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Edited by Kathleen Krafft

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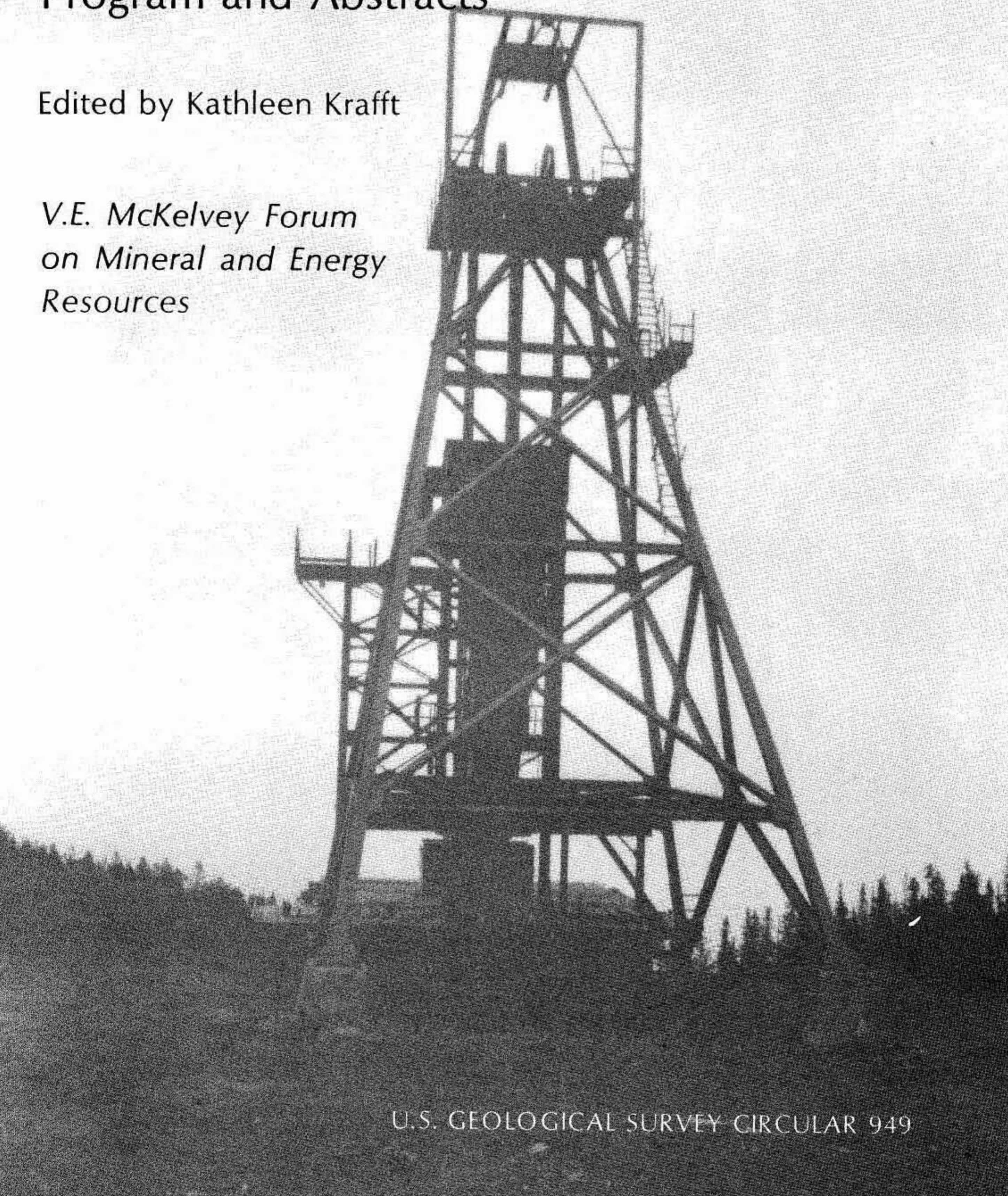

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1985

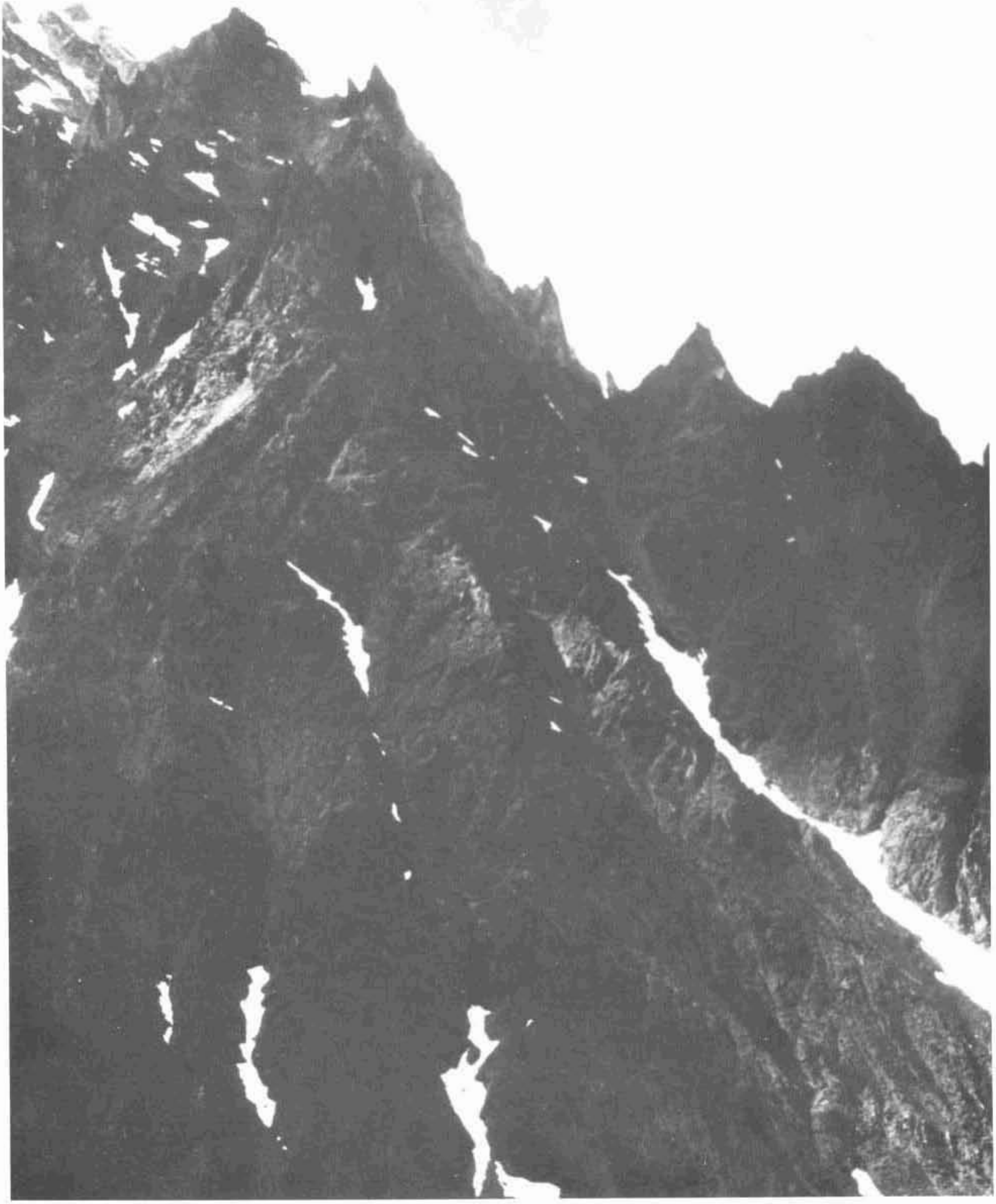
SOME GEOPHYSICAL GUIDES TO ORE IN SOUTHERN AND SOUTHWESTERN ALASKA

J.E. Case

In southern Alaska, massive sulfide deposits are associated with Late Cretaceous-Paleogene pillow basalt, sheeted dikes, and overlying flysch deposits. Most such mafic assemblages in Prince William Sound are characterized by prominent positive gravity anomalies. Magnetic anomalies over the volcanic belts are positive, but their amplitudes range widely. Where massive sulfide deposits occur on Knight Island and the Ellamar Peninsula, magnetic anomalies are relatively flat or negative—a strong indication of hydrothermal alteration accompanying mineralization. To the north and west, a belt of late Mesozoic gabbros, diorites, and ultramafic rocks of the northern Chugach Range and western Kenai Peninsula is indicated by large positive gravity and magnetic anomalies. These rocks may contain chromite, massive sulfide, magnetite, and gold deposits. The gravity and magnetic anomalies show that the complex continues beneath glaciers, alluvial cover, and water-covered areas.

On the Alaska Peninsula, ore deposits include porphyry copper-molybdenum types, some of which are accompanied by gold deposits. Few significant gravity anomalies have yet been identified, except that large granitoid plutons of Tertiary age commonly cause negative anomalies. Magnetic anomalies, however, have a twofold role in identifying granitoid plutons. First, most plutons cause prominent ovoid magnetic highs, which coincide with "centers of mineralization" as defined on the basis of geochemical anomalies and outcrop geology by D. Cox and D. Detra. Second, the most highly mineralized areas on or adjacent to the granitoid plutons are commonly expressed by subdued or relative negative anomalies, also indicating alteration associated with the ore-forming process.

Elsewhere in southern and southwestern Alaska, gold deposits in the flysch terrane west of the



Rugged topography, Chugach Mountains, southern Alaska

Alaska-Aleutian Range batholith are commonly associated directly or indirectly with granitoid plutons that cut the Mesozoic flysch. These plutons normally produce small-amplitude positive magnetic anomalies, or no anomaly at all, surrounded by negative anomalies caused by reversely magnetized pyrrhotite that resulted from metamorphism in contact aureoles.

Major positive magnetic anomalies on the Alaska Peninsula are produced by magnetite-rich sandstones of the Naknek Formation of Jurassic age whose sedimentary provenance is the Alaska-Aleutian Range batholith of Jurassic age. Whether fossil placer gold deposits might be associated with the Naknek Formation remains to be determined by geochemical sampling.

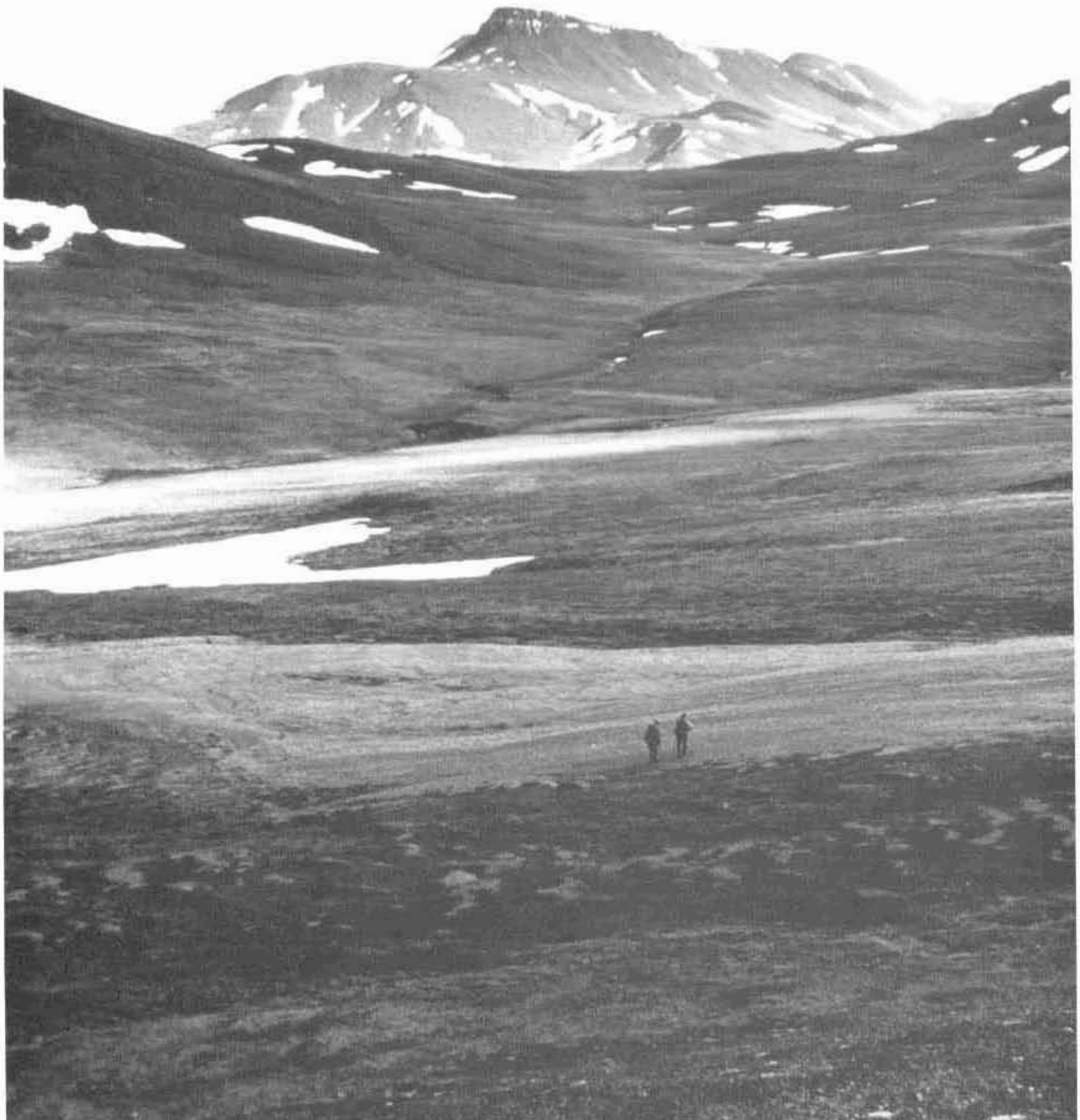
MINERAL RESOURCES OF THE SURVEY PASS QUADRANGLE, BROOKS RANGE, ALASKA

Donald J. Grybeck and Steven W. Nelson

The mineral resources of the Survey Pass quadrangle (mapped at 1:250,000) in the central Brooks Range were evaluated under the Alaska Mineral Resource Assessment Program (AMRAP) beginning in 1977. Like all AMRAP studies, the Survey Pass effort is not a literature search but is based on a comprehensive field program specifically tailored to collect and integrate geological, geochemical, geophysical, and mineral deposit data to achieve a modern (reconnaissance) assessment of the quadrangle's mineral resources.

The essential framework for producing the mineral resource assessment is the geologic map; more than half the effort in the study and considerable scientific talent in several disciplines was devoted to understanding the geology of the quadrangle. The geologic map was then used as the foundation for interpreting and integrating the geochemical, geophysical, and mineral deposit data with ore deposit models to define areas of mineral resource potential. The areas varied greatly in their apparent mineral potential, not only because of differences in their inherent mineral endowment but because of the considerable variation in the amount and the implications of the data that were available.

Seven terranes, bounded mainly by known or suspected north-dipping thrust faults, can be distinguished by stratigraphy, metamorphic grade, structural fabric, and magnetic signature. Almost all the rocks in the quadrangle are known or presumed to be Late Devonian or Early Mississippian in age, although they differ widely in



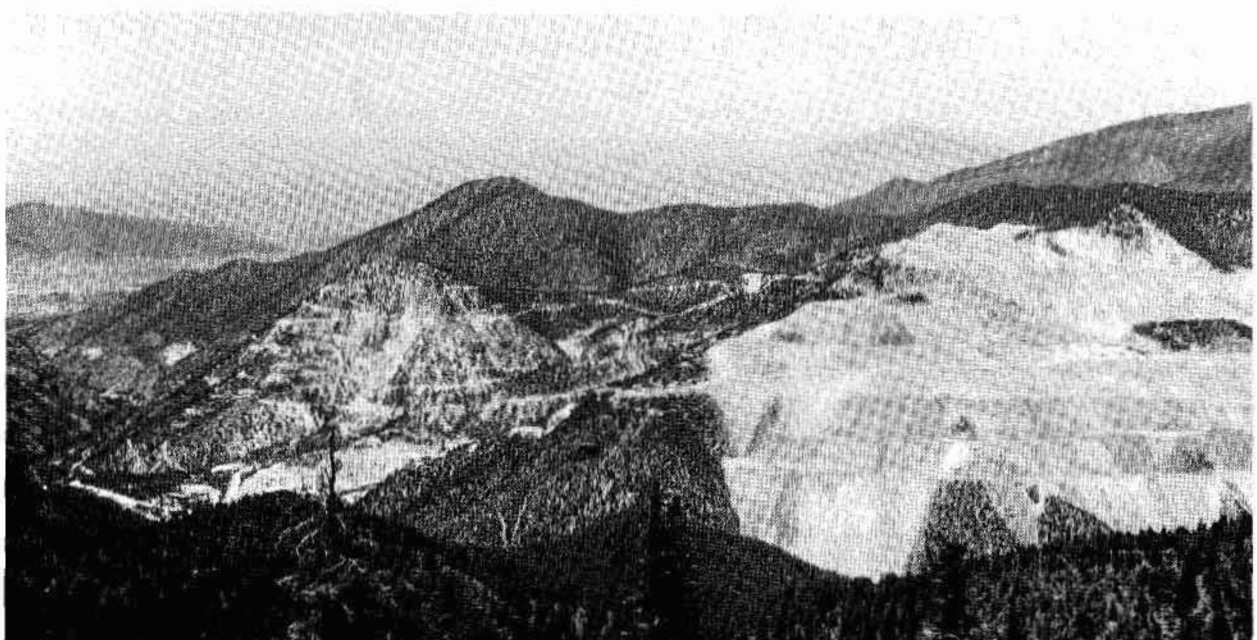
Geologists examining stratiform Zn-Pb sulfide deposit at Drenchwater Creek, northwestern Brooks Range, Alaska lithology. The northernmost terrane consists mainly of a thick, unmetamorphosed red-bed sequence deposited in a delta that covered much of what is now the Brooks Range in Late Devonian time. South of the red-bed sequence, four terranes consist of unmetamorphosed to low-grade rocks, mainly phyllites, and carbonates. South of them, the central portion of the quadrangle consists of low- to medium-grade calcareous to pelitic schist, gneiss, marble, and quartzite that surround two Devonian gneissic granite batholiths. The southernmost terrane, the "schist belt", consists of low-grade pelitic schists with scattered occurrences of blueschist. The schist belt also contains a distinctive sequence of felsic and calcareous schist, rhyolite, and mafic igneous rocks, which hosts large volcanogenic massive sulfide Cu-Zn-Pb(-Ag-Au) deposits.

Only two classes of deposits appear to be of major importance in the quadrangle: the volcanogenic massive sulfide deposits and several types of deposit associated with felsic plutonic rocks. Numerous lines of evidence indicate that additional massive sulfide deposits may exist in the schist belt, but only in its western half in the quadrangle. This study identified many skarn and other contact metamorphic deposits and veins containing various combinations of Pb, Zn, Cu, Ag, Au, Mo, Sn, W, and other elements around the Devonian granite batholiths, and the geochemical data indicate additional undiscovered deposits of this type. However, all the known deposits associated with the granites are small; most are little more than mineralogical occurrences. While the known granite plutons are an attractive environment for mineral deposits of several types, their roof zones, which were the most likely sites of mineralization, are largely eroded away. However, the geochemical, remote-sensing, and mineral deposit data strongly suggest that at least two large buried and previously unsuspected granitic plutons are present in the northern part of the quadrangle, and several more are suspected elsewhere.

BASE METALS, PRECIOUS METALS, AND MOLYBDENUM: NEW OCCURRENCE TYPES IN THE WESTERN UNITED STATES

Wayne Hall, Steve Ludington, Ted G. Theodore, and Norman J Page

Central Idaho Black Shale Mineral Belt (Hall)—A highly mineralized black shale belt 60 mi (95 km) long and 8–30 mi (13–48 km) wide of Ordovician to Permian age crops out on the east side of the Atlanta lobe of the Idaho batholith in central Idaho. These black shales occur in imbricated tectonostratigraphic plates separated by regional thrust faults. Mineralized resources include (1)



Open-pit molybdenite mine at Questa, New Mexico

A MULTIDISCIPLINARY RESOURCE ASSESSMENT OF THE CHUGACH NATIONAL FOREST, ALASKA

Steven W. Nelson

The Chugach National Forest, a 9,000-mi^2 (23,000-km^2) area, is the second largest national forest in the United States and the largest national forest evaluated under the National Forest Wilderness Act. A multidisciplinary resource assessment was conducted between 1979 and 1982. The largely reconnaissance-scale study by the U.S. Geological Survey included geologic mapping; regional aeromagnetic and gravity surveys; stream-sediment, panned-concentrate, bedrock, and organic-geochemistry studies (for hydrocarbons); and stable-isotope geochemistry and fluid-inclusion studies of specific mineral deposits. Concurrently, the U.S. Bureau of Mines conducted mapping and geochemical and mineralogical studies of mines, prospects, and mineral occurrences. From these studies, 25 resource areas were identified. To facilitate land-planning decisions, these areas have been ranked, from most favorable to least favorable, for potential for additional resources of those commodities (Au, Cu, oil, coal) with a history of production in the study area.

The geology of the national forest is dominated by two major lithologic units, the Late Cretaceous Valdez Group and the Paleocene and (or) Eocene Orca Group. Both groups, separated by the Contact fault system, consist largely of metamorphosed to unmetamorphosed graywacke, siltstone, and shale. The Orca Group has traditionally been considered to be somewhat less metamorphosed than the Valdez Group and to be further distinguished from it by the presence of mafic volcanic rocks and local beds of conglomerate. Our mapping, however, has shown that these rock types are found in both groups. Sedimentary rocks, in part younger than the Orca Group, crop out in the southeastern part of the project area. Plutonic rocks were emplaced in Eocene and Oligocene time. Most of the plutons are granitic in composition, but an early phase of the Oligocene plutons ranges in composition from quartz diorite to gabbro.

Previous studies[7] have suggested that the

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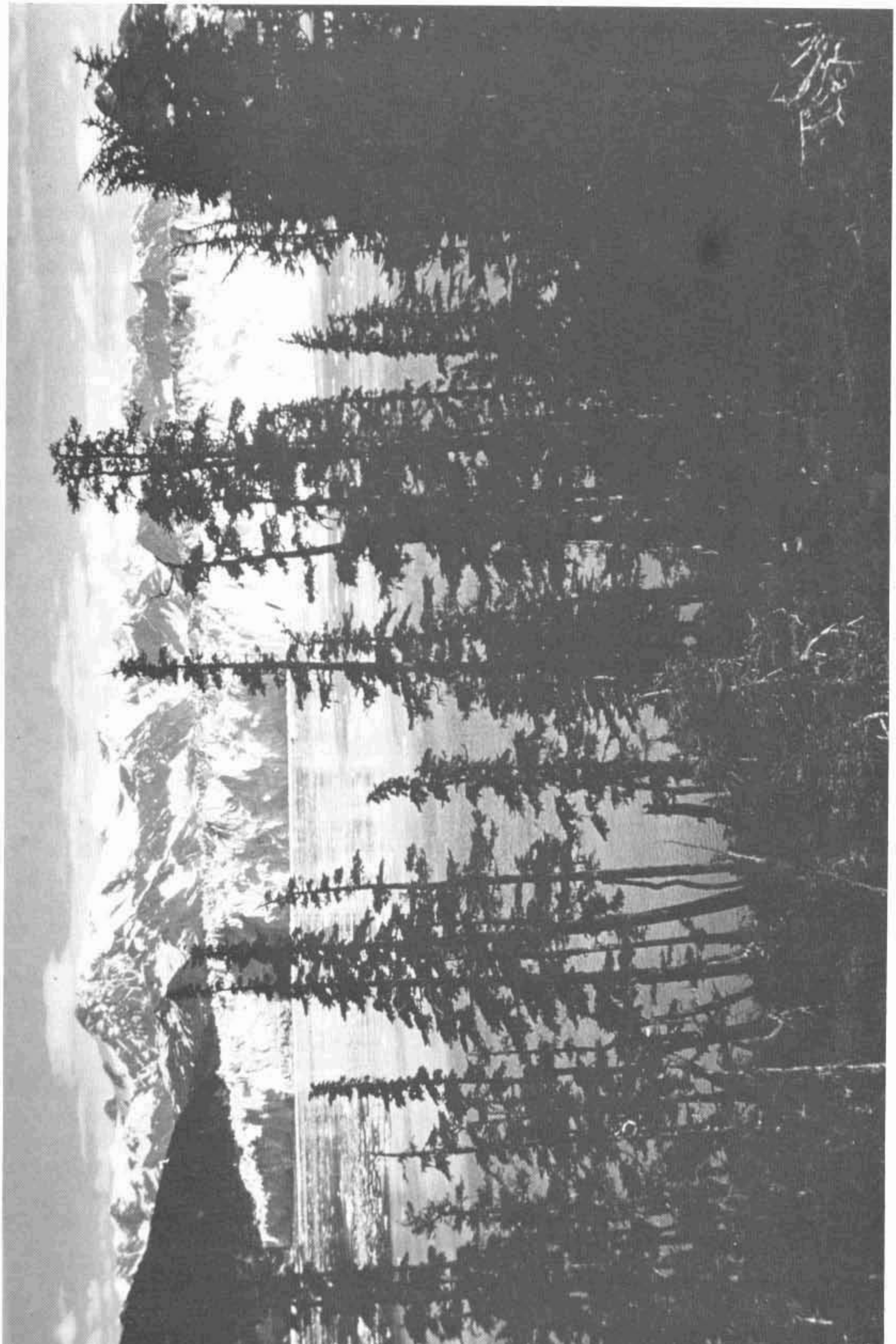
[7]Tysdal, R.G., and Case, J.E., 1982, Metalliferous mineral resource potential of the Seward and Blying Sound quadrangles, southern Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-880-H, scale 1:250,000.



Columbia Glacier entering Prince William Sound (tidewater), Chugach National Forest, and Chugach Mountains, southern Alaska

Valdez and Orca Groups represent two different metallic mineral provinces. The Valdez Group is characterized by deposits worked for gold and the Orca Group by deposits worked for copper. This distinction is weakened by our study, which shows that the copper deposits appear to be related to mafic volcanism and are generally found in, or spatially related to, mafic volcanic rocks in both the Valdez and Orca Groups and that the gold-bearing deposits occur in quartz fissure veins apparently hosted by various rock units. Gold, for example, is found in quartz veins that have been dated at 53 Ma, which cut Valdez Group sedimentary rocks, and in quartz veins cutting 34-Ma plutons. In these occurrences, the gold-bearing quartz veins occur along fractures and shears that cut across regional structure and fabric. Stable-isotope studies suggest, at least for the older veins, that hot meteoric water leached the gold from the country rock. In the Orca Group, gold occurrences are restricted to quartz veins cutting sedimentary rocks near the 51-Ma McKinley Lake pluton and to quartz veins cutting greenstone in a few small areas.

An estimated 264,000 oz. of gold have been recovered, from both lode and placer sources. During a 30-year period beginning in the 1900's, nearly 206,400,000 lb. of copper, with minor amounts of gold and silver, were produced. Most of the ore was produced from four mines, though small amounts of copper were mined from at least 17 other operations. The placer gold deposits are principally confined to the Kenai Peninsula area, although other occurrences have been identified in almost all of the metal-bearing resource potential areas.

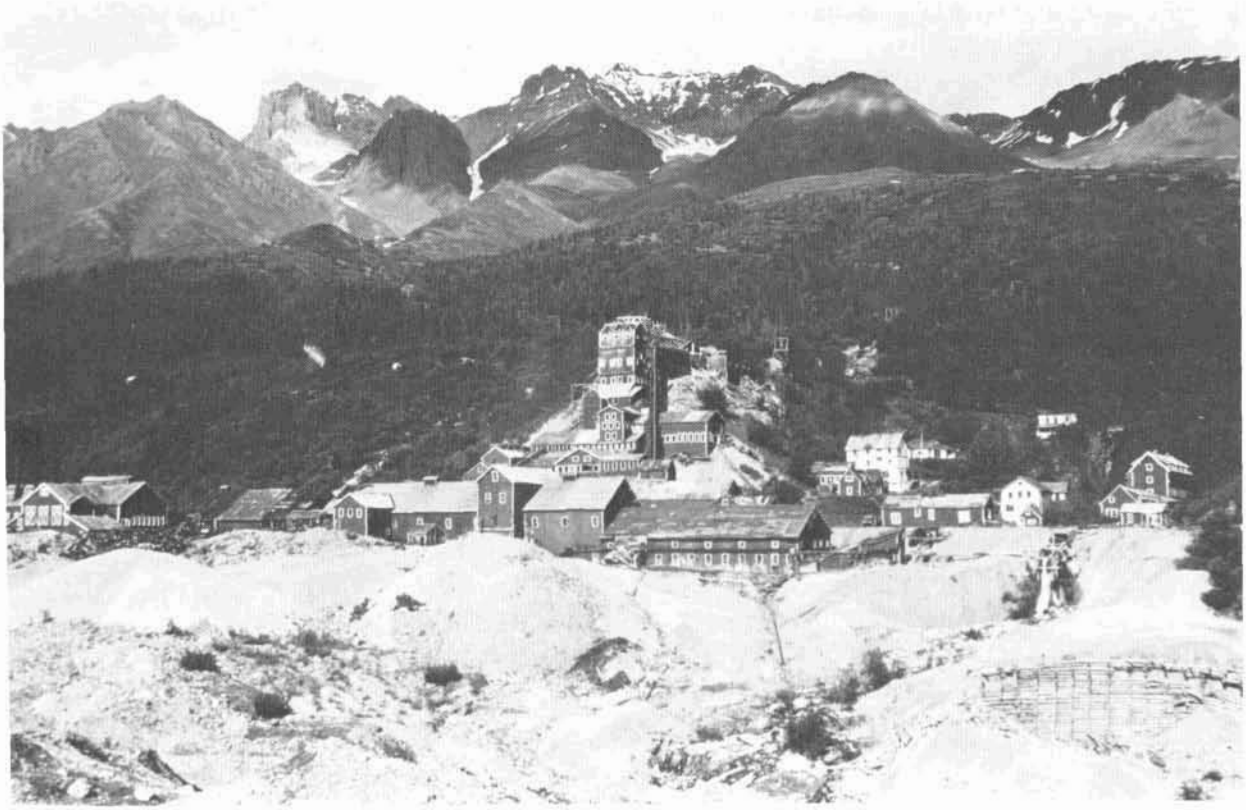
Extensive coal deposits occur in structurally complex Tertiary rocks in the Bering River area, and large tonnages of minable coal appear to be present. A total of about 20,000 tons of coal was produced intermittently in the early 1900's. The Katalla area has substantiated potential for oil and gas. The production of the field over a 30-year period was relatively small (154,000 bbl), and the complex structure and lack of suitable reservoir rocks in the area suggest that major fields are unlikely.

METALLOGENETIC HISTORY OF THE WRANGELLIA TERRANE, EASTERN ALASKA RANGE, ALASKA

Warren J. Nokleberg and Ian M. Lange

Much of the southern part of the eastern Alaska Range, in the Mt. Hayes, Gulkana, and Nabesna quadrangles, consists of the Wrangellia terrane, which exhibits a long and complicated stratigraphic and structural history and a long and complicated metallogenetic history. In the eastern Alaska Range, Wrangellia consists mainly of (1) a thick sequence of late Paleozoic island arc rocks, including submarine andesite flows, breccias, epiclastic rocks, volcanic graywacke, argillite, marble, and altered andesite and dacite porphyries, disconformably overlain by (2) Middle to Late Triassic Nikolai Greenstone, intruded by (3) cumulate mafic and ultramafic rocks probably comagmatic with the basalt flows of the Nikolai Greenstone, and disconformably overlain by (4) Late Triassic limestone. These and other terranes are unconformably overlain by Late Jurassic and Early Cretaceous flysch and intruded by isolated plutons of probable Late Jurassic and Early Cretaceous age. The Wrangellia terrane exhibits upper greenschist facies metamorphism with a weak cleavage or schistosity.

Six principal types of mineral deposits and occurrences are found in Wrangellia in the eastern Alaska Range: (1) Small areas of sulfides, up to a few meters wide, with anomalous concentrations of Cu, Pb, Zn, Ag, and Au, occur in fracture zones and are disseminated in hydrothermally altered late Paleozoic volcanic rocks. Common sulfide minerals are chalcopyrite, bornite, sphalerite, and pyrite. (2) Pods and lenses of massive sulfides and skarn deposits containing chalcopyrite and pyrite with anomalous concentrations of Cu, Ag, and Au occur in marble and in hydrothermally altered volcanic rock adjacent to Permian andesite and dacite porphyries. Maximum dimensions are a few meters. (3) Local disseminated sulfides with anomalous concentrations of Cu, Pb, Zn, and Ag occur in hypabyssal Permian andesite and dacite porphyries. These porphyries are often propy-



Kennecott mill and tailings at base of Bonanza Ridge, Wrangell Mountains, southern Alaska

litically altered, contain calcite and chalcopyrite veinlets, and are laced with disseminated chalcopyrite and pyrite. (4) Disseminated grains and lenses of Ni-bearing chromite occur in layers in cumulate mafic and ultramafic rock in extensive sills. (5) Disseminated sulfides with anomalous concentrations of Cu, Ag, and Au occur in various granitic plutonic rocks. These granitic rocks commonly contain very fine grained K-feldspar, quartz, secondary sericite, and pyrite, and minor chalcopyrite in fractures and isolated grains. (6) Sulfides with anomalous concentrations of Cu, Ag, and Au occur in quartz veins and associated altered Nikolai Greenstone and older metavolcanic rocks. The common sulfides are chalcopyrite, bornite, and pyrite.

Our preliminary accretionary terrane model relates the origin of these mineral deposits to the origin, migration, and accretion of Wrangellia. Initially, subduction formed a late Paleozoic island arc. During the early stages of the arc, disseminated and vein sulfide deposits formed in volcanic flows and associated rocks. Later, during the final stages of the island arc, sulfide deposits formed in skarn and volcanic rocks adjacent to shallow porphyries. Subsequent rifting during the Middle and Late Triassic resulted in submarine and subaerial extrusion of the Nikolai Greenstone and emplacement of associated cumulate mafic and ultramafic rock containing disseminated grains and lenses of chromite. In the Late Jurassic through Late Cretaceous, subduction and formation of an island arc along the leading edge of Wrangellia occurred during migration towards North America. This resulted in intrusion of plutonic rocks containing disseminated and vein base-metal sulfides and in local skarn formation adjacent to granitic plutons. Finally, Wrangellia was accreted onto the western margin of North America during the middle or Late Cretaceous, resulting in regional greenschist facies metamorphism and deformation that culminated in formation of late-stage quartz sweat veins and altered areas with Cu-, Ag-, and Au-bearing sulfides. This model may be an important predictive tool for mineral resource assessment and for discovery of new mineral deposits in Wrangellia throughout the North American Cordillera.

CHARACTERISTICS OF LODE-GOLD DEPOSITS IN THE PRINCE WILLIAM SOUND REGION, SOUTHERN ALASKA

Miles L. Silberman and Dawn J. Madden

Lode-gold deposits in low- to medium-grade metamorphosed, accreted sedimentary rocks are common and economically important throughout the world. Perhaps the best known examples of this deposit type are in the Klamath Mountains of northern California. Other occurrences are found in South Island (New Zealand), Papua New Guinea, southwestern Alaska, and parts of the Mother Lode Belts of central California. Because of the importance of deposits of this type, we decided to study in detail one region where they occur in order to determine their mechanisms of formation and localization. The deposits near Prince William Sound, southern Alaska, are particularly suited for detailed study now, after ten years of regional and local geologic study, when a comprehensive regional picture is emerging.

The deposits occur as narrow fissure veins emplaced along faults, fractures, and shears in metasedimentary rocks of the Upper Cretaceous Valdez Group in the Prince William Sound region. In some mining districts, the veins are peripheral to and cut small granitic stocks and plugs that intruded the metasedimentary rocks between 55 and 50 Ma and again at 35 Ma. In other districts, the veins occur in metasedimentary host rocks that lack plutonic intrusions but contain small felsic to intermediate dikes, which are locally altered and cut by the veins.

The veins consist of quartz and minor calcite; they contain generally low concentrations of sulfide minerals, predominantly arsenopyrite, and

Metamorphism (55–62 Ma)	Heating of thickened wedge, high-grade metamorphism at depth, lower grade near surface. Generation of metamorphic fluids, which leach metals from wedge sediments. Formation of metamorphic segregation quartz veins.
Intrusion (55–50 Ma)	Migration of melts to shallow depth, and emplacement as plutons and dikes. Contact metamorphism, faulting.
Uplift	Uplift by thermal expansion, or loss of compression, opening of fractures, extensional shearing.
Mineralization (55–53 Ma)	Influx of meteoric water, mixing with metamorphic fluids as they ascend, deposition of quartz, calcite, metals in open fractures and shears. Late stages of process driven by heat of anatectic granites.

PROCESSING OF LANDSAT IMAGERY TO MAP SURFACE MINERAL ALTERATION ON THE ALASKA PENINSULA, ALASKA

Frederic H. Wilson and James E. York[11]

Landsat images were digitally processed to facilitate assessment of the mineral resources of the Port Moller, Stepovak Bay, and Simeonof Island 1:250,000 quadrangles. Field mapping and assessment of these quadrangles were begun in 1983 as part of the Alaska Mineral Resource Assessment Program (AMRAP). It was quickly realized that time and budget constraints would limit mapping coverage. Therefore, at the suggestion of Roger Ashley, we used existing Landsat multispectral scanner imagery to aid in locating surface alteration, which could be field checked or related to stream-sediment or hand-sample geochemical data.

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[11]James E. York, Technicolor Government Services Inc.; work performed under U.S. Geological Survey Contract Number 14-08-001-20129.

ation of an area. They allow rapid selection of areas that merit detailed field examination and geochemical sampling.

THE ALASKA MINERAL RESOURCES ASSESSMENT PROGRAM

Gary R. Winkler

AMRAP (Alaska Mineral Resources Assessment Program), the prototypic U.S. Geological Survey regional resource assessment program, enters its second decade with the continuing goal to provide comprehensive information on the mineral and energy resource endowment of Alaska to

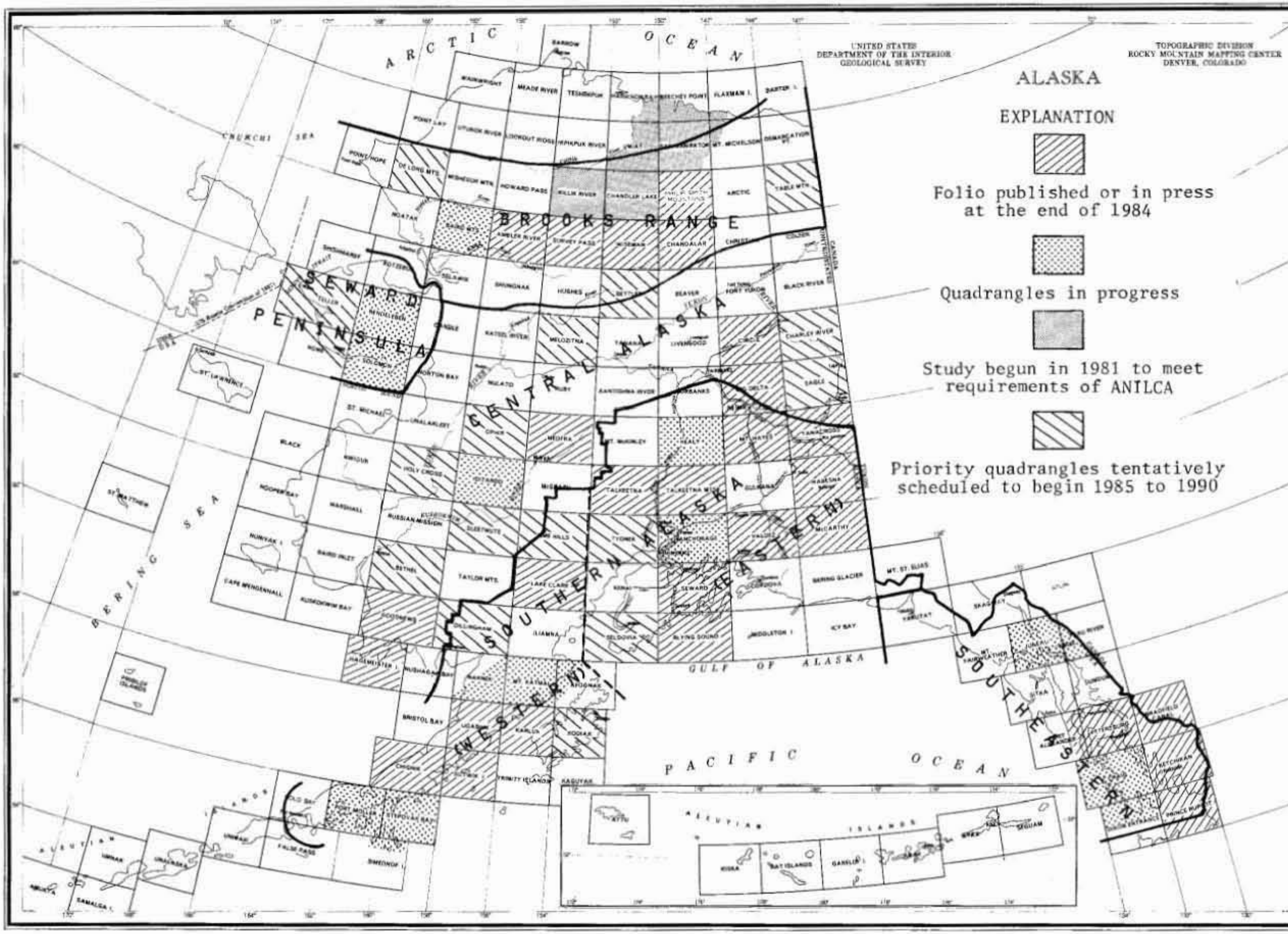

FIGURE 3.—Status of the Alaska Mineral Resources Assessment Program (AMRAP), February 1985, showing 1:250,000 quadrangles completed, in progress, or scheduled for study in the next five years. Regions of the State that are covered by summary mineral resource folios at scales of 1:600,000 to 1:1,000,000 are outlined by bold lines.

the public, the private sector, the academic community, and those who are concerned with national mineral policy. The program is designed (1) to provide information to land management agencies for decisions regarding the classification and allocation of Alaska's Federal lands in response to mandates of the Alaska National Interest Lands Conservation Act (ANILCA); (2) to produce systematic, state-of-the-art geoscience information to the mineral and energy industries, Alaska natives, and other public and private interests concerned with exploration and development of Alaska's resources; and (3) to expand the general knowledge of Alaska's complex geological setting, much of which is known presently only in reconnaissance.

In order to meet these broad objectives, AMRAP conducts four levels of study at progressively greater detail: Level 1, statewide compilations to identify the total mineral and energy resource base available for national needs; Level 2, synoptic regional assessments of geologic provinces (scale, 1:1,000,000), with an analysis of probable sizes and grades of potential resources (fig. 3); Level 3, interdisciplinary studies of key 1:250,000-scale quadrangles that are thought to have significant mineral or energy potential (fig. 3); and Level 4, investigations of mineral districts and deposits, energy provinces, and technical topics that will aid in interpreting the setting and character of specific mineral or energy resources in Alaska.

The core of the program presently is Level 3 studies. Fieldwork has been completed in 33 quadrangles, and complete folios (which include geologic, geochemical, and geophysical maps, a mineral and energy resource assessment, a summary circular, and derivative reports) are available for 19 of those quadrangles. Many individual folio components are available presently for the other 14, and investigations continue in 16 quadrangles. About 40 percent of the quadrangles intended for completion in the program are completed or are being studied. When key quadrangles in a large region or geological province have been completed (for example, the Seward Peninsula), a Level 2 synthesis is begun or updated. A regional mineral resource assessment for southeastern Alaska has been completed recently that has drawn upon new detailed Level 3 studies. A similar stage will be reached soon for the Alaska Peninsula, the Brooks Range, and the eastern part of southern Alaska (fig. 3). Synoptic mineral and energy resource assessments will provide up-to-date information on the potential for these regions and will show where additional information is needed.

Level 4 research investigations always have been an integral part of AMRAP. These studies include a broad spectrum of topical or detailed geological mapping, geochemical and isotopic studies, chronostratigraphic and biostratigraphic interpretation, geophysical studies, and evaluation of specific mineral or energy resource occurrences or commodities. Work currently underway on 40 projects will improve mineral deposit models, appraise specific resource potentials, and provide data that can directly aid exploration and development.

Two approaches in Level 4 studies will be accelerated in the next few years. First, detailed and comprehensive occurrence studies have begun of large, high-grade districts, such as the Red Dog and affiliated deposits in the western Brooks Range, and districts that have unique features, such as the southern Ambler district in the southwestern Brooks Range, where the copper-base-metal deposits are rich in cobalt. Secondly, detailed multidisciplinary studies of strategic commodities, such as tin and chromium, have begun because knowledge of Alaska's large apparent resources will be important in the future.