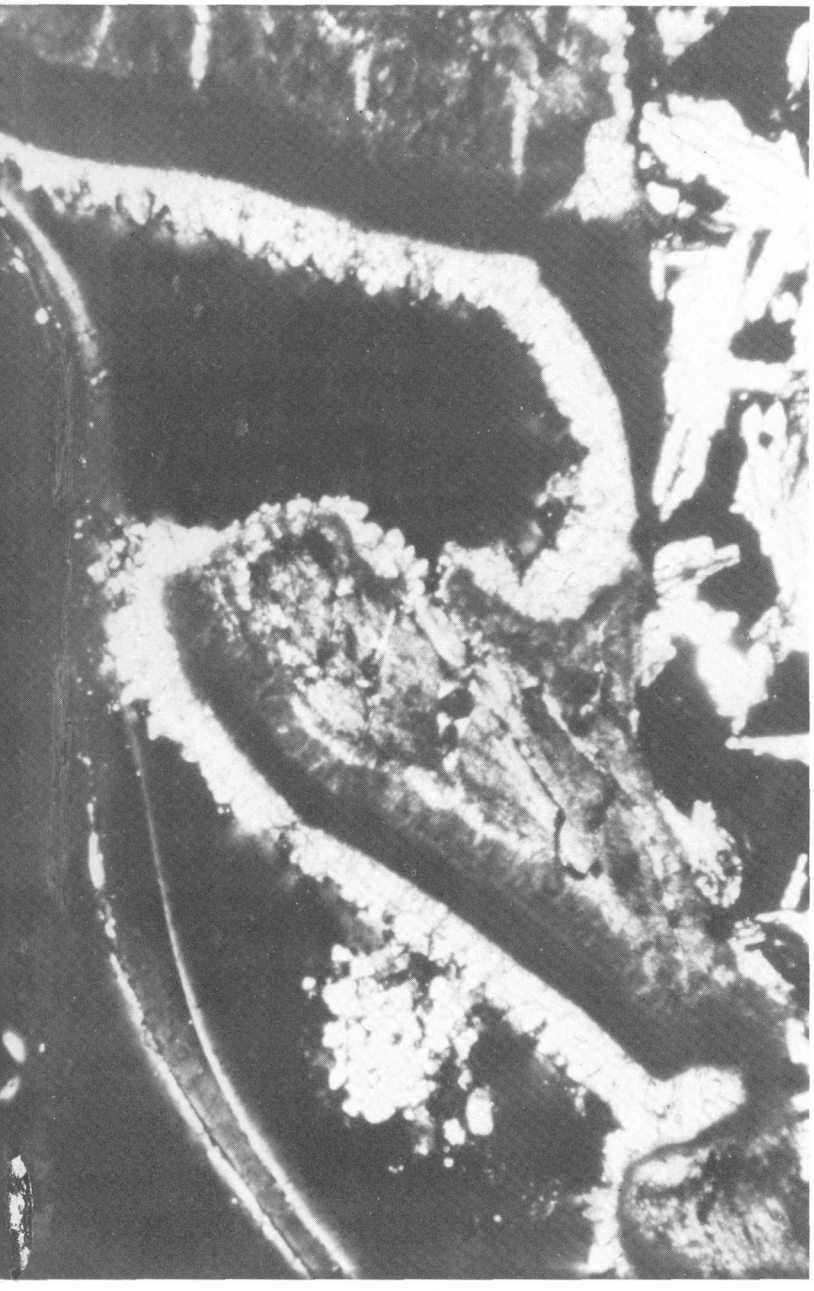

United States Geological Survey Yearbook, Fiscal Year 1979

Cover: Thin-section photomicrograph of basalt rock with sedimentary material and chemical precipitate lining a void in the rock. The sample was taken from the unsaturated zone of the Snake River Group basalt in the Snake River Plain, Idaho. Layers of clay particles (medium to dark brown) were deposited on altered basalt (yellow to light brown) by infiltrating sediment-charged waters during recharge. Crystalline carbonate (continuous white) lining precipitated from waters of later recharge. The dark area, generally to the left of the white crystalline lining, is the void.

Of special interest are chemical reactions in the unsaturated zone which might affect migration of waste radionuclides buried at the Department of Energy's Idaho National Engineering Laboratory. The picture was used in the study of hydrogeologic and geochemical conditions made by the U.S. Geological Survey at the laboratory. Magnification is approximately 400 times. (Photograph by Ruth Deike, USGS.)

UNITED STATES DEPARTMENT OF THE INTERIOR

CECIL D. ANDRUS, Secretary

GEOLOGICAL SURVEY

H. William Menard, Director

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Acknowledgments

We express our appreciation to the following persons who contributed to and assisted in the preparation of the fiscal year 1979 Yearbook: Paul Beauchemin; Bruce L. Beaudin; Charles W. Bennett, Jr.; Gordon Bennett; Granville Billingsley; Matilda G. Boccabella; Nancy C. Born; Winifred J. Bowcock; Paula Bowman; Arthur Bowsher; Brinton Brown; Henry Brown; Conni Bryan; Thomas Buchanan; Joseph F. Cain; James L. Caldwell; John R. Caracciolo; Robert Carter; Edith Chase; Paul Clarke; Charles Clifford; William A. Coe; Gary G. Collins; Stella Collins; Michele Connolly; Clarke H. Cramer; Ann Csonka; Larry R. Cullumber; Susan L. Cupertino; Spencer J. Dean; Catherine M. D'Agastino; George DeBuchananne; Beulah DiCarlantonio; Carl E. Diesen; Dona B. Dolan; Julia Doyle; Shelby Dreyer; Wendell A. Duffield; George Edelen; Terence N. Edgar; Melvin Edwards; John Elder; Jacky Eutize; John Ferris; Melissa Fox; Doyle G. Frederick; Lowell W. Goodman; Bette Goodrich; Mary E. Graziani; George Gryc; Kathryn Gunderson; Norman E. Gunderson; Nancy Hardin; George F. Hargrove, Jr.; Leonard D. Harris; Arthur K. Hiltbrand; Harold Hubbard; Carolyn S. Hulett; Joyce Humphrey; Norma Janke; Patty Jewell; James R. Jones; John Jones; Donald Jordan; John Kammerer; F. Paul Kapinos; Carl Koteff; Tom Kugel; Ken Lanfear; Robert Lantz; Dorothy Lathrop; Florence Lee; Susan Lee; Teri Leff; John J. Lenart; Anna Lenox; Karen Letke; Scotty Livingston; Stephen G. Lynch; David Lystrom; Richard MacDonald; Price McDonald; Bruce McFarlane; H. Lindy Mann; Faye W. Marshall; Jane H. Mastin; John D. Mayberry II; Keith L. Meekins; Gerald Meyer; John Moore; Harold Moritz; Roy R. Mullen; Beverly Myers; Janis C. Nash; Gary W. North; James T. O'Kelley; Office of Plans and Program Development, Topographic Division; William B. Overstreet; Alvin Pendleton; Charles M. Perrott; Sue Phillips; Wanda Jo Preece; Ronald E. Prehoda; William Price; William C. Prinz; Jerry Purdy; Martha Quigley; Gerald D. Rhodes; David Rickert; Charles D. Ritter; James Rollo; Lawrence C. Rowson; Frederick Ruggles; Kathleen B. Rutledge; Bob Ryder; Janet S. Sachs; Lynne Schlaaff; Robert Schneider; Robert Schrott; Loren Setlow; Clement F. Shearer; William Shope; G. I. Smith; Larry A. Soderbloom; R. B. Southard; Geoffrey Steele; Jerry Stephens; Roger M. Stewart; Theresa Swift; Paul G. Teleki; Donald Thomas; Lewis V. Thompson; Ralph J. Thompson; Jerry Tull; Buford Walling; David W. Weber; George Williams; Richard Witmer; Roger Wolff; Jim Wray; Russell L. Wylie; Valentine Zadnik; Earl T. Zeh; and Charles D. Zeigler.

Preface

The fiscal year 1979 Yearbook summarizes the activities of the U.S. Geological Survey in response to its scientific and regulatory missions and its responsibility for exploration of the National Petroleum Reserve in Alaska.

The main sections of this Yearbook are:

- The Year in Review—a brief overview of the significant events of the Geological Survey during fiscal year 1979.
- Perspectives—essays focusing on specific events (rather than scientific topics) and programs involving multi-Division participation.
- Missions, Organization, and Budget—a description of the Geological Survey's major duties and assignments and of the organizational structure that supports its missions.
- Division Chapters—a description of the significant accomplishments (rather than a comprehensive program by program discussion) of each of the nine operating Divisions and Offices.
- Appendices—provide supplementary information regarding key personnel, cooperators, and selected summary budgetary tables and an index.

Professional Paper, 1150, *Geological Survey Research* 1979, the latest in a series of annual reviews of technical results of the Geological Survey's research programs, supplements the Yearbook.

The Year in Review

In March 1979, the U.S. Geological Survey celebrated its 100th year of service to the Nation and 10 decades of stewardship of the land and its resources. During this year, as in the previous 99, the Survey discharged its national trust by collecting, analyzing, and disseminating earth science information and by continuing its somewhat more recent responsibilities of supervising the development of energy and mineral resources on Federal lands.

The basic mission of the Survey has changed over the years, and the scope of its activities and the power of analytic tools have also increased by several orders of magnitude—from the early surveys of then "remote" western areas of the United States to surveying and mapping the mountains of the Moon and the polar caps of Mars and from the use of surveyor's transits, picks, the travelling chemistry kits to interpretation of Earth imagery. These representative advances illustrate important and continuing trends for at no previous time have our earth resources been so precious or our consciousness of their finiteness so acute.

The Yearbook reports a broad range of the Survey's accomplishments during the past fiscal year and offers an overview of its future. Many of the topics touched on below will continue to be important resource issues in the coming decade.

ENERGY

Providing the earth science knowledge needed to satisfy the Nation's growing demands upon a declining energy resource base and addressing the environmental implications of satisfying those demands will continue to be a major responsibility for the Geological Survey in the foreseeable future.

During fiscal year 1979, the Department of the Interior, which manages the development of energy resources on Federal lands, proposed a new leasing program that would accelerate Outer Continental Shelf (OCS) oil and gas exploration and announced the resumption of coal leasing on Federal lands. Several recent legislative initiatives including the Outer Continental Shelf Lands Act Amendments of 1978, the Surface Mining Control and Reclamation Act of 1977, and the Natural Gas Policy Act of 1978 directly affected the programs and activities of the Geological Survey.

OUTER CONTINENTAL SHELF OIL AND GAS

The need to identify frontier offshore areas that have the potential to increase the Nation's oil and gas reserves and, consequently, would be favorable target areas for the accelerated Federal OCS leasing program continued to be a critical part of the Survey's mission during fiscal year 1979. These frontier areas are located in deep waters that have more hostile environments for development than the current oil- and gas-producing leased areas. The Survey's investigation will supply industry with the necessary knowledge to develop techniques and to design the equipment required to safely and successfully recover the oil and gas discovered in these frontier offshore areas.

During fiscal year 1979, 678 offshore oil and gas leases were offered for sale by the Department of the Interior. Based on evaluations made by the Geological Survey, 290 of those tracts were leased for exploration by the Bureau of Land Management (BLM). The revenue from the sale of these leases brought $2.8 billion into the Federal treasury. To comply with the Outer Continental Shelf Lands Act Amendments, the Survey devised new regulations governing industry operations on the OCS and began compilation of indexes and summary reports of OCS-related research and activities to better communicate scientific findings to the public.

In addition to assessments of oil- and gas-resource potential, the Survey also continued to provide analyses of geologic hazards in potential OCS leasing areas. An oilspill trajectory analysis computer model was developed that determines the probability or risk of an oilspill occurring in a proposed leasing area and the potential path that it may follow. This modeling technique was included in 10 environmental impact statements, which were used by BLM in their administration of the OCS leasing process during 1979.

COAL

The Secretary of the Interior announced an accelerated Federal coal leasing program on June 1, 1979. The Survey's role in the program is to provide geologic- and water-resources information and evaluations that can aid in the coal lease decisionmaking process. To respond to this need, the Survey completed the first of a series of coal folios covering three $1° \times 2°$ quadrangles, and the necessary field work was begun in many other quadrangles. These folios integrate information on the occurrence of coal on Federal lands with various environmental factors, such as geochemistry and ground stability, to assist Federal officials in the design of coal development plans that are in the best public interest. The Survey also expanded the program of water-data collection and analysis to meet requirements of the Surface Mining Control and Reclamation Act. To comply with other responsibilities in the coal leasing program, the Survey classified over 1.2 million acres of Federal land into Known Recoverable Coal Resource Areas, completed 146 map quadrangles under the Coal Resource Occurrence/Coal Development Potential Mapping Program, and developed 26 coal economic evaluations to support coal leasing decisionmaking.

The Grand Tetons. (Photograph by National Park Service.)

OIL AND GAS ONSHORE

Updated resource assessments of the Nation's onshore oil and gas are a vital part of the Nation's overall energy plan. The Survey responded to this need by conducting detailed reevaluations of the resources remaining in the Permian, Gulf of Mexico, and other significant petroleum basins. A revised overall assessment of onshore and offshore oil and gas resources will be forthcoming in the latter half of fiscal year 1980.

The Survey's long history of basic scientific research paid a dividend in fiscal year 1979. Continuing basic research studies resulted in the discovery of a concealed belt of sedimentary rock in the Appalachian region that has the potential of doubling the area favorable for oil and gas exploration.

The Survey provides substantial support in the development of oil and gas on Federal and Indian lands. In fiscal year 1979, roughly 6.4 percent of all oil and 5.9 percent of all natural gas produced domestically came from leases on these lands.

Total domestic production of oil and gas is on the decline because of diminishing existing reserves, and new reserves are replaced at about 50 percent of production. Private companies have expanded exploration activities into promising frontier areas on Federal lands in the overthrust belt of Utah, Wyoming, Idaho, and Montana. During fiscal year 1979, 3,550 new exploration and development wells were approved by the Survey following the completion of 3,660 environmental analyses.

While monitoring this exploration and development activity, the Survey began implementing procedures in the Natural Gas Policy Act which allow lessees or operators to charge higher prices for natural gas produced from certain categories of wells. From December 1978 to September 1979, the Survey processed 7,598 applications and made 4,469 determinations of various well categories described under the provisions of the Act which allow prices to be increased. At this time, approximately 300 applications for well reclassification are received each month.

During fiscal year 1979, the Survey also continued the exploration of the National Petroleum Reserve in Alaska (NPRA) through Husky Oil NPR Operations, Inc. Nine exploration wells were active during the year; five were completed, including one well that was reentered and completed to target depth and one well that was left for reentry in fiscal year 1980. Three wells were still drilling at the end of fiscal year 1979. The 16 wells drilled to date, including the 7 drilled by the Navy prior to the transfer of the Reserve to the Geological Survey, have been dry or, at best, had only slight indications of oil and gas. The primary aim of the drilling program was accomplished to assess the petroleum resources of NPRA and to support completion of the study mandated by Public Law 94-258, which called for "the best overall procedure to be used in the development and production, transportation, and distribution to the petroleum resources in the reserve." The Survey provided support to the Department of the Interior's Office of Minerals Policy and Research Analysis, which is charged with the responsibility of preparing the economic analysis. This report is due to be presented to the Congress by January 1, 1980. All data and results from drilling, geophysical surveys, and special studies continued to be released to the public during fiscal year 1979.

GEOTHERMAL RESOURCES

Geothermal energy is coming of age and will play an important role in solving the Nation's energy shortages in the next decade. During fiscal year 1979, the Survey updated its assessment of geothermal resources and attempted a first evaluation of low-temperature geothermal waters, which have the potential of adding to the resource base.

The Survey continued its support for the development of geothermal resources on Federal lands. In fiscal year 1979, the Survey supported the lease of 268 geothermal tracts consisting of 541 acres, a 30-percent increase over fiscal year 1978. During fiscal year 1979, the number of geothermal wells drilled on Federal, State, and private lands increased about 60 percent over the preceding fiscal year. Fewer wells (11 instead of 13) were drilled on Federal leases last year, but approvals to drill 336 wells have been issued.

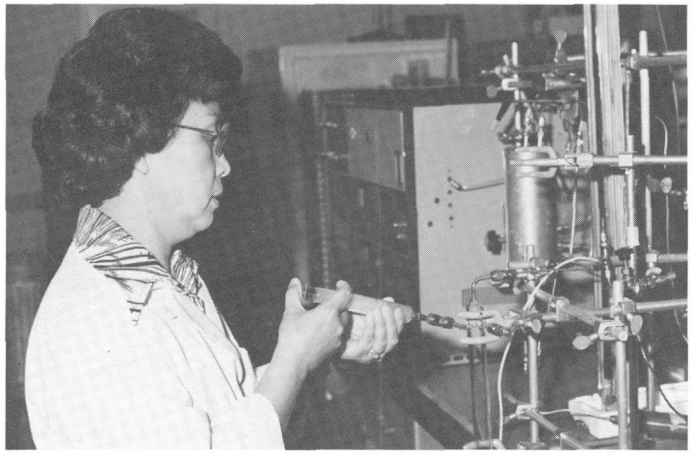
NUCLEAR ENERGY

The Geological Survey accelerated a research program to assist the Department of Energy in the selection and design of high-level nuclear-waste repository sites. During fiscal year 1979, studies were underway of the Waste Isolation Pilot Plant site in southeastern New Mexico; the shale and granite bodies in the Nevada Test Site area; the salt anticlines in the Paradox Basin, Utah; the Gulf Coast salt domes in Mississippi, Louisiana, and Texas; the bedded salt deposits in the Salina Basin, N.Y.; and the basalt formations in the Hanford Reservation area of Washington.

The Survey continued its efforts in support of the Department of Energy's National Uranium Resource Evaluation Program. These efforts are concentrated on conducting studies in 23 selected $1° \times 2°$ quadrangles in the conterminous United States to assess the uranium potential in each quadrangle and to develop uranium-resource assessment methodologies. Maps showing the results of these studies will be compiled and published.

MINERALS

There is increasing evidence that the Nation will soon experience shortages of critical mineral commodities in the same manner that it now experiences shortages in energy commodities. The mineral availability issue is closely entwined with the equally difficult issues addressed by the Wilderness Act of 1964 (Public Law 88-577). This act guarantees that increasing population and industrial expansion would not occupy and modify all of the Nation's lands and, thus, leave no areas preserved and protected in their natural unspoiled condi-



◀Hydrologist analyzing a water sample.

tion. During fiscal year 1979, the Survey responded to the implementation of the Wilderness Act by completing assessments of 3.5 million acres of land being investigated for potential withdrawal and designation under the National Wilderness Preservation System. Meanwhile, in response to the growing demand for a systematic appraisal of the Nation's mineral resources, the Survey continued its Alaska Mineral Resource Appraisal Program and Conterminous United States Mineral Appraisal Program (CUSMAP). These programs are committed to conducting geological, geophysical, and geochemical studies to determine the mineral resources in Alaska and selected 1° × 2° quadrangles in the conterminous United States. Maps showing the results of these studies will be compiled and published in 19 folios. To date, seven folios covering quadrangles in Alaska have been published, seven are in preparation, and field work is now in progress on five. CUSMAP will have three folios in press during fiscal year 1980, and field work and compilation are now in progress on 12 additional quadrangles. These efforts have already provided the Administration and Congress with useful information to aid in deciding the status of Alaskan lands and in assessing numerous other national mineral resources. The Survey expects to continue this effort in anticipation of the forthcoming BLM Wilderness Review, which is required by the Federal Land Policy and Management Act of 1976.

◀ Fertilizer and seed followed by compaction gives better results than drilling without compaction, Big Sky mine, Rosebud County, Mont.

▼ Reclaiming old spoils at the Rosebud mine, Colstrip, Mont.

WATER RESOURCES

The Survey amplified several of its programs that evaluate the Nation's water resources and continued to provide basic hydrologic data on surface and ground water in support of the numerous Federal agencies, State and local governments, and other groups charged with managing and developing water resources.

The National Water-Use Program, which is a joint Federal-State cooperative effort begun in 1977, made great strides in accomplishing its aim of being operational in all 50 States and Puerto Rico by fiscal year 1982. The objective of this Program is to enable Federal and State agencies to account for present water use and, thus, to project future water requirements.

Under the Regional Aquifer-System Analysis Program, 28 aquifer systems have been identified for study. In fiscal year 1979, studies began in three of these aquifer systems—the Southeastern Carbonate aquifers (Florida, eastern Georgia, and small areas in Alabama and South Carolina), the Northern Midwest Sandstone aquifers (Wisconsin, Minnesota, Illinois, Missouri, Iowa, and a small area in Indiana), and the Southwest Alluvial valleys (parts of Arizona, New Mexico, and Texas). For these three areas, significant accomplishments were the development of maps showing water quality, potentiometric surface, aquifer characteristics, and the confirmation of fresh ground water in the Continental Shelf sediments off the Florida coast.

River-quality assessments presently underway include those on the Potomac River Estuary, Md., the Truckee and Carson River basins, Nevada-California, the Schuylkill River, Pa., and the Apalochicola River, Fla. The purpose of these assessments is to define the character, interrelationships, and causes of existing river-quality conditions and to provide a basis for evaluation of different alternatives for river-quality management. Findings from the completed assessment of the Chattahoochee River indicating that storm-water runoff from Atlanta, Ga., contributed significantly to pollution of the river further underscored the need for development of techniques for managing urban storm-water runoff. To assist local agencies in addressing the problem of storm-water runoff, the Survey has begun studies that will provide the agencies with data and interpretive reports.

Over the years, new methods have been developed for recording and distributing the information collected at stream-gaging stations to improve the reliability of the data and the timeliness of distribution. A technique now being tested is the use of Earth satellites to relay measurements from 140 remote data-collection stations to a central processing and distribution facility.

MAPPING AND EARTH IMAGERY

During fiscal year 1979, the Survey published 3,546 new and revised maps at scales ranging from 1:24,000 to 1:500,000. This effort brought the completion of the 1:24,000-scale map series to 64.6 percent of the Nation. To meet high-priority and urgent needs, the Survey also produced 3,995 orthophotoquads as an interim mapping product.

The Geological Survey published maps at several other scales with significant national coverage and use. More than one-half the conterminous United States has been mapped at the 1:100,000 scale; this scale is of particular benefit to those involved in resource planning, inventorying, and conservation activities because information is portrayed on a regional basis. This coverage is up from about one-third at the end of fiscal year 1978.

The Survey initiated a digital mapping program as the first step toward use of the computer to collect and to integrate various types of data regarding the Earth's surface into specialized mapping products and information. Digital cartographic technology is revolutionizing the way map information is produced and used by an increasingly sophisticated scientific and land use planning community. Alaskan mapping programs were strengthened during the year when the decision was made to increase map coverage of the State's lands and resources. The Survey is using a variety of techniques, including aerial, Earth, and experimental radar imagery.

During fiscal year 1979, the Survey published a new 1:100,000-scale map for the XIII Olympic Winter Games in Lake Placid, N.Y., in cooperation with the Lake Placid Olympic Organizing Committee. The map is printed on both sides; one side shows the topographic map, and the other highlights the areas where key events will occur.

The Geography Program continued its effort to complete land use and land cover maps for the entire Nation by fiscal year 1982. During fiscal year 1979, an additional 260,000 square miles were mapped bringing the total square miles completed to 1.25 million since the beginning of the Program in fiscal year 1975. Of special note was the use of the Survey's land use maps in the analysis of population densities in the vicinity of Three Mile Island, Pa.

The Earth Resources Observation Satellite Data Center (EDC) began using a domestic communications satellite to relay Landsat image data from the Goddard Space Flight Center near Washington, D.C., to EDC in Sioux Falls, S. Dak. Used with the new EDC Image Processing System, the relay has made possible an all-digital process that greatly speeded the transfer of Landsat data from Goddard to EDC. This process will allow Landsat data to be used in applications that require quick access to such data. These applications include detecting and tracking oilspills and monitoring agricultural and range land through the seasons, forest fires, and floods.

The Survey published two new books on mapping during the year, the *Coastal Mapping Handbook,* prepared jointly by the Geological Survey and the National Ocean Survey of National Oceanic and Atmospheric Administration, and *Maps for America.*

Dr. Oskár Ádám (left), Head of the Department of and Coordinator of the Central Office of Geology/USGS, and Dr. H. William Menard, Director, U.S. Geological Survey, signing a memorandum of the visit of the Hungarian earth science delegation, April 30, 1979. ▶

NATURAL HAZARDS

Significant progress has been made in recent years in the development of techniques and systems to provide warnings of the possibility of impending natural disasters such as floods, landslides, and earthquakes. The Disaster Relief Act of 1974 gave the Geological Survey the responsibility for warning State and local officials of impending geologic hazards in their areas. To help meet this responsibility, a communications network for the transmission of technical information has been established in a majority of States.

During fiscal year 1979, the Survey made considerable progress in implementing the Earthquake Hazards Reduction Program. Seismicity studies of earthquake-prone regions were underway for much of the Nation; intensified studies were begun in San Francisco, Los Angeles, and San Diego, and research investigations have been focused on the central and southern California regions as well as several other areas of high seismicity around the world.

During fiscal year 1979, the Survey prepared flood-prone-area maps in 236 areas subject to urban flooding. In response to the Flood Insurance Act of 1968, 222 Housing and Urban Development flood-insurance studies were completed.

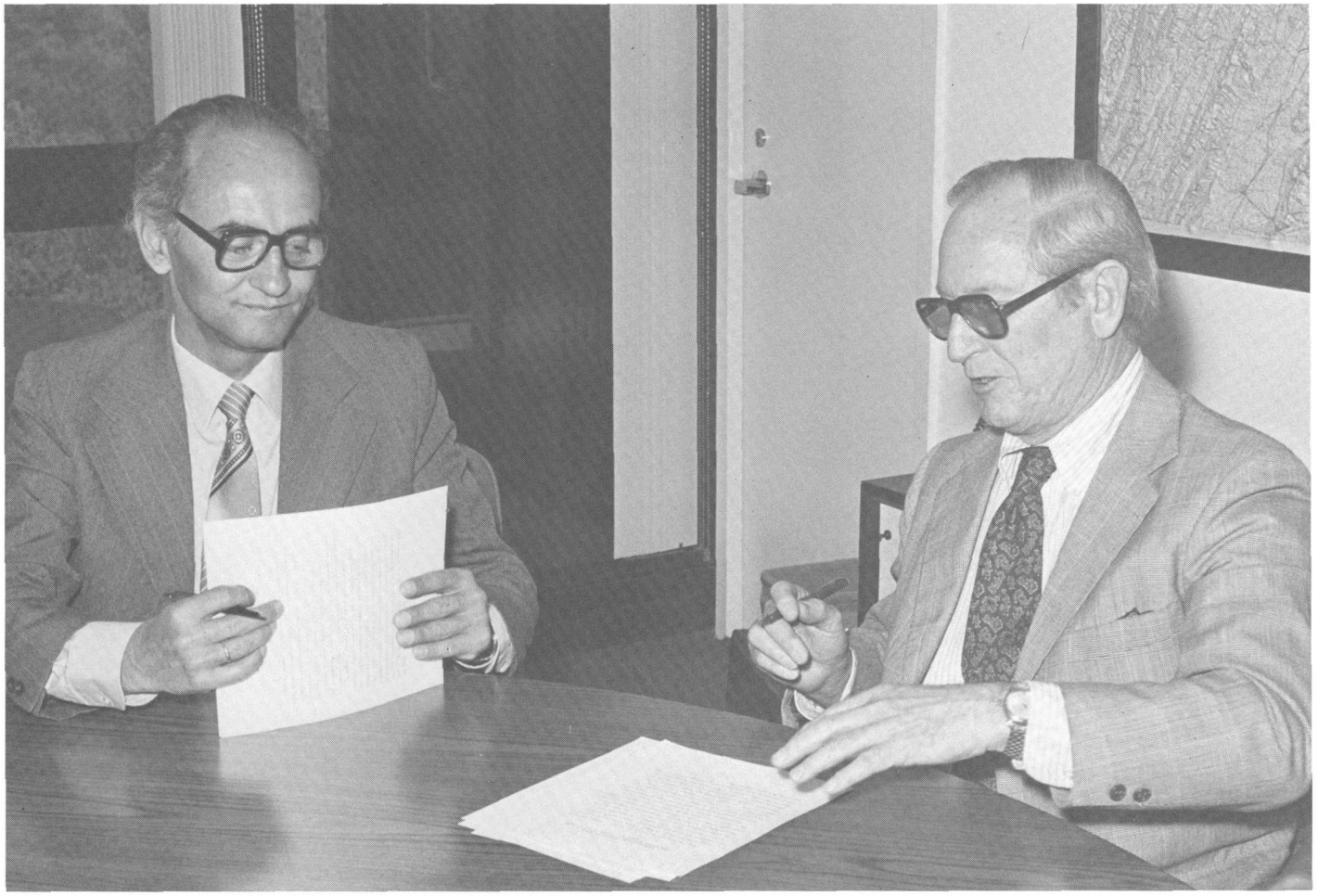
INTERNATIONAL ACTIVITIES

As an extension of the Survey's domestic program and in support of national foreign policy, the Survey undertook a wide variety of cooperative research, assistance, and (or) training programs with other governments or on behalf of other U.S. or international agencies.

Among the foreign countries with which the Survey dealt were Saudi Arabia, Botswana, Diego Garcia (Chargos Archipelago), Hungary, Mexico, Portugal, Somalia, Tunesia, Indonesia, the Philippine Islands, and Bolivia. The Survey assisted with such projects as surveying and cartographic support; hydrology planning; digital modeling of ground water; geothermal studies; identifying, evaluating, and planning for development of energy and energy-related resources; and geologic studies.

MANAGEMENT INITIATIVES

During fiscal year 1979, the Survey made several substantial improvements in the manner in which it conducts its business. Among these were the establishment



of the Office of the Data Base Administrator and several improvements in the areas of administrative and technical support and in the Equal Employment Opportunity Program.

DATA BASE ADMINISTRATION

The Survey is computerizing data, such as tables, text, maps, analog charts, and photographs, that were formerly available only in document form. With the long-term trend toward a more complete and unified representation of all earth science data components, coordination of data activities is of major concern. The Office of the Data Base Administrator was created to coordinate and to increase the compatibility of Geological Survey scientific and technical data bases and systems, both internally and externally. Recent efforts have involved the initiation of projects for the development of a Surveywide data-base inventory and a dictionary-directory of data elements and their attributes.

ADMINISTRATIVE AND TECHNICAL SUPPORT

Creation of the Senior Executive Service under the Civil Service Reform Act changed the roles and responsibilities of the Federal executive manager. The executive staff of the Survey welcomed this change and envisioned this new approach to top-level management as an opportunity to develop a more effective managerial framework for the conduct of the Survey's programs.

In a continuing effort to streamline administrative operations, the Survey implemented the computer-based Advance Procurement Planning System in fiscal year 1979. This system should reduce the time involved in processing contracts by increasing the coordination between the procurement officer and the project officer.

In searching for a more effective communications link between the computer user and his or her data, the Survey has increased its data communications services by expanding the TYMNET facility, a nationwide network that allows users to access distant computers at minimal cost. This expansion adds additional TYMNET lines into all sites and provides the capability to transmit at a higher speed. Research and planning are currently underway for access to ARPANET, a resource-sharing intercomputer network linking a variety of computers.

To improve the dissemination of the Geological Survey's technical and scientific information to the public, a new Public Inquiries Office was established in Menlo Park, Calif., at the Survey's Western Region Center. In fiscal year 1979, the Survey produced 10,147 topographic, hydrologic, and geologic maps of which over 9.3 million copies were sold to other Federal agencies, States, and the public by the distribution centers. Sales of open-file reports increased from 27,804 in fiscal year 1978 to 35,527 in fiscal year 1979.

EQUAL OPPORTUNITY OFFICE

Fiscal year 1979 constituted a period of major change in operation, organization and extent of responsibility for the Geological Survey's Equal Opportunity (EO) Program. During this period, the Survey's EO policy and program have been dominated by two major objectives: enlarging the EO staff and reorganizing the organizational structure of the EO Office. These actions were prompted by increased program requirements brought about by new Departmental guidelines and the Civil Service Reform Act of 1978.

On October 16, 1978, the newly structured organization and staffing plan in the format specified by Departmental EO Memorandum No. 78-11 was submitted to the Director, Office for Equal Opportunity, Department of the Interior, and subsequently approved. The staffing plan called for an immediate overall increase of nine positions including seven additional full-time personnel (an increase of 75 percent) and two additional less than full-time positions to provide essential support; this resulted in a total staffing of 25 (21 full-time and 4 part-time).

The organizational plan called for incorporating regional program responsibility of Mid-Continent States and Headquarters with Central Region and Eastern Region, respectively, to avoid duplication of efforts and to promote the efficient utilization of personnel.

The staffing and reorganization plans were accomplished in June 1979 to include the transfer of overall responsibility of the Minority Participation in Earth Science Program from the EO Office to the Regional Director's Offices.

The goal of the Equal Opportunity Office is to broaden and strengthen the Survey's effort to carry out a program designed to promote equal opportunity in every aspect of personnel policy and practice through increased monitoring guidance and technical assistance to all directorates. Fiscal year 1979 provided the personnel resources and a newly structured EO Office to meet such a goal. The long-range goal of ensuring equality of opportunity in employment for all Survey employees and applicants is no longer perceived by many as compliance of EO laws but a current program of operation.

CONCLUSION

As fiscal year 1980 begins, we expect to continue delivering the much-needed scientific support upon which so many of the Nation's goals rely. Although the Survey is a product of its distinguished past, we cannot allow ourselves to let the past dictate our future.

Navajo uranium mine and tailings piles, Wyoming.

Perspectives

THE U.S. GEOLOGICAL SURVEY AT 100—LEGACIES AND CHALLENGES

1879—CRISIS IN THE MINERAL INDUSTRY

When the U.S. Geological Survey was founded in 1879, the United States had just completed its Reconstruction era and the Nation was recovering from a major economic depression following the financial panic of 1873. Within the next two decades, the once isolated, rural, and agrarian Nation was well on its way to becoming a world, urban, and industrial power. In this development, mineral resources played a vital role as the value of the Nation's mineral products tripled between 1880 and 1890. In 1879, two outstanding problems of practical importance faced the mineral industry, one involving the great industrial metal, iron, and the other, the precious metals gold and silver. The use of steel in construction had increased rapidly during the 1870's. Although the United States possessed large reserves of iron, steelmaking processes then commonly used required a low-phosphorous low-sulfur pig iron, and there was a shortage of ores of suitable composition to meet the growing demands of industry.

The crisis in the production of precious metals and their use in currency involved complex political as well as business concerns. The Specie Resumption Act of 1875 provided for a return to the gold standard in 1879 by equating the "greenback" paper currency, first issued during the Civil War, with gold. The legislation also reduced by $82 million the amount of greenbacks in circulation as a response to Eastern requests for a sounder fiscal policy, rather than continuing the inflation of currency favored by agricultural interests in the South and West that sought cheaper money to repay debts and mortgages. Here, agricultural concerns merged with those of the mining industry in the West where new discoveries in the Comstock (Nevada) and other mining districts in 1876 had dramatically increased silver production. In response to political pressure for the free and unlimited coinage of silver, Congress passed the Bland-Allison Act in February 1878 over the veto of President Rutherford B. Hayes. As the Act required Secretary of the Treasury John Sherman to buy from $2 million to $4 million in silver each month for coinage, 1878 was a year of great monetary uncertainty.

On January 1, 1879, the Treasury Department resumed specie payments as required by the Act of 1875. Although Secretary Sherman confidently expected the Treasury's gold reserve of $200 million to cover any rush to convert paper to metallic currency, the amount of gold mined each year in the United States had been declining steadily through most of the decade as the production of silver steadily increased. Gold was the second major metallic ore in short supply in the United States.

1879—THE FEDERAL RESPONSE TO THE CRISIS

The U.S. Geological Survey was founded, 2 months after specie payments resumed, on March 3, 1879, when President Hayes signed an appropriations bill that contained an item giving the Director of the Geological Survey responsibility for administering a new organization charged with

> the classification of the public lands and the examination of the geological structure, mineral resources, and products of the national domain.

Congress established the Geological Survey to promote greater economy, efficiency, and utility in the conduct of geologic investigations by merging many of the functions of the three remaining Federal geological and geographical surveys of the Nation's territories in the West—organizations discontinued by the same legislation. More realistically, however, Representative Abram Hewitt of New York, one of the chief proponents of a national geological survey, had emphasized in the House debate on the bill that

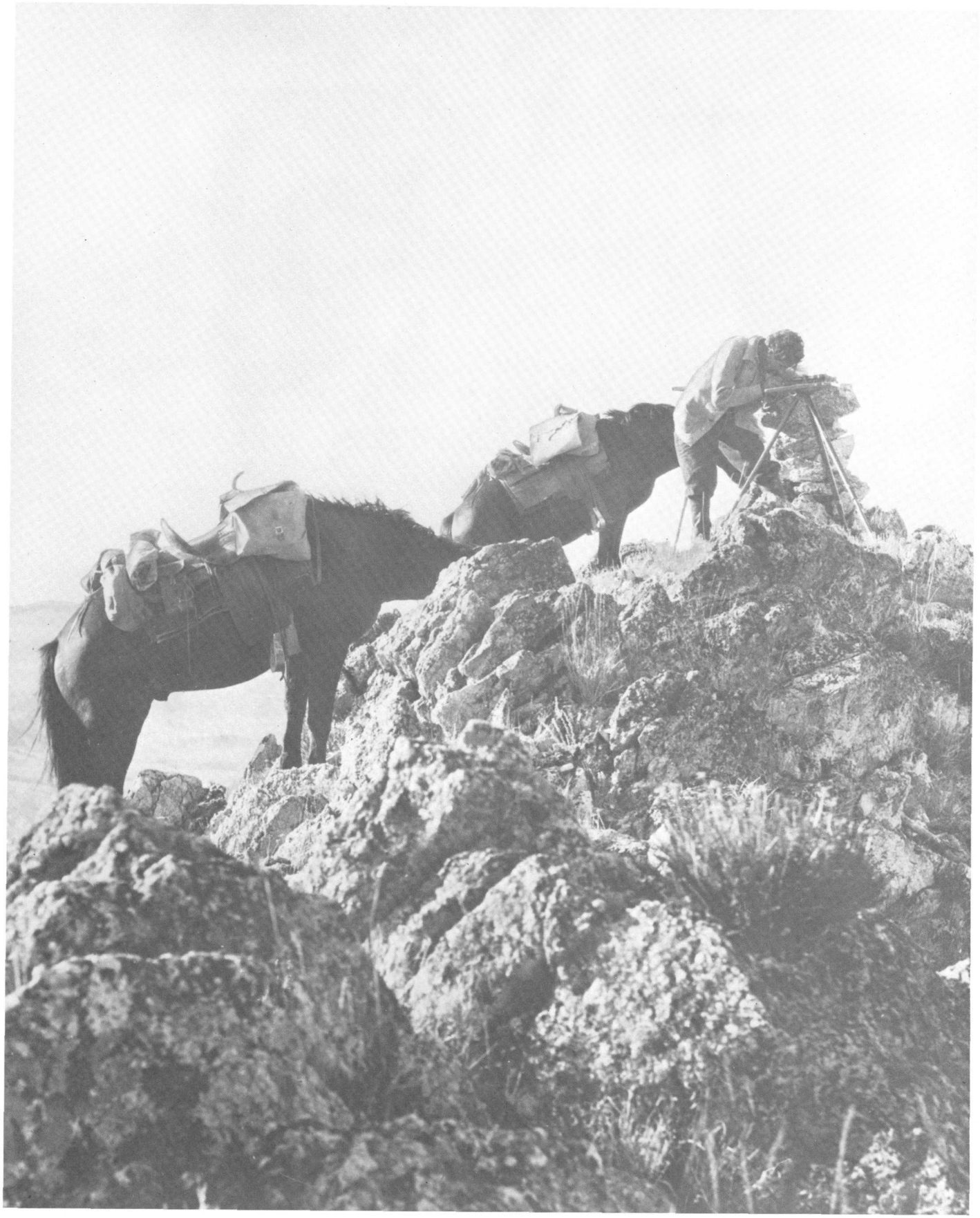
> The need of a thorough survey for the wise organization and distribution of American industry is in the future as imperative as a constitution on which to found our laws.

Founded as a bureau in the Department of the Interior, the Geological Survey joined the small number of Federal scientific and mapping agencies, both civilian and military, that had been established for practical purposes, although some of these organizations had extended their work into basic science.

THE SURVEY'S TRADITION OF APPLIED SCIENCE

Congress had authorized mineral-resources surveys of specific areas in the United States as early as the 1830's. In establishing subsequent reconnaissances and the territorial surveys that preceded the U.S. Geological Survey, Congress demonstrated its recognition of the growing importance of these natural resources to the Nation's development. Clarence King, the Geological Survey's first Director (1879-81), responded to the intent of the legislation and the Nation's critical need for precious metals, iron, and coal by organizing the new agency's work to produce immediate information of practical value on mineral resources.

In selecting his program, King established a unique role for the Geological Survey, one that ensured it



Triangulation station at the summit of Garfield Peak, Rattlesnake Mountains, Natrona County, Wyo., circa 1913. (Photograph by C. J. Hares.)

would be in competition with no other agency. His program also gained for the Survey a natural ally in the mineral industry, which, unlike agriculture, had a long and close relationship with science. The mineral industry, at least in the Eastern United States, had come so to appreciate the value of scientifically based exploration and development that the American Institute of Mining Engineers was established in 1871 because, as one of its first members observed, scientists were as essential to the industry's success as the furnaces and labor that ran it.

King's program responded to the Nation's needs for information on its mineral resources. With his personal participation, the Survey gathered statistics on nationwide mineral production and geological, geographical, and chemical data and analyses of mineral deposits in cooperation with the Tenth Census of 1880. Some of the Survey's foremost geologists conducted geological and technical studies of silver mining districts, especially the Comstock and Eureka in Nevada and Leadville in Colorado, and of the iron and copper ores of Michigan. With this work, King established two long-term principles that guided the Geological Survey's subsequent investigations in economic geology. First, research in mining geology was directed toward the immediate solution of specific problems, rather than the immediate advancement of basic science. Second, the field relations of ore deposits were examined systematically in their geologic context by accurate detailed mapping assisted by paleontological investigations and chemical and microscopical studies in the laboratory.

These studies yielded information on why these mining districts had been eminently successful so that the practical data could be applied in exploration and development elsewhere. By the mid-1880's, the Geological Survey's report on the Leadville district had taught the entire mining industry the value of geology in developing a district, demonstrated the structural control of ore deposits, and contributed ideas on the origin and genetic classification of these resources. Studies of gold ores and districts in the Sierra Nevada and the Rocky Mountains by Survey scientists in the 1880's and 1890's facilitated successful exploration and development in these areas that met the mining industry's needs arising from a renewed monetary crisis in 1890. The Survey's activities in Alaska originated with its initial investigations of the State's gold and coal resources in the 1890's to aid in meeting these needs. By 1900, the value of gold produced annually in the United States had more than doubled what it was in 1890, and the Nation adopted the gold standard as its monetary base.

I. C. Russell leading a U.S. Geological Survey party across the moraines of the Malaspina Glacier, southeast Alaska, circa 1890. (Photographer unknown.)

In the late 1890's, as the Geological Survey's work in economic geology won increasing recognition, the mining industry called for larger appropriations for the Survey and the establishment of a Cabinet-level Department of Mines, with the Survey as its nucleus. While Congress debated establishing such an organization, Survey geologists presented their ideas on the origin of ore deposits at a meeting of the American Institute of Mining Engineers that were described decades later as having established a benchmark in the investigation of ore deposits. The results of their work stunningly demonstrated that science could be advanced in the solution of practical problems and highlighted the advantages of directed research. When Congress failed to pass a bill for a Department or Bureau of Mines, Charles D. Walcott, the Survey's third Director (1894–1907), responded by organizing a Division of Mines and Mineral Resources within the Survey in 1900. Congress established a Bureau of Mines within the Department of the Interior in 1910, with a part of the Survey's Technologic Branch as the nucleus of the new agency.

THE SURVEY'S TRADITION OF BASIC SCIENCE

In establishing his mission-oriented goals and program of applied investigations for the Geological Survey, Director King did not neglect basic research. He intended the Survey information on mineral resources to aid the formulation of a genetic classification of ores, based on the origin and relations of mineral deposits, and thus to assist the mining industry and foster an increased understanding of the Earth and its history. Several pioneering studies in geophysics and microscopic petrography, which were undertaken by the

Geological Survey to support its mining geology program, eventually led to other advances in the earth sciences. By 1900, the petrographic microscope and new tools had familiarized geologists with quantitative measurement and stimulated demands for more exact methods of geologic investigation. Comprehending the mechanical, chemical, and thermal processes involved in the formation and distribution of ore deposits required the solution of problems of extraordinary difficulty. Work begun by the Geological Survey to analyze these processes led to the establishment in 1907 of the Geophysical Laboratory of the Carnegie Institution of Washington for fundamental studies of the properties and origins of rocks.

Deciphering the structural control of ore deposits led the Geological Survey to broad-scale regional interpretations to determine favorable structures and ultimately to interpretations of the geologic structure and history of the United States. Exploration required the development of new tools for the rapid evaluation of large areas. After World War I, the Geological Survey adopted aerial photography for mapping, first for planimetry, followed by topography, and then for geology. After World War II, geophysicists took to the air to delineate subsurface ore bodies and structures by their magnetic properties. These and other investigations involved the progressive use of newer and increasingly more complex technical methods of directly and indirectly acquiring data by vehicle, ship, aircraft, and then satellite-borne instruments. However, improved instrumentation and techniques of gathering data did not obscure the principal goal of investigations in geology, topography, water resources, and the regulation of mineral and energy resources on public lands. These investigations are still designed to secure as accurate and detailed an interpretation of the area analyzed as possible, within the time allotted for the work, and by whatever means the results are displayed.

The economic and mission orientation of the Survey's work as planned by King was revised and expanded in scope by Walcott when he became Director in 1894. Under Walcott and succeeding Directors, the Survey's investigations aided not only the mineral industry but many other practical objectives that could be advanced by a greater knowledge of the Earth and its natural resources. Basic and applied geology, Walcott affirmed, could not be separated; the Survey would undertake basic research not so much for its own sake but to meet specific needs for knowledge to solve specific problems. In 1894, the Survey obtained an appropriation for gaging streams and determining the water supply of the United States and, later, funds for studies of water quality. Walcott indicated the importance of investigating the geologic aspects of water by assigning some of the Survey's most experienced geologists, including G. K. Gilbert, to water-resources studies.

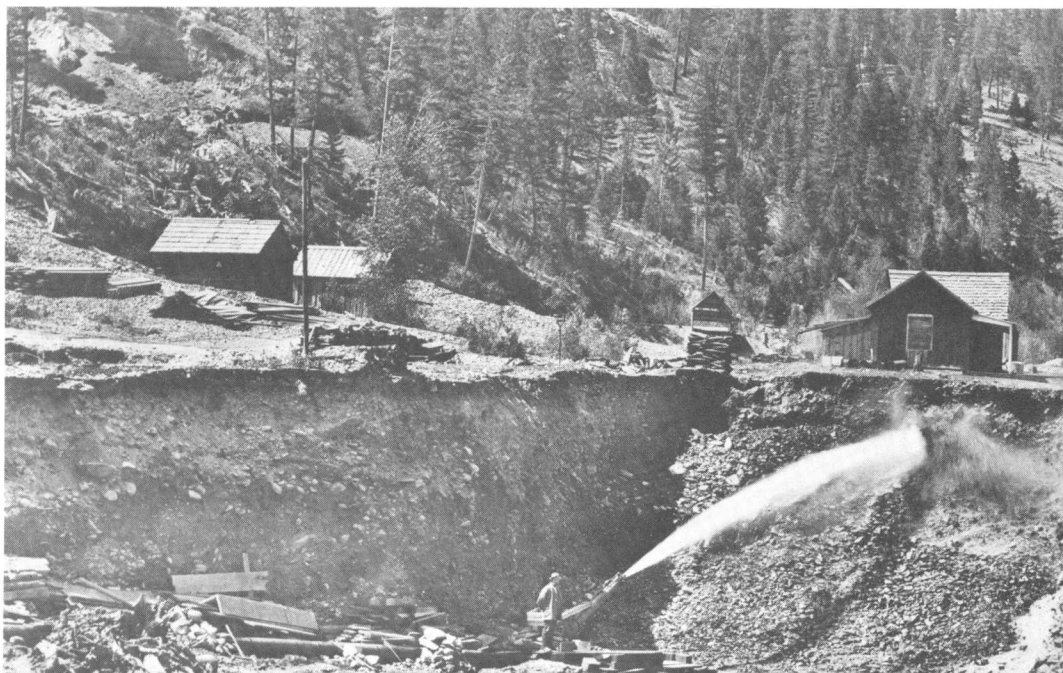
Mining the lode, Virginia City, Nev. (Photographer unknown.)

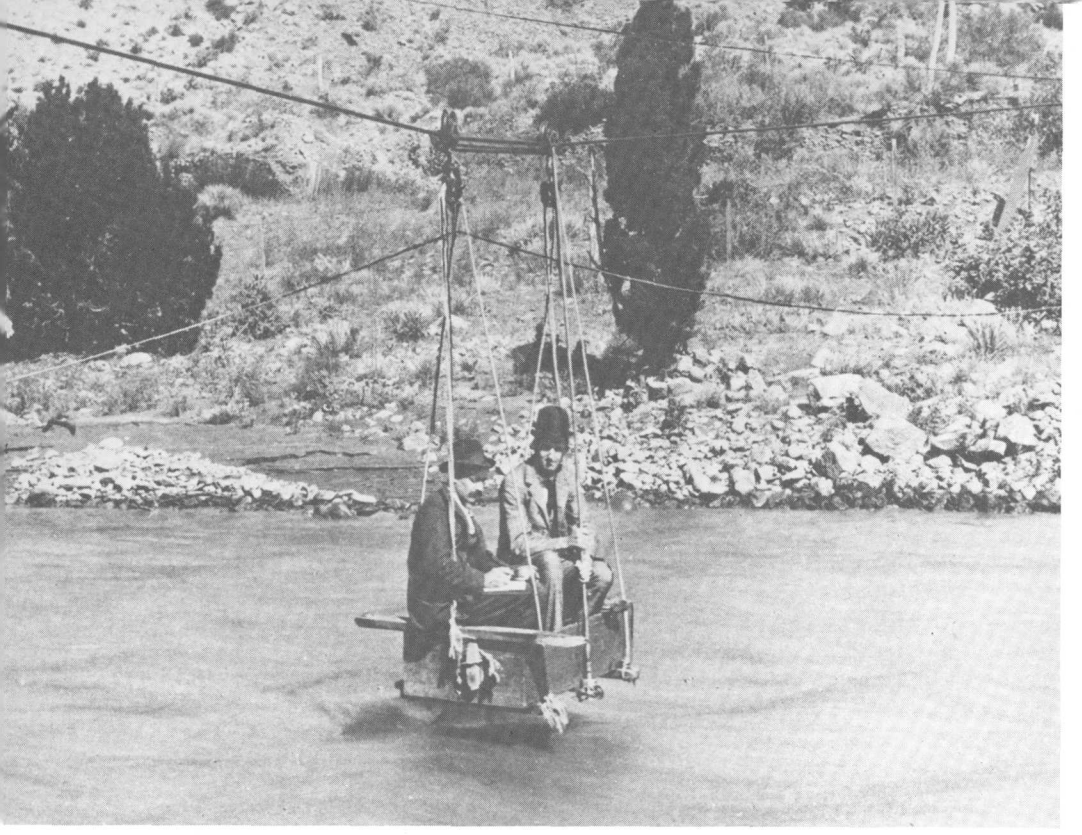
Much of the Geological Survey's work during this time reflected the increasing emphasis on the utility of Federal science that marked the turn of the century. However, Walcott and subsequent Directors did not neglect basic research. Walter C. Mendenhall, the fifth Director (1931–43), who had been Chief Geologist, reemphasized the continuing need for basic studies by stressing that without science to apply there could be no applied science. During the Survey's first 100 years, results of basic research were often applied in different ways to solve new problems. Gilbert's studies of the shorelines of Quaternary lakes in the Western United States during the late 19th century, for example, were originally completed to aid regional mapping and interpretations of climates and environment in the geologically recent past in those areas. However, Gilbert's work later formed the basis for several early investigations in engineering geology.

THE SURVEY'S TRADITION OF COOPERATIVE AND MULTIDISCIPLINARY SCIENCE

In addition to the Geological Survey's long-standing commitment to applied and basic studies in the earth sciences, its work during the past 100 years has been marked by

Placer mining Gibbonsville, Lemhi County, Idaho, circa 1899. (Photograph by Bailey Willis.)





Cable-suspended stream-gaging car used in measuring the velocity of streams with a current meter, Arkansas River near Canon City, Fremont County, Colo., 1890. (Photographer unknown.)

an increasing emphasis on cooperative and multidisciplinary studies. John Wesley Powell, the Survey's second Director (1881–94), extended shared programs originated by Director King to include cooperative mapping projects with several States. Powell called geology the most comprehensive of all sciences, though he held that its most fundamental connection was with topography. He authorized independent topographic mapping within the Geological Survey as a basis for the geological map of the United States authorized by Congress in 1882. Although Powell directed the Survey's geological work largely toward the preparation of the national geologic map by way of the geologic folios project, topographic mapping remained the largest single element in the Survey's program during his administration. During the 1880's, Powell arranged cooperative mapping projects with the surveys of several northeastern States; work was continued and was expanded by subsequent Directors. In 1902 and 1903, as an example, Director Walcott authorized a cooperative investigation by Geological Survey and Kentucky earth scientists of the areal and economic geology of the western Kentucky portion of the Illinois-Kentucky lead-zinc district. This portion of the Survey's tradition of cooperative studies culminated in the recently completed project (1960–78) by the U.S. and Kentucky Geological Surveys that mapped geologically all of the State's 7.5-minute quadrangles using topographic maps completed in the previous decade. The results of that work have already doubled the State's inventory of mineral commodities and advanced its investigations of engineering and environmental geology and planning for effective use of its land.

Some of the Geological Survey's earliest investigations involved the application of expertise in several scientific disciplines. Today, the Survey continues to participate in many cooperative multidisciplinary programs with local, State, and Federal agencies. In fact, the Survey has agreements for cooperative work with all of the States, numerous local and regional municipal government organizations, and many Federal agencies. The Survey derives a significant portion of its operating funds from these organizations for work in their behalf. Among the most visible of these investigations are the Survey's contributions to the scientific exploration of space, directed primarily by the National Aeronautics and Space Administration, by mapping the Moon and other astronomical bodies, training astronauts in the earth sciences, conducting investigations with data from Earth-orbiting satellites, and contributing to interplanetary studies by unmanned probes. Since World War II, the Geological Survey has also cooperated with the developing countries in assessing their mineral and energy resources. The advent of worldwide data from satellites enabled the Survey to join the cooperative global monitoring of seismic events and the mitigation of natural disasters and to conduct special studies based on satellite technology as well as technology transfer and training.

THE SURVEY'S EXPANDED RESPONSIBILITIES

After giving the Geological Survey authority to expand its operations nationwide in 1882, Congress subsequently assigned responsibilities to the Survey for evaluating the Nation's water resources, classifying and mapping its forest reserves, conducting subdivision and boundary surveys, classifying the public lands, supervising the exploration for and development of mineral and energy resources under Federal lease both on land and on the Outer Continental Shelf, and surveying U.S. possessions abroad. Between 1907 and 1934, the Geological Survey transferred some of these functions to newly established bureaus—Reclamation, Mines, Forest Service, and Grazing Service (now part of the Bureau of Land Management). In the years following World War II, the Geological Survey's commitment to research broadened and deepened as the Agency's investigations occupied new dimensions—polar regions, the sea floor, and space. In 1962, Congress authorized formal investigations by the Survey in areas outside the national domain. Since then, planetary studies, the use of Landsat imagery in mapping and geologic investigations, and added responsibilities for earthquake prediction, the reduction of the effects of earthquakes and other geologic hazards, and problems related to siting nuclear reactors and the disposal of hazardous wastes have provided even wider and newer fields to challenge the scientific spirit of the Survey.

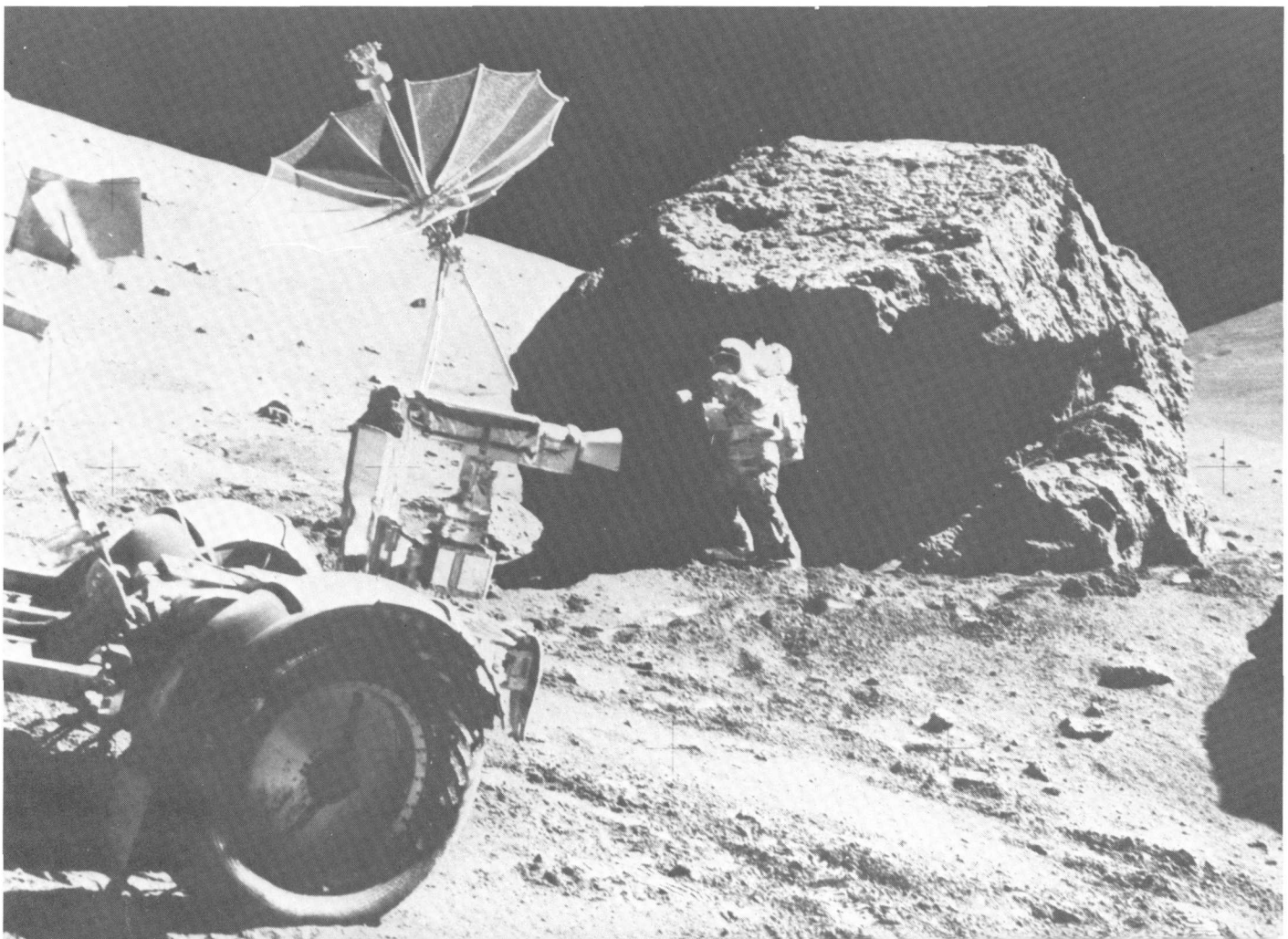
1979—THE CHALLENGES AHEAD

As it begins its second century of public service, the Geological Survey faces many of the same critical and difficult challenges that beset the Nation and the world at large. Solutions to problems that relate to the adequacy of future supplies of energy, minerals, and water resources; the wise and efficient use of our land; the reduction of damage to life and property from geologically related natural disasters; and the preservation of environmental quality require extensive knowledge of the Earth and its natural resources. The acquisition and dissemination of such knowledge to the persons responsible for the formulation and execution of governmental policies in the United States and to the general public remain basic responsibilities of the Survey. The challenges to the Survey in meeting these responsibilities increase as the Nation's growing population with its expanding needs press the limits of our finite land, resource base, and delicately balanced ecosystem. In many areas, the knowledge and tools at hand are insufficient for these tasks and must be refined and expanded to make it possible to find and appraise mineral deposits that have no surface indications of their existence; to predict the location, time, and magnitude of earthquakes; or to define geologically safe environments for the disposal of hazardous wastes.

In view of the rising costs of its operations and the growing public pressure for immediate solutions to problems, the Survey must increase the efficiency and cost effectiveness of its operations. These requirements pose challenges to develop and to adapt sophisticated technology to the acquisition and analysis of data, including the storage, analysis, and display of data by computer; the use of remote sensing; digitization of map information; and the automation of water-data collection. Another challenge to the Survey, and to other scientific and technical organizations as well, is to improve its communications with the users of its information, not only to provide data and analyses rapidly, but to supply them in forms that are readily understandable and usable.

No less challenging are the problems involved in the Survey's regulatory responsibilities as mineral leasing and associated exploration, development, and production activities on the public land expand to new environments, such as the deeper waters of the Outer Continental Shelf, and to areas where mining can significantly affect the ecosystem if it is allowed to proceed without regard to land reclamation and the protection of other natural resources.

Fortunately, the Survey's first century of operations generated experience and traditions that will help it meet the challenges ahead, not only those characteristics already named, but also legacies of excellence and objectivity in its work, flexibility in its approach, and a readiness to respond to increasing public needs for sound information about the Nation's natural resources and physical environment.



APPRAISAL OF FRONTIER OFFSHORE U.S. UNDISCOVERED OIL AND GAS RESOURCES

By RICHARD F. MAST and ROBERT J. LANTZ; ROGER A. KAHLER and GARY L. LORE
Geologic Division; Conservation Division

The decade of the 1970's was marked by a sharply increased dependence by the United States on foreign energy sources, particularly crude oil. Although this dependence has been growing for the last 20 years, it was made clearly visible to the American public by the Arab oil embargo of 1973. In the years since 1973, petroleum prices have continually risen, but, in 1979, a reduction in the availability of foreign oil supplies, caused principally by the civil revolution in Iran, accelerated the increase in the world price of crude oil and again underscored the need for the United States to reduce its dependence on foreign energy supplies.

Many petroleum geoscientists believe that significant quantities of conventional oil and gas may be developed offshore on the continental shelves, slopes, and rises surrounding the United States. Large offshore sedimentary basins are known to exist adjacent to both the conterminous 48 States and the State of Alaska. The location of these potential exploration areas are shown in figure 1.

Although the United States long ago began to produce oil and gas from offshore areas, major exploration efforts prior to 1973 focused on the southern California coast, the western Gulf of Mexico, and the Upper Cook Inlet of Alaska. Exploration in some frontier (essentially unexplored) offshore U.S. basins did not move forward because of technological and operational problems associated with the exploration, drilling, and development of oil and gas, especially in the Arctic regions. Other offshore basins were considered to be poor places in which to explore because their potential for major petroleum discoveries was considered to be too small.

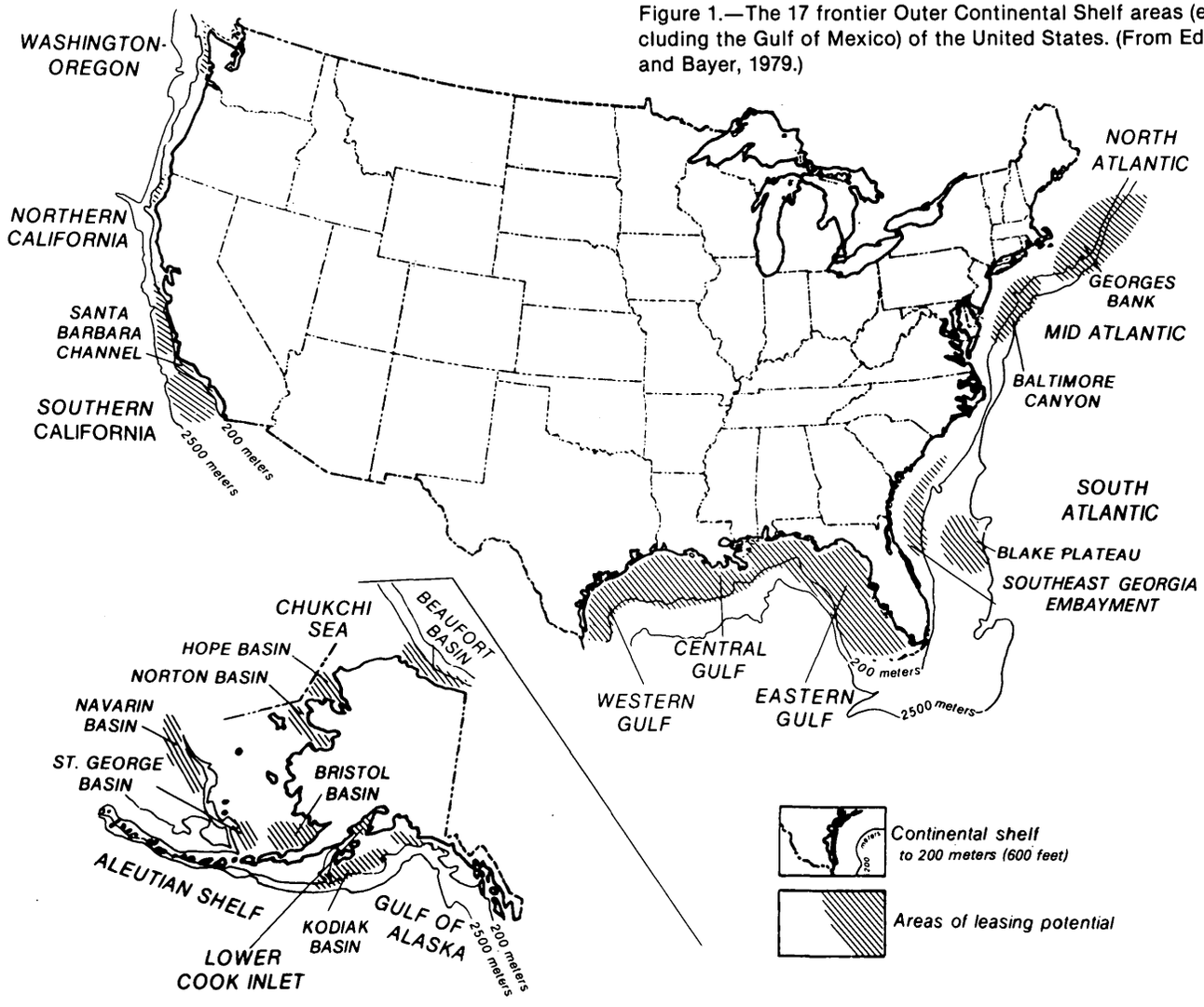


Figure 1.—The 17 frontier Outer Continental Shelf areas (excluding the Gulf of Mexico) of the United States. (From Edgar and Bayer, 1979.)

After the 1973 embargo, Government and industry refocused attention on the frontier offshore areas because resource specialists believed that the potential for finding large accumulations was better offshore than onshore. They believed that the long history of exploration, especially in the lower 48 States, had found most of the major onshore oil fields. Furthermore, the technology in drilling and development of offshore fields was improving, making exploration and development possible or potentially feasible in previously inaccessible areas and especially in deep water.

ESTIMATED POTENTIAL FOR OFFSHORE OIL AND GAS DEVELOPMENT

Estimates of the offshore undiscovered recoverable resources for oil and gas were published by the U.S. Geological Survey in Circular 725 (Miller and others, 1975). These estimates of the undiscovered producible oil and gas indicated that all of the U.S. offshore basin areas to 600 feet of water depth might contain, based on a low estimate at a 95-percent probability of occurrence, at least 10 billion barrels of oil and, based on a high estimate at a 5-percent probability of occurrence, at least 49 billion barrels of oil. Comparison of even the high resource estimate to all the domestic oil and gas which had been previously discovered, both onshore and offshore of approximately 145 billion barrels, indicated that this was not the large supply of oil which would completely solve our energy problems and eliminate our dependence on foreign sources. However, in comparison to our 1978 proven oil reserves of 28 billion barrels (American Petroleum Institute and others, 1979), offshore discoveries might make a significant contribution to our future energy supplies, especially if major accumulation could be found and developed quickly.

Offshore undiscovered recoverable gas resources were also estimated in Circular 725. It was estimated that all offshore basins to a water depth of 600 feet might contain, based on a low estimate at a 95-percent probability of occurrence, at least 42 trillion cubic feet of gas, and, based on a high estimate at a 5-percent probability of occurrence, at least 181 trillion cubic feet of gas. In terms of heating value, these gas estimates are approximately the equivalent of 7 billion to 30 billion barrels of oil. Taken together, the undiscovered recoverable oil- and gas-resource estimates indicate that there are significant targets for future offshore exploration. Large new offshore fields, if they could be discovered and developed quickly, would have significant impact on our near-term oil and gas supply problem because, in general, large fields have high rates of production in the years immediately subsequent to discovery and development. Additionally, estimated volumes of recoverable oil and gas resources offshore could increase in magnitude as technological advancements are made which make exploration and development in deeper waters or in hostile arctic environments feasible and as increased world crude oil prices allow exploration to proceed into areas of high cost, high risk, or low potential. Thus, one of the Survey's most important functions is to inform the Government to the best of its collective abilities about the future oil and gas resources that are likely to be discovered offshore. Therefore, in the process of assessing frontier areas, the Survey aggressively supports the search for future oil and gas resources and collects data from areas that may not be considered as exploration targets today but are possible exploration targets tomorrow. In this regard the Survey's programs support the development of appraisal methodologies and the appraisal of the Nation's offshore oil and gas resources. Petroleum-related geologic studies play a vital role in this program. These studies have as a common objective the gathering and analysis of geologic, geophysical, and geochemical data to develop information and concepts concerning petroleum occurrence and genesis needed to support the Survey's resource-appraisal efforts.

Throughout the entire history of oil and gas development, there has been serious disagreement among qualified resource experts about how much oil and gas remains to be discovered and which forecasting techniques give the most reliable estimates. In recent years, estimates of oil and gas resources for the Nation as a whole seem to be converging; however, there is still considerable controversy about how much oil and gas remains to be discovered and especially in which offshore areas it will be found. Although some of these differences of opinion can be explained on the basis of data input and the methods and assumptions used in making the appraisals, many cannot. There is honest disagreement about the magnitude of our undiscovered oil and gas resources.

Because of these disagreements and because of the significance of the numbers, resource appraisal must be a continuing effort. New data must be gathered and new appraisal techniques must be developed to improve our ability to estimate undiscovered recoverable resources and to update previous estimates. The methods employed by geoscientists to estimate recoverable undiscovered resources in frontier offshore basins are based, in general, on analogs from other basins or areas which have been heavily explored. The knowledge and concepts developed about the occurrence and distribution of hydrocarbons in these analog areas are then applied in a variety of ways to frontier areas. The reliability of resource estimates in frontier areas depends in large measure on the prediction of the modes of occurrence for petroleum in the area and the selection of appropriate analogs to be used in making resource assessments on the basis of geologic knowledge. The whole process is iterative; as new data are collected by the Survey in the area of interest, new concepts about hydrocarbon occurrence are developed, and new analogs must be selected and applied. In general terms, the better our knowledge of the modes of occurrence and the better our understanding of the geologic factors that control how rich the known petroleum producing areas are, the better our ability to assess the magnitude of undiscovered resources in frontier or developing regions.

SURVEY ORGANIZATIONAL RESPONSIBILITIES FOR RESOURCE APPRAISAL

One of the objectives of this article is to explain the responsibilities of the Survey for appraising and evaluating the undiscovered recoverable oil and gas resources of the U.S. offshore areas as related to the offshore leasing process and also to explain how different units within the organization interact cooperatively to produce estimates of the quantities of oil and gas that may be discovered in the future.

The Survey essentially produces two types of resource appraisals or evaluations which contribute to the Department of the Interior's offshore leasing programs. Regional or basin resource appraisals based on broad geologic studies are produced to help determine the Federal offshore 5-year leasing schedules as well as to input regional geologic understanding into the early phases of a lease sale. Although there are other factors involved, regional oil and gas appraisals help the Department of the Interior prioritize where and when a lease sale will be held. The Survey also produces detailed tract appraisals and resource economic evaluations. The tract evaluations, which are the result of detailed geologic engineering and economic studies, are used by the Department of the Interior to determine the lowest acceptable bid for leasing particular tracts to industry in a lease sale in the Federal offshore leasing program. Both kinds of appraisals, regional and tract, require understanding of the petroleum geology of the basin as well as detailed knowledge of the geology of smaller areas within the basins.

These resource evaluations and appraisals are the responsibility of the Survey's Geologic Division and Conservation Division. The Conservation Division has the responsibility for making the detailed tract evaluations, and the Geologic Division has the responsibility for assessing entire basin areas. Figure 2 shows the organizational structure within the Survey and the various units within each of the Divisions which carry out the underlying geologic studies and produce the needed appraisals and evaluations.

The individual organizations shown in figure 2 are quite similar in title, although some of these unit functions may vary considerably between Divisions in the details of their work. This similarity in structure results because resource-appraisal and resource-evaluation programs require the following essential kinds of activities:

- Regional activities designed to collect basic geologic data and to carry out studies needed to support petroleum appraisals at both the basin and the tract level.
- Topical studies designed to develop new understanding about the geologic factors that control the generation and accumulation of oil and gas and the economics of oil and gas exploration and production.
- Assessment methodology studies that develop techniques for the application of petroleum data to the resource-appraisal process and statistical methods to manage and to produce the desired output.

As shown in the figure, there is an important overlap in both Divisions between the regional and topical activities and the resource-appraisal and evaluation activities. Important interactions also occur between Divisions that help to integrate the results of regional geologic and topical studies done for basin appraisals which are principally carried out in the Geologic Division and the detailed geologic engineering and economic studies done for tract evaluation which are carried out in the Conservation Division.

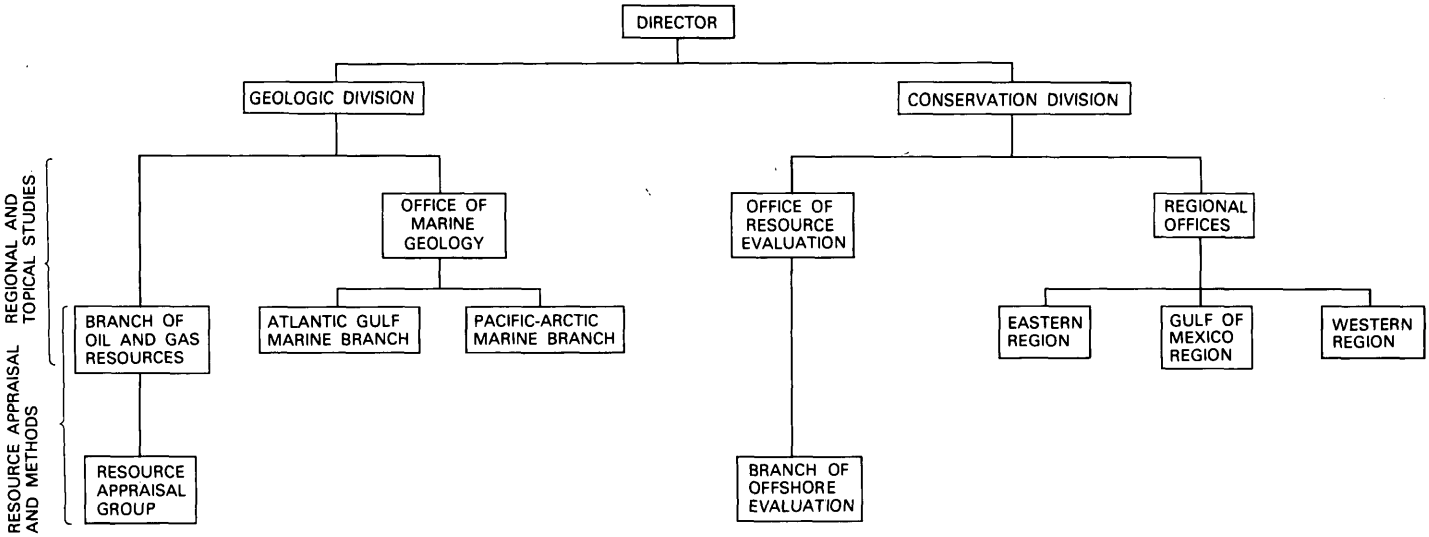


Figure 2.—Organizational units within the U.S. Geological Survey concerned with the appraisal of offshore oil and gas resources.

OIL AND GAS ASSESSMENT PROCESS

Estimates of undiscovered oil and gas resources are developed by studying the basic elements of the geology of offshore areas to determine the geologic history and the *likelihood* that oil and gas has been generated from organic materials in the basin sediments and then migrated into geologic structures or traps to form local accumulations, which are the targets for exploration. Using the results of these geologic studies, the quantities of oil and gas that may be contained in a province or a basin or in smaller areas within a basin, are numerically appraised by comparing the geology and geologic history of the area being appraised with similar areas in which the quantities are essentially known because these so-called analog areas have been heavily explored.

Resource appraisal is a very complex procedure because the reliability of the results depends upon knowledge of the geologic factors that control the process of oil and gas generation, accumulations, and entrapment; the specific geologic processes which have operated in the past; their effectiveness in the area being appraised; and the ability of the appraisers to apply meaningful analogs based on an understanding of geologic similarity between unexplored and explored regions. The geology and geologic history of the offshore frontier areas of the United States are not known in sufficient detail to allow exact appraisals of the quantities of oil and gas which will occur. Consequently, the appraisers indicate the uncertainty about the petroleum geology of an area or tract by appraising not only the quantities of oil and gas that may be contained there but also the probability at which these quantities may actually occur. Results of the resource appraisals are often reported in the form of graphs or distributions which reflect the uncertainty of the appraisers regarding the quantities of oil or gas that may occur (see fig. 3*A*).

At any specific probability level, these quantities are described as the least quantities that will occur at that level of probability; larger quantities are appraised at lower probability levels. In the analysis of frontier or essentially unexplored provinces or basins, the resource appraisals are made in two steps. First, the area is appraised under the condition that oil and gas occurs in commercial quantities. These estimates are called conditional estimates. This assumption cannot be made with certainty in frontier areas in which no petroleum has been discovered to date. Therefore, in the second step, the conditional estimates are modified by assigning a marginal probability or basinwide risk to the event "commercial oil found" and "commerical gas found" (Spur and Bonini, 1973). These marginal probabilities are then applied statistically to the conditional estimates to produce unconditional assessments (Miller and others, 1975) of the oil and gas that may occur in a basin (see fig. 3*B*).

Having normalized the assessments in all basins to the event "commercial petroleum found," it is now possible to aggregate, using statistical probability techniques, those assessments for a measure of the future petroleum expected to be discovered in the offshore. The assumption is made that the individual basins are independent of one another in terms of their oil and gas potential. As a result, probability-based resource appraisals of several areas or for the entire United States offshore can be aggregated and presented as a single probability distribution representing the amounts of oil and gas thought to be discoverable in very large areas.

Similar methods are used to estimate resources and to evaluate specific tracts within the basin. The major difference between basinwide appraisals and tract appraisals or evaluations is the level of detail that is applied to the geologic engineering and economic analyses. In tract evaluation where small areas are evaluated, the geology must be analyzed in much greater detail to

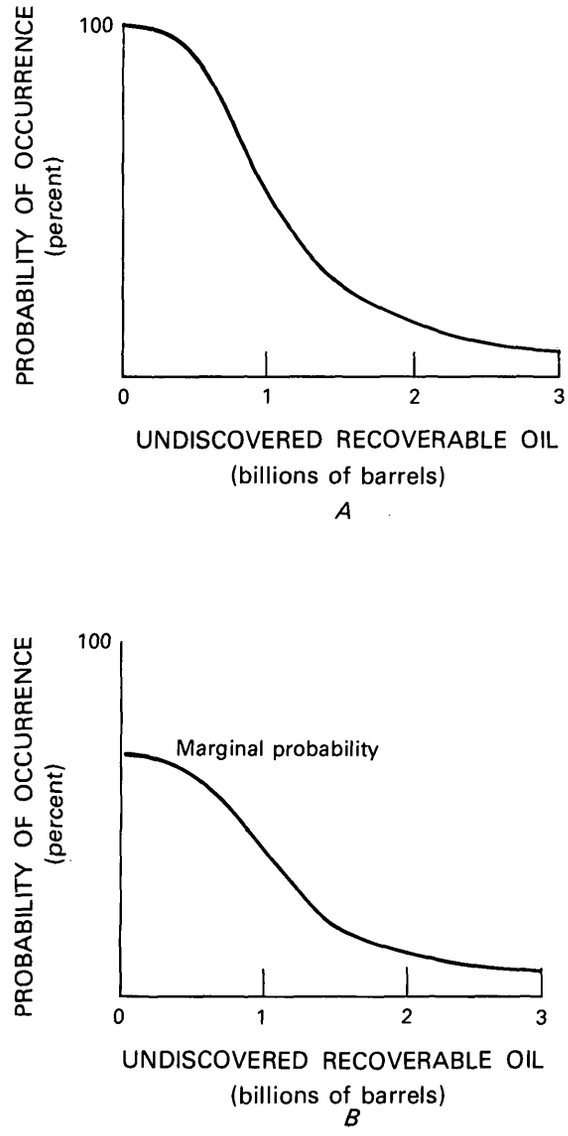


Figure 3.—Probability distributions of undiscovered oil. *A*, Unconditional estimates. *B*, Conditional estimates (marginal probability applied).

estimate such things as the apparent size of the trap and the quality of the reservoirs at that site. These parameter estimates are combined, using statistical probability techniques, to estimate the quantities of the oil and gas that may be discoverable at a specific site. Also, during the evaluation of tracts, emphasis is placed on tract-specific engineering and economic studies to determine the value of the resource thought to be contained under the tract being evaluated. Even at this scale of geologic investigation there still remains much uncertainty regarding the magnitude of the oil and (or) gas resources that may occur beneath the tract(s). The initial tract evaluations, made under the assumption that oil and gas does occur, are reported in terms of conditional probability distributions similar to those shown in figure 3*A*. In a manner similar to basin appraisal, tracts must be risked for the event that oil and gas does not occur in the specific structures or, more correctly, in the apparent traps being assessed; the concepts and procedure are the same as for determining marginal probability in basin appraisal. Through experience, we know that all structures are not traps, and, therefore, a specific tract may not contain oil and gas. In tract analysis, the geologic evidence at the specific site or analog data are employed to estimate the risk that oil and gas will not be found. The tract-specific risks that are estimated are similar to the basin marginal probability and, therefore, are applied to the conditional assessment to derive the unconditional assessment for each tract. Parallel to basin aggregation procedures, tracts are aggregated using statistical probability techniques to derive conditional probability-based resource estimates for a number of tracts together; for example all of the tracts that might be for sale in a forthcoming lease sale. In tract aggregation, different tracts may be geologically related; for example, tracts might have a common source for the generation of oil and gas, or they might be located over the same trap. Consequently, the interdependence between the occurrence of oil and gas on different tracts must also be assessed before the results can be aggregated statistically.

Ideally, if all of the potential traps could be identified for the entire basin and then analyzed using tract analysis and aggregated together, the resulting appraisals should approximately equate to the resource numbers derived from basin appraisal. The fact is that these two approaches sometimes yield what are, or what appear to be, inconsistent results. In part, it is this process that stimulates both the basin appraisers and the tract evaluators within the Survey to reevaluate the underlying geologic data and assumptions and to seek new data to develop new concepts about oil and gas occurrence in individual basins or basin areas.

The ultimate amount of oil and gas to be discovered in a petroleum province will never be known with complete certainty until all of the oil has been discovered. As the exploration process continues, new geologic and petroleum-resource data developed from drilling and other exploration methods are used to develop new hypotheses regarding sites or basins in which petroleum is likely to occur. In the exploration of a basin, geologists hold different opinions or concepts as to where and how much oil and gas may be found. It is these multiple hypotheses that cause explorationists to look in a variety of places for oil and gas. Because of the exploration activity that ensues from pursuing current exploration concepts, new data are acquired, new concepts are developed, and old ones are sometimes discarded. Also, the multiple exploration hypotheses give rise to apparent differences between basin appraisals and tract evaluations within a basin.

How does the Survey deal with the problem of geologists holding different perceptions, concepts, and opinions about the amounts of oil and gas that will be discovered in frontier offshore areas? This problem is approached in different ways in basin and tract assessment. In basin assessment, regional or area geological experts are asked to present details about the petroleum geology and the results of specific studies designed to appraise the geologic factors that control accumulations of oil and gas in the area to be appraised. Multiple hypotheses are usually expressed in these discussions, and the relationships between known analog areas are also discussed. The geologists on the appraisal team are resource experts who have a variety of professional backgrounds so that they can contribute their petroleum experience to these discussions. Each geologist on the appraisal team formulates his own judgments and is asked to develop his own resource estimates. These individual estimates are then reviewed and discussed. In some cases, new estimates are made, especially if new information is brought forward in these discussions. In this way, multiple hypotheses and varying opinions are brought together through individual assessments. These assessments are then either averaged or statistically aggregated to develop the basin or tract assessments.

In tract evaluation, groups of tracts are assigned to different teams of geologists. The differences of opinion within a team is one of the factors that influences the ranges given the distributions for the various geologic parameters. Statistical probability techniques are then applied to the distributions to arrive at a distribution of resources for the tract. A committee of experts conducts a review to insure consistency between teams regarding the methodologies employed and the use of analog data.

Geologists from the Conservation Division usually meet with Geologic Division geologists before an updated basin appraisal is made. At these meetings, geologic data for the area are reviewed and differing exploration concepts are discussed. In this way, economic information and geologic concepts from Conservation Division tract-evaluation studies feed back into the Geologic Division basin-appraisal programs. These meetings also are useful in identifying new data that is critically needed to improve the resource appraisals of the area.

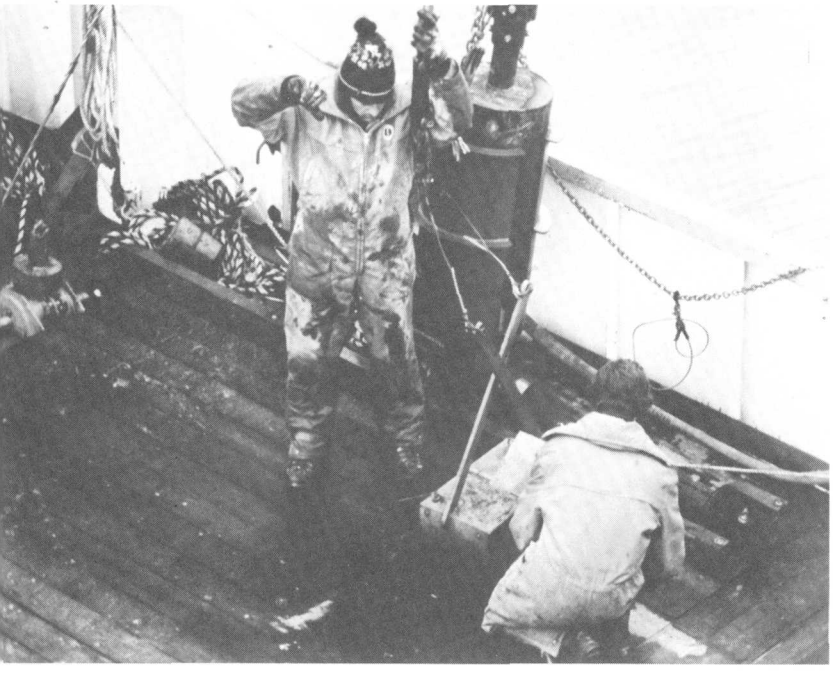
The data collected by the Geologic Divison's programs and the results of their geologic studies are published. Because of the scale of the basinwide programs, regionally spaced seismic data are collected as input to the basin-appraisal program. Public data collected in the basin-appraisal programs are used to develop public documents in support of the Department of the Interior's leasing program and nationwide assessments of oil and gas resources.

The Conservation Division, for the most part, collects the proprietary data developed by industry. Because of the very large volumes of data needed to make the specific tract evaluations, seismic data is collected by groups of companies to reduce the costs of data acquisition in the exploration process. This data can be acquired from industry by the Conservation Division but by law cannot be published or made public to protect the companies' investments in collecting the data. In addition, offshore Federal regulations require that exploratory development and production-well data on Federal leases be held confidential by the Government for 2 years after the well is drilled and completed or abandoned or until the lease expires, whichever occurs first.

Industry is also permitted to drill continental offshore stratigraphic test wells before a lease sale is held. Often this is the only rock sample data available to both industry and Government in frontier offshore areas. Rock samples from these wells can be used to investigate properties of potential reservoir rocks and to make assessments of the source rocks and the oil and gas generated in frontier basins. These data can be publicly released 60 days after the issuance of a lease within a 50-geographical-mile radius of the well. The Conservation Division has the responsibility to release this data. Because of the critical need for this kind of data in both the basin- and tract-assessment programs, the Conservation and the Geologic Divisions sometimes carry out cooperative studies of these wells and publish their data and interpretations together.

The scope of the Geologic Divison's basin-appraisal program also requires investigation of areas that are not now of current interest for offshore oil and gas exploration. These are principally areas in deep water along the continental slope and rise. Valuable data in these programs are collected and interpreted years before a lease sale is scheduled for some areas. This information may be available in published form before the Conservation Division begins its acquisition of the proprietary data.

Bottom sediment grab sampler.



THE SURVEY ROLE IN THE LEASING PROCESS

The procedure established by the Federal Government for issuing oil and gas leases on the offshore public lands include 14 major procedural components.

Component	*Responsibility*
1. Proposed leasing schedule	Department of the Interior.
2. Call for tract nominations	Bureau of Land Management (BLM).
3. Tract selection	BLM-Survey
4. Draft environmental impact statement (EIS).	BLM
5. Hearings	Do.
6. Final EIS	Do.
7. Secretarial Issue Document	Do.
8. Proposed Notice of Sale	Do.
9. States' comments	----
10. Department of Energy review	----
11. Final Notice of Sale	BLM
12. Presale evaluation completed	Survey
13. Sale	BLM
14. Postsale analysis	BLM-Survey

Figure 4 shows the flow of information into the various decision points built into the offshore leasing process. It is important to note that a large amount of information is generated for, and taken into consideration during, the offshore leasing process, especially in frontier areas.

The Department of the Interior has the following major clear-cut objectives which guide its leasing program:

1. Orderly and timely resource development.
2. Protection of the environment.
3. Receipt of fair market value.

These obligations constitute policy guidelines that control governmental schedules, decisions, and goals of leasing the offshore public lands. These objectives are all influenced by the resource-appraisal and evaluation activities of the Survey.

The initial step in the leasing process is the selection of general areas that are thought to be desirable for oil and gas leasing and that do not possess overwhelming environmental problems. Information on the geology, petroleum potential, and geological hazards of the various frontier areas is furnished by the Area Selection Program carried out within the Survey. The areas are arranged in sequence by priorities determined by weighing and balancing a number of sometimes conflicting considerations. Even though the leasing schedule is the first step in the leasing process, it must be based on a large amount of preexisting information, as indicated in figure 4. To make a 5-year schedule that is logical, data must be gathered and interpreted by the Area Selection Program well in advance of the scheduled sale dates. The

leasing schedule is used to determine the timing and initiation of individual sales procedures. The environmental appraisal is constantly updated as additional data are gathered and analyzed. It is the responsibility of the Survey to input any new resource or geologic hazards data it has which might influence changes in the schedule. Changing conditions in the domestic energy supply and distribution situation are also considered when publishing or revising proposed leasing schedules. Prior to the call for nominations, the Survey submits the Resource Report on the general call area to BLM. It is the purpose of this report to discuss the petroleum geology of the area as a basis for oil and gas appraisal and to emphasize geologic features of the basin used to predict occurrence in a general area where tracts might be nominated by industry. In frontier areas, this is a difficult task because the data available may not be sufficient to make these kinds of predictions. This portion of the Resource Report is prepared by either the Branch of Atlantic-Gulf of Mexico Geology or the Branch of Pacific-Arctic Geology, depending upon the location of the offshore area. Simultaneously, the Resource Appraisal Group of the Oil and Gas Branch begins to gather data to prepare estimates of the undiscovered recoverable resources. Although estimates were prepared for the Area Selection Program, they may have to be updated based on new information acquired since the leasing schedule was prepared. The Conservation Division Regional Office involved is also contacted to determine the input on which they have based their work in the general call area. The appropriate Branch of Marine Geology also prepares a section on environmental and geologic hazards for the Resource Report. All of this input is taken into consideration in recommending modification to the general call area. After all of the geologic data is assembled, the Resource Appraisal Group makes an oil and gas assessment of the call areas proposed in the Resource Report. This assessment data is transmitted to the Conservation Division Branch of Offshore Evaluation so they can prepare a section for the Resource Report on the infrastructure requirements for oil and gas development. The completed Resource Report is transmitted to BLM, which issues the call for nominations.

The call for tract nominations constitutes official notice to the public and the oil and gas industry of Government's intention to hold a lease sale in a given area. An additional purpose of the call for tract nominations is to obtain an indication of the amount of interest that exists for leasing or deleting each of the individual offshore leasing tracts included in the proposed sale area. The calls for tract nominations are usually issued for large contiguous areas that may include several million acres and numerous lease tracts which usually contain about 9 square miles or about 5,760 acres.

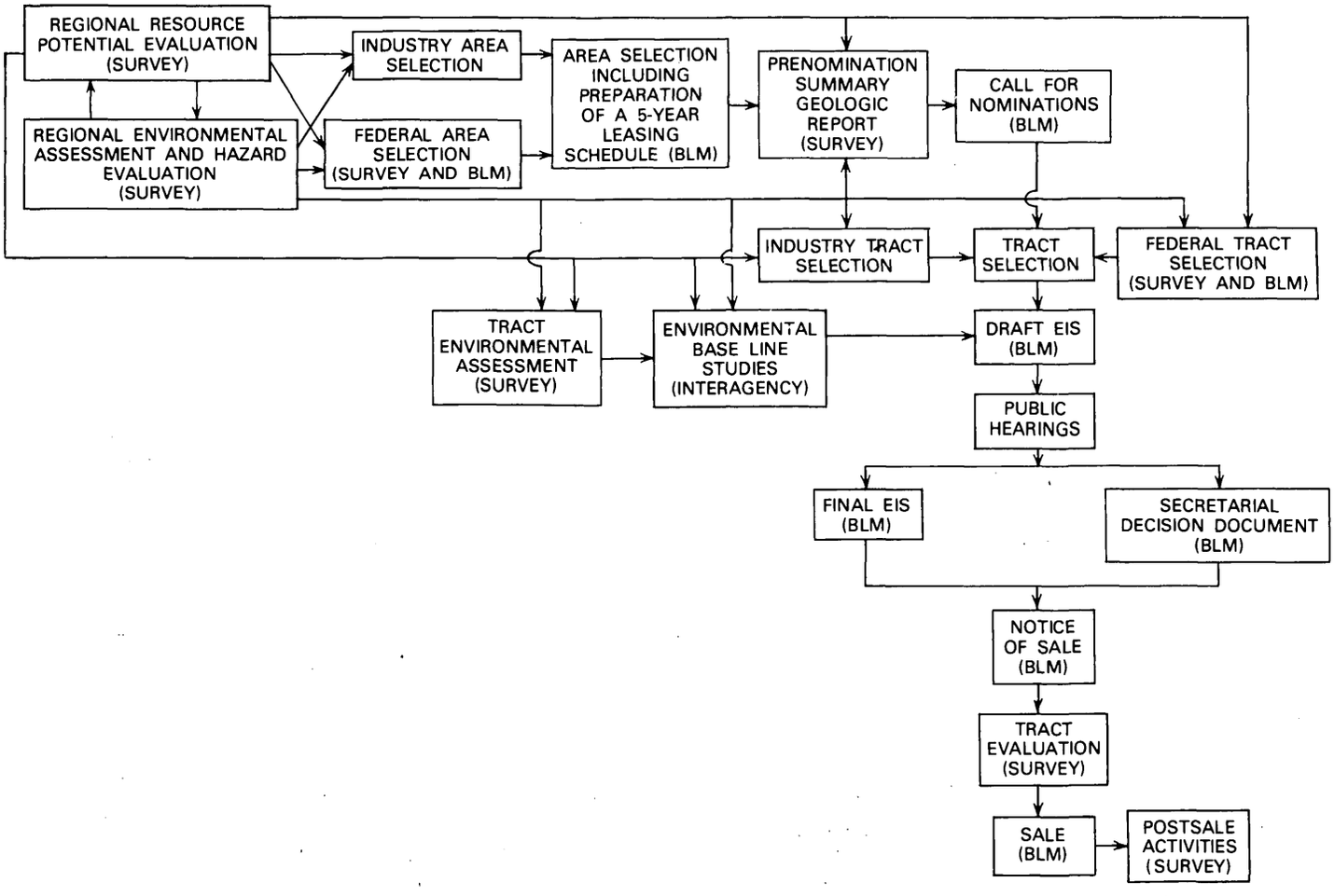


Figure 4.—Information flow into decision points—Outer Continental Shelf leasing process.

The call for nominations results in the identification of tracts which industry believes have economically attractive resource potential. It may also result in some of the tracts being considered for deletion from the sale on environmental grounds. Comments are requested both for and against the sale from any interested person or group. Thus, information may be gained about tracts that warrant additional study because they are desirable for leasing, or other specific tracts may require additional environmental appraisal or be eliminated from consideration for leasing because of particular environmental value or unusual environmental conditions. The majority of individual tracts within any proposed sale area generally do not have particularly high value for resource potential or unusual geologic hazard potential or do not warrant unique or special environmental consideration.

After receiving lists of tracts nominated for oil and gas leasing from interested oil companies as well as information on tracts submitted by the public and other Federal, State, or local agencies, specific tracts are selected for possible leasing. The tracts thus selected are judged by BLM and the Conservation Division not only on the basis of internally generated resource potential, environmental, technological, and economic information but also utilizing knowledge gained from replies to the call for nominations.

The selection process is complex and includes consideration of an evaluation of the number of nominations per tract; the need to initiate leasing in wildcat areas in terms of industry development capability, competition, and timely future availability of resources to consumers; tract leasing history; nomination patterns; consideration of the proper mix of tracts by water depth and distance from shore; the need to develop prospective geologic structures and trends; the need to protect tracts in imminent danger of drainage; consideration of which tracts are most promising for establishing production; and possible environmental impacts or possible conflicts with other uses of offshore areas which could result from the development of specific tracts under consideration. Some tracts may be deleted during the tract selection process because of overriding environmental considerations. The list of tracts selected for leasing is published so it is publicly available prior to the issuance of the draft environmental impact statement (EIS).

This next component of the leasing procedure involves the preparation of the EIS for each lease sale under the provisions of the National Environmental Policy Act (NEPA) of 1969. The statement actually comes in two steps; a draft EIS is prepared, which is then subject to open public hearings on its validity, factuality, and objectivity. Following the public hearings, a final EIS is prepared that includes consideration of all pertinent subjects and comments brought up in the hearings that were not addressed in the draft statement.

The Survey input for petroleum geology to the draft EIS is very similar to that in the Resource Report. There are sometimes long time delays in the preparation of the Resource Report; consequently, modification at this time may be necessary as new data or interpretations are available. Because the draft EIS identifies specific tracts to be offered for sale, the oil- and gas-resource estimates, geologic hazards, and environmental considerations portions of the Survey input to the draft EIS must be redone to focus on the sale area. The Conservation Division Regional Offices prepare the resource estimates for the sale area and provide tract specific hazards recommendations for inclusion in the final EIS. All of the considerations used in the basin-resource appraisal are available to them through the Resource Report, other published reports, and unpublished data of the Geologic Division.

The draft EIS is prepared by BLM as lead agency because they are responsible for the sale. During the preparation of the statement, BLM receives scientific guidance and assistance from the Geological Survey, National Oceanic and Atmospheric Agency, and many other Federal agencies with specialized knowledge; as indicated in figure 4, it is an interagency document. During the construction of the draft statement, numerous contacts are usually made with State and local officials and agencies, the academic community, environmental organizations, and private research groups. The contacts help BLM reach a maximum understanding of the environmental and economic concerns of the local citizens and to gain an understanding of how they view the issues involved.

The draft EIS, when completed, is submitted to the Council on Environmental Quality and made available to the public for consideration. Not less than 60 days after publication of the draft EIS, a public hearing is held, usually at a city in the vicinity of the proposed sale. Notice of the date and place of the hearing is published in the *Federal Register,* and a press release containing the pertinent information is also sent out. Comments submitted to the hearing are considered in the preparation of the final EIS.

Following consultation and coordination with other concerned Federal agencies, the draft statement is submitted to a review process. Comments and contributions received during the public hearings as well as any recent information not previously studied are considered, then incorporated in the final EIS. The final statement is submitted to the Council on Environmental Quality and is made available to the public.

After the final EIS is completed, a Secretarial Issue Document, which summarizes the factors associated with the proposed sale for the use of the Secretary of the Interior in making a final decision regarding the sale, is prepared. The decision is made not less than 30 days after the final statement is submitted to the Council on Environmental Quality. The Secretary considers the environmental, resource, economic, technical, and socioeconomic information available from the draft statement, public hearings, final statement, and the Secretarial Issue Document. He weighs all of the suggested alternatives and may seek any additional information he deems pertinent to arrive at the decision. If the decision is made to hold the sale, tracts to be offered for lease are selected, and leasing terms determined. Tracts may be withdrawn from leasing at any time up to the time of the sale, should previously unknown environmental data warrant. Just prior to a lease sale, teams of geologists,

geophysicists, and petroleum engineers from Conservation Division Regional Offices prepare range estimates or point estimates on a number of geologic and economic factors that are needed to estimate the potential value of each tract. These values are then analyzed by computer program. In the evaluation of tracts, just as in basin appraisal, the estimation of each factor involves some degree of subjectivity. The evaluation results are presented as probability distributions, and a determination is made of the most probable or statistical mean value. These tract evaluation results are used by BLM to determine if industry bids are acceptable for a lease on a given tract. These estimates, for obvious reasons, are not made public prior to the sale.

The terms and conditions of each lease sale are published in the *Federal Register* as a final notice of sale not less than 30 days prior to the date of the sale. Leases are usually sold on the basis of a cash bonus with a fixed one-sixth royalty or a cash bonus with a fixed sliding scale royalty determined by the amount of production. A small yearly rental of $3.00 per acre or a fraction thereof is assessed on nonproducing leases. At the lease sale, all sealed bids are opened and publicly read. Following the public opening, all bids are checked for technical and legal adequacy, qualification of bidders, sufficient advance bonus (20 percent at the time of bidding), powers of attorney, compliance certificates, and bonds. Acceptance or rejection of bids is not made until after the postsale analysis and a Department of Justice review.

Leases are issued or rejected based on an analysis of how the action on each individual tract relates to the Department of the Interior's policy on receipt of fair market value. Timely resource development is a prime consideration in scheduling the sale in the first place as are concerns for the environment. The environmental aspects of each tract, including opinions expressed at the public hearings, are discussed individually in the EIS. Orderly development is also discussed in the EIS and at public hearings. Estimates of resource economic value are made independently prior to the sale and express the Department's own opinion of lease value. All of the information described above, plus an analysis of conditions at the time of the sale and indications of competition expressed during the sale, are used in determining if a lease should be issued to the highest bidder.

If the high bid on a lease tract is found to be acceptable, BLM issues a lease to the successful bidder. Upon issuance of the lease, the remaining 80 percent of the bid price and the first year's rental becomes due.

FUTURE DIRECTION

The Department of the Interior is developing a new 5-year lease schedule for 1980 through 1985. Sales in six frontier areas occurred during the 1975 to 1980 lease sale schedule, and 78 exploratory wells have been drilled. Although additional wells are now being or will be drilled to further test some of these leases, the results of the first 78 wells in terms of the discovery of oil and gas have been discouraging.

Much of the drilling in frontier areas to date has been focused in the Baltimore Canyon trough, the Gulf of Alaska, southern California, the southeast Georgia embayment, and the Lower Cook Inlet where major structures were the principal targets. The results in the Gulf of Alaska were particularly discouraging, but only a small portion of that area was actually tested. Texaco and Tenneco announced some positive results in which gas in two wells and oil and gas in one well near the shelf break in Baltimore Canyon were encountered. It is not known at this time if these wells represent commercial discoveries. In addition, some of the data from the drilling in the Baltimore Canyon area indicate that deep water areas on the continental slope may be attractive for future oil and gas exploration (Edgar and Bayer, 1979).

On the shelf, the most promising frontier areas for future exploration that should be tested during the next 5 years are the Bering Sea, the Chuckchi Sea, and the Beaufort Sea surrounding northern Alaska. Current resource appraisals indicate that these areas may well contain in excess of 50 percent of the total oil assessed on the continental shelves in frontier areas of the United States. Thus, though the initial drilling results have been somewhat discouraging, new prospects have emerged, and many of the best areas still remain to be tested by drilling.

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THE QUIET REVOLUTION IN MAPPING

"Map . . . a drawing or other representation that is usually made on a flat surface and that shows the whole or part of an area (as of the surface of the earth . . .) and indicates the nature and relative position and size according to a chosen scale or projection of selected features or details (as countries, cities, bodies of water, mountains, deserts) . . . ."

—Webster's *Third New International Dictionary*, unabridged, 1966

The definition of a map from the most recent edition of Webster's Dictionary, while not inaccurate, is hopelessly out of date. It is true that maps are *usually* "made on a flat surface" and show "the whole or part of an area" and "indicate the nature and relative position and size" of "cities, bodies of water, mountains, deserts" and "according to a chosen scale or projection."

However, a map is much more, especially today. Maps portray more than "selected features." Maps also record the way these same features change. As floods and landslides, bulldozers, and steam shovels work their will, a series of maps over time builds a dynamic picture of the effects of nature and man upon the face of the Earth.

However, there is a major revolution underway which is bringing about profound changes in the nature of maps and mapping. This revolution results from several forces, such as public policies relating to resources and the environment, technology, and rapid and far-reaching changes in the requirements of the users of maps. And it confronts the cartographic community in general, and the Geological Survey in particular, with serious technical and management challenges and enormous opportunities to be of service. The extent of the changes as well as the opportunities can perhaps be better appreciated in light of mapping tradition.

THE MAPPING TRADITION

Maps, and the cartographers who make them, have been with us throughout recorded history. Two thousand years ago, the Roman geographer Strabo proclaimed Homer to be the first geographer and Anaximander to be the first Greek to make maps, some six centuries before Strabo's own time.

Yet, in some respects, it might be said that maps predate even the written word. Primitive people made maps of the location of water, food, and shelter by scratching with pointed sticks on the ground. Mapping has evolved as much from a primal need to express spatially the location and size of the things of the Earth as it did from rational calculation.

The use of maps has also reflected man's age-old pursuit of power and wealth. Kings and generals long used maps and charts to guide their armies and navies to conquer and to rule their neighbors or to defend themselves and to show routes of commerce and communications and sources of wealth.

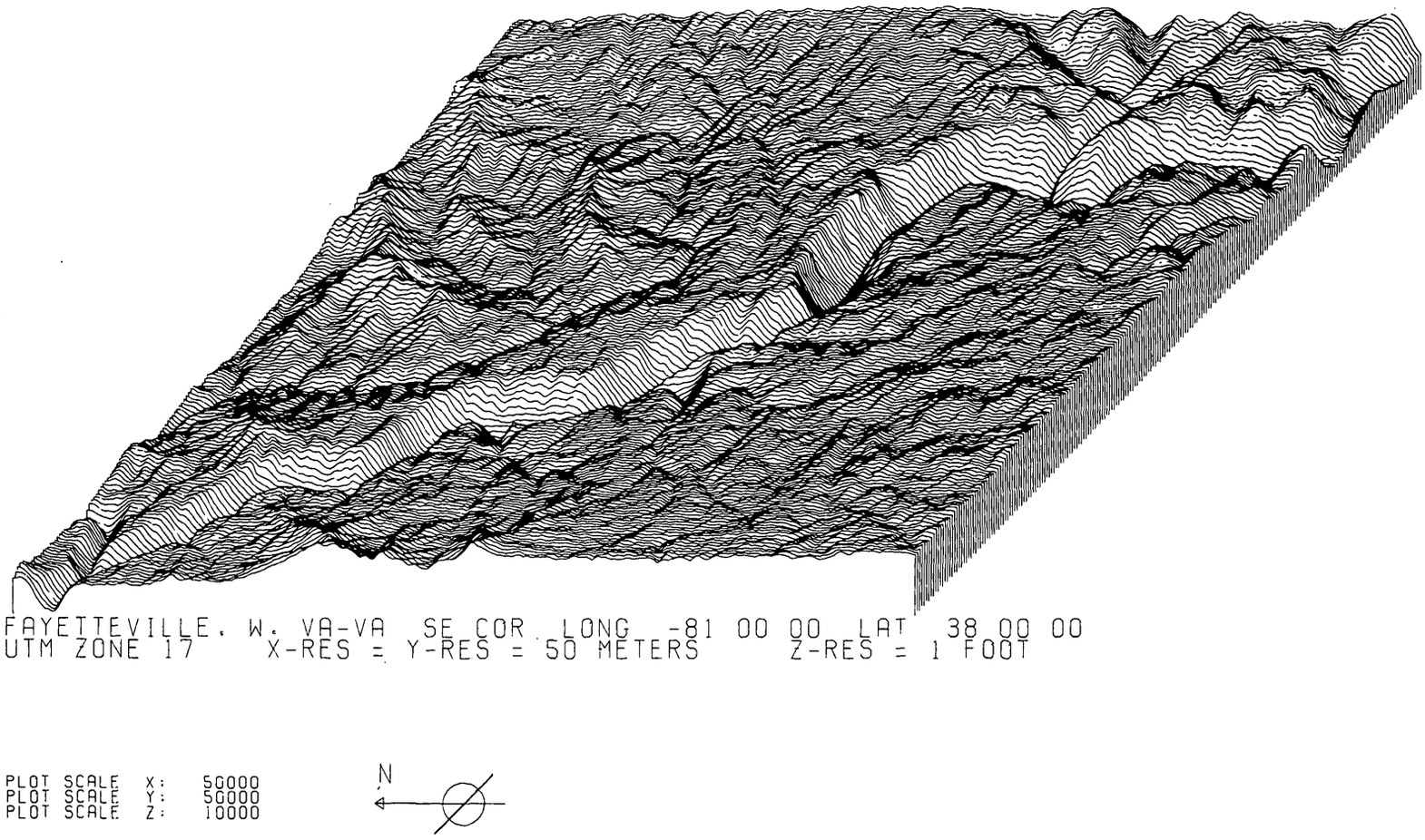
These interrelated needs of commerce, communication, and defense guided much of mapping's history in the United States. It is well known that George Washington, as a surveyor, traveled across the eastern mountains and into the valley of the Ohio. Less well known is the fact that, after his selection as Commander of the Continental Army, one of the first men he appointed was a geographer to prepare maps for the Continental Army. President Thomas Jefferson established an agency in the Treasury Department to chart coastal waterways and harbors because of their importance to the Nation's commerce and engaged Lewis and Clark to explore and chart the Louisiana Purchase.

This effort continued—and accelerated—during the rest of the 19th century. With the impetus provided by the continued expansion of the frontier and the military and defense needs of a growing Nation, the Federal Government, shortly after the Civil War, sent civilian scientific and engineering, and military expeditions into the West to assess natural resources and to find railroad and other transportation routes to the Pacific. Two of these expeditions were led by men who would become the first two Directors of the Geological Survey—Clarence King and John Wesley Powell. Both of these men brought back information in the form of maps, and, when the Geological Survey was established by Congress in 1879, it was only natural that a mapping program was an integral part of the new agency's activities.

The Geological Survey's mapping tradition, however, stemmed primarily from the resource interests of the Government and a desire for commercial exploitation of the Nation's vast treasures of land, water, and minerals. For much of the agency's century of service, deciding where to map and which maps to make has been related largely to the development of known resources and to the finding of new resources. It has been a distinctively utilitarian work. Indeed, when public policy demands began to change after World War II and led to the Survey's program to map the entire Nation in the standard 7.5-minute topographic series at 1:24,000 scale, there were some who complained that public funds were being spent for nothing more than surveying and mapping vast areas of uninhabited terrain. Yet uninhabited has never meant unimportant where things of the Earth are concerned; even the Antarctic Continent teaches much about the planet and the effects of people upon it.

The Geological Survey has endeavored to build toward complete cartographic coverage of the Nation, and this effort has been recognized through a series of directives giving the agency wide coordinating and leadership responsibilities for Federal mapping.

As it has from its inception, the Federal mapping program rests on three fundamental assumptions:



Digital elevation values derived by computer processing of stereo pairs of aerial photographs show topography of the land in new ways. The same digital data aids computer programs for volumetric analyses, such as mineral overburdens, transportation route planning, slope computations, and calculations for preserving or reclaiming land.

- Mapping the Nation is crucial to its economic development and environmental protection.
- Maps must contain many types of information built on a base of scientific validity and technical accuracy.
- Maps must communicate across a wide spectrum of customers and uses.

Accordingly, the National Mapping Program has evolved through a process of consultation with an ever-increasing number of Federal and State agencies, representing the widest possible range of users and uses. As their needs for maps and cartographic information were assessed, some products were changed, new ones developed, and completely new services added.

The effort has considerably affected the Geological Survey's mapping products and services. In the 1950's and 1960's, the Geological Survey published one basic series which was aimed at providing detailed national coverage—the 1:24,000-scale topographic quadrangle.

Extensive national map coverage is also available at other scales. More than one-half of the Nation is portrayed in maps at a scale of 1:100,000. The Nation is entirely covered in maps at a scale of 1:250,000. National coverage is also available at other smaller scales.

Perhaps more significant than the multiple scales of national coverage is the growth and expansion of subjects and themes treated by the maps themselves. Until the 1970's, maps by the Geological Survey dealt primarily with topographic mapping.

Today, the National Mapping Program publishes a variety of thematic and interpretive maps, from those showing energy sources, distribution, and uses to others that combine the topography of the land with the bathymetry (ocean floor contours) of sea charts to provide a single "family" of maps aimed at improving the capability to manage the Nation's coastal resources. The Survey also publishes a national series at the 1:2,500,000 scale showing land use and land cover.

What was for most of the Geological Survey's history primarily a topographic mapping service emerged in the 1970's as a comprehensive mapping organization with a full line of products and services, each developed and produced in response to specific public policies and national needs.

A TIME OF TRANSITION

The old truism "change begets change" appears to be at work in the Survey's mapping program, for it would seem that the establishment of the comprehensive National Mapping

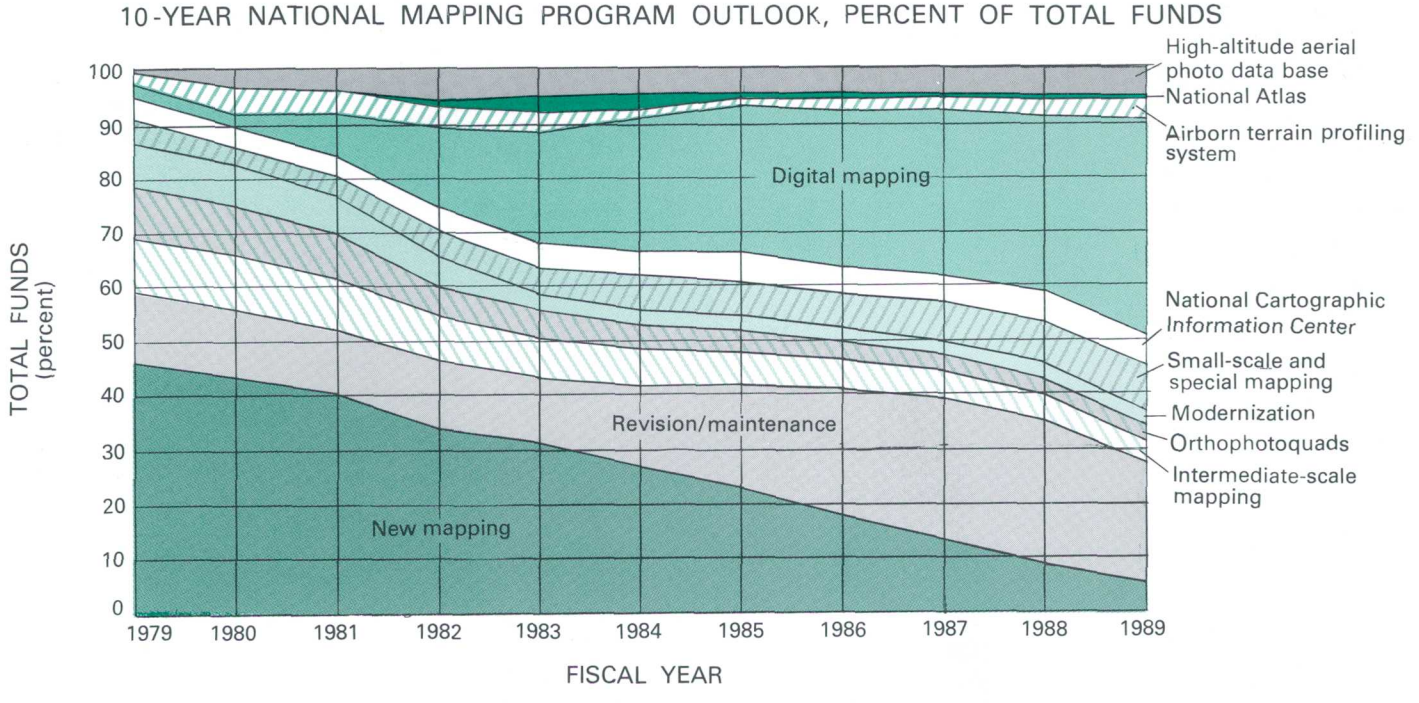
Program has been less a culmination of this tradition than a prelude to still more innovations and program changes. What, in fact, confronts the Geological Survey is nothing less than a cartographic revolution that is fundamentally changing the nature of the National Mapping Program. The challenge of the next decade will be to manage this change in ways that strengthen the Geological Survey's cartographic services to public policy and to customer needs.

To understand the wide scope of the challenge, one might begin with public policy: the American people's views regarding the national treasures of land, water, and minerals—the things that maps clarify, portray, and communicate.

If much of earlier public policy was devoted to resource development, it has now shifted to a greater emphasis on protection or conservation of natural resources. Environmental concerns, the effects of careless exploitation, and resource limits have shaped a very different public policy emphasis.

Public officials at all levels of government are now called upon to balance conservation and development. For every consideration of resource development, there are many of resource conservation. And neither set of issues may be resolved independently of the other. It is a public policy that allows resource development but also demands its conservation, asking government to reclaim, to protect, to give back to the Earth in some measure what has been taken.

Two consequences of this public policy change have been an increase in the number of government agencies that depend on maps and an increase in the complexity of their requirements. It is a substantial change from the Geological Survey's older mapping tradition, which largely supported the advance of geological investigations in exploring and classifying the national domain to speed development of its resources. For a



By fiscal year 1979, the Survey was undertaking a variety of programs to develop cartographic information in formats suitable for computer analyses by many Federal land and resource management agencies. Included was transfer to digital computer storage of cartographic information contained in the Survey's 1:2,000,000-scale base map series of the Nation.

long time, the Geological Survey was one of the best customers for its topographic maps, as it remains today. Now, however, there are many more Federal, State, local, and private customers who make a wide variety of uses of Geological Survey maps. Maps are their tools for making important decisions regarding vital and diverse public issues, such as management, coastal wetlands inventories, transportation, energy, conservation, resource estimates, flood insurance, civil defense and emergency preparedness, agricultural lands conservation, environmental protection, and many others. Just deciding what to map and how to map has become a complex process of widespread consultation and tough priority assessment.

At the same time, public policy and customer needs have expanded the scope of mapping; technology has similarly affected the nature of information people need and the methods for providing and using it. It is a highly interactive process. Public policy places demands on agencies, and they attempt to respond more quickly and fully by applying advanced technology. In turn, the Survey responds with different and innovative ways of surveying, collecting map data, compiling it, and providing it. New methods are also applied internally to speed and to improve the mapping process. Automated equipment delineates information on compilation sheets, aerial photographs are processed in new ways to derive terrain contours, and the new information produced by these processes is itself applied by customers to their own needs.

These are the forces of the cartographic revolution—public policy, changes in customer usage, and technology—coming together in a time of transition to change fundamentally time-honored ways in which cartographers have clarified, portrayed, and communicated things that describe the Earth.

THE DIGITAL CARTOGRAPHIC REVOLUTION

In responding to public policy changes and customer demands for cartographic information and products, the Geological Survey has evaluated its traditional methods of response. Out of this reevaluation has come a realization that increasingly sophisticated and technologically advanced customer demands require the Geological Survey to respond with a great deal more than traditional line maps. That "great deal more" is digital computer technology through which the Geological Survey can collect, organize, and disseminate cartographic information in ways suited to emerging uses of data in customers' own systems of analysis and management.

For much of the history of computer development since World War II the technology was too expensive and too limited to be economically applied to the enormous information content of cartographic products. This is no longer the case. Computer technology has become very inexpensive, as is exemplified by small calculators and electronic games in the home. One consequence of the widening influence of computer technology among map users is a rapid change in their need for cartographic information. At one time, a map, periodically revised, was enough, but this is no longer so. Major units of Federal and State Governments require information from maps that can be integrated into their own computer-based systems:

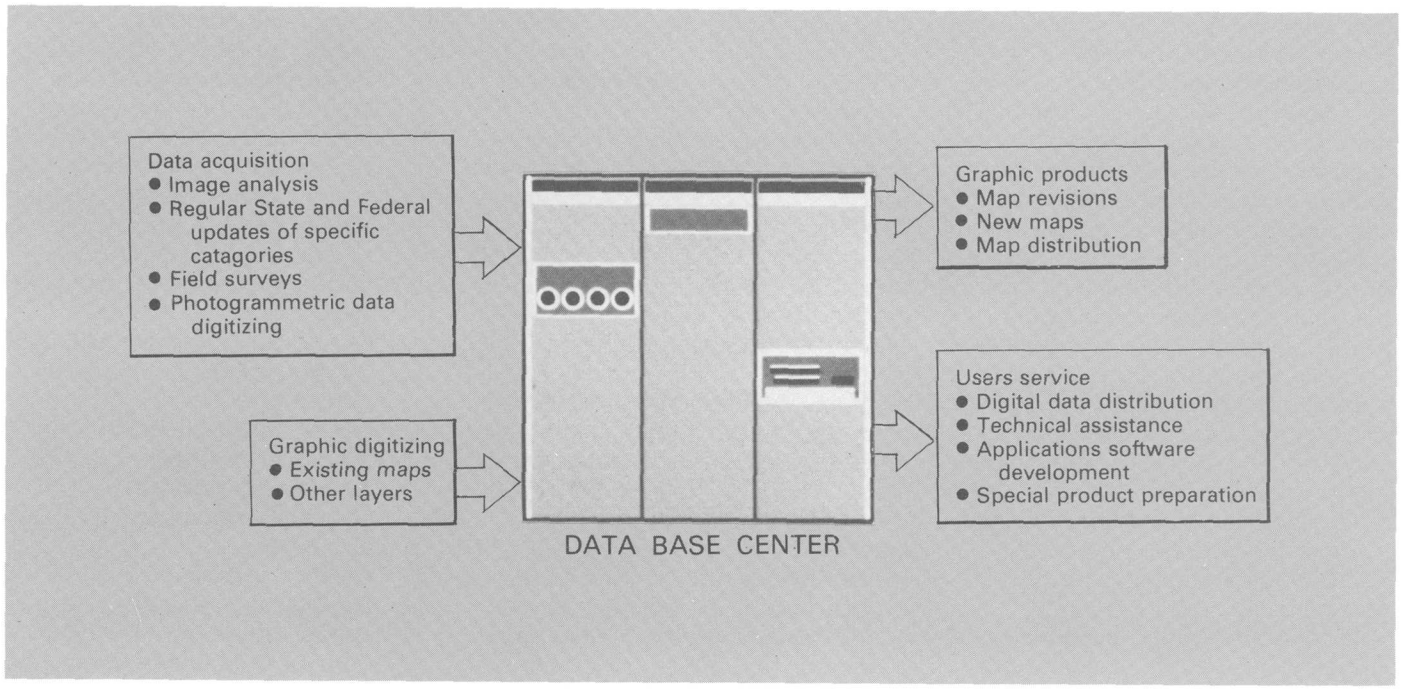
- The Forest Service uses terrain data in digital form for predicting likely paths of forest fires.
- The Federal Aviation Administration is using digital information on possible obstructions around airports (towers, mountains, tall buildings) for integration into obstacle-avoidance landing systems on board airliners.
- Energy agencies at Federal and State levels use many types of map information for integration into computer-based systems for assessing environmental and conservation issues.
- Federal land management agencies, such as the Bureau of Land Management (BLM) and the Forest Service, are looking to the Geological Survey for critical categories of map information for use in natural resource inventories.
- Terrain information expressed in digital form, boundaries, and land nets will help improve inventories of the Nation's natural resources, from important minerals to grasslands and from coal beds to important farmlands.
- To help protect wildlife, map data in computer form will help locate habitats so that they may be protected.
- Map information in digital form will also serve needs beyond the Nation's physical resources. To assist the Bureau of the Census to inventory America and Americans, the Geological Survey will be preparing boundary information from maps in digital form. These maps will help organize census information more quickly and accurately, which is of critical importance to a wide variety of social programs whose funding through political subdivisions is linked closely to census information.

These are but a few of the new and sharply increasing customer needs for digital map information–information in forms that may be integrated into computer-based systems of management, control, inventory, and analysis.

For some customers, a printed map will remain the answer to their needs. For others, data from parts of the cartographic process will be the answer. Some products will be in the form of pure digital information, while others may be in the form of analytical services. Still others may be in graphic formats that can be manipulated.

This emphasis on information from the entire cartographic process, with each part taking on distinct uses for customers, will mean a major transition for the Geological Survey over the next decade. The Survey will move from the task of preparing maps as the one final product to the task of creating and maintaining a national digital cartographic data base from which many intermediate and final products, analyses, and services will flow to customers.

This digital cartographic data base eventually may allow some customers



Building for future cartographic needs, the Survey plans to establish a cartographic data base that will accept information in a variety of formats. Outputs may range from graphics, such as press plates for map printing, to analytical services for customers.

to design their own products by taking information from the Suvey's data base, combining it with information of their own, and portraying it their way. An example of how conventional maps and other information already are used in this fashion is illustrated by the coal folio program.

The coal folio combines a variety of different information with 1:100,000-scale map bases for showing coal beds, overburden thicknesses, and reports on geochemistry of soils, water, and rock. It includes data on surficial and bedrock geology, geologic hazards, and engineering criteria needed for soil and rock stabilization analyses in connection with construction and mining. Customers are able to combine compatible Geological Survey land use maps for areas covered by the coal folio. Survey's hydrologic maps may also be integrated with the folio data base. BLM is converting surface- and mineral-ownership data to the Geological Survey's 1:100,000-scale map base so that it, too, may be integrated with the system. The broad effort will enable the Department of the Interior to improve substantially its management of the Nation's Federal lands.

The future for applying digital data, on the other hand, is illustrated by the National Coal Resource Data System. It is an interactive computer under development by the Survey that will quickly report the information about coal resources on either an area or a specific site basis and show it graphically on a base map or as an overlay. It has much of the information a manager needs for helping people develop the wise use of this important resource, including, for example, longitude and latitude (positions), political boundaries (ownership), terrain data, and point-source (specific site) information on coal, outcrops, mine workings, drill holes, and chemical and physical parameters of the coal. Much of the system's cartographic data is used in digital form to help analyses, as well as display of information.

These two systems illustrate the more responsive ways in which Earth resources information may be provided and how digital cartographic data will work in the future on an integrated and compatible basis with other kinds of information.

Interchangeability and compatibility of different data present the Geological Survey with a difficult challenge. In the past, cartographic information was viewed primarily for use in compiling a particular series of maps. But now and tomorrow, the information must be applied to a wide variety of other products and services.

Consider the benefits that might accrue from the ability to integrate such diverse data as weather, terrain, and rivers from satellites and other sources which could combine both fixed and rapidly changing information. Civil and emergency preparedness is an obvious example of a critical area that can benefit. Digital cartography will allow information from a natural or manmade disaster to be combined, as it occurs, with fixed cartographic and other data. Were a nuclear plant to leak radiation or a hazardous cargo to be accidentally dumped, weather and topographic information could be combined with site data to predict the spread of danger. This kind of prediction is already being done by the Geological Survey. Similar calculations are made to project the trajectory of oilspills as a part of analyzing potential environmental hazards associated with spills at proposed offshore leasing sites.

By combining stored cartographic data with other information, public officials could portray events in ways that would allow people to act more quickly and more wisely to save lives and property. The opportunity will be rich for the production of maps that

would be dynamic, reflecting temporal phenomena, and from them allow people to predict future phenomena. Such dynamic maps could even be transmitted directly into people's homes and offices as is now done with satellite weather data.

The prospect for using such diverse information focuses attention on the entire process of interagency and intergovernmental coordination and cooperation in collecting and maintaining digital cartographic information. In the past, the Geological Survey, as coordinating agency for Federal mapping, has met with other Federal agencies to assess their mapping needs so that priorities for new mapping and map revisions could be set. The process has grown in importance, and, today, a large number of Federal, State, and local units of government are canvassed in setting priorities.

The future, though, will require far more than setting priorities for map production. It will mean coordinating the development and acquisition of cartographic information, setting standards for its accuracy and use, and seeing to its widest possible compatibility with diverse public needs.

THE MANAGEMENT CHALLENGE

The cartographic revolution poses two management challenges to the Geological Survey. One is to mobilize information resources from within the Survey and from other Federal, State, and local agencies of government. The other challenge is to create a comprehensive data base for cartographic information with procedures for its widespread and multipurpose use.

Mobilizing information resources primarily challenges the Geological Survey's ability to foster a willingness to cooperate and to share throughout all levels of government. Many public agencies, particularly those responsible for land and resource management, produce large quantities of information, some of which is cartographic and may be well suited for inclusion in the cartographic data base. Much other information can be made far more useful if it can be combined with standard digital cartographic data.

Both cases require that information be in some ways compatible and that it be in forms or formats which encourage its multipurpose use. Achieving compatibility and standardization to some degree across organization lines and among many Federal and State agencies is a formidable task.

In creating a comprehensive data base, the Survey will emphasize organization and content that encourage widespread and multipurpose use—a data base that is also a service network. Its successful creation will depend on (1) data acquisition, (2) digitizing of graphics, (3) data-base management, (4) development of new computer-generated graphic products, and (5) customer services, including technical assistance to help people apply advanced technologies effectively.

Data acquisition will include collecting and updating various categories of information in the data base. It will have an interesting influence on the Geological Survey's historic view of map revision, which has meant revising all necessary data categories within a map quadrangle. But as the Survey moves into digital cartography, the focus of revision will shift from specific map quadrangles to sets of data on a geographic basis.

Acquiring data from sources other than the Survey's own field, scientific, and aerial surveys will contribute important classes of information, such as transportation and boundaries. Agreements will be established with other agencies so that data may be provided regularly and in proper formats. It will be a formidable task. The quality of data varies substantially from one place to another. Computers are unforgiving—they do not gloss over errors. And while organizations may compromise their differences or leave some things to another time, computers do not.

Important categories of information will continue to be collected directly by the Geological Survey. It is likely that the agency will prepare themes and data extracted from images obtained from both aircraft and spacecraft. And, of course, contour and elevation data will continue to be produced.

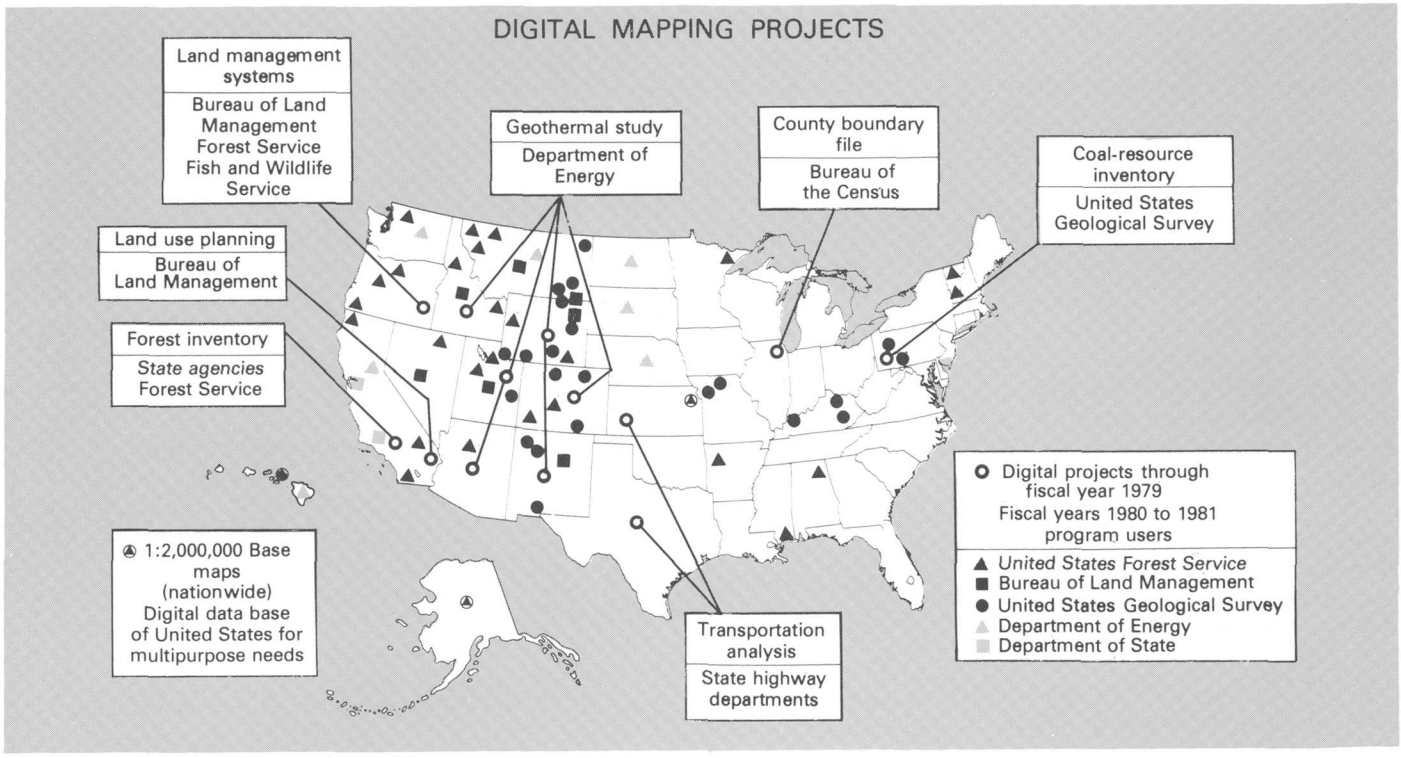
The second area of activity will be translation of visual—graphic—information into digital data. During the 1980's, the limited amount of graphics digitization now being performed will grow substantially as data is entered directly into the base from existing maps.

It is a necessary phase to build a data base from a valuable existing source of information, primarily the maps themselves. The ability to enter data directly from graphic sources is also important for another reason. Much cartographic information is graphic in its initial character—aerial photographs or line networks of one kind or another.

Promise of computerized or digital cartography will depend on a third important area of activity new to the Geological Survey—establishing and managing a massive national computer data base. It may contain in storage as much as several billion bits of data. Some scientists estimate the amount of data even higher. Which estimate one accepts depends on assumptions about the resolution or level of detail people will need. This data base is now being started at the Geological Survey by digitizing data from the 1:24,000-scale 7.5-minute topographic quadrangles.

The fourth area of activity, graphic products, opens new opportunities to apply cartographic information. One application might be automating preparation of plates used in printing maps. Computer-driven plotters already prepare some map overlays. In a few years, automation of other map compilation processes directly from the data base may enable the Survey to produce press plates automatically. Combined with other techniques, it could considerably shorten the 4 to 5 years it now takes from aerial photograph to printed map. The ability to automate the process of creating map graphics will also mean that more unusual or one-of-a-kind maps may be produced, bypassing what are now time-consuming and expensive manual steps.

The fifth area of activity, customer service, represents yet another area of change for the Geological Survey. In the past, service was primarily linked to product availability, helping customers find the maps they need.



Growing demands for cartographic information in digital formats are reflected in this projection of National Mapping Program elements and customer needs through fiscal year 1989.

In recent years, the activity has expanded to include creating a central resource through which people could identify not only the maps they need but also aerial photographs and satellite imagery, individual map feature overlays, and a variety of other items from the mapping process itself to indexes and catalogs of cartographic information.

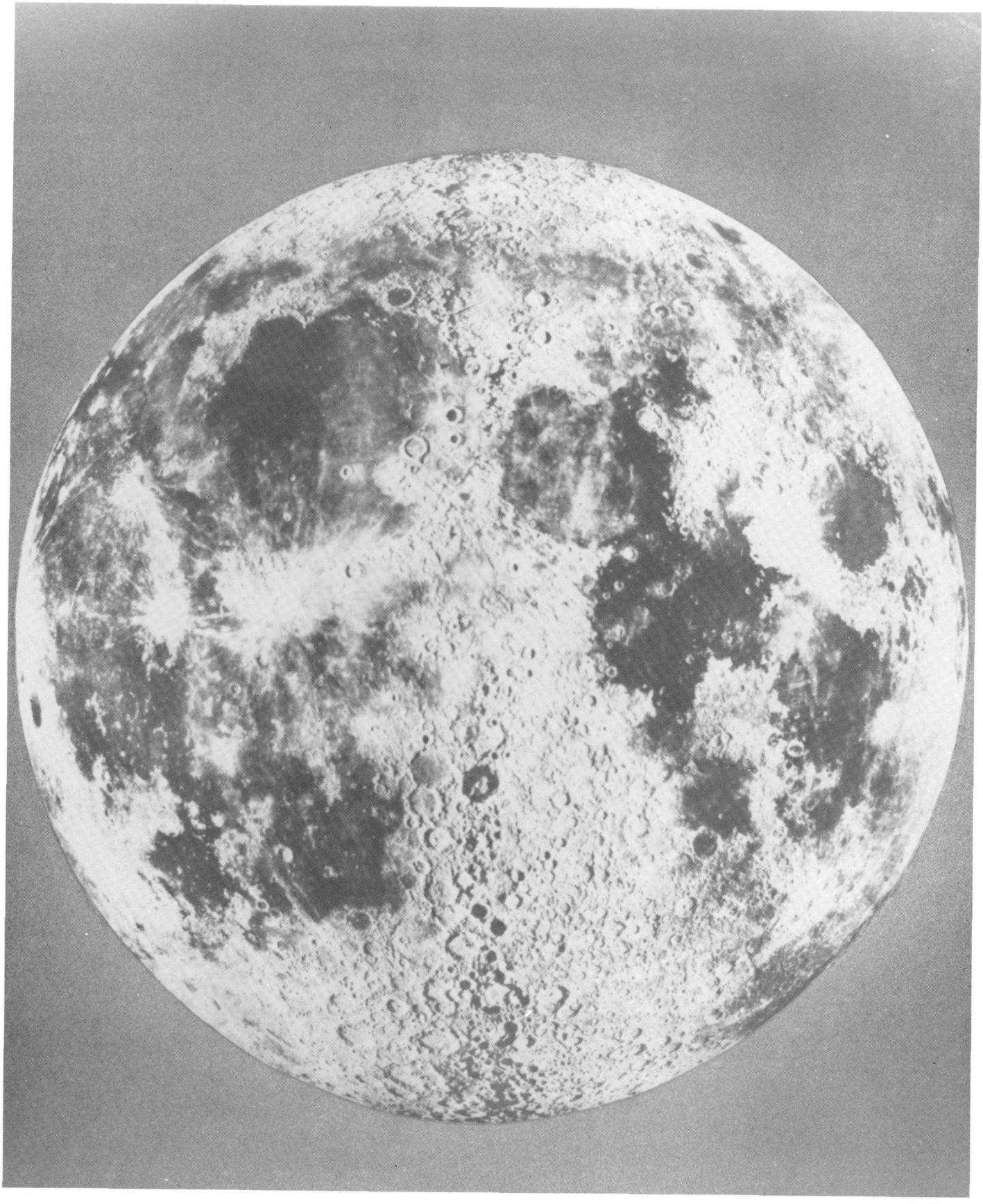
In the future, customer service will include technical assistance to help people apply cartographic information. Geological Survey representatives not only will help people find the information they need, they also will be able to aid other government agencies in applying that information to their own needs.

Data acquisition, graphics digitization, data-base management, graphic products, and customer service will be the major activities of the digital cartographic data base and network. They will be the key activities of the National Mapping Program by the 21st century.

Yet with so much change taking place, with so many new and revolutionary technological innovations to be applied, some things will remain the same. The same three fundamental assumptions about mapping that have guided the Geological Survey for a century will remain as valid as in King's and Powell's time.

Mapping the Nation is crucial. Wherever a decision must be made regarding the public welfare and national treasures of land, water, and minerals, people will continue to turn to maps for guidance. People will continue to demand maps and new cartographic data that meet the highest standards of scientific validity and technical accuracy. People will continue to expect maps to clarify as well as to portray and to communicate to a broad spectrum of customers and to cover a wide variety of uses.

The digital cartographic revolution does not change these old assumptions. It is a reassertion through renewal of their lasting importance. In a world of increasing complexity and technological sophistication, the cartographer's ability to clarify and to portray from myriads of data, to show the relationships among the things of the Earth and the effects of people upon them will help as never before to know the Nation better and to preserve and to protect its legacy of treasures for centuries to come.



Missions, Organization, and Budget

MISSION

On March 3, 1979, the U.S. Geological Survey celebrated the centennial anniversary of its establishment by Act of Congress. The Survey was originally charged with responsibility for the "classification of the public lands and examination of the geological structure, mineral resources, and products of the national domain." Over the years, the evolution of the earth sciences, the need to carefully manage the Nation's nonrenewable resources and to find new sources of scarce energy and mineral commodities, and mounting concern regarding the impact of man on the Nation's environment have added numerous other duties including topographic mapping, chemical and physical research, stream-gaging and water-resource assessments, and supervision of mineral exploration and development activities on Federal and Indian lands.

The most recently added responsibility is the exploration program of the National Petroleum Reserve in Alaska (NPRA), transferred from the Department of the Navy to the Department of the Interior in June 1977 under the Naval Petroleum Reserves Production Act of 1976 (Public Law 94-258). Under the Act, Congress also charged the Department of the Interior with the responsibility for operating the South Barrow gas field as a source of energy for the village of Barrow and several Federal installations including the Naval Arctic Research Laboratory. This responsibility for the operation of the gas field was assigned by the Secretary to the Geological Survey.

In general, the Survey's activities are oriented toward two basic missions, scientific and regulatory. The first mission is to collect, to analyze, and to publish information about the Nation's energy, mineral, land, and water resources; to conduct research to determine the geologic structure of the United States; and to develop an understanding of Earth processes and history. The second is to classify Federal lands as to their water and mineral potential and to supervise the activities of lessees who explore for and develop the mineral resources of Federal and Indian lands and the Outer Continental Shelf (OCS). Both missions and their supporting activities are directed towards the goal of assuring that the Nation's mineral resources are identified, conserved, and developed in an orderly, timely, and diligent fashion; that the American people receive a fair return on the value of their leased resources; and that mineral exploration and production activities on Federal and Indian lands are conducted with due regard for the interests of the communities directly affected and with minimum damage to other resource and environmental values.

Detailed supplementary budget and statistical tables are available upon request from the Office of Program Analysis, U.S. Geological Survey, 105 National Center, Reston, VA 22092.

ORGANIZATION

The Geological Survey is headquartered at Reston, Va., and maintains a nationwide organization consisting of three Regions and more than 160 offices located throughout the United States. The Survey is organized into four Program Divisions (Topographic, Geologic, Water Resources, and Conservation), two major Offices (Land Information and Analysis and the National Petroleum Reserve in Alaska), and three Support Divisions (Administrative, Computer Center, and Publications), each reporting to the Director of the Survey as shown in the diagram appearing on pages 140 and 141 in the section entitled "Organizational and Statistical Data."

A number of Assistant Directorships have been established to coordinate the activities and relations among the Divisions and the three Regional Offices and to render staff services to the Director and Associate Director in certain specified areas such as program analysis; land resources; energy, mineral, and water management; geologic engineering; and regulation.

The Geological Survey's field organization is made up of Regional Offices at Reston, Va., Denver, Colo., and Menlo Park, Calif., and a network of field and special-purpose offices. These offices coordinate and administer the work of the Survey's widely dispersed activities. The Water Resources Division, for example, has District Offices in 45 of the 50 States and 1 in Puerto Rico. The Conservation Division maintains 70 Area, District, and Inspection Offices close to its areas of work on the public lands and adjacent to areas of petroleum development on the OCS. A directory of the Survey's National Center and selected field offices begins on page 142.

Angel Arch along tributary of Salt Canyon is one of numerous natural arches that were formed in the Canyonlands National Park in Utah by erosion over the past 50 million years.

BUDGET

Total obligations incurred by the Geological Survey in fiscal year 1979 were $764.71 million, an increase of $66 million over the preceding year. Obligations for "Surveys, Investigations, and Research" were $418 million, an increase of $44 million over fiscal year 1978. Included in this increase were new or expanded programs for nuclear hydrology, wilderness mineral surveys, digital mapping, coal hydrology, geothermal investigations, and oil and gas programs. Obligations for "Exploration of National Petroleum Reserve in Alaska" were $216.88 million in fiscal year 1979, an increase of $14.18 million over the previous year.

Funds from other Federal agencies, States, and non-Federal sources amounted to $129.83 million, an increase of $17.95 million over fiscal year 1978. Included in this amount were $44.1 million from States, counties, and municipalities under the "Federal-State Cooperative Program," $3 million more than the fiscal year 1978 amount.

A 10-year comparative analysis of obligations incurred under direct and reimbursable program activities is presented in figure 1.

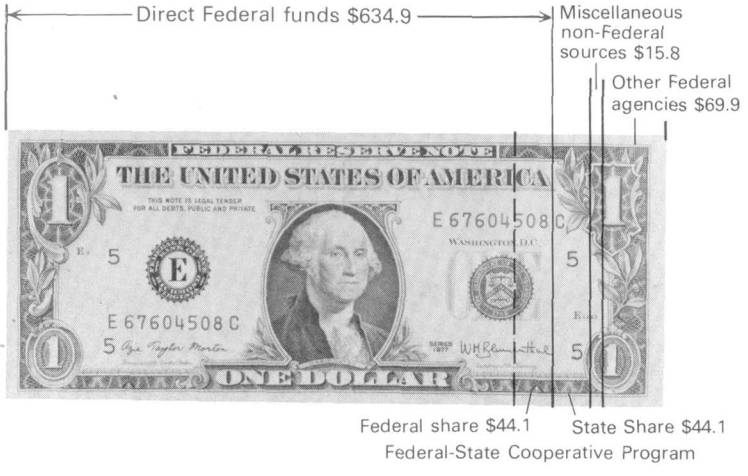
Just as the Survey performs services within its own field of expertise for other agencies using reimbursable agreements, outside sources are relied upon by the Survey for the accomplishment of an increasing share of its workload. Funds obligated for grants and contractual services have risen from less than $25 million in fiscal year 1973 (11.5 percent of total funds) to $120 million in fiscal year 1979 (21.8 percent of total funds, excluding NPRA). The $216.88 million obligated under "Exploration of National Petroleum Reserve in Alaska" was almost entirely for contractual services.

The table shows a comparison of obligations in fiscal year 1978 and 1979 by major budget activity, and the figure depicts the annual obligations incurred by each activity for the period 1969 to 1979.

U.S. Geological Survey obligations for fiscal years 1978 and 1979, by activity

[Dollars in millions. Data may differ from that in statistical tables because of rounding]

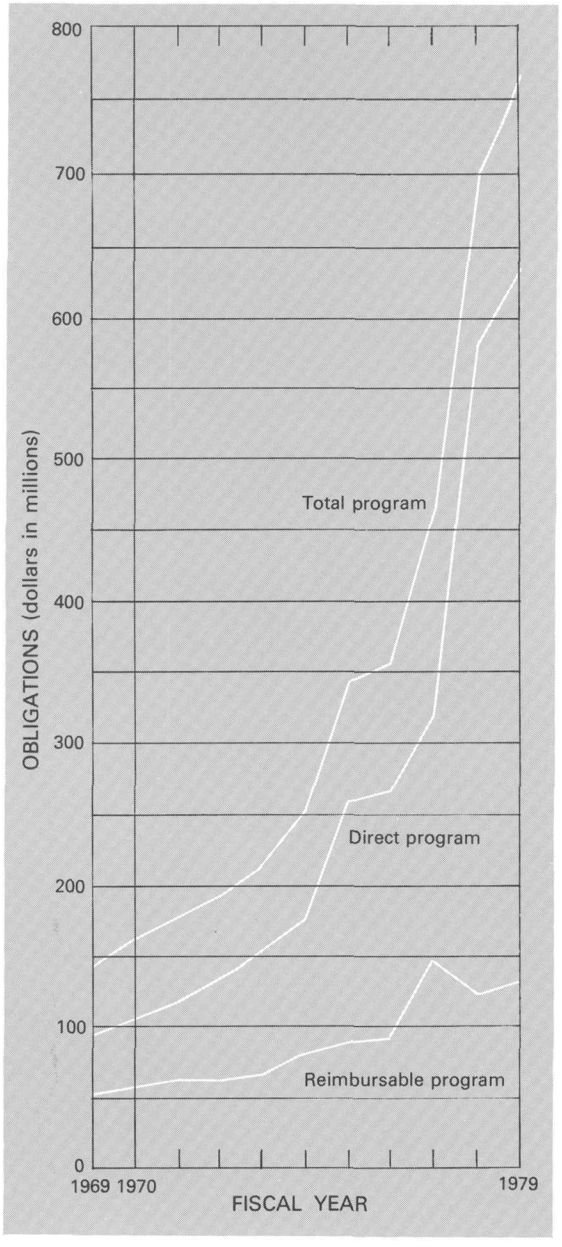
Activity	Fiscal year 1978	Fiscal year 1979
Total	**$698.27**	**$764.72**
Direct program	576.39	634.89
Reimbursable program	121.88	129.83
Alaska Pipeline Related Investigations	**272**	----
Topographic Surveys and Mapping	**69.52**	**74.56**
Direct program	61.36	65.58
Reimbursable program	8.16	8.98
Geologic and Mineral Resource Surveys and Mapping	**163.19**	**178.56**
Direct program	123.83	134.85
Reimbursable program	39.36	43.71
Water Resources Investigations	**146.01**	**168.60**
Direct program	78.49	96.85
Reimbursable program	67.52	71.75
Conservation of Lands and Minerals	**77.40**	**85.48**
Direct program	77.29	85.36
Reimbursable program	.11	.12
Land Information and Analysis	**23.22**	**23.96**
Direct program	18.13	19.96
Reimbursable program	5.09	4.00
General administration	**3.65**	**3.66**
Facilities	**10.77**	**11.74**
Miscellaneous services to other accounts	**1.51**	**1.26**
National Petroleum Reserve in Alaska	**202.70**	**216.89**
Direct program	202.60	216.89
Allocation transfer	.10	----



SOURCE OF FUNDS

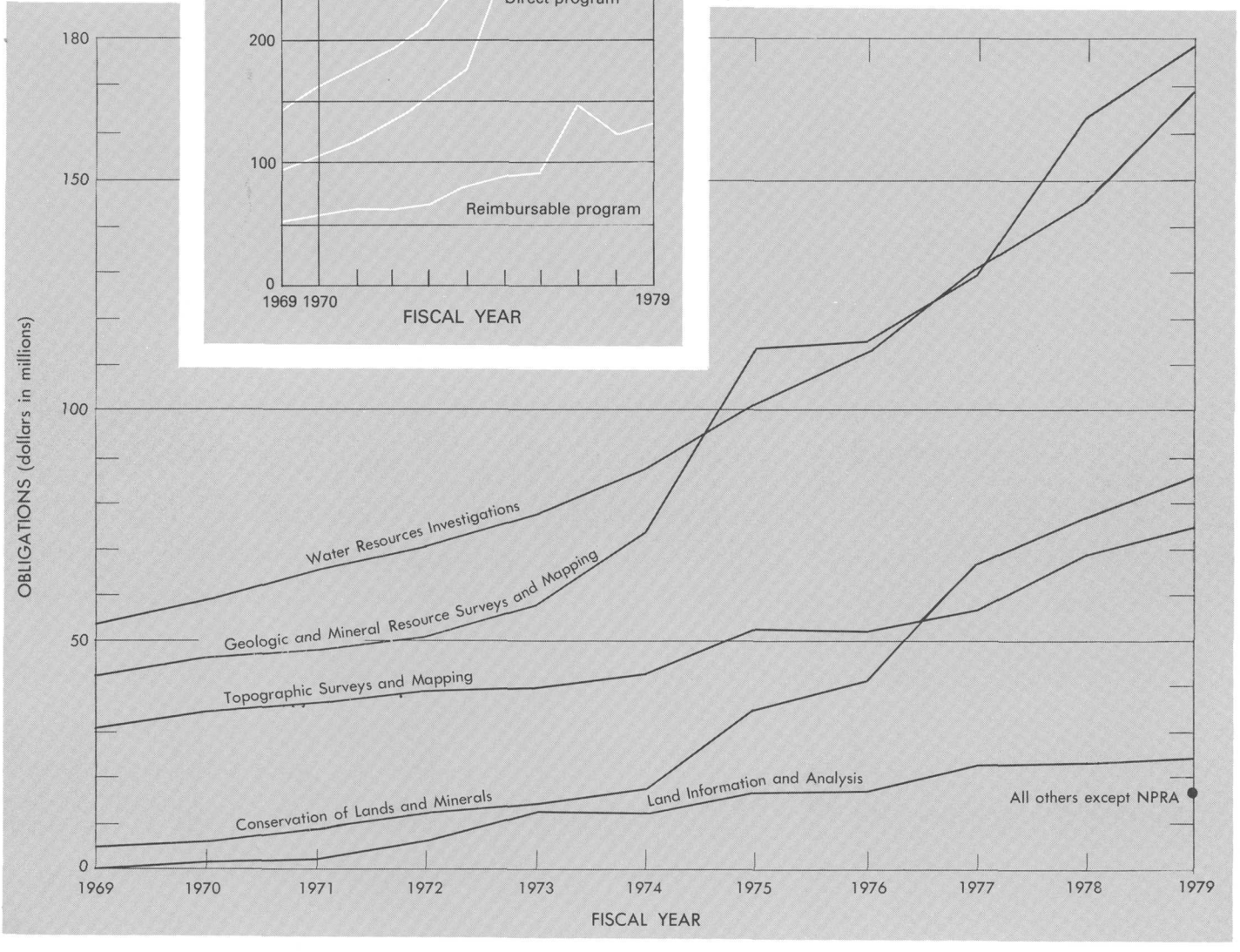
TOTAL $764.7 MILLION

USE OF FUNDS



◀ U.S. Geological Survey budget for fiscal years 1969 to 1979, by source of funds.

Figure 1.—U.S. Geological Survey budget for fiscal years 1969 to 1979, by activity.
▼



PERSONNEL

Although the workload of the Survey has grown dramatically during the past 6 years, its permanent employment has risen very little from 8,089 at the end of fiscal year 1973 to 9,470 at the end of fiscal year 1979, an increase of 17 percent. The increased responsibilities pursuant to the scientific mission have been accomplished with an essentially level full-time personnel work force; virtually all of the increases in full-time personnel have been directed to the rapid increases in the regulatory mission as energy exploration and development expands on Federal lands. Although much of the program increases have been "contracted out" as described in the preceding section, a substantial share of the additional work is being performed by the Survey's other-than-permanent employees, the number of which has more than doubled since fiscal year 1973, as shown in figure 1. The Survey has profited greatly from its historic relationship with this group, which has given it access to eminent specialists in many fields and has afforded it great flexibility in meeting surges in the workload. The arrangement also has unique advantages in bringing the academic community into close and continuing contact with Government on a personal level.

Staff distribution among the several Divisions is shown in figure 2. Scientists, engineers, and other professional people comprise roughly one-half of the Survey's total permanent staff, and technical specialists account for an additional 34 percent. Hydrologists and geologists predominate among the professional corps, 9 percent of whom have doctoral degrees. These and other aspects of the Survey's permanent work force are presented graphically in figure 3.

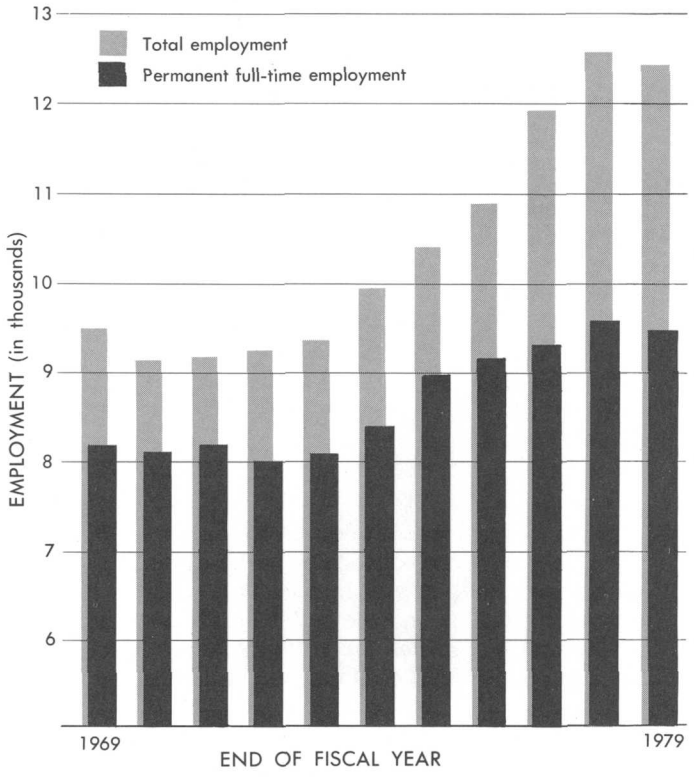


Figure 1.—U.S. Geological Survey end-of-year employment for fiscal years 1969 to 1979.

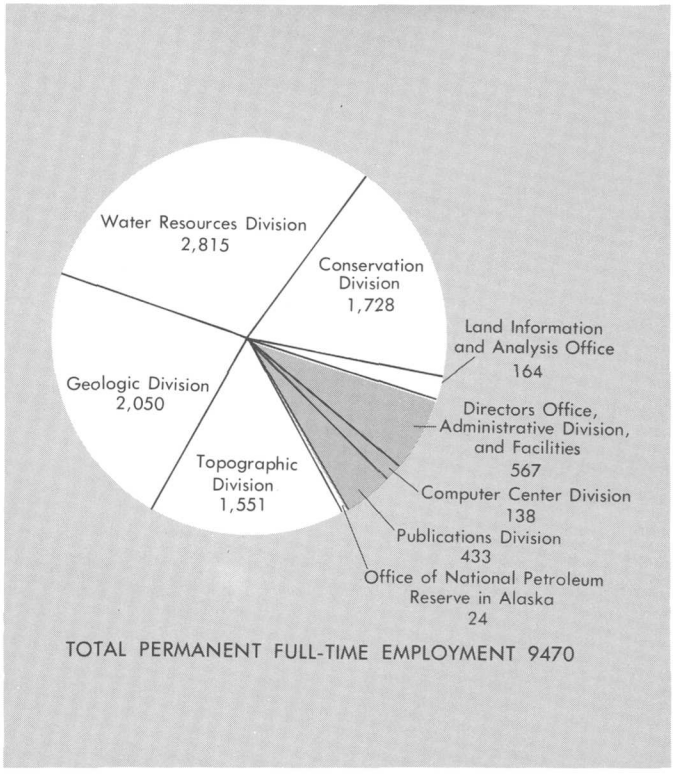


Figure 2.—Distribution of permanent full-time U.S. Geological Survey employees as of the end of fiscal year 1979, by organizational unit.

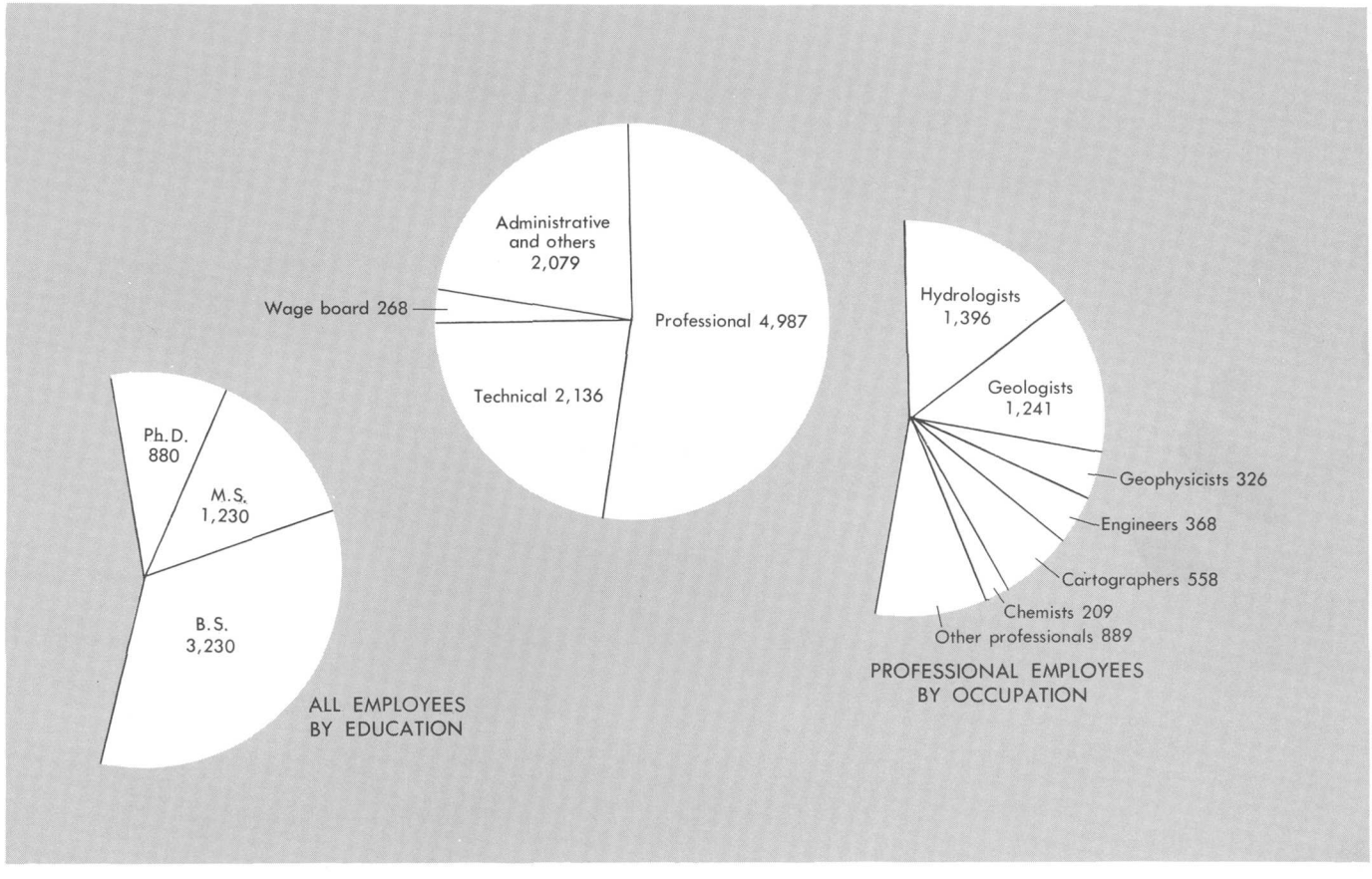


Figure 3.—Permanent full-time U.S. Geological Survey employees, by type.

Topographic Surveys and Mapping

MISSION

The U.S. Geological Survey's Topographic Division conducts the National Mapping Program, which produces maps and cartographic data delineating the physical features of land areas in the United States, in its territories and possessions, and in Antarctica. Under the National Mapping Program, the U.S. Geological Survey's Topographic Division assesses Federal and State requirements, sets priorities, and provides needed map products and cartographic services. Through its National Cartographic Information Center network, the Division also collects, catalogs, and distributes a wide variety of cartographic data produced by many Federal, State, local, and private organizations. Included are photographs and space images, maps and charts, geodetic data, and cartographic information in digital form. In addition, the Topographic Division provides technical assistance in the use of cartographic products and information to many public agencies.

ORGANIZATION

The Topographic Division is headquartered at the Geological Survey's National Center, Reston, Va. The Division staff consists of two offices, one for Research and Technical Standards and a second for Plans and Program Development. Mapping activities are carried out by four mapping centers, the Eastern Mapping Center, Reston, Va., the Mid-Continent Mapping Center, Rolla, Mo., the Rocky Mountain Mapping Center, Denver, Colo., and the Western Mapping Center, Menlo Park, Calif. A fifth, the Special Mapping Center, also in Reston, is scheduled for consolidation with the Eastern Mapping Center in early fiscal year 1980.

MAJOR ACTIVITIES

The National Mapping Program encompasses the following major activities:

- Quadrangle mapping and revision, which involves the production and revision of 7.5-minute maps at 1:24,000 scale in Inch-Pound System units and 1:25,000 scale in metric units for the conterminous United States, Hawaii, and developing areas in Alaska, and maps at 1:63,360 scale (Inch-Pound System units) and 1:50,000 scale (metric units) for Alaska.
- Digital mapping, a recent addition to the National Mapping Program involving the preparation of digital cartographic data in standard formats suitable for computer analysis and the provision of services to other Federal agencies for digitizing, editing, analyzing, and displaying digital cartographic data.
- Small-scale and special mapping, including preparation of maps and map products from the intermediate-scale (1:50,000 and 1:100,000) series to the small-scale U.S. base maps (1:2,500,000).
- The National Cartographic Information Center (NCIC), which acquires and disseminates information about the Nation's maps, charts, aerial and space photographs, geodetic control, digital cartographic information, and other related cartographic data.
- Research, development, and modernization of mapping to improve the quality of standard map products; to provide new products, such as digital cartographic data that make maps and map-related information more useful to people; to reduce costs and increase productivity of Government mapping activities; to acquire innovative and more useful equipment and to design and to develop new techniques and systems; and to build and to test components for an advanced airborne system designed to speed surveying important areas of the Nation.

BUDGET AND PERSONNEL

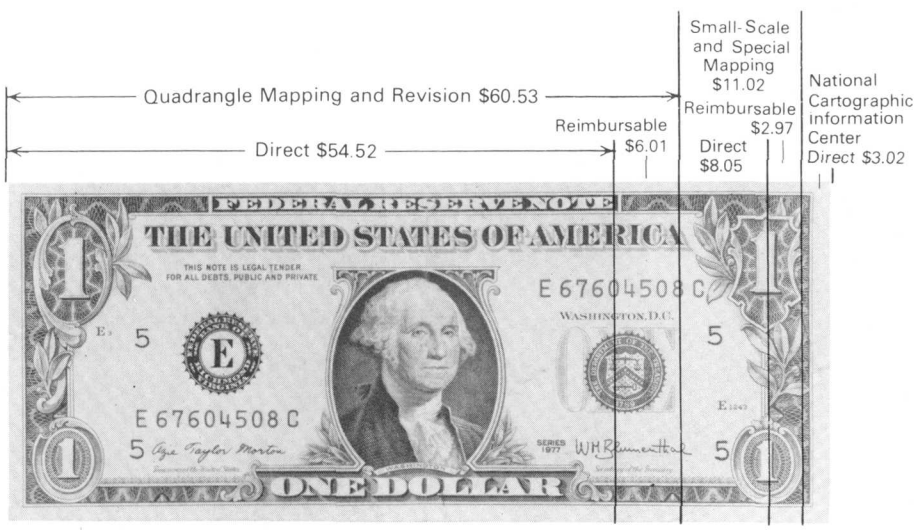
For fiscal year 1979, National Mapping Program obligations amounted to almost $74.57 million, an increase of 8.94 percent over fiscal year 1978. Included are funds from 40 States, which, when matched by Federal funds, amounted to over $6.7 million for cooperative mapping. The cooperative projects mutually benefit the State and national program by ensuring completion of map coverage sooner than would otherwise be possible.

The National Mapping Program of the Geological Survey is carried out through a combination of in-house efforts and contracts. The in-house effort involves about 1,551 career employees, many with special training in cartography, data processing, engineering, photographic technology, and the physical sciences. About 249 additional employees, many on work-study programs, serve as temporary aids.

SOURCE OF FUNDS

TOTAL $74.57 MILLION

USE OF FUNDS



Topographic Surveys and Mapping activity obligations for fiscal years 1978 and 1979, by subactivity

[Dollars in millions. Data may differ from that in statistical tables because of rounding]

Program	Fiscal year 1978	Fiscal year 1979
Total	**$69.52**	**$74.57**
Quadrangle Mapping and Revision	**56.47**	**60.53**
Direct programs	50.65	54.52
Reimbursable programs	5.81	6.01
States, counties, and municipalities	2.80	2.83
Miscellaneous non-Federal sources	1.67	.24
Other Federal agencies	1.34	2.94
Small-Scale and Special Mapping	**10.22**	**11.02**
Direct program	7.86	8.05
Reimbursable program	2.36	2.97
State, counties, and municipalities	.52	.54
Miscellaneous non-Federal sources	.32	.36
Other Federal agencies	1.52	2.07
National Cartographic Information Center	**2.83**	**3.02**
Direct programs	2.83	3.02

DIGITAL CARTOGRAPHY

Public and private organizations involved in land and resource planning and management are making increased use of computer-based analyses. These agencies require cartographic data in formats that are directly usable in their computer systems.

At the same time, advanced mapping systems use digital instruments to record and computers to process and to store information as streams of digital codes from which maps subsequently can be produced. The Geological Survey has undertaken a program to exploit these advanced production systems in response to specific identified requirements. This digital data service will be able to collect, to process, to store, and to distribute cartographic and geographic data in digital formats. Categories of cartographic data being digitized include line graphics, land nets, boundaries, transportation, hydrography, culture, and elevations.

DIGITAL TECHNOLOGY DEVELOPMENT

Geological Survey cartographers are taking advantage of computer technology to enhance many production procedures. With the modern digital cartographic equipment, it is possible to reorganize many phases of map production to allow greater flexibility in mapping techniques and products.

Digital data can be derived directly from stereoaerial photographs (stereomodels). Interactive editing and cartographic machine-plotting techniques are used for production of conventional map color separates. Data collected from the stereomodels can be used not only for producing final map separates, but also for establishing digital topographic data bases for map revision and data dissemination. The process involves online acquisition, formatting, filtering, and interactive editing of the topographic map data. The edited data can be plotted in final scribe copy, along with enhancements needed to produce color-separated bases.

DIGITAL DATA EDITING SYSTEM

Many interactive editing functions, such as line clipping, line extending, and stereomodel joining, can be performed on the digital map data. Internal editing can include any separate-to-separate feature for correlation needed for color composite register, such as registering contour reentrants with drains, offsetting buildings from roads to avoid conflict of symbology, and registering multifeature intersections. Other types of data editing include line smoothing, feature redigitizing, and placement of names and other text. The amount of editing required for each separate depends upon the amount of map detail that is required for the final scribing process. Many of the separates, such as transportation, drainage, and culture, require little smoothing of the data and are interactively edited to essentially a finished manuscript. In contrast, the contour separate requires so much interactive editing that it must be processed differently. The contour data are first edited to remove gross blunders and then machine scribed on a Mylar manuscript that is returned to the compiler for a final manual edit.

Edited Mylar plots can be generated by a digital map production system and given to a final scriber for touchup without the need of the initial map compiler rescribing. Plots of edited digitized separates have shown that content and register were identical for all color separates except the contour sheets. It was found also that, as a result of the interactive data acquisition process, a digital representation of the cartographic features in a 7.5-minute quadrangle can be stored on a magnetic tape or disk for future processing in map revision, data structuring, and map database construction.

The cost of digital interactive compilation over manual scribing has not been established. Research is continuing to evaluate these aspects and to establish and to develop a digital data base that will provide additional products and greater flexibility.

COORDINATE TRANSFORMATION SYSTEM

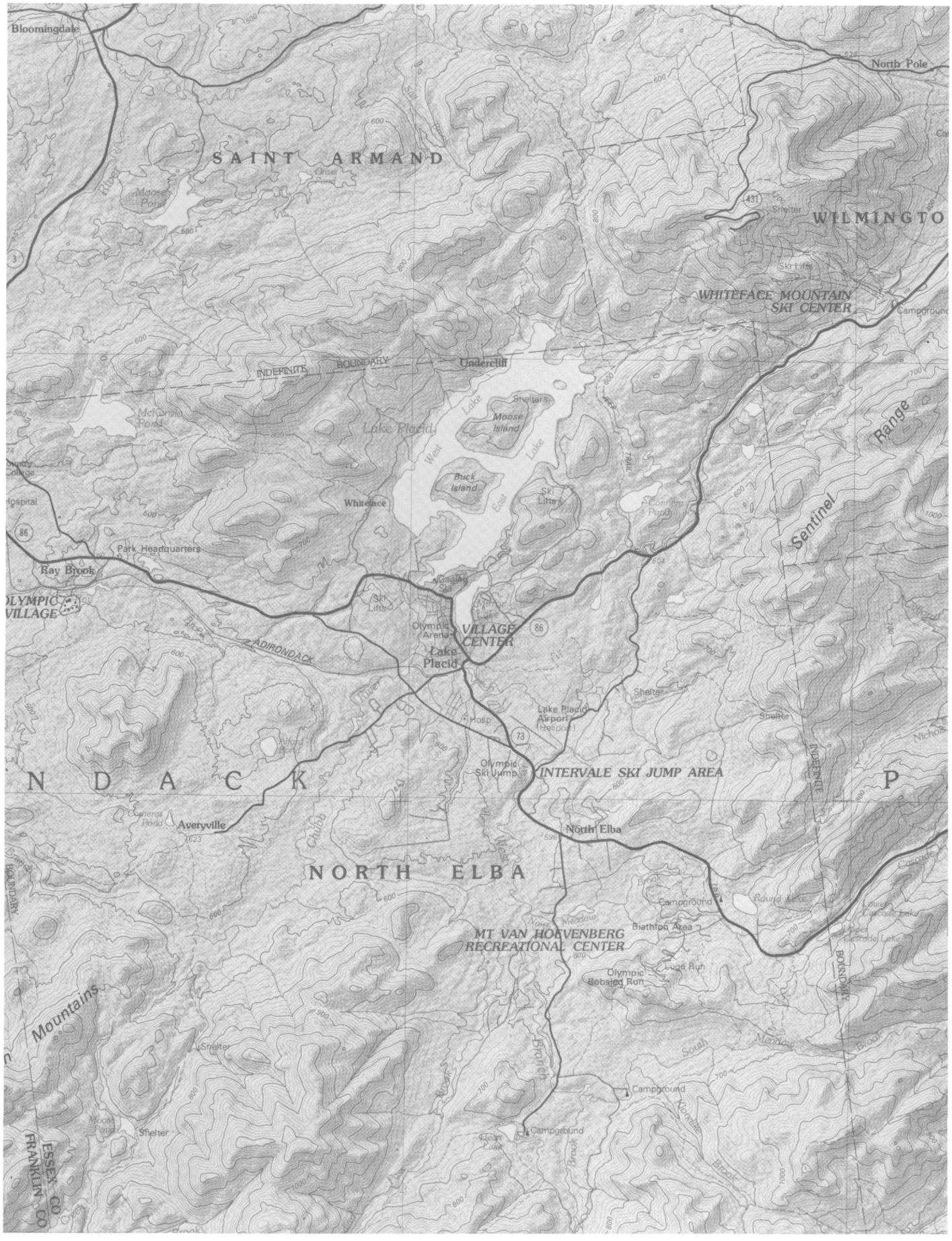
The Geological Survey is evaluating a multiple microcomputer data processor to transform sets of digital cartographic data from one map coordinate system to another. Currently, time-consuming transformation programs are run on expensive mainframe computers.

Preliminary design of the Coordinate Transformation System has been completed as a high-speed direct-memory-access interconnection scheme between a front-end processor minicomputer and remote microcomputer modules. After the network interconnect details are resolved, hardware will be assembled and performance measured and optimized.

MAP SCANNING AND DIGITIZING SYSTEM

Digital cartographic data collected during the map compilation may be stored in digital files for later use. However, the Geological Survey has about 35,000 map bases in its files for which the corresponding digital data have yet to be stored.

To produce digital data from these maps, the Geological Survey has designed a map scanning and digitizing system. The new system consists of the following subsystems: (1) raster scanning and editing, (2) raster recording and printing, and (3) data conversion and formatting. Maps measuring up to 36 inches by 36 inches and printed in 10 colors can be scanned and encoded during a single pass, creating digital data sets from standard map products. The interactive raster editing station uses a 19-inch color video tube for color analysis and reassignment, varying lines and fills, and generation of symbols, register marks, numbers, and text. The recorder and printer use a laser to record raster-formatted digital data on positive or negative photographic film.


Bloomingdale
North Pole
SAINT ARMAND
Moose Pond
Shelter
WILMINGTO
Ski Lifts
WHITEFACE MOUNTAIN SKI CENTER
Campground
INDEFINITE BOUNDARY
Undercliff
Shelters
Moose Island
Lake Placid
West Lake
Buck Island
East Lake
Ski Lifts
Whiteface
Range
Sentinel
Park Headquarters
Ray Brook
OLYMPIC VILLAGE
Olympic Arena
VILLAGE CENTER
Lake Placid
ADIRONDACK
Shelter
Lake Placid Airport (Heliport)
Hosp
Olympic Ski Jump
INTERVALE SKI JUMP AREA
Averyville
North Elba
NORTH ELBA
Campground
Round Lake
Cascade Lakes
MT VAN HOEVENBERG RECREATIONAL CENTER
Biathlon Area
Luge Run
Olympic Bobsled Run
BOUNDARY
Mountains
Shelter
Campground
Shelter
ESSEX CO
FRANKLIN CO

QUADRANGLE MAPPING AND REVISION

By the end of the fiscal year, virtually the entire conterminous United States had been mapped at 1:24,000 scale, either as a finished topographic map, a topographic map in advance state of compilation, or an orthophotoquad. The achievement culminates a three-decade effort by the Geological Survey to gain comprehensive cartographic coverage of the conterminous United States.

AERIAL PHOTOGRAPHY

Under Geological Survey sponsorship, 10 Federal agencies signed agreements that will lead to a high-altitude aerial photograph data base, which, when completed, will give the Nation a single continuously updated source of aerial photographs for a variety of land-management and resource-analysis purposes.

Aerial photographs of the land surface are essential to the mapping process. In fiscal year 1979, the Survey contracted for 163,908 square miles of aerial photography. Photographs of about three-fourths of the area were taken from altitudes higher than 39,000 feet; the photographs were for use primarily in photo-inspection and photorevision of published maps.

FIELD SURVEYS

Field surveys are needed to establish control points so that map features can be delineated in correct relationship to each other and to the Earth's reference systems. Horizontal ground control points are used to maintain correct scale, position, and orientation of the map, and vertical control points are used to govern the contours and spot elevations that show the shape and highlights of the terrain.

PRODUCTION AND REVISIONS

During the fiscal year, 948 new standard topographic maps were published, covering 54,036 square miles. Most of the maps were in the 7.5-minute 1:24,000-scale series (1:63,360-scale series in Alaska). There are 15 States with complete published topographic map coverage at 1:24,000 scale. In addition to being used directly at the published scales, these map series are also used to prepare small-scale and special maps.

As national coverage in the 7.5-minute series increases, the revision mapping workload increases. The need for revision of individual maps is determined by the amount of change detected in comparing the published maps with current aerial photographs. Maps are reviewed cyclically with emphasis on urban areas, coastal zones, airports, major transportation corridors, and other areas of high national interest. During fiscal year 1979, 3,329 7.5-minute maps were reviewed, and 2,024 revised maps were published.

Orthophotographs are produced by processing aerial photographs to correct image displacement caused by camera tilt and terrain variations. In a standard quadrangle format with grid and name information superimposed, the orthophotograph is called an orthophotoquad. It has many applications as a map substitute or as a companion product to a published line map. In fiscal year 1979, 3,884 orthophotoquads were prepared. Copies produced by printing presses are available for a small percentage of these, with the majority available in nonlithographic form (diazo print) on request to regional mapping centers.

METRICATION

In continued cooperation between Federal and State programs on metrication, the Geological Survey and the Commonwealth of Massachusetts completed the first part of a long-term effort transforming the State's Inch-Pound System unit 1:24,000-scale base maps to metric unit 1:25,000-scale maps.

NEW PUBLICATIONS

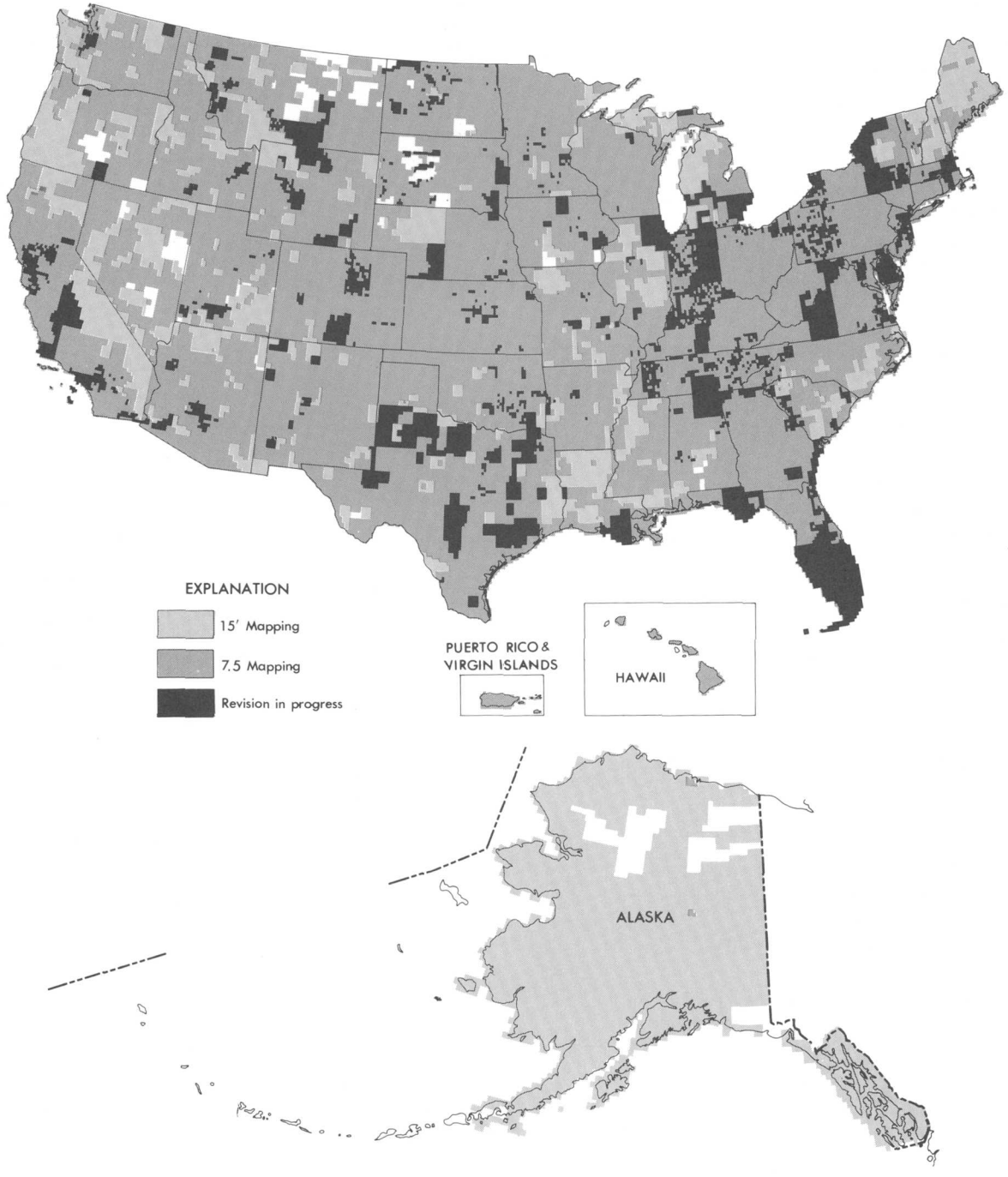
Two important books on mapping were published during the year. *Maps for America* summarizes the history, work, and products of Federal mapping organizations. The volume has received critical acclaim from the international cartographic community. It describes products of several Federal agencies, including the Survey and the National Oceanic and Atmospheric Administration. The *Coastal Mapping Handbook* was prepared jointly by the Geological Survey and the National Ocean Survey to provide technical mapping assistance to Federal, State, and local government agencies involved in coastal management, conservation, and development activities. It was the text for a series of workshops and seminars on coastal mapping conducted by the Geological Survey in conjunction with several local host agencies.

ALASKAN ACTIVITIES

The Survey accelerated its program to map Alaska's lands and natural resources during the year, using aerial, satellite, and experimental radar imagery. A primary aim of the accelerated program is to shorten response times to State and other Federal agency requests for cartographic assistance. The effort also aims to improve coordination of growing State and Federal mapping activites in Alaska, for which the Geological Survey is lead agency.

Mapping production for fiscal year 1979 (in square miles)

State	1:24,000-scale topographic	1:24,000-scale orthophotoquads	1:24,000-scale revisions	Intermediate scale
Alabama	1,120	---	1,197	5,431
Alaska	---	---	---	---
Arizona	2,400	---	1,178	9,246
Arkansas	248	2,933	1,342	1,418
California	1,412	25,924	3,101	19,903
Colorado	4,962	---	2,320	37,415
Connecticut	---	---	---	2,135
Delaware	---	---	---	---
District of Columbia	---	---	116	---
Florida	---	3,053	780	22,082
Georgia	---	1,123	504	15,495
Hawaii	---	6,219	---	---
Idaho	2,350	9,063	2,052	16,778
Illinois	516	---	2,736	3,841
Indiana	---	---	1,083	2,903
Iowa	3,157	---	278	4,035
Kansas	3,304	---	7,137	2,035
Kentucky	---	3,688	8,614	3,747
Louisiana	---	---	448	724
Maine	160	18,181	159	3,963
Maryland	---	11,491	928	937
Massachusetts	---	---	2,145	674
Michigan	823	5,024	486	3,136
Minnesota	202	---	52	6,253
Mississippi	262	---	376	1,733
Missouri	1,862	1,805	6,084	2,489
Montana	2,399	7,908	2,550	4,559
Nebraska	1,076	844	1,848	5,785
Nevada	856	8,958	522	28,235
New Hampshire	---	2,953	---	1,139
New Jersey	---	307	---	226
New Mexico	4,107	20,989	2,760	15,609
New York	---	---	5,665	5,950
North Carolina	1,512	6,999	2,844	2,281
North Dakota	3,038	---	152	12,180
Ohio	---	---	3,249	5,387
Oklahoma	2,040	1,264	847	6,430
Oregon	558	14,636	54	17,373
Pennsylvania	---	9,287	2,204	11,152
Rhode Island	---	---	---	---
South Carolina	251	2,441	558	5,389
South Dakota	4,752	6,940	3,745	7,142
Tennessee	---	838	2,904	4,308
Texas	4,343	---	11,968	9,869
Utah	798	20,043	3,944	28,301
Vermont	54	400	54	788
Virginia	---	---	7,906	7,134
Washington	498	13,221	1,616	13,425
West Virginia	---	5,620	986	3,377
Wisconsin	3,008	---	212	11,700
Wyoming	677	8,819	7,249	11,664
Guam	---	---	---	---
Puerto Rico	---	---	---	2,348
Samoa	---	---	---	---
Virgin Islands	---	---	---	---



Status of standard topographic mapping and revision.

NATIONAL CARTOGRAPHIC INFORMATION CENTER

The earliest maps were relatively simple portrayals of boundaries, distances, and routes from one place to another. Today, however, maps not only show more, they also are used for a multitude of additional purposes, from earth science investigations to recreation.

Map production has also become much more complex. The talents of many specialists are used, and data from many sources are brought together. Some of the information that goes into mapmaking is in the form of aerial or space photographs. Other information may come from reels of computer-based digital data.

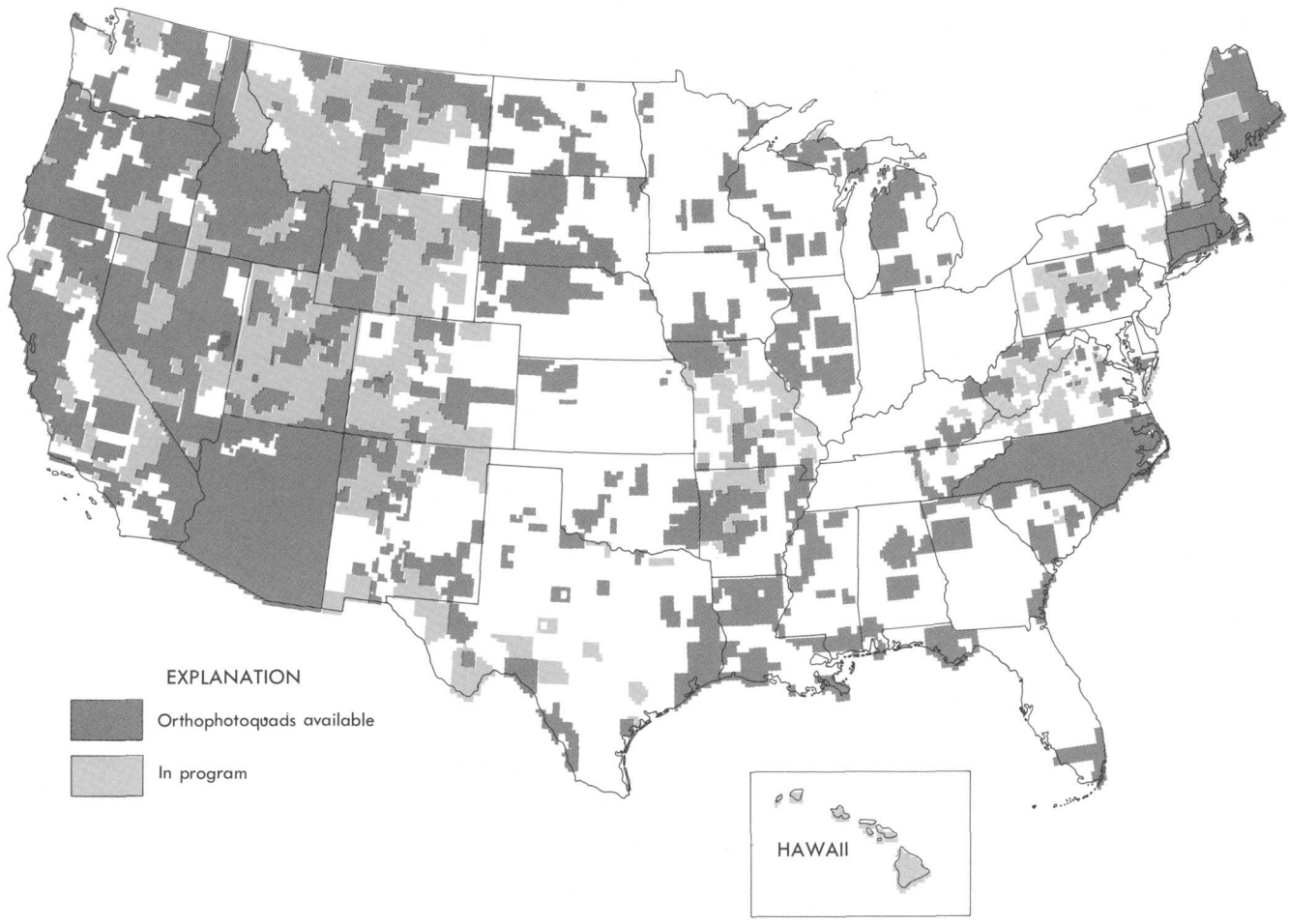
Cartographic information, therefore, has come to mean a wide variety of products and services, virtually the entire range of items that either go into or are produced by the process of compiling and publishing maps. It is the purpose of NCIC to make this cartographic data available to the public.

In fiscal year 1979, NCIC initiated a map and chart information system (MCIS), the most recent of four cartographic data reference systems. Eventually, MCIS will contain descriptions on nearly 800,000 of the Nation's maps and charts. The system is organized so that one may request descriptions of maps and charts by map name or by geographic coordinates.

The three other computer systems cover aerial photographs and descriptive records of any cartographic products in NCIC information systems.

NCIC also has many sets of maps stored on 35-mm roll microfilm. Considerable information is also stored on microfiche. Millions of aerial and space photographs may also be viewed from 16-mm cartridge copies.

To aid public access to the information, NCIC has offices at mapping centers in Menlo Park, Calif., Denver, Colo., Rolla, Mo., and Reston, Va. Additionally, the public can contact other Federal affiliates at the National Space Technology Laboratories at Bay St. Louis, Miss., and the Tennessee Valley Authority in Chattanooga, Tenn. There are also affiliated offices operated by agencies of State governments. Agreements with the States were signed for 10 new NCIC offices during the year, bringing the total to 21.



Status of orthophotoquad production.

INTERMEDIATE-SCALE, SMALL-SCALE, AND SPECIAL MAPS

INTERMEDIATE-SCALE MAPPING

The Geological Survey publishes an intermediate-scale series of maps at scales of 1:50,000 and 1:100,000 to meet a variety of customer requirements for formats and detail that cannot be met with the older 1:24,000- and 1:250,000-scale series.

These intermediates have a number of innovative features, including multiple feature-separation drawings that can be combined in various ways to produce special maps with varying levels of content. Feature symbolization has been designed for data capture, computer storage, and output. By the end of the fiscal year, intermediate-scale maps for approximately one-half of the conterminous United States were completed, up from about one-third in fiscal year 1978.

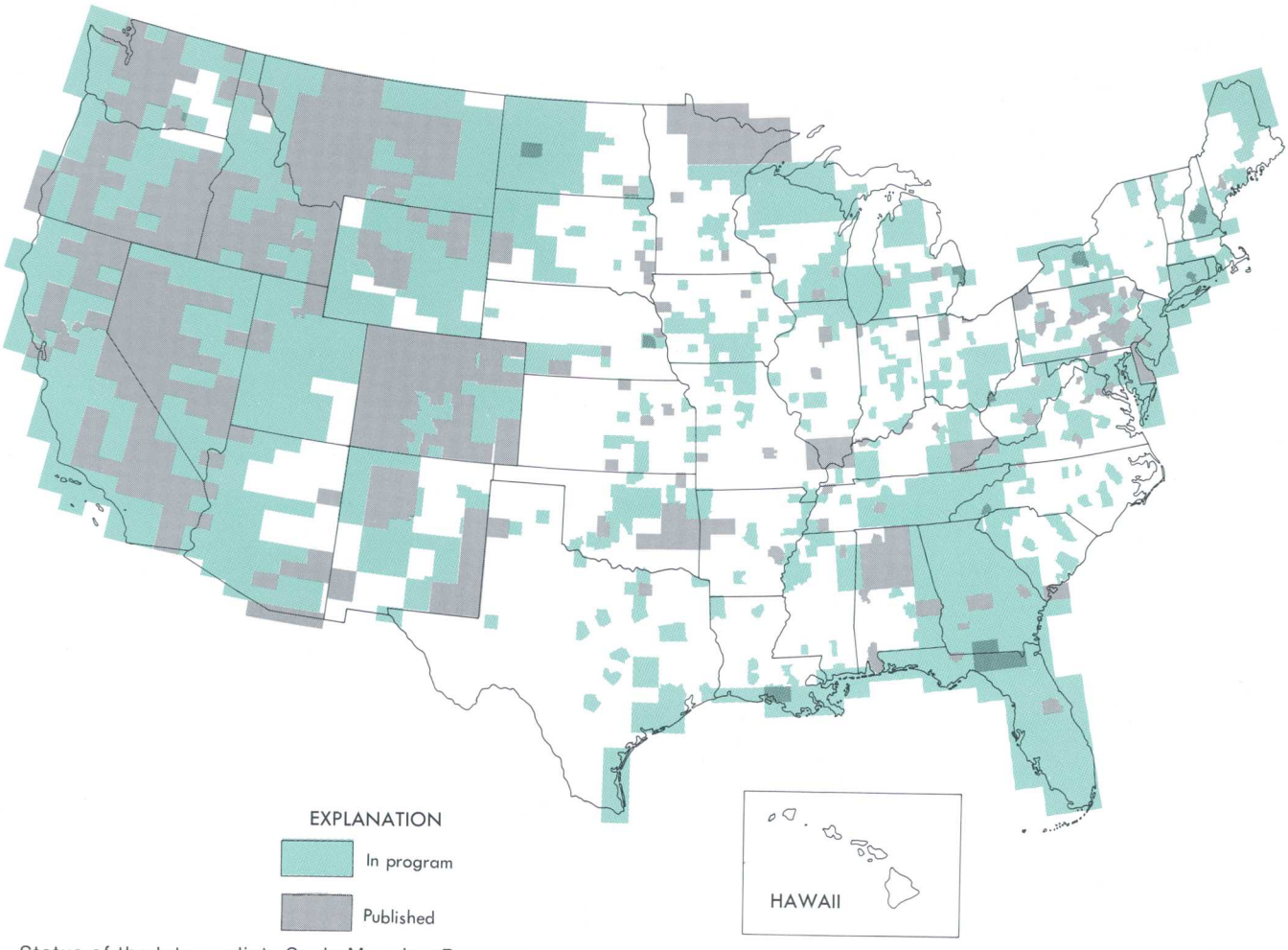
Under a joint agreement with the Defense Mapping Agency (DMA), the Geological Survey produced an additional 87 15-minute 1:50,000-scale metric topographic maps, compared to 86 the prior year. Total program goal is completion of about 2,100 maps, prepared in accordance with jointly developed specifications and yielding map materials that are being used directly in preparation of other intermediate-scale maps.

SMALL-SCALE MAPPING

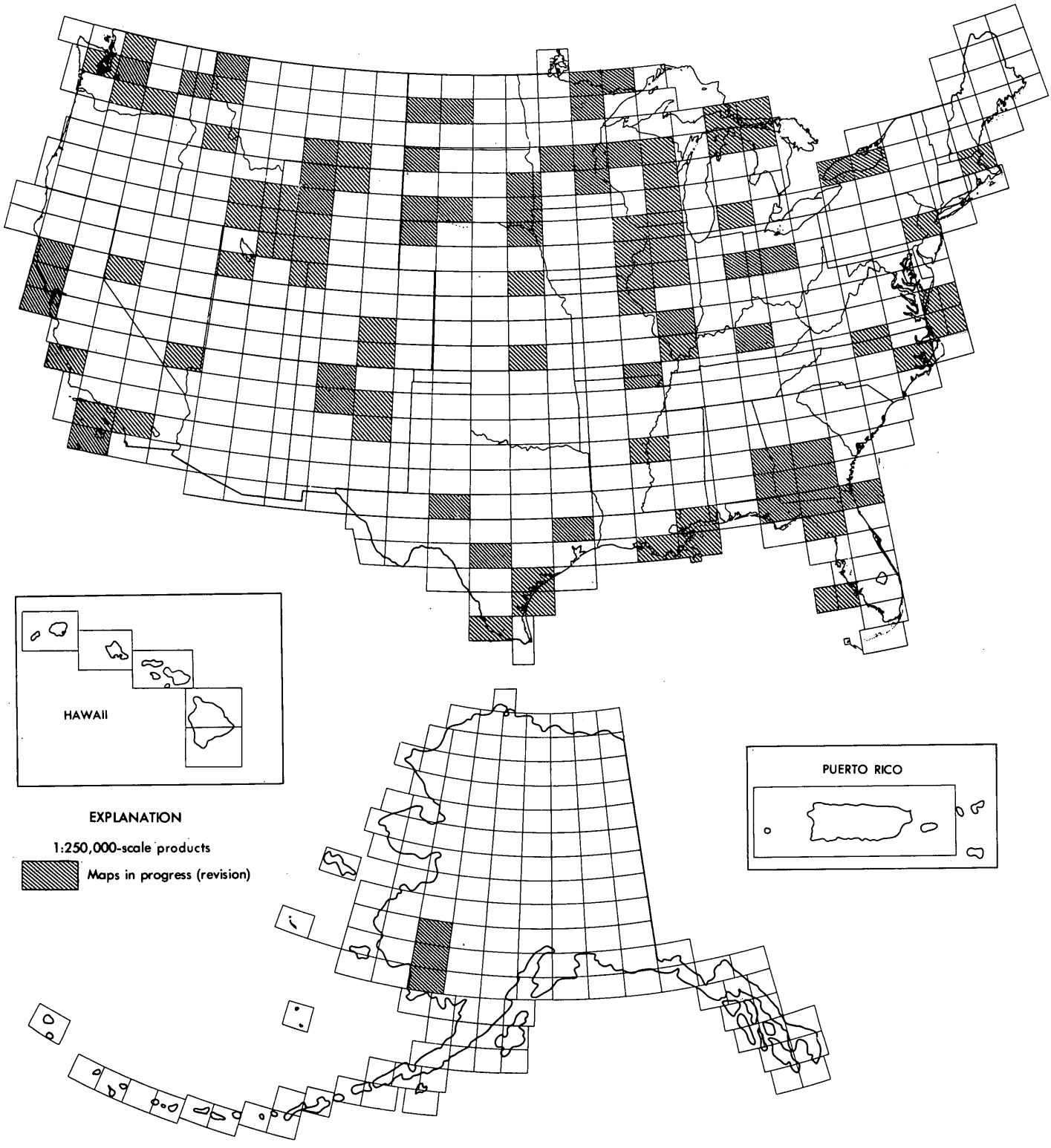
The 1:250,000-scale map series provides the smallest scale of complete topographic coverage available for the United States. These are widely used by Federal and State agencies as well as by the Survey for preparing State base maps, various geologic maps, and special-purpose maps, such as those showing land use and land cover information. During the fiscal year, 48 revisions were published, compared to 50 the previous year. Terrain data digitized from the contours on the 1:250,000-scale maps are available on magnetic tape from NCIC.

TOPOGRAPHIC AND BATHYMETRIC MAPPING

The joint Geological Survey–National Ocean Survey program for producing coastal area maps combining topography of the land and bathymetry of the ocean floor continued to make progress during the year. The series includes maps at 1:24,000, 1:100,000, and 1:250,000 scales; by fiscal year's end, 3, 1, and 16 maps, respectively, had been published with 100 planned for production in fiscal year 1980. The maps, used by State as well as Federal agencies, are a valuable tool for coastal area planning.



Status of the Intermediate-Scale Mapping Program.



Status of the 1:250,000-scale mapping production.

MAPS FOR RECREATION

Of the millions of Geological Survey maps purchased each year by the public, many are for recreation. They are often a constant companion for campers, hikers, canoeists, and others who enjoy the outdoors. Special National Park maps and regular topographic quadrangles covering other Federal and State recreation areas are particularly popular.

During fiscal year 1979, two maps of special interest to the public were published.

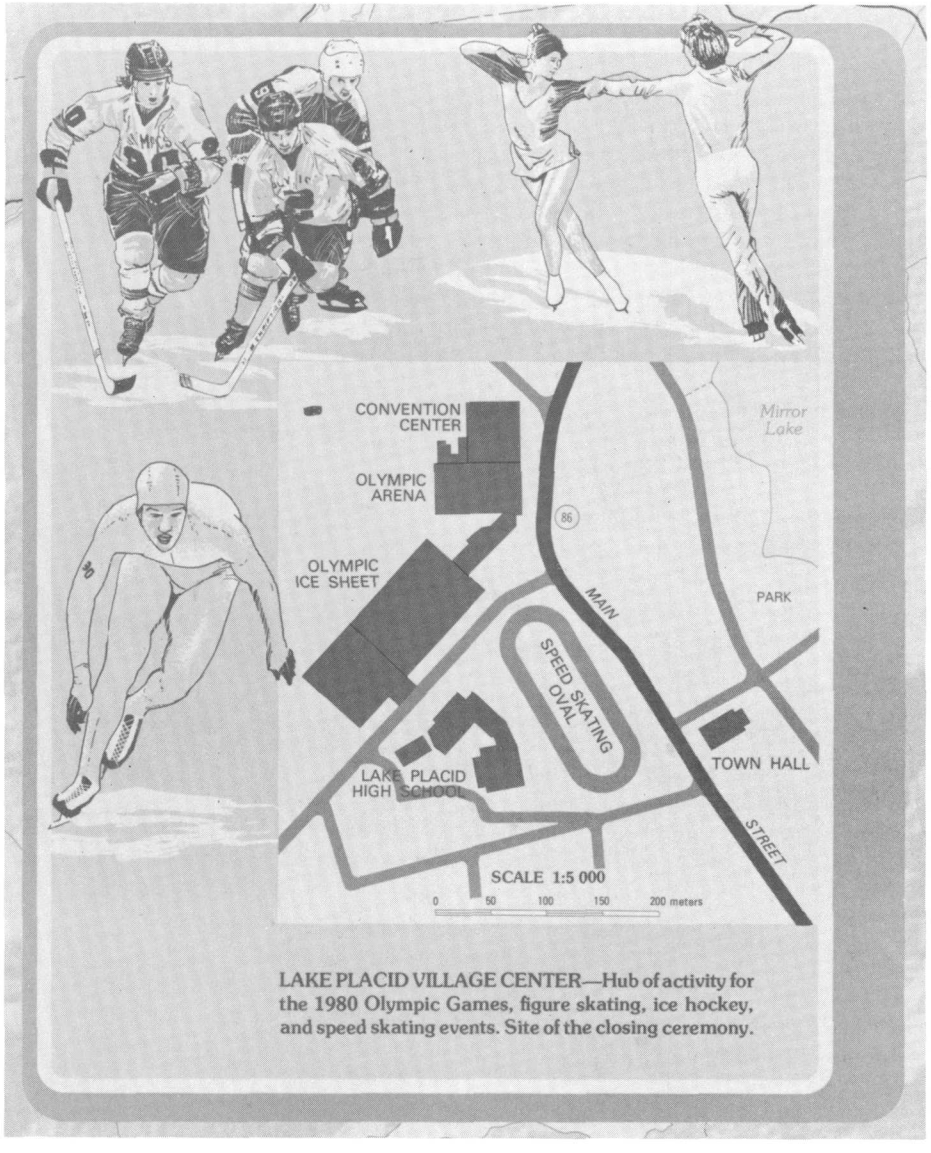
In anticipation of the XIII Olympic Winter Games in Lake Placid, N.Y., the Survey prepared a special-edition map in cooperation with the Lake Placid Olympic Organizing Committee. It is a full-color product printed on both sides, with one side featuring a 1:100,000-scale topographic map of the general area and the other side highlighting key event areas in more detail.

The 1:100,000-scale map was prepared in shaded relief by computer techniques instead of the traditional artistic rendering. It shows the shape and elevation of the land with contour lines at 20-meter intervals, primary and secondary highways, water bodies, campgrounds, hospitals, ranger stations, jeep trails, scenic lookouts, and other surface features.

The reverse side of the map features six detailed venues or insets of key areas involved in the XIII Olympic Winter Games. The six insets depict the Olympic Village and other event areas at various large scales, such as 1:5,000 and 1:10,000.

To assure widespread availability of the map, a special program was undertaken with the Geological Survey's map dealers.

An intermediate-scale map of Voyageurs National Park in Minnesota was published during the year. The park, which lies along the Canadian–U.S. border, is a popular water recreation area. The new map, prepared in cooperation with the National Park Service, combines both traditional cartographic symbology with recreation symbols matching those in the park itself. The map is at a scale of 1:50,000.



LAKE PLACID VILLAGE CENTER—Hub of activity for the 1980 Olympic Games, figure skating, ice hockey, and speed skating events. Site of the closing ceremony.

RESEARCH AND DEVELOPMENT—SURVEYS

AERIAL PROFILING OF TERRAIN

Since 1974, the Geological Survey has been developing technology that would enable surveyors to measure terrain profiles very accurately from low-flying aircraft. The system under development makes use of a laser altimeter for scanning the terrain and an inertial guidance system that very precisely records the position of the terrain profile for all three axes (x and y in horizontal and z for vertical) as it is gathered. The project has progressed from a developmental phase to present activity of fabricating a prototype system.

Aerial Profiling of Terrain (APT) represents a significant technological advance well beyond its intended use for profiling low-relief terrain, such as stream beds. It is a mobile precise three-coordinate reference platform that could guide many types of remote sensors. APT aircraft could carry aerial cameras, radars, magnetometers, or infrared scanners whose data would be precisely referenced to x, y, and z coordinates as it was gathered. Reference data of such precision increases usefulness of sensors, simplifies data reduction, and suggests new economies that would allow for many new types of aerial surveys.

The APT airborne instruments include a laser profiler, a TV camera, an inertial measuring unit, a laser tracker, an onboard computer, and a magnetic tape recorder. The airborne computer interacts continuously with the sensors, directing their actions and calculating initial alinement and calibration for navigation to the survey site and for the profile surveys. The laser tracking instrument updates data by measuring distances and directions to ground reflectors. In addition, the computer feeds data to the onboard magnetic tape recorder which is used later for computations that "smooth" the contour, eliminating effects of trees, buildings, and other objects along the terrain path.

The Survey plans to continue with APT until the operational prototype is completed and flight tested. Further activities will be based on the results of actual field tests of the prototype system. The fabrication and assembly phase began in October 1978 and is scheduled for completion in 1981.

INERTIAL SURVEYING WITH SPAN MARK

The Geological Survey selected the Camden, Tex., area for testing a new inertial surveying system (SPAN MARK) for horizontal and vertical mapping control along paved highways. It promises faster and more economical field surveys. The system, mounted in a four-wheel-drive van, surveyed 638 control points during a 15-day period; this involved measuring nearly 700 miles of double-run survey lines. The initial trunk lines, running between established geodetic triangulation stations, averaged 21 miles in length (the longest line was 38 miles). The largest error found was 2.5 feet and is well within the maximum allowed. The vertical accuracy of the system was carefully monitored, and 39 test points were established. The standard error of the 39 test points was 5.5 inches.

The largest vertical error, about 14 inches, was located where the net appeared weak because of greater spread than normal in the SPAN MARK elevations. This area of less-accurate elevations was caused by a greater spacing between vertical ties than the normal 9 miles. The vertical accuracy was sufficient for the production of 10-foot contour-interval maps.

Advanced digital computer technology transforms aerial photographs into image bases for mapping

RESEARCH AND DEVELOPMENT—PHOTOGRAMMETRY

ARBITRARY PHOTOCOORDINATE PASS POINTS

Pass points used to orient stereomodels in map compilation are usually selected as discrete objects or points on the ground that appear in each image. The Geological Survey is testing the feasibility of using arbitrary photocoordinate positions as pass points rather than discrete points marked on the photographs. The most recent test has used the TA3/P1 stereocomparator, but the procedure is designed for use with three analytical stereoplotters now on order.

For testing the procedure, pass points on 50 unmarked photographs were measured in four strips. Previous data using marked points were available for comparison. The triangulation results of the two methods were not significantly different, indicating that the elimination of the point-marking phase prior to point measurement is a main advantage of the procedure.

MAPPING FROM HIGH-RESOLUTION HIGH-ALTITUDE PANCHROMATIC PHOTOGRAPHS

The relative imagery characteristics of Kodak 2402 and high-resolution SO-022 panchromatic films, exposed in a standard mapping camera at high altitudes, have been investigated. Results indicate that the resolution on Kodak SO-022 film was only slightly higher than on 2402 film using photographs taken at 40,000 feet above mean terrain with a 6-inch focal-length camera.

The anticipated image motion at a 40,000-foot altitude with an airspeed of 400 knots is 7 feet ground scale during an exposure of 0.01 second. No appreciable difference in resolution could be observed between a target oriented along the flight line and one oriented across the flight line. This would indicate that for high-altitude photographs image motion is not a predominate factor in resolution problems.

Both geometric accuracy and the ability to photoidentify and to plot required map detail fell slightly short of meeting map accuracy standards. Enough promise does exist, however, to continue the search for a high-resolution film-camera combination that will satisfy mapping requirements using high-altitude photographs.

FORMATION OF DIGITAL FILES DIRECTLY FROM STEREOMODELS

Techniques were developed for collecting digital data during stereocompilation using an analog stereoplotter equipped with digital data collection hardware and file-building strategy for Digital Line Graph-2 (DLG-2) data files. The DLG-2 files consist of line map information edited to add attribute codes and to remove visible errors and inconsistencies. The procedure is divided into data collection, data processing, and interactive editing.

The project has shown that stereomodel digitization and the subsequent editing of these data are within the state-of-the-art and appear to be feasible in areas of low relief, such as the plains area of the Midwest. As a result of this work, flexible procedures for digitizing and editing stereomodel data have been adopted, and these procedures are being tested.

PLANIMETRIC COMPILATION FROM ORTHOPHOTOGRAPHS

The Survey has developed and put into operation an economical method for using orthophotographs in the topographic mapping process. For each new mapping project at 1:24,000 or 1:25,000 scale, two levels of photography are exposed, high altitude for producing an orthophotograph base and low altitude for compiling contours. Aerotriangulation with the high-altitude photographs requires much less horizontal ground control than is needed for lower altitude photographs.

Using photogrammetric instruments, high-altitude photographs are transformed into orthophotographs, each covering a 7.5-minute quadrangle area. The orthophotoimage is registered to a base sheet and is then printed on material allowing for direct scribing of features.

By reference to field-annotated photographs, all planimetric features that can be seen clearly on the image base are scribed in final form directly on the image. Several image bases are used so that the features can be color separated for printing. Each color separation is overprinted on the other bases in a prescribed sequence so that precise register of the separations is maintained throughout the process.

The stereomodels formed from the lower altitude photographs are scaled to discrete image points on the orthophotobase. Contours and other map features not clearly visible on the image base are compiled from the stereomodels. The contours are scribed in final form on a separate base, and the other stereocompiled features are transferred and scribed on the appropriate base. The completed scribed drawings are used to prepare color composites for the editing and subsequent final copy for preparation of pressplates.

The photobase mapping process reduces the cost and time to produce a standard topographic map by eliminating aerotriangulation of the many low-altitude photographs and by avoiding the preparation of manuscript copy prior to color-separation scribing. A companion orthophotoquad may be prepared as a byproduct of the process.

Application of advanced digital computer technology now enables the U.S. Geological Survey to transform aerial photographs into image bases for mapping, simultaneously deriving elevation information in digital form for use in a wide variety of earth science analyses.

RESEARCH AND DEVELOPMENT—SPACE APPLICATIONS

MAPSAT—AN AUTOMATED MAPPING SATELLITE

The Geological Survey has been investigating the concept for a satellite that, by continuous imaging with very high geometric fidelity in epipolar planes, will permit three-dimensional automated mapping of the Earth from space. Such a satellite, Mapsat, would use linear arrays of detectors to view a ground swath across the ground track of the satellite. Multiple arrays would provide both stereoscopic and multispectral imaging.

LANDSAT 3 RETURN BEAM VIDICON IMAGES

Landsat 3, launched on March 5, 1978, carries longer focal length return beam vidicon (RBV) cameras that provide substantially improved resolution and geometric fidelity as compared with the RBV's of earlier Landsats. Preliminary evaluation of the RBV images found that, while the normally produced images were lacking in image quality, specially processed images were excellent. When the new National Aeronautics and Space Administration (NASA) digital Image Processing Facility and the Earth Resource Observation Satellite Digital Image Processing System become fully operational, normal image quality is expected to be much better.

In an investigation on Landsat 3 RBV images, four RBV scenes of the Upper Chesapeake Bay were analyzed for geometric quality. (The RBV images are central perspective images with a narrow field of view.) Control points were identified on 1:24,000-scale topographic maps, and the RBV images of these points were measured on a comparator. A direct similarity transformation from image coordinates to Universal Transverse Mercator ground coordinates yielded a root-mean-square error of approximately 300 feet.

SATELLITE IMAGE MAPS

Lunar and planetary mapping

A project is underway to produce 1:250,000-scale lunar orthophotographs from high-oblique Apollo mapping camera photographs. The NASA Lunar and Planetary Photography and Cartography Committee has requested Survey support in extending orthophotocoverage into additional lunar areas covered by oblique photographs to complement the maps produced by DMA from vertically oriented Apollo photographs.

The use of high-oblique photographs required an in-house capability to rectify photographs with a 40-degree tilt and scales ranging from approximately 1:370,000 at 1:530,000 at X2 enlargement. All control data for the project were furnished by DMA. Attempts to rectify the photographs on the T-64 orthophotoscope, following initial rectification to a lunar control base on the E-4 rectifier, were unsuccessful due to the excessive tilt. Rectification on the Gestalt Photo Mapper (GPM-2) was also unsuccessful due to the amount of tilt involved and lack of sufficient contrast on the photographs necessary for automatic correlation between models. The problem of tilt may be overcome in the future when new software being formulated for the GPM-2 becomes operational, but the lack of contrast inherent in the original Apollo photographs might continue to present difficulties in electronic correlation.

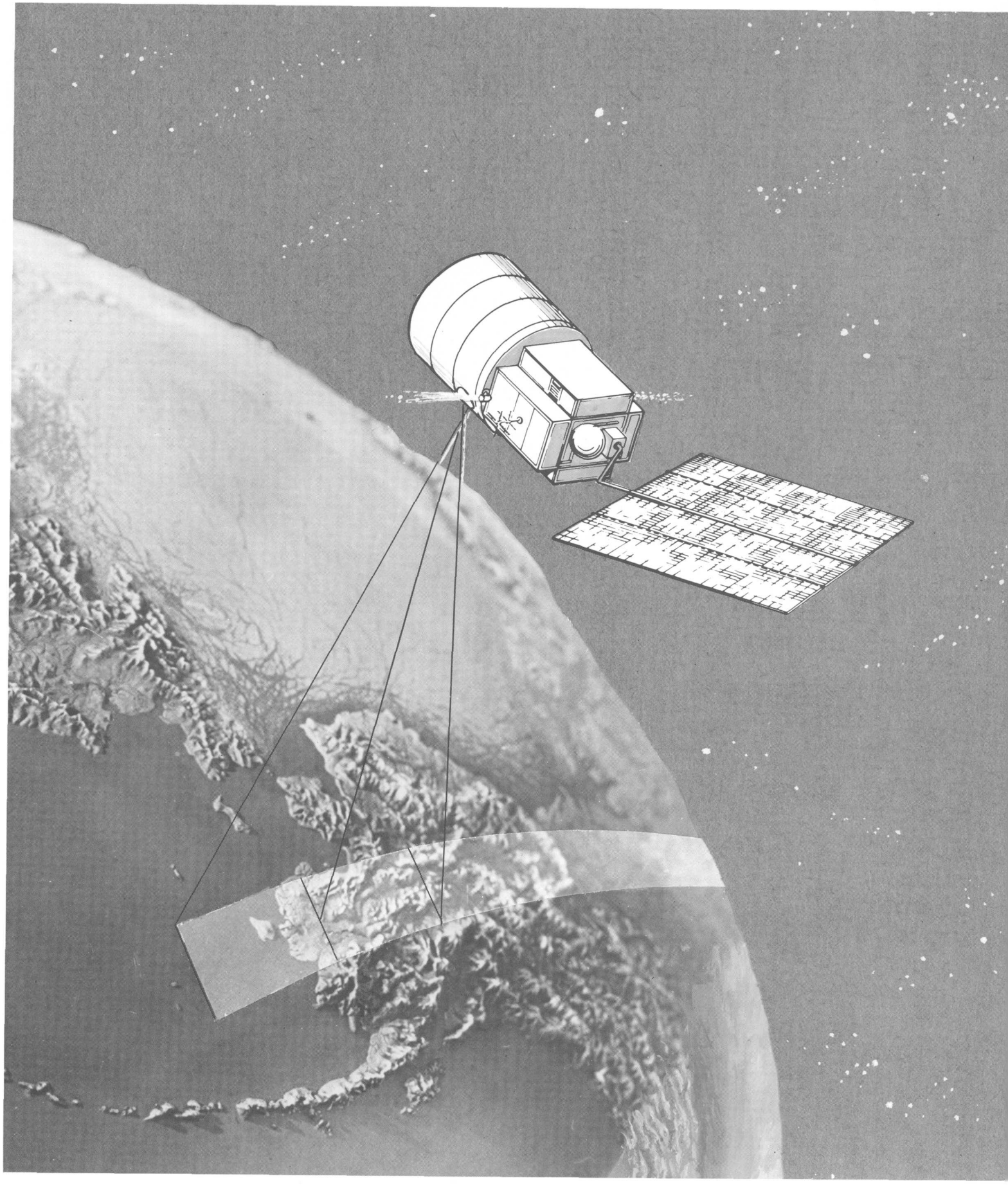
Further rectification experiments are being conducted on the Wild OR-1 orthophotograph system using digital profile data provided by DMA as input. Results obtained on the OR-1 will be instrumental in determining current capabilities for rectifying high-oblique Apollo photographs to produce 1:250,000-scale lunar orthophotomaps.

Stereocombination of Landsat and aeromagnetic data

Many earth scientists use stereopairs of aerial photographs to study landforms by interpreting the third dimension of terrain relief. During fiscal year 1979, the Geological Survey took two-dimensional digital Landsat data and stereocombined it with digital topographic data to generate a Landsat stereopair. The topographic data was used to alter the horizontal location of image points across one Landsat image so that when viewed in conjunction with an unaltered Landsat image, the viewer could interpret—could "see"—the terrain relief.

A new concept is being investigated by the Survey, whereby a parameter other than topography is displayed stereoscopically as the third dimension. Vertical aerial photographs and aeromagnetic data were recorded simultaneously over an area of New Mexico. The spatial variations in the magnetic field were correlated to the Landsat image of the area and used to generate a Landsat stereopair in which the strength of the magnetic field is shown continuously in place of natural terrain elevations.

With the development of digital data bases, stereocombined graphics can be produced based on a variety of data sets. Further research is needed to determine what types of data would warrant display in stereocombined forms as opposed to conventional contour graphics.



Geologic and Mineral Resource Surveys and Mapping

MISSION

The Geologic Division conducts programs to assess energy and mineral resources, to identify and to predict geologic hazards, and to investigate the effects of climate. The assessments resulting from these programs are vital to planning for the wise use and management of our natural resources and to mitigating the disastrous effects from geologic hazards.

In the last several years, the Survey's responsibility in assessing the Nation's resources has increased markedly, especially in the areas of energy—oil and gas, coal, geothermal, and uranium. Large areas designated by Congress for inclusion as Wilderness Areas have required mineral assessments, and additional areas are likely to be designated in the future. Studies are being done to evaluate the energy-resource potential of offshore areas and the environmental hazards that pose problems to the development of that energy. In addition, a major program for earthquake hazard mitigation and prediction is now well underway. Geologic hazards related to nuclear reactor siting are being investigated.

In support of these extremely important mission programs, extensive basic research is done continually on geologic processes and events. Basic research continues to be an important and strong part of the Division's programs and provides the capability needed to respond to emerging national problems.

The Geologic Division budget is presented to Congress under four subactivities that fulfill the above programs. A brief description of these subactivities is given below.

Land Resource Surveys supply basic data in the form of geologic, geophysical, and geochemical maps and reports. Research is conducted to predict and to delineate earthquake and volcano hazards, to identify environmental problems related to coal development and nuclear reactor siting, and to identify, to map, to report on, and to date geologic processes and historical natural events, including climatic changes.

Mineral Resource Surveys provide an assessment of the distribution, quantity, and quality of the mineral resources of the United States. During fiscal year 1979, these surveys were concentrated in Alaska, Wilderness Areas, and other public and Indian lands. Research is also conducted on the fundamental geologic processes that result in mineral formation.

Energy Resource Surveys provide assessments of the distribution, quantity, and quality of the Nation's coal, oil and gas, oil shale, uranium and thorium, and geothermal resources. Assessments of these resources are continually updated so that information is kept current.

Offshore Geologic Surveys investigate the continental margins of the United States and its territories to assess the potential mineral and energy resources and to identify environmental hazards that must be considered when siting offshore drilling platforms and pipelines.

The following 10 articles describe some of the research and assessments done by the Geologic Division in fiscal year 1979. Although they reflect only a small portion of the current programs, these articles represent typical ongoing activities of the Division.

Northern Cascade Primitive Area, Wash. Malachite Lake in foreground; Monument Peak on skyline. ▶

BUDGET AND PERSONNEL

In fiscal year 1979, obligations of the Geologic and Mineral Resources Surveys and Mapping activity were $178.55 million. This amount was supplemented by approximately $584 thousand from 11 States and $43 million from other Federal agencies and non-Federal sources.

At the end of fiscal year 1979, the Geologic Division had 2,050 permanent full-time employees and 944 temporary or part-time employees.

SOURCE OF FUNDS

TOTAL $178.55 MILLION

USE OF FUNDS

Geologic and Mineral Resource Surveys and Mapping activity obligations for fiscal years 1978 and 1979, by subactivity

[Dollars in millions. Data may differ from that in statistical tables because of rounding]

Program	Fiscal year 1978	Fiscal year 1979
Total	**$163.19**	**$178.55**
Land Resource Surveys	**69.02**	**69.50**
Direct programs	54.32	57.50
Reimbursable programs	14.70	12.00
States, counties, and municipalities	.48	.22
Miscellaneous non-Federal sources	.09	.10
Other Federal agencies	14.13	11.68
Mineral Resource Surveys	**39.01**	**54.32**
Direct programs	26.39	31.81
Reimbursable programs	12.62	22.51
States, counties, and municipalities	.30	.20
Miscellaneous non-Federal sources	8.42	10.71
Other Federal agencies	3.90	11.60
Energy Resource Surveys	**34.55**	**36.57**
Direct programs	27.83	30.18
Reimbursable programs	6.72	6.39
States, counties, and municipalities	.02	.02
Miscellaneous non-Federal sources	----	.02
Other Federal agencies	6.70	6.35
Offshore Geologic Surveys	**20.61**	**18.16**
Direct programs	15.29	15.36
Reimbursable programs	5.32	2.80
States, counties, and municipalities	.15	.14
Miscellaneous non-Federal sources	----	.09
Other Federal agencies	5.17	2.57

WILDERNESS MINERAL SURVEYS

The Wilderness Act of 1964 (Public Law 88-577) established a National Wilderness Preservation System to "assure that an increasing population accompanied by expanding settlement and growing mechanization does not occupy and modify all areas within the United States and its possessions, leaving no lands designated for preservation and protection in their natural condition." The Act also specified that areas designated as wilderness "shall be administered for the use and enjoyment of the American people in such a manner as will leave them unimpaired for future use and enjoyment as wilderness, and so as to provide for the protection of these areas, the preservation of their wilderness character, and for the gathering and dissemination of information regarding their use and enjoyment as wilderness." The Act designated 9 million acres of Forest Service wilderness, wild, and canoe areas for inclusion in the National Wilderness Preservation System and 5.5 million acres of Primitive Areas for review to determine their suitability for inclusion in the system. The U.S. Geological Survey and the Bureau of Mines were directed by the Act to conduct recurring mineral surveys of these areas to determine their contained mineral values.

Each Wilderness Area being investigated by the Geological Survey is assigned to a project chief who is responsible for coordinating all aspects of the study. These aspects include traversing the area for the purpose of identifying rock types and their geologic settings, collecting samples from rock units and stream sediments, aeromagnetic and gravity surveying, conducting analyses, interpreting all data, and preparing maps and reports that describe the potential mineral and energy resources of the area. These studies are conducted in areas that have extremely diverse geographic and climatic settings, ranging from cold craggy precipitous mountains to low humid semitropical swamps. The only access to some of the areas is by helicopter and even this mode of transportation requires expert maneuvering of the vehicle. Some of the other hazards encountered are wild animals and reptiles, as well as poisonous vegetation.

The mineral-resource data resulting from these surveys are presented to the President and the Congress and enable them to make wise decisions regarding the use of any economic mineral deposits found in potential Wilderness Areas. The data also assist the President and the Congress in determining the suitability of an area for inclusion in the National Wilderness Preservation System. Surveys of the Primitive Areas were to be completed by 1972, and those of the Wilderness Areas, by 1983.

The Geological Survey began a modest program in fiscal year 1965 to complete mineral surveys of the designated Wilderness and Primitive Areas as scheduled. Related legislation subsequent to the Wilderness Act and Forest Service reviews, including the comprehensive Roadless Area Review and Evaluation (RARE II) completed last year, added significantly to the number and size of areas requiring mineral surveys. By the end of fiscal year 1979, mineral surveys had been completed on 23 million acres (8.5 million more than specified in the original Act); however, surveys of 16 million acres of Forest Service lands still remained to be completed by fiscal year 1983. Also requiring mineral surveys, but with no set deadline, are 15.5 million acres identified by RARE II for instant wilderness, 4 million acres of game ranges and wildlife refuges, and an undetermined amount of Bureau of Land Management (BLM) lands that are being evaluated for their suitability for wilderness classification. The review by BLM will be completed in the last half of fiscal year 1980.

To cope with the increasing demands for resource information on Wilderness Areas, the Geological Survey has expanded the areas in which they are conducting wilderness mineral surveys from 700,000 acres per year in fiscal year 1977 to almost 6 million acres per year in fiscal year 1980. This expansion will be increased even further as BLM completes its RARE II later this year. The reservoir of geoscience knowledge and the expertise of individual Survey scientists, acquired over the years through basic research programs, have enabled the Survey to complete these mineral surveys within the specified deadlines.

Flat Tops Primitive Area, Colo. Trappers Lake in foreground.

APPLICATION OF REMOTE SENSING TO MINERAL-RESOURCE APPRAISAL

REGIONAL STRUCTURAL INFORMATION

One of the most striking results of analysis of Landsat images has been the discovery of numerous regional structurally controlled features that were not shown on maps compiled for previously studied areas. The images are especially useful for areas where little, if any, work has been done. These features, referred to as lineaments, are alinements of surface color tones and land forms, such as streams, escarpments, and mountain ranges, which, in many cases, are the surface expressions of fracture or fault zones (breaks or displacements caused by failure or movement of subsurface materials). Because of the importance of fractures and faults for localizing many ore deposits, lineaments are important to nearly all regional geologic studies and especially to mineral-resource evaluation.

In Nevada, for example, where the location of mineral belts has been debated for many years, seven major lineament systems identified in Landsat images appear to represent four broad structural zones that influenced the distribution of metallic minerals (figs. 1 and 2). Most of the metal-producing districts in Nevada are located within two of these zones, the Walker Lane Structural Zone (figs. 1 and 2) in southern Nevada and the Humboldt Structural Zone (figs. 1 and 2) in northern Nevada. Prior to analysis of Landsat images, the Walker Lane Structural Zone was documented as being a major fault zone, but the Humboldt Structural Zone was first identified in Landsat images as several very long northeast-trending lineaments transecting northern Nevada. The deformed nature of this 60- to 120-mile-wide zone is strongly indicated by the concentration of northeasterly oriented faults. The east-trending lineaments (B, C, D, figs. 1 and 2) appear to represent a broad structural zone in southern Nevada that influenced the distribution of metal deposits associated with volcanic rocks. On the other hand, metal deposits are notably lacking along one of these zones in southern Nevada (E, fig. 2) and the northern Nevada Rift (G, fig. 2), emphasizing the importance of other factors in ore deposition and the need for integrating lineament analysis from Landsat images with conventional field mapping and geophysical and regional geochemical studies.

ROCK TYPE INFORMATION

Many rock units can be distinguished by remote sensing techniques. In Landsat images, concentrations of iron oxide minerals, referred to as limonite, can be detected by employing computer-processing techniques. Concentrations of limonite are especially important in mineral-resource studies because they are commonly associated with rocks that were altered by the influx of potentially ore-bearing fluids. Maps showing the distribution of altered and unaltered limonitic rocks are compiled routinely and are evaluated using conventional field techniques. The resulting map showing altered rocks constitutes one of the important elements of the data set used for regional mineral-resource assessment.

In large areas where limonite is associated nearly everywhere with altered rocks, regional maps of altered rock can be compiled by remote sensing techniques for less than 25 percent of the cost of conventional methods. However, the benefit declines rapidly where unaltered limonitic rocks are widespread and where altered rocks that are deficient in iron oxide minerals are present. These two limitations can be largely overcome by acquiring images in two longer wavelength regions (1.6 and 2.2 micrometers). These two bands are to be included in the Landsat D Thematic Mapper imaging system planned for launch in 1982.

Mineral evaluations are significantly enhanced by using lineament and altered rock distributions that were located by remote sensing in combination with geophysical and geochemical data gathered by standard techniques. This approach was developed by conducting a jointly funded U.S.-Mexico experimental project in northern Sonora, Mexico, and was applied to mineral evaluation studies in the Western United States during fiscal year 1979. When this project began, only reconnaissance geologic maps were available. Therefore, analyses of lineaments and limonitic occurrences as seen in Landsat images were used to pinpoint promising mineral-resource areas for more detailed geologic mapping and geochemical surveys.

Analyses of lineaments mapped from Landsat images indicated the presence of prominent zones of numerous northeast-trending lineaments and of numerous, but widely distributed, northwest-trending lineaments. At least four northeast-trending lineament zones have been defined (fig. 3) and are interpreted to be systematic structural zones that influenced the formation of porphyry copper deposits in northern Sonora. Abnormally high lead content in stream sediment and major copper deposits located at Nogales, Cananea, and Nacozari, Mexico, are found along these zones (fig. 3). These data, along with other geochemical and geophysical data, have resulted in the identification of several specific areas that appear to have exceptional economic potential.

The method described above for mapping altered rocks with Landsat data is limited to areas that are covered by less than approximately 40 percent vegetation. However, in some cases, vegetational associations can be used to deduce information about the mineralogical content and texture of the underlying rocks. Prior to the availability of Landsat images, only relatively small areas characterized by anomalous vegetation were mapped using aerial photographs and field studies.

Research is being conducted to develop other remote sensing techniques that are especially applicable to mineral-resource studies. The results of these studies will provide guidance for designing future satellite systems which are specifically beneficial to mineral-resource evaluation.

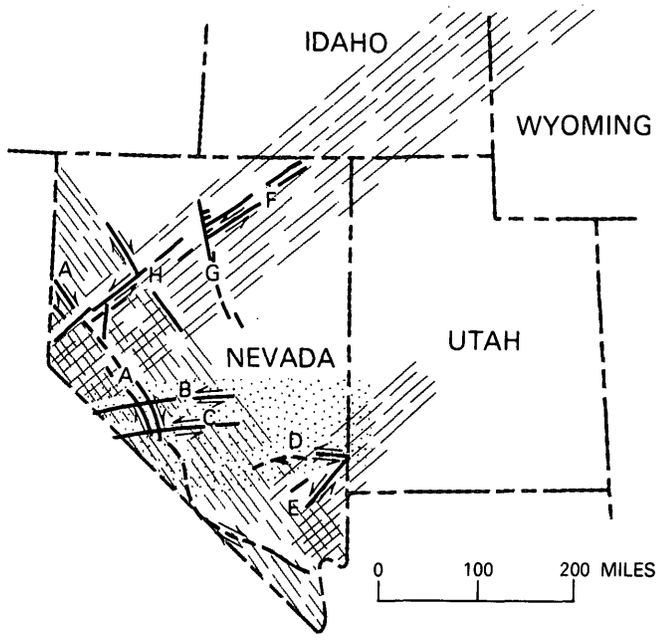


Figure 1.—Sketch map showing broad structural zones represented by major lineament systems in Nevada. Northeast-oriented ruled lines represent the Humboldt Structural Zone in northern Nevada and the Fahranagat Structural Zone. Northwest-oriented ruled lines represent the Walker Lane Structural Zone. The stippled pattern represents the Southern Nevada Structural Zone. Letters designate major lineament systems: A, Walker Lane; B, Pancake Range; C, Warm Springs; D, Timpahute; E, Fahranagat; F, Midas Trench; G, Northern Nevada Rift; and H, Rye Patch. Arrows indicate sense of movement.

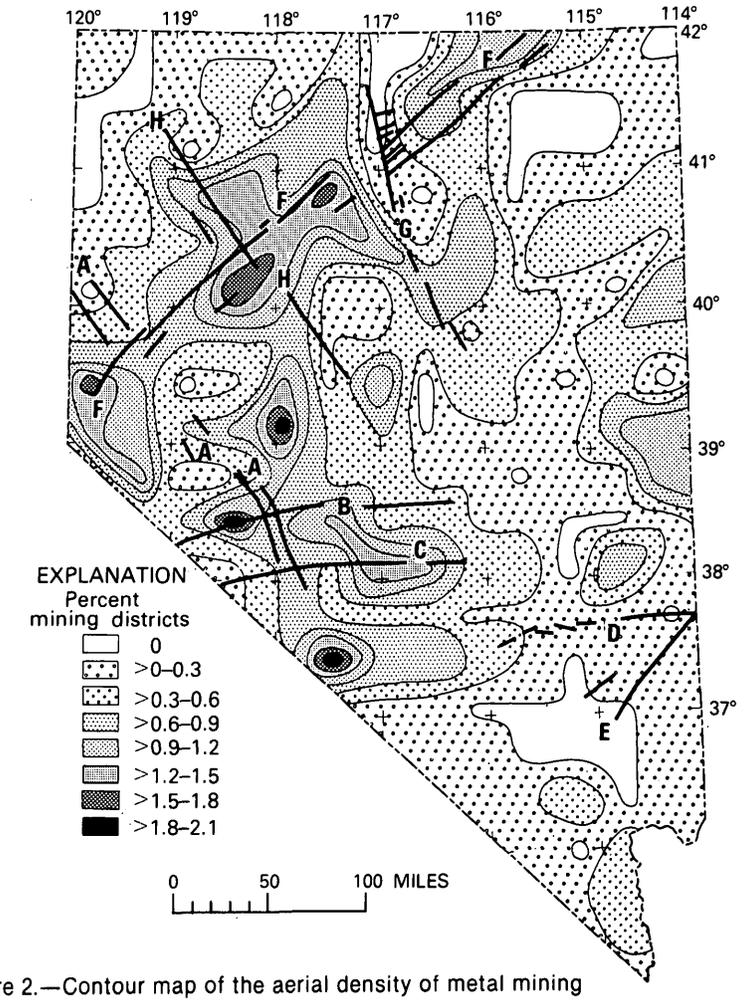


Figure 2.—Contour map of the aerial density of metal mining districts in Nevada and the major lineament systems delineated in figure 1.

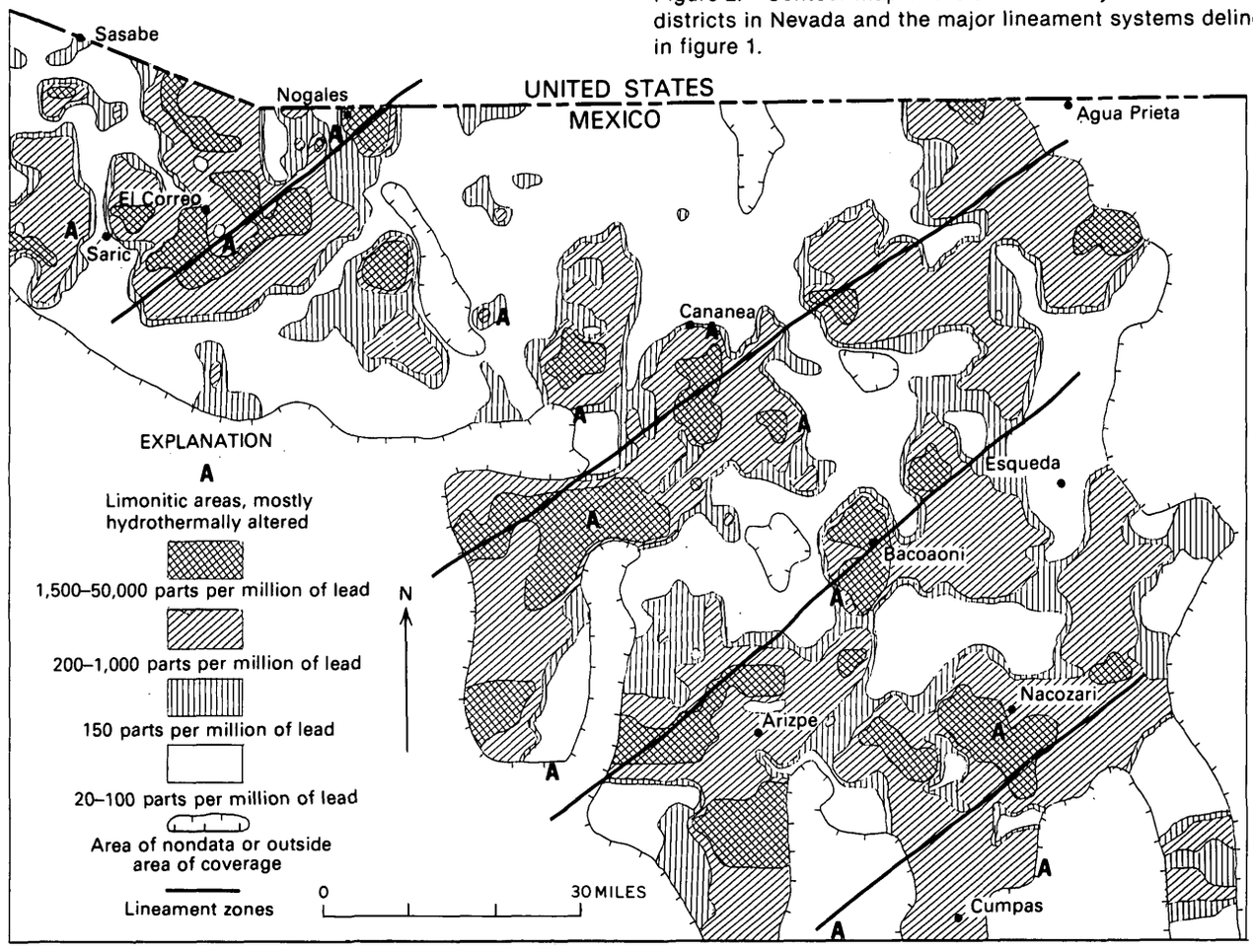


Figure 3.—Map of northern Sonora, Mexico, area showing regional correlation among northeast-trending lineament zones (heavy lines), limonitic hydrothermally altered rocks (A), and distribution of lead in stream sediments.

VOYAGER MISSION RESULTS

The arrival of the Voyager spacecraft at the Jupiter system marked an explosive expansion in the field of planetary geology. The Geological Survey provided scientific expertise in planning the mission, in designing the instruments, and in interpreting the mission results. The imaging cameras aboard Voyager 1 and 2 provided the world with the first closeup images and measurements of not only Jupiter and its newly discovered rings, but also of four new worlds comparable in size and physical properties to the Moon, Mars, Mercury, Venus, and Earth. This new information doubled the number of planetary bodies with which the Earth's physical characteristics, geologic processes, and history can be compared. One of the most intriguing aspects of the mission proved to be the astounding complexity and diversity of the four large Galilean satellites, Io, Europa, Ganymede, and Callisto.

The most exciting and geologically important finding was the discovery of active volcanism on Io. Io, innermost of the four large Galilean satellites, is very nearly the same size and density as our Moon. The complete absence of detectable impact craters on Io demonstrates that its surface is being continuously renewed by these active volcanic processes, which are believed to be sustained by tidal heating. Eight active volcanoes have been positively identified; many of these possess plumes that extend up to 150 miles above the surface. Io has the greatest surface relief of the Galilean satellites; this relief is in the form of calderas, scarps, and isolated mountains that rise above the landscape. A variety of studies are now underway, ranging from geologic mapping to thermodynamic studies of the volcanoes now thought to be erupting sulfur and sulfur dioxide.

Only limited images of Europa were obtained with resolutions of about 2.5 miles. Europa, also the size of our Moon, is slightly less dense and is thought to have a crust of ice, perhaps a frozen "ocean," that is 60 miles deep. Voyager 2 images revealed a highly reflective surface covered with numerous dark intersecting linear features that were visible at the limit of resolution. There are many theories as to the origin of the pattern, and it is generally believed that it is caused by crustal expansion due to freezing. Only three impact craters have been confidently identified, which suggests that the freezing episode took place after the early postaccretional meteorite impact bombardment, which formed densely cratered highlands on the Moon, Mars, and Mercury, had tapered off.

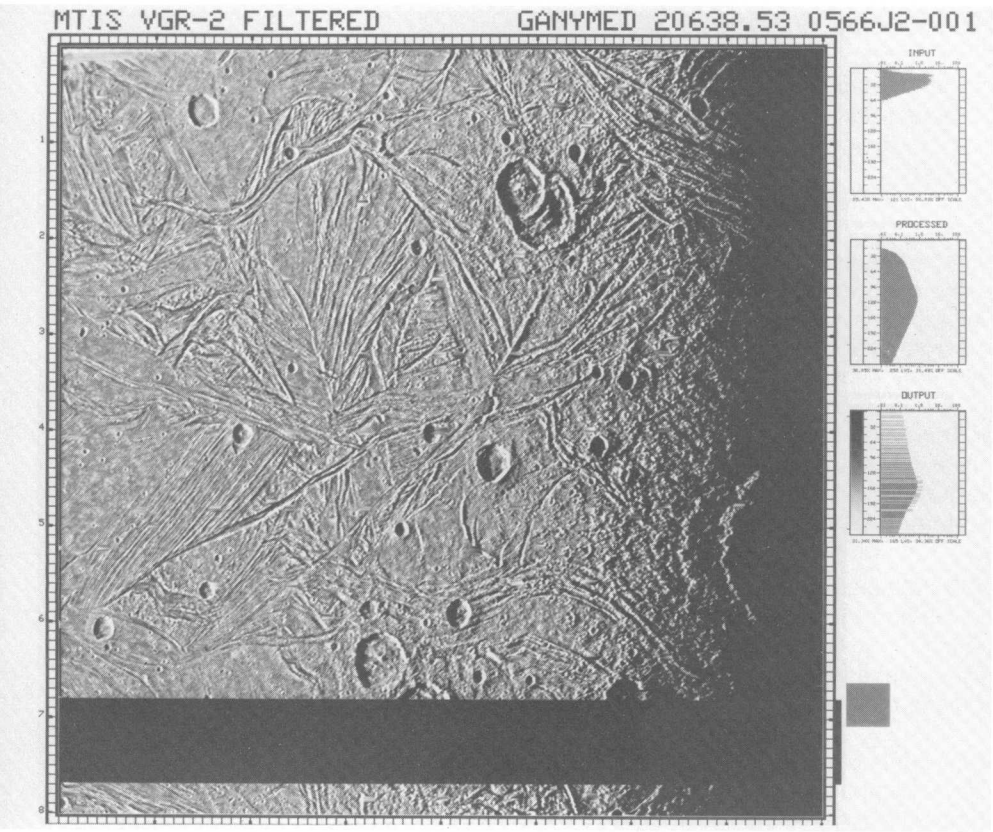
Ganymede and Callisto, the largest Galilean moons, are about the diameter of Mercury but have low densities, suggesting these exteriors are about one-half water or water ice. Two major types of terrain on Ganymede, dark cratered and grooved, are evident and continuous over the entire surface of the satellite. The grooved terrain is younger and consists of a complex network of parallel ridges and troughs, which occur in various sized segments, that divides the older heavily dark cratered terrain into isolated polygons. It appears that the dark-cratered terrain was formed after the heavy bombardment. Crater densities on the grooved terrain are extremely variable, suggesting that the grooves formed early in Ganymede's history, lasted for a long period of time (perhaps several hundred million years), and have since been inactive. Voyager 2 revealed an additional surprise in the form of subparallel concentric ring structures in various parts of the ancient dark-cratered terrain. These rings are thought to be the remnants of a huge ancient impact basin, most of which has subsequently been broken apart by tectonic activity.

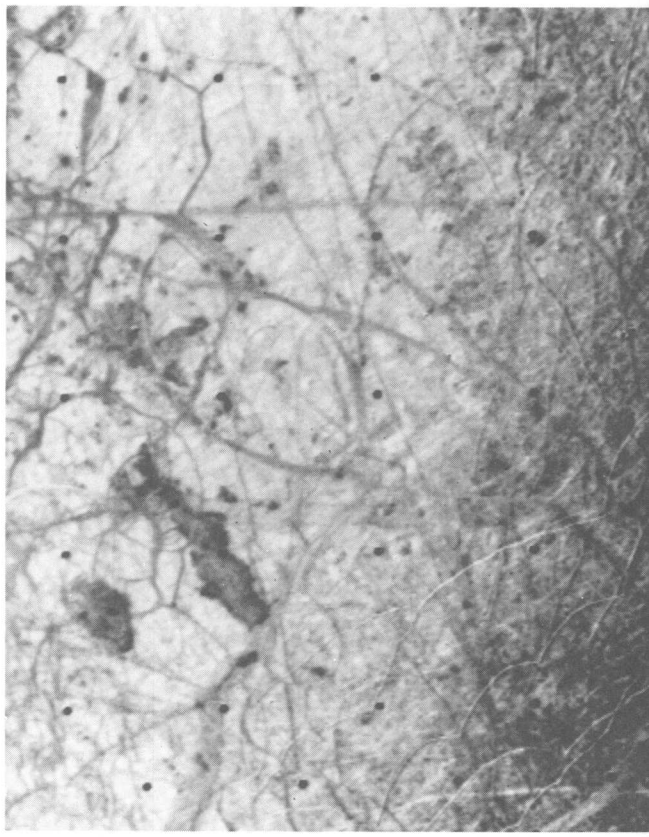
Callisto, the outermost of the large Galilean satellites, is probably the most densely cratered object yet seen in the solar system. Three large concentric ring structures, vestiges of enormous impact basins, are the only prominent features that interrupt the sea of craters. The complete absence of any large craters or measurable relief is indicative of viscous flow of an icy crust. Callisto's surface probably corresponds to the dark terrain of neighboring Ganymede.

Information gained from the Voyager Missions has greatly compounded the sum of knowledge concerning the evolution of the solar system. Detailed observations of the Galilean satellites have provided a base for studying other planetary objects of similar size and geologic history, such as the Earth and other terrestrial planets of the inner solar system. Both spacecraft have since left the Jupiter system, and equally successful encounters with Saturn are anticipated in 1980 and 1981. The U.S. Geological Survey will also play a major role in the investigation of the large satellites of Saturn.

◀ Voyager 2 image of Io. Two volcanic eruptions can be seen rising more than 60 miles above the lit crescent.

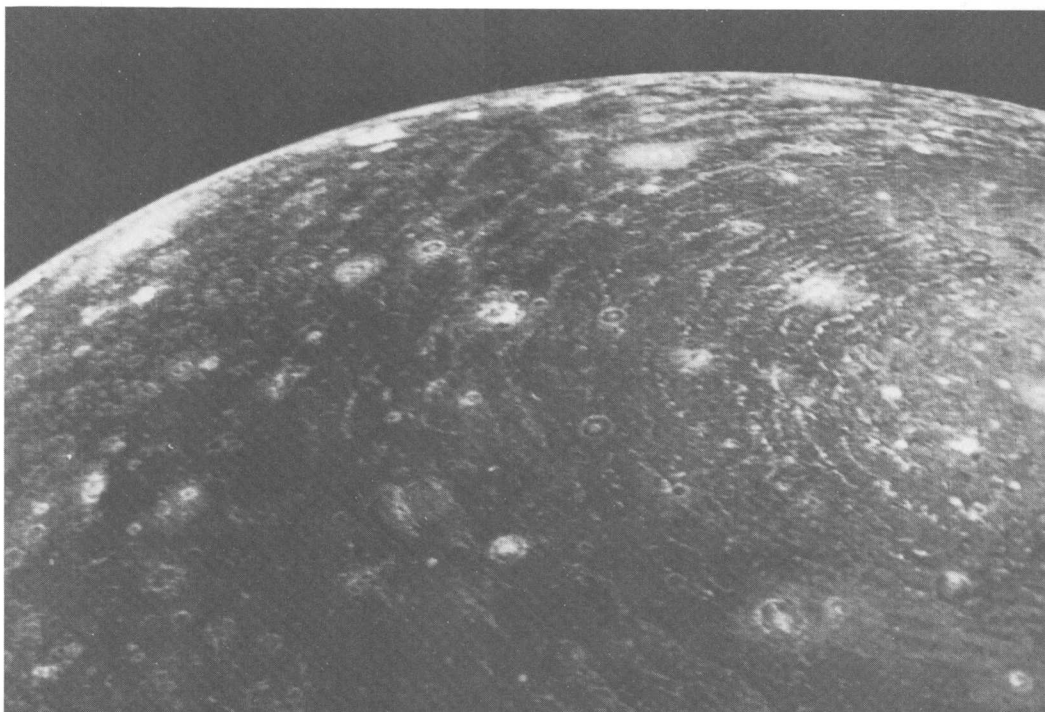
Voyager 2 digital mosaic of Europa. This object is the smoothest of the satellites; relief on its soft icy crust is less than 0.6 mile. ▼





▲ Voyager 2 digital mosaic of Ganymede. Ganymede, about the diameter of Mercury and less than one-half as dense, displays ancient dark-cratered terrain and younger brighter grooved terrains.

Voyager 1 image of Callisto, also about ▶ the size of Mercury and the same density as Ganymede. Callisto has the oldest preserved surface of the satellites. Remnants of enormous impacts have left concentric rings on its early soft icy crust.



OUTER CONTINENTAL SHELF ENVIRONMENTAL PROBLEMS

The Geological Survey is responsible not only for assessing the potential oil and gas resources of the Outer Continenal Shelf (OCS), but also for providing information on the environmental and safety hazards associated with the development of Federal offshore oil and gas leases. As offshore oil and gas development moves into increasingly severe environments and deeper waters, knowledge of environmental conditions and processes becomes ever more crucial to ascertaining that future operations can be conducted safely. The variety of problems being encountered in new OCS oil and gas lease areas has clearly identified the limitations in our knowledge of the processes governing conditions in frontier offshore areas. Therefore, there is a need for a concerted drive to obtain additional basic data on the offshore environment.

The diversity of conditions range from problems of ice and frozen soils in the Acrtic lease areas, to seismic hazards along the tectonically active Pacific Coast, to soil instability in most of the Gulf of Mexico, and to severe wind-wave-current conditions along the Atlantic Coast.

The Survey is studying environmental hazards and is evaluating their engineering significance in OCS areas.

Arctic.—In the Beaufort Sea, studies of ice gouging of the seafloor, offshore permafrost, and sea-ice movement are being conducted. In the Bering Sea and Norton Sound areas, ice gouging of sediments has been mapped, and investigations of gases emanating from seafloor craters formed by the gouging showed the gases to be thermogenic and biogenic (heat and organism generated) in origin.

Pacific.—In the Gulf of Alaska, analyses of cores from areas of submarine slumps have shown sediments to have weak shear strength, and slumping may have been triggered by earthquake ground motion. Large submarine slumps, up to 500 feet thick, have been mapped in northern California's Eel River Basin.

Gulf of Mexico.—Four years of data gathered on the Mississippi Delta offshore in the Gulf of Mexico show that storm waves can trigger submarine slumps. High gas and water contents in the sediments give rise to excess pore pressures that also weaken the sediment and make it susceptible to slumping. This will be further investigated by means of probes and cores that will obtain pressurized samples.

Atlantic.—The slope of the Atlantic Continental Margin is being investigated for potentially unstable areas. This will be accomplished by study and analysis of data derived from geophysical surveys and ground truth samples and additional information on the sediments that have been obtained from manned submersibles. Because the area is susceptible to storms, bottom currents and resulting sediment transport are being studied by current meters installed on the seafloor.

Various projects are shown for the OCS in the figure.


GEOCHEMISTRY OF GASES
BOTTOM CURRENTS
ICES COVER AND CURRENTS
SEDIMENT TRANSPORT
ENVIRONMENTAL STUDIES
SEDIMENT TRANSPORT
BOTTOM CURRENTS / BEDFORM MECHANICS
GEOLOGIC HAZARDS MAPPING
GEOTECHNICAL STUDIES
ENGINEERING PROPERTIES OF MARINE SEDIMENTS
GEOLOGIC HAZARDS MAPPING
ENVIRONMENTAL STUDIES
GEOLOGIC HAZARDS MAPPING
GEOLOGIC HAZARDS MAPPING
STRONG EARTHQUAKES MOTION (SEMS)
ENGINEERING PROPERTIES OF MARINE SEDIMENTS
SIDE-SCAN SONAR MAPPING (GLORIA)
ORGANIC GEOCHEMISTRY
ENGINEERING PROPERTIES OF MARINE SEDIMENTS
GEOLOGIC HAZARDS MAPPING
CURRENT MEASUREMENTS / SEDIMENT DYNAMICS
GEOLOGIC HAZARDS MAPPING
SEISMICITY (OBS) MEASUREMENTS
GEOCHEMISTRY OF GASES
DIGITAL SIDE-SCAN SONAR MAPPING
PORE PRESSURE MEASUREMENTS (GISP)
MASS MOVEMENT MONITORING
ENGINEERING PROPERTIES OF MARINE SEDIMENTS
TRACE ELEMENTS
GEOLOGIC HAZARDS MAPPING
SELECTED U.S. GEOLOGICAL SURVEY MARINE GEOLOGY ENVIRONMENTAL ENGINEERING ACTIVITIES
1979

THE ATLANTIC REEF

A promising area for future oil and gas exploration has been identified seaward of the OCS off the Atlantic Coast. The prospective area is what appears to be an extensive ancient buried reef, similar to the Great Barrier Reef that parallels the coast of Australia for over a thousand miles.

Reefs are regarded as potentially good reservoirs for oil and gas because they may be very porous and normally form in proximity to deep basins containing organic rich sedimentary rocks suitable for the generation of oil and gas.

For nearly a decade, geologists in industry, academia, and government have speculated about the presence of a buried reef off the Atlantic Coast. Following the oil crisis of 1973, the U.S. Geological Survey undertook a systematic regional geophysical survey of the OCS as an initial step in an offshore resource-assessment program. The geophysical data were used to delineate the major sedimentary basins on the OCS. The data also show an anomalous structure that has the characteristics of a reef. However, evidence supporting this interpretation has become available only recently. This evidence was obtained by using deep submersibles to sample rock exposed on the seafloor of the Continental Margin and from the drilling of an off-structure stratigraphic test well (COST B-3 well) by industry.

It appears that the buried ancient reef can be traced intermittently through the northern Gulf of Mexico, to the great petroliferous reef complex of the Golden Lane, and possibly even to the Reforma (site of a recent oil and gas discovery) and Campeche shelf provinces of Mexico. The reef is almost continuous along the Atlantic Margin from Maine to Florida. It occurs in water depths ranging from about 2,000 to 6,000 feet and is covered by 6,000 feet of sedimentary rocks. The reef is roughly 10,000 to 20,000 feet thick and 15 miles wide. It is bordered by thick layers of potential source rocks and appears to have a suitable seal above it to trap accumulated oil and gas. It is developed best along the seaward edge of the Baltimore Canyon Trough and, in fact, forms the eastern edge of this basin.

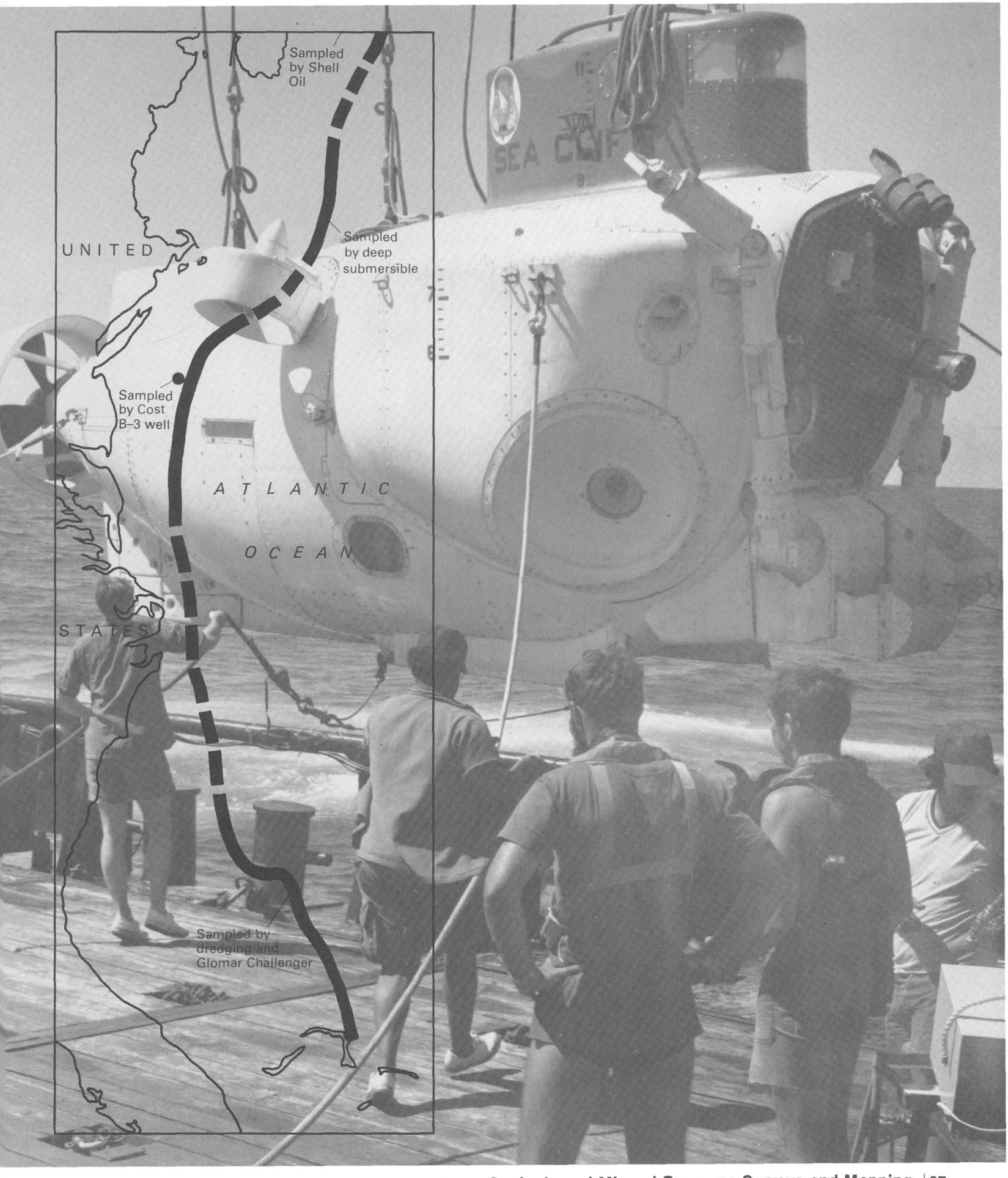
The core of the reef is limestone, possibly formed by the skeletons of growing fauna and flora, or carbonate sands. The forereef area may be characterized by coarse reefal debris that has broken off the core and fallen into deeper water. The ends of the forereef interfinger with the basin rocks that may be the source rocks of petroleum. The backreef rocks are probably limestones that grade into sands and muds derived from the land. Much of the Baltimore Canyon Trough is filled with these kinds of sands and muds.

The COST B-3 well drilled by industry encountered limestones with interbedded sands containing gas. These limestones are thought to be backreef rocks. The Survey has evaluated the petroleum potential of the reef complex. Estimates of resources in undrilled regions are made by comparing their geology and geologic history with those of similar regions that have been drilled—not all reefs make good reservoirs. Those reefs that have been raised above sea level prior to final burial and exposed through the leaching action of fresh water exhibit greatly enhanced reservoir characteristics such as porosity and permeability. Estimation of the chances that porosity enhancement has taken place is critical in the resource assessment. For this purpose, we compared the Atlantic reef system with Texas backreef production, reflecting those limestones that had not undergone porosity enhancement, and also with the highly productive Mexican reefs and the reefs of the Permian Basin of west Texas, where the leaching action of the fresh water has suitably enhanced the porosity. By using such comparative techniques, the Survey has estimated that the reef complex in the mid-Atlantic lease area may contain 1 to 6 billion barrels of recoverable oil and the entire Atlantic reef trend may contain 2 to 15 billion barrels of oil. In both cases, the assessment assumes that oil is present. However, if the amount of organic material in the source rocks is inadequate, or is of the wrong type, or was never exposed to sufficiently high temperatures, there may be no oil at all. There are many other factors that bear on whether or not oil will be preserved in the rocks.

Because of these assessments, BLM has extended the area boundary on the Call for Nominations in the forthcoming Sale 59 in the mid-Atlantic area to include the reef complex. The maximum water depth in this call area is about 8,000 feet. Industry has the capability to explore in about 6,000 feet of water, but current production is limited to a depth of about 1,000 feet. However, production systems capable of operating in much greater water depths have been built and tested in anticipation of economic discoveries in deep water.

The geologic investigations and studies described above contribute to the overall effort to discover new areas favorable for oil and gas exploration.

Jurassic-Cretaceous reef trend. ▶


Sampled by Shell Oil
Sampled by deep submersible
Sampled by Cost B–3 well
Sampled by dredging and Glomar Challenger
UNITED
STATES
ATLANTIC
OCEAN

A 3-MILLION-YEAR RECORD OF CONTINENTAL CLIMATE

A 3,050-foot core was recovered in 1967 from an area near the center of Searles (dry) Lake in southeastern California. A study, completed last year, shows that the core represents a detailed history of climate-controlled sediment deposition in this desert basin starting more than 3 million years ago. A surprising discovery is that the lake's record of climate history differs so conspicuously from the marine record of global glaciation, in that periods of major change occur at different times and the lengths of time that particular climatic patterns persisted differ by factors as large as four. The one similarity is that a marked resurgence of large continental ice sheets, according to studies of the marine cores, and the first establishment of a lake in this valley both began about 3.2 million years ago.

The deepest and oldest sediments in the core, 728 feet of reddish-brown desert fan gravels, rest on granitic bedrock, and 2,275 feet of lake deposits (clay, silt, and salts) make up the remainder of the valley fill. Sedimentation rates in this lake averaged 117 years per inch of deposits. This rate is 10 to 50 times faster than sedimentation rates of most deep-sea sediments that are widely used for studies of Quaternary climate, so this record provides much better resolution of short climatic events.

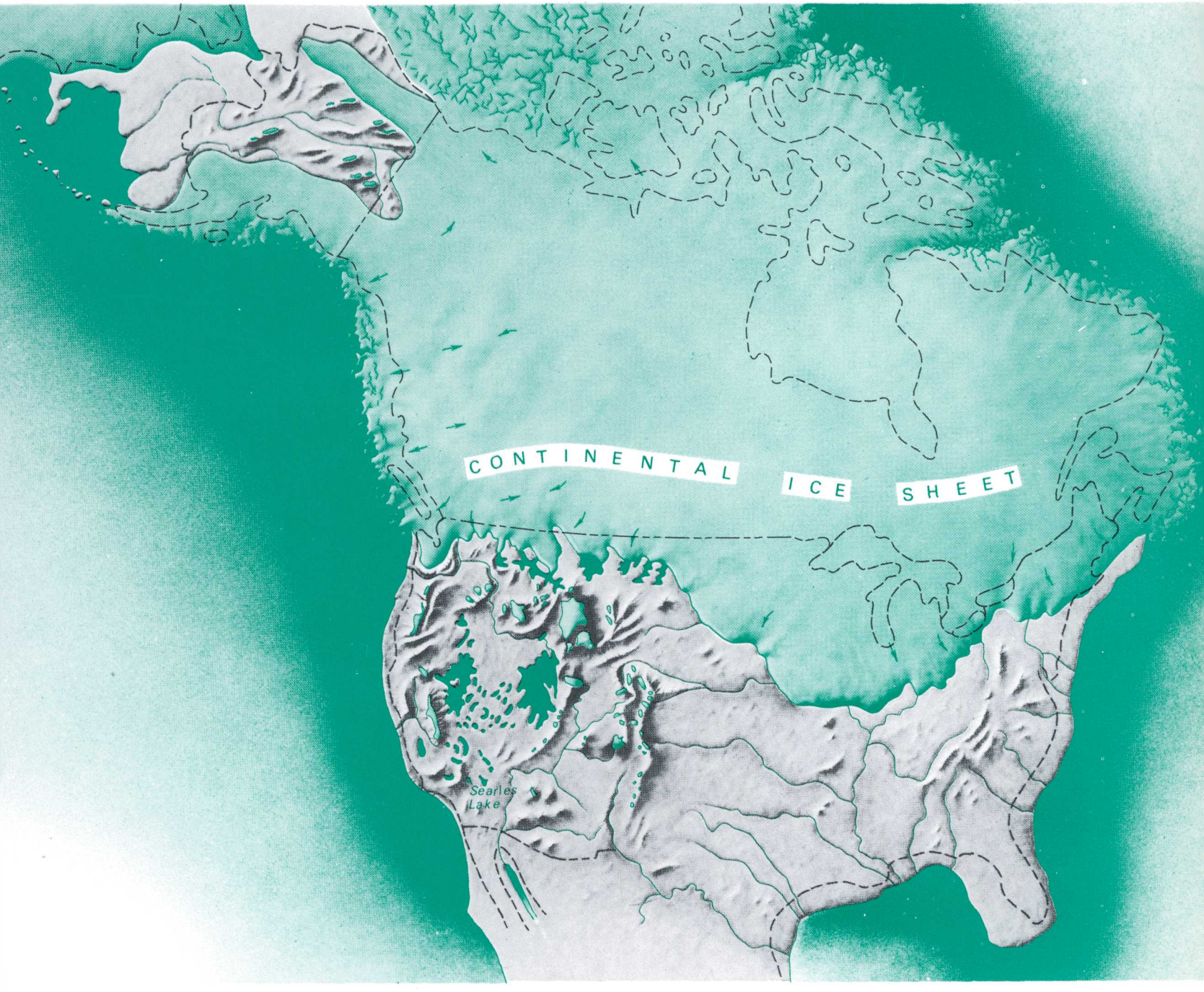
Regional climates are indicated by the sediment composition; salt beds and tan "dry" lake sediments indicate times of aridity when evaporation exceeded inflow of water into the lake; greenish silt and clay indicate times when perennial lakes occupied the valley, implying greater water accumulation as a result of increased regional precipitation. The upper 226 feet of lake sediments represent approximately the last 130,000 years. The underlying lake sediments have the following lithologies and ages and imply the indicated lake character and climate:

Depth (feet)	*Lithology and color of sediments*	*Age of base (thousands of years)*	*Lake character (implied climate)*
226–374	Salts and muds, olive brown.	330	Perennial, intermediate to shallow depths, fluctuating (humid to moderately humid).
374–546	Salts	650	Dry salt flat, briefly perennial (arid).
546–747	Muds, olive-brown, some salts.	1,020	Perennial, mostly shallow, brief dry periods (humid to moderately humid).
747–955	Mud, light to dark green.	1,400	Perennial, deep (very humid).
955–1,323	Salts and muds, olive.	1,940	Perennial, deep, periodically dry for brief periods (humid with periodic episodes of aridity).
1,323–1,777	Mud, brown	2,570	Dry playa, briefly perennial (arid).
1,777–2,275	Mud, olive brown.	3,170	Perennial, deep (very humid).

The shift from alluvial fan to lake basin deposition in Searles Valley took place about 3.2 million years ago. It could have been an indirect result of a volcanic eruption at that time which diverted a large river system to the north or a direct result of worldwide climate change.

Climatic reconstructions indicate a steady decrease over the 3.2-million-year period in the regional precipitation that controlled the runoff that fed the lake. This was caused, in part, by the gradual uplift of the Sierra Nevada, which created an increasingly effective rain barrier, but climatically

controlled variations in precipitation caused shorter term fluctuations of inflow that exceeded the more gradual physiographic change. The perennial lake deposits in Searles Valley are probably of the same age as deposits formed by glaciers in the Sierra Nevada which lie in the headwaters of the region that drained into the lake. This suggests that extensive glaciers existed in these mountains between 10,000 and 24,000 years ago, 30,000 and 130,000 years ago, 0.65 and 1.4 million years ago, and possibly between 2.6 and 3.2 million years ago.



Map showing the continental ice sheet and location of Searles Lake, Calif.

A POSSIBLE EXTENSION OF AN OIL AND GAS PROVINCE

The Appalachian Mountains form a linear geologic system in the Eastern United States that extends for over 1,000 miles southward from New York to Alabama. Continuous research by State, Federal, university, and industry scientists has been an ongoing process since the early 1800's. Although it would appear that this amount of long-term research would have been adequate to provide a good understanding of the geology of the area, this is far from the truth. Much of the previous work has concentrated on an intense study of surface relations that provided a two-dimensional framework. Subsurface data, which adds the third dimension to the framework, have been available only for the western part of the mountain system where deep drilling and seismic surveys have been used in the search for oil and gas. Only recently has enough subsurface data become available to augment the surface data in the eastern part of the Appalachians. These new data require a reevaluation of many long-held concepts, based entirely on surface studies, concerning the distribution of possible oil and gas source rocks within the Appalachian Mountain system.

In the past, geologists, basing their evidence on surface relations, believed that the Appalachian Mountain system could be divided into two main parallel parts, an eastern part, which includes the Blue Ridge and Piedmont and is composed of crystalline rocks (metamorphic and igneous), and a western folded and faulted part, which lately is called the Eastern overthrust belt and is composed of sedimentary rocks.

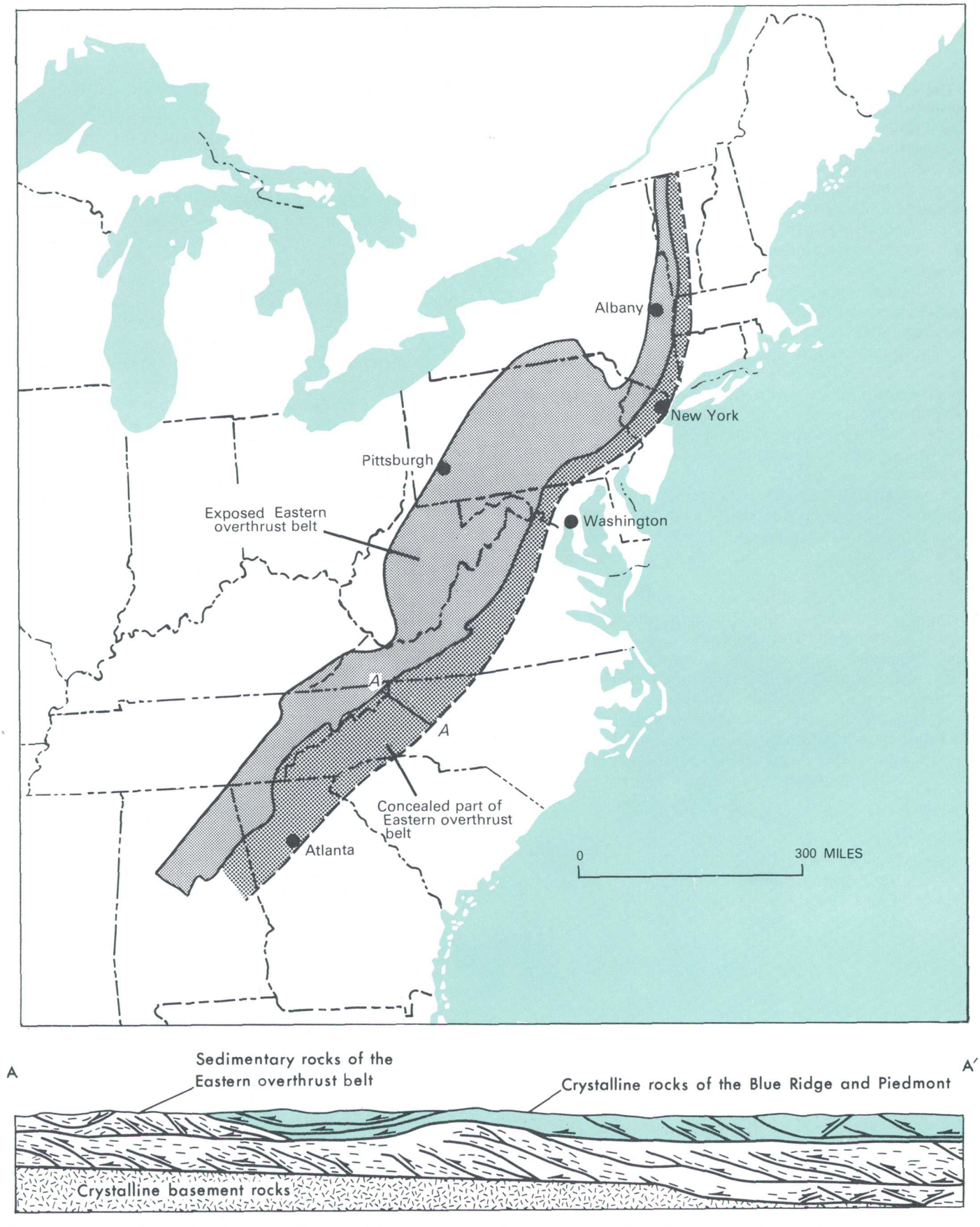
Sedimentary rocks in the Eastern overthrust belt have been a source of natural gas for more than 100 years. In comparison, the Piedmont has not received much attention from petroleum geologists because its crystalline rocks are considered to be the "basement" below which no sedimentary oil and gas source rocks were believed to exist.

Recent seismic surveys, utilizing refined geophysical methods for investigating deep in the Earth, have revealed that faulting has moved crystalline rocks of the Blue Ridge and Piedmont westward more than 100 miles and buried a large section of sedimentary rocks of the Eastern overthrust belt. From central Virginia southward, the main area for which subsurface data is available, the buried part of the overthrust belt is from 10,000 to more than 20,000 feet thick. This hidden and unknown part of the overthrust extends in the subsurface eastward for at least 60 miles and may even extend further. In Georgia, 150 miles southwest of the area covered by the Survey's data, seismic data acquired by others suggest that seismic reflections indicative of sedimentary rock extend in the subsurface perhaps completely across the Piedmont.

If these initial seismic data are representative, then a concealed belt of sedimentary rock is buried under the Blue Ridge and Piedmont from at least central Virginia to Alabama (see the figure). Because this buried belt is about as wide as that exposed in the southern part of the Eastern overthrust belt, the area for possible natural gas exploration is about doubled in size.

Of immediate interest to the petroleum geologist is the fact that the buried segment appears to be composed of sedimentary rocks similar to those currently being explored for natural gas in the exposed parts of the Eastern overthrust belt. However, like most unexplored frontier areas, data are not sufficient to assess the oil and gas potential of this hidden area. Because these sedimentary rocks occur beneath the Piedmont, where previous geologic concepts suggested such rocks would be unlikely, future exploration programs for oil and gas within the Appalachian region might well include this vast untested and unknown area.

Perhaps an even more far-reaching effect is that these new seismic data require a major rethinking of how the Appalachian regional framework was formed. Previous models of the overthrust belt have served as guides for petroleum exploration in overthrust belts around the world. Changes in our understanding of the Appalachian overthrust belt will have an important effect on the future search for oil and gas in other areas that have a similar structure.



Map showing the inferred regional distribution of the concealed sedimentary rocks of the Eastern overthrust belt beneath the metamorphic and igneous rocks of the Blue Ridge and part of the Piedmont. The interpreted seismic reflection section A–A' shows the continuity of sedimentary rocks of the Eastern overthrust belt eastward beneath the crystalline rocks of the Blue Ridge and Piedmont in Tennessee and North Carolina.

GEOTHERMAL RESOURCES

Geothermal resources are defined as the natural thermal energy within the Earth that can be used in economic competition with other forms of energy within the next few years. All of the thermal energy above surface temperature within the upper 6 miles of the Earth's crust, without regard to the economics of its production and use, is estimated to be about 32,000 billion-billion British thermal units. Most of this immense resource base is too diffuse to be extracted and used, but about 6.4 billion-billion British thermal units, the equivalent of 1.2 trillion or more barrels of oil, is judged to be a resource.

The resource assessment presented in Circular 790, an updated assessment of U.S. geothermal energy resources which was published in fiscal year 1979, highlights two points. First, the total national geothermal resource is many times greater than the part that is being recovered and used today. Second, exploitation of geothermal energy is coming of age, as demonstrated by a recent increase from 7 to about 16 percent in the annual rate of growth of geothermal electrical capacity worldwide.

At present, the United States produces electricity from geothermal energy only at The Geysers in California, the world's fastest developing geothermal field. Installed electrical capacity there is now 660 megawatts, up from 500 megawatts at the end of fiscal year 1977. The Geysers development taps a vapor-dominated hydrothermal convection system. Pilot plants for generating electricity from hot-water convection systems, which are more numerous, are now in the planning or construction phase at Imperial Valley, Calif., Valles Caldera, N. Mex., Roosevelt Hot Springs, Utah, Raft River, Idaho, and Puna, Hawaii. The new national assessment notes that the total amount of energy contained in all hydrothermal convection systems that have temperatures hotter than 194 °F is about 9 billion-billion British thermal units. The assessment notes further that about 25 percent (2.2 billion-billion British thermal units) of this, the equivalent of 430 billion barrels of oil, is recoverable.

The new assessment attempted a first evaluation of low-temperature geothermal waters (less than 90 °C) that are suitable for direct use in space heating, agriculture, and industry. Current knowledge does not allow a quantitative estimate of the low-temperature resource. However, areas of potential low-temperature resources are outlined in Circular 790, and an extensive list of low-temperature thermal springs and wells is tabulated, along with available data on water temperature and chemistry. The Geological Survey, in conjunction with the Department of Energy, Division of Geothermal Energy, and several State agencies, is continuing to study low-temperature resources, with the aim of producing a quantitative estimate of their magnitude in the near future. Examples of direct use of geothermal waters exist at Klamath Falls, Ore., where a large and growing proportion of buildings is heated by thermal waters that underlie much of the city, and at Boise, Idaho, where about 300 homes have been similarly heated throughout the 20th century.

About 0.4 to 4.2 billion-billion British thermal units of energy, equivalent to 75 to 780 billion barrels of oil, may be recovered from geopressured geothermal resources. The geopressured resources consist of thermal water and dissolved methane contained in the high-pressure aquifers of deep sedimentary basins, primarily in the northern Gulf of Mexico Basin. Much of the data available on this resource is by a byproduct of drilling for petroleum. The water is thought to be saturated with methane, which accounts for about one-half of the total energy available from such systems. The geopressured resource is clearly large and is the subject of continuing studies.

THE COYOTE LAKE EARTHQUAKE SEQUENCE

The largest earthquake in the San Francisco Bay area in 68 years occurred August 6, 1979, at Coyote Lake, in a rural area 65 miles southeast of San Francisco. The earthquake, which measured 5.9 on the Richter scale, was felt over a large area but caused only minor damage because of its location in a relatively unpopulated area. The event was caused by sudden slip on the Calaveras fault, one of several large faults that branch from and lie parallel to the San Andreas fault in the bay area. This complex fault system, which marks part of the boundary between two large crustal plates, has been under intensive study by the Survey for many years. Nearly 600 devices that monitor earthquakes, magnetic fields, crustal straining and tilting, and slow fault offset are in operation in the bay area. In addition, extensive mapping programs have been carried out to identify active traces of major faults. Because fault movement on the Calaveras and San Andreas faults was anticipated, the region near Coyote Lake was one of the most densely instrumented in the world. Immediately after the event, more instruments were rushed to the area to supplement the existing networks, and searches for ground cracking and fault offsets with movement were begun. Thus, Survey scientists had the rare opportunity to record much useful data in the immediate vicinity of a potentially damaging earthquake, in an area that had been mapped geologically. Because of the quantity and quality of the data recorded, the earthquake will undoubtedly become a textbook example.

Records made during the earthquake and aftershock sequence will be analyzed to obtain information about the faulting process itself and about the effects of the earthquake, including the response of structures and foundations to strong ground shaking. The mass of the data accumulated by Survey personnel in the years before the event will be carefully examined for precursory phenomena; that is, any unexpected changes in the properties of the Earth that were related to the impending earthquake and might have value in predicting future events. The complete analysis of the data will require years of study, but much useful information has already been obtained.

More than 50 seismometers of the Central California Network were within 30 miles of the earthquake. These sensitive instruments recorded more than 1,000 smaller events (aftershocks) in the 15 days following the main shock and showed that ground rupture occurred over a vertical zone 12.5 miles long and from 2.5 to 7.5 miles wide. The earthquake sequence was found to be unusual in that the largest aftershocks were smaller than expected, considering the size of the main shock. This anomaly may reflect that fact that some of the accumulated strain on the Calaveras fault is released by slow steady slip (fault creep), or it may indicate that some accumulated strain has yet to be released. Understanding why larger aftershocks were relatively rare is important because, when large aftershocks do occur, they may cause failure in structures already weakened by a main shock.

Field searches for ground cracking, slumping, and fault offsets, undertaken within a few hours after the earthquake, revealed a complicated pattern of small cracks over zones from 30 to 300 feet wide. The amount of offset measured in the field was 0.5 inch or less, which was not as much as would be expected from an event as large as the Coyote Lake earthquake. The zone of disturbance generally coincided with the Calaveras fault, as it had been previously mapped, demonstrating that the criteria used to identify active faults were valid. The length of the disturbed zone was about 18 miles, somewhat longer than the aftershock zone. It is not clear how much of the observed ground disturbance was due to rapid fault motion occurring during the earthquake and how much was due to shaking, slumping, and postearthquake slip.

The Calaveras fault, along with certain other faults in central California, displays fault creep, that is, the fault does not slip just during earthquakes, but rather it slips slowly at various points by a small amount from time to time. This more or less steady slip along the fault is responsible for releasing accumulated strain on some portions of the fault and may cause increased strain on portions that do not creep. The cumulative surface deformation caused by fault creep is used to determine the locations of creeping sections of the fault, and measuring devices are placed across the fault in these areas to measure the effect of individual creep events. A device of this type had been in operation near the southeastern end of the Coyote Lake rupture for several years preceding the earthquake. The records show that creep events ceased at that site 4 years before the earthquake. There is evidence of a similar decrease in creep rate before other earthquakes, and this sort of creep behavior will be carefully studied to see if it has predictive value.

The very strong shaking that occurs in the immediate vicinity of larger earthquakes usually overloads ordinary seismometers, and specially designed strong-motion instruments are required to obtain complete records of the shaking. Strong-motion records are of fundamental value in engineering design of buildings, dams, and other structures in seismically active areas. Because records of strong ground motion must be made near the source of an earthquake and because large earthquakes are relatively rare events, few strong-motion instruments have been in operation directly above sizable earthquakes. However, an entire array of such instruments, placed by the Geological Survey and the State of California, was recording during the Coyote Lake earthquake. Records of strong motion were obtained not only at the ends of the rupture zone but also along a line of instruments that started at the center of the rupture zone and extended 6 miles away from it. Forces as high as 40 percent of the force of gravity were recorded at sites near the rupture zone. These values fell to 25 percent a few miles away from the fault and decreased to negligible values at greater distances. The pattern of strength and frequency of shaking showed that the earthquake started at the northwest end of the rupture zone and that the break moved to the southeast. Because 80 aftershocks were recorded at 3 or more strong-motion recording sites, a description of fault failure during the main event can probably be worked out in considerable detail. The knowledge gained will be of value in predicting the character of strong ground motion near other faults and is expected to have an impact on engineering practices in areas subject to seismic hazard.

COAL FOLIOS

An important part of the Geological Survey's coal program is to organize, to compile, to evaluate, and to synthesize existing and new coal-resource-related information in the form of coal folios. This coal folio program provides information to BLM's land use planning activities and Resource Management Plan (RMP) for Federal land, and, therefore, it is closely tied to the Department of the Interior's Federal Coal Leasing Program. The Office of Surface Mining, Department of the Interior, requires folio-related information to fulfill its regulatory functions. State and local governments have become interested in the coal folio program because it provides the information they need to evaluate Federal plans and to plan for coal development within their jurisdictions.

A coal folio generally consists of maps (scale 1:100,000), other graphics, and supplemental text material. These materials present information related to the quantity and quality of coal resources and environmental geologic factors needed to assess potential utilization and reclamation of disturbed land after the coal has been mined. Information usually is presented on a topographic base map and published in the Coal Map (C-) Series. Related maps are published as each is completed. The folio format will vary according to the information required and available in different coal-bearing areas. For example, a folio for one area may include a separate map for each of the following topics: bedrock geology, including principal coal beds; surficial geology, with notations on the composition and physical properties of surface materials; detailed interlocked cross sections that establish the stratigraphic framework of the coal-bearing rocks; structure contours on the top or base of principal coal beds; isopach maps displaying thickness of principal coal beds; isopach maps of the overburden for the principal coal beds; estimated coal resources categorized according to Geological Survey standards; potential and actual geologic hazards that should be considered during coal-development planning; patterns of land-surface and mineral-right ownership; hydrologic and climatologic data; and other available and necessary coal-related information. A folio for a different area might include additional or fewer information components. In addition to the component elements of the folios, a wide range of supporting and derivative reports consisting of information not suited for graphic portrayal is commonly prepared.

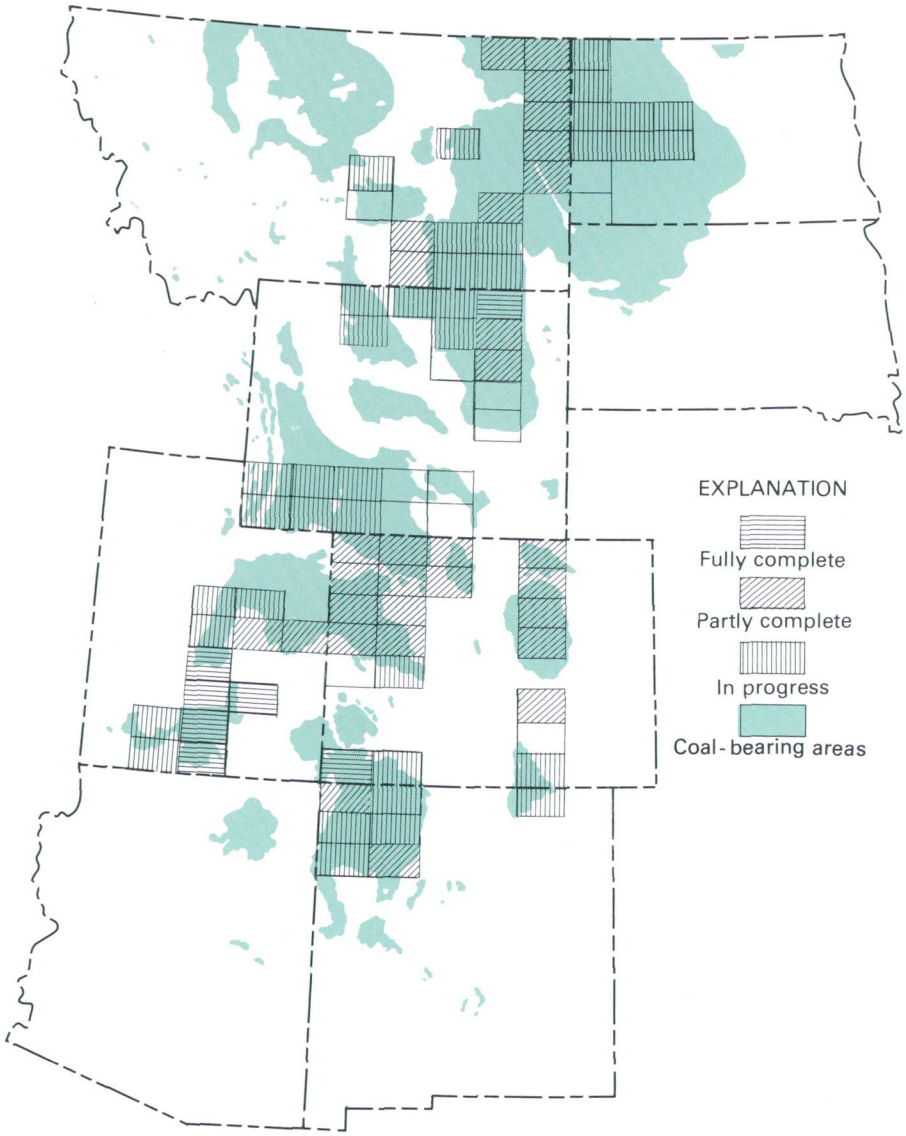
Regional coal-resource assessment studies are being conducted in areas covered by 24 1:100,000-scale (0.5° x 1°) quadrangles in the coal-bearing western part of the United States, and coal-related environmental geology studies are underway in areas covered by 73 1:100,000-scale quadrangles. In most cases, the whole area of a quadrangle will be studied—a 1:100,000-scale quadrangle covers more than 1,600 square miles, an area equal to 32 7.5-minute quadrangles; in other cases, only the coal-bearing part of the quadrangle has been or will be examined. The work presently planned, underway, and completed will result in a minimum of 60,000 square miles of mapping at 1:100,000 scale.

The evaluation of subsurface data is critical to the regional coal-resource-assessment program. This subsurface data is obtained by core-drilling in areas being considered for inclusion in the Federal Coal Leasing Program and where existing oil, gas, and water wells are either improperly located or were not adequately cored or logged. A total of about 90,000 feet of coal exploratory drilling was done in fiscal year 1979 to obtain samples for coal quality information, geotechnical testing for engineering data, establishment of local and regional geochemical baselines, determination of methane content of coals, study of rocks associated with coals, and many other purposes; about 3,000 feet of core samples were obtained.

Much information is obtained from geophysical logging of oil and gas test wells, water wells, and geophysical exploration drill holes. Some of the data derived from this logging are natural radioactivity measurements and density measurements. A total of more than 110,000 feet of various drill holes were logged geophysically in fiscal year 1979.

The results of this research are published as quickly as possible, so that they can be used by planners, mining and development industries, geoscientists, and all persons concerned with the safe and orderly development of the Nation's energy resources.

During fiscal year 1979, Survey geologists produced 23 coal-related and 246 environmental geologic maps, 30 coal reports and 24 environmental reports, and 12 coal-related and 8 environmental abstracts for scientific talks. Coal folios covering three quadrangles, the Kaiparowits Plateau (Utah) and Recluse (Wyoming) areas, were completed in fiscal year 1979. Maps and reports that contribute to 20 other folios were completed. Three folio areas in the southern Wasatch Plateau, Utah, were completed prior to fiscal year 1979. The index map shows the locations of completed folios, those partly completed, and areas of work in progress in fiscal year 1980.


EXPLANATION
Fully complete
Partly complete
In progress
Coal-bearing areas

Water Resources Investigations

MISSION AND ORGANIZATION

Effective management of water resources requires that up-to-date scientific hydrologic information be readily available for planners and managers. The Water Resources Division has the principal responsibility within the Federal Government for providing hydrologic data and appraising water resources to facilitate evaluation of water problems. The Division's program is designed to present impartial accurate data and scientific analyses. It supplies reports and maps to the public in Federal, State, and local publications; in technical journals; and through selected libraries.

The U.S. Geological Survey provides extensive support to the missions of other Federal agencies and, under the Federal-State Cooperative Program, to State and local agencies. In this way, the Survey keeps abreast of water-information needs at all levels of government and develops programs responsive to those needs. Through a network of offices (see page 78) in all 50 states, as well as in Puerto Rico and Guam, close communication is maintained with State and local agencies.

A major responsibility was assigned to the Survey in 1964 when it was designated the lead agency for coordinating water-data-acquisition activities of all Federal agencies, including information on streams, lakes, reservoirs, estuaries, and ground water. This coordination effort minimizes duplication of data collection among Federal agencies and strengthens the overall data base and its accessibility.

THE FEDERAL PROGRAM

The water-data collection, resource investigation, and research activities of this program are carried out in areas where the Federal interest is paramount. These include bodies of water in the public domain, river basins and aquifers that cross State boundaries, and other areas of international or inter-State concern. Activities include operation of surface- and ground-water quantity and quality measurement stations throughout the country, the Survey's Central Laboratories System, hydrologic research and analytical studies, and a variety of supporting services.

THE FEDERAL-STATE COOPERATIVE PROGRAM

Geological Survey programs have multiple objectives and serve the earth science and related information needs of a large number of government agencies and private groups. As major users of this information, State, regional, and local agencies have an important role in helping to define the scope of Survey programs. Accordingly, selected projects judged to be of mutual benefit to the Federal, State, and local governments are funded on a 50-50 basis in the Federal-State Cooperative Program.

In fiscal year 1979, the Water Resources Division joined in cooperative programs with 590 State and local agencies; much of the work was done by the Survey, but State and local agencies provided half the funds. The current work on developing a water-use data base in the Cooperative Program is being done by the States.

Through contact with those involved in water conservation, development, management, and use, the Water Resources Division anticipates and responds to changing priorities. Planning the annual program in each State is a mutual decision, with the Survey representing national interests and the cooperating agencies representing State and local interests. As the need arises for additional and new kinds of water information, programs are adjusted within the framework of priorities and resources. As a result, the work is problem oriented and interdisciplinary. The diverse program activities include collection of long-term multipurpose data (surface water, ground water, water quality, and water use); special interpretive studies of the physical, chemical, and biological characteristics of water; and appraisals for environmental impact evaluation, energy development, coastal zone management, subsurface waste storage, waste utilization, land use planning, flood plain management, and flood-warning systems.

The strength of the Federal-State Cooperative Program lies in (1) coordinated programming for water information that responds to identified and developing needs of people at all levels and relates to the environmental aspects of water use, (2) the quality and acceptability of the water data accumulated through uniform programs in 50 States and several of the territories, and (3) the nonadvocacy position of the Geological Survey in carrying out and reporting on its work.

SUPPORT OF MISSIONS OF OTHER FEDERAL AGENCIES

With funds transferred from other Federal agencies, the Geological Survey performs work related to specific needs of each agency. Examples of work done in cooperation with several of these agencies are as follows:

Department of Agriculture
Hydrologic studies on small watersheds, sediment studies, stream discharge and quality.

Department of Defense—Corps of Engineers
Tidal flows in estuaries, subsidence studies, streamflow data, groundwater studies, sedimentation and water-quality studies.

Department of Energy
Hydrologic and water-supply exploration studies at nuclear-explosion sites and at both operating and potential nuclear-waste sites; research in field of radiohydrology related to interaction between radioactive materials and various geohydrologic environments, both above and below ground; *hydrologic modeling.*

Department of Housing and Urban Development
Flood plain delineation, flood profiles, flood-frequency studies related to flood-insurance programs.

Department of the Interior:

Bureau of Indian Affairs
Hydrologic data collection, water resources appraisal studies, water-supply investigations on reservations.

Bureau of Land Management
Collection of hydrologic data, water-supply studies on public lands, effects of coal mining on hydrology.

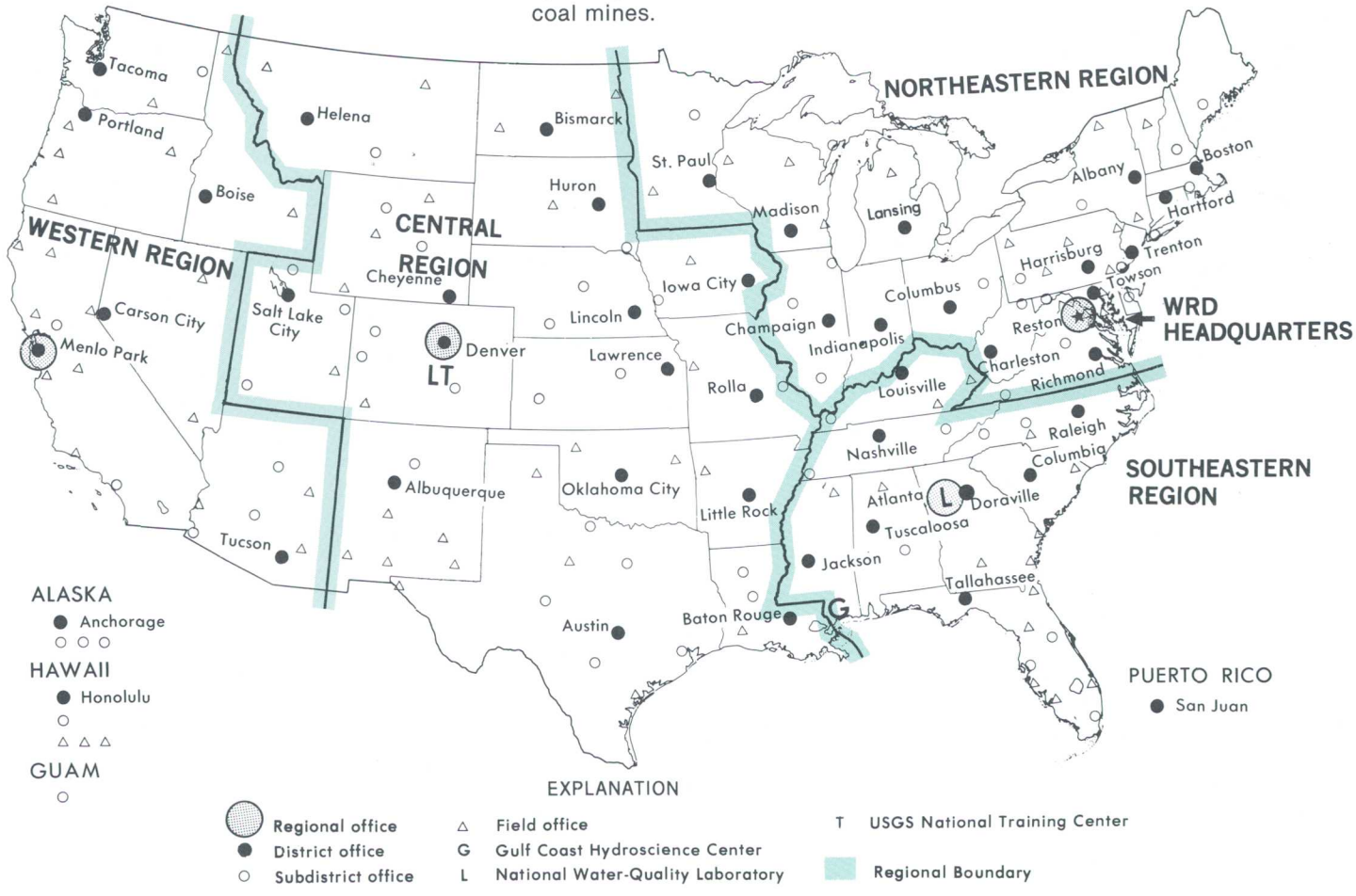
Bureau of Mines
Collection of hydrologic data, hydrologic studies of abandoned coal mines.

Bureau of Reclamation
Collection of hydrologic data, ground-water-resources, reservoir, and land-subsidence studies.

Fish and Wildlife Service
Collection of hydrologic data, ground-water recharge, water supply for fish hatcheries, instreamflow evaluations, relation of ground water to lakes.

National Park Service
Collection of hydrologic data, water-resources appraisals of National Parks and Monuments, flood-hazard, forest geomorphology, and ground-water studies.

Environmental Protection Agency
Studies related to energy research and development, municipal waste-disposal-site studies, relationship of ground water to lakes, collection of water-quality information.



Location of principal offices of the U.S. Geological Survey's Water Resources Division in the conterminous United States. Cities named are those where regional and district offices are located. Puerto Rico is included in the Southeastern Region, and Alaska, Guam, and Hawaii are included in the Western Region.

BUDGET AND PERSONNEL

In 1979, the Water Resources Division employed 2,815 full-time personnel. They included scientists and engineers representing all fields of hydrology and related sciences, technical specialists, and administrative, secretarial, and clerical employees. An additional 1,369 permanent part-time and intermittent employees assisted in the work of the Division.

The $168.6 million available in 1979 for the water resources investigations activities came from the following sources:

1. Direct congressional appropriations.
2. Congressional, State, and local appropriations for 50-50 funding in the Federal-State Cooperative Program.
3. Funds transferred from other Federal agencies.
4. Funds transferred from State and local agencies.

Water Resources Investigations activity obligations for fiscal years 1978 and 1979, by subactivity

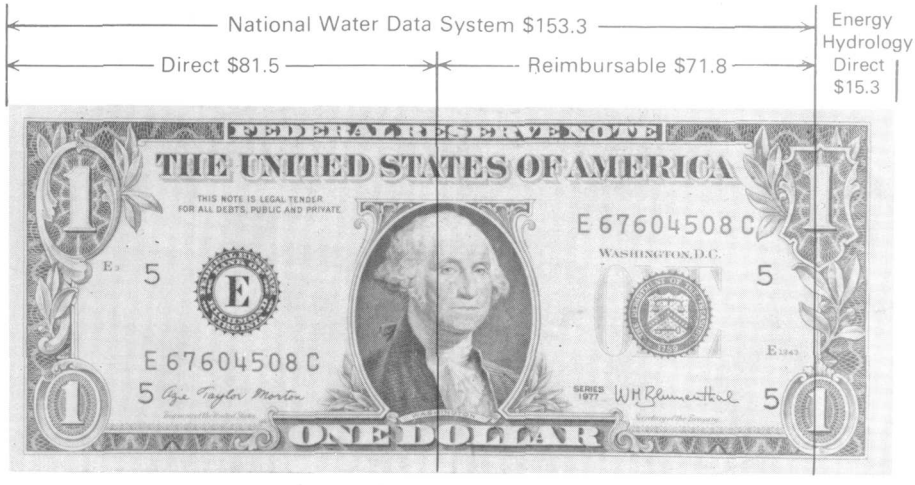
[Dollars in millions. Data may differ from that in statistical tables because of rounding]

Subactivity	Fiscal year 1978	Fiscal year 1979
Total	**$146.0**	**$168.6**
National Water Data System	**137.8**	**153.3**
Direct programs	70.3	81.5
Federal program	35.3	42.7
Federal share of Federal-State Cooperative Program	35.0	38.8
Reimbursable programs	67.5	71.8
States, counties, and municipalities	36.5	40.2
Miscellaneous non-Federal sources	1.4	1.7
Other Federal agencies	29.6	29.9
Energy Hydrology	**8.2**	**15.3**
Direct program	8.2	15.3

SOURCE OF FUNDS

TOTAL $168.6 MILLION

USE OF FUNDS



NATIONAL WATER-USE PROGRAM

Water-use data generally has been adequate to meet the needs of planners and managers. In recent years, however, water management has become increasingly complex, and the need for more accurate and complete qualitative and quantitative data on water use has become apparent. As a result, Federal and State agencies concerned with water-data acquisition have combined their efforts to implement a nationwide water-use data program.

The Geological Survey began the Federal-State Cooperative Water-Use Program in 1977. It is designed to collect, to store, and to disseminate water-use data. Many elements, covering a broad range of water uses, were selected to meet the needs of groups involved in the planning, management, and operation of water resources. The objectives of the Water-Use Program are (1) to account for the water used throughout the United States, Puerto Rico, and the Virgin Islands, (2) to organize the data collected so that they may be retrieved and used readily, (3) to provide data which will be uniform in quality, and (4) to be able to update data and to make projections of future water requirements.

The Program is financed through the Federal-State Cooperative Program. Direction, management, and methods development to provide for a consistent and comprehensive national program are responsibilities of the Survey. Manpower intensive field activities for acquisition of data are responsibilities of the local agencies which already have direct communication with the water-using community or can readily establish such communication.

As of July 1979, cooperative programs had been undertaken in 35 States, with field data collection activities underway in 15 States, and staffing activities underway in the remaining 20 States. The level of effort in each State reflects the availability of cooperative funding both at the State and Federal level.

A major requirement of the program was to develop a storage and retrieval system for the vast amount of information submitted from the States to the Survey. The storage and retrieval system is now in place. It collects data about the location and amount of withdrawal, return, and use of water and edits and updates the data.

The storage and retrieval system is vital to make the water-use data available, but the ultimate strength of the program will be determined by the validity of the data obtained. Three major considerations must be taken into account. The first deals with the measurement of water use; the second, with techniques for extrapolating sampled information to all of the facilities of a given geographic area; and the third, with selection of water-use measurements and extrapolation methods to provide the desired level of accuracy.

A water-use methods manual is being developed that addresses two topics. The first concerns methods that deal with the physical measurement of water use. This includes indirect methods such as the use of electric power consumption to estimate ground water pumped from wells. The second addresses methods that deal with the problems of extrapolating facility-site measurements to the population of facilities in a given geographical area. This includes descriptions of statistical sampling methods to be used in selecting sites or facilities for actual measurement or measurement verification.

The Water-Use Program is in its infancy, but mechanisms have been initiated to make it more responsive to the information needs of water managers throughout the Nation. The cooperative funding, the need for the data, and the efforts of State agencies should assure steady progress.

Examples of Some Types of Water-Use Data That Will Be Available

Domestic—Data concerning water used by residences, municipalities, and institutional establishments.

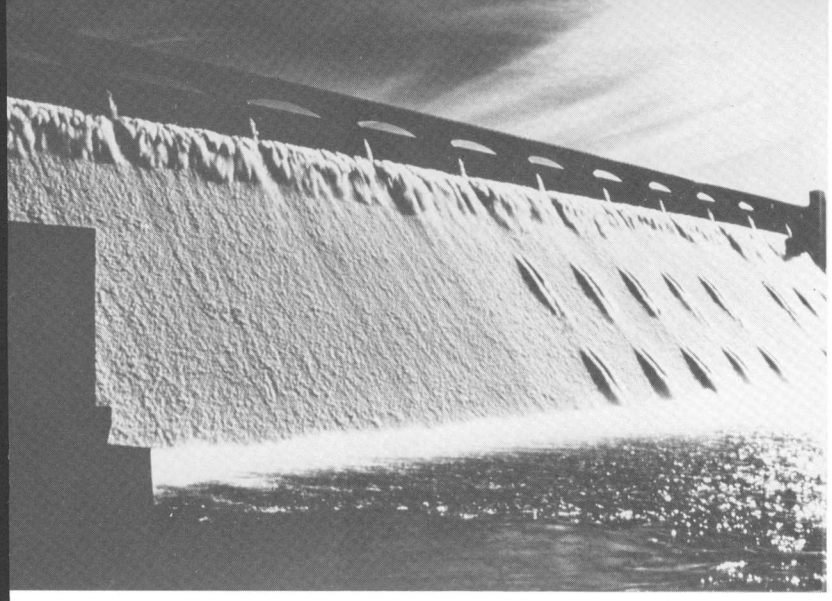
Industrial—Data concerning water used by manufacturing or processing facilities.

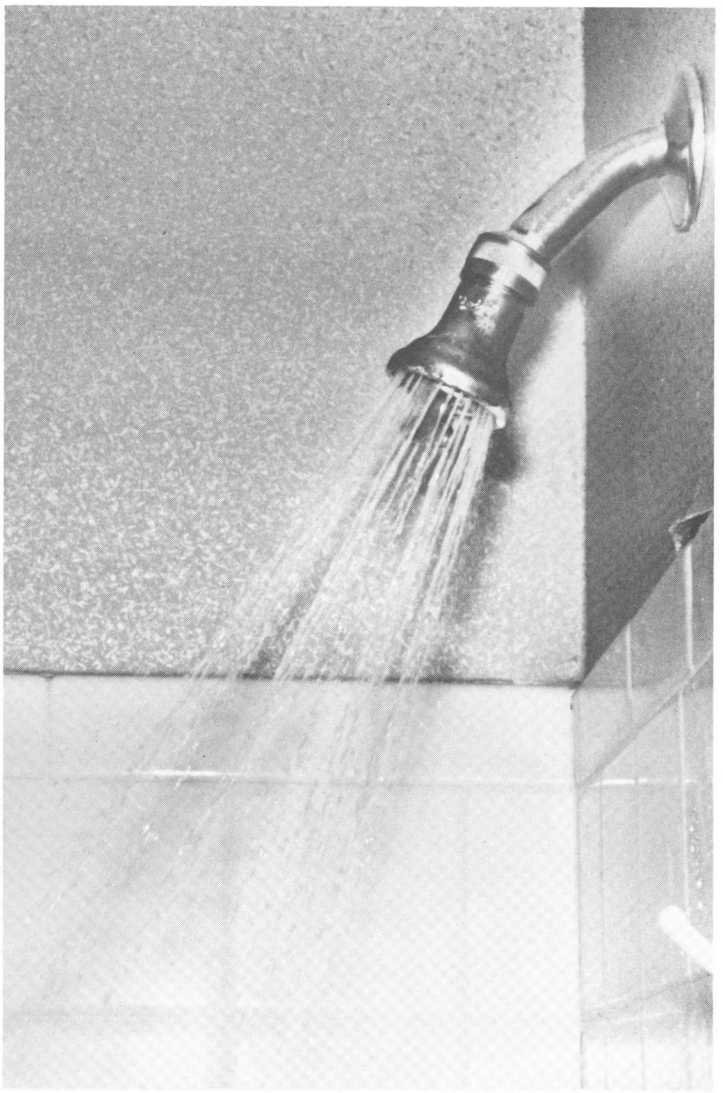
Agriculture-Irrigation—Data concerning water distributed on lands for the purpose of growing crops and pasture.

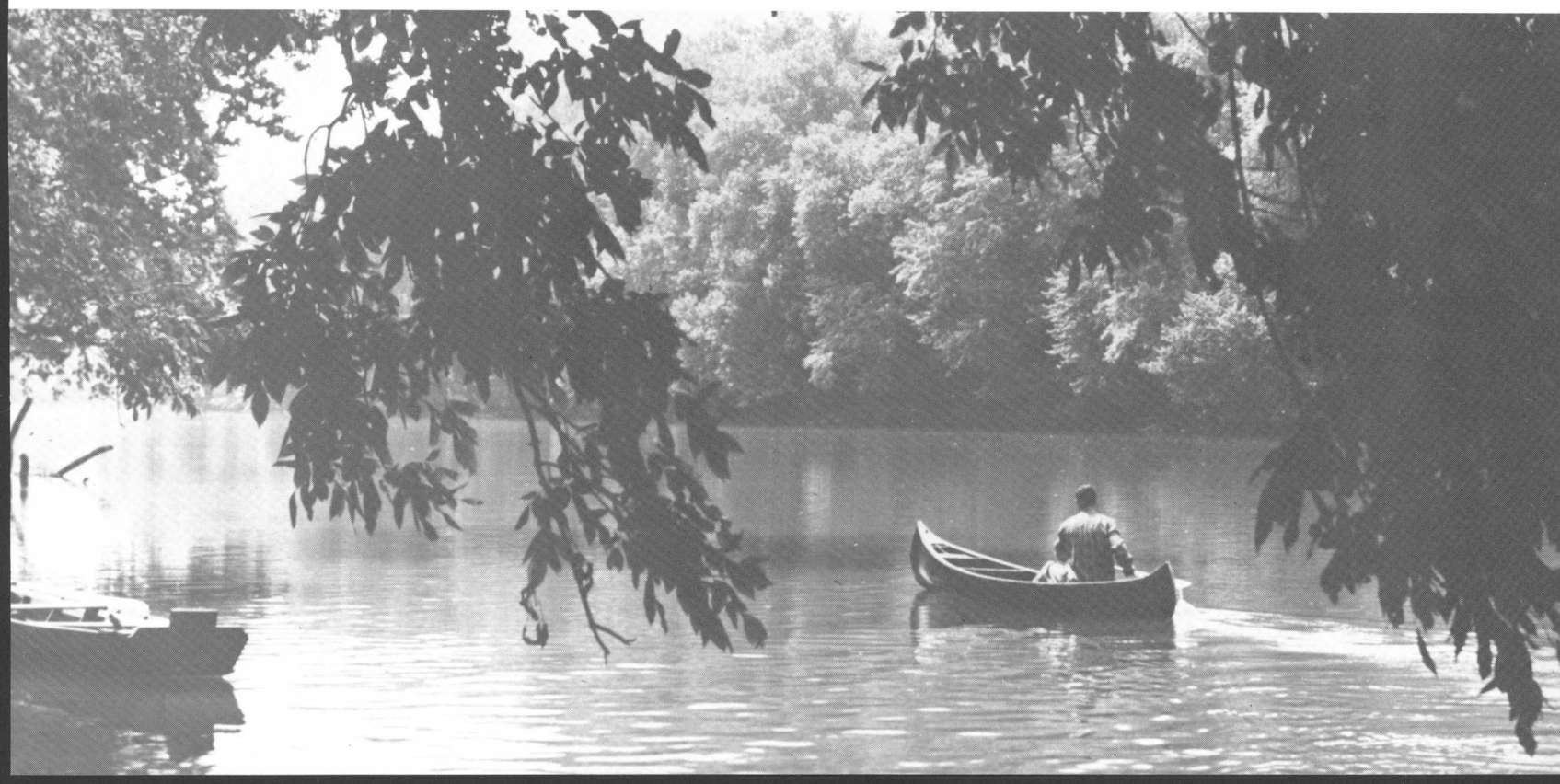
Power-Offstream—Data for offstream electric power generation including geothermal, hydroelectric offstream, fossil fueled, and steam electric.

Preservation—Specialized data concerning the use of water for maintaining and enhancing a natural resource such as wetlands.

Recreation-Instream—Data concerning the use of bodies of water for leisure and pleasure; for example, swimming and boating.







PARTICIPATION IN THE PRESIDENT'S WATER POLICY REFORM

The President's "Water Message to Congress on Water Policy Reform," transmitted June 6, 1978, as well as subsequent implementing directives, instructs the departments and agencies of the Federal Government to carry out policy reforms. The purpose of these policy reforms is to develop a more comprehensive and integrated approach to national water-resources management in light of emerging significant problems. Initiatives set forth include improvement in water planning, environment quality, water-resources management, and water conservation.

Nineteen interagency task forces were formed to identify and recommend ways to implement the stated initiatives. Task force leadership for two of the concerns, ground-water supply and instream flows, was assigned to the Geological Survey.

The Ground-Water Supply Task Force focused its efforts on improved consideration of the ground-water resource in Federal water planning and on expanded Federal cooperation with the States in order to resolve ground-water problems. The Task Force concluded that the ground-water resource is only weakly represented in the Federal water-planning process, and the final report offered specific recommendations, including institutional, planning, and other fundamental steps.

The Task Force also concluded that formal procedures should be established for collaboration and mutual technical and program assistance with the States to insure high levels of interchange and coordination, and it specified methods of accomplishment.

Finally, the Task Force proposed a National Ground-Water Advisory Commission as an effective means for confronting the policy, management, and legal predicaments surrounding the Nation's ground-water resources; for addressing the role of ground water in land and water utilization and protection efforts; and for recommending the necessary fundamental steps for overall improvement of national ground-water utilization and protection.

"Instream-flow" needs relate to the various instream uses of water and the amount of water needed to satisfy those uses. In that context, the Instream Flows Task Force addressed six major areas defined by the President.

Public workshops were held throughout the Nation. Seven reports document the conclusions and recommendations of the Instream Flows Task Force and the Ground-Water Supply Task Force.

- Technical assistance and information that is available to the States from Federal agencies on ground-water supply and instream flows were identified and a report provided to each State describing the types of data, sources, and agency contacts.

- The Task Force identified agency legislative authority to cope with instream-flow needs and annotated 28 pieces of pertinent Federal legislation.

- Major water-resources construction agencies reviewed their planning procedures to insure that instream flows are being adequately considered in current planning.

- In instances where the Task Force found Federal projects with problems relating to instream flows and where State cooperation was available, it was recommended that the appropriate Federal agency take specific action to follow through with the States to correct the problems.

- Guidelines were developed for determining instream-flow needs relative to minimum, maximum, and optimum flow; velocity; depth; and water quality. The quidelines also outlined situations in which instream flow should be paramount in the planning process. These guidelines were transmitted to the Task Force revising the *Principles and Standards for Water Resources Planning.*

- The Task Force determined that no additional Federal legislation is necessary to provide for instream flows in water-resources development, but a recommendation was made that Federal agencies develop procedures for quantifying economic and environmental values of instream flow to insure adequate consideration of all factors in water-project planning.

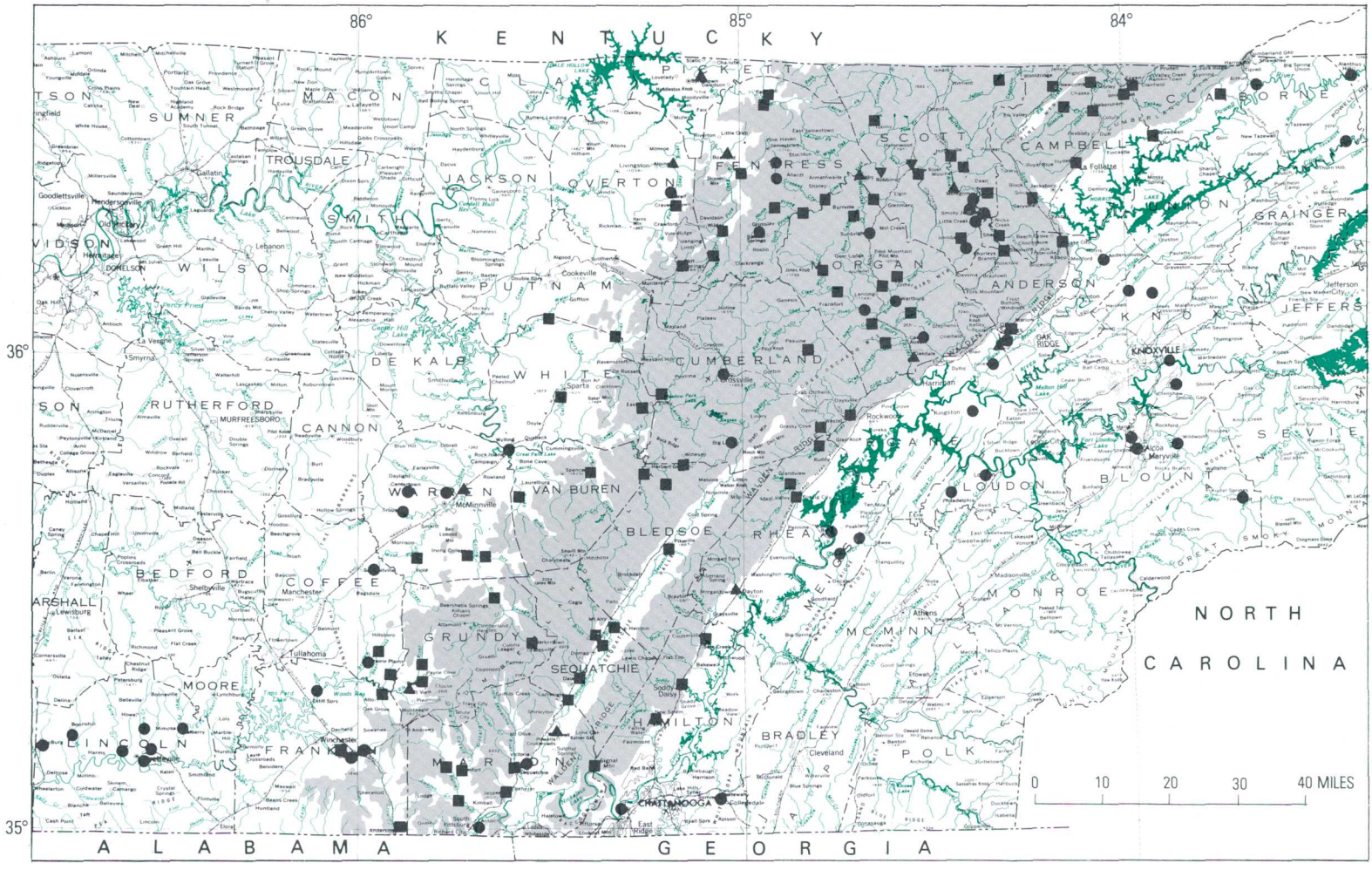
COAL HYDROLOGY PROGRAM

The passage of the Surface Mining Control and Reclamation Act of 1977 (SMCRA) set national policy regarding the control of the surface effects of coal mining on the environment. The potential for adverse impacts on water resources and the need to assess and to mitigate these potential impacts received considerable attention in the Act. One section of the Act (507(b) (11)) requires the "appropriate Federal or State agency" to "provide hydrologic information on the general area" to the mining permit applicant. The Congress recognized that this requirement could not be met by existing hydrologic data systems and, therefore, authorized new funds to begin acquiring the necessary information.

To meet the responsibility imposed by this new program, the Survey first analyzed the existing water-data networks in the coal regions of the Nation by using the requirements of SMCRA to assess network adequacy. The following general areas of deficiency were identified: (1) the lack of data on smaller drainage areas, (2) the need for additional water-quality information, and (3) the need for sediment data.

The Program, which has been implemented to remedy these deficiencies, has several facets. First, additional water-quality and sediment data collection was initiated at existing continuous record surface-water stations. Some of these continuous record stations have been designed as trend or reference stations. Trend stations are those downstream from major mining activities and will be used to evaluate the long-term impacts of mining and reclamation on stream flow and water quality. Reference stations are also long-term stations, but they were selected in areas unlikely to be influenced by mining. These stations will provide background data on natural variability and the effects of changes other than mining on the stream system. New trend and reference sites will be chosen and gages installed as dictated by changing needs and analysis of the data now being collected. By far the most numerous stations are synoptic measurement sites at which seasonal flow-event-related measurements are made and water samples collected for analysis for selected constituents. This network of synoptic stations provides broad areal coverage while also providing data on relatively small watersheds. An example of the surface-water data station activity being used to support SMCRA is shown by the figure below.

This is the network now being operated in Tennessee.



EXPLANATION

▲ Continuous record surface-water station, partially or completely funded by Coal Program

▼ Trend surface-water station, partially or completely funded by Coal Program

■ Synoptic surface-water data site funded by Coal Program

Area underlain by coal-bearing rocks

● Existing surface-water station, not funded by Coal Program

RIVER-QUALITY ASSESSMENTS

The objectives of the Geological Survey's River-Quality Assessment Program are to define the character, interrelationships, and causes of existing river-quality conditions and to devise and to demonstrate the approaches needed for developing technically sound information that decisionmakers can use in evaluating alternatives for river-quality management.

River-quality problems basically stem from two factors—the unique hydrology of a river basin and man's development and use of the land and water resources. In the broadest context, river-quality assessment is a problem-oriented approach for developing information that is appropriate and adequate for sound resource management.

Since initiation of the Survey's River-Quality Assessment Program in 1973, assessments have been made of the Willamette River, Ore., the Yampa River basin, Colorado-Wyoming, and the Upper Chattahoochee River basin, Georgia. Assessments presently underway include those on the Potomac River Estuary, Washington, D.C., the Truckee and Carson River basins, Nevada-California, the Schuylkill River, Pa., and the Apalachicola River, Fla.

The Potomac Estuary Study is a joint river-quality assessment and research project which began in fiscal year 1977 and will continue through fiscal year 1982. The purpose of the assessment is to develop the information required to evaluate alternatives for managing water quality in the tidal Potomac River and Potomac Estuary. The objective is to determine the relative impacts of municipal discharges, combined sewer overflows, urban runoff, and upstream runoff (upstream from the Washington, D.C., metropolitan area) on dissolved oxygen (DO) depletion and algal growth problems. A specific question is whether improvement in water quality can be achieved by advanced treatment of wastewaters, including denitrification, at the Blue Plains Treatment Plant. Such a measure would be operationally expensive. Therefore, an analysis of potential improvements in water quality is needed.

The Potomac River Quality Assessment is composed of three integrated elements: DO dynamics, algal growth dynamics, and materials transport. The DO element is designed to provide information on the source of all materials and on the processes which might affect DO levels in the tidal Potomac River. The work focuses on the five major processes affecting DO—carbonaceous deoxygenation, nitrification, deoxygenation by materials in benthic deposits, algal production-respiration, and reaeration. The first four processes remove oxygen from water, and preliminary investigations indicate that each is occurring at rates significant to cause major influences on DO levels in the tidal Potomac River.

The algal dynamics element has a twofold thrust: to ascertain the impact on DO levels of algal production and respiration and to determine the relative roles of different major nutrients, particularly nitrogen and phosphorous, in controlling the amount and species of algae that grow in the Potomac Estuary. One specific objective is to determine how nitrogen and phosphorus levels affect the timing and location of nuisance algal growths. A second specific objective is to collect information from all elements of the study to determine the sources of the nutrients that trigger undesirable algal growths. The important question is whether additional removal of major nutrients from municipal discharges, especially Blue Plains, would be sufficient to halt the undesirable growths.

The transport station element unifies the DO and algal elements of the assessment and also links the assessment and research components of the overall Potomac Estuary Study. In the transport station work, measurement cross sections have been established at Chain Bridge, Alexandria, Quantico, 301 Bridge, and Piney Point. Water samples are collected at these sections two to four times weekly and analyzed for nutrients, oxygen-demanding substances, and suspended sediment. The data will be used as input to a flow model to follow the movement of these substances through the estuary.

The research component of the Potomac Estuary Study is designed to answer specific questions concerning estuarine dynamics and to contribute important data and information to the assessment component. The research is comprised of six projects concerned with geochemistry, geomorphology, hydrodynamics, sediment transport, benthic ecology, and submerged vegetation. The geochemistry project is particularly important to the assessment component because it focuses on phosphorous cycling, especially the exchange of phosphorous between the water column and river-bed sediments.

Those working on the benthic ecology project made a discovery of major economic importance in fiscal year 1979 when surveys documented the first appearance in the estuary of the Asian hard-shelled clam, *Corbicula.* The Asian clam represents a potential nuisance because it is known to clog water-intake pipes.

The basins of the Truckee and Carson Rivers encompass 7,250 square miles spanning the California-Nevada State line in the Lake Tahoe area. Within the basins are the rapidly growing Reno-Carson City area (Nevada's second largest socioeconomic area), intense recreational development surrounding Lake Tahoe, and some of the most productive agricultural lands in Nevada. Both rivers traverse rapidly developing valleys between their headwaters in the Sierra Nevada Range and their termini in the deserts of Nevada. During the traverse, flow and quality are greatly diminished in each river by agricultural withdrawals coupled with agricultural wastewater returns and urban runoff.

The Truckee River ends in Pyramid Lake, a semisaline water body that is the habitat of two unique fish, the Lahontan cutthroat trout *(Salmo Clarki Henshawaii)* and the Cui-ui lakesucker *(Chasmistes Cujus),* on the endangered and threatened species list. The Carson River ends in agricultural return flows into a desert sink. The two basins are interconnected in the headwaters by diversion of treated municipal wastes from the Lake Tahoe basin and in their lower reaches by diversions from the lower Truckee River for irrigation of reclaimed lands in the Carson Desert. The long-term sustained water supply in the Truckee River basin will soon be insufficient to satisfy competing demands for agriculture, municipal supply, waste assimilation, fish maintenance, and recreation.

The major goal of the Truckee and Carson Rivers Study is development of methods for conducting river-

quality assessments in water-short areas. The program design treats the two interconnected basins as one hydrologic unit for the consideration of water-quality problems. The study has two major objectives: to document the existing hydrologic and institutional frameworks to provide the necessary basis for assessing river quality and to perform detailed evaluation of critical problems in specific reaches.

To meet the objectives, the Truckee and Carson Rivers Assessment has devised the following major elements: (1) development of a hydrologic atlas to fully describe, for the first time, the hydrologic characteristics of the basins, (2) detailing of the legal, institutional, and structural development of water resources in the basins and the current problems and conflicts, (3) development of a workshop approach to involve local management in the direction and results of the study, (4) development of a comprehensive streamflow model encompassing both basins to provide a quantitative hydrologic framework for water-quality analysis, (5) development of a water-quality transport model for dissolved oxygen and other constituents in selected reaches of the Truckee River, and (6) a detailed examination of selected fish habitats for specified reaches of the Truckee River.

The assessment is designed to provide a hydrologic overview of the two-basin system and to specially examine DO and fish-habitat-related problems in the Truckee River below Reno. The workshop will enable local water-quality managers to have input to the assessment and to have results described and discussed in great detail. The workshop will also point up other problems that will require future evaluation.

Waters of the Schuylkill River are used heavily for municipal and industrial water supply, recreation, and waste assimilation. Previous studies by the Pennsylvania Department of Environmental Resources (DER) have indicated numerous water-quality problems, of which DER considers the presence of trace metals and trace organic substances to be the most significant. The presence of trace substances is a concern from the standpoint of both the welfare of the general public and the protection of the aquatic ecosystem of the Schuylkill River and Delaware Estuary. Post-DER studies and a recent survey of river-bed sediments by the project staff have found high concentrations of trace metals and organic compounds that are considered to be priority toxic pollutants by the Environmental Protection Agency. These include lead, chromium, cadmium, copper, zinc, nickel, PCB's, chlordane, DDT, DDE, and DDD.

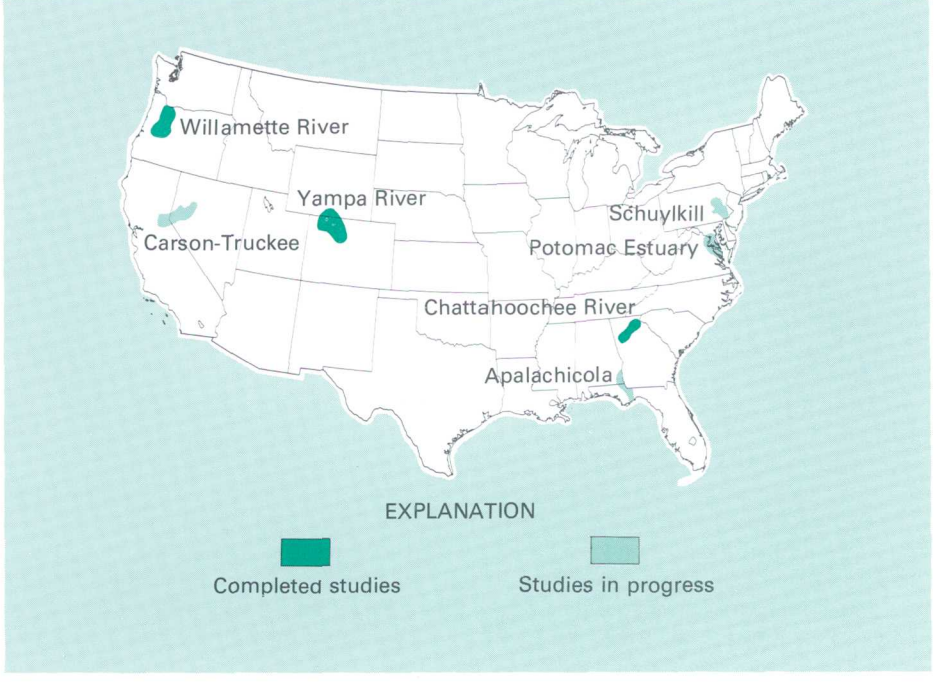
The Schuylkill River-Quality Assessment has two major objectives: to determine the source areas, distribution, and transport mechanisms of trace metals and trace organic substances in the Schuylkill River basin and to generally devise and demonstrate approaches, strategies, and methods for sampling trace substances in a river for the purpose of providing information suitable for planning and management.

Results of the study are intended to provide basin planners with useful information for managing trace substances occurrence. Potential management options include controlling or eliminating the sources of such substances and controlling the distribution of trace substances that attach to sediment through a program of periodic dredging of pools in the lower Schuylkill River.

The Apalachicola River is part of a relatively undisturbed river-wetland system whose extensive flood plain is inundated several months each year. The flood plain supports a great diversity and biomass of vegetation that provides an important source of nutrients and detritus (particulate organic matter) to the river system.

The Apalachicola Study has two major objectives: to devise and to evaluate approaches and methods for assessing the interrelations between hydrologic processes and the supply of nutrients and detritus transported from a wetland and to initiate the development of the data base required for eventual assessment of the impacts of river alterations on the Apalachicola system. The problem-solving orientation of other assessments cannot be followed because suitable field methodologies are presently lacking to assess the important wetland processes and their relationships.

The Apalachicola River basin is ideally suited for testing an array of general wetland assessment approaches and specific methods. The main processes addressed are (1) the relationship between flood plain hydrodynamics and flood plain tree communities, (2) the production and decomposition of leaf litter to produce nutrients and detritus, and (3) the transport of nutrients and organic matter from the flood plain. The net effect of these processes is the export of nutrients and detritus to Apalachicola Bay where these substances are utilized by abundant oyster, crab, and shrimp populations.



URBAN HYDROLOGY STUDIES

In recent years, the pollution level of many streams has declined as a result of efforts to clean up the discharges from industrial and municipal water-treatment plants. This reduction in pollution from point sources has made more obvious the extent of pollution from nonpoint sources such as urban streets. Definition of the urban storm-water pollution component has become a critical need in the effort to clean up the Nation's waters.

Prior to the last decade, the principal involvement of the Geological Survey in the field of urban hydrology was related to the flood potential of urban storm runoff. More recently, with impetus from the Federal Water Pollution Control Act (Public Law 92-500, Section 208), significant concern has been directed toward the problem of water-quality degradation resulting from urban runoff. During the past 6 years, pilot studies of urban storm-water quality were conducted in Denver, Colo., Portland, Ore., Philadelphia, Pa., and in the Miami and south Florida area. Much was learned from these studies relating to the collection and analysis of storm-water data. A finding in the Portland study was that concentrations of settleable solids and coliform bacteria in storm runoff were at times higher than in discharge from secondary waste-treatment plants.

A new program of urban storm-water studies was begun in 1979. The studies are patterned after the four pilot projects recently completed, but the goals have been broadened to meet the combined objectives of the Survey and the Environmental Protection Agency. An agreement between the two agencies specifies collaboration on a number of studies with the objective of establishing a nationwide data base and preparing interpretive reports that can assist local agencies in planning the management of urban storm water. Additional objectives are to develop methods of transferring study results to other areas and to test the effectiveness of management alternatives aimed at reducing pollutants washed into streams and lakes.

New studies were underway or were started in the following metropolitan areas during 1979: Bellevue, Wash., Denver, Colo., Long Island, N.Y., Rochester, N.Y., Milwaukee, Wisc., Salt Lake City, Utah, Chicago, Ill., Topeka, Kan., Minneapolis, Minn., and Salem, Ore.

These studies entail a data collection program for 2 to 3 years. Rainfall, runoff, and water-quality data are being collected on from 3 to 10 typical urban watersheds in each metropolitan area with the use of automatic recording and water-sampling equipment. The multiple water samples collected during each storm are analyzed for 20 or more water-quality constituents. These data are interpreted by using statistical procedures and complex watershed models. The results will be used to assess the magnitude of pollution from urban storm water compared to that from point sources and to test the effectiveness of management alternatives.

Almost 5 pounds of litter per day are deposited along each 100 feet of curb in commercial urban areas. Of this, about one-third is dissolved by rainfall during storm periods. A 2-week accumulation, if carried off in a 2-hour period, could have a peak pollution load of over 150 percent of that of treated sewage.

DATA RELAY AND IMPROVED INSTRUMENTATION

The Water Resources Division currently operates about 16,000 data-collection stations on rivers and streams throughout the United States. Data from these stations provide information for a wide variety of uses such as managing reservoirs; issuing flood warnings; allocating water for irrigation and hydroelectric power; monitoring the flow of streams to insure that treaties, contracts, and other legal agreements are honored; and monitoring the quality and quantity of the water in the Nation's rivers and streams.

Over the years, new methods have been developed for recording and distributing the information collected at the stream-gaging stations to improve the reliability of the data and the timeliness of distribution. One technique now being tested is the use of Earth satellites for relaying measurements from the data-collection stations to central processing and distribution facilities.

At the present time, measurements taken at most data-collection stations are automatically punched on paper tapes that are retrieved during visits to each site at intervals of 4 to 6 weeks. The tapes are manually checked for errors and then entered into devices that transmit the data on the tapes through telephone lines to computers located at the Survey's National Headquarters in Reston, Va. After the data have been edited and processed in these computers, they are available for retrieval through the Survey's national network of remote computer terminals. Although the measurements are recorded on site in a timely manner, the collection and processing under this system takes at least 4 to 6 weeks because the data are manually retrieved from the stations.

Satellite data relay has been under way for the past 7 years. During this period, data collected at selected remote stations (140 were operating in fiscal year 1979) have been transmitted through the satellite system to computers where they are received, processed, and distributed within minutes from the time they were recorded. Each station has been equipped with battery-operated radios containing the small computers that control both the acquisition of data from records and the data transmission to satellites. At intervals of 15 minutes to 3 hours, the radios transmit data to satellites orbiting 23,000 miles above the Earth's equator. The satellites relay the data to central receiving stations on Earth, and, from there, the data are transmitted over standard telephone lines to the Survey computers.

Two satellite data-collection systems are being evaluated: the Geostationary Operational Environmental Satellite Data Collection System operated by the National Oceanic and Atmospheric Administration-National Environmental Satellite Service and a commercial satellite system used by the COMSAT General Corp. under contract to the Survey. These systems differ from each other in a variety of ways, having different technical and managerial requirements.

Evaluations have demonstrated that there are other benefits to satellite data-collection systems in addition to the more efficient use of manpower and the time saved in collecting hydrologic data. Using satellite data-collection systems, technicians in the field offices have data available that are only hours old; this enables them to monitor the remote instrumentation daily and to identify sensor problems within hours, rather than weeks. Such monitoring activity significantly reduces the loss of data because of damaged or malfunctioning equipment. The availability of current data also makes it possible to sense critical hydrologic events at their outset. For example, a hydrologist in an office located at a distance from an actual data-collection site can monitor a rapidly rising river stage in time to warn of an impending flood.

Relaying data by means of satellites is proving successful on a small scale and may soon replace many time-consuming links in the chain of data collection and dissemination. The present network of 140 satellite-supported data-collection sites will grow in the next 10 years, and the capability to collect many different kinds of data may also increase. When data are needed from a certain area, the selection of sites in that area will no longer depend on the proximity of telephone or power-lines because satellites have equal accessibility to almost any point on the Earth, and power can be provided on the site by batteries charged from solar panels. The use of satellite data-relay systems has proven cost-effective and holds promise for contributing to more effective management of the Nation's water resources.

GEOHYDROLOGIC RESEARCH IN RADIOACTIVE WASTE DISPOSAL

It is generally recognized that wastes from the generation of nuclear power must be isolated from the biosphere. The Geological Survey's involvement in the problem of radioactive waste disposal results from the fact that the primary agent in the transport of radionuclides to the biosphere is water.

Studies in this program include geologic and hydrologic research of general applicability to the identification and characterization of waste-disposal sites, investigations of specific sites where wastes have been stored, and studies of regions or environments where waste-disposal sites might be located. The research program may be divided into three categories, high-level radioactive waste [1] studies, low-level waste [2] studies, and cooperative studies on behalf of the Department of Energy (DOE) related to both high- and low-level wastes. The first two categories are funded by Congressional appropriations to the Geological Survey. The third category is supported by DOE. The high-level waste studies and those performed on behalf of DOE are a joint effort of the Water Resources and Geologic Divisions.

The Survey's studies of high-level waste disposal, first initiated in fiscal year 1979, are influenced significantly by the fact that the responsibility for selection and design of waste-repository sites rests with DOE. The Nuclear Regulatory Commission and Environmental Protection Agency are responsible for licensing the facility and establishing criteria for judging its environmental effects. The Geological Survey's research on high-level wastes is designed to complement and augment the DOE program. As a result of the close coordination required, the two agencies have prepared a plan for screening successively smaller land units on a national scale, based on geologic and hydrologic considerations. The ultimate objective is to identify several waste-disposal sites.

The essential feature of the Survey's high-level waste studies is the emphasis on locating sites with relatively independent multiple barriers to nuclide transport. This concept was adopted to overcome deficiencies in our ability to characterize adequately the volumes of rock around a repository and to predict waste-rock-water reactions, natural events, and nuclide transport. The phrase "multiple barriers" refers to both manmade and natural barriers in the form of hydrodynamic, geochemical, and geologic characteristics that would impede radionuclide transport. One objective is the identification of environments or systems of rocks where such multiple natural barriers occur. A second objective is the identification and understanding of critical geologic properties and processes involved in radionuclide migration from a repository to the biosphere. In the context of identifying environments providing multiple natural barriers to radionuclide migration, investigations will be expanded for selected rocks that could serve as host media for emplacing the waste.

The principal purpose of the research in low-level waste disposal, which was started in the Survey in 1975, was to develop geohydrologic guidelines which can be used to establish technical criteria for selecting, evaluating, licensing, and operating new waste-disposal sites. The program was designed to be a 5-year endeavor, ending in fiscal year 1980. It includes detailed field studies of several commercially operated disposal sites, augmented and supported by research on hydrologic processes and the development of better methods for conducting field, laboratory, and modeling studies. The intent is to utilize these sites as field laboratories for long-term studies of the fate of buried wastes in relation to prevailing geohydrologic conditions. In view of the broad range and variety of geohydrologic conditions represented by the sites, this segment of the program is particularly useful for guidelines which the regulatory and operational agencies can use to establish technical criteria for licensing new sites.

In general these studies involve defining the following tasks:

- The geologic and hydrologic conditions at the site that are pertinent to the subsurface leaching and migration of waste radionuclides in ground water.
- Leach rates and source terms for modeling the transport of buried radionuclides.
- The extent, rate of movement, and concentration of migratory radionuclides in ground water.

The Geological Survey's cooperative studies on behalf of DOE include a variety of geologic and hydrologic studies of DOE low-level waste-disposal facilities and of areas or regions selected by DOE where high-level waste-disposal repositories might be located. The low-level waste-disposal facilities under study are at the Oak Ridge National Laboratory in Tennessee and the Idaho National Engineering Laboratory (INEL). Mineralogical, geochemical, and stable isotope studies of sedimentary deposits beneath a waste burial site at INEL have helped to show how major climatic fluctuations in the past 200,000 years have affected ground-water movement and the chemical alteration of minerals. This information is useful in assessing the potential effects of any future climatic changes on the subsurface mobility of waste radionuclides. (The cover picture of this volume relates to this study.) The areas under study where DOE is considering locating high-level repositories include bedded salt in the Waste Isolation Pilot Plant site in southeastern New Mexico; shale and granite bodies in the Nevada Test Site area; salt anticlines in the Paradox Basin, Utah; Gulf Coast salt domes in Mississippi, Louisiana, and Texas; bedded salt in the Salina Basin, N.Y.;

[1] Includes fission products that initially have a high level of beta and gamma radiation; also transuranic elements with a long toxic life. Transuranic waste contains long-lived alpha emitters at concentrations greater than 10 nanocuries per gram.

[2] Waste that does not fit the definition of high-level waste and in which the concentration of transuranic elements is less than 10 nanocuries per gram.

and basalt in the Hanford Reservation area, Washington. The Eleana argillite in part of the Nevada Test Site was eliminated as a potential repository site when studies revealed the extreme complexity of structural conditions.

Some general observations of the characteristics of radionuclide transport have been made on the basis of studies of 10 shallow low-level waste-disposal sites in humid to arid locations. These observations resulted from the Survey's low-level waste studies and the cooperative studies of DOE facilities (both described above). Waste tritium, a radioisotope of hydrogen, apparently has migrated lateral distances ranging from a few feet to more than 2,100 feet in ground water beneath 8 of the 10 sites, including all 6 of the sites in humid areas. Other nuclides such as cobalt-60, cesium-137, strontium-90, and transuranic elements (plutonium and americium) have migrated laterally from a few feet to about 300 feet. Dissolved organic compounds in the ground water appear to enhance the mobility of certain radionuclides at some sites. Arid-zone sites appear to have the least potential for nuclide migration in ground water. Quantitative determination of ground-water flow has proved to be extremely difficult at sites in arid regions and where there are fractured rocks.

◀Casks of low-level solid radioactive waste being buried in trenches at a commercial disposal site near Barnwell, S. C. The Water Resources Division of the U.S. Geological Survey is investigating the geologic and hydrologic characteristics of this site and several others in an effort to establish better technical guidelines for size selection and operation. (Photograph by J. M. Cahill)

Part of the U.S. Geological Survey's hydrologic investigations of low-level radioactive waste sites entails highly sophisticated sampling of subsurface leachate solutions in the buried waste. Brookhaven National Laboratory personnel, shown here at the Barnwell, S. C. disposal site, work in cooperation with the Survey and Nuclear Regulatory Commission in the collection and analysis of these samples. (Photograph by J. B. Robertson)▼

RESEARCH PROGRAM

The goal of the Research Program in the Water Resources Division is to develop a sufficient understanding of hydrologic systems to permit quantitative prediction of the response of these systems to either natural or manmade stresses.

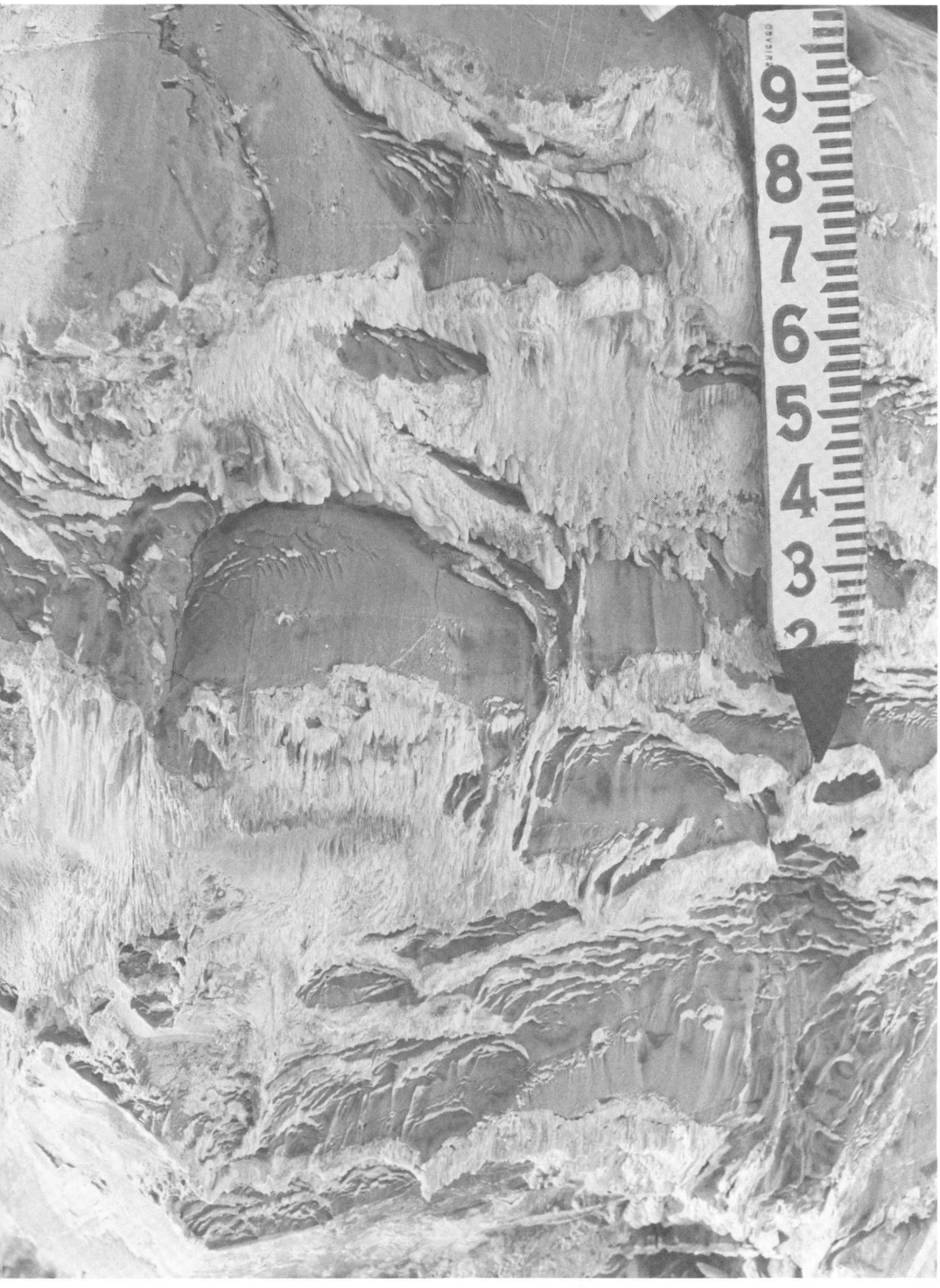
The approach to the research can be described as basic, which is exploration of the scientific principles controlling the quantity and quality of the Nation's water resources, and problem oriented, which involves support of the Survey's programs by providing operational and interpretative tools such as mathematical prediction models, sample collection, treatment, and analytical methods to provide meaningful data. The underlying principle of these efforts is that the information and understanding produced will be synthesized and made available to the scientific community and the general public as rapidly as possible. The products resulting from the research efforts are intended to provide the tools and basic understanding to facilitate the management and enjoyment of the Nation's water resources.

Some of the recent significant research results are summarized below.

- Using borehole geophysical tools, it was demonstrated that it is possible to describe the hydrothermal alteration, lithology, and fractures of igneous and metamorphic rocks. This is of importance in understanding the hydrology of geothermal areas.
- A branched-network flow model was completed that provides the capability to predict discharge data for streams. The model has been applied successfully to several river reaches including the Sacramento, Connecticut, Columbia, Hudson, and Detroit Rivers.
- Isotopic analyses of calcite precipitated on the bedrock beneath a modern temperate glacier show that this calcite records the oxygen isotope composition of the ice from that glacier. Extending this finding to calcite precipitated under Pleistocene ice sheets could improve the interpretation of ice-age temperatures.
- A three-dimensional ground-water model has been developed that includes consideration of the effect of exchange capacity or other solute retardation phenomena of porous media as well as the effects of radioactive decay on the composition of the water. This state-of-the-art model was designed for use on hydrological problems associated with radioactive waste disposal.
- A study of oil shale retort waste water interactions with soil showed that retort water dispersed soil colloids causing the soil to become impermeable. Soil humic and fulvic acids were extracted by retort water, and the soil-sorbed ammonia, from retort water.
- Methane-producing bacteria have been definitely identified in the native microbial population of the saline ground waters under Florida. The possibility of producing usable amounts of energy by feeding industrial wastes to these bacteria is being investigated.
- High concentrations of iron and manganese in well water have been linked to the occurrence of iron- and manganese-reducing bacteria. The bacteria appeared to be feeding on commercial organic drilling mud for their carbon and energy requirements.
- The community structure of benthic invertebrates was changed in a reach of Little Lost Man Creek affected by experimental injection of soluble nutrients and some trace metals. A preliminary report shows that the population of the widespread stream-living caddisfly, *Glossosoma*, decreased significantly below the injection point. Other evidences of biological stress and their causes are being sought in this study.
- Despite previously held concepts of some geomorphologists that blockfields (areas of very large boulders) are probably stable relects of the Pleistocene, studies in Virginia have shown that movements of blockfields can be correlated with high stream flows.
- Tree-ring analysis has been found useful for dating infrequent floods on ungaged streams and extending flood records on gaged streams. Using this technique on Passage Creek, Va., the flood record was extended back to 185l, compared to the gage record which extended only as far back as the 1930's.
- Tree-ring estimations of drought index in northern Virginia indicated that the first one-half of the 20th century contained near-average number of dry years but a disproportionately small number of near-normal years and a large number of wet years. By contrast, the last one-half of the 19th century included only about two-thirds as many wet years as expected from the average (1746–1975), with about one-fifth more near-normal years and one-seventh more dry years than average.
- Sequential filtration studies on trench leachate samples from the Maxey Flats, Ky., radioactive waste-burial site indicate that the preponderance of the plutonium in these leachates is not in colloidal or particulate form but is in true solution because it can pass through a 0.05-micrometer porosity filter. Chemical evidence suggests that most of the plutonium is present in organic complexes (mostly anionic), and some is so tightly bound that it is not removed from solution by a ferric hydroxide carrier precipitation at pH 7.5. These results are significant to studies of the migration of actinide in ground water near radioactive waste-burial sites.
- Evaluation of selected geomorphic features and hydrogeologic factors suggests that parts of the southern Great Basin, Nev., were marked by deep-water tables and long ground-water flow paths during the wet Pleistocene pluvial[1] periods, much as they are today. Water table rises due to future pluvials are not, therefore, likely to preclude use of the Nevada Test Site as a repository for radioactive wastes, provided other requisite conditions are met at this site.

[1] Period of high rainfall associated with glacial activity.

- Glacier mass balances now can be measured and computed far more accurately and completely. In addition to the usual snow, firn, and ice-balance components previously defined, methods have been developed for the determination of internal melt-water accumulation (melt water refrozen in fall below the summer surface plus melt water refrozen in spring during the thawing-out process), and the water produced due to the conversion of potential energy to heat of fusion as a glacier flows downhill.



The lighter colored material is calcite that recently precipitated beneath a modern mountain glacier (Glacier National Park, Mont.) when it overrode the dark-colored Precambrian calcareous bedrock. The rod points in the direction of the movement of the ice.

GROUND-WATER STUDIES

In fiscal year 1979, the Water Resources Division completed a series of professional papers, *Summary Appraisals of the Nation's Ground-Water Resources,* covering 21 regions in the United States. The appraisals address matters of urban area water management, land and water use planning, and the quantity and quality of ground-water supplies.

In some areas of the country, a great deal is known about the ground-water resources. However, integrated information on the aquifer systems for the entire country is inadequate for present needs. It is apparent that with the growing water demands for energy-producing industries, for irrigation, and to meet the needs of rapid urban growth, pumpage of ground water will increase dramatically in the coming decades. Information on ground-water resources must be upgraded if effective management of both surface- and ground-water resources is to be accomplished.

The Regional Aquifer-System Analysis Program (RASA) was established to develop ground-water information from a regional perspective, thus providing a basis both for regional management and for more detailed hydrologic investigations at the secondary scale. Twenty-eight aquifer systems have been identified for study under this Program. Some of these systems are interconnected aquifers and aquitards; others are simply groups of aquifers which are hydraulically independent but which are sufficiently similar to be studied in a single effort. Together, these 28 aquifer systems account for most of the ground-water reserves of the country.

Although each investigation is designed to fit the particular problems of its study area, all of the projects will use computer-based simulations to analyze the existing flow system and to provide predictive capabilities through which the effects of future pumpage, waste disposal, and other stresses can be evaluated. The simulations will be based upon a full assemblage of existing data and such new data as is required to fill critical gaps in the available information. In some cases, collection of this new data will require extensive field operations.

Information will be assembled on the quality of water throughout each aquifer system, again by bringing together all existing information and collecting any field data required to fill the gaps. An effort will be made to interpret this water-quality information in terms of the original flow pattern and the changes that have occurred in response to development, as inferred from the hydraulic simulations. Using the water-quality data in conjunction with predicted flow patterns, as derived from the hydraulic models, some insight may be gained into future quality problems.

Products from each study will consist of a series of reports, beginning with summaries of data as it is assembled, and culminating in interpretative reports including the results of predictive simulations.

The program will continue for approximately 10 years and will utilize such advances in investigative technology as may occur during that period. The average length of study of each aquifer will be approximately 4 years. Three studies were initiated in fiscal year 1978—the High Plains, the northern Great Plains, and the Central Valley of California. Studies of the Southeastern Carbonate aquifers, the Northern Midwest sandstone aquifers, and the Southwest Alluvial basins were initiated in fiscal year 1979.

Significant accomplishments under the RASA Program to date include the development of maps showing water quality, water level, and aquifer characteristics in all of the projects started in fiscal year 1978. Work on similar maps is underway for studies initiated in fiscal year 1979. Several test holes have been completed, and considerable data have been acquired from oil company sources. In the latter category, a drill stem test and a water sampling operation have been conducted on an exploratory well 50 miles off the coast of Florida confirming the existence of fresh water in the Continental Shelf sediments at that distance offshore.

The RASA studies are designed to complement the Geological Survey's continuing program of cooperative ground-water investigations. As a rule, investigations initiated under the Federal-State Cooperative Program are of subregional scope and frequently are oriented to the solution of specific problems. Because the RASA studies are designed to look at the regional picture, they will serve to tie together local investigations, whether past, present, or future; in terms of simulation, they will provide boundary flows for detailed local models. Thus, the RASA Program is expected to act as a stimulus for subregional and local hydrologic investigations.

WATER DATA COORDINATION AND EXCHANGE

OFFICE OF WATER DATA COORDINATION

In fiscal year 1979, the Office of Water Data Coordination (OWDC) continued its coordinating activities with Federal and other organizations and individuals. OWDC is counseled on these activities by two committees. The Interagency Advisory Committee on Water Data (IACWD) is composed of representatives from more than 30 Federal agencies. The Advisory Committee on Water Data for Public Use is composed of members from outside the Federal Government and includes representatives from professional and technical societies, State and regional water agencies, universities, and consultants. The OWDC activity involves the planning, designing, and documenting of water-data programs; development of standards for data acquisition and handling; and coordination of data activities of all Federal agencies.

At the 13th meeting of the IACWD, sponsorship of the Interagency Sedimentation Committee of the Water Resources Council was transferred to the IACWD. Now named the Sub-committee on Sedimentation, this working group published its annual report entitled *Notes on Sedimentation Activities—Calendar Year 1977.*

The first volume, which relates to coal resources, of a special five-volume index to the *Catalog of Information on Water Data* was published. Prepared in cooperation with the Office of Surface Mining, this index will provide information on the availability of water-resources data for the major coal provinces of the United States. In addition to the volume published for the Eastern coal province, the remaining volumes will cover the Interior coal province, the northern Great Plains and Rocky Mountain coal provinces, the Pacific Coast and Alaska coal provinces, and the Gulf Coast coal province.

Developing standards for collecting and handling water data is an important continuing interagency activity sponsored by OWDC. In the past year, chapter 5, "Chemical and Physical Quality of Water and Sediment," was updated, and chapters on "Snow and Ice" and "Hydrometeorological Observations" were completed.

Two new working groups were established to prepare chapters for the *National Handbook of Recommended Methods for Water-Data Acquisition.* The chapters will cover "Water Use Data" and "Data Handling and Exchange."

NATIONAL WATER DATA EXCHANGE

The National Water Data Exchange (NAWDEX), established in 1976, is a confederation of water-oriented organizations working together on a national basis to improve access to water information by assisting users in the identification, location, and acquisition of needed data. A central program office within the Water Resources Division coordinates this linkage and provides overall management of the program.

NAWDEX services are available through an expanded nationwide network of 60 Assistance Centers, located in 45 States and Puerto Rico, which provide direct access to NAWDEX and make local-area expertise available to aid in locating needed data. This network includes the facilities of 52 Geological Survey District and Subdistrict Offices, the Texas Natural Resources Information System (TNRIS), the Water Resources Research Institute of the Virginia Polytechnic Institute and State University, the Iowa Water Resources Data System, the Nebraska Natural Resources Information System, the Great Lakes Information Center, the Utah Division of Water Rights, the Utah State University Center for Water Resources Research, and the Colorado Water Resources Research Institute.

NAWDEX maintains two computerized data bases in the Geological Survey's computer system in Reston, Va., which are accessible by the Assistance Centers. The *Water Data Sources Directory* contains information compiled for more than 660 organizations. Information on other organizations will be added on a continuing basis. NAWDEX also maintains a nationwide indexing service through its Master Water Data Index. In 1979, this computerized index was expanded to identify more than 310,000 sites for which water data are available. Additional sites are being added on a continuing basis.

NAWDEX also has direct access to and disseminates water data stored in the Environmental Protection Agency's Storage and Retrieval System (STORET) and in the Geological Survey's National Water Data Storage and Retrieval System (WATSTORE). STORET services are available through the NAWDEX program office and through TNRIS. Data from WATSTORE are available through most of the Assistance Centers. NAWDEX also has service-exchange arrangements with the Environmental Data and Information Service of the National Oceanic and Atmospheric Administration, the Water Resources Scientific Information Center of the U.S. Department of the Interior, and the Water Document Reference Centre of the Canadian Department of the Environment. Various types of water data are available from data systems of other member organizations. NAWDEX can, therefore, readily assist users to locate data available for a specific geographic area.

FLOODS

BACKWATER AT BRIDGES AND DENSELY WOODED FLOOD PLAINS

A series of 22 *Hydrologic Investigations Atlases* designed to improve methods of computing the backwater effects of bridges on floodflows in densely vegetated areas was published by the Geological Survey in 1978-79. The atlases covered 10 sites in Mississippi, 7 sites in Louisiana, and 5 sites in Alabama. Thirty-five floods were measured.

The atlases provide flood data needed to develop improved computer models that can better predict the backwater effects where wide densely wooded flood plains are crossed by highway embankments and single-opening bridges. The reports and the methodology were developed by the Geological Survey in cooperation with the U.S. Department of Transportation, the Federal Highway Administration, the Alabama State Highway Department, the Louisiana Department of Transportation and Development, and the Mississippi State Highway Department.

Bridges and embankments can contribute significantly to the height of floodwaters and the amount of backwater that causes overland flooding. Improved accuracy in predicting these effects will not only result in more economical bridge designs but also can reduce substantially the potential damage from future floods.

Each atlas contains a descriptive text and shows flood measurements. Data are presented in metric units on enlarged topographic maps with scales ranging from 1:2,000 to 1:8,000. Measurements include water depths, velocities, and discharges through bridge openings together with peak water-surface elevations along highway embankments and valley cross sections; roughness coefficient values; and flood-frequency relationships.

DOCUMENTATION OF MAJOR FLOODS

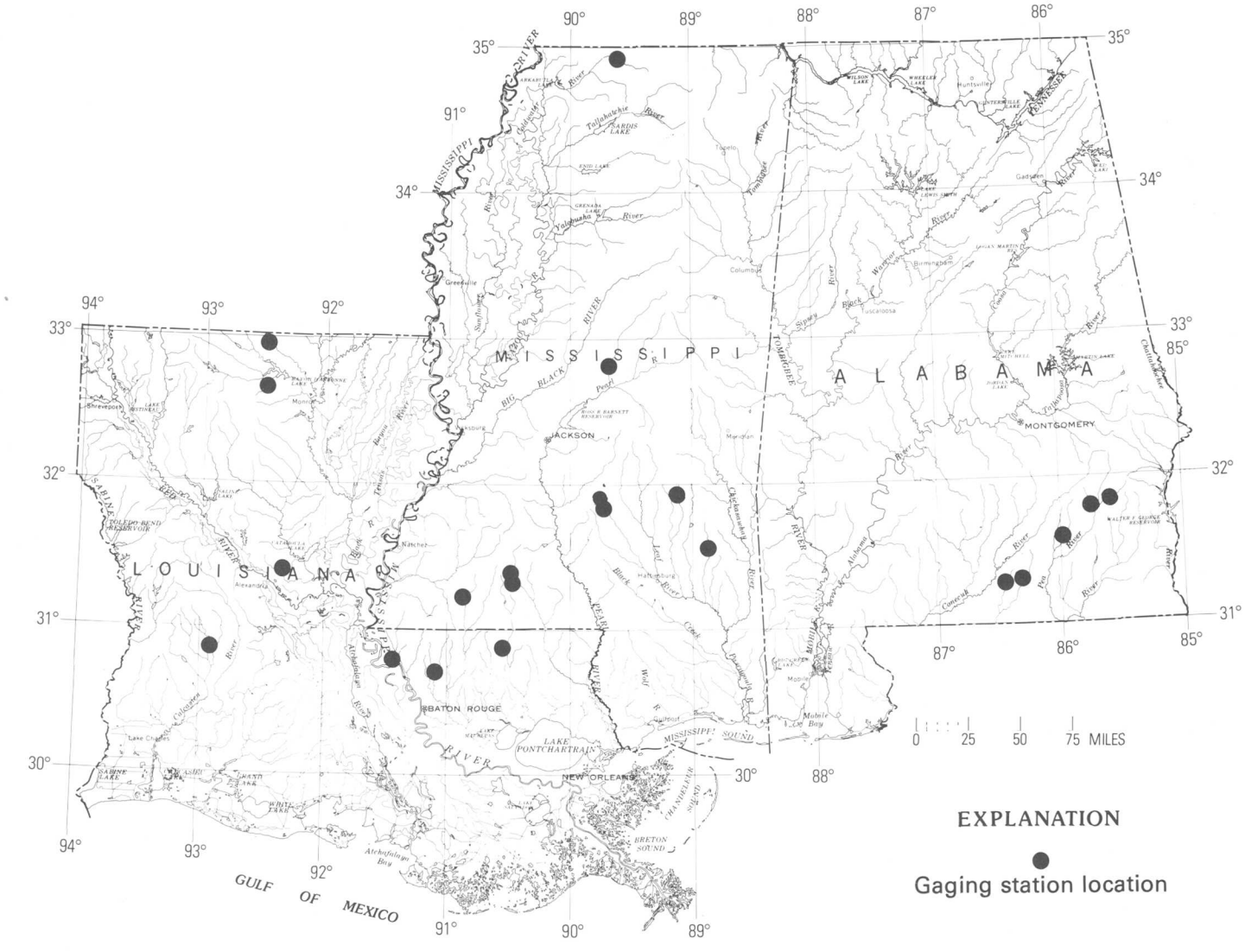
The Geological Survey and the National Weather Service have a long history of cooperation in monitoring and describing the Nation's hydrologic cycle—the movement of water as atmospheric moisture, as precipitation, as runoff, as streamflow, and as ground water and, finally, its evaporation into the atmosphere to begin the cycle again. The National Weather Service is the Federal agency responsible for monitoring and predicting atmospheric moisture and precipitation, for forecasting riverflow, and for issuing warnings of destructive weather events. The Geological Survey is the primary agency for monitoring the quantity and quality of the Earth-bound water resources. Documentation of major floods in the United States is an example of the cooperative working arrangement between the two agencies. Such investigations of disastrous floods which cause loss of life and billions of dollars in property damage provide the technical information needed to cope with future floods of catastrophic magnitude.

In 1979, in cooperation with the National Weather Service, the Geological Survey published Professional Paper 1087, *Maine Coastal Storm and Flood of February 2, 1976.* The report documents the meteorological and hydrological conditions associated with the flooding and contains a description of storm damage, including flood elevations at various locations.

Professional papers documenting the major floods which were under investigations in 1979 will be published. These are Mississippi and Alabama—April 1979; central Texas—August 1978; Powder River and Bighorn River basins, Montana and Wyoming—May 1978; Greater Kansas City, Missouri and Kansas—September 1977; Johnstown area, western Pennsylvania—July 1977; Appalachian region of Kentucky, Tennessee, Virginia, and West Virginia—April 1977; and Big Thompson River and Cache La Poudre River basins, Larimer and Weld Counties, Colorado—July-August 1976.

Study sites in the Bridge Backwater Investigation Project in Alabama, Louisiana, and Mississippi. ▶

Looking downstream toward single-opening bridge and highway embankment, Yockanookany River near Thomastown, Miss. Overflow on densely wooded flood plain may be more than a mile wide during a major flood. The width of the bridge opening is about 600 feet.



Conservation of Lands and Minerals

MISSION

The Conservation Division performs several evaluation and regulatory functions concerning the leasing, classification, operations, and use of mineral and water resources on Federal and Indian lands. These functions were delegated to the U.S. Geological Survey by the Secretary of the Interior and are accomplished through two major missions:

- Evaluation of resources, which includes the classification of public lands to identify areas containing potentially valuable leasable minerals and areas valuable for waterpower and water-storage purposes and evaluation of mineral resources on tracts of public land that are made available for private development through a competitive leasing process, are exchanged or are sold.
- Supervision of operations, which is associated with the exploration, development, and production of minerals from leased Federal, Indian, and Outer Continental Shelf (OCS) lands, including the collection of royalties for minerals produced and certain rentals.

The Geological Survey acquired data for the sound development of mineral resources, for protection of the environmental characteristics of public lands and also supported the missions of other Federal agencies. These agencies include the Bureau of Land Management (BLM), the Bureau of Indian Affairs, the National Park Service, the Bureau of Reclamation within the Department of the Interior and the Department of Defense, the Forest Service, the General Services Administration, the Environmental Protection Agency, and the Department of Energy outside the Department.

Production and value of all minerals produced from Federal and Indian lands are provided on a calendar year basis to be compatible with statistics published by the Department of Energy, the State governments, and private industry and to facilitate comparison of data.

In 1979, Federal and Indian lands supplied a significant portion of the Nation's mineral production. More than 14.8 percent of the oil, 29.42 percent of all natural gas, and 10.4 percent of the Nation's coal were produced from leases on Indian and Federal lands onshore and offshore. This production clearly demonstrates the importance of the contribution from these lands to the Nation's supply of petroleum and other minerals and has had a significant impact on the Nation's economy. For example, in 1979, the value of all mineral commodities produced from leased Federal and Indian lands exceeded $12 billion. Lease rentals, royalties from production of minerals, and various bonus payments provided more than $6 billion in revenue for the Federal Government. Tables 22 to 27 containing detailed statistical information can be obtained upon request from the Survey.

The authority to classify public lands and to regulate mineral development on Federal and Indian lands, to protect the environment, and to collect a fair return from extracted resources lies in a complex body of mineral and land laws, some of which date back to the 1870's.

Congress stipulated in the Act of March 3, 1879, which created the U.S. Geological Survey, that the Director of the Survey should classify the public lands to identify features pertaining to land values for many purposes. In 1906, the President directed the Secretary of the Interior to immediately withdraw from entry all valuable coal lands on the public domain. Coal lands in Alabama, Arkansas, and Wyoming were withdrawn and later classified under this directive. Subsequently, Congress passed the Withdrawal Act of 1910 which authorized the President to withdraw public lands from settlement, location, sale, or entry. This Act resulted in the immediate reservation of about 100 million acres of public lands for their potential coal reserves. Once withdrawn, the Geological Survey began to examine these lands and to classify them; the lands found to have no coal were restored to entry, and those found to contain workable coal beds were appraised and priced at varying amounts per acre. Because the lands withdrawn included some lands that were valuable for farming, Congress passed the Separation Acts of 1909 and 1910 which provided for the separation of the surface estate from the subsurface estate, thus permitting land claimants to obtain patents to the land surface while reserving to the United States the mineral deposits and the right to prospect and mine them.

The Mineral Leasing Act of 1920 ended the practice of disposing of coal lands at appraised values and provided for the leasing of coal and certain other mineral commodities. The leasable minerals on public lands now include oil, gas, coal, potash, sodium, phosphate, oil shale, asphaltic minerals, sulphur (only in New Mexico and Louisiana), and geothermal resources. Under the provisions of the 1920 Act as amended and supplemented, a permit to explore public lands for minerals other than oil, gas, oil shale, and geothermal resources may be obtained; however, if the land is determined by the Geological Survey to contain a known leasable mineral deposit, it is subject to competitive bidding for a lease. All minerals on acquired and Indian lands are leasable. A lessee is required to pay the Federal Government a stipulated royalty on production. Other laws authorize the leasing and management of metallic and nonmetallic minerals on Indian lands, railroad and other rights-of-way across public lands, acquired lands, and Outer Continental Shelf (OCS) lands.

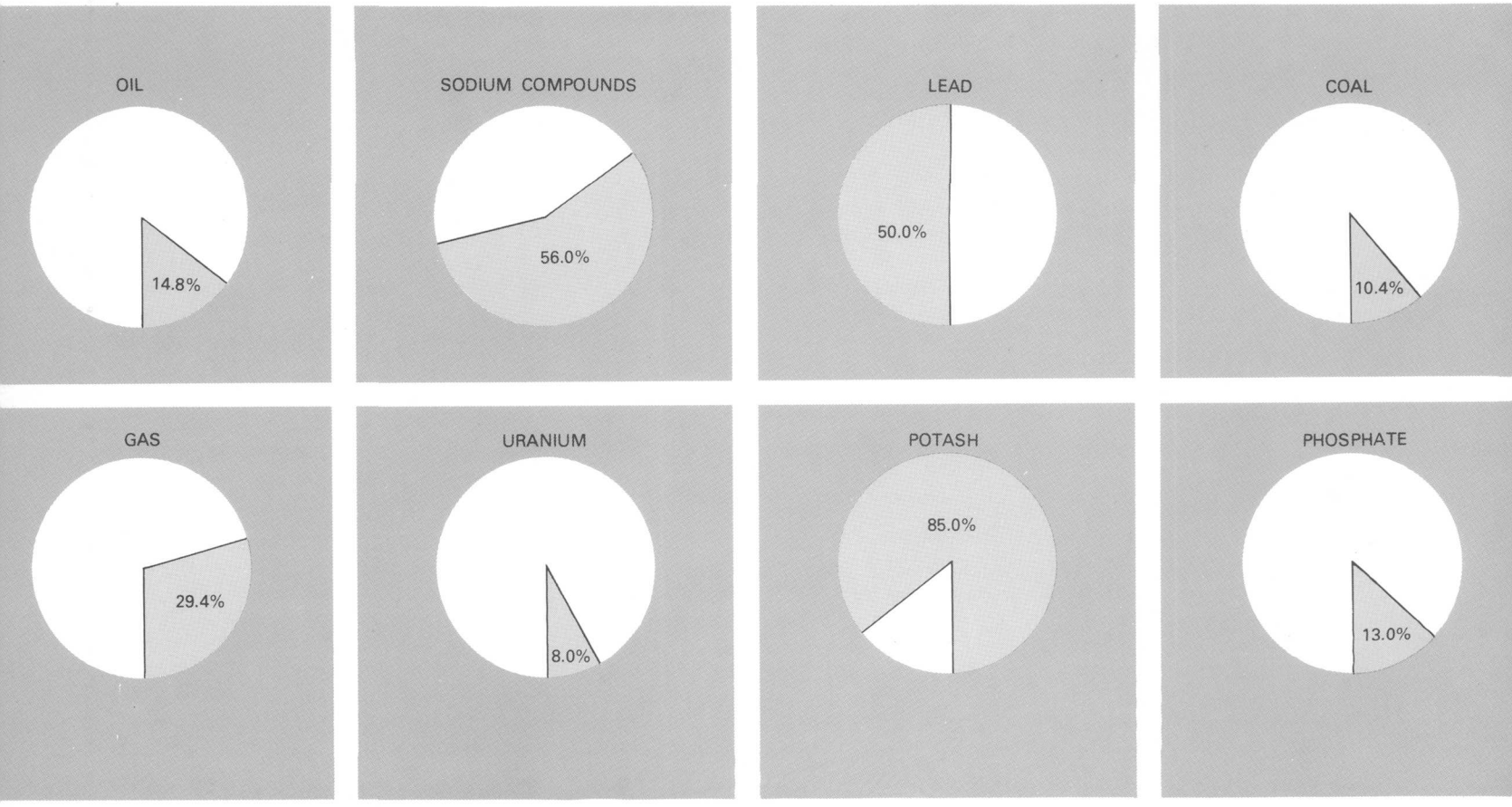
Pursuant to these various statuatory authorities, the Secretary of the Interior has promulgated numerous rules and procedures pertaining to the development of minerals on the Federal and Indian lands in the Code of Federal Regulations. The principal codes governing operations on Federal mineral leases are as follows:

- Outer Continental Shelf Leasing Regulations—Part 3300 of Title 43.
- Outer Continental Shelf Operating Regulations—Parts 225a, 250, and 260 (Proposed) of Title 30.

- Onshore Federal Lands Leasing Regulations—Parts 3100, 3200, and 3500 of Title 43.
- Onshore Federal Lands Operating Regulations—Parts 211, 221, 223, 225, 226, 231, 270, and 271 of Title 30.
- Indian Lands Leasing and Operating Regulations—Parts 171, 172, 173, 174, 176, and 177 of Title 25 and the pertinent onshore Federal operating regulations contained in Title 30.

Leasing regulations are issued by the Bureau of Land Management (BLM) and the Bureau of Indian Affairs, but some provisions of leasing regulations and all provisions of operating regulations are implemented and enforced by the Geological Survey.

Cordero Mine, a surface coal mining operation located 20 miles southeast of Gillette, Wyo., produced an estimated 4 million tons from a 60-foot coal seam mined in two benches. The Sun Oil Co. initiated work on July 22, 1976.



Production from Federal, OCS, and Indian lands as a percentage of total U.S. production in calendar year 1979 (estimated in part).

Coal drilling and mining operations in Colorado.

BUDGET AND PERSONNEL

The source of funds for these programs is described under the Conservation of Lands and Minerals Budget Activity in the Geological Survey Budget. Funds for these activities have increased by 10.4 percent to almost $85.5 million in fiscal year 1979. Program obligations for fiscal years 1978 and 1979 are shown in the table. The OCS lands subactivity was appropriated about $49.1 million an increase of 6.8 percent over the appropriation for fiscal year 1978. In fiscal year 1979, funding for the Federal and Indian lands subactivity increased to a total of approximately $36.2 million, which represents a 15.7-percent increase.

In response to an increased workload, the Division has expanded its employment base in such areas as economics, automated data processing, and environmental sciences, in addition to the traditional disciplines of geophysics, geology, and petroleum and mining engineering.

Conservation of Lands and Minerals activity obligations for fiscal years 1978 and 1979, by subactivity
[Dollars in millions. Data may differ from that in statistical tables because of rounding]

Subactivity	Fiscal year 1978	Fiscal year 1979
Total	**$77.5**	**$85.5**
Outer Continental Shelf (OCS) lands	**46.0**	**49.1**
Direct program	46.0	49.1
Reimbursable program	----	----
States, counties, and municipalities	----	----
Miscellaneous non-Federal	----	----
Other Federal agencies	----	----
Federal and Indian lands	**31.5**	**36.4**
Direct program	31.3	36.3
Reimbursable program	.2	.2
States, counties, and municipalities	----	----
Miscellaneous non-Federal	----	----
Other Federal agencies	.2	.2

SOURCE OF FUNDS

TOTAL $85.5 MILLION

USE OF FUNDS

THE GEOLOGICAL SURVEY HELPS IMPLEMENT THE SECRETARY'S COAL POLICY

On June 1, 1979, Interior Secretary Cecil W. Andrus established a new program directed at the development of Federal coal reserves in ways acceptable to State and local governments, the coal industry, environmental groups, and the public. This program was established after 2 years of intensive study by the Department of the Interior. The program allows for the competitive leasing of Federal coal to be resumed for the first time since an informal moratorium was imposed in 1971. Geological Survey personnel made major contributions in formulating the Secretary's Federal Coal Management Program by participating on task forces analyzing individual aspects of the Program; by assisting in the Secretary's Office of Coal Leasing, Planning, and Coordination; and by recommending various options for the Secretary's decisions.

The Federal Coal Management Program has two distinct elements, issuance of new leases and the management of new and existing leases. The major prelease activities in the competitive leasing phase support BLM in land use planning, activity planning, and lease sales; the major postlease activity is management of operations on leases. The Geological Survey provides geologic, engineering, and economic evaluation input primarily in the prelease program elements.

A critical portion of land use planning is the identification of areas with high and moderate potential for minable coal. Only areas of high or medium potential are considered for competitive leasing. By using established geologic and economic criteria, the Survey classifies lands with respect to their coal potential and land with minable coal into Known Recoverable Coal Resource Areas (KRCRA's). These areas are mapped to show their coal potential as part of the Coal Resource Occurrence/Coal Development Potential (CRO/CDP) Program. Data used in this analysis come from public, private, and industry sources. To date, this project has identified lands containing approximately 76.2 billion tons of Federal coal of high and medium development potential.

Initial tract delineation is proceeding in the Green River-Ham's Fork, Uinta SW Utah, and Alabama coal regions. Tract profile reports prepared by the Survey provide data on the geologic, engineering, environmental, social, and economic impacts of mining on each tract delineated. Tract selection, ranking, and regional environmental impact statements follow delineation.

After a sale is scheduled by the Secretary of the Interior, the Geological Survey must calculate the Coal Resource Economic Value (CREV) for each tract to be offered. CREV forms an integral part of the fair-market value or the minimum acceptable bid for each tract. The concept of fair-market value assures that the people of the United States receive a fair price for potential resources to be leased.

Outstanding preference right lease applications will be examined to determine the existence of commercial quantities of coal. Modifications of lease boundaries, right-of-way cases, emergency lease sales, and proposed land exchanges are also being evaluated.

In fiscal year 1979, the Survey conducted 26 economic evaluations of coal, completed 146 quadrangles as a part of the CRO/CDP Mapping Program, classified over 1.25 million additional acres in KRCRA's, completed administrative work on one comprehensive coal exchange and continued work on another, and conducted drilling operations (fig. 1) and drilled 606 holes with a cumulative depth of approximately 300,000 feet.

The Geological Survey is responsible for the review and approval of exploration plans submitted by coal lessees on Federal and Indian lands and for the inspection and enforcement of regulatory requirements, including reclamation of areas disturbed by exploration activities. During fiscal year 1979, coal lessees drilled 2,791 holes for a total footage of 610,088.

The Survey is also responsible for the review and approval of mining plans submitted by coal lessees on Federal and Indian lands and for the inspection and enforcement of regulatory requirements pertaining to coal mining operations based on the requirements mandated by the Mineral Leasing Acts. The regulations include rules concerning the formation of logical mining units, diligent development, maximum economic recovery, protection of other mineral resources from damage by coal mining operations, and the collection of royalties.

In addition to the supervision of exploration and mining operations by lessees on Federal lands, the Survey assists BLM in its responsibilities on coal leases by providing geologic, engineering, and economic evaluations when required in the periodic readjustment of the terms and conditions of coal leases, including changes in royalty rates and lease exchanges.

The production of coal was 55.6 million tons from Federal lands and 21.3 million tons from Indian lands during fiscal year 1979. Royalties derived from Federal and Indian leases amounted to $24 million.

The environmental protection and reclamation responsibilities of coal mining operations were transferred from the Geological Survey to the Office of Surface Mining (OSM) by the Surface Mining Control and Reclamation Act of 1977. The Survey, OSM, and BLM have finalized a memorandum of understanding for the purpose of coordinating their activities.

Figure 1.—Coal drilling and mining operations in Colorado.

OUTER CONTINENTAL SHELF ACTIVITIES

Oil and gas leases on the OCS are issued by BLM, but the Geological Survey implements and enforces the regulations concerning operations. The Geological Survey and BLM consult with each other on all the significant actions that precede each lease sale. The Survey provides BLM with the following information:

- Assessments of petroleum resources and other technical information used to identify areas to be leased and to schedule lease sales.
- Resource evaluations used to select tracts for each lease sale.
- Identification of geologic hazards.
- Mineral resource values for each tract to be used in determining the resource economic value.

The Survey's resource-evaluation activities on the OCS focus on identifying areas for future lease sales, advising BLM on the selection of tracts to be offered for each sale, estimating the value of oil and gas on each tract that is to be offered, and determining geologic hazards that affect specific tracts.

The Geological Survey supervises the activities of lessees who explore for, develop, and produce oil and gas on the OCS. The Survey ensures that operations are conducted in compliance with Federal laws and Department of the Interior regulations for the conservation of the mineral resources and the protection of the ocean environment and that the royalties collected for the Government are correct and current. (The supplementary tables are available upon request.)

Lease sales on the OCS conducted during fiscal year 1979 resulted in leasing 290 of the 678 tracts offered by the Federal Government to private companies. The Government received $2.79 billion in bonus bids. The results of the individual sales were as follows:

Sale No.	*Date*	*Region*	*Tracts offered*	*Tracts sold*	*Total bonus bids (in millions of dollars)*
65	10-31-78	Gulf of Mexico	89	35	61
51	12-19-78	do	128	81	872
49	2-28-79	South Atlantic	190	39	40
48	6-29-79	Southern California	148	54	573
58	7-31-79	Gulf of Mexico	123	81	1,248
			678	290	2,794

The production of hydrocarbons from the Cognac platform, located 12 miles southeast of the mouth of the Mississippi River in the Gulf of Mexico, began during fiscal year 1979. The platform is the heaviest, deepest water, steel drilling production platform in the world. It was also the first platform jacket to be installed in three separate sections. The platform is installed in 1,025 feet of water and weighs about 59,000 tons. The platform has slots for 62 wells and is designed so that two drilling rigs can conduct operations simultaneously.

During fiscal year 1979, of the nine new wells spudded in the Mid-Atlantic Ocean, eight were plugged and abandoned, and drilling continues on the ninth. One gas discovery with a show of oil was announced by Tenneco in Hudson Canyon NJ 18-3 Block 642. In the South Atlantic, of the four wells spudded, three were plugged and abandoned with no discoveries announced; drilling continues on the fourth. Five wells were drilled in Alaska's Lower Cook Inlet; three were plugged and abandoned with no discoveries announced. Two wells were drilled off southern California; both were plugged and abandoned without encountering significant hydrocarbons.

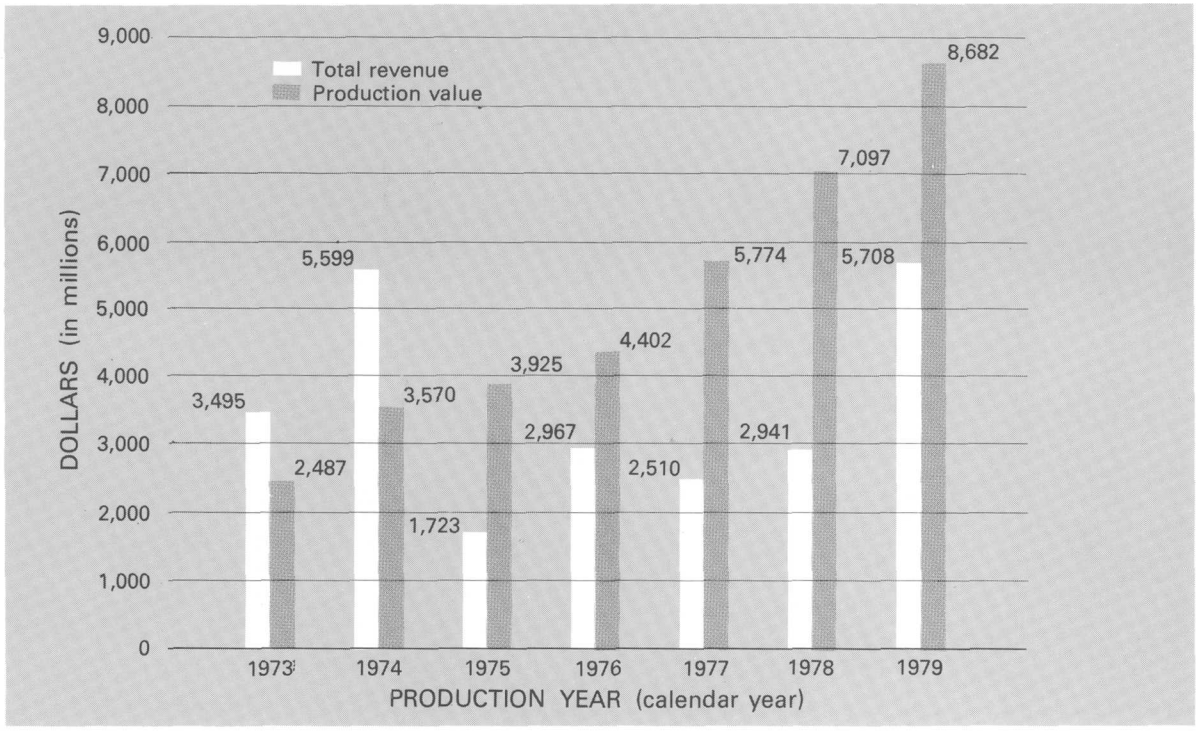
Drilling and production activities can be measured in several ways such as the number of approved applications for permit to drill, the number of hole starts, the number of new oil and gas well completions, and the number of production platforms installed.

Before a well is drilled on a Federal lease, the lease operator must submit an application for a permit to drill. During calendar year 1978, 1,189 permits to drill were approved. It is estimated that by the end of calendar year 1979, 1,150 permits will have been approved.

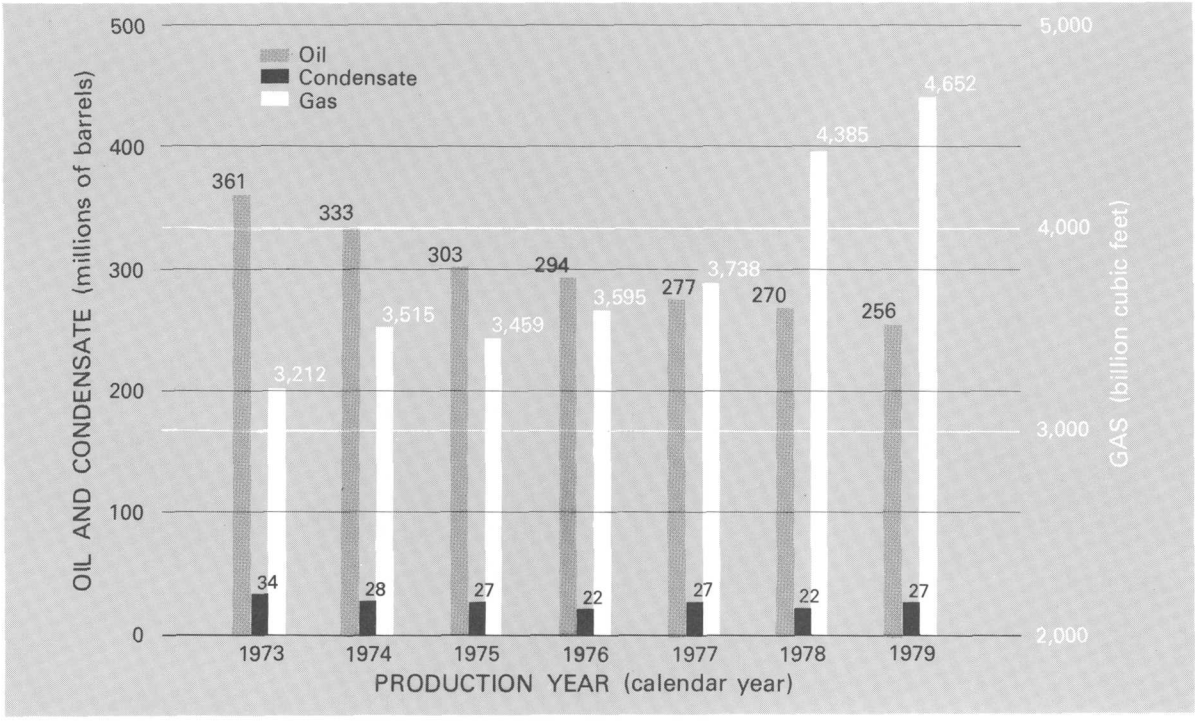
The number of new hole starts for calendar year 1979 is not expected to be significantly more than 1,148, the number reported for calendar year 1978. It is estimated that 226 new oil zones and 465 new gas zones will be completed on the OCS by the end of the calendar year 1979, as compared to 221 oil zones and 455 gas zones for calendar year 1978.

The number of production platforms on the OCS increased during the year. At the beginning of the year, 2,332 platforms had been completed on the OCS (7 in the Santa Barbara Channel off the Southern California Coast and 2,325 in the Gulf of Mexico), and an additional 143 platforms are likely to be installed by the end of 1979 (2 in the Santa Barbara Channel).

The accompanying graphs show the total revenues, values, and production of oil, condensate, and natural gas for 1973 to 1979 (1979 estimated in part). The production of oil is expected to continue its downward trend, and gas production is expected to increase. Condensate production, which is tied to gas production, is also expected to increase.



Revenue and Production Value, Outer Continental Shelf.



Oil, condensate, and gas production on the Outer Continental Shelf.

Glomar Pacific was the first rig to begin drilling on the Atlantic Outer Continental Shelf. ▶

Outer Continental Shelf platform in Gulf of Mexico. ▶

◀ Moon pool as seen from rig.

▼ Diver observing fish beneath platform structure.

IMPLEMENTATION OF THE OUTER CONTINENTAL SHELF LANDS ACT AMENDMENTS OF 1978

Enactment of the Outer Continental Shelf Lands Act Amendments on September 18, 1978, had a significant impact on the regulatory and resource-evaluation programs of the Geological Survey. The new law requires the compilation of new reports, the initiation of new studies, the development of new programs and the regulations to govern the implementation of those programs, and the revision of existing regulations to conform with the requirements of the new law.

A number of statutory provisions specify the reports to be submitted, their contents, and the deadlines for submission. The first of the required reports completed during fiscal year 1979 set forth recommendations for a program to assure proper training of any individual who is employed on any artificial island, installation, or other device located on the OCS and, as part of such employment, operates or supervises the operation of pollution-prevention equipment.

This report to Congress was prepared in consultation with the U.S. Coast Guard. Another report to Congress described the extent of delinquent lease royalty accounts during fiscal years 1977 and 1978. That report also included the new auditing, postauditing, and accounting procedures that have been adopted to assure accurate and timely payment of royalties and net profit shares. A report to the Comptroller General listed all shut-in oil and gas wells and wells flaring natural gas on leases issued under the Outer Continental Shelf Lands Act.

The new studies included one conducted in cooperation with the U.S. Coast Guard. The study evaluated the adequacy of existing safety and health regulations and the adequacy of the technology, equipment, and techniques available for the exploration, development, and production of the minerals of the OCS.

With the help of the Marine Board of the National Research Council, the Geological Survey is evaluating the alternative procedures for implementing the new amendments requiring that all new drilling and production operations and, wherever practical, all existing operations use the best and safest technologies available whenever failure of equipment would have a significant effect on safety, health, or the environment.

During fiscal year 1979, new regulations were developed that implemented the Secretary's responsibility to assess, to collect, and to impose civil penalties for failure to comply with a provision of the Act, of a lease or permit issued under the Act, or of any regulation or order issued under the Act. The new regulations were formulated as a result of close cooperation between representatives of the U.S. Coast Guard and of the Geological Survey.

The Survey was assigned a new responsibility for establishing air-quality standards during fiscal year 1979. Regulations describing proposed guidelines for the program should be published in early calendar year 1980.

The new and revised regulations to implement the requirements of the Outer Continental Shelf Lands Act Amendments of 1978 were divided on the basis of subject matter. Revision of the new regulations governing the processing of exploration plans and development and production plans published January 27, 1978, received highest priority.

Revised OCS Oil and Gas Information Program regulations became effective October 9, 1979, and the regulations governing oil and gas and sulphur operations in the OCS will be effective December 13, 1979. The new program for assessing, collecting, and compromising civil penalties will require the development and putting into place of complex practices and procedures to protect the rights of the persons who are accused of violations of the Act, a lease, a regulation, or an order. This must be done while providing an effective and efficient means for administering the governing provisions of the Act. Because these provisions relate to violations of regulations of the Coast Guard and the U.S. Army Corps of Engineers, the offices of the Conservation Division must coordinate with the Coast Guard and the Corps of Engineers to enforce the regulations.

Implementation schedule for new and revised OCS regulations required by the OCS Lands Act Amendments.

CFR No.	*Subject matter*	*Advance notice*	*Proposed rule*	*Public hearing(s)*	*End of public comment period*	*Final rule and implementation*
250.34	Exploration plans, Development/Production plan, and so forth.	---------	1-19-79 Los Angeles	2-27-79	3-16-79	9-14-79
				3- 1-79 New Orleans		Effective 12-13-79
				3- 5-79 Washington, D.C.		
252	OCS Oil and Gas Information Program.	---------	1-19-9	2-27-79 Los Angeles	3-16-79	Effective 10- 9-79
				3- 1-79 New Orleans		8- 7-79
				3- 5-79 Washington, D.C.		
250.57	Air quality ----------	12-27-78	5-10-79	6- 7-79 Los Angeles	7-13-79	---------
				6-12-79 New Orleans		
				6-14-79 Washington, D.C.		
	Best Available and safest technology.	2- 8-79	---------	---------	---------	---------
250	Regulation of lessees ----------	---------	3-12-79	5- 8-79 Washington, D.C.	5-18-79	10-26-79 Effective 12-13-79
251	Geological and Geophysical Exploration Regulations.	---------	2- 9-79	5- 8-79 Washington, D.C.	5-18-79	----------
250.50 250.51	Unitization ----------	---------	8-10-79	None	11- 5-79	---------

Fish in moon pool.

ACCOMPLISHMENTS UNDER THE NATURAL GAS POLICY ACT OF 1978

The Geological Survey began developing procedures to implement the Natural Gas Policy Act (NGPA) in late 1978. The NGPA allows lessees and operators to receive higher prices for natural gas produced from certain oil and gas wells requires that the Survey, as the jurisdictional agency for regulation of operations for OCS, Federal, and Indian lands, determine whether a given well is in a category that permits a higher price for gas. Once the determination is made, the Survey then forwards the application and determination to the Federal Energy Regulatory Commission (FERC) for concurrence. In the same manner, respective State agencies make determinations on the applications submitted for State and private lands under their jurisdiction. Through this process, the pricing policy set forth in the NGPA becomes a reality.

To implement the NGPA and the associated FERC regulations, the Geological Survey issued a "Notice to Lessees" to provide lessees and operators with the format to apply to have a well classified in a category that would have a higher gas price.

Categories of natural gas subject to NGPA pricing if not otherwise bound by contract	Prices by category (Dollars per million BTU's) December 1978	October 1979
New OCS leases—issued on or after April 20, 1979.	2.078	2.292
New onshore wells—began drilling or began increasing depth on or after February 19, 1977, with marker well.	2.078	2.292
New onshore reservoirs—not produced in commercial quantities before April 20, 1977, and so forth.	2.078	2.292
New reservoir, old OCS lease—reservoir not discovered before July 27, 1976, and so forth.	2.078	2.292
New onshore production well—began drilling on or after February 19, 1977, in compliance with spacing and proration unit rules, and so forth.	1.969	2.113
High-cost natural gas—began drilling on or after February 19, 1977, and completed deeper than 15,000 feet.	2.078	2.292
Stripper-well natural gas—well produced at its MER[1] over a 90-day period with average rate or more than 60,000 cubic feet per day, and so forth	2.224	2.452

[1] Maximum efficiency rate.

From December 1978 through September 1979, the first 10 months under the NGPA, the Geological Survey processed 7,598 applications and made 4,469 determinations. Operators of approximately one-ninth of the producing wells on OCS, Federal, and Indian lands have submitted requests for a determination decision. Currently, 300 additional applications are being submitted each month.

In addition to the determinations work, the NGPA makes necessary a change in traditional pricing for royalty purposes. Under the old Natural Gas Act, the price of gas was calculated for a producing area. Under the NGPA, pricing of gas is calculated for individual wells with an inflation factor that changes monthly. Thus, calculations for production royalty become more complex. A single lease may have many producing wells, with gas from each well being assigned a different price. Such a pricing method means that the Geological Survey must install a system whereby it can determine what the royalty price should be for a given lease under Title 30 CFR Part 250.66 by considering every well on the lease and the respective prices being paid by the buyers as against what the NGPA provides. Such a system is being developed but will require several months for implementation.

Pipe-laying activity in the Gulf of Mexico Outer Continental Shelf.

OIL AND GAS

Oil and gas produced from onshore Federal and Indian lands comprised about 6.4 percent of the oil and 5.9 percent of the gas produced in the United States last year. Production of oil and condensate and gas from Federal onshore and Indian lands for 1973 to 1979 is shown in the graph. The Geological Survey conducted geological investigations, environmental analyses, and other studies related to safety requirements, legal matters, and socioeconomic aspects related to carrying out the regulatory responsibilities related to producing this oil and gas.

During fiscal year 1979, the Geological Survey approved 3,550 Applications for a Permit to Drill (APD) (fig. 1) for exploratory (fig. 2) and development wells on Federal leases. The Survey prepared 3,660 environmental analyses (fig. 3) to consider the potential environmental impacts that might result from operations on Federal lands. This level of activity was the same as the previous fiscal year.

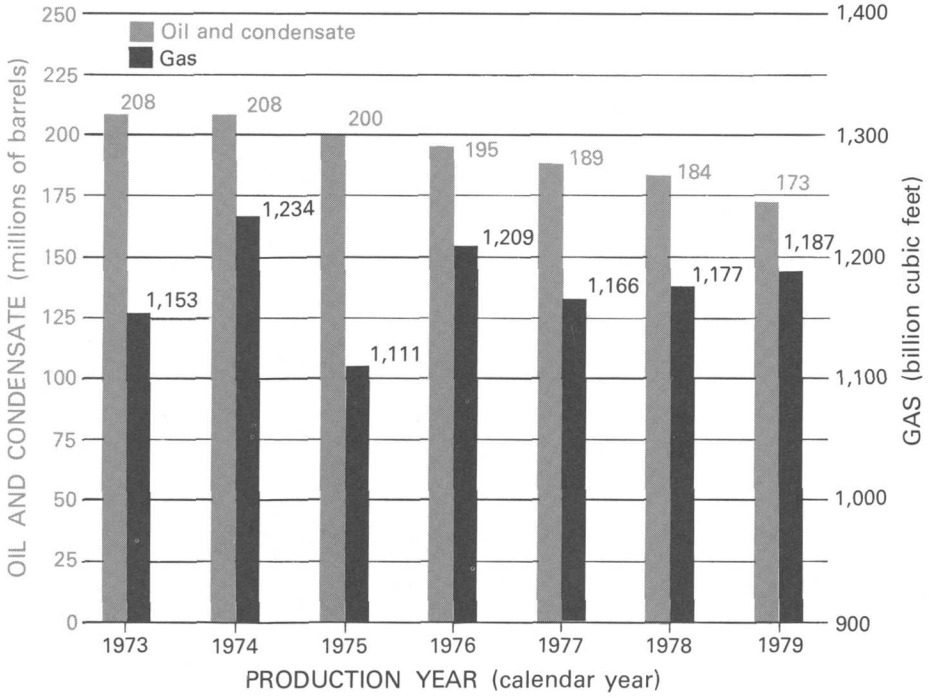
During fiscal year 1979, 2,610 new wells on Federal leases were started. Of these wells, 1,810 were completed as usable holes either for the production of oil and gas or for the injection or disposal of fluids.

The number of wells on Federal and Indian lands, the number of Federal and Indian leases, and the royalties collected from oil and gas production on these leases have continued to increase, even though the total domestic production of oil and gas is declining. Private companies are attempting to offset this decline in production by exploring in frontier areas such as the overthrust belt of Utah, Wyoming, Idaho, and Montana. They are also conducting research and trying new or improved methods of increasing the amount of oil and gas recovered from depleted and depleting reservoirs.

Formerly unattractive source rocks for oil and gas, such as the "tight gas sands" that occur in northwestern Colorado, eastern Utah, and northern Montana, have become attractive prospects because the present prices of oil and gas have made drilling for and producing oil and gas from these reservoirs economically feasible. Some "shut-in" remote areas will become producible when processing facilities and pipelines are built in these areas.

The development and use of improved primary methods and secondary and tertiary enhanced recovery processes have restored production at many oil fields that were produced by using primary methods only. Secondary recovery methods include repressuring or flooding with gas or water. Tertiary methods include flooding with chemical solvents or stimulation with heat to continue production after secondary recovery becomes uneconomic. In addition, well completion techniques and formation stimulation processes constantly are being improved and will continue to add increments of production to the total amount of oil and gas produced. During this period of uncertainty about the continued uninterrupted supply of energy minerals, industry is using every means available to explore for and develop new sources of oil.

Steam injection.



Oil, condensate, and gas production on Federal onshore and Indian lands.

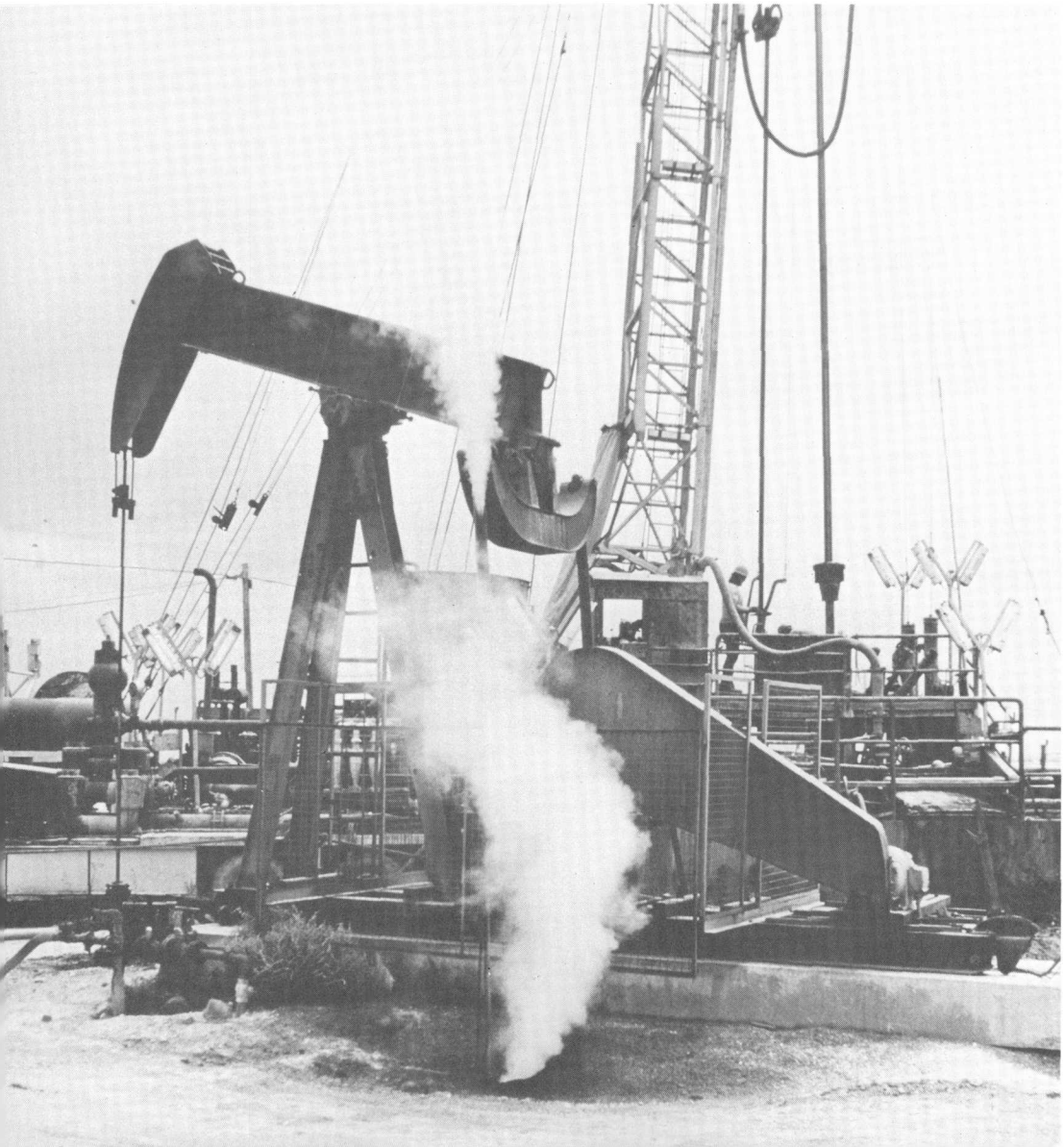
REVIEW OF APD

1 Administrative
- Lease status
- Ownership
- Bond
- Location

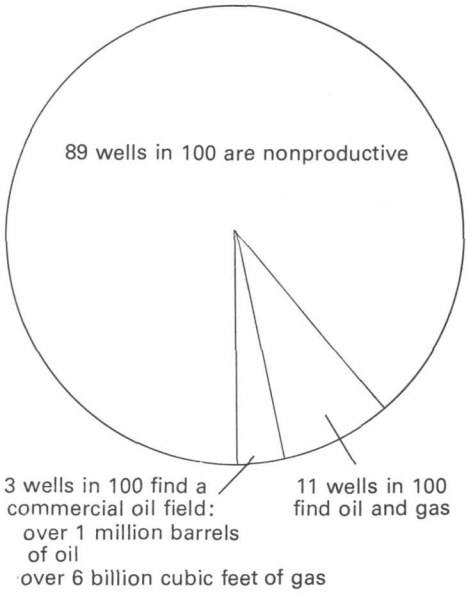
2 Technical
- Casing
- Cement
- Blowout preventers
- Drilling mud
- Safety and health

3 Surface use
- Roads
- Facilities
- Water supply
- Construction materials
- Waste disposal
- Well-site layout
- Restoration plans
- Other pertinent information

Figure 1.—Review of Application for a Permit to Drill.



▼ Figure 2.—Exploratory wells.



CONTENT OF ENVIRONMENTAL ANALYSIS

1 Description of the proposed action
What, where, when, how

2 Environmental considerations related to the proposed action
- A—Nonliving components
- B—Living components
- C—Ecological interrelationships
- D—Human values

3 Alternatives to the proposed action

4 Unavoidable adverse environmental effects of the proposed action

5 Controversial issues and conservation division responses

6 Determination

▲ Figure 3.—Content of environmental analysis.

GEOTHERMAL RESOURCES

Geothermal resources include the exploitable heat stored in the Earth's crust that can be utilized either by conversion of heat energy to electrical or mechanical energy or by direct utilization of the heat. Only a small fraction of the potentially exploitable geothermal energy is utilized commercially.

The Geothermal Steam Act of 1970 provided that the Secretary of the Interior lease Federal lands to private industry for exploration, development, and utilization of geothermal resources. Under regulations published in 1973, the Geological Survey supports the geothermal resources programs in several ways: evaluation and classification of the resources of Federal lands, assurance of compliance with applicable regulations before issuance of permits for exploration and development of resources on Federal lands, and supervision of the conduct of operations on leased Federal lands.

Beginning in fiscal year 1971, the Geological Survey started classifying Federal lands with geothermal resources adequate for commercial utilization or lands identified as having competitive interest of private companies as Known Geothermal Resource Areas (KGRA's). Lands within KGRA's are leased by competitive bidding. Other lands are leased noncompetitively to the first qualified applicant.

At the present time, the Geological Survey has established 108 KGRA's; these comprise 3.38 million acres and are within 11 Western States. At the end of 1979, 268 tracts comprising 541,000 acres had been leased within the KGRA's, an increase of nearly 30 percent over the preceding year. A total of 1,029 tracts comprising 1.75 million acres leased noncompetitively were active in fiscal year 1979, an increase in acres of 13 percent. The number of geothermal wells drilled on Federal, State, and private lands increased about 60 percent over the preceding year. Fewer wells (11 instead of 13) were drilled on Federal leases, but approvals to drill 336 wells have been issued.

The United States is the world's leading producer of electricity from geothermal resources. Nearly all U.S. production occurs at The Geysers in California, where 13 powerplants located on State and private lands, generate 663 megawatts of electricity, which is sufficient to meet the total demands of a city the size of San Francisco. The company plans for future developments include increasing power production to 2,000 megawatts within 20 to 25 years. Construction of a 110-megawatt plant on Federal land will commence in early 1980, and commercial production is scheduled for 1982.

The geothermal resource at The Geysers is the only one in the United States known to contain enough dry steam for commercial electrical power generation. At all other KGRA's with known commercial potential for electric power generation, the geothermal resources provide heated water rather than steam.

The power generation techniques needed to utilize hot water differ from those employed at The Geysers. Usually the geothermal water, which comprises approximately one-fourth of the fluid, is flashed to steam. The flashed steam drives turbogenerators, and the remaining liquid is injected back into the geothermal reservoir. Plants that will use flashed steam are in advanced stages of construction at East Mesa, Calif., a 48-megawatt plant; at Heber, Calif., a 45-megawatt plant; at Baca Ranch, N.M., a 55-megawatt plant; and at Roosevelt Hot Springs, Utah, a 20-megawatt plant.

Another technique for generating electrical power using heat from geothermal water is the "binary process." In this process, heat from the water is transferred by a heat exchanger to a second fluid having a low boiling temperature to produce vapor to drive a turbogenerator. A 10-megawatt plant using this technique has been completed on a Federal geothermal lease at East Mesa, Calif., and is nearing start-up (fig. 1). Other powerplants that will use the binary process are in various early planning stages.

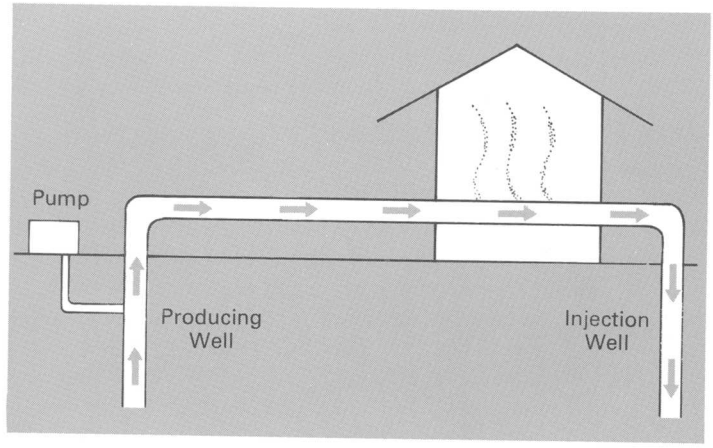
With present technology, electrical power generation is limited to geothermal water sources with temperatures above 150°C. Lower temperature waters offer a potential for numerous applications for direct use of heat energy in food and industrial processes, agriculture (fig. 2), space heating of buildings, and other uses.

Prior to 1979, direct use of geothermal water heat was limited to heating of buildings in Klamath Falls and a few other locations in Oregon, Idaho, and Nevada. In addition, hot water was utilized at an onion drying plant at Brady Hot Springs, Nev., a milk pasteurization facility in Oregon, and greenhouses in Lordsberg, N. Mex., and Marysville, Calif. At the end of fiscal year 1979, 21 projects are in advanced stages of planning and development in Texas and in eight Western States under Department of Energy sponsorship. Sixteen of these projects involve space and water heating of hospitals, schools, and other public buildings, and five will provide heat for food processing. Other applications include a rose greenhouse in Utah, a prawn farm in Coachella Valley, Calif., a sugar beet refinery at Brawley, Calif., and a cattle warming facility in South Dakota.

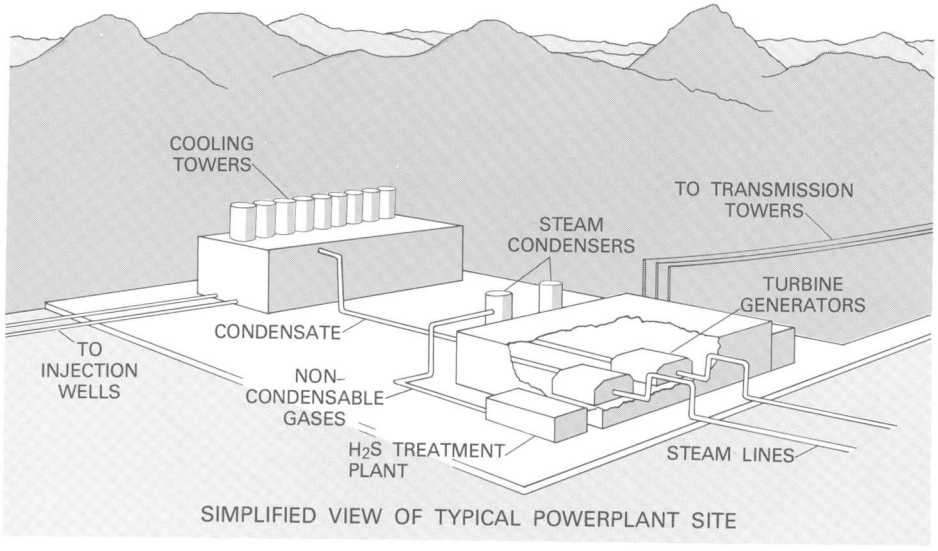
A variety of proposed applications for "cascading," whereby geothermal energy can be utilized more effectively by using the cooler spent water from one process for one or more separate subsequent processes, are in the early stages of planning and evaluation. For example, the use of waste water from electrical power generation can be used for industrial processes, and the waste from the industrial processes can be used for space heating of buildings.

Figure 1.—Final stages of Magma Power Co.'s 10-megawatt binary geothermal powerplant at East Mesa, Calif. Heat exchangers are at right. (August 1979.)

Figure 2.—Greenhouse using low-temperature geothermal resources.



Flow diagram of a greenhouse using low-temperature geothermal resources.



SIMPLIFIED VIEW OF TYPICAL POWERPLANT SITE

Land Information and Analysis Office

MISSION

During the 1970's, the general public became acutely aware of the energy crisis as reflected in long gasoline lines and escalating gasoline and fuel oil prices. The growing shortage of nonreplenishable energy resources such as petroleum poses but one of the critical environmental problems being addressed by the U.S. Geological Survey. Traditionally, the Survey has responded to environmental information needs on a case-by-case basis, utilizing one of its core disciplines—geology, hydrology, or cartography. However, during the last decade, it has become obvious that environmental studies must be a cooperative effort between the scientists in these diverse fields and specialists in other disciplines such as urban planning, economics, geography, and remote sensing. In addition, the information gap between these scientists and the potential users of these data—land-resource planners and decisionmakers—has widened because of advancing technology and increased specialization.

These two specific problems, the need for an integration of scientific disciplines and the requirement for information transfer from the earth scientist to the policy and decision makers, led to the creation of the Land Information and Analysis Office in 1975. The goals and efforts of the Land Information and Analysis Office illustrate the diversity of scientific work currently being done on these environmental problems.

The objectives of this Office are:

- Development and application of multidisciplinary earth sciences, other natural sciences, and geographic technology in support of land-resources decisionmaking and planning.
- Mapping current land use and land cover.
- Meeting Geological Survey obligations as required by the National Environmental Policy Act (NEPA).
- Collecting, processing, and distributing remotely sensed data and applying other aspects of space technology in support of land-resources planning and management and environmental impact analysis.

The task of achieving these objectives is carried on by the following multidisciplinary programs:

- Earth Sciences Applications (ESA).
- Resource and Land Investigations (RALI).

  (The combination of ESA and RALI is also known as the Land Resources Data Applications Program for budget purposes.)
- Geography.
- Earth Resources Observation Systems (EROS).
- Environmental Impact Analysis (EIA).

SELECTED ACCOMPLISHMENTS

During 1979, the Land Information and Analysis Office initiated and concluded a variety of multidisciplinary projects. A representative selection demonstrating the diversity of this effort is shown by the following short reports presented in this volume:

Tracking the Ixtoc 1 Oilspill Across the Gulf of Mexico.
Earthquake Prediction for a Seismic Gap in Alaska.
Interpretive Reports To Aid Regional Planners.
A Computer Model That Helps Protect the Environment.
Protecting the Environment in Alaska.
Land Use Maps and Data Application—Three Mile Island Powerplant Site.
Land Use and Land Cover Maps and Data for Our Nation.
Helping Planners and Decisionmakers Use Earth Science Information.
New Advances in Satellite Image Data Handling and Application.

BUDGET AND PERSONNEL

Obligations for Land Information and Analysis Office activities in fiscal year 1979 amounted to $23.96 million, an increase of 3 percent over fiscal year 1978 (see table).

The work of the Land Information and Analysis Office is partly accomplished through contracts to private industry and research grants. During fiscal year 1979, $8.51 million (36 percent) was expended on contracts. Contract services were the major source of operational support at EDC. Cooperative programs with State agencies were carried on by the Geography Program for land use and land cover mapping. The programs of the Land Information and Analysis Office employed 228 full-time career employees in 1979, of which 164 positions were assigned to the Office's programs and 64 were assigned to other Survey Divisions to support work of the Land Information and Analysis Office. There were also 74 temporary or part-time employees. In addition, contract support services at EDC amounted to 306 person years. Personnel of the Topographic Division assigned to EDC are included in the above numbers.

Land Information and Analysis Office obligations for fiscal years 1978 and 1979, by subactivity

[Dollars in millions. Data may differ from that in statistical tables because of rounding]

Program	Fiscal year 1978	Fiscal year 1979
Total	**$23.22**	**$23.96**
Earth Resources Observation Systems Program	**12.56**	**12.87**
Direct program	9.72	9.91
Reimbursable program	2.84	2.96
Miscellaneous non-Federal sources	2.15	2.36
Other Federal agencies	.69	.60
Environmental Impact Analysis Program	**5.21**	**5.21**
Direct program	3.26	4.29
Reimbursable program	1.95	.92
Other Federal agencies	1.95	.92
Geography Program	**2.65**	**3.47**
Direct program	2.60	3.40
Reimbursable program	.05	.07
States, counties, and municipalities	.05	.01
Other Federal agencies	----	.06
Land Resource Data Applications Program (ESA and RALI)	**2.80**	**2.41**
Direct program	2.55	2.36
Reimbursable program	.25	.05
Other Federal agencies	.25	.05

SOURCE OF FUNDS

TOTAL $23.96 MILLION

USE OF FUNDS

TRACKING THE IXTOC 1 OILSPILL ACROSS THE GULF OF MEXICO

On June 3, 1979, the Ixtoc 1 oil well, 50 miles off the coast of Mexico, blew out and caught fire. Totally out of control, the well poured as much as 100,000 barrels of oil per day into the Bay of Campeche. The oil flooded out into the Gulf of Mexico, threatening beaches in Mexico and the United States. It become imperative to determine the extent of the oilspill, to follow its movement across the Gulf of Mexico, and to obtain this information as quickly and economically as possible.

The Geological Survey investigated the use of multispectral scanner data from the Landsat 2 and 3 satellites to monitor the movement of the oil. Each Landsat image can inexpensively portray 13,225 square miles of the Earth's surface. Each satellite is able to scan a strip of images of the Gulf on one day and the adjacent strip on the west the next day. The entire Gulf of Mexico can be imaged in about a week.

Each of the two Landsat satellites now in orbit returns to nearly the same spot above the surface of the Earth every 18 days. Because their orbits are similar but 9 days apart, the two satellites can monitor a given feature, such as an oil slick, every 9 days for as long as both operate.

The illustrations show how Landsat data can be used to track the movement of a large marine oil slick.

Flames from the burning gas and oil leaking from the damaged Ixtoc 1 well are shown in figure 1. The gray fluid surrounding the flames is oil. A boom constructed later did not keep the oil from moving farther out into the Gulf of Mexico.

Oil and smoke streaming westward from Ixtoc 1 are shown in figure 2 in a digitally enhanced Landsat image. A thin coat of oil on the water appears black. The gray area represents thicker oil, and the whitish stringers are thick ropy heavy oil. Smoke from the burning gas and oil and clouds formed by superheating of the atmosphere appear white. The puffy white spots in the image are natural clouds.

Oil approaching the Mexican coast is shown in a photo-optically enhanced Landsat image in figure 3. The land is different shades of gray, and the clouds are white. The sea is light gray, and the oil is dark gray.

Some of the oil eventually reached the Texas beaches such as the one near Corpus Christi (fig. 4).

Important factors in the use of Landsat images to detect and monitor marine oil slicks are enhancement techniques, sun angle, and sea state. Special image enhancement is needed because differences in the reflectance of oil and water are subtle. Two common types of enchancement are photo-optical and digital. In photo-optical enhancement, the negative of the image is processed to increase film contrast in the same manner as for an ordinary photograph. To increase the contrast even more, the process is repeated.

When digital enhancement techniques are used, the brightness values of the innumerable tiny picture elements that make up a Landsat image are recorded on a computer-compatible tape and multiplied by a digital computer to increase the contrast of the image. The multiplication may be repeated several times to further increase the contrast. Enhancement can be observed and controlled through the use of specialized image analysis equipment.

Sun angle and sea state are also important in determining whether an oil slick can be detected by Landsat. Slicks are more easily spotted when winds are low to moderate and the sun is less than 50 degrees above the horizon because sun glitter is greatest under these conditions. The glitter results from the reflection of sunlight from extremely small waves. Because oil has a calming effect on the waves and removes the glitter, an oil slick commonly appears dark on Landsat images.

The use of Landsat to detect and track marine slicks has important environmental and exploration applications. Landsat data can assist in the following:

- Locating oil slicks that originated from manmade sources such as leaking wells, broken pipelines, and discharges from ships.
- Finding the origin of spills.
- Exploring for oil by detecting natural marine seeps from undersea sources of petroleum.

Development of oil resources on the Outer Continental Shelf of the United States is being monitored by the Geological Survey using geological, geophysical, engineering, and remote-sensing techniques. The use of satellites to monitor oil on the surface of the sea is an example of a new technique that may assist in safeguarding valuable offshore environments and at the same time help in developing a needed resource.

Figure 1.—Oil and gas from Ixtoc 1 burning in the Bay of Campeche on July 19, 1979. Photograph by Norm Tindell.

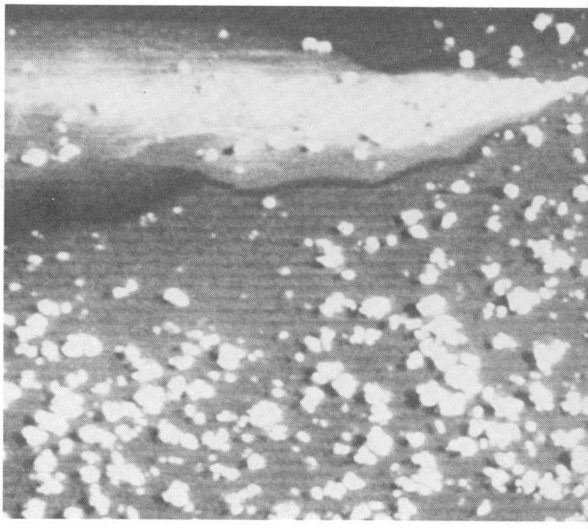
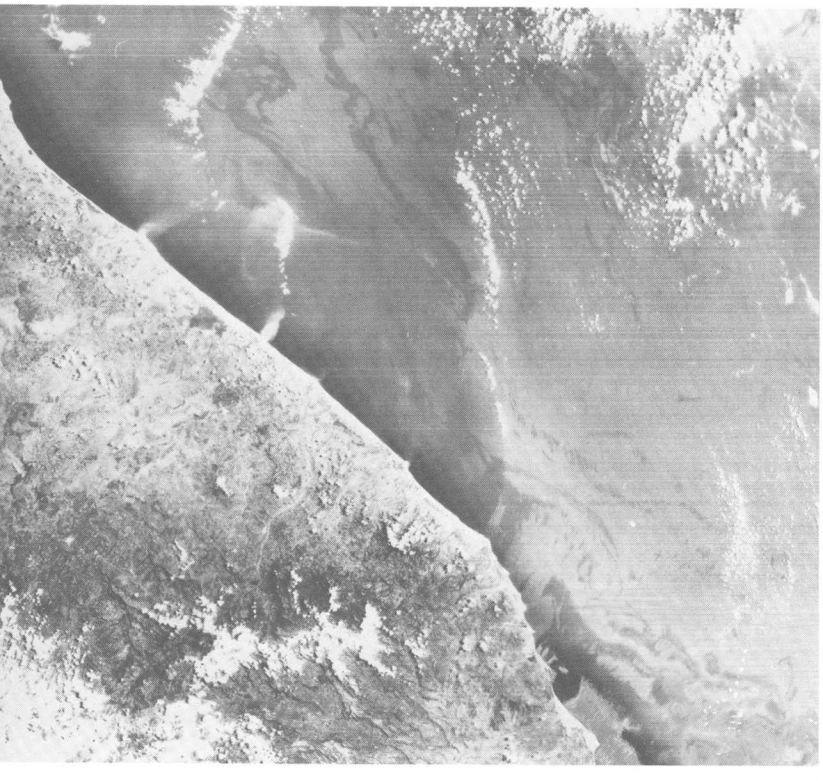
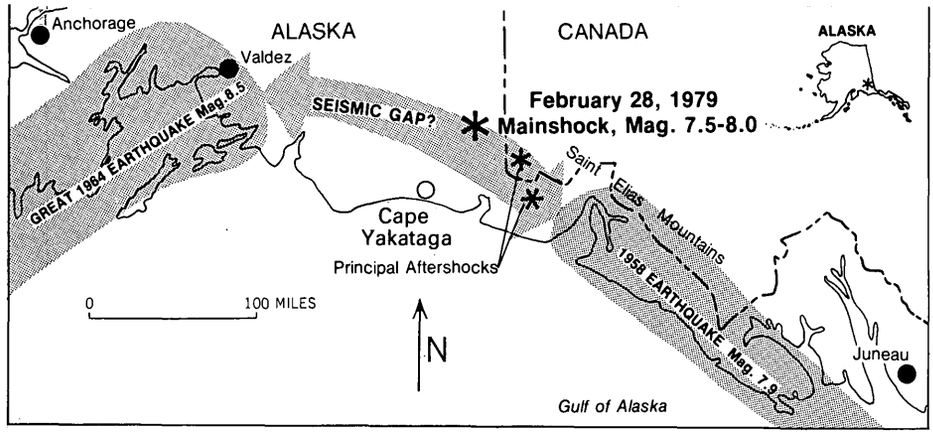


Figure 2.—Digitally enhanced enlargement of part of Landsat 3 image 30502-15532 showing oil and smoke from Ixtoc 1 on July 20, 1979.



▲ Figure 3.—Photo-optically enhanced part of Landsat 3 image 30505-16101 showing oil from Ixtoc 1 moving toward the Mexican shore north of Vera Cruz on July 23, 1979.

Figure 4.—Oil from Ixtoc 1 on the beach near Corpus Christi, Tex., on August 19, 1979. Photograph by Norm Tindell. ▶



A large earthquake with a Richter scale magnitude of 8 or more is likely in the Yakataga seismic gap area of south-central Alaska during the next several decades, according to scientists from the U.S. Geological Survey and the Lamont-Doherty Geological Observatory. The Survey has issued a Hazard Watch for the area.

EARTHQUAKE PREDICTION FOR A SEISMIC GAP IN ALASKA

During the past decade, the U.S. Geological Survey has acquired more responsibility and developed a greater capability for earthquake prediction and warning and hazard reduction.

The Geological Survey's responsibility in these areas was established by the Disaster Relief Act of 1974 and Executive orders in 1975 and 1976 which required the Survey to provide warnings of geologic-related hazards—volcanic eruptions, landslides, subsidence, glacier surges, and earthquakes. To meet this responsibility, the Survey established a program to:

- Increase awareness of geologic-related hazards among government officials, the private sector, and the general public.
- Identify geologic hazards, evaluate them, and disseminate information on the hazards in *Notices of Potential Hazard, Hazard Watches,* or *Hazard Warnings* (predictions).
- Assist public officials in evaluating possible mitigation measures.

The Geological Survey's capability for aiding in mitigating earthquake damage was enhanced by passage of the Earthquake Hazard Reduction Act of 1977 that led to the establishment of the Earthquake Hazard Reduction Program within the Survey. Under the Program, research is carried out on earthquake prediction and the identification of geologic hazards related to earthquakes.

While no formal earthquake prediction has been issued in the United States, the Nation's first earthquake Hazard Watch was issued for the area of Cape Yakataga, Alaska.

YAKATAGA SEISMIC GAP

On February 29, 1979, a strong earthquake shook a sparsely inhabited region of Alaska near Cape Yakataga, halfway between Juneau and Anchorage. The event, which had a magnitude of 7.7 on the Richter scale, was not as large as some other recent earthquakes in Alaska nor was there significant damage. Nevertheless, the earthquake commanded much attention because data gathered by a Geological Survey seismometer network showed that the movement was at the southeastern edge of a large seismic gap—an area that has not had a major earthquake in recent years but which lies between areas where great earthquakes have recently occurred. Seismic gaps are often subject to future great earthquakes.

The existence of seismic gaps was pointed out in 1965, and, since then, much work has been devoted to estimating the earthquake potential of seismic gaps and to understanding what causes gaps. Gaps may be explained by the theory of plate tectonics, which states that the Earth's crust is composed of large areas, called plates, that move as independent units. As the plates slowly slide against or over each other, a tremendous amount of stress builds up. This stress must be released, either by slow movement or by the sudden slippage of one plate past the other, thereby producing an earthquake. A seismic gap may then be interpreted as a segment of a plate margin that has not slipped recently while its neighboring segments have. Under these circumstances, the gap is thought to have a higher potential for an earthquake than the adjacent segments.

The plate margin segment near Cape Yakataga was identified by scientists from the Lamont-Doherty Geological Observatory at Columbia University as a seismic gap a decade ago. Movement in the gap occurred last during two great earthquakes that occurred in 1899. Movement occurred in the region southeast of the gap in 1958 and to the northwest in 1964. Stimulated by the February 29 earthquake, Lamont researchers restudied seismic data. They noted that seven large events, with magnitudes between 5.9 and 7.7, had occurred adjacent to the Yakataga gap since 1958, while no earthquakes of comparable magnitude occurred in those areas between 1933 and 1958. The interior of the gap has been free from comparable earthquakes since 1908. Similar situations have been observed elsewhere and have been followed by major earthquakes centered within the seismic gaps within a few decades. The amount of fault slip expected during an earthquake in the Yakataga area could be as much as 10 feet. If this amount of movement were to occur along the entire Yakataga seismic gap today, an earthquake larger than magnitude 8 on the Richter scale would be generated. Such an earthquake could produce damaging ground motion over an area as large as 30,000 square miles.

Based on these observations and interpretations, the Lamont group, working as part of the Survey's Earthquake Hazard Reduction Program, proposed that the Yakataga gap was likely to be the site of a great earthquake in the future and should be monitored intensively to detect any warning signs. In response to these suggestions, the Survey convened a committee to evaluate the probability of an impending earthquake in the Yakataga gap and to make recommendations for any necessary additions to the Survey program in Alaska. Although alternative interpretations of the available data on the gap seemed plausible, the committee generally agreed that a large earthquake was likely to occur within 100 years, that it might occur very soon, and that it probably would occur within a few decades. The committee also agreed that the area should be intensively monitored.

INTERPRETIVE REPORTS TO AID REGIONAL PLANNERS

Since 1970, experimental multidisciplinary urban-area studies designed to aid local and regional planners have been completed in five areas of the country; projects are currently active in four additional areas. These studies were made to promote the use of earth science information in regional planning and decisionmaking. The first study program, the San Francisco Bay Region Environment and Resources Planning Study, was cosponsored by the Earth Sciences Applications (ESA) Program of the Geological Survey and the Office of Policy Development and Research of the Department of Housing and Urban Development. It produced 71 basic data maps and reports and several technical reports that have been widely used by local and regional planners. A final series of interpretive reports for nonscientists is now being produced. The other urban area studies will result in similar reports.

Five interpretive reports have been published to date:

- Professional Paper 941-A, *Studies for Seismic Zonation of the San Francisco Bay Region*, 102 p.
- Professional Paper 942, *Flood-Prone Areas and Land-Use Planning*, 75 p.
- Professional Paper 943, *Flatland Deposits—Their Geology and Engineering Properties and Their Importance to Comprehensive Planning*, 88 p.
- Professional Paper 944, *Relative Slope Stability and Land-Use Planning*, 96 p.
- Professional Paper 945, *Quantitative Land-Capability Analysis*, 115 p.

The last three publications were published during 1979 and are described briefly below.

FLATLAND DEPOSITS

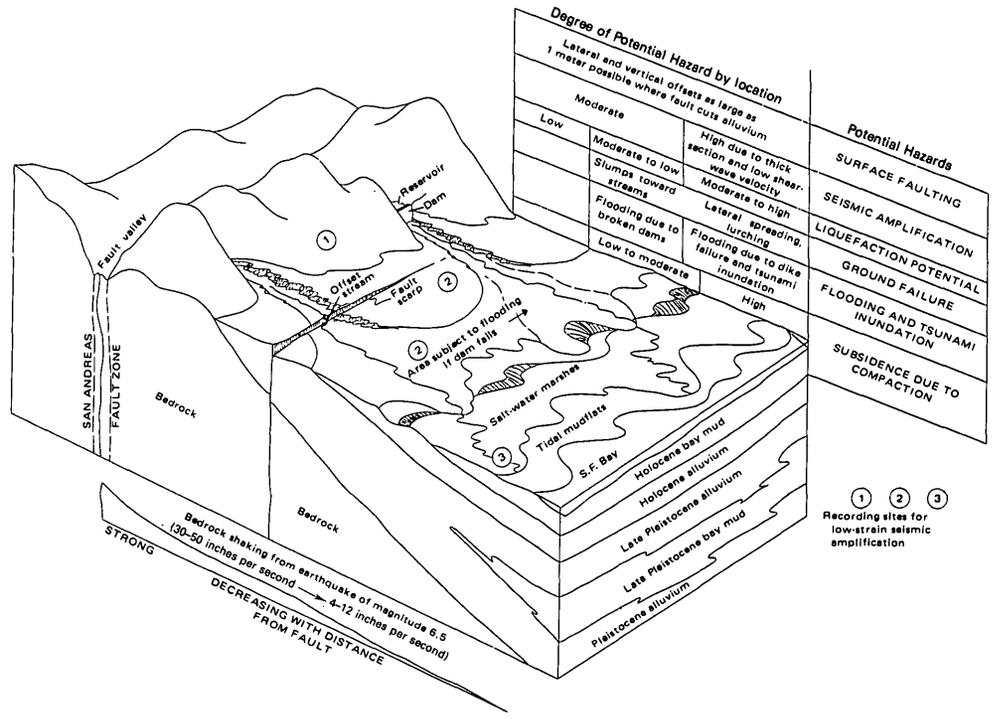
Professional Paper 943 and its accompanying maps describe 13 geologic units, including estuarine muds and marsh, alluvial-fan, channel, floodbasin, dune, and beach deposits. The units have different ages and engineering characteristics; decisions on the use of these lands must be based on the hazard and resource potential of each individual unit. In the report, each geologic unit is described in detail, and the potentials for geologic hazards such as subsidence, flooding, and liquefaction are evaluated, and resources—possibly including sand and gravel, peat, shells, and salts—are identified. In addition, each unit is rated on its relative capability to support agriculture, urban residential development, ground-water recharge, and sand and gravel extraction.

SLOPE STABILITY

In the San Francisco Bay region, landslides caused damage amounting to more than $25 million during the rainy season of 1968-69 and to more than $10 million during the 1972-73 rainy season. The possibility of damage has been increasing steadily as more development takes place on hillsides. These losses can be greatly reduced by using geologic information to recognize, to evaluate, and to map those areas and slopes that are potentially unstable and by applying this information in planning, designing, and managing the use of hillside areas. Professional Paper 944 presents the first standardized relative slope-stability maps of the entire San Francisco Bay region and discusses the implications and uses of the maps in the regional land use planning process. The relative slope-stability maps have a variety of uses for planning the location of nuclear-reactor sites, transportation and communication networks, and open space and recreational areas, and the control of urban growth.

QUANTITATIVE LAND CAPABILITY ANALYSIS

Professional Paper 945 describes a method of evaluating land use proposals by estimating the development costs related to various geologic and hydrologic characteristics and processes when the existing use of the land is converted to housing, commerce, or transportation. Costs can include potential damage from natural hazards such as floods, landslides, or earthquakes; fees for special investigations, designs, or construction practices; and the loss of potentially valuable resources such as sand and gravel. The total costs associated with all geologic problems for a specific use and a given area indicate the relative capability of that land to accomodate that use. Thus, capability maps can be produced for each proposed land use by displaying the sums of these development costs by area on a map. Such land-capability maps are a convenient means of graphically presenting the data needed to evaluate alternatives and to make better decisions on land use.



Potential seismic hazards on the alluvial plain and near the bay in the San Francisco, Calif., area. ▶

A COMPUTER MODEL THAT HELPS PROTECT THE ENVIRONMENT

The Oilspill Trajectory Analysis (OSTA) model is one of the many tools scientists and public decisionmakers use in an effort to ensure that the development of our domestic energy resources does not endanger our environment. The model is a sophisticated computer program that defines both the probability of an oilspill occurring and its potential paths. The OSTA model was developed by a Geological Survey team currently composed of a physical scientist, an oceanographer, a mathematician, and a computer technican. The model became fully operational during fiscal year 1979 and provides information for Outer Continental Shelf (OCS) lease sales and for development and production environmental impact statements.

The OSTA model determines the likelihood of an oilspill occurring within a given area and, through oilspill simulation, the possible movement of the oilspill and whether it will contact any environmentally sensitive resources. Because some resources, such as migrating birds, may be present in the study area for only part of the year, the model incorporates monthly vulnerability for each resource. The probability of oilspill occurrence is estimated from the volume of oil expected to be produced, the anticipated method of production, and the distance of transportation to shore. Movement of as many as 500 simulated oilspills per season is modeled based upon historic wind records and monthly ocean currents.

Output of the model includes tables of conditional probabilities of oilspills contacting any of 31 categories of vulnerable resources for 100 segments of the coast within 3, 10, and 30 days and the percentage of oilspills contacting a specific environmentally sensitive resource within the same periods. These periods reflect stages in the natural degradation of the oil and resulting decrease in its toxicity. The model calculates oilspill probabilities for each of the places where an oilspill could occur and combines these to determine the overall risks. The model provides the Department of the Interior with a method of realistically assessing oilspill risks associated with OCS development. To date, it has been used for analyzing oilspill risks for 10 OCS environmental impact statements. In addition, the OSTA model will be used to analyze the summer 1979 Ixtoc 1 oilspill in the Gulf of Mexico.

PROTECTING THE ENVIRONMENT IN ALASKA

The environmental consequences of potential petroleum development in the National Petroleum Reserve in Alaska (NPRA) dictated the preparation of a special environmental "draft" study completed during 1979. Section 105(b) of the Naval Petroleum Reserves Production Act of 1976 directed the President to conduct a study to determine the best procedures for developing, producing, transporting, and distributing petroleum resources of the Reserve.

The NPRA study includes analyses of the environmental impacts of development and production of petroleum resources in the Reserve and of transportation of those resources to the conterminous United States. The outstanding environmental concerns stemming from development and production are (1) impacts on wildlife, especially caribou and waterfowl, (2) depletion of gravel and water resources which are in limited supply, and (3) impacts on the culture and lifestyle of the Inupiat Eskimo communities, which rely on the hunting of Bowhead whales. Significant concerns for transportation of the petroleum resources from NPRA are (1) impacts upon the Inupiat culture and lifestyle through increased contact with modern society, (2) increased pressures on government and service organizations, (3) impacts on wildlife, particularly on caribou migration and habitat from pipelines and roads, and (4) potential oilspills along new pipeline or marine transportation routes.

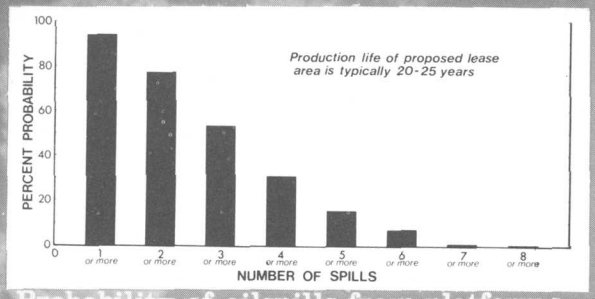
In the analysis of impacts, the development and experience at Prudhoe Bay and the construction and operation of the Trans-Alaska Pipeline System (TAPS) were used as general models. Together they represent the current level of technology and experience in the arctic environment. Because wellfield facilities vary widely with petroleum reservoir characteristics, no specific model was used. For the transportation of petroleum from NPRA to the terminals, the following general corridors were assumed for illustrative purposes: (1) from eastern NPRA to TAPS at Prudhoe Bay, (2) from eastern NPRA to TAPS south of Prudhoe Bay, and (3) from southwestern NPRA to the Bering coast at alternate sites north or south of the Bering Strait. A marine terminal at Barrow for submersible tankers was also considered briefly.

Environmental studies of this type are a critical element in the decisionmaking process, assuring both public officials and private citizens that environmental issues are addressed during the development of natural resources.

OILSPILL RISK ANALYSIS

Spill paths simulated from wind and current data are used to predict the probabilities of biological and recreational resources being impacted by oilspills.

Probability of number of spills greater than 1,000 barrels



Probability of oilspills from platforms and tankers during production life

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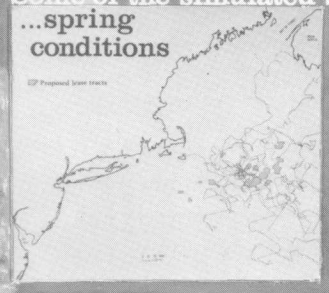
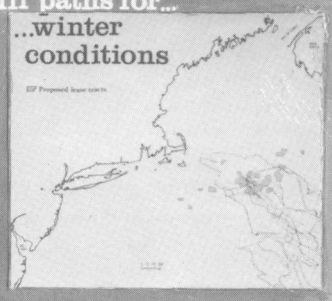
Path of pollutants

Some of the simulated spill paths for...





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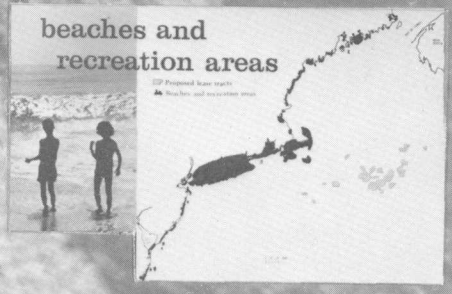
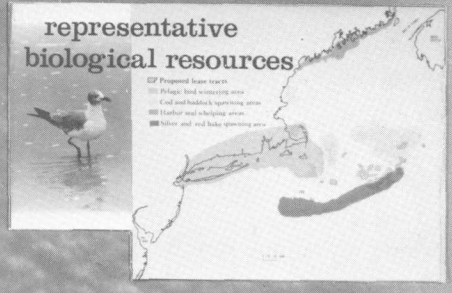
Location of vulnerable resources





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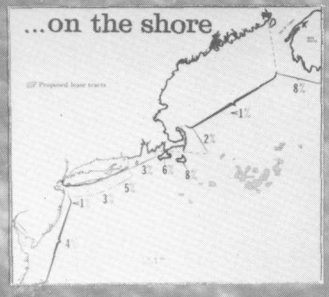
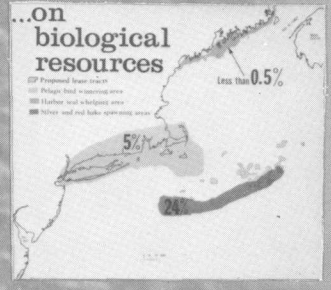
Probability of impact from oilspills





Examples from a North Atlantic lease area

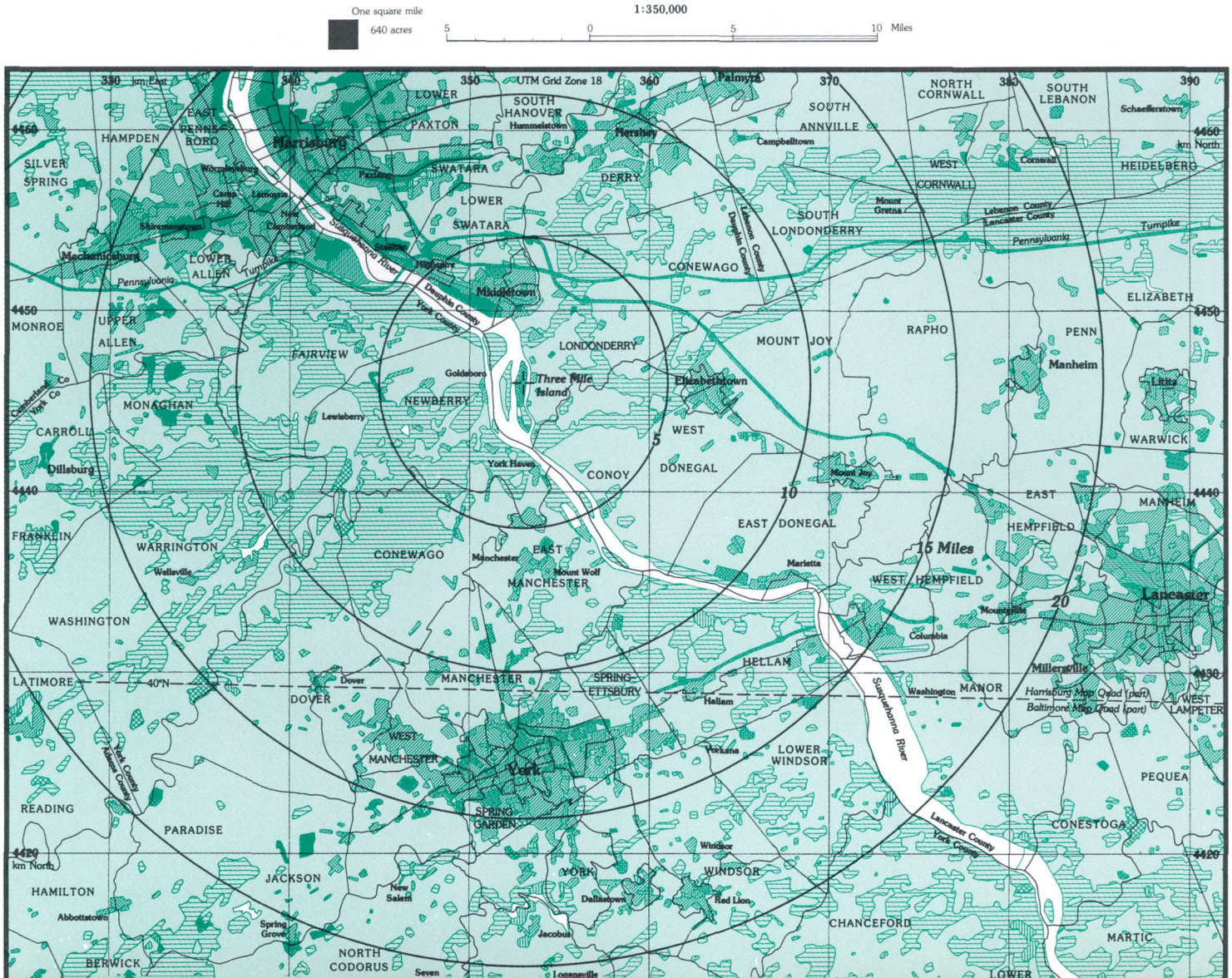
W/EIA-03

LAND USE MAPS AND DATA APPLICATIONS—THREE MILE ISLAND POWERPLANT SITE

In March 1979, a nuclear accident at the Three Mile Island powerplant on the Susquehanna River, 10 miles southeast of the State capital of Harrisburg, Pa., raised the question of how plant locations might affect nearby areas in the event of such accidents. To aid in evaluating and developing alternative solutions for control of hazards by decisionmakers, a special land use and land cover map, keyed to political units and Census statistical areas, was produced from existing data by a computer-driven mapping plotter. Plotted at a scale of 1:100,000, the computer-drawn map can also be rendered as an overlay for a standard Geological Survey topographic map at a scale of 1:250,000. The map identifies 19 land use categories in the area by colors and patterns (a full-color reproduction at 1:100,000 in this publication was not possible because of printing limitations). Concentric circles centered on the powerplant and place names were added for ease in evaluation of potential hazards and for use in future site planning. The digital data used in constructing the land use and land cover map are from a 1978 cooperative effort between the Pennsylvania Department of Environmental Resources and the U.S. Geological Survey.

Shortly before the accident at Three Mile Island, the Nuclear Regulatory Commission (NRC) inquired about land use information available from the Survey for use in selecting plant sites and powerline rights of way. The Survey provided a description of information products, some samples, and a status report. NRC ordered sets of the black-and-white land use and associated maps of the Harrisburg and Baltimore map quadrangles. When the accident occurred, the Survey volunteered to show how the land use data could be used, not only for site planning, but also in assessment of damage and planning of emergency relief measures. The map shows settlement patterns and also relates Census statistical areas to land use centered on the island. The NRC is referring to this map in its report of the accident. In addition, the Survey is currently exploring the possibility of making similar maps for approximately 70 other plant sites. The Survey is also helping NRC to provide a wide range of nationwide thematic maps showing earth science data and State base maps for use in site planning, environmental impact assessment, and emergency planning.

Computer-drawn map showing the Three Mile Island powerplant site.

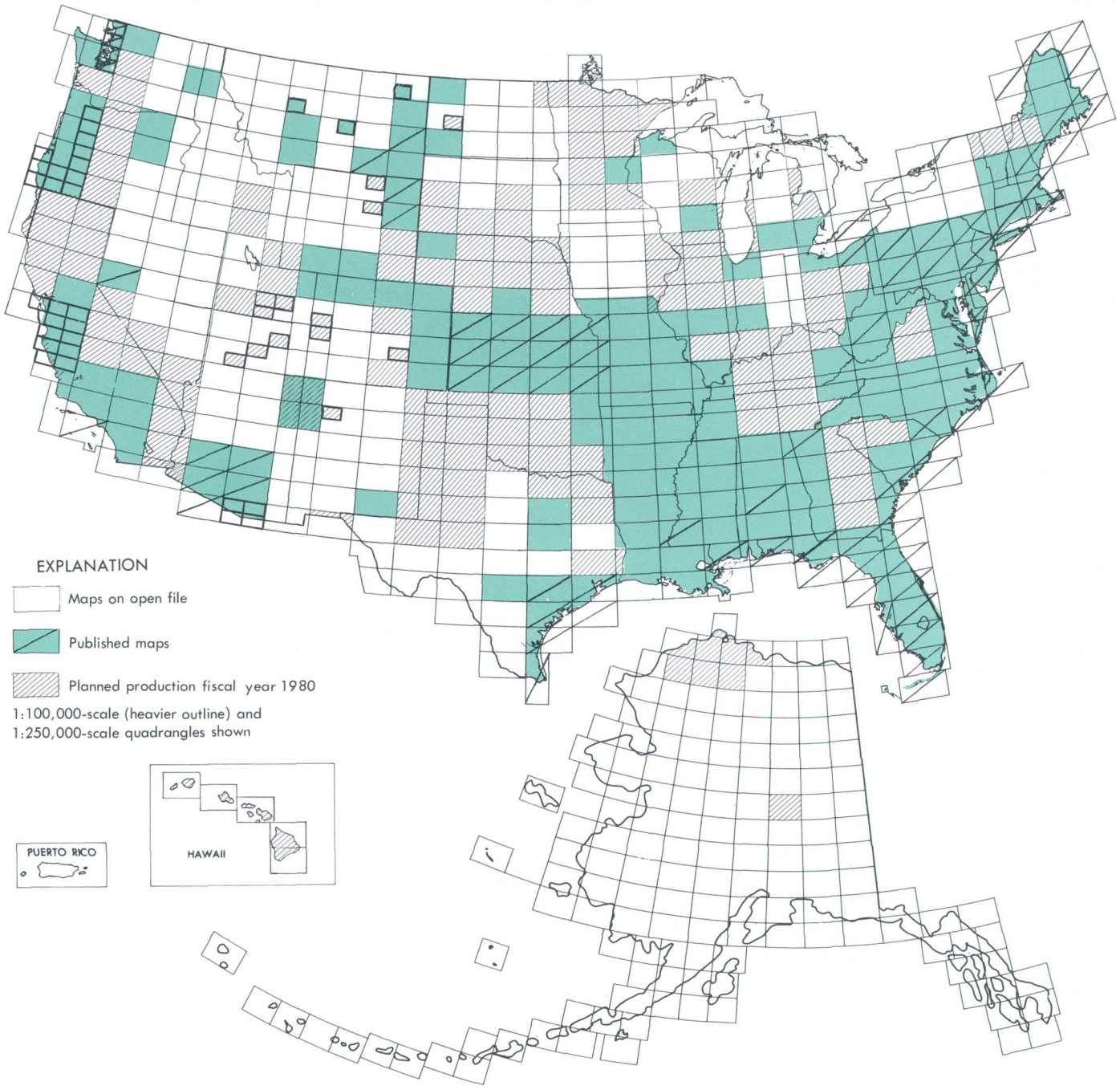


LAND USE AND LAND COVER MAPS AND DATA FOR OUR NATION

Land use and land cover maps for more than 1.25 million square miles of the United States were completed by the end of the fiscal year 1979. By 1982, maps will be completed for the entire Nation, except Alaska (for which maps will be completed in 1984). Such maps were not available in a current, reliable, and standardized format before the Geography Program's establishment in 1975. Compiled from high-altitude aerial photographs as primary source materials and a land use and land cover classification system developed for use with high-altitude and satellite data, these maps are being placed on open file for public use at a scale of 1:250,000; some selected areas are being compiled at 1:100,000. Also, a new Land Use Map Series was begun in fiscal year 1979 with the publication of 83 two-color land use and land cover maps at the same scales as the open-file maps. As shown on the index map below, these maps are now available for many areas of the country.

The land use and land cover map data are also being digitized and placed in the Geographic Information Retrieval and Analysis System. Digital data products include statistical summaries by counties, hydrologic units, Census county subdivisions, and for federally owned land and variable scale, black-and-white, or color-shaded computer plots. Analysis of such data to determine land use trends and patterns and to contribute to the solution of land-resource problems is facilitated by having the map information in a digital format.

▼Status of land use and land cover mapping.



HELPING PLANNERS AND DECISIONMAKERS USE EARTH SCIENCE INFORMATION

The current multi-Divisional and multi-Bureau efforts of the Survey illustrate the trend of this organization toward nontraditional roles. Decisionmakers and planners at all levels of government and the private sector have a vital need for the expertise available in the Survey. Five selected examples of this effort are cited below.

OUTER CONTINENTAL SHELF OIL AND GAS INFORMATION PROGRAM

During the past year, seven regional meetings were held to identify State and local information needs and issues as part of the initial development of *Indexes* and *Summary Reports* required by the Geological Survey Regulations and the Outer Continental Shelf Oil and Gas Information Program mandates.

Indexes were prepared for the Atlantic, Gulf, Pacific, and Alaska coasts. They list reports and documents used by the Federal Government in the decisionmaking process for leasing, exploration, development, and production of oil and gas from the OCS. Work has begun on the Mid-Atlantic and Pacific *Summary Reports;* these will include (1) geologic and geophysical data and updated oil- and gas-resource and reserve estimates, (2) projections of the magnitude and timing of any development, (3) methods of transportation to be employed, and (4) the general location and nature of nearshore and onshore facilities. Copies of the *Indexes* are available from the U.S. Geological Survey, 750 National Center, Reston, VA 22092.

The program's first direct technical assistance effort began with the signing of a cooperative agreement with the State of Alaska to prepare an issue analysis of information, planning, and programming needs for future Bering Sea OCS area activities.

COASTAL ZONE MANAGEMENT ACT COORDINATION

The Geological Survey established the office of the Coastal Zone Management Act (CZMA) Coordinator to handle the Survey's responsibilities under CZMA. These responsibilities include review of State CZM programs before their approval by the National Oceanic and Atmospheric Administration (NOAA) and development of working contacts with State CZM agencies to coordinate activities of mutual interest and concern.

During the year, the CZMA Coordinator has:

- Coordinated Survey review of the draft and final CZM programs of Alabama, Alaska, Delaware, Guam, South Carolina, and the Virgin Islands.
- Prepared and distributed to the coastal States a document describing the Survey's licensing and permit activities in the coastal zone.
- Developed procedures to facilitate the review of State CZM program documents and materials by the Survey's regional offices.
- Represented the Survey in the formulation of Departmental policy on estuarine and marine sanctuaries proposed by NOAA.
- Entered into a cooperative project with the University of Rhode Island to study the future role of the Survey in the coastal zone, particularly in the acquisition and dissemination of earth science information.

APPLICATION OF CONFLICT RESOLUTION TECHNIQUES TO ENVIRONMENTAL PROBLEMS

An experimental project was begun by the Geological Survey and the Council on Environmental Quality to test the ways in which conflict resolution processes could be used to improve the decisionmaking process for natural-resources management. Several approaches have been taken. Two training workshops in mediation were held for the National Park Service, and workshops are scheduled for other organizations. A number of conflict situations, both projected and present, have been studied, and discussions are underway about their use as case studies. One such case study for the Bureau of Land Management involves the use of off-road vehicles for special events on public lands in California. Other cases under consideration include conflicts about land use, outdoor recreation, timber management, and water resources. Techniques to be tested include mediation, facilitation, fact finding, and education.

URBAN WATER CONSERVATION PROJECT

The Geological Survey, in cooperation with the New England River Basins Commission, is evaluating water-conservation methods for use in urban areas. The first phase of the project included a comprehensive review of water-conservation literature, a survey of 218 urban New England water suppliers, and a methodology for evaluating urban water-conservation strategies. A summary and evaluation of a wide range of water-conservation measures used in urban areas across the Nation is being prepared.

A methodology for selecting the most effective conservation strategies is being developed to aid urban water managers. The methodology is being tested in two similar New England communities that have two different types of water-conservation programs. The two tests will assess the effectiveness of the methodology in predicting the impact of the conservation measures employed by the two communities and in developing alternative strategies for reducing the demand for water.

◀Selected publications demonstrating the involvement of the U.S. Geological Survey in new roles by providing earth science data needed for managing our Nation's natural resources.

WESTERN COAL PLANNING ASSISTANCE PROJECT

The Western Coal Planning Assistance Project, a joint effort of the Missouri River Basin Commission and the Survey, is designed to assist State and local governments in dealing with problems associated with coal/energy development. The project consists of two phases.

Phase I of the project culminated in meetings in Montana, North Dakota, and Wyoming at which the products of Phase I were described and discussed. These products are:

- Factbook for Western Coal/Energy Development
- Source Book for Western Coal/Energy Development.
- A Guide to Methods for Impact Assessment of Western Coal/Energy Development.
- Forecasts for Western Coal/Energy Development.

Copies of the reports are available from the U.S. Geological Survey, 750 National Center, Reston VA 22092.

Phase II will include updating and revising the Phase I products, expanding the information on the transportation of coal and coal products and the possible impacts on communities, and holding experiential workshops using the Phase I products and other natural resource, social, economic, and fiscal information.

NEW ADVANCES IN SATELLITE IMAGE DATA HANDLING AND APPLICATIONS

During the past year, a domestic communications satellite (Domsat) began to relay Landsat satellite image data from the National Aeronautics and Space Administration's (NASA) Goddard Space Flight Center (GSFC) to EROS Data Center (EDC). With the new EDC image processing system (EDIPS), this relay has made possible an "all-digital" format and greatly speeded data handling between the two facilities. EDIPS has both accelerated the processing of images and made possible the production of higher quality images. Faster processing of enhanced Landsat imagery is essential because new applications of these data to resource and environmental problems are increasing rapidly. An example of a new application of digital analysis techniques of Landsat images is the mapping and monitoring of changes in the terrain of arid regions.

DOMSAT RELAYS LANDSAT DATA

In May 1979, EDC began using a domestic communications satellite to relay Landsat image data to EDC from GSFC. The new link ensures timely availability of Landsat data and rapid access that makes possible more effective use of earth-resources imagery. Previous methods of transferring Landsat data involved shipping magnetic tapes and photographic film by a common carrier such as air freight, and a shipment could take as long as 4 weeks to arrive at EDC.

Two events made it possible to eliminate this delay. In 1976, commercial communications satellites became available. About the same time, new image processing systems were being developed at GSFC and at EDC for an "all-digital" format; with phasing out of the photographic film interface expected, it was feasible to look at the Domsat system as a viable data-transfer tool.

In 1978, NASA began using Domsat to relay unprocessed Landsat data to GSFC from its distant reception facilities in Alaska and California. In February 1979, both EDC and GSFC implemented the new digital-image processing capabilities, and a receiver antenna was installed at EDC. After the antenna was checked out, transmissions from GSFC through Domsat began.

Standing 46 feet high in front of the main building at EDC, the antenna consists primarily of a parabolic dish 33.8 feet in diameter. For 1 or 2 hours every morning, digital data transmitted from GSFC are received and recorded on high-density tapes. Typical turnaround time for the data for a Landsat image from original acquisition to arrival at EDC is now about 10 days—less than half the time once required.

LANDSAT IMAGES USED TO MAP AND MONITOR THE TERRAIN OF ARID REGIONS

The Geological Survey has undertaken projects based on the analysis of Landsat images to assess and monitor the land as a resource, beginning with the characteristics of arid regions. The method being evaluated for assessment of the ability of an arid area to support various uses is the Australian land systems approach. This method of land-resource mapping contrasts sharply with the usual U.S. methods that rely heavily on the mapping of geologic features, soils, and vegetation as single map units, followed by combinations of the data as a means of assessing land use capability. In the Australian method, each parcel of land is considered to be unique and is described in an integrated manner. Australian land systems maps integrate the data by showing areas where specific combinations of geology, soils, and vegetation occur.

Digital analysis of Landsat images has been found to be a useful method of classifying arid lands by the Australian approach. The Geological Survey has examined the technique and has concluded that it is a highly desirable first step in arid-region terrain evaluation. These methods of integrated terrain mapping and Landsat digital analysis also have potential use in the arid lands of the Western United States.

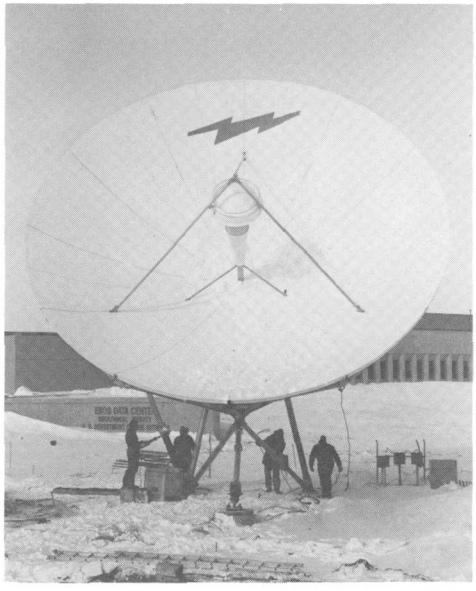
EDIPS IMPLEMENTED

The past year has brought about increased reliance on digital computers to process satellite imagery at EDC. Since February 1979, an integrated data-processing system, known as EDIPS, has been fulfilling two objectives—incorporation of greater geometric fidelity in Landsat image products and improved interpretability of Landsat products. The new system came about as part of a cooperative effort by EDC and NASA's GSFC.

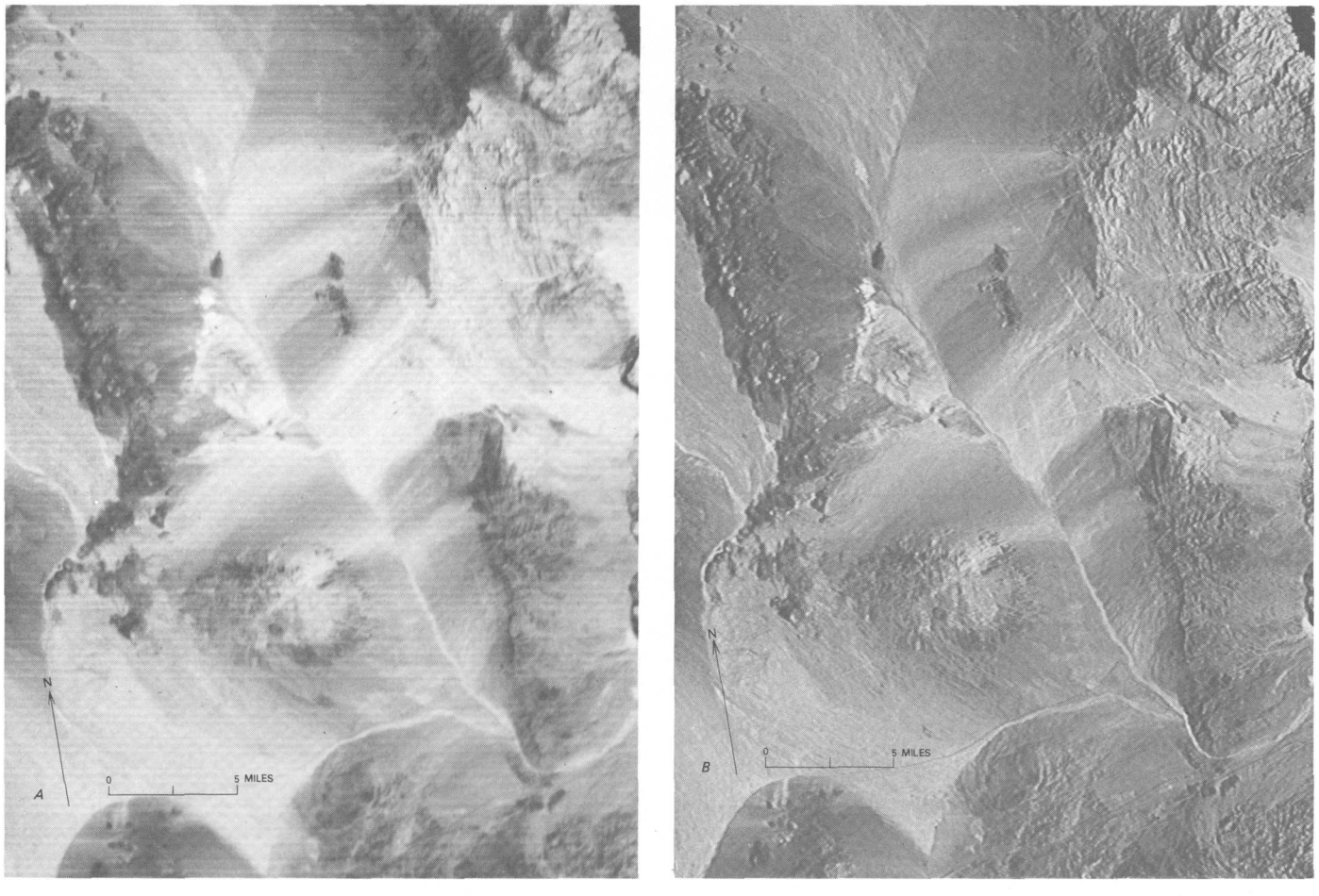
Special processing procedures using optional EDIPS capabilities are requested frequently. To magnify subtle variations in image brightness values, the brightness levels are "stretched" over the entire dynamic range of the film base to separate pixel radiances as much as possible. Another option, edge enhancement, employs a technique that can exaggerate the difference between a pixel's radiance and that of surrounding pixels. Detail along features such as shorelines and vegetation boundaries in the final image is thus sharpened. Although not every user of Landsat data requires enhanced images, these optional processing steps have proven valuable.

The new system has had an immense effect on EDC, strikingly evident in newer, faster, and better ways of doing things. Clearly, the computer will play an important role in the manipulation and interpretation of earth-resources data. As additional advances in image processing are made, increased usefulness and interpretability of data products will be assured.

The Domsat antenna linking EDC in Sioux Falls, S. Dak., with the Goddard Space Flight Center in Greenbelt, Md.



Oblique aerial photograph of Western Queensland, Australia, showing curved sand dunes with small clay depressions which may contain water. These constitute a "land system" which has a limited capacity for use but which is subject to erosion and deposition depending on the density of the protective vegetation on the dunes. Mapping such features and monitoring their changes with time provides guides to proper utilization of the land.



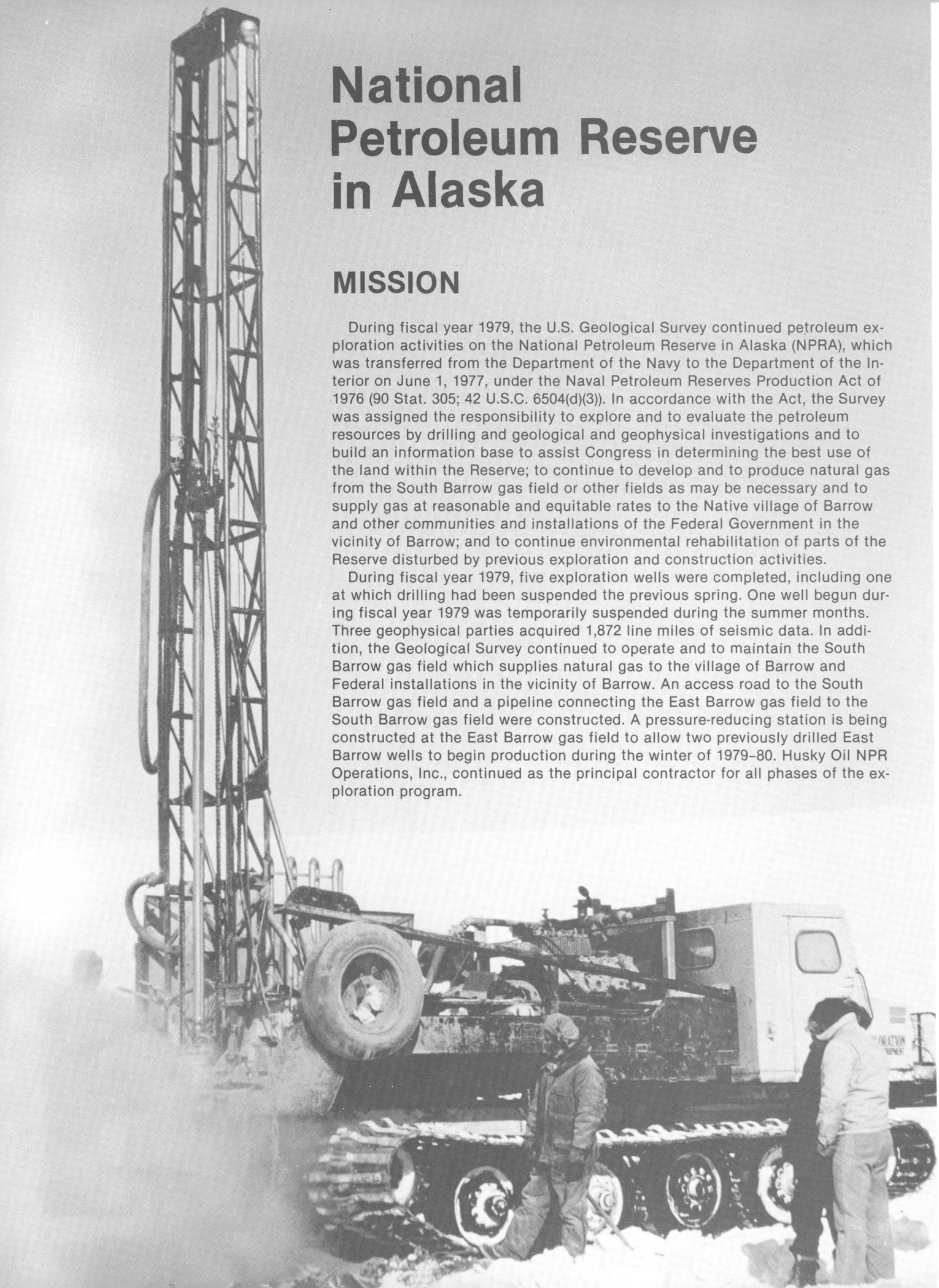
Enlarged part of Landsat image 1700-17422 showing an area near Needles, Calif., June 23, 1974. *A*, Standard product, photographically processed. *B*, Digitally enhanced product, processed by EDIPS.

National Petroleum Reserve in Alaska

MISSION

During fiscal year 1979, the U.S. Geological Survey continued petroleum exploration activities on the National Petroleum Reserve in Alaska (NPRA), which was transferred from the Department of the Navy to the Department of the Interior on June 1, 1977, under the Naval Petroleum Reserves Production Act of 1976 (90 Stat. 305; 42 U.S.C. 6504(d)(3)). In accordance with the Act, the Survey was assigned the responsibility to explore and to evaluate the petroleum resources by drilling and geological and geophysical investigations and to build an information base to assist Congress in determining the best use of the land within the Reserve; to continue to develop and to produce natural gas from the South Barrow gas field or other fields as may be necessary and to supply gas at reasonable and equitable rates to the Native village of Barrow and other communities and installations of the Federal Government in the vicinity of Barrow; and to continue environmental rehabilitation of parts of the Reserve disturbed by previous exploration and construction activities.

During fiscal year 1979, five exploration wells were completed, including one at which drilling had been suspended the previous spring. One well begun during fiscal year 1979 was temporarily suspended during the summer months. Three geophysical parties acquired 1,872 line miles of seismic data. In addition, the Geological Survey continued to operate and to maintain the South Barrow gas field which supplies natural gas to the village of Barrow and Federal installations in the vicinity of Barrow. An access road to the South Barrow gas field and a pipeline connecting the East Barrow gas field to the South Barrow gas field were constructed. A pressure-reducing station is being constructed at the East Barrow gas field to allow two previously drilled East Barrow wells to begin production during the winter of 1979–80. Husky Oil NPR Operations, Inc., continued as the principal contractor for all phases of the exploration program.



BUDGET AND PERSONNEL

During fiscal year 1979, $216.9 million was appropriated for drilling and related activities within NPRA. Of this amount, $194.1 million was allocated to continue the ongoing evaluation and assessment of the Reserve; $20.2 million, to operate the South Barrow gas field and to explore for and to develop additional gas reserves in the Barrow area; and $2.6 million, for the Environmental Rehabilitation Program which consists of the normal cleanup of current exploration drilling sites and rehabilitation of areas of the Reserve disturbed during previous petroleum exploration and construction activities.

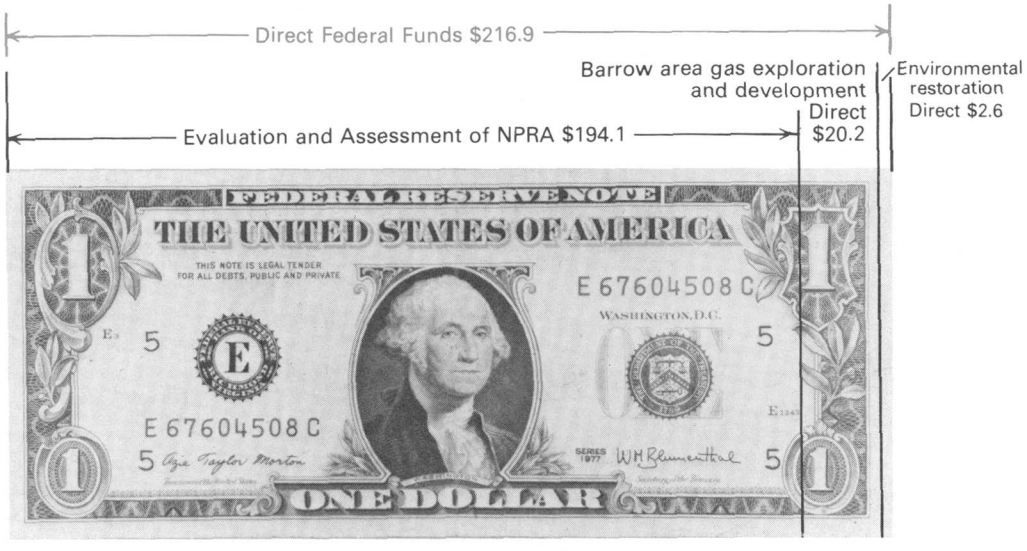
The Office of National Petroleum Reserve in Alaska was allocated 24 permanent full-time positions and 6 part-time positions for the fiscal year. Of the 30 permanent full-time positions, 3 have been staffed elsewhere in the Geological Survey to provide dedicated contract support to the program and to upgrade NPRA petroleum resource data as new information is acquired from the ongoing exploration program. The remaining 27 positions comprise the Operations, Exploration Strategy, and Liaison elements of the Office.

National Petroleum Reserve in Alaska activity obligations for fiscal years 1978 and 1979, by subactivity
[Dollars in millions. Data may differ from that in statistical tables because of rounding]

Subactivity	Fiscal year 1978	Fiscal year 1979
Total	**$202.7**	**$216.9**
Evaluation and Assessment of NPRA	**185.9**	**194.1**
Direct programs	185.9	194.1
Reimbursable programs	----	----
Barrow Area Gas Exploration and Development	**14.8**	**20.2**
Direct programs	14.8	20.2
Reimbursable programs	----	----
Environmental Restoration	**2.0**	**2.6**
Direct programs	2.0	2.6
Reimbursable programs	----	----

SOURCE OF FUNDS

TOTAL $216.9 MILLION



USE OF FUNDS

STATUS OF EXPLORATION DRILLING

South Meade Test Well No. 1, located 45 miles south of Barrow, spudded in February 1978 and drilled to a depth of 8,516 feet before spring breakup conditions required suspension of drilling. In December 1978, the well was reentered and completed to the "argillite" basement at 9,945 feet. The well was drilled to test for possible oil and gas accumulation in truncated onlap strata on the southern flank of the Barrow Arch. Minor gas shows were observed from many zones, but none was judged to be commercially significant. The well was plugged and abandoned in January 1979.

Inigok Test Well No. 1, located 60 miles south of Lonely, began drilling in June 1978 and continued drilling throughout the summer because an all-season drilling pad, roads, and airstrip had been constructed. The well was drilled to test a deeply buried east-trending faulted anticlinal feature separating the Umiat and Ikpikpuk Basins. Drilling was routine to 17,570 feet when native sulfur and high concentrations of hydrogen sulfide gas were encountered. After the sulfur and the gas were controlled, drilling continued. Only minor gas shows were noted in several zones, but no good reservoirs were found. Although "argillite" was not encountered due to early termination of drilling caused by excessive borehole drift, the well reached a depth of 20,102 feet, a new record for an Alaskan well. The well was plugged and abandoned in May 1979.

Tunalik Test Well No. 1, located 22 miles southeast of Icy Cape, was planned as a second deep test for fiscal year 1978, but drilling did not begin until November 1978 because the drilling rig could not be moved from the Kugrua well site before spring breakup. Numerous minor gas shows were encountered at both shallow and moderate depths in thin sandstones which had low porosity. High-pressure gas, which was encountered at about 12,550 and 14,725 feet, created severe drilling problems. Attempts to test the upper unit before drilling ahead failed. Further testing will be delayed until drilling has been completed. Target depth of the well is 21,000 feet; however, as of the end of September 1979, drilling was below 17.000 feet.

Ikpikpuk Test Well No. 1, located 42 miles southwest of Lonely, spudded in November 1978 on a drilling pad constructed during the previous winter. The well was drilled to test for possible oil and gas accumulations on the northern wedge of the Ikpikpuk Basin. The well was programmed to drill to "argillite" at 15,200 feet. Although drilling progressed approximately on schedule, the well did not reach target depth before spring breakup. The well was suspended at 14,210 feet in April 1979. When suspended, the well had penetrated no significant reservoir zones or oil shows. The borehole was prepared for reentry in fiscal year 1980.

Peard Test Well No. 1, located 70 miles southeast of Barrow, was drilled to test for possible oil and gas accumulations along the northern flank of the Meade Basin. Minor gas shows were noted in several zones, but no attractive reservoirs were found. The well spudded in January 1979 and was plugged and abandoned in April 1979.

East Simpson Test Well No. 1, located 55 miles southeast of Barrow, was a test of possible stratigraphic traps. Shows of oil and gas and residual oil were noted in several zones, but no significant reservoirs were found. Potential reservoir zones had low to moderate porosity and permeability. Structural and stratigraphic relations at the well indicate that the location is structurally too low in the trap, and a followup well is planned for fiscal year 1980 updip from the East Simpson Test Well No. 1 location to test for oil structurally higher in the trap. The well spudded in February 1979 and was plugged and abandoned in April 1979.

J. W. Dalton Test Well No. 1, located 3 miles east of Lonely, was drilled to test for oil or gas accumulations on the southern flank of the Barrow-Prudhoe high. Significant oil shows had been encountered in a nearby well located farther down the structure. At the Dalton location, significant amounts of heavy residual oil or tar were encountered, and tests of several zones recovered minor amounts of gas and heavy asphaltic oil. The occurrence of heavy oil and salt water may indicate that the well penetrated a reservoir just below the oil-water contact. If gas or oil is present in the reservoir, it may lie offshore. The well spudded in May 1978 and was drilled to "argillite" basement at 9,367 feet. It was plugged and abandoned in August 1979.

Lisburne Test Well No. 1, located 110 miles southwest of Umiat, was drilled in the southern part of the Reserve along the northern front of the Brooks Range to test a large deeply buried anticline identified from seismic data. This was the first exploration well in the Disturbed Belt of the Southern Foothills of NPRA. Drilling began in June 1979 but was temporarily suspended at a depth of 6,773 feet on August 15, 1979, due to a labor dispute at the rig. The drilling rig, support camp, and airstrip were being maintained with minimum staff pending resolution of the dispute. Target depth of the well is 15,000 feet.

Seabee Test Well No. 1, located 1 mile northwest of Umiat, was drilled in the southern part of the Umiat oil field to test deeper zones not previously tested in this area. Good oil and gas shows were noted in the Umiat Oil Zone, but no testing was performed because of the large-diameter borehole and of earlier tests made in shallow wells. Drilling was temporarily suspended at a depth of 6,651 feet on August 15, 1979, due to a labor dispute at the rig. The drilling rig, support camp, and airstrip were being maintained with minimum staff pending resolution of the dispute. Target depth is 15,000 feet.

Geophysical studies on NPRA continued during fiscal year 1979 with the acquisition, processing, and interpretation of 1,872 line miles of reconnaissance and detailed seismic surveys in various parts of the Reserve using three field geophysical crews, two in the Southern Foothills area and one in the northern coastal area. Approximately 500 miles of previously acquired seismic data were processed for special stratigraphic evaluation. To date, 11,407 line miles of seismic data have been collected and processed. In addition, various geologic studies are underway by the Geological Survey and by contractors to support oil exploration activities, which include structural and stratigraphic studies, geochemical investigations, and hydrologic and engineering studies.

The petroleum exploration activities on NPRA are coordinated with two related studies mandated by Public Law 94-258. One study, due January 1, 1980, relates to "the best overall procedure to be used in the development, production, transportation, and distribution of the petroleum resources in the reserve." This study is referred to as the Presidential Study or the 105(b) Study. It consists of an economic analysis by the Office of Minerals Policy and Research Analysis in the Department of the Interior and an environmental analysis by the Geological Survey. The second study, conducted by the Bureau of Land Management, is "to determine the values of, and best uses for, the lands contained in the reserve, taking into consideration (A) the natives who live or depend upon such lands, (B) the scenic, historical, recreational, fish and wildlife, and wilderness values, (C) mineral potential, and (D) other values of such lands." This study, referred to as the 105(c) Study, was compiled by the Bureau of Land Management and was submitted to Congress in April 1979. However, because land use designations and petroleum development decisions are so closely related, the Department of the Interior postponed making recommendations until submission of the Presidential Study on approaches for petroleum development.

Table 1 lists wells drilled by the Navy between 1975 and 1977, wells drilled in fiscal years 1978 and 1979, exploration wells planned for fiscal year 1980 by the Geological Survey, and development wells drilled in the Barrow gas fields in 1977 and 1978.

Table 1.—Summary of exploration drilling by the Department of the Navy and the U.S. Geological Survey

Name	Location	Date spudded	Date completed	Total depth in feet	Deepest horizon attained	Remarks
Cape Halkett No. 1.	18 miles ESE of Lonely.	3-24-75	5-23-75	9,900	"Argillite" basement (Devonian or older).	Dry, plugged and abandoned.
East Teshekpuk No. 1	25 miles of Lonely.	3-12-76	5-11-76	10,664	Granite basement	Do.
South Harrison Bay No. 1.	50 miles of Barrow.	11-21-76	1-27-77	11,290	Lisburne Group (Misississippian).	Poor oil shows; plugged and abandoned.
Atigaru Point No. 1.	44 miles SE of Lonely.	1-12-77	3-10-77	11,535	"Argillite basement (Devonian or older).	Do.
West Fish Creek No. 1.	51 miles SE of Lonely.	2-14-77	4-21-77	11,427	Kayk Shale (Mississippian).	Do.
South Simpson No. 1.	41 miles WSW of Lonely.	3-9-77	4-18-77	8,805	"Argillite basement (Devonian or older).	Dry; plugged and abandoned.
W. T. Foran No. 1.	23 miles ESE of Lonely.	3-7-77	4-16-77	8,864	...do...	Oil and gas shows; plugged and abandoned.
Drew Point Test Well No. 1.	14 miles W of Lonely.	1-13-78	3-13-78	7,946	...do...	Poor oil and gas shows; plugged and abandoned.
North Kilikpuk Test Well No. 1.	37 miles SE of Lonely.	2-27-78	4-14-78	7,395	Kingak Shale (Jurassic).	Do.
South Meade Test Wells No. 1.	45 miles S of Barrow.	2-8-78 (Reentered)	1-22-79	9,945	"Argillite" basement (Devonian or older).	Poor gas shows; plugged and abandoned.
Kugrua Test Well No. 1.	67 miles SW of Barrow.	2-13-78	5-30-78	12,588	Lisburne Group (Mississippian).	Dry; plugged and abandoned.
Inigok Test Well No. 1.	60 miles S of Lonely.	6-7-78	5-22-79	20,102	Kekiktuk Formation (Mississippian).	Encountered hydrogen sulfide and sulfur at 17,570 feet; poor gas shows; plugged and abandoned
Tunalik Test Well No. 1.	22 miles SE of Icy Cape.	11-10-78	...	[2] 21,000	[2] "Argillite" basement	Drilling at 18,156 feet as of 9-30-79.
Peard Test Well No. 1.	25 miles NE of Wainwright.	1-27-79	4-13-79	10,225	"Argillite" basement	Poor gas shows; plugged and abandoned.
Ikpikpuk Test Well No. 1.	42 miles SW of Lonely.	11-29-78	...	[2] 15,200	[2] "Argillite" basement	Suspended at 14,210 feet; to be reentered and completed early in fiscal year 1980.
East Simpson Test Well No. 1.	55 miles SE of Barrow.	2-19-79	4-10-79	7,739	"Argillite" basement	Oil and gas shows; plugged and abandoned.
J. W. Dalton Test Well No. 1.	3 miles E of Lonely.	5-7-79	8-2-79	9,367	...do...	Oil and gas shows; some heavy oil recovered during testing; plugged and abandoned.
Lisburne Test Well No. 1.	110 miles S. of Umiat.	6-11-79	...	[2] 15,000	[2] Lisburne-Endicott Group.	Suspended at 6,773 feet on 8-15-79, due to labor dispute.
Seabee Test Well No. 1.	1 mile NW of Umiat.	7-1-79	...	[2] 15,000	[2]Basal Cretaceous	Suspended at 6,551 feet on 8-15-79 due to labor dispute.
Walakpa Test Well No. 1.	15 miles S of Barrow.	Being planned.	...	[2] 3,500	"Argillite" basement (Devonian or older).	.....
West Dease Test Well No. 1.	28 miles SE of Barrow.	...do...	...	[2] 4,000	...do...	.....
East Simpson Test Well No. 2.	50 miles SE of Barrow.	...do...	...	[2] 7,600	...do...	.....
Koluktak Test Well No. 1.	75 miles S of Smith Bay.	...do...	...	[2] 4,500	Torok Formation (Cretaceous).	.....
Awuna Test Well No. 1.	150 miles S of Barrow.	...do...	...	[2] 15,000	Lisburne Group (Mississippian).	.....

[1] Drilling began. [2] Projected.

ACTIVITIES IN THE BARROW AREA

The Geological Survey continued to operate and maintain the South Barrow gas field (table 1) which supplies natural gas to the village of Barrow and Federal installations in the Barrow area. In compliance with congressional direction, no new wells were drilled pending completion of studies of possible alternative fuel sources for Barrow. The studies established that the continued development of local gas reserves is the most cost-effective manner of providing energy to the Barrow area. During fiscal year 1979, an access road was constructed to the South Barrow gas field and a pipeline was built connecting it to the East Barrow gas field; this allows both fields to be produced simultaneously. A pressure-reducing station is being constructed which will allow two previously drilled East Barrow wells to begin producing gas during the winter of 1979–80. One problem well (Barrow Well No. 6, drilled in 1964) in the South Barrow gas field was worked over and provided with more modern surface equipment.

Table 1.—Summary of drilling in Barrow area by the Department of the Navy and the U.S. Geological Survey

Name	Location	Date spudded	Date completed	Total depth in feet	Deepest horizon attained	Remarks
South Barrow No. 13.	5 miles SE of Barrow.	12-17-76	1-16-77	2,355	"Argillite" basement (Devonian or Older).	Shows of gas, suspended as marginal gas well.
South Barrow No. 14.	12 miles ESE of Barrow.	1-28-77	3-3-77	2,257	Sag River sandstone (Triassic).	Completed as a gas well.
South Barrow No. 16.	6 miles E of Barrow.	1-28-78	2-18-78	2,400	"Argillite" Basement (Devonian or Older).	Dry; plugged and abandoned.
South Barrow No. 17.	13 miles ESE of Barrow.	3-2-78	4-13-78	2,382	...do...	Suspended; edge well; produces water with gas.
South Barrow No. 19.	11 miles ESE of Barrow.	4-17-78	5-17-78	2,300	...do...	Completed as a gas well.

ENVIRONMENTAL REHABILITATION ON NPRA

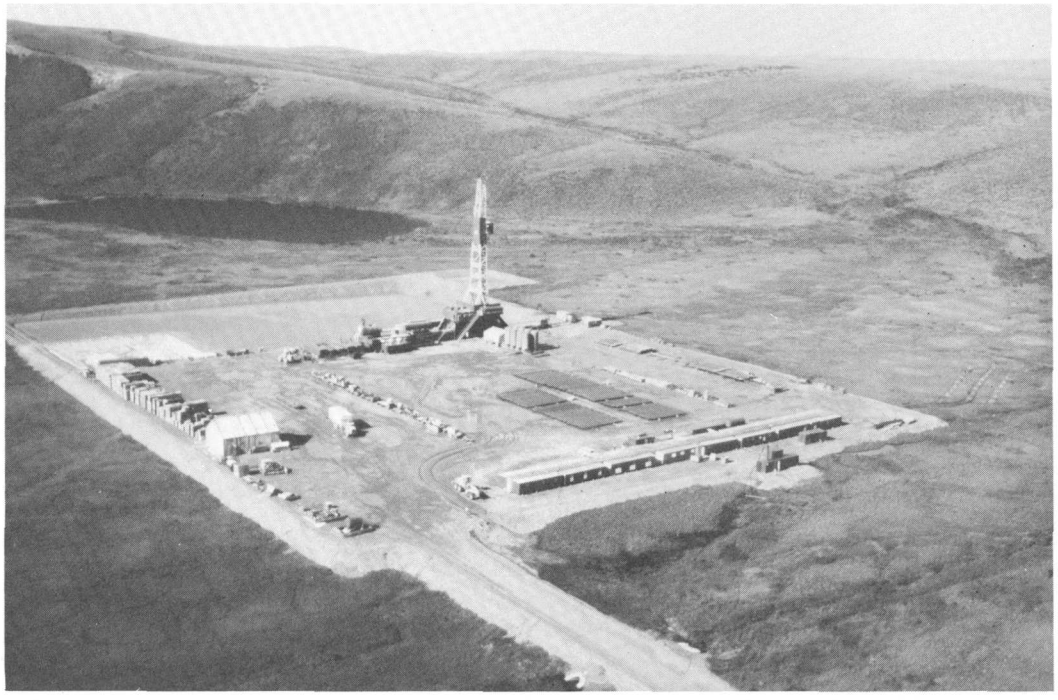
The Geological Survey environmental rehabilitation program on NPRA consists of two parts, the collection and consolidation of litter and debris left from previous construction and oil exploration activities and the cleanup and revegetation of current drilling sites.

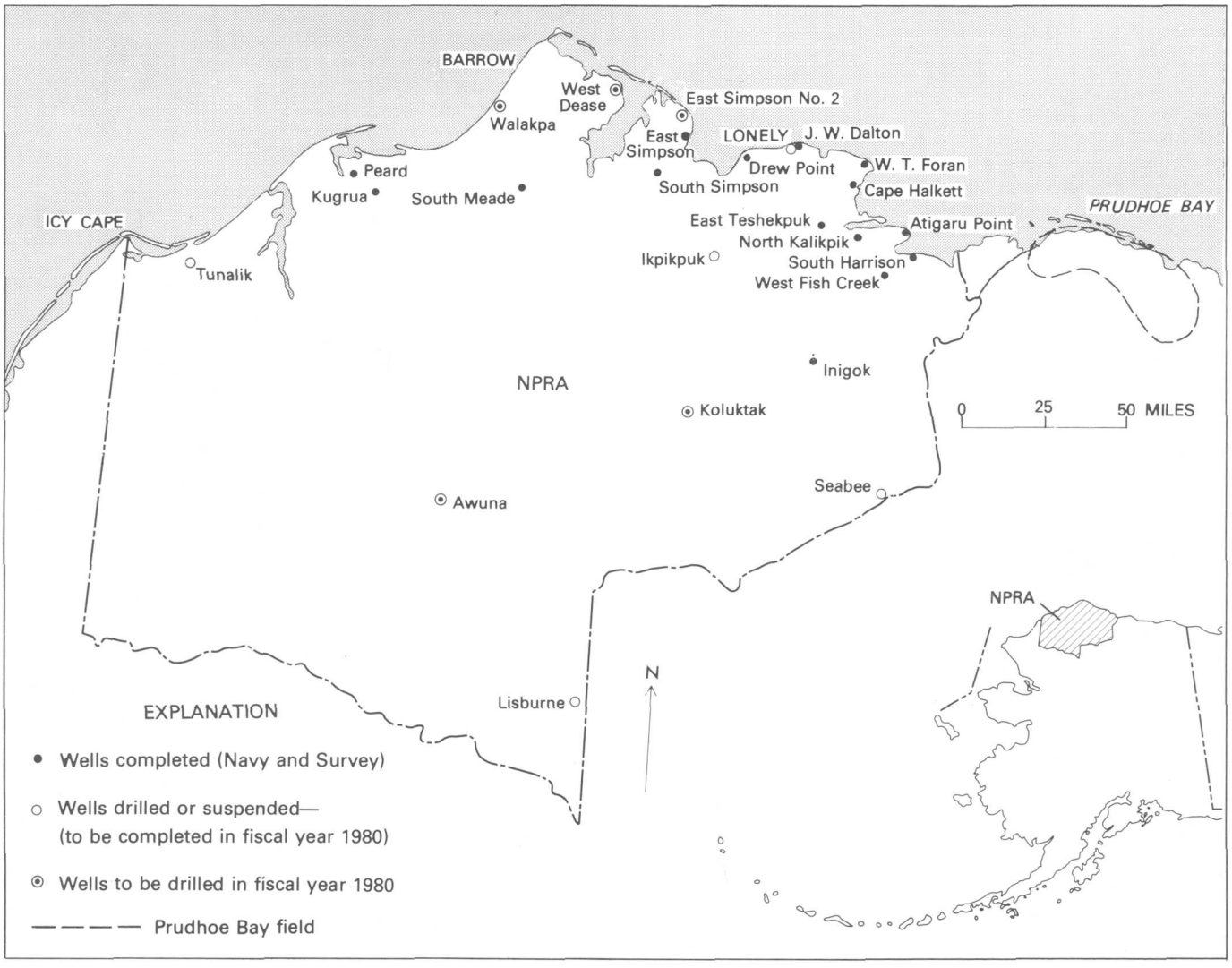
Early oil exploration and construction activities were accomplished with little consideration for environmental protection or effects of drilling operations on the tundra environment. Fuel drums, abandoned equipment and supplies, and other litter of exploration and construction were left in place at many sites. During fiscal year 1979, the Geological Survey collected over 2,800 tons of debris and waste materials from 36 old sites on and adjacent to the Reserve. These materials were consolidated and stockpiled at several collection points on the Reserve.

Current program site rehabilitation consists of an initial recontouring and revegetation of drilling sites with a second reseeding during the following year. During fiscal year 1979, initial rehabilitation work was performed at 10 sites and followup reseeding and refertilizing was completed at 4 sites. Seed and fertilizer were set out for next year's use at nine sites. Both cleanup and rehabilitation activities are accomplished by contract personnel.

Waste materials and abandoned oilfield equipment and supplies at old drilling site on NPRA. (Photograph by Roger Witmer, August 1979.)

Seabee drilling location near Umiat. (Photograph by Roger Witmer, August 1979.)

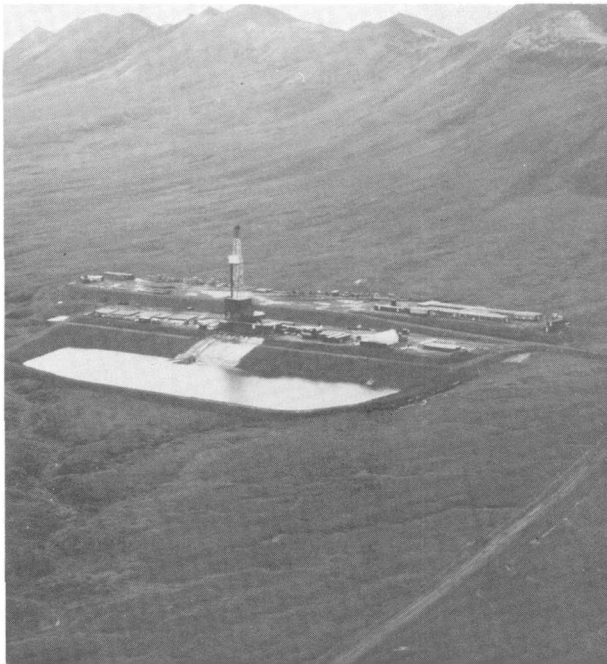




Location map of the National Petroleum Reserve in Alaska.

Tunalik drilling site, near the Arctic Ocean, in the western part of the Reserve (Photograph by Roger Witmer, August 1979.)

Lisburne drilling location in Southern Foothills of the Brooks Range. Access road connects drilling pad to all-season airstrip. (Photograph by Roger Witmer, August 1979.)



Program Support Divisions

ADMINISTRATIVE DIVISION

GENERAL ADMINISTRATION

The cost of executive direction and coordination of U.S. Geological Survey programs and administrative services provided by the Administrative Division is funded by General Administrative Expenses. During fiscal year 1979, these expenses amounted to 3.3 percent of the Survey's budget. Funding was derived from the following sources: the General Administration budget activity, $3.66 million; assessments on the directly appropriated activities, $10.60 million; and, assessments on the reimbursable programs, $4 million. No assessments are made on cooperative funds from State and local governments.

ADMINISTRATIVE MANAGEMENT

The activities of the Administrative Division are carried on at Survey Headquarters in Reston, Va., and at the three major Regional Centers—Eastern Region, also headquartered at Reston; Central Region, headquartered in Denver, Colo.; and Western Region, headquartered in Menlo Park, Calif. There are also satellite offices in Atlanta, Ga., Rolla, Mo., Metairie, La., Flagstaff, Ariz., and Anchorage, Alaska, which primarily provide personnel and facilities or supply management service functions to Survey installations in the immediate or nearby areas.

During fiscal year 1979, the Administrative Division implemented and coordinated a number of personnel management, procurement, and facilities improvements. Highlights associated with these management improvements are described in the following text.

IMPLEMENTING THE CIVIL SERVICE REFORM ACT

On October 13, 1978, President Carter signed the Civil Service Reform Act, which is designed to improve the Government's personnel management practices involved with hiring, training, rewarding, and removing Federal employees. Two of the key elements of the Act deal with executive personnel management and employee performance evaluation.

Senior Executive Service

The Senior Executive Service (SES) is a modern approach to executive management designed to make maximum use of top-level management resources. The objective of the SES is to attract and to keep top managers, to utilize their abilities in the most productive fashion, to increase their job mobility, and to pay them according to their performance. The Survey's executive corps has overwhelmingly embraced the SES concept. The flexibility afforded by the SES is expected to add an extra management dimension to the Survey's ability to meet the challenging demands it faces in the areas of diverse research and scientific and regulatory programs.

Performance Evaluation

The Civil Service Reform Act also gives special attention to the importance a well-designed and well-implemented performance evaluation system can have in motivating employees and increasing productivity. Representatives from all major Survey Divisions and Offices have formed a Performance Appraisal Task Force to work on plans for Bureau performance appraisal systems. These efforts are being aided by a contractor study of the Survey's job families and recommendations for performance appraisal systems which will provide meaningful and usable information about employee performance necessary for supervisors to make job assignments as well as reward and disciplinary decisions.

MINORITY BUSINESS ENTERPRISE PROGRAM

Reacting to a Presidential directive for all Government departments to triple their Minority Business Enterprise Program efforts above fiscal year 1977 levels, the Geological Survey established a $3.8 million goal for its fiscal year 1979 program. This target was over five times greater than the fiscal year 1977 level. Working closely with the Departmental Office of Small and Disadvantaged Business Utilization, the Survey awarded contracts amounting to over $9 million to minority businesses. This was accomplished through a concerted nationwide effort by scientific and research program managers and procurement offices to locate and to utilize minority firms.

ADVANCE PROCUREMENT PLANNING

During the fiscal year, an advance procurement planning system was initiated to establish communication and coordination milestones for project managers to use in providing procurement offices leadtime for all contracts totaling $10,000 or more. The objectives of this new approach are aimed at simplifying the entire procurement activity start to finish. It is expected to improve the scheduling and subsequent timely award of contracts re-

quired to support many of the Survey's scientific and research programs.

ENERGY CONSERVATION

In building operations for fiscal year 1979, the Survey achieved a reduction of approximately 21 percent in energy use when compared with fiscal year 1975 base-year data. This reduction exceeds the fiscal year 1985 20-percent reduction target established by the President. Also, for fiscal year 1975 through fiscal year 1979, the Survey validated energy use and square-footage information for buildings within the scope of the energy conservation program. At the Earth Resources Observation Systems Data Center located at Sioux Falls, approximately 75 percent of the solar energy construction work, begun in fiscal year 1978, was completed. When operational, this project will result in an estimated annual utility cost savings of $35,000.

FLEXITIME EXPERIMENTS BROADENED

In late fiscal year 1979, the Survey completed plans to expand its flexitime program by selecting four field-office installations and one headquarters operation involving about 1,000 Survey employees for 18-month experiments with new types of alternative work schedules. These experiments are permissible under the Federal Employees Flexible and Compressed Work Schedules Act (Public Law 95-390), which was signed into law in September 1978. This Act mandates that the Office of Personnel Management (OPM) monitor the experiments to determine if alternative work schedules can be used successfully by Federal agencies.

During the experiments, OPM will be collecting and evaluating data to determine the impact of the experiments on the efficiency of Government operations; public transportation and traffic; levels of energy consumption; service to the public; and opportunities for full-time and part-time employment, individuals, and families generally.

At the end of the experiments, participating Survey organizations will revert to the Survey's current flexitime system while OPM prepares a report on the results of the experiment for the President and Congress. If the experiments prove successful, the laws that regulate administrative workweeks, tours of duty, and certain pay provisions may be modified to permit Federal agencies to permanently use flexible and compressed work schedules.

COMPUTER CENTER DIVISION

Scientific research within the U.S. Geological Survey is supported by both batch and time-sharing computer facilities across the Nation. The primary batch processing installation consists of two IBM 370/155 computers, which are located in the National Center, Reston, Va. These computers are interconnected and can be thought of as one system. In addition to the 370's at the National Center, a contract with American Management Systems (AMS) was extended into fiscal year 1979 to continue provision of additional batch computing services. Through a telecommunications facility, users can now access the AMS computer as though it were part of the Survey's own computer system, ensuring the user identical procedures, regardless of which computer processes the data. During fiscal year 1979, more than 1,350 users from over 120 remote Survey locations, as well as the National Center, submitted approximately 450,000 jobs to these computers. This is an 18.5-percent increase in users and a 16.4-percent increase in jobs over fiscal year 1978.

The time-sharing needs of the Survey are largely supported by three Honeywell Multics systems located in Denver, Colo., Menlo Park, Calif., and Reston, Va. On the Multics system, many users can carry on a conversation with the computer at the same time. On Multics, users may be registered at one, two, or all three sites and are associated with at least one project at each site. At the close of fiscal year 1979, there were approximately 4,580 users registered on the three Multics systems, an 18-percent increase in users from fiscal year 1978. There was a 20-percent increase in the number of projects registered on the three Multics systems, bringing the figure to over 1,200. The average number of interactive sessions per month is currently 35,000, which represents an increase of 30-percent over last year.

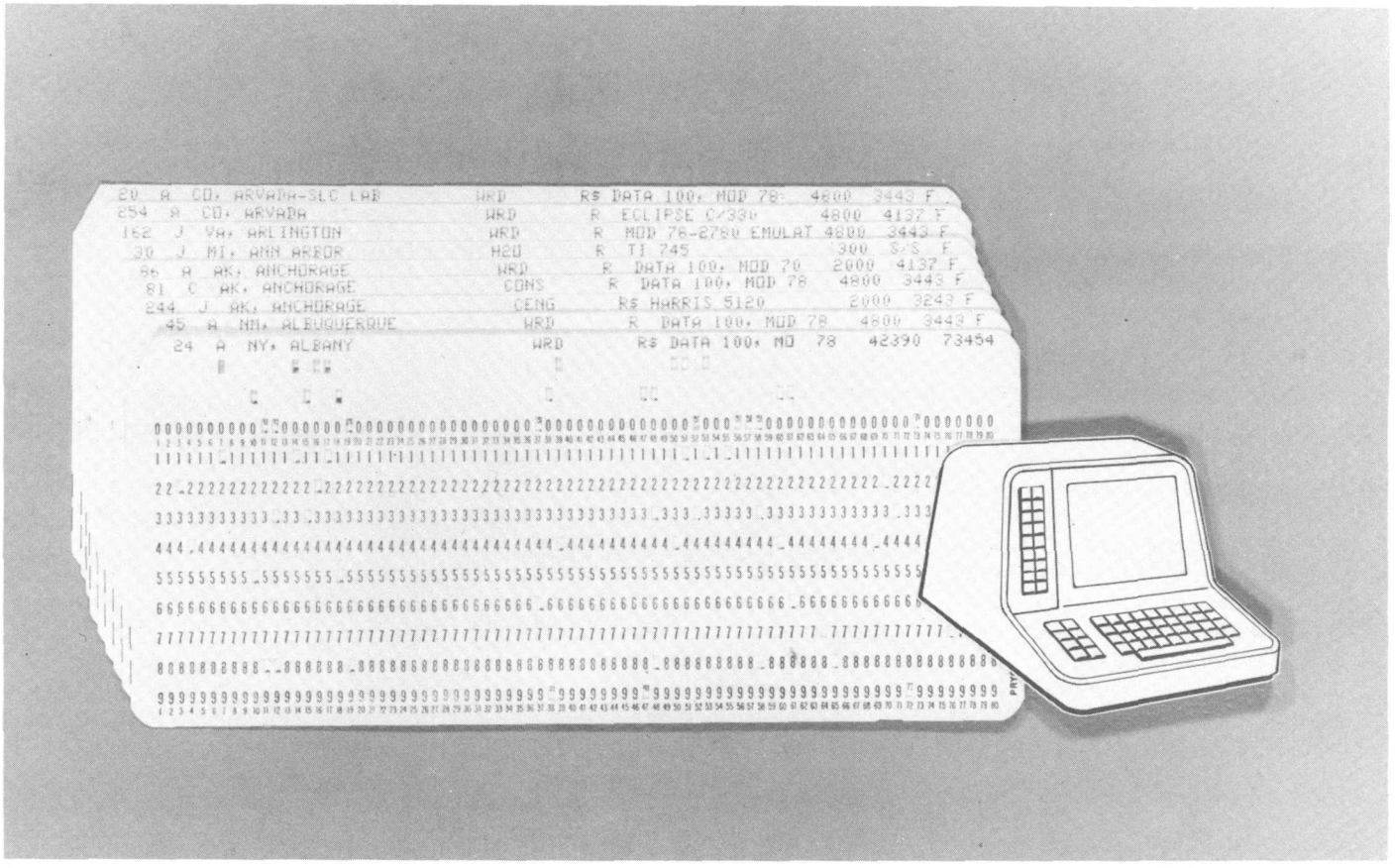
The Survey also operates Digital Equipment Corp. computer systems in Flagstaff, Ariz. During fiscal year 1979, a selection was made on a Floating Point Systems array processor for Flagstaff, and an evaluation was made of interactive color image display systems, one of which is about to be selected. These enhancements increase the ability of earth scientists to process and to study digital imagery. The major objective in acquiring this new equipment is that it will provide the capability of correlating digital Landsat photography with other types of earth science data and new ways of looking at the Earth and its natural resources.

The demand for more effective communications between earth scientists and their data has become a vital requirement for the mission of the Geological Survey. For that reason, the Computer Center Division has increased its data communications services significantly during fiscal year 1979. Of major importance was the approval for expansion of the TYMNET facility. TYMNET, a nationwide communications network, allows Survey scientists to access computers in other metropolitan areas for the cost of a local telephone call. This expansion brings additional TYMNET lines into all sites and adds the capability of transmitting at a higher speed. Also, with this upgrade, the IBM systems will be added to TYMNET.

However, the most significant event in the area of communications was the research and planning for the installation of ARPANET. ARPANET is a resource-sharing inter-computer network linking a wide variety of computers. The network was designed to provide efficient communications between heterogenous computers so that hardware, software, and data resources could be conveniently and economically shared by a wide community of users. Functionally, what this means is that the several Survey computer systems can be connected; data files and programs can be instantaneously transferred across the systems. Also inherent in such a communications network is the possibility of load leveling; that is, data processing can be passed from an overloaded system to an unsaturated one more conveniently. It should also be noted that, through ARPANET, it is possible to communicate with other members of ARPANET. This creates unique opportunities for Survey scientists to communicate with non-Survey data bases at sites that are also ARPANET members.

Other significant computer support activities during fiscal year 1979 include:

- Replacement of single density disks with dual density disks on both the IBM and Honeywell systems, which increased storage space by 25 percent and served as an energy saver as well as a space saver.
- Procurement of a Front-end Network Processor for the IBM's, which takes many routine input/output functions out of the central processing unit.
- Development of the specifications for the procurement of Uninterruptible Power Supply, which assures that local power outages do not affect the availability of the computer.
- Installation of a data migration system on Multics, which takes data that is using online storage, but has not been used recently, and transfers it to easily retrievable tape storage.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30 J MI: ANN ARBOR H2O R TI 745 300 S/S F
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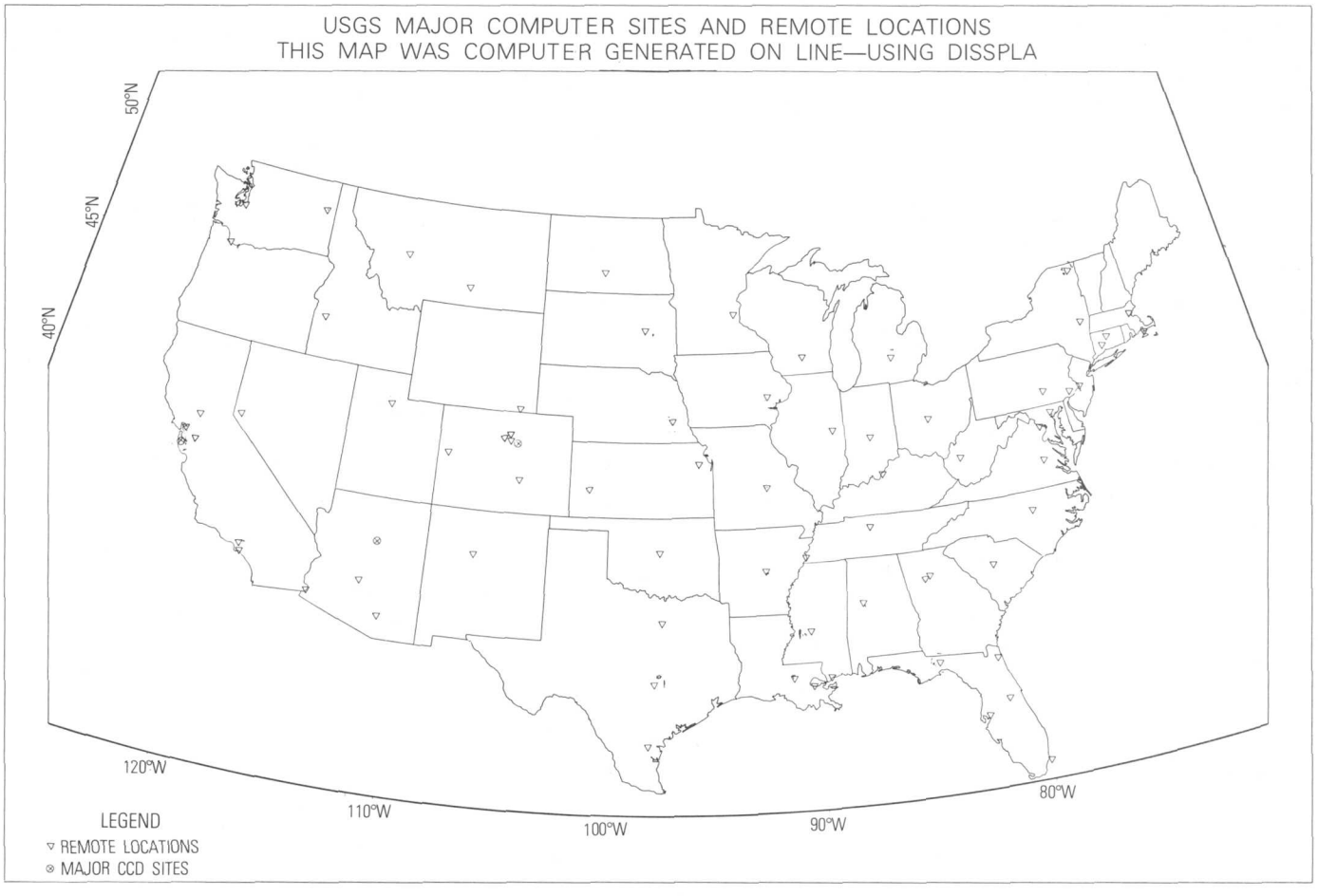
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PUBLICATIONS DIVISION

Results of research and investigations conducted by the U.S. Geological Survey are made available to the public through increasingly diverse information services and publications.

The Publications Division edits the Survey's scientific and technical publications, including professional papers, bulletins, water-supply papers, and circulars. The Division also prepares nontechnical booklets designed to communicate many of the Survey programs to the public. In addition to preparing reproduction manuscripts for geologic, hydrologic, and other thematic maps, the Division prints topographic and thematic maps and warehouses and distributes all Survey maps and books.

Major efforts were directed toward improvement of publications activities in fiscal year 1979. A multiyear program to modernize the system for distributing published products, which was initiated in fiscal year 1978, continued. The current manual system of order processing and inventory control is deficient in producing management information for efficient operations. The overall objective of this program, through automation and computerization, is to modernize and streamline all distribution operations to maximize responsiveness to customer demand and to do so in the most cost-effective manner. To date, a comprehensive in-house review of the existing distribution system, the development of alternative systems, and the selection of a new system to meet requirements have been completed. Design specifications for the new system are being developed.

In conjunction with this program, a map and book stock reduction activity is being carried out to eliminate surpluses above projected demands and to minimize growth in inventory.

Also in association with this program and as a conservation-type project, a contract to test the feasibility of recycling obsolete maps and converting them into mailing envelopes has been awarded. It is anticipated that the envelopes from this pilot project will be delivered by the contractor in early 1980.

The Survey designates interested local retail stores and other public facilities as dealers in Geological Survey maps. The designated dealers purchase the maps they wish to handle, establish their own resale prices, and resell the maps to the general public over-the-counter at their business establishments. In fiscal year 1979, a program was initiated to increase the map dealer program to make topographic and other maps available to the users as readily and economically as possible while minimizing Government involvement and encouraging private enterprise. In fiscal year 1979, there were 1,792 commercial dealers throughout the United States. Map sales to dealers were about 36 percent of the total copies of Survey maps sold.

A new Public Inquiries Office was established in Menlo Park, Calif., to improve dissemination of Geological Survey technical and scientific information to the general public at the Survey's Western Region Center.

During this fiscal year, considerable research effort was devoted to solving problems of reproducing high-quality imagery map products. Computerized satellite electromagnetic imagery and side-looking airborne radar photography both produce pictures comprised of picture elements (pixels) or scan lines. These pictures are difficult to reproduce by conventional halftoning methods without color aberration, moire, and the loss of detail. Results from the research showed that use of screenless printing techniques substantially reduced reproduction problems. Several printing production jobs were completed using the screenless techniques, and excellent customer comments were received.

The number of reports approved for publication by the Geological Survey continues to increase. About 60 percent of the 4,496 reports prepared in fiscal year 1979 were designated for publication in professional journals and monographs outside the Survey, about 28 percent were placed in the open file, and the remainder were scheduled for publication by the Survey. The Survey also produced over 10,147 topographic, hydrologic, and geologic maps in fiscal year 1979. Most of these maps were scheduled for publication. The open-file activity continued to grow during its second year of operation. The number of copies of open-file reports sold increased from 27,804 in fiscal year 1978 to 37,527 in fiscal year 1979, an increase of 35 percent.

Production highlights include the printing of 16,920,264 copies of 5,783 different maps, the distribution of 9,291,181 copies of maps of which 6,571,131 copies were sold for $6,297,769, the transmittal of 169 technical manuscripts to the Government Printing Office for printing, the distribution of 351,872 copies of technical reports of which 53,360 copies were sold for $173,102 and the release of 1,304 open-file reports of which 37,527 copies were sold for $279,311.

Guide to Information and Publications

Throughout this report, reference has been made to information services and publications of the Geological Survey. This section describes how and where the public may acquire information and obtain products.

To buy Survey book publications and maps of areas east of the Mississippi River or to request Survey circulars, catalogs, pamphlets, and leaflets (limited quantities free), write or visit:

U.S. Geological Survey
Branch of Distribution
1200 S. Eads St.
Arlington, VA 22202

To buy maps of areas west of the Mississippi River and to request Survey catalogs, pamphlets, and leaflets (limited quantities free), write or visit:

U.S. Geological Survey
Branch of Distribution
Box 25286, Bldg. 41, Federal Center
Denver, CO 80225

To buy Alaskan maps, residents of Alaska may write or visit:

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101 12th Avenue, Box 12
Fairbanks, AK 99701

To obtain information on the availability of microfiche or paper-duplicate copies of open-file reports, write:

U.S. Geological Survey
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Box 25425, Federal Center
Denver, CO 80225

To get on the mailing list for the monthly list of *New Publications of the Geological Survey* (free), write:

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12201 Sunrise Valley Drive
Reston, VA 22092

To subscribe to the *Earthquake Information Bulletin,* write:

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Government Printing Office
Washington, DC 20402

To buy books and maps of local areas and general interest, visit the U.S. Geological Survey Public Inquiries Offices in the following States:

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Los Angeles, CA 90012

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Dallas, TX 75242

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8105 Federal Bldg.
125 S. State St.
Salt Lake City, UT 84138

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1C402 National Center
12201 Sunrise Valley Dr.
Reston, VA 22092

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678 U.S. Courthouse
W. 920 Riverside Ave.
Spokane, WA 99201

Washington, DC:
1028 General Services Bldg.
19th and F Sts., N.W.
Washington, DC 20244

To obtain information on cartographic data, write or visit the U.S. Geological Survey, National Cartographic Information Centers (NCIC), in the following States:

California:
NCIC—West
345 Middlefield Rd.
Menlo Park, CA 94025

Colorado:
NCIC—Rocky Mountain
Box 25046, Stop 501
Bldg. 25, Federal Center
Denver, CO 80225

Missouri:
NCIC—Midcontinent
1400 Independence Rd.
Rolla, MO 65401

Virginia:
NCIC—Headquarters
507 National Center
12201 Sunrise Valley Dr.
Reston, VA 22092

NCIC—East
536 National Center
12201 Sunrise Valley Dr.
Reston, VA 22092

To obtain information on satellite and space photography, write or visit:

U.S. Geological Survey
EROS Data Center
Sioux Falls, SD 57198

To obtain assistance in locating sources of water data, identifying sites at which data have been collected, and specific data, write:

U.S. Geological Survey
National Water Data Exchange
421 National Center
12201 Sunrise Valley Dr.
Reston, VA 22092

To obtain information on ongoing and planned water-data acquisition activities of all Federal Agencies and many non-Federal organizations, write:

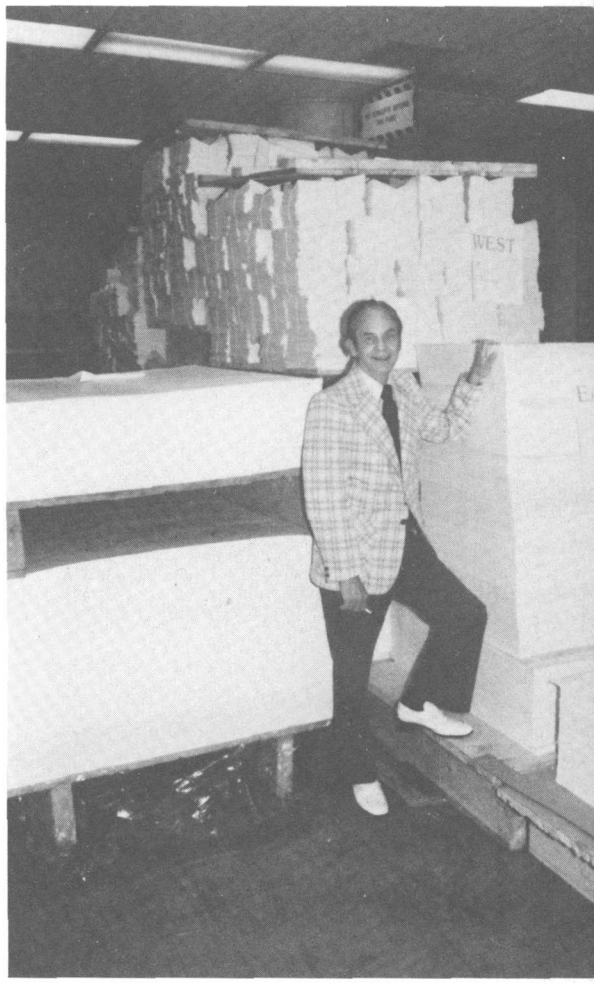
U.S. Geological Survey
Office of Water Data Coordination
417 National Center
12201 Sunrise Valley Dr.
Reston, VA 22092

To obtain information on water resources in general and about the water resources of specific areas of the United States, write:

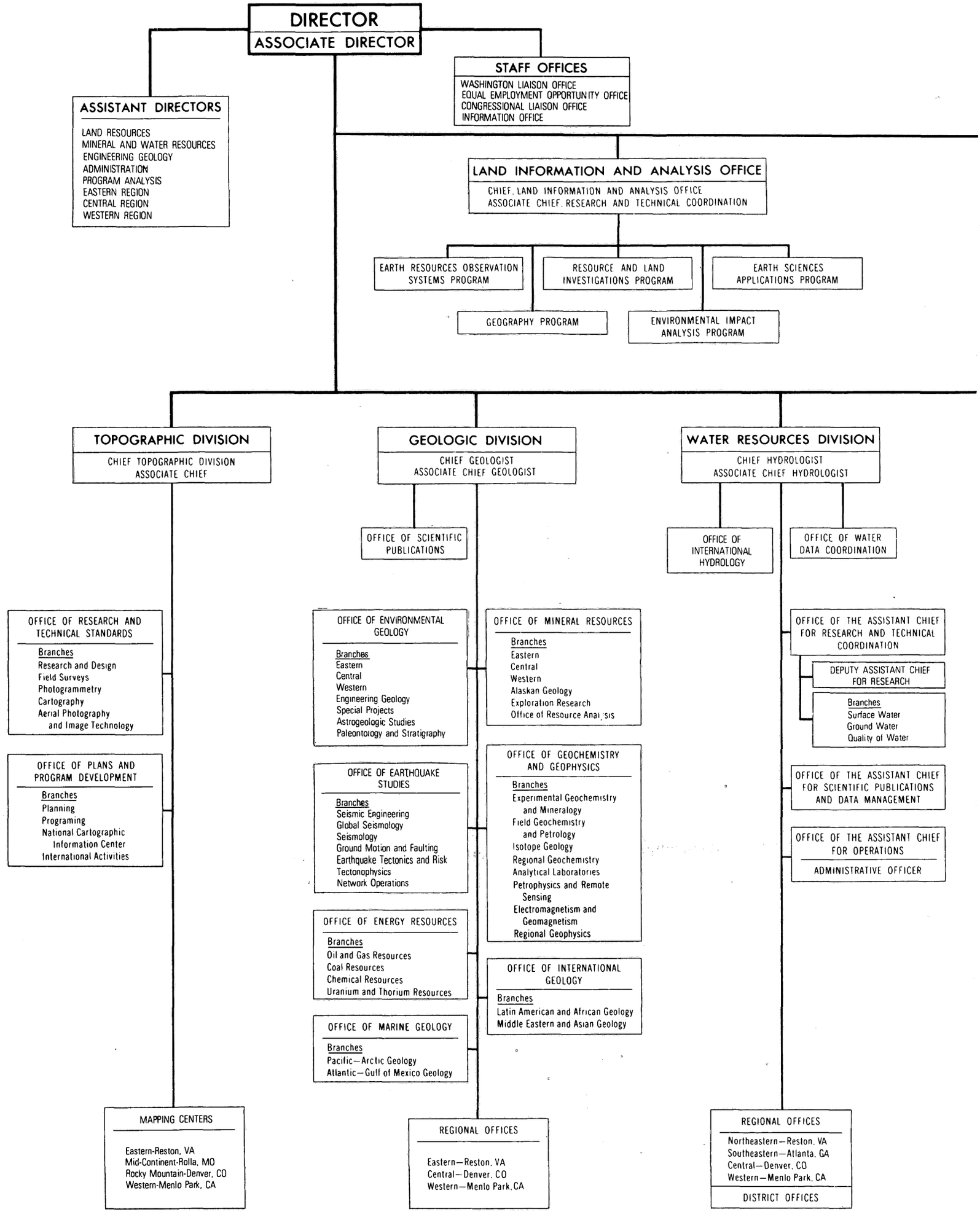
U.S. Geological Survey
Water Information Group
420 National Center
12201 Sunrise Valley Dr.
Reston, VA 22092

To obtain information on geology topics such as earthquakes, energy and mineral resources, the geology of specific areas, and geologic maps and mapping, write:

U.S. Geological Survey
Geologic Inquiries Group
907 National Center
12201 Sunrise Valley Dr.
Reston, VA 22092



William B. Overstreet, Chief, Publications Division, inspects skids of printed maps ready for shipment to distribution centers.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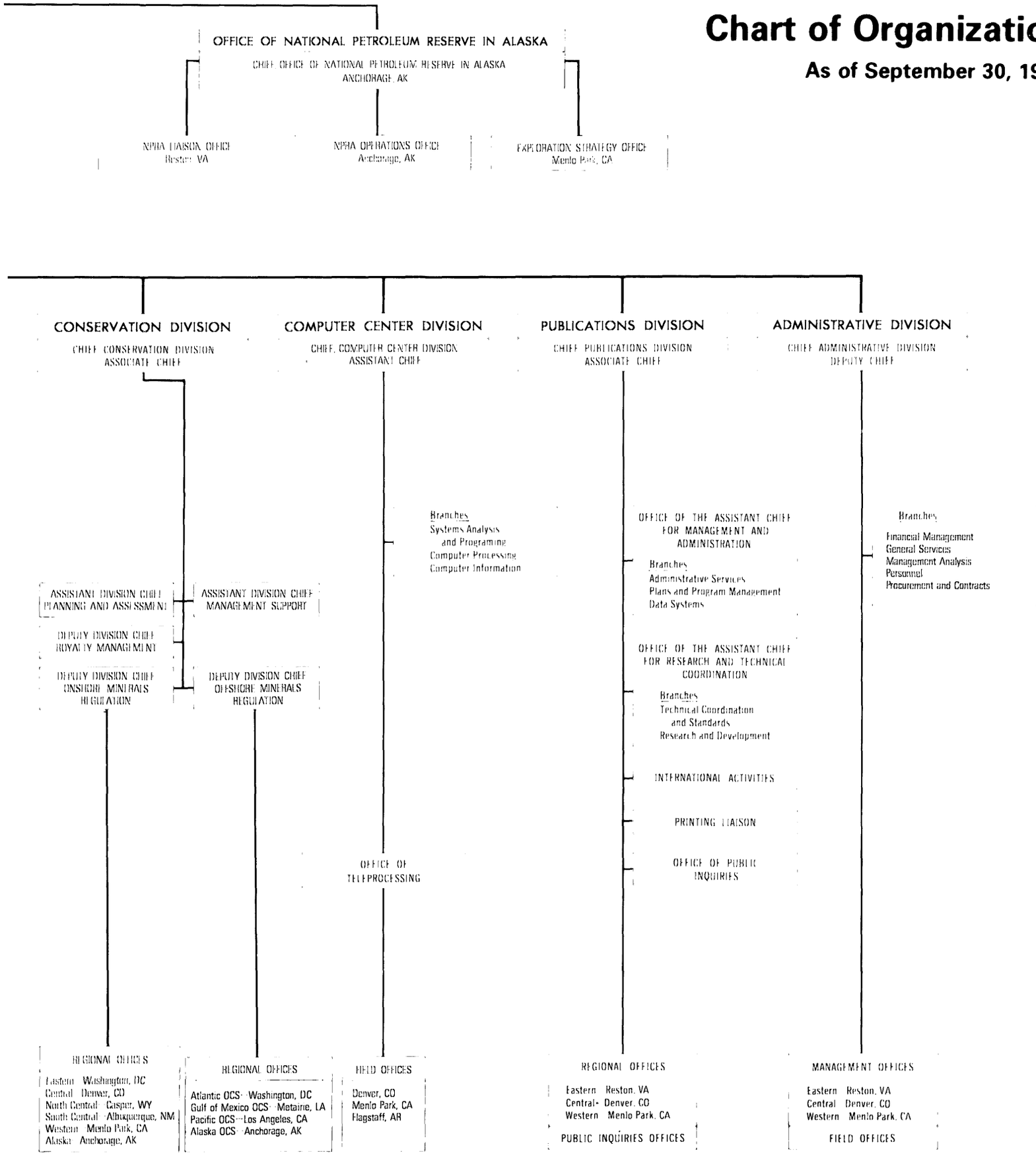
U.S. Geological Survey

Chart of Organization

As of September 30, 1979



U.S. GEOLOGICAL SURVEY OFFICES

HEADQUARTERS OFFICES

12201 Sunrise Valley Drive
National Center, Reston, VA 22092

[As of September 30, 1979. Update of this list is found on page 164]

OFFICE OF THE DIRECTOR

Official	Name	Telephone number	Address
Director	H. William Menard	(703) 860-7411	National Center, STOP 101
Associate Director	Joseph S. Cragwall	(703) 860-7412	National Center, STOP 102
Special Assistant (Washington Liaison)	Jane H. Wallace	(202) 343-3888	Rm. 7343, Interior Bldg., Washington, DC 20240
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Assistant Director—Geologic Engineering	Henry W. Coulter	(703) 860-7491	National Center, STOP 106
Assistant Director—Administration	Edmund J. Grant	(703) 860-7201	National Center, STOP 201
Assistant Director—Program Analysis	Dale Bajema	(703) 860-7435	National Center, STOP 105
Assistant Director—Eastern Region	[Vacant]	(703) 860-7414	National Center, STOP 109
Assistant Director—Central Region	Robert E. Evans	(303) 234-4630	Box 25046, STOP 101, Denver Federal Center, Denver, CO 80225
Assistant Director—Western Region	George E. Robinson	(415) 323-8111	345 Middlefield Road, Menlo Park, CA 94025
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* Office of Natural Petroleum Reserve in Alaska is headquartered in Anchorage, Alaska.

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REGIONAL MAPPING CENTER

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Eastern	Peter F. Bermel	(703) 860-6352	National Center, STOP 567
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Rocky Mountain	Albert E. Letey	(303) 234-2351	Box 25046, STOP 510, Denver Federal Center, Denver, CO 80225
Western	John R. Swinnerton	(415) 323-8111, ext. 2411	345 Middlefield Rd., Menlo Park, CA 94025

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WATER RESOURCES DIVISION

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Central	Alfred Clebsch, Jr.	(303) 234-3661	Box 25046, STOP 406, Denver Federal Center, Denver, CO 80225
Western	William H. Robinson	(415) 323-8111, ext. 2337	345 Middlefield Rd., Menlo Park, CA 94025

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Alaska	Harry Hulsing	(907) 277-5526	218 E. St., Anchorage, AK 99501
Arizona	Robert D. Mac-Nish	(602) 792-6671	Federal Bldg., 301 W. Congress St., Tucson, AZ 85701
Arkansas	Richard T. Sniegocki	(501) 378-5246	2301 Federal Office Bldg., 700 W. Capital Ave., Little Rock, AR 72201
California	Richard M. Bloyd	(415) 323-8111, ext. 2326	855 Oak Grove Ave., Menlo Park, CA 94025
Colorado	James F. Blakey	(303) 234-5029	Box 25046, STOP 415, Denver Federal Center, Denver, CO 80225
Connecticut	David McCartney	(203) 244-2528	135 High St., Room 235, Hartford, CT 06103

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Delaware	Walter F. White, Jr.	(301) 828-1535	See Maryland District Office
District of Columbia	Walter F. White, Jr.	(301) 828-1535	See Maryland District Office
Florida	Clyde S. Conover	(904) 386-1118	325 John Knox Rd., Suite F-240, Tallahassee, FL 32303
Georgia	John R. George	(404) 221-4858	6481 Peachtree Industrial Blvd., Suite B, Doraville, GA 30360
Hawaii	Benjamin L. Jones	(808) 546-8331	P.O. Box 50166, 300 Ala Moana Blvd., Honolulu, HI 96850
Idaho	Ernest F. Hubbard, Jr.	(208) 384-1750	Box 036 Federal Bldg., Room 365, 550 W. Fort St., Boise, ID 83724
Illinois	Larry G. Toler	(217) 359-3918	P.O. Box 1026, 605 N. Neil St., Champaign, IL 61820
Indiana	Dennis K. Stewart	(317) 269-7101	1819 N. Meridian St., Indianapolis, IN 46202
Iowa	Donald K. Leifeste	(319) 338-0581, ext. 521	P.O. Box 1230, 400 S. Clinton St., Iowa City, IA 52240,
Kansas	Joseph S. Rosenshein	(913) 864-4321	1950 Ave. A, Campus West, University of Kansas, Lawrence, KS 66045
Kentucky	Philip A. Emery	(502) 582-5241	572 Federal Bldg., 600 Federal Pl., Louisville, KY 40202
Louisiana	Albert N. Cameron	(504) 389-0281	P.O. Box 66492, 6554 Florida Blvd., Baton Rouge, LA 70896
Maine	John A. Baker	(617) 223-2822	See Massachusetts District Office
Maryland	Walter F. White, Jr.	(301) 828-1535	208 Carrol Bldg., 8600 La Salle Rd., Towson, MD 21204
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Michigan	T. Ray Cummings	(517) 372-1910, ext. 561	6520 Mercantile Way, Suite 5, Lansing, MI 48910
Minnesota	Donald R. Albin	(612) 725-7841	1033 Post Office Bldg., St. Paul, MN 55101
Mississippi	Lamar E. Carroon	(601) 969-4600	430 Bounds St., Jackson, MS 39206
Missouri	Donald L. Coffin	(314) 364-3680, ext.185	1400 Independence Rd., M.S. 200, Rolla, MO 65401
Montana	George M. Pike	(406) 449-5263	Federal Bldg., Room 428, 301 S. Park Ave., Drawer 10076, Helena, MT 59601
Nebraska	William M. Kastner	(402) 471-5082	406 Federal Bldg. and U.S. Courthouse, 100 Centennial Mall North, Lincoln, NE 68508
Nevada	Frank T. Hidaka	(702) 882-1388	227 Federal Bldg., 705 N. Plaza St., Carson City, NV 89701

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New Jersey	Donald E. Vaupel	(609) 989-2162	P.O. Box 1238, 436 Federal Bldg., 402 E. State St., Trenton, NJ 08607
New Mexico	James F. Daniel	(505) 766-2246	P.O. Box 26659, Western Bank Bldg., Rm. 809, 505 Marquette, N.W., Albuquerque, NM 87125
New York	Laurance A. Martens	(518) 472-3107	P.O.Box 1350, 343 U.S. Post Office and Courthouse Bldg., Albany, NY 12201
North Carolina	Ralph C. Heath	(919) 755-4510	P.O. Box 2857, Rm. 432, Century Postal Station, Raleigh, NC 27602
North Dakota	Grady Moore	(701) 255-4011, ext. 601	821 East Interstate Ave., Rm. 332, New Federal Bldg., 3d St. and Rosser Ave., Bismark, ND 58501
Ohio	[Vacant]	(614) 469-5553	975 West Third Ave., Columbus, OH 43212
Oklahoma	James H. Irwin	(405) 231-4256	201 N.W. 3d St., Rm. 621, Oklahoma City, OK 73102
Oregon	Stanley F. Kapustka	(503) 234-3361, ext. 4776	P.O.Box 3202, 830 N.E. Holladay St., Portland, OR 97232
Pennsylvania	David E. Click	(717) 782-3468	P.O. Box 1107, 4th Floor, Federal Bldg., 228 Walnut St., Harrisburg, PA 17108
Puerto Rico	Craig B. Bentley	(809) 783-4660	P.O. Box 34168, Bldg. 652, Ft. Buchanan, PR 00934
Rhode Island	John A. Baker	(617) 223-2822	See Massachusetts District Office
South Carolina	Rodney N. Cherry	(803) 765-5966	2001 Assembly St., Suite 200, Columbia, SC 29201
South Dakota	Richard E. Fidler	(605) 352-8651, ext. 258	P.O. Box 1412, 200 4th St., S.W., Rm. 308, Huron, SD 57350
Tennessee	Stanley P. Sauer	(615) 251-5424	A-413 Federal Bldg., U.S. Courthouse, Nashville, TN 37203
Texas	I. Dale Yost	(512) 397-5766	649 Federal Bldg., 300 E. 8th St., Austin, TX 78701
Utah	Theodore Arnow	(801) 524-5663	8002 Federal Bldg., 125 S. State St., Salt Lake City, UT 84138
Vermont	John A. Baker	(617) 223-2822	See Massachusetts District Office
Virginia	William E. Forrest	(804) 782-2427	200 W. Grace St., Rm. 304, Richmond, VA 23220
Washington	Charles R. Collier	(206) 593-6510	1201 Pacific Ave., Suite 600, Tacoma, WA 98402

WATER RESOURCES DIVISION/DISTRICT OFFICES—Continued

Office	Name	Telephone number	Address
West Virginia	David H. Appel	(304) 343-6181, ext. 310	3017 Federal Bldg. and U.S. Courthouse, 500 Quarrier St. E., Charleston, WV 25301
Wisconsin	William B. Mann	(608) 262-2488	1815 University Ave., ~~Rm. 200,~~ Madison, WI 53706
Wyoming	William Dudley	(307) 778-2220, ext. 2153	P.O. Box 1125, 2120 Capitol Ave., Rm. 5017, Cheyenne, WY 82001

CONSERVATION DIVISION

REGIONAL OFFICES

Eastern	George Brown	(202) 254-3137	1725 K. St., N.W., Suite 204, Washington, DC 20006
Central	George H. Horn	(303) 234-2855	Box 25046, STOP 609, Denver Federal Center, Denver, CO 80225
Gulf of Mexico Outer Continental Shelf Operations	A. Dewey Acuff	(504) 837-4720, ext. 9381	P.O. Box 7944, 434 Imperial Office Bldg., 3301 N. Causeway Blvd., Metairie, LA 70010
Western	[Vacant]	(415) 323-8111, ext. 2093	345 Middlefield Rd., Menlo Park, CA 94025

LAND INFORMATION AND ANALYSIS OFFICE

EARTH RESOURCES OBSERVATION SYSTEMS DATA CENTER

South Dakota	Allen H. Watkins	(605) 594-6123	EROS Data Center, Sioux Falls, SD 57198

NATIONAL PETROLEUM RESERVE IN ALASKA

DISTRICT OFFICES

NPRA Operations Office	Max Brewer	(907) 276-7422	2525 "C" St., Suite 400, Anchorage, AK 99503
Exploration Strategy Office	Arthur Bowsher	(415) 323-2917	345 Middlefield Rd., Menlo Park, CA 94025

PUBLICATIONS DIVISION

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Central	John L. Heller	(303) 234-4974	Box 25046, STOP 303, Denver Federal Center, Denver, CO 80225
Western	Fred Kunkel	(415) 323-2537	345 Middlefield Rd., STOP 61, Menlo Park, CA 94025

PUBLIC INQUIRIES OFFICES

Alaska	Margaret I. Erwin	(907) 277-0577	108 Skyline Bldg., 508 2d Ave., Anchorage, AK 99501

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Menlo Park	Bruce S. Dean	(415) 323-2817	345 Middlefield Rd., STOP 33, Bldg. 3, Room 122, Menlo Park, CA 94025
San Francisco	Jean V. Molleskog	(415) 556-5627	504 Customhouse, 555 Battery St., San Francisco, CA 94111
Colorado	Alice M. Coleman	(303) 837-4169	169 Federal Bldg., 1961 Stout St., Denver, CO 80294
District of Columbia	Bruce A. Hubbard	(202) 343-8073	1028 GSA Bldg., 19th and F. Sts., N.W., Washington, DC 20244
Texas	Jimmie L. Wilkinson	(214) 767-0198	1C45 Federal Bldg., 1100 Commerce St., Dallas, TX 75242
Utah	Wendy R. Hassibe	(801) 524-5652	8105 Federal Bldg., 125 S. State St., Salt Lake City, UT 84138
Virginia	A. Ernestine Jones	(703) 860-6167	1C402 National Center, STOP 302, 12201 Sunrise Valley Dr., Reston, VA 22092
Washington	Eula M. Thune	(509) 456-2524	678 U.S. Courthouse, W. 920 Riverside Ave., Spokane, WA 99201

BRANCH OF DISTRIBUTION OFFICES

Alaska	Natalie Cornforth	(907) 452-1951	101 12th Ave., Box 12, Fairbanks, AK 99701
Colorado	Dwight F. Canfield	(303) 234-3832	Box 25286, STOP 306, Denver Federal Center, Denver, CO 80225
Virginia	George V. DeMeglio	(703) 557-2781	1200 S. Eads St., Arlington, VA 22202

ADMINISTRATIVE DIVISION

REGIONAL MANAGEMENT OFFICES

Eastern	Roy Heinbuch	(703) 860-7691	National Center, STOP 290
Central	Jack J. Stassi	(303) 234-3736	Box 25046, STOP 202, Denver Federal Center, Denver, CO 80225
Western	Avery W. Rogers	(415) 323-2211	345 Middlefield Rd., STOP 11, Menlo Park, CA 94025

Cooperators and Other Financial Contributors

[Cooperators listed are those with whom the U.S. Geological Survey had a written agreement cosigned by Survey officials and the cooperating agency for financial cooperation in fiscal year 1978. Parent agencies are listed separately from their subdivisions whenever there are separate cooperative agreements for different projects with a parent agency and with a subdivision of it. Agencies with whom the Geological Survey had research contracts and to whom it supplied research funds are not listed.]

FEDERAL COOPERATORS

Department of Agriculture:
- Economics, Statistics, and Cooperatives Service
- Foreign Agriculture Service
- Forest Service
- Graduate School
- Rural Electrification Administration
- Science and Education Administration
- Soil Conservation Service
- Statistical Reporting Service

Department of the Air Force:
- AFWL/PRP Kirtland AFB
- Air Force Academy
- Hanscom Air Force Base
- Headquarters (AFTAC/AC)
- Vandenberg Air Force Base
- Wurtsmith Air Force Base, MI

Department of the Army:
- Army Research Office
- Corps of Engineers
- Electronic Proving Ground
- Fort Belvoir
- Fort Carson Military Reservation
- Rocky Mountain Arsenal
- White Sands Missile Range

Department of Commerce:
- National Oceanic and Atmospheric Administration:
  - National Marine Fisheries Service
  - National Ocean Survey
  - National Weather Service
  - Pacific Northwest Regional Commission

Department of Defense Agencies and Joint Service Schools:
- Defense Advanced Research Projects Agency
- Defense Intelligence Agency
- Defense Mapping Agency
- Defense Nuclear Agency

Department of Energy:
- Alaska Power Administration
- Albuquerque Operations Office
- Bonneville Power Administration
- Division of Geothermal Energy
- Federal Energy Regulatory Commission
- Grand Junction Office
- Idaho Operations Office
- Lawrence Livermore Laboratory
- Los Alamos Science Laboratory
- Morgantown Energy Technology Center

Department of Energy—Continued
- National Center for Thermodynamic Data
- Nevada Operations Office
- Oak Ridge Operations Office
- Office of Energy Research
- Office of International Affairs
- Richland Operations Office
- San Francisco Operations Office

Department of Health, Education and Welfare

Department of Housing and Urban Development

Department of the Interior:
- Bureau of Indian Affairs
- Bureau of Land Management
- Bureau of Mines
- Bureau of Reclamation
- Heritage Conservation and Recreation Service
- National Park Service
- Office of the Secretary
- Trans-Alaska Pipeline
- U.S. Fish and Wildlife Service
- Water Resources Council

Department of the Navy:
- Naval Oceanographic Office
- Naval Weapons Center, China Lake
- U.S. Marine Corps, Camp Pendleton

Department of State:
- Agency for International Development
- International Boundary and Water Commission, United States and Mexico
- International Joint Commission, United States and Canada
- Office of External Research

Department of Transportation:
- Coast Guard
- Federal Highway Administration
- St. Lawrence Seaway Development Corporation

Environmental Protection Agency:
- Corvallis Environmental Research Laboratory
- Office of Energy, Minerals, and Industry
- Office of Monitoring and Technical Support
- Office of Research and Development
- Region I, Boston, Massachusetts
- Region V, Chicago, Illinois

FEDERAL COOPERATORS—Continued

Environmental Protection Agency —Continued
Region VIII, Denver, Colorado
Region X, Seattle, Washington
Upper Mississippi River Basin Commission

General Services Administration

National Aeronautics and Space Administration

National Science Foundation

Nuclear Regulatory Commission

Tennessee Valley Authority

United States Arms Control and Disarmament Agency

Upper Mississippi River Basin Commission

STATE, COUNTY, AND LOCAL COOPERATORS

Alabama:
- Alabama Development Office
- Alabama Highway Department
- Geological Survey of Alabama
- Jefferson County Commission

Alaska:
- Alaska Department of Fish and Game
- Alaska Department of Natural Resources:
  - Division of Lands and Water Management
  - Division of Geological and Geophysical Surveys
  - Division of Policy Development and Planning
- Alaska Department of Transportation and Public Facilities
- Alaska Power Authority
- City and Borough of Juneau
- City of Craig
- Department of Environmental Conservation
- Fairbanks North Star Borough
- Kenai Peninsula Borough
- Municipality of Anchorage
- North Slope Borough
- Thomas Bay Power Commission
- University of Alaska

Arizona:
- Arizona Bureau of Geology and Mineral Technology
- Arizona Department of Health Services
- Arizona Game and Fish Department
- Arizona Water Commission
- City of Flagstaff
- City of Safford
- City of Tucson
- Flood Control District of Maricopa County
- Gila Valley Irrigation District
- Maricopa County Municipal Water Conservation District No. 1
- Metropolitan Water District of Southern California
- Pima County Board of Supervisors
- Salt River Valley Water Users' Association
- San Carlos Irrigation and Drainage District
- Show Low Irrigation Company
- University of Arizona

Arkansas:
- Arkansas Department of Pollution Control and Ecology
- Arkansas Division of Soil and Water Resources
- Arkansas Geological Commission
- Arkansas State Highway and Transportation Department

California:
- Alameda County Flood Control and Water Conservation District, Zone 7
- Alameda County Water District
- Antelope Valley-East Kern Water Agency
- California Department of Conservation:
  - Division of Mines and Geology

California—Continued
- California Department of Fish and Game
- California Department of Navigation and Ocean Development
- California Department of Water Resources
- California Regional Water Quality Control Board:
  - Colorado River Basin Region
  - Lahontan Region
  - North Coast Region
  - Santa Ana Region
- California Water Resources Control Board
- Carpinteria County Water District
- Casitas Municipal Water District
- City and County of San Francisco:
  - Hetch Hetchy Water and Power
- City of Barstow
- City of Merced
- City of Modesto:
  - Public Works Department
- City of San Diego
- City of Santa Barbara:
  - Public Works Department
- City of Thousand Oaks
- Coachella Valley County Water District
- Contra Costa County Flood Control and Water Conservation District
- County of Modoc:
  - Public Works Department
- County of San Diego:
  - Department of Sanitation and Flood Control
- County of San Mateo:
  - Department of Public Works
- Crestline—Lake Arrowhead Water Agency
- Desert Water Agency
- East Bay Municipal Utility District
- East Bay Regional Park District
- Fresno County
- Georgetown Divide Public Utility District
- Goleta County Water District
- Imperial County Department of Public Works
- Imperial Irrigation District
- Indian Planning Consortium—Central California
- Indian Wells Valley County Water District
- Kern County Water Agency
- Kings River Conservation District
- Lake County Flood Control and Water Conservation District
- Livermore Amador Valley Water Management Agency
- Los Angeles County Flood Control District
- Los Angeles Department of Water and Power
- Madera County Flood Control and Water Conservation Agency
- Madera Irrigation District
- Marin County Department of Public Works
- Marin Municipal Water District
- Merced Irrigaiton District
- Mojave Water Agency
- Montecito County Water District

California—Continued

Monterey County Flood Control and Water Conservation District
Monterey Peninsula Water Management District
Napa County Flood Control and Water Conservation District
Orange County Environmental Management Agency
Orange County Water District
Oroville-Wyandotte Irrigation District
Pacheco Pass Water District
Paradise Irrigation District
Placer County Water Agency
Riverside County Flood Control and Water Conservation District
Sacramento Regional County Sanitation District, Department of Public Works
San Benito County Water Conservation and Flood Control District
San Bernardino Valley Municipal Water District
San Francisco Water Department
San Luis Obispo County:
Engineering Department
Santa Barbara County Flood Control and Water Conservation District
Santa Barbara County Water Agency
Santa Clara Valley Water District
Santa Cruz City:
Flood Control and Water Conservation District, Zone 4
Santa Cruz County:
Flood Control and Water Conservation District
Santa Maria Valley Water Conservation District
Santa Ynez River Water Conservation District
Siskiyou County Flood Control and Water Conservation District
Soquel Creek County Water District
Terra Bella Irrigation District
Tulare County Flood Control District
Turlock Irrigation District
United Water Conservation District
University of California:
Division of Environmental Studies (Davis)
Los Alamos Scientific Laboratory
School of Forestry and Conservation (Berkeley)
Ventura County Flood Control District
Western Municipal Water District
Woodbridge Irrigation District
Yolo County Flood Control and Water Conservation District

Colorado:
Adams County Board of Commissioners
Arapahoe County
Arkansas River Compact Administration
Cherokee Water District
City of Aspen
City of Aurora
City of Colorado Springs:
Department of Public Utilities
Office of the City Manager
City of Fort Collins
City of Glenwood Springs
City of Northglenn
Colorado City Water and Sanitation District
Colorado Department of Health:
Water Pollution Control Division
Colorado Department of Highways
Colorado Department of Local Affairs
Colorado Division of Water Resources:
Office of the State Engineer
Colorado Division of Wildlife
Colorado Geological Survey
Colorado River Water Conservation District
Colorado Water Conservation Board
Colorado West Area Council of Governments
County of Jackson
Denver Regional Council of Governments
Douglas County

Colorado—Continued

Eagle County Commissioners
Elbert County
El Paso County:
Board of Commissioners
Water Association
Kiowa County
Larimer-Wild Regional Council of Governments
Metropolitan Denver Sewage Disposal District No. 1
Northern Colorado Water Conservation District
Pikes Peak Area Council of Governments
Pitkin County Board of County Commissioners
Pueblo Area Council of Governments
Purgatoire River Water Conservancy District
Rio Grande Water Conservation District
St. Vrain and Left Hand Water Conservancy District
Southeastern Colorado Water Conservancy District
Southwestern Water Conservation District
University of Colorado
Urban Drainage and Flood Control District
White River Soil Conservation District

Connecticut:
City of New Britain
City of Torrington
Connecticut Department of Environmental Protection
Midstate Regional Planning Agency
Northwest Regional Planning Agency
Town of Fairfield
Town of Manchester
Town of Southbury
Town of South Windsor
Town of Woodbury

Delaware:
Department of Natural Resources and Environmental Control
New Castle County, Public Works Department
University of Delaware:
Delaware Geological Survey

District of Columbia:
Department of Environmental Services

Florida:
Brevard County:
Board of County Commissioners
Broward County:
Department of Utilities
Division of Water and Waste Water
Environmental Quality Control Board
Water Resources
City of Boca Raton
City of Bradenton
City of Cape Coral
City of Clearwater
City of Cocoa
City of Deerfield Beach
City of Fort Lauderdale
City of Fort Walton Beach
City of Gainesville
City of Hallandale
City of Hollywood
City of Pensacola
City of Perry
City of Pompano Beach
City of Quincy
City of St. Petersburg
City of Sarasota
City of Tallahassee
City of Tampa
City of West Palm Beach
Collier County
Consolidated City of Jacksonville
Coordinating Council on the Restoration of Kissimmee River Valley and Taylor Creek-Nubbins Slough Basin

STATE, COUNTY, AND LOCAL COOPERATORS—Continued

Florida—Continued

- Englewood Water District
- Escambia County
- Flagler County
- Florida Atlantic University:
  - Department of Geography
- Florida Bureau of Water Resources Management:
  - Florida Department of Environmental Regulation
- Florida Department of Natural Resources
- Florida Department of Transportation
- Florida Division of Recreation and Parks
- Florida Keys Aqueduct Authority
- Florida State University:
  - Florida Resources and Environmental Analysis Center
- Hillsborough County
- Jupiter Inlet District
- Lake County
- Lake Worth Utilities Authority
- Lee County
- Leon County
- Loxahatchee River Environmental Control District
- Manatee County
- Marion County
- Metropolitan Dade County
- Miami-Dade Water and Sewer Authority
- Monroe County
- Nassau County:
  - Ocean Highway and Port Authority
- Northwest Florida Water Management District
- Old Plantation Water Control District
- Orange County
- Palm Beach County
- Pinellas County
- Polk County
- Reedy Creek Improvement District
- St. Johns County
- St. Johns River Water Management District
- Sarasota County
- Seminole County
- South Florida Water Management District
- Southwest Florida Water Management District
- Sumter County Recreation and Water Conservation and Control Authority
- Suwannee River Authority
- Suwannee River Water Management District
- Town of Highland Beach
- Town of Juno Beach
- Village of Tequesta
- Volusia County
- Walton County
- Windermere Water and Navigational Control District
- Winter Haven Lake Region

Georgia:

- Bibb County Board of Commissioners
- Chatham County
- City of Albany
- City of Brunswick
- City of Covington
- City of Valdosta
- Clayton County
- Consolidated Government of Columbus
- Dekalb County
- Department of Natural Resources:
  - Environmental Protection Division
  - Geologic Survey
- Department of Transportation
- Macon-Bibb County Water and Sewage Authority

Hawaii:

- City and County of Honolulu:
  - Board of Water Supply
  - Department of Public Works
- State Department of Health
- State Department of Land and Natural Resources:
  - Division of Water and Land Development
- State Department of Planning and Economic Development
- State Department of Transportation

Idaho:

- Idaho Department of Fish and Game
- Idaho Department of Health and Welfare
- Idaho Department of Transportation
- Idaho Department of Water Resources

Illinois:

- Bloomington and Normal Sanitary District
- City of Springfield
- Cook County:
  - Forest Preserve District
- DuPage County Highway Department
- Fountain Head Drainage District
- Illinois Environmental Protection Agency
- Illinois Institute of Natural Resources
- Kane County Highway Department
- McHenry County Regional Planning Commission
- Metropolitan Sanitary District of Greater Chicago
- Northern Illinois University:
  - Laboratory for Cartographic and Spatial Analysis
- Sanitary District of Bloom Township
- State Department of Registration and Education:
  - State Water Survey
- State Department of Transportation:
  - Division of Highways
  - Division of Water Resources

Indiana:

- City of Bloomington
- City of Chicago
- City of Columbus
- City of Fort Wayne
- City of Hammond
- City of Indianapolis
- City of Richmond
- Elkhart Water Works
- Indiana Board of Health
- Indiana Department of Natural Resources
- Indiana Highway Commission
- Town of Carmel
- Vincennes Water Department

Iowa:

- City of Ames
- City of Cedar Rapids
- City of Charles City
- City of Clear Lake
- City of Des Moines
- City of Fort Dodge
- City of Iowa City
- City of Harlan
- City of Marshalltown
- City of Sioux City
- City of Waterloo
- Des Moines Water Works
- Iowa Department of Environmental Quality
- Iowa Department of Transportation:
  - Highway Research Board
  - Highway Division

Iowa—Continued

Iowa Geological Survey
Iowa Natural Resources Council
Iowa State University:
Department of Agricultural Engineering
Engineering and Mineral Resources Research
Iowa Agricultural Experiment Station
Ottumwa Water Works
Sewage Disposal Plant
University of Iowa:
Institute of Hydraulic Research
University Physical Plant
West-Central Iowa Rural Water Association

Kansas:
City of Wichita
Kansas Department of Transportation
Kansas Geological Survey
Kansas-Oklahoma Arkansas River Commission
Kansas State Board of Agriculture:
Division of Water Resources
Kansas Department of Health and Environment
Kansas Water Resources Board
Northwest Kansas Ground Water Management District No.4
Southwest Kansas Ground Water Management District No.3
Western Kansas Ground Water Management District No.1

Kentucky:
City of Louisville
Kentucky Department of Commerce:
Division of Research and Planning
Kentucky Department for Natural Resources and Environmental Protection:
Division of Conservation
Division of Water Quality
Division of Water Resources
Kentucky Department of Transportation:
Division of Design
Kentucky Geological Survey, University of Kentucky

Louisiana:
Capital Area Ground Water Conservation Commission
City of Parish Government
Louisiana Office of Highways:
Department of Transportation and Development
Louisiana Office of Public Works:
Department of Transportation and Development
Louisiana State Planning Office
Sabine River Compact Administration (*see also* Texas)

Maine:
Androscoggin Valley Reginal Planning Commission
Cobbossee Watershed District
Greater Portland Council of Governments
Maine Department of Conservation:
Geological Survey
Maine Department of Environmental Protection
Maine Public Utilities Commission
Southern Kennebec Valley Regional Planning Commission
Town of Wilton

Maryland:
Anne Arundel County
Baltimore County
Calvert County
Caroline County
Carroll County
City of Poolesville
Garrett County
Howard County
Maryland Department of Health and Metal Hygiene
Maryland Department of Transportation:
The State Highway Administration

Maryland—Continued

Maryland Energy and Coastal Zone Administration
Maryland Geological Survey
Maryland Water Resources Administration
Montgomery County:
Office of Environmental Planning
St. Mary's County
Washington Suburban Sanitary Commission
Upper Potomac River Commission

Massachusetts:
Barnstable County
Department of Public Works:
Division of Highways
Division of Research and Materials
Division of Waterways
Lower Pioneer Valley Regional Planning Commission
Massachusetts Science and Technology Foundation
Metropolitan District Commission:
New England Interstate Water Pollution Control Commission
Water Division
State Water Resources Commission:
Division of Water Pollution Control
Division of Water Resources

Michigan:
Branch County
City of Ann Arbor
City of Battle Creek
City of Clare
City of Coldwater
City of Flint
City of Jackson
City of Lansing
City of Mason
City of St. Johns
City of St. Louis
City of Ypsilanti
Department of Agriculture:
Soil and Water Conservation Division
Department of Natural Resources:
Bureau of Management Services
Geological Survey Division
Department of State Highways and Transportation
Dickinson County Board of Road Commissioners
East-Central Michigan Planning and Development
Genesee County Drain Commission
Huron-Clinton Metropolitan Authority
Imlay City
Kalamazoo County Metropolitan Planning Commission
Kent County Airport
Macomb County
Oakland County Drain Commission
Otsego County Road Commission
Tri-County Regional Planning Commission
University of Michigan
Van Buren County Road Commission
Village of Clarkston
Washtenaw County

Minnesota:
City of Apple Valley
City of Eagan
City of Lakeville
Metropolitan Council of the Twin Cities
Metropolitan Waste Control Commission
Minnesota Department of Health:
Division of Environmental Health
Minnesota Department of Natural Resources
Minnesota Department of Transportation
Minnesota Pollution Control Agency
Minnesota State Planning Agency
Red Clay Project

STATE, COUNTY, AND LOCAL COOPERATORS—Continued

Mississippi:
City of Jackson
Department of Natural Resources:
Bureau of Geology and Energy Resources
Bureau of Land and Water Resources
Bureau of Pollution Control
Harrison County Board of Supervisors
Harrison County Development Commission
Jackson County Board of Supervisors
Jackson County Port Authority
Mississippi Air and Water Pollution Control Commission
Mississippi Board of Water Commissioners
Mississippi Geological Survey
Mississippi Research and Development Center
Mississippi State Highway Department
Pat Harrison Waterway District
Pearl River Valley Water Supply District

Missouri:
City of Springfield:
Sanitary Services Department
Department of Natural Resources:
Division of Environmental Quality, Laboratory Services Program
Division of Geology and Land Survey
Little River Drainage District
Missouri Department of Conservation
Missouri State Highway Commission
St. Louis County:
Department of Highways and Traffic
University of Missouri:
Department of Geography

Montana:
Department of Natural Resources and Conservation
Lewis and Clark County:
Board of Commissioners
Montana Bureau of Mines and Geology
Montana Department of Health and Environmental Sciences
Montana Department of Highways
Montana Department of State Lands
Montana Fish and Game Department
Montana State University
University of Montana
Wyoming State Engineer (*see also* Wyoming)

Nebraska:
Blue River Association of Ground Water Conservation Districts
Central Platte Natural Resources District
Kansas-Nebraska Big Blue River Compact Administration
Lower Loup Natural Resources District
Nebraska Department of Roads
Nebraska Department of Water Resources
Nebraska Natural Resources Commission
Nehama Natural Resources District
University of Nebraska:
Conservation and Survey Division
Water Resources Center

Nevada:
Carson City Department of Public Works
Carson Valley Conservation District
Nevada Bureau of Mines and Geology
Nevada Department of Conservation and Natural Resources:
Division of Environmental Protection
Division of Water Resources
Nevada Department of Highways

New Hampshire:
New Hampshire Water Resources Board
New Hampshire Water Supply and Pollution Control Commission

New Jersey:
Bergen County
Camden County:
Board of Chosen Freeholders
Delaware River Basin Commission
Morris County Municipal Utilities Authority
New Jersey Department of Agriculture:
State Soil Conservation Committee
New Jersey Department of Environmental Protection:
Bureau of Fisheries Management
Division of Fish, Game and Shell Fisheries
Division of Water Resources
North Jersey District Water Supply Commission
Passaic Valley Water Commission
Somerset County:
Board of Chosen Freeholders
Township of Cranford
West Windsor Township

New Mexico:
Albuquerque Metropolitan Arroyo Flood Control Authority
City of Albuquerque
City of Las Cruces
Costilla Creek Compact Commission
Elephant Butte Irrigation District
New Mexico Bureau of Mines and Mineral Resources
New Mexico Environmental Improvement Division
New Mexico Natural Resources Department
New Mexico State Engineer and Interstate Stream Commission
New Mexico State Highway Department
Pecos River Commission
Rio Grande Compact Commission

New York:
Central New York State Park and Recreation Commission
City of Albany:
Department of Water and Water Supply
City of Auburn
City of New York:
Board of Water Supply
Department of Environmental Protection
City of Rochester:
Department of Public Works
County of Chautauqua:
Department of Planning and Development
County of Cortland:
Planning Department
County of Duchess:
Civil Defense
County of Monroe:
Water Authority
County of Nassau:
Department of Public Works
County of Onondaga:
Department of Public Works
Water Authority
County of Oswego Planning Board
County of Putnam
County of Rockland:
Drainage Agency
County of Suffolk:
Department of Health Sciences
Water Authority
County of Ulster:
Ulster County Legislature
County of Westchester:
Department of Public Works
Hudson River-Black River Regulating District
Irondequoit Bay Pure Waters District
New York State Department of Education:
Museum and Science Service

New York—Continued

New York State Department of Environmental Conservation (*see also* Pennsylvania):
Division of Pure Waters
Land Resources and Forest Management Division
New York State Department of Health:
Division of Sanitary Engineering
New York State Department of Transportation, Planning and Railroads Bureau
Oswegatchie River-Cranberry Reservior Commission
Power Authority of the State of New York
State University of New York at Buffalo
Town of Clarkstown
Town of Warwick
Town of Waterford
University of the State of New York
University of Virginia (*see also* Virginia)
Village of New Paltz
Village of Nyack

North Carolina:
Agricultural Experiment Station
City of Burlington
City of Charlotte
City of Durham:
Department of Water Resources
City of Greensboro
City of Raleigh
City of Rocky Mount
City of Winston-Salem
State Board of Transportation
State Department of Natural Resources and Community Development

North Dakota:
North Dakota Geological Survey
Oliver County Board of Commissioners
State Department of Health
State Water Commission

Ohio:
City of Canton:
Water Department
City of Columbus:
Department of Public Service
Division of Water
Geauga County
Miami Conservancy District
Ohio Department of Natural Resources:
Division of Water
Division of Geological Survey
Division of Reclamation
Ohio Department of Transportation:
Division of Highways
Ohio Environmental Protection Agency
Three Rivers Watershed District

Oklahoma:
Central Master Conservancy District
City of Ada
City of Altus
City of Edmond
City of Guthrie
City of Lawton
City of Oklahoma City
City of Tulsa
Fort Cobb Reservoir Master Conservancy District
Foss Reservoir Master Conservancy District
Lugert-Altus Irrigation District
Oklahoma Department of Highways
Oklahoma Geological Survey
Oklahoma Pollution Control Coordination Board
Oklahoma State Health Department
Oklahoma Water Resources Board

Oregon:
Burnt River Irrigation District
City of Corvallis
City of Eugene:
Water and Electric Board
City of Lakeside:
Lakeside Water District
City of McMinnville:
Water and Light Department
City of Medford:
Public Works Department
City of Portland:
Department of Public Utilities
Department of Public Works
City of Reedsport
Clark County, Wash., Department of Public Works
Confederated Tribes of Umatilla Indian Reservation
Confederated Tribes of Warm Springs Indian Reservation
Coos Bay-North Bend Water Board
Coos County:
Board of Commissioners
Douglas County:
Department of Public Works
Lane Council of Governments
Lane County:
Office of the Chief Administrator
Mid-Williamette Valley Council of Governments
Multnomah County:
Board of Commissioners
Oregon Department of Environmental Quality
Oregon Department of Fish and Wildlife
Oregon State Highway Division
Oregon Water Resources Department
Rogue Valley Council of Governments
Wasco County

Pennsylvania:
Allegheny County:
Department of Planning and Development
Chester County:
Board of Commissioners
Health Department
Water Resources Authority
City of Bethlehem
City of Easton
City of Harrisburg:
Department of Public Works
City of Philadelphia:
Water Department
Delaware River Basin Commission
Delaware Valley Regional Planning Commission
Letort Regional Authority
New York State Department of Environmental Conservation (*see also* New York)
Ohio River Basin Commission
Pennsylvania Department of Environmental Resources:
Bureau of Surface Mine Reclamation
Bureau of Topographic and Geologic Survey
Bureau of Water Quality Management
Office of Resource Management
Pennsylvania Department of Transportation
Slippery Rock State College
Susquehanna River Basin Commission
Warminster Township

Rhode Island:
City of Providence
State Department of Environmental Management:
Division of Land Resources
Division of Water Resources
State Water Resources Board
University of Rhode Island Center for Ocean Management Studies

STATE, COUNTY, AND LOCAL COOPERATORS—Continued

South Carolina:
- City of Lancaster
- Commissioners of Public Works:
  - Spartanburg Water Works
- Division of Research and Statistical Services
- State Department of Highways and Public Transportation
- State Health and Environmental Control
- State Public Service Authority
- State Water Resources Commission

South Dakota:
- Black Hills Conservancy Subdistrict
- City of Sioux Falls
- City of Watertown
- East Dakota Conservancy Subdistrict
- South Dakota Department of Transportation
- South Dakota Department of Water and Natural Resources:
  - Division of Geological Survey
  - Division of Water Rights
- South Dakota School of Mines
- South Dakota State University

Tennessee:
- City of Franklin
- City of Lawrenceburg
- City of Memphis:
  - Light, Gas and Water Division
  - Public Works Division
  - Water Division
- Lincoln County Utilities Board
- Metropolitan Government of Nashville and Davidson County:
  - Department of Public Works
- Murfreesboro Water and Sewer Department
- Shelby County
- Tennessee Department of Conservation:
  - Division of Geology
  - Division of Water Resources
- Tennessee Department of Public Health:
  - Division of Water Quality Control
- Tennessee Department of Transportation:
  - Bureau of Planning and Programming
  - Office of Research and Planning
  - Bureau of Highways
- University of Tennessee

Texas:
- City of Austin
- City of Dallas
- City of Fort Worth
- City of Garland
- City of Houston
- City of Mesquite
- Pecos River Commission
- Sabine River Compact Administration
  - (*see also* Louisiana)
- Texas A & M
- Texas Department of Water Resources

Utah:
- Bear River Commission
- Department of Transportation
- Division of Parks and Recreation
- Salt Lake County:
  - Board of County Commissioners
  - Department of Water Quality and Water Pollution Control
- State Department of Natural Resources:
  - Division of Oil, Gas, and Mining
  - Division of Water Resources
  - Division of Water Rights
  - Division of Wildlife Resources
  - Utah Geological and Mineral Survey

Vermont:
- Agency of Environmental Conservation
- State Department of Water Resources
- Town of Springfield

Virginia:
- City of Alexandria:
  - Department of Transportation and Environmental Services
- City of Newport News:
  - Department of Public Utilities
- City of Roanoke:
  - Utilities and Operations
- City of Staunton
- Fairfax County Water Authority:
  - Engineering and Construction Division
- James City County
- Southeastern Public Service Authority of Virginia
- University of Virginia:
  - Department of Environmental Sciences
- Virginia Department of Conservation and Economic Development:
  - Division of Mineral Resources
- Virginia Department of Highways and Transportation
- Virginia State Water Control Board

Washington:
- Chelan County Public Utility District No. 1
- City of Bellevue Public Works Department
- City of Everett
- City of Seattle:
  - Department of Lighting
  - Water Department
- City of Tacoma:
  - Department of Public Utilities
  - Department of Public Works
- Clallam County Board of Commissioners
- Hoh Indian Tribe
- Lewis County Board of Commissioners
- Makah Tribal Council
- Muckleshoot Indian Tribe
- Municipality of Metropolitan Seattle
- Nisqually Indian Community Council
- Pierce County Board of Commissioners
- Quileute Tribal Council
- Quinault Indian Business Council
- Shoalwater Bay Tribal Council
- South Columbia Basin Irrigation District
- State of Washington:
  - Department of Ecology
- Washington State Department of Fisheries
- Washington State Department of Game
- Washington State Department of Natural Resources
- Washington State Department of Transportation
- Washington State University:
  - Department of Agricultural Engineering
- Yakima Tribal Council

West Virginia:
- City of Clarksburg, Water Board
- City of Morgantown:
  - Water Commission
- Randolph County Commission
- West Virginia Department of Highways
- West Virginia Department of Natural Resources:
  - Division of Forestry
  - Division of Water Resources
- West Virginia Geological and Economic Survey

Wisconsin:
- City of Middleton
- Dane County Regional Planning Commission
- Douglas County Soil and Water Conservation District
- Madison Metropolitan Sewage District
- Madison Water Utility
- Sokaogon Chippewa (Mole Lake) Community of Wisconsin
- Southeastern Wisconsin Regional Planning Commission
- State Board of Soil and Water Conservation Districts
- State Department of Justice
- State Department of Natural Resources
- State Department of Transportation:
  - Bridge Section
  - Division of Highways
- Town of Schleswig
- University of Wisconsin:
  - Department of Geography

Wisconsin—Continued

- University of Wisconsin Extension:
  - Geological and Natural History Survey
- Village of Oregon

Wyoming:
- Cheyenne Board of Public Utilities
- University of Wyoming:
  - Water Resources Research Institute
- Wyoming Department of Agriculture:
  - Wyoming Conservation Commission
- Wyoming Department of Economic Planning and Development
- Wyoming Department of Environmental Quality
- Wyoming Highway Department
- Wyoming State Engineer (*see also* Montana)

OTHER COOPERATORS AND CONTRIBUTORS

Coastal Plains Regional Action Planning Commission

Four Corners Regional Commission

Government of American Samoa

Government of Botswana

Government of Brazil

Government of Costa Rica

Government of Guam

Government of Hungary

Government of Iraq

Government of Kuwait

Government of the Northern Mariana Islands

Government of Saudi Arabia

Government of Trinidad and Tobago

Missouri River Basin Commission

Pan-American Health Organization

Puerto Rico:
- Puerto Rico Aqueduct and Sewer Authority
- Puerto Rico Department of Agriculture
- Puerto Rico Department of Health
- Puerto Rico Department of Natural Resources
- Puerto Rico Environmental Quality Board
- Puerto Rico Land Authority
- Puerto Rico Surgar Corp.
- Puerto Rico Water Resources Authority

Trust Territory of the Pacific Islands

United Nations:
- United Nations Development Program
- United Nations Education, Science and Culture Organization

Virgin Islands:
- College of the Virgin Islands
- Virgin Islands Department of Public Works
- Virgin Islands Planning Office

Budgetary and Statistical Data

[Data in these tables may differ slightly from data in the individual division chapters because of rounding; and totals may sometimes not add because of rounding.]

TABLE 1.—*Geological Survey budget for fiscal years 1974 to 1979, by activity and sources of funds*

[in thousands of dollars]

Budget activity	1974	1975	1976	Transition quarter	1977	1978	1979
Total	**$249,437**	**$338,764**	**$353,970**	**$102,858**	**$433,403**	**$698,272**	**$764,718**
Direct program	171,983	253,605	264,434	77,570	319,460	576,393	634,886
Reimbursable program	77,454	85,159	89,536	25,288	113,943	121,879	129,832
States, counties, and municipalities	32,443	35,124	35,006	8,956	39,621	40,784	44,124
Miscellaneous non-Federal sources	4,695	6,399	7,923	1,991	10,229	12,825	15,789
Other Federal agencies	40,316	43,636	46,607	14,341	64,093	68,270	69,919
Alaska Pipeline Related Investigations	**890**	**344**	**287**	**85**	**317**	**272**	------
Direct program	890	344	287	85	317	272	------
Reimbursable program	------	------	------	------	------	------	------
Other Federal agencies	------	------	------	------	------	------	------
Topographic Surveys and Mapping	**43,664**	**52,597**	**52,220**	**13,289**	**57,073**	**69,520**	**74,566**
Direct program	37,161	45,350	43,354	11,548	50,311	61,356	65,584
Reimbursable program	6,503	7,247	6,866	1,741	6,762	8,164	8,982
States, counties, and municipalities	4,942	4,995	3,675	882	3,268	3,320	3,371
Miscellaneous non-Federal sources	643	594	501	133	601	499	597
Other Federal agencies	918	1,658	2,690	726	2,893	4,345	5,014
Geologic and Mineral Resource Surveys and Mapping [1]	**73,563**	**114,477**	**115,554**	**32,194**	**130,269**	**163,193**	**178,556**
Direct program	49,877	89,018	92,322	24,829	100,007	123,830	134,846
Reimbursable program	23,686	25,459	23,232	7,365	30,262	39,363	43,710
States, counties, and municipalities	1,681	1,550	1,467	383	1,403	956	584
Miscellaneous non-Federal sources	2,684	3,751	4,936	1,120	6,439	8,510	10,914
Other Federal agencies	19,321	20,158	16,829	5,862	22,420	29,897	32,212
Water Resources Investigations [2]	**88,352**	**101,437**	**112,480**	**30,716**	**131,509**	**146,014**	**168,598**
Direct program	45,433	53,420	57,176	15,916	68,555	[3] 78,487	96,847
Reimbursable program	42,919	48,017	55,304	14,800	62,954	67,527	71,751
States, counties, and municipalities	25,820	28,546	29,735	7,672	34,761	36,457	40,156
Miscellaneous non-Federal sources	721	901	940	260	1,331	1,429	1,673
Other Federal agencies	16,378	18,570	24,629	6,868	26,862	29,641	29,922
Conservation of Lands and Minerals [4]	**18,213**	**36,082**	**41,677**	**13,386**	**67,427**	**77,409**	**85,484**
Direct program	18,172	36,032	41,489	13,375	67,239	77,299	85,362
Reimbursable program	41	50	188	6	188	110	122
Miscellaneous non-Federal sources	------	4	1	------	16	9	------
Other Federal agencies	41	46	187	6	172	101	122
Land Information and Analysis [5]	**13,003**	**16,994**	**17,278**	**13,919**	**23,476**	**23,226**	**23,965**
Direct program	11,458	15,461	14,908	7,795	17,698	18,132	19,959
Reimbursable program	1,545	1,533	2,370	6,124	5,778	5,094	4,006
States, counties, and municipalities	------	33	130	19	189	51	13
Miscellaneous non-Federal sources	593	1,093	1,496	469	1,741	2,153	2,333
Other Federal agencies	952	407	744	636	3,848	2,890	1,660
National Petroleum Reserve in Alaska	------	------	------	------	**9,154**	**202,704**	**216,886**
Direct program	------	------	------	------	2,079	202,598	216,886
Allocation transfer	------	------	------	------	7,063	106	------
Reimbursable program (Federal)	------	------	------	------	12	------	------
General Administration [6]	**3,517**	**3,671**	**3,398**	**1,491**	**3,760**	**3,650**	**3,661**
Direct program	3,517	3,671	3,398	1,491	3,760	3,650	3,661
Facilities	**5,475**	**10,309**	**9,500**	**2,530**	**9,494**	**10,769**	**11,741**
Direct program	5,475	10,309	9,500	2,530	9,494	10,769	11,741

See footnotes at end of table.

TABLE 1.—*Geological Survey budget for fiscal years 1974 to 1979, by activity and sources of funds*—Continued

Budget activity	1974	1975	1976	Transition quarter	1977	1978	1979
Miscellaneous services to other accounts	**$2,760**	**$2,853**	**$1,576**	**$253**	**$924**	**$1,515**	**$1,261**
Reimbursable program	2,760	2,853	1,576	253	924	1,515	1,261
Miscellaneous non-Federal sources	54	56	49	10	102	225	272
Other Federal agencies	2,706	2,797	1,527	243	822	1,290	989

[1] Includes Mineral Discovery Loan Program activity for fiscal years 1974 to1975; and parts of Geothermal Investigations, Minerals Policy, and Arctic Environmental Studies components of the Special Resource and Environmental Projects activity for fiscal years 1974 to 1975. Funds exclude the Land Resource Analysis Program for fiscal years 1974 to 1976.

[4] Excludes Employee Compensation Payments subactivity for fiscal years 1974 to 1976.

[3] Funds for the Airborne Positioning System, appropriated to Water Resources Investigations are included as obligations of Topographic Surveys and Mapping ($2,172 thousand).

[4] Includes parts of Geothermal Investigations component of the Special Resource and Environmental Projects activity for fiscal years 1974 to 1975.

[5] Budget activity funds are reconstructed for fiscal years 1974 to 1975 and include Earth Resources Observation System activity for fiscal years 1974 to 1975; Urban Area Studies and Energy Impact Evaluation components of the Special Resource and Environmental Projects activity for fiscal years 1974 to 1975; Land Resources Analysis Program of the Geologic and Mineral Resource Surveys and Mapping activity for fiscal years 1974 to 1975 and the Land Use Data and Analysis activity for fiscal year 1975.

[6] Funds include Employee Compensation Payments subactivity of the Water Resources Investigations activity for 1974 to 1976.

TABLE 2.—*Geological Survey Federal-State Cooperative Program funds for fiscal years 1974 to 1979, by State*

[In thousands of dollars]

State	1974	1975	1976	Transition quarter	1977	1978	1979
Total [1]	**$65,256**	**$70,151**	**$69,252**	**$17,482**	**$79,163**	**$80,598**	**$86,962**
Total State share [2]	32,443	35,124	35,019	8,986	40,617	40,784	44,123
Alabama	**1,094**	**1,212**	**1,124**	**171**	**1,234**	**1,074**	**1,075**
State share	554	623	550	87	607	532	537
Alaska	**897**	**1,162**	**782**	**202**	**1,141**	**1,275**	**1,421**
State share	410	410	407	101	561	654	753
Arizona	**1,144**	**1,248**	**1,255**	**335**	**1,393**	**1,552**	**1,721**
State share	576	646	639	177	700	783	878
Arkansas	**857**	**887**	**811**	**190**	**1,033**	**1,118**	**1,315**
State share	455	410	371	94	481	543	695
California	**4,789**	**4,690**	**4,825**	**1,271**	**5,336**	**6,079**	**6,003**
State share	2,280	2,337	2,473	675	2,714	3,091	3,135
Colorado	**1,484**	**2,445**	**2,199**	**662**	**3,052**	**3,036**	**3,581**
State share	837	1,324	1,196	349	1,564	1,561	1,784
Connecticut	**814**	**1,069**	**858**	**241**	**871**	**864**	**1,242**
State share	374	523	415	108	421	411	576
Delaware	**130**	**194**	**213**	**54**	**225**	**192**	**157**
State share	74	106	116	30	121	109	92
District of Columbia	**3**	**3**	**3**	**1**	**4**	**4**	**4**
State share	1	1	2	------	2	2	2
Florida	**5,083**	**5,575**	**5,763**	**1,481**	**6,428**	**7,219**	**7,415**
State share	2,552	2,781	2,851	735	3,202	3,667	3,819
Georgia	**3,239**	**3,083**	**2,510**	**552**	**2,452**	**1,706**	**1,919**
State share	1,611	1,531	1,243	275	1,209	866	942
Hawaii	**691**	**697**	**896**	**191**	**897**	**1,000**	**1,294**
State share	339	341	501	101	460	518	646
Idaho	**718**	**749**	**852**	**223**	**952**	**1,131**	**1,024**
State share	353	366	417	111	465	611	480
Illinois	**544**	**645**	**848**	**208**	**1,109**	**1,092**	**1,324**
State share	277	323	459	120	592	575	718
Indiana	**1,363**	**1,288**	**1,519**	**366**	**1,987**	**2,006**	**2,210**
State share	678	632	779	182	981	1,078	1,107
Iowa	**608**	**617**	**822**	**241**	**1,004**	**1,031**	**1,060**
State share	299	302	405	121	494	521	531
Kansas	**1,402**	**1,424**	**1,525**	**442**	**1,721**	**2,237**	**2,378**
State share	686	716	752	220	849	1,113	1,163
Kentucky	**2,451**	**2,728**	**2,828**	**717**	**3,015**	**2,407**	**1,425**
State share	1,122	1,229	1,300	327	1,433	1,018	709
Louisiana	**1,900**	**1,740**	**1,694**	**440**	**2,628**	**1,856**	**2,027**
State share	980	902	862	227	1,319	929	1,015

See footnotes at end of table.

TABLE 2.—*Geological Survey Federal-State Cooperative Program funds for fiscal years 1974 to 1979, by State*—Continued

State	1974	1975	1976	Transition quarter	1977	1978	1979
Maine	**$ 175**	**$ 248**	**$ 313**	**$ 89**	**$ 333**	**$ 382**	**$ 566**
State share	96	127	181	50	179	191	290
Maryland	**851**	**1,011**	**1,016**	**243**	**1,176**	**1,174**	**1,393**
State share	435	530	517	125	602	605	706
Massachusetts	**1,346**	**1,618**	**1,627**	**368**	**1,402**	**1,593**	**1,837**
State share	656	810	779	191	684	801	847
Michigan	**930**	**1,054**	**1,078**	**252**	**1,101**	**1,203**	**1,497**
State share	436	505	521	123	541	596	761
Minnesota	**1,903**	**1,639**	**1,191**	**320**	**1,082**	**1,759**	**2,330**
State share	966	817	625	198	566	949	1,249
Mississippi	**645**	**743**	**646**	**170**	**713**	**754**	**747**
State share	325	415	316	85	349	407	374
Missouri	**657**	**678**	**642**	**207**	**827**	**635**	**713**
State share	322	337	316	105	420	316	341
Montana	**505**	**587**	**596**	**146**	**1,330**	**676**	**734**
State share	255	287	301	76	673	338	402
Nebraska	**705**	**731**	**785**	**187**	**957**	**1,048**	**1,175**
State share	344	358	396	95	469	522	579
Nevada	**689**	**846**	**922**	**244**	**1,063**	**1,440**	**1,488**
State share	304	332	367	103	415	456	535
New Hampshire	**177**	**172**	**230**	**63**	**248**	**187**	**150**
State share	97	73	99	28	103	92	68
New Jersey	**1,051**	**977**	**1,090**	**276**	**1,269**	**1,437**	**1,427**
State share	530	501	565	143	642	851	800
New Mexico	**1,332**	**1,439**	**1,510**	**338**	**1,537**	**1,621**	**1,841**
State share	662	714	768	175	778	838	942
New York	**2,796**	**2,977**	**2,822**	**727**	**3,008**	**3,363**	**3,871**
State share	1,415	1,585	1,615	407	2,568	1,893	2,377
North Carolina	**1,586**	**1,885**	**1,462**	**379**	**1,805**	**1,713**	**1,633**
State share	771	942	724	197	894	858	817
North Dakota	**763**	**998**	**990**	**246**	**834**	**1,023**	**1,029**
State share	369	489	489	125	408	505	498
Ohio	**978**	**1,093**	**1,255**	**336**	**1,598**	**1,799**	**1,962**
State share	481	563	671	175	838	973	1,075
Oklahoma	**702**	**748**	**786**	**196**	**846**	**936**	**1,131**
State share	344	368	386	98	414	462	577
Oregon	**896**	**902**	**899**	**287**	**1,230**	**1,214**	**1,391**
State share	439	443	449	163	639	610	674
Pennsylvania	**2,357**	**2,415**	**2,510**	**554**	**2,718**	**2,688**	**2,847**
State share	1,195	1,209	1,269	284	1,365	1,366	1,301
Rhode Island	**97**	**110**	**124**	**31**	**145**	**160**	**233**
State share	52	54	60	16	72	80	117
South Carolina	**546**	**574**	**557**	**142**	**603**	**625**	**832**
State share	279	284	272	71	296	329	363
South Dakota	**471**	**515**	**528**	**146**	**562**	**662**	**761**
State share	227	251	259	73	275	331	382
Tennessee	**851**	**952**	**1,035**	**280**	**1,255**	**1,383**	**1,509**
State share	422	470	508	139	615	686	729
Texas	**4,046**	**4,261**	**4,351**	**1,102**	**4,621**	**4,525**	**4,588**
State share	2,027	2,100	2,148	550	2,354	2,244	2,299
Utah	**1,068**	**1,361**	**1,314**	**334**	**1,631**	**1,451**	**1,657**
State share	534	838	745	186	810	726	842
Vermont	**144**	**130**	**138**	**28**	**134**	**142**	**166**
State share	73	64	68	14	70	70	81
Virginia	**905**	**858**	**737**	**142**	**768**	**778**	**897**
State share	466	442	378	78	393	397	548
Washington	**2,121**	**2,208**	**2,115**	**509**	**3,271**	**2,537**	**2,859**
State share	1,037	1,104	1,066	265	1,653	1,243	1,378
West Virginia	**946**	**775**	**716**	**175**	**830**	**688**	**752**
State share	521	448	418	105	472	388	402
Wisconsin	**1,563**	**1,706**	**1,874**	**552**	**1,703**	**1,883**	**1,969**
State share	775	883	999	297	935	1,026	1,022
Wyoming	**698**	**853**	**754**	**167**	**903**	**901**	**819**
State share	328	514	397	86	391	381	412
American Samoa	**63**	**70**	**40**	**9**	**60**	**64**	**47**
State share	31	32	20	4	30	32	23

See footnotes at end of table.

TABLE 2.—*Geological Survey Federal-State Cooperative Program funds for fiscal years 1974 to 1979, by State*—Continued

State	1974	1975	1976	Transition quarter	1977	1978	1979
Guam	**$ 62**	**$ 65**	**$ 68**	**$ 18**	**$ 70**	**$ 85**	**$ 104**
State share	31	32	33	9	33	47	56
Northern Marianas	------	------	------	------	------	**18**	**40**
State share	------	------	------	------	------	9	21
Puerto Rico	**1,303**	**1,293**	**1,016**	**185**	**843**	**922**	**1,083**
State share	682	585	463	84	396	459	518
Trust Territories	**117**	**170**	**170**	**44**	**173**	**180**	**184**
State share	58	84	84	22	84	90	92
Virgin Islands	**([3])**	**33**	**18**	**2**	**32**	**70**	**94**
State share	([3])	31	9	1	16	35	43

[1] Includes Federal funds from direct program.
[2] Includes reimbursable program funds from States, counties, and municipalities.
[3] Included with Puerto Rico funds.

TABLE 3.—*Geological Survey reimbursable program funds from other Federal agencies for fiscal years 1974 to 1979, by agency*

[In thousands of dollars]

Agency	1974	1975	1976	Transition quarter	1977	1978	1979
Total	**$40,316**	**$43,636**	**$46,607**	**$14,347**	**$56,195**	**$68,164**	**$69,919**
Appalachian Regional Commission	189	179	------	------	------	------	------
Department of Agriculture	356	891	2,008	605	2,130	2,727	2,619
Department of Commerce	([1])	154	2,205	36	334	183	141
National Oceanic and Atmospheric Administration	2,001	434	1,513	772	1,947	1,708	1,464
Ozarks Regional Commission	60	49	------	------	------	------	------
Department of Defense	13,351	11,247	11,965	3,195	12,308	15,655	16,760
Department of Energy [2]	4,029	3,854	4,704	1,926	8,573	14,980	15,338
Bonneville Power Administration	(136)	(105)	(130)	(32)	(141)	(138)	(48)
Department of Housing and Urban Development	3,581	3,069	4,624	1,873	6,003	3,789	1,967
Department of the Interior	2,312	9,361	6,290	2,362	12,186	16,528	17,746
Bureau of Indian Affairs	340	697	759	277	915	2,385	4,345
Bureau of Land Management	251	5,114	3,682	1,467	9,011	10,791	9,712
Bureau of Mines	------	1,735	148	------	200	108	240
Bureau of Reclamation	676	721	790	267	1,199	1,871	1,975
National Park Service	529	617	576	230	542	791	771
Office of the Secretary	------	------	------	44	------	------	82
Office of Surface Mining	------	426	------	------	------	135	21
U.S. Fish and Wildlife Service	380	372	205	45	178	447	600
Department of State	2,177	1,698	949	221	1,075	1,010	1,455
Department of Transportation	------	4	470	240	313	193	149
Environmental Protection Agency	1,127	1,389	1,921	777	2,137	3,074	2,873
National Aeronautics and Space Administration	5,672	3,449	3,584	1,051	2,648	2,763	4,033
National Science Foundation	1,375	1,928	1,650	40	2,712	848	896
Nuclear Regulatory Commission	------	1,195	1,439	427	1,758	1,318	1,583
Tennessee Valley Authority	212	252	216	70	297	216	261
Miscellaneous Federal agencies	1,168	1,686	1,542	499	1,774	1,882	1,645
Miscellaneous services to other accounts	2,706	2,797	1,527	253	822	1,290	989

[1] Included in miscellaneous Federal agencies.
[2] Shown as Energy Research and Development and Federal Energy Administration prior to October 1, 1977; includes Atomic Energy Commission funds for fiscal year 1974. See also funds from Nuclear Regulatory Commission in fiscal year 1975.

The following tables, which have previously been a part of this section, are available upon request from the Office of Program Analysis, USGS Mail Stop 105, 12201 Sunrise Valley Drive, Reston, VA 22090.

Table 4.—Topographic Surveys and Mapping direct program funds for fiscal years 1974 to 1979, by subactivity

Table 5.—Topographic Surveys and Mapping Federal-State Cooperative Program funds for fiscal years 1974 to 1979, by State

Table 6.—Topographic Surveys and Mapping reimbursable program funds from other Federal agencies for fiscal years 1974 to 1979, by agency

Table 7.—Geologic and Mineral Resource Surveys and Mapping direct program funds for fiscal years 1974 to 1979, by subactivity

Table 8.—Geologic and Mineral Resource Surveys and Mapping Federal-State Cooperative funds for fiscal years 1974 to 1979, by State

Table 9.—Geologic and Mineral Resource Surveys and Mapping reimbursable program funds from other Federal agencies for fiscal years 1974 to 1979, by agency

Table 10.—Water Resources Investigations direct program funds for fiscal years 1974 to 1979, by subactivity

Table 11.—Water Resources Investigations Federal-State Cooperative Program funds for fiscal years 1974 to 1979, by State

Table 12.—Water Resources Investigations reimbursable program funds from other Federal agencies for fiscal years 1974 to 1979, by agency

Table 13.—Conservation of Lands and Minerals direct program funds for fiscal years 1974 to 1979, by subactivity

Table 14.—Conservation of Lands and Minerals reimbursable program funds from other Federal agencies for fiscal years 1974 to 1979

Table 15.—Land Information and Analysis direct program funds for fiscal years 1974 to 1979, by subactivity

Table 16.—Land Information and Analysis reimbursable program funds from other Federal agencies for fiscal years 1974 to 1979, by agency

Table 17.—Land Information and Analysis Federal-State Cooperative Program funds for fiscal years 1974 to 1979, by State

Table 18.—Program support funds for fiscal years 1974 to 1979, by activity

Table 19.—Geological Survey end-of-year employment for fiscal years 1974 to 1979, by organizational unit

Table 20.—Number of Geological Survey reports approved for publication for fiscal years 1974 to 1979, by organizational unit

Table 21.—Number of maps produced by the Geological Survey for fiscal years 1974 to 1979, by organizational unit

Table 22.—Oil and gas operations on Outer Continental Shelf lands for calendar years 1974 to 1979

Table 23.—Revenues from leases on Outer Continental Shelf lands for calendar years 1974 to 1979

Table 24.—Oil, gas, and geothermal operations on Federal and Indian lands for calendar years 1974 to 1979

Table 25.—Royalties from oil and gas leases on Federal and Indian lands for calendar years 1974 to 1979

Table 26.—Mining operations on Federal and Indian lands for fiscal years 1974 to 1979, by activity and by commodity

Table 27.—Revenues from mining leases on Federal and Indian lands for fiscal years 1974 to 1979, by commodity

Table 28.—Information products ordered from the EROS Data Center for fiscal years 1976 to 1979

Table 29.—U.S. Geological Survey Library operating statistics for fiscal years 1974 to 1979

Table 30.—Number and type of measurement sites (stations) of the U.S. Geological Survey, fiscal year 1979


U.S. GEOLOGICAL SURVEY
BENCH MARK
FOR INFORMATION WRITE THE DIRECTOR WASHINGTON, D.C.
COOPERATION WITH THE STATE
ELEVATION
ABOVE SEA
1879 FEET

UPDATE FOR U.S. GEOLOGICAL SURVEY OFFICES

HEADQUARTERS OFFICES

OFFICE OF THE DIRECTOR

Official	Name	Telephone number	Address
Assistant Director—Land Resources	Linn Hoover, Acting	(703) 860-7488	National Center, STOP 104

WATER RESOURCES DIVISION

Chief Hydrologist	Philip Cohen	(703) 860-6921	National Center, STOP 409

CONSERVATION DIVISION

Deputy Chief for Onshore Minerals Regulation	John Duletsky, Acting	(703) 860-7515	National Center, STOP 620
Deputy Chief for Offshore Minerals Regulation	Robert L. Rioux, Acting	(703) 860-7571	National Center, STOP 640

LAND INFORMATION AND ANALYSIS OFFICE

Chief	Gene D. Thorley, Acting	(703) 860-7488	National Center, STOP 104
Associate Chief	[Vacant]	(703) 860-7471	National Center, STOP 703

PUBLICATIONS DIVISION

Chief	Gary W. North, Acting	(703) 860-7181	National Center, STOP 341

SELECTED FIELD OFFICES

GEOLOGIC DIVISION

Regional Offices

Office	Name	Telephone number	Address
Eastern	Avery A. Drake, Jr.	(703) 860-6631	National Center, STOP 953

WATER RESOURCES DIVISION

Regional Offices

Southeastern	Robert J. Dingman	(404) 221-5174	Richard B. Russell Federal Building, 75 Spring St., S.W., Rm. 772, Atlanta, GA 30303

District Offices

Arkansas	Richard T. Sniegocki	(501) 740-6391	2301 Federal Office Bldg., 700 W. Capital Ave., Little Rock, AR 72201
Montana	George M. Pike	(406) 449-5263	Federal Bldg., Room 428, 301 South Park Ave., Drawer 10076, Helena, MT 59601
Nevada	[Vacant]	(702) 882-1388	227 Federal Bldg., 705 N. Plaza St., Carson City, NV 89701
South Carolina	Rodney N. Cherry	(803) 765-5966	Strom Thurmond Fed. Bldg., Suite 658, 1835 Assembly St., Columbia, SC 29201
Utah	Theodore Arnow	(801) 524-5663	Room 1016, Administrative Bldg., 1745 W. 1700 St., Salt Lake City, UT 84104

CONSERVATION DIVISION

Regional Offices

Central	[Vacant]	(303) 234-2855	Box 25046, STOP 609, Denver Federal Center, Denver, CO 80225
Gulf of Mexico Outer Continental Shelf Operations	Lowell Hammon, Acting	(504) 837-4720 ext. 9381	P.O. Box 7944, 434 Imperial Office Bldg., 3301 N. Causeway Blvd., Metarie, LA 70010
Western	John J. Dragonetti	(415) 323-8111 ext. 2093	345 Middlefield Rd., Menlo Park, CA 94025

PUBLICATIONS DIVISION

Public Inquiries Office

California:			
San Francisco	[Vacant]	(415) 556-5627	504 Customhouse, 555 Battery St., San Francisco, CA 94111
Colorado	[Vacant]	(303) 837-4169	169 Federal Bldg., 1961 Stout St., Denver, Co 80294

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As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interest of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. Administration.