutus*	Tracks noted
Charadriiformes:		
Semipalmated plover	*Charadrius semipalmatus*	
American golden plover	*Pluvialis dominica*	
Spotted sandpiper	*Actitis macularia*	Probable along streams
Northern phalarope	*Lobipes lobatus*	Seen in vicinity
Long-billed dowitcher	*Limnodromus scolopaceus*	
Semipalmated sandpiper	*Calidris pusilla*	
Least sandpiper	*Calidris minutilla*	
Pectoral sandpiper	*Calidris melanotos*	
Long-tailed jaeger	*Stercorarius longicaudus*	
Mew gull	*Larus canus*	Probable migrant, low elevation
Strigiformes:		
Great horned owl	*Bubo virginianus*	
Short-eared owl	*Asio flammeus*	
Boreal owl	*Aegolius funereus*	
Piciformes:		
Hairy woodpecker	*Picoides villosus*	Foraging sign noted
Downy woodpecker	*Picoides pubescens*	Foraging sign noted
Passeriformes:		
Alder flycatcher	*Empidonax alnorum*	
Violet-green swallow	*Tachycineta thalassina*	Seen feeding in RNA
Cliff swallow	*Petrochelidon pyrrhonota*	
Gray jay	*Perisoreus canadensis*	Seen in postburn forest
Common raven	*Corvus corax*	Seen in RNA
Black-capped chickadee	*Parus atricapillus*	
Boreal chickadee	*Parus hudsonicus*	Probable in spruce forest
Dipper	*Cinclus mexicanus*	
American robin	*Turdus migratorius*	Seen in RNA

See footnote at end of table.

Table 10—Checklist of birds known to occur or that may occur in the Limestone Jags Research Natural Area[a] (continued)

Order and common name	Scientific name	Comments
Varied thrush	*Ixoreus naevius*	Probable in spruce forest
Hermit thrush	*Catharus guttatus*	
Swainson's thrush	*Catharus ustulatus*	Seen in riparian shrubs
Gray-cheeked thrush	*Catharus minimus*	
Mountain bluebird	*Sialia currucoides*	
Townsend's solitaire	*Myadestes townsendi*	Seen in limestone tundra
Arctic warbler	*Phylloscopus borealis*	
Ruby-crowned kinglet	*Regulus calendula*	Seen in spruce forest
Water pipit	*Anthus spinoletta*	Seen in limestone tundra
Bohemian waxwing	*Bombycilla garrulus*	
Northern shrike	*Lanius excubitor*	In postburn young forest
Orange-crowned warbler	*Vermivora celata*	
Yellow warbler	*Dendroica petechia*	
Wilson's warbler	*Wilsonia pusilla*	Seen in white spruce forest
Gray-crowned rosy finch	*Leucosticte tephrocotis*	
Hoary redpoll	*Carduelis hornemanni*	
Common redpoll	*Carduelis flammea*	
Savannah sparrow	*Passerculus sandwichensis*	
Dark-eyed junco	*Junco hyemalis*	Seen in riparian shrub
Tree sparrow	*Spizella arborea*	
Chipping sparrow	*Spizella passerina*	
White-crowned sparrow	*Zonotrichia leucophrys*	Seen in riparian shrub
Golden-crowned sparrow	*Zonotrichia atricapilla*	
Fox sparrow	*Passerella iliaca*	
Lapland longspur	*Calcarius lapponicus*	
Snow bunting	*Plectrophenax nivalis*	

[a] Nomenclature follows U.S. Department of Agriculture, Forest Service (1979), and American Ornithologists' Union (1957).

Mammals—Table 11 is a list of mammals for Limestone Jags RNA. Limestone Jags RNA was selected, in part, to include Dall sheep that are isolated on "islands" of alpine habitat along the western edge of the Yukon-Tanana upland (table 1). In April 1983, the Bureau of Land Management began a study of Dall sheep in the White Mountains National Recreation Area in cooperation with the Alaska Department of Fish and Game. The estimated population of Dall sheep in the entire White Mountain region was about 140 animals in the mid-1980's, only half the number maintained in the 1970's (Bureau of Land Management 1984). Six Dall sheep were seen in the RNA during site documentation.

Table 11—Checklist of mammals known to occur or that may occur in the Limestone Jags Research Natural Area[a]

Order and common name	Scientific name	Comments
Insectivora:		
Masked shrew	*Sorex cinereus*	
Dusky shrew	*Sorex obscurus*	
Arctic shrew	*Sorex arcticus*	
Pygmy shrew	*Microsorex hoyi*	
Chiroptera:		
Little brown myotis	*Myotis lucifugus*	Possible in forest
Lagomorpha:		
Collared pika	*Ochotona collaris*	Near western margin of range
Snowshoe hare	*Lepus americanus*	Browsing sign noted
Rodentia:		
Hoary marmot	*Marmota caligata*	Seen in Limestone Gulch[b]
Arctic ground squirrel	*Spermophilus parryii*	
Red squirrel	*Tamiasciurus hudsonicus*	Seen in RNA
Beaver	*Castor canadensis*	Dams present in RNA
Northern red-backed vole	*Clethrionomys rutilus*	Trapped in area[c]
Tundra vole	*Microtus oeconomus*	Trapped in area[c]
Singing vole	*Microtus miurus*	
Muskrat	*Ondatra zibethicus*	
Brown lemming	*Lemmus sibiricus*	
Porcupine	*Erethizon dorsatum*	Possible in forest
Carnivora:		
Coyote	*Canis latrans*	
Gray wolf	*Canis lupus*	Seen near RNA, tracks in RNA
Red fox	*Vulpes vulpes*	
Black bear	*Ursus americanus*	
Grizzly bear	*Ursus arctos*	Seen near RNA, tracks in RNA
Marten	*Martes americana*	
Ermine	*Mustela erminea*	Seen in area[c]
Least weasel	*Mustela nivalis*	
Mink	*Mustela vison*	
Wolverine	*Gulo gulo*	Seen in area[c]
River otter	*Lutra canadensis*	
Lynx	*Felis lynx*	
Artiodactyla:		
Moose	*Alces alces*	Seen in RNA
Caribou	*Rangifer tarandus*	Seen in RNA
Dall sheep	*Ovis dalli*	Seen in RNA

[a] Nomenclature follows U.S. Department of Agriculture, Forest Service (1979).

[b] May be related to Alaska marmot (*Marmota broweri*).

[c] Guthrie (1988).

Dall sheep trails are carved into the high alpine ridges of Limestone Jags RNA, part of a network of trails that connect isolated patches of alpine tundra throughout the White Mountains (Bureau of Land Management 1984). Dall sheep habitat in the White Mountains is less favorable than typical Alaska Range or Brooks Range habitat; the limited habitat is probably responsible for the small horns seen in Dall sheep on Fossil Creek Ridge (Guthrie 1988). In the White Mountains, Dall sheep must travel across extensive lowland forests to journey between the isolated areas of alpine tundra. In lowlands, Dall sheep are subject to more effective predation than in alpine tundra because escape terrain (cliff habitat) is lacking (Nichols 1978a, 1978b). Escape terrain is absent over most of the subdued uplands of the White Mountains, so cliffs and pinnacles in Limestone Jags RNA are especially important for the Dall sheep of the western Yukon-Tanana uplands.

Caribou were observed in high alpine ridge habitat of the RNA. Limestone Jags RNA is within the range of the White Mountains resident caribou herd. Williams and Heard (1986) estimate that the population of the White Mountains herd was 800 caribou in 1983. From 1900 to 1950, the Limestone Jags RNA was part of the traditional calving ground of the large migratory Steese-Fortymile caribou herd (Valkenburg and Davis 1986). The Fossil Creek Ridge area has not been used as a calving ground since the early 1960's when the Steese-Fortymile herd declined from its 1920 peak of more than 580,000 animals to about 50,000 animals (Valkenburg and Davis 1986). Limestone Jags RNA is at the western edge of the traditional calving ground and was used mainly during high population stages of the Steese-Fortymile herd.

The hoary marmot, another species on the RNA type-need list (table 1), was found in Limestone Gulch. In the early stages of selecting RNA's in the White Mountains National Recreation Area, the Alaska marmot (*Marmota broweri* Hall and Gilmore) was the type-need species (Juday and others 1982). At the time, which marmot species inhabited the White Mountains was not known. Marmots that occur south of the Brooks Range are now generally regarded as hoary marmots. Hoary marmots make burrows in overhanging ledges or the spaces between large rock rubble (Curby 1982). Extensive talus on the south-facing slopes of Limestone Gulch provide excellent habitat for marmots (fig. 35). Limestone Jags RNA is at the western edge of the range of the collared pika, another small mammal grazer that inhabits burrows in talus piles (Mac Donald and Jones 1987).

Moose are the most commonly encountered large mammal in Limestone Jags RNA in the summer. They range from creek bottoms (fig. 36), where willows are heavily browsed (especially along Fossil Creek), to mountain tops, where moose droppings are common. There are several moose trails through the forest understory along Fossil Creek.

Bear scat was common along riparian areas, but scat and tracks were observed in spruce forest and on top of alpine ridges. Evidence of grizzly bear feeding, partially excavated willow rhizomes (underground stems), was observed. Cache Mountain just east of the RNA (fig. 6) is used intensively by grizzly bears for dens and spring feeding (Bureau of Land Management 1984).

Figure 35—Marmot escape terrain in large blocky talus near the bottom of Limestone Gulch. Just before this picture was taken, a Hoary marmot took refuge in the large hole in the center.

Figure 36—Moose antler on Fossil Creek bottomland. Note gnaw marks made by small mammals that consume antlers for calcium.

Beaver have constructed dams that impound Fossil Creek near the mouth of Limestone Gulch. Wolf scat was observed on alpine ridges, and wolves probably range throughout the area. Red squirrels were seen in white spruce forest of the RNA. The snowshoe hares in the RNA were seldom observed.

Fish—Arctic grayling were observed in Fossil Creek. Fossil Creek has not been inventoried for fish by the Bureau of Land Management because of the nature of the stream; during moderate or low water stages, Fossil Creek flows underground, thereby barring fish passage. The disappearing river surface is due to karst features, not to drought.

History of Disturbance

Mineral Potential

No known valid mineral claims are within Limestone Jags RNA. The national recreation area designation under ANILCA precludes further mineral claims. Mineral leasing is an option in the management of White Mountains National Recreation Area, although significant scientific, ecological, and recreational resources must still be protected. The White Mountains National Recreation Area resource management plan closes the primitive recreation management zone surrounding the RNA to mineral development for the life of the plan.

Samples of Tolovana Limestone collected during a mineral assessment of the WMNRA were exceptionally pure. McCammon and others (1988) estimate that 27 billion tons of high-calcium limestone may be present in the WMNRA. Lime for industrial use is generally available closer to population centers or other potential sources of demand in Alaska. Pure calcium carbonate of the Tolovana Limestone and basalt and sedimentary rocks of the Fossil Creek Volcanics are not promising hardrock mineral prospects. Placer gold, however, has been found in the upper Beaver Creek region since at least the early 1900's. Most of the gold produced and currently being mined in the Fairbanks Mining District comes from the Cleary sequence south of the RNA (Light and others 1987). Light and others (1987) believe that "hydrothermal mineralization associated with the intrusion of the Cache Mountain pluton is likely to be the source of the gold in O'Brien Creek." The summit of Cache Mountain is about 7 km east of the RNA, and O'Brien Creek is another 12 km east of the summit. The presence of gold on the eastern contact of the pluton suggests a low probability that a mineralized zone occurs along the western contact of the pluton at Fossil Creek, which is the eastern border of the RNA.

Research

Research opportunities at Limestone Jags RNA are particularly diverse. The area offers opportunities for studying botany, geology, wildlife, ecology, and climate. The RNA is an outstanding educational and interpretive resource, illustrating the results of landscape-forming processes and their effects on plants and animals.

Very few high-latitude karst landscapes have escaped destruction by glaciation. The few that have offer a special opportunity for comparing the development of karst features and rates of solution with better known midlatitude and tropical karst regions. The diverse limestone surfaces of the RNA (natural bridges, cliffs, benches, overhangs, and caves) offer the opportunity for studying differential rates of soil weathering and limestone dissolution.

The forest and alpine permanent plots established during the documentation of the RNA will be valuable for followup studies of vegetation changes in the area. As populations of Dall sheep and caribou vary over time, vegetation responses can be measured. Updating the bottomland old-growth forest plot at Fossil Creek on a 5- or 10-year basis should show changes in stream influences on the plot, tree growth, and mortality. Remeasurement of the plots in the burned area should reveal the regional pattern of early forest growth and new stand establishment.

A more complete search for caves is needed; the two known caves in the RNA need further exploration and measurement. Test excavations in the floor and debris cone at the entrance of Icedam Cave showed bones and other material of paleontological value (Guthrie 1988).

Continued work on the dynamics of the Dall sheep population should be integrated with habitat studies in the RNA and nearby areas.

Direct measurements of temperature, wind, precipitation, and snow depth are needed in different microclimate regions throughout the year. These data would be particularly useful for studies on ecology, limestone weathering, and hydrology.

The species in lush algal communities of mineral-rich cold springs in the RNA have not been identified.

Maps and Aerial Photographs

Limestone Jags is found on the Livengood C-1 and C-2 USGS topographic quadrangle maps (1:63,360 scale, 1951 base with 1969 revisions). Chapman and others (1971) produced a preliminary geologic map of the area that includes Limestone Jags at 1:250,000 scale. The most recent controlled vertical air photo coverage of the area (project 02655 ALK 60) is 1978 color infrared photography at a contact scale of about 1:63,000. Airphoto frames 5730 and 5731 provide stereo coverage of the northern half of the RNA; frames 5681, 5682, and 5683 provide stereo coverage of the southern half. The 1951 black and white aerial photographs (about 1:30,000 scale) that were used to prepare the topographic map base are available from U.S. Government archival sources. Color and black and white oblique air photos of the RNA taken in June 1982, April 1984, March 1986, March 1987, and June 1987 are available in the archive file on Limestone Jags at the University of Alaska Fairbanks. The Steese-White Mountain District Office of the Bureau of Land Management in Fairbanks can provide up-to-date information on maps and aerial photos of the area.

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Metric and English Units of Measure

When you know:	Multiply by:	To find:
Celsius (^oC)	1.8 (then add 32)	Fahrenheit (^oF)
Centimeters (cm)	2.54	Inches
Grams (g)	0.03527	Ounces
Hectares (ha)	2.47	Acres
Kilometers (km)	0.621	Miles
Meters (m)	3.281	Feet
Millimeters (mm)	0.254	Inches

References

American Ornithologists' Union. 1957. Check-list of North American birds. 5th ed. Baltimore, MD: The Lord Baltimore Press. 691 p.

Armstrong, R.H. 1983. A new, expanded guide to the birds of Alaska. Anchorage, AK: Alaska Northwest Publishing Company. 332 p.

Blodgett, Robert B.; Wheeler, Karen L.; Rohr, David M.; Harris, Anita G.; Weber, Florence R. 1987. A late Ordovician age reappraisal for the upper Fossil Creek Volcanics, and possible significance for glacial eustasy. In: Geologic studies in Alaska by the U.S. Geological Survey during 1986. Circ. 998. Washington, DC: U.S. Geological Survey: 54-58.

Brook, G.A.; Ford, D.C. 1978. The origin of labyrinth and tower karst and the climatic conditions necessary for their development. Nature. 275: 493-496.

Bureau of Land Management. 1984. Proposed resource management plan/final environmental impact statement for the White Mountains National Recreation Area. Fairbanks, AK: U.S. Department of the Interior, Bureau of Land Management. 317 p.

Chapman, R.M.; Weber, F.R.; Taber, B. 1971. Preliminary geologic map of the Livengood Quadrangle, Alaska. U.S. Geological Survey. Open File Map 71-66 (2 sheets).

Church, R.E.; Durfee, M.C. 1961. Geology of the Fossil Creek Area—White Mountains, Alaska. Fairbanks, AK: University of Alaska Fairbanks. 96 p. M.S. thesis.

Churkin, M., Jr.; Foster, H.L.; Chapman, R.M.; Weber, F.R. 1982. Terranes and suture zones in east central Alaska. Journal of Geophysical Research. 78: 3718-3730.

Corbel, J. 1959. Érosion en terrain calcaire. Annales de Géographie. 68: 97-120.

Curby, Catherine. 1982. The marmot in Alaska. Alaska Dep. Fish and Game Wildl. Noteb. Ser. Juneau, AK: Alaska Department of Fish and Game. 2 p.

Ford, T.D.; Cullingford, C.H.D. 1976. The science of speleology. London: Academic Press. 593 p.

Gabrielson, Ira N.; Lincoln, F.C. 1959. Birds of Alaska. Washington, DC: Wildlife Management Institute; Harrisburg, PA: Stackpole Company. 920 p.

Gjaerevoll, Olav. 1958. Botanical investigations in central Alaska, especially in the White Mountains. Part I: Pteridophytes and monocotyledones. NR 5. Trondheim, Norway: Det KGL Norske Videnskabers Selskabs Skrifter. 74 p.

Gjaerevoll, Olav. 1963. Botanical investigations in central Alaska, especially in the White Mountains. Part II: Dicotyledones. Salicaceae—Umbelliferae. NR 4. Trondheim, Norway: Det KGL Norske Videnskabers Selskabs Skrifter. 115 p.

Gjaerevoll, Olav. 1967. Botanical investigations in central Alaska, especially in the White Mountains. Part III: Sympetalae. NR 10. Trondheim, Norway: Det KGL Norske Videnskabers Selskabs Skrifter. 63 p.

Guthrie, Dale. 1988. Personal correspondence. Fairbanks, AK: University of Alaska.

Hale, Mason E. 1969. How to know the lichens. Dubuque, IA: Wm. C. Brown Company Publishers. 226 p.

Hall, E. Raymond. 1981. The mammals of North America. 2d ed. New York: John Wiley and Sons. 1181 p.

Haugen, R.K.; Slaughter, C.W.; Howe, K.E.; Dingman, S.L. 1982. Hydrology and climatology of the Caribou-Poker Creeks Research watershed. CRREL 82-26. Hanover, NH: U.S. Army Cold Regions Research and Engineering Laboratory. 42 p.

Hudson, Travis L. 1987. Suspect philosophy? Geology. 15: 1177.

Hultén, E. 1968. Flora of Alaska and neighboring territories—a manual of the vascular plants. Stanford, CA: Stanford University Press. 1008 p.

Jennings, J.N. 1983. Karst landforms. American Scientist. 71(6): 578-586.

Juday, Glenn Patrick. 1983a. Alaska's ecological reserves program: approaches, successes, and problems. In: Transactions of the 48th North American wildlife and natural resources conference; 1983 March 17-21; Kansas City, MO. Washington, DC: Wildlife Management Institute: 531-540.

Juday, Glenn Patrick. 1983b. Limestone landscapes of the White Mountains. Agroborealis. 15: 24-28.

Juday, Glenn Patrick. 1987. Selecting natural areas for geologic features: a rationale and examples from Alaska. Natural Areas Journal. 7(4): 137-156.

Juday, Glenn Patrick; Knapman, Larry; Field, Larry; Taylor, Dale. 1982. A preliminary report of ecological reserve project activity, Fairbanks District BLM—identification of type needs and candidate Research Natural Areas in the White Mountains NRA and Steese NCA. Unpublished report on file with Steese-White Mountains District, BLM. Fairbanks, AK: U.S. Department of the Interior, Bureau of Land Management.

Juday, Glenn Patrick; Taylor, Dale F. 1982. The contrast in structure between an upland and a bottomland white spruce (*Picea glauca* (Moench) Voss) forest in the White Mountains of interior Alaska. In: Proceedings, 33d Alaska science conference; 1982 September 16-18; Fairbanks, AK. Fairbanks, AK: American Association for the Advancement of Science, Arctic Division: 165. Abstract.

Light, Thomas D.; Cady, John W.; Weber, Florence R.; McCammon, Richard B.; Rinehart, C. Dean. 1987. Sources of placer gold in the southern part of the White Mountains Recreation Area, east-central Alaska. In: Geologic studies in Alaska by the U.S. Geological Survey during 1986. Circ. 998. Washington, DC: U.S. Geological Survey: 67-69.

Mac Donald, Stephen O.; Jones, Clyde. 1987. *Octotona collaris*. In: Mammalian species. American Society of Mammalogists. 281: 1-4.

McCammon, Richard B.; Light, Thomas D.; Rinehart, C. Dean. 1988. Mineral resource assessment for part of the White Mountains National Recreation Area. In: Geologic studies in Alaska by the U.S. Geological Survey during 1987. Circ. 1016. Washington, DC: U.S. Geological Survey: 71-74.

Mertie, J.B., Jr. 1917. The gold placers of the Tolovana district, Alaska. In: Mineral resources of Alaska, report on progress of investigations in 1916. U.S. Geol. Surv. Bull. 662-D. Washington, DC: U.S. Geological Survey: 221-277.

Mertie, J.B., Jr. 1937. The Yukon-Tanana region, Alaska. U.S. Geol. Surv. Bull. 872. Washington, DC: U.S. Geological Survey. 276 p.

Murray, B.M. [In press]. Systematics of the Andreaeopsida (Bryophyta): two orders with links to *Takakia*. Nova Hedwigia Beih.

Nichols, Lyman, Jr. 1978a. The Dall sheep in Alaska. Alaska Dep. Fish and Game Wildl. Noteb. Ser. Juneau, AK: Alaska Department of Fish and Game. 2 p.

Nichols, Lyman, Jr. 1978b. Dall's sheep. In: Schmidt, J.L.; Gilbert, D.L., comps., eds. Big game of North America—ecology and management, Wildlife Management Institute. Harrisburg, PA: Stackpole Books: 173-189.

Persson, Herman; Gjaerevoll, Olav. 1957. Bryophytes from the interior of Alaska. NR 5. Trondheim, Norway: Det KGL Norske Videnskabers Selskabs Skrifter. 74 p.

Porsild, A.E. 1974. Materials for a flora of central Yukon Territory. National Museums of Canada. Publications in Botany. 4. 77 p.

Prindle, Louis M. 1913. A geologic reconnaissance of the Fairbanks quadrangle, Alaska. U.S. Geol. Surv. Bull. 525. Washington, DC: U.S. Geological Survey. 220 p.

Santeford, Henry S. 1976. A preliminary analysis of precipitation in the Chena Basin, Alaska. Tech. Memo. NWS AR-15. Anchorage, AK: National Oceanic and Atmospheric Administration. 12 p.

Skarland, Ivar; Libby, Wilbur L. 1955. Anthropological reconnaissance trip to investigate caves in the White Mountains, Alaska, in the vicinity of Fossil Creek (147°30′W, 65°30′N), a tributary to Beaver Creek. Trip report and captioned photographs on file, Skarland Collection. Fairbanks, AK: University of Alaska Fairbanks, Rassmussen Library Archives.

Steere, W.C.; Murray, B.M. 1976. *Andreaeobryum macrosporum*, a new genus and species of Musci from northern Alaska and Canada. Phytologia. 33: 407-410.

Strahler, A.H. 1981. Physical geology. New York: Harper and Row. 612 p.

Underwood, Larry S.; Juday, Glenn Patrick. 1979. An ecological reserves report. Volume I: Establishing a system for Alaska. Comm. Rep. 38. Anchorage, AK: Federal-State Land Use Planning Commission for Alaska. 36 p.

U.S. Department of Agriculture, Forest Service. 1979. Species list of Alaska birds, mammals, fish, amphibians, reptiles, and invertebrates. Rep. 82. Juneau, AK: U.S. Department of Agriculture, Forest Service, Alaska Region. 102 p.

Valkenburg, Patrick; Davis, James L. 1986. Calving distribution of Alaska's Steese-Fortymile caribou herd: a case of infidelity? In: Gunn, Anne; Miller, Frank L.; Skjenneberg, Sven, eds. Proceedings, 4th international reindeer/caribou symposium; 1985 August 22-25; Whitehorse, YT. Spec. Issue 1. Rangifer. Harstad, Norway: Nordic Council for Reindeer Research (NOR): 315-323.

Viereck, L.A.; Dyrness, C.T.; Batten, A.R. 1986. The 1986 revision of the Alaska vegetation classification. Unpublished manuscript. Fairbanks, AK: U.S. Department of Agriculture, Forest Service, Institute of Northern Forestry. 112 p.

Viereck, Leslie A.; Little, Elbert L., Jr. 1972. Alaska trees and shrubs. Agric. Handb. 410. Washington, DC: U.S. Department of Agriculture. 265 p.

Weber, Florence. 1988. Personal communication. Fairbanks, AK: U.S. Geological Survey.

Wheeler, Karen L.; Forbes, Robert B.; Weber, Florence R.; Rinehart, C. Dean. 1987. Lithostratigraphy, petrology, and geochemistry of the Ordovician Fossil Creek Volcanics, White Mountains, east-central Alaska. In: Geologic studies in Alaska by the U.S. Geological Survey during 1986. Circ. 998. Washington, DC: U.S. Geological Survey: 70-73.

Williams, T. Mark; Heard, Douglas C. 1986. World status of wild *Rangifer tarandus* populations. In: Gunn, Anne; Miller, Frank L.; Skjenneberg, Sven, eds. Proceedings, 4th international reindeer/caribou symposium; 1985 August 22-25; Whitehorse, YT. Spec. Issue 1. Rangifer. Harstad, Norway: Nordic Council for Reindeer Research (NOR): 19-28.

Young, Steven B.; Walters, J.C. 1982. Proposed geological and ecological natural landmarks in interior and western Alaska. Volume 2: Contributions from the Center for Northern Studies 21. Wolcott, VT: Center for Northern Studies. 504 p.

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The 2083-hectare Limestone Jags Research Natural Area in the White Mountains National Recreation Area of central Alaska contains old limestone terrain features—caves, natural bridges, disappearing streams, and cold springs in a subarctic setting. A limestone dissolution joint-type cave in the area is one of the largest reported in high-latitude North America. A Silurian limestone and an Ordovician volcanic and sedimentary sequence are in disconformable contact in the Research Natural Area (RNA); the limited stratigraphic break between the two units is evidence of a major drop in sea level caused by ancient glaciation. The tilted and faulted rocks within and near the RNA have been interpreted to illustrate the process by which Alaska was accreted to the geologic core of North America. A wind gap in the area marks a former stream channel through the White Mountains that was stranded after Fossil Creek captured the drainage through headward erosion. Groundwater released during the winter into Fossil Creek freezes into thick accumulations of aufeis.

Limestone Jags RNA contains a rich diversity of habitats for vascular plants; the 303 species collected in the area represent nearly one-fourth of the flora of Alaska. Open, rocky limestone habitats support several plant species disjunct from the Rocky Mountains. A collection of the plant *Draba fladnizensis* in the RNA represents a marginal range extension from its previously known Alaska distribution. The only collection of the arctic moss *Andreaeobryum macrosporum* Steere & B. Murray south of the Brooks Range in Alaska is from the RNA. Alpine plant communities on basaltic rock in the RNA are especially lush and rich in lichens. An unusual form of open-canopied white spruce parkland occurs on dry limestone uplands. A closed-canopy, old-growth white spruce forest occupies productive bottomland sites of Fossil Creek. South-facing basalt slopes support a young paper birch and white spruce mixed forest that originated after a wildfire in the 1950's.

The RNA includes important alpine habitat of the resident White Mountain caribou herd; it was part of the traditional calving area of the migratory Steese-Fortymile caribou herd until the early 1960's. Vertical limestone cliffs and pinnacles in the RNA provide escape terrain for an isolated population of Dall sheep and perching sites for raptors, including golden eagle and peregrine falcon. Rocky overhangs and abundant talus on steep limestone slopes of the RNA provide excellent escape terrain for the hoary marmot. A relatively uncommon songbird, the Townsend's solitaire, is found in the RNA.

Keywords: Alaska, aufeis, basalt, caribou, cave, cold spring, Dall sheep, disconformity, ecosystems, hoary marmot, limestone, Natural Areas (Research), natural bridge, old-growth forest, Research Natural Area, scientific reserves, Townsend's solitaire, windgap.

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