PART TWO OF THE NATIONAL PARK SYSTEM PLAN NATURAL HISTORY

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Foreword

This report was undertaken in accordance with the Policy Guidelines of the National Park Service promulgated by the Secretary of the Interior on June 18, 1969. Point 8 of those Guidelines reads as follows:

> The National Park System should protect and exhibit the best examples of our great national landscapes, riverscapes and shores and undersea environments; the processes which formed them; the life communities that grow and dwell therein; and the important landmarks of our history. There are serious gaps and inadequacies which must be remedied while opportunities still exist if the System is to fulfill the people's need always to see and understand their heritage of history and the natural world.
>
> You should continue your studies to identify gaps in the System and recommend to me areas that would fill them. It is my hope that we can make a significant contribution to rounding out more of the National Park System in these next few years.

The Secretary's Advisory Board on National Parks, Historic Sites, Buildings, and Monuments considered this and a companion study of history themes at its 62d semiannual meeting, April 20-23, 1970, and recommended their approval by the Secretary of the Interior as establishing "valuable guidelines for further evolution of the National Park System Plan and a useful framework within which to present plans and priorities to the Bureau of the Budget and the Committees of the Congress for expansion of the National Park System." These guidelines are not a formal program for the acquisition of specific natural properties.

The recommendations of the Advisory Board were approved by the Secretary on June 10, 1970. "Part I, History" is published as a companion volume.

George B. Hartzog, Jr.
Director, National Park Service

Contents

Natural History Themes and Natural Regions

The significant natural, scenic, and scientific heritage of the United States of America should be represented ultimately in a completed National Park System. The questions have long been asked as to what a completed system means, what criteria can be used to define the contents of such a system, and what constitutes significance. Answers to such questions are fundamental in producing a realistic plan of what the National Park System should contain, and it is toward this end that the following analysis is made. The use of *themes,* or categories of natural phenomena, and *regions,* among which the theme characteristics differ significantly, are the essential aspects around which the study is made.

The analysis and categorization of the natural phenomena of the United States are efforts to organize these phenomena into a system of natural history themes having their bases in observable physiographic and biological features. Such a system should form a matrix into which present and future ideas, concerning natural history themes, may be incorporated.

The physiographic and biologic features of the country tend to be regionally oriented, thereby providing an opportunity to divide the country into relatively homogeneous areas or *natural regions* (figures 1a, b, c). These regions, based largely on Fenneman's (1928) classic physiographic divisions, give primary consideration to the geologic histories, structures, and landforms, which in turn influence considerably the climates, soils, vegetation, and animal life associated with the regions.

The *natural history themes,* in their broadest definitions, are a series of categories encompassing essentially all the natural phenomena of the country. Any major theme varies throughout its natural range and these variations generally become significant from one region to another. For example, the boreal forest theme is characterized differently in each region where it occurs—such as in the Middle Rocky Mountains where it is characterized by Engelmann spruce, subalpine fir, lodgepole pine, and white bark pine; in the Southern Appalachian Ranges by red spruce and Frazer fir; and in Interior and Western Alaska by white and black spruce. Each significant natural history theme within a natural region is called a *regional theme.* A single natural region may have as few as six or as many as 18 regional themes.

Each regional theme is described in the text of this report. The great complexity of each theme within each region can only be hinted at in this document and the summarizing statements identify only some of the more prominent aspects. In the descriptions of ecosystems, conspicuous plants and important aquatic animals are used as "indicator species," which imply the presence of associated organisms of the ecosystem.

Information relating to *significance of regional themes* and *adequacy of representation* within the National Park System is summarized on a master chart (figure 2).

Significance of regional themes Each regional theme is analyzed to determine the significance of the theme within the region (irrespective of representation

in the National Park System). A regional theme of *prime significance,* such as the Plains, Plateaus, and Mesas within the Great Plains Natural Region, is given a value of 2. Within the Great Basin Natural Region, plains are *significant but not of prime significance* and receive a value of 1. Within the Cascade Range Natural Region, plains have *little or no significance* and are assigned a value of 0, which on the master chart appears as a *gray square* and receives no further consideration.

Adequacy of representation in National Park System

For each theme having some or prime significance within the region, further analysis indicates the *adequacy of representation* within the National Park System. A regional theme such as Eastern Deciduous Forest in the Appalachian Range Natural Region receives *adequate representation* within the National Park System (NPSystem) and is recognized on the master chart by a *green square. Some representation* in the NPSystem describes the representation of this forest theme in the Interior Highlands Natural Region and is illustrated by a *yellow square,* and for further contrast, the Eastern Deciduous Forest has *little or no representation* in the NPSystem in the Gulf Coastal Plain and is represented by a *white square.*

Significance and representation

Numerical values are assigned to each regional theme depending upon the significance of the theme within the natural region and the adequacy of representation of the regional theme within the National Park System. All values are qualitatively derived and reflect the professional concensus of the authors and their consultants. The major factors considered are the quantity, quality, diversity, and uniqueness for each theme. The seven different possible combinations are listed below:

	0	Theme: has *little or no significance* in region
1	0 1	Theme: a) has *little or no representation* in NPSystem b) has *significance* (but not prime significance) in natural region
1	0.5 1	Theme: a) has *some representation* in the NPSystem b) has *significance* (but not prime significance) in natural region
1	1 1	Theme: a) is *adequately represented* in NPSystem b) has *significance* (but not prime significance) in natural region
2	0 2	Theme: a) has *little or no representation* in NPSystem b) has *prime significance* in natural region

Theme:

2 — 1 a) has *some representation* in NPSystem
2 b) has *prime significance* in natural region

Theme:

2 — 2 a) has *adequate representation* in NPSystem
2 b) has *prime significance* in natural region

To phrase it another way, the numerical value or "fraction" is the ratio of the value of representation in the NPSystem to value of the regional theme.

Using combined values for significance and representation

Although the values are not statistical equivalents, there is some value in treating them so. By summing horizontally the numerals representing the significance of the themes within the region, a total theme value for the region is attained. Similarly summing the numerals for adequacy of representation of the regional themes within the NPSystem, gives a total representation value. By dividing the total possible points available in the region into the total points for representation in the NPSystem, *the adequacy of natural region representation in the NPSystem* is derived. For example, the totals for the Appalachian Ranges Natural Region are $2 + 1 + 1 + 1 + 1 + 1 + 1 + 2 + 1 + 1 = 12$ possible points in the region; representation in the NPSystem is $1 + 1 + 0 + 0.5 + 0 + 0 + 1 + 2 + 0 + 1 = 6.5$; 6.5 divided by $12 = .54$ or 54 percent. After doing this for all regions, it becomes readily apparent that some regions are much better represented than others. Figures 3 and 4 and table 1 summarize this information for all regions.

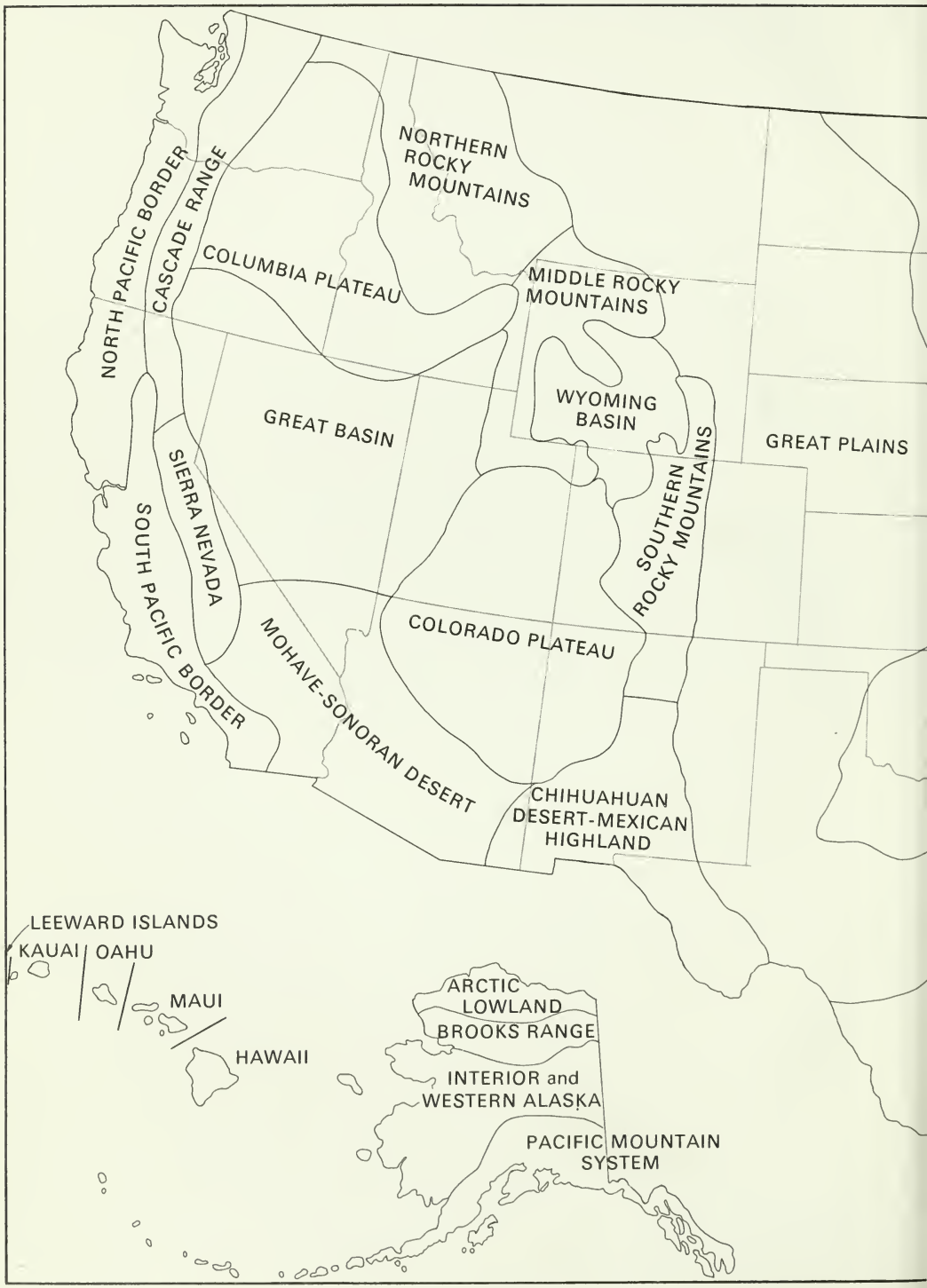
By summing vertically on the master chart, similar values are obtained for *Adequacy of Natural History Theme Representations in the NPSystem*. (*See* figure 5 and table 2 for summaries.)

Identifying gaps in the National Park System

A major gap in the National Park System is identifiable as (1) a natural region having poor representation in the NPSystem (table 1); (2) a natural history theme having poor representation in the NPSystem (table 2) or (3) a regional theme having prime significance and little or no representation in the NPSystem (table 3). All National Park System gaps, of varying degrees of significance, appear on the chart (figure 2) as white and yellow squares.

It should be noted that a single new park might provide adequate representation for many themes and in so doing provide a more ecologically complete and manageable unit. For example, a single park in the Great Basin encompassing a single mountain range (such as the Snake Range, Deep Creek Range, or Ruby Mountains, and immediately surrounding lowlands might provide adequate representation for 12 of the 16 unrepresented themes and thus raise the regional thematic representation of the Great Basin Natural Region from 11 percent to 78 percent.

Figure 1a. Natural Regions*



*Based upon Fenneman's (1928) *Physiographic Divisions of the United States*. Modifications are by the authors.

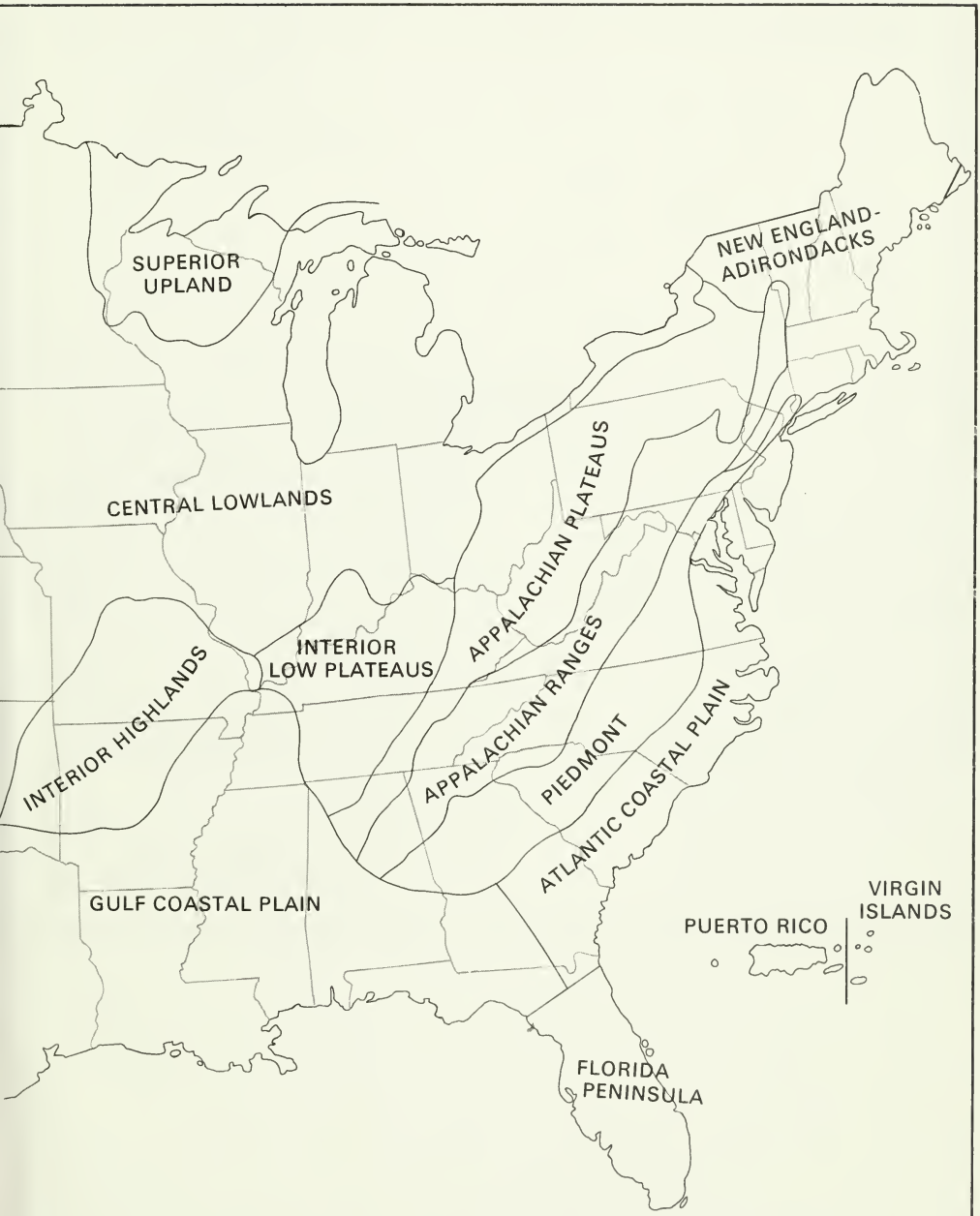
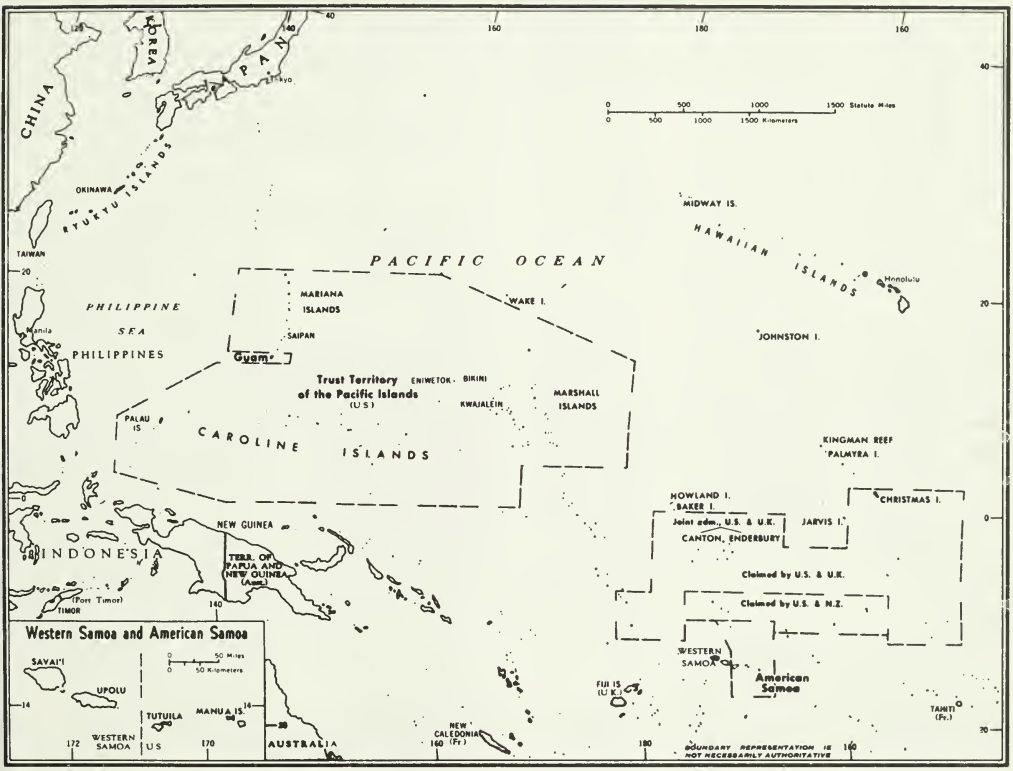


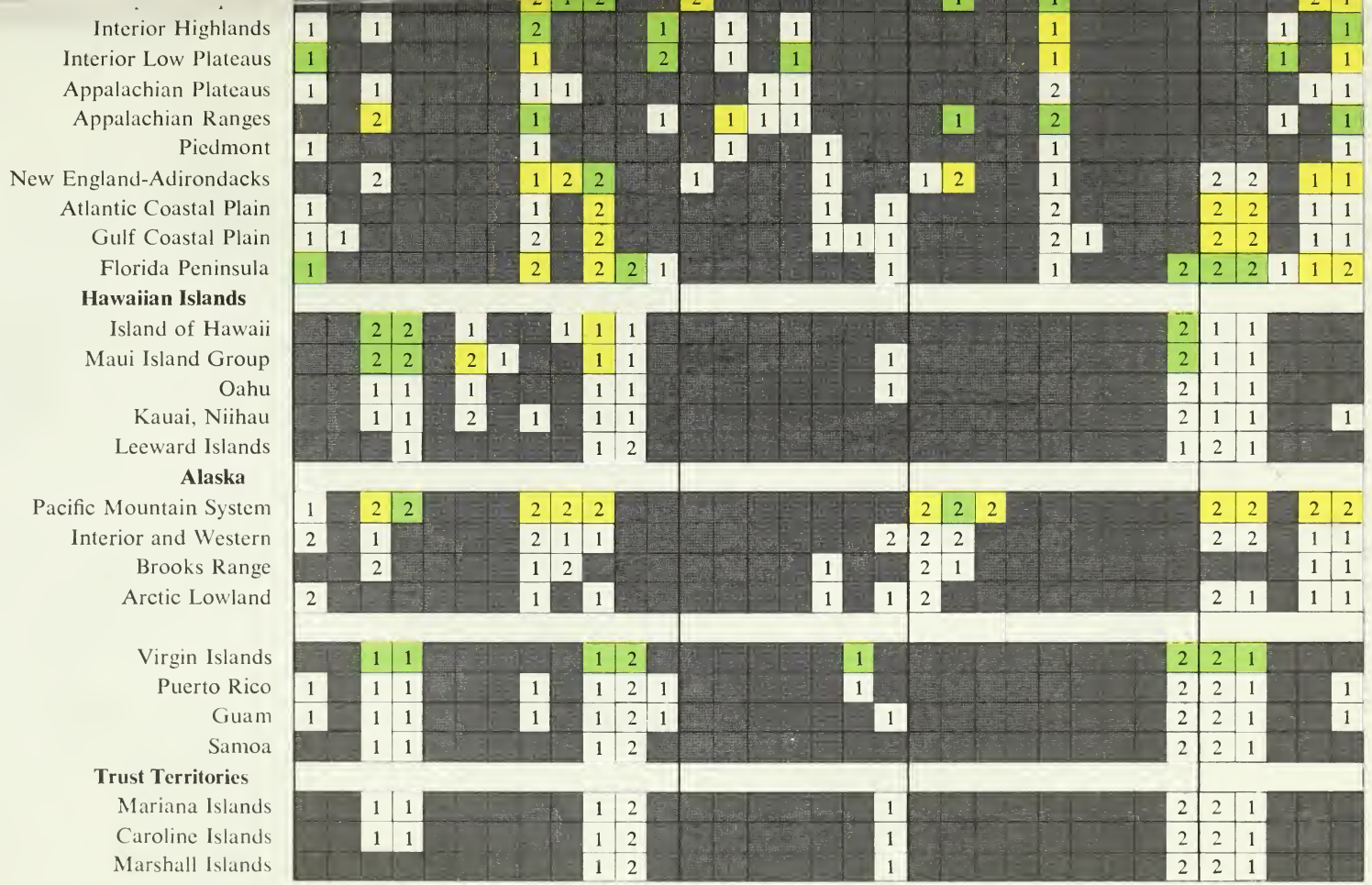
Figure 1b. Outlying Areas of the United States in the Caribbean

Figure 1c. Outlying Islands of the United States in the Pacific



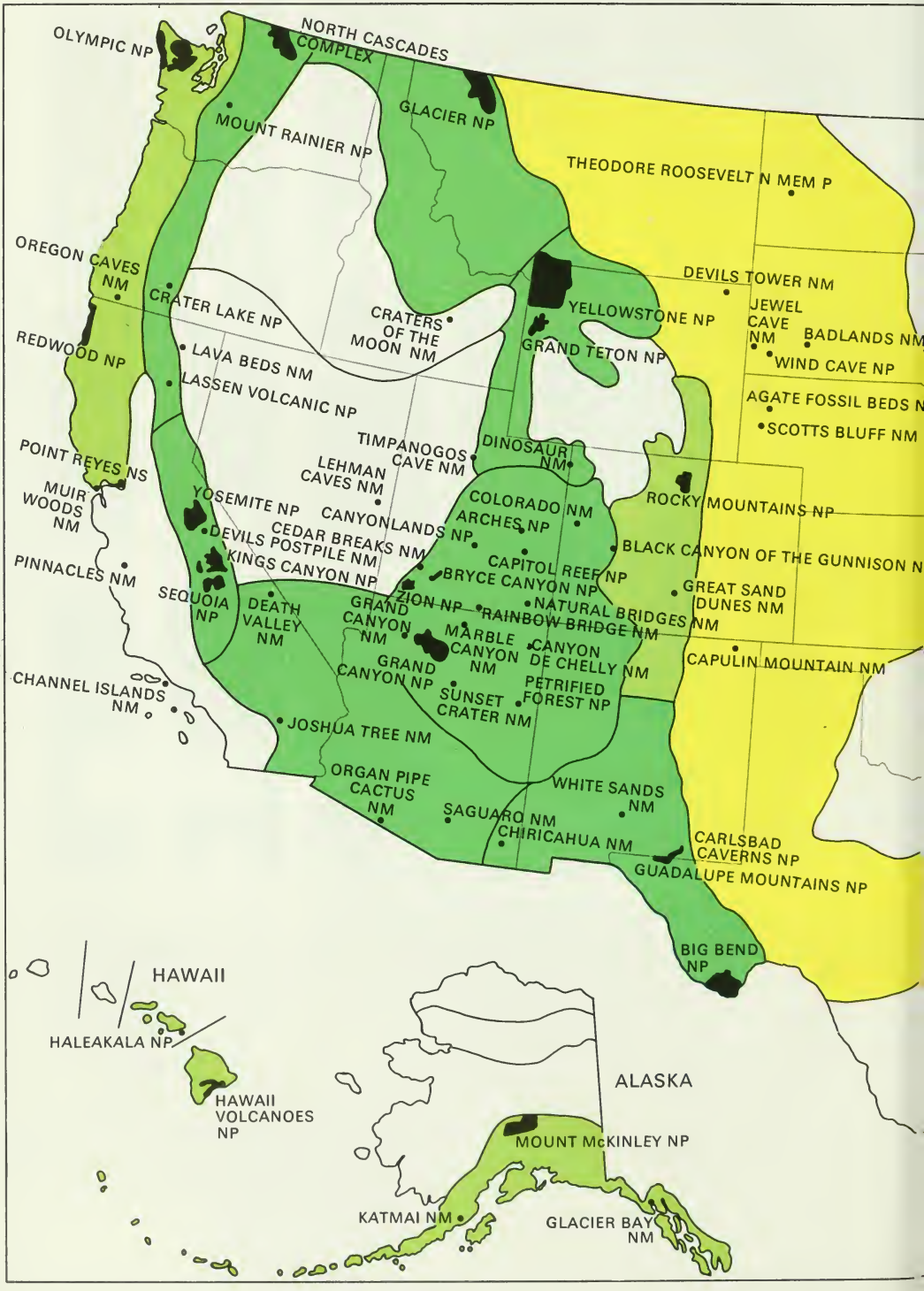
NOTE: Details of administration in South Pacific area, other than U.S., generally not shown.

Figure 2. Regional Theme Master Chart



*In connection with this natural area study the use of the term adequate refers to representation but does not mean full protection. In order to assure protection and provide for access there may be need for additional area.

Figure 3. Natural Regions Representation in the National Park System



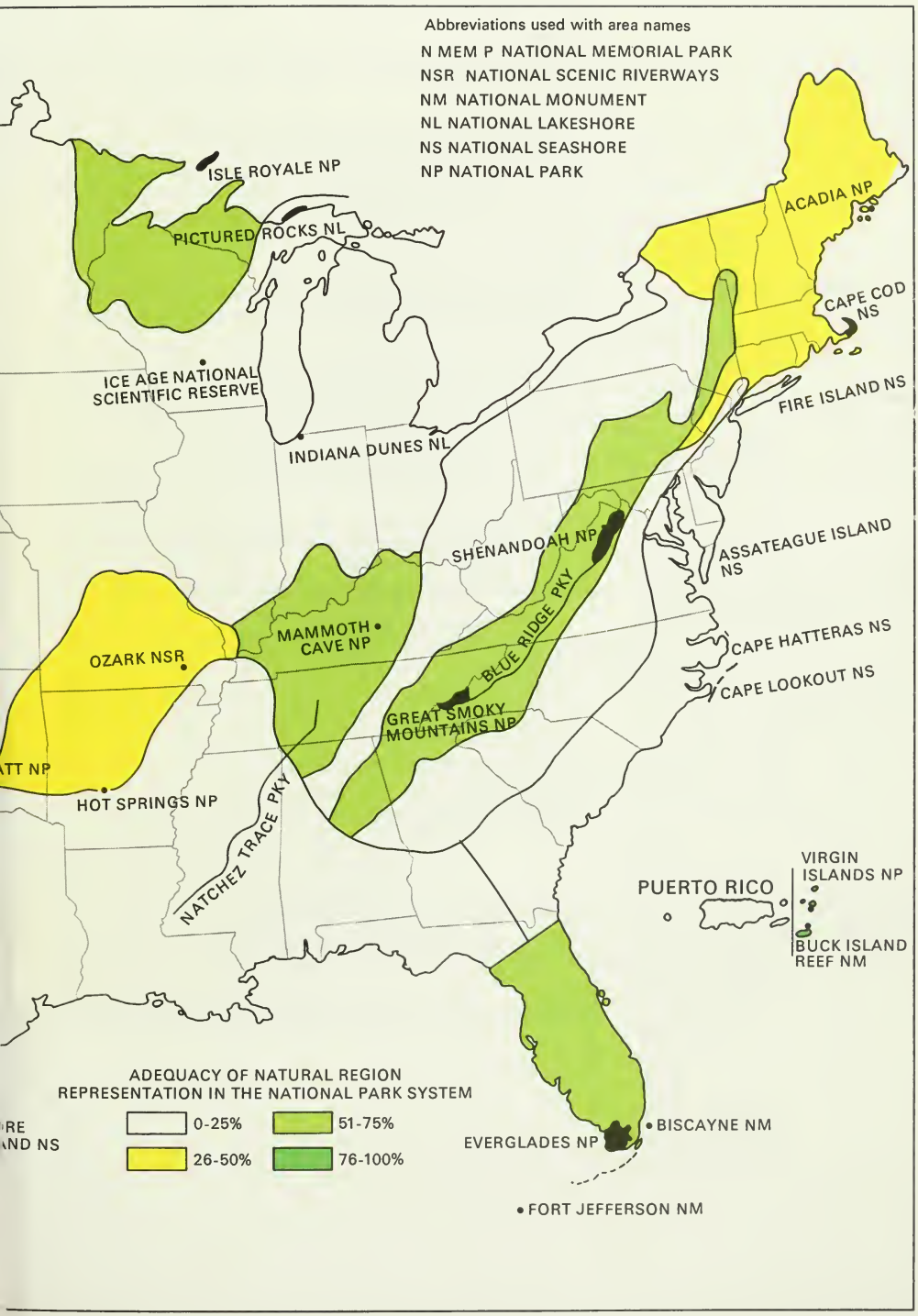

Abbreviations used with area names
N MEM P NATIONAL MEMORIAL PARK
NSR NATIONAL SCENIC RIVERWAYS
NM NATIONAL MONUMENT
NL NATIONAL LAKESHORE
NS NATIONAL SEASHORE
NP NATIONAL PARK
ISLE ROYALE NP
PICTURED ROCKS NL
ACADIA NP
CAPE COD NS
ICE AGE NATIONAL SCIENTIFIC RESERVE
INDIANA DUNES NL
FIRE ISLAND NS
SHENANDOAH NP
ASSATEAGUE ISLAND NS
MAMMOTH CAVE NP
BLUE RIDGE PKY
CAPE HATTERAS NS
OZARK NSR
CAPE LOOKOUT NS
GREAT SMOKY MOUNTAINS NP
HOT SPRINGS NP
NATCHEZ TRACE PKY
VIRGIN ISLANDS NP
PUERTO RICO
BUCK ISLAND REEF NM
ADEQUACY OF NATURAL REGION REPRESENTATION IN THE NATIONAL PARK SYSTEM
0-25%
26-50%
51-75%
76-100%
EVERGLADES NP
BISCAYNE NM
FORT JEFFERSON NM

Figure 4. Adequacy of Natural Region Representation in the National Park System

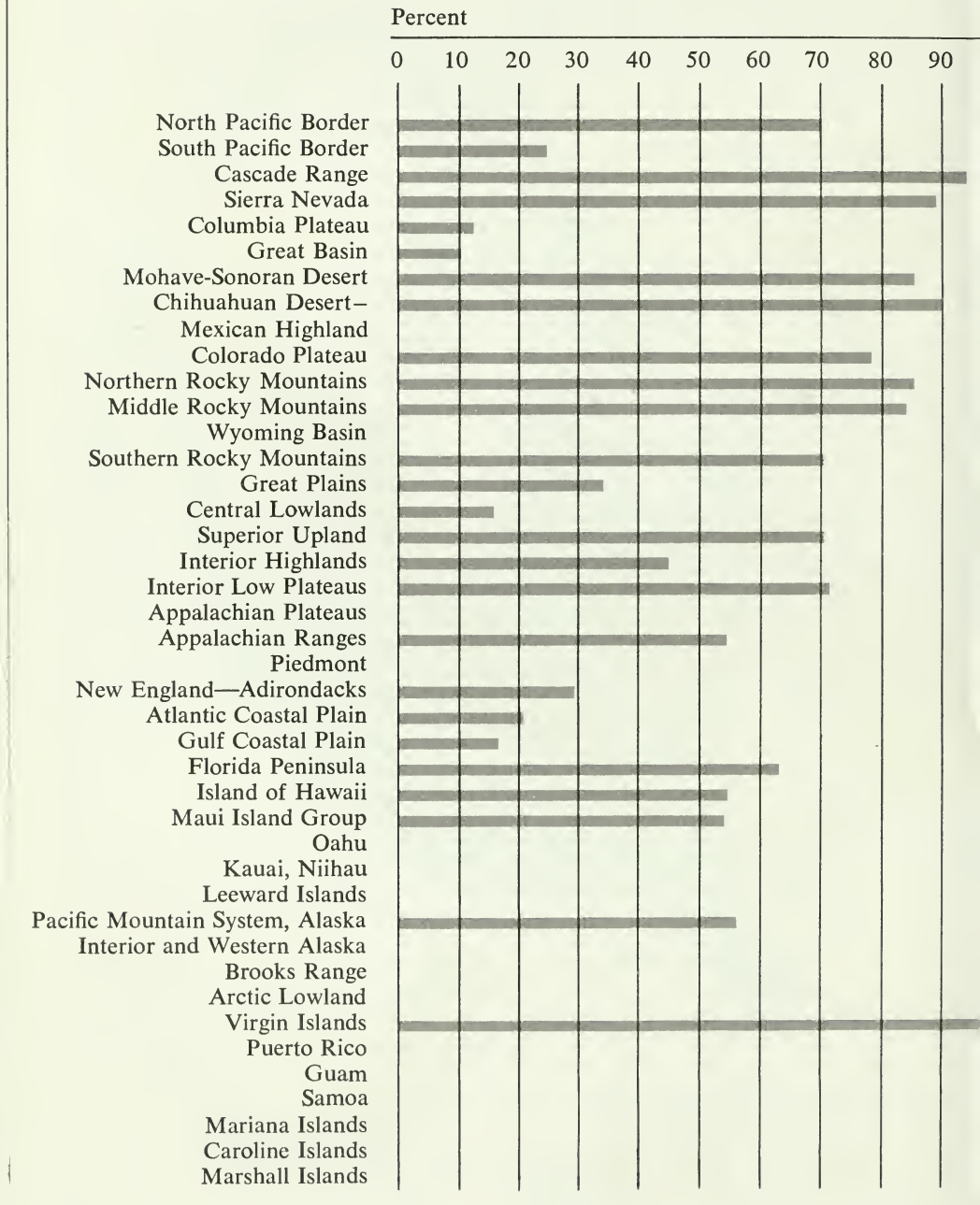


Figure 5. Adequacy of Natural History Theme Representation in the National Park System

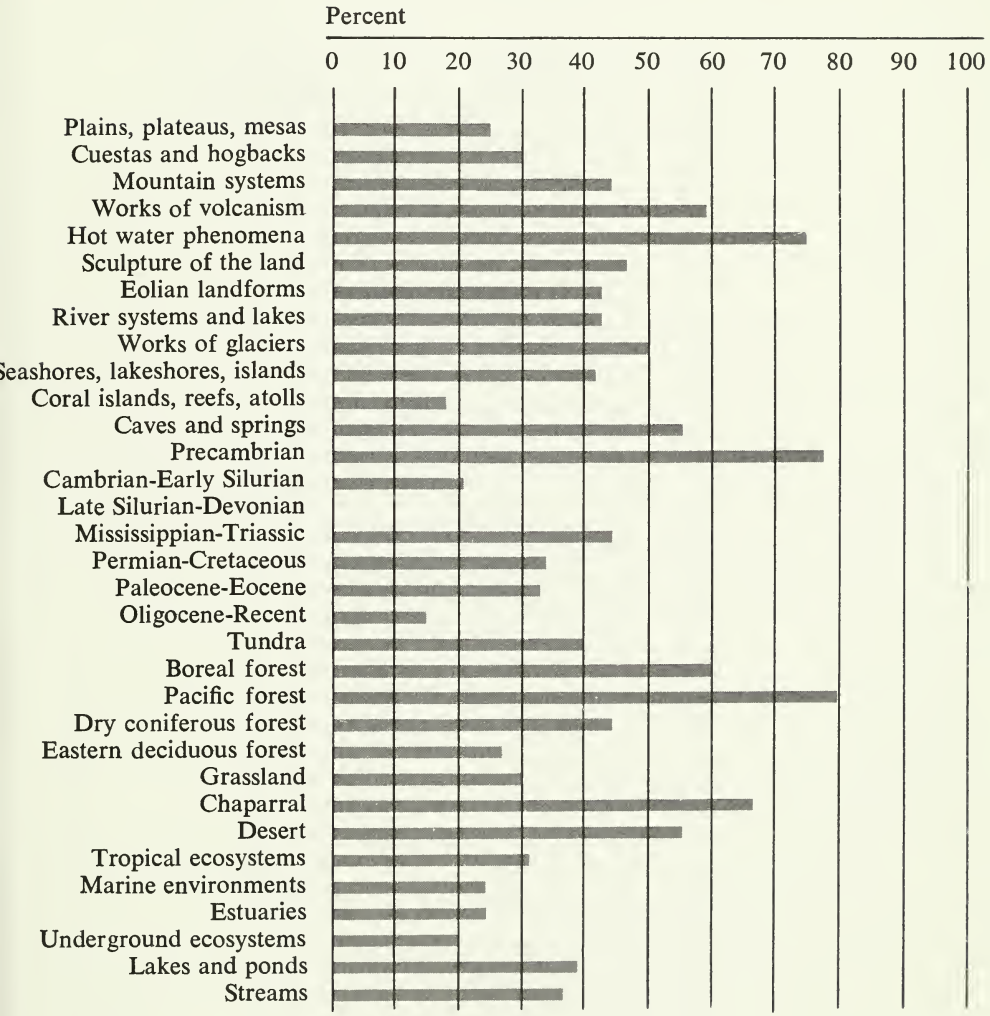


Table 1. Ranking of Natural Regions by adequacy of representation within the National Park System

100%	Virgin Islands
94%	Cascade Range
90%	Chihuahuan Desert–Mexican Highland
89%	Sierra Nevada
86%	Northern Rocky Mountains
86%	Mohave–Sonoran Desert
84%	Middle Rocky Mountains
78%	Colorado Plateau
72%	Interior Low Plateaus
71%	Southern Rocky Mountains
71%	Superior Upland
70%	North Pacific Border
63%	Florida Peninsula
56%	Pacific Mountain System, Alaska
54%	Appalachian Ranges
54%	Island of Hawaii
53%	Maui
45%	Interior Highlands
34%	Great Plains
29%	New England—Adirondacks
24%	South Pacific Border
21%	Atlantic Coastal Plain
17%	Gulf Coastal Plain
16%	Central Lowlands
12%	Columbia Plateau
10%	Great Basin
0%	Wyoming Basin
0%	Appalachian Plateaus
0%	Piedmont
0%	Interior and Western Alaska
0%	Brooks Range
0%	Arctic Lowland
0%	Oahu
0%	Kauai, Niihau
0%	Leeward Islands
0%	Puerto Rico
0%	Mariana Islands
0%	Caroline Islands
0%	Marshall Islands
0%	Guam
0%	Samoa

Table 2. Ranking of Natural History Themes by adequacy of representation within the National Park System

	Landforms
75%	Hot water phenomena
59%	Works of volcanism
56%	Caves and springs
50%	Works of glaciers
47%	Sculpture of the land
44%	Mountain systems
43%	Eolian landforms
43%	River systems and lakes
42%	Seashores, lakeshores, islands
30%	Cuestas and hogbacks
25%	Plains, plateaus, mesas
18%	Coral islands, reefs, atolls
	Geologic history
78%	Precambrian
44%	Mississippian-Triassic
34%	Permian-Cretaceous
33%	Paleocene-Eocene
21%	Cambrian-Early Silurian
15%	Oligocene-Recent
0%	Late Silurian-Devonian
	Land ecosystems
80%	Pacific forest
67%	Chaparral
60%	Boreal forest
56%	Desert
44%	Dry coniferous forest
40%	Tundra
31%	Tropical ecosystems
30%	Grassland
27%	Eastern deciduous forest
	Aquatic ecosystems
39%	Lakes and ponds
37%	Streams
24%	Marine environments
24%	Estuaries
20%	Underground ecosystems

Table 3. Most significant Regional Theme gaps in the National Park System

[Determined by those regions having themes with value of 2 and little or no representation in the National Park System.]

Plains, plateaus, and mesas
Great Plains
Central Lowlands
Interior and Western Alaska
Artic Lowland

Mountain systems
Great Basin
New England—Adirondacks
Brooks Range

Sculpture of the land
Columbia Plateau
Kauai

River systems and lakes
Central Lowlands
Gulf Coastal Plain
Interior and Western Alaska

Works of glaciers
Brooks Range

Coral islands, reefs, atolls
Leeward Islands
Puerto Rico
Guam
Trust Territories (3)
Samoa

Paleocene-Eocene
Wyoming Basin

Oligocene-Recent
South Pacific Border
Interior and Western Alaska

Tundra
Interior and Western Alaska
Brooks Range
Arctic Lowland

Boreal forest
Interior and Western Alaska

Eastern deciduous forest
Appalachian Plateau
Atlantic Coastal Plain
Gulf Coastal Plain

Grassland
Central Lowlands

Desert
Great Basin

Tropical ecosystems
Oahu
Kauai
Puerto Rico
Guam
Trust Territories (3)
Samoa

Marine environments
New England—Adirondacks
Leeward Islands
Interior and Western Alaska
Arctic Lowland
Puerto Rico
Guam
Trust Territories(3)
Samoa

Estuaries
New England—Adirondacks
Interior and Western Alaska

Lakes and ponds
Central Lowlands

Table 4. Listing by National Regions of areas of the National Park System having significant natural features.

North Pacific Border
Muir Woods NM
Olympic NP
Oregon Caves NM
Point Reyes NS
Redwood NP

South Pacific Border
Channel Islands NM
Pinnacles NM

Cascade Range
Crater Lake NP
Lassen Volcanic NP
Mount Rainier NP
North Cascades complex

Sierra Nevada
Devils Postpile NM
Kings Canyon NP
Sequoia NP
Yosemite NP

Columbia Plateau
Craters of the Moon NM

Great Basin
Lava Beds NM
Lehman Caves NM

Mohave–Sonoran Desert
Death Valley NM
Joshua Tree NM
Organ Pipe Cactus NM
Saguaro NM

Chihuahuan Desert–Mexican Highland
Big Bend NP
Carlsbad Caverns NP
Chiricahua NM
Guadalupe Mountains NP
White Sands NM

Colorado Plateau
Arches NP
Black Canyon of the Gunnison NM
Bryce Canyon NP
Canyon de Chelly NM
Canyonlands NP
Capitol Reef NP
Cedar Breaks NM
Colorado NM
Grand Canyon NM
Grand Canyon NP
Mesa Verde NP
Natural Bridges NM
Petrified Forest NP
Rainbow Bridge NM
Sunset Crater NM
Zion NP

Northern Rocky Mountains
Glacier NP

Middle Rocky Mountains
Dinosaur NM
Grand Teton NP
Timpanogos Cave NM
Yellowstone NP

Wyoming Basin
None

Southern Rocky Mountains
Florissant Fossil Beds NM
Great Sand Dunes NM
Rocky Mountains NP

Great Plains
Agate Fossil Beds NM
Badlands NM
Capulin Mountain NM
Devils Tower NM
Jewel Cave NM
Scotts Bluff NM
Theodore Roosevelt NMemP
Wind Cave NP

Central Lowlands
Ice Age Nat. Scientific Reserve
Indiana Dunes NL
Pictured Rocks NL
Platt NP
Sleeping Bear Dunes NL

Superior Upland
Isle Royale NP

Interior Highlands
Hot Springs NP
Ozark NSR

Interior Low Plateaus
Mammoth Cave NP

Appalachian Plateaus
None

Appalachian Ranges
Great Smoky Mountains NP
Shenandoah NP

Piedmont
None

New England–Adirondacks
Acadia NP
Cape Cod NS

Atlantic Coastal Plain
Assateague Island NS
Cape Hatteras NS
Cape Lookout NS
Fire Island NS

Gulf Coastal Plain
Padre Island NS

Florida Peninsula
Biscayne NM
Everglades NP
Fort Jefferson NM

Pacific Mountain System, Alaska
Glacier Bay NM
Katmai NM
Mount McKinley NP

Interior and Western Alaska
None

Brooks Range
None

Arctic Lowland
None

Island of Hawaii
Hawaii Volcanoes NP

Maui Island Group
Haleakala NP

Oahu
None

Kauai, Niihau
None

Leeward Islands
None

Virgin Islands
Buck Island Reef NM
Virgin Islands NP

Puerto Rico
None

Guam
None

Mariana Islands
None

Caroline Islands
None

Marshall Islands
None

Samoa
None

Mountain systems

The Olympic Mountains of Washington are the second highest and most scenic of the Pacific Coast Ranges. Mount Olympus (7,965 feet) and surrounding peaks receive the heaviest snowfall in the United States and support many glaciers. The Coast Range of Oregon is plateaulike in nature and reaches its highest point at Marys Peak (4,097 feet). The Klamath Mountains of northern California and southern Oregon resemble geologically the Sierra Nevada more closely than they resemble the Coast Ranges. These mountains are composed of metamorphosed and intruded Paleozoic and Mesozoic rocks, not Tertiary rocks. Some peaks of the Klamath Mountains reach nearly 9,000 feet. The Coast Ranges of northern California resemble those of Oregon. This theme receives adequate representation in Olympic and Redwood National Parks.

Eolian landforms

Sand dunes border 45 percent of the Oregon coast and 31 percent of the Washington coast from Cape Flattery south (Cooper, 1958). Some of these dune areas extend up to 3 miles inland. Lakes often occur behind dunes when they block small streams.

River systems and lakes

Surface water is an important feature of this region. Major rivers include the Columbia and a number of large coastal streams. Lakes are not as numerous as to the east, but are a significant feature. Some of the best examples of streams and lakes are located in Olympic National Park. Small streams are abundant in the upland areas. Water quality is high except in local areas subjected to municipal and industrial pollution. Typically, streams and rivers of the region are short and carry large amounts of water due to high rates of precipitation and runoff. Coastal stream flows are highest in middle to late winter, and lowest in autumn.

Works of glaciers

Pleistocene glaciation was extensive in the Olympic Mountains and in the Puget Sound area. Topographic effects of Pleistocene glaciation are spectacular in the Olympic Mountains and in the Trinity Mountains of northern California. The Puget Sound glacier pushes southward against the Olympic Mountains, depositing granite boulders from Canada on the Olympic Peninsula at altitudes up to 3,000 feet. Olympic National Park contains some of the most striking glacial sculpturing of this region as well as more than 60 existing glaciers.

Seashores, lakeshores, and islands

The waters of the Pacific Ocean pound across the narrow continental shelf with little reduction of force and create an eroded shoreline rather than a depositional one. The sandy or rocky beaches are usually bordered by steep bluffs. The seashores of the Pacific Northwest include some of the most scenic and interesting seashores in the United States. Coastlines at Olympic National Park, Redwood National Park, and Point Reyes National Seashore give adequate representation to this theme.

Caves and springs

Relatively few caves occur in this region. A few coastal caves exist such as Sea Lion Caves on the Oregon coast. Oregon Caves National Monument features a small cave dissolved from marble in the Siskiyou Mountains.

Geologic history

Eocene and Miocene rocks appear at the surface in the Coast Ranges and lowlands from central Oregon north to the Olympic Peninsula. Metamorphosed Cretaceous rocks compose the core of the Olympic Mountains. Mesozoic rocks, especially Jurassic, outcrop in northern California and southern Oregon. The Klamath Mountains are a complex of metamorphosed and intruded Paleozoic and Mesozic strata. Marine invertebrate fossils, especially gastropods and pelecypods, are abundant in the Eocene strata of Washington and Oregon coastal regions. Ammonites are common in the Cretaceous rocks of northern California.

Tundra

The only alpine tundra found in this region is included in Olympic National Park, where timberline is about 6,000 feet above sea level. The alpine flora has close affinities with that of coastal British Columbia. Red heather (*Phyllodoce empetriformis*) and white heather (*Cassiope mertensiana*) are conspicuous in the vegetation.

Boreal forest

This theme is found only in the Olympic Mountains of Olympic National Park. Subalpine fir is the dominant species with mountain hemlock and Pacific silver fir sometimes present. Englemann spruce, a codominant with subalpine fir over huge areas in the Rocky Mountains, is very rare in the Olympic Mountains. Whitebark pine is also very rare in the Olympic subalpine forest.

Pacific forest

The most luxuriant development of Pacific forest is found on the Olympic Peninsula, where western hemlock, western arborvitae, grand fir, Sitka spruce, and Douglas-fir are dominant species in lowland forests. Pacific silver fir and subalpine fir typify higher elevations here. Such forests occur all along the coastal region of Washington and Oregon. Coast redwood was once the dominant tree species along the coast of northern California. Olympic and Redwood National Parks and Muir Woods National Monument give this theme good coverage.

Dry coniferous forest and woodland

Mixed forests of Douglas-fir, sugar pine, incense cedar, white fir, and ponderosa pine occur at middle elevations in the Klamath Mountains and on the east slopes of the Coast Range in southern Oregon and northern California. Jeffrey pine forms open stands on serpentine rock at low elevations in the Siskiyou Mountains.

Chaparral

A mosaic of conifer forest, oak woodland, sclerophyllous scrub, and grassland occupies the interior valleys between the Coast Range and Cascade Range in Oregon—specifically the Willamette Valley, the Rogue Valley, and the Umpqua Valley.

Human disturbance has modified the vegetation so much that it is now difficult to determine the primeval vegetational conditions.

Marine environments

Cold water along the north Pacific coast is the result of the cold California Current, a branch of the North Pacific Current which flows southward. The narrow Continental Shelf is 10 to 20 miles wide. The cold current brings a rich nutrient supply. Nutrients are especially abundant off Cape Mendocino, Calif., where strong upwellings occur. Olympic and Redwood National Parks and Point Reyes National Seashore give some representation of this theme.

Estuaries

Estuaries are much more extensive in this region than along the south Pacific coast because here many moderately large rivers empty fresh water into the ocean. The drowned mouths of rivers have received little sedimentation and are in an early stage of estuarine evolution. Although the Columbia is the third largest river in this country (after the Mississippi and the Yukon), it carries a light sediment load and is not building a delta. The Puget Sound, an embayment carved by glaciers, receives moderate fresh water input from short rivers heading in the Cascade Range. Redwood National Park and Point Reyes National Seashore contain some estuarine habitat.

Lakes and ponds

Although a number of lakes in the region have been modified by man, relatively natural conditions are found in others. Cutthroat trout, rainbow trout, and Dolly Varden are native to many lowland lakes of the region. Most mountain lakes were originally barren of fish, although few remain so today.

Rivers and streams

Cutthroat trout are native to many coastal streams, particularly those north of Humboldt Bay. These are genetically different from interior populations of the species and several sea-run populations are known. Because of the relative isolation of these coastal streams, species composition in adjacent streams may be quite different. Rainbow trout are more typical of streams in the southern portion of the region. Pacific salmon and steelhead spawn in many of the coastal streams. Spawning runs have declined greatly throughout the region and have been entirely eliminated from some streams. Olympic National Park provides good representation of this theme.

Mountain systems

This region contains three mountain groups, each of which has a complex structure—the Coast Ranges, the Transverse Ranges, and the Peninsular Ranges. The Coast Ranges consist of late Mesozoic and Tertiary rocks which were folded and faulted from the Miocene to the Pleistocene. Elevations are mostly between 2,000 and 4,000 feet, and the highest peaks reach 6,000 feet. The Coast Ranges extend 400 miles north from a point just north of Los Angeles.

The Transverse Ranges, east and southeast of Los Angeles, trend east-west—at right angles to the major structural trends in California. The intrusive granitic rocks of these ranges resemble those of the Sierra Nevada, whereas the faulting and topography resembles that of the Great Basin and Mohave Desert. San Gorgonio Mountain, the highest peak of these ranges, is 11,485 feet.

The Peninsular Ranges extend north from Baja California to the Los Angeles area. These ranges resemble the Transverse Ranges, but trend north-south. Mount San Jacinto reaches 10,805 feet.

Works of volcanism

Intrusive volcanic rocks are abundant in this region and pyroclastic rocks are not uncommon. Pinnacles National Monument has rock formations carved by erosion of pyroclastic sediments.

River systems and lakes

The Sacramento and San Joaquin Rivers are the major surface water features in the region. Natural lakes are uncommon—Tulare Lake in the southern portion of the San Joaquin River region was the largest natural lake. This lake is now a swamp. Several small coastal rivers—the Santa Ana, Salinas, San Gabriel, and Los Angeles—have been completely disrupted by impoundments and diversion. As surface water in this region is a very valuable resource, it is utilized to the utmost. For this reason, manmade reservoirs, canals, etc., are the most conspicuous surface water features.

Seashores, lakeshores, and islands

This region has several hundred miles of scenic Pacific Ocean coastline, some of which has escaped development. Erosive action of the Pacific has commonly cut steep cliffs in the coast and formed sandy beaches. Dunes occur in a few areas. Marine terraces along the southern California coast are former shorelines of Pleistocene Age. Santa Cruz Islands have 14 such terraces, with the highest at an elevation of 1,700 feet. The Channel Islands are an extremely interesting island group which represent the summits of inundated mountain ranges which are very similar to the Great Basin ranges. Channel Islands National Monument includes two of the smallest islands.

Geologic history

Fossil deposits of this region provide an excellent record of Mesozoic and Cenozoic life at the western margin of the continent. Jurassic and Cretaceous rocks contain rich deposits of invertebrates, especially ammonites. Miocene and Pliocene rocks, which outcrop extensively in the Central Valley and

adjacent coastal areas, contain fine fossil records of both invertebrates and vertebrates. The Rancho La Brea tar pits, now surrounded by Los Angeles, have yielded abundant vertebrate fossils of Pleistocene age.

Paleozoic rocks are extensively exposed in the Transverse Ranges of southern California. Metamorphism has obliterated evidence of former life in many cases, but good early Paleozoic fossil beds occur in some of the Transverse Ranges.

Pacific forest

California has a remarkably large number of endemic conifers which occur in scattered forests near the coast. Four species of closed-cone pines occur in this area—Torrey pine, Monterey pine, bishop pine, and knobcone pine. All but the latter have a very narrowly restricted distribution. Digger pine and Coulter pine are locally abundant. Monterey cypress is a picturesque tree of the Monterey area. Coast redwood reaches its southern limit in the Santa Lucia Mountains south of Monterey, where the Santa Lucia fir also occurs.

Dry coniferous forest and woodland

The Coast, Transverse, and Peninsular Ranges have extensive forest composed of a mixture of coastal, Sierran, and inland species. These forests contain various combinations of the following species: ponderosa pine, Jeffrey pine, sugar pine, lodgepole pine, limber pine, white fir, and incense-cedar.

Grassland

The Central Valley of California is thought to have supported grassland vegetation before the coming of the white man. Small relict patches indicate that perennial bunchgrasses were dominants and that *Stipa pulchra* was the principal species. The climatic regime of this grassland region is quite different from that of the grasslands of central United States, which have most of the annual precipitation coming during late spring and summer. Here, the summers are extremely dry. Grazing and fire have essentially eliminated the natural vegetation of the Central Valley. Exotic annual grasses have replaced native grasses.

Chaparral

The Southern California coastal region has a "Mediterranean" climate with moist winters with moderate temperatures and warm dry summers. Such a climate is found in four other parts of the world—the Mediterranean region of Europe and North Africa, a coastal portion of Chile, the Cape region of South Africa, and the southwest tip of Australia. Vegetation of all these areas is similar in life form—with broad-leaved evergreen trees and shrubs with thick sclerophyllous leaves. In California, this type of vegetation is called "chaparral." Oaks and species of the genera *Ceanothus* and *Arctostaphylos* predominate. Chaparral is extremely rich in species, most of which are endemic to the region. Pinnacles National Monument contains a good sample of chaparral, though it fails to exhibit much of the variation present in this vegetation type.

Marine environments

The California Current brings cool water from the northern Pacific although the waters off the southern California coast

are considerably warmer than those of Washington and Oregon. Coastal winds periodically force the California Current offshore in the vicinity of Santa Barbara, causing upwelling of cold, nutrient-rich water which markedly increases productivity. The full force of the Pacific Ocean swell pours over the narrow and steeply sloping Continental Shelf, producing strong wave action. Channel Islands National Monument provides minimal representation of this theme.

Estuaries

San Francisco Bay, receiving fresh water from the combined Sacramento and San Joaquin Rivers, is the only large estuarine system in this region. Other estuaries are small coastal embayments at the mouths of small rivers. Little fresh water empties into the Pacific south of San Francisco Bay. Rivers of southern California are short and because of low precipitation their flow is small or intermittent.

Rivers and streams

Rivers and streams of this region originally contained an interesting and unusual fish fauna. Species present included the Sacramento perch, the only west slope sunfish, the thick-tailed chub, and the three-spined stickleback. Large spawning runs of Pacific salmon and steelhead formerly entered the rivers of the region. Due to impoundment, diversion, and pollution in many rivers, most of the native and anadromous fishes have been nearly extirpated.

Cascade Range

Mountain systems and the works of volcanism

Mountains of the Cascade Range were built up by lava flows, debris from volcanic explosions, and regional uplift. The rocks of the northern part of the range (included in North Cascades National Park) are largely sedimentary and metamorphic. Glacier Peak and Mount Baker are the only volcanic peaks of this section. However, from Mount Rainier south almost all the rocks are volcanic. The most spectacular feature of the middle and southern Cascades is the line of volcanoes which rise several thousand feet above the general level of the range. Mount Rainier and Lassen Volcanic National Parks include two outstanding examples of these volcanoes. Crater Lake National Park contains a caldera which resulted from the collapse of Mount Mazama, a Pleistocene volcano.

Hot water phenomena

In spite of the recent volcanic activity of the Cascades, thermal features are not particularly common. However, hot springs, steaming fumaroles, and sulfurous vents occur in Lassen Volcanic National Park. Steam vents are present on the summit of Mount Rainier.

River systems and lakes

This region is one of heavily glaciated uplands so lakes and streams are abundant. The Columbia River is the largest stream and crosses the region direct from east to west. Mountain lakes and streams are well represented in Mount Rainier and North Cascades National Parks. The unusual caldera-type Crater Lake is also under Park Service jurisdiction. Precipitation in the region is high, and surface waters are a significant feature. Several lakes in the southern part of the region were formed by recent lava flows.

Works of glaciers

During the Pleistocene the Cordilleran ice sheet engulfed the Cascade Range in the vicinity of Mount Baker and spread along the west slope as far south as Mount Rainier. In the Glacier Peak area, long valley glaciers descended the east slopes. One of the larger of these deepened and scoured the basin now occupied by Lake Chelan, which is 60 miles long and 1,500 feet deep, with its floor 400 feet below sea level. Mountain icecaps coalesced over the Cascades from Mount Rainier south to Crater Lake and Mount McLoughlin, forming an almost continous ice sheet along the Cascade crest and slopes. Mount Shasta and Lassen Peak had large ice caps.

Many small glaciers occur at present in the northern Cascades and on the higher volcanoes farther south. Emmons Glacier on Mount Rainier is the largest glacier in the United States outside of Alaska. This theme is well represented in Mount Rainier, North Cascades, Crater Lake, and Lassen Volcanic National Parks.

Caves and springs

Numerous lava-tube caves occur in the area south of Mount Saint Helens. One of these, Ape Cave, is more than 2 miles long and may be the world's longest lava-tube cave.

Geologic history

Mississippian, Pennsylvanian, and Permian rocks outcrop in North Cascades National Park and vicinity. Mesozoic rocks

are also sparingly present in the northern Cascades. The bulk of the Cascade Range is composed of Tertiary volcanics, and sedimentary and metamorphic rocks are essentially absent south of Seattle, Wash. Volcanism began during Eocene time and continued through the Oligocene, Miocene, and Pliocene. The great volcanic peaks of the Cascades—Mount Baker, Glacier Peak, Mount Rainier, Mount Adams, Mount Saint Helens, Mount Hood, Mount Jefferson, the Sisters, Mount Shasta, and Lassen Peak—have been active in late Pleistocene or Recent time. Fossils are extremely rare in the volcanic rocks of the Cascade Range.

Tundra

True tundra vegetation is present but rarely luxuriant in the Cascade Range because of the thin soils of the highest volcanic peaks. In contrast, lush subalpine and timberline meadows of the Cascades are unrivaled for their spectacular flower displays in late summer. Mount Rainier and North Cascades National Parks contain some of the best meadows. Subalpine meadows and true alpine tundra occur also in Lassen Volcanic and Crater Lake National Parks.

Boreal forest

Subalpine fir, mountain hemlock, and whitebark pine are the most important species of the high elevation forest in the Cascades. Engelmann spruce occurs in most parts of the Cascades, but is seldom a dominant species.

Pacific forest

Forests of the west slope of the Cascade Range strongly resemble those of the North Pacific Border region to the west. Western hemlock is the most important climax dominant at low to middle elevations. Douglas-fir is an important successional species. Pacific silver fir and mountain hemlock dominate at middle to high elevations. Red fir is an important species in the southern Oregon Cascades. North Cascades, Mount Rainier, and Crater Lake National Parks give excellent representation to this theme.

Dry coniferous forest and woodland

Douglas-fir and grand fir are dominant at middle elevations on the relatively dry east slopes of the central and northern Cascade Range. Ponderosa pine forests occur at lower elevations. Lodgepole pine, a successional species, forms extensive stands on recently burned sites. In the southern Cascades, ponderosa pine, Jeffrey pine, sugar pine, and white fir occur in this zone. This theme receives adequate representation in Lassen Volcanic and Crater Lake National Parks.

Lakes and ponds

Fishes native to the lakes of the region are mostly typical of the Columbia River system. Several species of suckers and large minnows, sculpins, cutthroat trout, rainbow trout, Dolly Varden, and burbot are characteristic inland fishes. Anadromous Pacific salmon and steelhead are also found in lakes of the region. Introduction of nonnative fish into previously barren mountain lakes, including Crater Lake, has been widespread. For the most part, natural associations of fish are found in only the most isolated lakes of the region.

Rivers and streams

Cutthroat trout, rainbow trout, Dolly Varden, a few suckers and minnows, one species of troutperch, and whitefish are some of the characteristic native fishes. Anadromous Pacific salmon and steelhead utilize the streams of the region as spawning areas. Considerable man-caused alteration of the streams of the region has resulted in the decline of many fish populations. Probably the least modified part of the region is in the North Cascades, and native associations of fishes are not uncommon there.

Sierra Nevada

Mountain systems

The Sierra Nevada is a huge, fault-block mountain range with a steep eastern escarpment and a gently sloping west side. It is 400 miles long and 40 to 80 miles wide. Mount Whitney, elevation 14,495 feet, is the highest point in the range. The east face of the range, rising 11,000 feet above the Owens Valley, forms one of the most abrupt topographic rises in the United States. The distinctive light-colored granitic rock was intruded during the Mesozoic. Uplift of the range took place mostly late in the Tertiary. Yosemite, Sequoia, and Kings Canyon National Parks contain some of the finest segments of the Sierra Nevada. These parks encompass only the west slope of the range, so that the spectacular east slope is nowhere contained in a national park.

Works of volcanism

The Sierra Nevada is composed largely of granitic rocks intruded during the Mesozoic. Volcanic rocks are present, but are not widespread. Devils Postpile National Monument contains a remarkable basalt formation exhibiting columnar jointing.

River systems and lakes

This region consists of dissected uplands containing the headwaters of a number of rivers. Most surface water flows to the west—eastern streams are relatively minor. Numerous glacially formed alpine lakes are a feature of the region. The most famous lake of the region—Tahoe—is located in a tectonic basin.

Works of glaciers

Extensive glaciers formed in the Sierra Nevada during the Pleistocene and extended as low as 5,000 feet in elevation. Several glaciers extended more than 15 miles from their source region. Nowhere else in the United States were glaciers so extensive at such a low latitude. Glacial sculpturing and polishing of the granitic rock of the Sierra is displayed at its best in Yosemite National Park. Sequoia and Kings Canyon National Parks also contain spectacular ice-sculptured terrain. (Important glacial moraines of the east slope of the range are conspicuously absent from the National Park System.)

Geologic history

The bulk of the Sierra Nevada is composed of an intrusive mass, the Sierra Nevada batholith, which was intruded during a long interval of the Mesozoic. Metamorphosed Paleozoic and Mesozoic strata outcrop in small areas, especially in the north. Eocene sedimentary deposits are common in the western foothills of the Sierra. Miocene and Pliocene volcanic rocks occur in scattered localities. These volcanic rocks often contain plant fossils which provide evidence of the chronology of uplift of the Sierra which took place in Pliocene and early Pleistocene times.

Tundra

The alpine flora and vegetation of the Sierra Nevada is quite different from that of any other region of western North America. Few alpine plant species found in the Sierra are also found in the Arctic tundra or in the Rocky Mountains. Many Sierra alpine species are endemic to that range. Many of these

endemic species have their closest relatives in the surrounding deserts. There are many similarities in the environments of desert and alpine areas of this range—especially short growing season and severe drought stress. Alpine areas of the Sierra receive heavy winter snowfall, but summers are extremely dry. Alpine plants of the Sierra Nevada are subjected to much greater drought stress than tundra species of the Arctic, the Cascades, or the Rocky Mountains.

Alpine vegetation of the Sierra is well represented in Sequoia, Kings Canyon, and Yosemite National Parks.

Boreal forest

The Sierra Nevada lacks the spruce-fir forest characteristic of most subalpine and timberline zones of North America. Spruce is absent from the Sierra. The high altitude fir species is red fir, which occurs in upper montane and lower subalpine situations. Timberline species of the Sierra Nevada include whitebark pine, lodgepole pine, foxtail pine (Mount Whitney area only), and mountain hemlock. Sequoia, Kings Canyon, and Yosemite National Parks have extensive subalpine forests.

Pacific forest

Important species of Pacific forest on the west slope of the Sierra Nevada include giant sequoia, sugar pine, incense-cedar, white fir, Jeffrey pine, ponderosa pine, Douglas-fir, red fir, and mountain hemlock. Good examples of such forest occur in Sequoia, Kings Canyon, and Yosemite National Parks.

Dry coniferous forest and woodland

Stands of ponderosa and Jeffrey pine occur at middle elevations on the east slope of the Sierra Nevada. Pinyon-juniper woodland occurs in scattered patches at low elevation.

Chaparral

Vegetation of the western foothills of the Sierra Nevada consists of dry oak woodland and chaparral. Digger pine and blue oak occur in open stands at an elevation of 3,000 to 4,000 feet. Broad-leaved evergreen scrub predominates at lower elevations. This vegetation type is rich in species, and, though its aesthetic appeal is not great, its potential interest for ecological study of plant interactions is high. Sequoia and Kings Canyon National Parks give adequate representation to this theme.

Lakes and ponds

Most of the alpine lakes were originally barren of fish life. Many of these have been stocked with introduced species of game fish. An inland form of cutthroat trout was native to Lake Tahoe and other lakes on the east slope. Rainbow trout are native to a few lakes on the west slope that are drained by the Sacramento and San Joaquin Rivers. Native fish associations are almost nonexistent in the lakes of the region today.

Rivers and streams

Rainbow trout were native to several of the Sacramento-San Joaquin tributaries and are still found in some, but mostly as the result of fish cultural activities. The headwaters of the Kern River still contain populations of golden trout which are endemic. Some of the best examples of mountain streams in the region are found in Yosemite, Sequoia, and Kings Canyon National Parks. Introduction of nonnative trout into streams

of the region has been widespread and native associations of fish species are found only in a few isolated regions.

Columbia Plateau

Plains, plateaus, and mesas

Broad lava plains are characteristic of much, but by no means all, of this region. The most plainlike topography occurs in parts of eastern Washington and in the Snake River Plain of Southern Idaho. Craters of the Moon National Monument represents this theme.

Mountain systems

The highest mountain mass of the Columbia Plateau is the Wallowa Mountains, a jumble of peaks in the northeast corner of Oregon composed of metamorphic and igneous rocks. Sacajawea Peak in the Wallowas reaches 10,033 feet. The Seven Devils Mountains of Idaho are the product of complex block faulting of basalts. Such ranges as the Strawberry, Ochoco, Blue, and Umatilla Mountains of Oregon are warped and dissected basaltic plateaus.

Works of volcanism

The Columbia River lavas, extruded mainly during the Miocene, cover 200,000 square miles of this region and have a thickness of more than 10,000 feet in some localities. The Snake River basalts, of Pliocene to Recent age, cover a large area in south-central Idaho. Some of the most outstanding volcanic features of the Snake River Plain—cinder cones and lava flows—are included in Craters of the Moon National Monument.

Sculpture of the land

Numerous streams and rivers have cut deep gorges into the volcanic rock of the Columbia Plateau—for example the Jarbidge, Bruneau, and Owyhee River Canyons at the southern edge of this region. The gorge of the Snake River along the Oregon-Idaho border is the deepest in North America. In a 40-mile stretch of Hells Canyon between the Wallowa and Seven Devils Mountains, the Snake River has cut a canyon which averages 5,500 feet deep. Its maximum depth is 7,900 feet.

The Grand Coulee of eastern Washington, 50 miles long and up to 1,000 feet deep, was cut by the Columbia River while it was temporarily displaced by glacial ice. This valley has no stream at present, but has several lakes which occupy rock basins cut by erosion at the base of former waterfalls. The Channeled Scablands of southeastern Washington consist of valleys cut by floodwaters from a huge glacial lake which suddenly were released when an ice-dam broke.

River systems and lakes

The largest lakes in the region are associated with the Grand Coulee. These have been altered in recent times by irrigation return waters. Much of the region is arid and many lakes are saline. The Columbia River and its main tributary, the Snake River, are the major streams. Both have been impounded along their courses. A considerable portion of the flow in the Snake River originates from springs upstream from Hells Canyon in Idaho. This system of springs is one of the largest in the United States. Several regions have disrupted interior drainage due to lava flows blocking stream courses. One such area is located near Craters of the Moon National Monument.

Works of glaciers

The northern border of the Columbia Plateau region corresponds closely with the southern limit of the Cordilleran ice sheet. Alpine glaciers formed during the Pleistocene in many of the mountain ranges of northeastern Oregon. Glaciers in the Wallowa Mountains were by far the largest of these (Crandell, 1965) attaining thicknesses of up to 2,000 feet. The Wallowas exhibit spectacular glacial sculpturing.

Caves and springs

Eleven of the largest springs in the United States are found in the Snake River Plain of southern Idaho. The Snake River Plain is largely composed of Pleistocene lavas. The large springs represent the return to the surface of waters that have entered the lava plain at various places. The largest group of springs is called Thousand Springs and is located near Twin Falls, Idaho.

Geologic history

A large percentage of the rocks of this region are basalts, extruded as lava flows from Eocene to Pleistocene. The two major outpourings of lava occurred during the Miocene (Columbia River basalt) and during the Pliocene and Pleistocene (Snake River basalt). Tertiary forests were frequently buried by volcanic ash and later covered over by basalt. A large number of fossil floras have been described from this region and petrified wood is abundant.

Permian and Triassic strata are exposed in the Wallowa Mountains. Late Paleozoic and early Mesozoic strata outcrop occasionally in other mountains of northeast Oregon. Tertiary rocks were deposited in a few intermontane basins. The John Day Basin of north-central Oregon contains abundant well-preserved vertebrate and plant fossils in tuffaceous beds deposited in rivers and shallow lakes during late Oligocene and early Miocene.

Tundra

Alpine vegetation in this region is largely confined to the Wallowa and Seven Devils Mountains. Alpine plant communities in these ranges are similar to those of the northern Rocky Mountains. Their scientific interest is largely due to their isolation from more extensive alpine areas.

Boreal forest

The higher slopes of the Wallowa Mountains, Seven Devils Mountains, and a few other ranges support a subalpine forest which is essentially a northern Rocky Mountain subalpine forest. Engelmann spruce and subalpine fir dominate this forest, with whitebark pine abundant near timberline.

Dry coniferous forest and woodland

Forests of ponderosa pine grade into Douglas-fir and grand fir at higher elevations in such ranges as the Wallowa and Blue Mountains. Lodgepole pine is successional in these forests as well as in higher elevation subalpine forests. Ponderosa pine and lodgepole pine (here an edaphic climax) cover huge areas of shallow volcanic soils in central Oregon. A western juniper zone in eastern Oregon is a northern counterpart of the pinyon-juniper zone of the Great Basin.

Columbia Plateau

Grassland

The Palouse Hills of Washington, as well as most of eastern Washington and Oregon and adjacent Idaho, were once covered by grassland vegetation. Cultivation and overgrazing has drastically reduced the area dominated by grasses. This prairie type, which receives most of its precipitation in winter, has dry summers—in contrast to the prairies of the Central States. Bluebunch wheatgrass, Idaho fescue, and Nevada and Sandberg bluegrass once dominated the Palouse prairie.

Deserts

Much of eastern Washington and Oregon receives 10 inches or less precipitation annually, and supports semi-desert vegetation similar to that of the northern Great Basin. Big sagebrush, other sagebrush species, rabbitbrush, and bur-sage are the dominant shrubs, with big sagebrush by far the most abundant. Bluebunch wheatgrass, Idaho fecue, and other grasses are interspersed among the desert shrubs.

Lakes and ponds

Many of the natural lakes in the Columbia Plateau region are too saline to support fish life. In lakes inhabited by fish, the species composition is characteristic of the Columbia River system. These include cutthroat trout, sculpins, Rock Mountain whitefish, and a number of minnows including the Columbia River squawfish. Reservoirs on the Snake and Columbia Rivers are the largest bodies of water in the region. Artificial stocking of introduced salmonid fish has obscured native distribution of fishes in most of the region.

Rivers and streams

The stream habitat in the region is primarily one of large rivers. Characteristic fish species are cutthroat trout, squawfish, several species of small minnows, several species of suckers, Rocky Mountain whitefish, and sculpins. Formerly, large numbers of anadromous Pacific salmon and steelhead spawned in smaller streams of the region. These spawning runs have been greatly depleted as a result of impoundments, pollution, and over fishing. Some of the smaller streams of the region may still contain native associations of fishes.

Great Basin

Plains, plateaus, and mesas

The Great Basin is not a single large basin as the name implies. It contains more than 150 desert basins separated by mountain ranges. These basins generally contain much alluvial fill of debris eroded from the surrounding mountain ranges. A closed basin frequently has an intermittent lakebed (playa) in its lowest portion, surrounded by a slope of alluvium (bajada) which grades into the bedrock slope of the eroded mountain range (pediment).

Mountain systems

The Great Basin contains more than 160 isolated, sub-parallel mountain ranges, alined roughly in a north-south direction. The ranges were formed by block-faulting during the past 30-40 million years. The mountain blocks were raised and the adjacent basins were depressed during faulting. The resultant "basin and range topography" is strikingly different from that of any other physiographic province. The Ruby Mountains, Snake Range, Deep Creek Range, Toiyabe Mountains, and White Mountains are among the major ranges.

Works of volcanism

The northwestern portion of the Great Basin, like the adjacent Columbia Plateau and Cascade Range has extensive Pleistocene and even Recent volcanic rocks. Lava Beds National Monument, on the Modoc Plateau of northeastern California, has lava flows as young as 5,000 years.

Hot water phenomena

The second and third largest centers of geyser activity in the United States are located at Beowawe, Nev., and at Steamboat Springs, Nev., respectively. When compared to the geysers of Yellowstone, those of Nevada are small and relatively unspectacular. However, they are of great scientific interest.

River systems and lakes

The entire Great Basin is characterized by closed drainage and arid conditions; consequently, permanent surface water is relatively uncommon. The present major lakes of the region are the saline remnants of two great Pleistocene drainage lakes —Lahontan and Bonneville. Following periods of precipitation, ephemeral sump lakes are created throughout much of the region. Rapid evaporation of these lakes leaves typical alkali-covered playas. Streams usually carry water as rapid run-off or "flash floods" and are dry most of the year. Present permanent river systems have been modified to provide irrigation water. Small, and often saline, springs are fairly common in the region. Many of these have also been modified by man to provide water for livestock or domestic use.

Works of glaciers

Pleistocene glaciation was extensive in some of the high mountain ranges of the northern Great Basin. The Ruby Mountains southeast of Elko, Nev., were the most heavily glaciated of the Basin ranges. Glacial features found here include deep U-shaped canyons, cirques, hanging valleys, glacial tarns, horns, glacial polish and striations, lateral and terminal moraines, and outwash deposits (Sharp, 1938). Other ranges of the Great Basin which had extensive Pleistocene glaciers are the Deep Creek, the Snake, and the Schell Creek Ranges.

Seashores, lakeshores, and islands

During pluvial periods of the Pleistocene, the intermontane basins of the Great Basin contained lakes much larger than any that exist today. The largest of these lakes, Lake Bonneville, covered more than 20,000 square miles and was about the size Lake Michigan is today. Lake Lahontan, in western Nevada, covered 8,000 square miles. About 100 smaller lakes existed. Former levels of the lakes are indicated by shorelines high on the slopes of presently dry basins. Some of the most prominent shorelines are those of Lake Bonneville along the west base of the Wasatch Range in Utah, where four distinct strand lines have been identified.

Caves and springs

Lehman Caves National Monument features an outstanding cavern dissolved in metamorphosed Cambrian limestone. Although the Great Basin is not well known for its caves, Paleozoic limestones are present in most mountain ranges of eastern Nevada and western Utah, and numerous caves are present. One area of possible special interest is a cavern system under the southern part of the Ruby Mountains in northeastern Nevada.

Geologic history

The site of the Great Basin region was located in the Cordilleran geosyncline, and thick sediments were deposited from Cambrian to Triassic and Jurassic. Limestones and dolomites are the most common rock types in the eastern Great Basin, whereas volcanic sediments and clastics predominate in the west. Folding and thrust faulting began as early as the Pennsylvanian and reached a climax in late Mesozoic. Following a long period of erosion, block faulting began in the Miocene and continued into the Pleistocene or Recent—creating the present basin and range topography. The basins are filled with late-Cenozoic deposits. The mountain ranges expose Paleozoic rocks in the east and Mesozoic rocks in the west portion of the Great Basin.

Typical Paleozoic invertebrate fossil assemblages are found in many mountain ranges of eastern Nevada and western Utah. Mesozoic fossils are not common in rocks of this age in western Nevada, but Jurassic icthyosaur remains at Icthyosaur State Monument south of Austin, Nev., are outstanding. Fossil wood and leaf impressions of angiosperm and coniferous forests are common in Cenozoic rocks of western and northern Nevada.

Tundra

Widely isolated "islands" of alpine vegetation are present in the Great Basin. The most extensive tundra vegetation of this region occurs in the Ruby Mountains of northeastern Nevada and the Deep Creek Range of west-central Utah. Alpine vegetation is also present in the Independence, Schell Creek, and Snake Ranges. These isolated tundra communities resemble those of the middle Rocky Mountains much more closely than they resemble Sierra Nevada alpine vegetation. No areas of alpine vegetation in the Great Basin are on land administered by the National Park Service. Many of these fragile areas are grazed regularly by domestic livestock.

Boreal forest

Subalpine forests of mountain ranges in the Great Basin show remarkable variation between ranges. Subalpine fir is the principal subalpine tree species in the Independence and Jarbidge Mountains. Engelmann spruce dominates the subalpine forests of the Snake and Schell Creek Ranges. Whitebark pine is the dominant conifer in the northern Ruby Mountains, but is absent from the southern Ruby Mountains where bristlecone and limber pine are the subalpine tree species. Bristlecone pines of the White Mountains, Snake Range, southern Ruby Mountains, and other ranges commonly exceed 3,000 years in age and may attain ages up to 4,900 years and older.

Dry coniferous forest and woodland

Pinyon-juniper woodlands are extensive on the lower slopes of most Basin ranges. White fir and limber pine forest are common at higher elevations. Ponderosa pine is present in only a few ranges. This theme is represented in the National Park System only at Lehman Caves National Monument on the east slope of the Snake Range, where a small stand of pinyon-juniper is present.

Desert

The Great Basin desert or "cold desert" is dominated by shrubs of the sunflower family (Compositae) and beet family (Chenopodiaceae). The flora is much poorer in species than in the Sonoran and Chihuahuan Deserts farther south, apparently because the plants must be adapted not only to extremely dry conditions but also to cold conditions. The annual precipitation ranges from 4 to 12 inches at low elevations. Average temperatures are much lower here than in deserts farther south, and killing frosts may occur at any time. Sagebrush and shadscale are the most characteristic shrubs of this desert. In areas of high salt concentrations, certain other species characteristically are distributed along the gradient from high to low salt concentrations of the soil. Great Basin desert is represented in the National Park System only in a very small area at Lehman Caves National Monument.

Lakes and ponds

Many of the permanent lakes (e.g. Great Salt Lake) are highly saline and entirely unsuitable for fish. Other lakes (e.g. Pyramid Lake) do contain fish populations although salinities may approach upper tolerance levels. The region as a whole contains scattered populations of fish species that were originally associated with either Lake Lahontan or Lake Bonneville. Fishes native to other river systems are restricted to the margins of the Great Basin where drainage has been disrupted. Fish species within the Great Basin show a high degree of endemism probably due to post-Pleistocene isolation and adaptation to severe conditions. Several springs in the region contain species of minnows or killifish that are found nowhere else. The Lahontan cutthroat trout is now considered endangered as much of its former habitat has been modified. Several other fish species restricted to the Great Basin are also considered endangered because of habitat alteration.

Streams and rivers

The major permanent streams in the Great Basin have been extensively modified by impoundments and diversion. A few minor permanent streams may remain in relatively free-flowing condition.

Plains, plateaus, mesas, and mountain systems

Physiographic features of this region are roughly similar to those of the Great Basin to the north. Mountain ranges and adjacent basins have been produced by block faulting in both areas. A major difference is that greater uplift has occurred in this region than in the Great Basin, and more erosion has also occurred. Precambrian basement rocks are widely exposed in the mountain ranges, and thick sections of Paleozoic and Mesozoic rocks are rare, due to an advanced stage of erosion. The ranges are typically smaller than those in the Great Basin, and the basins (often called bolsons) are larger. The mountains of Organ Pipe Cactus, Saguaro, and Joshua Tree National Monuments are characteristic of the smaller ranges of this region. The mountains of Death Valley National Monument are more like the ranges of the Great Basin region.

River systems and lakes

The major river system is the lower Colorado River. Its major tributary in the region, the Gila River, has become intermittent due to changes in land use during the past 80 years. In the Mohave Desert area, drainage is interior. The major river, the Mohave, is intermittent. Temporary playa lakes are a widespread feature of the entire region. The largest surface waters are reservoirs on the Colorado River.

Rivers and streams

Native fishes of the region are typical of the Colorado River system. Several large minnows, several suckers, killifish, and top-minnows are examples. Both water and fishes were more widespread during pluvial times. As in the case of the Great Basin, retreat of these waters has resulted in widely scattered groups of endemic fishes. The Devils Hole pupfish is restricted to a single spring located in Death Valley National Monument. Other significant species include the Gila trout in the headwaters of the Gila River.

Geologic history

Precambrian rocks predominate in the mountain ranges of this region except for the Death Valley and Southern Nevada sectors of the Mohave Desert. In the Sonoran Desert many ranges are composed entirely of Precambrian rock. Death Valley National Monument has excellent exposures of Cambrian, Ordovician, and Silurian strata. Mississippian, Pennsylvanian, and Permian formations outcrop in the cliffs of the Spring Mountains, west of La Vegas, Nev.

Mesozoic rocks are almost completely lacking in this region. Loosely consolidated sediments, dating from Miocene to Recent, fill the intermontane basins. No outstanding fossil deposits are known to occur in this region.

Boreal forest

Bristlecone and limber pine occur at 8,500–11,000 feet on isolated ranges in the Mohave Desert such as the Spring Mountains, the Sheep Range, and the Panamint Range. Engelmann spruce and subalpine fir form a subalpine forest on the highest slopes of the Santa Catalina Mountains and a few other ranges in southern Arizona. This theme receives representation in Death Valley National Monument, where

bristlecone and limber pine grow on Telescope Peak in the Panamint Range.

Dry coniferous forest and woodland

Pinyon-juniper woodland grows at 5,500–7,500 feet in the mountains of the Mohave Desert and is well represented in the mountains of Death Valley National Monument. Ponderosa pine, white fir, and Douglas-fir forests occur in many mountain ranges of southern Arizona, including the Rincon Mountains in Saguaro National Monument. Ponderosa pine and white fir also occur in the Spring Mountains and Sheep Range of the Mohave Desert.

Chaparral

Saguaro and Organ Pipe Cactus National Monuments have evergreen shrubs and small trees at middle elevations. Manzanita, several *Ceanothus* species, mountain-mahogany, and several scrub oaks are the dominant species of this zone. Alligator juniper and Mexican pinyon are often present.

Desert

This region has two major deserts—the Mohave and the Sonoran. The Mohave Desert includes southern Nevada and a large segment of southeastern California. Death Valley, where temperatures reach up to 134° F. and mean annual precipitation is less than 2 inches, is part of the Mohave Desert. The extreme environments, resulting from high temperature and low moisture availability, support very simple plant communities dominated by creosotebush and bur-sage. The majority of plant species found here are inconspicuous winter annuals which depend on autumn rains for germination. Reproductive success of desert rodents has recently been shown to depend on the presence of these small winter annual plants. Joshua-tree is a conspicuous species at upper elevations (3,000–4,000 feet) in the Mohave. Death Valley and Joshua Tree National Monuments give good representation of this desert type.

The Sonoran Desert lies mainly in Baja California and inland Mexico, but extends north into southern Arizona. In contrast to the Mohave, the Sonoran Desert is rich in species and has a mixture of bizarre life forms. Saguaro and organpipe cactus are large columnar forms characteristic of this desert. Creosotebush, bur-sage, mesquite, ocotillo, and paloverde are common. The weird desert life forms reach their ultimate in Baja California with such species as boogum tree (*Idria columnaris*) and elephant tree (*Pachycormis*). The portion of the Sonoran Desert within the United States is well represented in Saguaro and Organ Pipe Cactus National Monuments.

Mountain systems

Diverse types of mountains which are difficult to categorize occur in the region. Block-faulted ranges are most prevalent but these only remotely resemble the block-faulted ranges of the Great Basin. Some mountains are built of igneous intrusion; others are laccolithic. The Marathon Basin of Texas contains the roots of folded mountains closely resembling the Appalachians in structure. The Guadalupe Mountains are dominated by an uplifted Permian barrier reef complex.

With such a diversity of mountain types in this region, thorough representation is probably unfeasible. The Chisos Mountains of Big Bend National Park and the mountains of Guadalupe Mountains National Park give good representation to this theme.

Sculpture of the land

This theme receives excellent representation in Big Bend National Park and Chiricahua National Monument. Santa Elena and Boquillas Canyons on the Rio Grande in Big Bend National Park are up to 1,500 feet deep. Chiricahua National Monument contains remarkable rock formations and pinnacles eroded in cemented volcanic ash deposits.

Eolian landforms

Sand dunes are common features of the desert region of the Southwest and occur in the Mohave Desert, Sonoran Desert, and Great Basin as well as in this region. The fine white gypsum of the Tularosa Basin of New Mexico are included in White Sands National Monument. The gypsum is derived from Permian rocks exposed in ridges flanking the Tularosa Basin. Weathering has broken exposed gypsum crystals into small grains, which have been carried by the wind and built into dunes.

River systems and lakes

Surface water is a relatively uncommon feature of this region. Several large regions of interior drainage occur in the area, the most extensive lying east of the Rio Grande in Texas and New Mexico. Ephemeral sink lakes are a feature of these regions. The Rio Grande is the major river in the area while intermittent headwater tributaries of the Gila River drain the western portion. The entire area is extremely arid and portions of the Rio Grande occasionally dry up. The largest surface water areas are manmade reservoirs.

Caves and springs

Carlsbad Caverns National Park, in the northern Guadalupe Mountains, contains the largest and most beautiful underground chambers known. The largest of these chambers, the Big Room, is 1,800 feet long, 255 feet high, and has a floor space of 14 acres. Permian Capitan limestone was dissolved to form these caverns.

Geologic history

Rocks of either Permian or late-Tertiary age occur at the surface over most of this region, although Precambrian rocks and strata of most Paleozoic and Mesozoic periods are sparingly present. The Permian reef complex, exposed in the Guadalupe and Glass Mountains of Texas, is a unique feature in North American geological history. These reefs were built

by lime-secreting sponges, algae, and bryozoans. The best exposures of the reef complex are at the southern end of the Guadalupe Mountains and are included in Guadalupe Mountains National Park. Permian invertebrate fossils are abundant in the rocks of the reefs.

Boreal forest

Boreal forest covers very little area in this region and is of interest chiefly because of the isolation of the stands and because this is the southern limit of Engelmann spruce and subalpine fir. Englemann spruce is relatively widespread, occurring south to the Mogollon and Black Mountains in southwestern New Mexico and the Sacramento Mountains. Subalpine fir apparently occurs in the region only in the Sandia Mountains near Albuquerque and in the Mogollon and Black Mountains. White fir occurs in most of the higher ranges south to the Sacramento Mountains.

Dry coniferous forest and woodland

Ponderosa pine, Douglas-fir, and southwestern white pine are the most mesic conifer species south of the Sacramento Mountains and occur in widely isolated stands in interesting combinations. All three of these mesic species occur in the Gudadalupe Mountains, but only ponderosa pine and Douglas-fir are in the Chisos Mountains. The Davis Mountains have only ponderosa and limber pine (Wells, 1966). Several juniper and pinyon species are common in this region. This theme is well represented in Guadalupe Mountains and Big Bend National Parks and Chiricahua National Monument.

Grassland

Grassland and shrub savanna are widespread in this region. Important grass species are several grama grasses (*Bouteloua* spp.), galleta (*Hilaria jamesii*), tobosagrass (*Hilaria mutica*), and mountain and burlyleaf muhly (*Muhlenbergia* spp.). Desert shrubs have invaded the grasslands over much of the Southwest. Representative tracts of this grassland type are included in Big Bend and Carlsbad Caverns National Parks.

Chaparral

Mountain ranges rising out of the Chihuahuan Desert have a zone of evergreen shrubs and small trees at middle elevations. Scrub oaks, Texas madrone, alligator juniper, and manzanita are characteristic species. This theme is well represented in Guadalupe Mountains, Carlsbad Caverns, and Big Bend National Parks and Chiricahua National Monument.

Desert

The Chihuahuan Desert has the main portion of its area in Mexico, but it extends north into southern New Mexico and western Texas. Its elevation is mainly between 4,000 and 6,000 feet. Temperatures are warmer than those in the Great Basin, but cooler than temperatures in the Sonoran Desert. The plant communities are more complex than those of the Great Basin "cold desert," but less complex than many in the Sonoran Desert, partially as a result of the more frequent frosts here. Ocotillo, creosotebush, mesquite, sotol, century plant, and numerous cactuses are the most conspicuous plant species of the Chihuahuan Desert. This theme receives excellent

representation in Big Bend and Guadalupe Mountains National Parks. White Sands National Monument contains an atypical, but interesting, segment of this desert.

Lakes and ponds

Permanent lakes and ponds are now uncommon in the Chihuahuan Desert although they (and native fishes) were more widespread during pluvial times. Desiccation of the region has left scattered small populations of minnows and killifish, some of which are endemic to a single location. At least two of these populations are considered endangered—the Comanche Springs pupfish and the Big Bend gambusia. The latter species is endemic in Big Bend National Park.

Rivers and streams

The only major stream is the Rio Grande. Most other streams are intermittent. Impoundment of the Rio Grande has altered native fish distribution. Native fishes include gar-pike, catfish, three distinct groups of suckers, many species of minnows (particularly of the genus *Notropis*), killifish, topminnows, sunfish, darters, and one cichlid. This latter species (Rio Grande cichlid) is at the northern terminus of the range of distribution. The family is native to streams in tropical America and Africa.

Colorado Plateau

Plains, plateaus, and mesas

The characteristic topography of this region is that of broad plateaus bounded by receding escarpments. Some of these plateaus are the highest in the United States. The Aquarius Plateau of south-central Utah and Grand Mesa of western Colorado exceed 11,000 feet in elevation. This theme has excellent representation in areas of the National Park System. Outstanding examples are portions of the Kaibab Plateau (Grand Canyon National Park), the Paunsagunt Plateau (Bryce Canyon National Park), the Markagunt Plateau (Cedar Breaks National Monument), and Mesa Verde.

Cuestas and hogbacks

The receding escarpments at the plateau margins in this region characteristically form cuesta scarps. Perhaps the most famous of these are the south facing exposures of widespread extent—the Chocolate, Vermillion, White, Gray, and Pink cliffs composed of rock strata ranging in age from Triassic to Eocene. Hogback-type features are common in the Colorado Plateau. Structures such as the San Rafael Swell, Upheaval Dome, and the anticlines of the Paradox Salt Basin expose resistant sandstones which form hogbacks. This theme is moderately wel represented in Capitol Reef and Canyonlands National Parks.

Mountain systems

The mountains of the Colorado Plateau are domal structures produced by intrusions of stocks and laccoliths. These include the Henry, La Sal, Abajo, Navajo, Carrizo, and El Late Mountains. Thornbury (1965) points out that the Henry Mountains region is one of the classical areas of American geology, made famous by studies of Gilbert and more recently by Hunt. Dome mountains are nowhere represented in the National Park System.

Works of volcanism

About 15,000 square miles of the Colorado Plateau region is covered with eruptive igneous rocks. The three major volcani areas are in the High Plateaus of Utah, the San Francisco Peaks area of Arizona, and the Mount Taylor area of New Mexico. A smaller volcanic field in northeastern Arizona and adjacent New Mexico has produced volcanic necks, such as Shiprock, and lava-capped mesas and buttes, such as those in Monument Valley. One of the most recent eruptions of the region was at Sunset Crater (about A.D. 1065), now a nation monument. Lava flows are represented at Grand Canyon National Monument.

Sculpture of the land

Deep canyons are more common in the Colorado Plateau tha in any other part of the United States (Thornbury, 1965). T great amount of relief of the region is the result of incision o deep canyons below moderately flat terrain, rather than of mountain uplift. The arid climate and spasmodic rainfall promote canyon cutting. This theme is spectacularly represented at Grand Canyon, Zion, Bryce Canyon, Canyonlands, and Capitol Reef National Parks, and at Cedar Breaks, Natural Bridges, Black Canyon of the Gunnison, Colorado, Rainbow Bridge, and Grand Canyon National Monuments.

Colorado Plateau

River systems and lakes

The Colorado Plateau historically was characterized by turbid rivers and streams in deeply incised gorges; now, many streams are regulated by man. The major rivers are the Colorado and its major tributaries, the San Juan and the lower Green River. Much of the region is arid and surface water is not a significant feature. Lakes are uncommon—most being small and ephemeral. The most conspicuous surface water features in the region are the large reservoirs of the Colorado and San Juan Rivers.

Works of glaciers

Evidence for Pleistocene glaciation on the Colorado Plateau has been reported from the San Francisco Peaks, the La Sal Mountains, Grand Mesa, and the Markagunt, Aquarius, Fish Lake, and Wasatch Plateaus. Effects of glaciation are especially conspicuous on Grand Mesa, which has more than 400 glacial lakes. The La Sal Mountains are particularly important as an example of this theme because of a detailed study by Richmond (1962) of the glacial history of these mountains.

Geologic history

Rocks of Precambrian through Eocene age are exposed in the Colorado Plateau. Only two periods, Ordovician and Silurian, are missing from the nearly horizontal sequence of Paleozoic and Mesozoic strata exposed in the canyons of the Green and Colorado Rivers. Most of the Cambrian to Eocene sequence is exposed in Grand Canyon, Zion, and Bryce Canyon National Parks. Permian rocks are common at the surface in the southern portion of the Colorado plateau. Mesozoic rocks cover most of the remainder except for the Uinta Basin, in the north, which has early Tertiary rocks at the surface.

The bottom of the Grand Canyon is one of the few localities in the Colorado Plateau where Precambrian rocks are exposed. The oldest rocks are those of the Vishnu schist—the metamorphic core of a mountain range which existed at this site during the Precambrian. Rocks of the Grand Canyon series were deposited in later Precambrian time after the previous mountain range had been leveled by erosion. These strata were tilted and block-faulted as a second mountain range was uplifted at this site. After this range had been peneplaned, the Paleozoic strata exposed in the canyon were laid down. Probably nowhere else on earth is such a long span of geologic history revealed in a single series of cliffs.

A good representation of Paleozoic fossils occur in the rocks of Grand Canyon National Park. Triassic strata of Petrified Forest National Park contain one of the best fossil wood deposits in the world, along with fossil leaves and bones of amphibians and reptiles.

Tundra

Alpine vegetation occurs in the Colorado Plateau only on the San Francisco Peaks, the La Sal Mountains, and the High Plateaus. These communities closely resemble those found under similar environmental conditions in the southern Rocky Mountains and their significance is due mainly to their extreme isolation from the similar areas of the southern Rockies.

Colorado Plateau

Boreal forest

Subalpine forests of the Colorado Plateau strongly resemble forests of the southern and middle Rocky Mountains. Subalpine fir, Englemann spruce, blue spruce, white fir, and bristlecone pine are the characteristic species. Subalpine forest of this region is well represented in the National Park System, with good examples at Grand Canyon and Bryce Canyon National Parks and Cedar Breaks National Monument.

Dry coniferous forest and woodland

Pinyon-juniper woodland is very widespread in this region. The pinyon (*Pinus edulis*) is a different species from the pinyon of the Great Basin (*Pinus monophylla*). A different juniper (*Juniperus monosperma*) is also present. Ponderosa pine forest is an important forest type of the Colorado Plateau. Both pinyon-juniper and ponderosa pine forest are well represented at Grand Canyon National Park. This theme is represented at Zion, Bryce Canyon, Arches, and Canyonlands National Parks, and at Natural Bridges and other national monuments of this region.

Grassland

Tracts of grassland may have once been common in the Colorado Plateau, but they are rare at present. Virginia Park, in Canyonlands National Park, has one of the few remaining pristine grassland communities in this region. Other parts of Canyonlands National Park have moderately disturbed grasslands sites. Over-grazing during the past 100 years has probably resulted in the invasion of sagebrush into former grassland throughout most of its extent in this region.

Desert

Much of the Colorado Plateau is semi-arid to arid and has "cold desert" vegetation with many of the same species found in the Great Basin desert. Whereas Great Basin desert vegetation generally occupies basins with deep alluvial soil derived from adjacent mountain ranges, desert soils of the Colorado Plateau are often thin and are greatly influenced by the underlying bedrock. This situation results in interesting local variations of desert plant communities. Canyonlands, Arches, Zion, and Capitol Reef National Parks provide adequate representation of this theme.

Rivers and streams

The Colorado River and its major tributaries originally contained a fish fauna in which eight of 13 genera were endemic. These fish were adapted to a relatively warm and turbid stream habitat. Some of the more important forms were several large minnows including the Colorado River squawfish. Interior cutthroat trout, several unusual suckers, spinedace, killifish, and top-minnows were typical species. Watershed damage, impoundment, and ground water withdrawal have greatly altered conditions in the region. At least six species of fish are now extinct and about twice that number are considered rare or endangered. Although the Colorado River in Grand Canyon National Park is one of the least affected portions of the system, tailwater effects of the Glen Canyon dam have changed the aquatic habitat. Native associations of fishes in the region remain only in isolated areas.

Northern Rocky Mountains

Mountain systems

Three major types of mountain ranges are found in the Northern Rocky Mountains. The northern portion of this region contains ranges produced by folding and thrust faulting. Glacier National Park in northwestern Montana contains the Lewis Range, which is composed of Precambrian sedimentary rocks that have been carried eastward over Cretaceous rocks for 20 miles by thrust faulting.

In central Idaho, numerous ranges have developed on the igneous intrusive rock of the Idaho Batholith of Jurassic age which covers 16,000 square miles. These ranges lack the north-south alinement characteristic of other ranges in the Northern Rockies. The Sawtooth Range is an outstanding member of this group.

Topography in southwestern Montana resembles that of the Great Basin. Ranges produced by faulting, such as the Tobacco Root Mountains and the Madison and Jefferson Ranges, are separated by downfaulted intermontane basins.

Works of glaciers

The mountains of Glacier National Park exhibit some of the most outstanding glacial features found anywhere in the Rockies. The glacial topography here is distinctive because of the sedimentary rocks of the Lewis and Livingstone Ranges from which the glacial cirques, horns, and aretes were carved. The spectacular glacial topography of the Sawtooth Range of Idaho is carved from crystalline rocks of the Idaho Batholith.

River systems and lakes

This region contains many of the headwaters of the Missouri and Columbia Rivers. The largest lakes and rivers are located in the northern and western portions of the region. Numerous small lakes are located in the mountains of the remainder of the region. Mountain streams are abundant, and medium-sized rivers are characteristic of the intermountain valleys. As much of the region is mountainous, stream gradient is high. Most streams are relatively clear and low in dissolved solids. Mountain lakes and streams are well represented in Glacier National Park.

Geologic history

The Northern Rocky Mountain region has the most extensive exposures of Precambrian rocks in Western United States. Most of these Precambrian rocks are part of the Belt series, composed of late Precambrian sedimentary rocks—limestones, sandstones, and shales. Fossils are scarce in the Belt series, but algal reef deposits and worm burrows have been found in Beltian rocks of Glacier National Park.

Strata were deposited in the Northern Rockies during all periods of the Paleozoic, but subsequent uplift and erosion have removed them except in small disjunct patches. Ordovician through Permian strata are exposed in the Lost River Range and neighboring ranges of south-central Idaho. Other outcrops of Paleozoic rocks are scattered through western Montana.

Mesozoic sedimentary rocks are rare in the Northern Rockies, although extensive igneous intrusions date from the Jurassic or

Cretaceous. Tertiary rocks occur in some intermontane basins. Fossils are generally rare in rocks of this region.

Tundra

Timberline in the Northern Rockies is at an elevation of about 7,000 to 8,000 feet so that alpine tundra is fairly extensive even though mountain summits are much lower here than farther south. Sedimentary rocks are much more common here than elsewhere in the Rockies, and more variety in substrates (limestones, shales, sandstones, etc.) provides a greater variety of habitats for plants. Many arctic plant species reach their southern limits in the Northern Rockies and members of the heath family are more numerous here than farther south. Glacier National Park contains a good representative sample of alpine vegetation of the Northern Rockies.

Boreal forest

Engelmann spruce is the most abundant tree species of the subalpine zone of the Northern Rocky Mountains. Subalpine fir is a co-dominant climax species with spruce. Lodgepole pine is a successional species which may form pure stands after fire. Whitebark pine becomes more important with increasing altitude in the subalpine zone. Alpine larch is a beautiful tree which occurs locally in the Northern Rockies and North Cascades. All these characteristic subalpine species occur at high altitudes in Glacier National Park.

Pacific forest

Pacific forest extends eastward across northern Washington and southern British Columbia to the continental divide in northwestern Montana and southwest British Columbia. This inland Pacific forest occurs in an area of relatively mild and moist climatic conditions—where moist Pacific air frequently is carried inland in a narrow corridor. Western hemlock and western arborvitae are dominant climax species of this Rocky Mountain variant of Pacific forest. Western larch, western white pine, and Douglas-fir are important successional species in this forest, which is well represented in Glacier National Park.

Dry coniferous forest and woodland

Forests of ponderosa pine are very widespread in western Montana and in much of Idaho. Douglas-fir stands, frequently with grand fir, occur at slightly higher elevations. The only dry coniferous forest found in Glacier National Park consists of small open stands of Douglas-fir and limber pine. Thus, this theme is very poorly represented in the National Park System. Northern Rocky Mountain ponderosa pine needs representation.

Lakes and ponds

Waters in most of the region are well suited for cold- and cool-water fish species. Native fishes include cutthroat and Dolly Varden trouts, Rocky Mountain whitefish, suckers, sculpins, Montana grayling, and several small minnows. Anadromous fishes (Pacific salmon and steelhead) are present only in the northwest portion of the area. None of the larger species of the Mississippi province (catfish, paddlefish, etc.) are represented. Native game fishes have been reduced throughout the region and are presently found, for the most

part, as remnant populations in mountainous regions. Both the west slope cutthroat trout and the Montana grayling are considered rare or endangered. The cutthroat is present in Glacier National Park. Most lakes in the region have been stocked with introduced species for many years.

Rivers and streams

Impoundments on the Columbia River have greatly reduced anadromous fish resources in the area. Impoundments and diversions have altered many other streams in the region with deleterious effects on the native fish populations. Most of the larger streams that have not been regulated are located in wild areas under Forest Service (U.S. Department of Agriculture) or National Park Service jurisdiction. Few other smaller mountain streams have been regulated and populations of native fishes are still intact in many of these.

Cuestas and hogbacks

Anticlinal mountain ranges of this region, including the Bighorn, Beartooth, Wind River, Owl Creek, and Uinta Mountains, consist of a granite core flanked by steeply dipping strata of Paleozoic and Mesozoic ages. Resistant, steeply dipping strata of such formations as the Weber sandstone and the Mesa Verde group form hogbacks. Hogbacks are best developed at the margin of the Uinta Mountains, on the northeast slope of the Wind River Range, and on the east and west slopes of the Bighorn Mountains. Spectacular hogback-type ridges are contained in Dinosaur National Monument.

Mountain systems

Thornbury (1965) describes three types of mountain ranges in the Middle Rocky Mountain region. The Bighorn, Beartooth, and Wind River Mountains are broad anticlinal folds with cores of pre-Cambrian rocks. This type of range is not represented in national parks or monuments of this region. However, Rocky Mountain National Park of Colorado contains a portion of the Front Range which displays similar structure.

The Teton, Wasatch, and Wyomide Ranges display topography resulting from faulting. Such faulting is more characteristic of the Great Basin to the west. The Teton Range rises 7,000 feet above adjacent Jackson Hole in a horizontal distance of 3 miles. Grand Teton National Park contains this spectacular mountain range.

The Absaroka Mountains represent a third type of mountain range. These mountains are the remnants of a volcanic plateau which has been deeply dissected to form mountainous topography. Part of the Absaroka Mountains is contained in eastern Yellowstone National Park.

Works of volcanism

Igneous activity in this region has been concentrated in the Yellowstone National Park area. Volcanic eruptions and flows took place mainly during two periods, one in late Cretaceous and early Tertiary time and the other during late Tertiary and Pleistocene. Rocks of the Absaroka Mountains were deposited during the earlier period of activity. The Rhyolite Plateau, covering about half of Yellowstone Park, is the result of flows during the later period. The rhyolitic flow of the Pitchstone Plateau may be more recent than the latest glacial retreat. The famous thermal features of Yellowstone Park attest to continuing activity of volcanism there.

Hot water phenomena

Yellowstone National Park contains the most outstanding hot water phenomena in the world, including geysers, boiling springs, and mud pots. Geysers occur also in New Zealand, Iceland, and Nevada, but those of Yellowstone surpass them in size, power, and number. Yellowstone has approximately 10,000 separate thermal features.

Sculpture of the land

Some of the most spectacular canyon country of the United States occurs in the eastern Uinta Mountains. Here the Green and Yampa Rivers have cut through Precambrian, Paleozoic, and Mesozoic strata, forming such canyons as Flaming Gorge.

Horseshoe, Red, Lodore, Yampa, Whirlpool, and Split Mountain Canyons. The latter four canyons are included in Dinosaur National Monument. The Grand Canyon of the Yellowstone, in north-central Yellowstone National Park, is another excellent example of this theme.

River systems and lakes

Permanent surface water is a significant feature of the Middle Rocky Mountain region. The great majority of lakes are of glacial origin. Small alpine lakes are typical of the mountains while large piedmont lakes are located along the flanks of the mountain ranges. Many of the small alpine lakes and several of the largest lakes of the region are within national parks. Headwaters of the Missouri, Green, and Snake Rivers are located within this region. Except for the larger rivers in the intermountain valleys, gradient of the streams in the region is steep. Maximum flow is in June when most streams are turbid. Otherwise the waters are typically clear and contain small quantities of dissolved solids. Most of the major rivers have been impounded, although numerous streams are still free-flowing.

Works of glaciers

During the Pleistocene, northwestern Wyoming had the largest icecaps in North America south of the continental ice. Major centers of icecap formation were in the Wind River, Absaroka, and Beartooth Mountains. These icecaps were source areas for valley glaciers which frequently extended beyond the flanks of the ranges. Glacial scouring was particularly intense in the Wind River and Beartooth Ranges where lake basins are numerous and much of the surface displays fresh, relatively unweathered bedrock. Depositional glacial features are particularly well exhibited in Jackson Hole. Grand Teton and Yellowstone National Parks display a broad spectrum of glacial features. Perhaps the most significant deficiency in regard to this theme in the National Park System is the lack of an extensive ice-scoured plateau area such as those found in the Beartooth Plateau and Wind River Range.

Caves and springs

Calcareous rocks are not abundant in the Middle Rocky Mountains, and there are few caves. Timpanogos Cave National Monument includes an interesting cavern developed in the Madison limestone.

Geologic history

Rocks of every geologic period except Silurian are exposed in this region. Both sedimentary (Uinta Mountain group) and metamorphic Precambrian rocks are exposed in the cores of anticlinal mountain ranges. Paleozoic and Mesozoic rocks are exposed, often as hogbacks, on the flanks of these ranges. Cenozoic rocks occupy the intermontane basins. A great variety of Pleistocene deposits occur here, especially in Jackson Hole and Sunlight Basin. Love and Reed (1968) and Hansen (1969) have written excellent popular treatments of geologic history in the Teton and Uinta Ranges. The remarkable geologic sections exposed on the north and south slopes of the Uinta Mountains, the east and west slopes of the Bighorn

Mountains, and the north slope of the Wind River Range provide interpretive opportunities in geologic history rivaled only by the Grand Canyon. Localities such as Sinks Canyon in the Wind River Range give a geologic section from Precambrian to Eocene (vs. Precambrian to Permian in the Grand Canyon).

The Eocene fossil forests of Yellowstone National Park give abundant evidence of plantlife existing in this region during volcanic activity 40 million years ago. Forty square miles of such forests occur in Yellowstone. Dinosaur National Monument preserves one of the best known sites for remains of large Mesozoic reptiles.

Tundra

The Middle Rocky Mountains contain some of the prime areas of alpine vegetation in the United States. Timberline here is at an elevation of about 10,000 feet and peaks reach as high as 13,785 feet. Large areas of plateaulike terrain in the Wind River and Beartooth Mountains are at elevations between 10,000 and 12,000 feet. Snow lies until late in the summer in the glaciated basins of these plateaus, furnishing abundant moisture for luxuriant growth of alpine species. Where this alpine vegetation has escaped deterioration due to sheep grazing, it is unexcelled in this country. Good stands of alpine vegetation also occur in the Uinta and Absaroka Ranges. Good samples of alpine tundra are present in Grand Teton National Park, but these samples are small.

Boreal forest

Engelmann spruce and subalpine fir dominate the subalpine zone in all ranges of the Middle Rocky Mountains. Lodgepole pine is an important successional species throughout. Whitebark pine is abundant near timberline in all ranges except the Bighorn Mountains, where it is absent. This forest type is well represented in Grand Teton and Yellowstone National Parks.

Dry coniferous forest and woodland

Ponderosa pine forest is present in the Middle Rocky Mountains only in the Bighorn and Uinta Mountains. A few scattered ponderosa pines occur in the northern Beartooth Range, but this species is lacking from large areas including Yellowstone and Grand Teton National Parks. Douglas-fir and limber pine are the characteristic tree species of the lower forest border over most of the region. Yellowstone National Park contains extensive areas of open stands of Douglas-fir and limber pine with a sagebrush understory.

Lakes and ponds

Many of the alpine lakes in the Middle Rocky Mountain region were originally barren of fish life. Few remain in this condition today. Yellowstone Lake is the only major lentic body of water in which the native cutthroat trout has not been wholly or partially displaced by introduced salmonid species. The Montana grayling, a rare species, is present in a few lakes in Montana and Yellowstone National Park. Other native fish found in the lakes of the region include Rocky Mountain whitefish, suckers, sculpins, and a few minnows. As is typical of waters of mountainous areas, few fish species are present.

Rivers and streams

Fishes indigenous to the rivers and streams of the Middle Rocky Mountain region are derived from the fauna of the Northern Rocky Mountain province, the Bonneville province, and to a slight extent in the south, the Colorado River province. These generally coincide with the three major drainage systems which originate in the region. The cutthroat trout was the only native trout and has been extirpated in much of its former range. Wild populations of this species are present in the upper Yellowstone and Snake Rivers and in several smaller isolated streams. Both the Snake River and Yellowstone River populations are found in areas of the National Park System. Other species native to the region include several *Catostomus* suckers, mountain suckers, sculpin, Rocky Mountain whitefish, and several species of minnow.

Wyoming Basin

Plains, plateaus, mesas, and mountain systems

The Wyoming Basin can perhaps best be described as resembling topographically what much of the Rocky Mountains looked like at the beginning of the Miocene period, 25 million years ago, after the ranges had been largely buried in their own sediments. Additional uplift and extensive erosion have uncovered most ranges of the Rockies. However, mountain ranges in the Wyoming Basin are still mostly covered with a thick mantle of early Tertiary sediments. The resultant topography resembles that of the Great Plains. Several ranges protrude above the Tertiary rocks, including the Rattlesnake Hills, the Ferris Mountains, and the Leucite Hills. The region is dominated by large structural basins including the Green River, Wind River, Washakie, and Laramie Basins.

Sculpture of the land

The Wyoming Basin has much badland topography, of which Hells Half Acre near Casper and the Wind River badlands are best known. Numerous rivers flow in canyons cut through mountain ranges of the Wyoming Basin and through bordering ranges; these rivers are among the best existing examples of superposition of drainage systems. The Devil's Gate on the Sweetwater River and the gorge of the Bighorn River through the Owl Creek Mountains are particularly outstanding.

River systems and lakes

Permanent water comprises a very small portion of the Wyoming Basin. The only naturally occurring lakes in the area are evaporative (and usually temporary) lakes within the Great Divide Basin. Several large piedmont lakes are located on the flanks of the Wind River Mountains at the margin of the region. Major streams and rivers typically arise in mountain ranges adjacent to the Wyoming Basin and flow more or less directly through it. Streams arising within the area are usually intermittent. Waters flowing through the Wyoming Basin usually accumulate appreciable loads of dissolved and suspended solids.

Geologic history

A few small outcrops of Precambrian and Paleozoic rocks occur in the Wyoming Basin, but most outcropping strata are Mesozoic or Tertiary. Cretaceous, Paleocene, and Eocene strata are most extensive at the surface. Younger Tertiary strata are also common. This region has yielded abundant vertebrate fossil material for paleontological study—especially dinosaurs, mammals, and fish.

The most famous dinosaur localities are Como Bluff and Bone Cabin in the Jurassic Morrison formation near Medicine Bow, Wyo. Beds of the Eocene Green River formation west of Kemmerer, Wyo., contain some of the best known fish fossils in the world. Fossil Butte National Monument has been proposed to protect these fish fossils and associated deposits. Mammal bones of Paleocene and Eocene ages are abundant in the Wind River Basin, Green River Basin, and other basins of the region.

Fossil material from the Wyoming Basin has contributed much to the worldwide picture of Mesozoic and Cenozoic life.

The region should have representation in the National Park System.

Grassland and deserts

The vegetation of the Wyoming Basin is a semidesert of sagebrush and grasses, similar to much of the northern Great Basin and southern Columbia Plateau. Big sagebrush is the dominant shrub. Western wheatgrass, bluebunch wheatgrass, plains bluegrass, and needle-and-thread grass are important grasses. This vegetation is prime habitat for sage grouse and pronghorn.

Lakes and ponds

Indigenous fish are unknown from the saline lakes of the Wyoming Basin although several types of euryhyaline crustaceans have been found. These lakes also provide habitat for migratory waterfowl.

Rivers and streams

All major streams and rivers flowing through the Wyoming Basin have been extensively modified by impoundment and diversion. Fishes indigenous to the Bonneville province and the Colorado River province are characteristic of the west slope waters. East slope waters are inhabited by fish native to the upper Mississippi province. Species of the sucker and minnow families are most abundant. The only native trout, the cutthroat, has been extirpated within the region, although a few remnant populations exist in adjacent mountain streams.

Southern Rocky Mountains

Mountain systems

Mountain ranges of the Southern Rocky Mountains are mostly north-south ranges with an anticlinal structure. The cores of these ranges are Precambrian igneous and metamorphic rocks. Steeply dipping sedimentary rocks outcrop along the range margins. The only major range which fails to conform to the general pattern is the San Juan of southwestern Colorado, which is a complex of Tertiary volcanic rocks with no north-south orientation.

Rocky Mountain National Park includes a portion of the Front Range which typifies the anticlinal structure of ranges of the southern Rockies.

Works of volcanism

The major volcanic feature of the southern Rockies is perhaps the San Juan Mountains. Rocks were extruded from Miocene to Quaternary time. The volcanic rocks were greatly dissected by stream erosion and carved by glaciers up to 40 miles long during the Pleistocene. The resulting topography is highly distinctive and spectacular. No other mountain range in the United States closely resembles the San Juan.

Eolian landforms

Great Sand Dunes National Monument, at the west base of the Sangre de Cristo Range in south-central Colorado, contains some of the tallest sand dunes in the United States. Winds blowing across the San Luis Valley lose their velocity and ability to carry sand grains at the base of the mountain range. The dunes rise up to 600 feet above the valley floor.

River systems and lakes

The headwaters of the Platte, Colorado, and Arkansas Rivers and the Rio Grande are within the Southern Rocky Mountain region. Numerous small, shallow alpine lakes (most of glacial origin) are scattered throughout the mountains of the area. There are no large natural lakes, although several large reservoirs have been impounded. Impoundment and diversion of streams is widespread although many remain free-flowing. Small, clear mountain streams are typical of the uplands. The major rivers are located in the intermountain valleys. Turbidity is associated with the spring run-off and water quality is generally good.

Works of glaciers

Due to the large area at very high elevations, parts of the Southern Rockies were heavily glaciated during the Pleistocene. The Animas Valley in the San Juan Mountains contained a glacier 40 miles long, probably the longest in the whole Rocky Mountain System (Thornbury, 1965). Rocky Mountain National Park contains a good representation of glacial features—especially cirques and tarns.

Geologic history

This region was located east of the Cordilleran geosyncline and did not receive the thick Paleozoic and early Mesozoic sediments which were deposited farther west. Paleozoic sedimentary strata are thin here except for thick Pennsylvanian and Permian deposits derived from erosion of local uplifts. Several thousand feet of Cretaceous rocks were deposited over the region just prior to the Laramide orogeny. Tertiary sedi-

ments which filled basins surrounding the ancestral Rockies have been partially removed by erosion as a result of late Tertiary uplift.

Crystalline Precambrian rocks are extensively exposed in the cores of the broad anticlinal mountain ranges which characterize this region. Paleozoic and Mesozoic rocks are exposed on the flanks of the ranges. Tertiary rocks occupy most of the basins.

The most outstanding fossil deposits of the region are at Florissant, Colo., where Oligocene plants and insects are preserved in lacustrine sediments. The recently authorized Florissant Fossil Beds National Monument protects this site. Morrison, Colo., at the foot of the Front Range west of Denver was the site of the first finds of dinosaur fossils from the Jurassic Morrison formation.

Tundra

Alpine tundra covers large areas in the Southern Rocky Mountains, even though timberline is at an elevation of 11,000 to 11,500 feet, since numerous peaks exceed 14,000 feet. Arctic species frequently occur there as relicts—in isolated localities with particularly cool, moist microclimates or with unusual edaphic conditions. The species which are dominant in the alpine vegetation are mostly species endemic to the Rocky Mountains. Rocky Mountain National Park has excellent representation of this theme.

Boreal forest

Subalpine fir and Engelmann spruce are climax dominants in subalpine forests of the Southern Rockies. Lodgepole pine forms extensive subclimax stands, some of which show little evidence of invasion by spruce and fir 100 years after fire (Moir, 1969). Limber pine characteristically occupies dry, exposed slopes at high elevations. Bristlecone pine has a scattered distribution in the Southern Rockies, but is sometimes present near timberline. Rocky Mountain National Park contains extensive subalpine forests which contain all characteristic tree species except bristlecone pine.

Dry coniferous forest and woodland

Dense stands of Douglas-fir occur below the subalpine zone in the Southern Rockies. White fir and blue spruce are common associates of Douglas-fir in relatively moist sites. At lower elevations, ponderosa pine forms extensive stands. Dry coniferous forest receives adequate representation in Rocky Mountain National Park and Florissant Fossil Beds National Monument.

Lakes and ponds

Many of the alpine lakes were originally barren of fish due to natural barriers, but most have been artifically stocked in the past 90 years. Native fish included cutthroat trout, suckers, and several minnows. Natural associations of these fish in the lakes of the region are very rare, if present at all. Some of the best alpine lakes are located in Rocky Mountain National Park.

Rivers and streams

Rivers and streams are numerous in the Southern Rocky Mountain region and provide wide habitat spectrum. Moun-

tain streams are well represented in Rocky Mountain National Park. As with lakes, most streams have been stocked with introduced trout species and the native cutthroat trout has been nearly extirpated. A remnant population of the endangered greenback cutthroat trout is found in Rocky Mountain National Park. An isolated population of the Colorado River cutthroat trout has been reported from the headwaters of the Little Snake River in the northern part of the region.

Great Plains

Plains, plateaus, and mesas

The Great Plains region is largely plateaulike extending from the Rio Grande of Texas north to Montana and North Dakota and extending north in Canada to the vicinity of Great Bear Lake. This plateau extends eastward from the base of the Rocky Mountains and is largely composed of sediments derived from the ancestral Rockies. The surface of the Great Plains descends from elevations of 5,000–6,000 feet on the west to about 1,500 feet at the east edge. Considerable dissection has occurred so that the Great Plains does not typically present a monotonously flat surface.

Cuestas and hogbacks

Hogbacks occur in the Great Plains at the east base of the Rocky Mountains, especially in Colorado, and surround the Black Hills. In both instances, the Dakota sandstone forms the most spectacular hogbacks. Cuestas, developed at the edge of outcrops of flatlying strata of the Great Plains, occur especially where resistant strata are underlain by weak strata. One of the best examples is the Pine Ridge Escarpment of western Nebraska. Cuestas commonly occur at the eastern edge of the Great Plains.

Mountain systems

The Black Hills rise 3,000–4,000 feet above the surrounding plains, reaching an elevation of 7,242 feet at Harney Peak. This isolated dome-shaped mountain uplift has a core of Precambrian granite and metamorphic rocks, surrounded by a plateau of a Permian limestone, a valley with red soils developed on the Triassic Spearfish formation, and a Dakota sandstone hogback. Mount Rushmore National Memorial is in the granitic core of the Black Hills. Jewel Cave National Monument and Wind Cave National Park are on the limestone plateau.

Many other outlier mountain ranges occur in the Great Plains in west-central Montana. Most of these closely resemble ranges of the Northern Rocky Mountains.

Works of volcanism

Devils Tower and Capulin Mountain National Monuments give fairly good representation to this theme although their volcanic features are not typical of volcanic phenomena of the Great plains. Lava-capped mesas are common in northeastern New Mexico and adjacent Colorado. Raton Mesa is perhaps the best known of these. Sills, dikes, and volcanic plugs are also frequent in this area. The Spanish Peaks near Trinidad, Colo., are volcanic stocks. Another center of volcanism in the Great Plains is at the northern edge of the Black Hills, where numerous laccolithic peaks occur. Bear Butte, near Sturgis, S. Dak., is an igneous plug.

Sculpture of the land

The two most outstanding examples of badland topography—the White River badlands of South Dakota and the Little Missouri badlands of North Dakota—are both contained in the National Park System (in Badlands National Monument and Theodore Roosevelt National Memorial Park). Scotts Bluff National Monument in western Nebraska contains eroded topography fairly representative of that area.

Eolian landforms

The Sand Hills of western Nebraska consist of a 24,000-square-mile area of dunal topography. These dunes result from wind action on weathered sediments of the Pliocene Ogallala formation. The finer fractions of the sediments were carried away and deposited as loess. The sandy materials which were left were built into dunes.

River systems and lakes

This large area is characterized by large, low gradient rivers, fewer small permanent streams, and few lakes. The Missouri is the largest river and has been impounded several times—as have most of the major rivers in the region. One area of interior drainage is northeast of the Missouri River in North Dakota. The large reservoirs are the most conspicuous surface water features of the region. Several rivers are still free flowing in their major portion. These include the White River in South Dakota and Nebraska and the Colorado and Brazos Rivers and the Rio Grande in Texas. Only a few small streams are represented in areas of the National Park System.

Works of glaciers

Only the extreme northern portion of the Great Plains was glaciated during the Pleistocene. Some of the most interesting morainal deposits of the region are just east of Glacier National Park, where mountain glaciers descending from the Lewis Range met the continental ice sheet.

Caves and springs

Two important cave areas occur in the Great Plains—in the Black Hills of South Dakota and in the Edwards Plateau of Texas. Wind Cave National Park and Jewel Cave National Monument preserve characteristic Black Hills caves which were formed through solution of the Permian Minnekahta limestone. Caverns are common in the Cretaceous Edwards limestone of the Edwards Plateau.

Geologic history

Rocks of the Great Plains are mostly Mesozoic and Cenozoic, whereas the adjacent Central Lowlands to the east are primarily composed of Paleozoic rock. Much of the Great Plains is underlain by Cretaceous rocks. These Cretaceous strata are veneered by Tertiary sediments in many areas. The oldest rocks in the Great Plains are Permian exposures in the southern portion.

A large percentage of the rocks of the Great Plains were deposited as fluvial sediments carried by rivers flowing down from the ancestral Rocky Mountains. These sediments contain locally abundant vertebrate fossil material. Cretaceous deposits of Montana (especially along the Judith River) and of eastern Wyoming and western Nebraska and Kansas (Niobrara formation) have yielded important reptile fossils. Tertiary mammal faunas are well preserved in strata of the Great Plains. Badlands National Monument contains some of the best known mammal assemblages of Oligocene age. Agate Fossil Beds National Monument preserves Miocene mammalian deposits of similar quality. Paleocene, Eocene, and Pliocene mammal faunas should receive comparable preservation if appropriate sites can be located.

Boreal forest

An interesting variant of Boreal Forest occurs in the Black Hills of South Dakota. White spruce dominates the forests at the highest elevations here. This species is at the southern limit of its range in the Black Hills and is widely isolated from other stands of white spruce in the northern Rocky Mountains and the Boreal Forest of Canada. Lodgepole pine and paper birch occur here also.

Dry coniferous forest and woodland

Ponderosa pine forest covers most of the Black Hills area. This forest is found as far west as Devils Tower, where it is represented in Devils Tower National Monument.

Much of central Texas is covered by juniper-oak savanna. Stands of Ashe juniper in the Edwards Plateau are the habitat of the golden-cheeked warbler, the survival of which is dependent upon the survival of this vegetation type. Present agricultural practices in central Texas are eliminating the juniper stands.

Grassland

The most widespread vegetation type of this region is Short Grass Prairie. Annual precipitation averages 10 to 20 inches here. Buffalograss and blue grama are the most important species, with needle-and-thread and western wheatgrass locally dominant. Mixed Grass Prairie—a mixture of short grass species with such taller species as little bluestem, tall bluestem, and sand dropseed—covers the eastern edge of the Great Plains. The Nebraska Sand Hills, due to favorable soil-moisture conditions, support a variant of Tall Grass Prairie. Mixed Grass Prairie receives fairly good representation in the National Park System with tracts in Badlands National Monument, Wind Cave National Park, and Theodore Roosevelt National Memorial Park. However, the vast area of Short Grass Plains is nowhere represented in a natural area of the National Park System.

Underground ecosystems

Mohr and Poulson (1966) state that the Edwards Plateau is biologically one of the most important cave regions in the world. The caves of this area are believed to have more than 200 species of true troglobites (organisms living only in caves) of which only about 20 percent have been scientifically described. Fish (two described species), salamanders (four species), beetles, millipedes, amphipods, and isopods are among the known cave fauna.

Lakes and ponds

Natural lakes are a minor feature of the region. In the northern part of the region, there are a number of shallow and often saline lakes that provide waterfowl habitat. A few natural lakes are in the Black Hills and a number of fluviatile lakes are along some of the major rivers. Most lakes that will support fish have been artificially stocked and it is unlikely that any still exist with native fish associations intact.

Rivers and streams

Except where influenced by impoundment, rivers of the region are often turbid during much of the year. In the southern part of the region, the rivers may go dry in certain years. Natural

flows fluctuated greatly, although this has been controlled by impoundments in recent years. Fishes in the region are those of the Mississippi province—a very complex fauna. The minnow and sucker families are represented by a large number of species. Some of the large fishes include paddlefish, sturgeon, gar pike, channel catfish, and mud catfish. Sunfish, pike, buffalo fish, and bowfin are also present although their major center of distribution is farther east. Natural associations of these fish may still be found in some of the free-flowing streams of the region.

Plains, plateaus, mesas, cuestas, and hogbacks

Preglacial topography in the Central Lowlands resembled the present topography of the Interior Low Plateaus. The topography consisted of a series of broad cuestas or plateaus surrounding several domal uplifts. Escarpments had developed on resistant rock and lowlands on weaker rocks.

Over much of the central lowlands region, Pleistocene glaciation resulted in a leveling of the topography. The leveling was not so much a result of glacial erosion of high places as of filling up low places with glacial drift. A study in central Ohio showed an average drift thickness of 96 feet, with a 30-foot depth over uplands and 200 feet over preglacial valleys. Drift thickness up to 1,100 feet has been reported in northern Michigan (Thornbury, 1965). Thus the extremely flat topography in the Central Lowlands is largely the result of the drift cover. Some of the most noteworthy escarpments occur in driftless areas of Wisconsin.

Eolian landforms

Melting ice at the margins of Pleistocene glaciers contributed vast quantities of glacial outwash to southward-flowing rivers. Deep outwash deposits were laid down in valleys of such rivers as the Missouri, Mississippi, Illinois, and Wabash. Such valleys characteristically have sand dunes on their leeward sides and loess deposits on adjacent upland areas. Loess deposits hundreds of feet thick occur immediately adjacent to some valleys. The loess quickly becomes thinner with increasing distance from the source.

Large sand dunes occur locally on the shores of the Great Lakes. The largest of these, the Sleeping Bear Dunes, are over 400 feet high.

River systems and lakes

Surface water features in this very large area vary from intermittent small streams in prairie lands to the huge expanse of the Great Lakes. Nearly all the lakes in the region, including the Great Lakes, are in the glaciated area along the northern plain. The lower Missouri, middle Mississippi, lower Ohio, and upper St. Lawrence are the major rivers. A number of other large rivers—Wabash, Illinois, etc.—are significant features of the region. Most of the rivers have been impounded or otherwise regulated. Water quality varies from excellent to poor. Pollution is severe and widespread in Ohio and Illinois, and locally severe in other areas. A few rivers and streams are still relatively unaffected by pollution and impoundment. These include portions of the AuSable, White, Little Sioux, Big Sioux, Yellow, and Turkey Rivers. Very little surface water in the region is under National Park Service jurisdiction.

Works of glaciers

Throughout much of the Central Lowlands the thick glacial till deposits dominate the landscape, obliterating any glacial relief that existed. However, many more interesting glacial deposits are present. Terminal and lateral moraines, potholes, kames, eskers, and drumlins are present, as well as shorelines of glacial lakes. Ice Age National Scientific Reserve in Wisconsin preserves an excellent cross section of the glacial features of that State. Similar reserves are needed in other States.

Seashores, lakeshores, and islands

Shoreline features of the Great Lakes exhibit great diversity. Some lakeshores are low and marshy; others have high cliffs. Many sand beaches occur, and large sand dunes are present, especially on the east shore of Lake Michigan. Some of the most spectacular rocky cliffs of Lake Superior are included in Pictured Rocks National Lakeshore. Extensive sand dunes occur in Indiana Dunes National Lakeshore and Pictured Rocks National Lakeshore, but the largest dunes of the Great Lakes are in Sleeping Bear Dunes National Lakeshore.

Geologic history

Much of the Central Lowlands is veneered with Pleistocene till deposits. The underlying rocks, mostly Paleozoic, are exposed in river valleys and unglaciated areas. Cretaceous rocks are exposed at the western edge of this region. Precambrian rocks are exposed in the northwest portion of the region and in the Arbuckle and Wichita Mountains of Oklahoma.

The flat-lying strata of the Central Lowlands contain some of the best Paleozoic fossil deposits in the United States. Cambrian rocks, some with interesting trilobite faunas, are exposed in Wisconsin and on the Upper Peninsula of Michigan. Ohio has extremely rich Ordovician fossil invertebrate deposits. The Mississinewa shale of Indiana is well known for its Silurian graptolites and coral reefs. The Silurian Postdam sandstone in Wisconsin has abundant trilobites. Iowa has excellent Devonian limestone invertebrate faunas. Northwestern Ohio is well known for its Devonian fish deposits. The Pennsylvanian coalbeds of Illinois contain abundant plant fossils.

Eastern deciduous forest

This large region contains many variations of eastern deciduous forest. Braun's (1950) Beech-Maple Forest region and Maple-Basswood Forest region are wholly contained in the Central Lowlands, and two other forest regions cover a large area.

The Beech-Maple Forest region covers parts of Indiana, Ohio, and Michigan. Beech and sugar maple are the dominants here.

The Maple-Basswood Forest region occupies parts of southern Minnesota and Wisconsin. Sugar maple and basswood are its dominants.

The Hemlock-White Pine-Northern Hardwoods region occupies northern Michigan, Wisconsin, and Minnesota. This forest type is represented at Pictured Rocks National Lakeshore.

The Oak-Hickory Forest region has diverse species combinations and represents the transition from deciduous forest to grassland. Bur oak is the most prominent species at the forest-prairie transition in the north. Post oak and blackjack oak have a comparable role in the south and form oak savannas, known as "Cross Timbers" in eastern Texas and Oklahoma. White oak, red oak, and black oak are dominant species of closed deciduous forest.

Grassland

Tall Grass Prairie covered 400,000 square miles of North America as recently as 200 years ago. This grassland type receives the most rainfall and has the greatest productivity and the greatest species diversity of any North American prairie. Annual precipitation is only 20-30 inches, but is concentrated during the early part of the growing season. Tall bluestem and Indian grass reached heights of 6 to 8 feet and sent roots to comparable depths in the rich soil. Switchgrass, little bluestem, June grass, and grama grasses were other dominant species. Forbs, especially composites and legumes, were abundant. Tall Grass Prairie was well adapted to grazing and trampling by the bison and other herbivores and to periodic fires. It was the home of numerous birds, such as the greater prairie chicken, which are seriously declining in number due to habitat destruction. Very few patches of Tall Grass Prairie remain today because the productive land is being utilized for agriculture. This vegetation type will disappear if measures are not taken soon to preserve a segment of it.

Mixed Grass Prairie covers the western portion of the Central Lowlands and the eastern portion of the adjacent Great Plains. Grama grasses, little bluestem, tall bluestem, buffalograss, and sand dropseed are among the dominants of this grassland type. The National Park System includes no unit with significant amounts of either Tall Grass Prairie or Mixed Grass Prairie in this large region.

Lakes and ponds

Lakes are abundant in the northern portion of the region but are uncommon throughout the remainder. The fish fauna of these lakes is very complex. More than 170 species of fish are present in the Great Lakes. This fauna originated from four regions—central Canada, the Mississippi, St. Lawrence River system, and Atlantic coast. Most of the smaller lakes contain fewer fish species than the Great Lakes, but species are similar. Farther to the south, the fish fauna of the lakes is derived more from the Mississippi province. Native fish in the region include whitefish (over 40 species), suckers (19 species), many minnows, catfish (12 species), troutperch, gizzard shad, lake trout, yellow perch, white perch, burbot, black bass, and sunfish. In the Great Lakes, the non-native sea lamprey and alewife have greatly altered natural relationships. Natural associations of fish are still present in some of the smaller lakes of the region. Cultural pollution has affected a number of lakes, the most notable being Lakes Erie and Michigan. No significant lake habitat is located in areas of the National Park System of the region.

Rivers and streams

South of the glaciation area are located the major streams of the region which are part of the Mississippi system. A very short portion of the St. Lawrence River is adjacent to the northeast corner of the area and many short streams flow directly into the Great Lakes. In the northwest portion, the streams and rivers flow into the Red River which drains to the Arctic Ocean. As would be expected, the fish fauna of these streams is complex. Most widespread are the Mississippi

province fishes—suckers, minnows, sunfish, catfish, gar pike, bowfin, and perch. In the Red River and Great Lakes streams are typically found a more northern fauna—pikes, whitefish, burbot, troutperch, black bass, and perch. Anadromous species such as shad, alewife, sea lamprey, and, formerly, Atlantic salmon are found in the St. Lawrence system. The catadromous eel was widespread at one time. Cultural alteration of the streams of the region has been widespread. A few of the smaller streams still contain relatively intact native fish associations. Many streams in the central part of the region, particularly in the Ohio and Illinois River systems, have been devastated by pollution.

Works of glaciers

This region was repeatedly covered by advancing and retreating continental ice sheets during the Pleistocene. Scouring by the ice removed soil from vast areas and eroded the Lake Superior basin to a depth of about 700 feet below sea level. Most present topographic features date from the most recent glaciation. Lakes are very numerous in this region. Some lakes are developed in scoured rock basins, while others are on glacial deposits. Isle Royale National Park gives excellent representation to this theme. The glacial features of Isle Royale are mainly the result of erosion rather than deposition.

Seashores, lakeshores, and islands

The shoreline of Lake Superior, the largest fresh-water lake in the world, is cut in Precambrain granitic and metamorphic rock. Isle Royale is composed of similar rock. Because of isostatic rebound following the retreat of glacial ice, the outlet level of Lake Superior has fluctuated widely over the past 10,000 years and the shoreline has likewise fluctuated. Ancient shorelines are particularly well preserved on Isle Royale, where this theme is well represented. One of the ancient shorelines on Isle Royale is fully as well developed as the present shoreline.

Geologic history

This region has some Cambrian rock, but most of the rock is of Precambrian age and is part of the Canadian Shield. No fossils have been found in the Precambrian rocks of this area, although intensive studies of the rocks have been conducted. Classic studies in the vicinity of Rainy Lake on the Minnesota-Ontario border (site of authorized Voyageurs National Park) provide evidence of at least two cycles of mountain uplift on this site followed by near peneplanation. Isle Royale National Park exposes rocks of the Keweenawan System believed to be among the youngest of Precambrian rocks.

Boreal forest

Boreal forest of the Superior Upland is dominated by white spruce and balsam fir, with paper birch as a common associate. Jack pine is an abundant successional species, often forming pure stands after fire. This forest type is well represented in the coastal portions of Isle Royale National Park.

Eastern deciduous forest

The Superior Upland is at the ecotone between deciduous forest and coniferous forest. It is included in Braun's (1950) Hemlock-White Pine-Northern Hardwoods region. Sugar maple is the dominant species in deciduous forests, and yellow birch is its most common associate. White pine is a fire successional species which maintains many scattered individuals in climax stands. Red pine is a common fire successional species on dry sites. This forest type is well represented in the inland portion of Isle Royale National Park.

Lakes and ponds

Lakes are so abundant and diverse in this region that few accurate generalizations can be made concerning them. Flowage (clear-water) and seepage (brown-water) lakes are present. The fish fauna is composed predominantly of northern species although many Mississippi province fishes are found. Pike, perch, whitefish (many species), lake trout, burbot, pikeperch,

troutperch, and, formerly, grayling are some of the native fishes. Several species of whitefish are endangered and the grayling has been extirpated in the region. Mississippi province species include a number of suckers and minnows.

Rivers and streams

In general, stream habitat in the region is most suitable for cold-water fishes. Gradient of the streams and rivers is low and water quality is good. Native fish species include brook trout, sauger, yellow perch, walleye, whitefish, burbot, longnose sucker, white sucker, several minnows, and darters.

River systems and lakes

Glacially formed lakes and relatively small rivers and streams are characteristic of this region. The region contains the most outstanding examples of glacially scoured lake basins in the co-terminous 48 States—some areas average more than one lake per square mile. Lake Superior is the largest and most important lake in the area. Included in the region are the headwaters of the Mississippi and Rainy Rivers. Most of the surface water in the region is of high quality.

Plains, plateaus, and mesas

Several large plateaus dominate the northern part of this region. The topographic slopes of these plateaus locally correspond with dips of nearly horizontal rock strata. Escarpments are developed on the more resistant rock formations. The three major plateaus are the Salem Plateau (developed on Ordovician limestones), the Springfield Plateau (on Mississippian limestones), and the Boston Mountains (on Pennsylvanian sandstone). Considerable dissection has occurred in these plateaus, especially in the Boston Mountains. Elevations in the Boston Mountains exceed 2,000 feet. The Springfield and Salem Plateaus are largely between 1,000 and 1,500 feet.

Mountain systems

The Arkansas Valley, between the Boston and Ouachita Mountains is a lowland occupying a trough with Pennsylvanian sandstones and shales at the surface. Most of this lowland is between 300 and 600 feet above sea level, but numerous ridges rise to 2,000 feet or more. Magazine Mountain (2,823 feet) is the highest point in Arkansas.

The Ouachita Mountains lie south of the Arkansas Valley and reach altitudes up to 2,600 feet. These mountains are composed of folded and faulted Paleozoic sandstones and shales. The Ouachita Mountains structurally resemble the folded Appalachians, of which they are believed to be a southwestward continuation.

River systems and lakes

Lakes are uncommon in the region although streams are abundant, particularly in the Ozarks. The largest river in the region is the Arkansas. Manmade reservoirs are the most conspicuous water type in the area and most of the rivers have been impounded. Portions of several rivers in southeastern Missouri—the Current, Eleven Point, and Buffalo—are still free flowing.

Caves and springs

The limestone plateaus of southern Missouri have poorly developed surface karst features, even though most conditions ideal for optimum karst development are present—soluble limestones, humid climate, and deeply entrenched valleys. The relatively poor surface karst development results from an abundance in the limestones of chert, which weathers out to form a surface residue. Karst features are probably abundant beneath this chert residue. Therefore, although surface sink holes are not apparent, caverns are abundant. Missouri has more than 400 known caverns, mostly in the limestone plateaus of the southern part of the State. Large springs are abundant in the Salem Plateau, where they emerge from dolomites and dolomitic limestones. Big Springs, in Carter County, Mo., is the largest of these, with a daily flow of 252 million gallons. The source of water for the springs is rainfall absorbed by the permeable chert mantle covering the limestone plateau. Ozark National Scenic Riverways gives good representation to this theme.

Geologic history

Rock strata exposed in the Interior Highlands are all Paleozoic except for a 100-square-mile area in the St. François Moun-

tains of southeastern Missouri where Precambrian rocks reach the surface. The Salem Plateau of southeastern Missouri and northern Arkansas is developed on Ordovician limestone. The Springfield Plateau, which borders the Salem Plateau on the west, is developed on Mississippian limestone. The Boston Mountains are capped by Pennsylvanian sandstones and shales The Arkansas Valley is a trough with Pennsylvanian rocks at the surface. Sandstones and shales of Cambrian or Ordovician through Pennsylvanian age are exposed in the Ouachita Mountains.

Good fossil deposits occur over much of this region. Perhaps the best are in the Mississippian limestones of the Springfield Plateau.

Eastern deciduous forest

The Interior Highlands comprise the southern part of Braun's (1950) Oak-Hickory Forest region. Post oak, blackjack oak, Shumard's red oak, water oak, overcup oak, white oak, red oak, and black oak share dominance with various hickory species. Rich mixed mesophytic communities occur in deep ravines of the Boston Mountains. Shortleaf pine shares dominance with post oak and blackjack oak on dry sites on the Ozark Plateau. Shortleaf pine is especially abundant in the Ouachita Mountains and occasionally forms large pure stands. Limited representation of this theme occurs in Hot Springs National Park and Ozark National Scenic Riverways.

Rivers and streams

Fish species native to the region are members of the Mississippi fauna. The fauna in the upland region contains only a few species as compared to the lower Mississippi. Those species adapted to clear, cool waters are characteristic. Typical native fishes are walleye, sauger, black bass, suckers, and minnows. Sturgeon, paddlefish, bowfin, gar pike, and most sunfish are notably lacking.

Underground ecosystems

Caverns of the Interior Highlands have a rich fauna of troglobites which includes blind cave fish (two species), a salamander, crayfish (two species), amphipods (at least 14 species), isopods (six species), planarias (four species), and millipedes (three species).

Interior Low Plateaus

Plains, plateaus, and mesas

The Interior Low Plateau region consists of a series of plateaus separated by prominent escarpments. Most elevations in the region are between 500 and 1,000 feet above sea level. The rocky strata underlying the region are nearly horizontal. Structural domes developed along the Cincinnati arch occur in central Tennessee (Nashville dome) and central Kentucky (Jessamine dome). The oldest rock strata (Ordovician) are exposed at the centers of the domes, and outward dipping younger strata surround the structural domes. This structure of the rocks and the resistance of certain individual strata to erosion are strongly expressed in the topography. Mammoth Cave National Park is on a plateau capped by porous Mississippian sandstone and underlain by limestone.

River systems and lakes

This region is characterized by relatively large rivers and streams flowing generally northwest. Lakes are uncommon, most being small and shallow. Most of the rivers have been impounded, some in many places, and reservoirs are now the most conspicuous surface water feature. A number of smaller streams still remain free flowing.

Caves and springs

This region has some of the best and most extensive karst topography in the United States. Sink holes and caverns are abundant. Few large surface streams exist over much of the region. A variety of stages of karst development is present. Most large caverns occur in mature karst topography—where deep valleys have been cut in the plateau surfaces. Mammoth Cave National Park protects some of the largest and most interesting cave systems in the world.

Geologic history

Rocks of the Interior Low Plateaus range in age from Ordovician to Pennsylvanian, except for small Cretaceous deposits at the southwest corner of the region. Ordovician and Mississippian limestones cover much of the region. Pennsylvanian strata are confined to the northwest section. Invertebrate fossils are common, and often abundant, in the limestone.

Eastern deciduous forest

The Interior Low Plateau region corresponds closely with Braun's (1950) Western Mesophytic Forest region. The vegetation here is a remarkably varied mosaic of unlike climaxes and subclimaxes ranging from mixed mesophytic forest to grassland. Present-day vegetation bears little resemblance to the original vegetation over most of the area. For example, the famous bluegrass section of Kentucky was originally vegetated with an interesting combination of deciduous forest trees with an understory of "cane" (a grass, *Arundinaria gigantea*). Kentucky bluegrass is an introduced species. In an area where vegetation has been modified to such a degree, it would seem desirable to preserve what patches of original vegetation still exist. The "cedar glades" of the Nashville Basin of Tennessee have up to the present been little modified by civilization. Many endemic herbaceous species occur here on rocky limestone outcrops where red cedar is the major tree species.

Mammoth Cave National Park contains good samples of deciduous forest.

Rivers and streams

As previously indicated, most major rivers have been impounded. Pollution from mine drainage is a widespread problem in the region and a number of small streams have been devastated. The native fish fauna of the region is typical of the Mississippi province. Suckers, minnows, catfish, bass, black bass, shad, mooneye, and bowfin are some typical species. A few smaller streams containing native associations of fish species can probably still be found within the area.

Underground ecosystems

Fish (three species), arachnids (seven species), crayfish, numerous beetles, and millipedes are among the troglobites of the Interior Low Plateaus. Many species have distributional ranges covering most of the cave systems of this region due to extensive interconnecting passageways. Evolution has proceeded to an advanced stage here as a result of mixing of gene pools. High population levels of many species indicate that they are well adapted to the cave environment (Poulson and White, 1969). Mammoth Cave National Park gives good representation to this theme.

Appalachian Plateaus

Mountain systems

Rock strata of the Appalachian Plateaus are younger than rocks of the Appalachian Ranges region to the east. The rocks are predominantly clastic (limestone are scarce) and the strata have not been drastically folded as have those underlying the adjacent ridge and valley topography. When viewed from a distance, these plateau surfaces appear gently rolling, but major stream valleys may be incised as deeply as 2,000 feet. Elevation on the plateau surface are generally between 2,500 and 4,000 feet. The topography is strikingly different from that of adjacent regions.

River systems and lakes

Surface water features in this region are quite diverse. The northern portion was heavily glaciated and numerous lakes were formed, while lakes are uncommon in the remainder of the region. Many rivers and streams are located in the region —the headwaters of the Ohio, Delaware, and Susquehanna Rivers; the middle reaches of the Tennessee and Cumberland Rivers; and a variety of small streams. Reservoirs are a common feature of the middle and southern portions of the region. Water pollution is widespread in the region, much of it originating from mine drainage. Industrial and domestic pollution is more common in the Ohio Valley portion of the area. The best water quality is in the northern part of the region.

Works of glaciers

Pleistocene glaciers covered only the northernmost portion—in the Mohawk Valley, northern Allegheny Plateau, and Catskill Mountains of New York. Important glacial features include the Finger Lakes (occupying greatly deepened pre-glacial valleys which paralleled ice movement), the "through valleys" of west-central New York, extensive ground moraine, and periglacial boulders in northern Pennsylvania and southern New York.

Geologic history

Rocks of the Appalachian Plateaus were deposited at the western edge of the Appalachian geosyncline during the Paleozoic. These strata did not undergo folding and faulting at the end of the Paleozoic as did the same strata farther east in the Appalachian Ranges. Cambrian, Ordovician, Silurian, and Devonian strata corresponding to similar strata in the Appalachian Ranges are present here but are covered by younger Paleozoic rocks. Rocks of Pennsylvanian age cover the greatest portion of the area. Mississippian rocks outcrop along the east and west margins. Permian rocks outcrop in the central portion of the region. Devonian rocks are exposed in the far north section of the region—in New York and northern Pennsylvania.

Associated with coal deposits in Pennsylvania strata, numerous plant fossils occur which indicate the nature of the primitive swamp forests that provided the organic material present in the coal. Fossils in Permian rocks of this region contain the only record of Permian life found in eastern United States. Devonian strata outcropping in New York include some of the richest and best preserved known deposits of invertebrate fossils—especially brachiopods.

Eastern deciduous forest

The Eastern deciduous forest attains its optimum development in the Cumberland and southern Allegheny mountains and in the adjacent Cumberland and Allegheny Plateaus. Braun (1950) identifies this as the Mixed Mesophytic Forest region. Beech, tuliptree, basswood, sugar maple, sweet buckeye, red oak, white oak, and eastern hemlock are the most abundant tree species here, but 20 to 25 others may be important in climax stands of this area. Braun (1950) describes magnificent stands of this forest type, many of which have since been destroyed by lumbering and strip-mining. The northern part of the Appalachian Plateaus is part of Braun's Hemlock-White Pine-Northern Hardwoods region.

Lakes and ponds

The most significant lakes in the region are the New York Finger Lakes which lie partially in the lowland region to the north. Reservoirs are the most conspicuous surface water feature throughout the remainder of the region. The fish fauna of the region is most typical of the Mississippi province, but many Atlantic province fish species are found in the northern portion. In the north, lake trout, whitefish, brook trout, burbot, yellow perch, and white perch are typical species. Suckers, minnows, sunfish, catfish, black bass, and mooneye are among the species found in the southern and central parts of the region. Cultural pollution has become increasingly serious in many lakes where the processes of eutrophication have been accelerated.

Rivers and streams

Most of the major streams in the region have been impounded although many smaller streams remain free flowing. Mine drainage pollution is widespread in the central and southern parts of the region. Industrial and domestic pollution is locally severe in heavily populated areas. Fish species in the northern part of the region include brook trout, yellow perch, white perch, minnows, and suckers. Mississippi province fishes predominate in the central and southern portions. These include a variety of sunfish, black bass, catfish, suckers, and minnows.

Appalachian Ranges

Mountain systems

The Appalachian Range region includes Fenneman's Blue Ridge and Ridge and Valley provinces. The Blue Ridge is 550 miles long, extending from southern Pennsylvania to northeastern Georgia. In western North Carolina, the Blue Ridge is up to 80 miles wide. In northern Virginia and southern Pennsylvania, it often consists of a single ridge. It rises as much as 4,000 feet above the adjacent Piedmont Plateau, although 1,000 to 2,500 feet is more common. The Ridge and Valley province, just west of the Blue Ridge, occupies the region where complexly folded Paleozoic sedimentary strata have been eroded differentially. Outcropping sandstone forms ridges, whereas valleys are developed on limestones and shales. The ridges and valleys exhibit marked parallelism, usually in a northeast-southwest direction.

Great Smoky Mountains and Shenandoah National Parks give excellent representation of the northern and southern Blue Ridge. The National Park System includes no natural areas in the Ridge and Valley province. Therefore, this theme has less than adequate coverage.

River systems and lakes

Portions of the northern margin of the Appalachian Ranges were glaciated and contain the majority of natural lakes found in the region. The headwaters of nearly all middle and southern Atlantic coastal streams and many headwaters of rivers drained by the Mississippi River originate in this region. Streams and rivers of the region are numerous, usually small, rapid, and clear. Most of the large rivers have been regulated, but many small, free-flowing streams remain. Water quality varies from excellent to grossly polluted. Some of the best remaining river and stream habitats are in Great Smoky Mountains and Shenandoah National Parks.

Caves and springs

Numerous caverns are dissolved in the early Paleozoic calcareous rocks of this region. The greatest concentrations of caves is in the Great Valley of Virginia and in the extreme southern portion of the region (northeastern Alabama, northwestern Georgia, and southeastern Tennessee).

Geologic history

The sedimentary rocks of this region were deposited in the Appalachian geosyncline during the Paleozoic. Folding and thrust faulting deformed the previously horizontal strata late in the Paleozoic, but little metamorphism occurred. The Blue Ridge is underlain by Lower Cambrian and Upper Precambrian sedimentary rocks, mainly clastics, and Precambrian basement metamorphic and igneous rocks. The Ridge and Valley area is underlain by sandstones, shales, and limestones of Cambrian through Devonian age. Mississippian rocks are exposed in parts of the western side of the ridge and valley. Many of these Palezoic formations are richly fossiliferous, containing brachiopods, trilobites, corals, bryozoans, and other invertebrate forms. Few fossil deposits occur in Shenandoah or Great Smoky Mountains National Parks because they are located in mountains of predominatly Precambrian and early Cambrian rocks which are non-fossiliferous.

Boreal forest

Spruce-fir forests occur at high elevations in West Virginia, Virginia, North Carolina, and Tennessee. This southeastern boreal forest reaches its best development above an elevation of 5,500 feet in the Black and Great Smoky Mountains of western North Carolina and eastern Tennessee. Red spruce and Fraser fir are the dominant tree species. An evaluation of similarities and differences between the spruce-fir forests of the northern (New England) and southern Appalachians is given by Oosting and Billings (1951). The spruce-fir stands of Great Smoky Mountains National Park provide excellent representation of this forest type.

Eastern deciduous forest

The Appalachian Range region corresponds closely with Braun's (1950) Oak-Chestnut Forest region. Oak-chestnut forest no longer exists because all the chestnut trees were destroyed by the chestnut blight, a fungus disease. Oaks have filled in the niche formerly occupied by the American chestnut. Red oak, chestnut oak, scarlet oak, white oak, and tuliptree are the dominant species of climax forests over much of the region, but species composition is strongly affected by topography. Coves in the Southern Appalachians and ravines throughout this region may support stands of mixed mesophytic forest. Large areas of the Great Valley of Virginia are dominated by white oak. "Shale barren" communities of western Virginia and adjacent West Virginia contain a remarkable assemblage of endemic herbaceous species (not represented in the National Park System). Forests of Great Smoky Mountains and Shenandoah National Parks provide excellent representation of this theme.

Underground ecosystems

This region has more described species of cave organisms than any other in the United States. Beetles, crayfish, millipedes, amphipods, isopods, and planarias are prominent in the cave fauna. A species is often confined to a single cave or to a group of caves within a single valley. Resistant sandstone strata which form ridges prevent interconnecting passages between limestone cave systems of individual valleys. This situation results in many species, each with a small distributional range. Limited gene pools within a cave system have resulted in slow evolution, and, in general, cave animals in Appalachian caves are less well adapted to their environment (as evidenced by smaller populations) than those of the Interior Low Plateaus (Poulson and White, 1969). Thus these caves are important as "evolutionary laboratories."

Lakes and ponds

Lakes in the Appalachian Ranges are not numerous and most are in the northern portion. The native fish fauna is made up of species native to the Great Lakes and the northern Atlantic province. Brook trout, white perch, yellow perch, and a few suckers and bullheads are some typical fish species native to these lakes.

Rivers and streams

The fish fauna of the streams of the Appalachian Ranges contains some representatives of the Mississippi and Atlantic provinces. Few fish species of these provinces are well adapted to live in the rapid, cool streams of the region. Brook trout, several species of minnow, darters, sculpins, and a few suckers are some characteristic native fishes. In the lower courses of the rivers, there is a gradual transition to the fishes of the Mississippi and Atlantic provinces.

Piedmont

Plains, plateaus, and mesas

The Piedmont Plateau is characterized by gently rolling topography with occasional monadnocks. This topography is apparently the result of a former peneplain surface developed on metamorphic and plutonic rock. The Piedmont Plateau is between 10 and 125 miles wide. It is bounded on the east by the Fall Line and on the west by the Blue Ridge. Its elevation is between 200 and 1,800 feet, with 50 to 300 feet of local relief. Of special interest are granitic rock outcrops in the southern Piedmont from southern Virginia to Alabama. Some of these, such as Heggie's Rock near Augusta, Ga., are flat. Others, such as Stone Mountain, Ga., are huge domes of granite. National Park Service lands in the Piedmont are historical sites which are too small to adequately represent this region.

River systems and lakes

The area is characterized by large, slow rivers and few natural lakes. Many of the streams are turbid due to runoff from agricultural land. The eastern boundary of the Piedmont region is sharply defined in the rivers and streams by a fall line—waterfalls or cataracts. Many rivers have been impounded and reservoirs are the most conspicuous surface water feature.

Geologic history

The Piedmont occupies the site of part of the eastern, or eugeosynclinal, portion of the Appalachian geosyncline. Most rocks of the Piedmont are metamorphic or igneous and thus non-fossiliferous. Schists, gneisses, quartzites, slates, and granitic rocks predominate. Metamorphism was apparently most intense about midway between the Blue Ridge and the Fall Line. Rocks of the Piedmont were once thought to be mainly of Precambrian age. Most geologists now consider them to be part Precambrian and part early Paleozoic. Triassic rocks were deposited in downfaulted troughs from New Jersey to North Carolina and are exposed in strips along the eastern edge of the Piedmont. Important fossils, including dinosaur tracks, have been found in these Triassic rocks, which were laid down after metamorphism had ceased.

Eastern deciduous forest

Braun's (1950) Oak-Pine Forest region occupies most of the Piedmont. White oak, red oak, other oaks, and hickories are the major species of climax forests. Most of the forested land is in various stages of succession following abandonment of farmland. Loblolly, shortleaf, and Virginia pine cover vast areas in the Piedmont. Bottom-land forests on the floodplains of Piedmont rivers and streams are the most aesthetically attractive and species-rich forests of this region. Unfortunately most bottom-land forests of the Piedmont have been cut for timber or to make way for reservoir projects. Probably the most interesting plant communities of the Piedmont are those of the granitic flat rocks along the Fall Line from Virginia to Alabama. McVaugh (1943) describes these communities and discusses their many endemic species.

Rivers and streams

The fish fauna in the Piedmont region formerly included many anadromous and catadromous species. Shad, alewife, sea lamprey, herrings, stripped bass, smelt, and eel were the most abundant. Barriers, impoundments, diversions, and cultural pollution have reduced these fishes and nearly excluded them from the region. Native inland fish species included gar pike, bowfin, gizzard shad, channel catfish, large-mouth black bass, bluegill, crappies, bullheads, suckers, and a variety of minnows. Associations of these species are still present in many areas.

Mountain systems

Four major mountain groups occur in this region. The Adirondacks have an anticlinal structure and represent a southward extension of the Canadian Shield into the United States. Mount Marcy (5,344 feet) and Mount McIntyre (5,112 feet) are the highest peaks. The other three groups are part of the northern Appalachians. The Taconic Mountains, on the border between New York and New England, bear a structural resemblance to mountains of the Ridge and Valley province farther south. Some peaks of the Taconic Mountains reach 2,500 feet. The Green Mountains of Vermont resemble the Blue Ridge. Their highest peak is Mount Mansfield (4,393 feet). The fourth group, dominated by the White Mountains, has no counterpart farther south in the Appalachian Piedmont, where only low monadnocks rise above the plateau surface. The White Mountains are developed on a large granite pluton. Mount Washington (6,288 feet) is the highest peak of northeastern United States. Nearby Katahdin, Caledonia, Franconia, and Boundary Mountains are similar in structure to the White Mountains.

River systems and lakes

The entire region was glaciated and is well provided with lakes and streams. The larger and deeper lakes are in the northern portion—Lake Champlain being the largest. The major rivers and streams flow either into the St. Lawrence River or directly into the Atlantic Ocean. The northern part of the region has relatively high relief, and small, steep, clear streams are typical. Water quality is very good in most streams of the region. The lower reaches of rivers draining to the Atlantic are often devastated by cultural pollution, however.

Works of glaciers

None of New England or the Adirondacks escaped glaciation during the Pleistocene. Even the highest peaks of the White Mountains and Katahdin Range were apparently covered by the ice. Erosion greatly exceeded deposition. Till deposits similar to those of the Central Lowlands are absent, and even end moraines are scarce. Existing till deposits are very rocky. Glacial boulders are abundant. Ice-contact features, such as eskers and kames, are very abundant and spectacular in New England, especially in Maine. Eskers are also well developed in the Adirondacks.

Large glacial cirques exist in the White, Katahdin, and Adirondack Mountains. These cirques were probably occupied by glaciers following retreat of the continental ice.

Acadia National Park provides inadequate representation of this theme.

Seashores, lakeshores, and islands

The coastal plain bordering the Atlantic is submerged everywhere in New England except on Cape Cod. Submergence is a result of depression of northeastern North America by the load of late-Pleistocene glacial ice combined with the post-glacial sea-level rise. The coast is generally steep and rocky—composed of glacially scoured crystalline rocks. Cape Cod has an interesting combination of glacial and coastal features. Both moraines and sand dunes are present. Acadia National Park

and Cape Cod National Seashore give adequate representation to this theme.

Geologic history

The oldest rocks of this region are those of the Adirondack Mountains. The Precambrian Grenville series are metamorphic rocks which outcrop on the north and south sides of the Adirondacks. The core of these mountains is formed by igneous Precambrian rocks which were intruded into the Grenville series.

The geology of New England is basically a northward extension of Appalachian geology—with units corresponding to the Piedmont, Blue Ridge, and Ridge and Valley. Much of New England is part of the "crystalline Appalachians" with strongly metamorphosed early Paleozoic and igneous rocks. Rocks of New England and the Piedmont were deposited in the Appalachian eugeosyncline (King, 1959) and were deformed mainly during the Ordovician and Devonian periods. Small outcrops of non-deformed Mississippian rocks are exposed in New England, but later Paleozoic strata are lacking. Triassic rocks of the Newark series occur in the Connecticut Valley. Deposits younger than Triassic are found in this region only on Cape Cod and as scattered Pleistocene deposits (both marine and glacial).

Fossils are not common in this region, largely because of the predominantly metamorphosed and igneous rocks. Dinosaur footprints in rocks of the Triassic Newark series in the Connecticut Valley are outstanding, but dinosaur bones are scarce in this area.

Tundra

Timberline is exceeded in this region by a few peaks in the Adirondacks, many peaks in the White Mountains, and by Mount Katahdin. Bliss (1963) found that alpine tundra on Mount Washington in the Presidential Range more closely resembles Arctic tundra than it resembles alpine areas of Western United States. Alpine ecosystems in New England are characterized by moisture-loving species, especially by species in the heath family. Alpine tundra in Northeastern United States covers a relatively small area, has much aesthetic appeal, and is of great scientific interest.

Boreal forest

Red spruce and balsam fir dominate the boreal forest of northern New England and high elevations in the mountains. Black spruce is common in wet sites and near timberline in the White Mountains. White spruce, the climax dominant over huge areas of boreal forest to the north and northwest, is a successional species here. Forests of Acadia National Park represent this theme, but much better examples exist.

Eastern deciduous forest

Much of New England is part of the Hemlock-White Pine-Northern Hardwoods region (Braun, 1950)—characterized by alternation of deciduous, coniferous, and mixed forest communities. Sugar maple, beech, yellow birch, eastern hemlock, and white pine are climax dominants. Southern New England is part of the Oak-Chestnut Forest region.

Marine environments

The Continental Shelf north of Cape Cod is broad, with fairly deep water near shore and rows of banks and shallow water on the outer shelf margin. The cold Labrador Current carries abundant nutrients, making this an important fishing area. The broad shelf protects the coast from the full force of the ocean waves. Tidal range is large.

Estuaries

The estuaries of New England are drowned river valleys in an early stage of evolution—narrow embayments with open access to the sea. Rainfall is moderate and snowfall is heavy. Large amounts of fresh water are emptied into estuaries by swollen rivers during the spring. Salt marshes of Cape Cod National Seashore provide much less than adequate representation for this theme.

Lakes and ponds

The lakes in the northern portion of the region are typically unproductive and contain cold-water species of native fish such as brook trout, lake trout, whitefish, yellow perch, burbot, sculpins, and several small minnows and suckers. Shad, alewife, Atlantic salmon, eastern lamprey, and eel are common anadromous or catadromous species that are found in many lakes. Fresh-water populations of shad are common in the northern and eastern lakes. The smaller lakes in the southern portion of the region are often more productive and are more suited to such fish species as perch, bullhead, chubsucker, fallfish, and pickerel. Fresh-water populations of Atlantic salmon and Arctic charr are found in a few northern lakes. These landlocked forms, as well as the anadromous Atlantic salmon, are now considered rare or endangered in the United States.

Rivers and streams

Habitats vary from rapid, clear, mountain streams to large, low gradient, usually clear rivers. Native inland fishes include brook trout, yellow perch, pickerel, white perch, sculpins, minnows, and suckers. Enormous numbers of anadromous herring, lamprey, Atlantic salmon, and the catadromous eel were formerly found in most of the rivers of the region. Impoundment, diversion, and pollution have drastically reduced the number of these fishes in most areas. The northeastern streams and rivers have been modified less than most in the region. The Allagash River in Maine is an example of a major unpolluted and free-flowing stream.

Atlantic Coastal Plain

Plains, plateaus, and mesas

The Atlantic Coastal Plain is a seaward-sloping plain, averaging 75 to 100 miles in width, extending south from Long Island. Its maximum elevation at the western edge varies from sea level in New York, to 300 feet in Maryand, and to 800 feet in Georgia. Lithology of the underlying loosely consolidated sedimentary rocks is fairly uniform, unlike the situation in the Gulf Coastal Plain, so that alternating cuesta and lowland belts do not occur. Terraces are present at several levels on the outer coastal plain, resulting from variations in Pleistocene sea level and from coastal uplift. Dissection of parts of the inner coastal plain, as in the Sand Hills of North Carolina, has resulted in local relief of up to 300 feet.

River systems and lakes

The region is characterized by broad, slowly flowing, and relatively silt-free rivers and streams. Many are highly colored due to extensive swamp drainage. Large areas of salt- and fresh-water marshes adjoin the rivers of the region. Thousands of so called "bay" lakes extend from Georgia through North Carolina. These are elliptical or ovoid depressions of uncertain origin that are oriented generally in a northwest-southeast direction. They appear to be increasing in size at the present time—few exceed 20 acres—and most are quite shallow. Swamps cover large areas of the region. The most famous is the Okefenokee Swamp in the southern part of the region.

Seashores, lakeshores, and islands

The Atlantic coast is a zone of deposition. Beaches are characteristically broad and sandy. Cliffs are nowhere present. Much of the coastline in the northern portion is in drowned river valleys and is very irregular, especially in the Chesapeake Bay. Long, narrow, barrier islands are present off the coast of North Carolina, Maryland, New Jersey, and Long Island. The Sea Islands are off the coast of Georgia and South Carolina. Fire Island, Assateague Island, Cape Hatteras, and Cape Lookout National Seashores give excellent representation of the long, narrow, barrier islands with relatively little vegetative cover. The type of islands found from Cape Fear, N.C., south to Cumberland Island, Ga., need representation in the National Park System.

Geologic history

Loosely consolidated sediments of Cretaceous, Tertiary, and Quaternary age underlie the Atlantic Coastal Plain. The strata here are thinner and less varied than those of the Gulf Coastal Plain and limestones are not prominent as on the Florida Peninsula. Sand is especially abundant in Cretaceous and Eocene formations and soils are generally sandy. The total thickness of underlying sedimentary rocks exceeds 3 miles in the vicinity of Cape May, N.J. Invertebrate fossils are abundant in many coastal plain strata. Vertebrate fossils are not uncommon. Giant shark teeth are common in late Tertiary sediments.

Eastern deciduous forest

Coastal plain hardwood forests are intermediate between the temperate deciduous forests of the southeast and the sub-

tropical, broad-leaved evergreen forests of southern Florida. Beech, white oak, sweetgum, and red maple occur in mixed hardwood forests. Dry sites in the Sand Hills are dominated by turkey oak, post oak, and blackjack oak. Live oaks are climax dominants in the salt-spray zone along the Atlantic coast. Bald cypress and swamp black gum occupy swamps such as Dismal and Okefenokee. Pine forests and savannas, which exist because of fire and special edaphic conditions, are very widespread. Loblolly and longleaf pines are the most abundant trees of this region. Pond pine often grows in shrub bogs, dominated by ericaceous evergreen shrubs. White cedar swamps occupy frequently burned wet sites.

Marine environments

The Gulf Stream carries warm, subtropical water north along the southern Atlantic coast as far north as Cape Hatteras. The cold Labrador Current extends its influence south between the coast and the Gulf Stream as far south as Hatteras. The Atlantic coast has a gently sloping, moderately wide Continental Shelf. The tidal range is small to moderate. Assateague Island and Fire Island National Seashores give some representation to this theme.

Estuaries

Estuaries of the Atlantic coast exhibit great variety and have high productivity. The estuarine zone in the northern section (New Jersey, Delaware, Maryland) consists of a few large drowned river valleys and some small marsh and barrier beach systems receiving fresh water only from local runoff. The Chesapeake Bay is a unique estuary system, consisting of the drowned valleys of the Susquehanna River and numerous large tributaries. This large bay is isolated from direct ocean effects and has a reduced salt concentration. Along the southern Atlantic coast, evolution of drowned river valleys has proceeded to an advanced stage. Large rivers with a moderate sediment load have deposited much material at the river mouths, forming barrier beaches and extensive coastal marshes backed by swamps. Fire Island, Assateague Island, Cape Hatteras, and Cape Lookout National Seashores fail to adequately represent this theme. Representation is particularly desirable from Cape Fear, N.C., to Georgia.

Lakes and ponds

Lakes of the region typically contain the native fish species such as bullhead, sunfish, gizzard shad, suckers, bowfin, gar pike, and a variety of minnows. Although most of the "bay" lakes have rather low productivity, many contain extensive fish faunas.

Rivers and streams

The rivers and streams of the Atlantic Coastal region contain an abundant and varied fish fauna. Cultural alteration of stream habitat has reduced populations and altered species composition in many areas. Native fishes include suckers, bullheads, chubs, many sunfish, pickerel, gar pike, bowfin, gizzard shad, catfish, and largemouth bass. A number of anadromous fish are also found in the streams of the region.

These include striped bass, sea lamprey, summer and fall herrings, shad, alewife, smelt, and sturgeon. The catadromous eel is abundant and widespread where not affected by cultural alteration of the aquatic habitat.

Plains, plateaus, mesas, cuestas, and hogbacks

Topographic differences in the Atlantic and Gulf Coastal Plains result largely from the greater thickness, greater number, and greater variation in lithology of Cretaceous and Eocene formations deposited in the gulf region. The greater thickness and number of these strata result in widening of the coastal plain, and the increased variation in lithology results in differential erosion of the strata. The Gulf Coastal Plain is a belted coastal plain, with a series of lowlands developed on weak rocks and cuestas with infacing escarpments on resistant rocks. One of the better known lowland areas is the Black Belt, developed on the Cretaceous Selma Chalk, which was once famous for its rich soils and large cotton production.

River systems and lakes

The alluvial valley and delta of the Mississippi River are outstanding geological features. Similar features occur nowhere else in the United States on so grand a scale. The alluvial valley begins near the confluence of the Ohio and Mississippi Rivers. Its width varies from 25 to 125 miles. The river changed its course many times during the Pleistocene. Terraces along the valley result from base level changes due to rise and fall of sea level during the Pleistocene combined with upwarping. The Mississippi Delta has been laid down on the Continental Shelf during and since the sea level rise following the most recent glacial stage. The river has changed its course through the delta frequently in the past several thousand years. Most lakes are of fluviatile or coastline origin. Hundreds of deltaic-levee- or lateral-levee-type lakes are in the region. One of the largest examples of the former type is Lake Pontchartrain on the Mississippi Delta. In addition to the Mississippi, many large, low gradient rivers discharge directly into the Gulf of Mexico. Many of these are highly colored due to marsh drainage—most are turbid. Large inland marshes exist in the Yazoo Basin and extensive marshes are present along the coastline of the whole region. Considerable alteration of natural waters has occurred in the region. One possible result of this is the present encroachment of the gulf waters into the marshland of the Mississippi Delta. Reelfoot Lake, in western Tennessee, was formed by water which was diverted from the Mississippi River during an earthquake in 1812.

Seashores, lakeshores, and islands

Broad, sandy beaches are characteristic of much of the gulf coast. Extensive barrier islands occur off the coast of Texas and the Florida panhandle. Sand dunes are best developed on the Texas barrier islands. Padre Island National Seashore, Tex., includes 69 miles of the longest barrier island along United States shores.

Geologic history

The Mississippi River is currently estimated to carry 730 billion tons of solid and dissolved material to its mouth each year. This is the equivalent of 1 cubic mile of sediments every year (King, 1959). Other rivers to the east and west deliver additional sediments. Rivers ancestral to the Mississippi have been depositing sediments in a similar manner for more than 60 million years. Near the Louisiana coast, the total thickness

of Mesozoic and Cenozoic strata is probably about 8 to 10 miles (King, 1959).

Large areas of Cretaceous deposits outcrop in the inner coastal plain of the gulf region. Belts of Paleocene, Eocene, Oligocene, Miocene, Pliocene, and Pleistocene rock are encountered as one proceeds toward the gulf coast. Difference in rock lithology and rates of weathering result in distinctive topographic belts, lowlands, and cuestas paralleling the coast. Many of these strata are richly fossiliferous. The Eocene Claiborne group is one of the richest and most interesting fossil strata found anywhere (Ransom, 1964).

Eastern deciduous forest

Vegetation of the Gulf Coastal Plain is strongly influenced by geological substrate. Rapid vegetational changes are encountered when one passes from one zone of this belted coastal plain to another. Hardwood forest may occupy one geological belt, prairie and red cedar the adjacent belt, and pine forest the next zone. Pine forests occupy large areas in this region—loblolly pine in the north, slash and longleaf pine in the south. Live oak forests are widespread near the coasts. Beech-magnolia forests are an interesting combination of deciduous and evergreen broadleaved species. Evergreen magnolia, beech, several deciduous oaks, live oaks, and sweetgum are among the dominants. This forest type attains its best development on the bluffs of the Appalachicola River in Florida and Georgia, where several endemic tree species occur. Swamp forests are well developed along the lower Mississippi River, where bald cypress and water tupelo are dominants.

Grasslands

A coastal variant of Tall Grass Prairie occurs in the coastal plain of Texas and Louisiana. Many of the same species found in the Tall Grass Prairie farther north are present here—tall bluestem, little bluestem, switchgrass, Indian grass, and others. Texas needlegrass, seacoast bluestem, silver bluestem, and sacahuiste (*Spartina spartinae*) are a few of the additional dominants found here. More than 150 grass species occur in this area (Allen, 1967). Thus this coastal prairie is richer in species than the "typical" Tall Grass Prairie. Attwater's prairie chicken, once common in the coastal prairie of Texas and Louisiana, has now been reduced to less than 1,000 individuals due to habitat destruction (Fisher et al., 1969).

Marine environments

The Continental Shelf is wide where it borders the Gulf of Mexico. Warm tropical waters are moved gently by weak currents and small tidal ranges. Padre Island National Seashore gives partial representation to this theme.

Estuaries

Drowned river valleys along the gulf coast are in an intermediate stage of estuarine evolution. The estuaries are mostly moderate-sized embayments with barrier beaches and extensive marshes. Many large rivers empty fresh water with a high sediment load into the gulf. The estuarine zone of the Mississippi Delta is unique. Padre Island National Seashore is adjacent to Laguna Madre, an interesting estuary system with

extensive salt marshes. At certain seasons, parts of Laguna Madre may form a "negative estuary," where salt concentrations may be 2½ times that of ocean water.

Lakes and ponds

Fish populations are found in nearly all lakes of the region where conditions are suitable. Some species, notably the mosquito fish, can exist in waters totally devoid of dissolved oxygen for short periods. The fish fauna of the region contains many species. Commonly associated with the lakes are many suckers, bullheads, many small species of minnow, several herrings, crappies and other sunfish, gar, bowfin, and killifish.

Rivers and streams

The fishes of the rivers and streams of the Gulf Coastal Plain are members of the large and complex Mississippi province fauna and include many marine species that can tolerate low salinities. Some of the largest fresh-water fish in North America are found in this region: paddlefish, sturgeon, gar pike, channel catfish, mud catfish, buffalo fish, blue sucker, and sheepshead. Mooneye, bullhead, suckers, gizzard shad, skipjack, mud pickerel, white bass, black bass, sunfish, and a large number of small minnows are other typical fishes. Although considerable alteration of habitat has occurred during the past 100 years, many native associations of fishes still exist in the region.

Florida Peninsula

Plains, plateaus, and mesas

The Florida Peninsula is part of a platform of calcareous rocks which forms the coastal plain and Continental Shelf at the southeastern corner of the United States. Over half of this platform is submerged off the western coast of Florida. The emergent portion is a low plain reaching a maximum elevation of about 300 feet in the northern portion. The southern tip of the peninsula is very low lying and swampy. Water from Lake Okeechobee, at an elevation of 14 to 17 feet above sea level, flows southward and westward for up to 100 miles before reaching the sea. Everglades National Park includes part of the lowest-lying wetlands of the coastal plain.

River systems and lakes

Surface water is a significant feature of Florida. Thousands of solution-type lakes ranging in size from tiny ponds to lakes of many square miles in area are to be found in north and central Florida. Many of these lakes, particularly the larger ones, are quite shallow, but some are more than 100 feet deep. Swamps are also a significant feature and cover many square miles of the region. Artesian springs are abundant and are the headwaters of many large rivers and streams. Rivers and streams are of very low gradient, often colored by swamp drainage, and occasionally nearly obscured by vegetation. In some, notably the St. Johns River, tidal influences and salinity are present for many miles inland.

Diversion and drainage has altered natural drainage in some parts of the region—particularly in the south. Much of southern Florida is seasonally flooded by a slow moving, shallow river, many miles in width and choked with sawgrass. Open water sloughs are a feature. They are slow moving and more nearly permanent, deeper water drainages which generally pass through the more extensive seasonally flooded wetlands. Cypress swamps are also a conspicuous feature. These are characterized by dark-colored (due to tannic acid) water in contrast to the relatively clear water of the sawgrass "glades." Large portions of the region have been altered by interception and drainage of water to the Atlantic Ocean or the Gulf of Mexico. Most drainage is to the south under natural conditions.

Seashores, lakeshores, and islands

Most of Florida's sandy beaches on both the Atlantic and gulf coasts have been commercially developed. In addition to sandy beaches, Florida has mangrove swamps, broad salt marshes, and coral reefs bordering the sea. Everglades National Park has excellent representation of mangrove swamps. Biscayne National Monument provides good coral reef shoreline representation.

Coral islands, reefs, and atolls

The Florida Keys extend southwest in a 150-mile curve from south of Miami Beach to Key West. The eastern keys, which extend for about 110 miles, are long, narrow islands which were formed as coral reefs during a late Pleistocene interglacial period when sea level was about 25 feet higher than at present. The highest point in these keys is 18 feet above sea level. Live coral reefs occupy the shallow water at the east edge of the

keys. Biscayne National Monument includes several small keys and numerous coral patch-reefs. A group of western keys, from Bahia Honda Key to Key West, are composed of oolitic limestone which accumulated as a shoal in the late Pleistocene interglacial sea.

Caves and springs

Karst features are well developed in Florida's limestone rocks, especially in the north-central portion of the peninsula. Sink holes are abundant, and there are many underground passageways. Due to a high water table, most of the caverns are filled with water, but some in northern Florida occur above the water table. Artesian springs are numerous and large. Of the 75 largest springs in the United States, 17 are in Florida. Silver Springs, the largest, has an average daily flow of 500 million gallons.

Geologic history

The Florida Peninsula has probably long been part of the continental platform of North America, but it has only recently emerged from the sea. Sedimentary rocks as old as Cambrian, Ordovician, and Silurian underlie the peninsula. More than 15,000 feet of Cenozoic and Mesozoic rocks were penetrated by a well near the tip of Florida (Thornbury, 1965). The surface rocks of Florida are predominantly limestones, ranging in age from Eocene to Pleistocene. Oligocene strata cover much of northern Florida. Pliocene and Pleistocene formations outcrop in the south. The middle and late Cenozoic rocks are extremely rich in both vertebrate and invertebrate fossils. Mammal and fish faunas in some localities are outstanding.

Eastern deciduous forest

The Florida Peninsula region lies outside the Eastern Deciduous Forest formation as defined by Braun (1950), yet its forests have many genera and species in common with the regions to the north. Monk (1965) describes the mixed hardwood forest of north-central Florida—a forest type composed of broadleaf evergreen and deciduous trees. Pine forests, with such species as longleaf, slash, loblolly, and sand pine, cover large areas where fires burn periodically. Swamps are forested with cypresses and hardwoods. The percentage of temperate genera decreases and the percentage of tropical genera increases rapidly toward the southern end of the peninsula.

Tropical ecosystems

The vegetation of the southern Florida Peninsula is strikingly different from any other vegetation of the United States. Many plant genera and even some families of West Indian origin reach the United States only here. The complex vegetation pattern is highly dependent on geology and microtopographic differences. An elevation difference of only a few feet separates hammock forest from sawgrass marsh. The major community types are as follows (adapted from Davis, 1943):

1. Southeastern Coastal Plain Pine Forest Formation—Longleaf pine, slash pine, sand pine, and cabbage palm are dominant trees.
2. Broadleaf Evergreen Hardwood and Palm Forest For-

mation—Complex association of broadleaved evergreen hardwoods of tropical genera (mahogany, gumbo limbo, wild tamarind) occur on fire-protected upland sites in extreme southern Florida.

3. Fresh-water Swamp Forest Formation—Forests of bald-cypress and various hardwoods (red maple, pond apple, ash, etc.) occur in these habitats.

4. Marine Littoral Formation—Mangrove swamps and salt-marshes have soils covered by high tide or invaded by salt water.

5. Everglades Formation and Fresh-water Marsh Communities—Sawgrass and other fresh-water marsh species occur here in pure or mixed stands, and include small tree islands of willow, coco-plum, red bay, wax-myrtle, etc.

6. Grasslands and Low Shrub Prairie Formation—Dry and wet prairies are composed of various grasses, sedges, and rushes, with scattered tree islands and hardwood hammocks.

Everglades National Park provides good representation of each of these community types, with the exception of fresh-water swamp forests.

Marine environments

The Continental Shelf is very narrow off the east coast of Florida and very broad off the west coast. Warm tropical waters with small tidal range are present. This theme is well represented in Biscayne and Fort Jefferson National Monuments and Everglades National Park.

Estuaries

Precipitation is fairly heavy in Florida and many small rivers and streams carry fresh water into the sea. Extensive salt marshes occur behind barrier islands on the east coast and on the gulf coast north of Tampa Bay. Mangrove estuaries are well represented in Everglades National Park.

Underground ecosystems

Human access to caverns of Florida is difficult because of a high water table. An interesting fauna inhabits the underground streams and lakes; the region is best known for its blind crayfish, of which there are seven species. A salamander species, amphipods, and isopods are also present.

Lakes and ponds

Most of the lakes in the region are in solution-type basins and their water levels typically fluctuate. Many are suitable for fish, although dense vegetation makes some marginal. Fish species include bowfin, gar, catfish, crappie, largemouth bass, bluegill, chain pickerel, chubsuckers, a few minnows, and killifish. Shad, striped bass, and other anadromous species are found in a few lakes. Marine species are also occasionally found in lakes of the region.

Rivers and streams

Rivers and streams are characteristically slow moving, highly colored, and occasionally choked with vegetation. Marine species are often found some distance inland due to invasion of salt water. The St. Johns River is one of the few rivers that has a marine fauna in its headwaters and shows tidal influence 145 miles inland. An interesting marine mammal inhabiting

this and other rivers of the region is the manatee. Inland fish species include largemouth bass, bluegill, catfish, bowfin gar, killifish, mosquitofish, flagfish, and chubsuckers. Marine species include tarpon, stripped mullet, sea trout, gray snapper, snook, and drum.

Hawaiian Islands

Although the 1,600-mile-long Hawaiian Archipelago may in a broad sense be considered a single geomorphic or physiographic unit, there is sufficient diversity within the region to justify dividing it into several discrete smaller regions. For that matter, it can be argued that each side of each mountain on each major island is sufficiently different from any place else in the world to receive special consideration. However, in order to achieve a realistic balance, the Hawaiian Islands have been divided into five regions which provide a good representation of characteristic features and a reasonable consideration of unique features. The breakdown has a definite geomorphic and geographic rationale, but of equal importance are the biological considerations.

The islands probably began building on the sea floor 25 million years ago in the Miocene period. Except for the Island of Hawaii, which is chiefly Pleistocene, the major portions of the larger islands probably were built above sea level during Pliocene time. In general, the volcanoes became extinct from northwest to southeast with the old and greatly eroded Leeward Islands the oldest, Mauna Loa and Kilauea the youngest, and the remaining volcanoes intermediate in age.

Most endemic life forms in Hawaii have apparently established themselves by single chance migrations which could occur on any island offering suitable habitat. Successful movement from island to island or mountain to mountain and subsequent establishment and speciation were dependent on many factors including means of locomotion, habitat suitability, and distances between islands or mountains. Since fauna and flora distribution is greatly dependent upon geologic history, topography, and geography, the physiographic regions are, in effect, also biological regions.

In contrast to the great diversity in land biota from island to island, marine species appear to be relatively uniform or homogeneous throughout. An analysis of the inshore fish fauna, which comprises over 50 percent of the fish species and should be a good indicator of speciation, reveals little change in species composition from one locale to another. The Hawaiian inshore fish fauna as a whole, however, may contain about 50 percent endemic species. Major bottom habitats are volcanic rock, coral, coralline limestone, and sand.

Island of Hawaii

Mountain systems and the works of volcanism

Hawaii is the youngest, largest, and southernmost of the Hawaiian Islands. Of the five great volcanoes comprising this deepsea island, the extinct volcano, Kohala, is the oldest. The historically inactive volcano, Mauna Kea, rises 13,796 feet above sea level and is the highest peak in the Pacific. Hualalai has erupted once in historic time and the two southernmost volcanoes, Mauna Loa and Kilauea, are still very active and for the most part little eroded. Hawaii Volcanoes National Park, encompassing parts of Mauna Loa and Kilauea Volcanoes, contains the finest representations of active and recent volcanism in the Hawaiian Islands.

Sculpture of the land

The northeast slope of Kohala and Mauna Kea display the major stream erosional features on the island. The gorges, incised on the slope of Kohala, are more than 2,000 feet deep and the sheerness of the walls is as striking as any in the Hawaiian Islands.

Works of glaciers

During the Wisconsin glacial stage, an ice cap, estimated at 250 feet thick, covered the top of Mauna Kea. Evidence of glaciation are glacial moraines, drift, and striations.

Seashores, lakeshores, and islands

Waves driven by the nearly constant trade winds have cut high cliffs along the windward shorelines. Rapid submergences have caused alluviation of canyon mouths, especially of Kohala Mountain canyons, and reemergences have resulted in rapid marine erosion and concurrent stream erosion in canyon alluvium, leaving high gravel terraces.

Most of Hawaii's shoreline is sea cliff or rocky, with only a few scattered sand beaches present. Of interest is the black sand beach at Kalapana where the beach sand is composed of exceptionally fine black volcanic rock. Hawaii Volcanoes National Park contains several miles of Kilauea Volcano shoreline, which is mostly sea cliff.

Coral islands, reefs, and atolls

To be prepared.

Tropical ecosystems

This youngest, largest, and most geologically and topographically complex of the Hawaiian Islands exhibits a corresponding environmental diversity. This is caused by temperatures ranging from near tropical at sea level to alpine above tree line; moisture patterns ranging from orographic rainy region and soaking bogs to desert rain shadows; and substrate variations with extremes from fresh lava flows and ash deposits to deep ancient soils. These conditions provide an infinite ecological variety which are reflected in vegetation patterns.

Major native vegetation types are strand, mixed lowland forest, acacia koa forest, dryland sclerophyllous forest, *Heteropogon* grassland, *Metrosideros* forest, cloud forest, mixed mesophytic, *Metrosideros* woodland with *Gleichenia, Sophoro-Myoporum* parkland, high altitude wet cliffs, dry cliffs, microphyllous scrub, *Chenopodium* oahuense scrubs, tussock grassland, lava flows with pioneer vegetation, and ash and cinders with pioneer vegetation. Much of the lowland vege-

tation has been seriously altered and the nature and extent of the original vegetation can scarcely be surmised.

Striking differences occur in the vegetation aspects of the four large mountains on the island. Low, wet forests, bogs, and incipient bogs cover the top of the Kohala Range. Sphagnum is abundant at the heads of spectacular gorges, which contain a rich shrubby flora. The clinkery mass of volcanic rock on Hualalai's higher altitudes supports an open mixed microphyllous scrub with scattered *Sophora* and *Myoporum*. The upper reaches of Mauna Kea with its ash substratum presents a broad belt of *Sophora-Myoporum* parkland with open scrub vegetation mixed with the parkland that extends above it. The scrub reaches its highest altitude on this mountain. Barren volcanic rock caps Mauna Kea. Between 6,600 and 7,600 feet on Mauna Loa exists what is essentially a tree line zone. Although forest lobes and typical high altitude scrub extend beyond this zone in places, most of the upper Mauna Loa dome, with its slaglike lava flows, is barren or sparsely populated with mosses, ferns, or grasses.

Hawaii Volcanoes National Park contains representative samples of most vegetation types, even though several native species may not be represented. The major volcanoes have several vegetation types in common, but species composition may vary appreciably from one mountain mass to another.

Marine environments

To be prepared.

Estuaries

To be prepared.

Maui Island Group

Mountain systems and the works of volcanism

The four islands of Maui, Molokai, Lanai, and Kahoolawe share a common geomorphic attribute plus a geographic proximity which supports grouping them into a single natural region. During the late Pliocene and much of the Pleistocene the volcanic mountains of Maui, Molokai, Lanai, and Kahoolawe were joined or nearly joined, and channels separating these islands today are relatively narrow and shallow. Haleakala, the youngest volcano in this group, last erupted about 1790. It is generally considered to be a dormant volcano and an intermediate stage between the active volcanoes of the Island of Hawaii and the extinct volcanoes to the northwest. The 10,025-foot volcanic mountain contains the well-known Haleakala Crater and associated valleys—a spectacular example of major erosion and subsequent eruptions. Although the site of the last eruption is not within Haleakala National Park, the park otherwise contains the best preserved examples of volcanic landforms in the island group.

The remaining volcanoes in this group, with the exception of Lanai, consist primarily of severely eroded volcanic mountains. Features of particular interest include the old caldera on West Maui; the caldera and fault complex on East Molokai; and the crater, fault, and dike association on Lanai.

Sculpture of the land

Although much of Haleakala does not show extensive erosion, the geologic evidence indicates very large amphitheater-type valleys were once present. Two of these, Keanae and Kaupo Valleys coalesced at the summit to form a great depression. Subsequent eruptions masked several of the old valleys and partially filled others; Kaupo Valley, a notable exception, is largely filled by an enormous mudflow. Haleakala National Park incorporates the partially filled summit depression, now called Haleakala Crater; those portions of Keanae and Kaupo Valleys which penetrate the "crater" rim; and Kipahulu Valley. The middle and lower portions of Keanae and Kaupo Valleys, which form an integral part of this spectacular geologic feature, lie outside the park boundary.

West Maui, the older of the two Maui volcanoes is 5,788 feet high. Deep amphitheater-headed valleys converge toward the summit. A nearly circular depression with a deeply eroded gorge on the east side represents the ancient caldera of West Maui Volcano. The conspicuous pinnacle, Iao Needle, is an erosional remnant within the caldera.

The great eastern dome of East Molokai is eroded into grea amphitheater-headed valleys on the north and smaller ones on the south. The northern valleys tapped a large caldera which partially accounts for their large upper basins.

The canyon country of Lanai represents the major erosional feature on the island. An unusually high fault scarp shielded these valleys from lava flows and accounts for the peculiar valley alinements.

Eolian land forms

On West Molokai, a 5½-mile, cream-colored "coral" sand dune strip extends southwestward from Moomomi Beach. The cemented dunes reach heights of 60 feet and are remarkable in

that the sand source is separated from the dunes by a 600-foot cliff. On the Maui Isthmus, extensive calcareous dunes were formed during the Pleistocene when the sea level was about 60 feet lower.

Seashores, lakeshores, and islands

The coastlines vary from extensive coral sand beaches to sheer sea cliffs of impressive heights. The most extensive beaches are found along the Maui Isthmus, southern and western West Maui, and West Molokai. The great sea cliffs on windward Molokai, reaching a maximum height of 3,600 feet, may have been formed by the recession of a former fault cliff or a huge submarine landslide. The marine cliffs along the southwestern coasts of Kahoolawe and Lanai, in some places 1,000 feet high, are noted for their sheerness and are unusual in that their exposure is not on the windward side.

Coral islands, reefs, and atolls

Major coral reef development occurs along the leeward shore of East Molokai. The live fringing reef, several miles long, extends seaward for 1 mile. Reef development also occurs north of the Maui Isthmus and scattered along the southern and western Maui coast.

Geologic history

The lithified dune strip of West Molokai contains abundant shells of land snails dating back more than 40,000 years.

Tropical ecosystems

The north and east slopes of Haleakala are densely covered with acacia koa, *Metrosideros,* and cloud forests between elevations of 1,200 and 6,600 feet. Below 1,200 feet, the native lowland forest has largely been altered by man. Above 6,600 feet the forest gives way to a heathlike matrix and grassland, recently described as one of the finest native grasslands remaining in Hawaii. Well-developed mixed microphyllous scrub, sometimes called subalpine vegetation, dominates the upper west slope and portions of Haleakala Crater. Pioneer vegetation occurs on the desert-like ash and cinders. Dry sclerophyllous forest, once an important native forest, has been destroyed or severely altered, except for remnants persisting on the southwest slope of Haleakala. Typical strand communities occur along the coastline. Haleakala National Park contains representative samples of the major vegetation types except for dry sclerophyllous forest and adequate amounts of native grassland and strand communities.

Native vegetation on West Maui is primarily montane rain forest, steep wet cliffs with thin scrub covering, and extensively developed open bogs on the flat or gently sloping summit and uppermost ridges. The combined native vegetation of the West Maui Mountain is one of the best preserved, has one of the richest floras in the islands, and contains a high incidence of endemic bog and forest margin plant species.

West Molokai is low and dry and the original vegetation has generally been destroyed. Mountainous and wet East Molokai has mixed lowland forest in the valley bottom, montane rain forest and cloud forest on high slopes and ridges, bogs on relatively level places, and many native plant species on the

wet cliffs. Lanai vegetation, in the Molokai and West Maui rain-shadows, has largely been destroyed by overgrazing. Dryland sclerophyllous forest remnants suggest it was the dominant vegetation type. Kahoolawe is so severely altered from overgrazing that almost nothing is known of the original vegetation.

Marine environments

To be prepared.

Estuaries

To be prepared.

Oahu

Mountain systems and the works of volcanism

Two major volcanoes, the Waianae and Koolau, comprise the island of Oahu. The plateau separating the two mountains was formed by copious Koolau lava flows banking against the Waianae Mountains. Although the moderately old Oahu volcanoes display extensive erosion, numerous examples of volcanic activity, as recent as 5,000 years ago, are evident in secondary eruption sites such as Diamond Head, Salt Lake, Punchbowl, Kokohead, Tantalus, and Sugarloaf. There is no reason to believe that secondary eruptions may not occur again.

Sculpture of the land

Nearly 22 miles long and 2,000 feet high, the Pali, or great cliff on the windward side, is one of the most spectacular features in the islands. Its fluted form is due primarily to stream erosion, alluviation of the valley floors, and marine-eroded headlands. Some of the great amphitheater-headed valleys eroded so far headward that they passed beyond the ridgetop and beheaded leeward valleys. Huge stream-eroded valleys also exist on the southwest slopes of the Waianae Range.

Seashores, lakeshores, and islands

Extensive sand beaches are found on all sides of the island. Sea cliffs, so pronounced on the younger islands, are absent or nearly so.

Coral islands, reefs, and atolls

To be prepared.

Geologic history

Marine fossils are found at many places—the most extensive are on Oahu. The reef limestone may reach depths of 1,200 feet, alternating with layers of clay, tuff, and alluvium, along the coastal margins. Of 82 *Mollusca* studied, only three species appear to be extinct. Fossil oysters reaching a foot in diameter have been collected in the emerged reef at Black Point.

Tropical ecosystems

Except for the area above 1,600 feet elevation in the Koolau Range and on a few steep slopes of the Waianae Range, the vegetation of Oahu has been severely altered. On the leeward Koolau Range, well-developed montane rain forest persists. Landslide scars are very common and show all successional stages from bare soil to climax forest. Scrubby cloud forest, open peaty spots, and a small bog at the head of Kaipopau cover the highest elevations. The wet windward cliffs are too steep to support much vegetation except on ledges and small hanging valleys.

The much drier Waianae Range has montane rain forest on the highest elevations, an almost swampy forest at the top of Koala, and fine-mixed mesophytic forests on some of the steeper slopes and hanging valleys. A number of native plants, comprising the sand dune strand vegetation, are found at Kaena Point, at the western end of the island.

Marine environments

To be prepared.

Estuaries

To be prepared.

Mountain systems and the works of volcanism

Kauai, a dissected basaltic dome, is 5,170 feet high and 32 miles across. Spasmodic eruptions continued up to the end of the Pleistocene. The later volcanics are similar to the secondary eruption series on Oahu and are generally located in eastern and southern Kauai. The summit plateau, partly covered by the Alakai Swamp, is a remnant of a huge caldera floor. The estimated 400-foot rim has long since been eroded away by the extremely heavy rainfall (more than 600 inches some years). The ancient summit caldera, Olokele, ranks among the largest of the world and greatly exceeds in size any others in Hawaii. Subsequent erosion has greatly altered the topography and the caldera is not readily apparent.

Sculpture of the land

Steep and colorful walls characterize one of the island's most spectacular erosional features—Waimea Canyon. The canyon, 14 miles long and 2,750 feet deep, illustrates how even a small fault, diagonally crossing a volcanic dome, can concentrate water from several major drainages and give rise to a disproportionately large canyon. Wainiha and Lumahai gorges on the north slope are nearly as impressive as Waimea Canyon and illustrate the effectiveness of stream erosion on steep, wet volcanic rocks.

River systems and lakes

Despite the very high rainfall on portions of the islands, perennial streams are an oddity. Only on Kauai can perennial streams be found along most of the coast. There, streamflow is maintained by persistent mountain rainfall and by perched springs.

Seashores, lakeshores, and islands

To be prepared.

Coral islands, reefs, and atolls

To be prepared.

Tropical ecosystems

Kauai, the oldest of the main Hawaiian Islands, has the most highly evolved flora, with many endemic species. As on the other islands, the low elevation vegetation has been altered, and high elevation vegetation is relatively intact. Cloud forest and extensive bogs cover the highest elevations, which receive the greatest precipitation in Hawaii. Montane rain forest is found below the cloud forest and some excellent Koa forest grows on the higher western slopes. Wet cliff vegetation and mixed lowland forest are on the windward side. Much drier conditions on the lee side result in thinly grassed, scrubby vegetation with some mixed lowland forest. The proposed Kauai National Park would include outstanding segments of the native vegetation and a good cross section of all major vegetation types.

Almost nothing is known of the original vegetation of Niihau, but it is believed to have been primarily dryland sclerophyllous forest with *Heterogon* grasslands and some salt marsh.

Marine environments

To be prepared.

Estuaries

To be prepared.

Leeward Islands

Marking the summits of submarine volcanoes, 26 islets, reefs, and shoals known as the Leeward Islands extend northwestward from Niihau. Only low coral islands are found west of Gardner Island whereas many basaltic core remnants survive to the east.

Works of volcanism

Volcanic remnants of the Leeward Islands predate considerably the exposed portions of the main Hawaiian Islands. Except for Kaula, a secondary tuff core built on a reef platform, the volcanic islands are probably remnants of eroded primary volcanic domes. An eruption was reported in 1955 between Necker and Nihoa Islands.

Coral islands, reefs, and atolls

The non-volcanic Leeward Islands are classified as (1) emerged coral atolls or near atolls, (2) coral atolls or near atolls, and (3) shoals (probably submerged atolls). The living and emerged reefs are principally coralline algae. Kure, Green, Midway, Pearl and Hermes, Lisionski, and Laysan, ranging in elevation from 12 feet to 56 feet, are the major emerged coral atolls. Bensaleux, Fisher, Minor, Maro, Two Brothers, and French Frigate (excluding La Pérouse Pinnacle) are representative of the second category with approximately sea level elevations. Eight major shoals with elevations of −18 to −482 feet are identified.

Tropical ecosystems

The Leeward Islands have comparatively little and simple vegetation. The volcanic islands of Kaula and Nihoa have grassy slopes with a few depressed shrubs and a small group of palms on Nihoa. The remaining volcanic islands of Gardner, La Pérouse, and Necker are very sparsely vegetated. The sandy islets have a few strand herbs, a native shrub, and two introduced tree species. The original vegetation was five species.

Except for Laysan, the coral atolls apparently had only typical strand herbs and shrubs. Laysan, on the other hand, had a rich vegetation including various native trees, but introduced rabbits virtually wiped out the original vegetation.

Marine environments

To be prepared.

Estuaries

To be prepared.

Alaska

Alaska's major topographic features are comparable to and in a broad sense correlated with similar Canadian and United States features. The Alaskan coastal ranges are geologically and topographically equivalent to the coastal ranges of British Columbia, Washington, and Oregon. The Alaska Range correlates with the Sierra Nevada and Cascade provinces and the lowland between the Alaska Range and Brooks Range is somewhat comparable to the Colorado Plateau and the Basin and Range provinces. The Brooks Range is a geologic and topographic continuation of the Rocky Mountain complex and the Arctic Coastal Plain is the geologic equivalent of the Great Plains.

Plains, plateaus, and mesas

The 160-mile Copper River plateau has a generally flat and rolling terrain dotted with ponds and lakes. The gravel, sand, and silt deposits were primarily laid down by glaciers and melt waters during Quaternary time. The Cook Inlet-Susitna lowland topography is due to erosive glacial action and glacial moraine and out-wash depositions, which now enclose numerous lakes and swamps. Productive soil, suitable for agriculture, has developed on the less rugged parts.

Mountain systems

The Pacific Mountain System, consisting mainly of a broad belt of ranges paralleling the southern coast of Alaska, has been divided into seven mountain regions:

1. The coast range of Southeast Alaska has a granitic core belonging to the great Jurassic-Cretaceous batholith. Many offshore islands are separated from the mainland by fiords and drowned lowlands.
2. The St. Elias Range is, in some people's opinion, the most spectacular mountain range in North America. These mountains, consisting mostly of Paleozoic and Mesozoic sedimentary rocks, are the highest coastal mountains in the world. Mount St. Elias, 18,008 feet, is the fourth highest peak in North America. The mountain system is represented in Glacier Bay National Monument.
3. The Chugach-Kenai Mountains, although separated by two glacial fiords and a low mountain pass, are similar geologically and structurally. Not as high as the St. Elias Range, the intense glacial erosion has, nevertheless, created a very rugged terrain in the Paleozoic meta-sedimentary and volcanic rocks. Wave-cut terraces as high as 1,600 feet attest to recent and intermittent uplift.
4. The Wrangell Range, a cluster of volcanic mountains between the Chugach and Alaska Ranges, began forming in Tertiary time and continued into Recent time with the last eruption occurring in the 19th century. More than 12 peaks exceed 12,000 feet with Mount Blackburn reaching 16,523 feet. Rising conspicuously above the Copper River Plateau, the rugged snow- and glacier-covered Wrangell Mountains are among the most striking of Alaskan ranges.
5. The Talkeetna Mountains, an area 70 miles by 100 miles, reach elevations of 6,000–7,000 feet. A complex geologic history has resulted in a great variety of rocks being exposed on the ice-carved mountains.
6. The Alaska Range, one of the youngest and most striking mountain ranges in Alaska, includes Mount McKinley (20,320 feet), the highest mountain peak in North America. Forming an arc 600 miles long and 30–120 miles wide, the range forms the great mountain barrier between the Pacific Coast and interior Alaska. However, only from Mount McKinley southwestward does it form a drainage divide as six eastern rivers, rising in lowlands south of the range, flow northward through the Alaska Range to the Yukon and Tanana Rivers. This range is represented in Mount McKinley National Park.
7. The Aleutian Range forms a narrow belt of east-west

trending ridges from Mount Spurr, west of Anchorage, to the western tip of the Aleutian Island chain, a distance of 1,600 miles. This line of ridges, composed of Tertiary and older igneous rocks plus some sedimentaries, is surmounted by volcanic peaks 4,500–8,500 feet high. This range is represented in Katmai National Monument.

Works of volcanism

About 80 major volcanoes, of which 47 have been active since 1760, are contained in the 1,600-mile Aleutian Range. At least 20 large calderas, ranging from 1½–8 miles in diameter, are present above sea level. Submerged Buldir Caldera, between the islands of Kiska and Buldir, is apparently the world's largest caldera. Katmai National Monument contains outstanding volcanic features, including active volcanoes, Katmai Caldera, and the Valley of Ten Thousand Smokes. Recent volcanic activity is evident in the Wrangells and on Kruzof and Baronof Islands. Mount Edgecombe on Kruzof Island is noted for its striking symmetry.

River systems and lakes

The Pacific border region of Alaska contains an enormous number of lakes and streams. Most of the rivers and streams that drain to the Pacific Ocean are relatively short, but contain great amounts of water due to high precipitation and runoff. Major rivers emptying into the Gulf of Alaska are the relatively broad and placid Copper and Susitna Rivers. Streams draining the north slope of the Alaska Range are the headwaters of two of Alaska's largest rivers—the Kuskokwim and the Tanana. Most of the region was heavily glaciated and lakes are very abundant. A group of interconnected lakes of glacial origin are found on the Alaska Peninsula. Due to the relative lack of development, water quality is good and the area contains much water still in pristine condition. Examples of most of the water types in the region are represented in the three areas under National Park Service jurisdiction. Not represented are either of the two major rivers—the Copper and the Susitna.

Works of glaciers

During the period of greatest glacial expansion, nearly all the high ranges were covered by ice sheets. Moving down mountain valleys, long icy tongues coalesced into Piedmont glaciers, many of which spread far out to sea. Today, about 3 percent, or 20,000 square miles, of Alaska is covered by glaciers. These glaciers are largely confined to the Pacific Mountain Region and along with glacial-related phenomena are represented in the National Park System at Mount McKinley National Park and Glacier Bay and Katmai National Monuments. Not well represented are the long, narrow, and steep-walled fiords of southeastern Alaska.

Seashores, lakeshores, and islands

The coastline can be discussed under three sub-region headings:

1. Southeast Alaska has typically rugged coastline cut by channels, straits, and fiords. Glaciers extend to sea level in places and occasional flatlands occur at river mouths and

south of Yakutat Bay. The Alexander Archipelago contains many islands of various sizes. The very irregular mainland coastline plus the numerous islands result in a great many shoreline miles along this section of the continent.

2. The Kodiak Island-Gulf of Alaska area has a predominately rocky and steep coastline backed by high, rugged mountains. Numerous glaciers are at or near sea level and glaciation has deeply indented this coastline with fiords and sounds. Ridges, often extending as islands, separate the submerged indentations.

3. The Aleutian Islands have rocky steep-sided coastlines indented by fiords. Glaciated lowland and outwash plain border the sea on the east coast of Cook Inlet.

Tundra

Treeless areas vary considerably in this region. Glaciers, permanent snowfields, gravel and rock areas in front of retreating glaciers, volcanic peaks, and recent lava flows are generally barren. Sparse dry-tundra plants such as grasses, small flowering plants, and lichens inhabit the better drained soils above tree line. Moist-tundra vegetation, including cottongrass, willows, heath shrubs, dwarf birch, moss, and lichens, dominates more poorly drained slopes on the Alaska Range, Talkeetna Mountains, and Aleutian Range flanks. Tall-grass meadow communities, peculiar to the Aleutian Islands and Bering Sea coastal area, are distinctive in that Pacific coastal plants rather than arctic-alpine plants predominate. Modest amounts of wet tundra and coastal marsh are present along flood plains of major rivers. Barren-, dry-, and moist-tundra types are represented in Mount McKinley National Park and Katmai and Glacier Bay National Monuments.

Boreal forest

Boreal forest is generally restricted to the two plains regions, the Copper River plateau and Cook Inlet-Susitna lowlands, and along low-lying stream courses. Pure, white spruce stands or white spruce mixed with birch, black spruce, quaking aspen, balsam poplar, alder, and willow comprise the major forest types. This forest is represented in Mount McKinley National Park and Katmai National Monument, which contains the southwesternmost distribution of this forest type.

Pacific forest

Coastal forests of south-central Alaska consist primarily of pure stands of Sitka spruce or mixtures of spruce and western hemlock. Mountain hemlock and western red cedar may be present in smaller numbers. Southeastern Alaska forests are primarily Sitka spruce, western hemlock, and Alaska-cedar. Western red cedar, western yew, and Pacific silver fir grow in the southeasternmost reaches of the panhandle. Scrubby and malformed lodgepole pine, mountain hemlock, and Alaska-cedar are found in peat bogs or muskegs in southeastern Alaska. On well-drained lowlands and recently deposited alluvium and glacial materials, alder and cottonwood form extensive stands. Limited representation of major forest types occur in Glacier Bay National Monument.

Marine environments

To be prepared.

Estuaries

To be prepared.

Lakes and ponds

Among the almost innumerable lakes of the region, it is conceivable that some have never been visited by modern man. Anadromous fish are found in a number of lakes along the Pacific coastal region. These include all five species of Pacific salmon and, in the southern portion of the region, steelhead. Dolly Varden, sculpins, a few sucker species, and a few minnows are native throughout the area. Natural associations of fish species are the rule, rather than the exception, in lakes of the region. Many mountain lakes are still barren of fish life.

Rivers and streams

Many of the rivers and streams draining into the Pacific Ocean serve as spawning areas for Pacific salmon and steelhead. Although runs are not as abundant as formerly, enormous numbers of these fish may concentrate in specific areas. Cutthroat and rainbow trout are native in streams draining south of the Alaska Range while Dolly Varden are native in the entire region. As with lakes, native associations of fishes in the rivers and streams are generally intact. Fair representation of rivers and streams is found in the three areas under National Park Service jurisdiction. The enormous food supply associated with salmon runs in many streams and rivers attract large numbers of terrestrial carnivores. The largest population of bald eagles in North America is concentrated along the southeast coast of Alaska. Grizzly bears are also present in considerable numbers along the streams during spawning runs of anadromous fish.

Plains, plateaus, and mesas

Bounded by the Pacific Mountain System on the south, Brooks Range on the north, and Bering Sea on the west, and extending into Canada on the east is an extensive area of diverse topography drained primarily by the Yukon and Kuskokwim Rivers. An irregular assemblage of intricately dissected uplands and broad alluvium-covered lowlands characterize the topography. The lowlands average less than 600 feet in altitude; the western hills and ridgetops average 2,000 to 3,000 feet; and the interior uplands reach 4,000 to 5,000 feet. Occasional mountains of resistant intrusive igneous bodies surmount the uplands by an additional 1,000 to 2,000 feet.

Numerous lowlands and plains are scattered throughout this region. There appears to be no systematic trend to their locations. Some follow parts of major stream valleys, but elsewhere they show no such relationship. Lowlands may be slightly undulating plains, plains with low hills, exceptionally wide flood plains, or river deltas. Only locally are the lowlands free from surficial deposits of clays, silts, sands, and gravels, mainly of glacial and eolian origin, which characterize the region.

Mountain systems

Although not containing mountains comparable to the Alaska or Brooks Range, there are, nevertheless, hilly or low mountainous areas of sufficient height and extent to distinguish them from lowland plains. Western highland areas include the Seward Peninsula Highlands, Norton Sound Highlands, and Kuskokwim Mountains. The southern third of the Kuskokwims were glaciated during the Pleistocene.

The topography of the interior highlands ranges from subdued rolling hills to high rugged hills and mountains. The area has no continuous chains of mountains but rather is characterized by discontinuous groups of mountains on rolling upland. Marked topographic diversity has resulted from a long and complex geomorphic history dating back to the Tertiary period.

River systems and lakes

Water types within the region vary from large, clear, glacially formed lakes to brown sphagnum bog ponds and from clear torrential mountain streams to huge slow-moving, silt-laden rivers. This area contains the largest rivers in Alaska—the Yukon and the Kuskokwim. Surface water is a dominant landscape feature in many portions of the region. Lakes and ponds numbering in the hundreds of thousands are to be found. Many of these are associated with muskeg areas and glaciated uplands. Precipitation is not great, but evaporation is low and surface water does not percolate due to permafrost. Water in the region is generally free of cultural pollution. The large rivers are often turbid during the entire ice-free season. Large brown-water rivers and streams drain many muskeg regions. The eastern highlands of the area contain many smaller rapid streams while low gradient streams are characteristic of the remainder of the region. At the extreme south, several striking elongate piedmont lakes occupy fiord-like glacial troughs in the Wood River and Tikchik Moun-

tains. The glacial troughs were cut well below sea level.

Works of glaciers

During the Pleistocene, glaciation occurred locally over the highlands, but for the region as a whole, it was of quite limited extent. An exception to this generalization is the series of deeply cut fiordlike troughs in the Tikchik-Wood River Mountains.

Seashores, lakeshores, and islands

Much of Alaska's west coast is bordered by coastal lowland. The vast Yukon-Kuskokwim delta area, covered by marshy low tundra, has an indefinite coastal boundary, while other lowland areas have more regular coastlines backed up by 25–50 miles of coastal plain. The Seward Peninsula's north coast is fringed by a line of barrier islands enclosing a series of lagoons. Mountainous terrain borders the sea on parts of Seward Peninsula and the Kuskokwim Mountain region. Major islands are St. Lawrence, Nunivak, St. Matthew, and the Pribilofs.

Geologic history

The sea withdrew from interior Alaska only a million years ago, coinciding with the beginning of the Pleistocene. The past million years was marked by many glacial advances and retreats; mountain building; rapid evolutionary changes in flora and fauna in response to climatic changes; and extinction of many life forms, including the hairy mammoth, the saber-toothed tiger, and the wooly rhinoceros. Abundant bones and other remains of Pleistocene mammals are well preserved in permafrost.

Tundra

Scattered throughout interior and western Alaska are small and large patches of tundra. Interior Alaska has primarily dry alpine tundra on well drained highlands and a low-brush muskeg of willow, alder, dwarf birch, and heath shrubs, with a wet sedge and moss ground cover in wetter areas. Western Alaska tundra is more variable and extensive with large areas of dry upland tundra; moist willow-cottongrass tussock-heath tundra on moderately wet areas; and a wet sedge tundra on flood plains. Dense thickets of willow, alder, and dwarf birch occur on Seward Peninsula and locally throughout western Alaska.

Boreal forest

Interior Alaska vegetation is a vast mosaic of forest, muskeg, and tundra. White spruce, the major tree line species, grows to elevations of 2,000–3,000 feet in the interior, 1,000–1,500 feet on the south side of the Brooks Range, and 200–800 feet in western Alaska. White spruce may grow in relatively pure stands or mixed with black spruce, larch, paper birch, quaking aspen, balsam poplar, alder, and willow. Pure stands of black spruce occur on poorly drained soils and permafrost. Pure or nearly pure stands of quaking aspen and white birch are frequently observed seral stages following upland forest fires. Larch, nowhere forming pure stands, is best represented in the middle and lower Tanana Valley. Bog surfaces are covered by dwarf birches, heaths, and sedges growing on dense sphagnum moss.

Marine environments

To be prepared.

Estuaries

To be prepared.

Lakes and ponds

If all bog ponds and permafrost-formed lakes are considered, the number of lakes in the region is enormous. There are many clear-water lakes, a number having surface areas greater than 10,000 acres. Many lakes were and are barren of fish life in highland and muskeg regions, while many other lakes have native fish associations. Lake trout, Dolly Varden, arctic grayling, northern pike, whitefish, sheefish, burbot, sculpins, and longnose suckers are some of the more abundant native fishes. All five species of Pacific salmon are present in some lakes near the coastline, and occasionally in lakes far to the interior.

Rivers and streams

The region contains a great variety and number of streams and rivers. Native fishes include Dolly Varden, arctic grayling, whitefish, sheefish, burbot, sculpins, longnose suckers, and northern pike. Anadromous Pacific salmon utilize many of the rivers and streams as spawning areas. These spawning runs have not been depleted to a great extent. Little cultural modification of these rivers and streams has occurred, and native fish associations are to be found in most of them.

Brooks Range

Mountain systems

The Brooks Range includes a group of mountain masses extending from the Canadian border across most of Alaska. The highest peaks are only slightly more than 9,000 feet high, but despite their modest altitudes, by Alaskan standards, they represent the highest mountains to be found anywhere within the Arctic Circle. The Brooks Range structure is a large geanticline, compressed into numerous tight folds and broken by numerous faults. Late Tertiary uplift created the present range, and its rugged topography is chiefly a result of subsequent fluvial and glacial erosion.

River systems and lakes

Several large glacial lakes, sometimes clear blue-green and at other times milky, lie in mountain valleys formed by ancient glaciers and dammed by morainic debris. Lakes of this type are more common in the eastern half of the range than in the western half. The Brooks Range Divide separates waters flowing northward into the Arctic Ocean from those flowing southward into the Yukon River tributaries and westward into Kotzebue Sound. Near the drainage divide, steep stream gradients result in canyons with swift, turbulent water. Below the steep gradient reaches, north-flowing streams are generally braided until they pass through the glacial debris at the mountain front, where turbulence is prevalent. Major south-flowing streams are navigable by small boats and canoes. The Noatak River, the only major river lying entirely in the Brooks Range, bisects the range at the west end.

Works of glaciers

Although glaciation was not as extensive in the Brooks Range as in the southern Alaska Ranges, nevertheless, there is considerable evidence of Pleistocene glaciation. Many small glaciers still exist and large glacial cirques and troughs testify to widespread glaciation in the past. Evidence from four major glacial advances has been presented.

Geologic history

Rocks flanking the Brooks Range to the north are the same as those contained in the foothills belt of the Arctic Slope. Shales, limestones, cherts, sandstones, and conglomerates of Triassic, Jurassic, and Cretaceous ages, strongly folded and faulted, are exposed in the irregular topography.

Tundra

The Brooks Range, largely underlain by permafrost and blanketed by snow and ice during much of the year, is nearly devoid of trees. Plantlife consists mainly of grasses, sedges, forbs, lichens, mosses, and dwarf shrubs, many of which have circumpolar distribution. The dry or high tundra above about 2,500 feet is characterized by low matted woody plants, grasses, and herbs. A moist tundra dominated by sedges and willows occurs in very poorly drained sites up to about 2,500 feet. Dense to open brushy areas of willow, alder, and dwarf birch line the major valleys to 4,000 feet elevation.

Boreal forest

Limited boreal forest, chiefly white spruce mixed with paper birch, black spruce, and balsam poplar, may be found along

river courses at low elevations on the southern slope of the Brooks Range.

Lakes and ponds

Lakes are a significant feature in many parts of the region. Due to the extreme isolation of the whole area, little information is available on most of them. Many are undoubtedly barren of fish life due to barriers downstream. Native fishes include arctic grayling, arctic charr, Dolly Varden, lake trout, whitefish, sheefish, burbot, and sculpins. All five species of Pacific salmon have been reported from lakes in the region—mostly those nearer the coastal areas.

Rivers and streams

Flowing water is abundant and ranges from snow-fed torrential mountain streams to relatively large, slow-moving rivers. Native fishes include arctic grayling, arctic charr, whitefish, sheefish, burbot, and sculpins. Pristine conditions are the rule throughout the region.

Arctic Lowland

Plains, plateaus, and mesas

More than 600 miles long and 100 to 200 miles wide, the Arctic Lowland or Arctic Slope comprises one-seventh of the area of Alaska. Two distinct geologic and topographic parts are evident—the southern Foothills Belt and northern Coastal Plain. Lying between the Brooks Range and the Coastal Plain, the Foothills Belt consists of rolling plateaus and low linear mountains. Very irregular topography, with east-trending buttes, mesas, and ridges separated from each other, characterize the area. Most of the valleys have glacial moraines alongside, and outwash terraces extend seaward from terminal moraines.

The vast, monotonous Coastal Plain extends northward from the Foothills Belt. Relief is no more than a few feet and nearly half the area is covered with water. The Coastal Plain is noteworthy for the many phenomena, such as ice wedges, polygons, and other geometric patterns associated with permafrost.

River systems and lakes

Northward-flowing rivers originating in the mountains or foothills meander over wide flood plains. Near the coast, the streams split the numerous distributaries and empty onto very shallow, broad, mud flats.

The region is marked by thousands of lakes, swamps, and other low, wet areas. Numerous oriented lakes, equalled only by the Carolina Bays, imprint the landscape with their elliptical, ovoid, and rectangular shapes. No satisfactory explanation has been advanced to explain their remarkable orientation.

Seashores, lakeshores, and islands

The arctic shoreline is marked nearly everywhere by earth banks 3 to 30 feet high behind narrow pebble beaches. More or less continuous sandbars and islands lie offshore. Shallow lagoons, between the reefs and mainland, may remain open when the ocean is blocked with ice.

Geologic history

The geologic history of the Arctic Lowland is closely related to that of the Brooks Range. The oldest known rocks are of late Paleozoic age and extensive sedimentary deposition occurred during Triassic, Jurassic, and early Cretaceous periods. Marine shells and plant remains from those periods are evident. Fossil plants, including sequoia trees, have been recovered from Cenozoic deposits. Bones, horns, and tusks of mammals, such as the mammoth, mastodon, buffalo, musk ox, and horse, are fairly common among the younger (late Tertiary) rocks of the lowlands.

Tundra

The Arctic Lowland, underlain by permafrost, is a vast treeless plain. The wetter portions of the Foothills Belt is covered by a moist tundra of closely spaced cottongrass tussocks in association with low heath shrubs, moss, and lichens. Willow brush commonly grows along the streams. Small scattered areas of sparsely vegetated dry tundra are present on well-drained ridges. The Coastal Plain is predominately a wet sedge tundra

Lakes and ponds

Many, if not most, of the shallow permafrost-type lakes and ponds are not suitable for fish life, but fish populations are present in many other lakes. Native fish species include whitefish, sheefish, arctic charr, Dolly Varden, arctic grayling, blackfish, stickleback, sculpins, and burbot. Three species of Pacific salmon are found in lakes of the region near the coastal portion.

Rivers and streams

Lotic habitat is abundant. Most streams and rivers are of low gradient and many cease to flow during the long winters. Native fishes include those mentioned above.

Mountain systems and the works of volcanism

The U.S. Virgin Islands, a part of the Lesser Antilles Leeward Islands, include 50 islands and cays of which St. Croix, St. Thomas, and St. John are of significant size. The three islands have a combined area of 132 square miles with St. Croix having 84; St. Thomas, 28; and St. John, 20. The major islands share a common history of accumulations of volcanic rock, shallow intrusives, and limestone sediments during Upper Cretaceous; plutonic intrusion, folding, and uplift at the close of Upper Cretaceous; and cyclical uplift and development of three erosional levels during Tertiary time. From the third erosional cycle to the present, a series of submergences and emergences occurred, resulting in deposition of a coastal plain, subsequent dissection of the plain, coastal plain drowning, reef development, and irregular accumulation of clastic materials.

St. Thomas and St. John are generally mountainous and made up mostly of volcanic rocks, whereas St. Croix has three major landforms—the Northeast Range, the East Range, and an intervening coastal plain. Maximum elevations are 1,165 feet on St. Croix, 1,277 feet on St. John, and 1,556 feet on St. Thomas. A large graben separates St. Croix from the northern Virgin Islands.

The mountain system is represented in Virgin Islands National Park.

Seashores, lakeshores, and islands

Shorelines, varying considerably, can be categorized as follows: rocky promontory, linear rocky face, steep bank, coral bank, sand and coral beach, coral beach, boulder beach, gravel beach, sand beach, and mangrove swamp. Most of these shoreline types are represented in the National Park System.

Nearly 50 small off-shore islands and cays are included in the U.S. Virgin Islands. Because of their steepness or rugged shorelines, many are difficult to approach. Buck Island and several islands off St. John are included in the National Park System.

Coral islands, reefs, and atolls

Considerable reef development has occurred around St. John, at the eastern end of St. Thomas, around the eastern two-thirds of St. Croix, and at Buck Island. A portion of St. John's reefs and the Buck Island reefs are within the National Park System.

Geologic history

Foraminifera, coral, and mollusk fossils have been recovered from the Jealousy and Kingshill limestone formations on St. Croix and have been classified as Miocene and Oligocene in age.

Tropical region

The original forest cover of the Virgin Islands was removed during the plantation era of the 1700's, but most species of the native flora are believed to have survived—at least on St. John. Second-growth forests have reclaimed much of the land on this island and give some indication of what original conditions may have been like. The major vegetation types are:

1. Moist forest—a largely evergreen, hardwood forest of ravines, protected north slopes, and interior highlands.

2. Dry forest—a lower, more open, much less varied, and dry-weather deciduous forest of ridge crests, interior south and east slopes, and less exposed sites.
3. Dry forest with cactus—a tall columnar cactus and an agave associated with the dry forest along ridge crests.
4. Cactus woodland—xeric vegetation in which cactus and agave are dominant.
5. Wind-flattened scrub—low xeromorphic shrubs characteristic of low, east-facing sites.
6. Mangrove—tropical tidewater forest, limited to a few sites at coastal inlets and poorly drained areas.
7. Beach vegetation—a rather distinct type of forest and shrub growth which is able to withstand the strong marine influences.
8. Croton-acacia scrub—a typical secondary vegetation of cleared and overgrazed land.

All vegetation types are represented in the National Park System.

Marine environments

To be prepared.

Estuaries

To be prepared.

Puerto Rico

Rectangular-shaped Puerto Rico, 110 miles long and 35 miles wide, is the smallest and most easterly of the Greater Antilles. Lying well within the tropics at 18° north latitude, it is subject to persistent northeasterly tradewinds, which in combination with a variety of landforms results in diverse ecosystems. There is a fairly strong correlation between the major landforms of Puerto Rico and the associated vegetation zones.

Plains, plateaus, and mesas

Foothills and coastal lowlands comprise the regions north and south of the mountains. The coastal lowlands are very young and little dissected. Quaternary sediments cover the level alluvial plains. The northern foothills region, lying between coastal plain and mountains, is a heterogeneous region of round, smooth hills and more rugged topography. The northeast section is underlain by Cretaceous limestones, the inland limestone belt by Tertiary limestones, and the relatively inaccessible Atalaya Hills by Cretaceous shales, ash, and tuff. The southern foothills are characterized by low hills throughout the region and are underlain by Cretaceous rocks and limited Tertiary limestones.

Mountain systems

Mountainous topography, extending east-west and reaching elevations of 2,000–4,400 feet, runs the length of the island. The main row of monadnock peaks forms the backbone of the mountainous region and a maze of mountain spurs extend north of the monadnock line. A complex geologic history beginning in Upper Jurassic accounts for the deposition of volcanic material and marine sediments. Following major deposition in Cretaceous time, folding and uplift occurred with granitoid rocks being intruded; partial "peneplenation" occurred in Late Tertiary during which time the monadnock peaks were left standing; in the Pliocene, further uplift took place; and Pleistocene activity included partial submergence and major dissection.

Works of volcanism

Deposition of volcanic materials occurred during the Upper Cretaceous. Pyroclastic rocks predominate with tuff being not only the most common form but the most common rock on the island. Because of considerable weathering and erosion since the volcanic action, loose specimens of pyroclastic ejecta such as bombs and lapilli no longer exist. Such items can only be found bonded together as agglomerates.

River systems and lakes

Several continuously flowing streams drain the rainy windward portion of Puerto Rico. On the dry leeward slopes, intermittent streams predominate. The steeply walled valleys in the mountainous region contain swiftly flowing streams, whereas slower moving meandering streams with broad flood plains characterize the lowlands. High precipitation and very rapid runoff commonly result in almost instantaneous high water and flood conditions. Four fresh-water lagoons having depths of 5–6 feet are found on the island.

Seashores, lakeshores, and islands

The coast of the Cape San Juan Region has cut-back headlands, bars built across bays, considerable areas of tidal flats, and extensive beach ridges. The east and west coasts are characterized by palm-fringed beaches strung between headlands and marine cliffs standing behind protective beaches. Most of the relatively quiet south coast is gently sloping with little headward erosion evident. The north coast from Aquadilla to Camuy is characterized by 200-foot marine cliffs and protective beaches. East of Camuy, sand deposits cover most of the low coast. A series of sand dunes, exhibiting all stages of consolidation and dissection, fringe the shore.

Major islands politically attached to Puerto Rico are Vieques, Culebra, and Mona. Vieques and Culebra physiographically belong to the Lesser Antilles, but all three have several characteristics in common. They are all relatively low in elevation, receive little rainfall, and support a sparse dryland vegetation. Mona Island, 50 miles west of the main island, ends abruptly with 150- to 200-foot sea cliffs on all sides. The island is honeycombed with caves in the more soluble limestone layers. Vieques and Culebra, much closer to the main islands, are composed mostly of volcanic rocks.

Coral islands, reefs, and atolls

To be prepared.

Caves and springs

Extensive karst topography occurs in the limestone regions, particularly in the northern foothills region. Haystack hills, isolated or in rows; sinks; small solution valleys; underground drainage; and extensive caves are liberally scattered throughout the region.

Geologic history

Limestone formations dating from Cretaceous and Tertiary times include foraminiferal, radiolarian, coralline, molluscan, and algal types. A rich fossil coral fauna dating from lower Cretaceous has been found in the Río Matón Valley, west of Cayey.

Tropical region

Eight vegetation zones have been described in Puerto Rico. The regional vegetation patterns strongly correlate with climatic conditions which in turn reflect various physiography and air mass interferences. Beginning at sea level, the littoral zone includes a wide variety of communities including intertidal mangrove forests, tropical beach and strand complexes, and dune communities. Most lowland vegetation has been severely altered by man's activities and bears little resemblance to the original vegetation. However, occasional relict specimens, stands, or reasonably good second growth persists in places. Vegetation zones in this category include the lowland rain forest, seasonal evergreen forest and hill scrub in the north coastal zone, semi-deciduous forest in the southern coastal and foothills region, and lower montane forest from 660- to 2,500-foot elevation. From 2,500- to 3,300-foot elevation, the montane forest zone contains several variants including the sierra broadleaf forest, sierra broadleaf-palm forest, sierra palm forest, and sierra moss forest. Above 3,300 feet, the cool,

very moist and windy climate limits the vegetation to a montane scrub and elfin forest. This forest is temperate with its simple composition, well-marked dominance of a few species, and important moss component. The montane forest and montane scrub zones are relatively well-preserved in certain areas, particularly in the rainy Sierra de Luquillo Region.

Vegetation on the outlying islands has been greatly altered through man's activities.

Marine environments

To be prepared.

Estuaries

There is considerable variation in habitats along Puerto Rico's coastal zone. Salt-water ponds, lagoons, and shallows support algal meadows and turtlegrass beds. Cabo Rojo, Bahía Monsio José, and Bahía Fosforescénte are famous for their spectacular displays of marine bioluminescence.

Reef complexes support marine algal crusts on coral cliffs and kelp beds and mangroves on salt-washed rocks. Mangroves, forming a broken ring around the island, grow abundantly on fine sand and silt and cover considerable territory. Brackish-water rivers and lakes may have large floating mats of water-hyacinth, waterlettuce, and water lilies, and emergent grasses, sedges, and rushes in shallow areas.

Guam

Guam, the largest and most southerly of the Mariana Islands, lies in the western Pacific Ocean 1,200 miles east of the Philippines, 1,500 miles south-southwest of Japan, and 1,000 miles north of New Guinea. The island is 30 miles long, 4 to 8 miles wide, and, exclusive of reefs, 212 square miles in extent. Located between 13° and 14° north latitude, Guam is well within the tropical zone.

Plains, plateaus, and mesas

The northern half of Guam is a broad, gently tilting limestone plateau bordered by steep cliffs. Sloping southwestward, the plateau drops from elevations of more than 600 feet in the northeast to less than 200 feet near the center of the island. Rising above the level of the plateau are three prominent hills, two of which are inliers of volcanic rock and the third, limestone. The limestone plateau also includes the Orote Peninsula and the intricately dissected argillaceous limestone strip along the southeast coast.

Mountain systems and the works of volcanism

The southern half of Guam is primarily a dissected volcanic upland. A discontinuous mountain ridge, with peaks more than 1,000 feet high and a maximum elevation of 1,334 feet, parallels the west coast 1½ to 2 miles inland. The southern volcanic province is further divided into two areas: Central Guam made up chiefly of much-folded and much-faulted Eocene volcanic rocks, and South Guam, consisting mostly of Miocene flows, tuffaceous shales and reworked tuff breccia. The high ridge from Mount Lamlam north to Mount Alifan is capped by thick fossiliferous limestone, one of the oldest post-volcanic limestones on the island.

Geologic history

The geologic history of this island includes accumulation of volcanics, intense folding and overthrust faulting, deposition of shallow water limestones, renewed faulting, and a complicated series of emergences and submergences and associated erosion and deposition.

River systems and lakes

Permanent streams are found only in the southern half of Guam and include numerous streams and one large river system, the Talofofo.

Seashores, lakeshores, and islands

Guam has three basic types of shoreline, the extensive pitted, emerged, coral limestone; a low, swampy coast; and sandy beach.

Caves and springs

A 10-square-mile basin in the Fena Valley contains karst features in the Bonya limestone formation. Some small sinks are nearly 100 feet deep and 100 feet wide at the base, while others are 1,000 to 2,000 feet long. A portion of the Tolaeyuus River flows through a series of connected sinks to a cave where the stream flows underground for several hundred feet. Sinkholes ranging in size from a few feet to 75 feet deep are scattered over most of the northern plateau. The limestone cap on Mount Lamlam and Mount Alifan is characterized by steep limestone ridges resembling dorsal fins. A basin, nearly

one-half mile across and 200 to 300 feet deep, lies between the two ridges of Mount Lamlam and Mount Almagosa. The basin is probably an enlargement of sinks by solution.

Tropical region

Significant vegetation types of Guam are:

1. Forests of elevated hard limestones—variants include wild breadfruit forest found over large parts of the northern plateau, on the east coast south to Talofofo Bay and on Mount Lamlam-Mount Alifan Ridge, mixed moist forest east of Mount Santa Rosa, *Merrilliodendron* forest on terraces at Haputo, Pandanus forest common on interior areas on the plateau, and halophytic and xerophytic scrub on terraces and cliff edges near the sea on the east and north coasts.
2. Ravine forest of southern Guam—an uneven mixture of low, brushy, tangled trees in valleys and ravines having soils of volcanic origin and on limestones in the Talogogo drainage.
3. Marshes and swamps—several types of marshes are found in low places along the coast, along streams, in sinkholes, and other depressions or poorly drained areas. Swamp forests include mangrove swamps and *Barringtonia* swamp, a striking swamp forest type found only in Guam, and limited there to the Talofofo River.
4. Strand vegetation on sandy places and beach ridges within range of significant salt-water influence.
5. Grassland or savanna vegetation—associated mostly with volcanic soils are stands of swordgrass, a sharp-edged, canelike grass, and *Dimeria,* a soft tufted grass.
6. Vegetation of the argillaceous limestone area—an area so altered for agriculture that the original vegetation is unknown.

In identifying themes, two major interrelated categories of natural phenomena must be recognized. One, the *geological category,* results from forces and processes acting through and upon the earth's inorganic substance to produce landforms and other evidences of nonliving entities. The biological world is here represented as fossilized records of organisms but the fossils and the processes through which they are preserved are geologic. Themes within the geological category must take into account the historical aspects of the development of the earth's surface and the evolution of life. In this respect the geological time scale, recognized and generally accepted by geologists, provides a useful and workable tool. Individual themes must embrace segments of time of sufficient duration to include closely related events and associated land structures, environments, and stratigraphic formations, including fossiliferous deposits. Certain existing landforms and landscape features are of such prominence and importance as to require recognition and study under special themes outside of the historical context.

The second major category involves biological forms and processes. Since the foci of interest and importance lie in the interactions among the biological components and between the biological components and the abiotic environment, as well as in the individual life forms, this is more properly designated as the *ecological category*.

Within the *ecological category* themes are based primarily on the ecosystem which is defined as the natural community including its component organisms together with the abiotic environment, all forming an interacting system. As in the geological category there are some biological phenomena that have intrinsic interest apart from the ecosystem in which they occur.

The basic philosophy of a system of themes has implications and connotations that require explanation. Natural history is complex. To individual scientists, as to individual laymen, it may have very different meanings. These differences arise from the consideration of these entities and processes from various points of view. Collectively among human minds, natural history therefore becomes polydimensional and difficult to resolve into a generally acceptable rational system of categories of a nature that would be useful for purposes of evaluation and selection of representative areas. The only apparently reasonable alternative is a system of themes such as outlined below. These themes involve not only entities and processes but also the aspects from which they are viewed. By their very nature, themes intersect and overlap. Because of this, no single area is characterized solely by a single theme, although a single theme may be of overwhelmingly dominant importance.

GROUP I. LANDFORMS OF THE PRESENT

Landforms of the present include the principal features of the existing natural landscapes. Each landform possesses certain distinguishing qualities and characteristics which set it apart from the others. Moreover, each is a manifestation of geologic

events and processes that have determined its size, shape, composition, and structure. The qualities and characteristics of landforms, therefore, possess a dual significance. This theme describes the character of the landscape as a physical and scenic entity as it exists today, and illustrates present and past geologic events and processes.

Each of the themes embraces landforms with common major qualities and characteristics. The geologic events and processes which created the landforms within each theme are usually similar in some respects, but this is not always true. For example, plains are always level—or nearly level—areas of some considerable extent, but the underlying rocks may vary greatly in composition and structure.

Theme 1.
Plains, plateaus, and mesas

Plains, plateaus, and mesas are characterized by their level, or nearly level, surfaces. Plateaus and mesas are essentially segments of plains standing at some considerable elevation above the surrounding country. Plateaus may vary from the norm, however, in that their surfaces may be highly dissected by erosion or form the bases of mountains rising to still higher elevations.

Theme 2.
Cuestas and hogbacks

Cuestas are asymmetric ridges possessing a tilted dip-slope surface on one side, which is held up by a rock stratum relatively resistant to erosion, and possessing a steeper erosion scarp on the other side cut across the strata. Depending on the amount of cross drainage, their crests may be straight or scalloped. Cuestas are especially characteristic of the semiarid West, and may form the foothills of higher mountains.

Hogbacks are sharp-crested ridges formed on the more resistant rocks where the rock dips are steeper than those prevailing in cuestas.

Theme 3.
Mountain systems

Although mountains may represent various types—folded, fault block, dome, or volcanic—all of them are eminences standing either alone or as part of a range or group. Mountains stand conspicuously above the surrounding country, as a rule, and are characterized by relatively small summit areas and frequently by a considerable extent of bare rock surface. Their form, composition, and structure are manifestations of a wide variety of geologic events and processes and constitute veritable record books of the earth's history. Particularly worthy of attention are the folded structures visible in some areas of bare rock exposure.

Theme 4.
Works of volcanism

All landforms of the present representing the works of volcanism have been created by the movement and the intrusion or the extrusion of molten masses of rock called magma which subsequently cooled and solidified. Even today, in some places this magma reaches the surface in a molten condition and is extruded explosively to leave a crater or as extensive lava flows prior to solidification. Cone volcanoes, lava flows, ash deposits, sills, dikes, and volcanic necks are among the landforms representing the works of volcanism. Dikes and volcani

necks become prominent land features chiefly where they remain as walls and pinnacles following erosion of the invaded country rock. The surfaces of lava flows in many places have assumed bizarre shapes owing to flowage of lava after the surface is partly cooled, and intricate caverns develop below the surface. Lava flows, sills, and dikes commonly break into hexagonal columns perpendicular to the cooling surface, and these columns may produce striking erosion features.

Calderas are large circular basins associated with volcanic activity, and were produced either by erosion blowouts, or as subsidence basins.

Theme 5.
Hot water phenomena

Hot water phenomena such as geysers, hot springs, fumaroles, bubbling paintpots, hydrothermally altered or colored terrain, and siliceous sinter terraces are closely related in that they require water and sources of heat. As a rule, such features are found in areas still subject to volcanism or where volcanism has occurred in the comparatively recent geologic past.

Theme 6.
Sculpture of the land

This theme includes landforms produced by erosive action of water and wind, landslides, and other physical or chemical landshaping events or phenomena. Features resulting from the sculpture of the land by these processes commonly appear as "landforms superimposed upon landforms" such as occur when a stream valley or badlands topography is developed on a plateau or a mesa, or within a mountain system. Bare rock canyons, buttes, and rock needles are carved out of the bedrock. Pedestal or toadstool rocks usually have a hard cap rock which has protected weaker underlying strata from erosion.

Theme 7.
Eolian landforms

Sand dunes oriented both perpendicular and parallel to directions of major wind movement are prominent topographic features in places. Their shapes are determined in part by the influence of vegetation. The composing material may be quartz, calcareous, or gypsum sand.

Theme 8.
River systems and lakes

River systems and lakes are noteworthy features of the natural landscapes of which they are a part. Many rivers, not yet at grade, are characterized by waterfalls over the harder rock ledges. Others have reached grade and now meander in alluvial valleys. Some meandering rivers have been rejuvenated to produce incised meanders which may have vertical canyon walls.

Lakes bear a close relationship to the streams flowing into them which makes it practicable to include both river systems and lakes within the same theme. River systems and lakes are usually within or superimposed upon other landforms as in Sequoia and Kings Canyon National Parks. Here the upper reaches of river systems and a number of lakes lie within and upon the Sierra Nevada which is itself an outstanding example of a fault-block mountain system. The valley sides of both rivers and lakes commonly reveal evidences of earlier geologic history in the form of terraces.

Theme 9.
Works of glaciers

The works of glaciers include landforms produced by both mountain and continental glaciers. Among these forms or features are cirques, arêtes, tarns, hanging valleys, canyons with U-shaped transverse profiles, moraines, drumlins, eskers, and kames. These usually occur as landforms superimposed upon other landforms. The glaciers and their associated features on the Mount Rainier cone volcano are classic examples of this superimposed relationship. Glacial striae in thoroughly scoured areas are prominent features in many glaciated areas.

Theme 10.
Seashores, lakeshores, and islands

Along seashores and lakeshores, landforms occur which are peculiar to these environments and which have been produced by natural processes at work within them. Eroded cliffs, stacks, beaches, dunes, barrier beaches, sandbars, hooks, and sandpits are examples of landforms in this category. Closely related features are the offshore islands of many regions; these show transitions to more remote islands of other regions. Other landforms, of themselves worthy of recognition, are normally superposed on islands.

Theme 11.
Coral islands, reefs, and atolls

Coral islands, fringing reefs, barrier reefs, and atolls are landforms produced by the work of living organisms acting in concert with other processes. These landforms are always interesting and possess outstanding scientific value and esthetic beauty. The largest thing built by living organisms is not the Great Wall of China or the great power and irrigation projects of today but, rather, the enormous barrier reef fringing Australia's northeastern coast constructed by corals and algae.

Theme 12.
Caves and springs

Caves are subterranean features, most of which have been formed by solution of limestone or dolomite, though deposition of calcareous materials has in many instances alternated with solution and may have been the most recent event. Many caves are associated with underground streams. Locally, the rock cover over parts of such streams has been dissolved or otherwise eroded so that the stream is subaerial in parts of its course, underground in other parts. The open valley parts of such "blind rivers" or "lost rivers" are fascinating elements of the local landscape. In a more advanced stage of erosion, natural bridges may be formed. Many large streams that have flowed underground for considerable distances reappear at the surface as spectacular springs.

GROUP II.
GEOLOGIC HISTORY

The records of the geologic history of the earth are found in the rocks. These records may be read from the composition, structure, and relationships of rocks and the fossils they contain. Earth history embraces a period of billions of years. The development of the themes involves the location, identification, and evaluation of the more significant geologic records in terms of their value, usefulness, and suitability in illustrating the history of the earth and its life.

Theme 13.
The Precambrian Era

This theme embraces the entire span of the *Precambrian Era* between about 3 billion and 600 million years ago. This time

interval is characterized as *The Morning of Life* for within it the first life—algae, fungi, and soft-bodied marine plants and animals—developed on the earth. The distribution of Precambrian rocks is worldwide, but in the United States rocks of this age are found in the Cordilleran region and the Appalachian Mountains. They also occur in the Lake Superior region and in a few localities of the southern midcontinent west of the Mississippi River.

Theme 14.
The age of primitive invertebrates

This theme embraces the *Cambrian, Ordovician,* and *Early Silurian Periods*—a time span between about 600 and 420 million years ago. Life forms were restricted to the water and were, in time, dominated by shellfish of a bewildering variety. Trilobites, brachiopods, sponges, and corals thrived, and jawless fish representing the first vertebrates made their appearance.

Theme 15.
The rise of vertebrates and the first forests

The *Late Silurian* and *Devonian Periods* are embraced within this theme, a time span between about 420 and 350 million years ago. Life forms continued to exist primarily in the water, but terrestrial life began with the first land plants. During Devonian time, plant growth attained tree size; also primitive, land-living creatures became more firmly established and amphibians evolved.

Theme 16.
The great development of land life and changes in marine life

The *Mississippian, Pennsylvanian, Permian,* and *Triassic Periods* include a time span between about 350 and 180 million years ago. Crinoids attained their culmination; ammonoids and their successors, the ammonites, developed; the first reptiles appeared, and fish, including over 200 species of sharks, flourished. Trilobites became extinct but coal-swamp forests supporting a wide variety of insects prevailed.

Theme 17.
The age of reptiles

The age of reptiles embraces the *Permian, Triassic, Jurassic,* and *Cretaceous Periods,* a time interval between about 270 and 70 million years ago. This span embraces the great rise and extinction of dinosaurs and the flourishing of seagoing and flying reptiles. Modern plant types were on the rise during the latter part of this time interval.

Theme 18.
The emerging dominance of mammals

Theme 18 embraces the *Paleocene* and *Eocene Epochs* between about 70 and 40 million years ago. Mammals, most of them different from those of today, filled life niches which had been vacated by the extinct mammal-like reptiles, dinosaurs, and pterodactyls. Modern marine animals and fresh-water fishes were on the rise.

Theme 19.
The golden age of mammals

The "Golden Age of Mammals" includes the *Oligocene, Miocene, Pliocene, Pleistocene,* and *Recent Epochs* beginning about 40 million years ago, and extending to the present time. During this period modern life forms became well established. The age of prehistoric camels, horses, and dozens of other mammals, descendants of which are common today, are included. This is also the time (Pleistocene) of the remarkable

large mammals of the ice age, and the development of man and his civilization, as well as all modern life forms.

GROUP III. LAND COMMUNITIES OF PLANTS AND ANIMALS

There are literally thousands of kinds of land-dwelling plants and animals, and the number of associations among them are numerous. For purposes of survey of natural areas, characteristic groupings of some of the more common and conspicuous forms are referred to as communities in the themes below.

Since the kind of community is intimately related to a kind of environment, it is necessary to look upon a group of organisms plus their environment as constituting a basic unit, and such a unit is commonly referred to by biologists as an *ecosystem*.

The vegetative components of natural communities are generally more conspicuous than are the animal members and are more stable with respect to location and population density. Therefore, the name designations of land ecosystems stem from the types of vegetation which characterize them, but the animal populations and sometimes physical environmental features are often important elements in identifying and evaluating sites, as well as in shaping them.

Theme 20. Tundra

Tundra is a treeless area on which the principal vegetation consists of grasses, sedges, perennial herbs, and dwarf shrubs. Terrain is often poorly drained and climate alternates between a continuously cold, long, harsh winter and a very short, cool to cold summer. Arctic tundra often is underlain by permanently frozen ground called permafrost. Associated with the permafrost are such tundra peculiarities as solifluction (a flowing of soil downslope), soil polygons, and frost boils. Characteristic animals include such far-north mammals as arctic fox, arctic hare, caribou, and lemming.

Extensive arctic tundra exists in a broad plain across the northernmost reaches of North America with restricted occurrence of alpine tundra on high mountain slopes in the Rocky Mountains, Sierra Nevada, and other ranges. Here, many species of plants are closely related to the arctic tundra species but the mammals characteristic of arctic tundra are lacking. Among the common mammals are hoary marmot, bighorn, and pika.

Theme 21. Boreal forest

Just south of the tundra is a belt of forest stretching from western Alaska eastward to the Atlantic coast in Labrador, Newfoundland, and Nova Scotia. Two principal trees characterize this forest: white spruce and paper birch. In the eastern half, balsam fir and jack pine are also characteristic.

There is an extension of the northern forest southward along the Appalachian highlands to North Carolina and Tennessee. Here, white spruce is replaced by red spruce, paper birch is replaced by yellow birch, and, in North Carolina and Tennessee, balsam fir is replaced by the closely related Fraser fir.

A corresponding southward extension along the Rockies is characterized by subalpine fir and Engelmann spruce.

The climate of the boreal forest is scarcely less severe than

the tundra, but summers are longer, and precipitation somewhat greater.

Paper birch, aspen, jack pine, lodgepole pine, red pine, and white pine are very common successional species in the boreal forest, and may last many years as distinct communities of utmost beauty and value. Among the animals, woodland caribou, moose, snowshoe hare, timber wolf, red fox, red squirrel, marten, wolverine, lynx, and several species of grouse and thrush are common.

Theme 22. Pacific forest

Bordering the Pacific Ocean from Alaska to northern California is a region of mild temperatures and moderate to heavy precipitation. The region extends from the coast inland to include (with the exception of the Central Valley and southern fifth of California) the seaward slopes of the Cascade and Sierra Nevada Ranges. The essentially mountainous terrain of much of this region produces altitudinal zones that vary in climate and in the resulting plant and animal life. On the highest peaks there are perpetual fields of ice and snow; below this is the tundra; below the tundra are the forests of this theme. In the Sierra Nevada and Cascades the higher forests are usually referred to as subalpine, consisting of such trees as red fir, silver fir, mountain hemlock, and lodgepole, foxtail, and western white pines; the lower forests are called montane forests, consisting of white fir, sugar pine, ponderosa pine, sequoia, and many others. The forests at low altitudes along the coast consist mainly of coniferous trees such as western arborvitae, Douglas-fir, western hemlock, redwood, and Sitka spruce. Northward from the Olympic Peninsula, hemlock and Sitka spruce dominate. Southward from the Olympic Peninsula, Douglas-fir and redwood become increasingly dominant.

Animals common in this community include black bear, mule deer, coyote, cougar, raccoon, mountain beaver, golden-mantled ground squirrel, chickaree, and several species of chipmunks.

Theme 23. Dry coniferous forest and woodland

On the lower slopes of the Rocky Mountains, and the eastern slopes of the Cascade-Sierra system there occur belts of coniferous forest and woodland dominated by Douglas-fir, ponderosa pine, and pinyon-juniper. The climate here is warmer but drier than that of the boreal (or subalpine) forest of Engelmann spruce and subalpine fir above, with drought setting the lower limits of elevation where these dry forests give way to steppe or chaparral. Deer, black bear, porcupine, coyote, chipmunks, magpie, Steller's jay, and pigmy nuthatch are common animals.

Theme 24. Eastern deciduous forest

From a central area in the southern Appalachian highlands, mainly winter-deciduous tree species spread in all directions—northward to the Great Lakes area, westward through the first tier of States west of the Mississippi River, southward to the Gulf of Mexico, and eastward to the Atlantic coast. Oaks, hickories, maples, buckeye, basswood, tuliptree, hemlock, beech, and other hardwood species combine in various ways to

form several distinctive groupings such as the oak-hickory forest, the beech-maple forest, and the maple-basswood forest. Extensive pine forests mark areas in the Southeast where frequent burning prevents the growth of broad-leaved trees and maintains more desirable timber, forage, and game.

Climate in this region is characterized by moderate-to-cold winters and hot summers. Precipitation varies from about 30 to over 50 inches annually. The most northern portions may have continuous snow cover throughout the winter, but snow is rare in the southern portion.

White-tailed deer, raccoon, fox, thrushes, warblers, and the copperhead snake are common animals. Formerly, bison, cougar, and timber wolf ranged through much of the area.

Theme 25. Grassland (steppe)

Grassland is the most extensive formation in North America, extending westward from the edge of the eastern deciduous forests and covering the lowlands about the foothills of the Rockies to Sierra-Cascades and from southern Saskatchewan and British Columbia to southern Texas. Throughout the formation, the rainfall is so low that the soil regularly dries out and the grasses become dormant each year. Total annual precipitation ranges from between 30 and 40 inches in the east to about 7 inches just east of the Cascades. In the north, winters are long and very cold but, in the south, winter temperatures seldom drop much below freezing.

Because there are large differences of climate within the grassland formation, there are corresponding differences in the vegetation. Along the eastern border of the formation, where precipitation is greatest, "tall grass prairie" is the major vegetation type. Some of the dominant grasses are *Stipa spartea, Bouteloua gracilis, B. curtipendula, Andropogon scoparius, A. gerardi, Panicum virgatum,* and *Sorghastrum nutans.* Composites and legumes are especially conspicuous among the broad-leaved herbs. Tall grass prairie also dominates many sites formerly subject to regular burning in Illinois, Wisconsin, Minnesota, and Missouri, the combination of these sites often being referred to as the "prairie peninsula."

In the western portions of the central plains, where precipitation is lower, are the "short grass plains." *Bouteloua gracilis* and *Buchloe* are the major dominants in this area of short grasses.

Between the Rockies and the Cascade-Sierra system, rainfall is mainly restricted to winter, rather than being concentrated in summer, as east of the Rockies, and the character of the steppe is correspondingly different. Characteristic grasses are *Agropyron spicatum, Festuca idahoensis,* and *Oryzopsis hymenoides,* and over most of the area there is a conspicuous overstory of shrubs, especially sagebrush or shadscale. Much of the interior valley of California originally supported grassland in which *Stipa pulchra* was the leading dominant.

Bison, pronghorn, elk, coyote, wolf, jackrabbit, kit fox, badger, ground squirrels, prairie dog, pocket gopher, prairie chicken, sage hen, and black-footed ferret are characteristic of

grassland, but bison and elk were essentially restricted to the area of summer rainfall.

Theme 26. Chaparral

The dominant plants of chaparral are broad-leaved, mainly evergreen, species of shrubs or low trees, occurring as a dense scrub or woodland or in scattered arrangement with grass interspersed.

Two subdivisions may be made:

Woodland—evergreen forest trees including several oaks, tanbark-oak, California-bay, madrone, chinquapin, and wax-myrtle.

Scrub—shrubs of many genera and species, the most important of which are manzanita, chamise, buckbrush, scrub oak, and mountain-mahogany.

Theme 27. Deserts

Deserts range from areas with no vegetation to areas with sparse, shrubby vegetation. The most important common denominator of the vegetation is the virtual absence of perennial grasses. Throughout the deserts, variations in soil texture, drainage, and salinity produce distinctive variations in vegetation.

The North American desert is traditionally divided into three geographic subregions: Mohave Desert, Sonoran Desert, and Chihuahuan Desert. One common, simple community-type consisting mainly of an open stand of creosotebush occurs throughout.

The Mohave Desert occupies much of inland southern California and adjacent Nevada and northwestern Arizona. Joshua-tree is the outstanding characteristic plant.

The Sonoran Desert extends from southeastern California to the western edge of New Mexico. The species that characterize the Sonoran Desert are ocotillo and the cactuses, especially the saguaro, organpipe, and other conspicuous columnar species.

The Chihuahuan Desert of eastern New Mexico and southwestern Texas is characterized by mesquite, ocotillo, yucca, agave, sotol, and nolina.

Typical animals of the North American deserts include coyote, javelina, bobcat, bighorn, jackrabbit, pocket gopher, kangaroo rat, packrat, antelope ground squirrel, ring-tailed cat, rattlesnake, road-runner, raven, and numerous lizards.

Theme 28. Tropical ecosystems

Tropical areas are limited in the United States and possessions to Hawaii, Samoa, and other Pacific islands; Puerto Rico and the Virgin Islands; and the southern tip of Florida, including the Florida Keys. Astronomically speaking, the "tropics" occur in that area bounded by the Tropics of Cancer and Capricorn; but oceanic influences on southern Florida result in a vegetation that is outstandingly tropical in its character despite its extra-tropical position. Due to the geographic dispersion of tropical lands belonging to the United States, the vegetation is highly differentiated, so this theme is complex in its constituent parts.

Seasonal variation in the tropics is minimized by the fact that day length varies but little from 12 hours during all sea-

sons, eliminating the long-winter-night, long-summer-day regime of temperate areas. On the other hand, wind patterns, continental position, and mountain ranges giving rise to rain-shadow phenomena do create seasonally wet-and-dry areas in the tropics as well as in temperate regions. Altitudinal variations also create vast differences in climate, vegetation, and attendant animal life.

Tropical formations of major importance are:

A. Lowland rain forest—temperature more or less constant and warm, with any tendency toward drought offset by a coincident season of lower temperature.

B. Summer-deciduous forest—a forest with wet and dry periods alternating each year, and the trees, or many of them, leafless during the dry season.

C. Woodland and scrub formations—found in areas of still more pronounced drought, with small-leaved shrubs and low trees among which legumes are conspicuous.

D. Swamp and mangrove formations—forest or scrub growing where saline or fresh water covers the soil during at least part of the year.

E. Savanna—grassland, usually with scattered trees, related to abnormal soil conditions or recurrent burning of summer-deciduous forest.

F. Montane rain forest—evergreen forest of the cool, misty upper slopes of mountains, extending to upper tree line.

G. Alpine vegetation—nonforest vegetation of areas on mountains where there is sufficient heat for forest growth, as on Hawaii.

GROUP IV. AQUATIC ECOSYSTEMS

Collectively, aquatic plants and animals are at least as diverse as terrestrial forms. Although the concept of the *ecosystem* is equally applicable in the realm of aquatic biology, there are some difficulties in devising a classification of ecosystems that can be employed effectively in the survey and evaluation of natural areas. In part, these are the consequence of the philosophic problem of categorizing a very large number of essentially discontinuous fresh-water ecosystems. Further, although by no means unique to aquatic ecosystems, there is the practical problem of delineation of the ecosystem in terms of the area under consideration. For example, a lake as an ecosystem, in reality, should include the entire watershed and the plants and animals therein. The boundaries of a marine littoral ecosystem are even more difficult to delineate. Despite this type of difficulty, the concept of the ecosystem must nevertheless be applied vigorously in the evaluation of aquatic natural areas. A lake with an altered watershed is no longer natural, nor is a lagoon into which flows a polluted stream.

The system of themes used here for aquatic ecosystems is based extensively, although not completely, on geomorphological and other physical aspects of the environments of the aquatic ecosystems. Such a classification has obvious internal inconsistencies including many partially overlapping themes. Bearing in mind, however, that the function of the entire scheme is to provide the basis for the inclusion of ade-

quate and representative samples from the entire spectrum of natural history, such overlapping, rather than being a matter of concern, is one of insurance with respect to attaining the objectives of the system. It is only to be recognized that the system of themes for aquatic ecosystems has a structure that differs philosophically from that of the themes for terrestrial ecosystems.

Theme 29. Marine environments

Among the purely marine environments that can be included in protected areas, it is, of course, extremely difficult to divorce geological from biological influences. This theme is based on important changes in the biological community associated with relatively minor changes in substrate or exposure to wave action. Most conceivable marine sites will fit within the following divisions of this theme:

Exposed coastline with rocky substrate. A complex ecosystem characterized by maximum development of sessile animals and benthic algae (especially *Postelsia*). Wave action is severe; a splash zone is prominent; zonation is generally an obvious environmental feature. Examples: Cape Arego, Oreg.; and possibly Point Loma at the entrance to San Diego Harbor, Calif.

Exposed coastline with unconsolidated sediment. The animal community is simple, composed of organisms characterized by ability to burrow rapidly. Wave action, surf, tidal rips, and other water movements are severe. A plant community, at least in the ordinary sense, is nonexistent; the substrate consists of shifting sand or small pebbles.

Coral reefs. Examples may be found in the U.S. Virgin Islands, Florida, Hawaii, Samoa, and Guam. Exposure varies (i.e., windward and leeward sides). Reefs may be classified further into fringing, barrier, and atoll reefs. The biotic community is among the most complex known but also one of the best integrated. (*See also* Group 1, theme 11.)

Protected coastline with rocky substrate. Wave action is reduced in intensity. Zonation is often not very apparent. The splash zone may be reduced or absent. Examples: San Juan Islands; many areas near Santa Barbara, Calif., including Channel Islands.

Protected coastline with unconsolidated sediment. Included here are areas of extensive sand flats characterized by soft-bodied burrowing animals. This theme may be difficult to separate from lagoons below except on the basis of currents and general degree of protection. Examples: Discovery Bay, Wash.; Quincy Bay, Mass.

Lagoons. These are often extensive bodies of water completely protected from wave or current action. Organisms usually include eelgrass, *Zostera,* growing in extensive submersed meadows, and also characteristic animals. Examples: Mission Bay, Calif.; Sarasota Bay, Fla.

Tidal salt marshes. This is a type of community with little diversity among plants and animals. Tidal salt marshes are often underlain by extensive salt-marsh peat; they are frequently characterized by endemic or specific mammal or bird

populations. Examples: *Spartina* marshes, Sapelo Island, Ga.; *Salicornia-Distichlis* marshes, almost any bay in California; common from Puget Sound to Baja California.

Mangrove swamps. To a great extent these are the tropical replacements of the salt marshes. They are dominated by woody plants usually with stilt roots or pneumatophores. They occur in quiet tidal waters. Examples: Everglades National Park; all high Caroline Islands (Trust Territories).

Areas with extensive kelp beds. These are submarine forests with enormous brown algae in whose holdfasts live complex animal communities. Examples: much of the Pacific coast.

Theme 30. Estuaries

Estuarine ecosystems occupy the portion of rivers and/or arms of the sea between the head of tidal fluctuation and the open sea. They are characterized by marked gradients in salinity. The gradient in salinity and the tidal movements provide a series of habitats containing plants and animals that exemplify the transition from marine to fresh-water forms and from aquatic to terrestrial. Successions and the consequences of siltation are well illustrated. Relict forms may find in estuaries refuge from the forces of extinction. Isolation and partial isolation with their evolutionary consequences may be observed. In some cases, at least, this theme overlaps with, or is closely related to, lagoons, tidal salt marshes, and mangrove swamps in theme 29, or deltas in theme 33.

Theme 31. Underground ecosystems

Examples: many caves in Indiana and in the Ozarks.

Theme 32. Lakes and ponds

A single lake may present many characteristics and may typify different kinds of biological and geological interaction. The following divisions are based extensively on the ways in which biological characters of a lake are influenced by a variety of physical factors in the environment including geologic origin, location, climate, size (area and depth), and the chemical content of the water.

Large deep lakes. Large deep lakes are of interest and importance because of peculiar features with respect to stratification and restricted circulation, and because a relatively large fraction of the water mass is below the photosynthetic zone. Example: Lake Tahoe.

Large shallow lakes. In contrast to large deep lakes, these lakes tend to circulate more freely. Much more of the water is within the photosynthetic zone. Other factors being similar, such lakes are more productive. They are often major breeding sites for aquatic birds. Plant communities of the more eutrophic large lakes are characterized by abundance and diversity of forms. Examples: Mille Lacs and the Red Lakes, Minn.; Salton Sea, Calif. (Obviously there is a continuous spectrum between shallow and deep lakes.)

Lakes of complex shape. A lake with complex shape, but with essentially uniform type of water, frequently presents excellent opportunities for observations of the effects on biological communities and productivity of such factors as basin morphology, type of shore, and type of bottom. Included

are lakes with multiple basins and systems of interconnected lakes.

Crater lakes. Because of their origin, the morphology of their basins and the physical and chemical properties of their waters, many of these lakes tend to be extremely oligotrophic. They are usually isolated and have extremely small watersheds. Example: Crater Lake, Oreg.

Kettle lakes and potholes. Such lakes vary considerably in trophic state. Frequently they support a varied and abundant aquatic vegetation and are attractive to species of birds that require isolated aquatic or semiaquatic breeding territories.

Oxbow lakes. Attention should be given to the degree of trophic development and the rate of replacement by terrestrial communities. The more eutrophic oxbow lakes may be important breeding sites for waterfowl.

Dune lakes. Again attention should be given to the rate of replacement by terrestrial communities. The interpretive value of such lakes is obvious.

Sphagnum-bog lakes. Careful selection can give important illustrations of the evolution from aquatic communities to fen to bog.

Saline lakes. Saline lakes frequently contain unique communities of great interest and scientific value. They illustrate well the concept that the watershed is a part of the lake ecosystem.

Lakes fed by thermal streams. See thermal waters, theme 33.

Tundra lakes and ponds. These are, in reality, a part of the tundra ecosystem (Group III, theme 20). It includes a large fraction of the breeding North American geese and some other waterfowl. Low density is compensated by large total area. From the aspect of aquatic biology the shallow nature of these bodies and the long winter freeze exert distinctive and interesting effects on the communities therein.

Swamps and marshy areas. Properly selected examples will provide excellent illustrations of the evolution of aquatic communities. These areas support an abundance and diversity of animal life including many interesting species of birds and other animals. (They may be permeated by streams, ponds, and puddles.)

Sinkhole lakes. These are of importance and interest because of their origin from collapsed caves and because of previous or continuing association with underground stream systems.

Unusually productive lakes. See large shallow lakes, kettle lakes and potholes, and oxbow lakes. Example: Upper Klamath Lake, Oreg.

Lakes of low productivity and high clarity. See large deep lakes and crater lakes. Examples: Crater Lake, Oreg.; many montane lakes in Colorado.

Theme 33. Streams

Flowing waters are powerful molders of the earth crust and diverse habitats for life. As in the case of lakes and ponds, the biologic characteristics of streams are determined extensively by the physical properties of the streambed and by the nature

of the watershed. Streams are characterized within the following divisions of this theme:

Rapidly flowing streams. These are of varying size and with both gravel and rock bottoms. Such streams contain distinctive, specialized forms of substantial biological interest.

Slow meandering streams. These also include streams of varying sizes. Obviously, there is a spectrum of types between slow and rapid streams.

Deltas (both at seashore and at lakeshore). Deltas are often of major importance as breeding areas for waterfowl and shore birds. (*See also* estuaries.)

Springs. Especially important are springs in the desert or steppe, and those whose outflow disappears into the earth without connection to other bodies of water.

Thermal waters. These ecosystems contain organisms with unusual and biologically important thermal adaptations. Examples: springs and warm streams in Yellowstone and Mount Rainier National Parks.

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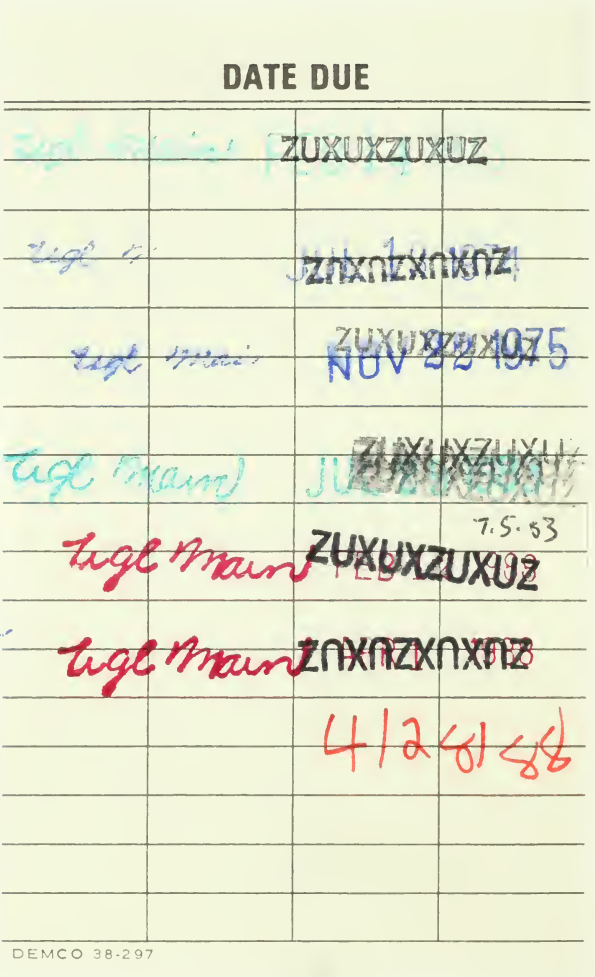

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