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A summary of recent significant scientific and economic results accompanied by a list of geologic and hydrologic investigations in progress and a report on the status of topographic mapping

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the modern Snake River westward from the Idaho border.

Reconstruction of the gradient of the youngest paleocanyon on the basis of elevations of flow remnants indicates a gradient comparable to that of the modern Snake; gradients of earlier drainages are marginally greater, possibly because of slight regional westward tilting that ended before 6 million years B.P. The maximum depth of the ancestral Snake River canyon 12.5 to 10.5 million years B.P. was at least 500 m, decreasing westward to zero at the mouth of the canyon. These depth figures provide an estimate of the minimum elevation of the plateau surface, as the canyon floor must have been above sea level, and are consistent with the variation in present elevations. Swanson and Wright conclude that, except for local areas of tectonism such as the Blue Mountains and Lewiston Basin, southeast Washington has remained remarkably stable over the past 12.5 million years, undergoing little elevation change and only modest westward tilting of a few tenths of a degree. This conclusion is consistent with the antiquity of the course of the Snake River, which throughout most of its length in Washington has remained in virtually the same location for the past 12.5 million years.

Stratigraphy of the Windermere Group

The Windermere Group makes up the uppermost Proterozoic Y and Z in northeastern Washington. It overlies the Belt Supergroup and is overlain by lowermost Cambrian quartzites. Recent mapping by F. K. Miller in the proposed Salmo-Priest Wilderness Area and earlier work in the Addy area to the southwest indicates the Windermere represents a complex period of deposition, uplift, and erosion.

At the U.S.-Canadian border, the Windermere Group is made up of, from oldest to youngest, Shedroof Conglomerate, 3,170 m; Leola Volcanics, 1,520 m; Monk Formation, 1,220 m; and Three Sisters Formation of Canadian usage, 2,470 m. Because of possible tectonic thickening, the thickness for the Shedroof is a maximum figure. The Gypsy Quartzite (Lower Cambrian) that unconformably overlies the Windermere is 1,700 m thick.

About 30 km along strike to the southwest, where the entire section is cut out by Cretaceous and Tertiary plutonic rocks, the thickness and stratigraphic relationships appear to be unchanged. About 15 km to the west, however, on the west side of a large fault of unknown attitude or displacement, the Three Sisters Formation is only 400 m thick, and the Gypsy Quartzite is 1,100 m thick. Full sections of the Shedroof, Leola, and Monk Formations are not exposed.

Where the Windermere again appears in the Addy area, 90 km to the southwest on the southwest side of the plutonic rocks, the Shedroof Conglomerate (called "Huckleberry Conglomerate") is only 500 m thick, the Leola Volcanics (called "Huckleberry Greenstone") are 1,240 m thick, and 1,070 m of Gypsy Quartzite (called Addy Quartzite) rests unconformably on the Leola, with no Three Sisters Formation present and only local 10- to 50-m remnants of Monk Formation preserved in pre-Gypsy structural lows.

ALASKA

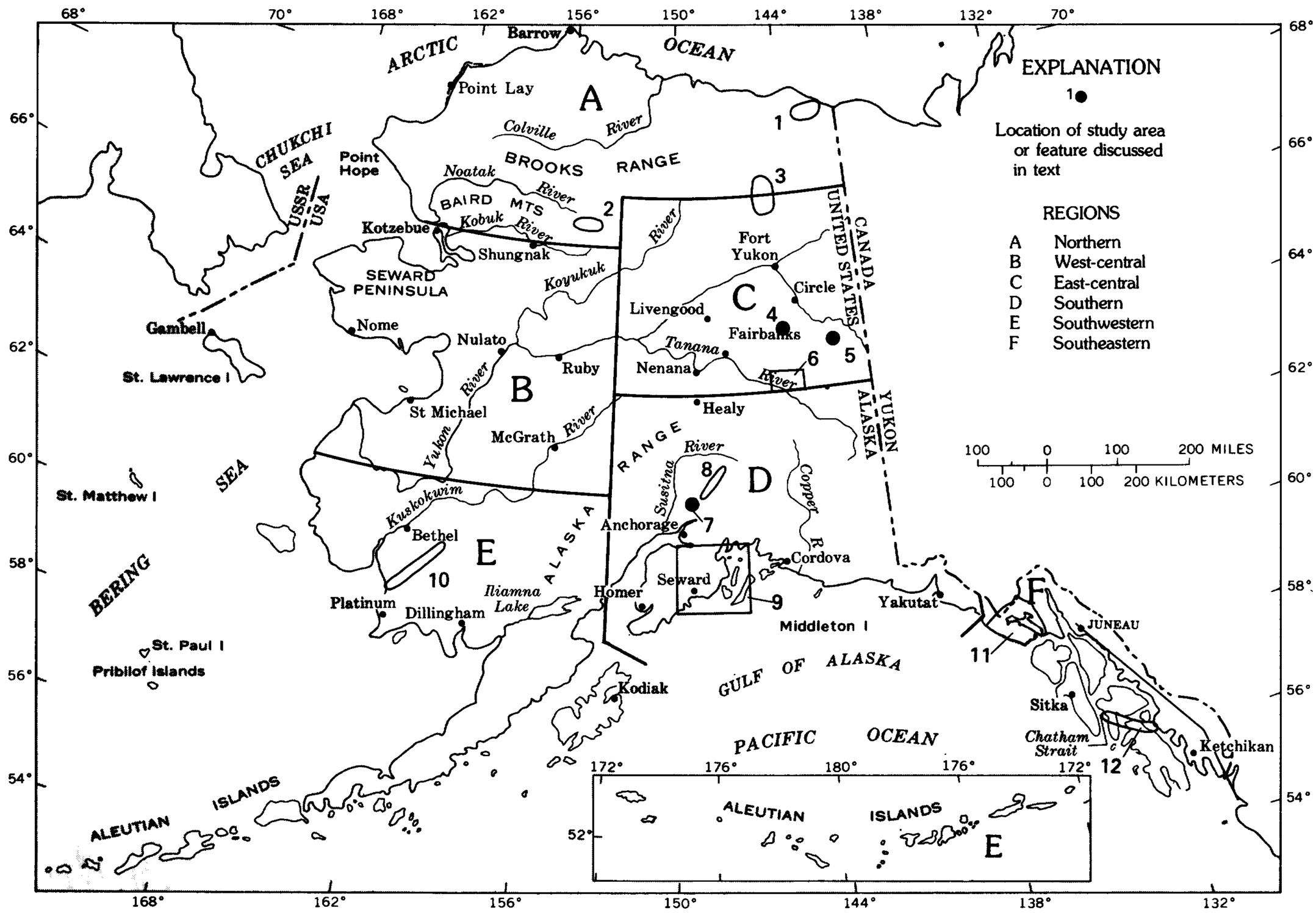
Significant new scientific and economic geologic information has been obtained from many field and topical investigations conducted in Alaska during the past year. Discussions of the findings are grouped under six subdivisions corresponding to five of the six major geographic regions and a general statewide category. Outlines of the regions and locations of the study areas are shown on the accompanying index map of Alaska.

STATEWIDE

Alaska Mineral Resource Assessment Program

Impending transfer of lands in Alaska, 90 percent of which currently are under Federal management, will affect for generations the allocation, accessibility, and development of Alaska's vast lands and natural resources. There is therefore an urgent and growing demand by public and private interests for objective and timely information on Alaska's mineral endowment. To meet this demand, the USGS's Alaska Mineral Resource Assessment Program (AMRAP), administered by H. C. Berg, has two closely coordinated objectives designed specifically to furnish information for decisions about Alaska's lands.

One objective, based on a 1:250,000-scale (1°×3°) quadrangle format, is a systematic multidisciplinary assessment of Alaska's economic mineral potential for long-range planning and development. Assuming increased levels of staffing and funding, the deadline for this goal is 1984. The other objective, based on a 1:1,000,000-scale map format, is a statewide mineral appraisal for near-term Department of the Interior and Congressional decisions on classifica-



tion of Alaska's lands. This appraisal, informally termed RAMRAP (Regional Alaska Mineral Resource Assessment Program), was completed for mainland Alaska and published in January 1978. A RAMRAP-type investigation of southeastern Alaska was begun in 1978; the tentative deadline for completing this investigation is 1980.

The AMRAP long-range program is being carried out mainly by geologists and subprofessionals in the Alaskan Geology Branch, in collaboration with specialists from other branches and subactivities in the Geologic Division. In addition, several geoscientists from the Alaska Division of Geological and Geophysical Surveys and the University of Alaska are collaborators.

The RAMRAP studies comprised the compilation, synthesis, and publication of basic geological, geophysical, geochemical, and Earth satellite data, and of regional (1:1,000,000-scale) resource assessments for all of mainland Alaska. In October 1978, these assessments were used extensively to update environmental impact statements for approximately 40,500,000 ha of proposed National Interest Lands in Alaska. This update, urgently requested by the Department of the Interior, was completed within a 1-week deadline imposed by the Department, a deadline that would have been impossible to meet without the RAMRAP reports.

As of the end of 1978, field studies leading to multidisciplinary resource assessment have been completed in 20 quadrangles (1°×3°) on a 1:250,000 scale and are underway in 9 others. These quadrangles aggregate approximately 360,000 km². Mineral resource assessment folios have either been published or are in press or advanced preparation for 19 quadrangles encompassing about 250,000 km². More than 166 other AMRAP-sponsored topical research reports on the geology, geochemistry, geophysics, and mineral resources of Alaska and a new tectonic (tectonostratigraphic) map of southeastern Alaska have been published.

Studies of ore genesis or of other mineral-deposit research problems are underway or completed in eight Alaskan mining districts, (1) Aleutian

Peninsula porphyry copper district, (2) Kennecott sabhka copper deposits, (3) Willow Creek gold district, (4) Hope gold district, (5) Orange Hill porphyry copper deposit, (6) Bornite sabhka copper deposit, (7) Arctic Camp massive copper sulfide deposit, and (8) Eastern Alaska Range volcanogenic sulfide deposits.

Resources data summarized

Mineral resources are known in all major subdivisions of Alaska and have been described in reports issued during the last 80 years by the USGS, the U.S. Bureau of Mines, and various Territorial and State of Alaska agencies. E. H. Cobb has summarized the published (and open filed) references to mineral occurrences in 16 quadrangles (1:250,000 scale) in Alaska (Cobb, 1977, 1978a, b), thereby making readily available data from old out-of-print reports as well as from results of current investigations.

Review of Precambrian rocks of Alaska

G. D. Eberlein and M. A. Lamphere have reviewed the evidence for age and distribution of Precambrian rocks in Alaska. Ten widely separated areas in Alaska contain rocks of Precambrian or probable Precambrian age. The age assignment in four areas is based on radiometric dating; in the other six areas, stratigraphic evidence is used to infer a Precambrian age. The Alaskan Precambrian rocks are of Proterozoic Z age; there is no evidence at this time for an Archean age. The Tindir Group along the Yukon River in east-central Alaska, which is considered equivalent to parts of the Windermere, Belt, and Purcell "Supergroups" of Canada, is the only sequence of Proterozoic rocks in Alaska that can be definitely related to Proterozoic stratigraphic sections in other parts of the North American cordillera. The Neruokpuk Quartzite and underlying strata of eastern northern Alaska are Precambrian on the basis of stratigraphic evidence. The Tindir(?) Group along the Porcupine River in east-central Alaska, schist of the northeastern Kuskokwim Mountains in central Alaska, and low-grade metamorphic rocks in the Livengood-Crazy Mountains region of east-central Alaska are probably Proterozoic, although their precise ages are not known.

Tectonomagmatic events in the interval 1,100- to 600-million-year age are recorded in schist of the Yukon-Koyukuk region in central Alaska, in the Kanektok terrane of southwestern Alaska, in gneiss in the Seward Peninsula (west-central Alaska), and in trondhjemite intrusive into the Wales Group of southeastern Alaska. The Wales Group and the Kanektok terrane are allochthonous and appear to belong to exotic terranes accreted to the North American craton during Phanerozoic time.

Mineral deposits occur in several areas of Precambrian rocks, but many of these deposits were produced during Phanerozoic mineralization episodes. However, banded iron formation within the Tindir Group of the Yukon River region and certain volcanogenic, stratabound base-metal deposits within the Wales Group in southeastern Alaska are believed to have been formed during the Precambrian Era.

Reconstruction of Paleozoic continental margin in Alaska and accreted terranes

According to Michael Churkin, Jr., and Claire Carter, a belt of Paleozoic rocks in central Alaska grades southward from limestone and dolomite into highly deformed sequences of shale, chert, turbidite, and volcanic rocks; it represents a transition from carbonate shelf to continental slope and rise and ocean floor. South of this reconstructed continental margin lie a series of terranes of oceanic affinity (for example, Chulitna, Wrangell, Chugach) that have been successively accreted to the continent. Some terranes, like the Yukon-Tanana, have been metamorphosed. Reconstruction of a similar facies change in thrust slices along the Brooks Range suggests that another collision-deformed Paleozoic continental margin extends across arctic Alaska. Along the southern Brooks Range, terranes of schist, volcanic rocks, and ophiolite are accreted to the collapsed Paleozoic continental margin in a succession similar to that in central Alaska. The apparent termination of the continental margin in southwest Alaska near the Aniak-Thompson Creek fault, the presence of a similar continental margin along the trend of the Brooks Range, and oroclinal bends in the Cordillera of northern Yukon and the Brooks Range suggest that the continental and accreted microplate framework of southwestern Alaska was offset right laterally northeastward to the present-day Brooks Range.

Paleotectonic setting of the Carboniferous of Alaska

The Carboniferous of Alaska represents preserved segments of several plates, according to an analysis by J. T. Dutro, Jr., and D. L. Jones. Northern Alaska was the leading edge of an Arctic plate that moved south nearly 1,000 km, starting in early

Mesozoic time. Extreme western Alaska, including the Lisburne Peninsula, Cape York, and St. Lawrence Island, was part of an east Siberian region. East-central Alaska was the shelf edge and slope of the northwestern part of the North American platform. South-central Alaska was an arc or forearc trench at the northern edge of a paleo-Pacific plate. Southeastern Alaska consists of at least two fragments of the western edge of the North American plate that probably moved independently northwestward in post-Triassic time. These fragments may once have occupied positions west of present-day Oregon, California, or Baja California. Scattered outcrops of deep-water, radiolarian-bearing, laminated cherts and argillites in central and southwestern Alaska are possible remnants of the ancient North Pacific oceanic floor that have been preserved between plates converging from all sides.

Microplate tectonics

As interpreted by D. L. Jones and N. J. Silberling, recent geologic and paleomagnetic studies have shown that Alaska constitutes a gigantic mosaic of separate, allochthonous tectonic elements (microplates, blocks, and fragments) that originated to the south and accreted to North America during Mesozoic time. More than 30 discrete tectono-stratigraphic elements have been recognized to date, and further analysis undoubtedly will reveal more. The best known microplate (Wrangellia) occurs in southern Alaska and further south to at least Vancouver Island.

NORTHERN ALASKA

Geology of Alaska bordering Arctic Ocean

J. T. Dutro, Jr., summarized the geology of northern Alaska in terms of six major depositional episodes separated by major unconformities. The youngest of these (Holocene to Early Cretaceous) reflects postorogenic deposition in the Colville Trough north of the Brooks Range. The Jurassic to middle Permian episode records the last sediments of northern provenance, followed by preorogenic deep-water deposits in the region that was to become the Brooks Range. A predominantly shallow-water carbonate suite of facies characterizes the Carboniferous, after a northeastward transgression in the Early Mississippian. The Late Devonian included a period of complex marine deposition in the Frasnian, succeeded by a postorogenic clastic cycle in the Famennian. Platform carbonate rocks dominate the Early Devonian and Silurian sequence and are underlain by deep-water Ordovician and Cambrian units that include thin-bedded cherts, argillites, and volcanic rocks. The latest Proterozoic Z in the Demarcation Point quadrangle is represented by dominantly shallow-water, weakly metamorphosed sedimentary rocks, including quartzites, phyllites, and quartzose carbonates. The older Proterozoic includes quartz-mica schists, quartzites, and phyllitic strata.

Igneous activity can be assigned to five general orogenic periods, Taconian (about 450 m.y.), Acadian (about 380 m.y.), Sudetian (about 330 m.y.), late Kimmerian (about 160 m.y.), and early Alpine (about 80-90 m.y.).

The post-Paleozoic evolution of the Arctic Ocean basin could have involved southward movement of an Arctic plate which encountered a northward-moving Pacific plate during Jurassic time. Continued opening of the central Arctic Basin from Late Cretaceous to Holocene time may have resulted in underthrusting the Arctic margin of Alaska beneath the Brooks Range orogen.

Model for predicting offshore permafrost in the Beaufort Sea

During the height of the worldwide continental glaciation about 18,000 years ago, sea level was lowered. According to D. M. Hopkins and R. W. Hartz, the Bering Sea shelf was exposed seaward to about the present-day 90-m isobath. The position of the shoreline in the Beaufort Sea 18,000 years ago is not yet established but lay somewhere seaward of the 20-m isobath. The cover of ancient marine silt and clay became frozen as did the underlying gravel. The total thickness of bonded permafrost formed at any particular place depended partly upon the duration of exposure to subaerial temperatures, but thicknesses of several hundred meters were formed in most areas of the shelf landward of the present 20-m isobath.

The major rivers flowing north from the Brooks Range aggraded and formed outwash fans extending across much of the present-day coastal plain; the edges of most fans lay within a kilometer inland of or seaward of the present coast. Seaward from the edges of the fans, the rivers removed the ancient marine silt and clay to form broad, shallow valleys graded to the shoreline of the time. By analogy with the braided gravel floodplains of present-day North Slope rivers, the top of the ice-bonded layer lay at depths of several tens of meters beneath the river channels, but at depths of less

than a meter beneath uplands mantled with overconsolidated silt and clay.

When sea level began to rise, the shallow valleys were flooded early. In the absence of a cover of ancient, overconsolidated marine silt and clay, the cold but salty sea water gained ready access to the underlying gravel. Ice in the gravel was thawed rapidly and deeply by salt advection. Ultimately, these valleys began to collect Holocene marine sediments carried by currents from river mouths.

When the sea transgressed over the slightly higher plains away from the sea valleys, salt water was prevented from gaining access to the potentially porous gravel substrate by the mantle of tight overconsolidated clay. Consequently, thawing of ice in the shallow-bonded permafrost could progress only by the heat diffusion and silt diffusion. Water temperatures are below zero, and silt diffusion progresses only slowly. Consequently, thawing has progressed extremely slowly and only to very limited depths in most areas mantled by overconsolidated clay.

If this model is correct, deep permafrost is to be expected throughout the area of Holocene sediments shown by P. W. Barnes and Erk Reimnitz (Barnes and Reimnitz, 1974) as extending westward from the mouth of the Sagavanirktok River to a point northwest of Oliktok Point, where it is joined by another belt of Holocene sediments extending northward from the mouth of the Colville River to the shelf break. Similar belts of Holocene sediments and deep permafrost should be present in as-yet-undiscovered sea valleys extending from the Shaviovik and Canning Rivers, and these should be overconsolidated clay and shallow, potentially ice-rich permafrost in other parts of the Beaufort Sea.

Mesozoic radiometric ages in Precambrian rocks

Radiometric age determinations by M. L. Silberman, C. L. Connor, and J. L. Morton indicate an age no older than Triassic for a unique occurrence of volcaniclastic rocks overlain by Precambrian carbonate rocks in the central Demarcation Point quadrangle (index map, loc. 1). Potassium-argon age determinations of 188±7 m.y. on plagioclase clasts contradict field evidence for a simple depositional relationship with the overlying Precambrian carbonate rocks and indicate that the volcaniclastic sequence is not of Precambrian age.

New age of metaplutonic rocks in the Survey Pass quadrangle, Brooks Range

The phyllite, quartz-mica schist, and marble that make up the metamorphic belt of the southern Brooks Range appear, on the basis of fossil evidence, to be Devonian in the Survey Pass quadrangle. These rocks are intruded by the Arrigetch Peaks and Mount Igipak plutons (loc. 2), large intrusive bodies ranging in composition from alkali feldspar granite to tonalite and exhibiting well-developed cataclastic texture from later recrystallization. Previous workers (Turner, Forbes, and Mayfield, 1978) interpreted these plutons to be Cretaceous in age and to represent synkinematic intrusions accompanying a major Cretaceous metamorphic episode (defined on the basis of K-Ar ages) that affected the entire metamorphic belt. As part of the study of the geology of the Survey Pass quadrangle, M. L. Silberman (USGS) and Douglas Brookins (University of New Mexico) obtained a preliminary rubidium-strontium whole-rock isochron age of about 360 million years from six samples of granitic rocks from the two plutons. Initial strontium-isotope ratio of the system of approximately 0.712 suggests that these granites were derived in large part from crustal material. These preliminary data rule out a Cretaceous age for the granitic rocks.

EAST-CENTRAL ALASKA

Late Paleozoic fossils in ophiolite, northeastern Alaska

Brian Holdsworth and D. L. Jones have identified Mississippian radiolarians and Permian conodonts from cherts in the ophiolite sequences in the Arctic and Christian quadrangles (loc. 3). The fossils occur in a small isolated chert layer within the synformal Christian complex of mafic rocks (Reiser, Lanphere, and Brosgé, 1965) and at three localities in the nearly continuous unit of chert and shale that separates the synform of mafic rocks from the underlying Devonian(?) wacke and shale. Devonian spores and Paleozoic plants of probable Devonian age were previously identified from the wacke by R. A. Scott and S. H. Mamay.

The new fossil ages support the conclusion of Patton and others (1977) that the basalt-diabase-chert complexes of the Rampart belt are late Paleozoic in age while the younger radiometric ages of the igneous rocks represent the age of tectonic emplacement. The fact that the Mississippian is represented by radiolarian chert only 20 km southeast of outcrops where it is represented by Lisburne Group limestone and Kayak Shale in the typical Brooks Range sequence supports the conclusion that the ophiolite has been faulted against the Brooks Range rocks.

Hot Spring area, Circle quadrangle

T. E. C. Keith and H. L. Foster studied a small area on Big Windy Creek (loc. 4) in the northeast corner of the Circle A–2 quadrangle where several hot springs are on both sides of the Creek. The hot water comes through granitic rock near its northern contact with regionally metamorphosed rocks. Temperature of the water is about 58°C and pH is about 6.9. The water is very high in HCO_3 and Na. Water chemistry is quite different from that of Circle Hot Springs to the north and from Chena Hot Springs to the west. Small sinter terraces have been deposited by the thermal waters. The older sinter contains some carbonate and amorphous material; a thin layer of silica on the outer surface of the terraces indicates that water chemistry has not been constant.

Cumulate gabbro and pillow basalt associated with the Mount Sorenson ultramafic complex

T. E. C. Keith and H. L. Foster found a sequence of periodotite, cumulate gabbro, and pillow basalt with associated red chert on the north side of the Seventymile River on the boundary between the Charley River and Eagle quadrangles (loc. 5). This sequence appears to be a part of the ultramafic complex near Mount Sorenson (exposed to the west) that has been displaced to the southeast by faulting. The sequence appears to be dipping south. The presence of cumulate gabbro and pillow basalt (seen for the first time in the Mount Sorenson area) strengthens the evidence that the ultramafic complex is part of a dismembered ophiolite.

Preliminary Proterozoic lead ages on zircon from augen gneiss, Big Delta quadrangle

A study to determine the nature and age of the protolith of a large body (approximately 700 km^2) of augen gneiss (loc. 6) in the Big Delta quadrangle is presently being carried out by Cynthia Dusel-Bacon. The augen gneiss has undergone amphibolite facies metamorphism and contains large eyes of potassium feldspar ranging from 3 to 7 cm in longest dimension. Cataclasis and recrystallization have affected the gneiss, obscuring its original texture and making its history difficult to interpret. Uranium-thorium-lead dating of zircons is being done by T. W. Stern. The first sample run yielded discordant ages ($^{206}Pb/^{238}U$, 317.3 m.y.; $^{207}Pb/^{235}U$, 341.7 m.y.; $^{208}Pb/^{232}Th$, 332.4 m.y.; and $^{207}Pb/^{206}Pb$, 511.3 m.y.). These preliminary data suggest a Proterozoic Z age. Additional samples are being analyzed in an attempt to define a discordia.

A microprobe investigation of the zircon separate used for dating identified two inclusions of Al_2SiO_5. Inclusions of this composition indicate that the protolith may contain material from a source that has experienced a weathering cycle. One of the possible origins of the augen gneiss might be porphyritic granite derived from arkosic material shed off the Canadian shield.

The augen gneiss is part of the Yukon crystalline terrane, a metamorphic complex bordered by the Tintina fault to the north and the Denali fault to the south. Knowledge of the history of the augen gneiss will shed light on the origin and geologic history of this part of Alaska.

SOUTHERN ALASKA

Regional geochronology of the Willow Creek area

About 20 K-Ar determinations, part of a study by M. L. Silberman and Béla Csejtey, Jr., of the geochronology of plutonic granitic rocks, metamorphosed sedimentary rocks, and hydrothermal alteration and mineralization in the Willow Creek area (loc. 7), indicate that a major Paleocene metamorphic event affected many of the apparent ages. Preliminary results were reported by Silberman and others (1978). The oldest rock unit, a quartz-mica schist of probable Jurassic prograde metamorphic age, has been retrograded from the amphibolite facies and has been intruded by now-metamorphosed Cretaceous(?) ultramafic rocks. Plutonic granitic rocks with irregular propylitic alteration zones include Jurassic hornblende diorite and Upper Cretaceous tonalite and biotite granite. Aplite, pegmatite, and lamprophyre dikes intrude the tonalite. Gold-bearing quartz veins that contain sulfides and sulfosalts, have sericitic selvages, and contain disseminated muscovite, cut the schist and granitic rocks. Upper Cretaceous and Tertiary sedimentary rocks overlie the schist and granitic rocks.

Potassium-argon mineral ages for the rocks are 56 to 66 m.y. for the schist, 89 to 91 m.y. for the ultramafic rocks, 69 to 78 m.y. for the tonalite, 65 to 67 m.y. for the biotite granite, 66 to 67 m.y. for the dikes, 56 to 66 m.y. for the quartz veins, and 58 m.y. for propylitized tonalite. These data can best be interpreted as reflecting the effects of a metamorphic hydrothermal event of Paleocene age that has partially to totally reset the K-Ar ages of the schist, the granitic and ultramafic rocks, and the quartz veins. This event also produced the prophylitic alteration of the tonalite.

Trondhjemite in the Talkeetna Mountains, south-central Alaska

Reconnaissance geologic mapping, by Béla Csejtey, Jr., and W. H. Nelson, in the Talkeetna Mountains, south-central Alaska, discovered a large pluton (loc. 8) of trondhjemite, a unique rock type previously not known to occur in southern Alaska.

The trondhjemite pluton is a discordant, northeast-trending, elongate, epizonal body of fairly uniform lithology, occurring in the central Talkeetna Mountains. The pluton is approximately 120 km long with a maximum width of about 15 km, and has been intruded into Lower and Middle Jurassic plutonic and metamorphic rocks. Large portions of the pluton have been sheared and saussuritized. Typically, the trondhjemite is a light-gray, medium- to coarse-grained rock with a granitic texture. A faint flow foliation is locally developed. Major rock-forming minerals are plagioclase (oligoclase to sodic andesine), quartz, K-feldspar (as much as 10 percent by volume), and biotite, with subordinate amounts of muscovite and opaque minerals. Color index ranges from 3 to 9. Average oxide percentages by weight of seven trondhjemite analyses are SiO_2, 70.30; Al_2O_3, 16.74; K_2O, 5.07; CaO, 3.33. Three K-Ar age determinations from the northern half of the pluton by M. A. Lanphere (USGS) and by D. L. Turner (University of Alaska), including concordant ages on a mineral pair of muscovite and biotite, yielded very similar numbers indicating emplacement of the trondhjemite pluton between 145 and 150 million years ago. The trondhjemite is the youngest member of a group of Jurassic plutonic and metamorphic rocks in the Talkeetna Mountains.

Geophysical ore guides in south-central Alaska

J. E. Case reports that at least 75 percent of the granitic plutons in the Seward and Blying Sound quadrangles (loc. 9) are nonmagnetic and have little or no gravitational expression. The few granitic bodies that are magnetic are close to the mafic belt in Prince William Sound, perhaps indicating that the granitic magmas were contaminated at a late stage of emplacement by mafic materials. The granites of the Chugach terrane are thought to be anatectic (Hudson, Plafker, and Lanphere, 1977) and are largely devoid of significant mineral deposits. The lack of magnetic expression of most of these bodies may constitute a "negative" ore guide.

In comparison, many of the highly mineralized (Cu-Mo) plutons of the Alaska Peninsula, especially in the Chignik and Sutwik Island quadrangles, are thought to be related to subduction processes and have pronounced magnetic expression.

SOUTHWESTERN ALASKA

Exotic Precambrian rocks in southwestern Alaska

The metamorphic complex along the Kanektok River, an isolated 160-km belt of Precambrian gneisses and schists in southwestern Alaska, trends northeastward from Jacksmith Bay on the Bering Sea coast across the northwest corner of the Goodnews quadrangle into the Bethel quadrangle (Hoare and Coonrad, 1959, 1961) (loc. 10). The maximum exposed width is about 14 km, and geological and geophysical data suggest that it is not appreciably wider in the subsurface. According to J. M. Hoare and W. L. Coonrad, the complex apparently consists of recrystallized sedimentary, volcanic, and intrusive dioritic and granitic rocks metamorphosed to the upper greenschist and lower amphibolite facies. There is no apparent metamorphic gradation between these rocks and the Paleozoic and Mesozoic rocks that flank them on either side.

Both geological and geophysical data indicate that the Precambrian belt is thin and rootless. Geological observations suggest that it overlies Cretaceous sedimentary rocks. Interpretation of aeromagnetic data by Andrew Griscom suggests that the Cretaceous rocks, in turn, overlie magnetic rock at a depth of 1 to 2 km. The gravity data also attest to the rootless character of the metamorphic belt. There is no variation in the normal gravitational field where two gravity traverses cross the metamorphic belt. This implies that the crystalline rocks do not extend to any appreciable depth.

The origin of this displaced belt of Precambrian rocks is problematical. But the tectonic framework of southern Alaska and recent evidence of very large northwest transport in south-central Alaska (Jones, Silberling, and Hillhouse, 1977, p. 2565–2577; Hillhouse, 1977, p. 2578–2592) suggest that it probably originated far to the southeast. It may be a rifted fragment of the Precambrian shield in Canada, or it may have come from farther south.

SOUTHEASTERN ALASKA

Mineral resources and aeromagnetic studies of Glacier Bay National Monument

Completion of a joint USGS–USBM study of Glacier Bay National Monument (loc. 11) resulted in the identification of nine important mineral deposits with identified resources located in six areas considered to also have undiscovered hypothetical resources. The USGS authors, D. A. Brew, B. R. Johnson, and Donald Grybeck, also reported the identi-

fication of seven additional areas with important geochemical and (or) geophysical anomalies. The elements of greatest economic interest are nickel, molybdenum, copper, zinc, and gold. The following brief descriptions are based on both USGS and USBM information contained in the open-file report (Brew and Morrell, 1978).

The Pacific beach sands favorable area which has had past production of placer gold, contains both identified-inferred and undiscovered hypothetical resources of ilmenite and gold. It is unlikely that these low-grade resources are now or will be in the near future economically attractive, even though large tonnages are present.

The Crillon–La Perouse favorable area includes the Brady Glacier nickel-copper magmatic deposit, which contains about 80 million metric tons of identified-indicated resources with 0.53 percent nickel, 0.33 percent copper, and an unspecified amount of platinum-group metals and 80 million metric tons of identified-inferred resources of the same grade. In addition, the favorable area also is estimated to have another 80 million metric tons of undiscovered hypothetical resources of the same grade.

The Mount Fairweather favorable area is very poorly known, but the ore environment is similar to that of the Crillon–La Perouse, and 82 million metric tons of undiscovered speculative resources with 0.53 percent nickel and 0.33 percent copper are estimated to be present.

The Margerie Glacier favorable area includes the Margerie Glacier porphyry-copper deposit, which contains 145 million metric tons of identified-inferred resources with 0.2 percent copper, 0.27 g/t gold, 4.5 g/t silver, and 0.01 percent tungsten, and the Orange Point volcanogenic sulfide deposit, which contains 0.25 million metric tons of identified-inferred resources with 2.7 percent copper, 5.2 percent zinc, 1 g/t gold, and 34 g/t silver, as well as 0.47 million metric tons of identified inferred-resources containing 0.4 percent copper, 0.3 percent zinc, 0.2 g/t gold, and 12 g/t silver. In addition, the favorable area also is estimated to contain 0.9 million metric tons of undiscovered hypothetical resources with 1.5 percent copper and 2.0 percent zinc, and further unquantified, undiscovered speculative copper and zinc resources.

The Reid Inlet favorable area has had past production of gold from the Reid Inlet vein deposits, and is estimated to contain about 480 kg of undiscovered hypothetical resources.

The Rendu Glacier favorable area includes the "massive chalcopyrite" skarn deposit, which contains 0.004 million metric tons of identified-inferred resources with 0.5 percent tungsten, 4.0 percent copper, 240 g/t silver, and 5.2 g/t gold. The favorable area also has unquantified, undiscovered speculative copper and tungsten resources.

The Muir Inlet favorable area includes the Nunatak molybdenum porphyry deposit, which contains 7.4 million metric tons of identified-indicated resources with 0.06 percent molybdenum and 0.02 percent copper, and 124 million metric tons of identified-indicated resources with 0.04 percent molybdenum and 0.02 percent copper, as well as 8.3 million metric tons of identified-inferred resources with 0.06 percent molybdenum and 0.02 percent copper. The area also is estimated to have 90 million metric tons of undiscovered hypothetical resources with 0.15 to 0.20 percent molybdenum and unquantified, undiscovered speculative resources of copper and molybdenum.

The Casement Glacier favorable area also contains unquantified, undiscovered speculative molybdenum and copper resources, and part of the area has unquantified, undiscovered speculative copper-zinc resources in a volcanogenic environment.

The White Glacier favorable area also contains unquantified, undiscovered speculative zinc and copper resources in a volcanogenic environment.

These deposits and favorable areas are in the parts of the Monument that are best known geologically and geochemically. The presence of significant mineral resources in other areas cannot be ruled out. Glacier Bay National Monument is highly mineralized in comparison with most areas of similar size elsewhere in southeastern Alaska, and it is likely that it contains more deposits and favorable areas of the types described here and perhaps other types of deposits as well.

Andrew Griscom reports that aeromagnetic data plus physical-properties measurements (58 samples) indicate that granitic rocks of Cretaceous and Tertiary ages east of the Tarr Inlet suture zone (Brew and Morrell, 1978) are magnetic, while similar rocks west of the zone are not magnetic. The magnetic properties of these granitic rocks may thus have been determined by the crustal rocks in which the plutons formed or up through which the plutons moved. Additionally, the aeromagnetic data and measurements by C. S. Grommé on 94 samples show that the gabbro complexes of the Fairweather Range are generally rather magnetic except for the southern two-thirds of the "Crillon–La Perous complex," which is only very slightly magnetic and is also associated with a nickel-bearing sulfide deposit. The

association may be a guide for prospecting of the nonmagnetic gabbro masses in this region.

Mineral resources in Kuiu-Etolin Islands Tertiary volcanic and intrusive belt

Reconnaissance geologic mapping in the Petersburg and Port Alexander (1:250,000) quadrangles by D. A. Brew, H. C. Berg, R. P. Morrell, R. A. Sonnevil, J. D. Cathrall, S. J. Hunt, and Carl Huie has delineated a N. 70° W. trending Tertiary intrusive and volcanic belt that may contain molybdenum, tungsten, and uranium resources. The belt, which is discordant to regional structural trends and intrusive belts (including recognized Tertiary basins), extends eastward from an intermediate-composition granitic intrusive-volcanic complex on central Kuiu Island to beneath Sumner Strait and on to Zarembo and Etolin Islands (loc. 12). The belt on Zarembo consists of a dike-and-flow complex of intermediate-to-silicic composition with minor granitic intrusions and on Etolin of granitic intrusions. Age of the belt is established on the basis of fossils from sedimentary strata interlayered with flows and on comparisons of the lithic and structural character of the granitic bodies with dated bodies in the "Coast Range" plutonic complex. These latter bodies contain molybdenum and perhaps uranium resources. Very preliminary synthesis of available stream-sediment and bedrock geochemical data suggests that the belt contains anomalous concentrations of tungsten.

New analysis of paleomagnetic data from Alexander terrane

Research on Paleozoic rocks of southeastern Alaska initiated by C. S. Grommé (USGS) has been continued by Meridee Jones (USGS) and Rob Van der Voo (University of Michigan). Initial results suggested no displacement of the rocks of the Alexander terrane. Further analyses, however, indicate that inclinations and declinations of poles for sample groups of late Middle Ordovician, Late Ordovician, Devonian, Late Devonian, early and Late Carboniferous ages deviate from predicted values and that a better match can be obtained for a paleoposition of the terrane at about lat. 40° N., long. 120° W., which is in western Nevada or northeastern California, a location suggested earlier by Jones, Irwin, and Ovenshine (1972). In addition, the paleomagnetic results of Van der Voo and others require a post-Carboniferous 25° counterclockwise rotation of the terrane. Restoration of the counterclockwise rotation would alter the direction of major facies change from northwest to due north and complicate the comparison of Silurian facies belts between southern Alaska and California used by Jones and others in their treatment of the Alexander terrane as a displaced continental fragment.

Intrusive belts of southeastern Alaska

Compilations and synthesis of available published and unpublished data on the distribution, composition, and age of intrusive rocks in southeastern Alaska by D. A. Brew and R. P. Morrell have resulted in the recognition of 21 distinct intrusive belts or areas. These belts record a variety of magmatic and tectonic events from the Precambrian to the Tertiary. The table below summarizes the geographic distribution and ages of most of the belts. Ages given are based on isotopically dated samples and on field evidence and inference.

In addition to the belts in the table, there are five belts of mafic and (or) ultramafic intrusive rocks, as follows: (1) Yakobi-Fairweather belt of layered and nonlayered gabbros of Tertiary(?) or Cretaceous(?) age, (2) central Baranof belt of serpentinized peridotite and serpentinite of Mesozoic age, (3) central Chichagof belt of hornblende gabbros closely associated with the Glacier Bay-Chichagof belt of Cretaceous granitic rocks, (4) Duke Island-Klukwan belt of concentrically zoned mafic-ultramafic complexes (Taylor, 1967), and (5) "Coast Range" plutonic complex "belt" of peridotite, dunite, and gabbro (Grybeck and others, 1977).

REGIONAL STUDIES AND COMPILATIONS OF LARGE AREAS

Synthesis and analysis of Appalachian orogen

Better understanding of the early Paleozoic geology of the American Appalachians is being sought through geologic synthesis and analysis on both sides of the North Atlantic by American geologists, together with geologists from nine other countries of the North Atlantic region, as a part of the Caledonide Orogen Project of the International Geological Correlation Program (IGCP). One such synthesis that includes both the Canadian and American Appalachians is the Tectonic-Lithofacies map of the Appalachian orogen at 1:1,000,000 scale (Williams, 1978) based on recent work of many geologists including that of 15 members of the USGS. Analyses of several aspects of the geology of the orogen, by means of compilation of certain kinds of data at 1:1,000,000 scale, are under way by a

Age		*Location*	*Composition*
Tertiary	~20–25 m.y.(?)	Kuiu-Zarembo-Etolin Island	Intermediate to silicic intrusive and flow complex.
	~20–25 m.y.(?)	"Coast Range" plutonic complex	Granite, alkali granite.
	~30–45 m.y.	Glacier Bay-Baranof Island	Granodiorite.
	~45–50 m.y.	"Coast Range" plutonic complex	Do.
Tertiary or Cretaceous.	------	Yakutat-Glacier Bay	Do.
		"Coast Range" plutonic complex	Do.
Cretaceous	~80–100 m.y.	Revillagigedo Island-Stephens Passage.	Granodiorite porphyritic diorite.
	~100–110 m.y.	Glacier Bay-Chichagof Island	Granodiorite.
Cretaceous (?)	------	"Coast Range" plutonic complex sill.	Tonalite.
Cretaceous and (or) Jurassic.	------	Revillagigedo-Prince of Wales Island	Granodiorite.
Jurassic	~140–150 m.y.	Chilkat Mtns.-Baranof Island	Do.
		Bokan Mountain	Alkali granite, granite.
		Texas Creek	Granodiorite.
Late Paleozoic (?)	~280 m.y.	Yakutat	Diorite, quartz diorite.
Silurian and (or) Ordovician.	------	Southeastern Chichagof	Syenite, monzonite.
		Southeastern Prince of Wales Island	Quartz monzonite, granodiorite.
		Annette Island	Trondhjemite.
Precambrian	>700 m.y.	Southwestern Prince of Wales Island.	Do.

team of Federal, State, and university geologists coordinated by R. B. Neuman. Among these aspects is a Time-of-Deformation map of the U.S. Appalachians, compiled by a team of six geologists, led by P. H. Osberg (University of Maine, Orono) (See Dallmeyer and others, 1978), that shows by means of color coding the ages of eight kinds of structural features such as faults, folds, and foliations. The patterns of this map emphasize the differences between the northern Appalachians, where late Paleozoic deformation is of limited extent and early Paleozoic structures dominate, and the central and southern Appalachians, where late Paleozoic structures are pervasive.