Chapter 9.
The Need for More Research, 1955–1958

It is both dangerous and poor economy to wait until an emergency is upon us before developing new methods, new concepts, and new applications of the geologic sciences.[1]

—Thomas B. Nolan

As members of the Eisenhower administration assessed the second Hoover Commission's recommendations for improving the Federal Government, they also took major steps to strengthen the North Atlantic Treaty Organization (NATO) and to foster world peace. On March 29, 1955, the Senate ratified the Paris treaties ending the occupation of the Federal Republic of Germany. The agreements reached Bonn on May 5, and West Germany became a formal member of NATO on May 9. British participation in NATO remained crucial, but Britain's leadership at home changed when Winston Churchill, increasingly ill, resigned on April 5. Anthony Eden, twice Churchill's Foreign Secretary, succeeded him as Prime Minister, and the Conservative Party increased its majority in the House of Commons in the national election on May 26. The Soviets remained concerned about their satellite nations in Eastern Europe (especially in view of the United States' announced policies and uprisings like the one in East Germany in 1953), NATO's strength and unity, and an economically strong and rearmed West Germany. On May 14, representatives from eight nations—Albania, Bulgaria, Czechoslovakia, the German Democratic Republic, Hungary, Poland, Romania, and the Soviet Union—met in Warsaw and signed a 20-year treaty of friendship and mutual defense known as the Warsaw Pact. Tito's Yugoslavia refused to join the agreement. After prolonged four-power negotiations in Vienna during May, Eisenhower signed on June 25 a peace treaty with Austria that returned sovereignty to the country on July 27. Austria, like Sweden and Switzerland, chose not to join NATO.

To try to secure a more tranquil world, President Eisenhower, Prime Minister Eden, French Prime Minister Edgar Faure, and Soviet Premier Nicolai Bulganin, accompanied by Nikita Khrushchev, the Communist Party's First Secretary, met in Geneva on July 21 to discuss peace and related issues. Khrushchev promptly showed Eisenhower who wielded the real power in the current Soviet Government. Eisenhower proposed a mutual "Open Skies" policy that would encourage the exchange of military information and allow reconnaissance overflights to forestall threats of war or surprise attacks. Neither U.S. radar installations in Turkey and elsewhere around the Soviet perimeter nor the planned reconnaissance surveys by balloons in the Air Force's Moby Dick Project[2] provided coverage sufficient to monitor the testing and deployment of Soviet strategic bombers and missiles. Adequate surety depended on information gained from images taken, during flights over Soviet test sites and bases, by high-resolution cameras made by Edwin H. Land's Polaroid Corporation and installed in a new high-altitude reconnaissance aircraft that could fly without refueling at least 4,000 miles at 430 miles per hour and altitudes of 70,000 feet, as recommended by James Killian, Jr.'s panel. After Killian and Land briefed Eisenhower, the President gave the new project to Allen Dulles'

Central Intelligence Agency (CIA), and its management there passed to Richard Bissell. The unarmed U–2, developed from a modified F–104 fuselage by Clarence L. ("Kelly") Johnson's team at Lockheed's secret "Skunk Works" facility, first flew in August 1955. The initial dozen production models of the new spy plane, a long-winged, glider-like aircraft powered by two turbojets, were deployed in the Far East by the Air Force and the CIA. At Geneva, the new Big Four also discussed the unification of the two Germanys and European security. West German militarization led the Soviet Union to oppose unification and reject the West's proposals for enduring European security. The Soviets unsuccessfully sought a European mutual-defense alliance that included a unified Germany but not the United States.

The Eisenhower administration announced on July 29 that the United States planned, as part of its activities during the International Geophysical Year (IGY), supported by the National Academy of Sciences-National Research Council (NAS–NRC) and the National Science Foundation (NSF), to have Project Vanguard place a dozen scientific satellites in orbit some 300 miles above the Earth. As Vanguard's launch vehicle, Eisenhower approved the Defense Department's recommendation to choose the Navy's scientific, but not yet enhanced, Viking rocket, rather than the Army's more powerful, nuclear-capable, and flight-tested Redstone intermediate-range ballistic missile (IRBM). The Soviet Union declared its intention, in *Science* for October 12, to place in orbit its own IGY satellite.

As IGY planning continued during 1955–56, the U.S. Geological Survey (USGS) moved to centralize and increase its capabilities in using electronic computers in mapping, scientific, and administrative operations, including payroll procedures. On February 27, 1956, an amendment to the Survey order[3] that established the Administrative Division in 1953 now founded within the Division a Computation Branch. The Survey order that followed on March 7, 1956, authorized an Advisory Committee on Electronic Computers that would report to the Director through the Executive Committee. The new five-member Advisory Committee, comprising one representative from each Division and one from the Director's Office, would be led by a chairman designated by the Director. The Advisory Committee was asked to "maintain familiarity with computer equipment and be alert to the application of its techniques to the scientific and administrative functions of the Geological Survey." Its members also would review the coordination of "tabulating and computing problems at such times as the available workload capacity of the [Computation] Branch is to be exceeded."[4]

The USGS appropriations for surveys, investigations, and research (SIR) for fiscal year 1955–56 gave the Geologic Division more than $5,718,000 of the $14,494,000 it received that year. The Division remained, as in recent years, heavily dependent on continued transfers from the U.S. Atomic Energy Commission (AEC), which again reduced its funding but this time only by $238,000 to $5,579,000. To the Geologic Division, the Department of Defense (DoD) transferred $1,361,000, the International Cooperation Administration (ICA) shifted $577,000, the Defense Minerals Exploration Administration (DMEA) provided $441,000, and the General Services Administration (GSAd) sent $259,000. From these and other Federal sources, the Division received a total of $8,539,000. The ICA, established within the State Department on June 30, 1955, pursuant to an Executive order of May 9,[5] replaced the Foreign Operations Administration.

Wilmot ("Bill") Bradley had been Chief Geologist for more than a decade, an interval longer than that served by any of his predecessors, and the Division's staff continued to support him. Players in the Pick and Hammer Club's show in April 1956 rejected attractive offers to leave the Division for higher paying jobs in academia, the AEC, consulting companies, or the oil patch. In the ode "Hi–Fi," sung to tune of "My Heart Belongs to Daddy" from Cole Porter's 1938 "Leave It to Me," Bradley knew, the geologists claimed, that they "couldn't be had":

So I want to warn you laddie,
Though your proposition is swell,
Yet my heart belongs to Bradley,
And our Bradley he treats us so well.[6]

Geologists in Charles ("Andy") Anderson's Mineral Deposits Branch mapped and studied the geology of active and potential mining sites as part of 98 projects operating in 29 States in fiscal year 1955–56. As before, Branch personnel worked to improve their understanding of the genesis and geologic setting of these and other mineral commodities and the physical and chemical factors controlling their localization and distribution in the wider crustal framework. The AEC supported 40 of these projects, but, in April 1956, it ended its support for the USGS search for uranium and vanadium on the Colorado Plateau. That physical-exploration program was the largest yet conducted by the USGS and was rivaled only by the agency's effort in Alaska's Naval Petroleum Reserve No. 4 (NPR–4). Beginning in November 1947, cooperative efforts by the USGS and the U.S. Bureau of Mines (USBM) in mapping, criteria development, diamond drilling, and core analyses discovered nearly 2.3 million tons of ore that averaged 0.34 percent uranium and 2.12 percent vanadium and was valued at about $96.5 million. Industry also adopted concepts developed during the USGS program, including the demonstration that buried stream channels in three sites in the Monument Valley of Arizona and Utah, disclosed by geologic mapping, geophysical surveys, and drilling, were favorable sites for uranium deposits. Related geochemical work in the Black Hills also identified some of its carbonate-cemented sandstones as uranium hosts. Branch members devoted considerable effort to mineral-commodity studies and to reviews of information about these commodities. Several major mining companies joined in an exploration program for Utah's Tintic district that used the results of USGS mapping and studies of rock alteration. Additional exploration by industry disclosed a new zinc-mineral district in Tennessee's Copper Ridge area, and USGS geologic maps aided new discoveries of iron ore in Idaho's Blackbird district and Michigan's Iron River district. Fourteen projects involved the Branch's cooperation with State agencies, and Branch scientists also continued geologic mapping and minerals appraisal with Puerto Rico's Economic Development Administration.

Fuel investigations were underway in 13 States during fiscal year 1955–56. Scientists from Ralph Miller's Fuels Branch and colleagues from the Scripps Institution of Oceanography cooperated in collecting and analyzing living foraminifers and sediments from the Continental Shelf to determine variations in types and numbers of species in different environments to aid in understanding the significance of variations in similar faunas from California's oil-bearing Miocene rocks. The USGS, the West Virginia Geological Survey, and several private organizations collaborated in detailed studies of cores from a West Virginia well, the initial one drilled in the heart of the northern Appalachian oil and gas basin that extended through the sedimentary sequence into the basement complex. Branch geologists finished compiling a new edition of the U.S. oil- and gas-fields map. They also compiled reports on the relation of oil-bearing black shales to other rocks in west-central New York and the spore assemblage of Ohio's oil-bearing Upper Devonian–Lower Mississippian rocks and prepared reports on oil shale in the Green River Formation of Utah's eastern Uinta Basin. The Piceance Creek Basin study led to determining that the amount of oil present in its oil-shale deposits was about double the amount previously estimated. Paul Averitt and his colleagues investigated deposits in 10 coal-producing States, published detailed reports on 14 coal-bearing areas, continued appraising coal reserves in 5 States, and began revising the coal map of the United States. USGS maps of the anthracite coals in eastern Pennsylvania provided geologic data and interpretations used in planning mine development and mine-water control in intensely mined areas. Branch scientists also continued intensive studies of uranium in western coals, particularly in

the Dakotas, Montana, and Wyoming. The results stimulated interest in commercial production of uranium from coal and led to the industry's discovery of ore-grade uranium in Tertiary coals in northwestern South Dakota.

Representing the increasing emphasis on marine geology and offshore resources by the Fuels Branch and the Geologic Division, a Branch geologist and three colleagues presented papers at a conference on the conservation of the natural resources of the Continental Shelf and overlying waters in the Americas. The conference, held at Ciudad Trujillo in the Dominican Republic during March 15–28, 1956, followed a call made at the 10th Inter-American Conference of the Organization of American States, the former Pan American Union, 2 years earlier in Caracas. Oceanographer John Lyman, who participated in Operation Crossroads at Bikini in 1946 and now directed the Division of Oceanography in the Navy's Hydrographic Office, reviewed the state of knowledge of Continental Shelves in the Americas. James Trumbull discussed the shelves' relation to continents and ocean basins, James Pepper evaluated their potential mineral resources, and Edwin M. Thomasson assessed specific problems related to developing petroleum resources in the Gulf of Mexico.

In fiscal year 1955–56, geologists of Edwin B. Eckel's Engineering Geology Branch continued their detailed mapping and investigations in several States, in five selected and principal urban areas, and on the site for the new academy for the Air Force. Branch members advanced bedrock and surficial geologic mapping in Massachusetts and Rhode Island and began similar cooperative and systematic mapping of quadrangles in Connecticut. Mapping also continued in support of regional planning for the development of roads, dams, and other major engineering works. Branch members made special studies for the National Park Service and the Federal Housing Administration to determine if construction operations at proposed sites would increase landslide hazards. David Varnes and Glenn Scott led a team—including J. Mark Cattermole, Roger B. Colton, Robert M. Lindvall, Paul P. Orkild, George Rozanski, and four other Branch geologists plus groundwater hydrologists William D.E. Cardwell and Edward D. Jenkins from the Water Resources Division—in continuing mapping and providing advice to the Air Force Academy Construction Agency about test wells, overburden, excavations, foundations, and groundwater at the selected site in Colorado Springs. The Air Force Academy, authorized by the 83d Congress and the President on April 1, 1954, opened in Denver in 1955 and moved to its new and permanent quarters at Colorado Springs in 1958. The report[7] by Varnes and Scott on the general and engineering geology of the Academy's site appeared in 1967, and 3 years later, it earned the Geological Society of America's Burwell Award.

Branch members also began planning engineering studies for the proposed interstate highway system. On June 29, 1956, Eisenhower finally reached another of his long-term goals when he signed the Federal-Aid Highway Act[8] that authorized the primarily military system, one whose need he recognized after accompanying in 1919 the Army's initial transcontinental motor convoy and observing the German autobahns after World War II. The 1956 statute provided $32.5 million over the next 13 years for constructing an interstate system of modern roadways and for completing construction of the Federal-aid system of highways.[9]

During fiscal year 1955–56, when William Benson left to serve as Program Director of the NSF's Earth Sciences Program, James Gilluly succeeded Benson as Chief of the General Geology Branch. Under Gilluly's direction, Branch geologists began studies of surficial geology in California's Death Valley and the adjacent Amargosa Valley astride the California-Nevada boundary, and the structural and volcanic history of the intervening Black Mountains (Amargosa Range), as the framework for investigations of the area's saline deposits. They also continued or completed mapping and studies in parts of Idaho's Mackay district and Snake River Plain, the Browning and Toston quadrangles and the Three Forks area of Montana,

Nevada's northern Shoshone Range, and the Kemmerer and Sage quadrangles in Wyoming. Cooperative work with State agencies included studies of the Carlin and Pine Valley quadrangles in Nevada and the Norwich area in Connecticut. Three more State geological maps, prepared in cooperation with their geological surveys, appeared in calendar 1955: New Hampshire, at 1:250,000, by Marland Billings; Montana, at 1:500,000, by Clyde Ross, David Andrews, and Irving J. Witkind; and Wyoming, at 1:500,000, by David Love, Joseph L. Weitz, and Richard K. Hose (which had been issued in 1952 in a preliminary and uncolored edition).

In fiscal year 1955–56, members of James Balsley's Geophysics Branch expanded their studies of the physical properties of minerals and rocks with limited funds but improved facilities for measuring electrical resistivity, dielectric constant, magnetic susceptibility, remnant magnetism, and dynamic elastic moduli. They began investigations of rock strength and elasticity, aided by an in-house analog computer designed and built to simulate the resistance and dielectric constant of a layered Earth. These scientists successfully used or prepared to test three experimental loggers for downhole geophysics—for acoustic, alpha-gamma (radon contamination), induced polarization, and thermal (conductivity) measurements—and developed a scintillation core scanner and a time-interval differentiator to identify isotopes. They used a sonar-type ground transducer to demonstrate that the high-frequency sonic method could determine shallow-depth geologic structures. Arthur Lachenbruch formulated a mathematical solution to heat-conduction problems caused by constructing heated buildings on permafrost. Branch members flew some 45,000 traverse miles of magnetic and radioactivity surveys in 14 States and Alaska. Aeromagnetic surveys of sedimentary basins in Alaska's Bethel and Copper River areas returned new data on their configurations and depths. John Henderson, Jr., and Isidore Zietz prepared an aeromagnetic map of Indiana's Precambrian basement, at 1:500,000, showing the average magnetic intensity by contours at intervals of 50 gammas, from similar surveys of 92 counties made during 1947–50. Radiometric surveys on the Texas Coastal Plain demonstrated that results could aid geologic mapping where poor surface exposures made difficult the fixing of formational boundaries. Branch members also continued to add to their expertise by additional academic training; Randolph ("Bill") Bromery completed a bachelor's degree in mathematics at Howard University in 1956 and then began part-time graduate studies at American University. As the fiscal year neared its end, Balsley's "Evils of Prostitution" memorandum to Bradley noted on June 20 that the Geophysics Branch's "most popular hustler, Airborne Surveys Section, has no time of her own." When the AEC took half of its business elsewhere, Balsley had to find $250,000 from other customers or cut loose some of his staff, and so he said yes to a monetary source in Pennsylvania that demanded more cooperation. Airborne Surveys' dowry in 1946 was $160,000 and all her own, Balsley lamented. Now, although in a $300,000 suite, only $80,000 of it represented SIR funds and all of it was promised to the external cooperators. Section members were unhappy, and Balsley thought they would have to stay that way until at least 1959, although he believed their hearts still belonged to Bradley but "this is just about all."[10]

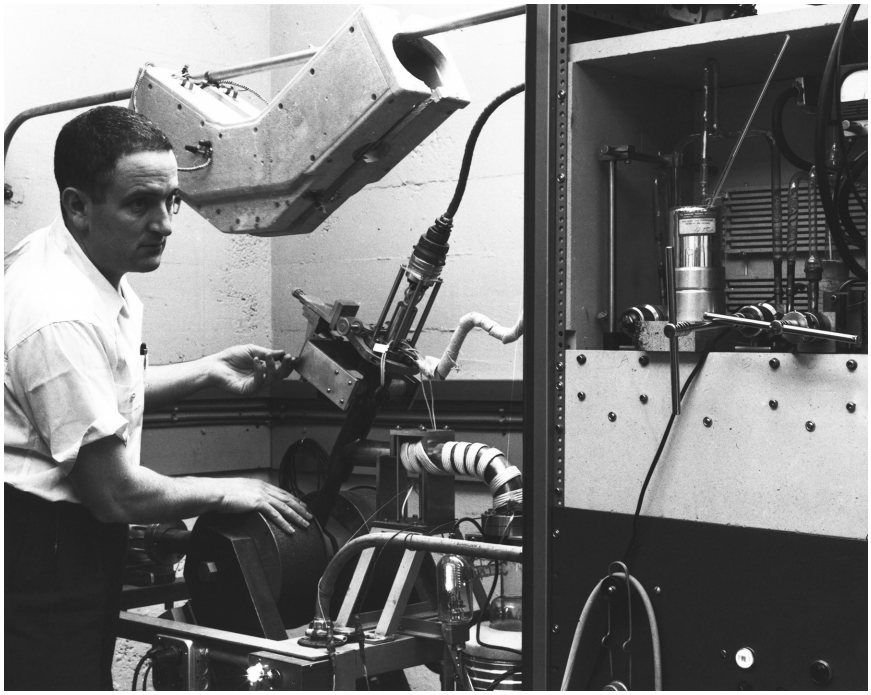
In fiscal year 1955–56, Geologic Division biostratigraphers, geobotanists, geochemists, and petrologists made chemical, mineralogical, paleontological, petrological, radiometric, spectrographical, stratigraphic, and related examinations of about 91,000 samples and specimens from within and outside the United States to support USGS geologic mapping, mineral exploration, and resources evaluation. More specifically, they completed studies of cerium-mineral compositions and all the rare-earth elements as phosphates, began examining methods proposed for disposing of radioactive wastes into geologic environments, and adapted improved instruments and techniques to advance those and related field and laboratory investigations. An X-ray spectrometer used in analyzing substances in thin and polished sections, and in very small samples, saved time. Using a new and rapid optical field


EXPLANATION
Magnetic contours
Contour enclosing area of lower magnetic intensity
LAKE MICHIGAN
Gary
South Bend
Tippecanoe River
Fort Wayne
Marion
Kokomo
Lafayette
WABASH RIVER
Muncie
Anderson
Richmond
INDIANAPOLIS
ILLINOIS
OHIO
Terre Haute
WHITE RIVER
Bloomington
EAST FORK
Vincennes
New Albany
Evansville
OHIO RIVER
KENTUCKY
N
From Indiana Geological Survey Misc. Map 4,1953
Compiled by Judson Mead, M. E. Biggs, and P. G. Holloway, 1953
10 0 40 Miles
Contour interval 50 gammas
Relative to arbitrary datum

◀ This map of Indiana (originally at about 1 inch = 33 miles) shows the State's average magnetic intensity by contours at intervals of 50 gammas. After the USGS and the Indiana Geological Survey cooperated in an aeromagnetic survey during 1947–50, the USGS published in 1949–52 magnetic-intensity maps (at about 1:62,500 and with 10-gamma contour intervals) of each of the State's 92 counties. USGS geophysicists John Henderson, Jr., and Isidore Zietz also published an aeromagnetic map of total intensity (at 1:500,000 and with 50-gamma contour intervals); a gravity-intensity map (at 1 inch = about 33 miles and with 5-milligal contour intervals); a same-scale theoretical contour map of the State's Precambrian basement surface, showing structural trends (with 500-foot contour intervals); and 1:250,000 magnetic maps of three counties, showing the correlation of anomalies and oil and gas fields. The USGS began cooperative topographic mapping with the States in 1884. These efforts subsequently expanded to include geologic, geophysical, and hydrologic investigations and maps. (From Henderson, J.R., Jr., and Zietz, 1958, fig. 9.)

test for rare-earth minerals and using automatic sample changer-recorders for the scintillation counters and X-ray diffractometers produced similar savings. Completing investigations of the albite-anorthite-orthoclase and albite-anorthite-orthoclase-water systems promised increased understanding of the geothermometry of feldspar-bearing rocks. Work on the geochronology of Pleistocene terrestrial samples and deep-sea cores produced a reliable sequence of radiocarbon dates for glacial events in North America and climate cycles elsewhere, and initial correlations to the worldwide standard. Checks on lead-alpha radiometric determinations of zircon ages showed them to be about 85 percent valid in rocks with good biostratigraphic control. Results of investigations of oxygen-isotope ratios in carbonates near ore deposits suggested that they might be useful in exploration. A new, inexpensive, rapid, and sensitive analytical method for uranium searches became the latest of the geochemical-prospecting techniques developed by the USGS and then used by governments and industries in other countries.

Reconnaissance investigations of mineral and fuel deposits in Alaska during fiscal year 1955–56 included searches for petroleum in the Lower Yukon-Koyukuk Basin that extended known formations north and west from the Yukon River, geologic mapping in the Nulato-Kateel River area, and studies of potential resources near Puale Bay on the Alaska Peninsula and those around Nelchina northeast of Anchorage. Coal studies, again concentrated in the Alaska Railroad belt, involved additional work in the Matanuska and Nenana fields. Geologists of George Gates' Alaskan Geology Branch continued to map and use systematic geochemical and radiometric techniques in studying mineralized areas, including tungsten and other deposits north of Nome, locales further north in the Baird Mountains, deposits in the Tofty area west of Fairbanks, and those in areas on Prince of Wales Island north of the Kasaan Peninsula and at Bokan Mountain-Kendrick Bay. In addition to continuing the 1:250,000 geologic-map series, they also advanced the glacial map of the Territory and gained improved knowledge of its metallogenic provinces. Thomas Payne published a map, at 1:5,000,000, of Alaska's Mesozoic and Cenozoic tectonic elements.



In this 1958 photograph, USGS geochemist and geophysicist Henry Faul (1920–81) adjusts a sample of biotite at the focal point of a mass spectrometer in the Geologic Division's Nucleonics Laboratory in Washington, D.C. Faul, educated at the Massachusetts Institute of Technology, served with the Manhattan Project (1943–46) before joining the USGS. There, he and other scientists used the mass spectrometer, the single-channel analyzer, and other laboratory instruments to determine the physical and chemical properties of minerals and rocks. By the lead-alpha method, which Faul helped to develop, and other uranium-based techniques, they fixed the radiometric ages of zircons and other minerals enclosed in igneous rocks. These techniques were supplemented by the use of potassium-argon (K-Ar) dating in the early 1960s. Faul left the USGS for posts in academia—the Southwest Center for Advanced Studies in Dallas (1963–66) and the University of Pennsylvania in Philadelphia. (Photograph from the USGS Denver Library Photographic Collection as Patterson, E.F., pef00489, https://www.sciencebase.gov/catalog/item/51dda0a0e4b0f72b4471ddaf; published in Yochelson and Nelson, C.M., 1979, p. 36.)

In fiscal year 1955–56, specialists in Frank Whitmore, Jr.'s Military Geology Branch (MGB) continued their work worldwide, principally for the Army and its Engineers. In 1956, the geologists and soils scientists in Frederick Betz, Jr.'s team in Europe began issuing from Heidelberg a second set of maps of West Germany, at 1:250,000, with data on construction materials, engineering geology, road construction, rock types, and terrain; with Soil Conservation Service (SCS) participation, they completed the maps on 20 sheets in 1961. Betz's team also continued to instruct and direct NATO personnel in the techniques of producing those maps. Mario A. Conti completed a lithologic map of Italy, at 1:1,250,000, that emphasized construction materials and underground installations. Betz's group in Salzburg closed its shop when the four-power occupation of Austria ended in July 1955. The principal request among a large number made by the Far East Engineer Command in Tokyo involved the discovery and evaluation of water resources for military use in the Republic of Korea. Members of the Pacific Geologic Mapping Program, now led by Gilbert Corwin as Charles Johnson's successor, returned to the Ryukyu's Ishigaki, southwest of Okinawa, to extend a military geology and mineral-resources reconnaissance at 1:50,000; Delos Flint and Raymond Saplis completed and issued the results in 1954. During June 1955, a team that included Richard J. Alois, Raymond Fosberg, Helen Foster, Harold May, and Carl Stensland begin mapping and studying Ishigaki's geology, soils, and botany; they completed their work in October 1956. The team finished its final reports on general and engineering aspects, mapped at 1:25,000, and tactical aspects of the terrain, at 1:50,000, in 1959–60. Also in 1960, David Doan, Fosberg, and James Paseur reported their similar investigations, with maps at 1:25,000, in the Ryukyu's Miyako Archipelago, also southwest of Okinawa, completed during November 1955–September 1956. In Alaska, MGB members continued reconnaissance studies for the Army Engineers of the Big Delta Military Reservation, the Gerstle River to the southeast, and areas in the Copper River Basin and on the Arctic Slope. For the Air Force, they resumed construction-related studies of Greenland and other areas in the Arctic.

Members of William Johnston's Foreign Geology Branch worked in fiscal year 1955–56 on projects for which fieldwork was complete, continuing, or beginning in Africa, Asia, and Latin America. With support from the International Cooperation Administration, they also helped to train 36 participants, from 16 countries, in the USGS domestic field program. Branch geologists completed the ICA-sponsored work on Iran's mineral resources. Anomalies disclosed by the USGS-assisted gravimetric surveys near Camaguey in Cuba were drilled for chromite deposits. William Hemphill finished his investigation in British Guiana by the end of calendar 1955. Also in 1955, the USGS began a new map series by publishing USGS biostratigrapher Wendell Woodring's geologic map of the Canal Zone and adjoining parts of Panama (at 1:75,000) as USGS Miscellaneous Geologic Investigations (I) Map I–1; three photogeologic maps of 1:24,000-scale quadrangles in Utah (I–2, I–3, and I–4) were dated 1954 but did not appear until 1955. Geochemist-spectrographer Kiguma J. ("Jack") Murata and economic geologist Charles T. Pierson began contributing their expertise to the ongoing reconnaissance surveys for uranium in Brazil. In Saudi Arabia, Aero Service completed photographing the Arabian Shield in 1955, and the entire Arabian Peninsula 4 years later; third-order vertical and horizontal control and shoran aided the photo compilation. Glen Brown and Richard Bramkamp promptly used the completed photos in detailed planning for a cooperative mapping project, conceived 2 years earlier by Director Wrather, to produce from the USGS and Aramco data a bilingual series of 21 geographic and 21 geologic maps to depict the whole Kingdom at 1:500,000. They planned to supplement this series, prepared with the assistance of Esther A. Holm and Simon H. Kfoury, with a geographic map and a geologic map of the Arabian Peninsula, both at 1:2,000,000.[11] John Reinemund began institutional development work with the

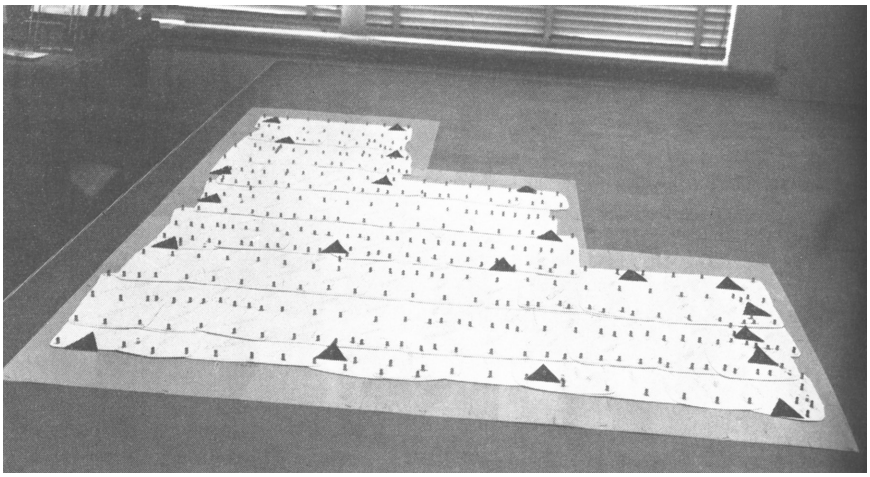
Geological Survey of Pakistan in October 1955. David Andrews started a multiyear examination of Indonesia's mineral resources in July 1955, as Arthur Kinkel, Jr., and Joe Peoples arrived in the Philippines to succeed Ronald Sorem when he completed in September his tour with Earl Irving's mineral-resources project. During the last half of calendar 1955, David Cerkel, Jr., Chief of the Conservation Division's Mineral Classification Branch, studied petroleum resources in the Philippines.

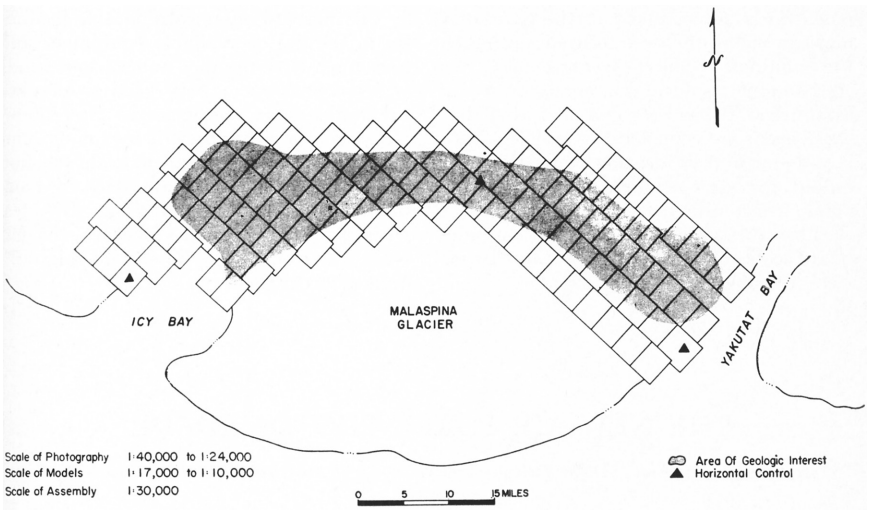
During the austral summer of 1955–56, the USGS returned to Antarctica with the Navy's Operation Deep Freeze, whose 1,800 men and 7 ships of Task Force 43 (TF 43) included attack transport *Wyandot* and three icebreakers—the Navy's new *Glacier*, its older *Edisto*, and the Coast Guard's *Eastwind*. Rear Admiral Dufek[12] led TF 43, accompanied by Rear Admiral Byrd, who flew his flag in *Glacier*, which he helped design, a ship with twice the power as, and 40 feet longer than, the 7 Wind-class icebreakers and carrying aft an enlarged deck for helicopters. Byrd, an early supporter of a strong science component for the IGY, now served as the honorary chairman of the NAS–NRC's U.S. Antarctic Committee and as Officer in Charge of U.S. Antarctic Programs, following his appointment by Eisenhower earlier in 1955. Byrd and his colleagues planned a 4-year Navy program to support preparations for and operations during the IGY. For the first year, fiscal 1955–56, the Navy supplied $17.8 million and the NSF provided $2.2 million from the appropriations for U.S. activities during the IGY that now totaled $39 million. An initial Antarctic Conference of the Comité Spécial de l'Anneé Géophysique Internationale (CSAGI) was held in Paris during July 6–10, 1955; at the first meeting and a second meeting in Brussels during September, Vladimir Beloussov accompanied the Soviet delegation. Ships of TF 43 arrived at McMurdo Sound on December 19. Its personnel constructed and provisioned a permanent base for scientific purposes only—Little America V and its 8,000-foot-long Air Operating Facility on Ross Island and the Ross Ice Shelf. Some 20 flights by two Lockheed P2V–2N Neptunes (modified for polar service) and two 4-engine Douglas R5Ds (the Navy's version of the C–54 Skymaster) explored and continued to drop claim markers on 800,000 square miles of Antarctica before the four aircraft returned to New Zealand on January 18, 1956. In addition to Laurence Gould, Chairman of the U.S. Antarctic Committee, and Paul Siple, Charles R. Lewis (who photomapped with William Hemphill the geology of the Desert Lake 1:24,000 quadrangle in Utah) accompanied TF 43 to study briefly the geology of McMurdo's Balaena Islands and other portions of the continent.[13] When TF 43 left McMurdo Sound in late March, some 90 persons remained to overwinter at Little America V. The Soviet Union's expedition arrived on January 5 to build and staff its Mirnyy Station, on the Queen Mary Coast, and two other stations.

Also in January 1956, Eisenhower personally revised National Security Council Report 5424 (NSC 5424). He deleted its call for mapping and permanent stations in Antarctica, emphasized that work there would be only for scientific purposes, and noted the United States' wish to reach an agreement with all claimants for unhindered exploration and scientific investigation, while also retaining U.S. rights on the continent. Shortly thereafter, when the promoters of the Federal mapping plan requested $56 million for large-scale coverage of Antarctica, the President asked the NSF's Director for the exact nature of the current U.S. commitment. When Alan Waterman cited only the IGY, Eisenhower arranged to delete any specific funds for new mapping efforts in Antarctica from the Federal budget for fiscal year 1956–57. To support U.S. participation in the IGY, the Operations Coordinating Board, the Navy Hydrographic Office, and the USGS agreed to have the USGS begin publishing in 1956 provisional reconnaissance maps, at 1:500,000, of 142,000 square miles in eight additional areas in Antarctica, using trimetrogon and radar photographs from Operation Highjump and subsequent expeditions. The Topographic Division also started compiling a 1:1,000,000 map of the Ross Ice Shelf.

The nearly $15,993,000 the Topographic Division received for fiscal year 1955–56 represented a loss of about $26,000 compared to the previous year's total. The new amount contained about $11,809,000 in SIR funds, a $310,000 increase, and $1,271,000 in reimbursements and direct payments from States, counties, and municipalities. Other Federal agencies transferred $2,783,000, a loss of about $397,000; that sum included $1,019,000 from the U.S. Bureau of Reclamation (USBR) and $1,472,000 from the DoD. The year's topographic-mapping program continued or began work in response to high-priority military and civil-defense requirements. This work included coverage of additional sites proposed for Nike antiaircraft missiles and of Fort Polk in Louisiana and Fort Huachuca in Arizona, the Special Maps Branch's 185 aeronautical charts of areas abroad prepared for the Air Force, the expanded highway program, and the needs of the Federal Civil Defense Administration. The Map Information Office's operations further increased when business and industrial activities again grew during the year. Some of the large rise in the strictly nontechnical use of maps and requests for map information, especially for recreational purposes, reflected the public response to articles in several national magazines advising persons that topographic maps were available from the USGS.

The Division began 1:24,000 cooperative-mapping programs with four new States. Indiana started a 10-year mapping effort by increasing its annual contribution from $50,000 to $200,000, and maps of more than 2,600 square miles were completed or revised during the year. West Virginia, completely mapped at 1:62,500 in 1899–1931, began its 1:24,000 coverage by providing $200,000 to be expended





The photograph (above) shows a stereotemplate system, devised in 1949 by USGS photogrammetrist Marvin B. Scher, for serially arranging aerial images. This system replaced the earlier slotted-template method. Stereotemplates "provided a practical means of accurate control extension" on an area basis. "Stereotemplates, when properly assembled and constrained by given horizontal control, would adjust to a common scale and thereby determine the absolute positions of desired supplemental control." The map (below) was formed by using the Scher stereotemplate assembly. The shaded area on the map represents the Neogene strata that cropped out north of the Malaspina Glacier, between Icy and Yakutat Bays, in southeastern Alaska. These rocks formed part of the oil-bearing sequences in the Gulf of Alaska Tertiary Province mapped by Don Miller and other USGS geologists. The USGS used Scher's stereotemplate system into the 1960s, when automated methods in photogrammetry began replacing it. (Photograph and quotations from Southard, 1984, fig. 11 and caption. Map from Scher, 1955, fig. 9.)

in fiscal years 1955–56 and 1956–57. The Kansas State Geological Survey, now led by Frank Foley as John Frye's successor, raised its contribution by one-third to $23,000, as an initial installment, and the State's highway department provided an additional $100,000 for priority coverage of specific quadrangles. Wyoming, where the Division had earlier mapped some quadrangles at 1:24,000, contributed initial funds to continue the effort in that State. The Division's air-photo coverage of Alaska's Brooks Range rose to 83 percent, and it also published 182 quadrangles at 1:63,360, which increased to 519 those issued for the Territory. Division topographers completed additional mapping at 1:24,000 of all of Oahu, 4 of 17 quadrangles on Maui, and the 3 that covered St. Thomas in the U.S. Virgin Islands. The Division accelerated its mapping of selected metropolitan areas to meet civil-defense requirements and printed maps of 16 cities. Division topographers finished planetable maps of beach and adjacent areas from Bay Shore to Montauk Point on New York's Long Island, as part of a congressionally authorized detailed study of beach erosion and hurricane damage.

The success of early tests of the prototype Orthophotoscope indicated that the new instrument could be applied as well in geologic, engineering, and military uses. Division engineers tested the initial model of their twin-camera mount and then loaned it to the Air Force for additional and more rigorous flight tests. Division members concluded that the new trimetrogon photography, taken with the latest precision cameras, ellipsoidal reflector-55 (ER–55) projectors, stereotemplates that extended ground control for phototriangulation, and vertical control by photoalidade, could be combined to form a photogrammetric unit to produce more accurate small-scale and large-contour-interval maps under the most adverse conditions of flight and available ground control. Efforts also continued to improve the efficiency of control surveys. In addition, the scribing process was extended to field surveys and adapted to stereocompilation work. The adoption of plotting scales equivalent to reproduction scales promised additional economic savings. The Division abandoned further development of the Twinplex plotter after the advent of successful super-wide-angle photography that eliminated the problems associated with using convergent or transverse low-oblique photos in aerotriangulation. Division mappers regularly used a field-survey system that combined technological advances introduced earlier in the decade—the pendulum alidade, the vehicle-mounted elevation meter, the electrical survey net adjuster, and the helicopter.

This photograph shows a cartographic technician tracing contours in ink on metal-mounted paper. The finished sheet was then photographed to produce a film for printing the topographic map; separate drawings were required for each color. Pen-and-ink drawing and aluminum mounts were used after 1942 because copper-plate engraving had to be abandoned when the U.S. war effort required ever-increasing amounts of copper. The consistency of lineweights depended on the skill of the technician, the fluidity of the ink, and the properties of the paper. In the mid-1950s, scribing replaced pen-and-ink drawing; scribers used tools that held modified phonograph needles to remove the colored coating on clear plastic sheets. This change increased economy, efficiency, and legibility in map production, partly because uniform lineweights were produced by the scribing tool. Thereafter, the scribing method "would not change significantly until the introduction of [digital] computers." (USGS photograph, about 1952, Rolla, Missouri; quotation from Stettner and Mathieux, 2008, p. [39].)

Two reports issued in 1955 by Presidential commissions charged with reviewing and revising water-resources policy, to which the USGS and other Federal agencies contributed their expertise, significantly influenced the work of the Water Resources Division. The second Hoover Commission's Task Force on Water Resources and Power, chaired by Admiral Moreell, included 25 other persons organized in 4 task groups to assess Federal water resources and power policies and organization. Moreell made Task Group B responsible for Reclamation and Water Supply. USGS hydrologists Glenn Hoyt and Walter Langbein completed for the Task Group and the Task Force three studies—"Federal Gathering of Basic Water Resource Facts," "Competition for the Use of Water," and "Flood Management Through Zoning, Insurance, and Forecasting." The Presidential Advisory Committee on Water Resources Policy, formed to review Federal policies and programs and recommend improvements in administrative organization to ensure water conservation and best use, aided the deliberations of Moreell's task force at Eisenhower's request. The President founded the new Committee, originally called the Cabinet Committee on Water Resources Policy,[14] on May 26, 1954, just 2 months after his discussions with the minerals-policy committee also chaired by Secretary McKay. McKay's new Committee included Agriculture Secretary Ezra Benson, Defense Secretary Charles Wilson, and their alternates. Commerce Secretary Sinclair Weeks, Health, Education, and Welfare (HEW) Secretary Oveta Hobby, and the Budget Bureau's Director Rowland H. Hughes participated on an ad hoc basis, also as Eisenhower requested. The new Committee received help from the also newly formed Inter-Agency Committee on Water Resources in trying to improve the coordination of existing policies, programs, and activities in investigation, planning, construction, operation, and maintenance by executive departments and their agencies. The reports by Moreell's task force and the second Hoover Commission recommended strengthening and expanding the Inter-Agency Committee on Water Resources by changing it to a "Water Resources Board,"[15] in the Executive Office of the President, composed of five civilians, one of whom would chair; the Secretaries of the Army, Interior, and Agriculture; the head of the Federal Power Commission; and several nonvoting members. The new Board would "determine the broad policies for recommendation to the President, and, with his approval, to the Congress" and "devise methods of coordination of plans and actions of the agencies at Washington * * * and in the field."[16] The second Hoover Commission, repeating a point made by the first Hoover Commission, included "adequate gathering of basic hydrologic data" among its dozen problems common to all branches of water development. Noting that "[m]any costly errors in the past have been due to inadequate data," the second Hoover Commission emphasized that:

> **[t]he importance of adequate hydrologic data cannot be overestimated.[17]**

Among the nine points recommended by the second Hoover Commission as a national water policy to Congress were calls for developing water resources for their "optimum use" and "maximum contribution to the national economic growth, strength, and general welfare." The Commissioners recommended that such development "should be generally undertaken by drainage areas—locally and regionally,"[18] as urged by John Powell and many others since the 1870s. They also resolved that "one Federal agency should be made responsible for collecting and revising the adequacy of hydrologic data."[19]

McKay's Committee on Water Resources Policy submitted its report on water-resources policy to Eisenhower on December 22, 1955. The Committee's members recognized four major problems that they felt continued to work against a more effective policy for developing the Nation's water resources. First, conflicting Federal laws, authorizing agencies to operate programs for different ends,

USGS hydraulic engineer Luna Bergere Leopold (1915–2006), the son of conservationist Aldo Leopold, worked for the Soil Conservation Service (later the Natural Resources Conservation Service) and the Army Engineers, and also served as a commissioned meteorologist with the Army Air Forces, before joining the USGS in 1949. Leopold combined in field and laboratory investigations the processes and results of erosion and sedimentation in river basins and reservoirs in arid and other regions. He served as Royal Davenport's field representative in the Western United States and then moved to Washington in 1955 as a research hydraulic engineer in Davenport's Branch of Technical Coordination. Leopold served briefly as Chief of Program Development in the Water Resources Division (WRD) before succeeding Carl Paulsen as Chief Hydraulic Engineer (later Chief Hydrologist) and Chief of the WRD (1957–66). Leopold increased the percentage of fundamental research in the WRD, while continuing his own and collaborative studies in river morphology and mechanics. Leopold returned to full-time research at Menlo Park in 1966 and moved to the University of California at Berkeley in 1972. He retired from the USGS in 1973 but continued as Professor of Geology at Berkeley. (Photograph from the USGS Denver Library Photographic Collection, Portraits, port1250, https://www.sciencebase.gov/catalog/item/51dda2dce4b0f72b4471dff5; see also Bull, 1986.)

Geohydrologist Raymond Lee Nace (1907–87) joined the USGS Ground Water Division (later Branch) in 1941. During World War II, he led an Army water-supply company and then a battalion in the European Theater of Operations. Nace, discharged as a Major in 1946, then served as the District Geologist in Idaho for the Water Resources Branch (later Division, WRD), led hydrogeologic studies at the U.S. Atomic Energy Commission's National Reactor Testing Station, and served as Regional Coordinator for the Pacific Northwest before becoming the WRD's Assistant Chief Hydraulic Engineer for Operations in 1956. While serving as Associate Chief Hydraulic Engineer during 1957–63, Nace also oversaw international activities. He then returned to research and later moved to North Carolina, but he continued to advise Luna Leopold and Ernest Hendricks, Leopold's successor as Chief Hydrologist, about the WRD's research program. Nace retired in 1977. (Photograph from the USGS Denver Library Photographic Collection, Portraits, in the "Last Name M–R" folder as Public Inquiries Office 64–5 [1a]; see also Heath, 1988.)

prevented improved cooperation and coordination with efforts by States, counties, and municipalities. Second, it was neither practicable nor desirable, financially or otherwise, for the Federal Government to assume responsibility for the complete development of these resources. Third, the concept of equal contributions for equal benefits continued to be applied unevenly at Federal, State, and more local levels. Fourth, considerable controversy continued unabated among proponents of State versus Federal water rights. The Committee's members, in making their recommendations to resolve the overall problem, recognized that a water-resources policy required "fundamental basic data." They called for an accelerated, more consistent, and better defined program of collecting data on "stream flows, rainfall, soil conditions, hydrology, meteorology, and other elements which control the quantity, the usability, and the desirability of water uses."[20] There was no single national problem or blueprint to resolve it, the Committee's members emphasized, but dozens of concerns that differed between States and areas. They believed, reflecting the administration's long-held views, that the current and predicted problems of each area could only be considered and resolved separately for each river basin, State, and region. The Committee hoped to bring the Federal programs "to a common understanding" and operations "upon a fixed and uniform pattern,"[21] in part by establishing a Coordinator of Water Resources, in the President's Executive Office, who also would permanently chair the Inter-Agency Committee on Water Resources. Eisenhower sent the report to Congress on January 17, 1956, as the Department of the Interior (DoI) began implementing the Committee's recommendations and continued to support resolving some water-resources problems by means of existing and proposed interstate compacts.

The Water Resources Division received during fiscal year 1955–56 about $7,655,000 in SIR funds, an increase of more than $996,000. During the year, California, Texas, New York, and Florida led the remaining 44 States and their municipalities, Hawaii, and Guam in contributing $537,000 more than in 1954–55, to raise the total to $4,614,000. Other Federal agencies supplied in all about $3,612,000, a total that included $1,102,000 from the Army and its Engineers, $996,000 from the USBR, $480,000 from the ICA, and $341,000 from the AEC. The Division amassed some $16,053,000 in total monies for 1955–56, or $2,152,000 more than in 1954–55. On May 3, 1956, Nolan's Survey order approved the reorganization, effective April 4 and for the second time in less than a decade, of the Water Resources Division. Chief Hydraulic Engineer Carl Paulsen's revision, based largely on work by Raymond Nace and Luna Leopold, aimed "to integrate the program planning and the operations of the division, to decentralize its administration and to improve facilities for the increasingly important general hydrological studies." The changes were designed, as Wrather long advocated, to emphasize basic research at the expense of service operations. The order established, in Paulsen's office, Assistant Chief Hydraulic Engineers (ACHEs) for Program and Development and for Operations and an Administrative Officer. While retaining the Division's Branches of Surface Water, Ground Water, and Quality of Water, with their area chiefs in the regions, the order also confirmed the newly renamed Branch of General Hydrology for work on

> **the broad fundamental problems of hydrology and * * * research and studies in specialized fields.[22]**

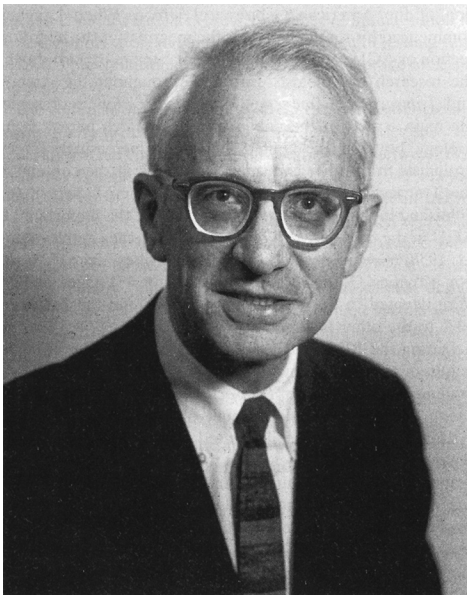
Paulsen, who planned to retire in 1957, gave the two new appointments as Assistant Chief Hydraulic Engineer to Leopold and Nace. On June 17, 1956, Paulsen appointed Leopold the ACHE for Program and Development. Nace, District Geologist in Idaho but on detail to headquarters in Washington as Staff Coordinator, Pacific Northwest, became the ACHE for Operations on July 18. Luna Leopold,

the son of conservationist Aldo Leopold, joined the USGS in 1949, investigated the geomorphologic relations among river depth, width, slopes, and water velocities, and served as Royal Davenport's field representative for the regions west of the Mississippi before moving to Washington in 1955 as a research hydraulic engineer in Davenport's office. After Davenport retired on December 31, 1955, the Technical Coordination Branch got a new Chief, Charles C. McDonald, and, in July 1956, was renamed the General Hydrology Branch to follow the Van Pelt Committee's recommendation.

Paulsen made additional changes in his staff and in the regions. He delegated line and program authority in the Division's four principal geographic areas to the new positions of Regional Hydrologist. To these posts, Paulsen appointed Arthur Piper, for the Pacific Coast Region, originally at Portland but moved to Menlo Park by July 1956; Sherman K. Jackson, for the Rocky Mountain Region, at Denver from March 1957; Henry Beckman, for the Mid-Continent Region, at Rolla from July 1957; and George Ferguson, for the Atlantic Coast Region, at Washington, D.C., until November 1956 and then at Arlington, Virginia. The Regional Hydrologists, who reported directly to Paulsen, were aided by area subchiefs appointed by and representing the Chiefs of the Surface Water, Ground Water, and Quality of Water Branches. In June 1956, Leopold succeeded Ferguson as Chief of the Branch of Program Control, another unit recommended by the Van Pelt Committee, before becoming ACHE for Program and Development. Paulsen discontinued the Program Control Branch and passed some of its functions to Leopold. Paulsen's reorganized office also included Staff Research Scientists and six Sections—Administrative (Frank Barrik, Jr.); Career Development (Roy Oltman); Foreign Hydrology (Thomas Eakin, aided by Roy Jackson); Planning (Kenneth Young); Publications, formerly, Technical Reports (William S. Eisenlohr, Jr.); and Radiohydrology (Victor Stringfield, and including George De Buchanne after his transfer in 1955). A DoI press release made these changes public on September 27, 1956.

During fiscal year 1955–56, Foreign Hydrology specialists continued the ICA-assisted, long-term projects in eight countries, and in Jamaica, where they also trained more than 100 local colleagues. Stuart Schoff examined aspects of Nicaragua's water resources during September 1955. John Cederstrom, from July 1955, and G. Chase Tibbitts, Jr., from April 1956, continued the Division's groundwater studies in Libya. Paul Jones succeeded George C. Taylor, Jr., in India during August 1955, as Arthur Garrett extended well-drilling operations. In July 1955, chemist Raymond T. Kiser and geophysicist Raymond E. Miller began work in George La Rocque's groundwater project in West Pakistan.

During fiscal year 1955–56, members of Joseph Wells' Surface Water Branch operated some 6,800 stations in the streamflow network. By year's end, the Branch's compilation of all streamflow records for 1888–1950 rose to 68 percent, and the unit published streamflow data for the lower Mississippi River, the Pacific Slope Basin in Washington, and the lower Columbia River. Branch members continued to develop techniques for relating single measurements of low flow in ungaged small streams to correlative records of flow at streamgaging stations in order to deduce the characteristics of small streams during intervals of low flow. An intensive review of the scope and adequacy of the streamgaging network in the Colorado River Basin produced methods applied in June 1956 in evaluating the national streamgaging network scheduled for completion within a year. Walter Langbein and John E. McCall pursued their inquiry about the value of continued data collection at a given site. The new hydrologic network was designed to aid planning for collecting basic surface-water data. The network consisted of (1) "primary" stations to be operated indefinitely to yield long-term trends, (2) short-term "secondary" stations to give area coverage, and (3) water-management stations. The Branch purchased an electronic computer to tabulate automatically daily discharges directly from the gage charts. Beginning in July 1954, Edgar G. Barron and his colleagues



Hydrologist Walter Basil Langbein (1907–82) left the Rosoff Construction Company in 1935 to join the USGS. In subsequent years, fieldwork took him to nearly all of the conterminous 48 States. Langbein studied drainage-basin capacities and reservoir storage, flood hydrology, flood-plain zoning, the geometry of stream channels, the hydrological cycle, the design of water-data networks, and water-sediment transportation. His research contributions "to the growth of scientific hydrology * * * introduced original concepts of both theoretical interest and practical importance." Like Luna Leopold and Raymond Nace, Langbein aided planning for and participated in the International Hydrologic Decade (1965–74). Langbein retired in 1968, but he continued to advise several USGS Directors and Chief Hydrologists about current and potential problems in U.S. water resources and research. (Quotation and photograph from Dooge, 1996, p. 2969; photograph also published in Matalas, 1983.)

developed a bubble-type pressure-sensing device to activate the stage recorder at streamgaging stations. This device was a less expensive instrument than the float-type recorders and represented a step toward eliminating expensive stilling wells. These gages sensed and recorded river stages by pressure, and so they did not require gage wells of heights equal to the full-stage range of the river. Experimental models were installed for field trials in several Districts between late 1955 and mid-1956.

The Surface Water Branch, as part of its flood and sediment investigations, published flood-frequency reports for Connecticut, Missouri, and Nebraska, continued similar studies in six other States, initiated additional programs with State highway departments, and began collecting and analyzing data for a nationwide study. Branch planners expected the data obtained to provide better definition of the flood-producing characteristics of small streams, knowledge required to design adequate and economical drainage and flood-control structures. Intensive field investigations documented and a preliminary report described the devastating floods of August–October 1955 in North Carolina. Similar studies followed the floods of December 1955–January 1956 in parts of the U.S. West Coast. Branch members regularly measured suspended sediment at some 200 locations and also continued investigating the sources, quantity, and movement of waterborne sediments and their effects on reservoir storage, navigable waterways, diversion works, and irrigation canals. As part of work in the Missouri River Basin, Bruce Colby, Charles Hembree, and Frank H. Rainwater published in 1956 their analysis of sedimentation in Wyoming's Wind River Basin. Rigorous field tests demonstrated a new recorder's ability to register continuously the electrical conductivity of water and promised to advance the more economical collection of additional information about the load of dissolved solids in river waters. Studies completed during the year demonstrated that graphic plots yielded curves showing the relation between the sediment loads of rivers and the rate at which they discharged water. When the graphic relation was supplemented by occasional direct determinations of sediment load, the method was used to compute the total load of sediments discharged during monthly and annual intervals; it proved accurate in solving problems in water-resource development.

Of the 550 investigations underway in Nelson Sayre's Ground Water Branch during fiscal year 1955–56, about 80 percent were in the Federal-State cooperative program, but some 100 concerned problems in which the primary interest was national or in which Federal agencies were directly concerned. The Branch directed the greater part of its effort toward area studies and reports on the geology and groundwater resources of geographic or hydrologic units, commonly of counties or groundwater basins. Supporting studies included research on the occurrence and movement of water in various geologic and hydrologic environments, systematic inventories of the demands on groundwater, and studies of water-level fluctuations. The results, besides adding directly to greater knowledge of hydrogeologic principles and processes, led to improved techniques for analyzing and solving water-supply problems. Inventories kept current provided records of operating experience with groundwater reservoirs. In 1955, Sayre appointed a 10-member Observation Well Committee, chaired by Russell Brown, to review the system of recording and publishing well records; the Committee's recommendations were implemented by the end of 1956. John Ferris and Sayre's "The Quantitative Approach to Ground-Water Investigations," published in *Economic Geology*, traced the history and development of the quantitative concepts and techniques by then widely used in appraising and interpreting groundwater resources.[23] In field studies, hydrologists continued to gain perspective on the factors that affected the artificial recharge of groundwater and the principles that controlled water movement through unsaturated porous media. The hydrologists also used a new electrical analog model for analyzing the hydraulic properties of nonhomogeneous aquifers.

Members of Kenneth Love's Quality of Water Branch analyzed some 65,000 nationwide samples during fiscal year 1955–56. They made detailed chemical-quality investigations of streams in the basins of the Colorado, Columbia, Missouri, and Pecos Rivers; in New York and the New England States; and in Alaska. The Branch maintained a sampling network on streams in the West to determine trends in mineral content that would affect continuing successful operation of the region's irrigation projects. Continuous recordings or daily observations of temperature were taken at more than 400 sites on major streams. Work continued on the inventory of the occurrence and quality of U.S. saline-water resources, as well as the series, begun in 1953, of comprehensive reports on the water resources of industrial-production areas. Branch scientists advanced their development of ways and means for collecting and appraising facts about radioactive substances dissolved in water that emphasized radio-elements in relation to chemical, geologic, and hydrologic factors.[24] They also studied specific terrains in Arizona, Colorado, Idaho, Nevada, and Texas.

Several laws enacted during fiscal year 1955–56 directly or indirectly influenced the responsibilities of and work by the Conservation Division. On July 15, 1955, a new statute provided "for the conservation of anthracite coal resources through measures of flood control and anthracite mine drainage * * * to conserve natural resources, promote national security, prevent injuries and loss of life, and preserve public and private property."[25] The act authorized the Secretary of the Interior to contribute for these conservation purposes up to $8.5 million, if Pennsylvania, which held the Nation's largest anthracite reserves, matched that or a lesser sum. The 84th Congress required the Secretary to report progress on or before each February 1 for the next 4 years; in 1962, an amendment authorized using any funds not expended for flood control to fill and seal abandoned mines. On July 23, 1955, the Multiple Surface Use Act[26] amended 1947's Mineral Leasing Act for Acquired Lands, and the general mining laws, to facilitate multiple use of the surface and subsurface resources of single tracts of public lands. Congress and the President intended the new law to prevent mining claims from being staked or used for nonmining purposes and to prevent timber waste on unpatented mining claims. The new statute authorized Federal management of surface resources, including timber and forage, of all unpatented claims staked after the act's passage and Federal acquisition of rights to surface resources of earlier claims. The law also excluded from the 1872 and other mining laws sand, gravel, and other common mineral materials and placed them under 1947's Mineral Leasing Act to be sold by competitive bids.

Related new laws followed in August 1955. Congress and the President agreed on August 1 to repeal the Timber and Stone Act of 1878 and its subsequent amendments.[27] On August 11, they authorized Arkansas, Louisiana, Oklahoma, and Texas to sign a contract to apportion the Red River's waters.[28] On the same day, a new statute provided "for entry and location, on discovery of a valuable source material, upon public lands in the United States classified or known to be valuable for coal," unless the lands were "embraced within a coal prospecting permit or lease." The new law authorized these actions and also those governing the discovery of the valuable source material, primarily uranium and other fissionables, "occurring within any seam, bed, or deposit of lignite."[29] The statute permitted entry under the mining and mineral-lease laws, provided a copy of a notice was filed within 90 days in the Bureau of Land Management's (BLM's) office in the State of location and claimants reported annually to the USGS Mining Supervisor the amount of lignite mined or stripped in recovering the more valuable source materials and paid for the former at 10 cents per ton. No extralateral rights conveyed. All lands subject to the new law would be withdrawn from all forms of entry under the act after 20 years, or 30 years as the President might order. Also on

August 11, the passage of the Mining Claims Rights Restoration Act permitted "the mining, development, and utilization of the mineral resources of all public lands withdrawn or reserved for waterpower development."[30] The new statute opened those lands covered by the Pickett Act of 1910[31] to entry for these purposes, but it reserved their waterpower rights to the United States. The law affected more than 7 million acres in 23 States and Alaska Territory. The measure also gave the Secretary of the Interior three options in assessing placer claims made under the act: (1) complete prohibition: (2) permission only if the claim's surface would be restored to its premining condition; and (3) a general, but not further specified, permission.

In 1956, Eisenhower continued to foster development of the public lands. On February 17, the President vetoed the proposed amendments that would have diluted the requirements of the Natural-Gas Act. He signed on April 11, despite significant opposition from conservationists and preservationists, and from participating projects, a bill that provided $760 million for the Colorado River Storage Project,[32] the USBR's irrigation-reclamation effort that involved four dams and reservoirs, powerplants, and transmission facilities. Eight months earlier, plans for a single dam in Hell's Canyon replaced those for three smaller dams elsewhere on the Snake River.

The Conservation Division, still the smallest of the USGS' four major programmatic units but the one continuing to be the least dependent on outside financing, drew on a little more than $1,840,000 during fiscal year 1955–56. That amount represented an increase of more than $94,000 over the sum available in 1954–55, but nearly $53,000 of the new total came from other Federal and nonfederal sources. Members of David Cerkel's Mineral Classification Branch handled nearly 28,900 cases during the year. The Branch's geologic reports and maps for official use were based on specific investigations by Branch geologists intended to aid engineers in planning and recommending to Federal lessees and other persons more efficient methods of recovery of the products involved. Branch members continued their regular work on fuel fields and unit plans, leasehold production limits, lease-sale recommendations, and the geologic significance of new discoveries. They also completed reports on seven power-dam sites in Alaska, a mineral-resources map of Washington, a report on the geology of dam sites on the upper Columbia River, structure-contour maps of Montana's Fort Peck Indian Reservation and the Montana Plains, a revised geologic interpretation of the southeastern Powder River Basin in Wyoming, a reconnaissance of phosphate deposits in northeastern Nevada, maps of Colorado's Ragged Mountain coal field and the State's Colorado Plains, a contour map of southeastern New Mexico's Yates Sand, and contour maps of two oil and gas fields—Greenwood in Kansas and East Orlando in Oklahoma. In 1955–56, the usual work by members of Arthur Johnson's Water and Power Branch in seven Western States and Alaska included 350 miles of channel surveys, examinations of 10 dam sites, and action on more than 5,700 hydraulic determinations on Interior and Federal Power Commission (FPC) cases. Branch members also began a program of systematic review and appraisal of land withdrawn for waterpower reserves and assembled material for use in periodic reports about the world's developed and potential waterpower. Members of Joe Turner's Mining Branch supervised almost 2,540 mining properties, about 720 more than in 1954–55, in 32 States and Alaska. Those mines produced more than 19.7 million tons of metals and nonmetals worth some $135.3 million and generated royalties of nearly $5.9 million, an increase of almost $424,000. Members of Harold Barton's Oil and Gas Leasing Branch supervised more than 115,000 properties on public, acquired, Indian, and Navy lands, where produced petroleum, natural gas, gasoline, and butane yielded $65.4 million in royalties, representing a gain of more than $4.9 million over royalties received in 1954–55. In Alaska, the DoI opened to exploration, as part of what it termed its widespread and responsible search for

oil, 1.2 million Federal acres in 470 leases in the area between Icy Cape and Cape Fairweather, in the eastern part of the Territory's Gulf of Alaska lands. On the U.S. Outer Continental Shelf (OCS), Branch personnel managed 367 leases originally issued by Louisiana and Texas under provisions of section 6 of the Outer Continental Shelf Lands Act of 1953 and 235 leases issued under section 8 of that statute. Petroleum produced from the OCS during 1955–56 yielded royalties, rents, and bonuses of more than $119.7 million.[33]

In January 1956, Congress began hearings on Interior's budget request for fiscal year 1956–57 and approved the President's nomination of a new Director for the USGS. On January 13, the day that Eisenhower appointed James Killian as Chairman of an eight-member Board of Consultants on Foreign Intelligence Activities (including Lt. General James Doolittle, Joseph Kennedy, and Robert Lovett), Secretary McKay appeared before Michael Kirwan's House appropriations subcommittee. To meet increased demands for Interior's services, McKay asked for $43.6 million more than in 1955–56, including salary increases under the Federal Employees Salary Increase Act of 1955,[34] to bring the Department's total funds to $504.4 million. Of that amount, $31.6 million was marked for the USGS and represented an increase of more than $5.3 million compared to the previous year's request. The latter sum included increases for topographic and geologic mapping and mineral and water-resources investigations "as recommended by the President's Cabinet Committee on Mineral Policy."[35] USGS programs, McKay continued, "have a broad application to our national economy. This service may not be especially spectacular to the layman, but directly or indirectly it provides the base for the future development and use of our mineral, water, and other resources." USGS investigations and research fueled by that money, McKay asserted, "have far-reaching effects"; these funds, he believed, were "truly an investment in the future of the Nation."[36]

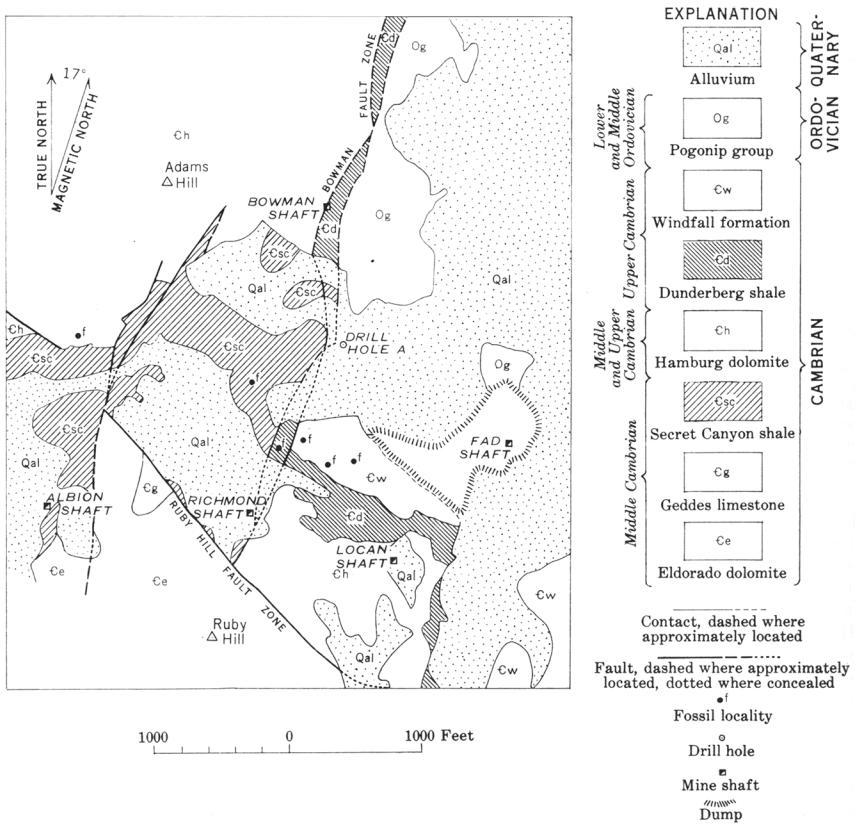
On January 17, Assistant Secretary Wormser again accompanied Acting Director Nolan to the USGS portion of the House subcommittee's hearings. Wormser initially referred to Nolan as Assistant Director and then, prematurely, as Director. Wrather knew he "was in for a long, slow recovery"[37] and tried to retire, but Wormser and McKay refused to act on Wrather's request, hoping that he would soon return to his duties. Finally, McKay visited Wrather at his home, and the Director convinced the Secretary to approve his retirement as of January 4 but effective on the 26th. McKay assured Wrather that he would move quickly to appoint a successor and recommended Nolan. Eisenhower accepted Wrather's resignation on January 18 and sent Nolan's name to the Senate on the same day. Wrather was delighted when the directorship passed to Nolan:

> **I was well pleased by his choice of Tom Nolan, my assistant. I felt that the new Director should again be chosen from the ranks. The Survey had been well shaken up during my incumbency and would profit if given an opportunity to become thoroughly adjusted to the changes we had initiated. Tom was well qualified to carry forward as I had taken care that he was thoroughly posted on everything I had done and was in agreement with the objectives.[38]**

The Senate confirmed Nolan's nomination on January 25, and he took his oath of office as the seventh Director 2 days later. Nolan, during his 11 years as Assistant Director, continued his research on the geology and mineral deposits of the Great Basin and especially those at Eureka. In recognition of the value of Nolan's contributions to geology, the NAS elected him as a member in 1951. For Nolan's "meritorious achievement in advancing the science of tungsten,"[39] Columbia University awarded him its K.C. Li Medal (in gold) and Prize of $1,000 in 1954.

Director Nolan expected the USGS to accrue nearly $51 million in direct and reimbursable funds during fiscal year 1956–57, or $2.3 million more than estimated

This map (originally at 1 inch = 1,000 feet) shows the geology of the area between Ruby Hill and Adams Hill in the lead-silver mining district of Eureka in east-central Nevada. USGS geologist Thomas Nolan concentrated his economic and related geologic studies of the Basin and Range Province on Eureka and the surrounding area, where USGS geologists Clarence King, Arnold Hague, and Charles Walcott established a standard stratigraphic section in the late 19th century. Nolan, while Assistant Director (1944–56), spent a month each summer extending his work at Eureka, aided by several field assistants. In 1956, Nolan, Charles Merriam, and James Williams summarized 22 years of investigations in reporting a detailed and revised stratigraphic section that included Cambrian, Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, Permian(?), and Lower Cretaceous rocks and fossils. (From Nolan, Merriam, and Williams, 1956, fig. 2.)



for 1955–56. Nolan now emphasized, as he did in previous year's hearings, the Cabinet Committee's recommendation to expand USGS "work in the minerals field." "Programs for the 1957 fiscal year," he continued, "provide for a start"[40] toward achieving that goal. Just a week ago, Nolan explained, the USGS Science Advisory Committee met in Washington "to review some of the things we are doing and propose to do." The advisers emphasized

> **the need for more research designed to develop principles that could be applied in the search for ore and principles that control the movement of water.[41]**

Kirwan asked Nolan to summarize for the record some of the details, presented as a new subactivity in the USGS printed briefing, of how the agency planned to expend the more than $1 million increase in implementing the national minerals policy. Nolan responded by citing two basic approaches, both of which reflected policies begun by Director King in 1879. Using one-half of these new funds, the USGS intended to prepare "geologic maps of rather large areas that are believed to be potentially mineral bearing," characterized by granitic rocks but in mountainous country "inadequately mapped or not mapped at all."[42] The other half of this new money would support "research on methods of ore finding—the business of getting new ideas on what controls the localization of ore."[43] Nuclear weapons and power, the petrochemical industry, the jet engine, automation, and other technological developments, Nolan claimed, continued to change concepts of available mineral resources. Nolan cited the value to industry and the Nation's mineral reserves of the geochemical and geophysical methods recently developed by the USGS and his hope that newer work on oxygen-isotope ratios, which reflected distances from ore bodies, would prove useful guides in prospecting. The additional $607,000 for a new hydrology program, Nolan replied to Kirwan's next query,

would not "solve the water problem," but it would "help attack it" by determining "the principles that control the movement, the occurrence, and the quality of water, both on the surface and underground."[44] Water, Kirwan and Nolan agreed, remained the Nation's "most serious threat" and simultaneously its "best friend."[45] "We hope to find out how we can work with it," Nolan responded, "rather than continually to battle it."[46]

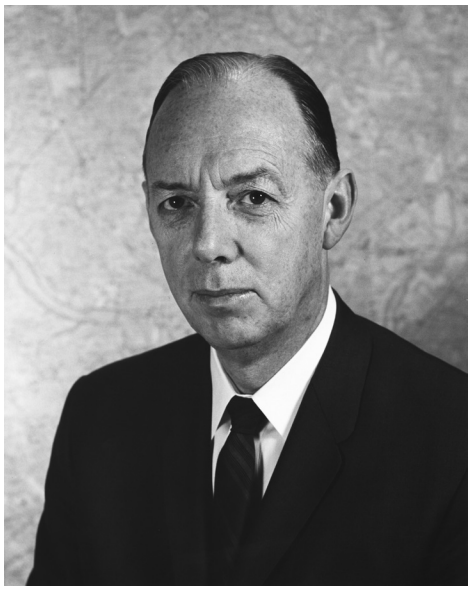
Kirwan then queried Nolan about the status of USGS facilities, especially about progress toward obtaining a new national center in the Capital area. The delay, Nolan replied, reflected uncertainties about the Office of Defense Mobilization's (ODM's) dispersal requirements to preclude major damage in an attack, which conflicted with USGS wishes to remain close enough to continue to deal effectively with the rest of the Federal Government in Washington. Within the last 2 weeks, the USGS and ODM's Lt. General Willard S. Paul agreed on a site they hoped would be approved and still "be within the intent of the directive for a building in the metropolitan area of Washington."[47] The USGS planned to move from Old Interior some seven blocks west to the even older Christian Heurich Brewery in Foggy Bottom. The Heurich Brewery, built in 1894, and subsequently enlarged, occupied the block bounded by 25th and 26th Streets and D and Water Streets, N.W., southeast of the present Kennedy Center, but the brewery had recently ceased operations. The Pick and Hammer Club's show on April 27, "Peter Pun, or The Light That Nearly Failed," burlesqued the lengthening search for a new national center building. "Pun," played by James Balsley, wired to "fly" across the stage, and three of the "Lost Boys" wondered, in "A Lot to be Thankful For," sung to "Floating Crapgame" from Frank Loesser's "Guys and Dolls" of 1950, "Where's the building?" and "Where's the spot?" They trusted Nolan to find a location for "the oldest established permanent floating Bureau in D. C."[48] Nolan, Pun, and the Boys knew that the USGS would neither occupy the brewery nor choose the site for the agency's new building.[49] Nolan reported better progress at Menlo Park, California, where the GSAd approved and the contractor recently broke ground for the USGS' second building, projected to contain 40,000 square feet. Planning continued for a same-sized third building, for topographic-mapping facilities there, at an estimated cost of $415,000. A total of 200,000 to 250,000 square feet, Nolan projected, would be needed to house USGS personnel and equipment at each of the Denver and Menlo Park centers.

Other members of the House subcommittee asked Nolan about continuing work by the USGS in water-resources investigations and topographic mapping. William Norrell asked about water problems in Arkansas' rice lands. Norrell, following Kirwan's guidelines to avoid extended replies, requested, for the record and himself, a statement about USGS cooperative work on that topic. To extend the submitted justifications, the agency described, under the title "Artificial Recharge Experiments in the Grand Prairie Region," its natural-laboratory studies were intended to develop fundamental principles of recharging groundwater reservoirs and apply them in this critical area. When Benton ("Ben") Jensen reiterated his long-standing concern for consolidating Federal mapmaking and favored doing so within Interior, Nolan reported progress both general and specific. The USGS, Nolan noted, was

> **essentially the only agency that prints and distributes the civilian edition of the topographic maps that are produced by Government agencies. No matter who has made any of the maps the average citizen can now get his map by writing to one place.[50]**

Nolan responded to Jensen's query of the previous year about cooperation with the Soil Conservation Service by assuring him that joint meetings already held would lead to continuing liaison to determine SCS needs and "schedule them much more effectively."[51] The requested increase of $200,000 for the mapping program in Alaska, Nolan continued, would fund, as requested by the DoD, revisions of the

Geologist Arthur Alan Baker (1897–1996), an Army veteran, joined the USGS in 1921. He worked briefly in Alaska before shifting to the Fuels Section for areal mapping and studies of economic geology, stratigraphy, and structure in Montana and then on the Colorado Plateau. There, Baker's investigations emphasized areas in southeastern Utah, and his results were used in part for public-land administration. Baker served as Hugh Miser's untitled assistant in supervising war-related fuels programs during 1941–46. Baker became a staff geologist in the Director's Office in 1952 and succeeded Julian Sears as Administrative Geologist in the following year. From 1956 to 1969, Baker served as USGS Associate Director, a new post, where he was responsible for oversight of the Conservation and Geologic Divisions and the Publications Office (later Division). Baker was subsequently Special Assistant to the Director. He retired in 1973. (Photograph from the USGS Denver Library Photographic Collection, Portraits, as port0286 (originally Public Inquiries Office 63–1 [1a]), https://www.sciencebase.gov/catalog/item/51dda264e4b0f72b4471df4d; published in Love and others, 1999.)



Topographic engineer Robert Henry Lyddan (1910–90) transferred from the Interstate Commerce Commission to the USGS in 1933. He mapped in Puerto Rico and in the Eastern United States before serving as Chief of Plans and Coordination (1946–55) in the Topographic Branch (later Division) and managed a fourfold increase in map production. In 1956, after a year as Atlantic Region Engineer, Lyddan became USGS Assistant Director and was responsible for oversight of the Administrative, Topographic, and Water Resources Divisions. He succeeded George Whitmore as Chief Topographic Engineer in 1968 and assumed responsibility for expanding the national mapping program, applying new technologies to mapping, and completing the National Atlas and national topographic coverage at 1:24,000. Lyddan retired in 1977. (Photograph from the USGS Denver Library Photographic Collection, Portraits, in the "Lyddan, Robert H.," folder as Public Inquiries Office 68–7 [1a].)

1:250,000 series and advance progress on the 1:63,360 series, especially the latter's quadrangles east of the 160th meridian.

The Senate appropriations subcommittee on Interior and its agencies heard Secretary McKay on February 27. McKay asked Senator Hayden's subcommittee to restore the $20.6 million the House cut from Interior's request and thus enable the Department to "keep pace with the increased demand on our resources"[52] and continue to respond to recommendations by the President's policy advisers for minerals and water resources. The USGS needed no similar request because the House approved unchanged the agency's request for $31,602,000, nearly $5 million more than the SIR appropriation for fiscal year 1955–56 and divided between salary increases of $1.4 million required by the Federal Employees Salary Increase Act of 1955 and expanded operations by the Geologic, Topographic, and Water Resources Divisions. On March 1, Wormser and Nolan repeated to Hayden's subcommittee McKay's and their recent emphases on the Nation's need for increased support for research on minerals and water resources. Wormser added his own request to provide adequate space and working facilities for the USGS, including those for adding trained personnel and improving the skills of all employees as recommended in January in the President's economic report. Nolan, as in the House hearings, introduced detailed justifications and the Senators asked fewer questions. The Nation's demand for water, Interior projected, would nearly double by 1975, from 250 billion to 450 billion gallons each day if the population doubled in the century's second half as it did in the first. Among conservation measures being considered, Hayden especially wanted to know if USGS tests could demonstrate if removing water-consuming plants, especially salt cedars and other phreatophytes in Arizona, would increase streamflow and produce more grass.

The USGS budget for fiscal year 1956–57 remained intact when Congress passed Interior's request to the President. When Eisenhower signed the measure on June 13, 1956, the SIR appropriation for the USGS was $31,602,000,[53] of which $5,070,000 could be used only for cooperation with States, counties, and municipalities in water-resources investigations. The USGS reported that it received total funds during 1956–57 of about $53,076,500, or $3.8 million more than the past year's sum. Of the new total, SIR funds actually received provided slightly more than $31,180,000, or 59 percent; States, counties, and municipalities paid directly or reimbursed nearly $7,397,000, or 14 percent; and other Federal agencies transferred almost $14.5 million, or 27 percent. For general administration, the USGS received $950,000 in SIR monies and nearly $534,500 in reimbursements from other agencies. The higher wages in the new Federal pay scale introduced in 1957 applied immediately to chemists, exploration geophysicists, physicists, and engineers. The scale temporarily omitted biologists and geologists, creating morale problems for the latter specialists in the USGS.

Nolan, promptly after becoming Director, urged Wormser and McKay to establish an Associate Director's post that McKay approved. On February 28, 1956, Arthur Baker, the former Administrative Geologist, filled the new position, with its day-to-day oversight responsibility for the Conservation and Geologic Divisions and the Publications Office (later Division). Although Nolan read many manuscripts himself, Hugh Miser continued to review all manuscripts for "Director's Approval"; those Miser questioned were passed to Baker for final decisions. As Assistant Director, Nolan selected Robert Lyddan, the Topographic Division's Atlantic Region Engineer since July 1955, who began serving in his new post on May 6, 1956. Lyddan oversaw daily operations by the Administrative, Topographic, and Water Resources Divisions. In 1957, Luna Leopold detailed hydrographer John Horton, the son of Albert Horton, as Lyddan's temporary staff assistant. Nolan followed these appointments by asking Wormser, on March 28, 1957, to approve the designation, as required by Interior's Manual, of persons to act, in succession,

for the Associate and Assistant Directors. Wormser approved on April 3 the two separate sequences of replacement. Two days later, a Survey order designated the positions whose occupants would serve (in succession) as Acting Associate Director: (1) the Director's Office Staff Coordinator (John Reed [Sr.]), (2) the Chief Geologist (Bill Bradley), and (3) the Chief of the Conservation Division (Harold Duncan). For Acting Assistant Director, the sequence would be (1) the Staff Coordinator, (2) the Chief Topographic Engineer (Gerald FitzGerald), and (3) the Chief Hydraulic Engineer (Carl Paulsen).[54]

Less than 6 months after Eisenhower nominated Nolan to lead the USGS, the President chose and the Senate confirmed a new Secretary of the Interior. On June 8, 1956, Frederick A. Seaton, who owned newspapers and television stations in Kansas, Nebraska, and South Dakota, took his oath of office to replace Douglas McKay as Interior Secretary. McKay resigned as Secretary on March 9 (effective April 15) to run for Wayne Morse's seat in the Senate but McKay lost the fall election to the incumbent. Seaton served as secretary to Alfred Landon in the Republican's campaign for the Presidency in 1936, was a Nebraska legislator during 1945–49, represented his State in the Senate in 1951–52, was a legislative assistant to Defense Secretary Wilson during 1953–55, and served as an administrative assistant and then a deputy assistant to Eisenhower in 1955. Seaton, like McKay, worked to meld private and Federal power organizations, but Seaton dealt more effectively with people and proved a better manager and a more moderate politician than McKay. Wormser continued as Assistant Secretary for Mineral Resources and directed the preparation of the Department's long-range minerals program that Seaton passed to Congress on June 4, 1957.

While Seaton settled in at Interior, the General Accounting Office (GAO) completed its review of USGS financial practices during fiscal year 1955–56. Ellsworth H. Morse, Jr., the Director of the GAO's Civil Accounting and Auditing Division, sent to Nolan, on June 27, 1956, the report of the audit conducted, with USGS cooperation, in Washington and at 11 selected field offices. The document, which also drew on the Van Pelt Committee's report, focused "principally on budgeting, accounting, and property management." Morse emphasized how the USGS could improve its allotment accounting structure, whose large number of accounts reflected responsibility "carried to the lowest level of operation," by exercising fund control "at a higher level and thereby afford management with a greater flexibility in the use of funds." Morse said the audit showed

> **a great need for a stronger central office administrative organization with authority equal to its responsibility in all phases of financial administration.[55]**

The GAO's report recommended "a vigorous program of administrative inspection and review of field office financial administration by the Administrative Division and by the internal auditor."[56] Specific suggestions involved (1) preparing and maintaining an accounting manual; (2) ensuring all accounting work was performed under the Administrative Division's jurisdiction; (3) including in budget requests the full disclosure of the costs to the operational funds of supporting work by the Director's Office and the Administrative Division; (4) conducting, with Interior and the GAO, "a comprehensive study to identify and classify direct and overhead costs," as the basis for adopting and maintaining "a well-designed and uniform system of accounting"[57] for headquarters and field offices; (5) strengthening the procedures for handling, reporting, and accounting for map sales; (6) obtaining Interior's approval for free distribution of maps; (7) improving practices and procedures in accounting for field-office property; and (8) enlarging and making permanent the agency's internal-audit unit. The report also repeated the finding, sent to Administrative Assistant Secretary Otis Beasley on December 6, 1955, from the

Frederick Andrew Seaton (1909–74), the 36th Secretary of the Interior (1956–61), was a newspaper publisher and an executive in broadcasting and banking prior to beginning his public service. He was Assistant Secretary of Defense for Legislation (1953–55) before becoming in 1955 an administrative assistant and then a deputy assistant to President Eisenhower. Seaton succeeded Douglas McKay as Secretary of the Interior on June 8, 1956, and served until he resigned on January 20, 1961. On December 6, 1960, in Public Land Order 2214, Seaton reserved about 8.9 million acres in Alaska as the Arctic National Wildlife Range. To preserve the Range's wildlife, wilderness, and recreational values, the Alaska National Interest Lands Conservation Act of December 2, 1980 (94 Stat. L., 2371) doubled its size, renamed it a Refuge, and prohibited oil and gas leasing and development. (Photograph from the Library of Congress, Prints and Photographs Division, 3c25772.)

audit of the Casper field office of the Conservation Division's Oil and Gas Leasing Branch. Billings for royalty charges to lessees were deferred until the Branch completed verifying the lessees' own computations, a practice that the GAO auditors believed compromised reliable and timely lease-account balances.

In the new fiscal year 1956–57, Nolan initiated corrective responses to the deficiencies noted in GAO's audit, aided by the internal-audit capability and other changes derived from the Van Pelt Committee's report. He also addressed recommendations for improving Federal training procedures, as recommended in the President's economic report in January 1956. Nolan established, on June 25, 1957, a USGS Committee on Training[58] composed of one representative from each Division and one person from the Director's Office. Nolan, who designated the Committee's chairman, asked its members to evaluate training needs agencywide and to provide coordination for and investigate the application of systems for the purpose of reporting, evaluating, and recording individual and group accomplishments. The Training Committee reported to the Director through the Executive Committee. Nolan expected the new Committee to address agency needs and methods for improving employee expertise, but the sing-along "Wonderments" that introduced the Pick and Hammer Show in April warned that:

> **Committee rule is with us, and we think you will agree,**
> **That upper level brass now shuns responsibility.**
> **Committees make the programs, policies, promotions too:**
> **There's hardly any function that the Brass now has to do.**
> **We thought they had been chosen for their brains and "derring-do."[59]**

The Geologic Division gathered for its work in fiscal year 1956–57 some $15,012,000, about $517,000 more than during the previous year. Of the new total, $6,776,000 represented the SIR appropriation; nearly $330,000, or almost $93,000 more, came from nonfederal sources; and other Federal agencies transferred almost $7,906,000, a loss of $633,000 but one offset by the gain in SIR monies. The Division continued to depend heavily on external funding (now almost 55 percent of total funds), especially the transfers of about $4,896,000 from the AEC and nearly $1,096,000 from the Army and its Engineers. The AEC's transfer again declined, by about $683,500, but increases in other transfers, especially an additional $197,000 from the ICA, almost made up the difference.

The research program in Bill Bradley's Division for 1956–57 supported the Eisenhower administration's national minerals policy by continuing existing efforts and beginning several new projects. On July 19, 1956, Eisenhower signed Congress' augmentation of the Defense Minerals Production Act of 1953; the new law provided "for the maintenance of production of tungsten, asbestos, fluorspar, and columbium-tantalum"[60] by purchase, before December 31, to add to the strategic and supplemental stockpiles. Congress and the President approved this legislation to provide for maintaining production of those materials in the United States and its territories and possessions. The new law authorized the Interior Department to establish and maintain a program to purchase those strategic commodities. On July 31, another statute made $21 million available until December 31, 1958, to Interior's Office of the Secretary for the necessary expenses in acquiring these strategic minerals.[61] Seaton delegated to Wormser's office the principal responsibility for administering those statutes, and all the available funds for producing and stockpiling tungsten and asbestos were spent by the end of fiscal year 1956–57. The Division expected its investigations of those and other strategic commodities to contribute, as did earlier and similar efforts, to a better understanding of the geologic processes involved in the formation and localization of ores.

To aid this work, the revised Survey order of June 14, 1957, modified the organization of the Mineral Deposits Branch.[62] Nolan and Bradley abolished the

positions of staff assistants for metals and nonmetals, established a staff assistant for mineral resources, and discontinued the Division's DMEA field offices in Beltsville, Maryland, and Madison, Wisconsin. The Branch continued to reorient its AEC program toward long-range studies of the geologic processes that governed the emplacement of uranium and thorium to gain new data on the size, shape, and mineralogy of these deposits. These investigations included the thermodynamic properties of ore- and rock-forming minerals, the physical properties of earth materials, the distribution of minor elements in intrusive rocks, the environment and geochemistry of ore-forming solutions, and the distribution of stable isotopes. Geologists in these projects established laboratories, devised testing procedures, and calibrated instruments, and they also began research on new or modified geophysical methods, on the use of color photography in photogeology, and on hydrogeochemical prospecting. The Division also began a series of geochemical, geophysical, and engineering studies of preshot and postshot conditions in the area affected by operations at the AEC's Nevada Test Site, as the shift to underground nuclear testing began in September 1957. For the Office of Minerals Mobilization (OMM), Division commodity geologists helped to prepare detailed materials surveys and summary reports on seven specific commodities and reviewed a number of others. Related work also continued on barite, beryllium, chromite, graphite, gypsum, magnesium, manganese, niobium-tantalum, platinum, potash, selenium, silica, titanium, and tungsten. Branch geologists also conducted 26 of their field projects, more than one-third of the total, in cooperation with the States.

During fiscal year 1956–57, William Pecora replaced Earl Ingerson as Chief of the Geochemistry and Petrology Branch as its geochemical studies increased in number and scope. By spectrographic analysis, Branch members determined amounts of uranium and thorium to as low as five micrograms in zircon crystals. They also finished a structure-contour map of Washington's Metaline lead-zinc district. Continued analyses of oxygen-16/oxygen-18 ratios, which varied with the distance from terrestrial hydrothermal conduits, distinguished those deposits from marine sedimentary minerals. Studies of oxidized zinc ores in California, Colorado, Nevada, and Utah disclosed large reserves of low-grade ore. Detailed

USGS geologist Gershon ("Robby") Robinson is shown here examining in 1958 some of the sandstones and shales in the Chinle Formation (Triassic), near the junction of the South and Middle Forks of Cimarroncito Creek, in northeastern New Mexico. USGS geologists, as part of regional mineral-fuel investigations, mapped, sampled, and studied the rocks, fossils, and physiography of this region; the historic and scenic area is popular with tourists and includes the Philmont Scout Ranch, where Explorer Scouts' skills were tested. During 1956–59, Robinson, William H. Hays, M.E. McCallum, Charles Read, and Alexander A. Wanek joined their work in a 1:48,000 geologic map of the Philmont country. (Photograph from the USGS Denver Library Photographic Collection as Patterson, E.F., 654; published in Robinson and others, 1964, fig. 7*1A*, and also in Yochelson and Nelson, C.M., 1979, p. 37.)

mapping by Branch members confirmed the occurrence of zoned ore deposits in New Mexico's Grants-Laguna area. Studies of the Hiland-Clarkson Hill region in Natrona County, Wyoming, demonstrated that its uranium deposits were influenced by southward tilting during the Pliocene and Pleistocene. A newly completed report assigned different geologic ages to the copper deposits of central Cochise County in Arizona. In Pinal County, just to the northwest, the San Manuel Mine, as earlier predicted, began producing copper from its estimated reserves, initially located by the USGS, of 500 million tons of low-grade ore, plus much smaller deposits of gold, molybdenum, and silver. The Pick and Hammer Club's show for 1957 highlighted the Branch's growing work in field geochemistry. Cast members claimed that "Geobotany is here to stay" and urged geologists to "Gather, gather flowers where you may,"[63] including posies (growing above lead) and daffodils (rising above molybdenum). They hailed the "GX" Section, led by Thomas Lovering since 1954, as "the darlings of the Survey" and Bradley's "special pet."[64] The Geochemical Exploration Section also developed methods, aided by its mobile wet lab, for tracing the dispersal patterns of a total of 21 different elements, also including copper, selenium, and silver. To the banjo-strumming tune of "The Yellow Rose of Texas," the GXs crowed:

We don't fret about our budget
Or where we get our dough,
For the whole of Bill's Division
Chips in for what we owe.
We are not a Branch but we don't care
For the Section grows and grows.
We'll soon be big as Minerals
Without financial woes.

* * * * *

We practice our geology
In our own peculiar way.
We feel that rock-collecting
Is certainly passé,
And we find that mapping contacts
Is an easy thing to do
So we leave that to Gilluly
And to his motley crew.[65]

In fiscal year 1956–57, members of the Director's Office and the Geologic Division began referring to Gilluly's General Geology Branch as the unit of "General Service Geology." Branch geologists, aided by the work of Division geochemists, geophysicists, and paleontologists, mapped in 10 areas in the conterminous United States and 1 in southeastern Alaska, largely to support the mineral-deposits programs. Specific mapping concentrated on geologically little-known locales in Alaska, Maine, and Washington. A preliminary version of the geologic map of western Oregon was prepared for publication. Detailed mapping in Montana yielded a better understanding of important structures and their relation to ore-bearing areas. General and engineering geologists finished studies of landslides along the Fort Randall Reservoir in South Dakota. At the Hawaiian Volcano Observatory (HVO), Gordon Macdonald ended his tour as Director in 1956 and joined the University of Hawaii but continued part time with the USGS. Jerry Eaton replaced Macdonald. In cooperation with the National Park Service, Andy Anderson, Gilluly, and Eaton guided the completion of plans for and construction at the HVO of a geochemical laboratory to facilitate systematic studies of the volcanic gases and other products as part of research on chemical volcanology in the national minerals program. William Rubey joined Philip Abelson, Harry Hess, King Hubbert, and six other colleagues as members of the NSF's Special Advisory

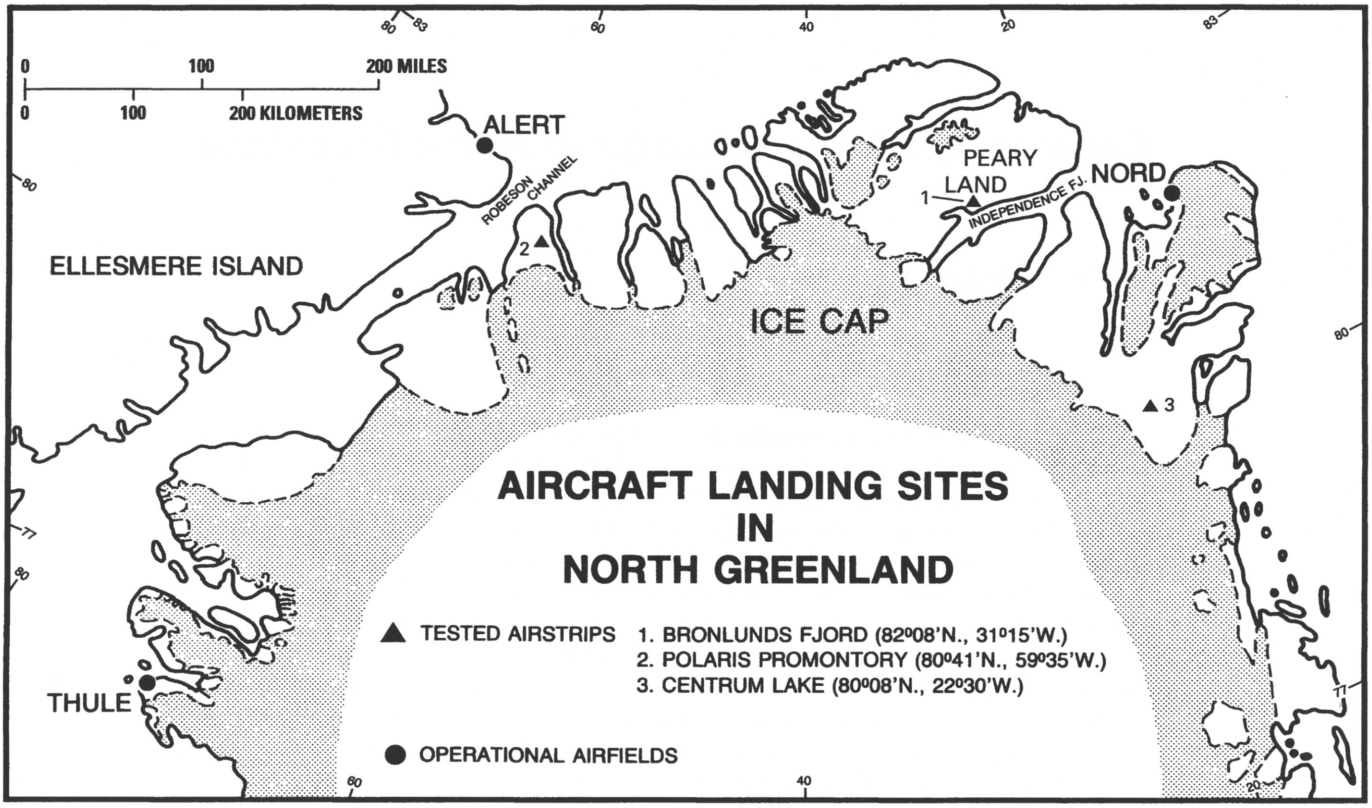
Panel[66] formed, as required by statute, to investigate "the need for a geophysical institute in the Territory of Hawaii."[67] In the Eastern United States, scientists produced a geologic cross section through the potential mineral-producing areas of the southern Appalachians and continued evaluating sea-cliff erosion along the New England coast. Compilers of the bedrock and surficial maps of Connecticut, Massachusetts, and Rhode Island emphasized engineering geology. Large-scale mapping continued in Puerto Rico; maps of six of the quadrangles neared completion, and three others reached 50 percent.

Gilluly's Branch remained responsible for studies of helium, especially those to aid exploration for new sources. The last significant new domestic source of helium dated from 1943. Between 1943–44 and 1956–57, the production of helium almost doubled to nearly 243 million cubic feet per year. In fiscal year 1956–57, Federal agencies accounted for 73.5 percent of that consumption. Domestic reserves, earlier deemed adequate for a century, were reduced to a 10-year supply. Helium's heightened use as a coolant led to the establishment of a Federal interagency group chaired by O. Hatfield Chilson of Colorado (who succeeded Clarence A. Davis as Interior's Under Secretary) and tasked with providing recommendations for the conservation of this gas. The USBM operated four helium plants. On June 2, 1957, the USBM's plant at Exell, some 30 miles north of Amarillo in Texas, began producing helium from new units constructed under contract during September–December 1956. Full production at the Exell plant would raise annual output at the facility from 150 million to 240 million cubic feet of helium. The USBM also increased its number of railway tankers and aided studies by the National Bureau of Standards (NBS) and the Navy of the cost and methods of producing and shipping liquid helium.

During fiscal year 1956–57, the Geophysics Branch again deployed two aircraft for its magnetic and radioactivity surveys, including magnetic surveys flown (in cooperation with the States) over eastern Pennsylvania, northern Wisconsin, and parts of Maine and New Hampshire. The results of aeromagnetic and radioactivity surveys of the Texas Coastal Plain were checked against those derived from field mapping. Branch members continued ground surveys of gravity in eastern California's Death, Long, Owens, and Panamint Valleys and its Mojave Desert; in western Colorado and eastern Utah; and in Minnesota's Cuyama and Mesabi iron districts. James Balsley, who continued his researches while Branch Chief, remained interested in determining the origin of the long, linear negative magnetic anomalies he identified in his aerial surveys of Precambrian to Triassic rocks. In August 1954, Balsley and Arthur Buddington participated in the NSF-sponsored symposium "Anomalous Magnetization of Rocks" held at UCLA's Institute of Geophysics.[68] Gustaf O.S. Arrhenius, Walter M. Elasser, John W. Graham, David Griggs, Lawrence W. Morley, Nagata Takesi, Linus Pauling, S. Keith Runcorn, Louis Slichter, John Verhoogen, and 13 other colleagues attended the symposium. They questioned the significance of the repeated observations in rocks of reverse-remnant polarity that differed from the present orientation of the Earth's magnetic field. Could the field's history be preserved in the geologic sequence of rocks with magnetic minerals? Did these magnetic minerals self-reverse or did the whole field reverse itself? Balsley and Buddington thought that their analyses of Precambrian igneous and metamorphic rocks from New York's Adirondacks favored self-reversal for their magnetite-ilmenite group, as distinct from their normal-oriented hematite-ilmenite group, and published their ideas in 1954.[69] They continued their investigations and summarized the results in a paper[70] presented at the annual session of the Indian Science Congress in Calcutta in January 1957. Balsley sought ways and means to test field reversals versus self-reversals to explain the variations in the studied rocks. Berkeley's Verhoogen began part-time work with the Branch to try to understand how these rocks acquired their remnant magnetism; the NSF supported his research on oxides with a grant of $12,500 during 1955–57.

During fiscal year 1956–57, Fuels Branch geologists conducted surface and subsurface mapping and stratigraphic studies in 22 States that were producing petroleum or that had significant potential for future production; the work included cooperative efforts with 3 of the States. Eugene C. Reed and Richard F. Svoboda (both of the Nebraska Geological Survey) and George E. Prichard and Jeannette Fox (USGS) completed for publication in 1958 a 1:500,000 map of Nebraska that showed test wells for oil and gas, anticlines and basins, oil and gas fields, pipelines, and the areal distribution of pre-Pennsylvanian rocks.[71] Several of their colleagues began subsurface investigations in the eastern part of the State. Research on samples from a deep test well in southwestern Mississippi indicated the presence of a structural uplift of considerable size that extended offshore oil possibilities eastward from Louisiana. Branch geologists also carried on investigations in 11 coal-producing States. Continuing appraisals of reserves in Alabama, Arkansas, Colorado, eastern Kentucky, and western Pennsylvania, they also nearly finished revising the coal map of the United States. The Branch also issued in 1956 the revised map, on two sheets at 1:2,5000,000, of U.S. oil and gas fields, compiled in 1955 by Ann C. Coe, Louis C. Conant, and Sophie Drakoulis.

Members of the Alaskan Geology Branch, making initial tests of hydrochemical and other geochemical prospecting methods, continued or completed mapping and studies of the usual wide range of deposits during fiscal year 1956–57. Geologists investigated the Stampede Mine's antimony, ilmenite in beach sands near Lituya Bay and in layered mafic intrusive rocks near Fairweather Bay, gold and tin placers in the Tofty-Eureka area and around Nome, high-grade limestone on the Alexander Archipelago's Heceta and Tuxekan Islands, nickel in the Funter Bay area, the Lost River Mine's tin, and other minerals around Glacier Bay. They prepared photogeologic maps of the Dixon Entrance, Iditarod, and Talkeetna Mts. 1:250,000 quadrangles and of areas near Juneau, Prince William Sound, and Sitka. Alaska's third oil-exploration boom, which began in 1955, continued unabated. Don Miller (south), Thomas Payne (central), and George Gryc (north) completed fieldwork for their description, presented in preliminary form at an American Association of Petroleum Geologists (AAPG) symposium in 1951, of possible petroleum provinces in the Territory. They published their summary in 1959 with 1:2,500,000 maps of the provinces and Mesozoic–Cenozoic tectonic elements (which superseded Payne's 1955 map) and maps and stratigraphic sections of the Cook Inlet and Gulf of Alaska provinces. Before USGS geologist George Plafker shifted to the oil industry in 1956, he and Miller issued reconnaissance reports on the Tertiary geology of all of the Gulf of Alaska province's Malaspina district and part of its Yakataga district; they were aided by age and paleoecologic determinations by Stearns MacNeil. Their colleagues continued stratigraphic-structure studies of the Nelchina area and completed similar investigations of Cretaceous rocks in the south-central part of Koyukuk Basin, much of which was already leased for oil and gas exploration. During fieldwork, geologists identified more coal resources in the Matanuska and Nenana fields, and the summary report on Alaska's coal regions neared completion. Engineering geology reports issued during the year described conditions in parts of the Fairbanks, Katalla, Nenana-Rex, and Susitna-Maclaren areas. The Alaska Road Commission passed, on September 12, 1956, from Interior to the Commerce Department, where it was reorganized as Region 10 of the Bureau of Public Roads. The Commission, aided by the USGS and other agencies, constructed more than 3,500 miles of roads in the Territory. On March 9, 1957, a magnitude 8.6 earthquake, with a focal depth of less than 20 miles, occurred south of the Andreanof Islands. The quake shook the Aleutians and killed livestock and damaged docks and houses on Adak, Attu, and Unimak. The waves from the resultant Pacific-wide tsunami caused some $5 million in damages on Hawaii, Kauai, and Oahu, but the early warning system established after the magnitude 8.1 event in 1946 prevented loss of life.



This map (originally at about 1 inch = 107 miles) shows locations of three austere landing fields (triangles) for U.S. Air Force (USAF) aircraft encountering emergencies while flying between airbases at Thule and Nord in northern Greenland and at Alert on Canada's Ellesmere Island. USGS geologists William Davies, Donald Klick, Daniel Krinsley, and George Stoertz plus Stanley Needleman (USAF Cambridge Research Laboratories), Lt. Colonel R.H. Wilson (USAF), and their colleagues combined data from aerial and ground photographs with information from published reports and maps in choosing these sites. During 1956–60, they field tested surface conditions, soil strengths, and depths to permafrost at the three sites to confirm their suitability as natural airstrips. At Jørgen Brønlund Fjord (triangle 1 and spelled differently in the map explanation), they sampled and mapped the surface clays and soils along the proposed airstrip in mid-August 1957 and in early July 1960. The frost-free interval at this site began in mid-June and ended in late August. Their test pit, analyzed with a cone penetrometer, reached permafrost at a depth of 24 inches in August 1957. (From Krinsley, 1998, fig. 1.)

The Military Geology Branch's studies in North America during fiscal year 1956–57 for the Army and its Engineers[72] concentrated on Alaska's airstrips, as part of the Austere Landing-Sites Project,[73] and on geology, permafrost, roads, and terrain, as part of Military Programs Arctic that began in 1950. Their efforts also aided the building, directed by Vice Admiral Richard Cruzen, of the third, and most northerly, line of Distant Early Warning (DEW) radar stations that began operations along its 3,000-mile length between Alaska and Baffin Island on July 31, 1957. The DEW line was extended to the Aleutians by 1959, when construction began at Clear, Alaska, on the first of three Ballistic Missile Early Warning Sites. MGB members began reconnaissance studies in the Copper River Basin, along the Johnson River, and in the Thompson Pass area. Donald Nichols, G. Williams Holmes, Troy Péwé, and their colleagues conducted engineering and geothermal studies around Glenallen and at Fort Greely south of Big Delta, completed mapping the geology of the Mt. Hayes D–3 quadrangle, started compiling a map of Alaska's surficial deposits, and advanced work toward a glacial map of the Territory. George E. Stoertz and Stanley M. Needleman reported their 1:50,000 mapping and investigations of ice-free sites in northern and eastern Greenland; their studies for the Air Force's Cambridge Research Laboratories were done in conjunction with test landings of a C–124 Globemaster transport at Jørgen Brønlund Fjord in Operation Groundhog. MGB Special Reports included terrain studies, at 1:250,000, of the 4th Army's area in the Southwestern States.

Members of the Military Geology Branch also completed studies outside North America. George Rozanski, who continued to prepare sheets for the hydrologic map of Asia, completed in 1965, finished a 1:500,000 geomorphic map of Guatemala. The MGB's Special Reports included an evaluation of the geology and engineering strategic structures in Western Europe by Arnold Mason, Perry F. Narten, and Mario Conti; a terrain and materials assessment of northern Greece, adjacent Turkey in Europe, and the northwestern portion of Asiatic Turkey; an investigation of water supplies along Middle East pipelines; a map of the water

The pilot of the U.S. Air Force C–124 Globemaster transport shown in this photograph visited the natural landing field at Jørgen Brønlund Fjord in northern Greenland several days before landing his aircraft there, parking at the airstrip's campsite, and being photographed. Emergency overruns of 500 feet (northwest end) and 700 feet (southeast end) on softer soils extended the harder inorganic-clay-soil airstrip, where flags marked its 5,000-foot length and 200-foot width. The airstrip occupied part of a "flat, dry lake plain or marine embayment" that was 0.5 mile wide, 3 miles long, nearly 10 feet above sea level, and less than 0.5 mile from the fjord. During an hour at the campsite, the 72.5-ton aircraft "produced a rut that was about 0.5 in[ch] * * * deep." (Photograph by George Stoertz, August 16, 1957, from Krinsley, 1998, fig. 6; quotations from Krinsley, 1998, p. 191 and caption of fig. 6.)

resources of Iran and Iraq, at 1:1,750,000; and terrain studies of Aden and adjacent Yemen and of Kashmir. Miscellaneous Papers issued by the Branch in 1956 included Henry Coulter's debriefing on Afghanistan and "Ric" Terman's classification of airfields.[74] Members of the Pacific Geology Mapping Program finished their last fieldwork during fiscal year 1956–57 in the Ryukyus and on Truk's soils and Yap's water resources in the Carolines. The MGB issued Arnold Mason's 1:50,000 summary of the bauxite deposits on Babelthuap in the Palaus. The Pacific mappers advised the Chief Engineer of the Army's Far East Forces, whose headquarters shifted from Tokyo to Hawaii on July 1, 1957, about the discovery and evaluation of water resources for military use in Okinawa, South Korea, and Taiwan. They also aided Navy personnel with engineering problems in the Marshall Islands.

To honor Frank Whitmore's 10th year as Chief of the Military Geology Branch, players in the Pick and Hammer Club Show in April 1957 reworded Gene de Paul and Johnny Mercer's "Jubilation T. Cornpone," from Broadway's "Li'l Abner" of 1956. In "Attack on the Right Frank," they touted Whitmore, who "concocted crises when the battle was won," proved Survey projects for the Army "quite in arrears" but "alleviated their fears," and sold the Army "on the woes of permafrost" and the need for "a map of Fort Knox" when its "interest waned and all support might be lost." He "gets us lots of dough" and "can always get more," the players acclaimed, but they closed with

Though the other Branch Chiefs here can keep us all in a buzz,
Who became so classified that no one knows what he does?[75]

During fiscal year 1956–57, members of the Foreign Geology Branch joined in fieldwork, provided technical advice and assistance to, and (or) trained at home and abroad geologists and mineral-resource specialists in or from 21 countries: Afghanistan, Bolivia, Brazil, Chile, the Republic of China, Costa Rica, Cuba, Ecuador, Egypt, India, Indonesia, Iran, Israel, Libya, Mexico, Pakistan, Peru, the Philippines, Spain, Thailand, and Turkey. In Chile, George Ericksen and Raymond Parker continued their mineral-resource studies and also aided U.S. efforts in planning for a geology department in the national university. The USGS remained almost totally excluded from Saudi Arabia, where King Saud favored Gamal Nasser's approach to the West rather than Crown Prince Faisal's. Sheikh Abdullah Tariki (historian Daniel Yergin's "Red Sheikh") was a geochemist trained at the University of Texas and by Texaco; he led the new Saudi Directorate of Oil and Mining Affairs (later the Ministry of Petroleum and Mineral Resources) established in 1955. Glen Brown kept USGS-Saudi relations active by joining the international experts who advised Tariki at his request. USGS engineering and mineral-deposits geologists spent 4 months aiding the Geological Survey of India. The USGS and the Geological Survey of Pakistan intended their cooperative program, begun under an agreement signed in October 1955 between the ICA and Pakistan's Government, primarily to advance the geologic mapping and resource appraisal of the country. The 30-person program, led by John Reinemund as Chief of Party during 1955–63, included joint geological reconnaissance studies of unmapped areas, detailed mapping and appraisal of mineral districts, and developing facilities and staff to improve the Geological Survey of Pakistan. Reinemund's field parties, including James A. Calkins, William Hemphill, Charles R. Meissner, Jr., Terry W. Offield, and Robert George Schmidt, mostly mapped coals and trained geologists. The joint effort centered on the Hindu Kush Range on Pakistan's northern border with Afghanistan, the North West Province's border mountains, and Pakistan's westernmost panhandle, with the ultimate aim of compiling a geologic map of Pakistan.

During September 4–11, 1956, Assistant Secretary Wormser and a delegation of USGS scientists participated in the 20th International Geological Congress at Mexico City; Jenaro González-Reyna served as one of the two Secretaries General.

At the 20th IGC, William Johnston, Jr., Chief of the Foreign Geology Branch, officially represented Director Nolan, who could not be present. Other USGS attendees, a mix of full- and part-time employees with varying lengths of service, included Alan Bateman, Arthur Buddington, Helen Cannon, George Cohee, Thomas Dutro, Mackenzie Gordon, David Hopkins, Earl Ingerson, Thomas Lovering, Arnold Mason, Eugene M. Shoemaker, George C. Taylor, Jr., Joshua Tracey, and some 20 others.[76]

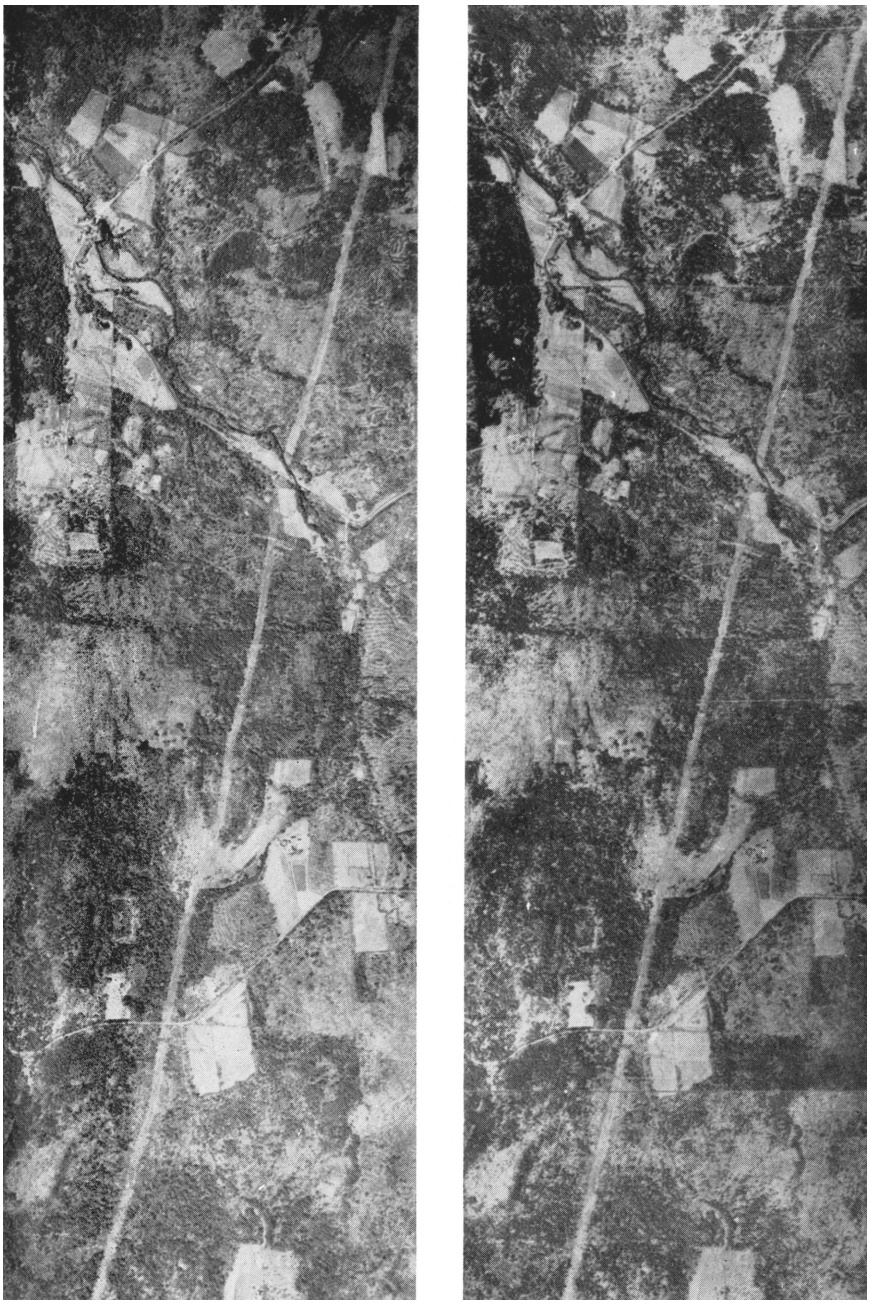
In the austral summer of 1956–57, the Navy's Operation Deep Freeze II continued to support U.S. preparations for the IGY, but without Admiral Byrd's direct participation. Byrd, who had intended to supervise the operation on site, stayed in Washington to assist Congress and Eisenhower in their efforts to establish a permanent organization for Antarctic service. Twelve Navy and Coast Guard ships, including icebreakers *Atka*, *Glacier*, *Northwind*, and *Staten Island*, formed part of Rear Admiral Dufek's TF 43, which returned to Antarctica seismologist Daniel Linehan, and journalist Walter Sullivan. During Deep Freeze II, glaciologist Albert G. Crary directed Little America V at Kainan Bay.[77] Other Americans served at bases named for Byrd, on Rockefeller Plateau; Wilkes, on the Windmill Islands, from which traverse parties explored more than 1 million square miles; and Ellsworth, on the Filchner Ice Shelf. Captain Finn Ronne, who led at Ellsworth, continued to air-drop claim markers as late as March 12, 1957. On October 31, 1956, Rear Admiral Dufek and six other officers and enlisted men landed in their R4D aircraft at the South Pole. Navy aircraft, based in New Zealand, carried building materials from Little America V to the Pole, where Paul Siple oversaw construction by Seabees of the new Amundsen-Scott Station and its dedication on January 11, 1957; Byrd died in Boston 2 months later. Three geologists were among the more than 200 persons who wintered over in 1956–57 at the U.S. IGY stations. From Ellsworth, John C. Behrendt, of the Arctic Institute of North America, examined the Filchner and Ronne Ice Shelves and geologized in the adjacent mountains. Johns Hopkins' Walter W. Boyd, Jr., studied glaciology from Little America V. USGS scientist Edward W. Remington investigated glaciology from Amundsen-Scott. Cartographer James D. O'Neal, on detail from the USGS and from Byrd's staff, accompanied a Chilean expedition that worked on the South Shetlands and on the northwestern part of the Antarctic Peninsula;[78] O'Neal transferred to the Army Engineers after his return from Antarctica. Before leaving Antarctic waters on March 29, Dufek's *Glacier* completed the survey of coastal sites begun by *Atka*. At the CSAGI's meeting in Paris in June 1957, the U.S. delegation suggested that scientific work in Antarctica be continued after the formal end of the IGY in 1958.

The Topographic Division drew on a total of about $17,068,000 during fiscal year 1956–57, some $1,075,000 more than in the previous year. SIR funds provided nearly $12,873,000, an increase of $1,064,000. Direct payments and reimbursements from States, counties, and municipalities added $1,554,000, an increase of $283,000. Other Federal agencies transferred more than $2,457,000, a reduction of $325,000, including about $1,071,000 from the USBR, some $658,000 from the U.S. Air Force (USAF), and about $540,000 from the Army and its Engineers. Nolan, Gerald FitzGerald, and George Whitmore began major changes in the Topographic Division by modifying FitzGerald's headquarters office. Under the new plan, John Davidson's Branch of Special Maps reported directly to FitzGerald, who established the two new posts of Assistant Chief Topographic Engineers (ACTEs) to manage two new Branches. Earle Fennell, the ACTE for Program Development, supervised three Program Sections—Planning, where Harold Williams succeeded George Druhot; Coordination, led by Channing Van Camp; and Control, managed by Franklin M. Mann—and Jerome Kilmartin's Map Information Office. Roland H. Moore, the ACTE for Research and Technical Standards, oversaw four Sections—Geodesy and Control Surveys, whose chief was being selected; Photogrammetry,

led by Russell Bean; Cartography and Map Editing, directed by Charles Fuechsel; and Instrument Design, under James Buckmaster. Regional Engineers continued to direct operations in their four geographic areas: Atlantic, at Arlington; Central, at Rolla; Rocky Mountain, at Denver; and Pacific, at Menlo Park, where the Division opened a new cartographic office for map-finishing operations. George Druhot shifted there to serve as Special Assistant to Robert O. Davis, new Western Region Engineer, who transferred from Denver after Conrad Ecklund retired; James M. Lawson succeeded Davis.

The Map Information Office in FitzGerald's Division continued to be the central depository for national-atlas maps, now including the 17 maps of climate, farming, population, and topography published by four Federal agencies. The Division, responding to recommendations by the President's policy committees for minerals and for water resources, accelerated its mapping of many quadrangles and selected others for new work to provide the needed base maps for investigations by the USGS and supporting organizations. The Division's defense-mapping program, begun in 1951 and already absorbing a large amount of the unit's mapping capacity, expanded again during fiscal year 1956–57 as the Division received additional priority requests. The new and enlarged cooperative programs yielded substantial increases in the number of projects intended to help meet civilian mapping needs, including those of civil defense. The Division issued new topographic maps, at 1:500,000, of Arizona and Oregon, forwarded for printing those of Colorado and Virginia, and worked on or planned similar maps for seven other States. Division topographers completed mapping Kentucky at 1:24,000 in 1956 at a total cost of $6,360,000, or about 28 cents per acre. The Division, in cooperation with the Kentucky Geological Survey, undertook a revision program in 1958, a year before the last of Kentucky's 707 quadrangle maps was published. In Connecticut, Massachusetts, and Rhode Island, revised maps would appear at 1:24,000, rather than the current 1:31,680 scale, so that all quadrangles in the three States would be converted to coverage at 1:24,000 by the end of fiscal 1958–59. Division topographers prepared for reproduction urban-area maps for 19 cities and advanced work on 16 others. They also continued compiling special-use charts of foreign areas for the Air Force's Aeronautical Chart Information Center. The Division circulated widely during the year its films on topographic-mapping procedures to help train U.S. personnel in military surveying and mapping units, foreign trainees under military and technical assistance programs of the Defense and State Departments, and persons in academia for instruction in engineering, forestry, and geology. These films also were shown at the meetings of professional surveying and mapping organizations throughout the United States. Members of the Division added to the expertise of 4 visiting foreign nationals and provided tours of facilities for 35 others. Some of them also participated in the meetings, held in Stockholm during 1956, of the 8th International Congress of Photogrammetry (July) and the Esselte Conference on Applied Cartography (August).

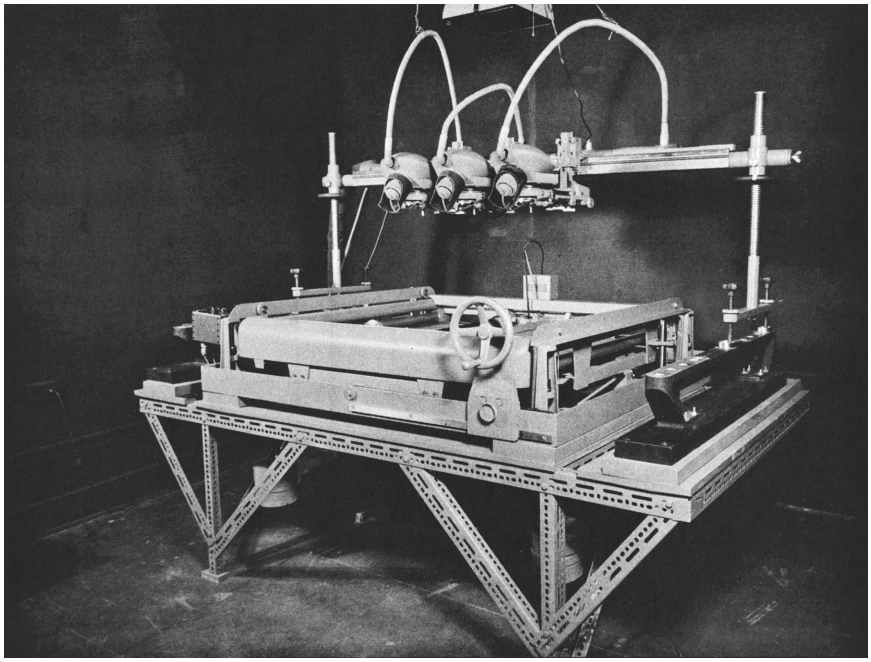
Better control methods within the Topographic Division led to increased map coverage. In the continental United States, Division employees established nearly 1,300 permanently marked triangulation stations to provide control for areas totaling more than 50,000 square miles. In Alaska, Division engineers completed all field control for the entire 125,000 square miles of the Brooks Range. That work required 30,000 square miles of triangulation and trigonometric leveling by 25 field parties, supported by 6 helicopters and additional fixed-wing aircraft. Despite the difficult terrain, these parties completed their work at a cost comparable to costs for similar efforts in the States. Newer and higher powered helicopters enabled USGS topographers to work in more remote and higher locales; they landed safely on 17 peaks taller than 12,000 feet, including Mounts Rainier and Whitney. The higher operational ceiling for the Bell 47G–2 enabled topographers Charles R. Lloyd, Jack Lyon, and Tovio J. Nelson, aided by a USGS photographer and a



This comparison of a perspective aerial photograph (at left) with an equivalent of an orthophotograph (rectified photograph, at right) demonstrates that relief (elevation) displacement, including the crookedness of the powerline (from upper right to lower left in the photograph), tilt displacement, and lens distortion in the perspective image were eliminated during the preparation and printing of the uniform-scale orthophotograph "with nominal accepted tolerances." (Photograph and quotation from Landen, 1959, fig. 25 and p. 252; also published in Bean and Thompson, 1957, fig. 11, and in Whitmore, G.D., Thompson, and Speert, 1959, fig. 7. For details about the principles of orthophotography and the development of the Orthophotoscope, see Bean, 1955.)

National Park Service (NPS) ranger, to determine more accurately Mount Rainier's height as part of topographic mapping in the surrounding area. By triangulation from three stations north of the mountain, they fixed Rainier's elevation at 14,410 feet, or 2 feet taller than the last USGS measurement in 1913.

Topographic Division members also continued their research and development intended, as before, to produce more economical and efficient methods of map production.[79] They hoped that a newly purchased microwave-radio device for accurately measuring distance (from hundreds of feet to 30 miles) would reduce materially the cost of horizontal-control surveys and also significantly increase accuracy. Division engineers built a barostat to provide an absolute standard for calibrating altimeters. They used a new electronic computer to program some office computation and installed an improved electrical-survey-net adjuster in each of its four regional centers. They also continued developing new photogrammetric



In the 1950s, Russell Bean's team developed the Orthophotoscope from an experimental "breadboard" version to an engineered prototype (shown here in 1956) deployed in the Topographic Division's Special Maps Branch. The Orthophotoscope, with ER–55 stereoprojectors and a photoscanner, produced distortion-free rectified photographic images that met the horizontal accuracy required by the national map accuracy standards. The new images, the equivalents of orthophotographs, were used to produce maps in less time, at lower cost, and with greater accuracy than previous methods. These maps would complete the long-promised national topographic coverage at a single standard scale and also serve as new bases for the compilation of geologic and other data and interpretations. The next (third) model in the development series was patented as the T–61 Orthophotoscope. Bean received a patent in 1959. Older stereoplotters continued to be used for high- or low-relief areas. (From Thompson, 1958, fig. 20. Also published in Bean and Thompson, 1957, fig. 6, and in Landen, 1959, fig. 24. For the experimental version of the Orthophotoscope, see Bean and Thompson, 1957, fig. 3, and Southard, 1984, fig. 12.)

instruments and techniques.[80] A commercial firm, using USGS specifications, produced a transforming printer to make equivalent prints from 20-degree, low-oblique photographs. The Division procured an automatic electronic dodging device and installed it on a projection-type diapositive printer, while developing a system for precisely controlling the geometric characteristics of diapositives to achieve greater accuracy. Division engineers completely redesigned the prototype Orthophotoscope.[81] In cooperation with the Interdivision Committee on Photogrammetric Techniques for Geology, the Topographic Division provided training courses in the fundamentals and applications of photogrammetry for geologists and engineers in other USGS Divisions. By now, the scribing technique was firmly established in stereocompilation, field surveying, and color separation.[82] The Division installed a map-evaluation program to determine the most economical and efficient methods of map production and to ensure that the maps complied with national map accuracy standards.

The Water Resources Division received almost $17,931,000 for fiscal year 1956–57, a gain of $1,877,000 over the previous year's total. The Division's SIR appropriation rose to $8,511,000, an increase of $856,000. Of the SIR funds, $5,070,000 was available only for cooperation with States, counties, and municipalities. These governments supplied a total of $5,133,000, a $519,000 gain, in reimbursements and direct payments. California, Texas, New York, Florida, and New Mexico, in that order, were the five largest contributors. Other Federal agencies transferred almost $4,092,000, which represented nearly $480,000 more than in 1955–56. The Army and its Engineers supplied $248,000 more than in the previous year, for a total of about $1,350,000, and the USBR's funds rose by almost $117,000 to $1,112,000. The largest proportional increase in funds, from about $182,000 to nearly $338,000, came from the U.S. Department of Agriculture (USDA). The Division now depended on outside sources for 53 percent of its overall funding.

During fiscal year 1956–57, the Division continued its second major reorganization since the end of World War II. Nolan and Paulsen designed the rearrangements to improve program planning, better integrate intradivisional operations, and facilitate general-hydrology investigations under a new Chief. On April 18, 1957, Nolan advised the Division Chiefs that Paulsen would retire when he reached age

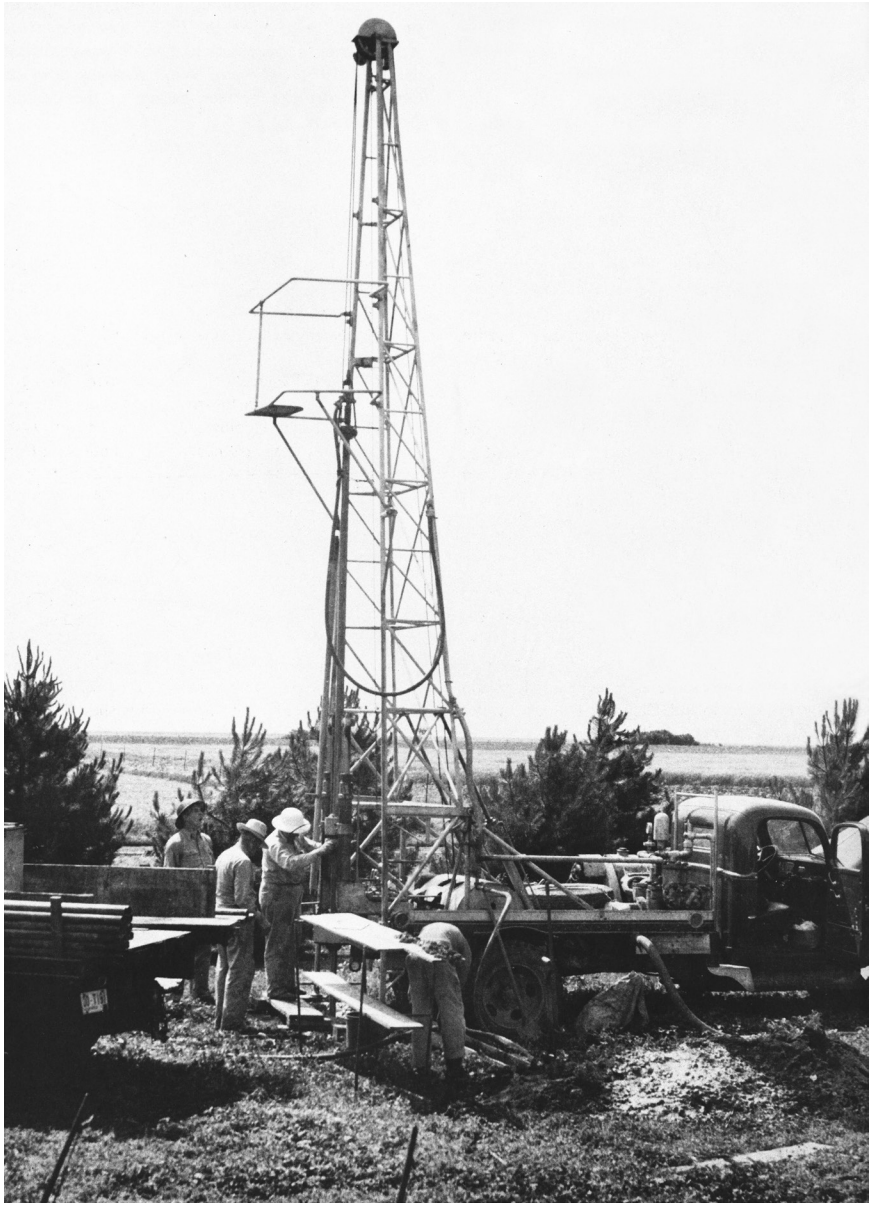
70 on the 22d. On April 30, Paulsen ended nearly 44 years of service with the Division, but he continued as Delaware River Master and as adviser to several international water commissions. Luna Leopold succeeded Paulsen as Chief Hydraulic Engineer, with the additional title of Chief of the Division (later Chief Hydrologist). Leopold chose Nace, also strongly research oriented, as his Associate Chief. As Assistant Chief, Leopold selected groundwater specialist Albert G. Fiedler, a 30-year employee who earlier worked for Paulsen and Meinzer. As USGS geohydrologist William B. Bull later recalled, Leopold quickly began asking fundamental questions about the amount and nature of basic research in the Division.[83] Leopold emphasized careful quantitative and qualitative field investigations, supported more active participation in the international scientific community, started process-oriented studies in geomorphology, increased cooperation with the Geologic Division and, like the agency's best managers since 1879, set high standards for hiring and operations.

Leopold's Division aimed some of its research during fiscal year 1956–57 toward explaining the principles governing the movement of water and entrained sediment through river channels to gain a better understanding of the long-term effects of reservoir impoundments, channel modifications, and climatic variations on channel erosion and sedimentation. To aid these studies, members of the Topographic Division completed and tested a photogrammetric system to replace hand measurement of water-flow effects for compiling contoured "maps" of sand configurations in the Water Resources Division's hydraulic test flumes. Water shortages in the West continued to highlight the need for additional research on the effects of runoff after the proposed removal of upland vegetation and of methods for suppressing evaporation from lakes and reservoirs. Division specialists studied records of storage in reservoirs to determine the amounts of water available for present development and to devise methods for defining optimum yield from reservoir regulation. They began analyses of the relative influence of climate and vegetation on measured sediment yields. Division scientists also studied advances or recessions of glaciers in relation to long-term fluctuations in water supplies. Continued increases in flood damage intensified the need for accurate methods of estimating potential floods in areas where streams remained ungaged and for developing hydrologic principles applicable in zoning urban lands subject to floods. On August 7, 1956, a new law provided "insurance against flood damage."[84] The Division demonstrated how its hydrologic data and analyses could aid appraisals of the flood potential and risks inherent in building on flood plains. Progress in the Division's theoretical and field studies of the mechanics of groundwater recharge advanced the understanding of the artificial recharge of depleted groundwater reservoirs. Robert W. Stallman developed numerical methods for analyzing regional water-level networks to define aquifer parameters and recharge-discharge characteristics.[85] Division engineers tested ultrasonic instruments to obtain initial continuous measurements of water velocities in locations unrecorded by present methods. Division members began a comprehensive study of the hydrology and evaluation of the water resources of the Delaware River Basin that they hoped would be completed during fiscal 1958–59. In eastern Pennsylvania, Division and other USGS scientists again served as consultants in a program designed to conserve anthracite-coal resources through mine drainage. Division personnel also continued to prepare comprehensive reports on the water resources of industrial areas and the requirements of specific industries.

The Surface Water Branch completed its review of the nationwide streamgaging network during fiscal year 1956–57, classifying all streamgaging stations as being either (1) hydrologic network or (2) water management. The Branch's hydrologic network provided basic data for hydrologic studies, and its water-management stations produced information where needed for specific purposes. Branch personnel obtained surface-water records at 6,900 sites, 100 more than in 1955–56, in the

conterminous United States, Alaska, Hawaii, and Guam. The Branch's compilation of all streamflow records for 1888–1950 reached 77 percent, and the unit published the volume for the Snake River Basin; the basin summary included records that were previously scattered through some 50 annual volumes in the series of Water-Supply Papers. Branch hydrographers, using funds transferred from the Soil Conservation Service, made rainfall-runoff analyses of maximum annual floods for more than 820 gaging stations in the United States, including all those that recorded runoff from drainage areas of less than 400 square miles. They completed flood-frequency analyses for Florida, North Dakota, and South Dakota and advanced similar regional analyses for the Colorado River Basin as part of the nationwide effort. The Branch also continued investigations of the quantity, movement, and sources of waterborne sediments and their effects on reservoir storage, navigable waterways, diversion works, irrigation canals, and water-supply systems.

Investigations in 44 States, Hawaii, and Guam by the Ground Water Branch during fiscal year 1956–57 ranged from research on the principles of the occurrence and movement of water in varied geologic and hydrologic environments,



In the 1950s, USGS geohydrologists studying groundwater obtained data and samples from this test hole and others drilled by rotary rigs owned by small companies under contract to the agency. These wells did not compete, as Layne-Western and smaller industrial firms complained to Congress, with commercial wells drilled to supply agricultural, industrial, rural, and urban users. Although the USGS convinced Congress that the agency's wells were drilled only to enable scientific observations, the legislators required that such specialized surveys be done only when administrators determined them to be in the public interest. (Photograph from Ferguson and others, 1990, p. 256.)

through studies of areas, to systematic continuing inventories of draft and observation of water-level fluctuations. Branch members concentrated on areal investigations and reports on the geology and groundwater resources of geographic or hydrologic units, commonly of counties or groundwater basins, to contribute to the nationwide coverage. They focused on the use and expansion of natural underground-storage facilities, which could be made to complement surface reservoirs in water management. Studies of artificial recharge near Amarillo, Texas, showed that at least 10,000 acre-feet of water could be stored in the Ogallala Formation (Miocene–Pliocene) beneath a square mile of land that contained the municipal McDonald well field. Investigations in California's San Joaquin Valley indicated that a groundwater storage capacity of some 90 million acre-feet existed in the interval between 10 and 200 feet below the land surface in an area of 10,000 square miles. In 1955, the 9 million acre-feet of groundwater pumped for irrigation in that area represented about two-thirds of all groundwater withdrawn for irrigation throughout California and at least one-fourth of U.S. total use.

The Quality of Water Branch increased its staff to 300 in fiscal year 1956–57, a gain of 240 persons since 1947. Branch members analyzed more than 60,000 samples from 500 sites during the year, compared to 17,500 a decade earlier. Most of the stream samples, including 75 from west of the Mississippi River, were collected to determine trends in dissolved mineral content to aid irrigation projects. Some 7,500 of the samples represented groundwater nationwide. Branch specialists improved their studies of water quality in streams by developing criteria for station-network operation to satisfy minimum national needs. They also continued, and made more intensive, the chemical-quality investigations in the selected river basins. Cooperative studies included those for governments in 16 States and 7 Federal organizations—the AEC, the USBR, the DoD, the Federal Housing Administration, the Public Health Service, the Tennessee Valley Authority (TVA), and the Veterans Administration. The Branch issued chemical-quality reports on the West's surface waters for 1953, as part of the continuing series, and on the Fort Belvoir area for 1954–55 by Charles N. Dufor. Branch members prepared reports on water salinity in the Delaware River estuary and the surface-water chemistry of Arkansas, New York, North Carolina, Texas, and Virginia and began studies of radium and uranium in groundwater in parts of the West.

This view shows the C.G. Glasscock Drilling Company's mobile platform "Mr. Gus II" being installed on a U.S. Government lease—Outer Continental Shelf (OCS) 134—in block 48, Grand Isle area, off Louisiana, on August 6, 1957. Six wells could be completed from the platform without changing its position. Heightened exploration, new discoveries, and greater production by oil companies in the Gulf of Mexico significantly increased both the supervisory responsibilities of the Conservation Division's Oil and Gas Leasing Division on that part of the OCS and the rents, royalties, and other payments made to the Federal Government. (Photograph from the USGS Denver Library Photographic Collection as Patterson, E.F., pef00010, https://www.sciencebase.gov/catalog/item/51dda096e4b0f72b4471dda5; published in Yochelson and Nelson, C.M., 1979, p. 47.)

In fiscal year 1956–57, Harold Duncan's Conservation Division continued to receive more than 97 percent of its funds from its SIR appropriation of about $1,940,000, or nearly 153,000 more than during the previous year. Other Federal agencies and nonfederal sources supplied $46,000, a $6,000 loss, for a total of nearly $1,987,000. During the year, the Division's supervisory work helped to return $132 million to the Federal Government. Public-land income remained divided. The Federal Treasury received 10 percent; 37.5 percent went to the States, for schools and roads; and the Bureau of Reclamation received 52.5 percent, for general use in the Western States. In Alaska, 90 percent went to the Territory and 10 percent to the Federal Treasury. Receipts from supervised operations on the Outer Continental Shelf and on military and naval lands went to the U.S. Treasury. Income from restricted Indian lands was received for the benefit of the tribes or allottees. To the Division's reactivated post of Assistant Chief, Duncan appointed his long-time assistant Robert Spratt.

As part of the Conservation Division's operations during fiscal year 1956–57, members of the Mineral Classification Branch processed a total of some 32,900 cases, some 4,000 more than in 1955–56. Now led by John C. Miller, who had replaced David Cerkel in 1956, Branch members also completed a mineral map of New Mexico and maps and reports on eight coal, gas, or oil fields and structures in Colorado, North Dakota, and Wyoming. Personnel of the Water and Power Branch prepared six reports as part of their systematic review of land withdrawn for waterpower reserves that resulted in recommendations for restorations to the public domain of 75,000 acres of recommended and previously withdrawn lands. Branch members added nearly 29,000 acres and eliminated about 29,000 acres, leaving some 7,128,500 acres of power-site reserves in 23 States and Alaska. They also surveyed 350 miles of stream channels and 15 dam sites and published maps of 110 miles of channels and 6 sites. The Mining Branch supervised nearly 3,300 properties in 32 States and Alaska, whose production of mineral commodities, worth some $143.7 million, generated more than $7 million in royalties. On October 31, 1956, a Survey order, signed by Acting Director Robert Lyddan and approved by Secretary Seaton on November 6, authorized the Regional Oil and Gas Supervisors to act on applications for suspension of operations or production, or both.[86] Members of the Oil and Gas Leasing Branch supervised production on nearly 106,300 properties, covering more than 77 million acres, on the public lands in 24 States and Alaska, 4,490 acquired-land leases, and 11,265 leaseholds on Indian lands; royalties from these wells totaled $108.2 million. Production from military lands and Naval Petroleum Reserve No. 2 (NPR–2) added another $3.5 million. On the OCS, Branch members supervised 533 leases, of which 298 were originally issued by Louisiana and Texas but then passed to Federal jurisdiction under section 6 of the Outer Continental Shelf Lands Act; the remaining 235 were issued under section 8 of the Act. Of the 322 wells spudded during the year, 177 produced oil and gas. Although gas production from the OCS in 1956–57 fell by 4 percent from production in the previous year, petroleum production rose by 58 percent, and total revenues from both resources reached $13.3 million. During the year, 182,700 acres were eliminated from the Katalla-Yakataga development contract on lands in southeastern Alaska.

Foreign-policy issues dominated the Presidential campaign in 1956, beginning with another crisis in the Middle East. Members of the Arab League, hoping to reverse the outcome of their unsuccessful war against Israel in 1948–49, blockaded Israel by land, exchanged fire with Israeli forces, and campaigned against the Jewish State in the United Nations (U.N.). On June 13, 1956, the last British forces withdrew from the Suez Canal, leaving its operations and defense to Egypt, whose voters elected Nasser their President on June 23. Secretary Dulles announced on July 18 that the United States would not fulfill its promise to fund the proposed

High Dam on the Nile at Aswan. Eight days later, Nasser nationalized the Canal, through which passed daily almost 1.5 million barrels of oil, and decided to use the Canal's revenues and increased Soviet aid to build the Aswan Dam. On October 5, the Soviet Union vetoed a French resolution in the U.N. Security Council to restore partial international control of the Canal. To avoid appeasement, to humble Nasser, and to recover the Canal, the British, French, and Israelis secretly planned and agreed, on October 24, to launch joint, supportive, and nearly simultaneous attacks on Egypt. American U–2 photographs disclosed their preparations. Israeli forces attacked Egyptian units in the Sinai Peninsula on October 29, drove them west toward the Canal, and planned to take all of the Sinai. The British and French demanded that Egypt return the waterway to their control.

When Nasser rejected the Anglo-French ultimatum, their air and naval forces struck Egyptian bases on October 31. Nasser closed the Suez Canal and ordered it blocked by scuttling ships. Three days later, Arab extremists severed Iraq Petroleum's pipeline that delivered 445,000 barrels of oil each day to the terminal on the Mediterranean. The twin stoppages removed more than 2 million barrels a day from the West's petroleum sources, or nearly two-thirds of its daily requirement of 3.25 million barrels. On November 2, only the Egyptians heeded the U.N.'s call for a cease-fire. The British, French, and Israelis rejected similar requests from the Soviet Union and the United States after Eisenhower telephoned Eden on the new trans-Atlantic line to express his displeasure.[87] The Israelis captured the remainder of the Sinai, and Anglo-French airborne and amphibious forces took Port Said and other key points in the Suez Canal Zone during November 5–6. They then agreed, under increasing diplomatic and related pressure from the two superpowers, to a cease-fire. A U.N. Emergency Force began occupying the Zone on November 15. In December, Anglo-French troops left the Zone, and U.S. Army Engineers and international specialists began to clear the waterway.

During the Suez Crisis, Hungarians, encouraged by the Eisenhower administration's earlier expressed intent to aid the liberation of Eastern Europe, rose against Soviet rule.[88] During the Communist Party's 20th Congress in February 1956, Khrushchev damned Stalin's personality cult and its effects. Khrushchev then renewed Beria's earlier efforts toward liberalizing the Warsaw Pact countries, but Khrushchev promptly ended the reforms when the Hungarians revolted. On October 23, police in Budapest fired on demonstrators who demanded that their government form a democracy and free the country from Soviet domination. After a week of turmoil, the Soviets promised the Hungarians free elections and a policy of neutrality and began withdrawing from Budapest. With the West's attention increasingly focused on Egypt, Soviet forces returned to Budapest. Soviet tanks and troops crushed all opposition in the country during November 1–4; some 25,000 Hungarians died, and another 100,000 fled the country.

The Suez Crisis and its resolution temporarily shattered the unity of the Western allies. The Eisenhower administration threatened to sell British bonds to adversely affect its currency and refused to replace the oil withheld from Britain and France by the Middle East's producing countries until the Anglo-French forces left Egypt. Oil production in the United States, as Daniel Yergin later recorded, proved sufficient to meet all of Europe's needs during the 1956–57 boycott.[89] The Interior Department reported a domestic oil surplus and estimated that some 300 billion barrels and a corresponding volume of natural gas would be discovered and recovered by new technological innovations. On August 1, 1956, Secretary Seaton, at the request of the ODM's Director Arthur Flemming, decided that the Middle East emergency required preparing the response plan authorized under the Voluntary Agreement Relating to Foreign Petroleum Supply as amended on May 8, to deal with expected shortages. The Foreign Petroleum Supply Committee, after meeting on August 7, promptly sent a plan to Seaton, who passed it to Flemming.

After consulting with representatives of the ODM, the Justice Department, and Interior, Seaton announced the plan on August 10. With some reservations, 16 oil companies became members of and participated in the Middle East Emergency Committee and its subcommittees on Information, Pipeline Transportation, Production, Refining, Statistical, Supply and Distribution, and Tankers. The Committee met regularly during December 1956–April 1957 to alleviate the shortages and avoid economic disruptions by establishing scheduled activities. Their work, and related efforts at home and abroad, used reserve production to supply an extra 3 million barrels per day, or about 90 percent of the normal requirements of the affected areas. In March 1957, the National Petroleum Council's report on "World Petroleum Tanker Construction" suggested to Seaton that future disruptions could be avoided, or minimized at least in large measure, by constructing more and larger oil-carrying supertankers in the next decade.

The two major U.S. political parties held their national conventions in August 1956. The Democrats met in Chicago on August 13, as violence grew on Israel's borders with Egypt and Jordan. The Party's delegates again chose Adlai Stevenson for President, rather than Governor Averell Harriman of New York (who was endorsed by Truman) or Senator Estes Kefauver of Tennessee. John F. Kennedy, Joseph Kennedy, Sr.'s second son and now the junior Senator from Massachusetts, placed Stevenson's name in nomination. After the first ballot, Kefauver withdrew his name and released his delegates to Stevenson, who left to the convention the selection of his running mate. Kennedy, who voted not to condemn McCarthy in December 1954, led Kefauver on the second ballot. When Kennedy lost on the third tally, he asked the convention delegates to make their choice unanimous. Stevenson and Kefauver campaigned for equal opportunities in education, public development of water power, fixed rates for parity payments to farmers, and, as Britain successfully tested a hydrogen bomb in May, an end to such future tests. Stevenson also proposed ending the draft and favored a worldwide halt to all nuclear testing. Republicans convened in San Francisco on August 20 and renominated Eisenhower and Nixon. Eisenhower claimed responsibility for the country's peace and prosperity. He and Nixon promoted gradual elimination of segregation, private and government development of water power, maintaining flexible parity rates, and continued testing of advanced nuclear weapons.

In October 1956, Soviet Premier Bulganin wrote to Eisenhower and endorsed Stevenson's proposal to halt testing of nuclear weapons. When the administration made the letter public on October 20, a little more than 2 weeks before Election Day, some U.S. officials accused Bulganin of interference. That charge paled into insignificance compared to events in Hungary that began only a day later. On October 23 representatives of 70 countries at a U.N. conference approved a statute that would lead to the establishment of the International Atomic Energy Agency (IAEA) on July 29, 1957. The U.S. Congress agreed and President Eisenhower signed a bill that provided for U.S. representation and participation in the IAEA. The events of October 1956 in Hungary and the Middle East created a sense of emergency, but they did not seem to affect the U.S. Presidential election. On November 6, Eisenhower defeated Stevenson by margins larger than those in 1952. Eisenhower won by almost 9.6 million popular votes and received 457 of 531 electoral votes. Again, the President's victory proved only a personal one; in elections for the 85th Congress, the Democrats increased their majority in the House to 33 seats and raised their slender margin in the Senate to 2.[90] The Soviet Union declared on November 16 that it would accept a modified form of the "Open Skies" policy proposed by Eisenhower in 1955 but later withdrew its pledge. On December 6, as the Soviets reorganized Hungary, Eisenhower ordered the DoD to set up emergency transportation to bring to the United States some 15,000 Hungarian refugees.

January 1957 proved an exceptionally busy month for President Eisenhower. On the 1st, he hosted a bipartisan executive-congressional conference on foreign policy, mutual security, and national defense. Four days later, Eisenhower addressed a special message to the new 85th Congress about the continuing critical situation in the Middle East, which, he emphasized, held two-thirds of the world's known oil deposits. Suggesting that U.S. armed forces might have to be deployed in the region to counter any Communist threats to its and U.S. security, he asked Congress for the authority to do so but pledged to use it only "at the desire of the nation attacked."[91] In addition to continuing the economic and military aid under the Mutual Security Act, Eisenhower added that he would request $200 million in discretionary funds in each of fiscal years 1957–58 and 1958–59. Anthony Eden resigned as Britain's Prime Minister on January 9. On the next day, Eisenhower congratulated Harold Macmillian (with whom he served in North Africa during World War II) as Eden's successor, and the President also reported on the State of the Union to a joint session of Congress. Eisenhower cited his continuing concerns for human liberty, welfare, and progress and for world peace, goals that guided his administration's legislative program. He repeated his request "for Congressional authorization to help counter this threat" of Soviet aggression in the Middle East, a matter "of vital and immediate importance to the Nation's and the free world's security and peace."[92] The President closed by renewing his offers of open-skies surveillance by unarmed sentinels, armament reductions, and new agreements to ensure world peace. He urged Congress to authorize U.S. membership in the proposed organization for trade cooperation and full participation in the IAEA. On January 16, three B–52s took off from their base in California on the initial round-the-world nonstop flight by jet aircraft and returned there 45 hours and 19 minutes later. They demonstrated that the U.S. Air Force could drop nuclear bombs anywhere. Yet to be shown was the same ability for rapid intervention by U.S. ground forces in the Middle East or elsewhere worldwide.

On the day the U.S. bombers began their flight, Eisenhower delivered his budget message for fiscal year 1957–58.[93] The President reemphasized his continued twin goals of balanced budgets and tax reductions. The estimates for 1957–58, he promised, would ensure receipts of $73.6 billion and expenditures of $71.8 billion, leaving a surplus of $1.8 billion, the third consecutive year that excess funds would be available to reduce the national debt. The President also noted the degree to which the Federal workforce had been reduced by 240,000 persons since 1953. To improve public service, Eisenhower continued to approve amendments to the Government Employees' Incentive Awards Act[94] and established the seven-member President's Committee on Government Employment Policy. He promised that vacant Federal jobs would not be filled by new hires unless those posts could not be abolished or filled by transfers. Any and all proposals to increase Federal payrolls, Eisenhower added, would be carefully and critically examined and evaluated. Eisenhower was reinaugurated as President on January 21, 1957, and videotaped coverage was shown on national television the next day. Reiterating a desire for peace, he hoped the United States would "pursue the right—without self-righteousness," "know unity—without conformity,"[95] "grow in strength—without pride in self," and "ever speak truth and serve justice"[96] in dealing with the world's peoples.

Eisenhower personally welcomed King Saud at Washington National Airport on January 30 for talks aimed at improving relations with Saudi Arabia and exploring how the two nations might cooperate within the U.N. Charter to resolve the continuing crisis and restore peace in the Middle East. The King already had agreed to a 5-year, unified military command with Egypt and Yemen, but he firmly opposed Soviet influence in the region. He now wished to renew Saudi-American relations "on the basis of amity and mutual interest," hoping that divine-given "wisdom and sagacity" would serve as guides "towards universal peace and good will."[97]

On February 6, during Saud's visit, Eisenhower accepted Flemming's resignation as ODM Director. Saud departed 2 days later, after agreeing to renew for a second 5 years the U.S. lease on the airbase at Dhahran in return for continued U.S. military equipment, services, and training. Meanwhile, Israel maintained some of its military forces outside two of the armistice lines agreed upon in 1956, in defiance of the U.N.'s call of November 2, 1956, and Eisenhower's personal request 6 days later to Premier David Ben-Gurion. On February 17, 1957, Eisenhower referred to the U.N.'s renewed resolution on February 2 and again asked Ben-Gurion to withdraw the forces still in the Gulf of Aqaba area and the Gaza Strip. The U.S. Army Engineers and the international specialists, under the protection of the U.N. Emergency Force, had nearly cleared the Canal, the President reported to the Nation on the 20th. Under increasing international pressure, Israel withdrew its remaining forces from the armistice lines by March 2. "To promote peace and stability in the Middle East,"[98] Congress approved on March 9 the "Eisenhower Doctrine" by authorizing the President to extend economic and military aid to any nation in the region that requested it. The new law provided $200 million in Mutual Security Act funds. Eisenhower appointed a special ambassador to the Middle East and met with Macmillan in Bermuda during March 20–24.

Secretary Seaton made his initial appearances in January and March 1957 before the appropriations subcommittees of the 85th Congress to justify Interior's portion of the budget for fiscal year 1957–58. The Department now required support for salaries for and operations by nearly 50,000 full-time or part-time employees, of whom about 7,330 were in the USGS. By the time Seaton testified, Interior's upper management had changed again. In addition to new Under Secretary Chilson, Ross L. Leffler of Pennsylvania became the Assistant Secretary for Fish and Wildlife, the fourth such topical post in the DoI, to oversee the new Fish and Wildlife Service, both established by the same statute on August 8, 1956, as part of a new "sound and comprehensive national policy * * * to strengthen the fish and wildlife segments of the national economy."[99]

On January 22, Seaton testified at the House subcommittee hearing. Michael Kirwan welcomed Seaton by assuring him that he was "going to make a good Secretary" and "do what is proper and right, not only for Interior but for the interests of the country."[100] Seaton urged the subcommittee to approve the requested increases in funding for the USGS for the topographic and geologic mapping required to implement the administration's national polices for minerals and water resources. The Secretary requested additional sums for purchasing certain strategic minerals during the adjustment interval after reaching the stockpile requirements for those minerals. Kirwan specifically mentioned the Nation's need for more water. He deplored past thefts and waste of this resource, the results of which he reminded Seaton, "You saw * * * on the trip with the President." Kirwan expressed his pleasure that Seaton was "making every effort to ask for increases in the budget." "You said," Kirwan emphasized, "we must continue to find the minerals, the best uses of water and timber—this is the department which develops and protects the wealth of the United States Government."[101] Kirwan, seconded by his Democratic colleague William Norrell, praised Seaton's written statement; Kirwan called it "one of the best" he had seen during his 14 years of service on the subcommittee. Kirwan hoped that Seaton would "accomplish many things which should have been accomplished many years ago."[102] On January 24, Seaton left for 10 days in Alaska, where Interior then stationed about 2,500 employees, including some 40 from the USGS.

The budget Seaton proposed for the USGS increased its SIR funds by nearly $7.2 million to $38,775,000, but deducting the costs of Civil-Service retirement would reduce the gain to $5.8 million. The USGS also asked to hold over and expend the $415,000 from the 1956–57 appropriation not yet used for work

connected with special-purpose buildings, which required an additional $940,000 in 1957–58. The GSAd's Public Buildings Service estimated the total of $1,355,000 would enable a third building of 81,000 square feet to be constructed, in a single step, for the Pacific Coast Center at Menlo Park. Approving the USGS budget would raise the total of the agency's 7,595 employees—6,961 permanent and 634 other full-time-equivalent (FTE)—authorized for fiscal year 1956–57 to 8,127—7,487 and 640—during fiscal 1957–58.

Director Nolan explained these numbers and other parts of the budget request when he and Assistant Secretary Wormser appeared before Kirwan's subcommittee on January 15. During the next fiscal year, Nolan estimated, the USGS would incur $39,190,000 in direct obligations and $19,650,000 more in those indirect. He asked for an increase in base of $1,365,000 to cover retirement funds. The additional $1,145,000 for topographic surveys and mapping, and the $1,375,000 expected from the States, would enable the USGS to complete standard maps for some 155,000 square miles during fiscal year 1957–58, compared to 131,000 and 121,000 square miles, respectively, in fiscal 1956–57 and 1955–56. The new work would help the agency fulfill the recommendation by the Presidential Advisory Committee on Water Resources Policy to complete mapping the country topographically within 15 years. Nolan asked for $1.3 million more for geologic and mineral-resource surveys and mapping, noting that "recent events involving the Suez Canal have shown the wisdom of the program to increase our capacity to supply our own mineral resource needs in this country."[103] Responses to his recent invited talk at the World Mining Congress in Los Angeles during the fall of 1956, Nolan reported, indicated a much wider interest, beyond that of the mining companies, in USGS methods in photogeology and geochemical prospecting. The agency asked for an additional $490,000, under general-service geology, to provide more mapping support required for the national water-resources policy.

The largest single increase in the USGS budget for fiscal year 1957–58 was $2,525,000 (requested to raise the 1958 base from $8,885,000 to $11,410,000) in SIR funds to add to estimates of $6.2 million in State cooperative funds and another $4 million in transfers from other Federal agencies. These funds would support USGS hydrologic activities, including the principal Federal program of basic research. During the years of continuously funded investigations of water resources by the USGS since 1894, Nolan pointed out to Kirwan's subcommittee, most of the effort "has of necessity gone into what might be called a measurement or data collecting program." "There is emerging now," he continued, "a need for a new kind of work, based on but differing from the measurement program—that is a need for interpretative studies that draw out from existing records the information that is most significant and place it in its most useful form." Nolan gave as examples "the adaptation of flood-frequency data for use in problems of zoning and flood insurance, and the investigation of the utilization of water in certain industries." Nolan proposed to continue these measurement activities, because upon them depended the coeval "sound interpretative work," but the USGS planned to "capitalize more fully on the data we have and to expand our knowledge of some of the fundamental phases of water and its disposition and movement in the hydrologic cycle." "A considerable part of the increase" requested for water-resources investigations, Nolan promised, would be used in meeting the need "for 'interpretive studies on an effective scale,'"[104] as stressed by the President's advisers on water-resources policy. When Kirwan asked for examples of recent results of this research, Nolan described the use of thin films, one molecule thick, on the surface of reservoirs to reduce losses by evaporation and the extension of phreatophytic studies to scrub juniper and salt cedar. Nolan expected the new electronic computers—the Burroughs Datatron, now on line, and other computers, now being tested—to improve economy and efficiency in the automatic processing of streamflow records and speed publication. Nolan also reported that 200 of the 340

new staff recently authorized by statute went to the Water Resources Division; Kirwan agreed that decision would prove more effective in solving the present drought than the "President flying over the country and saying 'Yes, we are in a heck of a mess for water.'"[105]

Nolan hoped that the House subcommittee would approve the full request of the USGS for SIR funds for fiscal year 1957–58. He reported that the agency would be required to locate its new building in the Washington area on Federal land in the District of Columbia. Few sites of appropriate size remained in the District. The USGS still wanted to be close to the other agencies with which it worked daily and also to avoid having to move some 2,000 of its employees across the city's normal traffic flow during the workweek. Near the hearing's end, Kirwan and Ben Jensen, also with 14 years of service on the subcommittee, agreed that they had "never doubted your requests and the need for what you requested. When we granted it we knew it would be a job well done for this country."[106] Jensen also urged a direct appropriation for the new building in the Capital. When Nolan suggested the USGS might make that request next year, Kirwan promised "a sympathetic ear."[107] The House subcommittee and its Committee on Appropriations approved $36 million in SIR funds for 1957–58, $2,775,000 less than requested, but $4,398,000 more than in 1956–57. As the USGS encountered difficulties in recruiting qualified personnel, the Representatives decided the new sum they provided represented the maximum effective expansion in fiscal 1957–58.

Representatives of Interior and the USGS presented their justifications to the Senate subcommittee on the DoI, still chaired by Carl Hayden, in mid-March 1957. Democratic Senators Dennis Chavez and Warren Magnuson and the five Republicans continued to serve on Hayden's subcommittee, but Democrats Richard B. Russell of Georgia and Lyndon B. Johnson (LBJ)[108] of Texas replaced Senators Clements and Holland. LBJ, supported by Russell and Sam Rayburn, rose rapidly in the Democratic leadership after his election to the Senate, from party whip in 1951, through minority leader in 1953, to majority leader in 1955. LBJ also grew increasingly conservative. He opposed expanded civil rights and Federal ownership of the offshore oil lands, and supported the Taft-Hartley Act against the labor unions, but he worked to pass through the Senate the 1957 Civil Rights Act[109] for Eisenhower, despite a day-long filibuster by South Carolina's Strom Thurmond. On September 9, the new law established a Commission on Civil Rights, created a Civil Rights Division within the Justice Department, and enabled the Attorney General to seek district-court injunctions to restore improperly deprived rights to vote; meanwhile, it also repealed the President's authorization, from 1866, to use Federal troops for enforcement. Although the U.S. Supreme Court declared school segregation unconstitutional in 1954, Arkansas' Governor Orville E. Faubus called out his State's National Guard on September 3, 1957, essentially to prevent African-American students from entering Little Rock's Central High School for the fall term. Faubus, failing to fulfill an agreement he reached with Eisenhower on September 14, refused to withdraw the Guard and did not do so until forced by a district-court injunction. Riots followed the Guard's departure on the 23d. The next day, Eisenhower federalized the Guard and authorized the deployment to Little Rock of 1,000 members of the 101st Airborne Division to restore order. After the African-American students began classes on September 25, Eisenhower gradually withdrew the paratroopers.[110] The crisis was resolved, but discrimination against minorities continued in the South and elsewhere in the Nation.

On March 13, Seaton asked Carl Hayden's Senate subcommittee to restore the $60.1 million, not including funds for the USBR and the four power administrations, cut by the House from Interior's budget, which included a reduction of $2,775,000 in the estimate for the USGS. Two days later, Wormser and Nolan reinforced Seaton's request for the USGS. Nolan told the subcommittee that appropriating less than the full estimate would pose problems for the agency. The USGS

would not be able to begin several new projects as responses to recommendations by the Cabinet committees for mineral and water-resources policies or keep trained personnel for the existing programs just expanded in response to those recommendations. Especially "in regard to geologists," he emphasized, "the sharp reduction [of another $1,339,000] in our Atomic Energy Commission program will make it difficult to maintain the present staff."[111] Part of the House's perception in making its cut, Nolan suggested, involved difficulties due to how the USGS was required to report part-time personnel. Many of the vacancies seen by the House's subcommittee as representing the agency's "inability to hire personnel," the Director explained, represented what he termed "normal vacancies." These gaps were caused by the continuing seasonal employment of university and college students and their teachers, the usual turnover in personnel, and the required planning for "rates of hiring in anticipation of program changes."[112] Nolan hoped the justifications for increased funding for topographic and geologic mapping, and for water-resources investigations, and all responses to recommendations by the Cabinet committees for raising the rate of mapping and undertaking additional fundamental research, including the hydromechanics of flowing water, would convince the Senators "that our ability to find personnel is not greatly out of line with our current needs or with the needs anticipated in 1958."[113] The additional reduction of more than $1 million in AEC funds, Nolan assured Hayden, would free nearly 110 employees for assignment elsewhere in the USGS or, if necessary, separation from the agency. Applications for the examination for GS–5 through GS–13 positions rose steadily in recent years, Nolan reported, increasing significantly the agency's eligibility lists in those grades. Qualified people, he emphasized, could be recruited to carry out the proposed programs if they were fully funded. Senator Henry Dworshak, who entered the chamber at this point, repeated the House subcommittee's concern that the needed technical personnel were not available and that AEC transfers actually funded all USGS work for the AEC.

Hayden then presented for the record the sources of the $59,582,000 the USGS expected to receive in fiscal year 1957–58. That total included $39,190,000 in SIR appropriations; $12,545,000 from other Federal agencies; $7,490,000 in reimbursements and direct payments from States, counties, and municipalities; and $357,000 from miscellaneous nonfederal sources. Nolan, queried by Dworshak, agreed that the requested budget increase of about $7 million would fund 526 new employees for the expanded programs. When the questions passed to facilities, Nolan reported plans to transfer some 250 employees from Sacramento to the new third building, out of four planned, at Menlo Park, but he said that a significant number of people would remain at Sacramento "to provide liaison with the State."[114] Building 2, encompassing 32,455 square feet, was completed and occupied, mostly by geologists, early in 1957 and acquired by the Government in 1960. To provide a combined national-regional center in Washington that met Federal requirements and recommendations by the USGS Science Advisory Committee, the agency planned, with the GSAd's approval, to occupy and build on the National Bureau of Standard's site on Van Ness Street, N.W., after the NBS moved to a location in Maryland. Nolan expected that arrangement would save a significant part of the estimated cost of $22 million. Dworshak agreed that USGS operations needed to be consolidated in Washington, but, as fears of inflation and the administration's mandate now held the lease-purchase program in abeyance, he objected to funding the building's construction by direct appropriation. No construction funds, or even those for planning, could be requested until at least fiscal 1958–59, Nolan assured the Senators, but the USGS must comply with the House's request to report possible alternatives. Dworshak then asked if any of the USGS employees in the Capital area could work more efficiently in the field. Nolan replied that lack of room in Washington already had accomplished a certain amount of dispersal, but some

work, like terrain intelligence for the Army Engineers, required the facilities for, the skills of, and close coordination by the agency's personnel in the District.

The Senate subcommittee and its Committee on Appropriations did not restore any part of the $2,775,000 the House cut from the USGS budget estimate. On July 1, 1957, Eisenhower signed Interior's appropriations bill for fiscal year 1957–58. The new law provided the USGS with $36 million in SIR appropriations for the coming year,[115] $4,398,000 more than in 1956–57 but $1,860,000 less than the amount the agency requested. Of the SIR total, $5.8 million was limited to investigations of water resources in cooperation with the States, counties, and municipalities. As of June 30, the USGS rolls held 7,606 employees, of whom 456 worked part time or seasonally. The agency's workforce included 101 people in the Director's Office, 228 in the Publications Office, 338 in the Administrative Division, 2,423 in the Water Resources Division, 2,400 in the Topographic Division, 1,817 in the Geologic Division, and 299 in the Conservation Division. Another 511 individuals were on furlough for military service, on unpaid leave, or on related nonpaid status.

As the new Federal fiscal year began on July 1, 1957, so did the International Geophysical Year, and a conference of experts from several nations met in Geneva through August 1 to discuss monitoring a proposed nuclear-test-ban treaty. On June 30, Eisenhower welcomed the IGY's opening and the "valuable scientific knowledge" expected to be obtained between then and the formal end of the IGY on December 31, 1958. The President believed that the IGY's "most important result" would demonstrate "the ability of peoples of all nations to work together harmoniously for the common good." He hoped that "this can become a common practice in other fields of endeavor."[116] During the IGY, scientists from 66 other nations, but not including the two Chinas, planned to participate in studies of the Earth's atmosphere and its electrical-conducting ionosphere, glaciers, lands, and oceans, and the Sun, concentrating on rapid changes in these entities. The IGY organization also sponsored work in gravity, magnetism, seismology, and topography to increase knowledge about the Earth and its interior. These investigations would involve at least 40,000 persons, in 13 research specialties, working at 4,000 primary and 4,000 subsidiary stations. IGY studies would focus on the Arctic and the Antarctic, as agreed in 1955. Personnel from 12 nations, operating from 60 stations, would have unrestricted access within the southernmost continent. The NSF received an additional $2 million for U.S. IGY activities during 1957–58 to raise its total to $39 million, of which $1.9 million supported U.S. work on Antarctica during that year.

During September 30–October 5, the U.S. Committee on the IGY hosted at the National Academy of Sciences a meeting, recommended by the CSAGI in June, to discuss the status of the IGY's rocket and satellite program. During this week, Eisenhower addressed the IAEA's initial meeting, and he accepted the resignation of Secretary of Defense Wilson. Delegates from the national IGY committees of seven countries—Australia, Britain, Canada, France, Japan, the Soviet Union and the United States—that were planning to orbit satellites were joined by representatives from many other nations that intended to receive scientific data from the satellites. The U.S. and Soviet attendees displayed designs for their satellites and their scientific instruments and plans for launching and observing the satellites, receiving their data, and modifying their orbits. The Soviets' *Radio* magazine for July asked amateur operators to be alert for signals from a satellite. They announced the successful launch of an intercontinental ballistic missile (ICBM) on August 11 but gave no date for orbiting their initial IGY satellite. The stations in the Satellite Tracking and Data Acquisition Network, being established worldwide to receive data on the agreed standard frequency from the IGY satellites, remained incomplete.

During the evening of October 4, the Soviet delegates at the IGY conference hosted a reception for their colleagues at the Soviet Embassy. Lloyd Berkner, Sydney Chapman, other delegates, and journalist Walter Sullivan were among the attendees. James Van Allen, who designed the scientific-instruments package for the Vanguard satellite to be launched in November, was in Navy icebreaker *Glacier* en route to Antarctica. In the midst of the soiree, Sullivan later recalled,[117] he learned from his newspaper's Washington office that Radio Moscow had just announced the successful orbiting of Sputnik, a 184-pound, polished aluminum-alloy sphere nearly 2 feet in diameter. Sullivan quickly informed Chapman and Berkner; they announced it to the attendees, who responded with applause. Professional and amateur radio operators around the world quickly picked up the "beep-beep" signal rapidly repeated by the satellite's only instrument, a battery-powered radio transmitter. Sputnik, in a nonpolar elliptical orbit that reached an apogee of 584 miles, circled the Earth every 96 minutes. The U.S. National Broadcasting Company's stations promptly put the satellite's signal on their airwaves, spreading wider the news of the Soviet Union's breakthrough achievement in space.

Daniel J. Boorstin, in his "The Americans—The Democratic Experience," recalled in 1973 the amazing influence of Sputnik on world opinion 16 years earlier. Sputnik, tiny and inert, except for its radio transmitter, caused an unprecedented furor worldwide.[118] The unexpected feat encouraged the Soviet people and their allies, and correspondingly depressed many persons in the Western Alliance. The Soviet Union, long presumed by many experts to be technologically less advanced than the West, had won what many people considered a race to place the first artificial satellite in Earth orbit. Confusion in the United States quickly turned to anger and then to fear. Did Sputnik represent just a loss of prestige or was it really a Pearl Harbor in space? To Lyndon Johnson, the Senate's Majority Leader, Richard Russell, Chairman of the Senate's Armed Services Committee, and other Members of Congress, the satellite represented a future military danger far more significant than the effects of lessened prestige or psychological disadvantage. Those and other legislators quickly called for congressional hearings.

Even President Eisenhower could not allay those concerns as inaccurate and ephemeral, when, at his news conference on October 9, members of the press corps asked what he was going to do about Sputnik. Eisenhower, although pleased that the Soviet satellite ended his concerns for open skies, or at least open space, denied a U.S.-Soviet race in space and summarized the intentions of and progress made toward orbiting the first of the U.S. scientific satellites planned for the IGY. "Now, so far as the satellite itself is concerned," he asserted, "that does not raise my apprehension, not one iota."[119] The Soviet satellite, the President continued, "involves no new discovery to science."[120] The United States intended to loft small test satellites in December and launch in March 1958 the Naval Research Laboratory's Vanguard, whose Viking-derived slender rocket would boost the 21.5-pound and instrumented satellite into orbit. Vanguard would transmit scientific data via the IGY's agreed standard of 108 megahertz. Sputnik used a different frequency, as Chapman reminded the Soviet delegates in his comments at the close of the IGY's Washington meeting on October 5. The Soviet rocket was an entirely different matter. Although the President confidently asserted that the Soviets would not soon orbit spy satellites or weapons platforms in space, they claimed the ballistic missile used to orbit Sputnik also could accurately deliver nuclear warheads on targets worldwide. How had the Soviets gained this technological advantage and to what degree was it a surprise and a threat?

Historians Walter A. McDougall, William E. Burrows, Thomas A. Heppenheimer, Roger D. Launius, and James E. Oberg analyzed the origin and development of robotic and manned ventures into space.[121] Soviet rocketry, like the American and German efforts, traced its beginnings to a time before World War I.

The tempo of rocket development increased in the next 2 decades and during World War II. As that conflict ended in Europe, the Soviet Union acquired some of Wernher von Braun's V–2 personnel, but the Soviets claimed they contributed only a little to an already well developed effort before being repatriated early in the 1950s. As the U.S. Air Force, Army, and Navy each sought greater control of the Nation's ballistic and cruise missiles, the Soviets informed the West in 1955 that they planned, like the United States, to orbit a scientific satellite within 2 years as part of the IGY's program. First Secretary Nikita Khrushchev announced, via Moscow radio on August 26, 1957, the 4,000-mile flight of a Soviet ballistic missile that had been launched 5 days earlier. The missile was designed, produced, and launched (after three failures) by a team led by Sergei P. Korolev (Korolyov), who was the Soviet counterpart of von Braun. Khrushchev warned the West that the new missile enabled his country's rocket forces to deliver thermonuclear and other warheads globally.[122]

The CIA's high-altitude U–2 aircraft began flights over the Soviet Union on July 4, 1956, principally to assess Soviet bomber strength. These overflights revealed no "bomber gap," and American superiority in these piloted aircraft continued to grow, as did Soviet rage when their interceptors failed to shoot down any of the U–2s. Subsequent U–2 missions passing over Leninsk (Tyuratam), east of the Aral Sea in the central part of the Kazak Soviet Socialist Republic (Kazakhstan), photographed the Baikonur rocket facility, northeast of Tyuratam. By late summer in 1957, Eisenhower and his advisers knew about but dared not publicize the preparations at Baikonur. On October 4, Korolev's team launched Sputnik before any of the much larger scientific satellites they designed for the IGY. The importance of this achievement was indeed, as Eisenhower emphasized, not the satellite but its launch vehicle, which the CIA had estimated could not be operational before 1969. The Soviet Semyorka R–7, a two-stage rocket, with its core engine and four outer boosters, produced 900,000 pounds of thrust and could carry a warhead weighing up to 5 tons.

The U.S. Defense Department continued its work in high-altitude rocketry in 1957. On March 25, Naval Research Laboratory (NRL) personnel in California launched an Aerobee, a balloon-carried rocket, or "rockoon," that James Van Allen helped to design, to study the effect of solar radiation on communications. This continuing investigation also formed part of U.S. scientific activities during the IGY, which Congress and the President supported by supplying $39 million to the National Science Foundation. By the time the Soviets orbited Sputnik, the Air Force Office of Scientific Research failed at Enewetak Atoll to launch successfully four of Project Farside's Harvie multistage rockoons. Late in October, the USAF lofted two Harvie rockoons to about three-quarters of the design altitude of 4,000 miles, but no data were received from the onboard scientific instruments.

Major General John Medaris and Wernher von Braun received news of Sputnik[123] on October 4 at Medaris' Army Ballistic Missile Agency's facility in Huntsville, Alabama, while hosting a predinner cocktail party for a visiting delegation led by Neil H. McElroy, president of Procter and Gamble and now also the newly designated Secretary of Defense. McElroy's group at Huntsville included lawyer and Secretary of the Army Wilber M. Brucker; General Maxwell Taylor, who succeeded General Matthew Ridgway as Army Chief of Staff in 1955; and Lt. General James M. Gavin, the Chief of Army Research and Development. Medaris and von Braun urged McElroy to authorize them to resume work on the Army's own well-tested rocket and its satellite. They promised, with hardware at hand, to launch within 90 days their multistage Jupiter-C, an improved Redstone, with its Orbiter-Project instrumented satellite as the fourth stage. McElroy took office on October 9, as Eisenhower faced the press, and von Braun's team, with Medaris' approval, began to ready a reserve Jupiter-C.

On November 3, as the U.S. Army and Navy prepared their own rockets and satellites, the Soviets orbited the 1,120-pound Sputnik 2, carrying the mixed-breed dog "Laika," to mark the coming 40th anniversary of the Bolshevik Revolution. The next day, McElroy officially told Medaris and von Braun to ready the Jupiter-C. Eisenhower again responded calmly when, via television and radio on the evening of November 7, he spoke about science and national security. The President emphasized the nature and power of U.S. retaliatory forces that could "bring near annihilation to the war-making capabilities of any other country."[124] He repeated his earlier claim that only the propulsion abilities of Soviet rockets, not their satellites, were militarily significant. Eisenhower remained confident that existing U.S. bombers and missiles were a force sufficient to deter the Soviets while America's industry and armed forces developed and deployed new weapons systems.

The President also called for higher priorities for scientific education and basic research.[125] Eisenhower reported that he had just appointed James Killian, Jr., as his Special Adviser for Science and Technology.[126] In a second address on November 13, Eisenhower distinguished between the funds for and priorities of the U.S. satellite programs and again requested action to improve education in science. On November 22, Eisenhower added the word "President's" to the Science Advisory Committee's name and transferred the Committee from the Office of Defense Mobilization to the Executive Office of the President. Eisenhower appointed Killian a member of the President's Science Advisory Committee (PSAC) and then the group's chairman. Early in 1958, Killian's PSAC included 17 other members: Robert Bacher; William O. Baker, vice president for research at Bell Labs; Rear Admiral Lloyd Berkner; Hans Bethe; Detlev Bronk, NAS president since 1950; Lt. General James Doolittle; James B. Fisk, Bell's executive vice president; Caryl P. Haskins, president of the Carnegie Institution of Washington; George Kistiakowsky; Edwin Land; Edward M. Purcell, professor of physics at Harvard; Isidor Rabi; Howard P. Robertson, professor of physics at Caltech; Paul A. Weiss, head of developmental biology at the Rockefeller Institute of Medicine; Jerome Wiesner; Herbert F. York, professor of physics at Berkeley and Director of the AEC's Livermore Laboratory; and Jerrold R. Zacharias, professor of physics at the Massachusetts Institute of Technology (MIT). Consultants to the PSAC included Hugh L. Dryden, Director of the National Advisory Committee for Aeronautics since 1947; Emanuel T. Piore, IBM's director of research; Herbert Scoville, Jr., the CIA's Assistant Director; and Alan Waterman, the NSF's Director.[127] Eisenhower asked the PSAC to provide perspective and advice on science and technology, especially as they related to national defense, nuclear weapons, nuclear-test detection, and arms control. He also requested Killian's group to recommend the best administrative responsibility for the IGY, related satellites, and the rest of the space program, and to facilitate more rational decisions on developing and using technological advances and improving education.

U.S. prestige, scientific hopes, and more than $110 million rode with the 3-pound, 6-inch-diameter Vanguard satellite when the countdown for the live-televised launch began at Cape Canaveral, Florida, on December 6, 1957. The rocket's first-stage liquid engine, expected to deliver 27,000 pounds of thrust, ignited successfully. The slender TV–3 rocket rose slowly off its pad, reached a height of nearly 4 feet, then sank back, and exploded in a spectacular fireball. This public failure of Vanguard, nicknamed "Flopnik," "Kaputnik," and worse, also generated additional gallows humor about the abilities of America's German rocket scientists.[128] More importantly, commentators questioned the quantity and quality of the products of the U.S. educational system in engineering and science. In quantity alone, the United States trailed the Soviets; in 1956, the Soviets graduated 70,000 engineers and the United States produced only 30,000. To address these deficiencies, the administration continued to evaluate actions recommended in the second interim report of Howard L. Bevis' Presidential Committee on Scientists and

Engineers that Eisenhower received on November 26. Although Vanguard failed on its first attempt, other U.S. ballistic missiles worked, and the Strategic Air Command's (SAC's) 1st Missile Division became operational on January 1, 1958. The next generation of U.S. ICBMs and IRBMs would use solid rather than liquid fuel. In February, General Bernard Schriever convinced McElroy to authorize Aerojet General to proceed with the development, for deployment early in the 1960s, of the Minuteman ICBM, a three-stage, solid fuel (Thiokol) rocket that would deliver a 1-megaton thermonuclear warhead on targets up to 8,000 miles distant.

Lyndon Johnson's Subcommittee on Preparedness, of Richard Russell's Senate Committee on Armed Services, began hearings on the U.S. space program in November 1957 and resumed them in January 1958 soon after the 85th Congress reconvened for its second session. Johnson's subcommittee heard testimony from Vannevar Bush, Edward Teller, Wernher von Braun, and other scientists and engineers, and then from Generals Gavin and LeMay, Rear Admiral Rickover (promoted to Vice Admiral later in 1958), and other members of the armed forces. The subcommittee's report had 17 recommendations, including the development of a rocket motor with 1 million pounds of thrust. On February 6, the Senate established a Special Committee on Space and Astronautics, with LBJ as Chairman; on July 24, the Senate founded the standing Committee on Aeronautical and Space Sciences.

In January and February 1958, as the Senate hearings continued, Eisenhower reported to Congress on the state of the Nation's defense and its economy. The President emphasized the Nation's two main tasks—building "strengths that keep the peace" and ensuring "governmental and fiscal soundness."[129] To reach these goals, Eisenhower would reorganize the defense establishment, accelerate its efforts, especially in areas affected by the new advances in science and technology, strengthen mutual-security aid and mutual trade, increase scientific cooperation with U.S. allies, and build intellectual capital by stimulating and improving education and research. He requested a supplemental defense appropriation of $1.3 billion for fiscal year 1957–58; an increase of $2.5 billion for missiles, nuclear-powered ships, and other defense projects in 1958–59; and an additional $1 billion spread over 4 years for topically balanced programs in the Department of Health, Education, and Welfare and the NSF. The NSF's "Basic Research—A National Resource," issued on October 15, 1957, influenced the content of Eisenhower's addresses in November on "Science in Our National Security" and "Our Future Security," in which he emphasized the importance of increasing Federal and other support for research. Many persons in the U.S. scientific community and in the NSF remained convinced that "the Federal Government must not exercise control over science."[130] Eisenhower's additional request for fiscal 1957–58 meant a fivefold increase in the NSF's funds for science education and a twofold gain in its monies to support basic research. The NSF also received an additional $3.7 million on March 28 for salaries and expenses, but not additional employees, in 1957–58. The President promised to curtail spending on older and some newer weapons systems and to restrain selected civilian programs, although he established on March 4 a five-member Career Executive Board, to report to him through the Civil Service Commission, "to assure the retention and effective use"[131] of top-rank career officers and executives in the Federal civil service. These changes would raise estimated expenditures in 1958–59 to $73.9 billion but still leave an after-receipts surplus of $0.5 billion.

During these months, the United States successfully launched a scientific satellite and began a program to send robotic spies into space. On January 31, 1958, the Army's Medaris-von Braun team at Cape Canaveral used a Jupiter-C/Juno rocket to place Explorer 1, the fourth stage, in an orbit whose apogee reached some 1,500 miles into space. The U.S. scientific satellite weighed just 31 pounds, but it contained a Geiger counter and other instruments designed and prepared by James Van Allen's group at the University of Iowa and William H. Pickering's Jet Propulsion

Laboratory (JPL) in Pasadena, California. Photographers recorded Pickering, Van Allen, and von Braun holding aloft a mockup of the vertical-striped, cylindrical-bodied satellite.[132] J. Wallace Joyce, who led the NSF's IGY Office, reported the success to the President. Early in February, Eisenhower authorized the implementation of Project Corona,[133] an Air Force-CIA operation directed by Richard Bissell and designed, with the aid of the USGS and other Federal agencies, to supplement the U–2 flights by gathering intelligence and mapping information on photographs taken from cameras in a series of Keyhole spy satellites[134] that bore the cover name Discoverer. Modified IRBMs and ICBMs, launched from Vandenberg Air Force Base, on the California coast north of Lompoc, would place these new satellites in polar orbits where they would eject photo-filled and parachute-equipped capsules that aircraft would retrieve in mid-air. Work also continued on Project Samos, the second reconnaissance effort by the USAF–CIA team, whose satellites would electronically scan their camera's photos and return them via signals as they passed over ground stations. On February 7, Secretary McElroy established an Air Force Advanced Research Projects Agency (ARPA, later DARPA), appointed Roy W. Johnson, General Electric's executive vice president, to lead ARPA, and transferred to it all U.S. space ventures. In March, Herbert York became ARPA's chief scientist.

Other U.S. satellites successfully orbited in 1958 provided data about the Earth's shape and information about its surrounding radiation belts. On March 16, Eisenhower again emphasized the civilian connection by saying that Waterman had just informed him that the Navy-NRL Vanguard 1 was in Earth orbit. The geodetic instrument in the 3.5-pound satellite returned data demonstrating that the Earth was slightly pear shaped. The Army's Explorer 3 succeeded on March 26, the day the President made public the new "Introduction to Outer Space," prepared by Killian's PSAC. The report recommended taking the fullest advantage of the military and scientific potential of space. Explorer 4, launched on July 26, also reached orbit. Instruments on these and later U.S. satellites detected inner and outer belts of radiation, trapped by the Earth's magnetic field. The belts, named for Van Allen, comprised a doughnut-shaped zone of electrons and protons some 150 to 31,000 miles above the Earth and helped to define the planet's magnetosphere. The President approved and the White House announced on March 27, new projects for the preparation and launching by ARPA of additional small scientific satellites for Earth orbits and initial lunar probes.

Some Members of Congress, encouraged by these U.S. successes in space, proposed establishing a department to unify Federal science and technology agencies, increasing funding to bolster Federal science and technology, and providing the ways and means to train additional scientists and engineers, especially those for work on defense projects. Members of the 84th and the 85th Congresses knew well the shortages of these specialists, and they introduced but did not pass alleviating measures. During those efforts, a combination of factors, including operations by 1955's Critical Skills Reserve Program, a smaller required number of draftees, and a greater number of graduates began to produce more than the expected pool of engineers and scientists. In both sessions of the 85th Congress, several Members introduced bills to try to remedy the remaining deficiencies. Senator Hubert H. Humphrey, Jr. (D–MN), sponsored a comprehensive measure in July 1957 and reintroduced it in 1958. Humphrey's bill proposed establishing a Cabinet-level Department of Science and Technology, standing Committees on Science and Technology in Congress, and national institutes of scientific research. His measure also contained authorization for a program of Federal loans and loan insurance for college and university education in the physical or biological sciences, mathematics, or engineering and the establishment of scientific programs abroad. During May 2–June 26, 1958, a subcommittee of the Senate's Committee on Government Operations held hearings on the bill. Killian, the NSF, and many NAS members opposed the bill and its centralization of Federal efforts in science and technology. After

Eisenhower founded the Federal Council for Science and Technology[135] (FCST) on March 13, 1959, opponents of Humphrey's bill claimed it was no longer necessary; the measure was tabled later that year.

The FCST, as recommended in 1958 by Killian's PSAC, was intended to improve the coordination and effectiveness of the research and development programs being conducted by Federal agencies. The FCST's members included Killian; representatives of the Departments of Interior, Agriculture, Commerce, Defense, and HEW; the NSF's Director; the AEC's Chairman; the State Department's Science Adviser; and the Bureau of the Budget's Assistant Director.[136] USGS Director Thomas Nolan represented Interior's Under Secretary on the FCST, which began a standing Committee on Oceanography, also chaired by Nolan, and asked it to review a report by the NAS–NRC Committee on Oceanography. William R. Thurston, with the USGS during 1942–51 and the Executive Secretary of the NAS–NRC's Division of Earth Sciences since 1955, served as the Secretary and Executive Officer of its Committee on Oceanography. Thurston also was an observer on the Interagency Committee on Oceanography that developed from the Navy's Subcommittee on Oceanography.

Congress, the Eisenhower administration, and the NAS also moved to improve U.S. efforts in aeronautics and space, separate their civilian and military components, and support the former more effectively but still give the highest priority to the military programs. Eisenhower, after consulting with Nixon, Bronk, Dryden, Killian, and Waterman, accepted the idea of using the existing National Advisory Committee for Aeronautics as the nucleus of the new Federal civilian agency for all nonmilitary aeronautical and space programs and projects. The new agency would make its information available to the world. Eisenhower, in his special message to Congress on April 2, 1958, agreed to support the bills introduced in Congress to establish the new Federal agency for aeronautics and space. The President also recommended founding a National Aeronautics and Space Board, with members appointed by him who would include eminent citizen-specialists, representatives of the Federal agencies most concerned, and at least one member of the DoD. He asked Congress to give the new agency the authority "to conduct research projects in its own facilities or by contract with other qualified organizations"[137] and promised to request a supplemental appropriation for the agency's operations in its initial year of operations.

These efforts received another boost when Korolev's Soviet team placed Sputnik 3 in Earth orbit on May 15. The satellite and its 2,925-pound scientific payload, designed, built, and originally scheduled to be the first Sputnik launched, again demonstrated the huge lifting capacity of the Soviet R–7 rocket. Sputnik 3 gathered significant data for the IGY about cosmic rays, ion concentrations, the magnetic field, micrometeors, and solar radiation. As one response, the U.S. National Committee for the IGY urged Bronk to appoint a Space Science Board (SSB). Bronk gave the new SSB, established in the late spring of 1958 and led by Berkner, two principal tasks. Bronk asked the SSB to advise the ARPA, the NSF, and the U.S. National Committee for the IGY about rocket-satellite programs, and he also requested it to look further ahead by examining the space program's "scientific problems, opportunities, and implications."[138] The SSB also served as U.S. liaison to the Committee for Space Research (COSPAR) founded in November by the International Council of Scientific Unions. COSPAR cooperated with three of the ICSU's new committees—the Special Committee on Antarctic Research (SCAR), founded in February 1958; the Special Committee on Oceanic Research (SCOR), established in August 1957; and the International Geophysics Committee. These groups collaborated with the NAS–NRC's existing equivalent bodies—the Committee on Polar Research, established in February 1958; the Committee on Oceanography, founded in July 1957; the Committee on Meteorology (1955), renamed the "Committee on Atmospheric Sciences" in 1958; and the Geophysics

Research Board (GRB), appointed by Bronk in 1960. The GRB's members included the persons chairing the four NAS–NRC committees and its two boards; the chairs and one other member of each of the four national committees for the international unions for astronomy, geodesy and geophysics, physics, and scientific radio; and several persons chosen at large.

In November 1957, Killian's PSAC evaluated the recommendations by a Presidential committee, founded earlier and led by H. Rowan Gaither, Director of the Ford Foundation, to find ways to decrease U.S. vulnerability to Soviet attacks. Gaither's panel recommended, but Eisenhower rejected, a 5-year program, costing some $44 billion, to increase the development and production of U.S. missiles, deploy them in dispersed but hardened sites, and construct a national system of fallout shelters. The President, seeking alternatives, asked Killian on April 8, 1958, to convene the long-delayed conference of experts to study the verification requirements needed for an effective agreement to ban nuclear tests. Killian appointed a PSAC Panel on Seismic Improvement, chaired by Lloyd Berkner and better known as the Berkner Panel. Among its 12 other members were Hugo Benioff; Hans Bethe; Maurice Ewing; David Griggs; Jack H. Hamilton, Geotechnical Corporation's vice president for research and engineering; Walter Munk, Scripps Institution of Oceanography (SIO); Jack E. Oliver, Lamont Geological Observatory; Frank Press, Director of Caltech's Seismological Laboratory and a NAS member in 1958; and Carl F. Romney, Air Force Office for Atomic Energy. The Berkner Panel reviewed existing and potential ways and means of verification, including the possibility of establishing a standardized global seismic network.[139]

On May 8, 1958, Eisenhower proposed having international technical advisers assess the possibilities of a nuclear-test-ban agreement based on a workable and effective monitoring system. Khrushchev accepted the offer on the following day. U.S. confidence came in part from the results of the AEC's Rainier underground nuclear test on September 19, 1957, at the Nevada Test Site (NTS). Charles Bates, Thomas F. Gaskell, and Robert B. Rice later noted in their "Geophysics in the Affairs of Man" that the Rainier test exploded a 1.7-kiloton warhead to determine the depth required to fully contain the released radioactivity,[140] observe the surface-ground motion created by the test, and identify any harmful effects on the site's groundwater. Radioactivity was well contained, and surface motion did not extend beyond 3 miles. Seismic waves from the shot, equivalent to an event of 4.6 magnitude on the Richter scale, were recorded by 46 stations, one as far away as the U.S. Coast and Geodetic Survey's facility at College, Alaska. At shorter distances from the NTS, six stations registered a significant compressional (or outward) initial signal rather than the lower amplitude P (primary or compressional) wave that preceded the arrival of the higher amplitude S (secondary or shear) wave generated by earthquakes. Critics pointed out that the two compressional waves might be confused. Successful monitoring required a new and enhanced worldwide standard seismographic network linked by electronic computers, a combination then being referred to as the "new seismology."[141]

On May 15, Eisenhower suggested that a group of experts and representatives from Britain, Canada, Czechoslovakia, France, Poland, Romania, the Soviet Union, and the United States convene in Geneva, on July 1, the Conference on the Discontinuance of Nuclear Weapons Tests. John Cockcroft, who led the British Scientific and Technical Mission in Washington during World War II and earned a Nobel Prize in physics in 1951, headed the British delegation in Geneva. Edward C. Bullard, of Cambridge University, served as one of Cockcroft's seismological advisers. Eisenhower objected to AEC Chairman Lewis Strauss' selection of Edward Teller to lead the U.S. team, and so Ernest Lawrence went instead, but James Fisk led the U.S. delegation and Robert Bacher filled its third seat. Advisers to the U.S. group included Hans Bethe; Harold Brown, Teller's Associate Director at the Lawrence

Radiation Laboratory; Berkeley's Perry Byerly; Jack Oliver; Frank Press; and Carl Romney. Evgeny K. Fedorov, Director of the Academy of Sciences' Institute of Applied Geophysics, led the Soviet delegation, which also included seismologists and nuclear-weapons experts. British, Soviet, and U.S. experts at Geneva remained concerned about distinguishing earthquakes from underground nuclear tests. They estimated (and the PSAC reported) that twice the number of natural earthquakes occurred whose released energy equaled that produced by underground tests of specific yields.[142] On August 21, after 30 formal sessions, the experts agreed on the technical feasibility of a control system to detect any violations of a worldwide suspension of nuclear tests.

On August 22, 1958, the U.S. and British Governments proposed, provided the Soviet Union halted its tests, a 1-year ban on such testing, effective October 31. Eisenhower's and Harold Macmillan's announcements extended a test race before the new deadline. Britain conducted 4 tests at Christmas Island between August 22 and September 23, 1958. The United States tested 37 devices in its Hardtack II series at the NTS between September 12 and October 30. Two of the tests in tunnels on October 16 and 30—the 5-kiloton Logan (4.4 magnitude) and the 22-kiloton Blanca (4.6 magnitude)—produced larger numbers of smaller and downward, or natural-looking, compressional waves than expected and led to recalculations that lowered Rainier's magnitude by 0.5. Those levels led U.S. experts to increase by a factor of 10 the whole number of seismic events not identified as natural or fabricated that released energy equivalent to 5-kiloton explosions.[143] Khrushchev agreed to consider the ban on August 29, but the United States detected and announced the resumption of Soviet tests before Khrushchev made them public on October 2. Negotiations aimed at banning underground nuclear tests resumed at Geneva among the United States, Britain, and the Soviet Union on October 31. The United States' revised estimates of the personnel needed for verification, claimed the Soviet delegation, would require unacceptable numbers of inspection groups and provide greater opportunities for spying. Eisenhower extended the U.S. test ban in 1959.[144] The Geneva talks ended on June 27, 1960, without reaching an agreement, but the United States and the Soviet Union ceased nuclear tests in the atmosphere and did not resume them until September 1961.

Bates, Gaskell, and Rice recorded how the Berkner Panel on Seismic Improvement analyzed the data from the Hardtack tests, improved the Geneva system for detecting and distinguishing between earthquakes and artificial explosions, and recommended a program of basic and applied research intended to secure better methods of seismological detection. The Panel drew on the work of the Air Force's ongoing seismic-research group, chaired by Roland Beers (Sr.). Beers' group included John N. Adkins, the Director of the Office of Naval Research's (ONR's) Earth Sciences Division; Hugo Benioff; Perry Byerly; Dean S. Carder, the U.S. Coast and Geodetic Survey's chief scientist; Maurice Ewing; Beno Gutenberg; Norman A. Haskell, USAF Cambridge Research Center; James B. Macelwane, St. Louis University; Frank Neumann, who shifted from the U.S. Coast and Geodetic Survey (USCGS) to the University of Washington in 1953; Caltech's Charles F. Richter; and Louis Slichter.

The Berkner Panel issued its report, "The Need for Fundamental Research in Seismology," as a State Department document on March 16, 1959. Since 1948, the report noted, the Air Force's panel sent some $8 million to academic, government, and industry laboratories for investigations aimed at improving the detection of nuclear explosions. By comparison, the NSF was spending only about $300,000 a year on similar studies. More than $52 million, the panelists suggested, would be required to fund a 2-year research program that would monitor new conventional and nuclear explosions, at a cost of $24 million; use $12 million to develop better detection systems, conduct additional basic and applied studies, and establish large seismic arrays; and use $16 million to modernize selected stations. On April 23,

Killian, Deputy Secretary of Defense Donald A. Quarles (an engineer who served earlier as Assistant Secretary of Defense for Research and Development and then as Secretary of the Air Force), and the AEC's new Chairman John A. McCone (who advised Secretary Forrestal and then served as Under Secretary of the Air Force) decided that the DoD would fund the Berkner Panel's recommendations, provided the AEC paid for and conducted the required tests at the NTS. Responsibility for funding passed to Herbert York, now the DoD's Director of Defense Research and Engineering, and accountability for operations, to the hitherto mostly missile-conscious ARPA. Two members of York's new Advisory Group on Seismology, Hugo Benioff and Norman Haskell, also served on the Berkner Panel. York's advisers, chaired by Frank Press, also included F. Gilman Blake, who led the Geophysical Research Division of Socal's California Research Corporation; John M. Gerrard of Texas Instruments; Walter Munk; Jack Oliver; and James T. Wilson, who chaired the University of Michigan's Department of Geology.

Eisenhower, meanwhile, made two changes in his Cabinet and appointed a new Chairman at the AEC. On October 23, 1957, Eisenhower accepted the resignation of Herbert Brownell, Jr., who earlier wished to leave as Attorney General. In November, Eisenhower replaced Brownell with William P. Rogers, a lawyer who served as one of Vice President Nixon's advisers and traveled with the candidate during the 1952 campaign. As Attorney General, Rogers established a Civil Rights Division in the Justice Department. On June 30, 1958, Lewis Strauss ended his second tour with the AEC. John McCone succeeded Strauss as chairman, and Strauss became Eisenhower's special assistant in the Atoms for Peace program. Arthur Flemming returned to the Eisenhower administration, on August 1, 1958, as Secretary of HEW, replacing Marion B. Folsom, who had served since Oveta Hobby resigned in 1955.

Commerce Secretary Sinclair Weeks began a comprehensive review of his department. Beginning in January 1958, the review by Weeks and his office staff of all his agencies concentrated on those with a science component. When Weeks resigned later in 1958, Eisenhower nominated Lewis Strauss as Weeks' successor. When the Senate refused to confirm Strauss in 1959, Eisenhower selected and the Senate approved Frederick H. Mueller as Secretary of Commerce. As part of the reorganization that followed the internal review of the Commerce Department, the Bureau of Public Roads, the Coast and Geodetic Survey, the Maritime Administration, the National Bureau of Standards, the Office of Technical Services, the Patent Office, and the Weather Bureau began reporting to a new Assistant Secretary for Science and Technology on March 2, 1960.

On July 3, 1958, Eisenhower, after twice in 2 years vetoing omnibus-appropriations bills for constructing, repairing, and preserving public works on rivers and harbors for navigation, flood control, irrigation, or multiple-purpose projects, signed an acceptable measure for these purposes. The new statute's first two titles covered rivers and harbors and flood control. Only the closest cooperation and partnership among municipalities, counties, States, and the Federal Government, the President emphasized earlier, would make the best use of each drop of water. So the new law's Title III, the Water Supply Act, declared Congress' policy of recognizing

> **the primary responsibilities of the States and local interests in developing water supplies for domestic, municipal, industrial, and other purposes.**[145]

The law also required "that the Federal Government should participate and cooperate with States and local interests in developing such water supplies in connection with the construction, maintenance, and operation of Federal navigation,

flood control, irrigation, or multiple purpose projects."[146] Senator Robert S. Kerr (D–OK), the chairman of the board of Kerr-McGee Oil Industries, Inc., was one of the measure's chief sponsors; he would chair the Select Committee on Natural Water Resources in the 86th Congress during 1959–61. In 1971, former Representative Frank Smith, then on the TVA's Board of Directors, would say that the 1958 act "established water supply as a firm purpose in the construction of federal water projects."[147]

Secretary Seaton, again calling for sound use of the Nation's natural resources, noted that the Census Bureau's projections suggested the country's population would reach 220 million as early as 1975. A large share of that increase would occur west of the Mississippi River, where survival depended on wisely using water resources. Sound use, he emphasized, required new and improved knowledge, especially of the effect of radioactive waste on U.S. water resources; research on this effect was one of the USGS' postwar responsibilities. Seaton also called for more efficient recovery and use of the Nation's helium resources. The four plants in Kansas, New Mexico, and Texas extracted 340 million cubic feet of helium in 1956–57 but also lost some 3 billion cubic feet when helium-bearing natural gas was used as fuel in the absence of extraction facilities. The administration planned to request funds to build 12 new helium-processing plants, if incentives would not encourage private industry to do so, and authority for a program to reserve by 1985 some 32 billion cubic feet of helium produced from these plants by storing it in the federally owned Cliffside Field just northwest of Amarillo.

The USGS, while continuing to evaluate the Nation's water and helium resources, and fulfilling its other responsibilities in science, mapping, and regulation, also hoped to participate in the growing U.S. effort in space. To meet these and other challenges, the agency strove to increase its funding at a time when the Nation's economic slowdown led the Eisenhower administration and Congress to favor fiscal retrenchment. On January 13, 1958, Interior Secretary Seaton appeared before the House appropriations subcommittee to defend the Department's budget for fiscal year 1958–59. Nevada's Royce A. Hardy, Jr., Felix Wormser's successor as Assistant Secretary for Mineral Resources, accompanied Seaton's group. As the Public Works subcommittee considered the sum Interior sought for the Bureau of Reclamation and the four power agencies, Seaton's request for the Interior Department and its remaining bureaus represented a decrease of almost $38.9 million compared to the equivalent estimate for 1957–58. Seaton assured Chairman Kirwan and the subcommittee's other members that he was "happy to report" that the DoI's programs could be continued "in a manner adequate to serve those needs of our country * * * with a reduction in the appropriations." In preparing the budget for 1958–59, Seaton continued, he again emphasized improving economy and efficiency by "curtailing or eliminating work of less importance in order to meet the additional requirements constantly placed upon the Department."[148] Most of Interior's agencies would lose some of their requested funds, including nearly $2 million for the USGS. The only overall gain for USGS programs would be $447,000—the sum of $197,000 from SIR appropriations and $250,000 from the States, counties, and municipalities—to increase cooperative water-resources investigations. Although nearly $1.8 million would "cover geologic and minerals resource surveys and mapping previously financed by the [U.S.] Atomic Energy Commission,"[149] the Geologic Division actually would lose more than $900,000 from its total funds available during the year.

Assistant Secretary Royce Hardy and USGS Director Thomas Nolan met with Michael Kirwan's subcommittee on January 16. Hardy continued as Interior's liaison to the Committee on Government Activities Affecting Prices and Costs and as its representative on the Council on Foreign Economic Policy. He also advised the Director of the Office of Civil and Defense Mobilization about the administration of the Federal strategic-stockpiling program and chaired the Oil Input

Appeals Board. "The responsibilities of the Geological Survey," Hardy emphasized, "include a group of functions that are becoming increasingly important with the growth of the country." "In view of our greater need for, and utilization of, our natural resources," he continued, "never in its history has this country so urgently needed the services performed by the Survey."[150] "The funds requested," Hardy concluded, "are the minimum necessary for continuing its activities with the effectiveness to meet present requirements."[151] "Recent events," Nolan then noted, "have emphasized the importance of anticipating the need for the kinds of basic data and fundamental research provided by the Survey, and have confirmed the wisdom of the committee in supporting these activities in the past." The space age, he continued, "has added to, rather than diminished the need for accurate geographic and topographic information."[152] New research and exploration programs, as demonstrated during and since World War II, took 10 to 20 years to significantly increase the availability of raw materials. Echoing Directors Mendenhall and Wrather, Nolan cautioned that

> **it is both dangerous and poor economy to wait until an emergency is upon us before developing new methods, new concepts, and new applications of the geologic sciences.[153]**

The Soviet Union demonstrated that it likewise considered this work an investment in its future growth and security, Nolan emphasized, by investing "heavily in geologic mapping and research." The Russian Federation, the largest part of the Soviet Union, operated "eight main geological research organizations, exclusive of the educational institutions and the Ministry of Geology," which alone employed 14,000 geologists, and the other Soviet Republics also financed their own geological institutes. Nolan pointed out the Water Resources Division's growing emphasis on analysis and interpretation to meet "an increasing demand for the solution of exceedingly complex water problems."[154] Members of the Conservation Division, he added, continued to face an ever-increasing workload. Nolan then reminded the subcommittee that a "solution of the Survey's housing needs in the Washington area continues to be one of our most critical problems"; solving it should meet "the physical requirements of the Survey's operations" and provide "a means of attracting and retaining skilled employees."[155]

Kirwan summarized the estimate for the USGS for fiscal year 1958–59. Congress and the President appropriated $36 million in funds for SIR operations by the agency for 1957–58 but they held $430,000 in reserve so the amount presently available was $35,570,000, to which transfer and repay funds added more than $21 million. The 1958–59 SIR amount included two gains—$1,178,000 to cover activities now funded by the AEC and $447,000 for water-resources investigations. The request also delineated two losses—$940,000 due to a nonrecurring item in the building program and $107,000 for topographic surveys. Kirwan termed the total SIR estimate of $36,750,000 for 1958–59 an increase of $1,180,000. Why, he then asked, could the USGS not locate a building site in the District of Columbia? The Old Soldiers Home was one of the sites considered, Nolan responded, but the General Services Administration made other arrangements for its use. The GSAd's General Counsel decided that the Lease-Purchase Act's expiration ended the authorization for a USGS building, and the agency would "have to start from scratch again"[156] if it still wanted one. In reply, Kirwan and Ivor Fenton both voiced their concern and frustration before asking about how the USGS used the $3 million increase, not including retirement costs, authorized for 1957–58.

The major portion of the $3 million increase, Nolan replied, went toward the estimated $1,355,000 required for the special-purpose structure (Building 3) to be constructed at Menlo Park to house the Western Mapping Center when it moved from Sacramento. Final plans and specifications were due from the contract

architect before May 1, after which bids would be requested and the 9-month construction contract let by June. Most of the additional $280,000 for topographic work funded new efforts in quadrangle mapping that supported the mineral- and water-policy programs. The Geologic Division devoted a large part of its $600,000 gain to mapping for the latter program four areas selected by the Water Resources Division—the Delaware River Valley, locales near Del Rio in Texas, those east of Colorado's Front Range, and lands near Carrizo and Corduroy in Arizona. Like the topographers, the geologists also concentrated on developing "new instruments and new principles." "One is a spectrometer," Nolan continued, for determining trace amounts of metals in small-grained ore minerals; "another is a small portable seismometer."[157] Geologic and geophysical work funded by the AEC was shifting in part from its Raw Materials Division to its Military Applications Divisions and its other units, including the studies, involving two conventional-explosives tests, begun in July 1956 and completed for the Rainier underground nuclear test in September 1957. The USGS helped to select the test site, a tunnel 2,000 feet long and built 820 feet below the surface in bedded rhyolitic tuffs of the Oak Spring Formation (Tertiary).[158] The agency also responded to concerns that the nuclear explosion might create fractures that would (but did not) vent radioactive gas to the atmosphere, cause an earthquake, or contaminate local groundwater. In related investigations, the USGS also aided determinations of safe and efficient disposal of radioactive waste from AEC plants. Of the Water Resources Division's nearly $1 million increase, about one-half matched larger cooperative offerings from non-federal sources, including those for a comprehensive survey of Puerto Rico's water resources and amelioration-oriented studies of the flood plains of Pennsylvania's rivers.

On January 16, 1958, Kirwan passed to a more troubling issue, the failure of the USGS to improve its accounting methods in 1956 after the Comptroller General reported deficiencies to the subcommittee in 1955. On January 10, 1957, the Comptroller General's Office issued its report on USGS accounting practices and sent it to Interior. Administrative Assistant Secretary Beasley forwarded Interior's comments to the GAO on July 30, noting that the Department planned to issue soon its new draft manual that established procedures and adequate control over cashflow. When Kirwan specifically asked if the accounts of the Surface Water Branch at Columbus, Ohio, were now corrected, Nolan admitted the he was "not familiar with that particular case." The USGS would keep single accounts for individual cooperative projects; then it would divide costs into two parts at year's end and bill cooperators for half the total cost. The new system would replace the one that billed cooperators "for a series of individual items that represent one-half of the cost."[159] Kirwan agreed that this might be a problem for some States and their systems but, he added, "we still must have a proper accounting of all funds, including charges to the proper accounts."[160] Kirwan then placed into the record, the GAO report's 10 principal findings and the reasons for the refutations or modifications by the DoI and (or) the USGS. Recommended changes included discontinuing regional disbursing officers, except in Hawaii; a study and trial of consolidated cooperative accounts; the distribution of indirect charges by electronic computers; new instructions for depositing monies from the sales of Government Printing Office (GPO) publications; drafting a purchasing guide and another for using and maintaining property stock levels and records. The USGS refused, as it did several times earlier in the decade, to delegate complete authority for Division operations to Division representatives at Denver. The agency also decided to avoid expensive and unnecessary administrative work by continuing map sales on credit.

Kirwan then assessed the sums requested for specific activities. Nolan's statement noted that the USGS had adequately mapped, for most users, about 42 percent of the country by July 1, 1957. Even with a loss of $107,000, Nolan asserted, the Topographic Division would still meet the Nation's needs for new and

revised maps. While the cost per person-year for producing these maps increased from $4,500 to $6,300 between 1947 and 1957, improved instruments and methods reduced the per-square-mile cost from $171 to $124. Allowing for price-index increases during the same interval, Nolan noted, "the equivalent price is $88 per square mile, approximately half of the cost of 10 years ago, although our salary costs have increased over 50 percent in that period."[161] USGS map printers now earned three times their salaries of 1945, while the average reproduction cost per map edition fell from $325 in 1945 to $295 in 1957. "Industry and business have not been able to accomplish this," Kirwan enthused, "I know that the committee is thankful and grateful for it. They will find it much easier to appropriate the funds that you are requesting."[162]

When the discussion moved to geological and mineral-resource surveys and mapping, Kirwan and Nolan returned to the AEC funds and a seeming overlap between the base of $1.54 million for the AEC activity under the Long-Range Minerals Program and the $3 million under the mineral-deposits investigations. The change, Nolan summarized, reflected the shift from rapidly discovering and blocking out new ore bodies to the geologic, geochemical, and geophysical studies required for finding additional deposits that could be developed to extend the AEC's present 10-year supply of uranium. The AEC decided in fall 1957, Nolan continued, that these longer range and more traditional USGS investigations would best be done by a transfer of base. When Kirwan read into the record a statement the day before by AEC Commissioner Willard Libby that uranium reserves were adequate for the next 2 or 3 decades, Nolan countered, as Kirwan intended, by citing the opinion of Jesse Johnson, Director of the AEC's Raw Materials Division. At the Budget Bureau's hearing, Johnson "emphasized the need for the longer-range geologic exploration by the Survey; not the physical exploration by the companies."[163] Nolan, encouraged by Kirwan, asked Johnson for a clarification and added to the record his confirmation of the 10-year reserve and his view that the USGS should continue its work of the past 12 years to maintain the "present satisfactory uranium-reserve position."[164]

Ben Jensen and Ivor Fenton then joined to query the USGS work funded by transfers from other Federal agencies, particularly topographic mapping for the Bureau of Reclamation. Nolan verified for Jensen the $21 million the USGS gained in fiscal year 1957–58 from sources other than its SIR appropriation. Nolan anticipated the USGS would receive transfers and repayments of some $17.2 million, of which about $7.6 million would be from States, counties, and municipalities to match an equal amount in USGS funds for cooperative work in topography and water resources. "Under present circumstances," Jensen, ever the self-described friend of the USGS but also of government economy, hoped the agency and the subcommittee "might be justified in making a saving below last year in your activities wherever it is possible to do so and where it does not interfere with our security program."[165] The equally friendly Fenton remained concerned about USGS priorities in meeting Federal needs for topographic maps and the total amount of the USBR's transfers—$18.3 million between fiscal 1945–46 and 1956–57, with another $2.2 million expected between 1957–58 and 1958–59. Nolan reminded him that Congress decided not to appropriate those funds directly to the USGS and that appropriations for all Interior agencies performing as-required work for the USBR were now in the DoI's other bill before the public-works subcommittee.

The increase of $447,000 for water-resources investigations, Nolan explained, would advance the program's three principal objectives—maintaining the nationwide network of observation stations, using the data collected to prepare descriptive and interpretative reports intended to aid the solution of "developmental and operational problems," and continuing "research on hydrologic principles, to increase our scientific ability to solve practical problems and add to the sum of scientific knowledge about water."[166] Continuing to strengthen research, analysis,

and interpretation, he emphasized, would "achieve better balance in the program, thereby increasing its usefulness in [solving] the increasingly complex water problems of the modern age."[167] When Kirwan asked which of the five subactivities was the most essential, Nolan distinguished between two groups of investigations—operations (surface-water, groundwater, sediment, and chemical quality) and planning (recommendations for water-resources policy).

Fenton recalled his flight in November over platforms with producing wells in part of the Outer Continental Shelf in the Gulf of Mexico. He asked for, and later received, the status of leases in Louisiana and Texas, and the amount of Federal revenue from them. Harold Duncan responded that about $300 million (later verified as $285 million) in bonuses, rentals, and royalties went to the Federal Treasury between August 1953 and June 1957, representing production of 27 million barrels of oil, 2.9 million barrels of condensate, and 293.4 billion cubic feet of natural gas. Duncan estimated that $14 million more would be added during 1957–58 by the daily production of 45,000 barrels of oil, 2,800 barrels of condensate, and 250 million cubic feet of gas. The subcommittee's questions ended with that exchange. "We are glad to have had you with us," said Kirwan in closing the hearing, "Continue to do the job you are doing and I think we will be satisfied."[168] The House Committee on Appropriations voted to hold the line on the SIR appropriation for fiscal year 1958–59, reducing geologic and mineral resources surveys and mapping by $750,000 and leaving the agency's total at $36 million, the same amount it received in 1957–58.

On March 25, Secretary Seaton asked Carl Hayden's Senate appropriations subcommittee to restore the cut, made in response to the shift of base from the AEC, and not slow down USGS work on mineral resources. Hayden agreed, adding, as before, that did not make "much difference which agency of the Government pays, just as long as we continue our efforts."[169] He also noted that the impasse in securing for the USGS a building in Washington meant that it would "be necessary to authorize the construction."[170] Three days later, Assistant Secretary Hardy and Director Nolan made the same plea to Hayden's subcommittee. In February, Eisenhower's Executive order revised the sequence, set by Truman in 1950, of Interior's administrators authorized to act as Secretary in Seaton's absence; Hardy now would so serve after the Under Secretary and the earlier appointed Assistant Secretaries but before Interior's Solicitor.[171] On March 19, Willard Libby wrote to Seaton to express his "hope that the Survey will be in a position to continue basic geologic studies related to uranium as part of its regular minerals investigation program. We consider such studies of great importance in assuring an adequate long-range uranium resource position." Libby also hoped to continue "close cooperation with the Survey on the other programs of the Commission" and to "expect to be able to enlist their aid on additional programs as the need arises."[172] Nolan reported Libby's increasing interest in and USGS work for the AEC on Project Plowshare, a national effort that planned to use nuclear explosions to mine oil shale and other sources of energy, fracture rock at and for construction sites, and excavate artificial canals and harbors.[173]

Hayden recalled his participation in passing 1925's Temple Act that authorized within 20 years, but did not fund, the completion of national topographic mapping and the Federal-State cooperation required for it. He asked about the decrease of $107,000 below the amount appropriated for topographic surveys and mapping during fiscal year 1957–58. "Will this result in a further deferment of our long-sought goal of adequate maps of the entire country?"[174] At the USGS' present rate of mapping 3 percent of the Nation each year, and assuming no raise in the proportions of funds for the increasingly important revisions, Nolan responded, "we look forward to a complete map in about 20 years—19 to 20 years."[175] That estimate, he continued, represented a reduction from the 30-year interval the USGS projected would be required 10 years earlier.

In reviewing these and other USGS programs, Hayden noted that the USGS expected to receive total funds of $54 million in fiscal year 1958–59. "Will this reduction of $3 million," Hayden queried, "result in the Survey having to separate experienced professional and technical personnel?"[176] "Yes it will," Nolan replied, "about 200 plus in the Geologic Division in the field of mineral studies," and "[i]f the House figure is sustained * * * about another 100."[177] The House, they noted, had twice reduced the original SIR request of $39.4 million to $36 million, not including the $2.8 million provided in 1957–58 by the AEC's Raw Materials Division. Agreements between the members of the House-Senate conference committee produced SIR appropriations for the USGS of $36,915,000,[178] of which $6,950,000 was limited to cooperation with the States, counties, and municipalities in water-resources investigations. On June 4, 1958, Eisenhower approved Interior's appropriations for fiscal 1958–59. Supplemental appropriations enacted on August 27 added $1.5 million more in SIR funds.[179] A second supplement, dated May 20, 1959, and also spurred by post-Sputnik developments, supplied another $3,073,200[180] that brought the year's total for the USGS to nearly $41.5 million or $2 million more than the original budget request.

As the USGS learned in June 1958 what SIR funds it could definitely count on for fiscal year 1958–59, the 1957–58 operating year drew near its close. The USGS reported total receipts of slightly more than $59,496,000 during 1957–58, or almost $6,420,000 more than in 1956–57. The SIR appropriation for 1957–58 of about $37,510,000 represented 63 percent of the year's total, an increase of $6,330,000. SIR funds for investigations in soil and moisture conservation rose by $36,000 to $165,500. Other Federal agencies transferred nearly $13,612,000, or a loss of $880,000. Nonfederal agencies provided some $8,374,000 in reimbursements and direct payments, or nearly $978,000 more than in 1956–57, but representing the same 14 percent of total funds received. The USGS received an additional $1,140,000 in special-purpose-buildings funds for its Pacific Coast Center, where the agency hoped eventually to raise its total floor space to 138,000 square feet. The USGS also received about $1,208,000 for general administration, not counting the $529,500 from other Federal agencies reported under the Divisions' substantive-activity totals. After Congress and the President approved on March 28 the transfer of $1.35 million[181] from any of Interior's other appropriations for 1957–58 to cover typhoon damage in the Trust Territory of the Pacific Islands, the USGS provided $150,000 as its share.[182]

During fiscal year 1957–58, Nolan made several administrative changes aimed at improving USGS management, staffing, and operations. Douglas R. Woodward succeeded Russell Wayland as Staff Engineer in the Director's Office. On February 13, 1958, a Survey order established an Exhibits Committee to improve the quality of USGS internal and external public displays of "the results of its scientific and engineering work."[183] The new advisory Exhibits Committee included members from each of the operating Divisions (designated by their Chiefs), the Publications Office's Exhibits Construction Officer, and the USGS Information Officer (Chairman). The Committee reported to the Director through the Executive Committee. On April 8, another Survey order abolished, as of April 1, two publishing groups—the Office of Geologic Reports' Section of Geologic Cartography and the Office of Illustrations—and transferred their functions, funds, personnel, and equipment to the Office of Publications' new Branch of Technical Illustrations. Arthur Baker, as Acting Director, asked the new Branch to aid in planning manuscript illustrations from the operating Divisions, turn the draft versions into final copy for publication, and arrange for securing "specialized base map materials." The order continued to make the Topographic Division responsible for preparing "final copy for quadrangle maps of the topographic map series and base or special maps."[184] A third Survey order on May 13 established the USGS Board of U.S. Civil Service Examiners, composed of at least one representative from each USGS Division and a

USGS geologist Eugene Merle ("Gene") Shoemaker (1928–97) trained at the California Institute of Technology (Caltech) and Princeton. After joining the USGS in 1948, he mapped and studied geology and uranium deposits on the Colorado Plateau. To this work, he added investigations of impact and volcanic craters and those resulting from nuclear and conventional explosions and laboratory projectiles. Sputnik confirmed Shoemaker's decision to try to go to the Moon. He began a USGS program in space geology in 1960 and cooperated with the National Aeronautics and Space Administration (NASA). Shoemaker, using images from telescopes and spacecraft, established a lunar chronostratigraphic scale. Addison's disease, diagnosed in 1962, kept Shoemaker out of the astronaut corps. As Chief of the USGS Astrogeologic Studies Group (later Astrogeology Branch), he helped to establish NASA's program of robotic and human exploration and sampling on the Moon. Shoemaker also led NASA's Manned Space Sciences Division (1962–66). He participated in the Ranger, Lunar Orbiter, Surveyor, Apollo (11–13), Voyager, and Clementine Programs. In 1962, Shoemaker began teaching part time at Caltech and chaired its Division of Geological and Planetary Sciences during 1969–72. Shoemaker and his wife Carolyn began mapping asteroids and comets at Palomar Observatory in 1982, and then collaborated with Canadian astronomer David H. Levy. An ounce of Shoemaker's ashes reached the Moon in 1998 in NASA's Lunar Prospector. (Photograph, 1965, from the USGS Denver Library Photographic Collection, Portraits, in "Shoemaker, Eugene M.," folder; see also Levy, 2000.)

This photograph looks northwest across Meteor (Barringer) Crater, a feature about 0.74 mile in diameter and located south of Winslow in northeastern Arizona. Eugene Shoemaker's investigation of the stratigraphy, structure, and mechanics of Meteor Crater in the late 1950s supported an origin by meteorite impact, rather than volcanism. Meteorite and nuclear-explosion craters both contained overturned strata on their outside rims and fused sedimentary particles. USGS geologist Edward Chao confirmed the impact origin when he and Shoemaker discovered natural coesite (pressure-shocked quartz) at Meteor Crater. Shoemaker and Chao's subsequent studies of similar structures in and outside the United States, Shoemaker's experiments with projectile and explosion-produced craters, and his studies of lunar craters confirmed that impacts commonly occurred on and off planet and were significant events in Earth-Moon history. (Photograph by USGS geologist David J. Roddy; from the USGS Denver Library Photographic Collection as Project Apollo (1960–73) pap00001, https://www.sciencebase.gov/catalog/item/51dda464e4b0f72b4471e1f5; published in Schaber, 2005, fig. 1.)

Director-named Chairman, all nominated by the Director and approved by the Civil Service Commission. Nolan asked the new Board to handle the work of recruiting, scheduling, examining, registering, and certifying qualified individuals in science, engineering, and technical positions. Nolan also requested the Board to advise him regarding USGS "policy in these and related functional areas."[185]

The Geologic Division received $15,396,000 for salaries and operations during fiscal year 1957–58, a modest gain of $384,000. SIR appropriations rose by almost $1,237,000, to a total of $8,013,000, and enabled the Division, at long last, to control more than half (52 percent) of its program. States, counties, and municipalities added $302,000, a loss of just over $9,000 from the previous year. Although the AEC again reduced its transfer, by nearly $924,000, its total of $3,972,000 kept it as the largest Federal contributor. The Army and its Engineers shifted $1,224,000, or about $128,000 more than the previous year's transfer; the ICA's contribution rose by $92,000 to $867,000; and the DMEA increased its transfer by $36,000 to a total of $504,000. The Navy contribution continued to fall, but the Air Force raised its transfer to nearly $139,000. Chief Geologist Bill Bradley chose Montis Klepper to succeed Dwight Lemmon as Assistant Chief Geologist (ACG) for Operations. Harold Bannerman (Program) and Lincoln Page (Trace Elements) continued to serve as the other ACGs. Raymond Becker replaced Robert Lindvall as Central Region Geologist in Denver. After John Rabbitt died suddenly on June 10, 1957, Mary Rabbitt transferred from her post as Assistant Chief of the Geophysics Branch to succeed her husband as the Division's Staff Assistant for Publications.

The growing U.S. effort in space led Nolan and Bradley, prompted by Eugene ("Gene") Shoemaker and other younger members of the USGS, to consider ways of mapping the Moon from Earth-based observations. In "To a Rocky Moon—A Geologist's History of Lunar Exploration," USGS program participant Don E. Wilhelms later (in 1993) analyzed the origins and subsequent development of the agency's mapping and other contributions to robotic and manned exploration and increased scientific understanding of the composition, structure, and history of the Earth's only natural satellite. G.K. Gilbert's studies of Arizona's Coon Butte area in 1891 led him to interpret that feature, later and better known as Meteor (Barringer) Crater,[186] as the result of explosive volcanism. After Gilbert studied the Moon through the Naval Observatory's reflecting telescope during 18 nights in August 1892, he decided in his next year's publication, "The Moon's Face—A Study of the Origin of Its Surface Features," that meteorite impacts had formed some of the lunar craters.[187] In the postwar years, astrophysicist Robert B. Baldwin and geologists Reginald Daly and Robert S. Dietz supported an impact origin for lunar craters.[188] Dietz joined the Navy Electronics Laboratory (NEL) in San Diego in 1946 and served as an oceanographer during Operation Highjump in 1946–47. In articles published during and after 1946, Dietz described the shatter cones in terrestrial rocks and the circular and radial symmetry, central peaks, and six other properties of lunar craters that reflected their impact origin and distinguished them from volcanic craters on Earth.

Shoemaker completed a master's degree in geology at Caltech in 1948 and promptly joined the USGS Colorado Plateau Project. He spent nearly all of 1948–52 in field mapping and uranium studies for the project in Colorado and Utah, then participated in the Distribution of Elements Project during 1952–55. Shoemaker also led the Investigation of Diatremes Project in 1952–60, while also working full time during 1957–60 on the Investigation of Geologic Processes Project. As part of these investigations, he mapped and studied the diatreme volcanoes of the Hopi Buttes and other areas of the Hopi and Navajo Indian Reservations, the nuclear-explosion craters at the Nevada Test Site, Meteor Crater, and similar features elsewhere that Columbia's Walter Bucher and other geologists interpreted as volcanic. Shoemaker, who also investigated ballistic theory and craters caused

by small projectiles and by nuclear and conventional explosives, became convinced that impacts caused many terrestrial and most lunar craters. The natural and nuclear craters shared geologic features and dispersal patterns and they also seemed similar in aspect to some of the lunar craters. Shoemaker read Gilbert's 1893 article, the 1946 articles by Daly and Dietz, and Baldwin's 1949 book, "The Face of the Moon"; he then read widely among subsequent publications, including the U.S. military's photographic atlases based on telescope-derived images that resolved features as small as 1,500 feet across.

Beginning in the 1830s, Edgar Allan Poe, Jules Verne, Konstantin Tsiolkovsky, H.G. Wells, and Hermann Oberth used varied craft and propulsion methods to take their characters and readers on imaginary voyages to the Moon. Von Braun's long-time wish, inspired by Oberth, to send a rocket to the Moon was no secret; it began even before his V–2 years. Von Braun, after relocating to the United States, promoted space travel in articles and interviews in *Colliers* during 1952–54 and in other magazines, on radio, and on television, including an appearance for Walt Disney's theme park "Tomorrowland." Shoemaker, a more recent but no less enthusiastic convert, believed the United States' expanding program in space would include plans for human exploration of the Moon and decided to go there as that venture's initial geologist. Shoemaker suggested to Nolan in 1956 that the USGS begin a four-person program of lunar studies. William Rubey, whose opinion Nolan then sought, did not think it a far-fetched idea, but Shoemaker's proposal progressed no further before the advent of Sputnik 1. "I'm not ready yet,"[189] Shoemaker responded to news of the Soviets' success, but other members of the USGS began maneuvering to participate in the mapping underway or being planned, with military sponsorship, to improve existing lunar atlases by using newer telescopic photography. As 1957 ended, the Air Force also continued to consider Project Red Socks—a proposed mission to the Moon that would use the new, two-stage Thor-Able rocket being developed from the IRBM, a modified Explorer as proposed by JPL's Pickering, and lunar-atlas data. The USAF, General Schriever suggested in June 1958, could develop a system (costing nearly $100 million) to place a man in lunar orbit by April 1960.

Members of the USGS Pick and Hammer Club quickly commented on the agency's attempts to hop on the U.S. space bandwagon. On May 2, 1958, the Club's "Missileaneous Players" presented "Lunar Ticks or How to Solve the Space Problem" as its annual show. In "Fun Demental," sung to the tune of Lester Lee and Zeke Manners' "Pennsylvania Polka," the Andrews Sisters' hit song in 1942, they asked to:

> **Strike up the music, the job has begun—**
> **The Lunar Mapping Program.**
> **Pick out your gimmicks and join in the fun—**
> **The Lunar Mapping Program.**
> **It started with Noolan, now we're on the run.**
> **It's bound to soon involve ya,**
> **Everybody wants to solve the**
> **En-ig-ma of Lunar Mapping Program.**[190]

After "Noolan" said "the Survey's got the dough,"[191] four Chiefs—"Leo Lunarpold," "Clod," "Firpo," and "Begorra"—assembled in the office of "Admiral Speed," a character inspired by John Reed (Sr.), Staff Coordinator in the Director's Office, and a Commander, U.S. Naval Reserve (USNR). To gain the prize, the Chiefs extolled the expertise in stratigraphic and structural geology of their operational units, Water Resources, Paleontology and Stratigraphy, Geophysics, and Geochemistry and Petrology. Crews from Leopold's, Cloud's, Balsley's and Pecora's units, trained and tested, sought "the honor / To be sent to map the moon."[192] "Speed" and the other former field men now on the Director's staff wanted to

lead the effort but decided they could not leave their well-padded chairs. As the program's funds came from the Army Engineers, "Speed" picked the previously unheard photogeologists of Frank Whitmore's Military Geology Branch. The new "Missileled Crew" used Johnny Burke and Jimmy Van Heusen's "Road to Morocco," the title tune from the Hollywood film of 1942, sung by Bing Crosby and Bob Hope, to announce that:

We're off to the moon in our rocket,
Make way, clear the road, here we come.
Tom Noolan he just told us that the job had to be done,
A ge-o-lo-gic map of green cheese really will be fun.
Our program is certainly sound—
Like Von Braun's can of Millers, we are moonward bound.[193]

The chosen ones were "quite prepared to tackle any crater big or small" as part of their terrain studies. "With scientific gadgets at our ev'ry beck and call," they promised, "That map will be no trick at all."[194]

As the USGS military geologists began their lunar studies, other members of the Geologic Division and their colleagues outside the agency continued to focus on an objective below the Earth's surface—drilling to and through the Mohorovicic discontinuity to investigate and sample the upper mantle. Better known as the "Moho," the discontinuity was named for the Croatian geophysicist Andrija Mohorovičić, Director of Zagreb's Institute for Meteorology and Geodynamics and professor at that city's university, who based his discovery in 1909 on the sharp increase of 1.2 kilometers per second in seismic-wave velocity across the crust-mantle boundary and on differences in travel patterns. Willard N. Bascom's "A Hole in the Bottom of the Sea," an insider's view through 1960 of the origins of Project Mohole, traced its beginning to a decision by Gordon Lill and Carl O. Alexis, of the Office of Naval Research, in Washington during the summer of 1952 to establish an informal organization that could deal more effectively with the wide-ranging proposals for research submitted to the ONR's Geophysics Branch. The meetings of the newly formed coeval organization, named the American Miscellaneous Society (AMSOC), became casual venues for more interdisciplinary evaluations of ideas not yet ready for formal presentations for funding. Lill and the other members of AMSOC eschewed both constitution and bylaws, operated without officers, and gave fanciful names to their informal divisions. When Maurice Ewing, who still directed Columbia's Lamont Geological Observatory (LGO) and continued to promote securing deeper cores from Atlantic Ocean sediments, encountered a deep-drilling discussion by members of AMSOC meeting at the Cosmos Club in 1956, they asked him to join them. That October, Frank B. Estabrook, a physicist at the Army Office of Ordnance Research, published a letter in *Science* describing the major geological and geophysical problems—those involving composition, density, gravity, isostasy, magnetism, radioactivity, seismicity, and temperature and pressure—that could be investigated by downhole sensing in and cores from a "research shaft"[195] to the Moho.

AMSOC's horizons expanded significantly on March 23, 1957, when Charles Behre, Hugo Benioff, Princeton's Harry Hess, King Hubbert, Walter Munk, and William Pecora, all members of the NSF's Advisory Committee for Earth Sciences in 1957–58, met with William Benson to evaluate a number of research proposals submitted to Benson's Earth Sciences Program at the NSF. The reviewers found all the proposals worthy, but they thought that none of those projects would likely yield a major increase of knowledge. The mantle-sampling project, Munk suggested, would produce a major advance.[196] Selecting a site on an oceanic island, like those already drilled in the Pacific by Harry Ladd's team, or a better site below the ocean itself, would reduce the depth of the Moho to less than 3 miles, and

fewer heat-generating radioactive minerals would be encountered in drilling in the thinner basaltic crust. Hess and Munk considered the project as the consummate opposite of a mission in outer space,[197] one that could generate favorable publicity for the earth sciences as well as draw in oil-company expertise and support. On April 20, when AMSOC met again at Munk's house in La Jolla, its members capped additional discussion by naming Lill to chair a project-evaluation committee. Hess, Ladd, Munk, Roger Revelle, and Joshua Tracey formed the rest of Lill's Committee on Deep Drilling. A week later, the new Committee met at the Cosmos Club, where Lill added William Rubey and Maurice Ewing. Oceanographer Arthur E. Maxwell, who served at the SIO and measured heat flow in the Pacific with Revelle before transferring in 1952 to the ONR's Geophysics Branch, joined Lill's Committee later in 1957.

On July 15, 1957, AMSOC requested funds from the NSF for a feasibility study, but, lacking a link to a formal organization, did not get them and sought support elsewhere. Hess and Revelle promoted a resolution in September at the meeting of the International Union of Geodesy and Geophysics (IUGG) in Toronto. There, they were seconded by British Petroleum's geophysicist Thomas Gaskell, who conducted seismic-refraction surveys to locate bedrock depths on Funafuti and Nukufetau in 1951 during the cruise of HMS *Challenger*, the Royal Navy's second survey ship of that name. The IUGG's resolution, approved on September 14, called determining the composition of the mantle a vital goal for geophysicists.[198] The document urged nations with deep-drilling experience (like the United States) to estimate the possibility and cost of drilling into the mantle at a site where the crust was thinnest.[199] During the discussion, a Soviet scientist informed attendees that his country already possessed the equipment for a Mohole and now was just looking for the best site, one presumably on land.

To this Sputnik-like challenge from the Soviets, independent oilman John W. Mecom of Houston responded positively at AMSOC's next meeting on December 6 at Rubey's home. Mecom's company held the world's depth record for oil wells, the one drilled in 1956 from the barge *Keystone* to a salt dome's flank 22,570 feet below a Louisiana bayou southwest of New Orleans. Mecom and the AMSOC members suggested a multiphase program that would drill three holes—one on land, to 35,000 feet, and then two at sea to penetrate first the sedimentary section and then through the crust to the mantle. Two days later, Hess, who chaired the NAS–NRC's Earth Sciences Division, asked the NAS–NRC to absorb AMSOC's project into the Earth Sciences Division and to seek up to $50,000 from the NSF to enable AMSOC to study the project's feasibility. Ewing (elected in 1948), Hess (1952), Munk (1956), Revelle (1957), and Rubey (1945) were members of the NAS. Munk and Revelle also sailed together on the SIO's Capricorn Expedition in the Pacific in 1952–53, with Maxwell and two other members of the SIO's staff—marine geologist and oceanographer H. William Menard and geophysicist Russell Raitt, Jr. Menard, a former Lt. Commander, USNR, earned a Ph.D. at Harvard in 1949, and Dietz promptly hired him for the Navy Electronics Laboratory. Menard joined Dietz and Revelle in the NEL–SIO Mid-Pacific Expedition in 1950 and in other cooperative research until he shifted to the SIO in 1955.[200] Columbia's Isidor Rabi, NAS member, Nobel laureate, and one of the participants in the discussions, was glad to focus on a topic other than space.[201] Geologist Willard Bascom, a NAS staff member fresh from installing instruments to measure Pacific Ocean waves during the IGY, became an enthusiastic convert to the drilling project. While at the SIO during 1951–54, Bascom, also participated in nuclear tests in the Pacific. Bascom, as Executive Secretary of the Meteorological Society in 1957, represented the United States at the IGY's Conference on Oceanography in Sweden; he became Executive Secretary of the NRC's Maritime Research Committee in 1958.

On April 26, 1958, an array of U.S. geophysicists met in the NAS' headquarters in Washington, at the invitation of William Thurston, to assess the Mohole

project and the possibilities for funding it. Harry Hess, who continued to serve with James Balsley, Charles Behre, William Heroy (Sr.), and Harold Urey on the NSF's Advisory Panel for Earth Sciences for 1957–58, chaired the session. Gordon Lill presented the plan, and Hess and Roger Revelle effectively responded, both historically and scientifically, to some attendees' objections about the project's cost and utility. Union Oil's A.J. Field then demonstrated its practicality. He showed movies of a well being drilled in 200 feet of water off California by use of the 98-foot-tall derrick amidships in *CUSS I*, a 3,000-ton, 260-foot-long, former Navy freight barge modified and operated by a consortium of four oil companies—*C*ontinental, *U*nion, *S*hell, and *S*uperior. Attendees voted unanimously to approve the project, and the NAS–NRC lauded its prospect of increasing basic knowledge of the Earth and providing "new insight into theories of continental drift."[202] The NSF provided for 1958–59 a preliminary grant to Thurston of $15,000, as a down-payment on the now specifically requested $30,000 for a 2-year feasibility study.[203] In September, as Gaskell published a project prospectus in *Nature* and the newly formed Global Marine Exploration Company bought *CUSS I*, Phillips Petroleum extended a well in western Texas' Pecos County to a depth of 25,000 feet at a cost of less than one-third the nearly $50 per foot then required for drilling in the Gulf of Mexico. In an expanded study, fueled by an additional $80,500 from the NSF to the NAS–NRC in fiscal year 1959–60, researchers led by John Adkins examined site surveys by the LGO and the Woods Hole Oceanographic Institution (WHOI), looked at *CUSS I* and Humble's *SM 1*, considered other drill ships worldwide, and sorted scientific objectives. Then, during April–July 1959, Bascom, Hess, Lill, and Maxwell combined to publish four additional prospectuses in the *American Geophysical Union Transactions* (reprinted in *American Scientist* in 1960), *Nature*, *Science*, and *Scientific American*.[204] They presented Project Mohole as a two-phase and multiple-drilling effort, in competition with the Soviet Union's as yet unverified program, at a cost of $5 million, or about equal to the price of a single satellite launch. "When going ahead in space, it is also important to go back in time," AMSOC's proverb proclaimed, "The ocean's bottom is at least as important to us as the moon's behind!"[205]

By then, Lill's Committee on Deep Drilling actively operated three advisory panels—Scientific Objectives and Measurements, Drilling Techniques, and Site Selection. Ladd led the Panel on Scientific Objectives and Measurements, with Balsley as his deputy. The panel's 10 other members were Harvard geophysicist Francis Birch, elected to the NAS in 1950; Lt. Colonel George Colchagoff, Air Force Office of Scientific Research; geophysicist Henri-Georges Doll, Schlumberger Well Survey Corporation's former research director and board chairman; LGO geologist David B. Ericson; marine geologist George H. Keller, Naval Oceanographic Office; John Lyman, who left the Navy Hydrographic Office in 1959 to serve as Assistant Director of the NSF's Oceanography Program; Arthur Maxwell; William Menard; William Pecora; and Hatten S. Yoder, Jr., a research petrologist at the Carnegie Institution of Washington's Geophysical Laboratory[206] and a newly elected member of the NAS. One representative each from Humble, Pan American, Phillips, Socal, Socony Mobil, and Texaco formed William Heroy's Panel on Drilling Techniques. Hess' Panel on Site Selection included geophysicist and oceanographer John B. Hersey, WHOI; John E. Nafe, LGO; Russell Raitt, SIO; and marine seismologist George G. Shor, SIO. Bascom's NAS–AMSOC staff, whose salaries were paid by the NSF, comprised a secretary, a scientist, 10 engineers, and 2 naval architects. They were aided by five consultants—a lawyer, a third naval architect, and three other engineers.

Geologists in Andy Anderson's Mineral Deposits Branch continued during 1957–58 to concentrate on longer term studies intended to increase knowledge of identified mineral deposits and their origins and histories as the keys to developing

new and improved exploration techniques. The Branch directed 126 projects, of which the AEC supported 27 and 20 others involved cooperative work with the States. Members of these projects mapped in the Little Dragoon Mountains of Arizona, the Grants and Laguna areas in New Mexico, the Holy Cross quadrangle in the Colorado Mineral Belt, and the Boulder Batholith west of Butte in Montana. Branch scientists expected their investigations of the water included in minerals to provide additional clues to the nature of ore deposition. Studies for the DMEA led to the discovery of significant amounts of lead ore in the Viburnum area of southeastern Missouri and the prospect of the deposit being developed as the largest in the district, as the overall study of lead-zinc areas in the Upper Mississippi Valley neared completion. Branch personnel continued to appraise boron resources and their mode of occurrence in response to the increasing use of that commodity in fuels. Branch geochemists participated in five exploration projects in 1957–58. They developed new methods for rapid analyses, in field and laboratory, to determine concentrations of mercury and tin in soils and rocks. They also perfected a new and more accurate technique for determining lead and zinc, when those occurrences were masked by interfering elements, and significantly improved the field spectroscope's accuracy and precision.

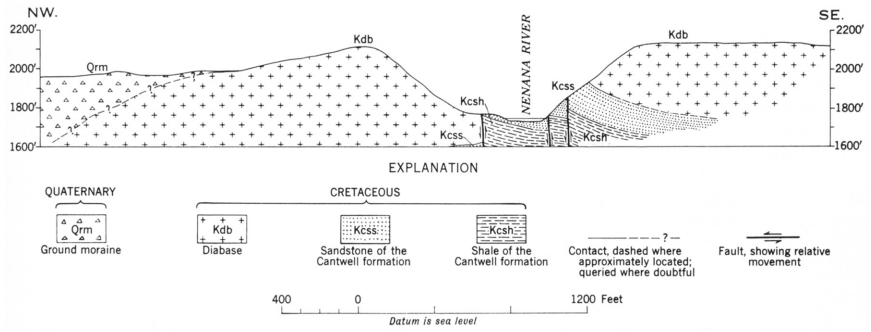
Members of the Trace Elements Planning and Coordination Office, led by Vincent McKelvey, completed more than 20,000 analyses during fiscal year 1957–58, but changes in U.S. requirements for uranium and thorium resulted in additional modifications to Anderson's Branch. By 1955, some 800 mines were producing uranium ore from the 12 large and high-grade deposits located on the Colorado Plateau since 1948. Sites near New Mexico's Ambrosia Lake yielded in 1956 additional large deposits, studied by Harry Granger, and other discoveries were made in Wyoming. The AEC began cutting back its guaranteed purchase program in 1956, the Colorado Plateau Project's peak year, when it employed 125 persons. Uranium and thorium were now being produced at more than five times the rate in 1952 and yielded stockpile reserves by 1957 of some 15,000 tons, even though the price for uranium ore remained fixed by the AEC at $31 per ton. In 1957, the AEC froze uranium-ore purchases by refusing to begin new contracts, a decision which led to harder times for miners that did not change significantly until uranium went on the free market in 1966. On May 13, 1958, Nolan and Bradley again revised a Survey order to modify the Mineral Deposits Branch,[207] reflecting the continuing decline of funding by the AEC's Raw Materials Division for the Branch's Colorado Plateau Project and related projects. The changes, effective June 30, ended the Colorado Plateau Project by abolishing the posts of Staff Assistant for Uranium and District Supervisor. By this order, the other District Supervisors became Area Supervisors at the offices at Beltsville in Maryland, Denver, and Menlo Park. Work continued only for the DMEA. By the late 1950s, Alfred Bush noted in his history of the Colorado Plateau Project, studies of uranium-bearing sandstones "in the Black Hills, in the Tertiary basins of Wyoming, and in the Texas Gulf Coastal area showed, as in the Colorado Plateau region, that the deposits lacked a consistent pattern of geologic relations and geologic history, such as might be expected if the deposits had a common hydrothermal origin."[208] Ideas on their genesis now favored a groundwater origin, as proposed for foreign deposits. Lorin Stieff and Thomas Stern's radiometric determinations of their age, originally thought to be Late Cretaceous-early Tertiary, indicated that they were older and that they had formed nearer the time when their sandstone hosts were deposited.

Work in two Branches—William Pecora's Geochemistry and Petrology and James Balsley's Geophysics—supported efforts in mineral-deposits investigations as well as advancing their specific responsibilities in their own programs and operations in fiscal year 1957–58. Members of Pecora's Branch completed nearly 22,000 analyses and determinations by chemical, mineralogical, radiometric, spectrographic, and X-ray methods and prepared some 16,000 thin sections. Lead-alpha

radiometry provided new geologic ages for granites in New England and batholiths in Western States and in Alaska. Brian J. Skinner, who shifted from the University of Adelaide to the USGS in 1958, developed a technique that linked a precision-controlled furnace with an X-ray diffractometer to determine the behavior of minerals at temperatures as high as 1,000 degrees centigrade to yield clues to their formation. In related laboratory and field studies, scientists continued to seek an improved understanding of the origins of deposits of boron, iron, phosphate, uranium, vanadium, and zinc ores. The 15 projects underway in Balsley's Geophysics Branch involved continuing aerial and ground magnetic and radioactivity surveys. These efforts included a 1:24,000 aeromagnetic survey over the Grace Mine, near Morgantown in Berks County, Pennsylvania, by Bill Bromery and his team, and aeromagnetic and ground surveys of two areas in New Mexico that showed potential for mineral fuels. Induced-polarization measurements indicated that the grades of some copper ores could be determined at mine faces. During the year, the Geophysics Branch published 27 aeromagnetic maps based on its surveys.

In 1957, James Gilluly left the General Geology Branch to succeed Ralph Miller as Chief of the Fuels Branch. Miller, who led the Branch from 1951, also chaired the Interdivision Committee on Photogrammetric Techniques for Geology during 1955–56. In November 1957, Miller began a year's detail to the Foreign Geology Branch to help the ICA prepare petroleum legislation for Afghanistan. At home, the United States had been a net importer of oil since 1953, and searches for new domestic sources continued nationwide. To support this effort, Branch geologists mapped and made stratigraphic studies in 29 States that were producing oil or that had significant potential for future production; six of the studies were conducted in cooperation with State agencies. They correlated Devonian shales in New York to aid exploration for oil and gas in the northern Appalachians. In Wyoming, Branch members determined that some overthrust remnants in Wyoming's Wind River Basin were old landslides and showed that Upper Cretaceous black sands marked shorelines, whose deposits commonly held petroleum. They began a stratigraphic study of areas in the southern Appalachians and an evaluation of petroleum possibilities on the Atlantic Coastal Plain and the adjacent Continental Shelf. The Branch's coal specialists investigated areas in 13 States, 5 of which also received assessments of total resources. Branch geologists supported the Interior Department's Long-Range Minerals Program, originally submitted to Congress in June 1957, revised and resubmitted in April 1958, and then approved by the legislators and the President. Interior designed the program to accelerate research and development by the USGS and the USBM as part of an effort to increase the production of copper, lead, zinc, and other commodities hampered by falling prices during the past year and also to provide stabilization payments to distressed producers in the mineral industry to encourage exploration. Using field and photogeologic techniques, Branch geologists completed or began the mapping at 1:24,000 of 16 quadrangles in Arizona, Colorado, Delaware, Idaho, and Texas to aid the USGS National Water Resources Policy Program.

During fiscal year 1957–58, members of Edwin B. Eckel's Engineering Geology Branch continued cooperative mapping in Connecticut, Massachusetts, and Rhode Island, investigations in nine metropolitan areas, and related work in eight more rural locales in Colorado, Montana, and Nebraska. Their research centered on landslides, classified by David Varnes on the basis of material contained and type of movement,[209] and also mudflows and the causes and rates of cliff erosion. For the Federal Housing Administration, Branch members studied several construction sites and conducted a 2-week course in geology for FHA engineers. After the Eisenhower administration began shifting in September 1957 from aboveground to underground nuclear testing at the Nevada Test Site, also the home of the Nuclear Rocket Development Station since 1956, Branch members continued to investigate preshot and postshot geologic conditions.

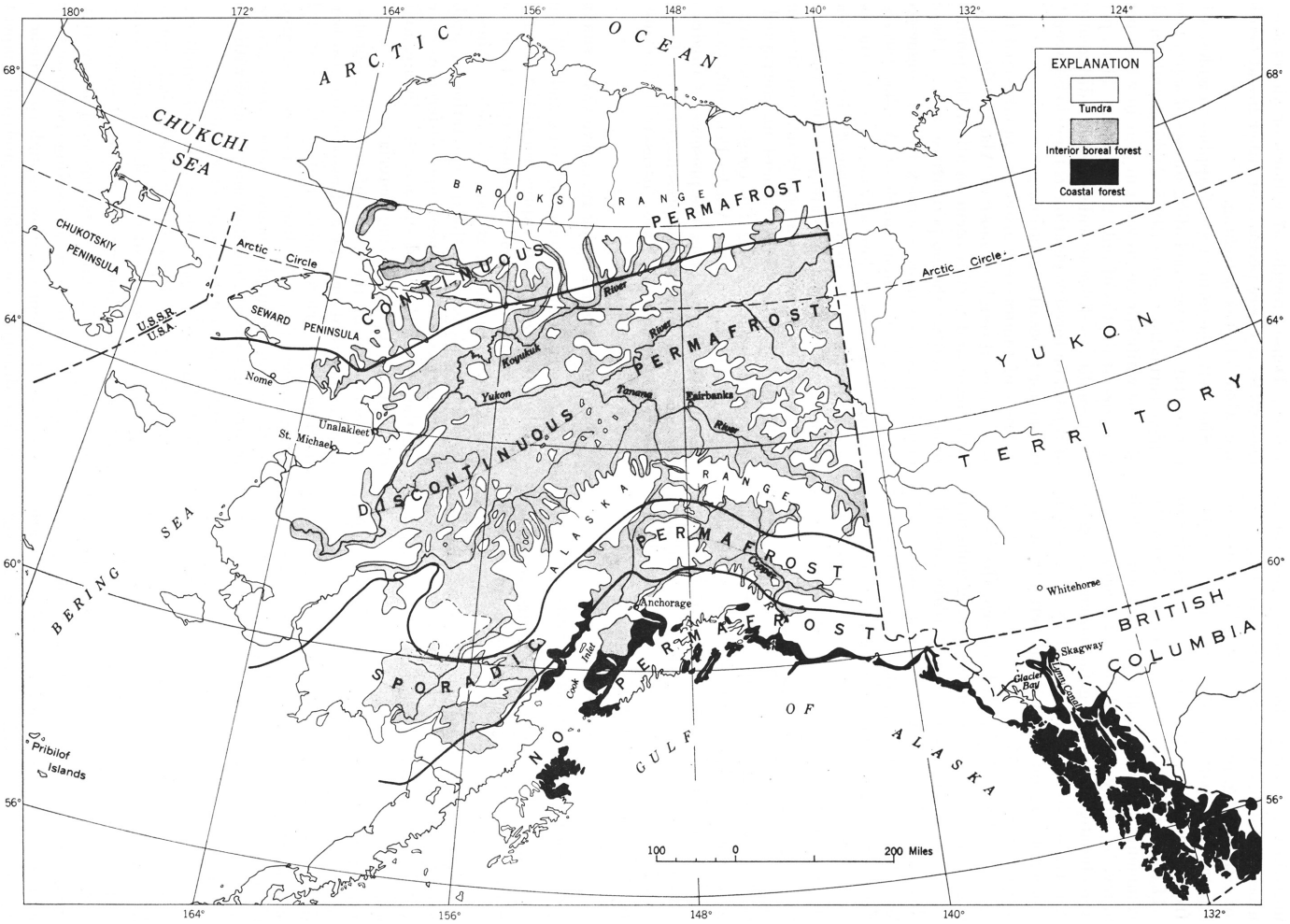


This geologic section (originally at 1 inch = 800 feet) shows a potential site for a dam across the Nenana River at mile 342.0 on the Alaska Railroad, south of Moody, as determined by USGS geologists Clyde Wahrhaftig and Robert Black during field studies in 1947–52; results were published in 1958. Building at this site, in a narrow and fault-controlled gorge of diabase and sandstone, would have required a "dam 200 feet high and 1,000 feet long at its crest" (and realigning 1–1.5 miles of track) that would pond a reservoir having an area of "about 2.5 square miles and a storage capacity of about 80,000 acre feet." The two geologists also mapped geology and studied landslides, icings, and frost heaving and settling and their effects on the maintenance of the track bed as part of engineering investigations between miles 322 and 385 of the Alaska Railroad. The railroad linked Anchorage and Fairbanks and also served adjacent coal fields, gold fields, and Mt. McKinley (now Denali) National Park. The railroad had been damaged and traffic delayed by landslides following the central Alaska earthquake on October 16, 1947. The geologists' work formed a part of USGS studies of the Quaternary and engineering geology of the central Alaska Range, particularly the Nenana River Valley and adjacent areas. (Geologic section and quotations from Wahrhaftig and Black, 1958, fig. 58, and p. 114; see also Wahrhaftig, 1958.)

Managerial changes also occurred in two other Branches in the Geologic Division during fiscal year 1957–58. J. Fred Smith, Jr., a veteran of studies of strategic minerals and of military and regional geology with the USGS since 1942, replaced James Gilluly as Chief of the General Geology Branch in December 1957. Preston Cloud, Jr., returned to the USGS on July 14, 1957, after taking 1,200 hours of leave without pay for non-USGS work in Europe, and resumed his former post as Chief of the Paleontology and Stratigraphy Branch (PSB). Charles W. Merriam, the Acting Chief during Cloud's absence, returned to full-time research. In addition to the PSB members' regular work of examining and reporting on collections referred from other units in the USGS, their research included X-ray studies of magnesium in foraminifer tests as a check on their biological affinities.

In Alaska during 1957, a discovery well along the Kenai Peninsula's Swanson River began producing 900 barrels of oil per day. Secretary Seaton then opened to leasing 20 million acres of public land in the Territory. In 1958, more than 5,000 leases were filed on 28 million acres of public lands in Alaska, especially around Cook Inlet. The Kenai discovery increased ongoing efforts by members of George Gates' Alaskan Geology Branch to assess potential petroleum resources in the Territory, especially in the Iniskin-Tuxedni, Koyukuk, and Nelchina areas, and in the Gulf of Alaska Tertiary Province, whose mollusks and other megafossils Stearns MacNeil continued to study while completing his analysis of those in Cenozoic deposits on the North Slope. Also in fiscal year 1957–58, Branch members continued studies of the Tofty-Eureka gold-tin district and applied field geochemical tests for commodities proved elsewhere to searches in Alaska. They also completed mapping tungsten deposits north of Nome and nearby tin deposits in the western Seward Peninsula. In work for the DMEA, Branch geologists almost finished mapping the deposit that produced uranium and thorium at Bokan Mountain at the south end of Prince of Wales Island. Branch members also conducted geologic and geophysical studies at Cape Thompson for the AEC's Project Plowshare. The Branch's engineering-geology investigations included mapping 100 square miles of surficial deposits near Fairbanks and some 80 square miles along the Alaska Railroad, surveying sites to aid the planning for dams proposed by the USBR for Devil Canyon and Denali, and mapping bridge sites along the highway from Nenana to Mt. McKinley (Denali) National Park for the Bureau of Public Roads. Geologists in the Alaskan Geology and Mineral Deposits Branches, joined by some of their colleagues elsewhere in the Geologic Division, mapped 2,200 square miles in 20 areas in the Territory and in Colorado, Montana, and other States for the Long-Range Minerals Program. The Division aimed this work at developing regional patterns of mineralization as guides to future exploration for mineral commodities in short supply but essential to national security. The Juneau (B–3) sheet by Fred Barker was issued in 1957 as GQ–100; it began the published 1:63,360 coverage of Alaska in the Geologic Quadrangle (GQ) Map series.

During fiscal year 1957–58, members of Frank Whitmore's Military Geology Branch continued or completed work, principally for the Army Engineers,



USGS botanist Robert S. Sigafoos compiled this map (originally at about 1 inch = 180 miles) of Alaska and part of Canada to show the distribution of areas of no permafrost; sporadic, discontinuous, or continuous permafrost; and coastal forest, interior boreal forest, and tundra. "Treeless areas [shown] are predominantly tundra but also include exposed bedrock, glaciers, sand dunes, and grasslands." USGS geologist David Hopkins and 10 geologists and geobotanists in the agency studied how the effects of groundwater and permafrost on each other influenced their distribution in Alaska. They found that "local differences in topography, lithology, and drainage result[ed] in sharp local differences in the character and distribution of permafrost that tend[ed] to obscure the regional zonation." Permafrost's distribution pattern, based on interpretations of aerial photographs and checked by ground observations, they concluded, was "not exclusively the product of present-day climates." The "poor relationship between surface manifestations and underlying permafrost" prevented them from constructing reliable keys for photointerpreting permafrost." (Map and quotations from Hopkins and others, 1955, fig. 11 and caption, and p. 113.)

in Alaska Territory and in California, Georgia, New York, and other States. Roy C. Kepferle, who joined the Fuels Branch in 1950 and transferred to the MGB in 1956, applied punch-card computer techniques to retrieving literature from the MGB's library. Other MGB members completed and sent to the Army Engineers a terrain study of Alaska's Big Delta area. They also cooperated with permafrost specialists from the USAF's Cambridge Research Center and the IGY's glaciological program in studies by Charles Lewis along the Arctic Coast near Barter Island, east of Camden Bay, and adjacent land areas south of the Beaufort Sea.[210] Simeon Muller reported on permafrost conditions and related problems at Ladd Field and elsewhere in the Fairbanks area, Galena on the Yukon River, Kotzebue, and Point Barrow, while Arthur Lachenbruch described three-dimensional heat conduction in permafrost beneath buildings in several areas and developed a probe for measuring in place the thermal conductivity of permafrost.[211] Lachenbruch and Max C. Brewer, who joined the USGS full time in 1950 and began directing research at the Naval Arctic Research Laboratory in 1956, studied the dissipation of the thermal effect in drilling wells in Arctic Alaska. Oscar J. Ferrians and Henry Coulter finished a 1:5,000,000 slope map of Alaska and northwestern Canada, with larger scale insets for Forts Greely and Churchill, as MGB Miscellaneous Paper 137.

Whitmore's military geologists also completed several Engineer Intelligence Studies (EIS) during 1957–58. For EIS 274, they analyzed the geology, terrain, construction materials, mineral and water resources, permafrost, soils, underground structures, and related aspects of the Yukon Flats district, Alaska. MGB members, in cooperation with their colleagues from the Army Engineers' Beach

Erosion Board and Engineer Detachment (Terrain) 517 in Washington, completed, as EIS 141, a "Terrain Study of Monterey-Estero Bays Area" in central California, with maps at 1:50,000. EIS 141 summarized information about possible airborne operations, existing airfields and potential sites, bridges, climate, coast and landing beaches, drainage, electric power, fuels, landforms, natural construction materials, railroads, roads, stream bank and bottom materials, surface-water and groundwater resources, terrain, trafficability, and urban areas; it was illustrated by ground photographs, maps at 1:50,000 and 1:250,000, and other graphics. For EIS 180, geologists analyzed the terrain in the 6th Army's area in the Western States. EIS 210 depicted, at 1:25,000, the military geology of the area in New York around West Point. EIS 211, "Military Geology of the Fort Benning, Ga. Area," printed by the Army Map Service in June 1959, depicted the area at 1:25,000 on 10 topographic quadrangles (Series V 845) that included those for Forts Benning and Mitchell. That report also contained a general index map at 1:100,000, Fort Benning and seven of the other 1:25,000 topographic quadrangles in shaded relief, terrain at 1:100,000, general geology and engineering geology at 1:100,000, geology with engineering data at 1:25,000 for Fort Benning and seven other quadrangles, water resources at 1:100,000, and surficial soils at 1:100,000 and 1:25,000.

Abroad, MGB members continued to aid the work of the Army Engineers and the Air Force in Greenland, Latin America, Germany, Africa, Asia, and the Pacific. Their worldwide summary, at 1:60,000,000, reported generalized conditions for cross-country movement by tanks. William Davies, Stanley Needleman, and Donald W. Klick examined and mapped, at 1:165,000, ice-free areas near Greenland's Polaris Promontory tested as landing sites in the 1958 continuation of the Air Force's Operation Groundhog. Mario Conti and Jules D. Friedman completed a geomorphic map of Brazil at 1:5,000,000. Botanist Raymond Fosberg spent March and April 1958 in a study of terrain and vegetation in Colombia. George Rozanski finished a hydrologic map of Honduras at 1:1,000,000 and, at the same scale, a similar map of Ethiopia-Somalia. Frederick Betz's team in Europe compiled geologic data about airfields and oil-shale deposits in Germany. Three reports included maps at 1:5,000,000 or 1:5,500,000 of the Middle East and summarized the region's water resources (EIS 183), cross-country movement (EIS 208), and the suitability of areas for airborne operations and airfield construction (EIS 231). EIS 214 contained the results of terrain studies of Afghanistan. Jack Rachlin studied cross-country movement in and the construction materials and water resources of the area around Lampang in Thailand that contained significant deposits of copper, iron, and lead. George S. Corchary completed a wide-ranging geological reconnaissance of South Korea. Gilbert Corwin discussed intelligence methods used in the Pacific Geologic Mapping Program, EIS 257 summarized the MGB's knowledge of vegetation in Micronesia (with a map at 1:20,000,000), and a Special Report described seismic activity in the Mariana Islands.[212]

Geologists in William Johnston's Branch of Foreign Geology during 1957–58 participated, with local colleagues and with ICA aid, in economic-mineral and other investigations, and in education programs, in Afghanistan, Brazil, Chile, the Republic of China, Ghana, India (where oil was discovered in 1 of its 26 sedimentary basins), Indonesia, Iran, the Republic of Korea, Libya, Mexico, Pakistan, Peru, the Philippines, Saudi Arabia, Thailand, and Turkey. More than 70 participants, from 24 countries and sponsored by the AEC, the ICA, and the U.N.'s Eisenhower Fellowship Program, were trained in photogeologic and other field and laboratory techniques in the USGS domestic programs and also at U.S. universities. Three principal field projects continued in Brazil. John Dorr 2d, aided by Joel Pomerene, Arthur Rynearson, Norman Herz, Charles H. Maxwell, Samuel Moore, Robert G.L. Reeves, and George C. Simmons, investigated Minas Gerais iron deposits. Donald D. Haynes, who served with the Colorado Plateau Project during 1952–56, John J. ("Rod") Matzko, who earlier participated in USGS radioactivity investigations in

Alaska, Charles Pierson, and Max White studied the uranium occurrences in Brazil. Alfred J. Bodenlos, Robert Johnson, who previously worked in Peru, and Jacques F. Robertson studied base metals in Brazil. Harold Bannerman spent April–June 1958 advancing the education of Brazil's student geologists. George Ericksen, assisted by William D. Carter, Russell Gibson, Samuel Moore, and Kenneth Segerstrom, continued mineral-resources investigations in Chile. Frank Simons and John Straczek summarized in 1958 the results of USGS investigations of Cuba's manganese deposits during November 1940–September 1945.

In the Eastern Hemisphere, Gus Goudarzi and James L. Gualtieri advanced the USGS geologic mapping of Libya. Glen Brown and geologists and topographers in the USGS and Aramco, with the continuing sponsorship of the U.S. State Department and Saudi Arabia's Ministry of Petroleum and Mineral Resources, continued compiling the bilingual 1:500,000 geographic and geologic quadrangles as aids in planning any future Kingdom-wide program of exploration and development. Brown also continued providing advice about water resources to the Saudi Ministry of Agriculture and Water. From October 1957 through June 1960, John Albers contributed to institutional development in India, while Paul W. Richards studied mineral deposits and also advised the director of the national geological survey. Walter Danilchik, who served with the Fuels Branch during 1951–57, spent January–June 1958 aiding institutional development in Pakistan, while Richard Bogue continued mineral investigations there during April–June. David Andrews continued to lead mineral-resource studies in Indonesia, assisted by Raymond Becker, Robert Johnson, and Howard Weeks. Darwin Rossman and James F. Harrington investigated selected mineral deposits in the Philippines, while David Cerkel, Jr., continued to look for evidence there that might lead to new oil deposits.

South Korea's President Rhee avidly sought to base a steel industry on his country's domestic deposits of iron ore, but those known were too small and too low in grade. David Gallagher returned to South Korea during July–December 1957, and William Johnston also sent there geophysicist Robert B. Hall, who earlier operated a tripod-mounted Askania magnetometer in Harold James' Michigan Iron Project and served on one flight with James Balsley's airborne-magnetometer team. Aero Service Corporation personnel flew an aeromagnetic survey over a large portion of South Korea, and Gallagher interpreted the data. Hall's ground-magnetic traverses checked the more promising anomalies on Aero Service's map in the northeast corner of the country near the demilitarized zone. He found there, in granite gneiss, local concentrations of magnetite grains whose iron grade did not exceed 15 percent in the richest zones, too low to be considered economic. South Korea later imported ore from Australia and the Philippines to make steel at a plant near the port of Ulsan. The MGB also completed relief-map coverage of South Korea at 1:150,000 in 1957.

In 1958, the NSF received two supplemental appropriations for the IGY—$2 million on March 28 and $2.5 million on August 27—both of which would be available until June 30, 1960. The NSF provided $1.9 million for U.S. IGY Antarctic programs during 1957–58. During the austral summer, the Navy deployed three of its icebreakers, *Atka, Glacier* (flag), and *Staten Island*; the Coast Guard's *Westwind*; and seven other ships in Operation Deep Freeze III to support IGY and other activities on and off Antarctica. As in 1956–57, Rear Admiral George Dufek led the operation as commander of the Naval Support Force Antarctica and the Antarctic Projects Officer; Gerald L. Ketchum directed Task Force 43, accompanied by geologist Laurence Gould, who continued to chair the U.S. IGY Committee's Antarctic group.[213] Albert Crary led U.S. IGY activities on the continent. Two members of the USGS returned for a second year's service in Antarctica. John Behrendt's geophysical survey covered the Filchner and Ronne Ice Shelves and the Dufek Massif in the Pensacola Mountains.[214] Walter Boyd, Jr., operating from Little America V, ran a glaciological and seismic traverse across Marie Byrd Land and the Ross Ice

Shelf. The Geologic Division's Troy Péwé and Norman R. Rivard examined the geology around Lake Fryxell, named for Péwé's professor at Augustana, in the McMurdo Dry Valleys. On the Filchner Ice Shelf, between Berkner Island and the Luitpold Coast, and in the Pensacola Mountains, inland from the Ronne Ice Shelf, William H. Chapman tested the Topographic Division's new electronic equipment and methods for establishing map-control points.[215] From the Ellsworth Station, personnel in two ski-equipped C–47s tested another new electronic-positioning system by surveying a large area out to a radius of some 400 miles. U.S. aircraft stopped dropping claim markers on October 23, 1957, 8 days after the initial commercial flight from Christchurch in New Zealand landed at McMurdo.

Representatives of Argentina, Australia, Belgium, Britain, France, Japan, Norway, the Soviet Union, and the United States attended the first meeting of the ICSU's SCAR, held during February 3–5, 1958, at The Hague in the Netherlands. During the austral summer, a British IGY party collected rock specimens for paleomagnetic studies from 60 sites on Powell Island and adjacent islands in the South Orkneys, and a Soviet tractor-borne group operating from the Mirnyy Station reached the Pole of Inaccessibility. On March 2, British explorers Vivian Fuchs and Edmund Hillary, and their multinational team, completed a 99-day, trans-Antarctic passage on tracked vehicles via the Amundsen-Scott Station at the South Pole. To try to reach a more important goal for Antarctica, on May 2, the U.S. State Department invited representatives from Argentina, Australia, Belgium, Chile, France, Japan, New Zealand, Norway, South Africa, the Soviet Union, and the United Kingdom to participate in a Conference on Antarctica, to be held in Washington in June, to begin discussions aimed at securing a multinational treaty.

During fiscal year 1957–58, the Topographic Division received $18,318,000, which was $1.25 million more than in 1956–57. That monetary gain came principally from a SIR appropriation of more than $14,242,000, or 78 percent of the Division's total funds and an increase of nearly $1,370,000 from the amount available in 1956–57. Other Federal agencies transferred to the Division about $2,106,000, about $351,000 less than in the previous year. The USBR provided $1,169,000, a $98,000 increase, but the Air Force and the Army shifted only $798,900, or a loss of $399,000. Nonfederal sources reimbursed or directly paid the USGS more than $1,969,000, of which $1,765,000, a gain of almost $211,000, came from the States and their political subdivisions. Technological improvements enabled the Division to decrease by $107,000 its expenditures on the mapping of all standard topographic quadrangles. As Nolan told Kirwan, the per-person-year cost of topographic mapping increased by $1,800 during 1947–57. In the same interval, the per-square-mile cost of mapping decreased by $47 to $124 or $88 after allowing for price-index increases. Salaries rose by more than 50 percent in those 10 years, but average reproduction costs per edition fell.

Gerald FitzGerald retired as Chief Topographic Engineer on September 30, 1957. On the following day, George Whitmore, the Deputy CTE and "Supervisory Cartographer," became the CTE and the Chief of the Topographic Division. When the Civil Service Commission approved the position-classification standards for the Cartographer series on November 25, George Whitmore began changing the Division to an engineer-technician unit. Trying to ensure continuing high standards in hiring and operations, the Division developed a training program for engineering students and a career-development program for graduate engineers. By May 21, 1958, Nolan and Whitmore completed the reorganization of Topographic Division headquarters begun in 1957, and it went into effect in fiscal year 1958–59. No one immediately succeeded Whitmore as Deputy CTE, but the position would later be renamed "Associate Chief," and Earle Fennell would fill it in 1961. Until then, Assistant CTE Fennell led Program Development and supervised two Branches—John Davidson's Program Planning and Franklin Mann's Program

USGS topographic engineer and photogrammetrist George Dewey Whitmore (1898–1981) worked for R.H. Randall and Company (1917–32) and the Planning Commission of Toledo, Ohio (1932–33), before joining the Tennessee Valley Authority. In the TVA, Whitmore rose to lead the Maps and Surveys Division's Surveys Section; from 1943, he also served as the Division's Assistant Chief, responsible for all war-related activities. Whitmore transferred to the USGS in 1946 as Chief of the Topographic Branch's Research and Technical Control Division. After a year as Deputy Chief Topographic Engineer, he succeeded Gerald FitzGerald as Chief of the Topographic Division in 1957. Whitmore continued to promote the Orthophotoscope and other photogrammetric improvements that he hoped would help USGS topographers to complete two programs—the national topographic coverage, due before 1976, and, resurveys at 1:24,000 of all of the included 1:62,500 maps, except for Alaska, due by 1980. Whitmore also guided the Division's reconnaissance-scale mapping in Antarctica and its contributions to satellite imagery. Whitmore retired in 1967. (Photograph from the USGS Denver Library Photographic Collection, Portraits, in the "Whitmore, George D.," folder as Public Inquiries Office 75–75 [1a]; see also Thompson, 1983.)

Control and Analysis—and Jerome Kilmartin's Map Information Office. Assistant CTE Roland Moore led Research and Technical Standards and supervised four Branches—Russell Bean's Research and Design; Charles H. Buckley's Field Surveys; Photogrammetry, where Harold J. McMillen succeeded Bean; and a renamed Cartography, temporarily vacant after Charles Fuechsel's transfer. Whitmore's office also included an Assistant to the Chief Topographic Engineer and Division Officers for Administration and for Training. The Branch of Special Maps, now under M. Kerwin Linck after Davidson's shift, continued to report to Whitmore, who, with Fennell, Linck, and others, began to reevaluate the Branch's functions and organization as it neared the end of compiling aeronautical charts for the Air Force. Division members continued a 3-year study, begun by Robert O. Maxson's Map Use Research Section, of how the Division's maps were used by government agencies and the public, as well as by internal groups.

The Topographic Division's reorganization retained its four geographical field areas, each under a Region Engineer: Fuechsel's Atlantic, at Arlington; Daniel Kennedy's Central, at Rolla; James Lawson's Rocky Mountain, at Denver; and Robert O. Davis' Pacific, at Sacramento. Each Region Engineer's headquarters office contained an Assistant Region Engineer and five Sections—Cartography, Field Surveys, Plans and Production, Photogrammetry, and Administrative Services. In addition, an Alaska District Engineer resided at Fairbanks. Engineers directed the Hawaii Project from Honolulu and the Puerto Rico Project, now revising the 1:20,000 coverage, from San Juan.

Nolan and George Whitmore also decided that all future large-scale manuscript maps, except for those for Alaska, would be prepared under 1:24,000-series specifications, although some might be prepared initially at 1:62,500, and then open-filed for immediate use. That choice might enable both series to be produced from the same color-separation materials. Whitmore also continued to chair the U.S. Technical Advisory Committee on Antarctic Mapping. Division specialists also provided information about air-photo coverage and geodetic control to U.S. participants in the IGY. In June 1958, Whitmore's "The Role of Photogrammetry in an 'Open Skies' Program" appeared in *Photogrammetric Engineering* to promote the Division's potential contributions to the Eisenhower administration's continued effort to secure international support for its proposed agreement.[216]

To support mapping operations and products in 1957–58, the Topographic Division let commercial contracts for nearly 106,000 square miles of precision aerial photography and received an additional 14,000 square miles of coverage from the Air Force for defense-related compilations. The Division prepared about 2,900 maps for publication during the year, including new 1:500,000 maps of Colorado, Kentucky, North Carolina, and Utah. The Division completed for printing and distribution some 1,180 new standard topographic quadrangles, nearly 50 others compiled by other agencies, standard maps for 12 urban areas prepared by combining the 1:24,000 coverage in each, 45 special-use maps for other USGS Divisions and 5 other Federal agencies, and the civilian versions of about 360 military maps. The USGS and the Army Engineers agreed to have the USGS, as part of its responsibilities for domestic mapping, maintain the Army Map Service's former 1:250,000 series, and the Map Information Office issued an index to the civilian editions of mapping photography in Alaska by the USAF, the U.S. Navy (USN), and the USGS during 1948–57. The Division also continued cooperative mapping programs with 32 States, of whom Arkansas, Kansas, Minnesota, and Ohio significantly increased their monetary contributions, and new work began in Florida, Oregon, and Texas. The year's new mapping at 1:24,000 in the States depicted almost 60 square miles; another 90 square miles were mapped at 1:62,500.

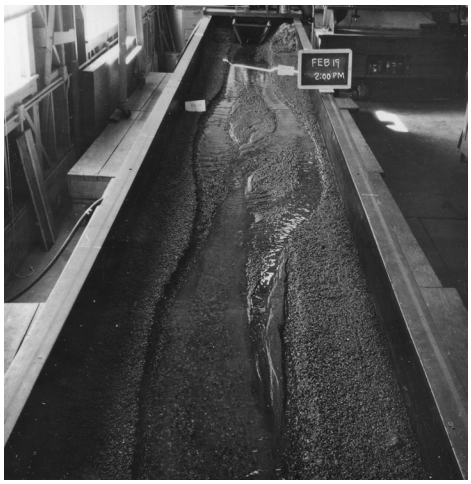
Division members continued or began to test newly developed equipment for field surveys and compiling topographic maps. These devices included improved elevation meters, more precise leveling rods, enhanced alidades and stadia rods,

ground panels, 35-millimeter photographs taken from small aircraft to improve the identification of control points, and electronic digital computers to convert geodetic control to plane coordinates on a production basis. Efforts were made to program analytical aerotriangulation by the direct geodetic restraint method. Testing continued on a new automatic-dodging contact printer that used infrared light to quench ultraviolet; a contract was let to test this technique on projection printers. James Buckmaster, Atherton H. Mears, and others improved instrumentation for altimetry. The Orthophotoscope was redesigned again, and orthophotographic mosaics were checked in the field. In cooperation with the Lincoln Laboratory at the Massachusetts Institute of Technology (MIT), Division specialists tested the Lincoln Raydist system's accuracy in determining the spacing of air-photo images. Division members also developed plans for the unit's initial analytical plotter.

The Division's Map Information Office published new editions of index maps showing the status of topographic mapping, aerial photography and aerial mosaics in the conterminous United States; all three were in the format for the ongoing U.S. national atlas. The Office continued to serve as the central repository for maps produced by this second program designed to produce a new and comprehensive atlas. In 1952, the American Geographical Society, with financial support from the American Council of Learned Societies and guidance from Samuel W. Boggs, the State Department's Geographer, completed a prototype atlas. Ten major publishers agreed not to print the volume and referred the responsibility for the compilation and production of a final version to the Federal Government. At the recommendation of the Association of American Geographers, the NAS–NRC established late in 1954 an interagency Committee on the National Atlas of the United States, chaired by Carleton S. Barnes, the Agriculture Department's Geographer. The new Committee included representatives from the USGS and 11 other Federal mapping agencies. The NAS–NRC asked its interagency Committee "to draft basic specifications and to coordinate the cartographic work of those agencies so that maps they normally made for other purposes could be accumulated as a looseleaf collection that would eventually become the national atlas."[217] As part of the second pilot program, the cooperating agencies began producing thematic sheets, using the standards specified by the Committee, and sent them to the USGS Map Information Office. During 1957–58, Federal agencies deposited 42 additional sheets for the atlas.

While continuing to provide technical assistance abroad, members of the Topographic Division extensively trained three civil engineers from Iceland and conducted briefer courses for cartographers from Brazil and the Sudan and a photogrammetrist from Thailand. Representatives of the Division traveled to a meeting in Tehran in October 1957 to promote Topographic Mapping for Economic Development. Other Division personnel compiled a report on U.S. cartographic activities between fiscal years 1954–55 and 1956–57 for presentation at the 8th Pan American Consultation on Cartography held in Havana in February 1958, the same month that the 1st Symposium on Natural Resources in Cuba convened in that city.

During fiscal year 1957–58, Luna Leopold's Water Resources Division accrued $20,902,000, nearly $3 million more than the total it received in 1956–57. The Division's SIR funds rose by $2 million to $10,516,000, or 51 percent of the total, but $5.8 million of that sum could be used only for cooperative investigations with States, counties, and municipalities. The States and their political subdivisions reimbursed or directly paid $5,830,000 to the Division, a gain of nearly $697,000 and a total to which California, Texas, New York, Florida, and New Mexico, in that order, were the principal contributors. Other Federal agencies transferred more than $4,289,000, an increase of $198,000 and including nearly $1,528,000 from the Army and its Engineers and about $362,000 from the Agriculture Department. Funds from the USBR, the ICA, and the AEC fell by a total of almost $75,000.



Luna Leopold developed this braided channel (above) in sand beds in three flume-river runs at a Caltech laboratory during 22 hours on February 19, 1954, as part of a multiyear study with M. Gordon Wolman (Abel Wolman's son) of braided, meandering, and straight rivers and creeks in the American West. The surface pattern and cross sections proved similar to those in Horse Creek (at right) near Daniel in Sublette County, Wyoming. A run in March 1954 duplicated dunes in fine sediments. These experiments showed "that at a given grain size, shear velocity is not the sole determinant of bed transport." Wolman joined Johns Hopkins University's faculty in 1958, but he continued part time with the USGS. (Quotation from Leopold and Wolman, 1957, fig. 52 caption. Braided-channel photograph (at left) from the USGS Denver Library Photographic Collection as Leopold, L.B., llb00081, https://www.sciencebase.gov/catalog/item/51dd795ae4b0f72b4471adb3; published in Leopold and Wolman, 1957, fig. 35. Horse Creek photograph (at right), ibid., fig. 30; see also Wolman and Leopold, 1957.)

The Division's monies for studies of soil and moisture conservation increased by $36,000 to a total of more than $165,000.

Chief Hydrologist Leopold continued to combine management with research and publication. In Leopold's only major administrative change in the Division during fiscal year 1957–58, Philip LaMoreaux, District Geologist of Alabama since 1945, succeeded Henry Beckman as Mid-Continent Regional Hydrologist in March 1958. LaMoreaux moved the regional office from Rolla to Tuscaloosa. Leopold established a career-development program for the Division while investigating major issues. In 1956, Leopold and civil engineer James P. Miller, Director of the University of Pittsburgh's Water Resource Engineering Program, published their analysis of hydraulic factors of ephemeral streams and their relation to the drainage net. Two related publications by Leopold appeared in 1957—one on the braided, meandering, and straight patterns of river channels, and the other about the formation of flood plains—both coauthored by M. Gordon ("Reds") Wolman, Abel Wolman's son, who joined the USGS in 1951. Gordon Wolman also began chairing Johns Hopkins' Department of Geography in 1958, the year Leopold briefly discussed water's role in the conservation movement. Stanley A. Schumm completed a longer analysis of the relations between the shapes of alluvial channels and their transported sediment, and he advanced his study of how different types of sediment influenced erosion and deposition in ephemeral-stream channels. In May, the U.S. Inter-Agency Committee on Water Resources' Subcommittee on Evaluation Standards began revising its report on proposed practices for economic analysis of river-basin projects; the subcommittee's recommendations appeared in 1959.

Members of Joseph Wells' Surface Water Branch during fiscal year 1957–58 operated some 7,000 gaging stations in the 48 States, Alaska, Hawaii, Guam, and Puerto Rico, in cooperation with 205 State, municipal, and Federal agencies that

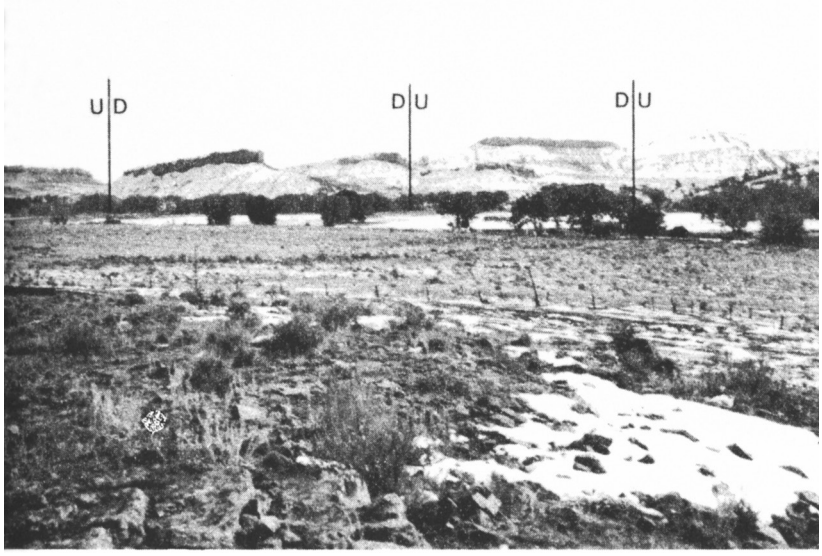
also included the FPC, the State Department, and the TVA. Branch members, aided by Walter Langbein and others, began appraising the national network to improve the comprehensive and systematic collection of streamflow data. As the compilation of records for 1888–1950 reached 89 percent of completion, the Branch published reports for Alaska and for the Ohio River Basin and the Missouri River Basin. Work continued on the nationwide study of regional flood frequency, and State reports were open-filed as they were completed, but reports on major floods continued to appear as Water-Supply Papers. For the Soil Conservation Service, Branch members conducted rainfall-runoff investigations of maximum annual floods in 49 larger drainage basins and runoff studies of such floods in 630 smaller basins, those having areas of 400 square miles or less.

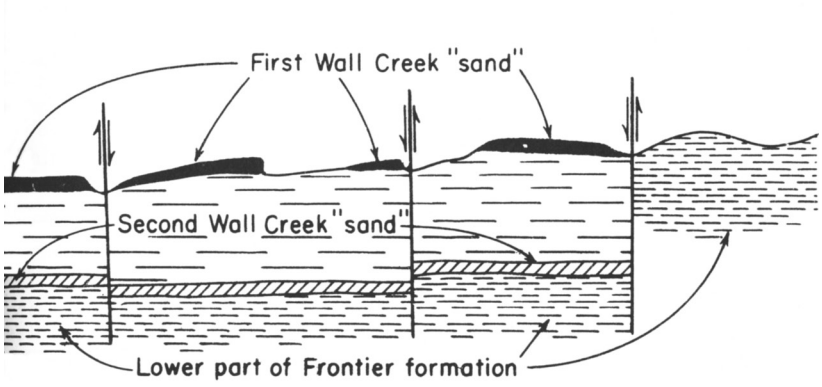
Members of Nelson Sayre's Ground Water Branch pursued some 600 investigations during fiscal year 1957–58, four-fifths of which were in cooperation with State and local agencies in 44 States, Alaska, Hawaii, Guam, Puerto Rico, and the U.S. Virgin Islands. Branch members continued to concentrate on developing a better understanding of the occurrence and movement of groundwater in various geohydrologic environments, including those of the Nevada Test Site. In November 1957, about 2 months after the Rainier test, Alfred Clebsch, Jr., began a 3-month study of the 1,400 square miles in the NTS and surrounding areas aimed at formulating a plan to determine the possibility of groundwater contamination from the Logan and Blanca tests scheduled for 1958 and others in the future. A committee of six USGS geologists and hydrologists—Edwin B. Eckel, Stanley Lohman, Arthur Piper (who advised the AEC during the NTS' atmospheric tests), Charles Read, Charles Theis, and Harold Thomas—approved Clebsch's plan. Operations based in Las Vegas began early in 1958, and geohydrologist Isaac J. ("Ike") Winograd joined Clebsch and geochemist Francis B. Barker that July. Data from water samples, including those from AEC tunnels, extended existing and subsequent information from geologic mapping, effects of the explosions on the containing rock, studies of heat flow and geochemistry, and gravity and seismic surveys. Clebsch, Barker, and Winograd initially reported their data and interpretations to the AEC as trace-element investigations in the USGS series of Open-File Reports. Other specific studies by Branch members included inventories of drawdowns of water supplies and areal fluctuations of water levels as read in observation wells. Thomas Robinson published a comprehensive catalog of phreatophytes and estimates of the amounts of water consumed by these plants.

During fiscal year 1957–58, members of Kenneth Love's Quality of Water Branch collected data on the chemical quality of water at some 550 stations nationwide. Branch members also gathered information about the sources, quantity, and movement of waterborne sediment at about 220 locations, and they made continuous, daily, weekly, or monthly observations of water temperature at more than 600 sites. Branch members continued to establish criteria for a national network of water-quality stations. They also began a worldwide study of major contributions of dissolved solids carried from the lands to the oceans, including the potential use of tritium as a tracer and age determiner. Publications by Branch specialists included a study of uranium and radium in groundwater on the Llano Estacado of New Mexico and Texas; the chemical character of public water supplies in Alaska, Hawaii, and Puerto Rico; the chemistry of iron in natural waters; a primer on the study and interpretation of water analyses; and hydrologic and tracer studies of New York's Mohawk River at the Knolls Atomic Power Laboratory.

Among special investigations conducted during fiscal year 1957–58, members of Charles McDonald's General Hydrology Branch and some of their colleagues from the Division's other Branches began a study of the hydrology of the Colorado River above Lees Ferry, Arizona, that involved the occurrence, use, availability, and chemical quality of surface water and groundwater and the relations between them. This project mirrored the ongoing investigation, in cooperation with the

Army Engineers, of the Delaware River Basin. Other studies were finished on the copper and petroleum industries' water requirements, and one was begun on the steel industry. Summary studies initiated for urban water resources included those for Los Angeles; Springfield, Massachusetts; and Syracuse, New York. Those for States involved Arizona, Georgia, Oklahoma, Oregon, and Rhode Island. Reports were published for North Carolina's Neuse and Yadkin-Pee Dee River Basins. Branch hydrologists G. Earl Harbeck, Jr., and Gordon E. Koberg; Max A. Kohler, the U.S. Weather Service's Chief Hydrologist since 1952; and their colleagues in the USBR and the Navy's Bureau of Ships and its Electronic Laboratory published their investigation of water loss by evaporation from Lake Mead during March 1952–September 1953. Using measuring techniques developed at Oklahoma's Lake Hefner, and published in 1954, they reported a water loss during the 1953 water year of 875,000 acre-feet. Continuing and wide-ranging investigations of water in its natural solid state by the USGS ended with the death of François Matthes in 1948. To resume that work, the Division placed Mark Meier on full-time status to continue his earlier part-time studies of the mechanics and hydraulics of glaciers, especially those in the northern Cascades, ice melting and runoff precipitation, and the responses of glaciers to climate change, all aimed at understanding how they affected water supply. As part of ongoing work on soil and moisture conservation, Division members also investigated the water supplies of grazing areas in California, Idaho, Nevada, and Utah. They also studied runoff and sediment yields for public-land reservoirs in Arizona, Colorado, Montana, New Mexico, Utah, and Wyoming, and the effects of water spreading on water yield and sediment movement in the Cheyenne River Basin.





This photograph (above), taken from the road between Kaycee and Barnum in southern Johnson County, Wyoming, looks southeast toward the bluffs beyond the Powder River. The upper Wall Creek Sandstone Member (the first Wall Creek "sand" of water-well drillers) of the Frontier Formation (Cretaceous) forms the dark-colored ledges on the skyline. The formation's lower shales form the snow-covered rocks in the foreground. The three normal faults depicted in the photograph and in the geologic section (below) display vertical displacements of 300 to 500 feet; D (down) and U (up) represent relative motion along the fault planes. As part of the Interior Department's program for developing the Missouri River Basin, the U.S. Bureau of Reclamation proposed building a dam about 12 miles west of Kaycee (scene of the Johnson County "war" of 1892) and extending the Sahara Canal to irrigate 10,000 additional acres principally for use by the area's cattle industry. During July–October 1950, USGS geohydrologists Francis A. Kohout and Francis A. Koopman mapped (at 1:24,000) the surficial geology of 320 square miles in the area of the Powder River's Middle and North Forks and sampled water from 88 springs and wells in the region. USGS hydrologist Donald A. Warner concluded "that an adequate supply of water could not be obtained from the [three] Wall Creek 'sands.'" Water from these sands also "would require considerable treatment to make it satisfactory for domestic use." (Quotations of Warner's conclusions, photograph, and geologic section from Kohout, 1957, p. 346 and fig. 49; see also Hembree and others, 1952.)

Under Leopold's leadership, the Water Resources Division expanded its activities in research and development in fiscal year 1957–58. Division members investigated the nature of water movement through sand and other porous and permeable material, the mechanism and extent of saltwater encroachment and contamination in areas where excessive pumping or related factors upset the land-ocean hydrologic balance, water flow near river mouths where tides reversed flow direction, water-sediment relations in laboratory flumes to improve mathematically based descriptions of flow conditions, the chemical source and form of dissolved iron, the downstream effects of land conservation on water quality and quantity, and the effectiveness of using hexadecanol and other thin-surface-film chemicals to suppress evaporation in reservoirs.

The Division also continued providing technical assistance to studies of surface-water and groundwater resources abroad, with some personnel on detail to the ICA, and training local colleagues there or in the United States. During fiscal year 1957–58, Division members participated in investigations and training as part of long-term projects in Afghanistan, Chile, India, Iran, Libya, Pakistan, Peru, and the Philippines. Division hydrologists also spent 3-month intervals in British Guiana, Cambodia, and Turkey. Robert W. Devaul joined Robert Dingman's studies of groundwater in Chile. Chase Tibbitts and Robert C. Vorhis, aided by James R. Jones, assessed groundwater resources in Libya. John A. Baumgartner conducted similar investigations in Iran, as did Edward Bradley and P. Eldon Dennis in Iraq. F.D. Bertleson, Robert L. Cushman, Raymond Kiser, and George LaRocque, Jr., assisted personnel from the Army Engineers' Far East District in groundwater studies in Pakistan. Richard Murray and Leonard Snell continued similar work in the Philippines. In the United States, other members of the Division trained visiting specialists from Afghanistan, Chile, the Republic of China, Colombia, Greece, India, Pakistan, the Philippines, Tanganyika (Tanzania), Turkey, and Yugoslavia.

Harold Duncan's Conservation Division received almost $2,367,000 during fiscal year 1957–58, a gain of almost $380,000 over the previous year's total. The $2,225,000 in SIR funds represented an increase of nearly $285,000, while funds from other Federal agencies rose by more than $94,000, to about $139,000. On February 12, 1958, Eisenhower's Executive order transferred to Secretary Seaton responsibility for enforcing the requirements of the Connally "Hot Oil" Act of 1935.[218] Two days later, a Secretarial order shifted to the Conservation Division, effective February 21, four functions from Interior's Office of Oil and Gas in the Administrative Assistant Secretary's Office.[219] The order made the Division responsible for assisting administration, cooperating with States in preventing waste in oil and gas production, adapting uniform oil and gas conservation laws, keeping informed of facts required to exercise responsibilities, and supervising the operations of the Federal Petroleum Board (FPB) in enforcing the requirements of the Connally Act. The FPB, composed of a chairman, a member, and an alternate member, operated from offices in Kilgore, Texas, principally in field-inspection operations in Louisiana, New Mexico, and Texas, and, to lesser degrees, in Arkansas, Kansas, Mississippi, and Oklahoma. During the year, the FPB received monthly reports from about 9,600 producers, 464 pipeline managers, and 71 processors and refiners. Oil-field-operation reports increased by 278 fields, and producing-well summaries rose by 2,437. The FPB's staff monitored 2,826 leases (and visited 1,606 of them) and 5 pipelines, traveled to 483 oil fields, and conducted 1,184 interviews. Fifteen cases of alleged violations were before the FPB at the beginning of 1957–58, and five more began during the year. Court action closed eight cases in 1957–58, yielding fines of nearly $121,000.

In fiscal year 1957–58, members of John Miller's Mineral Classification Branch completed maps and reports on oil and gas fields and areas in Colorado, Utah, and Wyoming; phosphate in the three-corners area of northeastern Nevada,

northwestern Utah, and southern Idaho; power sites in Montana and Oregon; classifications of sedimentary basins in Alaska; and oil and gas occurrences in Arizona. Although Branch members processed nearly 1,450 fewer cases than in 1956–57, for a total of about 31,450 in 1957–58, the increased work in New Mexico required opening offices in Carlsbad and in Farmington. They also geologically appraised 263 unit plans and participating-area proposals and reported the geologic significance of 200 new discoveries of oil and gas on Federal leaseholds.

Work by the members of Arthur Johnson's Water and Power Branch during fiscal year 1957–58 involved them in surveys and related determinations of the waterpower and water-storage possibilities of locales in Alaska, California, Idaho, Montana, Oregon, and Washington that covered 250 miles of stream channels and 35 dam sites. They also completed 10 reports on land withdrawn for waterpower; these reports resulted in the return to the public domain of 60,000 acres of reserves. Their classifications added nearly 160,000 acres to the waterpower-site reserves and eliminated 82,500 acres, leaving a total of about 7.2 million acres, a gain of some 77,000 acres, in 23 States and Alaska. They also reduced reservoir-site reserves by 920 acres to about 193,000 acres. Fred F. Lawrence, Carl E. Nordeen, and Harold L. Pumphrey completed a history of land classification as it related to waterpower and water storage.

On August 13, 1957, a new law amended the Mineral Leasing Act of 1920 by repealing the maximum limit of 5,120 acres placed by some States on phosphate leases held by an individual, a corporation, or an association.[220] The national limit of 10,240 acres now applied to all States and added to the work of Joe Turner's Mining Branch. At the end of fiscal year 1957–58, the Branch remained responsible for slightly more than 4,000 mining properties in 32 States and Alaska, of which more than one-half were located on public lands. The production of 20.3 million tons of mineral commodities from these properties during the year yielded revenues of $142.5 million and royalties of $6.75 million, which represented a decrease of some $0.35 million compared to royalties in 1956–57.

When Harold Barton retired in 1957, Johnson Mitchell took over as Chief of the Oil and Gas Leasing Branch. Mitchell's staff managed more than 119,000 properties on 93.1 million acres of public lands in 23 States and Alaska during fiscal year 1957–58. The 27,223 wells on these properties produced 132.6 million barrels of oil, 439.5 billion cubic feet of natural gas, and 224.2 million gallons of gasoline and butane worth a total of $440.6 million and yielded royalties of $53.8 million. Oil and gas from wells on acquired, Indian, and military lands and from NPR–2, worth nearly $104.9 million, added $56.9 million more in royalties. By now, nearly 1.6 million acres of the Outer Continental Shelf were leased to industry by the Federal Government and the States of Louisiana and Texas. The 224 producing wells drilled on the OCS during the year raised the total to 681, which represented increases of 45 percent for oil and 7 percent for gas. Production of these OCS fuels yielded revenues of nearly $70.9 million and royalties of more than $15.8 million, the latter a gain of $2.5 million over the previous year's sum. During the year, Branch members approved 73 new unit plans and terminated 35 others on the onshore public lands, leaving a total of 335 approved plans covering 6.1 million acres. On the OCS, the approval of 1 plan and the end of 2 others left 13 plans in operation that covered 333,900 acres.

Fiscal year 1957–58 ended on June 30 without a resolution of the struggle between the civilian and military agencies in the Federal Government for control of the organization proposed to direct and enhance the Nation's efforts in outer space as a long-term response to the Soviet Sputniks. The dispute reflected earlier contests over funds and programs among the Interior and War Departments' science and mapping agencies in the West in the 1870s, the War Department's Office of the Chief Signal Officer and the Smithsonian Institution in the 1880s, the Treasury

Department's U.S. Coast and Geodetic Survey and the Naval Hydrographic Office in the 1880s and 1890s, and the Revenue Cutter Service, the Life Saving Service, and related organizations in the 1910s. Those controversies produced three new U.S. agencies—the Geological Survey in the Interior Department in 1879, the Weather Bureau in the Agriculture Department[221] in 1890, and the U.S. Coast Guard in the Treasury Department[222] in 1915. Would the new space agency be under civilian or military control and would it include a basic science component?