

1991 Annual Report on Alaska's Mineral Resources

U.S. GEOLOGICAL SURVEY CIRCULAR 1072



Prepared in cooperation with the Bureau of Land Management, the Fish and Wildlife Service, the Minerals Management Service, the National Park Service, the U.S. Bureau of Mines, the U.S. Forest Service, and the Department of Energy, as mandated by Section 1011 of the Alaska National Interest Lands Conservation Act, Public Law 96-487, of December 2, 1980



AVAILABILITY OF BOOKS AND MAPS OF THE U.S. GEOLOGICAL SURVEY

Instructions on ordering publications of the U.S. Geological Survey, along with the last offerings, are given in the current-year issues of the monthly catalog "New Publications of the U.S. Geological Survey." Prices of available U.S. Geological Survey publications released prior to the current year are listed in the most recent annual "Price and Availability List." Publications that are listed in various U.S. Geological Survey catalogs (see back inside cover) but not listed in the most recent annual "Price and Availability List" are no longer available.

Prices of reports released to the open files are given in the listing "U.S. Geological Survey Open-File Reports," updated monthly, which is for sale in microfiche from the U.S. Geological Survey Books and Open-File Reports Section, Federal Center, Box 25425, Denver, CO 80225.

Order U.S. Geological Survey publications by mail or over the counter from the offices given below.

BY MAIL

Books

Professional Papers, Bulletins, Water-Supply Papers, Techniques of Water-Resources Investigations, Circulars, publications of general interest (such as leaflets, pamphlets, booklets), single copies of periodicals (Earthquakes & Volcanoes, Preliminary Determination of Epicenters), and some miscellaneous reports, including some of the foregoing series that have gone out of print at the Superintendent of Documents, are obtainable by mail from

**U.S. Geological Survey, Books and Open-File Reports Section
Federal Center, Box 25425
Denver, CO 80225**

Subscriptions to periodicals (Earthquakes & Volcanoes and Preliminary Determination of Epicenters) can be obtained ONLY from

**Superintendent of Documents
U.S. Government Printing Office
Washington, DC 20402**

(Check or money order must be payable to Superintendent of Documents.)

Maps

For maps, address mail orders to

**U.S. Geological Survey, Map Distribution
Federal Center, Box 25286
Denver, CO 80225**

Residents of Alaska may order maps from

**U.S. Geological Survey, Map Distribution
New Federal Building - Box 12
101 Twelfth Ave., Fairbanks, AK 99701**

OVER THE COUNTER

Books

Books of the U.S. Geological Survey are available over the counter at the following U.S. Geological Survey offices, all of which are authorized agents of the Superintendent of Documents.

- ANCHORAGE, Alaska--4230 University Dr., Rm. 101
- ANCHORAGE, Alaska--605 West 4th Ave., Rm G-84
- DENVER, Colorado--Federal Bldg., Rm. 169, 1961 Stout St.
- LAKEWOOD, Colorado-- Federal Center, Bldg. 810
- MENLO PARK, California--Bldg. 3, Rm. 3128, 345 Middlefield Rd.
- RESTON, Virginia--National Center, Rm. 1C402, 12201 Sunrise Valley Dr.
- SALT LAKE CITY, Utah--Federal Bldg., Rm. 8105, 125 South State St.
- SAN FRANCISCO, California--Customhouse, Rm. 504, 555 Battery St.
- SPOKANE, Washington--U.S. Courthouse, Rm. 678, West 920 Riverside Ave.
- WASHINGTON, D.C.--U.S. Department of the Interior Bldg., Rm. 2650, 1849 C St., NW.

Maps

Maps may be purchased over the counter at the U.S. Geological Survey offices where books are sold (all addresses in above list) and at the following Geological Survey offices:

- ROLLA, Missouri---1400 Independence Rd.
- FAIRBANKS, Alaska--New Federal Building, 101 Twelfth Ave.

1991 Annual Report on
Alaska's Mineral Resources



Frontispiece. R/V *Karluk* in Growler Bay, Glacier Island, Prince William Sound. To study hydrocarbon contamination following the 1989 *Exxon Valdez* oil spill, the USGS conducted a 7-day cruise aboard this vessel in 1990 to sample sediments on and adjacent to selected heavily oiled beaches. Photograph by P. Carlson.

1991 Annual Report on Alaska's Mineral Resources

JILL L. SCHNEIDER, Editor

Prepared in cooperation with the Bureau of Land Management,
the Fish and Wildlife Service, the Minerals Management Service,
the National Park Service, the U.S. Bureau of Mines,
the U.S. Forest Service, and the Department of Energy,
as mandated by Section 1011 of the Alaska National Interest
Lands Conservation Act, Public Law 96-487, of December 2, 1980

A summary of mineral resource activities in Alaska for the year 1990

U.S. GEOLOGICAL SURVEY CIRCULAR 1072

U.S. DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, JR., Secretary



U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

Any use of trade names and trademarks
in this publication is for descriptive
purposes only and does not imply
endorsement by the U.S. Government

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1991

Free on application to the
Books and Open-File Reports Section
U.S. Geological Survey
Federal Center, Box 25425
Denver, CO 80225

CONTENTS

Summary	1
Energy resources	1
Oil and gas	1
Arctic National Wildlife Refuge	2
<i>Exxon Valdez</i> oil spill	2
Coal and peat	2
Uranium	3
Geothermal resources	3
Nonfuel-mineral resources	3
Metallic minerals	3
Industrial minerals	4
Introduction	4
Mineral programs	4
Department of the Interior	4
U.S. Geological Survey	4
U.S. Bureau of Mines	7
Minerals Management Service	7
Bureau of Land Management	8
Fish and Wildlife Service	8
National Park Service	9
Department of Agriculture	9
U.S. Forest Service	9
Department of Energy	9
Contacts for further information	9
Energy resources	12
Oil and gas resources	12
Overview of production and prices	12
Exploration	12
Production activity	15
North Slope	15
Cook Inlet	16
Leasing activity	16
Transportation	16
Activity by Federal agencies	18
Minerals Management Service	18
Leasing and exploration activity	18
Future sales	20
National resource assessment	20
Joint Federal-State studies	20
Monitoring programs	20
U.S. Geological Survey	20
Alaska's petroleum systems	20
North Slope	22
Interior basins	22
Gas hydrates	23
Thermal maturity map of Alaska	24

Energy resources—Continued	
Oil and gas resources—Continued	
Activity by Federal agencies—Continued	
Bureau of Land Management	24
Fish and Wildlife Service	24
Kenai National Wildlife Refuge	24
Activities under Section 1008 of ANILCA	27
Resource activity impact assessment	27
Department of Energy	28
Petroleum research	28
Arctic National Wildlife Refuge	28
Fish and Wildlife Service	28
<i>Exxon Valdez</i> oil spill	29
Fish and Wildlife Service	29
Minerals Management Service	31
National Park Service	31
U.S. Geological Survey	31
U.S. Forest Service	31
Coal and peat resources	32
Activity by Federal agencies	34
U.S. Geological Survey	34
U.S. Bureau of Mines	34
Bureau of Land Management	35
Fish and Wildlife Service	35
Department of Energy	35
Uranium resources	35
Activity by Federal agencies	35
U.S. Geological Survey	35
Geothermal resources	36
Nonfuel-mineral resources	36
Metallic minerals	36
Industry activity	36
Economic and regulatory overview	36
Precious metals	38
Other metals	40
Activity by Federal agencies	40
U.S. Geological Survey	40
Alaska Mineral Resource Assessment Program	40
Precious metals	43
Strategic and critical minerals	43
Other metals	43
Cooperative programs with Soviet scientific agencies	43
Trans-Alaska Crustal Transect Program	45
National Petroleum Reserve in Alaska	45
U.S. Bureau of Mines	46
Minerals availability program	46
Policy analysis	47
State mineral activities	47
Mineral land assessment	47
Site-specific mineral investigations	50
Research activities	50
Bureau of Land Management	51
Fish and Wildlife Service	51
Minerals Management Service	52

Nonfuel-mineral resources—Continued	
Metallic minerals—Continued	
Activity by Federal agencies—Continued	
Minerals Management Service—Continued	
OCS Mining Program, Norton Sound lease sale	52
National Park Service	52
U.S. Forest Service	53
Tongass National Forest	53
Chugach National Forest	54
Industrial minerals	54
Activity by Federal agencies	55
U.S. Bureau of Mines	55
Bureau of Land Management	55
Fish and Wildlife Service	55
U.S. Forest Service	56
References cited	56
Appendix 1. Alaska mineral reports released during 1990 and early 1991	57
Department of the Interior	58
U.S. Geological Survey	58
U.S. Bureau of Mines	61
Minerals Management Service	62
Bureau of Land Management	63
Fish and Wildlife Service	63
National Park Service	63
Non-Federal reports	64
Alaska Division of Geological and Geophysical Surveys	64
Additional non-Federal publications	65
Appendix 2. Roles of Federal agencies in mineral programs	66
Department of the Interior	66
U.S. Geological Survey	66
U.S. Bureau of Mines	66
Minerals Management Service	67
Bureau of Land Management	68
Fish and Wildlife Service	68
National Park Service	68
Department of Agriculture	68
U.S. Forest Service	68
Department of Energy	69

FIGURES

Frontispiece. Photograph of R/V *Karluk* in Growler Bay, Prince William Sound.

1. Map of Federal land ownership in Alaska 5
2. Photograph of Usibelli Group in Nenana coal field, central Alaska, showing interlayered coals and sandstones 6
3. Map showing national wildlife refuges in Alaska 10
4. Photograph of NPS geologist collecting mineralized rock samples in Kantishna area of Denali National Park and Preserve 11
- 5–7. Maps showing:
 5. Locations of exploratory oil wells, oil and gas fields, and possible petroleum-bearing onshore sedimentary basins 13
 6. Areas of oil and gas lease sales 17
 7. Offshore geologic province boundaries as defined by MMS and USGS for national assessment and location of joint MMS-State studies 21

8. Photograph of organic-rich limestones in Kandik Basin, east-central Alaska 23
9. Map showing thermal maturity data coverage for Alaska 25
10. Map showing onshore favorable petroleum provinces and locations of DOE-funded research in 1990 26
11. Photographs of FWS personnel releasing eagles into wild after rehabilitation following 1989 *Exxon Valdez* oil spill 30
12. Photograph of USGS geologist examining oiled beach gravels on Smith Island, Prince William Sound 32
13. Map showing areas of potential coal and uranium resources and ACE-proposed port sites 33
14. Photograph of unmanned hydraulic monitors in Tofty mining district 37
- 15–17. Maps showing:
 15. Areas of significant industry activity involving metallic minerals (excluding uranium) in 1990, and mine and deposit locations 39
 16. Status of USGS level III AMRAP quadrangle studies, January 1991 41
 17. Locations of USGS level IV AMRAP metallic-mineral and TACT studies in 1990 42
18. Photograph of USGS, ADGGS, and Soviet geologists preparing to board helicopter to visit ophiolites in Koryak Mountains, Soviet Far East 45
19. Map showing locations of USBM mineral studies in 1990 48
20. Photograph of mining claims in Denali National Park proposed for acquisition by NPS 53
21. Photograph of new adit for Kensington lode-gold mine on Lynn Canal 55

TABLES

1. Fluctuation in price of Alaska North Slope crude oil 12
2. Alaska exploratory oil wells drilled in 1990 14
3. Alaska OCS leases and wells drilled, 1976–1990 18
4. Proceeds from lease sales on Alaska OCS planning areas 19
5. Producing leases, Beaufort Sea planning area 19
6. Mining production in Alaska, 1987–1990 37
7. Level IV studies of USGS Alaska Mineral Resource Assessment Program and related studies active in 1990 44
8. U.S. Bureau of Mines activity in mining districts and at strategic and critical mineral localities in 1990 49

ACRONYMS AND ABBREVIATIONS

ACE	U.S. Army Corps of Engineers
ADEC	Alaska Department of Environmental Conservation
ADGGS	Alaska Division of Geological and Geophysical Surveys
AFOC	Alaska Field Operations Center
AMHL	Alaska Mental Health lands
AML	Abandoned Mineral Lands
AMRAP	Alaska Mineral Resource Assessment Program
ANILCA	Alaska National Interest Lands Conservation Act
ANWR	Arctic National Wildlife Refuge
bbl/d	barrels of oil per day
BLM	Bureau of Land Management
BPX	BP Exploration
BTU/LB	British thermal units per pound
CAMA	Central Arctic Management Area
CFR	Code of Federal Regulations
CRREL	Cold Regions Research and Engineering Laboratory
CWA	Clean Water Act of 1977, as amended
DOE	Department of Energy
DOI	Department of the Interior
DST	Deep stratigraphic test
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
FEIS	Final Environmental Impact Statement
FWS	Fish and Wildlife Service
MAS	Minerals Availability System
mcf/d	Million cubic feet of natural gas per day
MCIS	Mineral Claim Information System
MILS	Minerals Industry Location System
MMS	Minerals Management Service
MRDS	Mineral Resources Data System
NEPA	National Environmental Policy Act
NOAA	National Oceanographic and Atmospheric Administration
NPDES	National Pollution Discharge Elimination System
NPRA	National Petroleum Reserve in Alaska
NPS	National Park Service
NTIS	National Technical Information Service
OCS	Outer Continental Shelf
PCB	Polychlorinated biphenyls
PGM	Platinum-group metal
REE	Rare-earth element
SCLDF	Sierra Club Legal Defense Fund
TACT	Trans-Alaska Crustal Transect
TAPS	Trans-Alaska Pipeline System
TLMP	Tongass Land Management Plan
TTRA	Tongass Timber Reform Act
UAF	University of Alaska at Fairbanks
USBM	U.S. Bureau of Mines
USCG	U.S. Coast Guard
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
VNII-1	Soviet All Union Institute of Gold and Rare Metals Research

CONTRIBUTORS

DEPARTMENT OF THE INTERIOR

Bureau of Land Management

Gary Brougham
Joseph Dygas
Don Keill
Mike Menge
Tom Mowatt
Ruth Stockie

Fish and Wildlife Service

Ann Rappoport

Minerals Management Service

Dorothy McLean

National Park Service

Judith Alderson

U.S. Bureau of Mines

Steven Fechner

U.S. Geological Survey

Kenneth Bird
Kendell Dickinson
David Howell
James Riehle
Jill Schneider
Gary Stricker

DEPARTMENT OF AGRICULTURE

U.S. Forest Service

Roger Griffin

DEPARTMENT OF ENERGY

Rod Malone
Harold Shoemaker

1991 Annual Report on Alaska's Mineral Resources

Jill L. Schneider, *Editor*

SUMMARY

Section 1011 of the Alaska National Interest Lands Conservation Act (ANILCA) of 1980 requires that "On or before October 1, 1982, and annually thereafter, the President shall transmit to Congress all pertinent public information relating to minerals in Alaska gathered by the United States Geological Survey, Bureau of Mines, and any other Federal agency." This report has been prepared in response to that requirement.

This circular is the tenth in a series of annual ANILCA reports. The report provides information about current Alaskan mineral projects and events during 1990; the emphasis is on Federal activity. The report addresses both onshore and offshore areas of Alaska.

The U.S. Geological Survey (USGS), U.S. Bureau of Mines (USBM), and Minerals Management Service (MMS) are the principal Federal agencies that publish information about energy and mineral resources in Alaska. Their reports and data form the basis for decisions by other Federal agencies regarding land use, access, environmental impacts, and mining claim evaluation. The time required for sample analysis, data synthesis, and publication is lengthy; as a result, scientific reports are generally issued a year or more after initial sample and data collection. Other sources of information for this report include additional Federal and State publications, trade and professional journals, newspaper articles, presentations at public meetings and hearings, and press releases.

Information is provided for two broad categories of minerals: energy resources and nonfuel-mineral resources.

Energy Resources

Oil and Gas

Alaskan oil and gas production in 1990 totaled 665.5 million barrels of oil and natural gas liquids, a 5.2-percent decrease from 1989 levels, plus 205 billion cubic feet of dry

natural gas, a 5-percent increase. This was the second straight year of decreased oil production. Daily oil production averaged 1.82 million barrels, and oil prices for the year averaged \$21.50 per barrel. The eight-billionth barrel of crude oil flowed through the Trans-Alaska Pipeline System (TAPS) in late December 1990. The North Slope produces 98 percent of the State's oil, and Cook Inlet produces 99 percent of the State's gas.

The Alaska Oil and Gas Conservation Commission approved 173 drilling permits in 1990; this was a 31-percent increase over the 132 wells permitted in 1989. Thirteen exploratory wells and 114 development and service wells were drilled. Shell Western continued its wildcat drilling in the Chukchi Sea; four of eight proposed wells have been completed. Exploratory drilling also resumed in Cook Inlet. Seismic surveys were conducted on the North Slope and in the Cook Inlet region, as well as in the Beaufort and Chukchi Seas. Neither the Federal Government nor the State held oil and gas lease sales in 1990.

On the North Slope, the increased application of well-stimulation strategies, such as water flooding, high-pressure reservoir fracturing, and gas reinjection, elevated Prudhoe Bay production in the second half of the year. Conoco defined the Schrader Bluff pool in the Milne Point field. Agreement over causeway construction and breaching was reached between ARCO Alaska, BP Exploration, and the U.S. Army Corps of Engineers (ACE), paving the way for development of the Point McIntyre offshore oil field. In the Cook Inlet area, a new drilling unit was established on the Kenai Peninsula for the production of natural gas, and a new gas pipeline will bring McArthur River gas from Granite Point to the Beluga power station. Oil production and shipping were disrupted early in the year by eruptive activity at Redoubt Volcano but returned to normal by June.

The MMS prepared for 1991 oil and gas lease sales in the Beaufort Sea, Navarin Basin, and Chukchi Sea, and continued its cooperative studies with the Alaska Division of Geological and Geophysical Surveys (ADGGS) on the thermal evolution of the Beaufort Sea continental margin. Preliminary results of the national resource assessment for the Alaska Outer Continental Shelf (OCS) were released in May. Long-term monitoring programs of the MMS evaluate the possible environmental effects of offshore oil and gas exploration and production.

The USGS identified seven petroleum systems in Alaska: three on the North Slope, two in Cook Inlet, and two in the Gulf of Alaska. North Slope petroleum plays and assessment results were published. The USGS also continued its evaluation of oil potential in the Brooks Range's northern foothills and in the Kandik basin of east-central Alaska, as well as the petroleum source potential of coals in the Middle Tanana basin. Researchers are investigating the potential production of gas from hydrate complexes, and the thermal maturity map of Alaska is being updated.

In 1990, the Bureau of Land Management (BLM) completed resource assessments in the south-central Alaska planning area and continued an assessment in the Western Arctic planning area. In addition, the BLM continued to pursue interest in a lease sale in the National Petroleum Reserve in Alaska (NPR). BLM geologists continued their ongoing minerals studies, with special emphasis on the North Slope and nearshore Beaufort Sea. The TAPS oil spill contingency plan has been revised.

In keeping with its mission to protect fish, wildlife, and habitat, the Fish and Wildlife Service (FWS) conducted environmental monitoring, contaminant analysis, and remedial cleanup programs with respect to petroleum-related activities in various parts of Alaska. The FWS issued 11 special-use permits for geologic work in seven refuges and reviewed 25 permit applications related to oil and gas activities for the ACE in order to recommend measures to minimize habitat losses. Two Federal OCS environmental impact statements and 14 State oil and gas lease sales were reviewed.

The Department of Energy (DOE) continued to sponsor seminars presenting new technological petroleum research findings, to coordinate interagency petroleum research, and to study the applicability of recovery techniques to gas-hydrate reservoirs in the Arctic.

Arctic National Wildlife Refuge

During 1990, the FWS completed the third year of its 5-year continuing studies program for the 1002 area on the coastal plain of the Arctic National Wildlife Refuge (ANWR). The program focuses on a better understanding of the area's ecosystems so that there can be effective mitigation of possible development activities. Review of the study program and mitigation analysis is ongoing.

In response to two lawsuits, the FWS compiled a list of the documents that made up the administrative record for preparation of the 1987 report to Congress on ANWR. The FWS and BLM continued to respond to public and Congressional inquiries regarding oil and gas potential of the 1002 area and the potential impacts of development activities on fish and wildlife. To better address these questions, BLM scientists continue to supplement their ANWR studies by reviewing all pertinent geologic and geophysical information.

Exxon Valdez Oil Spill

The oil tanker T/V *Exxon Valdez* ran aground on Bligh Reef on March 24, 1989, spilling more than 11 million gallons (262,000 barrels) of Prudhoe Bay crude oil into eastern Prince William Sound; the oil eventually spread south and west as far as the Alaska Peninsula. In two years, Exxon has spent \$2 billion on cleanup operations. Bioremediation of oiled beaches has proved to be the most effective technique employed.

The FWS has remained active in oil-spill response operations. The FWS cooperated with the U.S. Coast Guard (USCG) Federal on-scene coordinator in assessing the status of national wildlife refuge shorelines and in monitoring cleanup activities. Other programs undertaken to protect Department of the Interior (DOI) trust resources included the protection of nesting bald eagles from disturbance by cleanup activities. The FWS also continued natural resource damage assessment and restoration planning for the spill area. The MMS provided both staff for cleanup activities and funds for damage assessment studies. The Office of Oil Spill Coordination of the National Park Service (NPS) permitted myriad phases of the cleanup operations, and NPS staff surveyed, prioritized, and monitored beach cleanup within park units. The NPS Katmai Field Office was reopened to provide logistical coordination for aircraft, ships, and personnel. For comparison with their 1989 work, the USGS resampled bottom sediments in Prince William Sound to identify oil contamination. Personnel from the U.S. Forest Service (USFS) studied the spill's environmental impacts on national forest lands in order to recommend remedial actions.

Coal and Peat

Alaskan coal production hit a record high in 1990 at 1.58 million short tons, valued at \$45 million. About 50 percent of the coal was used for in-state power generation, and the rest exported to South Korea for the same purpose. The production of peat, used primarily as an agricultural soil conditioner, expanded 27 percent over 1989 levels to 65,000 cubic yards, valued at \$400,000.

All of Alaska's commercial coal is produced from a single mine in central Alaska by the Usibelli Coal Company, which received the DOI's 1989 "Excellence in Surface Coal Mining and Reclamation" award for its mine-water treatment operation. Coal developments planned for Wishbone Hill in the Matanuska Valley and Beluga on the west side of Cook Inlet have been suspended pending the resolution of the Mental Health Lands issue. Coal resources on the western North Slope might be developed for local use.

The USGS completed its resource studies of Tertiary coals on the eastern North Slope and continues its geo-

chemical research on samples from the Healy coal fields. The USBM evaluated coal deposits that might utilize port sites proposed by the ACE, and the BLM managed a coal lease in the Jarvis Creek field near Delta Junction. The FWS reviewed proposals for both the Diamond Chitna and Wishbone Hill coal mines in south-central Alaska. A grant from the DOE is financing the construction of a new power plant at the Usibelli coal mine at Healy.

Uranium

Alaska's uranium resources remain undeveloped due to low market value coupled with high exploration and development costs. USGS uranium research continued at a low level; most of the activity relates to previously collected data.

Geothermal Resources

Geothermal resources in Alaska are associated with widespread young volcanic activity in the south-central part of the State. No Federal research was funded for geothermal studies in 1990.

Nonfuel-Mineral Resources

Metallic Minerals

During 1990, Alaska's mineral industry experienced positive growth in the production and exploration sectors for the fourth consecutive year. Total mineral production values nearly doubled to \$534 million, mainly due to metals production at the Greens Creek and Red Dog mines. Exploration costs rose to \$56.7 million, the highest since 1981, but development expenditures fell to \$11.4 million. Zinc replaced gold as the second most valuable mineral commodity in the State, after oil and gas; zinc production of 181,200 tons was valued at \$253.7 million. Silver production doubled, and lead production increased fivefold. The closure of three mining operations dropped gold production to 89,204 troy ounces and tin production to 57,000 pounds.

Much precious-metals activity again focused on gold. In southeastern Alaska, the Alaska-Juneau, Jualin, and Kensington mines are in various stages of advanced exploration. The Valdez Creek mine in central Alaska reopened under new owners after extensive development work. Exploration drilling continued in the Valdez Creek area, at the Fort Knox deposit near Fairbanks, at Illinois Creek in southwestern Alaska, and at the Big Hurrah property on the Seward Peninsula. Offshore from Nome, the megadredge *Bima* was closed down after several unprofitable years. Canadian minerals exploration in British Columbia is begin-

ning to have an economic impact on the southeastern Alaska towns of Haines, Juneau, and Wrangell.

The mining industry celebrated the successful production of base and precious metals at both the Red Dog zinc-lead-silver deposit in northwestern Alaska and the Greens Creek silver-zinc-gold-lead mine on Admiralty Island. A major setback occurred when the operators of the Quartz Hill molybdenum mine in southeastern Alaska were denied a permit to discharge mine tailings into the Wilson Arm/Smeaton Bay fjord; as a result, mine development has been indefinitely suspended.

The Alaska Mineral Resource Assessment Program (AMRAP) continues to be the focus of USGS mapping and mineral assessment in Alaska. In 1990, USGS scientists released numerous reports on geologic mapping, mineral resource assessment, and specialized geologic studies of Alaska lands; initiated and continued research, field studies, and report-writing for mineral assessments of 30 1:250,000-scale quadrangles; and performed specialized geologic studies on a detailed scale for 41 projects around the State.

Site-specific studies were conducted on precious-metal deposits and strategic and critical mineral deposits. The USGS published its findings on mineral resources of the Tongass National Forest. Two teams of Soviet geologists visited Alaska as part of the comparative study of lode mineral deposits in the USSR Far East, Alaska, and western Canada, and a team of USGS geologists visited the USSR Far East to study ophiolites and their related mineral deposits. Work on the USGS Trans-Alaska Crustal Transect program in 1990 included (1) detailed geologic mapping, (2) magnetotelluric, seismic-refraction, and seismic-reflection surveys, and (3) interpretation, publication, and presentations of project findings.

The USBM examined the potential for mineral development near ACE-proposed port sites. Other studies considered the feasibility of cyanide use in precious-metal extraction under Arctic conditions, the hazards associated with abandoned mine sites in the Chugach National Forest, and the impacts of permitting and environmental costs on mining. Mineral assessment programs were carried out in the Ketchikan and Valdez Creek mining districts. Deposits that contain strategic and critical metals, minerals, and materials were also investigated. The USBM's research activities included the characterization and beneficiation of strategic and critical mineral deposits, evaluation of Soviet placer mining technology, evaluation of mining deep placer deposits, mine closure studies in arctic and subarctic climates, and sampling offshore mineral deposits. The USBM Mineral Institute program provides funding for both the University of Alaska at Fairbanks and the University of Mississippi Marine Minerals Technology Center. The USBM also co-funds the Cold Regions Research and Engineering Laboratory's permafrost tunnel research facility. The Alaska Technology Transfer Office in Anchorage was closed in 1990.

A 4-year mineral resources inventory was initiated for the Colville mining district in the southern portion of the NPRA. The BLM, USBM, and USGS will collaborate on this interagency project.

Seven mineral patents were issued by the BLM, and 244 mining operations were active on BLM-administered lands. The FWS reviewed applications for permits or permit modifications for placer mining, mineral assessment, gold dredging, and other mineral activities both on and off national wildlife refuges. The FWS also monitored mining activities and initiated or continued several studies of contaminants associated with mining operations. The MMS is planning a competitive OCS minerals lease sale of gold-bearing placers in Norton Sound south of Nome.

The NPS published the final environmental impact statements on the cumulative effects of mining in Denali, Wrangell-St. Elias, and Yukon-Charley Rivers National Parks and Preserves; this action led to the dissolution by the U.S. District Court of the injunction against mining in these three parks. Congress approved \$6 million to initiate purchase of mining claims in the Kantishna District of Denali National Park and Preserve. The NPS also drafted regulations for the implementation of ANILCA Section 1010, which will govern Federal mineral activities on national park lands; continued validity determinations on unpatented mining claims; approved one plan of operations for proposed mining; and conducted revegetation studies on previously mined land in Denali National Park and Preserve.

The USFS continued its revision of the Tongass National Forest land management plan and confirmed Kennecott Mining's extralateral rights at Greens Creek. The USFS also conducted mineral validity examinations and inventories of environmental and safety hazards on mining claims in national forests.

Industrial Minerals

The use of nonmetallic nonfuel resources in Alaska rose only slightly in 1990 due to the lack of major construction projects in the State. Combined sand and gravel output totaled \$41.8 million; building stone production totaled \$22.1 million. The export of glacial ice to Japan and Hawaii continues to escalate, forcing the State to issue permits and enact regulations regarding ice harvest.

Two USBM reports summarized the industrial minerals of the Juneau and Valdez Creek mining districts. The BLM made a number of mineral materials sales. The FWS continued permitting and monitoring small sand and gravel operations in support of local transportation and industry in various areas of Alaska. The USFS sold sand, gravel, and quarried stone for use in the construction of timber sale roads, breakwaters, and airports.

INTRODUCTION

Section 1011 of the Alaska National Interest Lands Conservation Act (ANILCA) of 1980 requires that "On or before October 1, 1982, and annually thereafter, the President shall transmit to Congress all pertinent public information relating to minerals in Alaska gathered by the United States Geological Survey, Bureau of Mines, and any other Federal agency." The USGS subsequently was delegated as the lead agency in responding to this requirement. This circular, the tenth in its series, synthesizes information made public in 1990.

The USGS and the USBM are the principal Federal agencies that generate information about onshore mineral resources in Alaska; the MMS is the prime agency reporting on resource activities in Alaska's coastal waters. Their data, analyses, and reports are used by other agencies for resolving questions on land use, access, environmental impacts, and mining claim evaluation.

As used herein, the term "public information" includes results of Federal projects as published in Government reports and professional and trade journals; oral presentations by representatives of Federal and State agencies and industry at symposia, conferences, and other public forums; and proceedings volumes, press releases, and newspaper articles. Unless otherwise indicated, references cited are listed at the end of this report; appendix 1 lists additional mineral reports published or released in 1990. Data from the ADGGS annual report on Alaska's mineral industry are cited in parts of this circular.

This report focuses on energy resources (oil, gas, coal, peat, uranium, and geothermal) and nonfuel-mineral resources (metallic and industrial minerals).

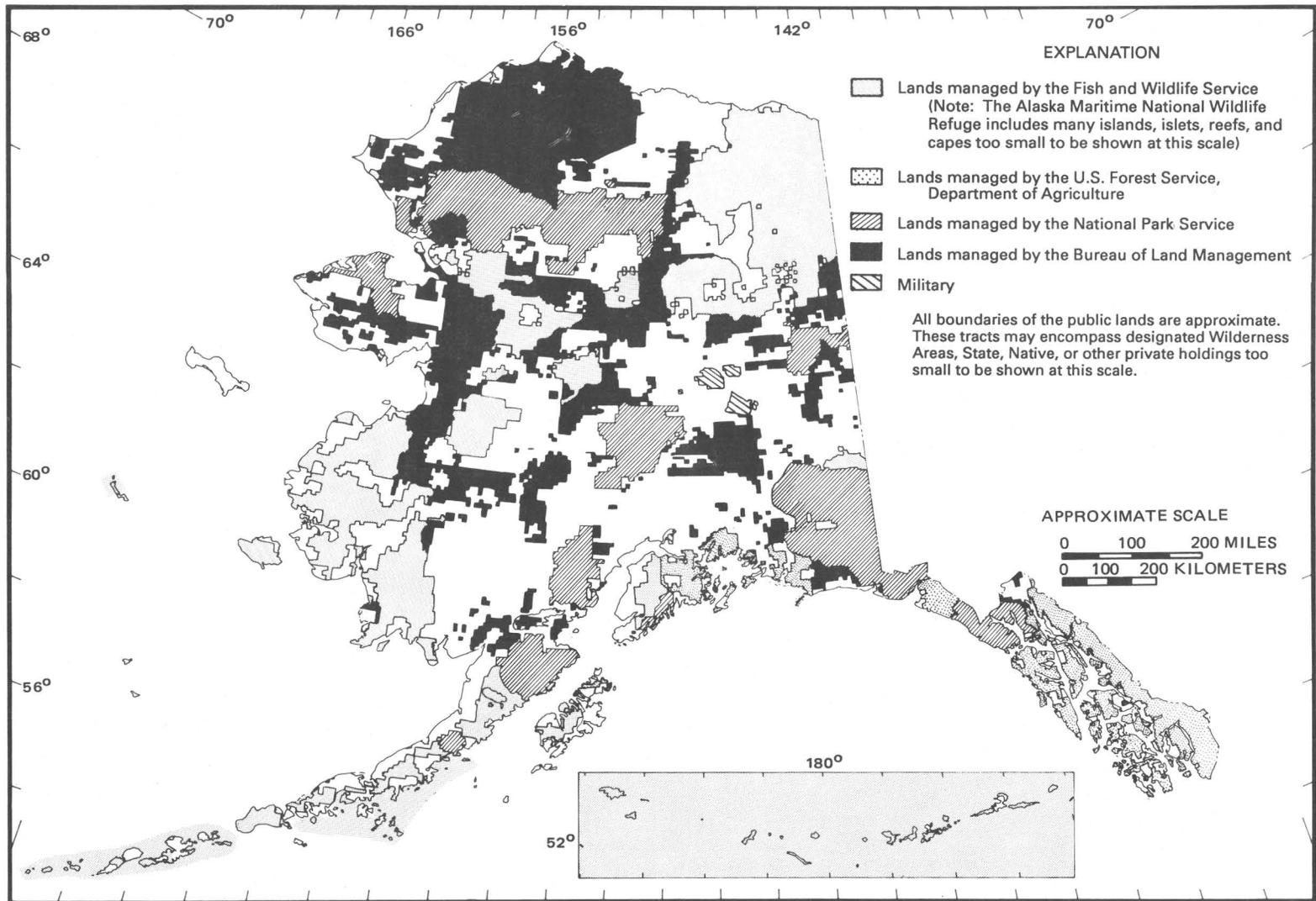
The next section describes the current mineral programs of land-management and other Federal agencies in Alaska. The roles of these agencies as they relate to minerals are discussed in appendix 2. The distribution of lands under Federal management is shown in figure 1.

MINERAL PROGRAMS

Department of the Interior

U.S. Geological Survey

As directed by Section 1010 of ANILCA, the Secretary of the Interior requires an assessment of "the oil, gas, and other mineral potential on all public lands in the State of Alaska in order to expand the data base with respect to the mineral potential of such lands." AMRAP is one of the major responses of the USGS to this legislation. The goal of this program is a systematic investigation of the State's mineral resources through four progressively more detailed levels of



Base from maps prepared by the Bureau of Land Management in 1987.

Figure 1. Federal land ownership in Alaska (boundaries as of June 1987).

study. Geologic studies at levels I and II are general and cover large areas. Studies at level III draw on many geologic disciplines to produce resource assessments at scales of 1:250,000 and 1:125,000. Level IV research focuses on detailed studies of specific mining districts, mineral deposits, or topics relating to the genesis of mineral deposits. In 1990, level III studies were under way in 30 quadrangles, and a total of 41 level IV studies were in progress.

USGS AMRAP publications are a key source of information about Alaska's geology and resource potential. AMRAP studies are essential for the determination of the distribution and potential of national mineral and energy endowments, for the formulation of public policy affecting resource and land management, and for the improvement of resource assessment technology in minimizing potential impacts from development. These studies, which develop the concepts, models, and techniques needed to identify new mineral deposits, are vital to the minerals exploration industry.

The USGS performs its work in Alaska through several programs in addition to AMRAP. Among the programs active in 1990 were (1) studies of mineral resources on

public lands, (2) the Development of Assessment Techniques Program, whose goal is to improve the ability to identify and evaluate mineral resources, (3) the Strategic and Critical Minerals Program, for identifying the potential of these resources to meet national military and economic needs, (4) the Oil and Gas Investigations Program, which focuses on studies of petroleum-forming processes and potential source regions in order to produce reliable estimates of undiscovered petroleum resources (fig. 2), and (5) the Geothermal Investigations Program, which focuses on studies of the nature, distribution, and energy potential the Nation's geothermal resources. The mineral-related aspects of many of these programs are more fully described in later sections of this report.

Other USGS programs that are not mineral-specific include (1) the Earthquake Hazards Reduction Program, which seeks to mitigate earthquake losses through providing data and evaluations for land-use planning, engineering, and emergency preparations, (2) the Volcano Hazards Program, which includes studies on the assessment, reduction, and prediction of volcanic hazards, and (3) the Geologic Framework Program, involving both general and special-

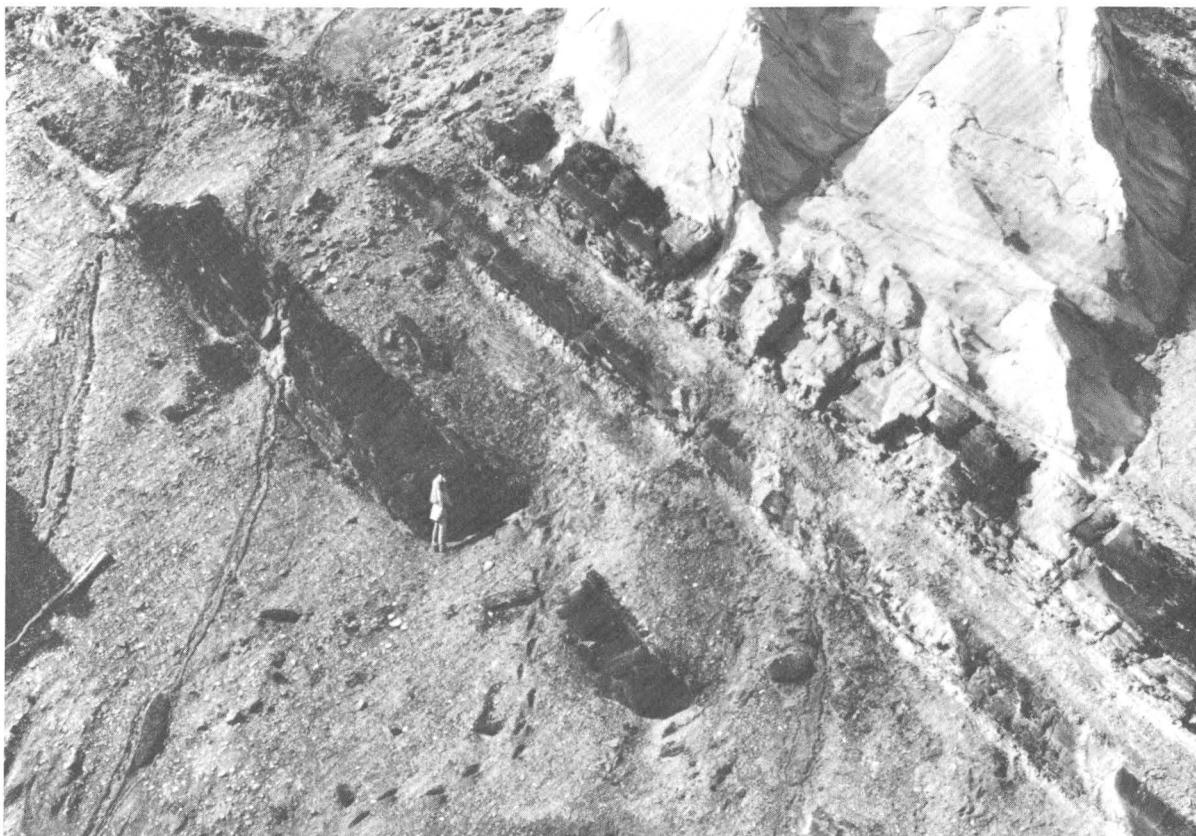


Figure 2. Outcrop of Usibelli Group in Nenana coal field, central Alaska, showing interlayered coals (dark) and sandstones (light). Under the USGS Oil and Gas Investigations Program, vitrinite reflectance determinations were made from these coals for use in compiling the thermal maturity map of Alaska. Photograph by R. Stanley.

ized research on the regional geology of Alaska. In addition, the Trans-Alaska Crustal Transect (TACT) program is a multidisciplinary approach to study the Earth's crust along a corridor from the Pacific Ocean to the Arctic Ocean. This program is coordinated with the Trans-Alaska Lithosphere Investigation, which utilizes earth scientists from the ADGGS, University of Alaska, other universities, and private industry.

Economic-geologic information for mineral occurrences in the United States and worldwide is available through computerized files of the USGS Mineral Resources Data System (MRDS). In Alaska, records on metallic minerals contain 2,051 entries for forty 1:250,000-scale quadrangles in the south-central and southeastern areas of the State. Data in these files include mineral-deposit size, type, description, location, reserves, and pertinent literature references for known or potentially locatable mineral resources (Leonard and Huber, 1987). Geologic information from the Alaska MRDS files can be used to complement economically oriented data from the Mineral Availability and Mineral Industry Location Systems computerized files of the USBM, discussed in the next section. Further MRDS information can be obtained from Donald F. Huber, Central and Western Regional Representative, U.S. Geological Survey, MS 984, 345 Middlefield Road, Menlo Park, CA 94025.

U.S. Bureau of Mines

During 1990, the Alaska Field Operations Center (AFOC) and various research centers of the USBM were active in the programs listed below; further information on the scope and nature of these programs can be found in appendix 2.

Mineral land assessment.—The USBM's major emphasis in Alaska is the development of areal and commodity-oriented mineral assessments. An integral part of this program focuses on evaluations of mining districts in the State, including assessments of the type, quantity, distribution, reserves, and beneficiation potential of specific mineral deposits. The program also emphasizes site-specific investigations of deposits that contain strategic and critical minerals and advanced materials. USBM scientists locate, map, and estimate the size and grade of mineral deposits; they also collect samples for ore characterization and beneficiation research.

Minerals availability.—The two computerized components of the minerals availability program are the Minerals Availability System (MAS) and the Minerals Industry Location System (MILS) data bases. MAS contains information on reserve estimates, mineral extraction and beneficiation methodologies, environmental constraints on mining, and cost analyses for selected major mineral deposits. MILS lists basic information on the identification and location of known mineral deposits.

Policy analysis.—The policy analysis program compiles analyses of mineral data with respect to local and national needs. Technical, institutional, political, social, and economic parameters are used to identify mineral issues.

State mineral activities.—A USBM Alaskan State Mineral Officer compiles and analyzes mineral data to report on activities and trends within Alaska's mining industry.

Minerals research.—Minerals research in Alaska includes efforts to improve mining technology, mineral extraction, and environmental aspects of the mineral industry, while considering Alaska's distinctive climate and geologic conditions. Research is administered by one or more of nine USBM research centers in the lower 48 States, or by Washington headquarters, as is the case with university cooperative programs such as the Mineral Institutes. Although funded by the USBM, Mineral Institutes utilize university staff and facilities to conduct their work. Researchers from the University of Alaska at Fairbanks and University of Mississippi Mineral Institutes were active in Alaska in 1990.

Much of the USBM's work involves highly speculative, long-range research that promises major technological improvements. Corporate industry often cannot afford to conduct such research; the Nation, however, cannot afford to do without it. A primary goal of this research mission is the communication of USBM research results to industry, government, and the general public.

Minerals Management Service

The primary mission of the MMS in Alaska is the management of mineral resource exploration and development on Federal OCS lands. Management efforts are primarily focused on the leasing of offshore areas for oil and gas exploration and development. However, the MMS also has the authority to lease OCS lands for ocean mining of hard minerals.

Prior to an OCS lease offering, the MMS appraises the economic worth of leasable offshore territory and assesses the environmental risks associated with development of resources on or beneath these lands. Following a thorough process of public review and comment, the MMS selectively makes these lands available to interested parties through competitive OCS lease sales. The MMS then regulates post-lease exploration, development, and production activities to ensure that operations are conducted in a safe and environmentally acceptable manner. The MMS inspects operations to ensure compliance with applicable laws, regulations, and lease terms. Finally, the MMS is responsible for the collection and accounting of royalty and rental revenues generated by the leased properties. At present, no minerals are being developed or produced on the Alaska OCS.

The MMS does not oversee the onshore exploration and development of Federal mineral commodities in Alas-

ka. It is responsible, however, for the collection of royalties, bonus payments, and lease rentals generated from onshore Federal and certain Native lands. Productive leases in the Beaver Creek and Swanson River oil and gas fields as well as the Beluga, Cannery Loop, and Kenai gas fields provide the bulk of this kind of revenue. Specific data on production and revenues from these fields may be obtained from the Minerals Management Service, Royalty Management, Lakewood, CO 80225.

The MMS also conducts regional studies of the geological history and petroleum potential of Alaska's offshore basins for the National Resource Assessment, the MMS-USGS inventory of America's oil and gas resources. Results of these studies have been published as part of the MMS OCS report series. A list of titles is provided elsewhere in this circular. Copies of these reports may be obtained from the MMS regional office library in Anchorage.

Bureau of Land Management

Principal activities of the BLM that are related to Alaska's onshore mineral and energy resources are (1) assessment of the mineral potential of BLM planning areas and, through the planning process, identification of how the minerals can best be managed under the multiple-use concept, (2) development of the terms and conditions, through the planning process and environmental review in accordance with the National Environmental Policy Act (NEPA), for mineral exploration and development on BLM lands, (3) providing mineral resource and economic evaluations to determine mineral values for lease sales, land exchanges, and Federal land disposal, (4) issuance and management of Federal leases in coordination with the responsible surface-managing agency, (5) administrative maintenance and adjudication of federally recorded mining claims, determination of the validity of claims, critical review of Federal mineral validity reports, and issuance of mineral patents, and (6) regulation of mining activities on BLM lands to protect the environment.

The BLM is responsible for enforcing the environmental and technical stipulations of the Agreement and Grant of Right-of-Way for TAPS, the overall goal of which is to maintain a continuous supply of energy with minimal environmental impact. In addition, the BLM issues land-use authorizations and conducts mineral and materials sales to support preconstruction activities for the planned natural-gas pipeline and other projects. The BLM has also provided assessments of mineral-potential studies for other land-managing agencies, such as the FWS and NPS, and for input to Congressional initiatives, such as the opening of ANWR to leasing.

Administrative responsibilities for minerals require close coordination with other surface-management agen-

cies. Generally, in the case of onshore leases, the BLM issues leases and integrates leasing with other land uses in cooperation with the surface-management agency. To assure proper surface and subsurface protections after a lease is issued, the BLM enforces the regulations of 43 CFR 3160 with respect to the lease stipulations and permit conditions for exploration and development activities.

Fish and Wildlife Service

The two primary missions of the FWS in Alaska are to protect and conserve fish and wildlife and their habitats, and to administer 77 million acres of national wildlife refuge land. Adjunct activities include fish and wildlife research; biological and habitat monitoring; law enforcement; and agency review of, and comments on, permit requests, environmental impact statements (EIS's), and other items. The FWS also cooperates with other Federal and State agencies in similar efforts on behalf of wildlife throughout Alaska.

Mineral activities on FWS lands in Alaska must conform to the agency's mission of protection and conservation. Exploration and resource development in national wildlife refuges is subject to FWS restrictions and protective stipulations. For this purpose, the FWS conducts an environmental contaminants program that includes the sampling and reporting of contaminants in waters, sediments, and organisms affected by oil and gas exploration and development, placer mining, and other mineral activities.

Section 1008 of ANILCA calls for establishing a program for oil and gas leasing on Federal lands south of latitude 68° N., pursuant to the Mineral Leasing Act of 1920 as amended. All leasing, exploration, and production would be subject to permits and stipulations designed to protect fish, wildlife, and subsistence activities. This program does not apply to those refuge lands where the Secretary of the Interior determines, after consideration of the national interest, that oil and gas exploration or development would be incompatible with the purposes of the refuge. Section 304(g) of ANILCA cites a comprehensive conservation planning process as the means for identifying parts of refuges where leasing or related activities may be compatible. Comprehensive Conservation Plans for all 16 national wildlife refuges in Alaska were completed by late 1988.

The FWS makes recommendations to other Federal agencies for mitigating adverse environmental impacts. The FWS reviews ACE and Environmental Protection Agency (EPA) permit applications under Section 402 of the National Pollution Discharge Elimination System (NPDES), Section 404 of the Clean Water Act of 1977 (CWA), as amended, and Section 10 of the Rivers and Harbors Act of 1899, as amended; these applications may involve public or private lands. The review includes recommendations for

minimizing habitat losses in all proposals for new or modified roads, pads, well sitings, and operations.

The locations of the 16 national wildlife refuges managed by the FWS in Alaska are shown in figure 3.

National Park Service

The NPS does not manage minerals in the same sense as other Federal agencies because the vast majority of park units are closed by law to leasing, disposition, and mineral location. The NPS is directed by its Organic Act and other Federal laws to protect park resources and, more specifically, to protect them from adverse impacts that can result from mineral exploration and development activities. Minerals management programs of the NPS protect park resources by controlling activities relating to the exercise of valid existing rights. Valid existing rights are Federal, State, Native, and other private mineral or fee lands, or interests in lands whose ownership was typically established prior to the time the park unit was created. Examples of valid existing rights that are regulated by the NPS are patented and valid unpatented mining claims and non-Federal oil and gas rights.

NPS minerals management activities in Alaska include mineral examinations to determine claim validity (fig. 4); evaluation of proposed mining plans including completeness determination, engineering analysis, impact assessment, and bonding; compliance monitoring of approved operations; mineral valuation appraisals; and mining claim acquisition and site reclamation, where appropriate. Major programs have been undertaken to survey, aerially photograph, and map mining claims; to prepare topographic maps of mining claims (scale 1:1,200, 10-foot contour interval); to inventory abandoned mineral lands; to perform hydrologic monitoring; to reclaim abandoned and acquired mining claims; and to conduct reclamation research. Guidelines for NPS management and regulation of mineral-related activities are discussed in appendix 2.

Department of Agriculture

U.S. Forest Service

Under a memorandum of understanding with the BLM, the USFS jointly administers the general mining laws on its own lands in Alaska. An example of this joint responsibility is the patent issued to U.S. Borax and Chemical Company for mining claims at the Quartz Hill deposit near Ketchikan. The BLM issued this patent on the basis of favorable findings in a mineral report prepared by USFS mineral examiners.

The USFS cooperates with DOI agencies, particularly the BLM, in issuing mineral leases and assuring mitigation

of surface impacts of lease activities. The USFS also cooperates with State agencies and the private sector in development of energy and mineral resources on inholdings. One such inholding is the Bering River coal field, under consideration for possible development in a joint venture by Chugach Alaska and others.

In Alaska, 23 million acres of land is administered by the USFS (fig. 1), whose regional office is in Juneau. Offices for the Chugach National Forest are located in Anchorage, Girdwood, Seward, and Cordova; Tongass National Forest offices are in Sitka, Ketchikan, and Petersburg.

Department of Energy

In Alaska, the DOE is focusing its efforts on petroleum, coal, and geothermal resources. The DOE in Alaska administers current petroleum acts and congressional mandates relating to energy, monitors grants, and oversees contracts for energy-resource studies. DOE funding helps support USGS resource-assessment studies and research by the University of Alaska.

To develop a better understanding of both conventional and unconventional petroleum resources and to provide fundamental information to accelerate utilization of these resources, the DOE emphasizes resource and technological investigations that continue to expand the body of essential and basic scientific knowledge concerning conventional and heavy petroleum, shale oil, tar sands, and gas hydrates. Gas hydrates are a specific target of DOE research in Alaska.

The DOE is working to evaluate Alaskan coal in terms of its contribution to total national resources. Coal research currently centers on utilization methods suitable to Alaskan coals and conditions.

The DOE closed its regional office in Anchorage in 1985. Requests for information about DOE Alaskan activities should be addressed to the office listed below.

Contacts for Further Information

Department of the Interior

Bureau of Land Management
Edward F. Spang, State Director
Federal Building
222 West Seventh Avenue, No. 13
Anchorage, AK 99513-7599

Fish and Wildlife Service
Walter O. Stieglitz, Regional Director
1011 East Tudor Road
Anchorage, AK 99503-6119

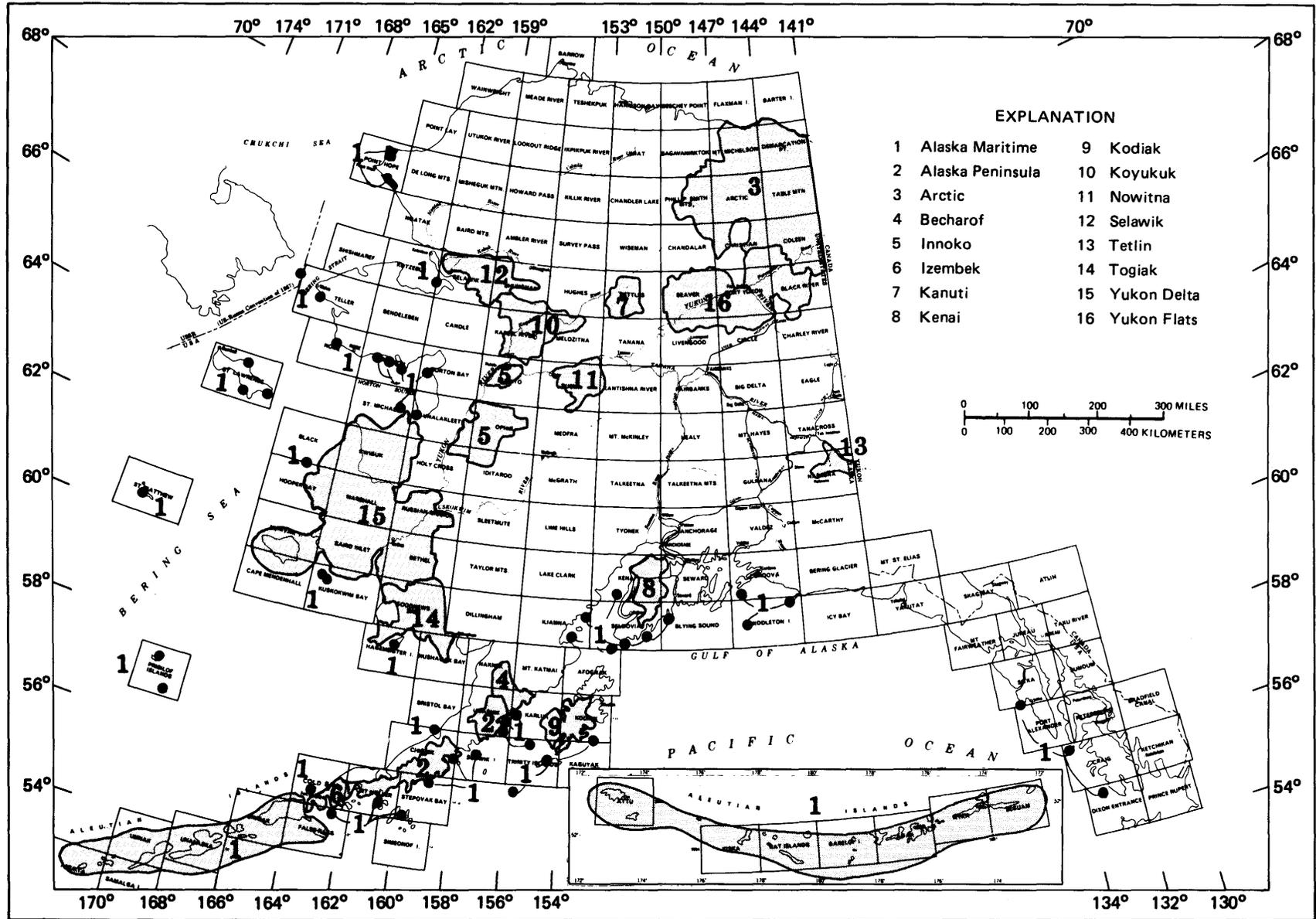


Figure 3. National wildlife refuges in Alaska. 1:250,000-scale quadrangles are outlined and labeled.

Minerals Management Service
Alan D. Powers, Regional Director
Alaska OCS Region
University Plaza Building, Rm. 110
949 East 36th Avenue
Anchorage, AK 99508-4302

National Park Service
Jack Morehead, Regional Director

Alaska Regional Office
2525 Gambell Street, Room 107
Anchorage, AK 99503-2892

U.S. Bureau of Mines
Donald P. Blasko, Chief
Alaska Field Operations Center
201 East Ninth Avenue, Suite 101
Anchorage, AK 99501



Figure 4. NPS geologist collects mineralized rock samples in Kantishna area of Denali National Park and Preserve. Analysis of samples for metal content helps determine validity of mining claims. Photograph by S. Hicks.

U.S. Geological Survey
 Willis H. White, Chief
 Branch of Alaskan Geology
 4200 University Drive
 Anchorage, AK 99508-4667

Department of Agriculture

U.S. Forest Service
 Michael Barton, Regional Forester
 Alaska Region
 P.O. Box 21628
 Juneau, AK 99802

Department of Energy

Hydrocarbon resources
 Harold Shoemaker
 Morgantown Energy Technology Center
 P.O. Box 880, 3610 Collins Ferry Road
 Morgantown, WV 26507

ENERGY RESOURCES

Oil and Gas Resources

Overview of Production and Prices

Oil and gas remain the most valuable commodities produced in Alaska. Alaska's two oil-and-gas producing areas, the Arctic North Slope and Cook Inlet (fig. 5), provided a total of 665.5 million barrels (1 barrel = 42 U.S. gallons) of oil and natural gas liquids, 205 billion cubic feet of dry natural gas, and 1,859 billion cubic feet of casing head gas in 1990 (Alaska Oil and Gas Conservation Commission Bulletin, February 1991). This represents a decrease of 5.2 percent from 1989 oil levels, the second straight year of reduced production; gas production, however, increased 5 percent over 1989. Daily production fluctuated widely due to Cook Inlet shut-ins and North Slope maintenance work, but averaged 1.82 million barrels of oil per day (bbl/d), about 100,000 bbl/d less than in 1989. Toward the end of the year, however, production rates increased to nearly 2 million bbl/d, making Alaska the number one crude-oil producer in the United States (Alaska Journal of Commerce, February 11, 1991).

Alaska North Slope crude oil prices rode a bumpy roller coaster throughout the year, starting at \$19.05/bbl for oil delivered to the West Coast (\$19.52/bbl to the Gulf Coast), rising and falling from February through July, and then rising again to October's high of \$32.54/bbl (West Coast); rates then dropped sharply at the end of the year (table 1). Generally, prices averaged \$21.06/bbl for oil delivered to the West Coast (\$21.51/bbl to the Gulf Coast),

Table 1. Fluctuation in price of Alaska North Slope crude oil

[Data from Alaska Report; BP Exploration's Alaska North Slope contract crude oil price represents 95 percent of production. Contract price is based on average of spot market price for Alaska North Slope crude for prior month; price is set at beginning of each month (Alaska Report, May 11, 1988). WC, delivered to West Coast; GC, delivered to Gulf of Mexico]

Date	Cost per barrel	
	WC	GC
12/6/89 -----	\$17.52	\$18.05
1/3/90 -----	19.05	19.52
2/7/90 -----	20.00	20.22
3/7/90 -----	19.21	19.77
4/4/90 -----	17.85	18.34
5/2/90 -----	14.71	15.11
6/6/90 -----	14.44	14.86
7/3/90 -----	\$13.15	\$13.68
8/8/90 -----	15.58	16.03
9/5/90 -----	25.89	26.40
10/3/90 -----	32.54	32.54
11/7/90 -----	31.52	32.06
12/5/90 -----	28.74	29.64
1/3/91 -----	\$23.77	\$25.01

more than \$4/bbl higher than in 1989. Alaska's treasury is especially vulnerable to crude oil prices because 83 percent of its current income is derived from royalties and taxes paid on State-owned oil and gas leases (Alaska Department of Natural Resources, 1986). Each \$1 change in the price of crude oil translates to an approximately \$150-million gain or loss in State revenues.

Alaska received its fourth annual \$4.02-million payment from the Minerals Management Service for its share of revenues generated by Federal Alaskan OCS sales held between 1978 and 1986 (Alaska Report, April 25, 1990). After the initial settlement of \$309.2 million in 1986, graduated payments over 15 years will total an additional \$134 million.

Exploration

Drilling.—Thirteen exploratory wells were active in 1990, two less than in 1989: seven were on the North Slope, one offshore from ANWR, one in the Beaufort Sea, three in the Chukchi Sea, and one in Cook Inlet (fig. 5; table 2). Most of the wells were plugged and abandoned; only one BP Exploration (BPX) well and Shell's Crackerjack (OCS-Y-1320) well in the Chukchi Sea were not completed.

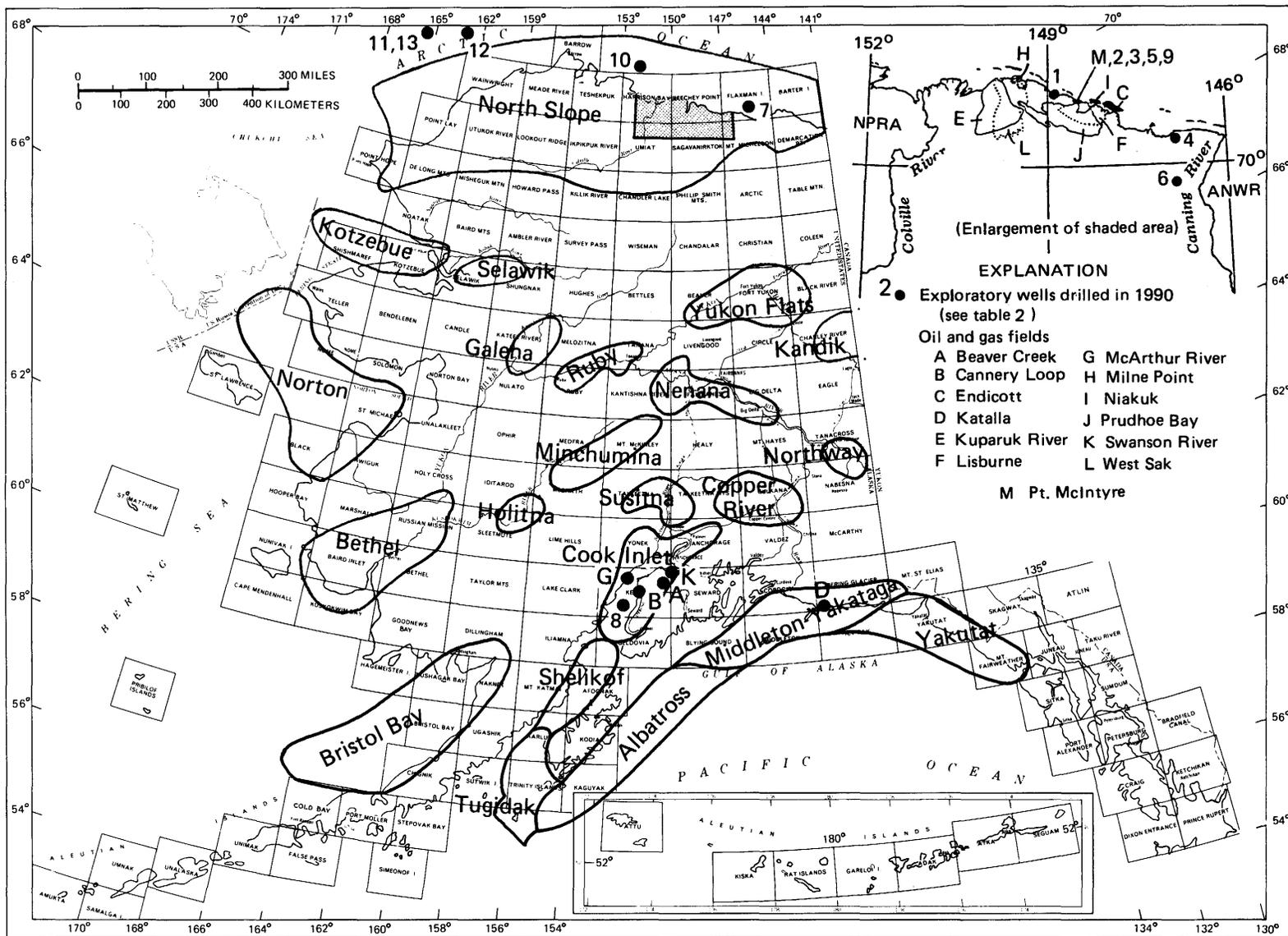


Figure 5. Locations of exploratory oil wells drilled in 1990, oil and gas fields, and possible petroleum-bearing sedimentary basins (outlined). Basins adapted from Kirschner (1988). 1:250,000-scale quadrangles are outlined and labeled.

Table 2. Alaska exploratory oil wells drilled in 1990

[See figure 5 for locations. Locations for onshore and State offshore wells given in section-township-range; SM, Seward Meridian; UM, Umiat Meridian. Locations for Federal offshore wells given by latitude and longitude. P&A, plugged and abandoned]

Well No.	Company	Well name	API No.	Location	Total depth (feet)	Date completed (1990)	Remarks
Onshore and State offshore waters							
1	BPX	Fawn Lake	50-029-22007	25-12N-13E,UM	8,360	3/10	P&A
2	BPX	Pt. McIntyre No.6	50-029-22000	14-12N-14E,UM	11,920	3/28	Suspended
3	ARCO	Pt. McIntyre No.8	50-029-21996	16-12N-14E,UM	11,100	3/29	Delineation, oil
4	Conoco	Badami No.1	50-029-22017	9- 9N-20E,UM	13,595	4/27	P&A
5	ARCO	Pt. McIntyre No.7	50-029-22018	16-12N-14E,UM	14,130	4/29	Delineation, oil
6	ARCO	GYR No.1	50-223-20018	32- 4N-20E,UM	8,020	4/30	P&A
7	ARCO	Stinson No.1	50-689-20022	2- 9N-25E,UM	16,156	8/20	P&A
8	ARCO	Sturgeon No.1	50-733-20418	25- 5N-17W,SM	7,206	10/23	P&A
9	BPX	Pt. McIntyre No.9	50-029-22096	14-12N-14E,UM	14,375	12/22	Suspended
Federal offshore waters							
10	ARCO	OCS-Y-0267 (Fireweed)	55-232-00003	71°05'17"N 152°36'12"W		12/90	P&A
11	Shell	OCS-Y-1320 (Crackerjack)	55-382-00003	71°25'08"N 165°32'29"W		Suspended	
12	Shell	OCS-Y-1413 (Burger)	55-352-00001	71°15'05"N 163°11'40"W		8/90	P&A
13	Shell	OCS-Y-1275 (Popcorn)	55-038-00002	71°51'16"N 165°48'25"W		9/90	P&A

Permitting.—The Alaska Oil and Gas Conservation Commission approved 173 drilling permits through December 31, 1990, for 148 development wells (134 on the North Slope, 14 in Cook Inlet), 8 exploratory wells (6 on the North Slope, 2 in Cook Inlet), and 17 service wells (16 on the North Slope, 1 in Cook Inlet)(Alaska Oil and Gas Conservation Commission, May 1991). This was a 31-percent increase over the 132 drilling permits issued in 1989.

Seismic.—To date, over 1 million line-miles of geophysical data have been acquired by private and public concerns in Alaskan Federal OCS planning areas. In 1990, seismic data were gathered in the Beaufort Sea (2,700 line-miles) and in the Chukchi Sea (600 line-miles). Seismic surveys were also conducted onshore in the Cook Inlet region and on the North Slope.

Bonding.—The MMS has proposed increased two-tier bonding levels for offshore operators in order to assure proper cleanup of drill sites (Alaska Report, January 31, 1990). Exploration activities would require a \$200,000 bond for individual leases and \$1 million for area-wide coverage; development and production operations would require bonds of \$500,000 (individual) and \$3 million (area-wide). The present single-tier levels are set at \$50,000

(individual) and \$300,000 (area-wide), regardless of activity.

Beaufort Sea.—The MMS and Alaska agreed on regulations for Northstar, the first OCS drilling unit to be jointly managed by Federal and State agencies (fig. 5). Within the unit's seven leases, the MMS holds 7,495 acres, and the State owns 23,343 acres. Discovered in 1983, this field contains an estimated 150 million barrels of recoverable oil. Elsewhere, Exxon dropped its plans to drill a delineation well in the 1977 Point Thompson gas discovery, relinquishing three State-owned leases covering 16,989 acres.

Camden Bay.—Controversy over Alaska's 1987 Lease Sale 50 off the coast of ANWR was settled in April 1990, when the State Senate passed legislation ratifying the sale and amending coastal zone management laws (Alaska Report, April 25, 1990). Environmental groups had tried to stop the sale on the grounds that development of offshore resources would require onshore facilities in ANWR that are currently prohibited. ARCO Alaska completed drilling the Stinson 1 exploratory well on a Camden Bay lease in 1990.

Chukchi Sea.—Shell Western continues its wildcat drilling program in the Chukchi Sea. One well has been

drilled in each of the Burger, Crackerjack, Klondike, and Popcorn prospects; four additional wells are planned. Shell Western was awarded the "Conservation Award for Respecting the Environment" by the MMS in recognition of its 1989 Chukchi Sea drilling program (Alaska Report, June 6, 1990). Texaco's plans for drilling in the Chukchi Sea, approved by the MMS, have been impeded by the North Slope Borough's legal challenge to the company's oil-spill contingency plan; Texaco has appealed to the U.S. Department of Commerce to overturn the State's ruling (Alaska Report, November 14, 1990). The Soviet Union has also expressed an interest in collaborating with an American company for oil exploration in the Soviet Chukchi Sea (Anchorage Daily News, May 15, 1990).

Cook Inlet.—Exploration activities in Cook Inlet showed a resurgence after six- and four-year hiatuses for offshore and onshore efforts, respectively. ARCO Alaska drilled the Sturgeon 1 wildcat in the Big River prospect in Redoubt Bay, on a State-owned lease near Kalgin Island (no. 8, fig. 5). The well was plugged and abandoned as a dry hole in late October (Alaska Oil and Gas Conservation Commission Bulletin, December 1990). Stewart Petroleum spudded their wildcat in the West McArthur River Unit in mid-December. In addition, ARCO Alaska and Conoco have obtained permits for exploration drilling in the Cook Inlet area.

Effects of oil spills.—Disagreement over oil-spill contingency plans caused the postponement of Texaco's drilling efforts in the Chukchi Sea and delayed Stewart Petroleum's wildcat in the Cook Inlet. In Bristol Bay, oil and gas leases are under their second one-year moratorium on drilling, which is due to expire September 30, 1991. The ban was imposed after the 1989 *Exxon Valdez* oil spill to allow time to evaluate environmental consequences of oil development on area fisheries. Federal studies are under way to determine the potential effects of an oil spill here, and also to determine whether the Federal Government should buy back these leases, valued at approximately \$95 million, and impose a permanent ban on drilling in the area (Anchorage Times, July 25, 1990).

Production Activity

During 1990, there were 1,498 producing oil wells, 111 gas wells, and 539 service wells active in Alaska. Of these, 114 development and service wells were drilled in 1990: 14 in Cook Inlet, one in the East Barrow gas field, 13 in the Endicott oil field, 24 at Kuparuk River, four at Milne Point, two at Pt. McIntyre, and 56 at Prudhoe Bay. Little information on these wells has been released to the public, but some data are made available through the Alaska Oil and Gas Conservation Commission's monthly bulletins and the Petroleum Information Corporation's weekly Alaska Report.

North Slope

In December, the eight-billionth barrel of North Slope crude oil was produced. Overall production from the North Slope averaged 1.79 million bbl/d, 90,000 bbl/d less than in 1989. Part of this loss was due to extensive maintenance and repair work by ARCO Alaska and BPX at their Prudhoe Bay facilities, dropping production from 1.4 million bbl/d to 1.2 million bbl/d from June through mid-September (Alaska Report, April 4, 1990). As a counterbalance, well-stimulation strategies accelerated production from the Prudhoe Bay field during the last half of the year. High-pressure fluid injection was used to fracture the reservoir, and the resultant cracks were held open by the injection of sand (up to 75 tons per well). These fractures allowed the oil to flow more freely into the wellbore, producing improvements as great as 400 percent. Cost per well for this procedure is between \$250,000 and \$400,000, and the enhanced recovery is currently forecasted to last for two years (Alaska Journal of Commerce, September 17, 1990). Also, as North Slope fields age, the amount of natural gas produced along with the oil increases. By separating out this "casinghead gas" and injecting it back into the reservoir in a highly compressed state, future oil recovery is enhanced. Additional large gas-handling compressors (GHX-2) are currently under construction. The original estimate for recovery of in place oil from the 24-billion-barrel Prudhoe Bay field was 9.4 billion barrels, but with water flooding, high-pressure fracturing, and gas reinjection, estimates for total recovery are currently 11 billion barrels (Rintoul, 1991).

Most development drilling on the North Slope occurred in the Prudhoe Bay and Kuparuk River oil fields, the two largest producers in the United States. Conoco drilled and defined the Schrader Bluff pool in the Milne Point field; production from Schrader Bluff could add as many as 6,000 bbl/d to the current 20,000 bbl/d produced from the Kuparuk River pool (Alaska Journal of Commerce, July 23, 1990). Due to better-than-expected reservoir performance, BPX has revised upward its estimate of recoverable oil in the Endicott field from 350 million barrels to 390 million barrels (Alaska Journal of Commerce, July 9, 1990). Development by ARCO Alaska and BPX of the Point McIntyre field, located beneath the waters of Prudhoe Bay, was delayed as a result of the assessed environmental impacts of causeways linking proposed production facilities on artificial offshore islands to shore-based facilities. A settlement was reached with the ACE in late 1990 requiring additional breaching in both the West Dock and Endicott causeways, at a cost of \$50 million (Anchorage Daily News, December 1, 1990). By 1992, anticipated production from the Point McIntyre and nearby Lisburne fields will exceed 60,000 bbl/d. BPX also received State approval for its proposed 1.25-mile-long Niakuk causeway, needed to harvest the 58 million barrels of recoverable oil in the Niakuk field; addi-

tional permits from the ACE are being sought (Anchorage Daily News, December 1, 1990).

Cook Inlet

Development drilling was conducted in Cook Inlet's oil and gas fields by ARCO Alaska, Marathon Oil, Shell Western, and Unocal. A new 640-acre drilling unit was established around the site of the Mike Pelch 1 well on the Kenai Peninsula for the production of natural gas. Cook Inlet Region Inc., an Anchorage-based Native corporation, began drilling a development well in the West Fork field, abandoned by Seagull Energy in 1986 after producing 1.5 billion cubic feet of gas (Alaska Report, November 28, 1990). A 23-mile pipeline currently transports McArthur River gas from Trading Bay to Granite Point; in August, Marathon Oil began construction of an additional 16-mile pipeline to transport the gas from Granite Point to Chugach Electric's Beluga power station.

There are two producing oil fields on the Kenai Peninsula. At the Swanson River field, 27 producing wells totaled 5,642 bbl/d during 1990, an 11-percent increase over 1989. Workovers were conducted at three wells, and four wells were plugged and abandoned. Field production to date represents recovery of 46 percent of the estimated original in-place oil reserves. The Swanson River field also produces daily 300,000 cubic feet of natural gas, which is reinjected on site to help maintain downhole formation pressure. The Beaver Creek oil field produced a maximum output of 34 million cubic feet per day (mcf/d) from three gas wells, and 540 bbl/d from two oil wells. Operations in these fields are regulated by the BLM and FWS.

Unocal purchased Amoco's interest in 4 Cook Inlet oil platforms in July and now controls 7 of the Inlet's 15 platforms. Production from the four platforms is about 5,100 bbl/d, and Unocal estimates that 11 million barrels of developed reserves remain in the fields (Alaska Report, July 18, 1990). Unocal may spend as much as \$300 million over the next 5 years to enhance this recovery (Fairbanks Daily News-Miner, October 19, 1990).

In early 1990, mudflows generated by eruptive activity at Redoubt Volcano disrupted operations at the 1.9-million-barrel-capacity Drift River oil terminal on the west side of Cook Inlet. Fearing the environmental consequences of an oil spill there, the Alaska Department of Environmental Conservation (ADEC) shut down production at 10 Cook Inlet platforms, reducing production 65 percent to 16,000 bbl/d. The ADEC also reduced the amount of oil stored at Drift River to 150,000 barrels and limited oil-storage time to 12 hours from tanker arrival. Under these conditions, 12 days would be required to load a 400,000-barrel tanker; as a result, Unocal suspended its shipping operations in March. Operations were fully restored in June when the facility

began to receive 18,000 bbl/d, and allowed capacity was expanded to 380,000 barrels. The terminal operators have also raised 54-foot dikes around the tanks, at a cost of \$17 million.

Leasing Activity

Neither the State of Alaska nor the Federal Government held oil and gas lease sales in 1990, but the Alaska Senate did vote to ratify the 1987 Camden Bay lease sale. The State's Division of Oil and Gas has planned 13 sales for the period 1991-1995 covering offshore regions of Cook Inlet and the Beaufort Sea, and onshore areas of the Kenai Peninsula, North Slope foothills, and Kuparuk uplands (fig. 6). Federal OCS lease sales planned for 1991 are Beaufort Sea 124, 21 million acres; Navarin Basin 107, 28 million acres; and Chukchi Sea 126, 23 million acres.

Transportation

Trans-Alaska Oil Pipeline.—The eight-billionth barrel of crude oil flowed through TAPS in late December 1990; throughput reached a maximum of 2 million bbl/d, but averaged 1.8 million bbl/d. The TAPS operator planned to spend \$450 million in 1990 on maintenance and repairs to the pipeline, three pumping stations, and the marine terminal in Valdez (Alaska Report, May 30, 1990). As many as 947 anomalies in the pipe had been detected as of November 1990, but only 27 of these were in critical areas that require lowering internal pressures and reducing the flow rate of oil in the pipe. Reinspection of 19 sites revealed no corrosion, and further testing indicated that the integrity of the pipe is not in jeopardy and that full pumping pressures can be maintained. The State of Alaska derives a revenue of about \$2,000 per minute from the pipeline when flowing at full capacity.

Gas Pipelines.—Proposals for two gas pipelines are competing to transport North Slope gas to markets. The Yukon Pacific Corporation has obtained a permit to ship a total of 16.5 trillion cubic feet of gas to Pacific Rim countries from a proposed liquid-natural-gas plant in the Valdez area. Their Trans-Alaska Gas System would run 800 miles along the route of the existing TAPS. Korea Gas has promised to purchase 2 million tons annually, but Yukon Pacific needs an additional 5 million tons in initial purchase agreements before starting pipeline construction and needs 14 million tons in total sales to make the project profitable (Alaska Report, March 21, 1990). The U.S.-Canadian consortium of Northwest Alaska Pipeline-Foothills Pipeline have proposed to build the Alaska Natural Gas Transportation System, a 4,800-mile pipeline through Canada to the lower 48 States. Recoverable reserve estimates for North Slope gas may be large enough to support both pipelines

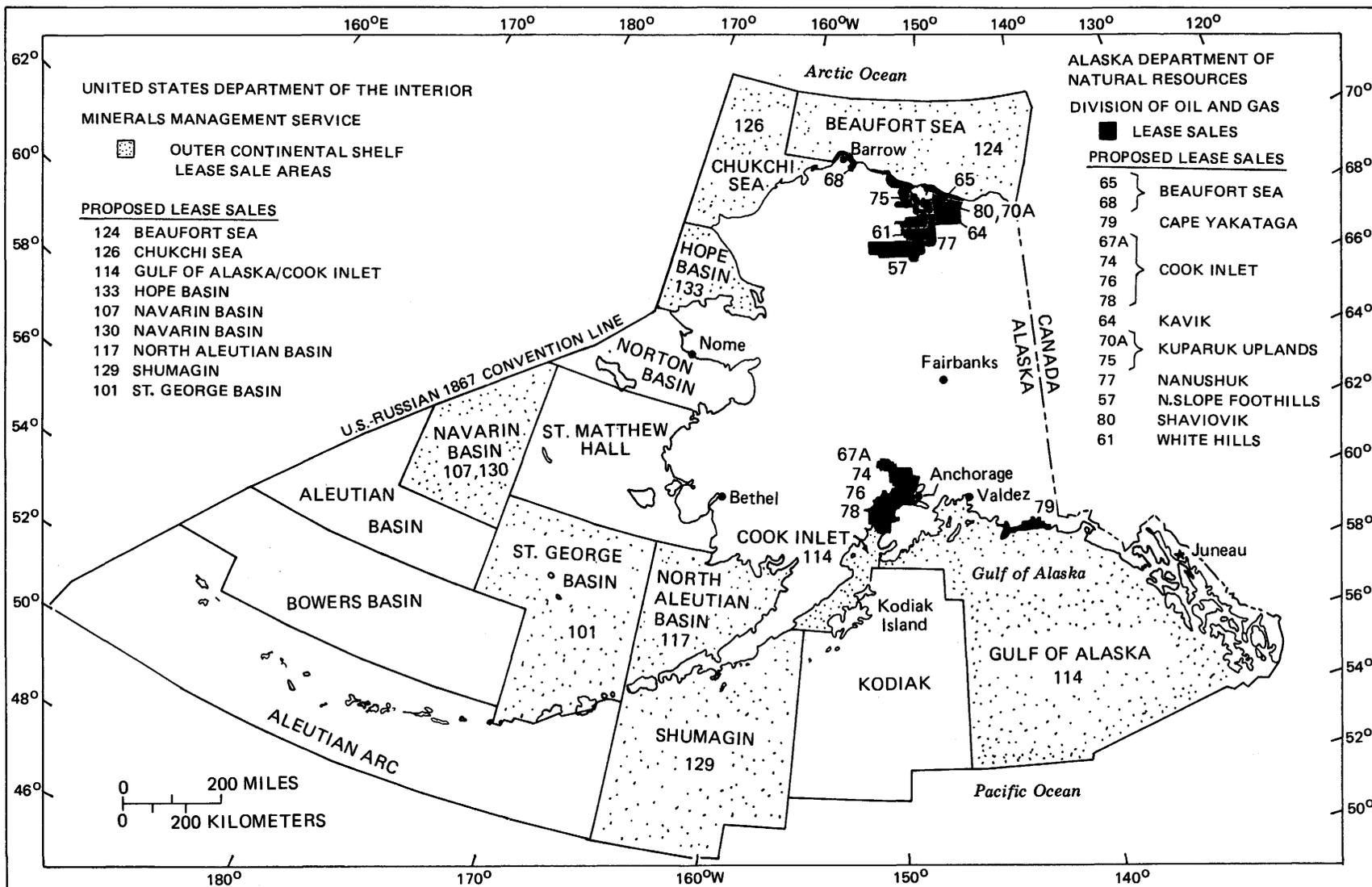


Figure 6. Areas of oil and gas lease sales and Alaska OCS Region planning areas (area boundaries based on MMS protraction diagrams, November 1986).

(Fairbanks Daily News-Miner, August 28, 1990), but any gas currently produced is being reinjected in the fields to enhance oil production.

Shipping.—In the aftermath of the *Exxon Valdez* oil spill, a number of companies are already using double-hull oil tankers, and legislation is pending that would require all oil-transporting ships or barges larger than 5,000 gross tons to be outfitted with a double hull. In 1990, some shippers temporarily suspended operations to Cook Inlet refineries, fearing the consequences of another spill in Alaskan waters. Fines as high as \$175,000 have been levied against companies without up-to-date oil-spill contingency plans (Anchorage Daily News, May 23, 1990). The USCG received \$50 million toward the mobilization of equipment and personnel dedicated to spill prevention, oil containment, and recovery operations. Some of that capital will pay for (1) a navigational aid in Bligh Sound (site of the *Exxon Valdez* grounding), (2) satellite tracking systems, and (3) a science center at Cordova to study long-term effects of oil spills. To cover future spill operations, a \$1-billion national fund will be financed by a nickel-per-barrel tax on crude oil, to be paid by the producers (Anchorage Daily News, July 27, 1990). In the future, all spills must be under control within 72 hours. This requirement will dictate the kinds of equipment that each company must have access to during shipping operations.

Activity by Federal Agencies

Minerals Management Service

Leasing and Exploration Activity

Since 1976, the DOI has held 15 oil and gas lease sales on the Alaskan OCS (fig. 6, table 3), offering over 98 million acres. The DOI has leased 8.1 million acres (1,477 leases) and has received over \$6.4 billion in high bonus bids (table 4). Oil companies continue to hold 894 leases on the OCS; 583 leases have been relinquished or have expired. No lease sales were held on the Alaska OCS in 1990.

Fourteen Deep Stratigraphic Test (DST) wells and 74 exploratory wells have been drilled since 1976 (table 3). In 1990, three exploratory wells were completed, and drilling of a fourth was temporarily suspended until the 1991 drilling season (fig. 5, table 2). Most of the exploratory wells have been permanently plugged and abandoned. Eight leases have been classified as “producing” (table 5); however, none of them are considered to be economically productive under current economic conditions. As defined by MMS regulations at CFR 250.11, a “producing” lease is one from which oil or gas, or both, can be produced in quantities sufficient to yield, after completion of the well, a return in excess of the cost of producing the hydrocarbons at the wellhead. The producing leases lie within the Beaufort Sea planning area; four of them have been relinquished.

Table 3. Alaska OCS leases and wells drilled, 1976–1990

[DST, deep stratigraphic test well]

Planning area (sale dates)	Number of tracts leased	Number of wells drilled	Number of active leases
Beaufort Sea (1979,1982,1984,1988)	574	21	469
Chukchi Sea (1988)	350	4	350
Cook Inlet Basin ¹ (1977,1981,1982)	100	14 (1 DST)	0
Gulf of Alaska (1976,1980,1981)	112	13 (1 DST)	0
Kodiak Shelf		6 (6 DST)	
Navarin Basin (1984)	163	9 (1 DST)	22
North Aleutian Basin ² (1988)	23	1 (1 DST)	23
Norton Basin (1983)	59	8 (2 DST)	0
St. George Basin (1983)	96	12 (2 DST)	30

¹Includes Lower Cook Inlet and Shelikof Straits.

²Leases currently under one-year moratorium and concurrent one-year suspension of operations until September 30, 1991.

Beaufort Sea planning area.—In the Beaufort Sea planning area, a total of 574 leases have been awarded in four separate sales held in 1979, 1982, 1984, and 1988. A fifth sale, OCS Sale 124, is presently scheduled for 1991. Twenty leases were relinquished during 1990, and 6 expired; 71 will expire in 1992, 194 will expire in 1994, 2 will expire in 1995, and 202 will expire in 1998. The status of an additional 20 blocks that received bids remains undetermined subject to questions of U.S.-Canadian jurisdiction.

Twenty-one exploratory wells have been drilled in Federal waters in the Beaufort Sea planning area. ARCO Alaska drilled the Fireweed (OCS-Y-0267) well in 1990.

Chukchi Sea planning area.—One lease sale was held in the Chukchi Sea planning area in 1988, and a second sale is scheduled for 1991. The 350 leases awarded in the first sale are all due to expire in 1998.

Four exploratory wells have been drilled in the Chukchi Sea planning area. The Klondike (OCS-Y-1482 No. 1) well was completed in 1989; the Burger (OCS-Y-1413 No. 1) and Popcorn (OCS-Y-1275 No. 1) wells were completed and plugged in 1990. Drilling of the Crackerjack (OCS-Y-1320) well was started in 1990, but was temporarily suspended due to ice conditions; the well will be re-entered in the 1991 drilling season.

Cook Inlet planning area.—In the Cook Inlet planning area, a total of 100 leases were awarded in three sales

Table 4. Proceeds from lease sales on Alaska OCS planning areas

Planning area	Sale	Year	Proceeds (\$)
Beaufort-----	BF ¹	1979	488,691,138
	71	1982	2,055,632,336
	87	1984	866,860,327
	97	1988	114,631,636
Chukchi-----	109	1988	478,032,631
Gulf of Alaska -----	39	1976	559,836,587
	55	1980	109,751,073
	RS-1	1981	170,496
Lower Cook Inlet-----	CI	1977	398,471,313
	60	1981	4,405,899
	RS-2	1982	0
Navarin-----	83	1984	516,317,331
No. Aleutian-----	92	1988	95,439,500
Norton-----	57	1983	317,873,372
St. George -----	70	1983	426,458,830

¹Held jointly with State of Alaska: total sale revenues \$1,056,082,635.

held in 1977, 1981, and 1982. All have been relinquished or have expired.

Thirteen exploratory wells and one DST well were drilled in the lower Cook Inlet and Shelikof Strait. All have been permanently plugged and abandoned.

Gulf of Alaska planning area.—A total of 112 leases in the Gulf of Alaska planning area were awarded in three OCS sales held in 1976, 1980, and 1981. All of these leases have been relinquished or have expired. A lease sale planned for the lower Cook Inlet/Gulf of Alaska area (OCS Sale 114) has been postponed pending results of studies of the *Exxon Valdez* oil spill.

Twelve exploratory wells and one DST well were drilled in the Gulf of Alaska. All have been permanently plugged and abandoned.

Kodiak Shelf planning area.—Six DST wells were drilled in 1976 and 1977. No lease sales are currently scheduled for the Kodiak planning area.

Navarin Basin planning area.—In the Navarin Basin planning area, 163 leases were awarded in a single sale in 1984. Seventeen blocks located within an area of disputed U.S.-Soviet jurisdiction also received bids, but the bid deposits were refunded with interest in December 1988.

Table 5. Producing leases, Beaufort Sea planning area

[As defined by MMS regulations at CFR 250.11, producing lease is one from which oil, gas, or both, can be produced in quantities sufficient to yield, after completion of well, return in excess of cost of producing hydrocarbons at wellhead]

Lease number	Prospect name	Number of wells drilled
OCS-Y-0181 -----	Seal	1
¹ OCS-Y-0191 -----	Salmon	2
² OCS-Y-0195 -----	Tem	1
² OCS-Y-0196 -----	Tem	1
³ OCS-Y-0197 -----	Tem	1
OCS-Y-0370 -----	Sandpiper	1
OCS-Y-0371 -----	Sandpiper	1
OCS-Y-0849 -----	Hammerhead	2

¹Relinquished 12/88.

²Relinquished 7/90.

³Relinquished 6/90.

Twenty-two leases, due to expire in 1995, are held at present; the remainder have been relinquished. A second lease sale is scheduled for 1991.

Eight exploratory wells and one DST well were drilled in the Navarin Basin. All of these wells have been permanently plugged and abandoned.

North Aleutian Basin planning area (Bristol Bay).—One sale was initiated in the North Aleutian Basin planning area in January 1986. A preliminary injunction postponed completion of the sale until October 1988. The 23 leases awarded were placed under a one-year moratorium and concurrent one-year suspension of operations from October 1, 1989, to September 30, 1990, to allow time to study information gathered from the *Exxon Valdez* oil spill and to evaluate environmental consequences of oil development on Bristol Bay fisheries. A second moratorium and suspension of operations was imposed for the period from October 1, 1990 to September 30, 1991. Pending completion of the moratorium and suspension, the expiration date of the leases will be extended to the year 2000. One DST well has been drilled in the North Aleutian Basin.

Norton Basin planning area.—Fifty-nine leases were awarded in a single lease sale held in the Norton Basin planning area in 1983; all leases have been relinquished. Six exploratory wells and two DST wells were drilled; all have been permanently plugged and abandoned.

St. George Basin planning area.—In the St. George Basin planning area, 96 leases were awarded in a single sale held in 1983. Thirty leases are held at present and are due to expire in 1994. Ten exploratory wells and two DST wells, all now permanently plugged and abandoned, were drilled in the St. George Basin.

Future Sales

The draft MMS 5-year comprehensive natural gas and oil resource management program, drawn up in April 1988, has been modified. No lease sales were scheduled for 1990. In 1991, sales are scheduled for the Navarin Basin (Sale 107), Beaufort Sea (Sale 124), and Chukchi Sea (Sale 126) planning areas (fig. 6). A sale in St. George Basin (Sale 101) is scheduled for 1992, and sales in Norton Basin (Sale 120) and Hope Basin (Sale 133) are scheduled for 1993. Three sales have been postponed: Cook Inlet (Sale 114) pending outcome of studies on the consequences of the *Exxon Valdez* oil spill; North Aleutian Basin (Sale 117) through congressional moratorium; and Shumagin planning area (Sale 129) for lack of industry interest.

National Resource Assessment

In the autumn of 1986, the MMS and USGS jointly launched a national inventory of oil and gas resources. The USGS evaluated the resource potential of onshore areas and Alaska State waters extending 3 miles from shore. The MMS assessed the offshore areas extending from the 3-mile limit to approximately 200 nautical miles seaward, including the OCS Exclusive Economic Zone. Personnel from both agencies met in 1986 and 1987 to review and coordinate the geologic interpretations supporting the assessment. The MMS again reviewed and updated its assessment in January 1990. Data and methodologies were presented to the Association of State Geologists and to the National Academy of Sciences; comments by these organizations will be used to refine future assessment procedures.

The MMS assessment estimated the amount of undiscovered oil and gas resources on the Alaskan OCS. Several OCS planning areas extend far seaward of the continental margins and include areas of deep oceanic basins. The areas seaward of the continental shelves were considered to offer only negligible resources, based on logistical, economic, and geologic considerations. Some planning areas were redrawn in order to obtain geologically rational province boundaries. The outlines of the assessment provinces are shown in figure 7.

The results of the 1987 joint assessment were published in 1989 by the DOI (Mast and others, 1989). This publication updates similar inventories published by the USGS (Dolton and others, 1981) and MMS (Cooke, 1985). The 1990 assessment has not yet been published, but some preliminary results are available from the MMS office in Anchorage (Minerals Management Service, 1990).

Joint Federal-State Studies

In 1975, the MMS (then Conservation Division, USGS) and the State of Alaska initiated joint geologic studies along certain coastal areas of Alaska where geologic

data were of mutual interest and where such data promised insights into the petroleum potential of adjacent onshore and offshore areas (fig. 7). Prior collaborations had investigated such areas as the Gulf of Alaska, Cook Inlet, Kodiak Islands (Kodiak shelf), Seward Peninsula-Kuskokwim drainage (Norton Basin), Pribilof Islands (St. George Basin), Alaska Peninsula (North Aleutian Basin), Waring Mountains (Hope/Selawik Basins), and the northeastern Brooks Range (Kaktovik Basin). Since 1984, the cooperative work has been funded by grants from the Studies Related to Continental Margins Program, sponsored by the MMS and administered by the Bureau of Economic Geology, University of Texas at Austin. In recent years, the focus of these studies has shifted to the Arctic Slope and ANWR, where fission track studies are being used as a tool for measuring the thermal evolution of the Beaufort continental margin, particularly as it bears on the maturation history of key source rock sequences (O'Sullivan, 1988, 1989).

Monitoring Programs

The MMS conducts long-term periodic programs to monitor possible environmental effects of offshore oil and gas exploration and production. These programs include inventories of seabirds and ringed seals, studies of whale populations and migrations, collection and analysis of marine mammal tissues for hydrocarbon compounds and heavy metals, and chemical analysis of bottom sediments and biota from the Beaufort Sea. Recently, the MMS sponsored collection of heavy-metal data from Norton Sound in preparation for the OCS Mining Program, Norton Sound lease sale.

U.S. Geological Survey

The North Slope, interior basins, gas hydrates, and thermal history studies are the principal efforts directed toward onshore oil and gas resources. These research projects are funded under the Onshore Oil and Gas Investigations and Alaska Mineral Resources Assessment Programs. Highlights from these programs were presented during 1990 at various technical meetings, including the USGS McKelvey Forum in Houston (Carter, 1990), the American Association of Petroleum Geologists conference in San Francisco (American Association of Petroleum Geologists, 1990) and the Geological Association of Canada meeting in Vancouver (Geological Association of Canada, 1990).

Alaska's Petroleum Systems

The following discussion summarizes a basic study by the USGS of petroleum systems in Alaska (Magoon, 1990a, 1990b).

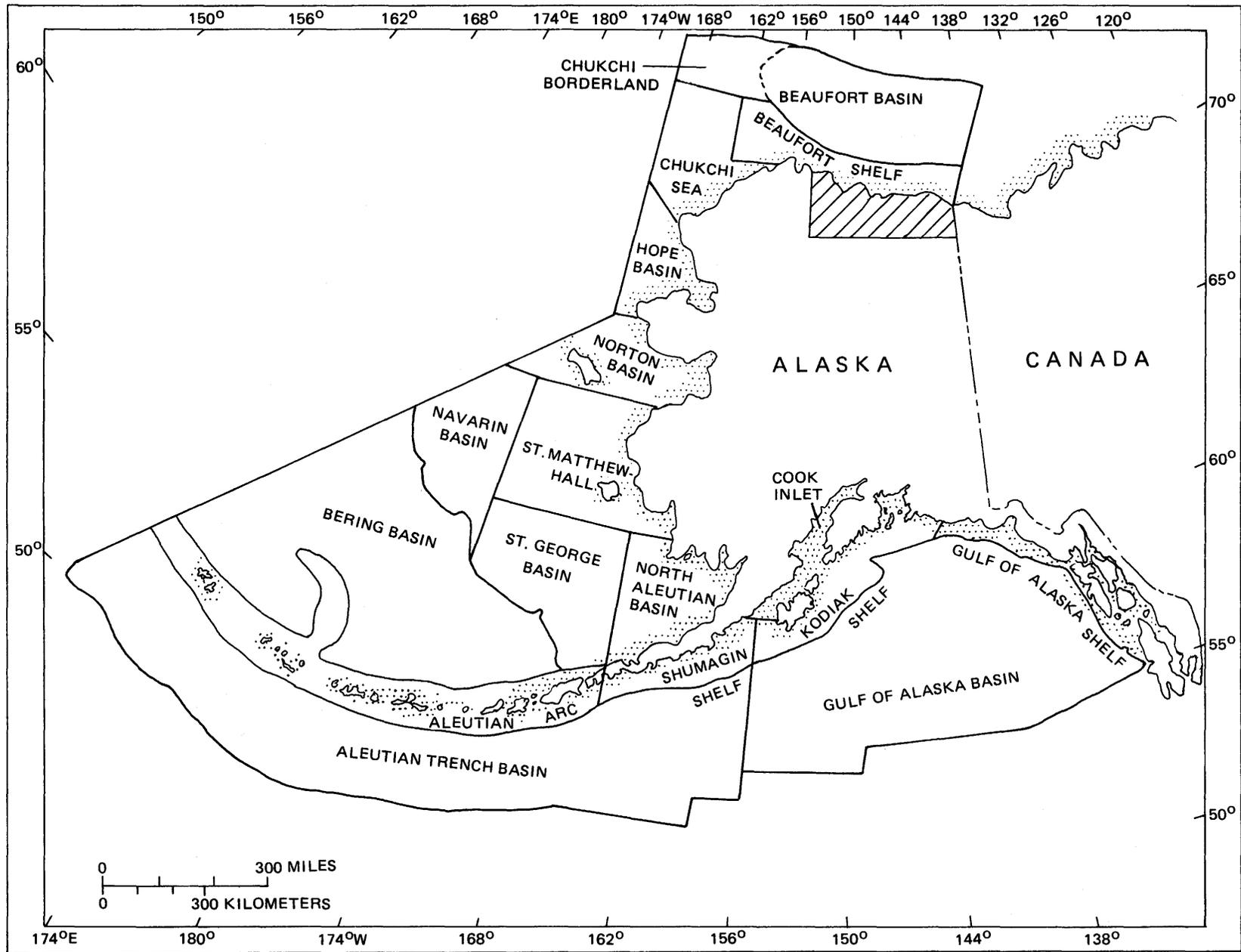


Figure 7. Offshore geologic province boundaries (bold lines; dashed where approximately located) defined by MMS and USGS for national assessment; also shows location of 1990 joint MMS-State studies (lined area).

A petroleum system encompasses all those elements that are essential for an oil and gas deposit to exist: petroleum source rock, migration path, reservoir rock, oil and gas accumulations, trap, and seal; the system's name is a combination of the source and reservoir rocks. To date, seven petroleum systems have been identified in Alaska: three on the North Slope, two in the Cook Inlet area, and two in the Gulf of Alaska.

Volumetrically, the Ellesmerian petroleum system on the North Slope is the largest of the seven. Based on oil-to-source-rock comparisons, the Shublik Formation and Kingak Shale are the primary source rocks for the 12 billion barrels of recoverable oil in the Endicott, Kuparuk River, Lisburne, Prudhoe Bay, and other North Slope oil fields. The other two petroleum systems on the North Slope are the Hue-Sagavanirktok and Torok-Nanushuk. In and adjacent to ANWR, extracts of the Hue Shale compare favorably to surface oil-seeps and oil-stains from the Sagavanirktok Formation. More tenuous are the geochemical correlations of rock extracts from the Torok Formation with the shallow Nanushuk oil accumulations such as those found in the Umiat oil field (70 million barrels of recoverable oil) and as seeps in the Simpson area of NPRA. The light, low-sulfur oils expelled from the source rocks of these two systems differ significantly from the heavier, high-sulfur oils of the Ellesmerian system.

The Cook Inlet area contains two petroleum systems: the Tuxedni-Hemlock and the Beluga-Sterling. Based on organic geochemical parameters, Tuxedni Group extract is similar to the 600 million barrels of recoverable oil in the Granite Point, McArthur River, Middle Ground Shoal, Swanson River, and Trading Bay fields; 80 percent of this commercial oil is produced from the Hemlock Conglomerate. The Beluga-Sterling system involves the shallow microbial gas being produced from the Kenai, North Cook Inlet, and other fields that originated from coal measures or associated sedimentary rocks of the Beluga Formation; the reservoir for most of the 8 trillion cubic feet of gas in these fields is the Sterling Formation.

Two petroleum systems have been identified in the Yakutat terrane in the Gulf of Alaska: the Poul Creek and the Stillwater-Kulthieth. The Poul Creek Formation is both source rock and reservoir rock for the abandoned Katalla oil field. Based on rock extracts and sedimentary facies relations between the Kultheith, Tokun, and Stillwater Formations, the Stillwater Formation is judged to be the main source for oil in the Yakataga and Malaspina districts. Organic geochemical information indicates that the Poul Creek and Stillwater-Kulthieth are two separate and distinct petroleum systems.

North Slope

Details from the North Slope segment of the 1987 MMS-USGS national assessment of undiscovered oil and

gas resources continue to be released. North Slope petroleum plays and individual play assessment results were described and reported (Bird, 1991). Another paper describes the methodology of the North Slope assessment, including procedures followed in the economic analysis of oil and gas resources in this region (Attanasi and others, 1991). These reports are listed in appendix 1, USGS section.

Other USGS studies focus on the tectonic development and petroleum potential of the Brooks Range fold-and-thrust belt. Of the 10,000 billion barrels of oil estimated to have been generated in the Arctic Alaska microplate (Hubbard and others, 1987), only about 70 billion barrels (less than 1 percent) of in-place oil has been discovered in the North Slope petroleum province. It is anticipated that the Brooks Range foothills may contain some of the "missing" oil. The presence of fracture-filling solid bitumen has already been reported in numerous areas (Howell and others, 1991a, 1991b; Molenaar and others, 1988; Patton and Tailleux, 1964). Using as a model the giant oil fields of the Zagros fold-and-thrust belt in central Iraq and Iran, thermal history studies of minerals and organic particles in northern Alaska should provide insight into the complex interplay of oil and gas formation and rock deformation. Results of this work should delineate areas or trends where the chances for discovering oil and gas are optimal.

Interior Basins

USGS scientists continue their work on the geology and petroleum potential of the interior basins of Alaska (those south of the North Slope as shown on fig. 5). Studies in the Kandik basin of east-central Alaska focus on the tectonic history of this fold-and-thrust belt and its comparison to similar basins in the Brooks Range and the Rocky Mountain Cordillera. Preliminary results suggest that the region experienced tectonic contraction in Cretaceous time, producing thrust sheets that advanced from west to east. Much of the strata was buried to depths where temperatures were far in excess of the oil preservation window (Howell and others, 1991c). In the eastern part of the basin, however, shallower strata display a thermal history below the upper threshold of the oil preservation window (fig. 2, fig. 8). Further research into the basin's tectonic history will help clarify the petroleum potential of this frontier area.

The petroleum source potential of Mesozoic and Tertiary coals and mudrocks in the Middle Tanana basin is currently being evaluated. Analytical results show an abundance of gas-prone kerogen and a wide range of thermal maturity related to burial depth and proximity to igneous intrusions (Stanley and others, 1990). A new map of the simple Bouguer gravity of the Nenana/Middle Tanana basin was completed (Valin and others, 1991), and a preliminary compilation of gravity and geology was prepared (Frost and

Stanley, 1991). The facies architecture, depositional environments, sedimentary petrology, and energy resource potential of Tertiary rocks in the Nenana basin area are discussed in new reports by McLean and Stanley (1991) and Stanley and others (1991). These five reports are listed in appendix 1, USGS section.

Continued studies for source-rock and reservoir potential are directed at the sedimentology of Tertiary fluvial and lacustrine deposits in the northern foothills of the Alaska Range; a one-week field program in 1990 resulted in 1,000 new paleocurrent measurements from the Tertiary Usibelli Group in the Nenana coal field.

Gas Hydrates

Gas hydrates are naturally occurring solids composed of rigid cages of water molecules that entrap mainly methane. They may occur in onshore areas where permafrost thickness is greater than 800 feet. Studies by the USGS, funded in part by the DOE, suggest that the zone in which methane hydrates are stable is areally extensive beneath most of the North Slope coastal plain province. Thus far, all

gas hydrates found in the area are geographically restricted to the region overlying the eastern part of the Kuparuk River oil field and western part of the Prudhoe Bay oil field. They occur in six laterally continuous Upper Cretaceous and lower Tertiary sandstone and conglomerate units. Calculations suggest that 8-10 trillion cubic feet of gas is trapped within these hydrates (Collett and others, 1989).

Recent drilling and geologic analysis in the Prudhoe Bay and Kuparuk River fields revealed the presence of a gas-hydrate/free-gas contact at the predicted base of the methane-hydrate stability zone. This relationship is important because gas production from the free-gas zone would also lower pressures in the overlying gas-hydrate reservoir; the ensuing decomposition of the hydrates would free additional gas for production. Future work will focus on the relation between the gas hydrates and associated free-gas accumulations. A similar gas-hydrate/free-gas relationship might also exist in the Walakpa gas field, discovered by the USGS's NPRA program in 1980. The Walakpa field, 20 miles southwest of Barrow, is currently undergoing development drilling. The USGS conducts these hydrate studies in cooperation with the North Slope Borough.

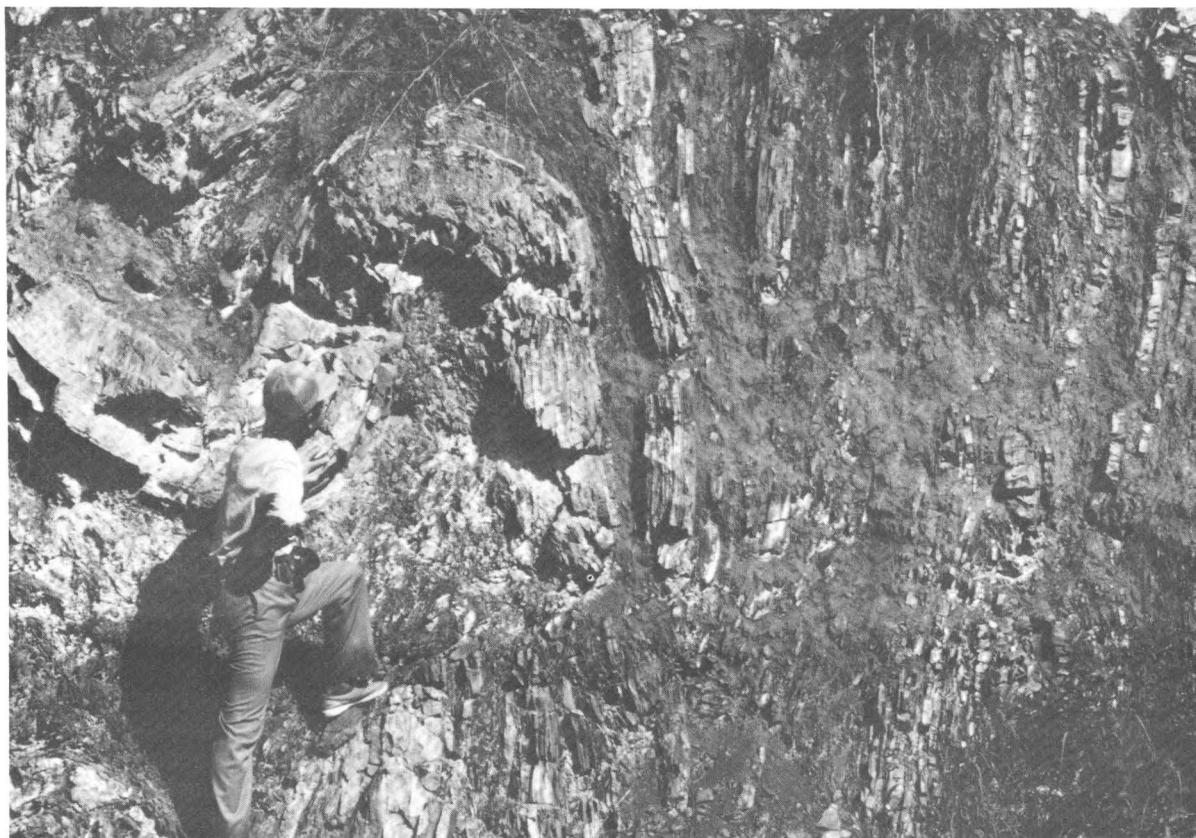


Figure 8. Tightly folded, organic-rich limestones are exposed along the Tatonduk River, Kandik Basin, east-central Alaska. These limestones contain hydrocarbons in sufficient quantities that the rocks have a fetid odor and can be made to burn. Photograph by M. Johnsson.

The thermal maturity map of Alaska portrays a continuum in thermal alteration from unaltered and unconsolidated sediments, through thermally altered sedimentary and metamorphic rocks, to volcanic and plutonic rocks. A critical aspect of the map is the identification of those areas with the low-temperature thermal history appropriate for the generation and preservation of oil and gas. Data for the lower temperatures come from measurements of vitrinite reflectance (fig. 2), illite crystallinity spacings, and conodont alteration indices. By the end of 1990, thermal information on low-temperature sediments reflected 2,808 localities and 6,450 measurements (fig. 9). Data for the plutonic and higher grade metamorphic rocks are derived from an upcoming publication (Dusel-Bacon, 1991a). A preliminary version of the thermal maturity map was presented at the Fall 1990 meeting of the American Geophysical Union (Johnsson and others, 1990); an updated version should be published by early 1992. The Dusel-Bacon and Johnsson papers are listed in appendix 1, USGS section.

Bureau of Land Management

Mineral resource assessments were completed for the 33-million-acre South-central Alaska planning area. An energy and mineral resource assessment is continuing in the Western Arctic area (including NPRA). This study will include a detailed oil and gas study of the Utukok Special Management Area and an analysis of the metallic mineral potential of southern NPRA.

The Branch of Mineral Assessment completed and published its synthesis of bedrock geology of the northern Rocky Mountain Cordillera at the Alaska-Yukon border (Banet, 1990b). At least ten areally extensive units of pre-Ellesmerian clastic carbonates were identified in outcrop. Drill-stem tests from wells immediately west of ANWR have produced oil and condensate from these units. Seismic data indicate that some of these same rocks are present in ANWR. In addition, three technical papers dealing with the oil and gas resources of northern Alaska were presented at the Fifth Circum-Pacific Energy and Mineral Resources Conference in Honolulu (Banet, 1990c; Mowatt and others, 1990b; Mowatt and Mowatt, 1990a). These four reports are listed in appendix 1, BLM section.

The Branch of Pipeline Monitoring is part of the BLM Division of Minerals. The Branch's principal function is to ensure compliance with the terms and conditions of the Right-of-Way Grant issued to the Alyeska Pipeline Service Company for TAPS. Following the *Exxon Valdez* incident, the TAPS Oil Spill Contingency Plan has been revised through the cooperative efforts of Alyeska and State and Federal agencies; the revised 14-volume plan received final approval on April 3, 1991. On November 16, 1989, the

DOE's Office of Fossil Fuels issued an export license to the Yukon Pacific Corporation for export of North Slope natural gas to Pacific Rim countries from the company's Trans-Alaska Gas System. The Branch of Pipeline Monitoring is in the process of issuing temporary use permits for preliminary activities related to this project. Activity regarding Northwest Alaska Pipeline Company's proposed Alaska Natural Gas Transportation System has continued at a low level. To better coordinate the above actions with corresponding State agencies, the Branch of Pipeline Monitoring has co-located with the State Pipeline Coordinator's Office. For a copy of the Annual Report of the Branch of Pipeline Monitoring, contact the BLM Public Affairs Office in the Federal Building in Anchorage.

In establishing and implementing an oil and gas leasing program as required by Section 1008 of ANILCA, the BLM has made land available for noncompetitive oil and gas leasing in three areas south of latitude 68° N. Both the Minchumina and the Denali-Tiekel-Slana areas were opened in 1982 and the Seward Peninsula in 1983 (fig. 10). As of September 30, 1990, the BLM had 4,021 leases on 735,028 acres in these areas. On the Seward Peninsula, five leases on 12,640 acres were issued during 1990. These leases are the last of the offers that had been suspended by the preliminary injunction during the lawsuit *National Wildlife Federation v. Burford et al.* in 1985; this injunction was vacated on November 4, 1988. Except for NPRA and potentially ANWR, all BLM-administered oil and gas estates in Alaska are now handled under the leasing system established by the Federal Onshore Oil and Gas Leasing Reform Act of 1987. Drilling and production operations on BLM leases are administered through the BLM's Branch of Lease Operations.

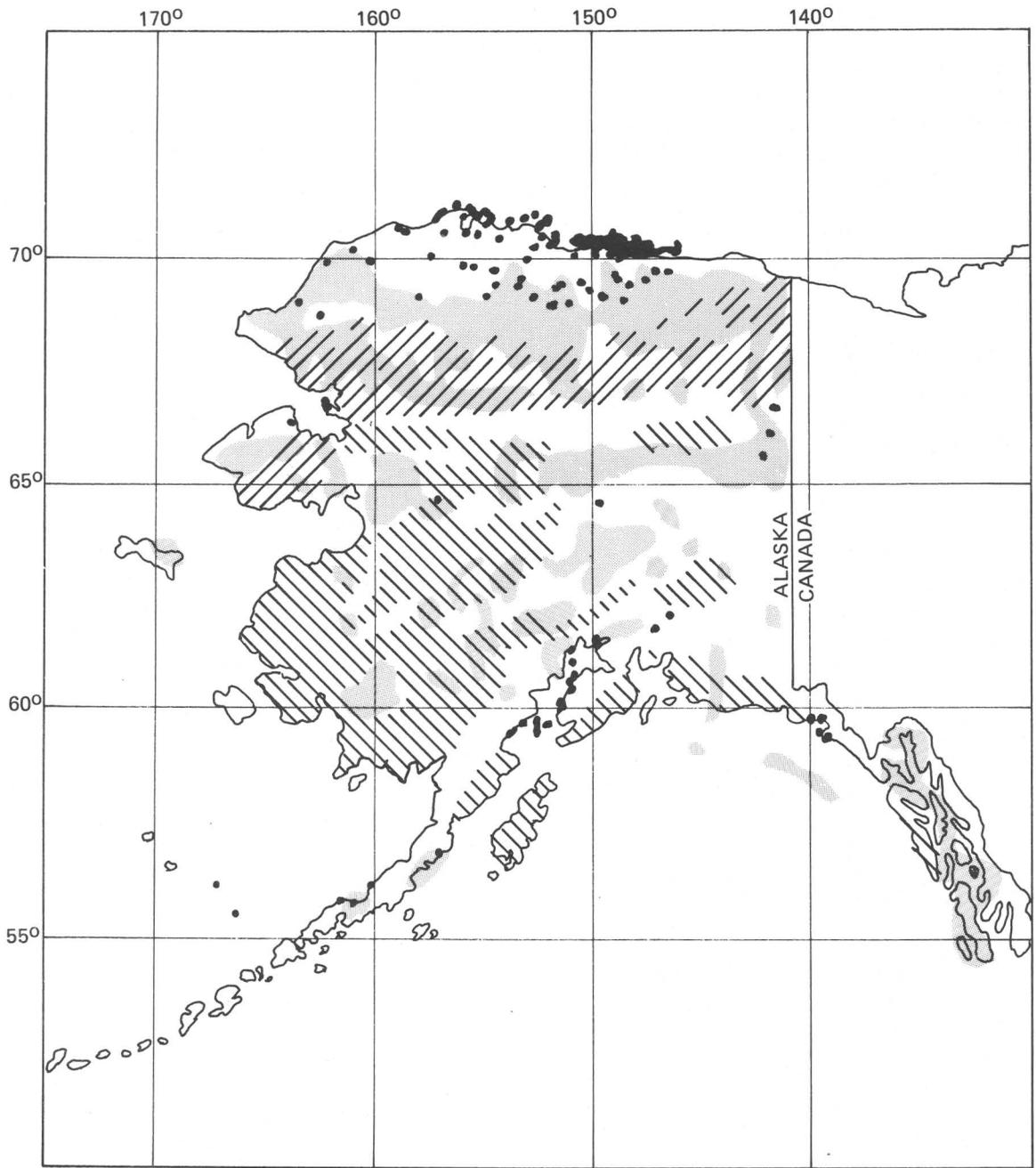
Fish and Wildlife Service

Kenai National Wildlife Refuge

The Kenai National Wildlife Refuge is the only refuge in Alaska from which oil and gas have been produced. Production statistics for the Swanson River and Beaver Creek oil fields in 1990 are discussed in the section "Production Activity - Cook Inlet." Operations in both fields are overseen by the FWS and BLM.

Cleanup of soils contaminated with polychlorinated biphenyls (PCB's) at the Swanson River field was completed in September 1990. The on-site Circulating Bed Combustor unit, designed to destroy PCB's through an incineration system, processed 33,480 tons of PCB-contaminated soils. Final processing of stockpiled contaminated materials should be attained by the end of 1991.

Cleanup work began on an aromatic hydrocarbon spill at the pipe and supply yard for the Swanson River field. ARCO Alaska proposes to use an airstripping unit to



NOT AN EQUAL-AREA PROJECTION

EXPLANATION

Areas for which vitrinite reflectance or pyrolysis data exist

Surface data (onshore and offshore)

Subsurface data

Area of dense conodont color alteration index data (Harris and others, 1987)

Area of poor sample coverage (January 1991)

Crystalline rocks or Holocene overburden

Figure 9. Thermal maturity data coverage for Alaska.

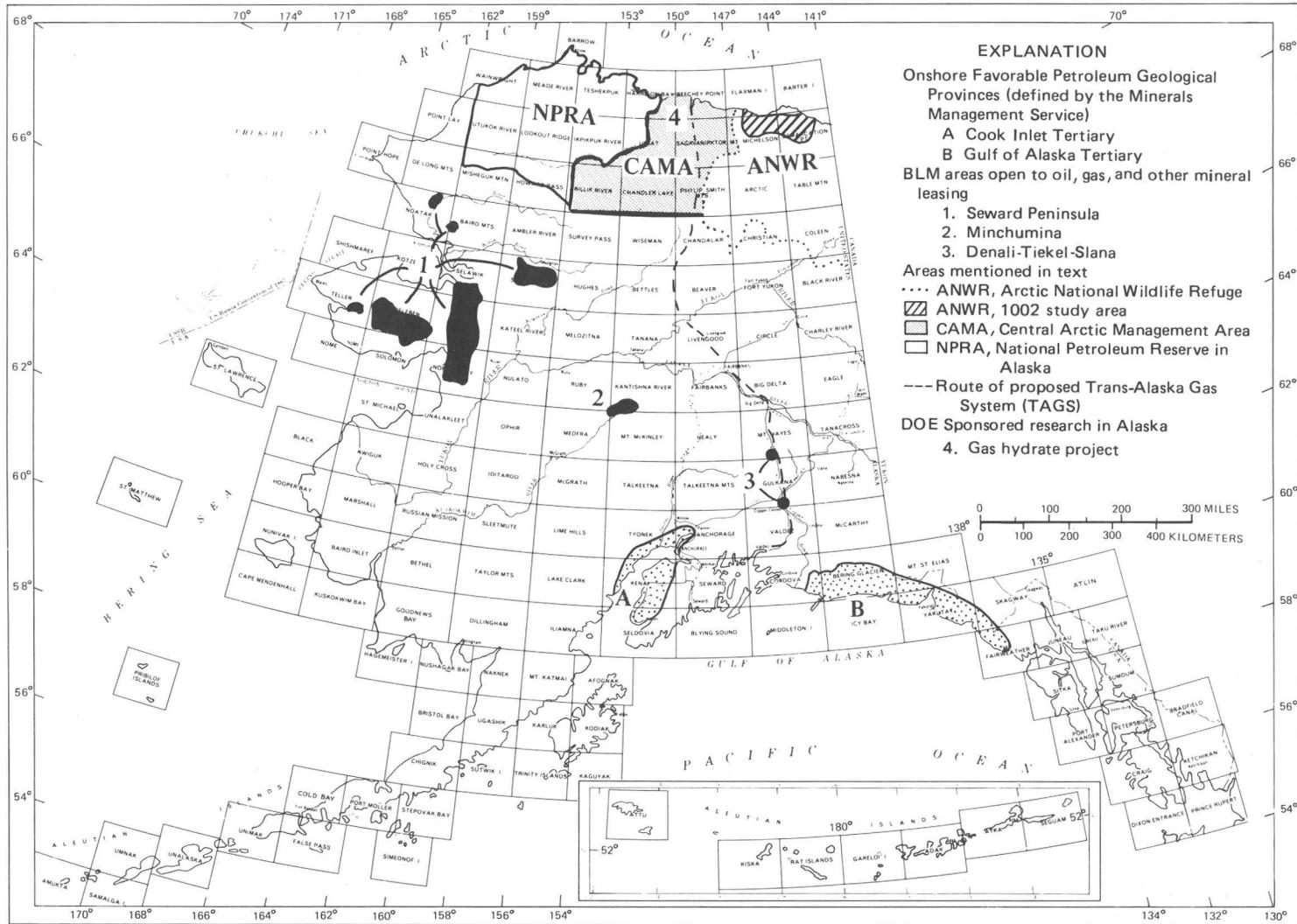


Figure 10. Onshore favorable petroleum provinces (land units referred to in text) and locations of DOE-funded research in 1990.

remove the contaminants from water and soil at the site. ARCO Alaska also completed work on delineating several crude oil spills at operating facilities in the Swanson River field. These spills are apparently chronic, resulting from actual spills, as well as leaks from tanks and flare pits throughout the field. The FWS, BLM, ADEC, and ARCO Alaska will work together to develop a remediation plan for the sites.

Remediation of a crude oil spill at Marathon Oil's Beaver Creek facility continued. Contaminated soils are being excavated and incinerated *in situ*. Remediation of this site is expected to be completed by January 1992. Marathon also contoured and seeded an abandoned gravel pit at the production facility.

Activities under Section 1008 of ANILCA

Section 1008 of ANILCA provides for oil and gas studies on refuges in Alaska to gather information for use in future land-management decisions. In 1990, special-use permits were issued for surface geologic work in the following national wildlife refuges (number of permits in parentheses): Alaska Maritime (three), Alaska Peninsula (one), Arctic (three, all outside the 1002 area), and Kodiak (one). In addition, the Becharof Refuge issued one permit for a study of natural petroleum seeps, Izembek issued one permit for seismic station maintenance, and Kenai issued one permit for a winter seismic study. These special-use permits include numerous stipulations for ensuring that permitted activities are environmentally sound, compatible with refuge purposes, and designed for the specific locale and activities of the proposal. Regional policy requires posted bonds of at least \$10,000 for surface geologic studies and \$100,000 for seismic studies in Alaska refuges. Copies of resultant data must be submitted to the FWS, after which the data remain confidential in storage with the BLM.

Resource Activity Impact Assessment

Permitting.—In 1990, the FWS commented on four Section 404 CWA permits dealing with oil pipelines and wells in south-central Alaska. Reviews under Section 10 of the Rivers and Harbors Act were undertaken for Cook Inlet and Knik Arm pipeline plans. The FWS also is reviewing the Section 404 CWA permit application and environmental assessment for the Birch Hill natural gas well proposal, access to which would include Kenai Refuge lands. Under a Memorandum of Agreement with the BLM, the FWS is providing a biologist to coordinate FWS concerns with the proposed Trans-Alaska Gas System pipeline.

For the northern part of the State, FWS reviews were completed on 19 Section 404 CWA permits and permit

modifications. These involved oil spill contingency projects, mine site rehabilitation projects, and TAPS. Inter-agency work on North Slope oil and gas developments included comments on NPDES permits, review of ADEC solid waste permits, and comments on the EPA proposal to limit offshore disposal of drilling wastes. Technical assistance was provided to the EPA and ACE regarding impact monitoring studies in the Lisburne and Endicott oil fields, identification of resource values and potential conflicts in the Colville River Delta, the Abbreviated Permitting Procedure for oil and gas development permits on the North Slope, projected impact of the proposed Niakuk causeway in the Beaufort Sea, and resources of the Beaufort and Chukchi Seas.

Lease Sales.—The FWS reviewed and commented on three State oil and gas lease sales in Cook Inlet, and on 11 proposed sales in northern Alaska. For MMS, the FWS reviewed draft EIS's for Navarin Basin Lease Sale 107 and for Beaufort Sea Lease Sale 124. The FWS also provided technical comments on the OCS 5-year leasing plan and for three exploration/oil spill contingency plans for OCS lease sales in the Beaufort and Chukchi seas.

Monitoring.—The FWS conducts environmental monitoring on North Slope oil and gas activities. These include analyses of caribou tissues for contaminants and water quality monitoring of ponds, lakes, reserve pits and other features of the oil development area. Peregrine falcon feathers and eggs collected from the Colville River Delta were analyzed for mercury and organochlorine contaminant residues for comparison with similar data from the Nome offshore mining area. Baseline data were collected on nesting bird use of proposed development sites in the Kuparuk oil field. Avian migratory patterns were studied for use in the evaluation of site enhancement. The FWS worked to finalize reports on previous studies of trace metals in shallow Arctic marine sediments contaminated by drilling effluents and on waterfowl contamination at Prudhoe Bay.

The FWS works with various government agencies and the oil industry on appropriate rehabilitation/restoration of oil development facilities. A report was completed on abandoned oil exploration wells on the Becharof Refuge (Jackson, 1991). Exxon USA granted \$150,000 to the "Take Pride in America" program for the cleanup of one such site and access road that had been abandoned since 1959. The FWS rewrote a contingency plan for responding to oil spills in Alaska and reviewed Alyeska's oil spill contingency plans for their pipeline and marine operations.

Land Acquisition.—As lead agency, the FWS, in conjunction with the BLM, NPS and USFS, published the final report in response to the Alaska Submerged Lands Act of 1988 (U.S. Fish and Wildlife Service and others, 1990). This report, "Analysis of Inholdings, Acquisition Priorities, and Recommendations to Reduce Impacts on Conservation System Units in Alaska," includes priorities for acquiring lands within conservation system units such as national

wildlife refuges that are currently patented to, or selected by, Natives, Native corporations, or the State of Alaska. Prioritization was based on multiple factors, including threats to fish, wildlife, and their habitats from activities such as oil, gas, and minerals development.

Department of Energy

Petroleum Research

A primary petroleum target is the gas-hydrate reservoir, which contains gas in a solid, icelike form. Occurrences of such hydrates have been identified on Alaska's North Slope (fig. 10), and the technology for characterizing and developing this resource is under study as part of the DOE's Environmental and Advanced Research subprogram. Using both in-house and contractors' facilities, subprogram efforts have recently been concentrating on laboratory testing of natural and synthetic gas hydrates to define the pressure and temperature conditions necessary for their formation and dissociation, as well as the geophysical and mechanical properties of the hydrates and their reservoirs (Morgantown Energy Technology Center, 1987). Arctic research studies to determine in-place conditions of gas-hydrate deposits have been initiated by DOE in cooperation with the USGS and with ARCO Alaska, BPX, Exxon, and Conoco. As part of the research on gas hydrates, geologic basin reports have been published for a number of offshore areas in a series titled "Geological evolution and analysis of confirmed or suspected gas hydrate localities." Volume 12 is "Basin analysis, formation, and stability of gas hydrates in the Beaufort Sea" (Krason and Finley, 1989). This series of studies is being conducted by Geoexplorer International.

Arctic National Wildlife Refuge

During development and passage of ANILCA, the coastal plain of the ANWR in northeastern Alaska was the subject of conflicting interests; these ranged from designating the area as wilderness to leaving the area open for oil and gas development. As a result, Section 1002 of ANILCA sets out specific management constraints on a 1.5-million-acre strip along the coastal plain of the current 19.5-million-acre ANWR. This portion of ANWR's coastal plain is known as the 1002 area (fig. 10). Section 1002 requires that the Secretary of the Interior (1) conduct a comprehensive, continuing baseline study of the fish and wildlife resources of the 1002 area, (2) develop guidelines to initiate and monitor an oil and gas exploration program, and (3) prepare a report to Congress describing the fish, wildlife, and hydrocarbon resources; the potential impacts and development scenario for petroleum exploration and production; and rec-

ommendations regarding possible oil and gas exploration, development, and production, should those activities be allowed in the 1002 area.

The FWS was designated as principal coordinator for the Section 1002 resource assessment and conducted a baseline study of the area's fish, wildlife, and habitats. The Report to Congress (Clough and others, 1987) was prepared under the provisions of a 1983 interagency memorandum of understanding among the FWS, BLM, and USGS. Specific agency roles and research are described in that report. The Secretary recommended that the 1002 area should be opened to an orderly oil and gas leasing program in a manner that would avoid unnecessary adverse effects on the environment. During 1990, Federal agency activities regarding the 1002 area focused on responding to political and public inquiries regarding the final report findings and on continuing a research and study program.

Fish and Wildlife Service

During 1990, the FWS continued to respond to congressional inquiries concerning the potential for, and impacts from, oil and gas leasing and development on ANWR's coastal plain. Although measures to open ANWR had been introduced in previous sessions of Congress, it was widely recognized that there would be no further legislative action regarding the 1002 area until Congress had dealt with the issue of oil spill legislation.

Recognizing that a variety of regulatory and planning processes would immediately be initiated if legislation is passed that opens the coastal plain to oil and gas activities, the FWS continues to pursue a biological study program in the area. The goal of the study program is directed at achieving a better understanding of the area's natural dynamics, the altered ecosystem dynamics that might result from oil and gas activities, any associated adverse impacts, and the means to avoid, minimize, or rectify those adverse impacts. In 1990, the FWS completed the third year in its 5-year study program. Baseline water quality and contaminant data from 1988-89 studies of pond water and sediment, lagoon sediment and fish, birds and bird eggs, invertebrates, and emergent vegetation were readied for analysis. In addition, one red fox and five arctic foxes were collected from the Prudhoe Bay area for contaminant residue analysis to compare with future ANWR fox analyses as part of baseline studies.

Four contaminant studies in the 1002 area continued. Data based on 1987-88 water, soil, and sediment samples were summarized for the contaminant study of the Kaktovik Inupiat Corporation's exploratory well. Data on hydrocarbon concentrations in soil and vegetation resulting from three fuel spills during 1984 seismic explorations were also summarized.

The "1002 Work Group," composed of FWS and BLM representatives, continued to occasionally coordinate

on management issues and processes relative to the 1002 area.

The FWS compiled a list of the documents that made up the administrative record for preparation of the 1987 congressional report on ANWR. This action was in response to lawsuits filed against the Department of the Interior: *Natural Resources Defense Council et al. v. Manuel Lujan et al.* (Civil number 89-2345, filed August 22, 1989), and *Gwich'in Steering Committee v. Manuel Lujan et al.* (Civil number 89-2393, filed August 28, 1989).

Exxon Valdez Oil Spill

The oil tanker T/V *Exxon Valdez* ran aground on Bligh Reef on March 24, 1989, spilling more than 11 million gallons (262,000 barrels) of Prudhoe Bay crude oil into eastern Prince William Sound. Containment efforts by the Alyeska Pipeline Service Company, Exxon USA, and the USCG could not halt the spread of oil and ensuing pollution of beach and marine habitat. Oil from the tanker moved southwest and eventually washed up on approximately 1,500 of the 3,500 miles of coastline in Prince William Sound, as well as impacting additional coastlines in the Gulf of Alaska, the Kodiak Archipelago, and the Alaska Peninsula.

Exxon has spent over \$2 billion on cleanup operations. Beach cleanup techniques have displayed varying degrees of success. Mechanical rock washers and the kerosene solvent Corexit 9580 are now believed to create or exacerbate environmental problems and have been banned from further use (Anchorage Daily News, July 20, 1990). The most successful cleaning method, known as bioremediation, has employed the dual application of fertilizers and oil-eating bacteria (Anchorage Times, July 11, 1990). Bioremediation also proved successful in a spill at the Kuparuk field where oil penetrated several inches into the tundra (Fairbanks Daily News-Miner, November 9, 1990).

Interagency monitoring crews were composed of personnel from the ADEC, FWS, NPS, USCG, and USFS, and included oil spill specialists, marine biologists, and geologists. These crews surveyed coastlines, observed oil spill impacts, selected sites for cleanup, and monitored cleanup operations. The Natural Resources Trustees Council was formed of State and Federal agency heads for damage assessment and restoration planning.

A large part of the 262,000 barrels (11 million gallons) of oil spilled from the T/V *Exxon Valdez* has either sunk to the bottom, been consumed by bacteria, washed ashore, or floated out to sea. The long-term effects of the spill will continue to be a topic of study and controversy. The USCG and Exxon believe that the cleanup operations were a success, whereas components of the State and environmental groups are less satisfied. As a final footnote, the ill-fated tanker has been repaired, renamed the T/V *Exxon*

Mediterranean, and reassigned to operate in the Persian Gulf.

Fish and Wildlife Service

During the second year following the *Exxon Valdez* oil spill, the FWS remained active in response operations. The FWS cooperated with the USCG Federal on-scene coordinator in assessing the status of national wildlife refuge shorelines and in monitoring cleanup activities. Other programs were undertaken to protect DOI trust resources. Additionally, the FWS continued natural resource damage assessment and restoration planning.

The FWS participated with the multi-agency Spring Shoreline Assessment Team in surveying 144 miles of refuge shoreline. Status of oiling was documented, and specific treatments recommended. Cleanup activities were monitored on all refuge shorelines. Since only a small percentage of refuge shorelines was surveyed by the USCG and Exxon, the FWS independently surveyed an additional 950 miles of refuge shoreline, documenting oil on 115 miles of shoreline and recoverable oil on 15 segments. After the FWS reported to the USCG, these 15 segments were cleaned.

The FWS worked closely with the USCG and Exxon to protect nesting bald eagles from disturbance by cleanup activities. Locations and status of eagle nests were mapped, and protective measures implemented. Buffer zones were established around active nests to exclude human activity, including aircraft movement. Cleanup crews were to be removed temporarily if the eagles became agitated. As the fledglings aged and became less sensitive to disturbances, or as nests became inactive, these measures were relaxed. The program was very successful.

Spring planning ensured that procedures and facilities were in place to respond to any additional wildlife oiling in 1990. Fortunately, this proved unnecessary, and wildlife rehabilitation centers were closed in August (fig. 11). Procedures were also established for the retrieval of dead wildlife and for their submittal to the FWS.

The FWS continued as DOI representative in assessing injuries to natural resources resulting from the oil spill. Sea otters and migratory birds were studied. The FWS cooperated with the other trustee agencies in providing important hydrocarbon analyses and mapping services. Study data were reviewed and synthesized, and future assessment activities were planned. The FWS also implemented several restoration feasibility projects.

In 1991, the FWS expects to cooperate with the USCG in assessing select FWS shorelines and monitoring any required cleanup activities. Where needed, the bald eagle protection program will be reestablished. The FWS will continue to be actively involved in the Natural Resource Damage Assessment and Restoration Planning program.



Figure 11. FWS personnel release eagles (top) back into the wild in 1990 after their rehabilitation following the 1989 Exxon Valdez oil spill. The eagles wear radio transmitters so their progress can be followed with tracking devices (bottom). Photographs by B. Batten.

Minerals Management Service

While the MMS had no direct responsibility for response or damage assessment, the agency provided staff to assist the cleanup and monitoring efforts; an additional \$300,000 was directed to fund studies to assess the effects of the spill. MMS staff helped develop damage assessment programs, assisted in surveys and rehabilitation of seabirds and marine mammals, participated as members of a Resource Advisory Team, and provided technical expertise and assistance to the FWS and the Alaska Department of Fish and Game. Funding also was provided for a study on weathering of crude oil in sea water, for studies on the effects of oil on different species of fish and crustaceans, for surveys of sea otters and seabirds, and for collection of sediment samples for chemical analysis. In addition, support was provided for monitoring the performance of satellite-tracked surface oil drifters, for overflights of the spill, and for studies to determine the social impact of the spill on communities adjacent to the spill's path. The MMS/NOAA research vessel #1273 was provided for use as a field sampling station. Funding from the MMS National Studies Program enabled the USGS to deploy the Gloria Project survey ship *M/V Farnella* in 1989 and the smaller USGS-owned *R/V Karluk* in 1990 to collect bottom-sediment samples.

National Park Service

The *Exxon Valdez* oil spill impacted three National Park System units: Kenai Fjords National Park, Katmai National Park and Preserve, and Aniakchak National Monument and Preserve. In these park units, several hundreds of miles of shoreline and the resources supported thereon were affected by the oil and cleanup operations.

In 1990, the NPS continued to be involved in the full range of cleanup activities through its Office of Oil Spill Coordination in the Alaska Regional Office in Anchorage. Although the pace of response activities was lower than in 1989, a significant amount of work was accomplished. In Katmai National Park and Preserve, 57 work orders were approved through the Federal on-scene coordinator; the cleanup operations were conducted by Exxon. Kenai Fjords National Park had three such work orders and operations. Oil monitoring and damage assessment were carried out in all three affected park units. To support this level of operations, the NPS issued Special Use Permits for fuel caches, helicopter landings, cleanup techniques, research methodologies, and placement of remote weather stations. The NPS also ensured the protection of archaeological resources from potentially disruptive activities by on-site surveys and evaluations prior to each shoreline cleanup.

To provide logistical coordination of aircraft, ships, and personnel, the NPS reestablished its Katmai Field Office in Kodiak for the cleanup season. Park rangers and resource managers from the NPS accompanied the various

cleanup and monitoring crews working along park shorelines. These personnel conducted shoreline and wildlife surveys, documented locations of contaminated zones, prioritized shorelines requiring treatment, suggested reasonable and appropriate treatment methods, monitored shoreline treatment, and provided wildlife protection to cleanup crews. Personnel and logistical support were also provided to the FWS, USCG, State agencies, and Exxon.

The NPS continued to assist State and Federal natural resource trustees in developing and executing damage assessment activities. The NPS also continued as the DOI representative to the Restoration Planning Work Group. In addition, the NPS continued to participate in the development of the criminal case against the potentially responsible parties, and its investigative unit in the Office of Oil Spill Coordination continued to assemble case materials in support of the criminal case and potential damage assessment litigation.

U.S. Geological Survey

In 1990, the USGS continued its oil-spill research by undertaking two sediment-sampling cruises in Prince William Sound. The study will attempt to determine the fate of the spilled oil as a part of the sedimentologic processes in this fjord environment. Funding for these cruises was provided by the MMS and USGS; NOAA provided a ship of opportunity for the June cruise.

All sample stations were located along the oil slick's trajectory. In June, a USGS scientist aboard the NOAA ship *Davidson* resampled 11 stations in deep basins first sampled in 1989 (Carlson and Reimnitz, 1990). In August, the USGS conducted a 7-day cruise on the *R/V Karluk* to investigate areas adjacent to six heavily oiled beaches (frontispiece; fig. 12). For this study, nearshore bottom morphology and sediment distribution were surveyed using acoustic-profiling techniques, and both beach and offshore shallow-water sediments were sampled.

Samples from the two cruises were analyzed for hydrocarbons, microfossils, and sediment characteristics. These analyses will permit comparisons of samples collected 50 days after the oil spill to deep-water samples collected 430 days after the spill and beach and shallow-water samples collected 505 days after the spill. Results show that, although no oil had entered the sediment substrate within 50 days after the spill (Rapp and others, 1990), spilled oil is contained in sediment samples collected 1½ years later. The amount and consequence of this oil are not yet known. Further results of these cruises will be reported as they become available.

U.S. Forest Service

The Chugach National Forest encircles Prince William Sound and includes Bligh Reef, where the *T/V Exxon*

Valdez ran aground. During the spring and summer of 1990, the USFS assigned personnel to six interagency monitoring crews working in Prince William Sound. The crews spent 8 weeks studying the changes that had occurred over the winter. Their role was to observe national forest lands, identify areas still covered with oil, observe primary and secondary environmental impacts of the oil, and recommend remedial actions to be implemented during 1990.

Survey crews will again be sent into the Sound in April 1991 to document any changes that occurred during the winter of 1990-91. The crews will visit about 400 beaches and determine appropriate cleanup options. Cleanup is expected to begin on June 1, 1991.

Proposals for restoration projects have been submitted to the Trustees Council for consideration and public review. It is anticipated that some restoration projects will be funded in 1991.

Coal and Peat Resources

Alaskan coal production hit a record high in 1990 at 1.58 million short tons, a 9-percent increase over 1989 and 2 percent over 1988's previous record of 1.55 million short tons (Swainbank and others, 1991). All production is from the Usibelli coal mine at Healy in central Alaska (fig. 13).

Approximately half of the coal produced is used for in-state power generation, and the rest exported to South Korea.

Alaska stands poised to become an important coal mining and export center in the years to come (Alaska Department of Natural Resources, 1990). Estimates of high-rank coal resources in Alaska total 3.0-3.3 trillion tons, the energy equivalent of 10 trillion barrels of oil. Low concentrations of sulfur, nitrogen, and metallic trace elements make Alaska's coals among the most environmentally safe in the world, and the lower moisture content yields higher energy output per ton. These factors, plus increased demand in the Asian Far East for coal-generated power, high in-state development potential, and Alaska's position in the center of expanding Pacific Rim trade routes, are all important elements supporting Alaska's budding prominence in the world coal market.

Domestically, the market for Alaskan coal is uncertain and may be already saturated. Iraq's invasion of Kuwait, and concurrent loss of oil production there, did not increase domestic requirements for coal (Anchorage Daily News, September 28, 1990). The oil embargo in the early 1970's had already forced utility companies to wean themselves from oil-generated power. Today, oil provides only 4 percent of the Nation's electrical power, and utilities are not expected to convert the few existing oil-fired plants to coal. While oil prices nearly doubled during the Kuwaiti conflict,



Figure 12. USGS geologist examines oiled beach gravels on Smith Island, Prince William Sound, 16 months after 1989 *Exxon Valdez* oil spill. Analysis of beach and offshore sediment samples reveals the presence of oil in sediment substrate in many locations along the oil slick's trajectory. Photograph by P. Carlson.

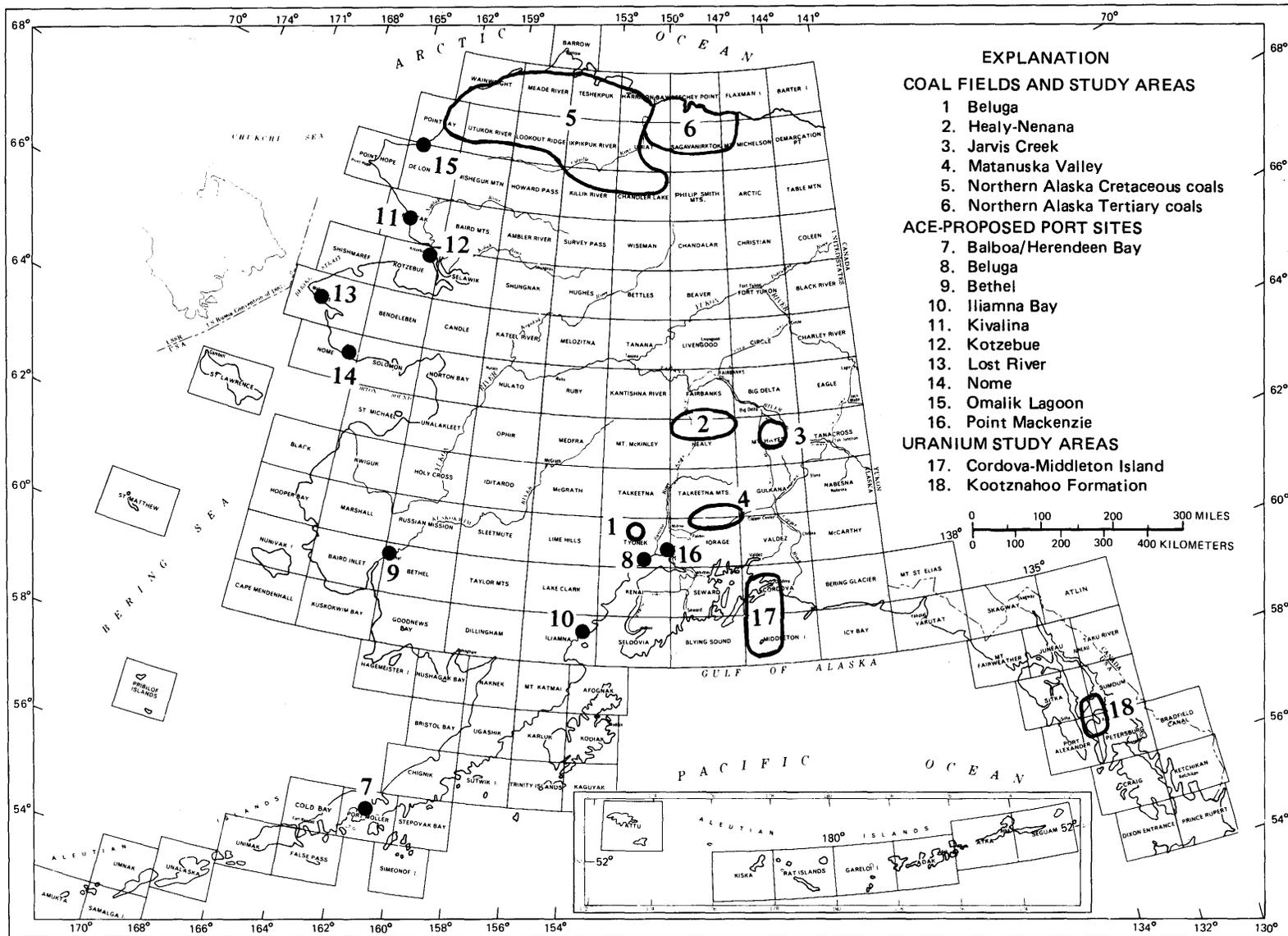


Figure 13. Areas of potential coal and uranium resources and ACE-proposed port sites. 1:250,000-scale quadrangles are outlined and labeled.

coal prices remained steady. In addition, warm winter weather decreased the demand for coal, and stockpiles rose 14.4 percent nationally (Anchorage Times, March 20, 1991).

Construction at the Wishbone Hill coal mine in the Matanuska Valley (fig. 13) was slated to begin in September 1990 (Alaska Journal of Commerce, February 19, 1990). Core samples are routinely taken for analysis. Coal from Wishbone Hill is of high rank (10,400-13,200 Btu/lb) and has low sulfur (0.2-0.6 percent) and low moisture (3-9 percent) contents (Alaska Department of Natural Resources, 1990). The mine is expected to employ 215 people and export one million short tons per year to Japan.

The final environmental impact statement (FEIS) for the Diamond Chuitna coal mine in the Beluga coal field (fig. 13) was issued in February 1990, but it failed to address a proposed port road, thereby facing a legal challenge within a week of its release (Anchorage Times, February 8, 1990). The Alaska Superior Court ruled that the proposal must include the port road (Anchorage Daily News, May 28, 1990). The new permit work should not hold up development of the mine, which is proposed to start operating in the mid-1990's. Situated 45 miles west of Anchorage, the mine could produce up to 12 million short tons per year and employ more than 800 workers.

On July 9, 1990, the Alaska Superior Court put on hold all State-sponsored land conveyances, permits, and leases on Alaska Mental Health lands (AMHL) (Alaska Journal of Commerce, August 23, 1990), including the coal developments at Wishbone Hill, Healy, and Diamond Chuitna. The AMHL program was created at Statehood by the Federal Government to be held in trust by the State, and part of the revenues generated therefrom were to provide funding for Alaska's mentally ill. AMHL revenues were to be based on a percentage of the land's value. Mental-health workers claim that these one million acres of AMHL, including some of the most valuable acreage in the State, have been undervalued for years, cheating patients out of valuable program dollars. The long-standing dispute finally resulted in the 1990 Superior Court decision. The present State administration supports the \$2.24-billion valuation approved last year by an interim AMHL commission (Anchorage Daily News, December 23, 1990), and if this valuation is accepted by the courts, the coal projects would be allowed to proceed as scheduled.

The North Slope of Alaska contains an estimated 3.2 trillion short tons of coal, including 1.9 trillion short tons of high-rank coal (Stricker, 1991; Roberts and others, 1991) (fig. 13). The Arctic Slope Regional Corporation owns substantial portions of the coal fields in the western part of the North Slope and would like to develop this resource (Alaska Journal of Commerce, April 23, 1990). The main obstacles to large-scale development in this area are the lack of a transportation infrastructure and the short ice-free shipping season. However, the coal could be used locally to heat Native villages and to run electric generators in Nome and

Kotzebue that presently use State-subsidized oil. A successful small-scale mining operation in the western Arctic might also interest the military and the Red Dog mine in using coal to meet their power needs.

Usibelli Coal Mines Incorporated was nominated for the U.S. Department of Interior's 1989 "Excellence in Surface Coal Mining and Reclamation" Award (Alaska Report, January 10, 1990). The company was nominated for its work on collecting and treating all mine water to drinking water standards before returning it to Hoseanna Creek, the drainage for the mine's operations.

Peat mined in Alaska is used primarily in agriculture and greenhouses as a soil conditioner; minor amounts are burned locally in villages for heat. After holding steady for four years, peat production increased 27 percent in 1990 to 65,000 cubic yards, up 14,000 cubic yards from 1989 (Swainbank and others, 1991).

Activity by Federal Agencies

U.S. Geological Survey

Branch of Coal Geology personnel have completed resource studies of the Tertiary coals in the Sagavanirktok Formation in the east-central portion of the North Slope (fig. 13). These coals are also low-sulfur, with a mean of 0.37 percent and a range of 0.08-2.02 percent total sulfur (Roberts, 1991). The coal beds are wedge-shaped and dip northeast, such that recoverable resources increase with depth. Coal estimates total 671 billion short tons over the following depth intervals: 209 billion short tons at 0-500 feet of overburden; 93.5 billion short tons at 500-1,000 feet of overburden; 352 billion short tons at 1,000-6,000 feet of overburden; and 16.5 billion short tons at greater than 6,000 feet of overburden (Roberts and others, 1991).

Branch of Coal Geology personnel continue to investigate the major-, minor-, and trace-element distribution in the Usibelli coal mine near Healy (fig. 13). In 1990, a face channel of 28 samples from the No. 4 bed was collected for chemical analysis. Previous work by Affolter and Stricker (1987) at the Usibelli mine indicates that many trace elements vary both vertically and horizontally within the three coal beds being mined. The subbituminous coals mined at Healy have some of the lowest reported sulfur values for any coal presently mined in the United States, containing 0.1-1.5 percent total sulfur (Stricker, 1991).

U.S. Bureau of Mines

The USBM examined the potential for coal development in the areas adjacent to Omalik Lagoon, Kotzebue, Beluga, and Point MacKenzie (fig. 13). These evaluations were done for a study by the ACE on the future needs of

port site facilities in Alaska. The results were published in 1990 as open-file reports (Sherman and others, 1990a, 1990b, 1990c; U.S. Bureau of Mines, 1990a). These reports are listed in appendix 1, USBM section.

Northwestern Alaska.—The most likely scenario for developing the coal resources of northwestern Alaska would be small-scale production for regional use. Coal could be produced at prices equivalent to \$1.28/gallon fuel oil at Kotzebue and \$1.46/gallon fuel oil at Omalik Lagoon; however, the villages' oil-fired power plants would have to be converted to burn coal. Large-scale production of coal for export is presently infeasible due to high costs, technical hardships of operating in an arctic environment, and the short ice-free shipping season.

South-central Alaska.—Port sites at Beluga and Point MacKenzie would be well supplied from expanded coal development in central and south-central Alaska. The Beluga coal field is regarded as having the world's largest surface-minable reserves of low-sulfur coal close to tidewater and ocean shipping, and the modeled mine could ship 12 million short tons of coal per year for 30 years from the Beluga site. The Point MacKenzie site could be the destination for coal from the Usibelli coal mine in Healy and the Wishbone Hill mine near Palmer. The Usibelli mine currently ships 750,000 short tons per year to Korea via Seward, and Wishbone Hill could ship approximately 1.1 million short tons per year for 10 years.

Bureau of Land Management

The BLM continued its management of a lease in the Jarvis Creek coal field south of Delta Junction (fig. 13) and awarded a permit to Hobbs Industries to conduct exploration activities on the lease. Coal from this field is a potential feedstock for gas production, which would be used to generate electrical power for the U.S. Army base at Fort Greeley. Interest in additional coal leasing on Federal land is currently growing.

The BLM has been assessing the coal potential of NPRA in cooperation with the ADGGS and other agencies. Two technical papers dealing with coal resources in northern Alaska were presented at the Fifth Circum-Pacific Energy and Mineral Resources Conference in Hawaii (Gibson and Mowatt, 1990; Mowatt and others, 1990b). These papers are listed in appendix 1, BLM section.

Fish and Wildlife Service

The FWS has been reviewing and commenting on the EIS and Section 404 CWA permit for the Diamond Chuitna coal mine proposed for development on the west side of Cook Inlet. The FWS also is reviewing plans for the proposed Wishbone Hill coal development north of Palmer.

These reviews include technical recommendations to mitigate possible fish and wildlife habitat losses.

Department of Energy

The construction of a state-of-the-art mine-mouth power plant at the Usibelli coal mine in Healy has moved into the first phase of public comment (Anchorage Times, October 10, 1990). The plant is being financed by a \$93.9-million Clean Coal Technology cooperative agreement monitored by the DOE's Pittsburgh Energy Technology Center. The 50-megawatt power plant will provide electricity to railbelt communities, as well as demonstrate a new coal-burning technology in Alaska. The plant is intended to burn Alaska's low-sulfur coal producing virtually no smokestack emissions by scrubbing out particulate matter, nitrogen-oxide compounds, and sulfur dioxide.

Uranium Resources

The United States uranium mining industry did poorly in 1990 because the price of uranium remained low, a condition resulting not only from the abundance of cheap imported uranium, but also from the unexpectedly low domestic demand during the 1980's. Inventory liquidations during 1990 also helped to keep the current U_3O_8 spot price low (Chenowith, 1990). More than 20 percent of the electricity used in the United States during 1990 was generated from nuclear power plants, yet only 25 percent of the uranium consumed came from current production. As a result, the Secretary of Energy declared the domestic uranium industry to be nonviable for the sixth straight year.

Uranium exploration expenditures in Alaska were nonexistent during 1990, as they have been since 1983. The outlook for the development of Alaska's uranium resources remains bleak due to high exploration costs, remote mills, and distant markets.

Activity by Federal Agencies

U.S. Geological Survey

A core program in uranium research is carried out by the USGS in the Branch of Sedimentary Processes. This program is designed to keep the United States abreast of geologic and technologic advances in uranium research and to maintain the capability to carry out such work. Current research on Alaska's uranium resources is limited to using previously acquired data due to the lack of funding for field work or other new data collection.

A report describing uranium mineralization and its relation to diagenesis in the Tertiary Kootznahoo Formation

was released during 1990 (Dickinson and Vuletich, 1990). Another recent report described uranium and thorium anomalies in the National Uranium Resource Evaluation (NURE) data from the Cordova and Middleton Island areas of south-central Alaska (Goldfarb and others, 1989). Both these reports are listed in appendix 1, USGS section.

Geothermal Resources

Hot springs occur throughout Alaska and historically have been used on a small, highly localized scale for recreation, space heating, and agriculture. However, with widespread young volcanic activity on the Aleutian Islands, the Alaska Peninsula, the Wrangell Mountains, and elsewhere in the State, the potential exists for geothermal energy production to serve many population centers.

No Federal research was funded for geothermal studies in 1990.

NONFUEL-MINERAL RESOURCES

Metallic Minerals

Industry Activity

Economic and Regulatory Overview

In 1990, Alaskan minerals exploration and production grew for the fourth consecutive year. Strong base-metal and precious-metal prices spurred exploration expenditures to \$56.7 million (Swainbank and others, 1991), a 19-percent increase over 1989 and the highest since 1981. Mineral production totaled \$534 million, nearly double the value of 1989 production (table 6); this was due to the first shipments of zinc concentrate from the Red Dog mine and to increased zinc-lead-silver production at the Greens Creek mine. Metallic minerals accounted for 79.5 percent, industrial minerals for 12 percent, and coal and peat for 8.5 percent, by value, of reported mineral production. In contrast to expanding exploration and production values, development expenditures in 1990 plummeted 90 percent to \$11.4 million after completion of the Red Dog and Greens Creek mine infrastructures in 1989. Lack of development coupled with mine closures lowered the number of people employed by the mining industry to 3,866 workers, down 7 percent from 1989 levels. The total value of Alaska's mineral industry, defined as the sum of exploration, development, and production expenditures, rose 31 percent overall to \$602 million, compared to the previous all-time high of \$553 million in 1988.

Gold lost its ranking as principal ore commodity in 1990 as a result of the closure of two mining operations: Westgold pulled its dredge *Bima* from offshore Nome be-

cause of low gold prices (Anchorage Times, September 21, 1990), and Cambior Mines closed its Valdez Creek placer operations throughout most of the year for development work (Anchorage Times, November 13, 1990); Cambior plans full-scale production in 1991 (Swainbank and others, 1991). Placer gold production totaled approximately 192,800 ounces (oz) from 216 sites around the State (fig. 14); the Greens Creek mine produced 38,000 oz lode gold. A full three-quarters of 1990 exploration expenditures involved the Alaska-Juneau, Jualin, and Kensington gold properties in southeast Alaska, and the Ester Dome and Fort Knox gold prospects near Fairbanks (Anchorage Daily News, January 1, 1991).

The leading ore metal by value was zinc, due mainly to the start-up of production at the Red Dog mine. Silver production doubled, and lead production increased fivefold, largely as a result of activity at the Greens Creek mine. Greens Creek is the largest underground silver lode mine in the United States (Alaska Journal of Commerce, August 20, 1990) and produced 7.6 million oz silver in 1990 (Anchorage Daily News, January 1, 1991). Tin production plummeted after the 1989 closure of the Lost River operation on the Seward Peninsula; all tin produced in 1990 came from placer mines in central Alaska (fig. 14).

The State government announced its dedication to opening legal access to mineral deposits on Federal lands and to streamlining the State permitting process for placer mining (Anchorage Daily News, December 26, 1990). State law currently requires the reclamation of mined lands to stable, but not necessarily original, condition; small parcels (up to 5 acres) or volumes (1,500 cubic yards) are exempt. The required performance bond of \$750/acre can be satisfied by annual payments into a bond pool (Fairbanks Daily News-Miner, April 18, 1990). Although Alaska closed 289,500 acres of land to new mineral exploration in 1990, more than 90 percent of the 80 million State-owned acres remains open. Only 15 percent of Alaska's Federal lands, the largest ownership block in the state, are available to mineral entry (Alaska Journal of Commerce, October 19, 1990).

An EIS issued by the NPS concludes that the 30 mines that had operated within Denali, Wrangell-St. Elias, and Yukon-Charley Rivers National Parks and Preserves had damaged the environment and should be purchased rather than allowed to reopen (Fairbanks Daily News-Miner, April 26, 1990). The NPS will receive about \$6 million in its 1991 budget to begin purchasing patented and unpatented claims in the Kantishna district of Denali National Park (Fairbanks Daily News-Miner, December 7, 1990).

The Alaska Miners Association's annual fall convention in Anchorage was the largest since 1981. The highlight of the convention was a two-day symposium on the metallogeny of the Soviet Far East, Alaska, and western Canada. The symposium, sponsored in part by the USGS, included presentations by geologists from the three countries.

Table 6. Mining production in Alaska, 1987–1990

[Values calculated from 1990 annual price averages of gold, silver, platinum, zinc, and lead; other values directly supplied by mine operators. Data from Swainbank and others (1991). NR, no report; W, information withheld by mine operators. oz, ounces; lb., pounds; yd³, cubic yards]

	Volume				Value (x \$1,000)			
	1987	1988	1989	1990	1987	1988	1989	1990
Gold (troy oz) -----	229,700	265,500	284,617	231,700	104,516	112,837	108,724	89,204
Silver (troy oz) -----	54,300	47,790	5,211,591	10,135,000	391	282	27,361	50,675
Platinum (oz) -----	W	25	W	NR	W	14	W	NR
Lead (tons) -----	NR	NR	9,585	44,220	NR	NR	7,672	30,954
Zinc (tons) -----	NR	NR	19,843	181,200	NR	NR	29,383	253,680
Tin (lb. metal) -----	288,000	300,000	194,000	57,000	460	950	672	200
Tungsten (short tons) -----	160	240	NR	NR	11	14	NR	NR
Mercury (lb) -----	NR	W	W	NR	NR	W	W	NR
Sand and gravel (million tons) ---	16.7	17.2	14.4	15.1	42,660	48,750	39,875	41,800
Building stone (million tons) ----	1.8	3.6	2.9	3.2	11,620	24,650	20,340	22,100
Jade and soapstone (tons) -----	3.6	W	57.0	W	78	W	1,140	W
Coal (tons) -----	1,508,927	1,551,162	1,452,353	1,576,000	42,355	44,300	41,465	44,990
Peat (yd ³) -----	46,000	55,000	51,000	65,000	299	375	352	400
Totals -----					202,390	232,172	276,984	534,003



Figure 14. Unmanned hydraulic monitors in Tofty mining district of central Alaska are used to strip overlying frozen silts prior to mining the buried gold- and tin-bearing gravels. Photograph by W. Yeend.

Mineral activities in British Columbia are having an economic impact on southeastern Alaskan communities. Geddes Resources of Canada continued its second year of exploration at the Windy Craggy copper deposit in the St. Elias Mountains of British Columbia. Having proven-plus-probable reserves of 113 million tons, the deposit could provide numerous jobs in the Alaskan seaport of Haines, if current plans to truck ore to the community for shipping to smelters are realized (Anchorage Daily News, December 23, 1990). Due to the potential effects on the commercial salmon fishery and socioeconomic impacts on Haines, the State of Alaska has requested more information from Geddes as part of the public comment and permitting process. Two other communities affected by Canadian minerals activity are Wrangell, through which Cominco supplied its exploration program of a gold property on the Iskut River (Anchorage Times, June 15, 1990), and Juneau, which served as a supply and transportation center during the exploration of a gold-silver find on the Taku River (Anchorage Daily News, August 11, 1990).

Precious Metals

Exploration and mining feasibility studies continued at a number of known lode gold mines and deposits shown on figure 15.

Three gold properties in southeastern Alaska are in the advanced stages of exploration. A 1989 drilling program by Echo Bay Mines at the Alaska-Juneau mine resulted in estimates of 44.6 million tons of reserves at 0.05 oz/ton gold (Fairbanks Daily News-Miner, November 9, 1990). The company applied for Juneau city permits to reopen the mine and will make a final decision after all permits have been obtained (Anchorage Daily News, Nov. 21 1990). Placer Dome located a new stockwork zone of sphalerite and free gold during a winter drilling program at the Jualin gold property (Northern Miner, July 9, 1990). Co-owners Echo Bay Mines and Coeur d'Alene Mines budgeted \$60 million for 1991 construction at the Kensington gold mine. Ore reserves there contain an estimated 1.7 million oz gold, 92 percent of which is potentially recoverable (Anchorage Daily News, December 15, 1990). A draft EIS for the Kensington mine is currently in preparation by the USFS.

Two areas in central Alaska received attention during 1990. At the Golden Zone property, Placer Dome carried out surface exploration to extend previously defined reserves of 1.56 million tons having 0.16 oz/ton gold (Northern Miner, August 20, 1990). In the Valdez Creek area, activities were carried out on three properties (Anchorage Times, November 13, 1990). Low gold prices forced closure of the Valdez Creek placer mine in autumn of 1989; creek diversion necessary for further mining was carried out during the mine's closure (Northern Miner, August 27,

1990). After modification of the original permit, Cambior reopened the mine in autumn of 1990 with a more efficient washing plant. CanAlaska Resources announced a lode-gold discovery upstream from the Valdez Creek mine, found during an area-wide drilling program initiated in 1989, and Mining Management announced plans to begin development of an underground placer shaft 6 miles from the Valdez Creek site.

In the interior region of the State, Central Alaska Gold, in a joint venture with Battle Mountain Exploration, announced plans to put the Nixon Fork mine into production in 1991 or 1992. The mine is a small, high-grade gold-copper deposit 35 miles northeast of McGrath (Fairbanks Daily News-Miner, November 8, 1990). Fairbanks Gold increased the estimated value of its Fort Knox property north of Fairbanks, based on results of a 1990 drilling program (Anchorage Times, July 11, 1990); preliminary assays on bulk samples yielded an unweighted average of 0.04 oz/ton gold (Northern Miner, December 17, 1990). Silverado Mines entered an agreement with American Copper and Nickel to develop the nearby Ester gold property, estimated to contain 78,000 tons of reserves with 0.15 oz/ton gold (Northern Miner, February 5, 1990).

In southwestern Alaska, Alaska Apollo Gold Mines announced an agreement with Franklin Mining of Albuquerque to develop the Shumagin gold property on Unga Island; production is slated to begin in about two years (Anchorage Daily News, February 22, 1990). Vinta Exploration carried out a drilling program on 124,000 acres at Illinois Creek. Preliminary results indicate estimated reserves of 1.68 million tons with 0.07 oz/ton gold and 2.05 oz/ton silver; updated figures should be available in early 1991 (Northern Miner, November 12, 1990).

The main mining event in western Alaska during 1990 was the shutdown of the world's largest operating gold dredge offshore from Nome after 5 seasons. The *Bima*, a converted tin dredge brought from Asia, made a profit in only 2 years of operation since starting in 1986 when gold was selling at \$490 per ounce (Anchorage Times, September 21, 1990). Onshore, Placer Gold halted its lode-gold exploration in the Rock Creek area north of Nome, citing sub-economic concentrations (Anchorage Times, February 20, 1990). Aspen Exploration, however, announced its plans for several years of continued exploratory efforts in the area with new partners, Tenneco Minerals and Great Basin Exploration and Mining (Anchorage Times, May 16, 1990); several million tons of reserves having 0.10 oz/ton gold would be needed to support production (Anchorage Times, August 25, 1990). East of Nome, Solomon Resources explored for continuation of the Big Hurrah vein, which has 370,000 tons of reserves containing 0.36 oz/ton gold (Mining Journal, September 7, 1990).

The Bering Straits Trading Company entered into a joint venture with authorities of the Soviet Union to develop gold properties in the Soviet Far East, and near Nome

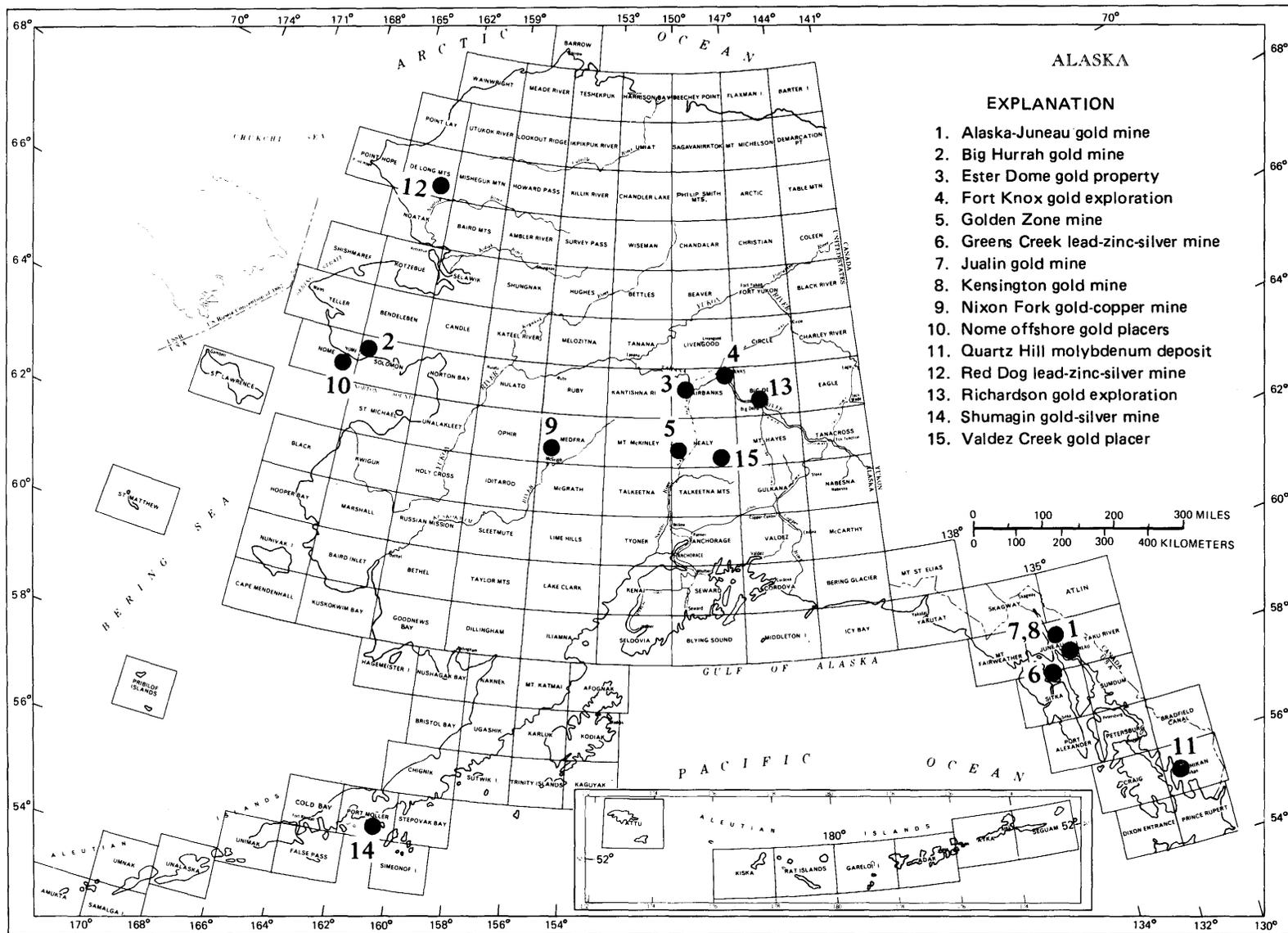


Figure 15. Areas of significant industry activity involving metallic minerals (excluding uranium) in 1990, with mine and deposit locations referred to in text. 1:250,000-scale quadrangles are outlined and labeled.

and Fairbanks in Alaska (Mining Journal, May 11, 1990). Tri-Valley Corporation of California is considering a proposal for a Soviet institute to join Tri-Valley in developing a 64-square-mile gold play near Richardson, Alaska, citing the Soviets' expertise on mining in northern regions (Miner's News, June-July, 1990).

Other Metals

Mineral deposits and properties discussed in this section are also shown on figure 15.

Red Dog, the world's largest lead-zinc mine, shipped its first ore concentrates in July 1990, thereby nearly doubling the state's mineral production of the previous year. The deposit has 85 million tons of proven lead-zinc-silver ore reserves, and the discovery of additional resources through continued exploration could soon move the deposit into the position of having the world's largest reserves (Alaska Journal of Commerce, August 20, 1990). The mining pit is small, a reflection of the deposit's high grade and shallow depth to the ore. Beneficiation incorporates the most modern techniques for lead-zinc recovery; predicted recovery and outputs are 75-80 percent for lead (120,000 tons/year concentrate) and 90 percent for zinc (560,000 tons/year); silver is recovered as a by-product of lead concentrate. During the 3-month ice-free shipping season in the Chukchi Sea, the concentrates were trucked 52 miles from the mine to a shallow-water port northwest of Kotzebue, then barged 4-6 miles offshore to ore tankers. A joint venture of the mining firm Cominco Alaska and the landowner NANA Regional Corporation, the mine employs 60 percent local residents and has a predicted lifetime of 50 years (Northern Miner, May 21, 1990; Anchorage Times, July 8, 1990). Calling it Cominco's most important mining operation, the firm's president said it is one of the company's lowest-cost open-pit producers and has the margin to remain profitable even if zinc prices fall (Northern Miner, January 22, 1990).

Elsewhere in northwestern Alaska, Moneta Porcupine Mines reached an agreement with GCO Minerals of Houston to explore, and bring into production in the next few years, the Lik property, 14 miles from Red Dog. Preliminary reserve estimates are 18.2 million tons of ore grading 10.2 percent zinc, 3.3 percent lead, and 1.5 oz/ton silver (Northern Miner, May 28, 1990, and June 25, 1990).

In southeastern Alaska, the Greens Creek mine celebrated its first anniversary of production in July 1990. The mine improved on its first year by shipping 400,000 tons of lead, zinc, silver, and gold ore (Anchorage Daily News, January 1, 1991). Employing 400 people, the mine's estimated lifetime is 10 years (Alaska Journal of Commerce, August 20, 1990). Also in southeastern Alaska, the Sealaska Corporation signed a 5-year agreement with American

Copper and Nickel for mineral exploration of corporate lands on Prince of Wales Island (Anchorage Times, August 18, 1990).

Following a successful appeal by the Sierra Club Legal Defense Fund, the Environmental Protection Agency denied U.S. Borax and Chemical a permit to discharge tailings into the Wilson Arm/Smeaton Bay fjord as part of its operating plan for mining of the Quartz Hill molybdenum deposit (Anchorage Daily News, May 9, 1990). As a result, the company has put on hold for the indefinite future any plans to mine this deposit in the Misty Fjords National Monument (Anchorage Daily News, October 25, 1990).

Activity by Federal Agencies

U.S. Geological Survey

Locations of USGS studies carried out during 1990 are shown on figures 16 and 17.

Alaska Mineral Resource Assessment Program

AMRAP studies are conducted at four progressively more detailed levels to produce comprehensive assessments of the mineral and energy resources of Alaska. Level I studies are statewide in scope, and published maps are generally at a scale of 1:2,500,000. No level I studies are being pursued at this time.

Level II studies address large parts of the State, and resultant maps are generally published at a scale of 1:1,000,000. Level II studies of geology and mineral resource potential are ongoing on the Alaska Peninsula and in the eastern Alaska Range.

Level III studies consist of multidisciplinary evaluations involving team studies of selected 1:250,000-scale quadrangles; these continue to be the primary focus of AMRAP. Geologic, geochemical, and geophysical data are gathered to produce an inventory of areas defined to have mineral resource potential. Although numerous projects have been recessed or scaled down due to the lack of funding, level III studies are in progress in 30 quadrangles. Field work is complete, and reports are in preparation or in press, for the Baird Mountains, Bendeleben, Bethel, Chandler Lake, Goodnews/Hagemeister Island, Iditarod, Killik River, Livengood, Mount Katmai/Naknek, Port Moller/Stepovak Bay, Simeonof Islands, and Solomon quadrangles. Field work continues in the Atlin, Juneau, Lime Hills, and Taku River quadrangles. Pre-assessments have been completed for the Bethel, Lime Hills, Seldovia, Sitka, Sleetmute, and Table Mountain quadrangles. To date, level III AMRAP assessments have been published for 25 quadrangles (fig. 16). AMRAP-sponsored publications now number approximately 600 documents.

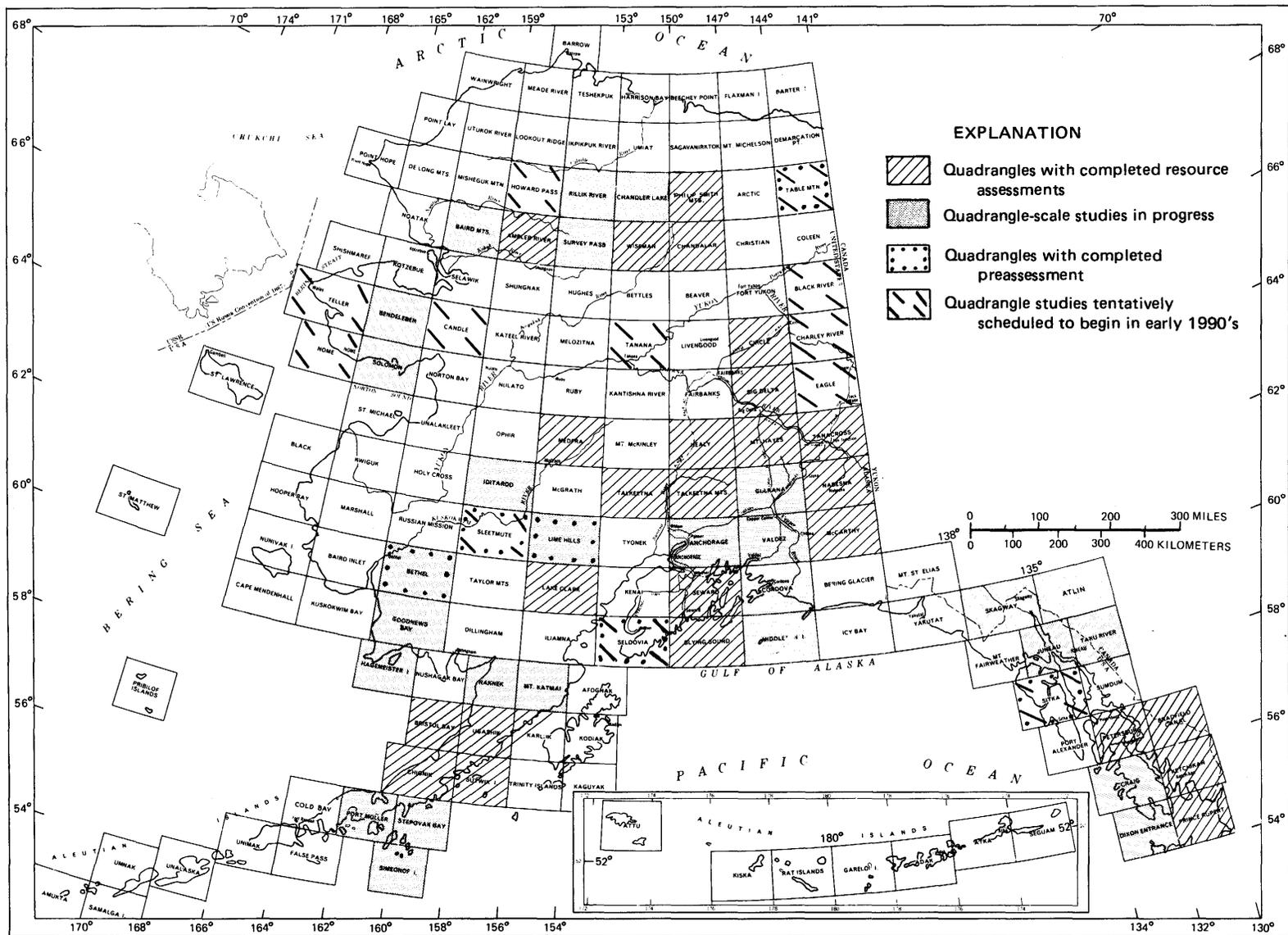


Figure 16. Status of USGS level III AMRAP quadrangle studies as of January 1991. 1:250,000-scale quadrangles are outlined and labeled.

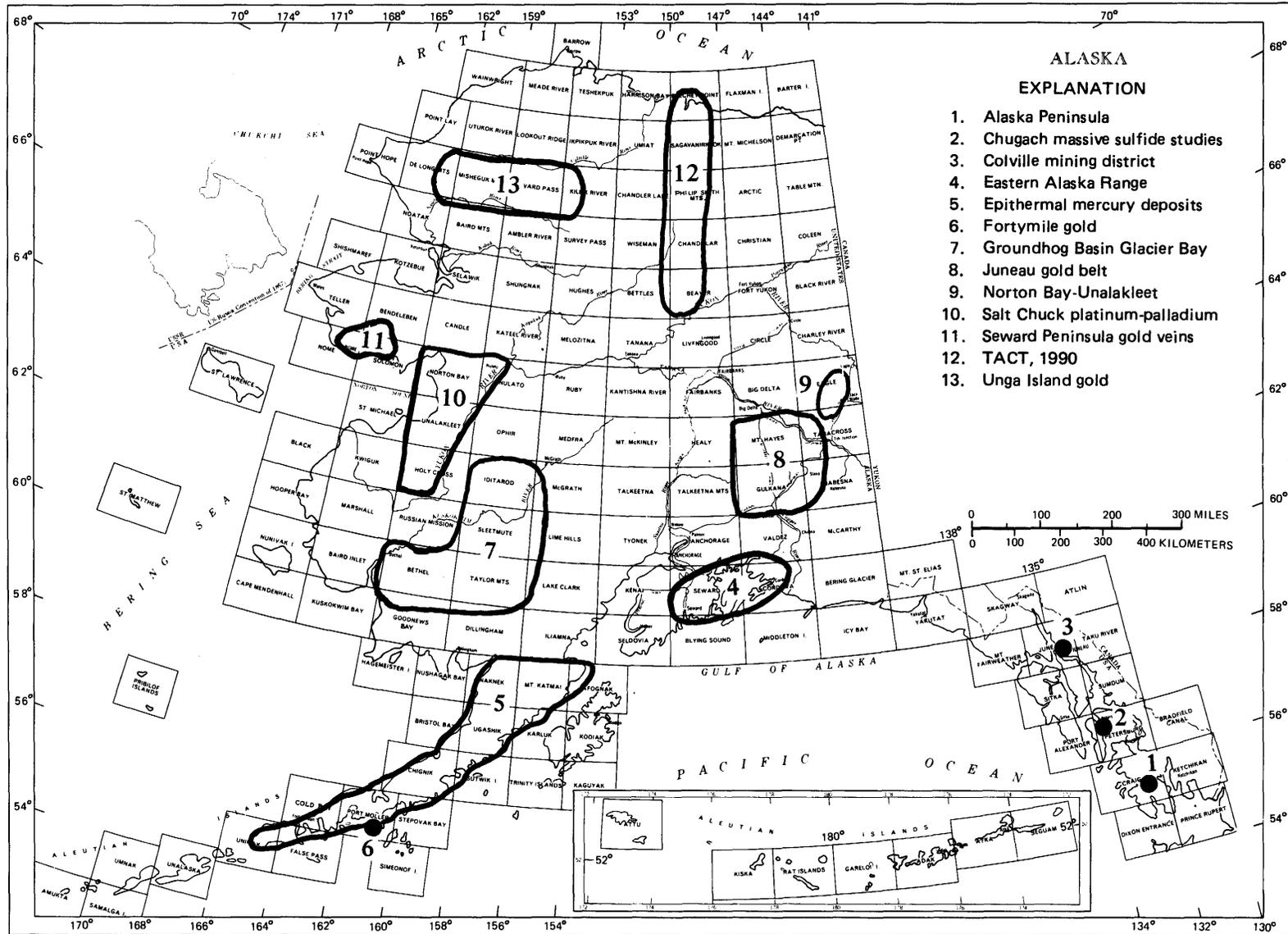


Figure 17. Locations of USGS level IV AMRAP metallic-mineral and TACT studies in 1990. 1:250,000-scale quadrangles are outlined and labeled.

Level IV studies consist of detailed mapping (1:63,360 or larger scale) and sampling of individual mineral deposits or mining districts, and related research. Ongoing level IV activities in Alaska include studies of gold-vein deposits at and near the Apollo mine on Unga Island, geochemical studies of massive sulfide deposits in mafic volcanic rocks of the Chugach and Prince William terranes, and metamorphic and structural studies in the central and western Brooks Range (fig. 17; table 7).

Major reports published recently as a result of AMRAP projects and related mineral-resource projects include an assessment of undiscovered mineral resources of the Tongass National Forest (Brew and others, 1991a, 1991b; Drew and Brew, 1990), metamorphic-facies maps of all regions of the State (Doyle and others, 1991; Dusel-Bacon, 1991a, 1991b; Dusel-Bacon and others, 1991a, 1991b, 1991c), geochemistry and geologic controls on mineralization in the Bethel quadrangle (Frost, 1990; Frost and Box, 1991), a preliminary geologic map and discussion of areas favorable for mineralization in the Baird Mountains quadrangle (Karl and others, 1990; Goldfarb and others, 1990a), a preliminary assessment of the resource potential of the Sitka quadrangle (Karl and others, 1991), and a description of gold placers in the Circle District (Yeend, 1990b). Numerous short papers have also been published in the volumes on geologic and geochemical studies by the USGS in Alaska (Dover and Galloway, 1990; Goldfarb and others, 1990d). All of these papers are listed in appendix 1, USGS section.

Precious Metals

USGS geologists are involved in several studies of precious-metal occurrences in Alaska. Present research (fig. 17; table 7) focuses on gold-quartz veins north of Nome, lode-gold mineralization of the Apollo and Shumagin mines on the Alaska Peninsula, lode-gold deposits in southeastern Alaska, metallogenesis of the eastern Alaska Range, mining geophysics of central Alaska, and the geology of placer-gold deposits. Many level III AMRAP studies also involve research related to precious-metal deposits. Reports published in 1990 include gold analytical results from several south-central and interior quadrangles (Cathrall and others, 1990), lead isotope results from vein occurrences in the Yukon-Tanana area (Church and others, 1990), a study of mineralizing fluids in the Juneau gold belt (Goldfarb and Leach, 1990), gold determinations in the Iditarod quadrangle (Hopkins and others, 1991), areas favorable for gold mineralization in the Anchorage quadrangle (Madden-McGuire and Winkler, 1991), and a discussion of gold placers of the Eureka Creek and Tofty areas and the Circle District (Yeend, 1990a, 1990b). These reports are listed in appendix 1, USGS section.

USGS geologists are studying the occurrence of strategic and critical minerals in Alaska. Current research (fig. 17; table 7) includes studies of mafic and ultramafic rocks and their associated deposits of platinum-group metals (PGM), chrome, nickel, and cobalt; tin commodity studies are also ongoing. The DOI has given high priority to the identification of strategic mineral deposits in Alaska, partly to improve information about resource potential before further land withdrawals by Congress, and partly out of concern over the stability of foreign suppliers (Anchorage Times, August 3, 1990).

Other Metals

Research on other metals and geologic background investigations (fig. 17; table 7) are continuing on a north-western Alaska crustal study, a geologic and mineral-resource study of the eastern Norton Bay area, the Yukon-Koyukuk geologic transect, a geophysical study of the Yukon-Koyukuk basin, a mining geophysics study of central Alaska, a study of metamorphic terranes in interior Alaska, and metamorphic-facies mapping of Alaska. Topical publications during 1990 detailed the results of studies on mercury and antimony deposits in southwestern Alaska (Goldfarb and others, 1990b, 1990c; Gray and others, 1990a, 1990b, 1991). These five papers are listed in appendix 1, USGS section.

Mineral-resource data for the Tongass National Forest in southeastern Alaska were compiled as part of a revision of the USFS management plan for the Nation's largest national forest (17 million acres). Results include a 1989 USBM compilation of data on the discovered mineral resources of the forest and a recent USGS publication that estimates the undiscovered locatable mineral resources of southeastern Alaska (Brew and others, 1991). Based on geology, geophysics, geochemistry, mineral economics, and exploration history, the USGS report defines 124 tracts that are permissive for the occurrence of undiscovered mineral resources; each tract was judged to contain one or more types of mineral deposits. Probabilistic estimates of the undiscovered mineral resources include 168 metric tons of gold, 7,550 metric tons of silver, 5 million metric tons of copper, 2.2 million metric tons of zinc, and 0.45 million metric tons of molybdenum. Lands currently open to mineral entry in the Tongass National Forest are estimated to contain slightly over half of the undiscovered locatable mineral resources of southeastern Alaska.

Cooperative Programs with Soviet Scientific Agencies

In 1987, joint studies were proposed during a visit of the Chief Geologist and Chief of the Branch of Alaskan

Table 7. Level IV studies of the USGS Alaska Mineral Resource Assessment Program and related projects active in 1990

[Project chiefs are listed in parentheses. Projects marked by asterisk are of statewide scope]

Areal mineral-resource assessments
*Alaska mineral resources, probability estimations (W.D. Menzie) Alaska Peninsula, geology and mineral resources (F.H. Wilson) Colville mining district, geology and mineral resources (J.M. Schmidt, USGS; S. Fechner, USBM) Eastern Alaska Range, metallogenesis (W.J. Nokleberg) Fortymile district, placer gold deposits (W.E. Yeend) Juneau gold belt, lode gold deposits (R.J. Goldfarb) Norton Bay-Unalakleet area, geology and mineral resources (W.W. Patton, Jr.) *Placer gold deposit studies (W.E. Yeend) *Placer platinum deposit studies (J.B. Cathrall) Southwestern Alaska, epithermal mercury deposits (J.E. Gray) *Tin commodity studies (B.L. Reed) Western Brooks Range, mineral deposits (J.M. Schmidt)
Areal energy-resource assessments
Nenana basin coal fields, genesis of trace elements (G.D. Stricker) Nenana basin coal studies (C. Wahrhaftig) Nenana basin, geologic framework and petroleum potential (R.G. Stanley) Northern Alaska coal resources (G.D. Stricker) Yukon-Kandik basin, petroleum potential (H.E. Cook)
Exploration geophysical studies
Central Alaska, mining geophysics (D.L. Campbell) *Statewide gravity network (D.F. Barnes) Yukon-Koyukuk basin and its borderlands, geophysics (J.W. Cady)
Biostratigraphic studies
*Brachiopod and conodont paleogeography (J.T. Dutro, Jr. and A.G. Harris) Brooks Range and Arctic Slope studies (L.N. Marinovich) *Paleozoic and Mesozoic radiolarians (C.D. Blome and B.L. Murchey)
Framework or process studies
*Alaska mafic and ultramafic rocks (R.A. Loney) *Alaska metamorphic-facies map (C. Dusel-Bacon) Alaska Peninsula, Upper Mesozoic stratigraphy (R.L. Detterman and F.H. Wilson) Apollo and Shumagin mines, gold mineralization (W.H. White) Central Alaska metamorphic studies (J.H. Dover) Chugach massive sulfide deposits, geochemistry (S.W. Nelson) Groundhog Basin-Glacier Basin silver-tin-lead-zinc deposits (R.J. Newberry and D.A. Brew) Interior metamorphic terranes, structural analysis (J.H. Dover) Katmai region, Tertiary magmatism (J.R. Riehle and M.A. Lanphere) Northwestern Alaska crustal study (A.B. Till)

Table 7. Level IV studies of the USGS Alaska Mineral Resource Assessment Program and related projects active in 1990—Continued

Framework or process studies
*Paleomagnetism of accreted terranes (C.S. Gromme) Salt Chuck platinum-palladium deposits (R.A. Loney) Seward Peninsula gold veins (B.M. Gamble) Yukon-Koyukuk crustal transect study (W.W. Patton, Jr.)
Exploration geochemical studies
Western Brooks Range, stratabound base-metal deposits (K.D. Kelley)
Isotopic and radiometric studies
*K-Ar studies and radiometric age file (N. Shew) *Lead isotope studies of Alaska mineral deposits (S.E. Church) *Uranium-lead and rubidium-strontium isotope studies (J.N. Aleinikoff)

Geology to the Soviet Far East Branch of the USSR Academy of Sciences. In 1988, two study proposals were exchanged, and memoranda of understanding were signed in 1989 between the USGS and the USSR Ministry of Geology, and between the National Science Foundation and the USSR Academy of Sciences.

The first proposal involves the comparative metallogenesis of lode mineral deposits in the USSR Far East and Alaska. As one of its goals, the study proposes to refine extrapolated trends in geology and lode mineral deposits from western Alaska across the Bering Strait into lesser known areas of the USSR Far East. In 1989, a team of USGS geologists visited the Soviet Far East for five weeks. In 1990, the USGS and State of Alaska sponsored visits by two teams of Soviet geologists. Several mineral deposits near Nome and Fairbanks and in south-central Alaska were visited; some tours were hosted by private industry. Agreements were reached during the year for the Soviet scientists to prepare a tectonic-magmatic map of the USSR Northeast and to release lode deposit data. Canada joined the international effort during the year, and guidelines were established for publishing metallogenic maps of the USSR Far East, Alaska, and western Canada. A new tectonic-magmatic map of Alaska will also be produced.

The second proposal encompasses a joint comparative study of the geologic setting and age of ophiolites and their host terranes in Alaska and the USSR Far East. Ophiolites typically mark fossil boundaries of lithospheric plates, and the study of ophiolites can lead to insights into the mechanisms of plate subduction and terrane accretion. Moreover, ophiolites commonly contain copper, chromium,

nickel, and cobalt deposits. Soviet geologists toured several Alaskan ophiolite deposits in 1989. In 1990, geologists from the USGS and ADGGS visited important ophiolite localities in the USSR Far East (fig. 18). Joint compilation of an Alaska-Soviet Far East ophiolite map with cross-sections, associated mineral deposits, tables of chemical analyses, and rock ages was drafted.

Eight Soviet geologists, an engineer, and two interpreters attended the Alaska Miners Association's convention in Anchorage during November 1990. The group was the largest contingent of Soviet earth scientists to visit Alaska in this century (Alaska Miner, December 1990). Soviet, Canadian, and Alaskan scientists presented papers at a special two-day forum on the geology and metallogeny of the Soviet Far East, Alaska, and western Canada.

Trans-Alaska Crustal Transect Program

Started in 1984, the TACT Program is a major multidisciplinary investigation of the geology, tectonics, and deep crustal structure of Alaska along a corridor that paral-

lels the trans-Alaska pipeline. This investigation will provide critical geologic groundwork for any future mineral studies in the corridor. Results prior to 1990 include extension of 1:63,360-scale geologic mapping to the southern flank of the Brooks Range, acquisition and analysis of seismic-refraction, seismic-reflection, and magnetotelluric data along different parts of the transect in central and southern Alaska, and numerous publications. Six weeks of geologic field work in 1990 focused on the study of structural and stratigraphic problems in the southern Brooks Range. Planned field work in the northern Brooks Range was curtailed due to adverse weather conditions. Geophysical field work in 1990 consisted of magnetotelluric soundings and seismic-refraction and -reflection studies, mainly in the Brooks Range and north to Prudhoe Bay, for purposes of defining major crustal features and crustal thicknesses.

National Petroleum Reserve in Alaska

A cooperative 4-year study of mineral resources of the Colville mining district in the southern portion of the



Figure 18. Geologists from USGS, ADGGS, and Soviet Academy of Sciences prepare to board Soviet-made MI-8 helicopter at Mainits Lake in order to visit outcrops of ophiolitic rocks in Koryak Mountains of Soviet Far East. Photograph by S. Nelson.

NPRA was initiated by the USGS and USBM in 1990. The overall objective of the study is to evaluate the mineral potential of the Colville mining district for the BLM. The evaluation will include a USBM compilation of data on known deposits and a USGS estimate of the undiscovered mineral resources. Collective activities in 1990 included the compilation of available geologic, geophysical, and geochemical data and the start-up of geologic and geochemical field studies, including topical studies relevant to the mineral-resource evaluation. The BLM has assisted the USGS in compiling remote-sensing satellite imagery of the study area.

U.S. Bureau of Mines

The USBM's AFOC is responsible for conducting four programs under the USBM's Directorate of Information and Analysis and for coordinating work with other USBM field and research centers throughout the United States. The USBM's Research Directorate is responsible for several ongoing projects in Alaska, through both the Mineral Institute program and the nine USBM research centers.

Minerals Availability Program

The USBM looked at mineral development potential near proposed port sites, studied cyanide use in precious-metal extraction under Arctic conditions, evaluated abandoned mine site hazards in the Chugach National Forest, and assessed the impacts of permitting and environmental costs on mining. The Mineral Industry Location System (MILS) data base received widespread use from the public sector.

Port site evaluation.—The USBM examined the potential for minerals development in the areas adjacent to Balboa/Herendeen Bay, Beluga, Bethel, Iliamna Bay, Kivalina, Kotzebue, Lost River, Nome, Omalik Lagoon, and Point MacKenzie (fig. 13); coal development impacting Beluga, Kotzebue, Omalik Lagoon, and Point MacKenzie are discussed in the "Coal and Peat Resources" section. The evaluations were done for a study by the ACE on the future needs of port site facilities in Alaska. The USBM maintains a comprehensive data base of over 7,000 mineral locations in Alaska and has the expertise to evaluate the economic significance of these deposits. The USBM inventoried the mineral deposits around the port sites, listed the commodities found in each mineral deposit, and determined the likelihood of mineral development around each site. The results were published in 1990 as open-file reports (Sherman and others, 1990a, 1990b, 1990c; U.S. Bureau of Mines, 1990a). These reports are listed in appendix 1, USBM section.

The USBM used its data base to determine the number and type of mineral deposits within a radius of 100 miles around each site; for Point MacKenzie, deposits were identified that lie within 30 miles of a major road or the railroad. The USBM identified 859 deposits that meet the criteria for development within the proposed access area of the ports. The deposits contain aluminum, antimony, asbestos, barium, bismuth, calcium, chromium, clay, coal, cobalt, copper, diatomite, fluorine, gemstone, gold, graphite, iron, kyanite-group minerals, lead, mercury, mica, molybdenum, niobium, pumice, silver, sulfur, tin, uranium, and zinc. Major commodities utilizing each port would include copper-molybdenum at Balboa/Herendeen Bay, lead-zinc at Kivalina, tin at Lost River, gold at Nome, and copper and gold shipped to Point MacKenzie. Ports already exist at Nome, serving the south-central Seward Peninsula, and at Kivalina, linked to the Red Dog mine by the DeLong Mountains Transportation System. Point MacKenzie, however, would be in direct competition with Anchorage and Seward for any increased traffic. At this time, the lack of known accessible mineral deposits in the Bethel and Iliamna Bay areas precludes the likelihood of port development at these two sites.

Cyanide leach technology.—Data on cyanide use in Alaska have been collected over a 2-year period. The data include information concerning the chemistry of cyanide leaching, types of leach operations available (heap vs. vat), environmental effects on leaching, environmental impacts caused by leaching, and economic information to conduct a feasibility study of a gold-leach operation in Alaska. The costs of a hypothetical heap-leach mining operation in Alaska were compared to those in Nevada (Herzog, 1990). Although there are a few problems unique to northern heap leaching, this study showed that heap leaching is economically feasible in Alaska. However, an Alaskan precious-metal deposit that would be amenable to cyanide heap leaching requires a recoverable metal value twice that of similar deposits in Nevada for a 15-percent return. The increased costs of Alaskan heap leaching stem from circumstances such as shorter leach season, larger holding ponds to accommodate heavy snow melt, permafrost insulation, heavier vegetative cover, and the higher costs of labor, transportation, and shipping.

Chugach National Forest.—In 1989, the USFS requested the USBM to locate and assess hazards associated with abandoned mine sites in the Chugach National Forest. In 1990, the USBM used the Chugach RARE II (Roadless Area Review and Evaluation, part 2) data base for initial identification of potential mine hazards. A cursory evaluation of the 662 properties identified hazards at 306 sites. Approximately 100 properties were determined to contain potentially very high-risk hazards. Of these 100, the inactive mines with the most serious hazards and the highest potential for public visitation were chosen by the USFS for

on-site evaluation. Eight such properties were visited by the USBM and USFS during 1990. At each property, physical hazards (rotten timbers, weak rock, old equipment, abandoned explosives) and environmental hazards (mercury contamination, stream sedimentation, acid mine drainage) were investigated. For each mine visited, the USFS was advised of its location, history, physical and environmental hazards, and mitigation recommendations. The USFS will use the information for planning hazard abatements on these properties.

Permitting and environmental constraints.—The USBM published a report detailing the costs of mine permitting requirements and procedures for placer and lode mines in Alaska (Sherman, 1990a). For placer mines, the study found that increased operating costs and lost production time during a short operating season account for a markedly decreasing rate of return as effluent treatment is increased. Lode mines face greater permitting and compliance costs than similarly sized placer mines due to the physical impact of their operation. Direct permitting costs for lode mines average 4 percent of total project cost, and total permitting and compliance costs are approximately 8 percent. Indirect costs associated with compliance include mitigation, monitoring, and reclamation.

Public information.—The Minerals Industry Location System (MILS) data base continued to receive widespread use by the government, industry, and the public. In addition to on-site visitors, 10 reports and 4 map overlays were generated in 1990 in response to information requests. One such report was prepared for a State Senator, detailing mineral development potential along the route of the proposed Trans-Alaska Highway, from Prospect Creek Camp on the Dalton Highway, through Bettles and Bornite, to Nome on the Seward Peninsula. Major mineral deposits along the route include the Bornite, Arctic, Sun, and Smucker copper deposits. Within 24 hours of the request, the USBM had prepared (1) a map showing the proposed route and location of mineral deposits along the route, (2) a list of the 374 deposits showing name, type, current status, and primary commodity, and (3) an estimate of the gross dollar value for deposits with known reserves along the road corridor.

Policy Analysis

All 16 quadrangles in southeast Alaska were digitized, and the land status updated to June 1988; 27 quadrangles in south-central and north-central Alaska were also digitized. Land status was updated in a draft form to June 1989 in 16 of these quadrangles.

Initial compilation of the Mineral Claim Information System (MCIS) was completed (Sherman, 1990b). There are approximately 73,100 active claims (30,700 Federal and 42,400 State) on the 1990 MCIS data base, a drop of 7.5

percent from the 79,100 claims (33,900 Federal and 45,200 State) active in 1989.

State Mineral Activities

The State Mineral Officer wrote the annual preliminary "Mineral industry survey of Alaska in 1990," summarizing significant nonfuel mineral activity. Legislative and executive actions of interest to the mineral industry were monitored and reported monthly. News items were prepared for the weekly "Mineral Alerts" and for the bimonthly survey "Minerals and Materials." Mineral briefing profiles were prepared for DOI and USBM officials as required. Mineral news of interest to the USBM and its commodity specialists were forwarded weekly.

Minerals information and analysis are provided through a series of scheduled and unscheduled publications and reports, and through other responses to inquiries from State and Federal agencies, industry, and the public. One priority is the identification and evaluation of issues, problems, and trends, in order to provide the USBM additional opportunities for constructive action in the minerals field.

Mineral Land Assessment

During 1990, the USBM conducted mineral land assessment activities in the Ketchikan and Valdez Creek mining districts and prepared for 1991 field work in the Colville mining district (fig. 19, table 8). Each mining district study is designed to determine the mineral development potential of the district by identifying and assessing known mineral resources and reserves, evaluating the probability that more resources exist, and determining the feasibility of mining certain deposit types. The studies include site-specific evaluations when the presence of significant minerals is noted. The USBM produces annual "data dumps" of the field mapping and analytical results; a final executive summary is published at the end of the study. The mining district studies are done in cooperation with other Federal and State agencies.

Ketchikan.—Field work in the Ketchikan mining district commenced in 1990. More than 150 mines, prospects, and mineral occurrences were investigated on southern Prince of Wales Island. More than 1,300 rock, placer, and limestone samples were taken, and approximately 3 miles of underground workings were mapped. Analytical results provided by an outside contractor have been coupled with field data, and analytical tables were generated. A narrative summary of 1990 field activities will be published in 1991.

Valdez Creek.—In 1990, the USBM completed its 4-year assessment of the mineral resources and mineral development potential of the 5.7-million-acre Valdez Creek

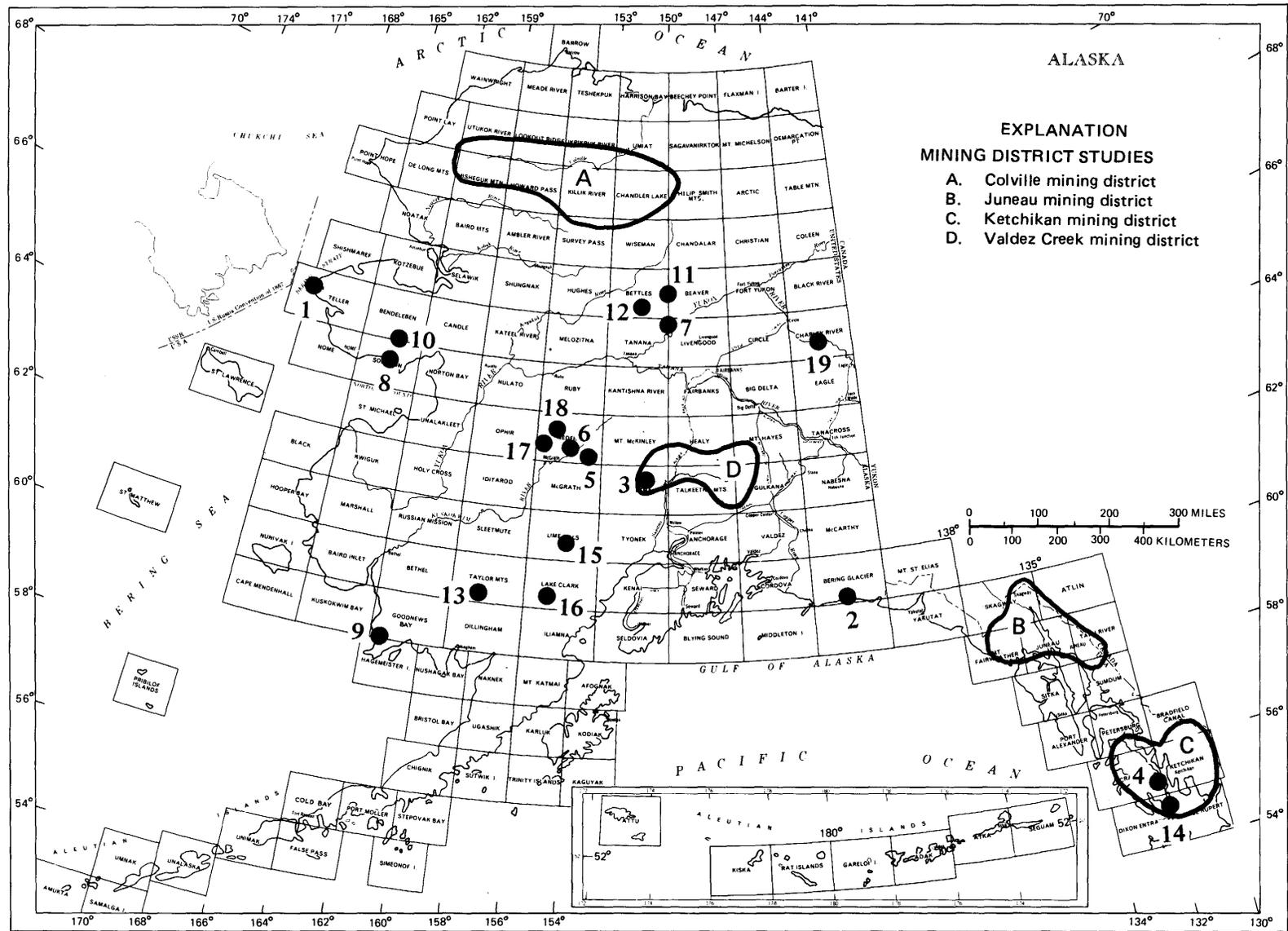


Figure 19. Locations of 1990 USBM mining district studies (A,B,C,D) and studies of strategic and critical minerals (1-19) listed in table 8. 1:250,000-scale quadrangles are outlined and labeled.

Table 8. Areas of U.S. Bureau of Mines activity in mining districts and at strategic and critical mineral localities in 1990

[Locations shown on figure 19. REE, rare-earth elements; PGM, platinum-group metals]

Mining districts	
Study area	Deposits of major interest
A. Colville mining district -----	Lead, zinc, barite, phosphate, coal
B. Juneau mining district -----	Placer and lode gold, volcanogenic and sediment-hosted massive sulfide, molybdenum porphyry
C. Ketchikan mining district ----	Placer and lode gold, massive sulfide, chromium, PGM
D. Valdez Creek mining district-	Placer and lode gold, massive sulfide, tin, chromium, PGM
Strategic and critical minerals	
Study area	Elements of interest
1. Cape Prince of Wales -----	Sn, REE, Ti
2. Cape Yakataga -----	Au, PGM
3. Coal Creek -----	Sn
4. Dora Bay -----	REE
5. East Fork Hills -----	Mn
6. Egries Prospect -----	Mn
7. Five Mile area -----	W, Ga, Ge
8. Golovin Bay -----	REE
9. Goodnews Bay -----	PGM
10. Kauchaiuk -----	REE
11. Ray River -----	Sn, REE
12. Sithylenkat -----	Sn, W
13. Sleitat Mountain -----	Sn, W
14. Stone Rock Bay -----	REE
15. Tired Pup Creek -----	REE
16. VABM Black -----	Sn
17. Win prospect -----	Sn, Nb, Ag
18. Won prospect -----	Sn, Ag
19. Yukon River -----	V

mining district. Work encompassed rock and stream-sediment geochemistry and the detailed examination of 176 known mineral occurrences. The USBM collected and analyzed 1,632 rock and 781 placer samples and tested 7 bulk samples for beneficiation characteristics. Reports were published on geochemical sampling results (Balén, 1990a), gold- and PGM-bearing conglomerates (Fechner and Herzog, 1990; Herzog, 1990), industrial minerals (Southworth, 1990), and overall mining feasibility in the district (Balén, 1990b). They are listed in appendix 1, USBM section. The ADGGS completed a composite geologic map and mineral-

resource assessment of the district for inclusion in the executive summary, the draft of which will be published in 1991.

The USBM located 19 new mineral occurrences within the Valdez Creek mining district. Reconnaissance sampling identified 10 gold placers, some with subsidiary PGM and/or tin, and nine lode occurrences (two gold-silver, three PGM with chromium, nickel, and (or) cobalt, three copper, and one zinc). The potential for additional mineral location in the district is high: geologic conditions are favorable, and the district's rugged terrain has left many remote areas yet to be explored.

A probabilistic mineral resource and economic assessment conducted jointly by the USBM and ADGGS found that the bulk of development potential, excepting placer gold, lies in plutonic-related deposits such as skarns, vein-replacements, porphyry types, and ultramafic-hosted. This assessment partly reflects the quantity and variety of intrusive igneous rocks found in the district, as well as the variety of large plutonic-related deposits known to exist. Much of this endowment is highly speculative, however, since so little is known about the plutonic rocks in the district. The assessment results will be published as an open-file report in 1991. A second assessment by the USBM investigated the economic mining feasibility for eight mineral deposit models, based on real and hypothetical deposits that occur within the district (Balén, 1990). Results of the study were inconclusive but could be used in a preliminary manner to evaluate the mining potential of real mineral prospects that are similar to the models.

Colville.—The Colville mining district is located in northern Alaska and includes the southern part of the NPRA. A minerals study of the area was requested by the BLM for the district's Land Management Plan. Access is currently restricted for much of the public land in the district, but this could change with legislative action. An original inventory in 1977 and 1978 by the USBM (site-specific) and USGS (regional) had already identified coal resources and areas of zinc-lead-silver mineralization, as well as rocks with high fluorine, phosphate, rare-earth elements (REE), barium, vanadium, and chromium contents. The present study is aimed at discovering additional resources and evaluating the development potential of all deposits in the mining district.

A joint team of USBM, USGS, BLM, and ADGGS personnel conducted a geologic reconnaissance of the southern Colville mining district in the summer of 1990. Nine mineralized locations were visited, and source rocks were located for three previously identified geochemical anomalies. A pyritized conglomerate east of Kivliktort Mountain contained 44 percent zinc; a breccia west of Kivliktort Mountain contained up to 6 oz/ton silver, 31.5 percent zinc, and 2.76 percent lead; and a mineralized zone west of Koiyaktot Mountain contained up to 7.48 oz/ton silver, 49.91 percent zinc, and 1.55 percent lead.

Through field studies, deposit modeling, and beneficiation and metallurgical testing, the USBM is conducting site-specific investigations to locate, characterize, and quantify deposits that contain strategic and critical minerals and advanced materials. The USBM has investigated occurrences of chromium, cobalt, gallium, germanium, indium, manganese, niobium, PGM, REE, tantalum, tin, vanadium, yttrium, and zirconium at nearly 300 sites in Alaska.

Reconnaissance work was done at several localities in 1990 to identify future projects (fig. 19; table 8). On the Seward Peninsula, beach sands at Golovin and nearby radioactive dikes in the Kachauik Mountains were evaluated for REE and zirconium contents. In the Cape Prince of Wales area, marine placer deposits were investigated for titanium-bearing ilmenite and accessory REE-, tin-, tungsten-, and zirconium-bearing minerals. Forty-five core samples were collected from the sea floor. The University of Mississippi Marine Minerals Technology Center, Continental Shelf Division, provided most of the funding for this project.

In central Alaska, four sites were visited. The Egries sedimentary occurrence near Medfra was examined, as well as manganese-bearing sedimentary rocks in the nearby East Fork Hills. Reported grades of 22 percent manganese at the Egries occurrence were confirmed. A deposit characterization project studied the germanium-tungsten mineralization at the Five Mile project area. Drilling was recommended on the basis of the findings. An examination of the oil shales and phosphatic shales along the Yukon River near Eagle successfully identified vanadium-bearing shale beds containing about 0.5 percent vanadium oxide together with uranium and phosphates. One of the previous USBM investigations in the eastern and central Alaska Range concentrated on possible PGM potential near Chistochina (Foley and Summers, 1990). Although significant deposits have yet to be found in the Alaska Range, impressive copper-nickel-PGM mineralization has been discovered in similar rocks in Canada at Welgreen, Yukon, 50 miles east of the Alaska border.

Four areas of onshore marine placers were identified and mapped in the Cape Yakataga area by a team of USBM personnel from Alaska and the Albany Research Center, and personnel from the University of Mississippi Marine Minerals Technology Center. The placer sands contain gold and garnet, with minor PGM-, REE-, titanium-, and zirconium-bearing minerals. The principal resource potential appears to lie offshore. Sample reduction and analyses will be conducted in 1991.

In southeastern Alaska, REE deposits near Dora Bay on Prince of Wales Island are similar to those at Bokan Mountain, but are unique in their significant concentrations of heavy REE's and yttrium (Barker and Mardock, 1990). Investigations were also completed in the Stone Rock Bay area where REE and copper mineralization occurs as irreg-

ular masses of radioactive phosphatic carbonate rock resembling carbonatite; REE-oxide contents are 1-4 percent.

Much attention was given in 1990 to tin deposits, which may also contain niobium, REE, and tungsten by-products. Most of the tin deposits in Alaska occur on land available for exploration and development, and are located near water or road access. USBM tin investigations are nearing completion at the Coal Creek, Ray River, Sithylenkat Lake, Sleitat Mountain, Win, and Won prospects.

Research Activities

Bulk samples of strategic and critical mineral deposits from Cape Yakataga and Stone Rock Bay have been sent to the USBM research centers in Albany, Oregon, and Salt Lake City, Utah, to characterize their mineralization and to determine the best beneficiation techniques for recovery of the economic minerals. The Twin Cities Research Center in Minnesota investigated the feasibility of in-situ mining of Alaska's deep placer deposits.

An investigation of placer mining operations in the Soviet Far East was conducted in 1989 (Barker and Skudrzyk, 1990). Soviet methods were evaluated and compared with placer mining technology used in Alaska; results were presented at the Twelfth Annual Alaskan Conference on Placer Mining in Fairbanks (Barker, 1990). These two papers are listed in appendix 1, USBM section. Similar presentations were also given at the Western Gold Show in San Francisco, the Canadian Whitehorse Geoscience Forum, and at the Spokane Research Center. The final report is in preparation.

The USBM and the University of Alaska at Fairbanks (UAF) hosted a delegation of four mining specialists from the Soviet Union's All Union Institute of Gold and Rare Metals Research (VNII-1). Mining operations near Nome, Fairbanks, Circle, Healy, and Valdez Creek were visited. At the conclusion of the tour, VNII-1 and the UAF School of Mineral Engineering proposed a one-year exchange of research specialists. Of specific interest to UAF was the application of Soviet underground placer technology to deeply buried Alaskan placers. Areas of Soviet interest include improved blasting technology for arctic conditions, computer-assisted mine ventilation systems, and reclamation practice in arctic environments, including control of toxic metals.

Researchers from the Spokane Research Center continued their program to develop technology for underground mining of deep placers. Work included physical property tests on samples from the Valdez Creek placer gold mine, numeric modeling of alternative mining methods, and initial tests of soil samples from the Goodnews Bay placer platinum deposit. A second project is studying mine closure in arctic and subarctic environments, examining issues such as reclamation, revegetation, slope stability,

ground-water quality, long-term monitoring of mine sites, bonding, and environmental liability.

The USBM Mineral Institute program supports several projects at the UAF School of Mineral Engineering. This program receives 2:1 matching funds from the State of Alaska and the USBM that are used for various faculty and graduate student projects, scholarships, and other appropriate mineral industry activities. One such project entailed the field testing of electrical thawing probes to be used in the mining of permafrost placer gravels. The USBM also continues to support the operation of the ACE Cold Regions Research and Engineering Laboratory permafrost tunnel near Fox. Support funds routine maintenance of the facility and is shared equally with the ACE and UAF.

Finally, the USBM closed its Alaska Technology Transfer Office in Anchorage.

Bureau of Land Management

In 1990, there were filings/recordings of a total of 29,566 Federal mining claims in Alaska. The total number of active mining operations on BLM-administered lands included 133 Notices (5 acres or less total surface disturbance) and 111 Plans of Operations (greater than 5 acres of total surface disturbance). Seven mineral patents for 56 claims conveying 1,204 acres into private ownership were issued by the BLM during fiscal year 1990. Additionally, patent of one mining claim was denied for insufficient title evidence and lack of diligence on the part of the applicant. Decisions were issued that resulted in the closure of 8,480 claims.

Work continued on an automated minerals data base for BLM lands containing BLM-generated mineral-potential information, minerals data (well, seismic, and other), and a minerals bibliography. At the Fifth Circum-Pacific Energy and Mineral Resources Conference in Hawaii, technical papers were presented on the mineral resources of western Arctic Alaska, the Red Dog deposit, and PGM relationships in mafic-ultramafic rocks in northwest Alaska (Mowatt and others, 1990a, 1990c; Mowatt and Mowatt, 1990b). These papers are listed in appendix 1, BLM section.

Fish and Wildlife Service

In keeping with its primary mission, efforts of the FWS relating to mineral activity emphasize fish, wildlife, and habitat protection on refuge lands. Mining is not always compatible with these goals. However, in areas where mining claims were located before the refuge was established, claims may remain "active." By the end of 1990, the number of active mining claims on refuge lands (fig. 3) had been reduced from 123 claims on eight refuges in 1989 to 69 claims on four refuges: Alaska Peninsula (55 claims), Arctic (9 claims), Becharof (1 claim), and Tetlin (4 claims).

For northern Alaska, reviews and comments were provided by the FWS to the ACE on 16 applications for permits or permit modifications for placer mining, mineral assessment, gold dredging, and Cominco's Red Dog zinc-lead mine.

In south-central Alaska, the FWS reviewed operations at the largest placer mine in the State, the Valdez Creek mine near the Denali Highway. Reviews were also conducted at the Bear Creek/Tuluksak River area in the Yukon Delta Refuge and at the Salmon River on the Togiak Refuge. These mines were evaluated relative to resident fish bypass facilities, Section 404 CWA permits, and environmental assessments. Three reports on placer mining impacts on refuges were completed (Crayton, 1990; Jackson, 1990a, 1990b). These reports are listed in appendix 1, FWS section.

Several mining proposals in southeast Alaska continue to involve the FWS. Until the EPA denied the Section 402 NPDES permit application for the Quartz Hill molybdenum mine proposed in the Misty Fjords National Monument east of Ketchikan, the FWS had provided informal input to the USFS regarding mitigation plans and monitoring studies. The FWS has been involved, as applicable, in predevelopment consultation on studies, proposals, EIS's, water quality, and toxic waste issues for the A-J gold mine in Juneau, the Kensington and Jualin gold mines north of Juneau, and the Windy Craggy copper mine northwest of Haines. Although the Windy Craggy deposit is in Canada, its development will produce downstream repercussions in Alaska.

The FWS initiated or continued several studies of contaminants and the effects of mining in wildlife refuges. These included data summaries of previous baseline contaminant studies, conducted from 1985 to 1989, of river water, sediment, and fish from the Kanuti, Koyukuk, Nowitna, Selawik, Tetlin, and Yukon Flats Refuges. These data will be used to identify potential impacts of placer mining. Study proposals were developed and reviewed for further investigations of mercury and other trace-metal contamination in the Koyukuk, Nowitna, and Yukon Flats Refuges. As part of a continuing study of elevated mercury concentrations found in certain fish in the Kanuti Refuge in 1985-89 studies, tissues from sculpin, wolf, and marten were collected. Water-quality data were collected from Upper Braided Creek in the Alaska Peninsula Refuge for use in evaluating impacts of planned mining operations in that area. Preparatory to cleaning up two old placer mines on the Yukon Delta Refuge, the waste oil and materials from drums left at those sites were analyzed.

On non-refuge lands, sediment and vegetation samples were collected for metals analysis from placer mining settling ponds and gravel pits in order to evaluate strategies for settling-pond rehabilitation. A fish kill in Fish Creek downstream of placer mining near Tanana was investigated. The FWS assisted the Alaska Department of Fish and Game in the investigation of contaminant problems at the Red Dog mine and reviewed WestGold's draft annual report for

1989 studies associated with NPDES/State contaminant-monitoring requirements for gold dredging near Nome.

The FWS worked to finalize reports on previous studies of trace metals in shallow Arctic marine sediments contaminated by drilling effluents and on waterfowl contamination at Prudhoe Bay.

Minerals Management Service

OCS Mining Program, Norton Sound Lease Sale

The MMS has scheduled a competitive OCS mineral lease sale in Norton Sound for areas south and southeast of Nome (fig. 15). The sale focuses on gold-bearing placer deposits at or near the sea floor in Federal waters at depths ranging from 60 to 100 feet. The proposed sale includes an area of 147,050 acres that extends up to 10 miles seaward of the State of Alaska's 3-mile coastal water limit. Preliminary studies indicate that the sale area could yield as much as 1,060,000 oz gold, although expected production is estimated at 530,000 oz.

Industry responses to a Request for Comments and Nominations in March 1988 revealed that sufficient interest existed to justify proceeding with an offshore gold sale. Onshore mining of stream and beach placers near Nome has occurred intermittently since the first gold discoveries in 1899. Since that time, miners have recovered 4.5 million oz gold from the Nome mining district and over 6 million oz total from the Seward Peninsula. For the past 5 years, Westgold used the floating dredge *Bima* to mine 21,750 acres of mineral leases in State of Alaska waters landward of the proposed sale area, extracting approximately 130,000 oz gold during that time. However, at the end of the 1990 season, Westgold ceased production, citing high operating costs, and put the *Bima* up for sale.

National Park Service

The NPS Alaska Regional Office, Minerals Management Division, is organized into two branches: Resource Assessment, and Mining and Minerals. Personnel from both branches review mining plans of operations and evaluate available natural, cultural, physical resource, and engineering information on areas subject to mineral-related operations. They also conduct claim validity examinations and develop and implement long-term reclamation programs. In addition to the Regional Office in Anchorage, the Denali and Wrangell-St. Elias National Parks and Preserves have professional minerals-management staffs of environmental specialists and geologists who implement park-specific aspects of the minerals management programs. Major accomplishments during 1990 are detailed below.

1. During 1990, the NPS continued to operate under

the court-ordered injunction that suspended mining operations in, and required EIS's for, Denali National Park and Preserve, Wrangell-St. Elias National Park and Preserve, and Yukon-Charley Rivers National Preserve. In these three areas, mining operations could proceed only if court-approved. For all other National Park System units in Alaska, mining plans of operations could still be submitted and approved by the NPS if all regulatory requirements were met, including the completion of environmental assessments and a finding of no significant impact. In May 1990, FEIS's for the three parks under injunction were released to the public; in August, copies of the FEIS's were filed with the U.S. District Court. In its Record of Decision on January 2, 1991, the court dissolved the injunction and approved the NPS recommendation to acquire all patented and valid unpatented mining claims in these units on a "willing seller" basis (fig. 20). Pending acquisition, the NPS will continue to process complete plans of operations for mining activities under the existing regulations.

In fiscal year 1991, Congress approved \$6 million to begin the purchase of mining claims in Denali National Park and Preserve. Claims in the Kantishna mining area will be purchased from willing sellers during 1991. Negotiations with one claimant were nearing completion at the end of 1990.

2. The provisions of Section 1010(b) of ANILCA require that regulations be promulgated under which Federal agencies would conduct their AMRAP activities in units of the National Park System. During 1990, an interagency working group was formed to address the issue; the group was coordinated by the DOI Office of Program Analysis and included representatives from the NPS, BLM, FWS, MMS, USBM, and USGS. The draft regulations were written at 36 CFR Part 9, Subpart D, to apply only to AMRAP activities in National Park System units in Alaska. At year end, the regulations were being reviewed at the departmental level, and an environmental assessment for the regulations was being prepared.

3. Mineral examinations for claim validity determinations were made on 17 placer and 17 lode claims in Denali National Park and Preserve.

4. Black and white and color aerial photography was done in the Kantishna area of Denali National Park and Preserve and in the Kennicott area of Wrangell-St. Elias National Park and Preserve. Surveying of 25 mining claims in Denali was completed.

5. The NPS received six plans of operations for proposed mining activities during the 1990 mining season in Denali National Park and Preserve, Kenai Fjords National Park, and Wrangell-St. Elias National Park and Preserve. After processing and review, including NPS preparation of environmental assessments, one plan in Wrangell-St. Elias was determined to be complete and received approval for the season. One permit for access to a mining claim in Yukon-Charley Rivers National Preserve was issued. Two

operations, one each in Bering Land Bridge National Preserve and Wrangell-St. Elias National Park and Preserve, continued mining under previously approved plans.

6. Work continued on the Glen Creek Reclamation Project for a former placer mining site in Denali National Park and Preserve. This project aims to restore Glen Creek and its floodplain to a more natural state and to assist in the revegetation of the site. After site preparation of 27 acres in 1988, native plants from park sources were planted in the reclaimed area in 1989. Revegetation experiments initiated in this area in 1990 are providing data to determine the types of former mining sites and tailings that will revegetate naturally. Transplanted alder seedlings thrive on sites that fail to regenerate of their own accord.

7. The Alaska Region has instituted an Abandoned Mineral Lands (AML) program that documents features on or associated with former mining operations in the parks. Program objectives are to eliminate and/or mitigate safety hazards and to preserve any significant natural and cultural resource values. In 1990, 12 AML site inventories were completed in Denali and Wrangell-St. Elias National Parks and Preserves. A total of 8 tons of mining-related debris was removed from the Peavine Bar site in Wrangell-St. Elias Park.

8. The Cultural Resources Division of the NPS continued to ensure that all mineral-related activities were ac-

complished under the mandates of the National Historic Preservation Act. Multidisciplinary cultural-resource field crews conducted intensive ground surveys in four park units. Five historic mining sites were documented under the Alaska Region's AML program.

U.S. Forest Service

Tongass National Forest

Management Plan.—The revised Tongass Land Management Plan (TLMP) contains a prescription for minerals management, the first time such a treatment has been used in the National Forest planning process. Controversy over the prescription has erupted between the mining industry, which, while generally supportive of the prescription, believes that it was too narrowly applied, and environmental groups, which contend that it amounted to a land “give-away” to the mining industry.

The Tongass Timber Reform Act (TTRA), PL 101-626, created an additional 296,080 acres of wilderness in the Tongass National Forest, bringing total wilderness acreage there to 5,693,246 acres. Following passage of the TTRA, 63 percent of the Tongass National Forest is now open to mineral entry. Due to new policies set forth in the



Figure 20. North-looking view of mining claims in Kantishna area of Denali National Park and Preserve that are proposed for acquisition by National Park Service. Photograph by D. Schramm.

TTRA, it was decided to prepare a TLMP supplement, which should be published in September 1991.

Greens Creek.—The Greens Creek mine, the largest producing silver mine in the United States, is located in the Admiralty Island National Monument, administered by the Tongass National Forest. Discovered in 1974, the original eight "core" claims were staked that year, and the deposit was first drilled in 1975. The mine's development and production is authorized under ANILCA Section 503(f)(2)(A); the USFS completed a Mine Development EIS for the project in January 1983. Under the provisions of ANILCA Section 503(e)(1), USFS mineral examiners evaluated nine new mining claims in 1987, notifying the Greens Creek Mining Company in September 1988 that the claims were valid, thus increasing the viable ore reserves of the mine. The mine was aggressively developed, and production began in February 1989. In March 1990, based on the projected geometry of the deposit, Kennecott Greens Creek Mining claimed extralateral rights under the provisions of the 1872 General Mining Law. Extralateral rights allow the company to pursue development of the downward extent of the ore body beyond the vertical boundaries of the valid mining claims. The USFS evaluated the company's assertion and recognized the company's case for extralateral rights in May 1990. This is one of the few modern-day applications of extralateral rights to a working mine.

Quartz Hill.—U.S. Borax and Chemical Corporation's Quartz Hill molybdenum deposit is in the Misty Fjords National Monument, on a 152,000-acre tract that is excluded from designation as wilderness. Evaluation and development of the deposit is authorized under ANILCA Section 503(f)(2)(A). The USFS completed the Mine Development FEIS for Quartz Hill in October 1988. The two sites considered in the FEIS for marine tailings disposal were the Boca de Quadra fjord and the Wilson Arm/Smeaton Bay fjord. In his Record of Decision, the Alaska Regional Forester concluded that, environmental impacts being almost equal, tailings disposal in the Wilson Arm offered distinct economic advantages. The EPA, a cooperator in the preparation of the FEIS, issued a draft discharge permit for Wilson Arm in November 1988.

The Sierra Club Legal Defense Fund (SCLDF) appealed the USFS decision on behalf of several environmental and commercial fishing organizations, contending that economics should not have been an element of the Regional Forester's decision due to the environmental sensitivity of Misty Fjords National Monument. On January 11, 1990, the Regional Forester reaffirmed his decision, noting that Congress specifically directed the USFS to consider the effect of mitigation measures on the economic viability of the project. However, in May 1990, citing SCLDF information and other reasons, the EPA reversed itself and announced plans to deny the disposal permit. In September 1990, the EPA, with the concurrence of the State of Alaska, issued a final decision to deny the discharge permit for Wilson Arm.

As a consequence of this action, U.S. Borax and Chemical Corporation has suspended further permitting activities on the Quartz Hill project.

Other.—There is a considerable amount of exploration and development activity in the Juneau Gold Belt of the Tongass National Forest. Many of these activities are regulated by the USFS through required plans of operations. The Juneau Ranger District is presently preparing a Mine Development EIS for the Kensington gold project (fig. 21). The USFS also conducted a mineral patent examination on the Kasaan Peninsula near Ketchikan.

Chugach National Forest

The USFS conducted a mineral patent examination near Moose Pass on the Kenai Peninsula. The results of the examination will be forwarded to the BLM, which will then decide if the patent should be granted.

The USFS completed a three-year study of the cumulative effects of placer mining on water quality in the Chugach National Forest. Stream sampling was based on the type and intensity of mining occurring on a given drainage system. Weekly samples were taken above and below the mine sites and tested for pH, alkalinity, conductivity, total suspended solids, and turbidity. A report will be prepared by the end of the summer of 1991; no significant impacts have been noted at this time.

The Chugach National Forest is also being inventoried by the USBM for environmental and safety hazards that may have resulted from past mining activities. For this investigation, the USFS is providing field and technical assistance to the USBM through a partnership agreement. The inventory began in 1990 on the Kenai Peninsula and will be extended into the Prince William Sound area for the 1991 field season. The USBM will prepare a report that includes the type and severity of identified hazards as well as recommended mitigation measures.

In 1992, the USGS and USBM will be conducting minerals investigations in the upper regions of Unakwik Inlet and College Fjord and in an area between the Copper River Delta and the Tasnuna River. The resultant information on mineral potential will be used to update the minerals inventory for the Chugach National Forest.

Industrial Minerals

The use of nonmetallic, nonfuel resources in Alaska recovered only slightly from 1989 levels; this reflects the continuing lack of significant urban and industrial construction (Swainbank and others, 1991). Sand and gravel production was up 5 percent to 15.1 million tons, and building stone production rose 10 percent to 3.2 million tons (table 6). Jade and soapstone production figures were not available for 1990.

As reported last year (Schneider, 1990), Alaskan gla-

cier ice has become an exportable commodity for its status symbol quality when used in exotic drinks. Enough companies have expressed interest in the trade that the Alaska Department of Natural Resources has had to establish regulations for the ice harvest (Anchorage Daily News, April 22, 1990). Because most harvesting has occurred in Prince William Sound and the bays of Kenai Fjords National Park, the regulations are in response to environmental concerns over the impacts of increased marine traffic in these waters (Fairbanks Daily News-Miner, August 6, 1990). Twenty-one temporary permits have been issued to eight harvesters; the State is waiting to learn more about the developing market, which is mainly represented by Japan and Hawaii (Anchorage Daily News, December 23, 1990).

Activity by Federal Agencies

U.S. Bureau of Mines

A published USBM investigation concluded that the Valdez Creek mining district may contain economic quanti-

ties of industrial materials such as argillite, basalt, intrusive rock, limestone, perlite, sand and gravel, and zeolites (Southworth, 1990). A USBM Special Publication also summarized the industrial minerals of the Juneau mining district (Maas, 1990). Both reports are listed in appendix 1, USBM section.

Bureau of Land Management

The disposal of salable mineral materials, namely sand and gravel, continued to be a minor activity for the BLM in Alaska.

Fish and Wildlife Service

The FWS continued to review, permit, and monitor small sand and gravel operations in various parts of the State to support local transportation and industry. Minor amounts of gravel were removed from three sites in the Izembek Refuge.



Figure 21. New adit for Kensington lode-gold mine on Lynn Canal in Tongass National Forest. From 1897 to 1904, 12,000 tons of ore was mined from surface and shallow workings. The USFS is preparing an environmental impact statement for the mine's current development by Echo Bay Mines and Coeur d'Alene Mines. Photograph by R. Griffin.

Annually, the USFS permits the removal of many thousands of tons of sand, gravel, and stone. Nearly 2.8 million tons of this material, in the form of quarried stone, is used in the construction of timber-sale roads. Lesser amounts are used by State and local governments for the construction and maintenance of breakwaters, airports, and roads.

REFERENCES CITED

- Affolter, R.H., and Stricker, G.D., 1987, Variations in element distribution of coal from the Usibelli mine, Healy, Alaska, *in* Rao, P.D., ed., Focus on Alaska's Coal '86, Conference proceedings: University of Alaska at Fairbanks, Mineral Industry Research Laboratory Report 72, p. 91-99.
- Alaska Department of Natural Resources, 1986, Oil and gas resources of Alaska: Alaska Division of Geological and Geophysical Surveys Information Circular 31, 9 p.
- , 1990, Alaska's high rank coals: Alaska Division of Geological and Geophysical Surveys Information Circular 33, 36 p.
- Alaska Journal of Commerce [published weekly by OCA Publishing, 3710 Woodland Drive, Suite 2100, Anchorage, AK 99517].
- Alaska Miner [published monthly by Alaska Miners Association, 501 West Northern Lights Boulevard, Suite 203, Anchorage, AK 99503].
- Alaska Oil and Gas Conservation Commission Bulletin [published monthly by the State of Alaska, Alaska Oil and Gas Conservation Commission, 3001 Porcupine Drive, Anchorage, AK 99501].
- Alaska Report [published weekly by Petroleum Information Corporation, P.O. Box 102278, Anchorage, AK 99510].
- American Association of Petroleum Geologists, 1990, Annual Meeting, San Francisco, California, June 1990, Technical Program Summary and Abstracts: American Association of Petroleum Geologists Bulletin, v. 74, no. 5, p. 575-797.
- Anchorage Daily News [published daily by Anchorage Daily News Incorporated, 1001 Northway Drive, Anchorage, AK 99508].
- Anchorage Times [published daily by Anchorage Times Publishing Company, 820 West Fourth Avenue, Anchorage, AK 99501].
- Balen, M.D., 1990, The feasibility of mining in the Valdez Creek mining district, Alaska: U.S. Bureau of Mines Open-File Report 40-90, 58 p.
- Barker, J.C., and Mardock, C., 1990, Rare-earth element- and yttrium-bearing pegmatite dikes near Dora Bay, southern Prince of Wales Island: U.S. Bureau of Mines Open-File Report 19-90, 41 p.
- Brew, D.A., Drew, L.J., Schmidt, J.M., Root, D.H., and Huber, D.F., 1991, Undiscovered locatable mineral resources of the Tongass National Forest and adjacent areas, southeastern Alaska: U.S. Geological Survey Open-File Report 91-10, 73 p., 16 maps, scales 1:250,000 and 1:500,000.
- Carlson, P.R., and Reimnitz, Erk, eds., 1990, Bottom sediment along oil spill trajectory in Prince William Sound and along Kenai Peninsula, Alaska: U.S. Geological Survey Open-File Report 90-39, 102 p.
- Carter, L.M.H., ed., 1990, USGS research on energy resources, 1990—Sixth annual V.E. McKelvey forum on mineral and energy resources, program and abstracts: U.S. Geological Survey Circular 1060, 99 p.
- Chenowith, W.E., 1990, Developments in uranium in 1990: American Association of Petroleum Geologists Bulletin, v. 74, no. 10B, p. 380-386.
- Clough, N.K., Patton, P.C., and Christiansen, A.C., eds., 1987, Arctic National Wildlife Refuge, Alaska, coastal plain resource assessment—Report and recommendation to the Congress of the United States and final legislative environmental impact statement: Washington, DC, U.S. Fish and Wildlife Service, U.S. Geological Survey, and Bureau of Land Management, 2 v., 208 p.
- Collett, T.S., Bird, K.J., Kvenvolden, K.A., and Magoon, L.B., 1989, The origin of natural gas-hydrates on the North Slope of Alaska, *in* Dover, J.H., and Galloway, J.P., eds., Geologic studies in Alaska by the U.S. Geological Survey, 1988: U.S. Geological Survey Bulletin 1903, p. 3-9.
- Cooke, L.W., 1985, Estimates of undiscovered, economically recoverable oil and gas resources for the Outer Continental Shelf as of July 1984: Minerals Management Service OCS Report, MMS 85-0012, 45 p.
- Dolton, G.L., Carlson, K.H., Charpentier, R.R., Coury, A.B., Crovelli, R.A., Frezon, S.E., Khan, A.S., Lister, J.H., McMullin, R.H., Pike, R.S., Powers, R.B., Scott, E.W., and Varnes, K.L., 1981, Estimates of undiscovered recoverable conventional resources of oil and gas in the United States: U.S. Geological Survey Circular 860, 87 p.
- Fairbanks Daily News-Miner [published six days a week by the Fairbanks Publishing Company, 200 North Cushman, Fairbanks, AK 99701].
- Foley, J.Y., and Summers, C.A., 1990, Source and bedrock distribution of gold and platinum-group metals in the Slate Creek area, northern Chistochina mining district, east-central Alaska: U.S. Bureau of Mines Open-File Report 14-90, 49 p.
- Geological Association of Canada, 1990, Vancouver '90: Annual Meeting, Geological Association of Canada, Program with Abstracts, v. 15, 236 p.
- Harris, A.G., Lane, H.R., Tailleir, I.L., and Ellersieck, Inyo, 1987, Conodont thermal maturation patterns in Paleozoic and Triassic rocks, northern Alaska—Geologic and exploration implications, *in* Tailleir, Irv, and Weimer, Paul, eds., Alaska North Slope geology: Pacific section meeting, Society for Sedimentary Geology (SEPM), Bakersfield, California, June 1985, and Alaska Geological Society, SEPM Book 50, v. 1, p. 181-191.
- Herzog, D.A., 1990, Cyanide leach technology and its applicability to Alaskan conditions: U.S. Bureau of Mines Open-File Report 39-90, 31 p.
- Howell, D.G., Bird, K.J., Lu, H., and Johnsson, M.J., 1991a, Tectonics and petroleum potential of the Brooks Range fold-and-thrust belt—A progress report, *in* Bradley, D.W., and Ford, A.B., eds., Geologic studies in Alaska by the U.S. Geological Survey, 1990: U.S. Geological Survey Bulletin 1999, p. 112-126.
- Howell, D.G., Johnsson, M.J., and Bird, K.J., 1991b, Solid bitumen at Atigun Gorge, central Brooks Range front—Implications for oil exploration in the North Slope fold and thrust belt [abs.]: American Association of Petroleum Geologists Bulletin, v. 75, no. 3, p. 598.
- Howell, D.G., Johnsson, M.J., Underwood, M.B., Lu, H., and Hillhouse, J.W., 1991c, Tectonic evolution of the Kandik region, east-central Alaska—Preliminary interpretations, *in* Bradley, D.C., and Ford, A.B., eds., Geologic studies in Alaska by the U.S.

- Geological Survey during 1990: U.S. Geological Survey Bulletin 1999 p. 127-140.
- Hubbard, R.J., Edrich, S.P., and Rattey, R.P., 1987, Geologic evolution and hydrocarbon habitat of the "Arctic Alaska microplate," *in* Tailleir, Irv, and Weimer, Paul, eds., Alaska North Slope geology: Pacific section meeting, Society for Sedimentary Geology (SEPM), Bakersfield, California, June 1985, and Alaska Geological Society, SEPM Book 50, v. 2, p. 797-830.
- Jackson, R., 1991, Becharof National Wildlife Refuge contaminants study—Report of findings: Anchorage, Alaska, U.S. Fish and Wildlife Service, Ecological Services, 21 p.
- Kirschner, C.E., 1988, Map showing sedimentary basins of onshore and continental shelf areas, Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map I-1873, 1 sheet, scale 1:2,500,000.
- Krason, J., and Finley, P., 1989, Basin analysis, formation, and stability of gas hydrates in the Beaufort Sea, v. 12 of Geological evolution and analysis of confirmed or suspected gas hydrate localities: Department of Energy/Morgantown Energy Technology Center, 227 p.
- Leonard, K.R., and Huber, D.F., 1987, Status of Alaska Mineral Resources Data System, *in* Hamilton, T.D., and Galloway, J.P., eds., Geologic studies in Alaska by the U.S. Geological Survey during 1986: U.S. Geological Survey Circular 998, p. 15-18.
- Magoon, L.B., ed., 1990a, The petroleum systems—Status of research and methods, 1990: U.S. Geological Survey Bulletin 1912, 88 p.
- 1990b, The geology of known oil and gas resources by petroleum system—onshore Alaska, *in* Plafker, George, Jones, D.L., and Berg, H.C., eds., Geology of Alaska, v. G-1 of Geology of North America: Boulder, Colorado, Geological Society of America, Decade of North American Geology series [in press].
- Mast, R.F., Dolton, G.L., Crovelli, R.A., Root, D.H., and Attanasi, E.D., U.S. Geological Survey; Martin, P.E., Cooke, L.W., Carpenter, G.B., Pecora, W.C., and Rose, M.B., Minerals Management Service; 1989, Estimates of undiscovered conventional oil and gas resources in the United States—A part of the Nation's energy endowment: U.S. Department of the Interior, 44 p.
- Mineral Alerts [published weekly by the U.S. Bureau of Mines, Washington, DC].
- Minerals and Materials [published bimonthly by the U.S. Bureau of Mines, Washington, DC].
- Minerals Management Service, 1990, Resource estimates for the Alaskan outer continental shelf: Minerals Management Service, Alaska OCS Region, Focus sheet, May 1990, 2 p.
- Miner's News [published six times a year by Graphic One, Incorporated, P.O. Box 5694, Boise, ID 83795].
- Mining Journal [published weekly by The Mining Journal Limited, P.O. Box 10, Edenbridge, Kent TN8 5NE, England].
- Molenaar, C.M., Egbert, R.M., and Krystinik, L.F., 1988, Depositional facies, petrography, and reservoir potential of the Fortress Mountain Formation (Lower Cretaceous), central North Slope, Alaska, *in* Gryc, George, ed., Geology and exploration of the National Petroleum Reserve in Alaska: U.S. Geological Survey Professional Paper 1399, p. 257-280.
- Morgantown Energy Technology Center, 1987, Gas hydrates technology status report: DOE/METC-87/0246 (NTIS/DE87001027), 25 p.
- Northern Miner [published weekly by Northern Miner Press Limited, 7 Labatt Avenue, Toronto, ON M5A 3P2, Canada].
- O'Sullivan, P.B., 1988, Apatite fission-track study of the thermal history of Permian to Tertiary sedimentary rocks in the Arctic National Wildlife Refuge, northeastern Alaska: Alaska Division of Geological and Geophysical Surveys Public-Data File 88-42, 184 p.
- 1989, Thermal history of Mississippian to Tertiary sedimentary rocks of the North Slope, Alaska, using apatite fission-track analysis: Alaska Division of Geological and Geophysical Surveys Public-Data File 89-2F, 130 p.
- Patton, W.W., Jr., and Tailleir, I.L., 1964, Geology of the Killik-Itkillik region, Alaska: U.S. Geological Survey Professional Paper 303-G, 92 p.
- Rapp, J.B., Hostettler, F.D., and Kvenvolden, K.A., 1990, Comparison of Exxon Valdez oil with extractable material from deep-water bottom sediment in Prince William Sound and the Gulf of Alaska: U.S. Geological Survey Open-File Report 90-39-B, 26 p.
- Rintoul, Bill, 1991, Alaska drilling/production: Pacific Oil World, v. 83, no. 1, p. 40-46.
- Roberts, S.B., 1991, Cross-section showing subsurface coal beds in the Sagavanirktok Formation, vicinity of Prudhoe Bay, North Slope, Alaska: U.S. Geological Survey Miscellaneous Investigations, 1 sheet [in press].
- Roberts, S.B., Stricker, G.D., and Affolter, R.H., 1991, Reevaluation of coal resources in the Late Cretaceous-Tertiary Sagavanirktok Formation, North Slope, Alaska, *in* Bradley, D.C., and Ford, A.B., eds., Geologic studies in Alaska by the U.S. Geological Survey: U.S. Geological Survey Bulletin 1999, p. 196-203.
- Schneider, J.L., ed., 1990, 1990 annual report on Alaska's mineral resources: U.S. Geological Survey Circular 1056, 67 p.
- Sherman, G.E., 1990a, Permitting and environmental constraints—Their impact on mining in Alaska: U.S. Bureau of Mines Open-File Report 35-90, 28 p.
- 1990b, Mining Claims Information System—A database retrieval program for active mining claims in Alaska: U.S. Bureau of Mines Open-File Report 50-90, 7 p.
- Stricker, G.D., 1991, Economic Alaskan coal deposits, *in* Gluskoter, H.J., Rice, D.D., and Taylor, R.B., eds., Economic geology—U.S., v. P-2 of Geology of North America: Boulder, Colorado, Geological Society of America, Decade of North American Geology series [in press].
- Swainbank, R.C., Bundtzen, T.K., and Wood, J.E., 1991, Summary of Alaska's mineral industry for 1990: Alaska Division of Geological and Geophysical Surveys Public-Data File 91-6, 8 p.
- U.S. Fish and Wildlife Service, Bureau of Land Management, National Park Service, U.S. Department of Agriculture, U.S. Forest Service, 1990, Alaska Submerged Lands Act Report—Analysis of inholdings, acquisition priorities, and recommendations to reduce impacts on conservation system units in Alaska: Anchorage, Alaska, U.S. Department of the Interior, 23 p. plus appendices.

APPENDIX 1.—ALASKA MINERAL REPORTS RELEASED DURING 1990 AND EARLY 1991

The following selected publications contain pertinent information about energy resources and other minerals in Alaska released during 1990 or early 1991; these are in addition to the reports listed in the previous References Cited section. This listing is only a selection of relevant

reports from the publications of any agency. Reports by Federal or State agencies can generally be obtained from the agency offices in Alaska, or are available at the Alaska Resources Library, Federal Building, 701 C Street, Anchorage, AK 99513-7599.

The USGS publishes a monthly listing of its own releases, "New Publications of the U.S. Geological Survey," available free from the U.S. Geological Survey, 582 National Center, Reston, VA 22092. These listings are also compiled into an annual volume, "Publications of the U.S. Geological Survey, 1990." Information about the prices and sources of listed reports is given in these two publications and is also available from the USGS Earth Science Information Centers.

The USBM's central distribution office is the Branch of Production and Distribution, 4800 Forbes Avenue, Pittsburgh, PA 15213. Many USBM reports are available from the U.S. Government Printing Office in Washington, DC, or from the National Technical Information Service (NTIS) in Springfield, VA 22161. USBM reports listed here are available from the USBM library in Juneau; for further information, contact the Chief, Alaska Field Operations Center, 201 East 9th Avenue, Anchorage, AK 99501.

MMS publications may also be purchased from NTIS, which issues listings of all available MMS volumes. A limited number of complimentary reports are available at the MMS Library/Public Information Room, Alaska OCS Region, Minerals Management Service, 949 East 36th Avenue, Room 110, Anchorage, AK 99508-4302; phone (907) 271-6439.

Department of the Interior

U.S. Geological Survey

- Allen, M.S., 1990, Gold anomalies and newly identified gold occurrences in the Lime Hills quadrangle, Alaska, and their association with the Hartman sequence plutons, *in* Goldfarb, R.J., Nash, J.T., and Stoesser, J.W., eds., *Geochemical studies in Alaska by the U.S. Geological Survey, 1989*: U.S. Geological Survey Bulletin 1950, p. F1-F16.
- Allen, M.S., and Slaughter, K.E., 1990, Mineralogic data and sample locality map for nonmagnetic heavy-mineral-concentrate samples collected from the eastern portion of the Lime Hills quadrangle, Alaska: U.S. Geological Survey Open-File Report 90-67, 64 p., 1 sheet, scale 1:250,000.
- Allen, M.S., Malcolm, M.J., Motooka, J.M., and Slaughter, K.E., 1990, Geologic description, chemical analyses, and sample locality map for rock samples collected from the eastern portion of the Lime Hills quadrangle, Alaska: U.S. Geological Survey Open-File Report 90-69, 49 p., 1 sheet, scale 1:250,000.
- Armstrong, A.K., and Kelley, J.S., 1990, Petrology and reservoir quality of the Katakaturuk Dolomite, Arctic National Wildlife Refuge [abs.]: *American Association of Petroleum Geologists Bulletin*, v. 74, no. 5, p. 600.
- Attanasi, E.D., Bird, K.J., and Mast, R.F., 1991, Economics and the

national oil and gas assessment—The case of onshore northern Alaska: *American Association of Petroleum Geologists Bulletin* [in press].

- Barnes, D.F., 1990, Gravity, gravity-change, and other geophysical measurements in Glacier Bay National Park and Preserve, *in* Milner, A.M., and Wood, J.D., Jr., eds., *Proceedings of the Second Glacier Bay Science Symposium*: Anchorage, Alaska, National Park Service, p. 12-18.
- Barnes, D.F., and Morin, R.L., 1990, Gravity contour map and interpretation of gravity data for the Chugach National Forest, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1645-F, 1 sheet, scale 1:250,000.
- Bird, K.J., 1991, Geology, play descriptions, and petroleum resources of the Alaskan North Slope (Petroleum Provinces 58-60): U.S. Geological Survey Open-File Report 88-450-Y, 52 p.
- Brew, D.A., Drew, L.J., Schmidt, J.M., Root, D.H., and Huber, D.F., 1991a, Assessment of undiscovered mineral resources, Tongass National Forest, southeastern Alaska [abs.], *in* Good, E.E., Slack, J.F., and Kotra, R.K., eds., *USGS research on mineral resources, 1991—Seventh annual V.E. McKelvey forum on mineral and energy resources, program and abstracts*: U.S. Geological Survey Circular 1062, p. 6.
- , 1991b, Undiscovered locatable mineral resources of the Tongass National Forest and adjacent areas, southeastern Alaska: U.S. Geological Survey Open-File Report 91-10, 73 p., 16 maps, scales 1:250,000 and 1:500,000.
- Cady, J.W., 1990, Alaska as a frontier for aeromagnetic interpretation, *in* Hanna, W.F., ed., *Geologic applications of modern aeromagnetic surveys*: U.S. Geological Survey Bulletin 1924, p. 75-84.
- Carlson, P.R., Mann, D.M., Huggett, Q.J., and Bishop, D., 1990, *Gloria* investigation of the exclusive economic zone in the Gulf of Alaska: U.S. Geological Survey Open-File Report 90-71, 17 p.
- Cathrall, J.B., Antweiler, J.C., VanTrump, G., and Mosier, E.L., 1990, Gold analytical results and gold signatures from the Anchorage, Charley River, Healy, Iditarod, Juneau, Mount Hayes, Mount McKinley, Ophir, Ruby, and Talkeetna quadrangles, Alaska: U.S. Geological Survey Open-File Report 90-210, 25 p.
- Church, S.E., Gaccetta, J.D., and Delevaux, M.H., 1990, Pb-isotope results from syngenetic and epigenetic vein occurrences and implications for their genesis, Yukon-Tanana terrane, Alaska [abs.]: *Geological Association of Canada, Program with Abstracts*, v. 15, p. A24.
- Church, S.E., and Motooka, J.M., 1989, Geochemical maps showing the distribution of selected leachable metals in stream sediments from the Mount Katmai and parts of the Afognak and Naknek quadrangles, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2021-B, 2 sheets, scale 1:250,000.
- Collett, T.S., 1990, Potential geologic hazards of Arctic gas hydrates [abs.]: *American Association of Petroleum Geologists Bulletin*, v. 74, no. 5, p. 631-632.
- Collett, T.S., Kvenvolden, K.A., and Magoon, L.B., 1990, Characterization of hydrocarbon gas within the stratigraphic interval of gas-hydrate stability on the North Slope of Alaska, U.S.A.: *Applied Geochemistry*, v. 5, no. 3, p. 279-287.
- Detterman, R.L., Case, J.E., Church, S.E., Frisken, J.G., Wilson, F.H., and Yount, M.E., 1990, The Alaska Mineral Resource Assessment Program—Background information to accompany folio of geologic and resource maps of the Ugashik, Bristol Bay, and western part of Karluk quadrangles, Alaska: U.S. Geological

- Survey Circular 1046, 15 p.
- Dickinson, K.A., and Vuletich, April, 1990, Diagenesis and uranium mineralization of the Lower Tertiary Kootzahoo Formation in the northern part of Admiralty Trough, southeastern Alaska: U.S. Geological Survey Bulletin 1888, 12 p.
- Dover, J.H., 1990, Geology of east-central Alaska: U.S. Geological Survey Open-File Report 90-289, 66 p.
- Dover, J.H., and Galloway, J.P., eds., 1990, Geologic studies in Alaska by the U.S. Geological Survey, 1989: U.S. Geological Survey Bulletin 1946, 121 p.
- Doyle, E.O., Dusel-Bacon, Cynthia, and Box, S.E., 1991, Distribution, facies, ages, and proposed tectonic associations of regionally metamorphosed rocks in southwestern Alaska and the Alaska Peninsula: U.S. Geological Survey Professional Paper 1497-B, 61 p. [in press].
- Drew, L.J., and Brew, D.A., 1990, Using mineral-deposit models to assess the undiscovered mineral resources of the Tongass National Forest, southeast Alaska [abs.]: International Association on the Genesis of Ore Deposits (IAGOD), 8th Symposium, Ottawa, Canada, August 1990, Program with Abstracts, p. A229.
- Dusel-Bacon, Cynthia, 1991a, Map and table showing metamorphic rocks of Alaska, in Plafker, George, Jones, D.L., and Berg, H.C., eds., *Geology of Alaska*, v. G-1 of *Geology of North America: Boulder, Colorado, Geological Society of America, Decade of North American Geology series*, 2 sheets, scale 1:2,500,000 [in press].
- 1991b, Metamorphic history of Alaska, in Plafker, George, Jones, D.L., and Berg, H.C., eds., *Geology of Alaska*, v. G-1 of *Geology of North America: Boulder, Colorado, Geological Society of America, Decade of North American Geology series* [in press].
- Dusel-Bacon, Cynthia, Brew, D.A., and Douglass, S.L., 1991a, Metamorphic facies map of southeastern Alaska—Distribution, facies, and ages of regionally metamorphosed rocks: U.S. Geological Survey Open-File Report [in press].
- 1991b, Metamorphic facies map of southeastern Alaska—Distribution, facies, and ages of regionally metamorphosed rocks: U.S. Geological Survey Professional Paper 1497-D [in press].
- Dusel-Bacon, Cynthia, Csejtey, Bela, Jr., Foster, H.L., Doyle, E.O., Nokleberg, W.J., and Plafker, George, 1991c, Distribution, facies, ages, and proposed tectonic associations of regionally metamorphosed rocks in east- and south-central Alaska: U.S. Geological Survey Professional Paper 1497-C [in press].
- Ford, A.B., Brew, D.A., and Loney, R.A., 1990, The Sitkoh Bay composite plutons: Silurian or older alkalic magmatism on eastern Chichagof Island, southeastern Alaska: U.S. Geological Survey Open-File Report 90-297, 41 p.
- Frost, G.M., and Stanley, R.G., 1991, Preliminary geologic and Bouguer gravity map of the Nenana basin area, central Alaska [abs.]: Geological Society of America, Abstracts with Programs, v. 23, no. 2, p. 26.
- Frost, T.P., 1990, Geology and geochemistry of mineralization in the Bethel quadrangle, southwestern Alaska, in Goldfarb, R.J., Nash, J.T., and Stoeser, J.W., eds., *Geochemical studies in Alaska by the U.S. Geological Survey, 1989: U.S. Geological Survey Bulletin 1350*, p. C1-C9.
- Frost, T.P., and Box, S.E., 1991, Lithologic and tectonic controls on mineralization in the Bethel quadrangle, southwestern Alaska [abs.], in Good, E.E., Slack, J.F., and Kotra, R.K., eds., *USGS research on mineral resources, 1991—Seventh annual V.E. McKelvey forum on mineral and energy resources, program and abstracts: U.S. Geological Survey Circular 1062*, p. 29-31.
- Frost, T.P., Motooka, J.M., and Bradley, Leon, 1990, Geochemical results, sample localities, and descriptions of some rocks from the Proterozoic Kilbuck terrane, Goodnews quadrangle, southwestern Alaska: U.S. Geological Survey Open-File Report 90-681, 8 p.
- Goldfarb, R.J., Bailey, E.A., Folger, P.F., and Schmidt, J.M., 1990a, The use of heavy-mineral concentrate data to show geochemical favorability for Zn-Pb-Ag and Cu-Co mineral occurrences in the Baird Mountains quadrangle, northwestern Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2152, scale 1:250,000.
- Goldfarb, R.J., Gent, C.A., Gray, J.E., Miller, M.L., and Pickthorn, W.J., 1990b, Oxygen, hydrogen, and sulfur isotope studies of Hg-Sb epithermal systems, southwestern Alaska [abs.]: Geological Association of Canada, Program with Abstracts, v. 15, p. A48.
- Goldfarb, R.J., Gray, J.E., Pickthorn, W.J., Gent, C.A., and Cieutat, B.A., 1990c, Stable isotope systematics of epithermal mercury-antimony mineralization, southwestern Alaska, in Goldfarb, R.J., Nash, J.T., and Stoeser, J.W., eds., *Geochemical studies in Alaska by the U.S. Geological Survey, 1989: U.S. Geological Survey Bulletin 1950*, p. E1-E9.
- Goldfarb, R.J., and Leach, D.L., 1990, Source of synorogenic fluids of the northern Cordillera—Evidence from the Juneau gold belt, Alaska [abs.]: NUNA Research Conference on Greenstone Gold and Crustal Evolution, Geological Association of Canada, Abstracts, p. 41-42.
- Goldfarb, R.J., Nash, J.T., and Stoeser, J.W., eds., 1990d, *Geochemical studies in Alaska by the U.S. Geological Survey, 1989: U.S. Geological Survey Bulletin 1950*, chapters A-F.
- Goldfarb, R.J., O'Leary, R.M., Sutley, S.J., and Tripp, R.B., 1989, Geochemical survey of the Cordova and Middleton Island 1° x 3° quadrangles, south-central Alaska: U.S. Geological Survey Bulletin 1865, 32 p.
- Goldfarb, R.J., and Pickthorn, W.J., 1991, Synorogenic, auriferous fluids of the Juneau gold belt, southeast Alaska—Stable-isotope evidence for a deep crustal origin [abs.], in Good, E.E., Slack, J.F., and Kotra, R.K., eds., *USGS research on mineral resources, 1991—Seventh annual V.E. McKelvey forum on mineral and energy resources, program and abstracts: U.S. Geological Survey Circular 1062*, p. 32-33.
- Gray, J.E., Detra, D.E., Eppinger, R.G., Hill, R.H., Slaughter, K.E., and Sutley, S.J., 1990a, Geochemical data and sample locality maps for stream-sediment and heavy-mineral-concentrate samples, and mineralogic data of nonmagnetic, heavy-mineral-concentrate samples collected near five cinnabar-stibnite mineral occurrences in the Kuskokwim River region, southwestern Alaska: U.S. Geological Survey Open-File Report 90-299, 73 p., 5.25" diskette.
- Gray, J.E., Detra, D.E., Goldfarb, R.J., and Slaughter, K.E., 1991, Geochemical exploration criteria for epithermal cinnabar-stibnite deposits, southwestern Alaska [abs.], in Good, E.E., Slack, J.F., and Kotra, R.K., eds., *USGS research on mineral resources, 1991—Seventh annual V.E. McKelvey forum on mineral and energy resources, program and abstracts: U.S. Geological Survey Circular 1062*, p. 34-35.
- Gray, J.E., Frost, T.P., Goldfarb, R.J., and Detra, D.E., 1990b, Gold associated with cinnabar- and stibnite-bearing deposits and mineral occurrences in the Kuskokwim River region, southwestern

- Alaska, in Goldfarb, R.J., Nash, J.T., and Stoesser, J.W., eds., *Geochemical studies in Alaska by the U.S. Geological Survey, 1989: U.S. Geological Survey Bulletin 1950*, p. D1-D6.
- Hopkins, D.M., Gray, J.E., and Slaughter, K.E., 1991, Low-level gold determinations using flow injection-atomic absorption spectrophotometry—An application to precious-metal resource assessment in the Iditarod quadrangle, southwestern Alaska [abs.], in Good, E.E., Slack, J.F., and Kotra, R.K., eds., *USGS research on mineral resources, 1991—Seventh annual V.E. McKelvey forum on mineral and energy resources, program and abstracts: U.S. Geological Survey Circular 1062*, p. 39.
- Howell, D.G., Johnsson, M.J., and Bird, K.J., 1990, Geodynamics and petroleum potential, Brooks Range, Alaska [abs.]: Geological Association of Canada Program with Abstracts, v. 15, p. A61.
- Johnsson, M.J., Bird, K.J., Howell, D.G., Magoon, L.B., Stanley, R.G., Valin, Z.C., Harris, A.G., and Pawlewicz, M.J., 1990, Preliminary thermal maturity map of sedimentary rocks in Alaska [abs.]: *Eos (Transactions American Geophysical Union)*, v. 71, no. 43, p. 1617.
- Karl, S.M., Dumoulin, J.A., Ellersieck, Inyo, Harris, A.G., and Schmidt, J.M., 1990, Preliminary geologic map of the Baird Mountains and part of the Selawik quadrangles, Alaska: U.S. Geological Survey Open-File Report 89-551, 65 p., 1 sheet, scale 1:250,000.
- Karl, S.M., Goldfarb, R.J., Kelley, K.D., Sutphin, D.M., Finn, C.A., Ford, A.B., and Brew, D.A., 1991, Mineral-resource potential of the Sitka quadrangle, southeastern Alaska [abs.], in Good, E.E., Slack, J.F., and Kotra, R.K., eds., *USGS research on mineral resources, 1991—Seventh annual V.E. McKelvey forum on mineral and energy resources, program and abstracts: U.S. Geological Survey Circular 1062*, p. 45-46.
- Karl, S.M., and Koch, R.D., 1989, Maps and preliminary interpretation of anomalous rock geochemical data from the Petersburg quadrangle and parts of the Port Alexander, Sitka, and Sumdum quadrangles, southeastern Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1970-C, 40 p., 7 sheets, scale 1:250,000.
- Kelley, J.S., 1990, Generalized geologic map of the Chandler Lake quadrangle, north-central Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2144-A, 19 p., 1 sheet, scale 1:250,000.
- Kelley, K.D., 1990, Interpretation of geochemical data from Admiralty Island, Alaska—Evidence for volcanogenic massive sulfide mineralization, in Goldfarb, R.J., Nash, J.T., and Stoesser, J.W., eds., *Geochemical studies in Alaska by the U.S. Geological Survey, 1989: U.S. Geological Survey Bulletin 1950*, p. A1-A9.
- Kelley, K.D., Slaughter, K.E., and Motooka, J.M., 1990, Results of inductively coupled plasma-atomic emission spectroscopy analyses of minus 30-mesh stream sediment samples from within and adjacent to the National Petroleum Reserve, Alaska: U.S. Geological Survey Open-File Report 90-501, 22 p., 1 sheet, scale 1:500,000.
- Kirschner, C.E., and Grantz, Arthur, 1990, Impact origin of the Avak structure, Arctic Alaska, and genesis of the Barrow gas field [abs.]: *American Association of Petroleum Geologists Bulletin*, v. 74, no. 5, p. 696.
- Koch, R.D., 1990, Reconnaissance geologic map of the Bradfield Canal quadrangle, southeastern Alaska: U.S. Geological Survey Miscellaneous Field Studies Map [in press].
- Kvenvolden, K.A., and Grantz, Arthur, 1990, Gas hydrates of the Arctic Ocean region, in Grantz, Arthur, Johnson, G.L., and Sweeney, J.F., eds., *The Arctic region, v. L of Geology of North America: Boulder, Colorado, Geological Society of America, Decade of North American Geology series*, p. 539-549.
- Lange, I.M., Nokleberg, W.J., Newkirk, S.R., Aleinikoff, J.N., Church, S.E., and Krouse, H.R., 1990, Metallogenesis of Devonian volcanogenic massive sulfide deposits and occurrences, southern Yukon-Tanana terrane, eastern Alaska Range, Alaska, in Pacific Rim Congress '90, Gold Coast, Queensland, Australia: Parkville, Victoria, Australia, Australasian Institute of Mining and Metallurgy, Proceedings, v. 2, p. 443-450.
- Light, T.D., Tripp, R.B., and King, H.D., 1990, Interpretation of reconnaissance geochemical data from the Healy quadrangle, Alaska: U.S. Geological Survey Bulletin 1894, 36 p., 3 sheets, scale 1:250,000.
- Madden-McGuire, D.J., and Winkler, G.R., 1991, Areas of mineral-resource favorability with emphasis on gold and chromite, Anchorage 1° x 3° quadrangle, southern Alaska [abs.], in Good, E.E., Slack, J.F., and Kotra, R.K., eds., *USGS research on mineral resources, 1991—Seventh annual V.E. McKelvey forum on mineral and energy resources, program and abstracts: U.S. Geological Survey Circular 1062*, p. 50-51.
- Magoon, L.B., and Anders, D.E., 1990, Oil-source rock correlation using carbon isotope data and biological marker compounds, Cook Inlet, Alaska Peninsula, Alaska [abs.]: *American Association of Petroleum Geologists Bulletin*, v. 74, no. 5, p. 711.
- Magoon, L.B., and Kirschner, C.E., 1990, Alaska onshore national assessment program—Geology and petroleum resource potential of six onshore Alaska provinces: U.S. Geological Survey Open-File Report 88-450-T, 47 p.
- Malcolm, M.J., Allen, M.S., and Slaughter, K.E., 1990, Analytical results and sample locality map of the nonmagnetic heavy-mineral-concentrate samples collected from the eastern portion of the Lime Hills quadrangle, Alaska: U.S. Geological Survey Open-File Report 90-68, 83 p., 1 sheet, scale 1:250,000.
- McLean, Hugh, and Stanley, R.G., 1991, Reconnaissance sandstone petrology and provenance of the Cantwell Formation, central Alaska, in Bradley, D.C., and Ford, A.B., eds., *Accomplishments of the U.S. Geological Survey in Alaska, 1990: U.S. Geological Survey Bulletin 1999*, p. 170-179.
- Molenaar, C.M., Bird, K.J., and Magoon, L.B., 1990, Petroleum geology of the coastal plain of the Arctic National Wildlife Refuge, northeastern Alaska: *American Association of Petroleum Geologists Bulletin*, v. 74, no. 5, p. 723.
- Motooka, J.M., Allen, M.S., Malcolm, M.J., and Slaughter, K.E., 1990, Analytical results and sample locality map for stream-sediment samples collected from the eastern portion of the Lime Hills quadrangle, Alaska: U.S. Geological Survey Open-File Report 90-70, 103 p., 1 sheet, scale 1:250,000.
- Nelson, W.H., and Csejtey, Bela, Jr., 1990, Stratigraphy and structure of the Ekokpuk Creek area, north-central Brooks Range, Alaska: U.S. Geological Survey Bulletin 1848, 8 p.
- Newberry, R.J., Brew, D.A., and Crafford, T.C., 1990, Genesis of the Greens Creek (GC) volcanogenic massive sulfide (VMS) deposit, S.E. Alaska—A geochemical study [abs.]: *Geological Association of Canada Program with Abstracts*, p. A96.
- Nokleberg, W.J., Lange, I.M., Singer, D.A., Curtin, G.C., Tripp, R.B., Campbell, D.L., and Yeend, Warren, 1990, Mineral resource assessment maps of the Mount Hayes quadrangle, eastern Alaska Range, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1996-A, 22 p., 4 sheets, scale 1:250,000.

- Nokleberg, W.J., Roback, R.C., Lange, I.M., and Yeend, Warren, 1990, Map showing locations of metalliferous lode and placer mineral occurrences, deposits, prospects, and mines, Mount Hayes quadrangle, eastern Alaska Range, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1996-C, 62 p., 1 sheet, scale 1:250,000.
- Phillips, R.L., Grantz, Arthur, and Mullen, M.W., 1990, Preliminary stratigraphy of piston cores from southeastern Northwind Ridge, Arctic Ocean: U.S. Geological Survey Geologic Open-File Report 90-51, 1 sheet.
- Richter, D.H., Duffield, W.A., Sawyer, D.A., Ratte, J.C., and Schmoll, H.R., 1991, Geologic map of the Gulkana A-1 quadrangle, south-central Alaska: U.S. Geological Survey Geologic Quadrangle Map [in press].
- Rowan, E.L., Bailey, E.A., and Goldfarb, R.J., 1990, Geochemical orientation study for identification of metallic mineral resources in the Sitka quadrangle, southeastern Alaska, *in* Goldfarb, R.J., Nash, J.T., and Stoesser, J.W., eds., *Geochemical studies in Alaska by the U.S. Geological Survey, 1989: U.S. Geological Survey Bulletin 1950*, p. B1-B12.
- Scholl, D.W., and Stevenson, A.J., 1990, Regional factors affecting petroleum potential of the Aleutian accretionary prism [abs.]: *American Association of Petroleum Geologists Bulletin*, v. 74, no. 5, p. 758.
- Slaughter, K.E., Gray, J.E., Hageman, P.L., Kilburn, J.E., Love, A.H., and Peacock, T.R., 1990, Geochemical data and sample locality maps for stream water and vegetation samples collected near five cinnabar-stibnite mineral occurrences in the Kuskokwim River region, southwestern Alaska: U.S. Geological Survey Open-File Report 90-340, 24 p., 5.25" diskette.
- Stanley, R.G., Flores, R.M., and Wiley, T.J., 1991, Fluvial facies architecture in the Tertiary Usibelli Group of Suntrana, central Alaska, *in* Bradley, D.C., and Ford, A.B., eds., *Accomplishments of the U.S. Geological Survey in Alaska, 1990: U.S. Geological Survey Bulletin 1999*, p. 204-211.
- Stanley, R.G., McLean, Hugh, and Pawlewicz, M.J., 1990, Petroleum source potential and thermal maturity of the Tertiary Usibelli Group at Suntrana, Alaska, *in* Dover, J.H., and Galloway, J.P., eds., *Geologic studies in Alaska by the U.S. Geological Survey, 1989: U.S. Geological Survey Bulletin 1946*, p. 65-76.
- Sutley, S.J., Goldfarb, R.J., O'Leary, R.M., and Tripp, R.B., 1990, A comparison of geochemical exploration techniques and sample media within accretionary continental margins—An example from the Pacific Border Ranges, southern Alaska, U.S.A.: *Journal of Geochemical Exploration*, v. 37, no. 2, p. 255-275.
- Till, A.B., Yount, M.E., and Riehle, J.R., 1990, Redoubt Volcano, Cook Inlet, Alaska—A hazard assessment based on eruptive activity through 1968: U.S. Geological Survey Open-File Report 90-246, 34 p., 2 sheets, scale 1:125,000.
- Valin, Z.C., Bader, J.W., Barnes, D.F., Fisher, M.A., and Stanley, R.G., 1991, Simple Bouguer gravity anomaly maps of the Nenana basin area, Alaska: U.S. Geological Survey Open-File Report 91-33, 5 sheets, scales 1:250,000 and 1:500,000.
- Winkler, G.R., compiler, 1990, Preliminary geologic map, cross sections, and summary geochronology of the Anchorage quadrangle, southern Alaska: U.S. Geological Survey Open-File Report 90-83, 2 sheets, scale 1:250,000.
- Yeend, Warren, 1990a, Gold placers, geomorphology, and paleo-drainage of Eureka Creek and Tofty areas, Alaska, *in* Dover, J.H., and Galloway, J.P., eds., *Geologic studies in Alaska by the U.S. Geological Survey in 1989: U.S. Geological Survey Bulletin 1946*, p. 107-109.
- 1990b, Gold placers of the Circle district, Alaska: U.S. Geological Survey Bulletin 1943 [in press].
- Yehle, L.A., Schmoll, H.R., and Dobrovolsky, Ernest, 1990, Geologic map of the Anchorage B-8 SE and part of the Anchorage B-8 NE quadrangles, Alaska: U.S. Geological Survey Open-File Report 90-238, 37 p., 2 sheets, scale 1:25,000.

U.S. Bureau of Mines

- Balen, M.D., 1990a, Geochemical sampling results from Bureau of Mines investigations in the Valdez Creek mining district, Alaska: U.S. Bureau of Mines Open-File Report 34-90, 218 p.
- 1990b, The feasibility of mining in the Valdez Creek mining district, Alaska: U.S. Bureau of Mines Open-File Report 40-90, 58 p.
- Barker, J.C., 1990, Placer mining (surface) in the Soviet Far East: *in* Twelfth Annual Conference on Alaska Placer Mining, Fairbanks, Alaska, March 29-30, 1990, Proceedings [in press].
- Barker, J.C., and Skudrzyk, F., 1990, Mining in Siberia—Americans get a look: U.S. Bureau of Mines, *Minerals Today*, March 1990, p. 13-14.
- Bennett, R.B., 1990a, Index of Bureau of Mines publications on Alaska: U.S. Bureau of Mines, Alaska Field Operations Center, Juneau, 83 p.
- 1990b, Index to publications for proposed reopening of the Alaska-Juneau mine: U.S. Bureau of Mines, 9 p.
- Fechner, S.A., and Herzog, D.A., 1990, Gold- and PGM-bearing conglomerate of the Valdez Creek mining district, Alaska: U.S. Bureau of Mines Open-File Report 12-90, 53 p., 2 sheets.
- Herzog, D.A., 1990, Gold- and PGM-bearing conglomerate of the Valdez Creek mining district, Alaska, *in* Twelfth Annual Conference on Alaska Placer Mining: Fairbanks, Alaska, March 29-30, 1990, Proceedings [in press].
- Maas, K.M., 1990, *Industrial Minerals*, v. 3 of Mineral investigations in the Juneau mining district, Alaska, 1984-88: U.S. Bureau of Mines Special Publication, 115 p.
- Meyer, M.P., 1990, Selected coal deposits in Alaska: U.S. Bureau of Mines Open-File Report 33-90, 393 p.
- Minerals Yearbook* [published annually by the U.S. Bureau of Mines, Washington, DC].
- Sherman, G.E., Coldwell, J.R., Herzog, D.A., and Meyer, M.P., 1990a, Analysis of Balboa Bay, Beluga, Point MacKenzie, and Lost River as port sites for use by the mineral industry: U.S. Bureau of Mines Open-File Report 36-90, 54 p.
- Sherman, G.E., Herzog, D.A., Coldwell, J.R., and Meyer, M.P., 1990b, Analysis of Iliamna Bay, Kotzebue and Nome as port sites for use by the mineral industry: U.S. Bureau of Mines Open-File Report 21-90, 35 p.
- Sherman, G.E., Meyer, M.P., and Coldwell, J.R., 1990c, Analysis of Bethel, Kivalina (Red Dog), and Omalik Lagoon as port sites for use by the mineral industry: U.S. Bureau of Mines Open-File Report 22-90, 30 p.
- Southworth, D.D., 1990, Industrial minerals of the Valdez Creek mining district, Alaska: U.S. Bureau of Mines Open-File Report 28-90, 29 p.
- U.S. Bureau of Mines, 1990a, Mineral deposit inventory for ten Alaska port sites: Alaska Field Operations Center, U.S. Bureau of Mines

Open-File Report 15-90, 262 p.

———1990b, U.S. Bureau of Mines research '89-90—A summary of significant results and economics in mineral technology: U.S. Bureau of Mines, 157 p.

Minerals Management Service

OCS Reports and Maps are authored by the MMS professional staff. OCS Studies are generally contractually prepared environmental, socioeconomic, and technological studies.

Berman, M., 1990, Alaska statewide and regional economic and demographic systems—Effects of OCS exploration and development: Minerals Management Service OCS Study, MMS 90-0065, 148 p.

Boehm, P., LeBlanc, L., Trefry, J., Marajh-Whittemore, P., Brown, J., Schutzberg, A., and Kick, A., 1990, Monitoring hydrocarbons and trace metals in Beaufort Sea sediments and organisms: Minerals Management Service OCS Study, MMS 90-0054, 230 p.

Burden, P., Richardson, J., Isaacs, J., Jensen, W., and Radtke, H., 1990, Commercial fishing industry of the Bering Sea: Minerals Management Service OCS Study, MMS 90-0026, 327 p.

Burden, P., Richardson, J., Braund, S., Witten, E., and Moorehead, L., 1990, Economic impacts of the S.S. *Glacier Bay* oil spill: Minerals Management Service OCS Study, MMS 90-0081, 145 p.

Crecelius, E.A., Apts, C.W., and Lasorsa, B.K., 1990, Concentrations of metals in Norton Sound seawater samples and human hair samples, 1989: Minerals Management Service OCS Study, MMS 90-0010, 32 p.

Downs, M.A., Galginaitis, M., Petterson, J.S., Palinkas, L.A., Oswald, W., VanStone, J., Nebesky, W.E., Smythe, C.S., and Rodin, M., 1990, Northern institutional profile analysis, Beaufort Sea: Minerals Management Service OCS Study, MMS 90-0023, 500 p.

———1990, Northern institutional profile analysis, Chukchi Sea: Minerals Management Service OCS Study, MMS 90-0022, 800 p.

Galginaitis, M., 1990, Subsistence resource harvest patterns, Nuiqsut: Minerals Management Service OCS Study, MMS 90-0038, 230 p.

———1990, Subsistence resource harvest patterns, Kaktovik: Minerals Management Service OCS Study, MMS 90-0039, 230 p.

Gundlach, E.R., and Reed, M., 1990, Shoreline segment characteristics handbook for SMEAR model application: Minerals Management Service OCS Study, MMS 90-0001, 3530 p.

Johnson, P.P., 1990, Multiple-stage deformation along the southern flank of the North Chukchi High, Chukchi Sea, Alaska [abs.]: American Association of Petroleum Geologists Bulletin, v. 74, no. 5, p. 687.

———1990, Multiple-stage deformation along the southern flank of the North Chukchi High, Chukchi Sea, Alaska [abs.], in 41st Arctic Science Conference, Anchorage, Alaska, October 8-10, 1990, Proceedings: American Association for the Advancement of Science, Arctic Division, p. 47.

Johnson, S.R., 1990, Monitoring Beaufort Sea waterfowl and marine birds: Minerals Management Service OCS Study, MMS 90-0048

[in press].

Knapp, G., 1990, Economic and demographic systems analysis, Nome, Alaska: Minerals Management Service OCS Study, MMS 90-0068, 39 p.

———1990, Economic and demographic systems analysis, Unalaska and Cold Bay, Alaska: Minerals Management Service OCS Study, MMS 90-0069, 53 p.

MBC Applied Environmental Sciences, 1990, Alaska OCS Study Region, Third Information Transfer Meeting, Conference Proceedings: Minerals Management Service OCS Study, MMS 90-0041, 233 p.

———1990, Workshop to design baseline and monitoring studies for the OCS mining program, Norton Sound, Alaska: Minerals Management Service OCS Study, MMS 90-0059, 183 p.

Minerals Management Service, 1990, Alaska update, September 1988-January 1990—Outer Continental Shelf oil and gas activities: Minerals Management Service OCS Information Paper, MMS 90-0012, 81 p.

———1990, Alaska OCS region, Alaska regional studies plan, final, FY 1991-1992: U.S. Department of the Interior, Minerals Management Service.

Moore, S., and Clarke, J.T., 1990, Distribution, abundance, and behavior of endangered whales in Chukchi and western Beaufort Sea: Minerals Management Service OCS Study, MMS 90-0051, 243 p.

Richardson, W.J., Greene, C.R., Koski, W.R., Malme, C.I., Miller, G.W., Smultea, M.A., and Wursig, B., 1990, Acoustic effects of oil production activities on bowhead and white whales during spring migration near Point Barrow, Alaska, 1989 phase: Minerals Management Service OCS Study, MMS 90-0017, 305 p.

Roger, T., and Dayton, P., 1990, Migration of the northern fur seal (*Callorhinus ursinus*) pups on the Bering Sea: Minerals Management Service OCS Study, MMS 90-0058, 36 p.

Sherwood, K.W., 1990, Seismic stratigraphy and structural geology of the northeast Chukchi Basin, in Stubbs, G.S., ed., Second Symposium on Studies Related to Continental Margins, Austin, Texas, May 21-23, 1989, Proceedings: Texas Bureau of Economic Geology, p. 9-17.

———1990, Geological evolution of the northeast Chukchi Basin—Suspect terrain with Arctic Alaska plate [abs.], in 41st Arctic Science Conference, Anchorage, Alaska, October 8-10, 1990, Proceedings: American Association for the Advancement of Science, Arctic Division, p. 47.

Steffy, D.A., 1990, Regional overpressuring of Neogene clays in the Navarin Basin, Bering Sea, Alaska, v. 3 of Oceans '90, Conference Proceedings: Marine Technology Society, p. 555-561.

Steffy, D.A., Risley, D.E., Zerwick, S.A., and Thurston, D.K., 1990, Geology along the U.S.-U.S.S.R. border, Navarin Basin to the Chukchi Sea [abs.], in 41st Arctic Science Conference, Anchorage, Alaska, October 8-10, 1990, Proceedings: American Association for the Advancement of Science, Arctic Division, p. 47.

Thurston, D.K., 1990, Wrench tectonics in the Chukchi Sea, Alaska: Minerals Management Service videotape, 26 min. (available from MMS Alaska OCS Office, in English or Russian).

Treacy, S.D., 1990, Aerial surveys of endangered whales in the Beaufort Sea, fall 1989: Minerals Management Service OCS Study, MMS 90-0047, 104 p.

U.S. Department of Commerce and U.S. Department of the Interior, 1990, OCSEAP final reports of principal investigators, NOAA/

- OCSEAP, v. 68: Minerals Management Service OCS Study, MMS 90-0056, 629 p.
- 1990, OCSEAP final reports of principal investigators, NOAA/OCSEAP, v. 69: Minerals Management Service OCS Study, MMS 90-0074, 419 p.
- 1990, OCSEAP final reports of principal investigators, NOAA/OCSEAP, v. 70: Minerals Management Service OCS Study, MMS 90-0084, 652 p.
- U.S. Department of Commerce, NOAA, and U.S. Department of the Interior, 1990, Outer Continental Shelf environmental assessment program, comprehensive bibliography, June 1990: Minerals Management Service OCS Study, MMS 90-0043, 648 p.
- U.S. Department of the Interior, 1990, Beaufort Sea oil and gas lease sale 124, draft environmental impact statement: Minerals Management Service, Alaska OCS Region, MMS 90-0006, 2 vol.
- 1990, Beaufort Sea oil and gas lease sale 124, final environmental impact statement: Minerals Management Service, Alaska OCS Region, MMS 90-0063, 550 p.
- 1990, Chukchi Sea oil and gas lease sale 126, draft environmental impact statement: Minerals Management Service, Alaska OCS Region, MMS 90-0035, 2 vol.
- 1990, OCS mining program, Norton Sound lease sale, second draft environmental impact statement: Minerals Management Service, Alaska OCS Region, MMS 90-0032, 750 p.
- U.S. Fish and Wildlife Service, 1990, Monitoring of populations and productivity of seabirds at St. George Island, Cape Pierce, and Bluff, Alaska: Minerals Management Service OCS Study, MMS 90-0058 [in press].
- Ward, D.H., and Stehn, R.A., 1990, Response of Brandt and other geese to aircraft disturbances at Izembek Lagoon, Alaska: Minerals Management Service OCS Study, MMS 90-0046, 193 p.

Bureau of Land Management

- Banet, A.C., Jr., 1990a, Petroleum geology and geochemistry of the Arctic National Wildlife Refuge 1002 area: U.S. Bureau of Land Management, Alaska Technical Report 12, 26 p., 7 pl.
- 1990b, Bedrock geology of the northernmost bulge of the Rocky Mountain Cordillera: U.S. Bureau of Land Management, Alaska Technical Report 13, 62 p.
- 1990c, Bedrock geology of the northernmost bulge of the Rocky Mountain Cordillera [abs.], *in* Fifth Circum-Pacific Energy and Mineral Resources Conference, Honolulu, Hawaii, 1990: American Association of Petroleum Geologists Bulletin, v. 74, no. 6, p. 959.
- Gibson, C.N., and Mowatt, T., 1990, Occurrences and characteristics of coals, western Arctic Alaska [abs.], *in* Fifth Circum-Pacific Energy and Mineral Resources Conference, Honolulu, Hawaii, 1990: American Association of Petroleum Geologists Bulletin, v. 74, no. 6, p. 974.
- Mowatt, T.C., Dygas, J., and Gibson, C., 1990a, Red Dog mineral deposit, northwest Alaska—Discovery, delineation, and implications for other mineral resources regionally [abs.], *in* Fifth Circum-Pacific Energy and Mineral Resources Conference, Honolulu, Hawaii, 1990: American Association of Petroleum Geologists Bulletin, v. 74, no. 6, p. 993.
- Mowatt, T.C., Gibson, C., and Dygas, J., 1990b, Energy resources, western Arctic Alaska [abs.], *in* Fifth Circum-Pacific Energy and

Mineral Resources Conference, Honolulu, Hawaii, 1990: American Association of Petroleum Geologists Bulletin, v. 74, no. 6, p. 993.

- 1990c, Mineral resources, western Arctic Alaska [abs.], *in* Fifth Circum-Pacific Energy and Mineral Resources Conference, Honolulu, Hawaii, 1990: American Association of Petroleum Geologists Bulletin, v. 74, no. 6, p. 993.
- Mowatt, T.C., and Mowatt, J.C., 1990a, Diagenetic relationships and reservoir quality implications, Brookian clastic sequence, National Petroleum Reserve, Alaska [abs.], *in* Fifth Circum-Pacific Energy and Mineral Resources Conference, Honolulu, Hawaii, 1990: American Association of Petroleum Geologists Bulletin, v. 74, no. 6, p. 993.
- 1990b, Platinum and palladium in mafic-ultramafic igneous rocks, northwestern Alaska [abs.], *in* Fifth Circum-Pacific Energy and Mineral Resources Conference, Honolulu, Hawaii, 1990: American Association of Petroleum Geologists Bulletin, v. 74, no. 6, p. 994.

Fish and Wildlife Service

- Crayton, W., 1990, Placer mining impacts, Tuluksak River, 1987, 1988, 1989—Report of findings: Anchorage, Alaska, U.S. Fish and Wildlife Service, Ecological Services, 37 p.
- Jackson, R., 1990a, Innoko National Wildlife Refuge placer mining study—Report of findings: Anchorage, Alaska, U.S. Fish and Wildlife Service, Ecological Services, 21 p.
- 1990b, Togiak National Wildlife Refuge placer mining study—Report of findings: Anchorage, Alaska, U.S. Fish and Wildlife Service, Ecological Services, 17 p.
- 1991, Becharof National Wildlife Refuge contaminants study—report of findings: Anchorage, Alaska, U.S. Fish and Wildlife Service, Ecological Services, 21 p.

National Park Service

- Barker, L.R., and Huston, A.E., eds., 1990, Death Valley to Deadwood, Kennecott to Cripple Creek—Proceedings of the Historic Mining Conference, Death Valley National Monument, January 23–27, 1989: San Francisco, California, U.S. National Park Service, 219 p.
- Milner, A.M., and Wood, J.D., Jr., eds., Proceedings of the Second Glacier Bay Science Symposium: Anchorage, Alaska, U.S. National Park Service.
- U.S. National Park Service, 1990a, Denali National Park and Preserve, Alaska—Final environmental impact statement and cumulative impacts of mining: Anchorage, Alaska, U.S. National Park Service, 2 vol., 364 p.
- 1990b, Wrangell-St. Elias National Park and Preserve, Alaska—Final environmental impact statement and cumulative impacts of mining: Anchorage, Alaska, U.S. National Park Service, 2 vol., 521 p.
- 1990c, Yukon-Charley Rivers National Preserve, Alaska—Final environmental impact statement and cumulative impacts of mining: Anchorage, Alaska, U.S. National Park Service, 2 vol., 358 p.

Non-Federal Reports

Alaska Division of Geological and Geophysical Surveys

List includes publications by the ADGGS and other publications with ADGGS authors:

- Anderson, A.V., 1990, Middle Devonian to lower Mississippian clastic depositional cycles, upper Kongakut River, northeastern Brooks Range, Alaska—Preliminary results: Alaska Division of Geological and Geophysical Surveys Public-Data File 90-2-B, 8 p., 2 sheets, scale 1:395.
- Barker, J.C., Robinson, M.S., and Bundtzen, T.K., 1990, Marine placer development and opportunities in Alaska: *Mining Engineering*, v. 42, no. 1, p. 21-25.
- Bundtzen, T.K., and Swainbank, R.C., 1990, Summary of Alaska's mineral industry in 1989: Alaska Division of Geological and Geophysical Surveys Public-Data File 90-10, 7 p.
- Bundtzen, T.K., Swainbank, R.C., Deagan, J.R., and Moore, J.L., 1990, Alaska's mineral industry, 1989: Alaska Division of Geological and Geophysical Surveys Special Report 44, 100 p.
- Clautice, K.H., 1990, Geologic map of the Valdez Creek mining district: Alaska Division of Geological and Geophysical Surveys Public-Data File 90-30, 1 sheet, scale 1:250,000.
- Clautice, K.H., Harris, E.E., Liss, S.A., Kline, J.T., Bundtzen, T.K., Gilbert, W.G., and Nye, C.J., 1990, Analytical results for rock, pan concentrate, and stream-sediment samples from the Talkeetna Mountains B-2 quadrangle and the northern part of the Talkeetna Mountains A-2 quadrangle: Alaska Division of Geological and Geophysical Surveys Public-Data File 90-31, 25 p., 1 sheet, scale 1:63,360.
- Clautice, K.H., Liss, S.A., and Nye, C.J., 1990, Preliminary rock and stream-sediment geochemistry from parts of the Talkeetna Mountains A-2 and B-2 quadrangles, southcentral Alaska: Alaska Division of Geological and Geophysical Surveys Public-Data File 90-9, 12 p., 1 sheet, scale 1:63,360.
- Clough, J.G., and Roe, J.T., 1990, Coal resources of northwest Alaska—Final report: Alaska Division of Geological and Geophysical Surveys Public-Data File 90-17, 65 p., 10 sheets, scales variable.
- Dillon, J.T., and Reifensstuhl, R.R., 1990, Geologic map of the Wiseman B-1 quadrangle, southcentral Brooks Range, Alaska: Alaska Division of Geological and Geophysical Surveys Professional Report 101, 1 sheet, scale 1:63,360.
- Division of Geological and Geophysical Surveys, Energy Section, 1990, Palynology report of outcrop samples from North Slope, Alaska: Alaska Division of Geological and Geophysical Surveys Public-Data File 90-21, 21 p.
- Hakkila, G.A., 1990, Alaska Division of Mining reference manual for channel morphology: Alaska Division of Geological and Geophysical Surveys Public-Data File 90-23, 24 p.
- Hanks, C.L., 1990, Balanced cross-sections of the Aichilik River and Okpilak batholith regions, northeastern Brooks range, Alaska: Alaska Division of Geological and Geophysical Surveys Public-Data File 90-2-A, 18 p., 2 sheets, scale 1:125,000.
- Kline, J.T., Bundtzen, T.K., and Smith, T.E., 1990, Preliminary bedrock geologic map of the Talkeetna Mountains D-2 quadrangle, Alaska: Alaska Division of Geological and Geophysical Surveys Public-Data File 90-24, 13 p., 1 sheet, scale 1:63,360.
- LePain, D.L., and Crowder, R.K., 1990, Detailed measured sections from the Endicott Group (Mississippian) in the Shublik Mountains, Fourth Range, and Franklin Mountains, northeastern Brooks Range, Alaska: Alaska Division of Geological and Geophysical Surveys Public-Data File 90-2-C, 73 p.
- Merritt, R.D., Coal resources of the Susitna Lowlands, Alaska: Alaska Division of Geological and Geophysical Surveys Report of Investigations 90-1, 181 p., 3 sheets, scale 1:250,000.
- Metz, P.A., 1990, Major mineral deposits and their significance in the evolution of the Yukon-Tanana terrane, Yukon and Alaska—A review [abs.]: *Geological Association of Canada Program with Abstracts*, v. 15, p. A88.
- Munter, J.A., Maurer, M.A., and Moorman, M., 1990, Evaluation of the hydrology and geology of the Moonlight Springs area, Nome, Alaska: Alaska Division of Geological and Geophysical Surveys Public-Data File 90-8, 25 p.
- Newberry, R.J., Burns, L.E., and Solie, D.N., 1990, Gold favorability in the Eagle quadrangle, Alaska, as predicted by discriminant analysis for non-porphyry granitic rocks: Alaska Division of Geological and Geophysical Surveys Public-Data File 90-16, 18 p., 2 sheets, scale 1:63,360.
- 1990, Cretaceous-Tertiary (K-T) plutons and related ore deposits of the Yukon-Tanana (YT) and adjacent terranes, Alaska-Yukon [abs.]: *Geological Association of Canada Program with Abstracts*, v. 15, p. A96.
- 1990, Identification of tin- and gold-related plutons in the Yukon-Tanana and adjacent terranes, Alaska, through mathematical discriminant analysis and fractionation models [abs.]: *Geological Association of Canada, Program with Abstracts*, v. 15, p. A96.
- O'Sullivan, P.B., 1990, Preliminary results of 11 apatite fission-track analyses of samples from the Galbraith Lake-Toolik Lake region, North Slope, Alaska: Alaska Division of Geological and Geophysical Surveys Public-Data File 90-7-A, 17 p.
- 1990, Preliminary results of seven apatite fission-track analyses of samples from the Cobblestone Creek region, Chandler Lake quadrangle, North Slope, Alaska: Alaska Division of Geological and Geophysical Surveys Public-Data File 90-7-B, 13 p.
- 1990, Preliminary results of 25 apatite fission-track analyses of samples from five wells on the North Slope of Alaska: Alaska Division of Geological and Geophysical Surveys Public-Data File 90-32, 36 p.
- 1990, Results of nine apatite fission-track analyses of samples from outcrop localities in Ignek Valley and along the Sadlerochit River, Arctic National Wildlife Refuge, Alaska: Alaska Division of Geological and Geophysical Surveys Public-Data File 90-33, 16 p.
- Pessel, G.H., Robinson, M.S., Clough, J.G., Imm, T.A., Reifensstuhl, R.R., Ryherd, T.J., Myers, M.D., and Mull, C.G., 1990, Preliminary geologic map of the Gilead Creek area, Sagavanirktok A-2 quadrangle, Arctic Foothills, Alaska: Alaska Division of Geological and Geophysical Surveys Public-Data File 90-18, 7 p., 1 sheet, scale 1:63,360.
- Ray, S.R., 1990, Hydrologic and water quality investigations related to placer mining in interior Alaska—Summer 1989: Alaska Division of Geological and Geophysical Surveys Public-Data File 90-28, 61 p.
- Reger, R.D., and Bundtzen, T.K., 1990, Multiple glaciation and gold placer formation, Valdez Creek valley, western Clearwater Moun-

- tains, Alaska: Alaska Division of Geological and Geophysical Surveys Professional Report 107, 29 p., 1 sheet, scale 1:63,360.
- Reger, R.D., Bundtzen, T.K., and Smith, T.E., 1990, Geology of the Healy A-3 quadrangle, Alaska: Alaska Division of Geological and Geophysical Surveys Public-Data File 90-1, 13 p., 2 sheets, scale 1:63,360.
- Reifenstuhel, R.R., 1990, Vitrinite reflectance data for some early Tertiary through Jurassic outcrop samples, northeastern Alaska: Alaska Division of Geological and Geophysical Surveys Public-Data File 90-5, 3 p.
- Robinson, M.S., and Myers, M.D., 1990, Colville River geologic transect—Vitrinite reflectance, palynology, TAI, and fission track data, central North Slope, Alaska: Alaska Division of Geological and Geophysical Surveys Public-Data File 90-12, 5 p., 1 sheet, scale 1:250,000.
- Robinson, M.S., Smith, T.E., and Metz, P.A., 1990, Bedrock geology of the Fairbanks mining district: Alaska Division of Geological and Geophysical Surveys Professional Report 106, 2 sheets, scale 1:63,360.
- Solie, D.N., Burns, L.E., and Newberry, R.J., 1990, Gold favorability in the Big Delta quadrangle, Alaska, as predicted by discriminant analysis for non-porphyrty granitic rocks: Alaska Division of Geological and Geophysical Surveys Public-Data File 90-13, 16 p., 2 sheets, scale 1:250,000.
- Solie, D.N., and Harris, E.E., 1990, Analytical results from pan concentrate samples, Tyonek D-6 and parts of adjacent quadrangles, Alaska: Alaska Division of Geological and Geophysical Surveys Public-Data File 90-22, 5 p.
- Wiltse, M.A., 1990, Detailed geology reconnaissance traverse of Upper Dry Creek, Healy quadrangle, Alaska: Alaska Division of Geological and Geophysical Surveys Public-Data File 90-11, 1 sheet, scale 1:63,360.
- Additional Non-Federal Publications**
- Barnes, P.J., 1990, The Prudhoe Bay well planning system, and application used to evaluate potential well locations [abs.]: American Association of Petroleum Geologists Bulletin, v. 74, no. 5, p. 605.
- Bloomberg, R., 1990, Alaska starts repairing miles of corroded pipeline: Engineering News Record, v. 224, no. 10, p. 35-36.
- Bolze, D.A., 1990, Outer Continental Shelf oil and gas development in the Alaskan Arctic: Natural Resources Journal, v. 30, no. 1, p. 17-64.
- Bronston, M.A., 1990, Offshore placer drilling technology—A case study from Nome, Alaska: Mining Engineering, v. 42, no. 1, p. 26-31.
- Brooks, L.D., 1991, ANWR issues revisited: Geophysics, v. 10, no. 2, p. 35-39.
- California Mining Journal, 1990, Alaska's gold mining reaches four-decade high: California Mining Journal, v. 60, no. 1, p. 16.
- 1990, Alaska mining claim maps available: California Mining Journal, v. 60, no. 2, p. 32.
- 1990, Mining claims in Alaska: California Mining Journal, v. 60, no. 3, p. 3.
- 1990, Study reports mining could become Juneau's no. 1 private industry: California Mining Journal, v. 60, no. 3, p. 4.
- 1990, Alaska mineral production for last year may top \$500 million: California Mining Journal, v. 60, no. 6, p. 3.
- Coel, R.J., 1990, Biogeochemical cycling of gold in a placer deposit, Livengood, Alaska [abs.]: Geological Society of America Abstracts with Programs, v. 22, no. 3, p. 14.
- Cooke, A., 1990, Eileen west end development, Prudhoe Bay field, Alaska [abs.]: American Association of Petroleum Geologists Bulletin, v. 74, no. 5, p. 633.
- Crow, P., 1990, Federal land access issues threaten activity: Oil and Gas Journal, v. 88, no. 23, p. 74-80.
- 1990, Adamant on ANWR: Oil and Gas Journal, v. 88, no. 52, p. 19.
- Crowe, D., and Brown, P., 1990, High-grade gold mineralization associated with high salinity hydrothermal fluids, Mt. Estelle pluton, central Alaska Range [abs.]: Geological Society of America Abstracts with Programs, v. 22 no. 7, p. A41.
- Currier, B.H., 1990, Lisburne reservoir limited-drainage test—A pilot test case history: Society of Petroleum Engineers Formation Evaluation, v. 5, no. 4, p. 337-343.
- Drumheller, R.E., 1990, Oil and gas development in Alaska in 1989: American Association of Petroleum Geologists Bulletin, v. 74, no. 10B, p. 37-41.
- Eos, 1990, Under a volcano: Eos (Transactions American Geophysical Union), v. 71, no. 3, p. 201.
- Ewing, H., 1990, Mining begins at Red Dog: Alaska Geographic, v. 17, no. 1, Supplement, p. 86-87.
- Eyles, N., 1990, Glacially derived, shallow-marine gold placers of the Cape Yakataga district, Gulf of Alaska: Sedimentary Geology, v. 68, no. 3, p. 171-185.
- Follmann, E.H., and Hechtel, J.L., 1990, Bears and pipeline construction in Alaska: Arctic, v. 43, no. 2, p. 103-109.
- Hale, P.B., 1990, Offshore hard minerals, in Grantz, Arthur, Johnson, G.L., and Sweeney, J.F., eds., The Arctic region, v. L of Geology of North America: Boulder, Colorado, Geological Society of America, Decade of North American Geology series, p. 551-565.
- Herbert, C.F., and Spencer, A.C., 1990, Juneau, Alaska, gold—Juneau gold mining district, in Hollister, V.F., ed., Discoveries of valuable minerals and precious metals deposits related to intrusion and faults, v. 2 of Case histories of mineral discoveries: Littleton, Colorado, Society for Mining, Metallurgy, and Exploration, p. 163-182.
- International Oil Scouts Association, 1990, International oil and gas development yearbook (review of 1989), Exploration: Austin, Texas, Mason Map Service, v. 60 [Alaska, p. 5].
- 1990, International oil and gas development yearbook (review of 1989), Production: Austin, Texas, Mason Map Service, v. 60 [Alaska, p. 6].
- Jameson, J., 1990, Reservoir description of the Lisburne field, Prudhoe Bay, Alaska [abs.]: American Association of Petroleum Geologists Bulletin, v. 74, no. 5, p. 684.
- Kennedy, A., 1990, Red Dog zinc-lead mine—Alaskan success for Cominco: Mining Magazine, v. 163, no. 6, p. 418-425.
- Kirkham, R.A., and Harvey, D.B., 1990, Geology of the Kensington vein, southeast Alaska [abs.]: Geological Association of Canada Program with Abstracts, v. 15, p. A70.
- Lambert, J.B., Frye, J.S., and Poinar, G.O., 1990, Analysis of North American amber by carbon-13 NMR spectroscopy: Geoarcheology, v. 5, no. 1, p. 43-52.
- Mapmakers, 1990, Cook Inlet ownership map, updated for last two years: 2 sheets [Mapmakers, 259 S. Alaska, Palmer, AK 99645].
- McDonald, W.R., Johnson, J.L., and Sandberg, R.G., 1990, Treatment of Alaskan refractory gold ores—Updating data for economic

- development of regional gold deposits: *Engineering and Mining Journal*, v. 191, no. 6, p. 48-53.
- Munger Oilogram, 1991, Annual California-Alaska oil and gas review, 1990: *Munger Oilogram*, 110 p.
- Newberry, R.J., Burns, L.E., Swanson, S.E., and Smith, T.E., 1990, Comparative petrologic evolution of the Sn and W granites of the Fairbanks-Circle area, interior Alaska, in Stein, H.J., and Hannah, J.L., eds., *Ore-bearing granite systems—Petrogenesis and mineralizing processes*: Geological Society of America Special Paper 246, p. 121-142.
- Newkirk, S.R., and Duke, N.A., 1990, Metallogenesis and sulfur isotope geochemistry of massive sulfide and epigenetic gold mineralization of the Delta district, southern Yukon-Tanana terrane, Alaska Range [abs.]: Geological Association of Canada Program with Abstracts, v. 15, p. A96.
- Noyes, H.J., 1990, Alaska Natives—A major Pacific Rim mineral force, in *Pacific Rim Congress '90, Gold Coast, Queensland, Australia, 1990*: Parkeville, Australia, Australasian Institute of Mining and Metallurgy, Proceedings, v. 3, p. 731-740.
- Oil and Gas Journal*, 1990, MMS issues draft EIS for Navarin area: *Oil and Gas Journal*, v. 88, no. 22, p. 27.
- 1990, Alaska ramping up North Slope, Cook Inlet lease sale program: *Oil and Gas Journal*, v. 88, no. 30, p. 25.
- 1990, Beaufort sale due to cover 3,894 tracts: *Oil and Gas Journal*, v. 88, no. 49, p. 35.
- Piggott, N., 1990, Hydrocarbon sourcing systems of southern Alaska [abs.]: Geological Association of Canada Program with Abstracts, v. 15, p. A105.
- Rintoul, Bill, 1990, Alaska drilling/production: *Pacific Oilworld*, v. 82, no. 1 (57th annual review), p. 56-60.
- 1990, Alaska—Still the best hope?: *Pacific Oilworld*, v. 82, no. 8, p. 4-10.
- Robertson, S.B., 1990, Solid-fill causeways on Alaska's Beaufort Sea coast—Their influence on coastal oceanography and fishes, in *Ports and harbors—Our link to the water*: The Coastal Society, 11th International Conference, Boston, 1988, Proceedings, p. 359-368.
- St. Aubin, L.A., and Metzger, R.R., 1990, Development of the Endicott field (Kekikuk Formation), North Slope, Alaska [abs.]: *American Association of Petroleum Geologists Bulletin*, v. 74, no. 5, p. 770.
- Sawkins, F.J., 1990, The Red Dog zinc-lead-silver deposit, western Brooks Range, Alaska, in Sawkins, F.J., *Metal deposits in relation to plate tectonics*, 2d edition, v. 17 of *Minerals and rocks*: New York, Springer-Verlag, p. 309-312.
- Skills Mining Review*, 1990, U.S. nonfuel mineral industries experience strong year in 1989: *Skills Mining Review*, v. 79, no. 14 [Alaska, p. 10-11].
- 1990, Fall meeting on metallogeny of Soviet Far East and Alaska: *Skills Mining Review*, v. 79, no. 22, p. 3.
- Swanson, S.E., Newberry, R.J., Coulter, G.A., and Dyehouse, T.M., 1990, Mineralogical variation as a guide to the petrogenesis of the tin granites and related skarns, Seward Peninsula, in Stein, H.J., and Hannah, J.L., eds., *Ore-bearing granite systems—Petrogenesis and mineralizing processes*: Geological Society of America Special Paper 246, p. 143-159.
- Tippee, B., and Williams, Bob, 1990, Operators boost offshore action where leases, permits available: *Oil and Gas Journal*, v. 88, no. 23, p. 64-72.

APPENDIX 2.—ROLES OF FEDERAL AGENCIES IN MINERAL PROGRAMS

Department of the Interior

U.S. Geological Survey

The mission of the USGS is to develop and interpret the geologic, topographic, and hydrologic data necessary for prudent management of the Nation's minerals, land, and water. The USGS carries out its mission through research that produces geographic, cartographic, and remotely-sensed information; geologic, geochemical, and geophysical maps and studies; energy, mineral, and water resource assessments; geohazards research, including toxic waste studies; and participation in multidisciplinary projects, maintaining data bases, and publishing reports and maps.

In Alaska, the USGS is active in assessing minerals, including metalliferous and energy resources. Field and laboratory researchers also gather information about domestic petroleum, coal, uranium, and geothermal resources. At the request of land-managing agencies, the USGS provides mineral resource assessments for land planning, including wilderness studies. Within Alaska, the USGS maintains offices for its Geologic, National Mapping, and Water Resources Divisions. Within the Geologic Division, the Branch of Alaskan Geology is the primary USGS office studying mineral resources in Alaska; the Branch is headquartered in Anchorage with a field office in Fairbanks. Other Alaska Branch geologists are stationed in Menlo Park, California. During the summer field season, many USGS scientists from other branches within the Geologic Division conduct mineral-related research in Alaska.

U.S. Bureau of Mines

The mission of the USBM is to help ensure that the Nation's mineral supplies are adequate to maintain national security, economic growth, and employment. The USBM's Alaska Field Operations Center (AFOC) has headquarters in Anchorage and offices in Juneau and Fairbanks. The AFOC carries out its mission through five programs:

1. *Minerals availability program.*—This program is part of a worldwide USBM program responsible for developing the Minerals Availability System (MAS) computer data base and the Mineral Industry Location System (MILS), a subset of MAS. MILS contains basic information about the identification and location of known mineral deposits. MAS is more extensive, containing information about reserve estimates, mineral extraction and beneficiation methodologies, environmental constraints to mining, and cost analyses for selected major mineral deposits. A computer and communication system allow the information

to be stored, manipulated, and retrieved as computer-plotted map overlays and printouts of MAS/MILS data, enabling rapid and uniform development of cost data for MAS mineral-deposit evaluations. MAS and MILS mineral-deposit data are cross-indexed to several other minerals-information data bases.

2. *Policy analysis.*—This program emphasizes the analysis of newly developed and existing mineral data to interpret their significance in the context of local and national mineral needs. Assessment of technical, institutional, political, social, and economic factors that affect the supply of, and demand for, domestic and international minerals is the key to identifying mineral issues.

3. *State mineral activities.*—This program covers minerals-related activities in Alaska and assists in developing and releasing nonfuel-mineral-industry information. The program also provides the USBM with direct communication to the ADGGS, the Alaska Division of Mining, other minerals-oriented government agencies, industry, private firms, and individuals. The USBM's State Mineral Officer collects, analyzes, and reports mineral data and develops information regarding activities and trends in the mining industry. This program produces the annual USBM Minerals Yearbook chapters and Mineral Industry Surveys.

4. *Mineral land assessment.*—This is the USBM's major Alaskan program, conducted in cooperation with other Federal and State agencies. Mineral assessments are both areal and commodity-oriented. In support of the Secretary of the Interior's commitment to assess the mineral potential of public lands in Alaska, the AFOC initiated a program in 1985 to evaluate mineral resources of the mining districts in the State. The program seeks to identify the type, amount, and distribution of mineral deposits; related studies will determine their economic feasibility. Legislative effects on mineral development will also be addressed. The USBM has completed its study of the Juneau mining district; studies of the Ketchikan and Valdez Creek mining districts are in progress.

A statewide program provides an inventory and specific technical evaluations of Alaska's strategic and critical mineral and advanced material deposits on Federal lands that are closed to mineral entry, and on lands that are open to entry but not of current interest to industry. In addition to locating, mapping, and estimating the size and grade of deposits, the USBM obtains bulk samples for metallurgic research to determine recovery and extraction methods and costs. These studies are undertaken in cooperation with the USBM Research Centers in Albany, Oregon, and Salt Lake City, Utah. These investigations provide reserve estimates of marginal and submarginal deposits in Alaska and its coastal waters.

5. *Minerals research.*—The USBM is attempting to provide solutions to mining, mineral recovery, and environ-

mental problems in Alaska through a number of research efforts and technology transfer. Several research projects are currently being conducted in Alaska by USBM research centers or at universities sponsored by the USBM's Mineral Institute Program. USBM and university research centers cooperate with the AFOC to solve mineral utilization problems.

Minerals Management Service

The MMS was created in 1982 with a twofold mission: (1) to collect and disburse revenues generated from mineral leases on Federal and Indian lands, and (2) to oversee the orderly development of America's offshore energy and mineral resources while properly safeguarding the environment. The MMS supervises mineral leasing, exploration, development, and production on the OCS. It is responsible for oil rig safety, oil rig pollution control regulations, determination of the environmental impact of resource development, and estimation of oil and gas resources. The MMS also has the authority to lease the OCS for ocean mining of hard minerals. At present, revenues from the Alaska OCS are primarily derived from competitive leasing activities; no development or production occurs there at this time. The responsibility of MMS for onshore Alaskan minerals is limited to the collection of royalties, bonuses, and rents from Federal and certain Native lands. The MMS also holds occasional Synthesis Meetings and Informational Transfer Meetings, Regional Technical Working Group Meetings, Coordination Team Meetings, and public hearings on Environmental Impact Statements. To determine public concerns for consideration and inclusion in EIS's, scoping meetings related to specific planning or subject areas are held in the local villages. The public is invited to attend these meetings and can contact the MMS Regional Office for specific subjects, dates and times.

In Alaska, the MMS is active in assessing the oil and gas potential of offshore basins through the analysis of geophysical and geologic data. This work is integrated into the National Resource Assessment and is a basis for evaluations of the potential monetary worth of individual OCS lease blocks, for appraisals of the resource potential of entire basins, and for the formulation of geologic models of basin development. The MMS also conducts specialized studies of Deep Stratigraphic Test (DST) wells and exploratory wells drilled on OCS lands. All of this work is carried out at the MMS Regional Office in Anchorage, Alaska. The results of these studies are published through the MMS OCS Report series or in appropriate scientific journals. The MMS also sponsors resource-oriented geologic studies through the Program for Studies Related to Continental Margins, which funds research by State agencies and affiliated academic institutions.

Bureau of Land Management

The BLM manages Federal onshore mineral resources. The BLM also works cooperatively with the NPS, FWS, and USFS to provide technical evaluation of the mineral-related issues on lands under these agencies' jurisdiction.

Multiple-use resource management decisions concerning all minerals on the 92 million acres of land currently managed by the BLM in Alaska (fig. 1) are made through the Resource Management Planning process. The BLM first identifies the mineral potential of each planning unit. The effects of minerals exploration, development, and production, and land abandonment and rehabilitation are then analyzed in regard to the needs and sensitivities of the other resources present. Mitigation measures are developed and evaluated to reduce or avoid adverse impacts of the anticipated mineral activities. Field monitoring of all phases of mineral activity ensures that no unnecessary or undue degradation occurs. The BLM also provides resource management for retained Federal mineral estates on an additional 100 million acres.

Fish and Wildlife Service

The FWS provides Federal leadership to conserve, protect, and enhance fish and wildlife and their habitats for the continuing benefit of people. In Alaska, the FWS seeks to accomplish this mission through programs that implement provisions of the Endangered Species Act, Marine Mammal Protection Act, Fish and Wildlife Coordination Act, National Wildlife Refuge System Administration Act, ANILCA, Rivers and Harbors Act, Clean Water Act, various migratory-bird laws and treaties, and other statutes.

Under ANILCA, 16 refuges in Alaska (fig. 3) were created or enlarged to conserve fish and wildlife populations and their habitats, as well as other values. Except for valid rights existing at the time of establishment, these refuges are closed to entry and location under mining laws. The refuges are open to entry under leasing laws but are closed to the mining of coal by the Federal Coal Leasing Amendments Act of 1975 and are closed to geothermal resource leasing by the Geothermal Steam Act of 1970. Although many traditional activities have been deemed appropriate for these refuges, other uses, including oil and gas leasing, will be permitted only when such activities are compatible with the purposes for which a specific refuge was established.

National Park Service

In 1916, Congress established the National Park Service and stated that the fundamental purpose of the Nation's

parks, monuments, and other reservations was "to conserve the scenery and natural and historical objects and the wildlife therein and to provide for the enjoyment of same in such a manner and by such means as will leave them unimpaired for the enjoyment of future generations" (39 Stat. 535). NPS management policies are based on the concept of conservation and preservation while providing for appropriate enjoyment of natural and cultural resources within the park system.

Congress enacted the "Mining in the Parks" Act in 1976, declaring that a continued application of the mining laws of the United States to park units conflicts with the purposes for which the parks were established and that all mining operations in park units "should be conducted so as to prevent or minimize damage to the environment and the other resource values" (90 Stat. 1342). The NPS manages mining activities on park lands through regulations found at Title 36 CFR, Part 9, Subpart A. These regulations apply to mining-related activities on patented or valid unpatented claims located under the Mining Law of 1872, and proposed plans of operations for such claims must conform to the statutes. Regulations at Title 36 CFR, Part 9, Subpart B, also require plans of operation for operators who, within park units, must access their nonfederally owned oil and gas rights on, across, or through federally owned or controlled lands or waters.

Department of Agriculture

U.S. Forest Service

The mission of the USFS is to provide a continuing flow of natural-resource goods, including mineral and energy resources, to help meet national needs, and to contribute to meeting such needs worldwide. It is the responsibility of the USFS to encourage and support environmentally sound mineral enterprises on Federal lands under its administration. In managing the use of these resources, the USFS objective is to minimize unnecessary adverse environmental impacts to surface and cultural features and values that might result from lawful exploration and development operations. This objective is accomplished through the application of reasonable conditions that do not interfere with well-planned mineral operations. The USFS also provides research information and technology to help with post-mining reclamation. In implementing this policy, the USFS Chief directed that:

1. A key objective of the minerals program is to encourage and facilitate the orderly exploration, development, and production of mineral resources.
2. Minerals, like range, recreation, timber, water, wildlife, and wilderness, are one of the multiple uses the USFS manages.
3. USFS managers must develop a good understand-

ing of the minerals industry, its practices, and the minerals laws and regulations.

4. Managers must develop a strong working relationship with the minerals industry.

5. Visibility and interaction with the minerals industry must be increased by attendance and participation of line officers and appropriate staff at industry and professional association activities and meetings.

6. Directories, organization charts, and receptionists direct the mineral industry to personnel who have minerals-administration responsibilities.

Department of Energy

The DOE's mission is to reduce the Nation's vulnerability to disruptions of energy supplies and to mitigate any adverse impacts on the Nation should a shortage occur. With regard to Alaska, the energy sources currently being addressed by the DOE are fossil fuels (petroleum and coal) and geothermal.

The strategy for responding to petroleum-supply interruptions is to rely on the free market, supplemented as necessary and appropriate with other measures, such as the Strategic Petroleum Reserve. The DOE's Fossil Energy Re-

search and Development Programs are aimed at careful consideration of the alternatives available and the relative chances for success in fostering an adequate supply of energy at a reasonable cost through long-term, high-risk research and development. Alternatives for increasing domestic petroleum supplies include (1) DOE's Unconventional Gas Recovery Program, which emphasizes the development of advanced technologies for the extraction of natural gas from resources that are classified as unconventional because of unique geologic settings and production mechanisms that are not now well understood, and (2) DOE programs for developing tertiary oil recovery, tar sands, and heavy-oil deposits.

The purpose of the DOE's Geothermal Energy Program is to develop the technology needed by industry for the use of geothermal resources. DOE research is aimed toward improving methods used to locate, extract, and convert geothermal heat to usable forms of energy. Through DOE funding in Alaska, Federal and State agencies have researched and published several studies of specific geothermal systems.

A further purpose of DOE programs is to generate data essential to the private sector's decisionmaking process to facilitate the development of commercial projects.

SELECTED SERIES OF U.S. GEOLOGICAL SURVEY PUBLICATIONS

Periodicals

- Earthquakes & Volcanoes (issued bimonthly).
- Preliminary Determination of Epicenters (issued monthly).

Technical Books and Reports

Professional Papers are mainly comprehensive scientific reports of wide and lasting interest and importance to professional scientists and engineers. Included are reports on the results of resource studies and of topographic, hydrologic, and geologic investigations. They also include collections of related papers addressing different aspects of a single scientific topic.

Bulletins contain significant data and interpretations that are of lasting scientific interest but are generally more limited in scope or geographic coverage than Professional Papers. They include the results of resource studies and of geologic and topographic investigations; as well as collections of short papers related to a specific topic.

Water-Supply Papers are comprehensive reports that present significant interpretive results of hydrologic investigations of wide interest to professional geologists, hydrologists, and engineers. The series covers investigations in all phases of hydrology, including hydrogeology, availability of water, quality of water, and use of water.

Circulars present administrative information or important scientific information of wide popular interest in a format designed for distribution at no cost to the public. Information is usually of short-term interest.

Water-Resources Investigations Reports are papers of an interpretive nature made available to the public outside the formal USGS publications series. Copies are reproduced on request unlike formal USGS publications, and they are also available for public inspection at depositories indicated in USGS catalogs.

Open-File Reports include unpublished manuscript reports, maps, and other material that are made available for public consultation at depositories. They are a nonpermanent form of publication that may be cited in other publications as sources of information.

Maps

Geologic Quadrangle Maps are multicolor geologic maps on topographic bases in 7 1/2- or 15-minute quadrangle formats (scales mainly 1:24,000 or 1:62,500) showing bedrock, surficial, or engineering geology. Maps generally include brief texts; some maps include structure and columnar sections only.

Geophysical Investigations Maps are on topographic or planimetric bases at various scales; they show results of surveys using geophysical techniques, such as gravity, magnetic, seismic, or radioactivity, which reflect subsurface structures that are of economic or geologic significance. Many maps include correlations with the geology.

Miscellaneous Investigations Series Maps are on planimetric or topographic bases of regular and irregular areas at various scales; they present a wide variety of format and subject matter. The series also includes 7 1/2-minute quadrangle photogeologic maps on planimetric bases which show geology as interpreted from aerial photographs. Series also includes maps of Mars and the Moon.

Coal Investigations Maps are geologic maps on topographic or planimetric bases at various scales showing bedrock or surficial geology, stratigraphy, and structural relations in certain coal-resource areas.

Oil and Gas Investigations Charts show stratigraphic information for certain oil and gas fields and other areas having petroleum potential.

Miscellaneous Field Studies Maps are multicolor or black-and-white maps on topographic or planimetric bases on quadrangle or irregular areas at various scales. Pre-1971 maps show bedrock geology in relation to specific mining or mineral-deposit problems; post-1971 maps are primarily black-and-white maps on various subjects such as environmental studies or wilderness mineral investigations.

Hydrologic Investigations Atlases are multicolored or black-and-white maps on topographic or planimetric bases presenting a wide range of geohydrologic data of both regular and irregular areas; principal scale is 1:24,000 and regional studies are at 1:250,000 scale or smaller.

Catalogs

Permanent catalogs, as well as some others, giving comprehensive listings of U.S. Geological Survey publications are available under the conditions indicated below from the U.S. Geological Survey, Books and Open-File Reports Section, Federal Center, Box 25425, Denver, CO 80225. (See latest Price and Availability List.)

"**Publications of the Geological Survey, 1879- 1961**" may be purchased by mail and over the counter in paperback book form and as a set of microfiche.

"**Publications of the Geological Survey, 1962- 1970**" may be purchased by mail and over the counter in paperback book form and as a set of microfiche.

"**Publications of the U.S. Geological Survey, 1971- 1981**" may be purchased by mail and over the counter in paperback book form (two volumes, publications listing and index) and as a set of microfiche.

Supplements for 1982, 1983, 1984, 1985, 1986, and for subsequent years since the last permanent catalog may be purchased by mail and over the counter in paperback book form.

State catalogs, "List of U.S. Geological Survey Geologic and Water-Supply Reports and Maps For (State)," may be purchased by mail and over the counter in paperback booklet form only.

"**Price and Availability List of U.S. Geological Survey Publications**," issued annually, is available free of charge in paperback booklet form only.

Selected copies of a monthly catalog "New Publications of the U.S. Geological Survey" available free of charge by mail or may be obtained over the counter in paperback booklet form only. Those wishing a free subscription to the monthly catalog "New Publications of the U.S. Geological Survey" should write to the U.S. Geological Survey, 582 National Center, Reston, VA 22092.

Note.--Prices of Government publications listed in older catalogs, announcements, and publications may be incorrect. Therefore, the prices charged may differ from the prices in catalogs, announcements, and publications.

