The Geology of North America
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Chapter 1

Introduction

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PURPOSE AND SCOPE

The Geology of Alaska summarizes the onshore and offshore geology, tectonic evolution, and mineral resources of Alaska and the adjacent continental margin. The volume was prepared at a particularly appropriate time because it follows a period during which there has been an explosive increase in the amount, quality, and regional coverage of earth science data collected in Alaska and because the unifying concepts of plate tectonics and accretionary terranes have become available as a framework for interpreting the data. These new concepts have led to recognition that all of Alaska, except possibly for one area that underlies less than one percent of the state, consists of lithotectonic terranes (also referred to as "suspect" or "tectonostratigraphic" terranes) that have been added to, displaced from, and/or rotated to varying degrees relative to autochthonous parts of the continental margin (Silberling and others, this volume, Plate 3). Thus, a first-order division of the geology of Alaska can be made into (1) the small area of probable autochthonous rocks in east-central Alaska; (2) terranes underlain by known or probable pre-Late Proterozoic continental crust that were part of the North American miogeocline; and (3) terranes, flysch basins, and overlap assemblages that have either been added to, or built along, the south and west margins of the miogeoclinal assemblages in a belt 550 to 700 km wide (Fig. 1). Much of the geologic research in Alaska during the past 15 years has focused on defining these lithotectonic terranes on the basis of their biostratigraphic, magmatic, metamorphic, structural, and paleomagnetic histories. These data have been used to constrain the degree of allochthoneity and the timing of emplacement of individual lithotectonic terranes.

In this introductory chapter we first present brief overviews of the physiographic, tectonic, and geologic setting of Alaska. We then summarize major aspects of the history of geologic and geophysical research in Alaska. Finally, we outline the organization of the volume and the areal or topical coverage of the various contributions. Substantial overlap with the companion volume on the Canadian Cordillera (Gabrielse and Yorath, 1991; Monger, 1989) is inevitable because the political boundary bears no relation to geologic boundaries and because many important geologic relations of the northern Cordillera are within Canada. Excellent recent overviews of the western Cordillera concerning plate and terrane tectonics concepts include those of Coney (1989), Oldow and others (1989), and classic syntheses of the tectonics of North America, including Alaska, by King (1969a, 1969b).

The region covered in this volume includes all of Alaska and its offshore margins between the international boundaries with Russia and Canada. It spans the North American continent between the Arctic Ocean basin on the north and the Pacific Ocean basin on the south. The continent is about 1300 km wide at the border with Canada and it widens to as much as 2000 km in western Alaska near long 170°W. The intraoceanic part of the Aleutian arc ranges from 75 to 180 km wide. The east-west dimension of the region ranges from about 1100 km along the Arctic margin at lat 70°N to 3600 km along the Pacific Ocean margin at lat 58°N, where it includes the entire Aleutian arc. This area is about 3.4×10^6 km^2, of which 1.52×10^6 km^2 is onshore and the remainder is offshore (Fig. 1). For purposes of comparison, this total area is equal to ~40% of the onshore conterminous United States.

PHYSIOGRAPHIC AND GEOLOGIC SETTING

Onshore Alaska is divisible into a number of domains that reflect broadly both the underlying geologic complexity and ongoing neotectonic deformation and volcanism (Fig. 2). We describe briefly the major physiographic subdivisions to acquaint the reader with the most important geographic features in Alaska that are cited throughout this book, as well as their relations to major physiographic provinces elsewhere in the western Cordillera.

Arctic coastal plain

The Arctic coastal plain in northern Alaska is part of the Interior Plains physiographic division of North America that extends through Canada and the conterminous United States along

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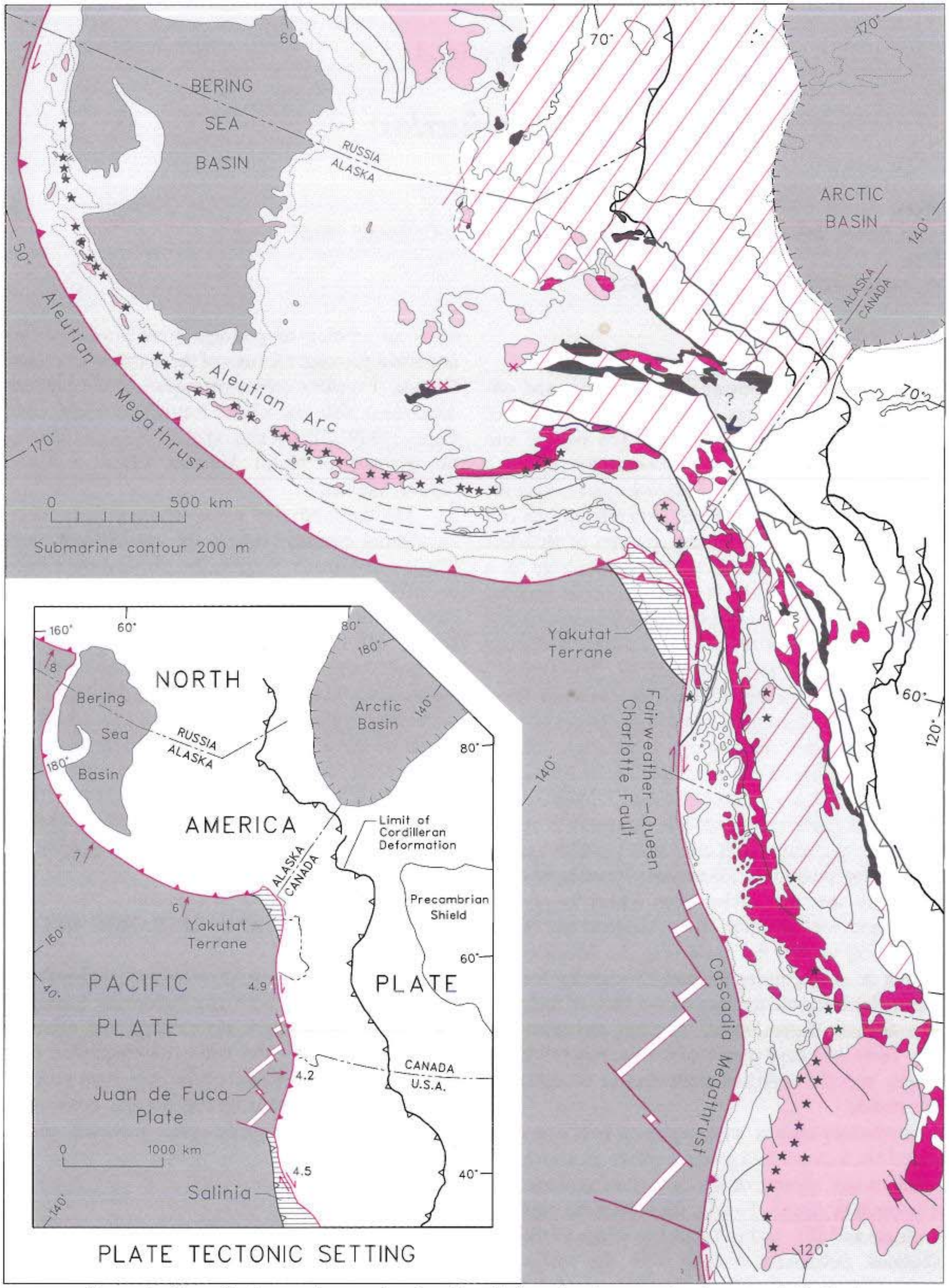


Figure 1. Generalized tectonic map showing the relation of major tectonic elements of Alaska to contiguous regions of Canada, the northern conterminous United States, and eastern Russia. Modified from King and Edmonston (1972), Silberling and others (1993), and unpublished data of Nokleberg and others. Explanation of patterns and symbols on facing page.

the east side of the Rocky Mountains. In Alaska, the plain is alluvium covered and slopes gently northward from maximum elevations of about 200 m along the southern margin of the province. It is underlain by at least 300 m of permafrost, and has many thaw lakes. A polygonal network of vertical ice wedges close to the surface underlies most of the plain away from water bodies. A dune field covers much of the coastal plain west of the Colville River. Subsurface exploration indicates that it is underlain by a sequence of Paleozoic and early Mesozoic miogeoclinal rocks which appear to have affinities with rocks of the North American miogeocline in the Ellesmere basin of Arctic Canada.

Cordillera of North America

All of Alaska south of the Arctic coastal plain lies within the Cordillera of North America (also variously referred to as the "Cordilleran orogenic belt" and the "Cordilleran orogen"). The Cordillera extends southeastward along the Pacific Ocean margin as far as Guatemala. The Cordillera in Alaska can be broadly subdivided into (1) a northern mountainous belt, (2) a central low-lying intermontane region, and (3) a southern mountainous belt. This part of the Cordillera in North America is unique in that the predominantly northwest trending topographic belts to the south bend abruptly into complex arcuate and linear east-west to southwest trends (Fig. 2B).

Northern Cordillera. The northern Cordillera in Alaska is equivalent to the northern part of the Rocky Mountain system of North America that extends southward through Canada and the northern part of the conterminous United States. In Alaska, these mountains are dominated by the east-west–trending Arctic Foothills, Delong Mountains, Baird Mountains, and Brooks Range, in which average summit elevations are between 1000 to 1500 m in the western part and rise to 2100 to 2400 m in the eastern part. During many of the Pleistocene glaciations, the central and eastern Brooks Range, as well as the Baird and Delong Mountains and Noatak lowland, were covered with a mountain ice cap that imposed a characteristic glacial topography, and nourished ice tongues that extended into lower lying areas to the north and south. Fission-track data and the presence of river terraces suggest that the mountains are young and rising.

The stratigraphy and structure of this region exhibit affinities with the geology of the North American miogeocline in both adjacent parts of Canada and the Ellesmere basin of Arctic Alaska.

Interior Alaska. Between the mountain barriers of northern and southern Alaska is an extensive region that is drained into the Bering Sea mainly by the Yukon and Kuskokwim river systems. This region is part of the intermontane Plateaus physiographic province that extends southward through Canada and into the conterminous United States, where it includes all of the Great Basin and Colorado Plateau. The entire region is commonly referred to simply as "interior" Alaska, even though it extends to the Bering Sea coast. Wide alluvium-covered lowlands border the Bering Sea and broad alluvium-floored interior lowlands and basins are distributed along the major drainages. The anomalous Yukon Flats are located about 800 km from the coast, but they are as flat as a coastal plain and are less than 200 m above sea level. Elsewhere the region consists of plateaus, hills, and rolling uplands in which average summit elevations are mainly between 600 and 1500 m. Numerous domes, ridges, and mountains rise 300 to 600 m above the general upland level. Interior Alaska was free of ice throughout the Pleistocene, except for ice caps over the Ahklun Mountains in southwestern Alaska and the southern mountains of the Seward Peninsula, and small cirque and valley glaciers in some of the highland areas elsewhere. Ice-free areas of interior Alaska served as part of the migration route for humans and other land animals from Eurasia to the Americas.

The geology in much of this region is poorly exposed because of an extensive cover of loess and vegetation, as well as the effects of mass wasting related to permafrost. Pre–mid-Cretaceous basement rocks in the region include displaced and rotated lithotectonic terranes of Late Proterozoic and Paleozoic age with affinity to the North American miogeocline, Devonian to Early Jurassic terranes of oceanic affinity, domi-

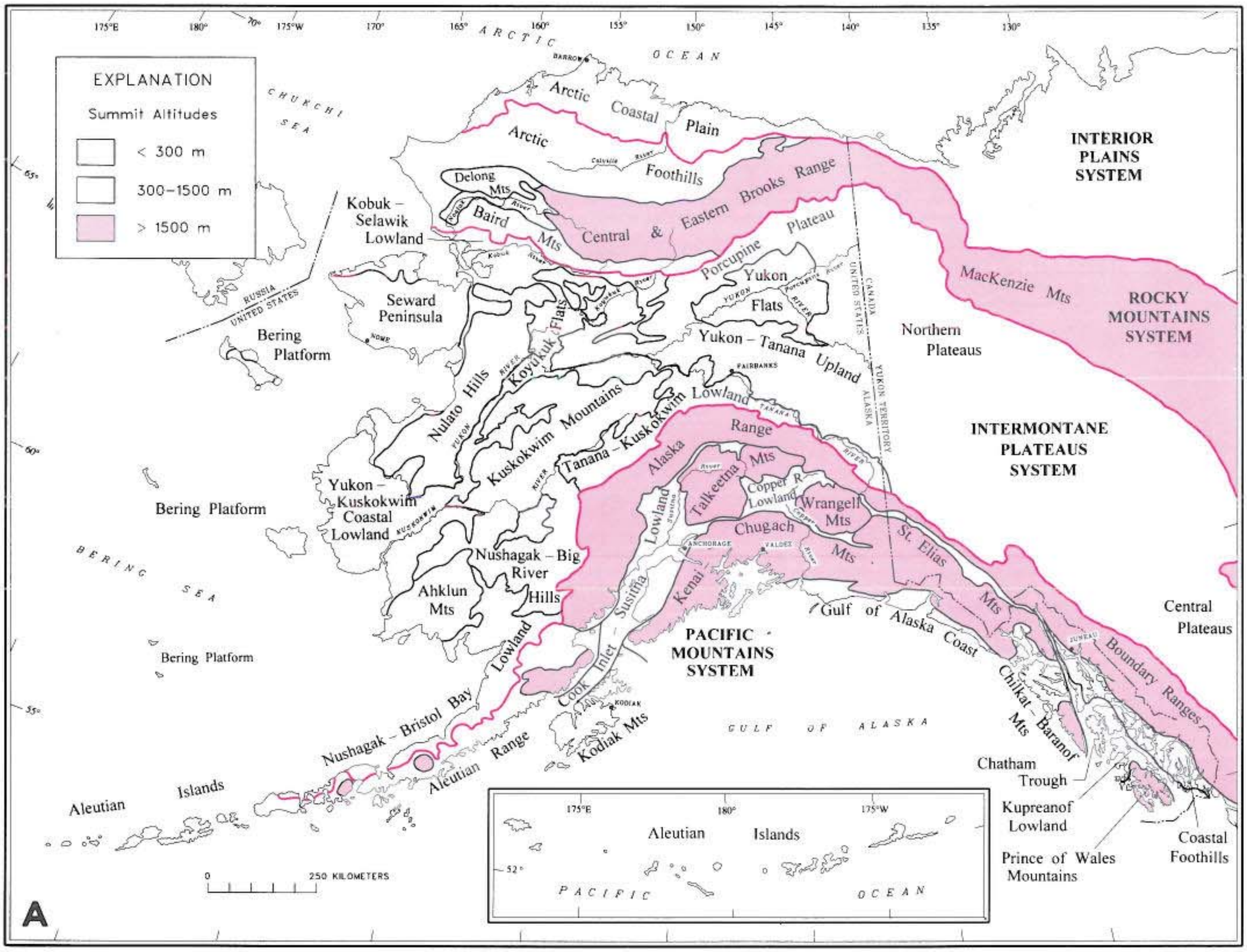
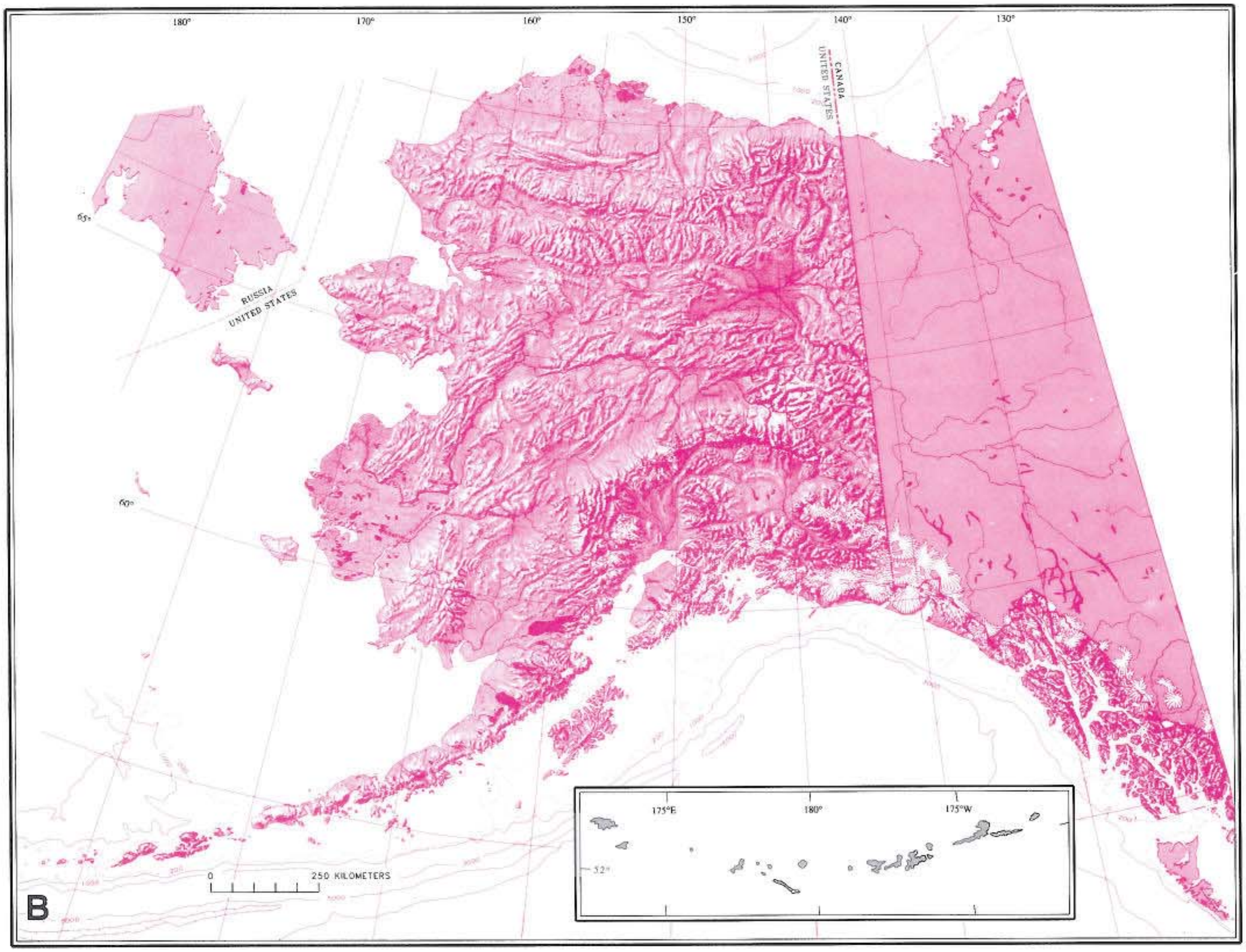


Figure 2. Physiography of Alaska and adjacent parts of Canada. A: Physiographic subdivisions of Alaska from Wahrhaftig (this volume, Plate 2). Heavy black lines bound Alaska physiographic divisions; heavy red lines bound major North American physiographic systems. B (on facing page): Shaded relief map is from Harrison (1969).

nantly Jurassic and Early Cretaceous intraoceanic arc terranes, and small terranes of uncertain affinity. Older rocks in much of this region are concealed by mid-Cretaceous and younger plutonic rocks, arc-related volcanic rocks, flysch basins, and alkalic basalt. Basement beneath a large part of western interior Alaska and the Bering Sea shelf is unknown; limited data suggest that it may be constructed mainly of mid-Cretaceous and younger magmatic and clastic rocks.

Southern Cordillera. The southern Cordillera is part of the Pacific Mountain system of North America that rims the Pacific Ocean margin from Alaska to Central America. Physiographically, the southern Cordillera in Alaska, like the Pacific Mountain system in Canada and the conterminous United States, is made up of two rugged mountain belts with an intervening discontinuous lowland belt (Fig. 2).

The northern mountain belt in mainland Alaska consists of the Alaska Range, which describes a convex-north bend roughly parallel to the Gulf of Alaska margin. To the west, the Alaska Range extends into the Aleutian Range and Aleutian Islands, which form a convex-south arc; the continuation of the Alaska Range into southeastern Alaska and Canada comprises the linear Boundary Ranges and the subparallel Coastal Foothills. The southern mountain belt in south-central Alaska is made up of the Saint Elias, Chugach, Kenai, and Kodiak mountains, and the Chilkat-Baranof and Prince of Wales mountains in southeastern Alaska. The lowland belt between the northern and southern mountains includes, from west to east, the Cook Inlet–Susitna and Copper River lowlands and the island-studded Kupreanof lowlands in southeastern Alaska. These lowlands are connected by narrow and discontinuous valleys along the southern margin



of the roughly circular Talkeetna Mountains and along the north side of the Wrangell and St. Elias mountains.

Except for the Saint Elias Mountains, most of the summit altitudes in the southern Cordillera are between 2000 and 3000 m. The Saint Elias Mountains include several extremely high mountains, including Mount Logan (5745 m) in Canada and Mount Saint Elias (5488 m) in Alaska. A compact group of mountains rising to 4000 m lies in the Chugach Range just north of Prince William Sound. Three isolated groups of mountains over 3000 m surmount the Alaska Range; the highest of these is the group that culminates in Mt. McKinley, at an altitude of 6180 m the highest peak in North America.

The entire southern Cordillera has been glaciated episodically during the Pleistocene, and lowlands were filled with broad ice fields fed from mountain ice caps or networks of giant valley glaciers. Depositional glacial landforms, including arcuate belts of moraines and stagnant-ice topography, abound in the lowlands, along with large lakes in ice-carved basins within and along the mountain fronts, and numerous lakes in ground moraines and stagnant-ice topography. Extensive networks of mountain glaciers and ice fields exist in parts of the Alaska, Aleutian, Kenai-Chugach, Talkeetna, Wrangell, Saint Elias, and Coast mountains. The glaciers invade the margins of the lowlands and, along the Gulf of Alaska, they form the largest piedmont glacier lobes in the world (Malaspina and Bering glaciers). Glaciers currently extend to tidewater at numerous bays and fiords and at one locality along the open Gulf of Alaska coast (La Perouse Glacier).

Many large rivers in the southern Cordillera cross the mountain ranges through deep canyons. Most notable of these are the Copper, Delta, Nenana, Susitna, and Alsek rivers in southern Alaska and the Stikine and Taku rivers in southeastern Alaska. They are probably antecedent streams that predate Neogene uplift of these mountain ranges.

All of the southern Cordillera is underlain by accreted intraoceanic arc and plateau terranes, arc-related accretionary prisms, and flysch basins that range in age from Proterozoic through Cenozoic; the terranes are extensively intruded by post-accretion plutons mainly of mid-Cretaceous and Paleogene age and are overlapped by Late Cretaceous and younger basinal strata and volcanic rocks. Much of the present mountainous topography is the result of Paleogene deformation and uplift related to ongoing accretion of the Yakutat terrane along the northern Gulf of Alaska (Fig. 1). In the Aleutian Islands, Alaska Range, and Wrangell Mountains much of the mountainous topography is constructional, consisting of stratovolcanoes related to the Aleutian magmatic arc. An isolated stratovolcano also occurs near Sitka in southeastern Alaska (Fig. 1).

TECTONIC SETTING

Mainland Alaska and its submerged extensions span the North American plate from the passive trailing margin along the Arctic Ocean basin to the tectonically active southern boundary with the Pacific plate; the intraoceanic part of the Aleutian arc (west of about long 170°W) lies along the relatively passive northern margin between the arc and the Bering Sea basin (Fig. 1). Most of Alaska south of the southern Brooks Range has been a locus of plate-tectonic activity intermittently since Late Proterozoic time and the entire region was dominated by large-scale convergence or oblique convergence since the Late Triassic. We infer from geologic and paleomagnetic data that the continental margin in Alaska had an original northwest to north trend (in present coordinates) and that the present east-west to southwest structural trends in central and western Alaska are the result of large-scale late Early Cretaceous to early Tertiary counterclockwise rotations. Plate reconstructions (Engebretsen and others, 1985) indicate dominantly orthogonal convergence during the subduction of the Farallon plate (100–85 Ma) and dominantly dextral-oblique convergence during the subduction of the Kula plate (85–55? Ma). After about 55 Ma, Pacific–North American plate relative motions were northwesterly with dextral to dextral-oblique convergence on the northwest-trending transform margin and orthogonal convergence on the northeast-trending Aleutian Arc margin. Total subduction beneath the south margin of Alaska is about 7000 km since formation of the Kula plate in mid-Cretaceous time, and the coast-parallel dextral component during this interval is about 2000 km (Engebretsen and others, 1985).

At present, the Pacific plate is moving northwest relative to Alaska at rates that range from 4.9 cm/yr along the Queen Charlotte–Fairweather transform fault system in the east to as much as 7.7 cm/yr at the western end of the Aleutian arc; the small Yakutat terrane is coupled tightly to the northwest-moving Pacific plate and is currently being accreted to the southern margin of Alaska (Fig. 1). Stress trajectories derived from neotectonic data suggest that late Cenozoic mountain-building deformation and seismicity throughout Alaska and adjacent parts of Canada are driven mainly or entirely by interaction between the Pacific plate (and Yakutat terrane) and the southern margin of the continent (Plafker and others, this volume, Plate 12). Manifestations of this plate interaction include the development of the Aleutian magmatic arc and trench, active dextral displacement on the Queen Charlotte–Fairweather transform fault and on northwest- to west-trending intraplate faults, basaltic volcanism throughout much of interior and western Alaska and on the Bering Sea shelf, extreme uplift and topographic relief in the coastal mountains and Alaska Range, intense ocean-verging compressional deformation within and adjacent to the Yakutat terrane, and by some of the most active seismicity in the world, including the largest earthquakes and measured horizontal and vertical coseismic deformation recorded in North America.

REGIONAL GEOLOGIC SETTING

Major crustal types known or inferred to underlie mainland Alaska and adjacent parts of Canada are (1) continental crust of the Cordilleran miogeocline, (2) heterogeneous crust consisting mainly of amalgamated magmatic arcs, oceanic plateaus, melange, and flysch belts in southern and western Alaska, and (3) a narrow intervening discontinuous belt of oceanic crustal rocks (including ophiolite) that in part overrides the adjacent rocks (Fig. 1). These original crustal types have been extensively modified and obscured by magmatism, metamorphism, and overlapping sedimentary deposits that are mainly of Cretaceous and Cenozoic age, and they have been disrupted by Late Cretaceous and Cenozoic faulting and large-scale rotations. Together these tectonic processes have produced the complex structural trends that characterize much of Alaska and that are reflected in the topography (Fig. 2B). The western half of the Cenozoic Aleutian magmatic arc is built on younger oceanic crust and the eastern half of the arc extends across older accreted crust that constitutes the basement along the southern margin of Alaska.

The early continental margin of North America, including what is now northern and eastern Alaska and northern Canada, was shaped by Late Proterozoic rifting beginning at about 850 Ma and by intermittent rifting that continued into early Paleozoic time. Rifting was followed by gradual subsidence of the continental margin and initial deposition of thick bedded sequences of Late Proterozoic and Paleozoic age that constitute the Cordilleran miogeocline, which extends inland to the Precambrian shield (inset map, Fig. 1). Early Proterozoic (2.1 Ga) metamorphic rocks are exposed only in small isolated areas of western Alaska where their structural relations to nearby miogeoclinal rocks are unknown (Fig. 1); their isotopic signatures are compatible with an origin in a continental-margin magmatic arc (Decker and others, this volume).

From the inception of the Cordilleran miogeocline in Late Proterozoic time, the continental margin has been affected repeatedly by plate-tectonic activity to form the present Cordilleran orogenic belt. Manifestations of this tectonism in Alaska and adjacent parts of Canada include early Paleozoic rift-related sedimentation and magmatism as well as Silurian(?) and Devonian to Early Mississippian continental margin magmatism and deformation that may be arc related.

Mainly during Jurassic and Cretaceous time, plate convergence along the continental margin resulted in formation of a collage of diverse intraoceanic arcs, arcs on possible rifted continental crust, arc-related accretionary prisms, flysch basins, oceanic plateaus, and vast slabs of oceanic crustal rocks (Fig. 1). The emplacement of these disparate terranes was accompanied by repeated episodes of deformation, magmatism, and metamorphism within the accreted assemblages and in adjacent parts of the miogeocline and by initial formation of the Cordilleran fold and thrust belt with associated foreland basins in northern Alaska and Canada (Fig. 1). The oceanic crustal rocks are the remnants of vast Devonian to Early Jurassic marginal sea basins that were closed between the continental margin and the intraoceanic terranes. Although they were greatly modified by subsequent tectonism, magmatism, and erosion, these remnants of deep-sea crust are a fundamental feature of the Cordilleran orogenic belt because they delineate the suture zones along which the autochthonous or parautochthonous rocks of the continental margin are juxtaposed against the outboard collage of predominantly noncontinental rocks (Fig. 1).

From about mid-Cretaceous to early Tertiary time an Andean arc system was developed along the continental margin of Alaska and British Columbia in response to rapid convergence between the Kula and North America plates. Voluminous arc-related volcanism, plutonism, and associated metamorphism in a belt as wide as 500 km welded the accreted terranes to one another and to the continental margin. Arc-related magmatic rocks and volcanogenic sediments probably built much of the crust that underlies the Bering Sea shelf and adjacent parts of western Alaska, and an arc-related accretionary prism as wide as 300 km developed along the seaward side of the arc.

The present complex structural configuration of mainland Alaska evolved mainly during this Cretaceous to Early Tertiary interval as a result of large-scale rotations and translations, some of which occurred simultaneously. During late Early Cretaceous time the Arctic Ocean basin formed by counterclockwise rotation of northern Alaska away from the Arctic Canada segment of the continental margin. Probably during this same time interval, continental fragments in central Alaska (Ruby terrane) were initially rotated clockwise away from the southern Brooks Range. During Late Cretaceous to early Tertiary time much of the Cordillera south of the Brooks Range was disrupted by hundreds of kilometers of offset along the Tintina and Denali faults and their major splays. In central and western Alaska, this faulting accompanied, or was immediately followed by, counterclockwise oroclinal rotation and associated displacements on preexisting transcurrent faults.

HISTORY OF GEOLOGIC AND GEOPHYSICAL RESEARCH

Geologic and geophysical investigations in Alaska have taken place in five general phases that overlap to varying degrees. They are (1) the period of Russian ownership from 1741 to 1867; (2) pioneering explorations and investigations of metallic minerals and fuels from 1867 to about 1906; (3) reconnaissance geologic mapping and expanded metallic minerals and fuels investigations from 1907 to about 1939; (4) systematic reconnaissance geologic mapping in the more accessible parts of Alaska and accelerated investigations of metallic minerals and fuels from 1940 to about the time of Alaska statehood in 1959; and (5) detailed geologic mapping, resource investigations, and topical studies throughout Alaska and contiguous offshore areas since 1960. Geologic concepts since 1960 can be subdivided into three subgroups: an early period dominated by geosynclinal theory; a second period beginning in the mid- to late 1960s during which the concepts of plate tectonics emerged; and a period beginning in the late 1970s in which it was recognized that most of Alaska consists of terranes that are displaced and rotated in varying degrees relative to the North America continental margin.

The following summary is based largely on two unpublished manuscripts by R. M. Chapman and D. J. Grybeck of the U.S. Geological Survey that provide detailed historical overviews of geologic and geophysical investigations in Alaska and the evolution of geologic concepts. Additional historical data and data on resource exploration and production are given in appropriate chapters in this volume. A helpful introduction to the geologic literature of Alaska was prepared by Grybeck (1976), and Hopkins (1983a, 1983b) compiled data on the status of geologic mapping in Alaska through 1982. We begin this section with a brief discussion of some of the unique aspects of field work in Alaska.

Note on the logistics of geologic field work in Alaska

The problems of working in Alaska are unique, and to a large extent they have shaped the progress of geologic research. Formidable obstacles to field investigations are its vast size, its remoteness from the conterminous United States, the scarcity of road and rail access, and barriers to ground travel posed by rugged mountain ranges, extensive regions of swampy tundra, swift icy rivers, and extensive glaciers.

Most of the early exploratory work in Alaska was along the coast and major drainages where boats could be used for travel. Elsewhere, traverses were primarily by foot except in some parts of southern Alaska where horses could be used. Geologic investigations during the early years in Alaska often had to be carried out concurrently with topographic surveys because of the absence of suitable base maps. Field seasons routinely were long, arduous, and hazardous with only sporadic communication with the outside world. As eloquently described by Smith (1939, p. 4), "Some of the conditions of field work in the early days would stagger any but those possessed of indomitable courage and perseverance as well as keen technical insight. Many of the best-founded present-day beliefs were first reached by those early geologists from some chance observation made during the intervals snatched from the racking grind of back-packing or other labors entailed in the grim necessity of self-preservation under the exigencies of exploratory work."

Except in the vicinity of the limited road and railroad network, geologic field work requiring overland or boat travel remained basically unchanged in much of Alaska until the late 1950s, when helicopters came into general use. However, access and logistics were significantly improved beginning in the late 1920s, when light fixed-wing aircraft became practical for moving and supplying personnel, for reconnoitering, and for taking aerial photographs. The availability of aerial photographs for mapping beginning in the late 1920s also did away with the need to conduct topographic surveys along with the geologic mapping. In the mid-1940s, tracked vehicles such as the U.S. Army "weasel" began to be used in winter geophysical surveys on the North Slope and in support of geological investigations in areas of low and moderate relief. The use of portable short-wave radios, beginning in the mid-1940s, ended the isolation of field parties in remote parts of Alaska and greatly expedited the logistics and safety of field work.

It was the increasingly routine use of helicopters for logistic support beginning in the mid- to late 1950s that revolutionized field work for geologists and geophysicists in Alaska. Helicopters have made all but the most rugged parts of Alaska accessible for investigation and they significantly improve the efficiency and quality of field work by reducing the time required in getting to and from study areas.

Russian Alaska: 1741 to 1867

The first recorded observations on the geology of Alaska were made in 1741 by the German naturalist Georg Wilhelm Steller at the time of Vitus Bering's brief discovery landing in the New World at Kayak Island in the Gulf of Alaska. During the ensuing period of Russian occupation of Alaska, the primary impetus for exploration was to exploit the fur trade, to consolidate Russian territorial claims, and to further missionary interests. Nevertheless, some prospecting and mining was carried out by the Russians. The first recorded mining venture in Alaska was on the Kenai Peninsula, where a placer gold mine was operated from 1848 to about 1850. The Russians also began producing coal in 1854 from deposits at Port Graham on the southern Kenai Peninsula for use as fuel for steamships, but the mine was abandoned after about 10 years.

Published knowledge of the geography of Alaska was scarce and largely confined to maps of the coast and major drainages. Geologic and geographic information about the interior was derived from a few reconnaissance expeditions by the Russians and by surveys for a telegraph route across Alaska that was to connect by submarine cable with Siberia.

From 1867 to 1906

In 1867 Alaska became a possession of the United States through purchase from Russia and territorial status was conferred in 1912. Following the change of ownership of Alaska, mining and exploration activity continued at a low level almost until the end of the century. In 1877 the first lode-gold mine began production in Alaska near the former Russian capital at Sitka, and by 1882 the Treadwell lode mine near Juneau began operation. The bonanza gold discoveries in the Canadian Klondike on the upper Yukon River in 1896 started a stampede to the north that quickly spread into Alaska. In 1898 the rush to Alaska began in earnest with discovery of rich gold placer deposits near Nome. Within a few years, gold prospecting and important discoveries spread throughout Alaska. Gold mining has made a major contribution to Alaska mineral production every year since 1877, except during World War II when a moratorium was imposed on gold mining.

Deposits of copper and associated precious metals were known in Alaska as early as 1867 and important copper deposits were mined in the Prince William Sound area from 1897 to 1930 and in the Ketchikan area from 1906 to 1941. The bonanza copper deposits near Kennicott were discovered in 1900 and the district produced large amounts of copper and silver from 1911 until the mines closed in 1938. Cinnabar deposits in the Kuskokwim River region have been mined since 1902 and are the source of all the mercury produced in Alaska. Coal was mined on a small scale from several deposits throughout Alaska in the period from 1880 to 1915. Seeps of oil and gas were long known to the native people along the Gulf of Alaska coast, on the Alaska Peninsula, and in northern Alaska. In 1902 the shallow Katalla oil field was developed in a seepage area and it produced small quantities of oil until the refinery burned and the field was abandoned in 1933.

A systematic effort spurred by the influx of gold prospectors was begun in 1898 by the U.S. Geological Survey (USGS) and U.S. Army to investigate Alaskan resources and to produce topographic and geologic maps. The geologic investigations focused mainly on areas having potential for gold, copper, and mineral fuels. Although most of the early publications on Alaskan geology emphasized mineral resources, regional geologic maps were routinely prepared along the routes of travel. In addition to the work of Federal agencies, the USGS and the American Geographical Society of New York jointly sponsored I. C. Russell's two expeditions in 1889 and 1891 to the Mount Saint Elias area and the studies of the effects of the great 1899 Yakutat Bay earthquakes that were carried out in 1906 by R. S. Tarr and G. C. Martin. A major scientific expedition to parts of the south coast of Alaska in 1899 that included geologic observations was privately funded by Averill Harriman. The earliest geophysical studies in Alaska were a few pendulum gravity measurements along the coast made by T. C. Mendenhall of the U.S. Coast and Geodetic Survey.

First synthesis of the geology of Alaska. In 1906 A. H. Brooks, who was then head of the Alaska Division of the USGS, published the first summary of the geology and physiography of Alaska (Brooks, 1906). At that time, less than 25% of Alaska had been visited by geologic parties, and the geology of the state could be depicted on a page-size map with 10 map units. Major geosynclinal and geanticlinal areas were delineated, but faults are absent from the map and structure sections. Nevertheless, the broad outlines of the geography and physiography were delineated and many of the stratigraphic units still in use in Alaska had already been defined. A noteworthy achievement was the recognition of the limits of Pleistocene glaciation and the fact that much of interior Alaska had not been covered by continental glaciers.

From 1907 to 1939

Geologic mapping and metallic mineral resource investigations continued throughout this period and they were expanded to the basinal areas in a search for coal and petroleum. Exploration for coal was carried out in the Controller Bay and other coal fields of southern Alaska by private companies and the USGS. Mining of coal in the Matanuska Valley from 1916 to 1970 and near Healy in the Alaska Range since 1918 was stimulated by completion of the Alaska Railroad in 1914. The Fairbanks Exploration Company experimented with seismic, electrical, and magnetic surveys as aids to delineating placer gold deposits in permafrost. Basinal areas were investigated by company and USGS parties throughout Alaska, and unsuccessful test wells were drilled by oil companies during the 1920s and 1930s along the Gulf of Alaska and on the Alaska Peninsula. Naval Petroleum Reserve No. 4 (Pet-4) was established in northern Alaska by Presidential Proclamation in 1923. Under an agreement with the U.S. Navy, the USGS conducted reconnaissance geologic and geographic surveys to evaluate the petroleum potential of Pet-4 from 1923 to 1926. The National Geographic Society funded glaciological studies in the Yakutat Bay area by R. S. Tarr and G. S. Martin in 1909 and 1910 as well as research on the 1912 Katmai eruption by C. N. Fenner and R. F. Griggs. Private funds also supported the outstanding geologic mapping carried out by E. deK. Leffingwell in the Canning River area of the eastern Brooks Range between 1906 and 1914. Nevertheless, by 1939, less than half of what was then the Territory of Alaska had been surveyed by geologists, even by minimum reconnaissance standards (Smith, 1939).

Second synthesis of the geology of Alaska. P. S. Smith, who became head of the USGS in Alaska in 1924, wrote the second comprehensive publication on the geology of Alaska (Smith, 1939). Smith's summary mainly described the general distribution, lithology, and relative ages of rock units and Quaternary deposits as well as metallic mineral deposits and coal resources. The accompanying map, at 1:2,500,000 scale, depicted the geology of about half of the territory with 16 map units; an accompanying table shows the age, lithology, and correlations of stratigraphic units. Structural data are not shown on the map and there is no section on structure in the text. The limits of Pleistocene glaciation, however, were well defined, the general distribution of permanently frozen ground (permafrost) and its importance in placer-gold mining were clearly recognized, and most of the active volcanoes in Alaska are shown. In 1941 Smith published the first in a series of reports on the petroleum potential of Alaska.

From 1940 to 1959

From about 1940 until 1959, there was a dramatic increase in the amount and diversity of earth science research in Alaska.

World War II and postwar investigations by USGS and other federal agencies. World War II provided the impetus for exploration by the USGS throughout Alaska to locate strategic mineral resources and petroleum. Construction related to military activities provided the incentive for USGS mapping of surficial deposits and permafrost that was to continue as an important program into the late 1950s. In northern Alaska, a modern oil-exploration program, including test drilling, was conducted by the U.S. Navy through Arctic Contractors in Pet-4 from 1944 to 1953, and resulted in the discovery of several noncommercial oil and gas deposits. In conjunction with exploration in Pet-4, the USGS continued geologic mapping in Pet-4 and other basins; this led to a summary publication on the geology and petroleum potential of Alaska (Gryc and others, 1951). Military needs spurred acquisition of aerial photo coverage for all of Alaska and these photographs were extensively utilized to speed up geologic mapping using photogeologic interpretation. In 1944 USGS geologists and geophysicists began a search for radioactive minerals in support of the secret atomic research program that led to development of one uranium mine in southeastern Alaska.

A joint topographic mapping program by the USGS, Army Corps of Engineers, and U.S. Coast and Geodetic Survey begun in 1948 produced reconnaissance 1:250,000 topographic map coverage of Alaska by 1953, and in 1989 modern topographic map coverage was completed at scales of 1:62,500, 1:63,360, and 1:250,000. At the request of the War Department, the USGS conducted a systematic reconnaissance of the geology of the Aleutian Islands from late 1945 through 1954.

The postwar years witnessed a significant expansion of topographic, geologic, and geophysical mapping, drilling, and earth science research. Exploration for minerals by industry remained active, and mines in Alaska produced gold, coal, silver, platinum, and mercury. Much of the mapping by the USGS and other federal agencies was conducted as part of the requirements for land classifications and management related to establishment of the State of Alaska in 1959. An innovation in the early 1950s was the first use by the USGS of geochemical analysis of plant and soil samples as a guide to metallic minerals exploration.

Petroleum exploration and Cook Inlet discoveries. Renewed postwar exploration and drilling activity for petroleum by oil companies was rewarded in 1957 by the discovery of a commercial oil deposit on the Kenai lowland, and in 1963 by discovery of a major oil field offshore in the adjacent Cook Inlet. Since 1957 almost two dozen oil and gas fields have been discovered onshore and offshore throughout the Cook Inlet basin. Oil production peaked in the Cook Inlet basin in 1970 and declining production is projected to the late 1990s. The Cook Inlet discoveries sparked a boom in leasing and exploratory drilling throughout southern Alaska that was accompanied by an emphasis on geologic mapping in basinal areas by the USGS.

Geophysical studies. A variety of geophysical methods began to be applied to investigations in Alaska during this period by the USGS. In the early 1940s magnetic and resistivity methods began to be used in mineral resource studies and in the mid-1950s aeromagnetic and radiation surveys were employed. Exploration for petroleum in Pet-4 and elsewhere in Alaska employed seismic reflection, aeromagnetic, and gravity surveys beginning in the mid-1940s. Offshore geophysical studies included submarine gravity measurements off the continental margin by the Lamont Geological Observatory, and explosion refraction experiments in the Skagway and Prince William Sound areas by the Carnegie Institution in 1956 and by the Scripps Institution of Oceanography in 1956–1957 at Dixon Entrance and at three sites near Kodiak, Unimak, and Adak islands. The University of Wisconsin and Woods Hole Oceanographic Institution released a preliminary list of Alaskan gravity stations in 1959, and in 1958 the USGS began a long-term gravity mapping program that provided reconnaissance coverage of much of Alaska by 1977.

Compilations of geologic mapping and research in Alaska 1957–1959. By 1959, reconnaissance geologic studies had been carried out in about 80% of the territory. However, geologic maps at scale of 1:250,000 or smaller were available for only about one-third of the territory and no more than a few percent was covered by more detailed larger scale maps. Although numerous areas remained essentially unknown, coverage was adequate for compilation of a significantly improved geologic map of Alaska at a scale of 1:2,500,000 that had 55 map units and showed many of the major faults for the first time (Dutro and Payne, 1957). The book *Landscapes of Alaska: Their geologic evolution* (Williams, 1958) summarized in layman's terms the physiography of Alaska and its geologic underpinnings, and a comprehensive treatment of the physiography of Alaska was written by Wahrhaftig (1965). A compilation by Payne (1955) depicted major Mesozoic and Cenozoic tectonic elements of Alaska at a 1:5,000,000 scale and discussed them in terms of discrete orogenies, and subparallel geosynclinal sedimentary basins and geanticlinal source regions. These concepts were to influence thinking on the tectonics of Alaska until the late 1960s, after which they began to be displaced by more mobilistic plate and accretionary tectonics models. The geology and stratigraphy of possible petroleum basins in Alaska was summarized by Miller and others (1959); in this synthesis discussions of tectonic framework of the basins followed Payne's geosynclinal concepts. This was followed by similar summaries that focused on the petroleum resources of Alaska but also provided excellent synopses of the geologic setting (Gates and Gryc, 1963; Gates and others, 1968).

Early concepts of crustal mobility in Alaska. Some of the first studies to suggest large-scale crustal mobility in Alaska include: (1) the recognition that seismic zones associated with volcanic arcs, including the Aleutian arc, occur along major complex reverse faults that dip from the trench beneath the magmatic arc (Benioff, 1954); (2) the interpretation of the Denali fault as a major San Andreas–type dextral strike-slip fault along which hundreds of kilometers of displacement occurred (Saint Amand, 1957); (3) studies of the effects of the 1958 Lituya Bay earthquake (M_s = 7.9) that documented that the Fairweather fault is a major strike-slip structure along which at least 4 m dextral displacement occurred during the earthquake (Tocher, 1960); and (4) interpretations by Carey (1958) that the Arctic- Ocean basin formed as a rotational rift of Alaska away from the Canadian Arctic islands and that western Alaska is a gigantic counterclockwise oroclinal bend about a pivot in Prince William Sound.

Post-1960 investigations

After Alaska became a state, there was a marked expansion in the number of organizations doing geologic work in the state and in the diversity of the studies. Contributions were increasingly made by the newly formed Alaska Geological Survey (now the Alaska Division of Geological and Geophysical Surveys [ADGGS]), by students and faculty members in the Geology Department of the University of Alaska, which began a graduate program in 1959, and by faculty and students from several universities outside the state.

Regional mapping and metallic minerals and land-use investigations. Since 1960, the USGS has continued to carry out statewide regional mapping and minerals evaluations. Geologic mapping and mineral resource investigations were initially undertaken by the USGS to fill important gaps in geologic knowledge of Alaska. Later, much of the work was done as part of national programs, including: (1) efforts to delineate gold, silver, and platinum resources (1965 to 1969); (2) land and resource evaluations required for land selections as part of the Alaska Native Claims Settlement Act of 1971 that still continue; (3) studies of areas designated or proposed for wilderness classification (1969 to the early 1980s); and (4) the Alaska Mineral Resources Assessment Program, which began systematic multidisciplinary geologic, geophysical, and geochemical studies of 1:250,000 scale quadrangles (1974 to present).

Exploration by industry for metallic minerals peaked in the early 1980s and declined thereafter due to unfavorable metals prices, but several deposits containing very large resources of molybdenum, copper, lead, zinc, gold, tin, tungsten, cobalt, fluorite, and beryllium have been delineated. Of these, production began from the Greens Creek zinc-lead-copper-silver-gold deposit in southeastern Alaska in 1989 and from the Red Dog zinc-lead-silver-barite deposit near Kotzebue in 1991, making these the first producing base-metal mines in Alaska since 1941.

1964 earthquake and geologic hazards studies. In 1964, the destruction wrought by the largest earthquake ever recorded in North America (M_W = 9.2) brought a new awareness of geologic hazards that stimulated geotechnical studies by government agencies, private companies, and academia. Comprehensive studies were made of the geologic effects of the earthquake and tsunami and the resulting damage to the works of man and ecosystems by the USGS, other federal and state agencies, and geotechnical companies. Among the notable new results of this research were (1) some of the earliest compelling evidence for crustal plate convergence and large-scale thrust faulting in an arc environment; (2) the first demonstration of a direct relation between coseismic vertical displacement of the sea floor and generation of a destructive tsunami; and (3) the earliest application of geologic techniques (now referred to as "paleoseismology") to determine the recurrence intervals of earthquakes (Plafker, 1965; Plafker and Rubin, 1967).

In 1974, a long-term program of geologic studies was undertaken by the USGS to identify and evaluate potentially active surface faults and other earthquake-related hazards throughout Alaska. Significant contributions to the geologic hazards assessment have also been made by geotechnical contractors to the oil companies, by State of Alaska personnel, and by researchers from universities.

At the time of the earthquake, two seismographs operated in Alaska. As a direct result of the disaster, between 1966 and 1972 the University of Alaska and the U.S. Coast and Geodetic Survey (now the National Oceanographic and Atmospheric Administration) established a regional seismograph network of nearly 40 stations throughout Alaska. Since 1971, the USGS has operated a regional seismic monitoring network of as many as 54 stations in southern Alaska in response to the need to develop seismic design criteria for the Trans-Alaska oil pipeline and for offshore petroleum drilling platforms in the Gulf of Alaska. In addition, the University of Alaska operated local networks of as many as 17 stations to study the details of seismicity in northeastern, northwestern, and central Alaska.

Petroleum exploration and the Prudhoe Bay discovery. Interest in petroleum increased dramatically after Alaska emerged as a potential world-class producer in 1968, when the supergiant Prudhoe Bay field on the North Slope was discovered. The field contains roughly 13 billion barrels of recoverable oil and nearly 30 trillion cubic feet of gas. Since production began in 1977, oil from Prudhoe Bay and other oil fields discovered nearby has far outstripped all other mineral production in Alaska in value, and the income from this production has been a mainstay of the economy of Alaska. After the Prudhoe Bay discovery, intensified geologic and geophysical investigations by industry quickly expanded throughout adjacent areas of the North Slope and most of the onshore and offshore basins, providing a vast amount of new information on the surface and subsurface geology.

In 1974 the U.S. Navy renewed its program to explore Pet-4. In 1976 Congress transferred Pet-4 to the Department of Interior and renamed it the National Petroleum Reserve in Alaska. The continuing exploration responsibility and the contract to Husky Oil NPR Operations, Inc., were assigned to the USGS in 1976. Under this program, 28 exploration holes were drilled, including the two deepest exploratory wells in Alaska, and additional geophysical and geologic studies were completed.

During the 1970s and early 1980s an explosive growth of information by the USGS and oil companies on the continental shelves of southern and western Alaska was stimulated by federal and state petroleum lease sales. Much new geophysical coverage of the continental shelves was provided by aeromagnetic surveys and by surface ship gravity, magnetic, and seismic reflection and refraction surveys by the USGS, U.S. Coast and Geodetic Survey, Oregon State University, Lamont-Doherty Geological Observatory, and private industry. Geologic information offshore was obtained from bottom samples by ships of the USGS and petroleum industry and from drilling of test wells by oil companies, including 6 in the Bering Sea, 19 in the Gulf of Alaska, and 9 in lower Cook Inlet and Shelikof Strait. Since the late 1980s exploration has extended offshore onto the Arctic Ocean continental shelf, where 65 exploratory wells were drilled and three commercial oil fields were discovered as of 1993.

Miscellaneous research programs. From 1968 to 1971 construction of the Trans-Alaska pipeline and other major facilities related to production of Prudhoe oil required intensive geotechnical investigations and surficial geologic mapping by engineering firms and the USGS, with special emphasis on the distribution and foundation properties of permafrost in unconsolidated deposits in and near the pipeline corridor and on heat flow. A landmark analysis by Lachenbruch (1970) of the thermal effects of a heated pipeline in permafrost had a major impact on decisions to elevate the pipeline above ground in most permafrost areas. In 1971 core drilling on the ocean floor and lower continental slope at 5 sites off Kodiak Island and at 10 sites both north and south of the Aleutian Ridge as part of the Deep Sea Drilling Program of the National Science Foundation provided the first deep-sea data on the stratigraphy and structure along the ocean-continent interface. A program of marine geologic and geophysical investigations has been carried out in the Beaufort and Chukchi seas intermittently since 1969 by the USGS from a USGS research vessel and U.S. Coast Guard icebreakers. From 1984 through 1992, the USGS carried out a multidisciplinary study (TACT) to determine the structure, composition, and evolution of the Alaskan crust along a north-south transect across Alaska, generally along the Trans-Alaska oil pipeline corridor, and offshore across the continental margin in the Gulf of Alaska. Among the new insights provided by the uniform and high-quality geophysical and geologic data are multiple underplating of oceanic crust beneath the southern continental margin, possible large-scale underthrusting of flysch beneath parts of interior Alaska, and the complex structural imbrication and detachments in the upper crust beneath parts of the Brooks Range. In 1989 the National Science Foundation sponsored a marine deep seismic reflection transect (EDGE) across the eastern Aleutian arc and trench between Kodiak Island and the mainland that provided new data on the configuration of the subducting oceanic plate and the internal structure of the arc accretionary prism and overlying forearc basin. The 1992 eruption of Mt. Spurr near Anchorage resulted in establishing the Alaska Volcano Observatory by the USGS to carry out volcanological and geophysical studies and to develop eruption prediction capabilities at Mt. Spurr and other active volcanoes in Alaska.

Status of geologic mapping. In 1980, the fourth and most recent geologic map of Alaska was published at 1:2,500,000 scale

(Beikman, 1980, this volume, Plate 1). By that time, an estimated 80% of Alaska was mapped by reconnaissance standards, about 30% was covered by geologic maps to modern standards at scales of 1:250,000 or larger, and about 2.5% was covered by more detailed larger scale maps (Hopkins, 1983a, 1983b). The 1980 geologic map is the first to show coverage for all of Alaska, although the geology in some areas is generalized. The map delineates 62 stratigraphic units, 5 metamorphic rock units, and 114 igneous rock units as well as most of the major faults. Ages of the stratigraphic units are considerably improved over earlier maps thanks to more refined dating by microfossils such as nannoplankton, radiolarians, conodonts, and palynomorphs. Ages and classifications of crystalline rocks were improved by isotopic dating methods and by a variety of high-precision geochemical and isotopic petrologic techniques. Important syntheses that contributed to the structural features shown on Beikman's geologic map include the study of major strike-slip faults in Alaska by Grantz (1966) and delineation of the principal tectonic elements of Alaska in the classic tectonic map and accompanying text by King (1969a, 1969b).

Considerable new geologic mapping has been completed since the publication of the 1980 map. As of 1993, about 50% of the state has been mapped by detailed reconnaissance or better standards at 1:250,000 scale, and almost 10% is covered by larger scale geologic maps. Much of the post-1980 map data have been incorporated in the various contributions in this volume.

Plate tectonic concepts in Alaska. During the mid-1960s the concepts of plate tectonics grew and developed largely outside Alaska, and by the late 1960s the global plate tectonic theory was fully developed (Isaacs and others, 1968). However, Coats (1962) published a remarkably insightful, but rarely cited, synthesis of the tectonics and magmatism of the Aleutian arc that predated by several years the plate tectonic explanation of magmatic arcs at convergent plate margins. Coats correctly interpreted (1) that the origin of the dipping zone of seismicity beneath the Aleutian arc occurs along a megathrust above underthrusting oceanic crust and its sedimentary cover; (2) the relation between the position of the active volcanoes and depth to the underthrust oceanic crust; and (3) the role of fluids derived from the downgoing slab and magmatic differentiation in determining compositions of erupted volcanic rocks. The time-sequential sections drawn by Coats (1962, Fig. 9) differ only in detail from many of the post-plate tectonic models for the Aleutian arc. Coats's interpretation of convergence at the Aleutian arc was dramatically confirmed by studies of the tectonic deformation and seismicity associated with the 1964 Alaska earthquake at the eastern end of the Aleutian arc (Plafker, 1965, 1969).

Most of the success of plate tectonics in interpreting geologic history is based on the concept that the interactions of a small number of rigid plates and the resulting tectonic response provide modern analogs for interpreting past tectonic regimes and orogenesis (Dewey and Bird, 1970). Thus, petrotectonic assemblages in the rock record can be used to deduce plate tectonic settings (Dickinson, 1972) from which paleogeographies and scenarios of plate tectonic evolution can be reconstructed. In Alaska, this approach is applicable to understanding the evolution of the Cretaceous and Tertiary arcs along the southern margin of Alaska. However, it soon became apparent that plate tectonic models had little relevance to understanding much of the geology of the remainder of Alaska or of parts of the Cordillera to the south. For example, stratigraphic and structural studies in northern Alaska provided support for Carey's (1958) hypothesis for rotation of Arctic Alaska away from the margin of Arctic Canada and suggested large-scale north-south shortening by thrusting (>240 km) with resultant juxtaposition of disparate facies, including sheets of oceanic crustal rocks along the southern margin of the Brooks Range (Tailleur and Brosgé, 1970). Similarly, in central Alaska, the rotated and geologically disparate belts of rocks could not be related to plate tectonics models.

Accretionary tectonics in Alaska. The importance of accretionary tectonics began to be recognized in the early 1970s, with the emergence of the general concept of the Cordillera as a collage of displaced terranes, each of which must be analyzed as a complex succession of possibly unique tectonic events, rather than as the result of Cordillera-wide orogenies (Helwig, 1974). Berg and others (1972) and Jones and others (1972) were the first to define and describe terranes in southeastern Alaska, and by 1978 the first terrane map of southeastern Alaska was published (Berg and others, 1978). The terrane concept as a method of regional tectonic analysis gained some credibility with publication of the landmark paper on the allochthonous Wrangellia terrane (Jones and others, 1977), in which paleomagnetic data provided quantitative evidence for post-Triassic northward displacement measured in thousands of kilometers. Subsequently, terrane recognition and analysis (Coney and others, 1980) have been major topics of study throughout the Cordillera and evidence for large-scale telescoping, delamination, and wedging of upper crustal rocks has accumulated from structural and geophysical studies (for example, Coney, 1989; Oldow and others, 1989; Fuis and Plafker, 1991; Grantz and others, 1991). In Alaska, about 50 terranes and subterranes have been defined (Silberling and others, this volume, and several earlier publications) and terrane concepts have played and will continue to play an important role in attempts to reconstruct the tectonic evolution and deep crustal structure of Alaska.

ORGANIZATION OF THIS VOLUME

This volume represents the third attempt to synthesize the geology of Alaska, following those of Smith in 1939 and Brooks in 1906. The volume consists of 33 chapters and 13 plates. Besides this introduction, chapters in this volume are divided into two sections: 12 chapters that summarize and interpret the geology of major regions of Alaska (Fig. 3) and 20 chapters that cover a spectrum of topical subjects. The chapters are supplemented by 13 plates, all of which are at 1:2,500,000 scale, except for the maps showing metallogenic provinces (Plate 11), which are at 1:5,000,000 scale.

The regional and topical chapters contain diverse and occasionally conflicting interpretations of the geology of Alaska. We feel that such diversity is inevitable given the complex geology and our imperfect knowledge of many key problems at the time this volume was written. Important areas for future research are highlighted by these differences in interpretation.

Plates

The first three plates provide coverage of the geology (Plate 1), physiography (Plate 2), and lithotectonic terranes (Plate 3) of Alaska. They are reproductions of previously published maps and depict the geology as known before 1980 (Beikman, 1980), the physiographic provinces as delineated by Wahrhaftig (1965), and the lithotectonic terrane subdivisions as of about 1987 (Silberling and others, 1993). Much of the geologic mapping and data relevant to terrane definitions and interpretations obtained since these maps were compiled have been incorporated in the other plates and chapters of this volume.

Plates 4, 5, and 13 are comprehensive maps of the distribution, lithology, and ages of metamorphic, plutonic, and volcanic rocks in Alaska. Also shown in Plate 13 are tables of geochemical data for many of the pre-Cenozoic volcanic belts. Plate 6 includes a new geologic map and regional structure sections that cover the Brooks Range and North Slope. Plate 7 depicts the geology and structure of sedimentary basins of Alaska and its continental margins, the locations of oil and gas fields, and many of the important wildcat wells drilled for petroleum. Plate 8 shows locations of published, and some unpublished, isotopically dated crystalline rocks in Alaska and it includes an extensive tabulation of data relevant to the dated samples. Plates 9 and 10 are isostatic gravity and aeromagnetic maps for Alaska and parts of the continental margin. Plate 11 shows the locations of major metallic mineral deposits of Alaska and their relations to lithotectonic terranes. Plate 12 comprises a map and tables depicting neotectonic features of Alaska including seismicity, distribution and relative ages of late Cenozoic faults, distribution and composition of young volcanic rocks, thermal springs, Holocene vertical and horizontal displacement rates, and horizontal stress trajectories. An accompanying text describes the tectonic setting and evaluates earthquake hazards.

Regional chapters

The regional chapters (2 to 13) present comprehensive summaries of the bedrock geology of nine major regions of onshore Alaska and three major offshore regions covering the Arctic Ocean margin, the Bering Sea margin, and the Aleutian arc (Fig. 3). Areas not covered by the onshore regional chapters consist primarily of Quaternary unconsolidated deposits or volcanic rocks and basinal sequences that are shown on the map of sedimentary basins of Alaska (Plate 7) or are discussed in topical chapters. The stratigraphy and geologic history in these chapters are discussed in the traditional oldest-first chronological order to facilitate comparisons among the various geologic elements in each region.

Interpretations of the geologic history in the regional chapters are based on summaries of the bedrock stratigraphy, crystalline rocks, and structure, together with relevant geochemical, isotopic, paleomagnetic and other geophysical data. The rocks of the onshore regions are so heterogeneous, varied in age, and discontinuous, that it is helpful to discuss the geology in terms of stratigraphic and structural assemblages, or terranes, rather than individual formations (see discussion in Chapter 33). However, the terrane concept is not accepted by all geologists working in Alaska, and in a few of these regions the authors have chosen to avoid the use of terrane terminology to describe disparate structurally juxtaposed geologic units.

Topical chapters

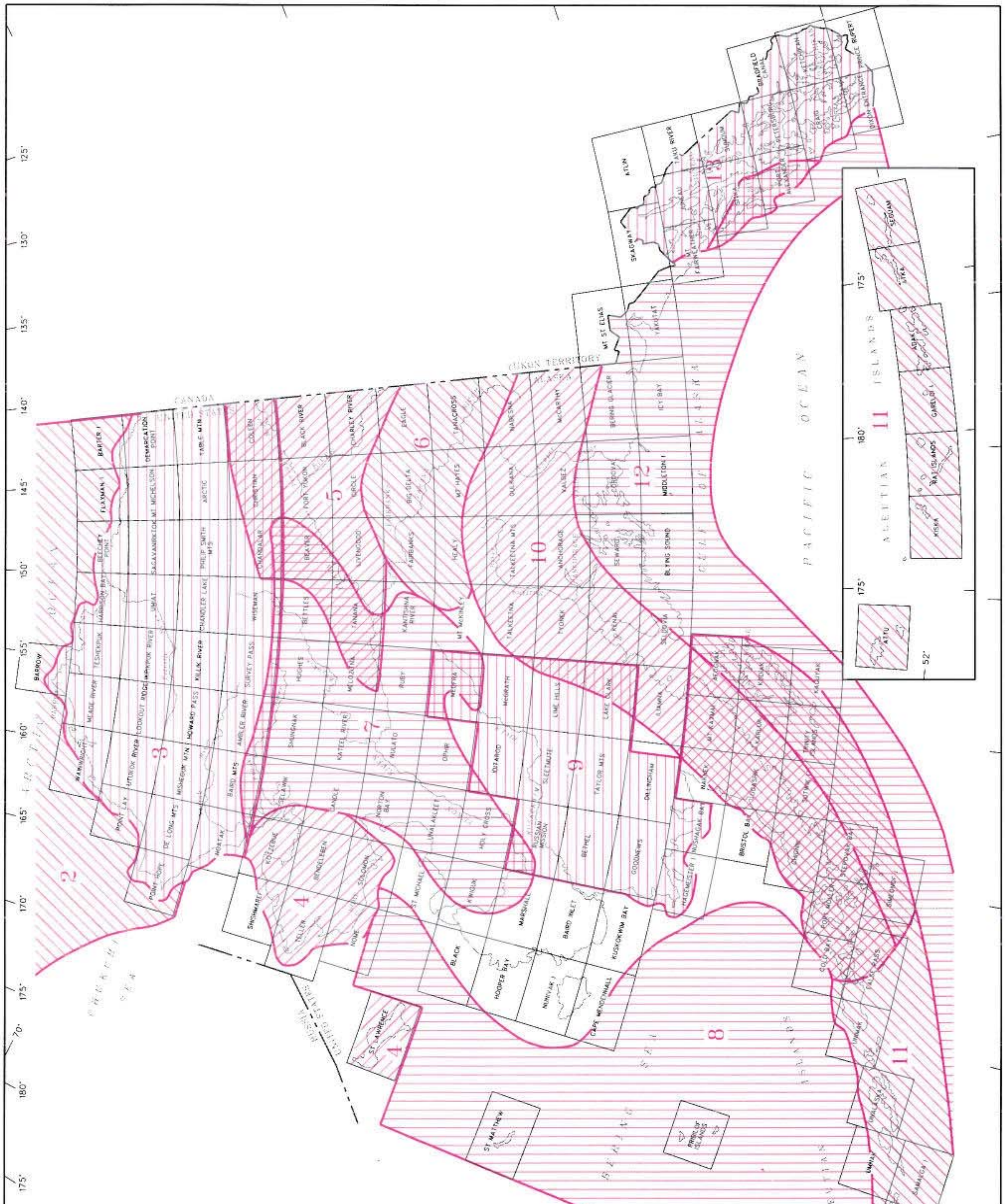
The topical chapters are summaries of geologic features and phenomena in Alaska that span geographic boundaries of the regional chapters. They include summaries, interpretations, and discussions of time-independent features of Alaska, including magmatic arcs and major belts of crystalline rocks, sedimentary basins, paleomagnetic data, glacial history and permafrost, and mineral and energy resources. Eight plates contain maps and tabular data that complement topical chapters.

Crystalline rocks. Chapters 15 to 25 highlight the distribution, petrology, chemistry, age, and evolution of igneous and metamorphic rocks throughout Alaska or in large regions of the state.

The Aleutian arc is the dominant tectonic feature of southern Alaska and its magmatic rocks and their evolution are the focus of Chapters 22 to 24; various aspects of the arc rocks are also included in regional and topical chapters that include the arc (Chapters 10, 11, and 18) and Plate 5. The petrology, structure, age, and evolution of crystalline rocks in Alaska are summarized in chapters describing magmatic belts (Chapters 16 to 20 and Plates 5 and 13), metamorphic assemblages (Chapter 15 and Plate 4), and ophiolitic rocks (Chapter 21). Isotopic compositions of intrusive rocks were used to interpret the general composition of the crust in much of Alaska in Chapter 25.

Sedimentary basins. The stratigraphy, structure, resource potential, and evolution of the basins of interior Alaska (exclusive of the Cook Inlet basin) are the subjects of Chapter 14. The petroliferous Cook Inlet basin and basins of the North Slope are discussed in Chapter 30, and coal-bearing areas are described in Chapter 31. Coastal and offshore basins along the Bering Sea and Gulf of Alaska are covered in regional chapters (Chapters 2, 8, 11, and 12). The sedimentary basins of Alaska and its shelves are shown in Plate 7.

Paleomagnetic data. Paleomagnetic data in Alaska have provided a major impetus for inferring that large regions of the state are allochthonous with respect to their surroundings and in formulating the concept of tectonostratigraphic terranes. The paleomagnetic data used in evaluating latitudinal displacements and rotations in Alaska are reviewed and summarized in Chapter 26.


PACIFIC OCEAN
GULF OF ALASKA
BERING SEA
ALEUTIAN ISLANDS
CHUKCHI SEA
ARCTIC OCEAN
YUKON TERRITORY
ALASKA
CANADA
UNITED STATES
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GARELOI
ADAK
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ST MATTHEW
PRIBILOF ISLANDS
ST LAWRENCE
BARROW
ANCHORAGE
FAIRBANKS
NOME
BETHEL
SKAGWAY
PRINCE RUPERT

Figure 3. Areas described in regional chapters in this volume. Large numbers indicate chapter numbers; intersecting hachure patterns indicate areas of overlap between chapters. Unpatterned areas are characterized by unconsolidated deposits, minor young volcanic rocks, and basinal strata that are described in topical chapters or are shown on the geologic map of Alaska (this volume, Plate 1), the map showing sedimentary basins of Alaska (this volume, Plate 7), and maps showing distribution of Late Cretaceous and Cenozoic volcanic rocks (this volume, Plates 7 and 12). Base map shows standard 2° and 3° quadrangles in Alaska.

Quaternary geology. Special aspects of Alaskan geology concern its Quaternary glacial history, periglacial phenomena, and neotectonic activity. Chapter 27 summarizes the glacial history with its implications for migrations of early humans across the Bering Strait. The distribution and nature of permafrost as well as its importance to engineering works in the Arctic are discussed in Chapter 28. Neotectonic data are compiled in Plate 12.

Mineral and energy resources. The mineral and energy resources of Alaska are of major economic importance to the state. The distribution, significance, and genesis of metallic minerals, petroleum, coal, and geothermal resources are the focus of Chapters 29 to 32.

Chapter 29 and Plate 11 summarize the distribution and the geologic and tectonic setting for major mineral deposits in Alaska and interpret their origin according to mineral-occurrence models. Chapter 30 and Plate 7 present data on the geology and models for petroleum generation and accumulation in the productive North Slope and Cook Inlet basins. Chapter 31 is a synthesis of the distribution, geologic occurrence, grade, and reserves of the enormous coal resources throughout Alaska and considers models for their origin. Chapter 32 evaluates Alaska's untapped geothermal resource potential in the context of distribution of thermal springs, heat flow, and young volcanic belts.

Tectonic overview and synthesis. The last chapter of the volume is a brief overview and synthesis of the tectonic evolution of Alaska. Chapter 33 is illustrated by figures showing lithotectonic terranes, composite terranes, magmatic belts, and data on rotations, translations, and plate motions. A set of eight figures shows an interpretation of the Phanerozoic evolution.

For the reader unfamiliar with the geology of Alaska, we suggest that one way to gain an appreciation of the location, physiography, geology, and tectonic evolution of the major elements that make up Alaska would be to begin with the first and last chapters of this volume.

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