Chapter 10.
A New Cycle, 1958–1961

> **A transition from an exploration of a geographical frontier to an intellectual one characterized the early work of the Geological Survey. In recent months, some of our more inquisitive younger members have proposed various studies of the geography of the individual components of "outer space." Perhaps we are about to see the beginning of a new cycle in the history of the Geological Survey in the public service.[1]**
>
> **—Thomas B. Nolan**

On July 29, 1958, President Eisenhower, working closely with Senator Lyndon Johnson, secured the passage of and signed the National Aeronautics and Space Act to separate partially civilian and military activities. The new law established the National Aeronautics and Space Administration (NASA) to promote civilian research and development, as part of larger efforts to "provide for research into problems of flight within and outside the earth's atmosphere"[2] and to expand

> **human knowledge of phenomena in the atmosphere and space.[3]**

"It is the policy of the United States that activities in space should be devoted to peaceful purposes for the benefit of all mankind," Congress declared, but the legislators also claimed that "the general welfare and security of the United States" required an "adequate provision * * * for aeronautical and space activities."[4] The new organization's work and its results would promote "close cooperation among all interested agencies of the United States" and "cooperation by the United States with other nations and groups of nations."[5] The statute provided the Eisenhower administration with authority to "engage in a program of international cooperation * * * pursuant to agreements made by the President with the advice and consent of the Senate."[6] The law established the National Aeronautics and Space Council, over which the President would preside and by which he would be advised on policies and programs. The Council's eight members included the Secretaries of State and Defense; NASA's Administrator, who received the responsibilities of the discontinued National Advisory Committee for Aeronautics (NACA); the Chairman of the U.S. Atomic Energy Commission (AEC); and four other persons appointed by the President—one from a Federal department or agency and three from private life. Military activities in space remained the responsibility of the Department of Defense (DoD), but NASA would have a Civilian-Military Liaison Commission with a Chairman, appointed by the President; one or more members each from the DoD, the Air Force, the Army, and the Navy, as assigned by the Secretary of Defense; and NASA representatives, assigned by the Administrator and equal in number to those from Defense.

Additional sections of the act covered NASA's rules and regulations for employment, property acquisition, gifts or donations of service, contracts, cooperation with other agencies with their approval, advisory committees, and regular reports through the President to Congress. Eisenhower nominated T. Keith Glennan, Case Institute of Technology's president and a member of the National Science Foundation's (NSF's) National Science Board, as NASA's Administrator.

Hugh Dryden became Glennan's Deputy Administrator. Congress and the President provided direct and supplemental appropriations of $47.8 million on August 14 and $80 million more 13 days later; these monies[7] funded NASA's salaries and expenses, research and development, and construction and equipment during fiscal year 1958–59.

NASA absorbed existing civilian and military units and their funding, personnel, and facilities. To NASA, when it began operations on October 1, 1958, came some of the Advanced Research Projects Agency's (ARPA's) satellite projects and its lunar probes, the Naval Research Laboratory's (NRL's) Vanguard Project, and five NACA research centers—Langley in Hampton and Wallops at Temperanceville in Virginia, Ames at Moffett Field and Dryden at Edwards Air Force Base in California, and Lewis at Cleveland in Ohio. In December 1958 and January 1959, the Army, under protest, began transferring to NASA administrative responsibility for the Jet Propulsion Laboratory (JPL) in California and elements of General John Medaris' Ballistic Missile Agency in Alabama. The JPL continued under Caltech's management. Medaris retired, but Wernher von Braun stayed on and the facility at Huntsville later became the George C. Marshall Manned Space Flight Center. On January 1, 1959 (effective on January 15), NASA established the Beltsville Space Center in Maryland; the agency renamed it the Goddard Space Flight Center on May 1. Von Braun's facility, along with Saturn, the huge booster rocket under development but now not needed by the Defense Department, officially passed to NASA by agreement with the DoD on October 21, 1959, the President on November 2, 1960, and Congress on March 15, 1961, when the legislators approved the administration's reorganization-transfer plan. NASA, as later organized administratively, comprised four program offices—Manned Space Flight, Space Science and Applications, Advanced Research and Technology, and Tracking and Data Acquisition. NASA asked Lloyd Berkner's Space Science Board to form a committee to report on the potential for orbital stations, probes to Mars and Venus, and detecting extraterrestrial life.

As NASA began operations, the United States continued to log successes and failures in its ongoing contest with the Soviet Union in space. Both countries tested launch vehicles, placed additional scientific satellites in Earth orbit, sent other robotic spacecraft to the Moon and beyond, and selected the initial persons for travel into space. The Soviets reported only their successes and so broadcast no space news during the remainder of 1958, as three of their lunar probes failed during September–December before the fourth succeeded. During a flight of 34 hours, instruments on Soviet Lunik (Luna) 1 discovered the solar wind before the spacecraft hurtled past the Moon at a distance of 3,700 miles on January 4, 1959. Three U.S. Vanguards and one of two Explorers failed during May–September 1958. The Air Force's Thor-Able rocket successfully carried Pioneer 1 into space on October 11, but the probe, intended for lunar orbit, did not escape the Earth's gravity and burned up when it reentered the atmosphere. Pioneer 3, launched on December 6, failed to reach the Moon, but the probe did return new data on the outer Van Allen belt. On February 17, 1959, Vanguard 2 carried meteorological equipment and a camera that took pictures of the Earth's cloud cover. On February 28, an Air Force Thor-Agena sent up Discoverer 1, the first of Project Corona's military reconnaissance satellites. The satellite failed to assume a polar orbit.

On April 9, 1959, in a blaze of publicity broadcast live nationwide, NASA announced the selection of its seven Mercury astronauts. All of the selectees were military test pilots with college or university degrees and more than 1,500 hours of flying time. Three of the new astronauts—L. Gordon ("Gordo") Cooper, Jr.; Virgil I. ("Gus") Grissom; and Donald K. ("Deke") Slayton—were Air Force captains. Lieutenant M. Scott Carpenter, Lt. Commander Walter M. Schirra, Jr., and Lt. Commander Alan B. Shepard, Jr., represented the Navy. Lt. Colonel John H.

Glenn, Jr., was the only Marine.[8] The Mercury astronauts persuaded von Braun's team to turn its newly designed and McDonnell-produced capsules into spacecraft by adding viewports and flight controls for Mercury's missions planned to begin in 1961. Until then, the U.S. Air Force (USAF) and NASA would launch nonhuman passengers. In May 28, 1959, monkeys Able and Baker reached an altitude of 300 miles in the nose cone of a Jupiter intermediate-range ballistic missile (IRBM), returned, and were recovered alive. Four mice in Discoverer 3, launched on June 3, died when the satellite failed to reach orbit and crashed.

U.S. efforts to develop viable monitoring methods to enable successful verification under a treaty to ban nuclear tests continued along with the Nation's efforts in space and those toward extending the rule of law above and beneath the Earth's surface. The freedom of the seas, as defined by Hugo Grotius and his successors since the early 17th century, now was imperiled by the claims of the United States and other nations to the water and seabed resources of areas well beyond the 3- or 12-mile limits earlier agreed upon. The United Nations' (U.N.'s) initial Conference on the Law of the Sea[9] (UNCLOS [I]) was held in Geneva in 1956 to propose laws for national and international waters. Four UNCLOS treaties emerged in 1958—(1) Convention on the Territorial Sea and Contiguous Zone, (2) Convention on the Continental Shelf, (3) Convention on the High Seas, and (4) Convention on Fishing and Conservation of Living Resources of the High Seas—and they were ratified and became effective during September 1962–March 1966 but without the United States as a signatory. The original definition of the Continental Shelf, the adjacent coastline outside the territorial sea to a depth of 200 meters, or beyond to depths where natural resources could be exploitable, continued to prove troublesome, and UNCLOS II held in 1960 failed to refine the limits of territorial seas. The U.N. extended its concerns to the legalities and the uses of outer space by establishing, on November 24, 1958, an ad hoc Committee on the Peaceful Uses of Outer Space.[10] The continuance of nuclear-weapon tests also remained an international concern. President Eisenhower and British Prime Minister Harold Macmillan, in a joint statement on March 29, 1959, asked the Soviet Union's Premier Nikita Khrushchev to agree to a moratorium on such tests below magnitude 4.5, because of the difficulty of detecting them, and to authorize tripartite research on improving control methods for these lesser magnitude tests. Members of the Soviet delegation at the test-ban talks in Geneva refused on May 11 to cooperate in this new venture because they still considered as adequate the seismic-system upgrade agreed upon in December 1958. Eisenhower also announced, early in May 1959, that Project Vela, the U.S. effort to detect nuclear explosions more effectively, was underway. Vela contained three principal monitoring components—Hotel, for high-altitude aircraft and orbiting satellites; Sierra, for surface detectors; and Uniform, for tests underground and underwater.[11]

New and continuing crises in the Middle East, the Far East, and Berlin in 1958–59 again demanded attention from members of the Eisenhower administration while they continued to work toward arms control and related efforts for peaceful international relations. On July 14, 1958, leftist nationals, encouraged by Egypt's Gamal Nasser, killed Iraq's King Faisal (ibn Ghazi) II and Crown Prince Abdullah and overthrew their West-affiliated government, placing that country, formerly Lebanon's protector, under Ba'athist control. Since February 1, Nasser also led the new and pro-Soviet United Arab Republic (UAR) that linked Egypt and Syria. In Lebanon, President Camille Chamoun led a Christian-Muslim coalition government since 1952. Chamoun sought reelection, which required a constitutional change, but he faced an incipient pro-Muslim and anti-Western insurgency allegedly encouraged by Nasser. On July 14, after Faisal's death, Chamoun asked

Eisenhower for U.S. military support. Eisenhower promptly told Congress that Lebanon, deemed vital to U.S. interests in the region, faced indirect external aggression. Eisenhower, applying his own doctrine, ordered 6,000 U.S. Marines into Lebanon in Operation Bluebat, to safeguard American lives, protect oil pipelines, and assure Lebanon's independence and territorial integrity.[12] They were joined by an Air Force strike group and some 8,500 U.S. paratroopers flown in from West Germany. Two months earlier, the Army reactivated XVIII Airborne Corps as the principal element in the new Strategic Army Command, a rapid-reaction force deployable worldwide under the new policy of gradual response and limited war as an alternative to massive retaliation and all-out conflict. The Lebanese held orderly elections on July 31 that made General Fuad Chehab the new president. On August 21, a U.N. resolution sponsored by Arab countries provided the circumstances for the withdrawal of U.S. and British forces from Lebanon and Jordan. The last U.S. troops left Lebanon on October 25, as Eisenhower pledged when the United Nations assumed responsibility for that country.

By then, renewed aggression by the People's Republic of China (PRC), encouraged by the Soviet Union, drew heightened responses from other U.S. forces. On August 23, Chinese Communist artillery again bombarded the offshore islands of Quemoy and Matsu, both still occupied by armed forces of the Republic of China. A deployment of U.S. air and naval forces from bases in Japan and the Philippines again helped to defuse the crisis. After Eisenhower suggested a ceasefire on October 1, PRC forces began brief halts during that month, but they did not stop shelling the islands until December. A month earlier, on November 10, Khrushchev again insisted that NATO forces leave West Berlin and threatened to transfer Soviet authority in East Berlin to the Democratic Republic of Germany. American-Soviet exchanges of diplomatic messages and emissaries during December 1958–August 1959 resolved this situation without additional military posturing and led to an agreement enabling Khrushchev to come to the United States and Eisenhower to visit the Soviet Union.

While the crises in Lebanon and the Taiwan Strait abated, others in the Caribbean and the Middle East took their places. On January 1, 1959, as Commandante Fidel Castro's forces captured Santiago and Santa Clara, President Fulgencio Batista resigned and fled Cuba, capping the 3-year struggle by Castro and his insurgents to topple the dictator.[13] Havana fell to the rebels on the next day, and the United States recognized the new Cuban Government. Castro, and the older political leaders in Cuba who supported him, failed to restore the 1940 constitution and then hold national elections. During April 15–17, Castro, premier since February, visited New York City and claimed that his revolution was humanistic rather than communistic. His government then tried and executed 600 so-called war criminals, passed agrarian reforms designed to nationalize U.S. companies' lands, and sought economic and military support from Khrushchev in return for Cuban sugar and minerals. Castro also began efforts to export a version of his revolution in the Caribbean, especially to the Dominican Republic, Haiti, Nicaragua, and Panama. When the Organization of American States' 21 foreign ministers next met, during August 12–18, the U.S. representative denounced these Cuban activities and requested a regional investigation of them. While the ministers' group condemned dictators, it also opposed efforts to overthrow them.

Additional troubling events occurred in Tibet and Iraq, and Eisenhower's Secretary of State resigned. At the Baghdad Pact's meeting during January 17–30, 1959, John Foster Dulles promised its members military support under the Eisenhower Doctrine. On March 5, the United States signed bilateral defense agreements with Iran, Pakistan, and Turkey. The Dalai Lama left Tibet for India and exile on March 17, after a failed revolt by his supporters against the PRC's nearly decade-long occupation. A week later, Iraq withdrew from the Baghdad Pact, after Gamal Nasser denounced the alliance that 5 months later became the Central Treaty Organization

(CENTO), headquartered at Ankara.[14] Dulles, in increasing ill health, resigned as Secretary of State on April 15. A week later, Republican Governor Christian A. Herter of Massachusetts replaced Dulles, who died on May 24.

In the midst of these larger and lesser traumas, the 85th Congress and the President enacted additional reforms to improve national defense and education. On August 6, 1958, a new law reorganized the Department of Defense to increase efficiency, economy, and civilian control, improve activities and operations by the Joint Chiefs of Staff, and perhaps end interservice disputes "to promote the national defense."[15] Congress released on March 30, 1959, testimony by Admiral Arleigh A. Burke, who, as the Chief of Naval Operations since 1955, pushed the development and production of the Polaris IRBM and supported an increased U.S. capacity for fighting limited wars, or so-called small wars. General Maxwell Taylor, his tour as Army Chief of Staff nearing its end, and now designated as the next commander of NATO's forces, also repeated his recommendation for developing this flexible-response option to massive retaliation and did so again in 1960 in his book "The Uncertain Trumpet."

While plans and actions progressed for improving national defense, some persons continued to comment on Congress' lack of interest in passing measures introduced in its 84th sessions to alleviate the Nation's shortage of engineers and scientists. In March 1958, Howard Meyerhoff, from his bully pulpit in *Geotimes*, wondered how and where all the new scientists and engineers would be educated, placed, and used. Meyerhoff, as a member of the Federal Scientific Manpower Commission (SMC) in Washington since 1953, hoped the success of Explorer would "return us to sanity and give us better perspective on the job to be done." The effect of that satellite and its successors, Meyerhoff continued, might "assist us [the SMC] in injecting some sound thinking into Federal policies affecting scientific and engineering manpower."[16] Congress responded to these and similar suggestions by passing a bill that became the National Defense Education Act[17] when Eisenhower signed it on September 2. The new statute provided for strengthening the national defense through a fund of $295 million to provide $1,000 loans, at 3-percent interest over 10 years, to college students; the loans could be repaid at 50 cents on the dollar if the student-borrowers thereafter taught in an elementary or high school for 5 years. The law also authorized grants of $280 million to State schools, with matching grants from the States, for improved facilities for teaching modern foreign languages and science; $28 million for language study in colleges and universities; $18 million for increased use of visual media in education; and 5,500 fellowships for graduate students in training to become college or university teachers. The act directed the National Science Foundation to establish a Science Information Service to be advised by a Science Information Council composed of Federal librarians and other citizens appointed by the NSF's Director.

In other sectors of the administration's domestic front in 1958, the Republicans gained voters in a new State but lost seats in the midterm congressional elections. Bills for statehood for Alaska were introduced beginning in 1916. On March 19, 1955, the Territory's legislature passed an act authorizing a constitutional convention, Alaska's voters approved the convention's draft on April 24, 1956, and the Territorial Government sent it to the U.S. Congress for ratification. Congress and the President agreed, on September 7, 1957, "To grant to the Territory of Alaska title to certain lands beneath the Territory's tidal waters," including the "oil, gas, and all other minerals" but not their "marine animal and plant life, waterpower, or the use of water for the production of power." In gaining the authority of the Submerged Lands Act of 1953, Alaska received "all the right, title, and interest of the United States"[18] in and to the lands between high mean tide and the pierhead line, a boundary that the Army Engineers fixed as parallel to low mean tide. The new law excepted those lands on which were located U.S. facilities, reservations, or holdings for native tribes and the oil and gas deposits in the intertidal zone off the coast of

Naval Petroleum Reserve No. 4 (NPR–4). The Federal Government retained the rights of first refusal for purchasing, in wartime or for national defense, the oil and gas elsewhere in this zone and free navigation through its waters. The statute authorized Alaska's legislature to manage and dispose of any tract of these lands, and the revenue from them, but only after the Secretary of the Interior and the Territorial Governor approved the Engineers' map showing its established pierhead line. A year later, on July 7, 1958, Eisenhower signed the enabling act for statehood.[19] Eisenhower's proclamation on January 3, 1959, admitted Alaska as the Nation's 49th State.[20] The Federal Government, which held title to more than 99 percent of Alaska's lands, granted the new State authority to select within 25 years as much as 400,000 acres from vacant, unappropriated, and unreserved lands in national forests in the State and up to another 102,550,000 acres from its public lands. Alaska chose 6.5 million acres during its first year as a State. Five percent, less Federal costs, of the proceeds of all land sales by Alaska would go to support its public schools.

On the day Alaska became a State, the two houses of the 86th Congress convened their first sessions. Two months earlier, in the mid-term elections on November 4, 1958, the Democrats raised their margin in the House to 284–153 and that in the Senate to 65–35.[21] These results reflected the voters' reaction to a yearlong economic recession, brought on by industrial overexpansion and reduced exports, which Eisenhower's personal popularity did not overcome. By the previous March, nearly 5.2 million Americans were unemployed, and the antirecession legislation that Congress passed in the fall did not help to revive sufficiently the Nation's economy. Charges of corruption in the White House also hurt the Republicans' cause. On September 22, Sherman Adams, Assistant to the President (who functioned as Eisenhower's chief of staff), resigned after the disclosure of gifts he received from a Boston industrialist in return for access to and influence with Federal regulatory agencies. New Hampshire's Adams, a former Representative during 1945–47 and Governor during 1949–53, served as Eisenhower's floor leader at the 1952 Republican convention. Now, Eisenhower said that he continued to need Adams' aid, but Adams generated no bipartisan support in Congress and so he departed. The Republicans did somewhat better in the gubernatorial races; among the winners was Nelson Rockefeller in New York.

The U.S. Geological Survey (USGS) received from all sources in fiscal year 1958–59 a total of just over $63,650,000 for salaries and operations by the agency. Of that sum, more than $41,178,000, or 65 percent, represented surveys, investigations, and research (SIR) appropriations; nearly $12,846,000, or 20 percent, came from other Federal sources; and the States and other nonfederal sources provided almost $9,120,000, or 15 percent. SIR appropriations grew by more than $3,668,000, and Federal transfers declined by nearly $766,000, continuing the trend that slowly made the USGS less dependent on its Federal cooperators. At year's end, the agency's staff totaled 6,638 permanent employees, 62 fewer than the official ceiling of 6,700. Of the permanent employees, 27 were in the Director's Office, 15 in the Public Inquiries Office, 22 in the Texts Office, 318 in the Administrative Division, 332 in the Publications Office, 324 in the Conservation Division, 1,441 in the Geologic Division, 1,958 in the Topographic Division, and 2,201 in the Water Resources Division. The USGS also employed an additional 1,074 seasonal personnel during the year, for a total of 7,712. Director Nolan reorganized the Administrative Division to try to improve its performance. On March 9, 1959, a Survey order modified the Administrative Division to include in Washington, D.C., the Office of the Executive Officer and five Branches—Budget and Finance, Computation, Organization and Management, Personnel, and Service and Supply.[22] The headquarters offices for the Division's four field areas—Atlantic Coast, Mid-Continent, Rocky Mountain, and Pacific Coast—continued to operate, respectively, at Arlington, Rolla, Denver, and Menlo Park.

The total receipts of nearly $17,105,000 for fiscal year 1958–59 in Wilmot ("Bill") Bradley's Geologic Division represented a gain of $1.7 million over the previous year. Of that sum, the SIR appropriation of nearly $11,346,000 was almost $3,333,000 more than in 1957–58. These amounts reflected the change of base in AEC funds that followed its Raw Materials Division's recent request for the USGS to emphasize its more traditional and longer term geological, geochemical, and geophysical investigations, and the agency's newer studies for some of the AEC's other Divisions. The AEC still supplied nearly $2,217,000, the largest transfer by any Federal agency, but the loss of about $1,755,000 represented by that new sum was covered by the gain in SIR monies. The Army and its Engineers increased their support by $75,000 to a total of nearly $1,299,000; the International Cooperation Administration's (ICA's) contribution rose by about $239,000 to reach $1,106,000,[23] and the Interior Department's Office of Minerals Exploration provided nearly $291,000. Bradley made only one significant administrative change in his office's staff during the fiscal year. On July 1, 1958, Andrew Brown replaced Lincoln Page as Assistant Chief Geologist for Trace Elements. Bradley also formalized Vincent McKelvey's appointment as head of the Trace Elements Planning and Coordination Office (TEPCO).

Also on July 1, 1958, Warren Hobbs succeeded Charles ("Andy") Anderson as Chief of the Mineral Deposits Branch. Anderson, elected to the National Academy of Sciences (NAS) in 1957, and his colleague S. Cyrus ("Cy") Creasey, an economic geologist who began serving with the USGS in 1941, published in 1958 their analysis of the geology and the copper and other ore deposits of Arizona's Jerome area. Creasey continued to study that State's copper deposit at San Manuel as structural investigations in the Pima District by other geologists suggested that major copper bodies might be extended along faults. Donald A. Brobst summarized the barite resources in the United States. Other members of Hobbs' Branch continued for Interior projects begun for the Defense Minerals Exploration Administration on manganese deposits in Montana's Phillipsburg area, Idaho's Coeur d'Alene mining district, and the regional relations of North Carolina's pegmatite districts. Their investigations of Nevada's Ely district aimed to extend the area of known porphyry-copper deposits. The studies directed at extending the uranium occurrences at New Mexico's Ambrosia Lake, then containing the Nation's largest known reserves, were planned to determine the physico-chemical controls on deposition. Branch geologists also began to study the newly discovered but low-grade bauxite deposits on Kauai in Hawaii Territory. Geophysicists George V. Keller of the USGS and Pasquale H. Licastro of HRB-Singer published for the USGS their measurements of the dielectric constant and electrical resistivity in 27 cores from the Morrison Formation (Jurassic) on the Colorado Plateau.[24] Their analysis indicated that these properties were potential exploration tools, as high resistivities were associated with low water content, and high dielectric constants, with high water content. Henry Faul and three of his colleagues published a primer on scintillation counters for wider geologic use. Robert Garrels and Esper Larsen 3d finished their compilation of geochemical and mineralogical studies of Colorado Plateau uranium; a separate and nationwide study neared completion for a map (at 1:5,000,000) of uranium in U.S. sedimentary rocks. Vincent McKelvey published a comprehensive treatment of the Phosphoria, Park City, and Shedhorn Formations in the western phosphate field; the publication included sections by Thomas M. Cheney, Earle Cressman, Richard Sheldon, Roger Swanson, and James Williams.[25]

Members of James Gilluly's Fuels Branch mapped and studied stratigraphic sequences during fiscal year 1958–59 in 24 States that produced or might produce petroleum; agencies in 6 of the 24 States cooperated in advancing this work. For the Office of Civil and Defense Mobilization, Branch members, with their colleagues in Interior's Office of Oil and Gas and in the U.S. Bureau of Mines, combined their expertise to project the overall potential of the Nation's petroleum industry in 1975. Branch geologists investigated coal-bearing areas in 10 States, continued appraising reserves in 5 States, and began revising the evaluation of Washington's coal resources. They also finished recasting the U.S. coal map and started redoing the USGS Circular on U.S. coal resources. Gilluly's memorandum to Branch members, dated August 6, 1958, offered constructive criticism that helped to improve these and subsequent project reports.[26]

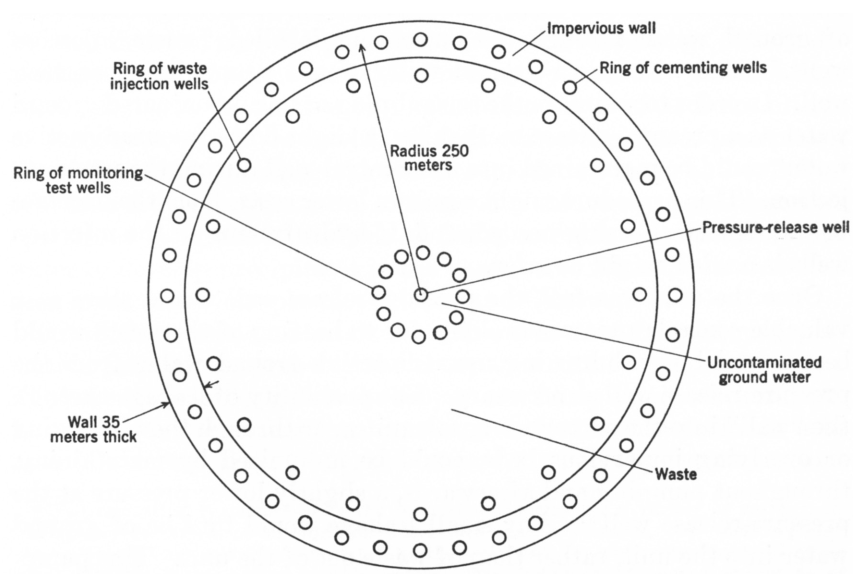
Scientists in Fred Smith's General Geology Branch in fiscal year 1958–59 continued to map quadrangles at 1:24,000 and other scales for the ongoing Geologic Quadrangle (GQ) map series. Members of a committee, chaired by George Cohee and composed of representatives of the USGS and the American Association of Petroleum Geologists, began compiling a new tectonic map of the United States, exclusive of Alaska and Hawaii, on two sheets at 1:2,500,000, and hoped to complete it by 1961. Clyde Ross and Richard Rezak, drawing on their own fieldwork and earlier efforts by USGS geologists since 1901, published a report on the rocks and fossils of Glacier National Park aimed at reaching an audience beyond the usual readers of the agency's Professional Paper series. In October 1958, as the Hawaiian Volcano Observatory (HVO) occupied a second wing, behind and north of the first building, Kiguma ("Jack") Murata replaced Director Jerry Eaton and was designated Scientist in Charge, and the HVO was transferred from the General Geology Branch to the Geochemistry and Petrology Branch. Eaton, while leading the HVO, installed a network of telemetered short-period seismographs[27] that improved earthquake prediction tenfold; he also developed a precise water-tube leveling system for the long-base tiltmeter site to improve the tracking of bulging at Kilauea.[28] Geologic, geochemical, and geophysical studies at the HVO continued to be applied toward increasing its scientists' ability to predict the timing and location of eruptions and to improve their understanding of volcanic processes and the formation of ore-bearing rocks. Scientists returning to or newly assigned to the HVO continued to find it difficult to locate housing closer than 35 miles away at Hilo.

Members of Edwin B. Eckel's Engineering Geology Branch in fiscal year 1958–59 studied urban areas around Denver, Knoxville, Los Angeles, Omaha, Portland in Oregon, San Francisco, and Seattle. Branch members published formal maps of parts of the Knoxville and San Francisco areas and a preliminary map of landslides in Los Angeles' Pacific Palisades locales. They also released an open-file version of a preliminary geologic map of New Jersey's Atlantic City area and its beaches. Cooperative mapping programs continued in Connecticut, Massachusetts, Rhode Island, and Puerto Rico; in the last effort, scientists, aided by the Commonwealth's Economic Development Administration, extended the work beyond the San Juan metropolitan area.

Investigators in William Pecora's Geochemistry and Petrology Branch in fiscal year 1958–59 concentrated on the geochemistry of seawater, especially the concentrations of its major elements, to increase understanding of the processes of depositing marine sedimentary minerals. Accurate equilibrium measurements of radioactive protactinium and thorium successfully dated layered ocean-bottom sediments. Branch members studied the ratios of light isotopes in mineral deposits as clues to ore genesis and aids to exploration for new occurrences. Areal studies continued on the geochemistry and geology of iron and other elements in submarginal sedimentary deposits and massive sulfide veins in the Southeastern United States. In the West's Basin and Range Province, analyses of geochemical halos in valley fill suggested that sampling groundwater and basal alluvial conglomerates might disclose deposits of copper, lead, and zinc. Variations in oxygen-carbon isotope ratios different from the original ratios in central Colorado's carbonate rocks led to the recognition of hydrothermal-dolomite halos related to sulfide ores at Gilman; researchers hoped that these observations might guide future exploration. Branch scientists also investigated the geology and geochemistry of rare-earth deposits, including the beryllium occurrences near Colorado's Lake George that remained one of the principal domestic sources of that commodity. Their studies based on heavy minerals helped to locate a new tungsten deposit in western Colorado.

Other studies by members of Pecora's Branch led to the discovery of an assemblage of rare borate minerals in sodium-carbonate deposits in the Green River Formation (Eocene) of Colorado and Wyoming. The identification in southwestern Idaho of erionite, a fibrous zeolite used to separate gases and oil in purifying water, led to the discovery of a commercial-sized deposit by the mineral industry. Branch scientists continued developing more accurate and faster field and laboratory methods of identifying and determining concentrations of beryllium, fluorine, niobium, rhenium, tantalum, and other and rarer elements. A new electron-probe analyzer, fabricated by Isidore Adler, enabled elements in minute grains of minerals and rocks to be identified by X-ray analyses without destroying the samples. Branch members also prepared and analyzed, or provided to the Division's other geologists, some 13,000 thin and polished sections, while analyzing nearly 14,000 samples by chemical, polarizing-microscopic, spectrographic, X-ray, and other methods. Among the research results published during the year was Edwin Roedder's experimental analysis of the radioactive waste generated in processing nuclear fuel and possible solutions for disposing of it in the deep, brine-saturated, and glass-sand beds known as salaquifers; the work was done for the AEC's Division of Reactor Development. Roedder, now widely considered an expert on fluid inclusions as guides to ore formation at Creede in Colorado and elsewhere, served as Chief of the Branch's Solid State Group since joining the USGS in 1955. Esper Larsen, Jr., and three of his colleagues published their compilation of lead-alpha radiometric ages for Mesozoic batholiths in Western North America and continued to assess the distribution of uranium in these intrusions. Clifford Frondel, a veteran of the Office of Scientific Research and Development (OSRD) and Larsen's colleague at Harvard, extended his X-ray and related analyses of uranium and thorium in a comprehensive publication on their systematic mineralogy.

In fiscal year 1958–59, members of the Airborne Surveys Section in James Balsley's Geophysics Branch flew magnetic and radioactivity surveys that totaled 80,000 traverse miles over 11 sites; they also continued to complete aeromagnetic maps of quadrangles, areas, and counties in States nationwide. The preliminary results of aeromagnetic surveys flown over southwestern Pennsylvania correlated well with the geologic data and disclosed several new magnetic anomalies similar to those generated by known magnetite deposits. Ground-based geophysicists tested



USGS geologist Edwin Roedder suggested that enclosing wells with an impervious cement wall (as shown in this cross section) before injecting high-level radioactive solutions of acidic aluminum nitrate would increase safety in storing these solutions in deep and brine-saturated permeable beds (salaquifers) well below any potable water. Prior large-scale exploration and tests of potential sites would be required to determine the nature of chemical reactions between the injected radioactive wastes (radwastes) and the surrounding earth materials. Removing highly dangerous and heat-producing long-lived isotopes, aging to remove short-lived heat-producing isotopes, and chemically pretreating the radwastes or the salaquifers, Roedder added, would yield safer storage. USGS geologists and hydrologists continued in the 1950s to investigate methods of safely disposing of radioactive waste from nuclear-reactor fuels. (From Roedder, 1959, fig. 6.)

in field and laboratory electrical-prospecting methods in northern Maine's sulfide-ore districts and in copper and iron occurrences around Lake Superior. Variable-frequency electromagnetic techniques applied in northern Wisconsin's Gogebic Iron Range yielded estimates of magnetic susceptibility and content of taconites as aids to tracing covered deposits of these low-grade iron ores. A mobile magnetometer located small masses of subsurface serpentine rocks in California. Geophysics Branch scientists, cooperating with geologists and geochemists from other Branches in the Geologic Division continued studies of valley-fill deposits in the Basin and Range Province aimed at discovering new ore deposits in the two-thirds of the region covered by Cenozoic alluvial deposits. As part of this program, they began work in the porphyry-copper district around Arizona's Twin Buttes, already known for major deposits under the alluvium. Branch members advanced their investigations of the physical properties of rocks with a view to increasing their understanding of the environments in which igneous and metamorphic rocks, and their associated ore minerals, were formed and modified. With engineering geologists, they applied the results of their experiments on the solubilities and formation of minerals in water and steam under high pressures and temperatures in studying the results of underground nuclear tests. In investigations of products from industrial nuclear processes, they cooperatively searched for minerals containing radioactive isotopes of cesium and strontium for future utilization without endangering groundwater supplies. After determining clay capacities for absorption, they experimented on crandallite and vermiculite as absorbers of radioactive isotopes.

As part of these studies, Balsley, advised by his former Assistant Branch Chief Mary Rabbitt, established a Rock-Magnetics Project in the Geophysics Branch at Menlo Park in 1959. Balsley asked Allan V. Cox and Richard R. Doell, the new project's scientists, to concentrate on determining whether rocks with anomalous magnetism represented field reversals or self-reversals. Geologist and historian William Glen emphasized the USGS-Berkeley connection in his "Road to Jaramillo"; Cox and Doell were former geophysics students of John Verhoogen (still working part time with the USGS), and their years at Berkeley overlapped in the early and mid-1950s. Cox spent three summers in Alaska with USGS field teams that included Henry Coulter, David Hopkins, Troy Péwé, and Clyde Wahrhaftig, who, with Robert Black completed engineering geology studies along the Alaska Railroad. Cox became a full-time employee with the agency in 1957 and earned a Ph.D. at Berkeley in 1959. Cox, who worked on Cenozoic volcanic sequences and their paleomagnetism in Oregon, with Parke D. Snavely, Jr., and basalts in Idaho, with Howard Powers and Harold E. Malde, met the Berkeley-trained Rabbitt and Balsley through Wahrhaftig. Doell earned his doctorate at Berkeley in 1955. He taught for a year at the University of Toronto, where he worked with J. Tuzo Wilson; he went to Ellesmere Island with a Canadian team during the summer of 1956 to prepare for the International Geophysical Year (IGY). Doell then taught at the Massachusetts Institute of Technology (MIT) during 1956–59. The NSF granted Doell $16,600 in 1956–57 for a 3-year study of magnetism in sedimentary rocks, and he renewed his acquaintance with Balsley in Balsley's seminar at MIT. By the summer of 1958, as Glen related, Cox and Doell prepared for a multiyear collaboration at Menlo Park, and Cox described it to Balsley that September.[29] The duo intended to find a better explanation for and chronology of rock magnetism, goals whose origin Balsley and other USGS geophysicists could trace to George F. Becker's comments at a session on the present problems of geology and geophysics held at the International Congress of Arts and Sciences in St. Louis in 1904. There, on September 21, Becker challenged his colleagues by calling for additional basic research on the phenomenon, reported 3 years earlier in France by Jean Brunhes, "that lavas and strata indurated by lavas retain the polarity characteristic of the locality in which they cooled. The time may come," Becker added,

when this will lead to determinations of the relative age of lavas, the duration of periods of eruption and possibly even the absolute determinations of date.[30]

Victor Vacquier joined the Scripps Institution of Oceanography (SIO) in 1957 and received in 1958–59 a grant of $68,000 from the NSF for an investigation of anomalies in electrical conductivity. Balsley later recalled that Vacquier borrowed and modified a USGS fluxgate magnetometer and deployed it successfully from some of the SIO's ships. The USGS later lent another magnetometer to the Lamont Geological Observatory for towing behind its ships. The tendency of fluxgate magnetometers to drift in aircraft, Balsley remembered, could be dealt with "by circling back to cross the traverses and correct them from a common magnetic base." To overcome ship speed, Vacquier "developed a drift-free proton-precession magnetometer." He towed it behind the U.S. Coast and Geodetic Survey's *Pioneer* off California's coast, located magnetic anomalies, and produced a map showing the black-and-white lines of negative and positive linear anomalies that he compared with the traces of the faults delineated by the SIO's William Menard during the same ship's earlier bathymetric survey of that area. The faults, to Balsley's surprise, "lined up with obvious shifts in the linear magnetic anomalies."[31] In their flights across the United States, Balsley remembered, his teams recorded many linear anomalies on the continent but never any like those off California.

Cox, like other geologists before him, viewed volcanoes and volcanic rocks as "magnetic tape recorders."[32] He and Doell now proposed collecting rock samples with magnetic minerals from as many well-documented locales as possible worldwide and accurately determining their magnetic orientations and radiometric ages. Doell joined Cox in Menlo Park in March 1959. With aid from Balsley (who still hoped to return to research), Louis Pakiser's Ground Surveys Section, the Administrative Division's Chief Glendon Mowitt, and the General Services Administration (GSAd), Cox and Doell began operations in June in a tarpaper shack near the one that housed Arthur Lachenbruch. To help Cox and Doell "build a first-class magnetic laboratory,"[33] Balsley, who still favored self-reversals, detailed to them instrument technician Major Lillard, who built Balsley's spinner magnetometer. Geochronologist Ronald W. Kistler, who began working part time for the USGS in 1953 and continued that affiliation while earning a doctorate at Berkeley in 1960, provided initial potassium-argon (K-Ar) isotope dates. Kistler established the potassium-argon-dating facility at Menlo Park in 1959 and determined radiometric dates for western rocks, including the granites collected by Paul C. Bateman. Kistler and John D. O'Bradovich, also trained at Berkeley, joined Menlo Park's part of Samuel Goldich's Isotope Geology Branch in December 1961, 2 years after Goldich returned to the USGS. Cox and Doell found it increasingly difficult to get age determinations from Kistler, O'Bradovich, and other members of the Isotope Geology Branch, who were dating rocks for the economic geologists. Cox and Doell decided, if funds permitted, to invite to the team their own K-Ar specialist. At Berkeley, geologists Garniss H. Curtis and Jack F. Evernden,[34] whom the NSF granted $55,800 in 1958–59 for 2-years' work in K-Ar dating, and physicist John Reynolds, who began the K-Ar program at Berkeley in 1955, introduced G. Brent Dalrymple and several other students to that rock-dating technique. Curtis, Evernden, and Dalrymple worked principally on Cenozoic volcanic rocks. Dalrymple met Cox and Doell in the White Mountains in 1961 and hoped to join them after completing his doctorate.

On July 9, 1958, a major earthquake, generated along a portion of the Fairweather fault, heavily shook the northeastern coast of the Gulf of Alaska and especially Lituya Bay, a high-walled inlet, 2 miles wide and 7 miles long, just southeast of Cape Fairweather. The quake, measured at a Richter magnitude of 7.9 was assigned a modified Mercalli intensity of XI. At the epicenter, just southeast of


m
m
k
g
g
k
k


r
d
F
e
b

◀ These photographs look northeast across Lituya Bay, just southeast of Cape Fairweather in southeastern Alaska, before (above, in 1954) and after (below, in August 1958) the magnitude 7.9 earthquake and subsequent tsunami of July 9, 1958. In these photographs, Mt. Carillon, at an elevation of 12,726 feet, is on the skyline at right. Earlier giant waves devastated the shoreline areas of Lituya Bay in 1853 or 1854 (at k) and in 1936 (g). Lateral moraines (m) indicate a recent advance of ice. The 1958 earthquake generated a rockslide (r) that plunged into Gilbert Inlet, sheared off part of Lituya Glacier, and surged up the opposite slope to an elevation of more than 1,700 feet (d). Runups extended as much as 3,600 feet inland at Fish Lake (F) and deforested an area of 4 square miles. Two persons died when the tsunami, in passing seaward, sank their fishing boat, which was under way near the entrance of the bay. Two anchored boats (at b and e) survived. USGS geologist Don Miller, then nearby at Glacier Bay while studying the Gulf of Alaska Tertiary Province, assessed the tsunami's results by gathering data on the ground and from the air. (Photographs from Miller, D.J., 1960, pl. 3*A*, *B*.)

Lituya Bay, displacement along the right-lateral, strike-slip fault reached 3.5 feet vertically and 21.5 feet horizontally. At bay's head, a rockslide displaced some 40 million cubic yards of material. The debris flow crossed the Gilbert Inlet, sheared off the front of the Lituya Glacier, and drove water far up the opposite shore to topple trees at elevations as high as 1,720 feet. The wave surge completely deforested an area of 4 square miles. The tsunami also passed, at about 100 miles per hour, west down the bay and into the gulf, sinking a fishing boat and killing its two-man crew. Don Miller, then on the USGS power barge *Stephen R. Capps*, just 40 miles to the east in Glacier Bay, flew over the devastated site on July 10. His subsequent studies on the ground, combined with survivors' accounts of this and earlier and similar tsunamis in the area, recorded the effects of four lesser runup events between the 1850s and 1936 and indicated that they might occur again.[35]

Elsewhere in Alaska during the rest of fiscal year 1958–59, geologists in George Gates' Alaskan Geology Branch mapped some 850 square miles in detail and another 34,000 square miles at reconnaissance scales. Aeromagnetic and gravity surveys by members of the Geophysics Branch aided ongoing investigations of actual and potential petroleum areas in Alaska. In addition to continuing to map and assess Alaska's coal fields, Alaskan Geology Branch members completed four commodity maps that showed the occurrence and distribution of 13 elements. Other members of the Branch worked in engineering geology and combined their investigations of permafrost with those by the Military Geology Branch. This work involved mapping surficial deposits near Fairbanks, examining construction sites at military installations, and preparing a reconnaissance map of potential routes for a Fairbanks-Nome highway to be built under the direction of the U.S. Bureau of Public Roads.

In fiscal year 1958–59, members of Frank Whitmore's Military Geology Branch (MGB), in cooperation with the Air Force's Cambridge Research Center and the IGY's glaciological program, examined areas along the Arctic Coast and adjacent inland locales. Other MGB staffers completed investigations for the Army Engineers of terrain and permafrost conditions on Alaska's Arctic Slope, along the Copper River and Kuskokwim River, and on the Seward Peninsula. Their colleagues in the Branch continued or began investigations of the effects of nuclear explosions on rocks, soils, and vegetation.

With transfer funds from the Army Engineers, and later those from NASA, USGS geologists started compiling a photogeologic map of the Moon and expanded that effort to related lunar studies. The MGB's Robert J. Hackman, Arnold Mason, and Maxim Elias, aided by geologists William Fischer and Annabel B. Olson, compiled terrain and geologic data for the Lunar Mapping Program by using Fischer's modern stereoplotters to study recent telescopic images of the Moon's nearside, the nearly 60 percent of the lunar surface visible from the Earth. In 1959, Elias completed a 6-page preliminary study of the Moon's terrain as MGB Miscellaneous Paper 222; it included ideas about the feasibility of gathering additional information on the surface's physical characteristics and engineering properties. A 170-page lunar bibliography followed in 1960.

Hackman, in compiling a lunar geologic map for the Army Engineers, drew on his years of experience as a USGS geophotogrammetrist. He interpreted air photos and field data in preparing geologic maps for the Navy Oil Unit in NPR–4 before photogeologically mapping 70 quadrangles for the Colorado Plateau Project between 1952 and 1959. During this interval, Hackman invented "several photogrammetric instruments, including the Stereo-Slope Comparator, the Isopachometer, an adjustable profile plotter for the Kelsh and Multiplex plotters, a circular trigonometric computer for geologic instruments, several models of photo holders for use with a stereoscope, and various types of stereoscopes."[36] Beginning in 1959, he applied some of those photogrammetric and other technological developments in evaluating photographs taken through telescopes at five observatories—Lick

(California), McDonald (Texas), Mount Wilson (California), Pic du Midi (France), and Yerkes (Wisconsin).

Some of these photographs were published in the two lunar atlases[37] compiled by astronomer Gerard P. Kuiper, who directed the combined McDonald and Yerkes Observatories, and then by Kuiper and four collaborating astronomers. In 1954, Kuiper, then at the University of Chicago, published an analysis of lunar surface features[38] in which he ascribed maria (the large, dark, plainlike areas) to the almost complete melting of the Moon by its radioactive heat during its first billion years. Kuiper proposed three intervals—premelting, maximum-melting, and postmelting—in the development of the surface features by both impact and volcanic events. Harold Urey, also at Chicago, thought the Moon would prove to be the solar system's Rosetta Stone; he favored an accreting and cold Moon, believing that volcanism, not internal heating, formed the maria. Kuiper decided to compile a lunar atlas detailed enough to help settle the acrimonious dispute with Urey. The NSF supplied initial funds in April 1957, but the USAF's Cambridge Research Center provided the bulk of the necessary monies that fall for the initial atlas. Kuiper established a Lunar and Planetary Laboratory at Tucson, and his British colleagues joined him there for additional work in the fall of 1958, as Urey retired from the University of Chicago and moved to the University of California at San Diego. As Hackman and his colleagues continued to compile their lunar maps, the Army Map Service tried but failed in November 1958 to generate its own stereophotogrammetric lunar atlas. The AMS was thwarted, as Don Wilhelms later noted, by deficient data and old stereoplotters.

Late in 1958, as Wilhelms later recalled, Eugene ("Gene") Shoemaker, by then at Menlo Park and encouraged by NASA's founding and by two colloquiums on lunar and planetary exploration, renewed his offer to begin a lunar-studies program within the USGS. Shoemaker intended, as Wilhelms remembered,

> **to assemble an overall picture of the Moon's structure and history by examining it first through the telescope and later in photographs taken by spacecraft[39]**

as a prelude to recommending

> **where on the lunar surface the field work should be conducted, and samples collected.[40]**

This time, Shoemaker discussed the proposal with Assistant Chief Geologist Montis Klepper in Washington and again when Klepper visited Menlo Park. Their talks, like those in 1956, yielded no decision, but new events at NASA influenced Shoemaker's determination to continue preparing for a future lunar program. NASA established at Langley a Space Task Group, and Homer E. Newell, a Naval Research Laboratory mathematician, came aboard as Deputy Director in the Office of Space Flight Development, led by Abe Silverstein, a mechanical engineer and NACA veteran since 1929. In NASA's Office of Space Flight Development, Project Mercury received its name late in November 1958 just before Pioneer 3 was launched in early December. Newell hired physicist Robert Jastrow, an NRL consultant who earlier taught at Berkeley and Yale, to lead Goddard's Theoretical Division and appointed him in January 1959 to chair an ad hoc Working Group on Lunar Exploration at the JPL that included Frank Press, Harold Urey, and a number of other NASA advisers and employees. Jastrow's Working Group planned by early in 1960 a four-part spacecraft program, including hard landings in Project Ranger, within 12–18 months; rough landings, by using rockets as brakes; satellites in lunar orbits; and soft landings and returns to Earth in Project Apollo, within 3–4 years. On March 23, NASA gave the lunar program a priority second only to Project Mercury.

During 1958–59, members of William Johnston's Foreign Geology Branch continued to cooperatively appraise mineral resources abroad, improve the national surveys and educational institutions of other countries, and share knowledge in the earth sciences by disseminating their own publications or publishing bilingual reports with their colleagues. More than 50 members of the Branch and other units in the Geologic Division participated in the cooperative program during the year. They conducted fieldwork in Brazil, Chile, the Republic of China, India, Indonesia, Libya, Mexico, Pakistan, Peru, the Philippines, and Thailand. They also provided advice to the governments of Afghanistan, Burma, Ghana, Iran, Japan, Jordan, the Republic of Korea, Nepal, the Netherlands Antilles, Paraguay, Saudi Arabia, and Turkey. In the United States, nearly 90 participants from 24 countries, sponsored by the AEC, the ICA, and the United Nations, were trained in parts of USGS domestic programs and in the graduate schools of cooperating academic institutions. Twenty-four young geologists from 15 countries enrolled in a seminar in Washington, D.C., and received 7 months of field and office training in photogeological techniques from members of the Geologic and Topographic Divisions. The staff of the USGS Library, an administrative unit of the Geologic Division since its transfer during fiscal year 1947–48, expanded its efforts to make, or obtain from other Federal sources, translations from the Russian of useful earth-science articles and books published in the Soviet Union.

The composition of the Foreign Geology Branch's teams in several countries changed during 1958–59 as geologists completed existing tours of service or began new tours. Ralph Miller, who returned to research in the Fuels Branch after his work for the ICA, again was detailed to the Foreign Geology Branch to serve 29 months as the Chief of Party in Mexico. Joel Pomerene and Arthur Rynerson completed their tours with John Dorr's iron project in Brazil; Robert Morris and Mackenzie Gordon, Jr., arrived there, respectively, in September and January to advance geological education. Thor H. Kiilsgaard, who joined the USGS and Defense Minerals Exploration Administration (DMEA) work in 1951, began studies of ore deposits in southern Peru; he was on detail from his regular assignment as Staff Assistant to Albert Weissenborn, who managed the Mineral Deposits Branch's efforts for the DMEA. The USGS issued a 1:1,000,000 geologic map of Paraguay, by Edwin B. Eckel, using a topographic base compiled by Gladys H. Benedict from a Paraguayan map of the same scale and U.S. Army Air Forces (USAAF) trimetrogon photography taken during 1943–45. Eckel's bilingual map

The manganese-bearing arkose forming the hill in this photograph's background is part of the Misiones Sandstone (Triassic) and crops out just southwest of Yaguarón in eastern Paraguay. To the left of and beyond the central palm tree, the joints and other fractures in this feldspar-rich sandstone are filled with manganese veinlets, but samples of these veinlets proved to contain less than 10 percent manganese dioxide. USGS support for the Truman administration's Point Four Program in Latin America included reconnaissance studies and mapping of the geology and mineral resources of Paraguay completed by Edwin B. Eckel, in cooperation with some of its Government's geologists, during 6 months in 1952. Eckel judged the manganese deposit as noncommercial in size, but he directed future searches for other mineral occurrences to several areas of Precambrian rocks. Eckel also published a geologic map of Paraguay at 1:1,000,000 and a soils map of the country at about 1 inch = 30 miles. (Photograph from Eckel, 1959, fig. 54.)

of 1958 accompanied his 1959 report on his 6-months' reconnaissance in 1952 of Paraguay's geology and mineral resources that was conducted under the auspices of the Point Four Program and the Institute of Inter-American Affairs, and with cooperation from the Ministerio de Obras Públicas y Communicaciones' Departmento de Geología. R.C. Douglas and William W. Doyel served with George Ericksen's mineral-resources team in Chile during the first half of 1959. Gus Goudarzi started compiling, from the Army Map Service's 1:250,000 series, and other U.S. and British sources, a 1:2,000,000 bilingual topographic map of Libya; his work received support from the U.S. State Department and the Kingdom of Libya's Ministries of National Economy and of Petroleum Affairs and Industry. Goudarzi and Louis Conant intended to use Goudarzi's base to compile a geologic map of Libya. Vincent McKelvey, sponsored by the ICA, spent 2 months during the fall of 1958 in Jordan advising its Government about the country's phosphate and related commodity resources. James F. Seitz joined the Branch's mineral investigations in India in July 1958. J.F. Gude began serving with the minerals team in Pakistan in January 1959, and Joel Pomerene began work with the minerals team in the Philippines.

The USGS, on August 23, 1958, and through Interior Secretary Seaton, received statutory authority to operate officially in two additional areas outside the national domain and to use therein its direct appropriations for the first time. The new law extended

> **the authority vested in the Secretary of the Interior, to perform surveys, investigations, and research in geology, biology, minerals, and water resources, and mapping * * * to include Antarctica and the Trust Territory of the Pacific Islands.[41]**

To work officially in most other foreign locales, including Saudi Arabia, USGS personnel remained dependent on detail to and funding by other Federal departments or agencies. General authority for USGS work in all areas outside the national domain, if determined by the Interior Secretary "to be in the national interest,"[42] did not become law until September 5, 1962. On August 28, 1958, a second new statute officially authorized "details and transfers of Federal employees for service with international organizations." The new law allowed "The head of any Federal agency * * * to detail for a period not exceeding three years any employee of his department or agency to an international organization requesting services."[43] That statute also provided measures for retaining the allowances, compensation, privileges, rights, seniority, and other benefits due detailed or transferred personnel, whether or not the international organization(s) reimbursed the United States. The act of August 23, 1958, also authorized the compilation of "maps of Antarctica from materials already available and from such additional material as may result from the several expeditions in support of the International Geophysical Year."[44] The Topographic Division began long-range planning for mapping all of Antarctica at 1:250,000.

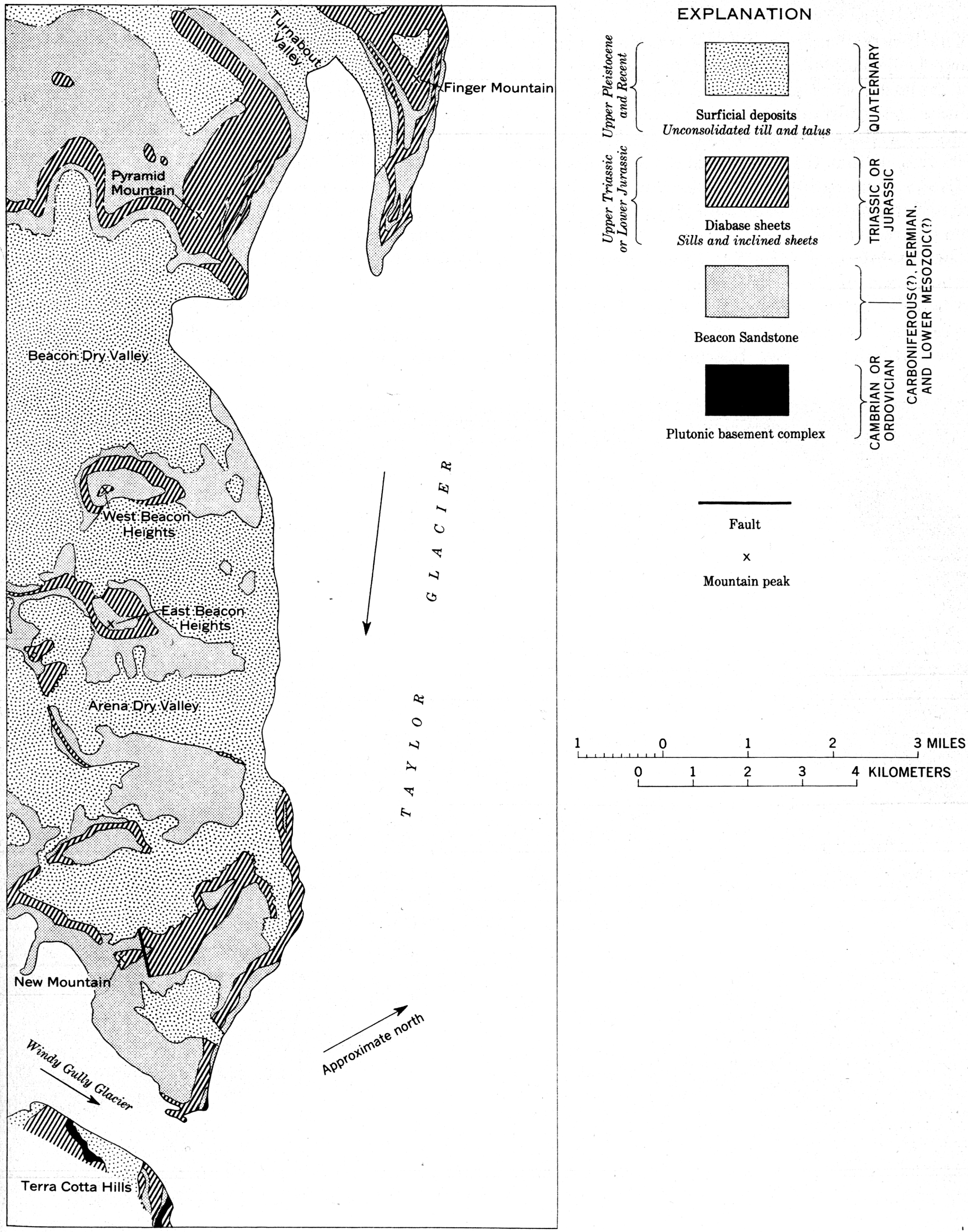
During the austral summer of 1958–59, the IGY's international activities in Antarctica continued, as agreed after the Comité Spécial de l'Anneé Géophysique Internationale (CSAGI) met in Moscow in July and August 1958. The International Geophysical Cooperation agreement in 1959 extended the IGY for a year beyond its scheduled end on December 31, 1958. On that day, the NAS transferred to the NSF responsibility for the administration, coordination, and funding of all subsequent U.S. research activities on the continent. The NSF established a U.S. Antarctic Research Program in March 1959 and chose to direct it chemist Thomas O. Jones, who left his post as acting head of the NSF's Office of Scientific Information. John Reed (Sr.) joined the 20-member Interdepartmental Committee on Antarctic Research. The IGY's 11 archives of its World Data Center A included a repository for geomagnetism, gravity, and seismology established in Washington, D.C., as part of the U.S. Coast and Geodetic Survey's Geophysics Division.

This photograph, taken in November 1958, looks southwest from the Taylor Glacier toward the west wall of the Beacon Dry Valley in Victoria Land, eastern Antarctica. The three major units of the Beacon Sandstone are present—the sandstone of New Mountain underlies talus slopes, the sandstone of Pyramid Mountain forms the conspicuous light-colored cliffs, and the sandstone of Finger Mountain forms the highest slopes and capping ledges. The thick dark layers are diabase sills. Pyramid Mountain is on the skyline at right. (Photograph by USGS geologist Philip Hayes; from the USGS Denver Library Photographic Collection as Hamilton, W.B., hwb00387, https://www.sciencebase.gov/catalog/item/51dc7c67e4b097e4d3838c23; cropped versions were published in Hamilton and Hayes, 1963, fig. 7, and in Yochelson and Nelson, C.M., 1979, p. 39.)

Rear Admiral George Dufek's Naval Support Force Antarctica intended to evacuate all U.S. stations at the end of 1958, but it received a new mission to provide logistical support for U.S. research in Antarctica for as long as necessary. In Operation Deep Freeze IV, Dufek continued as the Navy's Antarctic Projects Officer, and Edwin A. McDonald commanded Task Force (TF) 43; its nine ships included icebreakers *Edisto*, *Glacier*, *Northwind*, and *Staten Island*.[45] During the austral summer, USGS geologists surveyed the volcanic peaks of the Executive Committee Range in Marie Byrd Land and other areas of Antarctica. Warren B. Hamilton and Philip T. Hayes studied the geology of the McMurdo Dry Valleys; Hamilton joined the USGS in 1952 and investigated the Sierra Nevada and Idaho batholiths and the tectonics of the Blue Ridge and Great Smoky Mountains. Charles Johnson sailed in *Glacier* to geologize on Beaufort Island in the Ross Sea and at nearby Cape Bird on Ross Island. John Behrendt, now on the University of Wisconsin's faculty, examined areas in Coats Land, west of Queen Maud Land, and parts of the Filchner Ice Shelf. USGS topographic engineer William Chapman, held over from Deep Freeze III, spent a total of 18 months at the Byrd Station accompanying round-trip traverse parties to the Horlick Mountains and to other areas to fix the location of peaks and other landmarks intended to be used for mapping control.[46] Operations ended at Little America V on January 18, 1959. Later, the United States transferred its Ellsworth Station to Argentina and its Wilkes Station to Australia.

George Whitmore's Topographic Division received more than $19,158,000 during fiscal year 1958–59, a gain of about $840,000 compared to the total received in the previous year. The Division's SIR appropriations rose by $431,000 to $14,674,000. Increases by the Army, its Engineers, and other Federal agencies more than made good the loss of nearly $365,000 in funds from the Bureau of Reclamation as the total of such transfers climbed by $166,000 to $2,272,000. States, counties, and municipalities provided direct and repay funds of about $2,013,000, a nearly $248,000 increase, as the Division's nonfederal monies rose to a total of $2,212,000.

On July 10, 1958, a Secretarial order transferred to the USGS the domestic-names functions of Interior's Office of Geography "that relate to domestic geographic names (names of locations within the United States, its territories and


Turnabout Valley
Finger Mountain
Pyramid Mountain
Beacon Dry Valley
West Beacon Heights
East Beacon Heights
Arena Dry Valley
TAYLOR GLACIER
New Mountain
Windy Gully Glacier
Approximate north
Terra Cotta Hills
EXPLANATION
Upper Pleistocene and Recent
Surficial deposits
Unconsolidated till and talus
QUATERNARY
Upper Triassic or Lower Jurassic
Diabase sheets
Sills and inclined sheets
TRIASSIC OR JURASSIC
Beacon Sandstone
CARBONIFEROUS(?), PERMIAN, AND LOWER MESOZOIC(?)
Plutonic basement complex
CAMBRIAN OR ORDOVICIAN
Fault
x
Mountain peak
1 0 1 2 3 MILES
0 1 2 3 4 KILOMETERS

◀ This geologic map (originally at 1 inch = 1.7 miles) shows the type area of the Beacon Sandstone in the Beacon Heights area, west of McMurdo Sound, in eastern Antarctica. USGS geologists Warren Hamilton and Philip Hayes used published information, aerial and ground photographs, and their ground observations in mapping the composite type section of 8,000 feet in and near Beacon Heights. Their four map units included the plutonic basement complex (Cambrian or Ordovician), the Beacon Sandstone (Carboniferous[?], Permian, and lower Mesozoic[?]), diabase sills and sheets (Triassic or Jurassic), and till and talus (Quaternary). Two of the three arrows show direction of ice flow. The Beacon Sandstone contained the *Glossopteris* flora; the wide distribution of these fossils in the Southern Hemisphere remains one of the principal supports for continental drift. Hamilton and Hayes examined the Beacon Sandstone type section in November 1958 during the International Geophysical Year (IGY). During the IGY (July 1957 through December 1958), scientists from 67 nations participated in astrophysical, geodetic, geophysical, glaciologic, gravimetric, magnetic, meteorologic, oceanographic, seismologic, solar, and topographic studies using data from ground-based observations and those made by balloon- and rocket-borne instruments. Personnel from 12 nations, operating from nearly 60 stations, received unrestricted access within Antarctica. That cooperation helped leaders to formulate and enact the Antarctic Treaty, which was signed December 1, 1959, and became effective in 1961. (Map from Hamilton and Hayes, 1963, fig. 3.)

the Commonwealth of Puerto Rico, and adjacent waters).” This order reserved authority for “final approval of the Board on Geographic Names [BGN]” to “the Secretary, the Under Secretary, or an Assistant Secretary.” Also transferred from the Office of Geography to the USGS were “[a]ll records, files, books, periodicals, maps and other materials that relate to domestic geographic names.”[47] The order directed the USGS to determine when investigations should be made; provide the BGN’s meeting place, an Executive Secretary, and other staff aid; and promulgate the BGN’s decisions. The order, as amended on August 8, delayed the transfer until October 1. In the Division’s only major internal administrative change during the fiscal year, Charles Davey retired as Atlantic Region Engineer in November 1958 and was succeeded by Charles Fuechsel.

In fiscal year 1958–59, Topographic Division personnel mapped in 40 States, the District of Columbia, Puerto Rico, and the U.S. Virgin Islands. Florida, Ohio, and Tennessee significantly increased their financial support for cooperative mapping. Field parties mapped more than 38,000 square miles at 1:24,000 and another 54,000 square miles at 1:62,500 (in the conterminous United States) and at 1:63,360 (in Alaska). Mapping in California and Texas depicted 7,000 square miles at those scales. Division members established more than 350 permanently marked triangulation stations to provide control for areas totaling some 30,700 square miles. They also ran about 6,840 linear miles of transit traverses, another 3,100 miles by electronic traverses, and 15,400 miles of leveling. The Division let contracts with industry for some 73,300 square miles of precision aerial photography to support its domestic mapping program, and the Air Force provided air-photo coverage of an additional 5,555 square miles to use in compiling topographic maps for the Defense Department. Nearly 2,440 maps were sent to the Publications Office for printing and distribution; of these, almost 1,340 represented new USGS standard topographic quadrangles; the remainder were new maps for other agencies, revisions, reprints, State index maps, civil editions of DoD maps, and special-format maps. The Division raised its total of published topographic maps to more than 21,000. A new 1:500,000 topographic map of Tennessee appeared during the year, as work continued on equivalent sheets for nine other States. The urban-mapping program[48] issued composite maps for four areas—Denver, Honolulu, Norfolk-Portsmouth-Newport in Virginia, and Philadelphia. The Division also mapped for other USGS Divisions, and provided cartographic aid to the Army Map Service’s 1:1,000,000 coverage of North America, the Bureau of the Budget’s photomosaic, the Interstate Commerce Commission’s special compilation, the Office of Civil and Defense Mobilization’s special coded overlays, the Post Office Department’s rural routes, and a new edition of the U.S. Water Resource Development map.

The Topographic Division also introduced new instruments and methods to improve its geodetic surveys. A new signal lamp’s two-transistor circuit produced flashes at constant intervals to provide the means to avoid past problems created by observations under difficult daytime conditions. Additional new electronic equipment for measuring distances yielded improved accuracy at reduced cost. Division personnel tested the direct geodetic restraint method, the fully analytical system of aerotriangulation that verified the geometrical approach and the accuracy of the electronic-computer program. They also used provisional analog equipment from the Jerie-International Training Center, at Delft in The Netherlands, to test aerotriangulation’s horizontal and vertical block adjustments and yield corrections of discrepancies in measurements of position and elevation. Division members cooperated with colleagues in the Army Engineers’ Research and Development Laboratories in testing the accuracy of the Decca system used to determine accurately aircraft positions when making a series of photo-exposure stations.

The Topographic Division also concentrated during 1958–59 on improving the precision of its photogrammetric equipment to speed the completion of the topographic map coverage of the Nation at the now standard large scales.

Division members completed a long-range plan to replace the Multiplex system and continued to modify the Twinplex instrumentation and its calibration to increase accuracy. Developing an orthophotomap, however, proved difficult. As most of the requests for orthophotographs continued to come from geologists within and outside the Geologic Division,[49] who wished to use them as bases for compilation, the Topographic Division envisioned many potential applications but by this time actually made few practical uses of orthophotoproducts. In July 1958, the Topographic Division formed an Orthophotography Use Study Group, composed of one representative from each Branch in Roland Moore's Office of Research and Technical Standards, except for the Branch of Cartography. The new group met to determine the best uses of orthophotogrammetry in new mapping or in revising the Division's standard topographic-quadrangle series.

Topographic Division personnel began reengineering the initial Universal Orthophotoscope to further automate the application of electronic readouts to accommodate the existing dichromatic projectors. They also designed a simpler and less expensive model, using only ellipsoidal reflector-55 (ER–55) projectors, to yield orthophotographs under most terrain and photographic conditions. Division designers planned to have their orthophotoscopes make possible the production of three principal photo-image products—orthophotographs for fieldwork; orthophotomaps, with contours and extensive color-enhanced cartographic treatment, in the standard 1:24,000 quadrangle format and with relative horizontal and vertical reference systems; and orthophotoquads, monochromatic maps in standard quadrangle format, without contours, and with little or no cartographic treatment.[50] Progress toward generating actual orthophotomaps depended on overcoming the Division's limited production and reproduction capabilities. The Branch of Special Map's prototype Orthophotoscope remained the only one in the Division, reproduction of continuous-tone photography still depended on the half-tone process, and the high-altitude photographs from the Army Map Service and photographs obtained for stereocompilation remained inadequate sources for good orthophotomosaics. In 1959, the Division began planning and then operations to shift from analog to digital photogrammetry.

Members of the Topographic Division provided continuing technical aid and training at home and abroad to foreign colleagues in fiscal year 1958–59. Division personnel also prepared and issued an experimental 1:1,000,000 map of the Knox Coast, along eastern Wilkes Land, and gathered in Washington a collection of geodetic-control data, maps, photographs, and other cartographic materials to support the planned comprehensive mapping of Antarctica.

Luna Leopold's Water Resources Division received funds from all sources in fiscal year 1958–59 that totaled about $22,764,000, or $1,862,000 more than in 1957–58. Of the SIR appropriation of nearly $11,278,000 (an increase of nearly $762,000), $6,950,000 was limited to cooperative work with the States and their political subdivisions. They supplied the USGS with almost $6,796,000 in direct and repay funds, representing a gain of nearly $967,000. California's $705,000 and lesser amounts from Texas, New York, Florida, New Mexico, Arizona, Pennsylvania, and Utah provided the major portion of these cooperative funds. Other Federal agencies supplied about $4,418,000, an increase of almost $129,000. The Army and its Engineers raised their total transfers by $232,000 to nearly $1,760,000, and the ICA and the AEC also increased their contributions by a total of almost $214,000. Transfers by the Bureau of Reclamation, the Agriculture and State Departments, and the Tennessee Valley Authority (TVA) fell by about $466,000. Federal and State cooperative funds now represented about 60 percent of the total monies received by the Division, by far the largest such dependency within the USGS. The Interagency Committee on Water Resources' Subcommittee on Hydrology completed a report, published by the Government Printing Office (GPO) in 1959, on Federal programs for collection of data on water use.

Leopold's reorganization of his Division drew an inevitable comment from the Pick and Hammer Club. The "Wonderments" introduction to the Club's show in April 1959 closed with a verse that observed:

> **Our Water Resources laddies felt that they should change their ways.**
> **To be more like geologists could bring them naught but praise,**
> **The brand-new brass soon learned to play the old reshuffling game,**
> **But just as in Geology the outcome was the same—**
> **They're swapping jobs each month so all can share the blame.[51]**

As part of the Division's technical-assistance outreach, water-resources projects supported by the ICA's $498,000 continued in Afghanistan, Chile, Iran, Libya, Pakistan, Peru, the Philippines, and Saudi Arabia. William Doyel completed during September 1958 his tour in Libya with Chase Tibbitts' team, who gained the services of Thomas G. Newport in April 1959. Eldon Dennis and Edward Bradley finished their service in Iraq in September 1958 and returned to the United States, but Bradley left again for 3 months' work in Jordan during April–June 1959. In Iran, John Baumgartner completed his work in March 1959 and was succeeded by Alvin F. Pendleton, Jr. Nelson Sayre spent more than 2 months with Division hydrologists in Pakistan late in 1958. Regular turnover of personnel continued in Pakistan, as elsewhere, when Robert Cushman left in December 1958 and George LaRocque departed in June 1959. Meanwhile, John B. Cooper completed a 6-month tour in Pakistan during March 1959, an interval that overlapped the assignment there in January of David W. Greenman. Their colleagues on similar assignments in British Guiana, Cambodia, Tunisia, and Turkey also aided the modernization or expansion of investigations of those countries' surface water and groundwater. Division personnel provided in-country training to more than 100 colleagues in the cooperating nations. This experience was needed, especially in view of continuing problems with water quality abroad; on August 25, 1958, 25 people died in New Delhi after drinking contaminated water. Division members also helped to train in the United States personnel from Afghanistan, Brazil, British Guiana, Chile, the Republic of China, Guatemala, India, Pakistan, the Philippines, Tanganyika, and Turkey.

During 1958–59, the Surface Water Branch operated and maintained a national streamgaging network of 7,100 stations in 49 States, Hawaii, Guam, and Puerto Rico. Branch members continued streamflow measurements for the 19 interstate compacts and investigations of U.S.-Canadian boundary waters for the International Joint Commission. Research on surface water included continuing studies in field and laboratory of flow in open and constricted channels and in different climate and land conditions. Branch members continued to experiment with electronic computers, but they did not succeed in using vacuum-tube models to read gage heights from automatically recorded data on strip charts, compute the discharges, and record the results on punch cards. During the year, the Branch published streamflow reports for basins nationwide, including the South Atlantic Slope (James River to Savannah River), the St. Lawrence River, the Great Basin, and some on the Pacific Slope. The special summary of streamflow records for 1888–1950 now was more than 98 percent complete. Reports also nearly finished included those for California's Central Valley, the Upper Missouri River Basin, and the Upper Mississippi River Valley. Work continued for those on the Gulf of Mexico basins, the North Atlantic Slope, the Upper Colorado River Basin, other basins in California, and those in Hawaii. Similar studies began for the Columbia River Basin. As part of ongoing countrywide analyses of regional flood frequency, Branch members finished those for New England and the Lower Colorado River Basin and issued one for the Delaware River Basin. They also released open-file preliminary and cooperative reports on Florida, North Dakota, Ohio, and South Dakota and published reports of specific floods in the United States in 1952, Illinois in 1954, and Indiana in 1954 and 1957. For the Soil Conservation Service (SCS), Branch specialists studied runoff from maximum annual floods in 1,426 drainage areas of less than 400 square miles and provided hydraulic data for 38 drainage-structure sites to the highway departments of 11 States. They also began a manual of hydrology, to describe the standard surface-water techniques used in the Branch, and they issued separately its first six chapters.

On January 14, 1959, Luna Leopold's memorandum named Philip LaMoreaux, then Mid-Continent Regional Hydrologist at Tuscaloosa, as Nelson Sayre's successor as Chief of the Ground Water Branch. Sayre, Branch Chief since December 1946, returned to research as a Staff Scientist in Leopold's office. Charles McDonald took over temporarily as Mid-Continent Regional Hydrologist at Rolla. Branch members conducted during fiscal year 1958–59 some 640 investigations in the 49 States, Hawaii, and Puerto Rico. Work in areal hydrology and geology comprised three principal efforts. One of the major cooperative "Regional" studies involved continuing work in parts of nine States in the 900,000-square-mile area of the Mississippi Embayment. "System" studies included those of Idaho's Spokane River Basin and Arizona's Verde Valley. "Type" investigations, the least inclusive of the three kinds of areal hydrology and geology studies, encompassed work on the hydrology of volcanic and limestone terranes, specifically geohydrologic conditions in basalt terranes, to locate and develop groundwater supplies in the Pacific Northwest and apply the results to similar areas. Branch members researching the occurrence and movement of groundwater strove to develop analytical methods for hydrologic systems and regions, investigate saturated flow to understand better the dynamics of groundwater and surface-water relations, study the mechanics and properties of groundwater reservoirs and porous media, and examine the relation of regional flow and geologic environment to the distribution of constituent minerals. Gerth E. Hendrickson summarized, on a map at 1:750,000, the occurrences of groundwater in Kentucky. As part of investigations of saltwater encroachment in coastal areas, work continued in eight Southeast States, seven Northeast States, and Hawaii. Hilton Cooper, Jr.'s generic analysis[52] of the dynamic balance of freshwater and saltwater in a coastal aquifer in 1959 generated a study of the Biscayne aquifer near Miami, Florida. One Branch team programmed two analog computers to process geologic and hydrologic data on the responses of water-bearing formations to withdrawing or injecting water as an aid to investigating hydrologic systems.

The Branch of Water Quality supplemented its nationwide investigations of water chemistry and radioactivity, concentrating on uranium and radium, with detailed studies of surface-water and groundwater conditions in the basins of the Colorado, Columbia, Connecticut, Missouri, Pecos, and Yadkin-Pee Dee Rivers and in several river basins in Alaska. John D. Hem's study and interpretation of natural water's chemical characteristics, published in 1959, emphasized the inorganic aspects of water chemistry; his discussion of the significance of properties and constituents in natural waters became a standard reference.[53] Branch members completed reports on the chemical quality of South Dakota's surface waters that emphasized the concentrations of boron, fluorine, and selenium; the analytical methods for determining strontium; and the nationwide distribution of uranium and radium in groundwater. They began measuring the level of synthetic detergents in groundwater in the United States and also continued studies of worldwide runoff of solids from lands to oceans. Selected closed lacustrine basins in California and Nevada became their natural laboratories for studies of dissolved minerals and the distribution and behavior of minor elements. Other specialists in the Branch measured in detail and analyzed stream-sediment loads in the Colorado, Middle Rio Grande, and Missouri River Basins. In related studies, they investigated how the shape and unevenness of stream channels influenced sediment transport and the bedload discharge of sediment. They also developed automated equipment to measure sediment discharge from streams and improved techniques and standards for interpreting sediment data and records. For the Bureau of Reclamation and the Soil Conservation Service, Branch members studied stream sediments in the Colorado and Rio Grande River Basins and in Nebraska's Medicine Creek watershed. For the SCS, they also continued to examine the sediment yields and trap efficiency of small-watershed reservoirs. They also completed a study of the Delaware River Basin's geology, groundwater, and sediments; the report, documented by a hydrologic atlas and text, passed to the Army Engineers to become part of the Engineers' comprehensive plan for basin development.

Harold Duncan's Conservation Division drew on total funds of more than $2,696,000 during fiscal year 1958–59, nearly $333,000 more than in the preceding year. The Division's SIR appropriation represented all but $262,000 of the new sum. Eisenhower signed a law on August 14, 1958, that reamended 1877's Desert Land Act "to permit entries on disconnected tracts of lands, which, in the case of one entryman, form a compact unit and do not exceed in the aggregate three hundred and twenty acres." Persons who made valid desert-land entries, before June 16, 1955, on lands subject to the 1910 and 1914 acts "may, if otherwise qualified, make one additional entry, as a personal privilege, not assignable, upon one or more tracts"[54] subject to 1934's Taylor Grazing Act, as subsequently amended. On August 19, 1958, a new statute amended the Atomic Energy Act of 1954 by releasing to claimants the reserved public and acquired lands, set aside by Executive order or statute during 1945–47, of "radioactive mineral substances, fissionable materials, or source material, together with the right to enter upon the land and prospect for, mine, and remove the same."[55] Two days later, the Minerals Exploration Act,[56] intended to restimulate exploration for and discovery of mineral reserves, except organic fuels, in the United States, its Territories, and possessions, provided additional support for programs run by Interior's DMEA. The DMEA transferred its responsibilities and staff to its successor, the Office of Minerals Exploration (OME)[57] established on September 11 by a Secretarial order to implement the statute of August 21. Interior's Office of Minerals Mobilization, established in 1955 and also reporting to the Office of Defense Mobilization, shifted from aiding the DMEA's work to helping the OME's efforts. To each contract, the OME could contribute 50 percent, or up to $250,000, toward the costs of exploring for strategic and critical commodities, including antimony, asbestos, bauxite, beryl, cadmium, chromite, cobalt, columbium, copper, corundum, industrial diamonds, fluorspar, graphite, kyanite, lead, manganese, mercury, mica, molybdenum, monazite, nickel, platinum, piezoelectric quartz crystals, rare earths, rutile-brookite, selenium, talc, tantalum, thorium, tin, uranium, and zinc.

Members of the Mineral Classification Branch completed during fiscal year 1958–59 geologic reports on foundation conditions at 18 potential dam sites in Alaska and 13 others in Oregon. They also finished geologic and (or) structure-contour maps of 10 specific coal and oil fields and areas in Colorado, Montana, and Wyoming, including Teapot Dome and West Sussex in Wyoming. Branch members processed more than 33,600 cases involving the disposal of Federal lands, some 8,200 of which dealt with the reservation or release of minerals and the remainder with Federal leasing of the mineral rights. They completed or revised 66 definitions of producing oil and gas fields on Federal lands, geologic appraisals of proposals for 315 unit plans and participating areas, reports on the geologic significance on 194 new discoveries of oil and gas on or affecting Federal-land leaseholds, reviews of 55 appeals from the Bureau of Land Management's decisions about Federal-land disposals, and some 330 reports for other Federal agencies on the mineral potential of specific public lands.

The Water and Power Branch's staff during fiscal year 1958–59 surveyed 370 miles of steam channels and 20 potential sites for dams on 22 rivers and lakes in Alaska, California, Colorado, Idaho, New Mexico, Oregon, and Washington. They also published maps for 96 miles of streams and 12 dam sites. Their reviews recommended the restoration of 190,000 acres of public lands, 113,000 proposed and 77,000 previously withdrawn. Classifications by Branch members added some 85,000 acres to the power-site reserves and eliminated nearly 68,400 acres, leaving reserves of more than 7.2 million acres in 24 States. They also prepared more than 8,650 reports for the Bureau of Land Management (BLM) and the Federal Power Commission (FPC).

By the end of fiscal year 1958–59, members of the Mining Branch supervised more than 4,000 lease, permit, and license properties on public, acquired, and Indian lands in 34 States. The production of coal and mineral commodities from these lands totaled more than 26,159,000 tons, representing a year's gain of about 5,841,000 tons; their value of nearly $170,028,000 (about $27,513,000 more than in 1957–58) yielded royalties of almost $7,832,000, an increase of nearly $1,077,000. The production of phosphate rock and shale produced during 1958–59 fell by about 7,300 tons, a loss helping to validate the need for the projected future increases under the hoped-for stimulation of the Phosphate Mining Act, but the value of these commodities, reflecting market realities, also declined by $202,000 and royalties decreased by nearly $34,000. On May 20, 1959, Branch members attended an interagency meeting in Washington that the Public Health Service sponsored to foster cooperation in devising measures to protect miners from the effects of radon gas, silica dust, and other dangers to health in uranium mines.

Members of the Oil and Gas Leasing Branch again increased their operations during fiscal year 1958–59. They supervised more than 130,600 properties on 107.4 million acres of public lands, a gain of 14.3 million acres from 1957–58. Private companies completed about 1,660 wells, of which some 1,070 produced oil and gas, 173 fewer than in 1957–58, to raise the total of producing wells to about 16,850, or 110 more. The production from these wells rose to some 145 million barrels of oil, an increase of 12.4 million; almost 443 billion cubic feet of natural gas, a gain of 3.4 billion; and nearly 310 million gallons of gasoline and butane, a

This 1960 photograph shows USGS mining engineer J. Paul Storrs observing coal-stripping operations on the Edna Company's lease near Oak Creek in Routt County, northwestern Colorado. USGS supervision of mining operations on the public lands grew in the 1950s as old mines increased their production and new mines began operations. These activities increased the royalties, rents, and other payments made by coal firms through the USGS to the U.S. Treasury. (Photograph from the USGS Denver Library Photographic Collection as Patterson, E.F., pef00703, https://www.sciencebase.gov/catalog/item/51dda0a9e4b0f72b4471ddbb.)

rise of 84.7 million. The total value of these fuel resources rose by $20 million to $406.7 million and returned to the U.S. Treasury royalties of more than $57 million, a gain of $3.4 million. On the Outer Continental Shelf (OCS), nearly 900 wells on more than 200 leases, with 12 unit plans, produced 64 percent more oil and 95 percent more natural gas than in 1957–58, raising their total value to nearly $126.8 million and yielding royalties and rentals of $24.8 million. Branch members approved 80 new unit plans for onshore fields and terminated 42 others, leaving 373 in operation for a gain of 38, but OCS unit plans decreased by 1 to a total of 12.

Interior's Office of Oil and Gas transferred nearly $212,500 to the USGS for the Federal Petroleum Board's administration of the Connally "Hot Oil" Act during 1958–59. The FPB processed about 10,300 monthly producers' reports, some 460 monthly pipeline reports, and 65 processor-refiner reports. The number of reporting oil fields rose by 153 during the year to a new total of 3,853. FPB monitors visited 783 oil fields and conducted 1,479 interviews. By year's end, 17 cases of alleged violations of the Connally Act remained on the docket, and 8 were still under investigation by the Attorney General. The FPB, while preparing a report on an additional case, continued to study 8 others. Court action closed 3 other cases and the fines paid totaled about $58,000.

Some 3 months earlier, on January 27, 1959, Chairman Michael Kirwan began his House subcommittee's evaluation of Interior's budget estimates for fiscal year 1959–60. He welcomed to the subcommittee's deliberations two new members, elected in 1954—Winfield K. Denton (D–IN) and E. Keith Thomson (R–WY), who succeeded Hamer Budge. Kirwan then recognized Seaton, saying that he "has made a good Secretary."[58] Seaton thanked Kirwan, assuring him "that, from personal experience, kind words are at times at a premium at the Department of the Interior because of the very nature of the job."[59] The Secretary brought along Under Secretary Elmer F. Bennett, the former Solicitor, who replaced Hatfield Chilson in 1958.

Seaton, in reiterating the President's hope to avoid bigger deficits and higher taxes, proposed a budget for Interior in fiscal year 1959–60 of $364.1 million, excluding reclamation and waterpower funds. That sum had been reduced by the Budget Bureau from the original request of $404.8 million that included pay increases. The Department, Seaton confirmed for Kirwan, could live with the reduced amount in 1959–60 and still meet its obligations to the Nation. The cuts, intended to help the Eisenhower administration reach its goal of a balanced Federal budget of $77.3 billion, fell most heavily on the Bureau of Indian Affairs, the National Park Service, and the Fish and Wildlife Service. To meet the Nation's increasing needs for minerals and water, Seaton proposed to continue in 1959–60 the U.S. Bureau of Mines (USBM) and the USGS programs at the expanded 1958–59 level. The $42,517,600, including $217,600 to enforce the Connally Act, proposed for the USGS represented an increase of $650,000. Of that sum, $500,000 would go to meet larger offerings by the States for the agency's cooperative water-resources investigations and $150,000 to fund the increased work of supervising oil and gas mining leases on public lands. Interior also estimated the number of USGS employees, permanent and the part-time and seasonal full-time equivalents, would rise from the 7,445 authorized for 1958–59 to 7,510 during 1959–60.

Kirwan's subcommittee considered the USGS budget request on the afternoon of January 28. To save time, Nolan inserted into the record a long statement of justifications for the $42.5 million for salaries and operations requested for fiscal year 1959–60. In his prepared remarks, Nolan reported "substantial progress in reversing the trend, which developed during and after the war, of dependence upon substantial transfers of funds, or repay accounts, from other agencies," one that especially represented a "significant shift in the Geologic Division's financing."[60] Two changes in the SIR language authorized expenditures for the Federal

Petroleum Board's enforcement of the Connally Act and for USGS work in Antarctica and the Trust Territory of the Pacific Islands as authorized by the 1958 statute. Nolan projected total funds from all sources, including those covering pay raises, in 1959–60 would reach about $63,819,600, a gain of $152,000 compared to the sum available in 1958–59.

Kirwan's subcommittee, as before, reviewed all the USGS justifications for its activities for the coming fiscal year. Nolan displayed additional statistics showing that costs declined from $171 to $120 per square mile, or $77 if calculated for cost-of-living adjustments, for topographic mapping and surveys between fiscal 1946–47 and 1957–58, while typical hourly wages increased from $1.31 to $3.64 and the cost per new map edition fell from $324 to $290. During 1959–60, work would continue on 4,300 quadrangles at 1:24,000, 1:62,500, and 1:63,360 and begin on 900 sheets at 1:24,000 and 240 sheets at 1:62,500. Nolan later assured Thomson that the National Geographic Society was almost wholly dependent on the USGS when compiling its maps. The completion of national coverage on adequate maps, Nolan added, now stood at 43 percent, reflecting the increased demand for 1:24,000 mapping, but Kirwan did not press him to name a completion year or a projected cost of finishing the remaining maps.

Nolan, while justifying geologic and mineral-resource surveys and mapping, reported the discovery of several new ore deposits in the West, including a cobalt body in Idaho worth an estimated $30 million. The new "rocket-generated demand for solid fuel propellants and heat- and pressure-resistant alloys,"[61] Nolan emphasized, "has been superimposed upon the long existent, but ever-increasing need for conventional raw materials."[62] "These demands," he continued, "spotlight the need for basic geologic research to determine their mode of occurrence and to develop new exploratory methods and tools for use in the search for commercial sources of supply."[63] Part of the $1.5 million supplemental appropriation for fiscal year 1958–59, Nolan explained, was "being used to make modest starts on several high-priority studies of the type recommended by the National Science Foundation Advisory Committee on Minerals Research,"[64] including new work in Arizona's Bradshaw Mountains, at Ely in Nevada and Phillipsburg in Montana, in Washington's Hunters quadrangle, and in the iron-ore areas of the Southeastern United States. New work for the AEC, funded by an additional $1.5 million, involved pre-test efforts in Nevada, Alaska, and New Mexico for the Division of Military Applications, aerial measurements of background radiation and changes suggested by tests on reactors in Georgia and New York for the Division of Biology and Medicine, and other studies for the Division of Research. Nolan pointed out that the work for the Project Plowshare studies "provide[s] unusually fine opportunities for research on these factors [of ore-deposit formation] under physical conditions that would be impossible to duplicate in the laboratory."[65] In reviewing USGS work in Alaska and the Arctic, Nolan noted that the agency's geophysicists assigned to IGY and related activities on Ice Island T–3 used their instruments to determine ice thickness and suitability for landing aircraft. John Reed (Sr.) continued to oversee these operations by USGS personnel as part of his responsibilities as Chairman of the Arctic Committee of the National Academy of Sciences and National Research Council's (NAS–NRC's) U.S. National Committee on the IGY.

What was the USGS doing, Kirwan then asked, "to reduce the amount of time it takes to complete projects"? In the Geologic Division, he noted, "84 of the present projects were started over 10 years ago; 6 projects are over 25 years old."[66] That problem, Nolan replied, involved two linked parts—the time required for field or laboratory work and the interval needed to write a report. Both considerations were affected by the line-itemized appropriations required before 1950 and the backlog created when researchers completed reports delayed by their contributions to the war effort. "The situation became acute about 2 years ago," Nolan continued, so "we made the first of a series of reorganizations designed to cut down and eventually eliminate this delay."[67] Nolan and Bradley transferred all the Geologic Division's illustrators to the Director's Office unit and then moved the combined unit to the Office of Publications. Nolan explained that the delays in processing reports reflected the differences in three principal types of projects, especially those involving repay or transfer funds: (1) continuing and long-term observations or compilations, like those at the HVO or for *Geophysical Abstracts*; (2) part-time efforts by managers, staff, and when-actually-employed academics, rather than full-time line personnel; and (3) personnel reassignments and resignations, or funding fluctuations. Changes already were in place, Nolan continued, to provide flexible periodic reviews of projects in their planned and time-limited successive stages. New procedures also governed the preparation of final reports (as compared to interim ones) to reduce the number of persons reviewing each report and the time required to get them to the printer; these changes would increase the speed of completion and publication "without sacrificing our technical standards."[68] Kirwan summarized by asking, "Do you think we will do better from here on?"[69] "I think," Nolan replied, "I can guarantee it."[70]

The subcommittee then focused on the two significant increases in the USGS request for fiscal year 1959–60: $500,000 for water-resources investigations, to match larger offerings from States and municipal agencies, and $150,000 for the ever-expanding workload in mineral-lease supervision. Half of the additional funds requested for the water-resources cooperative program would go to surface-water studies, $175,000 to groundwater investigations, and the remaining $75,000 to sediment and water-quality investigations. Nolan cited a recent study that expected water use in the United States to treble by 1980. Kirwan again raised the issue of the delay in reporting, citing that 25 of the 58 annual reports of streamflow data in 1957 and 1958 took 2 to 2.5 years to complete. Nolan responded by emphasizing that each district office made the weekly or bimonthly reports of raw data immediately available to cooperating government agencies and to industry. These records were used mostly by engineers in planning construction projects and were not needed for day-to-day operations. Nolan agreed that the USGS should make every effort to get out immediately the needed information. In subsequent discussions, Nolan assured Denton that USGS cooperative work on water resources with the Army Engineers and the Public Health Service did not conflict with their operations. When Denton asked about funding for studies of the States' areas not in the public domain, Nolan repeated his request for a water appropriation not restricted to the cooperative program, but no change was authorized. All but $25,000 of the $150,000 asked for mineral-lease supervision, Nolan continued, would support staffing at newly active areas, closer monitoring of the OCS leases in the Gulf of Mexico and off California, and greater capacity for royalty accounting. The 16 new personnel would be responsible for the 10,000 new oil and gas properties and wells expected to provide an additional $65 million in production and $8 million in royalties. Three additional people would help handle the work involving the estimated additional $25 million in minerals production and $1.8 million in royalties.

Kirwan closed his review with a query, later renewed by Thomson, about the intra-agency transfers and lack of uniformity in the assessment financing of USGS Division and Branch headquarters. Subcommittee investigators reported a shift of $100,000 for the Office of Public Inquiries from administration to program funds, after the subcommittee disallowed $90,000 for this purpose in the supplemental appropriation for fiscal year 1958–59. The USGS used none of the $1.5 million so received, Nolan responded, for that purpose. Kirwan then asked what was "being done to set up a more effective audit program,"[71] as recommended by the General Accounting Office's report for 1955 and required by the Budget and Accounting Act of 1921.[72] Marion E. Young, the USGS Chief Inspector since 1955, Nolan advised, continued to perform internal audits of agency officers, "under the cognizance of the staff coordinator [John Reed, Sr.], who has been designated the chief inspecting officer of the Survey. The Chief of each of the Divisions * * * has been designated as a deputy inspection officer for his Division."[73] Young, Nolan noted, was auditing the remaining 50 of the 200 USGS national, regional, and district offices. Nolan intended to ask each of the Division Chiefs to designate a person to assist Young's audits. Nolan already had changed USGS administrative procedures in response to Young's discovery of the continued charging of expenses to accounts on funds available rather than work performed and other questionable practices in approving travel vouchers, inventorying property, and utilizing excess property.

The House approved a $517,600 reduction in the USGS budget. Even with that loss, the agency's proposed appropriation increased by $3,585,000, including about $3,217,000 for costs required by the Federal Employees Salary Increase Act of 1955 and $150,000 for mineral-leasing supervision, compared to the total for fiscal year 1958–59. The House Committee on Appropriations decided to fund the cooperative water-resources investigations at slightly less than $7 million, the same level as in 1958–59.

The appropriations review then passed to Carl Hayden's Senate subcommittee, which also included new members. Four of them were Democrats—Alan H. Bible (NV), Robert C. Byrd (WV), Estes Kefauver (TN), and John McClellan (AR)—appointed after Spessard Holland and Warren Magnuson received other congressional assignments. Bible won a special election in November 1954 to fill the seat vacated by the death of Patrick McCarran; Bible defeated Ernest S. Brown, who had been appointed to the seat temporarily. Byrd served in the House during 1953–59 and in the Senate during 1959–2010. McClellan, who represented Arkansas in the House during 1935–39, before being elected to the Senate in 1942, now also chaired the latter's Committee on Government Operations. In the only change in the subcommittee's Republican membership, Thomas H. Kuchel (CA) won a special election in November 1954 to fill the seat vacated when Richard Nixon resigned to become Vice President. Kuchel, although the Minority Whip, attended the Senate subcommittee's hearings more frequently than Majority Leader Lyndon Johnson, the Chairman of the standing Committee on Aeronautical and Space Sciences, or Richard Russell, the Chairman of the Committee on Armed Services.

Seaton asked Hayden's Senate subcommittee on May 11, 1959, to restore the House's cuts of nearly $19.7 million from Interior's budget request for fiscal year 1959–60, including the reductions of $400,000 for the Office of Minerals Exploration and the elimination of the $500,000 increase requested for USGS cooperative investigations of water resources. Nolan addressed Hayden and six other members of the Senate subcommittee on May 18, but only Hayden queried Nolan. Hayden quickly reviewed the major activities, focusing on the request for water-resources investigations and especially on those in the Lower Colorado River Basin. The States, Nolan agreed, would be able to meet the larger figure requested by the USGS. They continued to require the "additional basic information on the availability and nature of water resources" and "to determine the significance of these basic data in relation to proposed developments."[74] Hayden, as before, thought it "imperative that we provide a matching dollar for every dollar that the States make available."[75] Hayden, for the legislators' better understanding, linked the need for streamflow records for planning water-storage projects to the USGS cooperative program with the States. In addition to the completed revisions of the 1:24,000 topographic maps of Kentucky's 40,400 square miles, Nolan reported map revisions underway in Connecticut, Massachusetts, and Rhode Island. Ohio, he added, proposed a 3-year cooperative program to complete the topographic mapping of that State that would provide up to $1 million to the USGS, and the agency quickly approved the agreement. If any part of the additional $500,000 requested for cooperative water-resources investigations was not matched by the States, Nolan assured Hayden that the remaining sum would not be expended for other purposes without

Congress' approval. Nor would the USGS, Nolan added, decrease its ongoing program in the Colorado River Basin. Two months earlier, Nolan also promised the Administrator of the Arizona Power Authority that the USGS would not deemphasize the collection of basic water data to concentrate on interpreting it. The Senate Appropriations Committee voted to restore the $500,000.

On June 23, 1959, Eisenhower signed Interior's appropriations bill for fiscal year 1959–60. The total monies included $42,350,000 in SIR funds for the USGS, of which $7,450,000 was available only for cooperative water-resources investigations with the States and their political subdivisions.[76] At the fiscal year's end, the USGS reported total obligations of slightly more than $65,328,000, of which about $42,037,000, or 64 percent (1 percent more than in 1958–59), represented SIR appropriations. The USGS also recorded an average total of 7,248 employees; 6,578 of them were permanent (the ceiling was 6,840) and 670, seasonal. Of the permanent employees, 2,122 were paid from reimbursable funds, as were 222 of the seasonal appointees. Of this total, 276 were support personnel employed outside the four program Divisions—256 in general administration and 20 in the soil- and moisture-conservation program. Other Federal agencies supplied about $12,363,000, or 19 percent, a loss of nearly $483,000. Nonfederal sources contributed almost $10,928,000, or 17 percent, a gain of about $1,302,000; all but almost $500,000 of this sum came from reimbursements and direct payments from States, counties, and municipalities.

During fiscal year 1959–60, Nolan acted to fulfill his promise to Kirwan to reform the USGS publication process, the agency dedicated its third building at Menlo Park, California, and it received from Interior additional support for consolidating USGS operations in the Washington metropolitan area in the long-sought new headquarters building. A Survey order, dated July 17, 1959 (effective July 1), established the Publications Division as the agency's sixth Division.[77] Publications Officer Robert Moravetz became the Chief of the new Division, which received the funds, personnel, and equipment of the Office of Publications and the Office of Texts from the Director's Office. These units joined three others—the Branch of Technical Illustrations, the Branch of Map Reproduction, and the Branch of Distribution—already shifted from the Topographic Division to the Director's Office. On November 24, 1959, Seaton, Nolan, Donald McLaughlin, other members of the USGS, representatives of the Federal, State, and local governments, and private citizens participated in the dedication of Building 3, the Western Mapping Center, at Menlo Park. The two-story building, encompassing 71,500 square feet and designed specifically by Robert O. Davis, the Pacific Region Engineer, and his staff for topographic-mapping operations, was constructed on Federal land and with Federal funds for $12 per square foot. Buildings 1 and 2 on the Menlo Park campus passed to the General Services Administration in 1960, as later did Building 3. The USGS also hoped to arrange for additional new buildings at Menlo Park that would house only the library or be shared by members of the Administrative, Geologic, Publications, and Water Resources Divisions.

To try to reach a higher priority goal, the USGS resumed its quest for a new national center. Under the 1949 statute, as amended in 1954 and 1956, the GSAd delegated to the Secretary of the Interior the authority to contract for studies of new facilities sought by the Department before the act lapsed in 1957. The Public Buildings Act[78] of September 9, 1959, gave the authority for all construction, alteration, or acquisition of Federal buildings to the GSAd's Administrator. On January 22, 1960, Seaton's Secretarial order redelegated a part of this authority to the USGS Director. Nolan could now "negotiate a contract for personal or professional services"[79] for a study of the USGS offices in some 20 buildings scattered throughout the Washington area between Arlington, Virginia, and Beltsville, Maryland. The contract study would gather the preliminary information required to design the proposed new centralized facility, whose floor space would be no less than 600,000 square feet.

For fiscal year 1959–60, the Geologic Division received total funds of $16,620,000, nearly $485,000 less than the previous year's total, for the salaries of and operations by its 1,600 employees, 110 fewer than in 1958–59. Of the Division's 1,490 permanent employees, 386 depended on reimbursable funds, as did 32 of the 110 seasonal employees. The Division's SIR appropriation of about $11,417,000 represented a gain of about $72,000, and monies from nonfederal sources, for investigations in 18 States and Puerto Rico, rose by more than $33,000 to $363,000. Funds from other Federal agencies fell by about $590,000 to about $4,839,000. The AEC transferred $1,746,000, a $470,000 decrease; the Army and its Engineers supplied about $1,290,000, or only $8,000 less; the ICA increased its funding by more than $38,000 to almost $1,145,000; and the NSF provided nearly $58,000, as William Rubey rejoined the National Science Board.

On July 1, 1959, Andy Anderson succeeded Bill Bradley as Chief Geologist (CG), after Nolan agreed to give Anderson 1 month each year to continue his field studies, the same arrangement Nolan secured from several Secretaries of the Interior. Bradley, after 15 years as CG, returned to research and the completion of his 1:250,000 geologic map of part of southwestern Wyoming and adjacent States; the *American Journal of Science* honored Bradley with a festschrift volume in 1960. Preston Cloud, Jr., James Gilluly, and Frank Whitmore, the Chiefs of 3 of the Division's 10 program Branches, also ended their tours on the same day that Anderson took over as Chief Geologist. Anderson and Nolan quickly began planning the first major reorganization of the Geologic Division since the reforms instituted after Bradley succeeded Gerald Loughlin as CG in 1944. John Reed (Sr.), the Chairman of the Arctic Committee, left Anderson's staff in 1960 to serve as Executive Director of the Arctic Institute of North America in Montreal; Reed also became an Honorary Lecturer at McGill University. Anderson brought George Gryc east from Menlo Park to replace Reed as staff geologist.

During fiscal year 1959–60, the USGS principal participants in Project Mohole—James Balsley, Harry Ladd, William Pecora,[80] William Rubey, and Joshua Tracey—drew the expected attention of the agency's Pick and Hammer Club. On April 29, 1960, the Club's annual show in Washington[81] presented the "d'Oily Cards" in "Last Weeks of the Association for the Advancement of Politics in Geology, or Mo-ho-ho and a Barrel of Funds." The players lampooned the American Association of Petroleum Geologists, black-box geophysicists (yet again), several USGS managers and their units, polar wandering and continental drift, and "oil in Araby."[82] The show closed with "No Moho, No Less,"[83] sung to the tune of 1933's "Flying Down to Rio," from the Fred Astaire-Ginger Rogers film of the same name, to urge a U.S. victory in this latest scientific-technological race with the Soviets. The players serenaded "Glibbly S. Bunkum, Chief of the Branch of Intolerable Phenomena,"[84] who led the show's deep-drilling project, with:

Yo-ho-ho, drilling to the Moho
Drilling to the Moho through the muck and the slime
Hey, Buster, let's get through the crust there
Got to reach the Moho and we've got to make time
We'll make it, for our rig can take it,
Searching for the Moho 'way down under the ground.
Send a Schlumberger to Moho 'neath the sea-oh
For a gamma count to tell us what's
The story there,
We'll get there—
So Moho, everything will soon show
Un-con-form-i-ty that will be
So profound.[85]

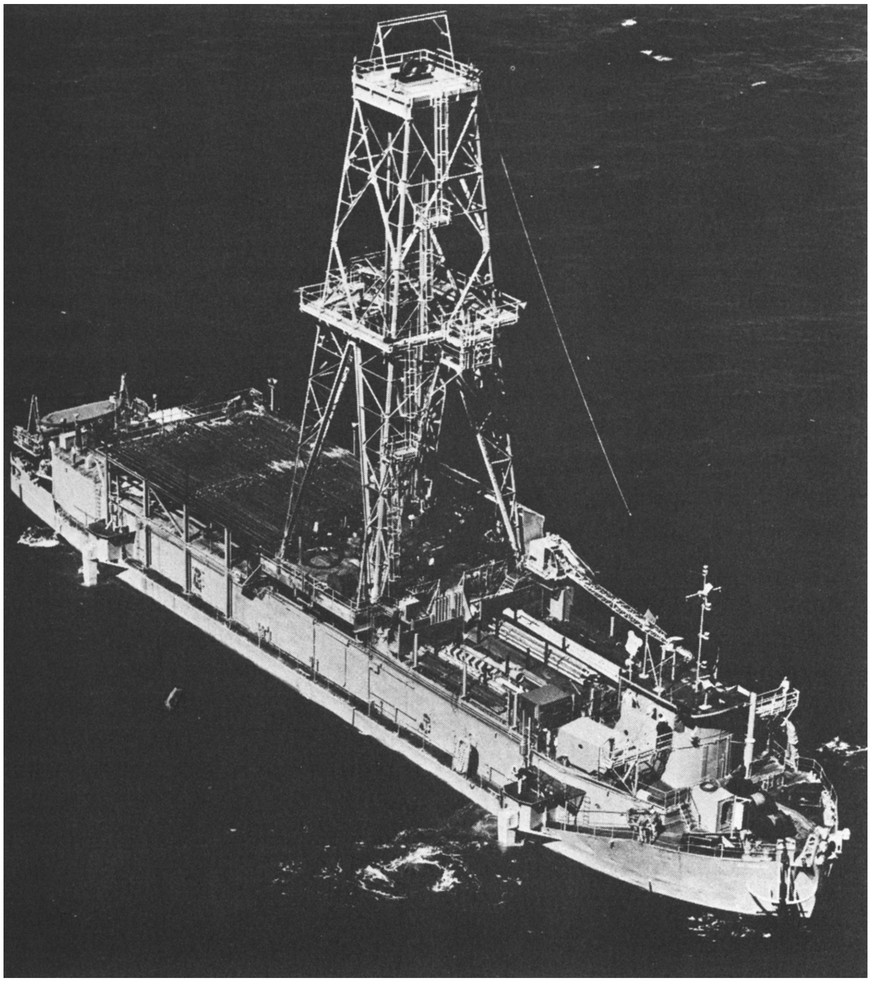
At last, in "Endothermic Research," set to college football's "Buckle down, Winsocky," the players pleaded that only Bunkum again could save them after they reached the Moho:

For the oil will flow
And the gas will blow
We will roll in dough
If you will only plug the hole![86]

By July 1960, in addition to Gordon Lill and Willard Bascom, the American Miscellaneous Society's (AMSOC's) Technical Director since 1959, the NAS–AMSOC group included William Heroy (Sr.), Harry Hess, Harry Ladd, Arthur Maxwell, Walter Munk, Roger Revelle, William Rubey, and Joshua Tracey. They were aided by two military liaisons, Lt. Colonel George Colchagoff and geographer Leonard S. Wilson, who led the Army Office of Research and Development's Environmental Sciences Division. Maurice Ewing resigned from AMSOC in April, once it became clear that the drilling tests would be done in the Pacific rather than in the Atlantic. On July 7, AMSOC added William Bates of Shell Oil, geophysicist-oceanographer John Hersey, and Captain Harold E. Saunders, a retired Navy hydrographer who served as a technical adviser to the Bureau of Ships and also chaired the U.S. Advisory Committee on Antarctic Names.

The NSF provided the NAS–NRC and John Adkins with $172,550 in fiscal year 1959–60 to support a year of experimental drilling in deep water and added to it $130,665 for 1960–61. The NSF sent an additional $8,700 to the USGS to fund the latter's cooperation during 1960–61 in the "Experimental Drilling Program (Project Mohole)."[87] The 14-member NAS–AMSOC now requested $1.25 million, a sum later increased to $1.8 million, from the NSF for Phase 1 of Project Mohole and received $1,364,000 during 1960–61, in addition to the funds provided to Adkins, now the Office of Naval Research's Assistant Chief Scientist. On December 23, 1960, the NSF awarded Global Marine Exploration Company nearly $736,000 for the modification in February 1961 of *CUSS I* at San Diego for drilling in March five preliminary holes to penetrate sediments more than 3,000 feet below the waters off La Jolla. To hold *CUSS I* on station, Bascom devised a new dynamic-positioning system that used four 200-horsepower outboard motors positioned in opposite pairs near the bow and stern, an array of radar and sonar buoys, and Sperry gyrocompasses. Bascom and some of AMSOC's staff planned to leave for San Diego on January 1. *CUSS I*, after refitting, would be towed late in March to the deeper well site, surveyed initially by William Menard and Russell Raitt, and then in more detail by Bascom. The site was in international waters about 220 miles southwest of San Diego and between Guadalupe Island and the west coast of Mexico's Baja California. There, the barge's drillers would attempt, while operating through about 11,700 feet of water, to penetrate and sample the sediments and the uppermost portion of the underlying crust.[88] If they succeeded, AMSOC members would have to decide whether to recommend modifying *CUSS I* or another existing barge for additional sediment-sampling holes elsewhere (to determine the oceans' age) and the Mohole (to identify compositional or crystal-structure changes at the interface) or to propose funds for building a new ship specially designed for those purposes.

Investigations by geologists in Warren Hobbs' Mineral Deposits Branch during fiscal year 1959–60 led to new discoveries of sedimentary iron ore in Arizona's Christmas area (in Gila County south of Globe) and a 200-foot-thick iron-bearing formation, north of Iron Mountain, in northwestern Michigan's Dickinson and Iron Counties. Branch members also recognized additional geologic guides to future exploration for lead, silver, and zinc in the Coeur d'Alene district in Idaho, metal deposits in the Butte area of Montana, and copper in Arizona's Pima district



A consortium of four oil companies—*C*ontinental, *U*nion, *S*hell, and *S*uperior—modified this U.S. Navy freight barge as a ocean drilling ship, renamed *CUSS I*, and used it in Project Mohole. USGS and other scientists helped to plan and establish Project Mohole, an American Miscellaneous Society effort supported by the National Academy of Sciences and funded by the National Science Foundation, to drill through the Earth's oceanic crust past the Mohorovicic discontinuity and investigate and sample the upper mantle. After preliminary drilling off La Jolla, California, in 1960, *CUSS I* was deployed and began operations early in 1961 at a site east of Mexico's Guadalupe Island and about 220 miles southwest of San Diego. There, at about 11,700 feet beneath the waves, the ship's drill rig returned cores from two holes from 100 to 600 feet below the ocean floor. Federal funding for Project Mohole ended in August 1966 before the crust-mantle interface was reached, but the technology used by the Project's participants and the results they obtained later made possible newer purpose-built ships like *Glomar Explorer* and *JOIDES Resolution* and worldwide sediment sampling by an academic consortium's Deep Sea Drilling Program and its successor, the Ocean Drilling Program. (National Science Foundation photograph, from Cochrane, 1978, figure on p. 561; also published on cover 1 of *Geotimes*, v. 5, no. 8, May–June 1961. For a portside view of the ship, taken from water level, see Bascom, 1961, pl. 6.)

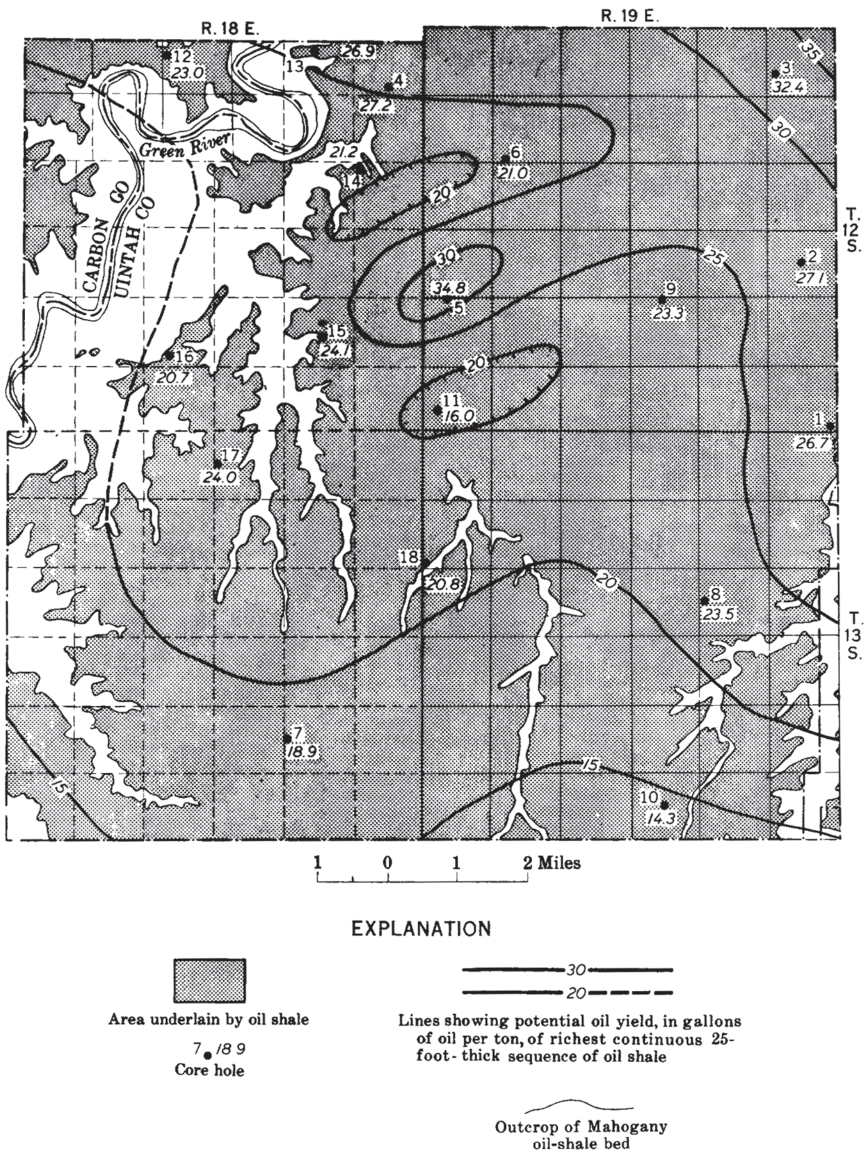
and in Michigan's Upper Peninsula. Their colleagues studied new mineral associations of beryllium-bearing minerals—bertrandite, beryl, and phenacite, all rather similar in physical appearance to feldspar and quartz—in association with fluorite and scheelite along vertical quartz veins in Nevada's Mount Wheeler Mine. They also identified beryllium in beryl and phenacite in bedrock samples from the Lost River Mine and the Cape Mountain and Ear Mountain areas in the tin district of Alaska's Seward Peninsula. Studies of clay beds in Maryland indicated that some of those deposits could be used as fire clays and others, called "bloating clays," in manufacturing lightweight concrete aggregate. Flint-clay deposits were mapped and investigated in northeastern Kentucky. Detailed investigations of uranium deposits in Arizona's Gila County, New Mexico's Ambrosia Lake, South Dakota's southern Black Hills, several basins in Wyoming, and Texas' Palagana salt dome produced data on local conditions during ore deposition and defined new targets for exploration. Uranium studies also concentrated on coals in northwestern South Dakota's Cave Hills area. This and related work on other coals in Idaho, Montana, New Mexico, North Dakota, and Wyoming better defined these uranium bearers as low-rank, high-ash, volcanic-material-laden coals, whose uranium content increased toward fractures, permeable layers, or other groundwater conduits. The concept that circulating groundwater leached uranium from the volcanic materials and deposited it in the coals led to discovering several uranium-bearing lignites and determining additional new areas for exploration. Richard Fischer discussed the vanadium-uranium deposits, mapped at 1:31,680, of the Rifle Creek area in

Colorado, and Richard Sheldon recorded the geochemistry of uranium in the Phosphoria Formation's phosphorites and black shales. Some of their colleagues completed a survey of strategic graphite.

Thomas Hendricks succeeded James Gilluly as Chief of the Fuels Branch on July 1, 1959. During fiscal year 1959–60, George Gryc, Don Miller, and Thomas Payne completed the delineation (at 1:2,500,000) of 22 possible petroleum provinces in Alaska—6 in the southern part of the new State, 3 pre-Cenozoic and 10 Cenozoic provinces in the State's central portion, and 3 in the northern part of the State.[89] A USGS team led by William B. Cashion published the results[90] of their geologic mapping, stratigraphic studies, and drill-core analyses (done in 1953–54) of Naval Oil Shale Reserve No. 2 (NOSR–2), an area of 140 square miles on the southern flank of the Uinta Basin in northeastern Utah. This work extended evaluations made during 1913–49 of the three NOSRs, including No. 1 and No. 3 in Colorado. Cashion reported two oil-shale zones in the Green River Formation that reached their maximum thickness in NOSR–2's northeastern portion; the larger of them, covering more than 110 square miles, averaged an estimated 15 gallons of oil per ton and held a total estimated reserve of 3.8 billion barrels. Physicist Gerald W. Johnson, who ended his tour as the head of the Lawrence Radiation Laboratory's Test Division in 1959 to become that Lab's Associate Director for Tests and Peaceful Applications, suggested that nuclear devices be detonated to extract the oil shales in the NOSRs. In an overview of U.S. black shales, Vernon E. Swanson assessed their oil yield and uranium content. At the end of the fiscal year, some parts of the petroleum industry remained concerned about an oil surplus. Editorials published in the *Oil and Gas Journal* and other industry periodicals suggested ways and means to end oversupply, especially by restraining flush production, coordinating supply and demand, and enacting modern conservation legislation. Paul Averitt and his colleagues finished their latest estimate of U.S. coal reserves; they concluded that some 1,660 billion tons remained in the ground, of which about half seemed recoverable. They also prepared studies of coal fields and areas in Kenai in Alaska, Mesa Verde and Trinidad in Colorado, Square Buttes in western North Dakota, southern Knob Terrace in Utah, and southwestern Washington.

By fiscal year 1959–60, members of William Pecora's Geochemistry and Petrology Branch regularly determined by rapid analytical methods the trace amounts of more than 20 diagnostic elements.[91] They also demonstrated their improved ability to help to predict and assess volcanic eruptions. These scientists developed new techniques for using resin collectors to determine the molybdenum and other ionic contents of natural waters. They also perfected methods and instruments to analyze the trace amounts of antimony, arsenic, and mercury in vegetation and a fluorometric procedure to identify concentrations of 1 to 10 parts per million of beryllium in rocks. Helen Cannon recorded the development

The oil shales shown in this 1916 photograph of strata in the Green River Formation (Eocene) occupy the north side of Argyle Canyon in Carbon County in northeastern Utah. The richer oil shales form the dark horizontal band in the middle of the canyon's side and are separated by lighter colored shales from a second oil-shale sequence about 1,000 feet below. In 1913–25, geologist Dean E. Winchester and his USGS colleagues originally mapped (at 1:250,000) Naval Oil Shale Reserve No. 2 (NOSR–2) and areas in the surrounding Uinta Basin that contained oil shales as future sources of fuel. The strata shown here occupy an area about 30 miles west of NOSR–2, which was just east of the Green River. USGS geologists remapped NOSR–2 at a larger scale during 1949–54. In 2000–2001, the U.S. Department of Energy returned the undeveloped NOSR–2 to the Northern Ute Indian Tribe. (Photograph from Winchester, 1919, pl. VIIA; also available as three separate images in the USGS Denver Library Photographic Collection as Winchester, D.E., winc0434, winc0435, and winc0436, https://www.sciencebase.gov/catalog/item/51ddd366e4b0f72b44721fa8, https://www.sciencebase.gov/catalog/item/51ddd368e4b0f72b44721faa, and https://www.sciencebase.gov/catalog/item/51ddd369e4b0f72b44721fac.)



This map (originally at 1 inch = 1.8 miles) portrays the potential oil yield for the richest continuous 25-foot-thick sequence of oil shale in Naval Oil Shale Reserve No. 2 (NOSR–2) in northeastern Utah. Partly to support the U.S. Bureau of Mines' work on synthetic fuels, USGS geologists returned after World War II to field studies of oil shales in the Green River Formation (Eocene) of western Colorado and adjacent Utah. USGS geologist William Cashion and his colleagues extended work completed by Dean Winchester and other USGS geologists during 1913–25 in the Uinta Basin that included the 140 squares miles of NOSR–2. During 1949–54, the USGS team mapped in detail the geology of NOSR–2 and assessed samples from 18 diamond-drill cores. They delineated principal oil-shale sequences 15 and 25 feet thick with estimated yields of 15–30 gallons of oil per ton. (From Cashion, 1959, fig. 39.)

of botanical methods for uranium prospecting on the Colorado Plateau. In field studies, scientists continued to gather data on plant ecology and geomorphology that showed systematic relationships among plant type, soil composition, topographic form, and water availability. Investigations in the Potomac Basin indicated that its present landscape was formed by lengthy erosion under conditions similar to present ones rather than through erosion-cycles that generate peneplains. Studies of beta-spodumene showed that the lithium-silicate mineral shrank when heated and swelled when cooled; adding it to ceramic materials facilitated molding precise forms that retained their exact sizes after firing. Studies of deuterium aided investigations of mineral formation and ocean currents. Analyses of liquids from minute bubbles in fluorite deposits in Illinois showed that early-formed minerals contained fluids similar to waters normally present at that locality but later-formed minerals held fluids containing progressively less deuterium. Samples of water originating in Antarctica were found to contain 1 percent less deuterium than those from other oceans. Investigations in Pecora's and other Branches were aided by the acquisition or development of an electron microprobe X-ray analyzer (to identify minerals), a heating stage for the X-ray diffractometer, and a cooling cell for microscopically studying temperature effects in fluid inclusions in minerals.

Earle Cressman, of the USGS, and Martin C. Noger, of the Kentucky Geological Survey (KGS), later described how in 1959 Kentucky's Government and its agencies began planning with the Geologic Division and General Geology Branch to cooperate in geologically mapping the Bluegrass State, using as bases the topographic maps of 707 quadrangles recently completed at 1:24,000 by the Topographic Division.[92] The Kentucky Society of Professional Engineers' resolution of February 21, 1959, urging this new cooperative mapping was well received by Kentucky's Governor Albert B. ("Happy") Chandler and the State's Legislative Research Commission, its Department of Economic Development, its Chamber of Commerce, and its Geological Survey. In March, Wallace W. Hagan, the State Geologist and Director of the KGS since 1958, and now also Governor Chandler's representative to the Interstate Oil Compact Commission, suggested this additional cooperative effort to USGS Director Nolan. Hagan, at Nolan's request, tested USGS interest in conversations with Associate Director Baker and Chief Geologist Bradley in April. Hagan then gained formal approval from his advisory board, the State Government, the University of Kentucky, the Chamber of Commerce, and several State geological societies, railroads, and mineral-industry companies. In Washington, during July 10–17, 1959, Hagan, Nolan, and other members of the USGS worked up a preliminary agreement. They would seek funds for a 10-year effort, costing an estimated $12 million, to begin in fiscal year 1960–61. The State and Federal Governments each hoped to supply $300,000 to fund that year's operations and to provide an additional $600,000 each during fiscal 1961–62.

Other members of the General Geology Branch continued to map and investigate areas and ore deposits nationwide during fiscal year 1959–60. This effort included the Leesburg area in Idaho, the Merced Peak area in California, and the uranium-mineralization area in Wyoming's Shirley Basin. Additional studies continued, in cooperation with other Division scientists, of batholiths in the Cascade Range, the Sierra Nevada, and the Front Range; the Idaho Batholith; and Montana's Boulder Batholith.

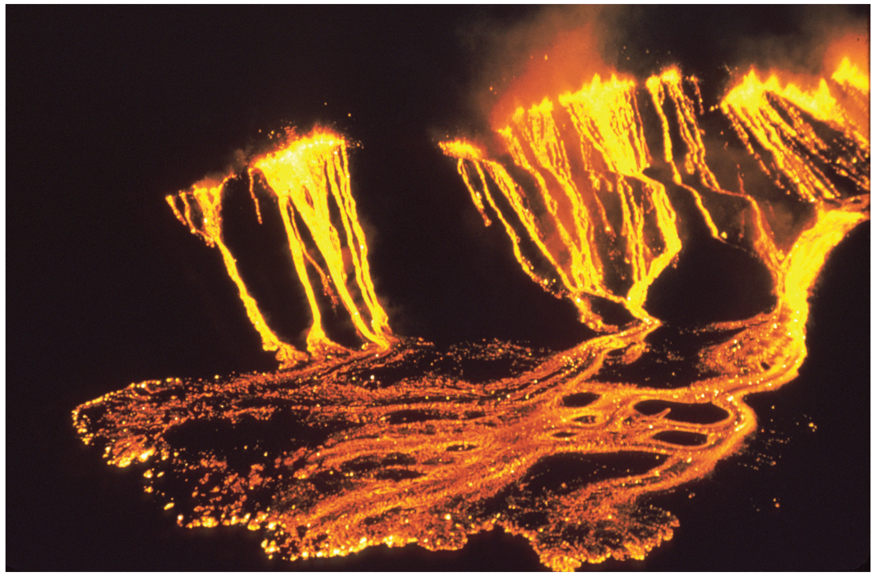
At 11:39 p.m. on August 17, 1959, a magnitude 7.3 earthquake struck the Madison Canyon area west of the Hebgen Dam and Lake area in southwestern Montana, slightly less than 20 miles northwest of West Yellowstone. The shallow-focus quake, measured in Pasadena and the largest yet recorded in Montana, was felt over an area of 600,000 square miles. Structural damage and faulting, respectively, received intensity values of VII and X. The shock reactivated large and small faults, yielding new scarps of up to 20 feet high, tilted the floor of Hebgen Lake and dropped it 22 feet, changed the groundwater regime, and caused landslides, rockfalls, and rock avalanches. The quake moved 37 million cubic yards of material in 1 minute into Madison Canyon to dam its river at a point 6 miles below Hebgen Lake. That debris left 26 persons dead or missing in the area's campgrounds; rockfalls killed 2 others 15 miles west of Hebgen Lake. Debris and subsidence from the main shock and the 1,300 aftershocks, of magnitude 5.75 to 6.5, which occurred at 5-minute intervals thereafter, affected an area of nearly 380 square miles, from which the U.S. Forest Service rescued more than 200 other persons. The quake damaged property valued at $11 million. Hebgen Dam, completed in 1915, was damaged but held. Water topped the quake-caused earthen dam on September 10, but the Army Engineers built a spillway a half-mile long and 200 feet wide to drain the earthquake lake, then 6 miles long and 190 feet deep.

At the time the Hebgen Lake earthquake occurred, two USGS geologic parties were in the area participating in the ongoing program of investigating Cenozoic tectonism in southwestern Montana, western Wyoming, and eastern Idaho. Irving Witkind, Jack B. Epstein, and Epstein's geologist-wife Anita G. Epstein (later Harris), who mapped the complex structures on the east flank of the southern Madison Range, were encamped above Hebgen Lake. Witkind, a stratigrapher and structural geologist with the USGS since 1946, co-compiled the 1955 geologic map

This view looks southwest toward the Madison Canyon landslide and earthquake lake on August 21, 1959, before the latter was drained by the Army Engineers. The magnitude 7.3 Hebgen Lake earthquake that struck the Madison Canyon area in southwestern Montana on August 17 reactivated large and small faults, changed the groundwater regime, and caused landslides, rockfalls, and rock avalanches. The quake moved 37 million cubic yards of material in 1 minute into Madison Canyon to dam its river at a point 6 miles below Hebgen Lake and leave 26 people dead or missing. The results of the main shock and the 1,300 aftershocks affected an area of nearly 380 square miles, from which more 200 other persons were rescued, and where damaged property was valued at $11 million. USGS scientists joined Federal colleagues from the U.S. Forest Service, the National Park Service, and the U.S. Coast and Geodetic Survey in conducting intensive studies, organized by USGS geologist Charles Hunt, of the Hebgen Lake earthquake's geology, hydrology, and seismology. Preliminary reports began appearing on September 16, 1959, and continued into 1962; the combined and comprehensive analysis followed in 1964. (From U.S. Geological Survey, 1964b, frontispiece).

of Montana. The second group, led by Jarvis B. ("Jerry") Hadley, who mapped parts of the Appalachians for the USGS during 1944–50, was quartered about 50 miles to the northwest near Ennis and west of the north end of the Madison Range. Witkind, Hadley, and their Montana teammates were soon joined by George Fraser, Warren Hamilton, Bradley Myers, Frank Swenson, and other USGS geologists, geophysicists, and hydrologists, for a total of 25 such specialists; they began intensive studies, organized by Charles Hunt, of the effects of the Hebgen Lake earthquake and its aftershocks. The USGS scientists, and personnel from the U.S. Coast and Geodetic Survey (USCGS), the U.S. Forest Service (USFS), and the National Park Service (NPS), joined in these and related studies and in planning a comprehensive report on the quake's geology, hydrology, and seismology. Their investigations included epicenters and foci; faults and scarps, landslides, earthflows and rockfalls, and other ground responses; wave motions, regional seismicity, and seismic history; effects on surface waters and groundwaters, especially chemistry, movement, sediments, and springs; and damage to structures. The USCGS issued a preliminary report on September 16; USGS and other initial reports began appearing in print in October and continued into 1962.[93] The USGS published a combined and comprehensive analysis as its Professional Paper 435 in 1964.[94]

During fiscal year 1959–60, maps and charts continued to appear in the USGS series of Coal Investigations (C) Maps and Charts, Geologic Quadrangle (GQ) Maps, Geophysical Investigations (GP) Maps, Hydrologic Investigations Atlases (HA), Mineral Investigations Field Studies (MF) Maps, Mineral Investigations Resource (MR) Maps, Miscellaneous Geologic Investigations (I) Maps, and Oil and Gas Investigations Charts (OC) and Maps (OM). One of the new I-Maps was being compiled by Dallas L. Peck (and published at 1:500,000 in 1961 as I–325) to



This photograph of fountaining lava, taken from the Byron Ridge overlook, shows the view west toward Kilauea Iki, a collapse (pit) crater on the eastern side of Kilauea Caldera, on the Island of Hawaii. Kilauea Iki began erupting lava during shortly after 8 p.m. (Hawaiian time) on November 14, 1959. Scientists at the USGS Hawaiian Volcano Observatory (HVO), on the opposite side of Kilauea, quickly began taking photographs and making preliminary observations, which were supplemented later by detailed geochemical, petrological, and seismic studies. (Photograph from the USGS Denver Library Photographic Collection as hvo00022, https://www.sciencebase.gov/catalog/item/51dc7973e4b097e4d3838902; published as a black-and-white image in Richter and others, 1970, fig. 5, middle.)

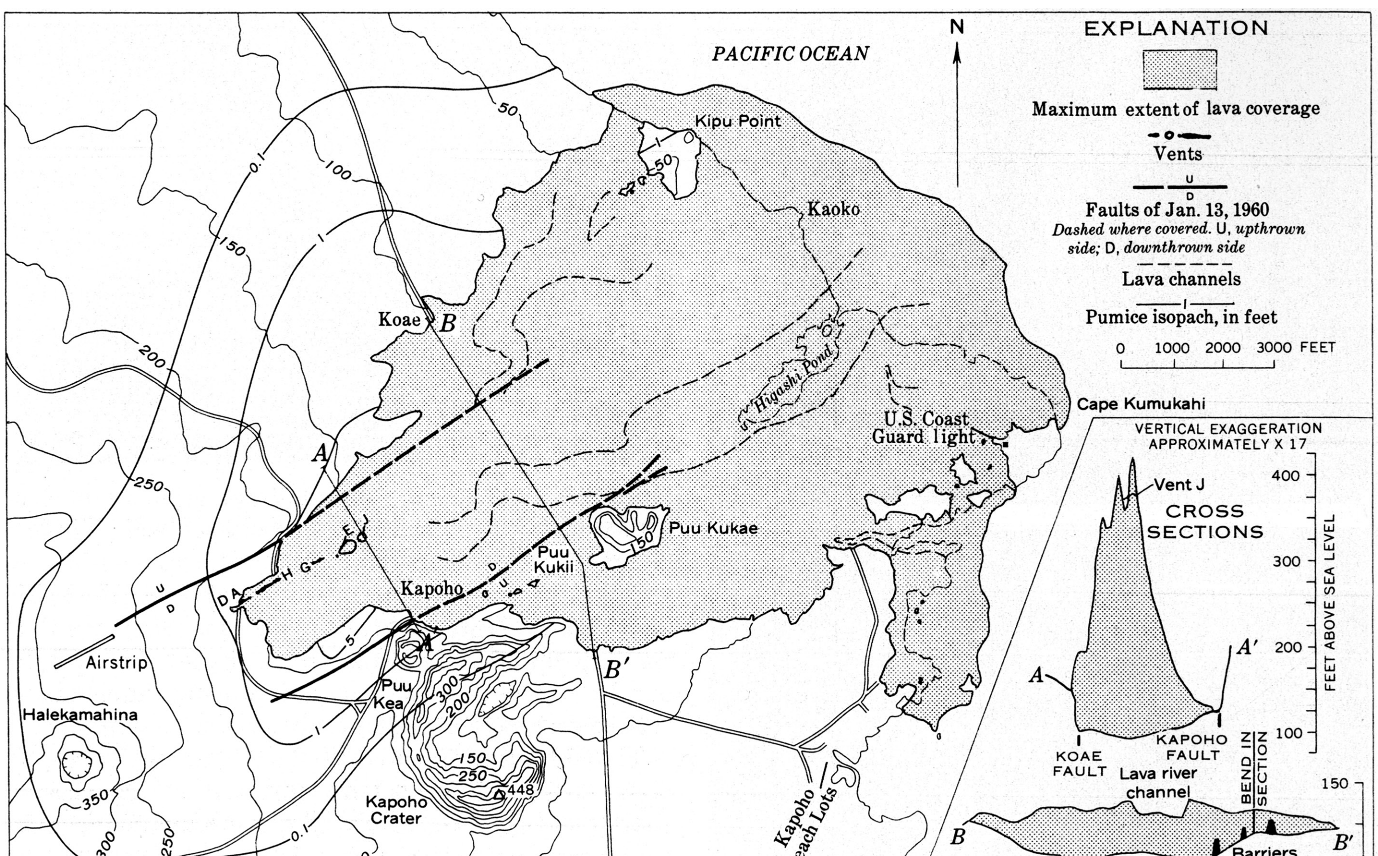
show the geology of Oregon west of the 121st meridian, an area from just east of Bend to the Pacific coast. Peck was trained by Richard Jahns at Caltech; joined the USGS in 1951, while still a graduate student; worked with Paul Bateman, Ogden L. Tweto, and Francis Wells; and earned a Ph.D. with Marland Billings at Harvard in 1960. That year, the last of another series of I-Maps completed the photogeologic coverage at 1:24,000, issued since 1954 as part of the Colorado Plateau Project, of quadrangles in Utah and adjacent parts of Arizona, Colorado, New Mexico, and Wyoming. Robert Detterman, Robert Hackman, William Hemphill, Allan Kover, Robert Morris, Charles L. Pillmore, John S. Pomeroy, John C. Reed, Jr., and their colleagues prepared these maps. No map in any of these topical series, as opposed to those topographic, included areas on the Hawaiian Islands. There, on the main island of Hawaii, Kilauea Iki erupted on November 14, 1959.[95] Scientists at the Hawaiian Volcano Observatory, using data from the new portable tiltmeter system and the seismic array, detected the coming eruption and issued an alert. The fire-fountain eruption continued through February 1960. Although the resulting lava flow devastated a large area near the village of Kapoho, no lives were lost.

Specialists in Edwin B. Eckel's Engineering Geology Branch continued during fiscal year 1959–60 their cooperative work, with members of the General Geology, Geophysics, and other Branches, toward assessing sites for dams, selecting locations for and evaluating the effects of underground nuclear tests, and analyzing the potential hazards and actual results of earthquakes and landslides, especially in urban areas. Eckel discussed in print the opportunities for and responsibilities of earth scientists in those nuclear years. Examinations by Branch members at Devils Canyon, some 125 miles north of Anchorage, led to shifting the dam site 100 feet upstream to avoid a shear zone in the wall rocks and also to relocating the spillway site to reduce construction costs by using a newly found preglacial valley. Louis Currier applied seismic methods in subsurface examinations of sites for highways and building foundations in Massachusetts. William H. Diment and the members of his project at the Nevada Test Site continued to advise the AEC on aspects of the work done before and after the underground nuclear tests. Diment and his team studied the local geology and structure, especially the properties of tuff, and examined the effects of seismic shock and high temperatures and pressures on the rocks. These investigations and their analyses of methods of detecting such tests led to a crustal-refraction study, a seismic-scaling law, and a comparison of the seismic signatures of the tests and the Hebgen aftershocks. Harvard-trained Diment also wrote the proposal sent to ARPA that led to funding for Louis Pakiser's future

Crustal Studies Branch. For the AEC, members of Eckel's and other Branches in the Geologic Division, aided by geohydrologists from the Water Resources Division, continued studies of radioactive-waste disposal.

During fiscal year 1959–60, members of James Balsley's Geophysics Branch continued or began new experimental and related investigations of the physical properties of rocks—deformation, electrical, magnetic, mechanical, optical, thermal, and thermodynamic—to aid explanations of empirical observations. A new map, at about 1:937,500 (with contours at 50 and 250 gammas), by Balsley, Randolph ("Bill") Bromery, and Kenneth Emery, showed the results of their airborne magnetometer reconnaissance off California. Density analyses of more than 2,000 samples from the Los Angeles area helped to integrate surface and subsurface geologic mapping with gravity surveys by facilitating a compartmentalized lithodensity model used to calculate the residual regional gravity gradient that showed the area's crust thickening landward. Recent drilling and seismic surveys in three locations in Indiana confirmed John Henderson, Jr., and Isidore Zietz's predictions in 1958 of the depths to Precambrian basement rocks. Harold James' team published a 1:24,000 map of the geology and layered magnetic rocks in northern Michigan's Iron River-Crystal Falls district. A second aeromagnetic map (coauthored by Bromery) interpreted the data gained during the survey of the 1:24,000 Allentown quadrangle that covered parts of three counties in Pennsylvania. Airborne-radioactivity surveys continued to aid geologic mapping, especially in areas of poor exposures and low surface relief in Maine, Michigan, and Virginia. Small differences in radioactive-mineral content distinguished specific rocks; felsic (acidic) igneous rock and shales were more generally radioactive than mafic (basic) igneous rocks and carbonates. Trials with electrical-resistivity and induced-polarization

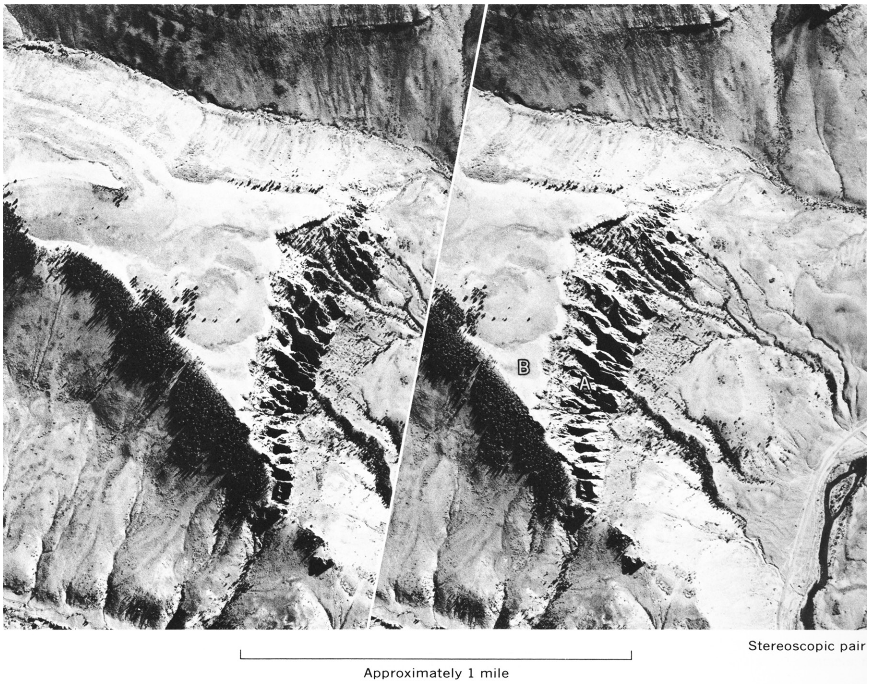
This map (originally at about 1 inch = 3,600 feet) shows the maximum area covered by lava and the thickness of the pumice blanket from the eruption of Kilauea Iki in 1959–60. Lava covered Kilauea Iki's crater, and pumice blanketed an elliptical area that extended more than 2 miles to the southwest when flows ended on December 20, 1959. A flank eruption began to the southeast of Kilauea Iki at the eastern end of the East Rift Zone near the village of Kapoho on January 14, 1960. When activity ended on February 18, lava and pumice covered 2,750 acres of land, two villages, and a U.S. Coast Guard station, but no lives were lost. (Map from Richter and others, 1970, fig. 75.)



This 1960 photograph shows USGS geophysicist Randolph Wilson ("Bill") Bromery (1926–2013) inspecting the magnetic-detector unit (or "bird") of the agency's C–53D aircraft (N19924) on the flight line at Washington National (now Reagan Washington National) Airport. Bromery flew with the Tuskegee Airmen in World War II and joined the USGS in 1948. He rose to lead a field team, then a project, and later planned and supervised the USGS geophysical program in the Eastern United States. During those years he earned degrees at Howard and American Universities and began work on a Ph.D. at Johns Hopkins University. Bromery left the USGS in 1967 for teaching and then administrative posts at the University of Massachusetts at Amherst. (Photograph from the USGS Denver Library Photographic Collection as Patterson, E.F., pef00756, https://www.sciencebase.gov/catalog/item/51dda0bae4b0f72b4471ddcf; published in Yochelson and Nelson, C.M., 1979, p. 35).

methods in Maine, Michigan, and Virginia advanced the geologic mapping of metamorphic rocks buried under alluvial or glacial deposits. Induced-polarization studies helped searches for low-grade metallic ores not concentrated enough to produce other electrical, gravity, or magnetic anomalies; under favorable conditions, measurements aided estimates of grade as well as location. The Branch acquired a new instrument that converted seismic observations into numerical form for more rapid encoding in its electronic computers. Branch scientists, in cooperation with colleagues elsewhere in the Geologic and Water Resources Divisions, continued, with AEC support, to study montmorillonite, vermiculite, and other clay minerals to determine their ability to retain cesium, strontium, or other high-level radioactive wastes by ion exchange, absorption, or other processes. They also investigated deep sedimentary basins that might safely store injected liquid radioactive wastes and determined the natural background radioactivity of many areas proposed for nuclear installations. A joint study with the National Cancer Institute and Maryland's Washington County Health Department determined the distribution of the county's natural radioactivity. Investigations of the magnetic susceptibility of rocks yielded a measurable difference between cancerous and noncancerous tissue from both animals and humans, perhaps due to iron depletion in the former group.

During fiscal year 1959–60, members of George Gates' Alaskan Geology Branch again aided their colleagues in Eckel's Branch while continuing their own mapping and related studies. For William Fischer's Photogrammetry Section, the results of isopach mapping by Irving Witkind, William Hemphill, Charles Pillmore, and Robert Morris that used photogeologic methods in the Monument Valley area of Arizona appeared as the fourth of four parts. The fourth part demonstrated the application of procedures and stereoscopic instruments described in the initial three parts, during 1956–58, by Hemphill, Richard Ray, and Pillmore.[96] Ray also completed a longer discussion of the use of aerial photographs in geologic interpretation and mapping. Samuel Keller and Hillard Reiser described the geology of the Mount Katmai area, and David Hopkins published a preliminary history of the Bering land bridge that alternately was submerged or exposed to link Alaska and Chukotka during the Cenozoic. An interpretation by John Reed (Sr.) of the geology of the Mount McKinley quadrangle (at 1:250,000) was published in 1961.



In this stereopair view (originally at about 1:20,000) of an area of flat-lying igneous rocks in Colorado, a harder and more resistant welded tuff (B) caps a softer and well-dissected pyroclastic unit (A). USGS and petroleum-industry geologists increasingly used stereoscopes, stereometers, and plotters to analyze aerial photographs and explore large areas in less time than the longer intervals required for traditional fieldwork. Successful photogeology required developing skills in recognizing the colors, patterns, shapes, sizes, textures, and tones that indicated sharp or subtle changes in geologic regimes. Whenever possible, initial results were checked by observations on the ground. Many of the maps in the new Geologic Quadrangle (GQ) series, which the USGS began issuing in 1949, were based on photogeologic methods. (From Ray, 1960, fig. 39.)

Edward H. Cobb, who entered the Branch in 1946, completed four Mineral Investigations Resource Maps, MR–8 through MR–11, at 1:2,500,000, that summarized the known occurrences of antimony, bismuth, chromium, cobalt, copper, lead, mercury, molybdenum, nickel, platinum, tin, tungsten, and zinc in Alaska.

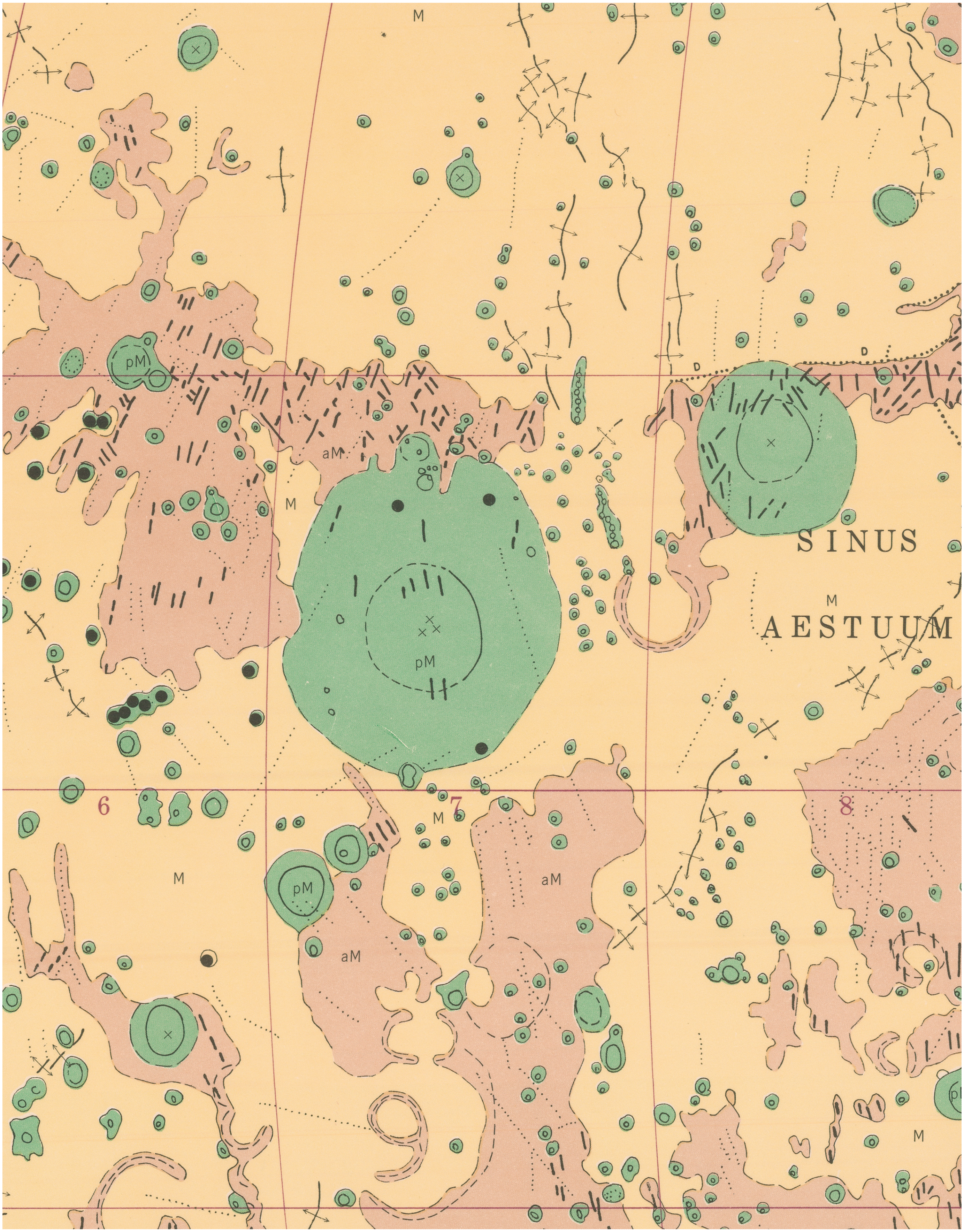
On July 1, 1959, Charles Merriam succeeded Preston Cloud as Chief of the Branch of Paleontology and Stratigraphy as Cloud joined Anderson's staff. There, Cloud promoted marine geology,[97] especially studies of marine carbonates, before leaving to become a professor at the University of Minnesota in 1961. Cloud directed the large increase in the Branch's staff and work; during Cloud's decade as Chief, its staff grew from 15 to 60 people, and the scope of its research and service to other units similarly expanded. Work continued toward completing the paleotectonic atlas of the Permian. The Branch gained a new member when Frank Whitmore ended his 13 years as Chief of the Military Geology Branch[98] on July 1, 1959, and returned to research on Cenozoic vertebrate biostratigraphy, especially that of whales and other marine mammals. Donald Dow succeeded Whitmore as Chief of the MGB, and Roy Kepferle replaced Gilbert Corwin as head of the Branch's Pacific Geologic Mapping Program. Kepferle principally oversaw the preparation of the program's remaining island reports and miscellaneous studies. He served until the program ended and all but one of its remaining reports appeared in 1960; the water-supply supplement to the report on Guam was issued in 1962. Also in 1960, the MGB completed the last of the Ragmanko Project's 149 geologic maps (at 1:250,000), begun in 1955, of Korea, the Kurile Islands, Manchuria, and Sakhalin. That project's second phase produced 17 same-scale maps of the PRC's southern coast, likely with the aid of both existing maps and the U–2 and other new aerial photography.

The preparation of maps to support, directly or indirectly, NASA's lunar program continued during fiscal year 1959–60. The Air Force's Aeronautical Chart and Information Center (ACIC) at St. Louis, led by Robert W. Carder, kept its lunar atlas[99] secret from the Army Map Service, which continued to support USGS efforts by Robert Hackman's group in Donald Dow's Military Geology Branch. The USAF's ACIC published in February 1960 the initial 1:1,000,000 sheet of its lunar astronomical charts, airbrushed by photogrammetrist Patricia M. Bridges, who later joined the USGS. The compilations by Hackman and Arnold Mason also drew on visual interpretations that they and others made by using the telescopes at three observatories— Leander McCormick, at the University of Virginia in Charlottesville; Naval, at Flagstaff, Arizona; and Yerkes at Williams Bay, Wisconsin. Hackman used surface reflectivity and regularity or irregularity of terrain features in compiling their relative ages on the lunar base prepared by the ACIC. The AMS published Hackman's map in July 1960. A revised version, the "Generalized Photogeologic Map of the Moon," at about 1:3,800,000, appeared in 1961 as sheet 1 of the 4-sheet Engineer Special Study of the Surface of the Moon that was published as USGS Miscellaneous Geologic Investigations Map I–351.[100] Hackman portrayed thereon the lunar "seas" and highlands (uplands) by using three stratigraphic units. From older to younger, they included pre-maria, maria, and post-maria rocks. These units conformed in sequence, but not in origin, to Kuiper's three divisions and emphasized impact origins for craters and volcanic origins for maria. Wilhelms later called Hackman's cartography the "first modern lunar geologic map based on stratigraphic principles."[101] Additional sheets of Map I–351 depicted (2) "Lunar Rays," by Hackman; (3) "Physiographic Divisions of the Moon," by Hackman and Mason; and (4) "Description and Evaluation of the Physiographic Regions," by Mason and Hackman. This work led directly to a 26-page engineer study of the Moon's Kepler quadrangle as MGB Miscellaneous Paper 223 in 1961. Mason, bedeviled by influences both personal and professional, died by his own hand that October.

Gene Shoemaker studied impact craters and their mineral products on Earth, under the influence of earlier published and unpublished work by David Griggs, Edward Teller, Harry Hess, and others. In October 1959, Shoemaker, at the invitation of Kuiper, who was studying Crater Tycho, joined Robert Dietz, Robert Hackman, Arnold Mason, and Annabel Olson at the McDonald Observatory, northwest of Fort Davis, Texas. While there, they also looked at the complex and "cryptovolcanic" Sierra Madera crater, and Dietz found mineral evidence for its impact origin. Shoemaker also encouraged Edward Chao and other colleagues to work on these topics and on tektites, to which some geologists, but not Urey, assigned a lunar origin.

Chao, born in Soochow (Suzhou), some 50 miles west of Shanghai, worked for the Geological Survey of China in Szechuan, came to the United States in 1945, earned a doctorate in geology at Chicago in 1948, joined the USGS in 1949, and was naturalized in 1955. Initially, Chao worked on engineering geology in the MGB, where he prepared 1:250,000 lithologic maps of North Korea and, with William Davies, studied Mammoth Cave's sediments for the National Park Service. Chao shifted to the Branch of Geochemistry and Petrology in 1956, where he studied silicate minerals from the Green River Formation for Charles Milton and contributed estimates of zirconium and other elements in the Earth's crust to studies of geochemistry by Michael Fleischer. In May 1960, Chao began studies of the origin of tektites and "impactites," which led to his discovery of nickel-iron spherules in tektites and of natural coesite. Chao's study by X-rays of minerals in sheared samples of the Coconino Sandstone from Meteor Crater showed patterns that matched those of coesite, a high-pressure and high-density form of silica created artificially in 1953 by chemist Loring Coes, Jr., of the Norton Company. Chao demonstrated that coesite could be produced naturally at the surface by impact-shock metamorphism[102] rather than being formed like diamonds (also newly synthesized) at great depths below the Earth's surface. The Interior Department's Information Service issued a news release on June 17, 1960, touting, especially for NASA and Congress, this USGS discovery in "space geology,"[103] for which Chao and Shoemaker shared in 1965 the Wetherill Medal from Philadelphia's Franklin Institute.

Chao, Shoemaker, and Beth M. Madsen (a geologist trained at Wisconsin, who joined the USGS in 1951) reported the discovery of natural coesite at Meteor Crater in July 1960.[104] That find, with the earlier supportive stratigraphic and related studies, helped to validate the interpretation of the crater as an impact feature.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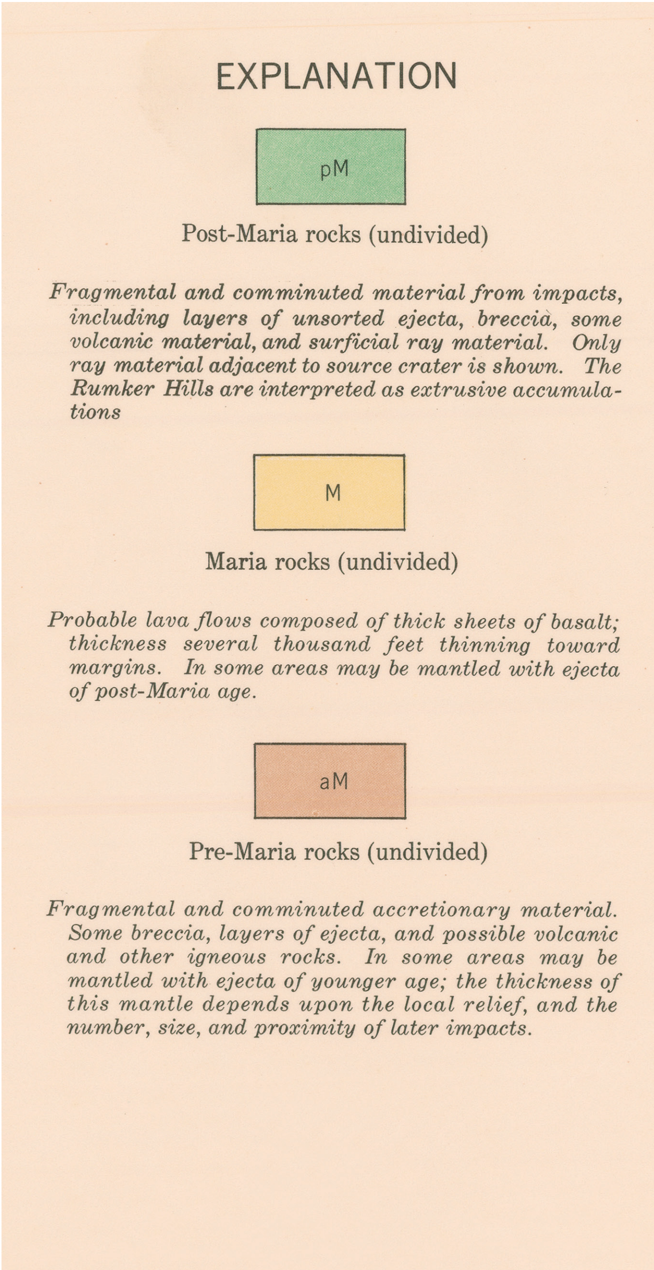
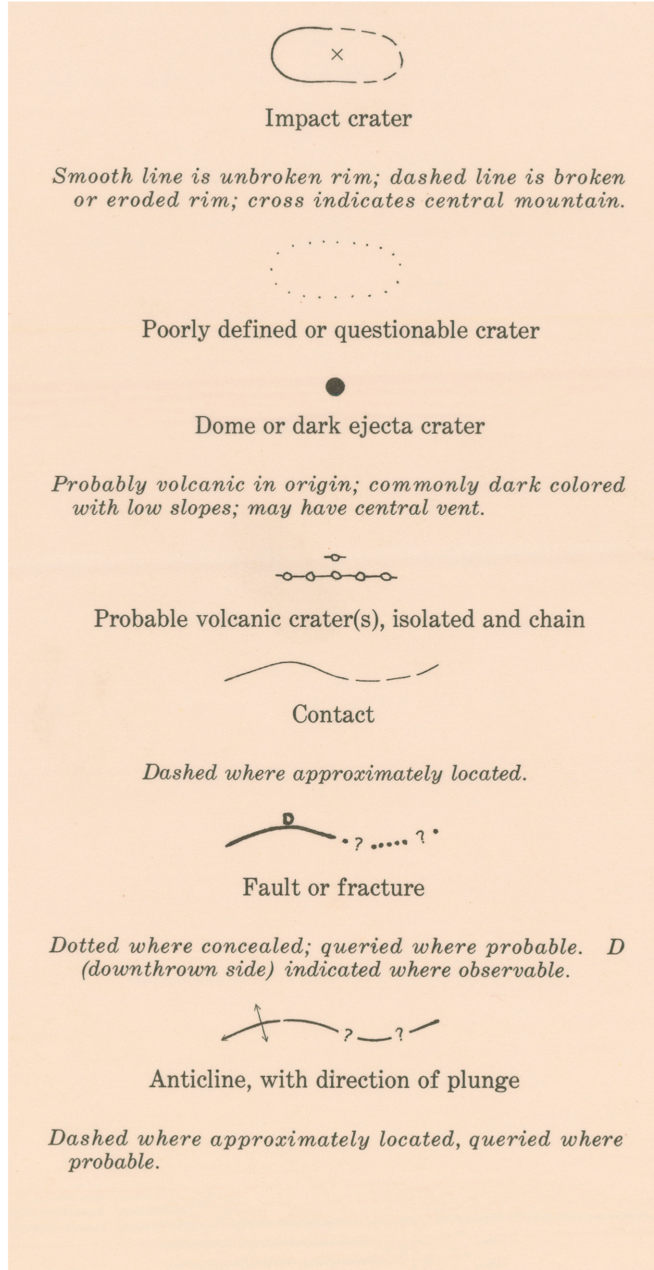


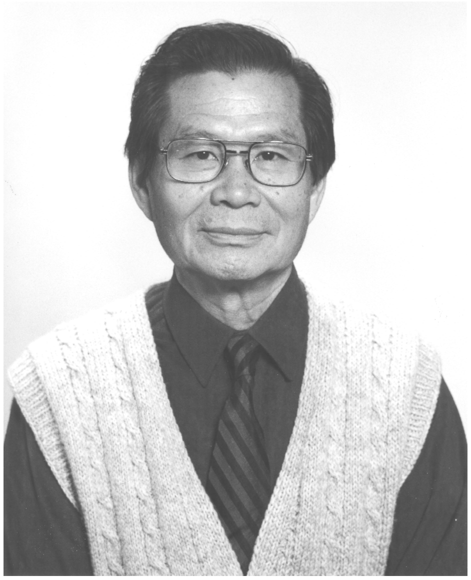


This portion of the generalized photogeologic map (originally at 1:3,800,000) of the nearside of the Earth's Moon shows the 18.6-mile-wide Crater Copernicus (the large crater in grid square J7, directly east of [that is, to the left of] Sinus Aestum), and surrounding features of the Imbrium Serentatis in the northwest quadrant of the nearside. The next largest crater shown in this part of the map is Eratosthenes. The map's grid extends from east to west (numbers 1–18) and north to south (letters A–H, J–N, P–T). The map appeared as sheet 1 of USGS Miscellaneous Geologic Investigations Map I–351 in 1961. The three-unit map portrays pre-maria, maria, and post-maria rocks. USGS photogeologist Robert Hackman compiled this map by interpreting telescopic photographs from four observatories—three in the United States and one in France. Robert Dietz (U.S. Coast and Geodetic Survey); Gerard Kuiper (Director, Lunar and Planetary Laboratory, University of Arizona); Maxim Elias (formerly with the USGS and now a consultant); Chester A. Watts (U.S. Naval Observatory); USGS scientists William Fischer, Annabel Olson, and Eugene Shoemaker; and colleagues from the Army Corps of Engineers aided the compilation. Sheet 2 (by Hackman) of this Army "Engineer Special Study of the Surface of the Moon" depicts lunar rays; sheet 3 (by Hackman and Arnold Mason, project chief in the USGS Military Geology Branch) shows the physiographic divisions (10 major highlands and lowlands, plus lesser bays, hills, mountains, and seas). Sheet 4 (by Mason and Hackman), "Description and Evaluation of the Physiographic Regions," contains text and an interpretative table. Shoemaker, Hackman, and their USGS colleagues subsequently used high-albedo Crater Copernicus to test Shoemaker's crater-count method. They combined the results with analyses of overlapping rays (Copernicus overlapped Craters Aristarchus and Kepler) and interpretations from other superpositional methods to determine relative ages on the lunar surface, work up a time scale, and prepare 1:1,000,000 geologic maps, including those of the Kepler region (I–355) in 1962 and the Copernicus quadrangle (I–515) in 1967. (From Hackman and Mason, 1961; see also Ashworth [1989], Wilhelms [1993], and Whitaker [1999].)

USGS photogeologist Annabel Brown Olson (1922–92) is shown here using paired stereoscopic photographs and a plotter to measure the diameter of nearside craters on the Moon. Her results contributed to the mapping and relative-age determinations of terrain features by the Military Geology Branch's Lunar Mapping Project. Olson, educated at Chicago and Stanford, served with the California Division of Mines and Geology before joining the USGS in 1950. She worked with the MGB in Tokyo, learned photogeologic mapping from William Fischer, applied that technique in the Navy Oil Project and the Colorado Plateau Project, and checked her results by field observations. In 1969, Olson returned to mapping the surface of the Moon and then Mars. During the 1970s and 1980s, she used stereoscopic photographs and color infrared imagery to map geology and coal resources in New Mexico. (Photograph from U.S. Geological Survey, 1961, p. [110].)

Chao's and Shoemaker's coeval work on Bavaria's Ries Basin in West Germany demonstrated a similar origin for that crater. Shoemaker also conducted experiments on the ballistics of ejecta from artificially created craters, both explosive and impact, and large and small, and compared their ejecta patterns to those of Copernicus, its satellite craters, and other lunar craters old and new. He presented his results in March 1960 at the 8th Lunar and Planetary Exploration Colloquium in March, sponsored, as were the seven preceding ones since 1958, by North American Aviation's Missile Division in Downey, California. Shoemaker also described his view of the penetration mechanics of high-velocity meteorites at the 21st International Geological Congress in Copenhagen in August 1960.[105]

In 1960, Shoemaker returned to trying to establish a formal unit in the Geologic Division for lunar studies, while earning a doctorate at Princeton using the results of his studies of Meteor Crater. Early in the year, Shoemaker offered his lunar-studies program to USGS managers for the third time. He now approached Chief Geologist Anderson, who asked the opinion of Loren Stieff, Shoemaker's friend and colleague from the Colorado Plateau Project. Stieff queried colleagues at the JPL and the Smithsonian, who agreed to promote a USGS study of tektites, as Shoemaker readied a second proposal for crater studies and lunar mapping. These investigations would be funded by an initial $200,000 transferred from NASA to the USGS. By May, Shoemaker, Stieff, Chao, and several colleagues were in Menlo Park or Washington as the nucleus of a USGS program of space geology, but Hackman refused Shoemaker's offer to relocate to Menlo Park. The new USGS unit, which Shoemaker named the Astrogeologic Studies Group (ASG), began formal operations there, Wilhelms later recalled,[106] on August 24, 1960, 4 days after NASA began transferring funds to the USGS. By October, Shoemaker added three more geologists to the ASG, renamed the Branch of Astrogeology[107] in 1961.



Edward Ching-Te Chao (1919–2008), born in Suzhou, worked for the Geological Survey of China in Szechuan (1941–45) before relocating to the United States. He earned a doctorate in geology at the University of Chicago in 1948. He served with the USGS Military Geology Branch (1949–56) and the Geochemistry and Petrology Branch (1956–60) before joining Eugene Shoemaker's newly formed Astrogeologic Studies Group (later Astrogeology Branch). Chao, in studying the origin of tektites and impact metamorphism, used X-ray analysis to identify natural coesite in sheared samples of sandstones from Meteor Crater. He extended this work in a cooperative investigation of Ries Crater in southern Germany. Chao aided the National Aeronautics and Space Administration in planning for studies of lunar samples from Project Apollo, helped Shoemaker and others to train astronauts, and served on the teams that investigated the lunar specimens returned by the 11th, 12th, 16th, and 17th missions. In 1977, Chao shifted to the Coal Resources Branch, where his team applied lunar-studies methods to investigations of coal petrology. In 1984, Chao began USGS coordinating activities under the Earth Science Protocol signed by the United States and the People's Republic of China (PRC) and also investigated the PRC's rare-earth-elements deposit at Bayan Obo in Inner Mongolia. He retired from the USGS in 1994. (Photograph by USGS photographer David F. Usher, about 1965.)

They included Richard E. Eggleton, who mapped for the Engineering Geology Branch the "Chantilly" site for the Dulles International Airport in Virginia; Charles H. Marshall, one of the photogeologic mappers in Utah; and Henry J. Moore 2d, Shoemaker's field assistant in the Colorado Plateau Project. Shoemaker and his team kept well informed about NASA's plans for manned missions in space later in the decade, including Project Gemini, following the last of the Mercury missions, to place two-man spacecraft in orbit to photograph the Earth and gather scientific data. On July 28, 1960, NASA announced that its Project Apollo, a name chosen by Abe Silverstein, subsequently would loft three-man capsules into Earth orbit and perhaps later into orbit around the Moon. Shoemaker, now 32, still hoped to be the astronaut-geologist who would accompany the Apollo lunar circumnavigation, or, even better, a subsequent lunar landing. Wilhelms thought that Shoemaker intended to have Stieff lead the ASG, while Shoemaker sought ways and means to qualify as an astronaut, but Stieff left the USGS later in 1960 to become a physical-science administrator at the Air Force Technical Applications Center.

Shoemaker also worked up a more detailed lunar stratigraphic scheme while he waited for Anderson's decision, visited Kuiper in Tucson, and considered offers to shift to the JPL or to the RAND Corporation. Shoemaker combined the results of his own investigation, Patricia Bridges' prototype lunar-atlas sheet of the region around Crater Copernicus, and his colleagues' terrestrial and lunar studies in preparing a preliminary stratigraphic column for the Copernicus area[108] based principally on the superposition of deposits, craters, and other terrain features. Shoemaker grouped materials from crater rims (ejecta blanket), crater sides ("talus"), crater floors ("breccia"), domes, maria, ray material, and regional material in seven "classes" by age. He defined five time-stratigraphic units at "system" level—pre-Imbrian (oldest), Imbrian, Procellarian, Eratosthenian, and Copernican (youngest). Shoemaker later subdivided the Imbrian System into two series—Apenninian (older) and Archimedian (younger)—as he and his colleagues extended the stratigraphic column to other areas on the Moon's nearside. He presented his scheme twice in December 1960—in Leningrad (St. Petersburg) at the 14th Symposium of the International Astronomical Union and, with the Ries Basin study, in New York City at the annual meeting of the Geological Society of America (GSAm). Hackman used the new scheme in his Engineer Study of the Kepler quadrangle, issued in 1961 for the Army Engineers as MGB Miscellaneous Paper 223, and in his 13-unit "Geologic Map and Sections of the Kepler Region of the Moon," at 1:1,000,000 and published in 1962 as USGS Map I–355. That map's text and the three same-scale quadrangles of the Lansberg region that closely followed it, Wilhelms recalled, "were simple statements of mapping principles, stressing the then-novel idea that the surface of the Moon is [geologically] heterogeneous" and produced a workable stratigraphy for the nearside. Hackman's Kepler quadrangle "introduced a major innovation into lunar geologic mapping." Thereafter, Wilhelms continued, geologic-unit descriptions in USGS lunar maps "had two parts: *characteristics*, the objectively observable properties, including coarse topography; and *interpretations*, the speculations on origin and inferred terrain properties."[109]

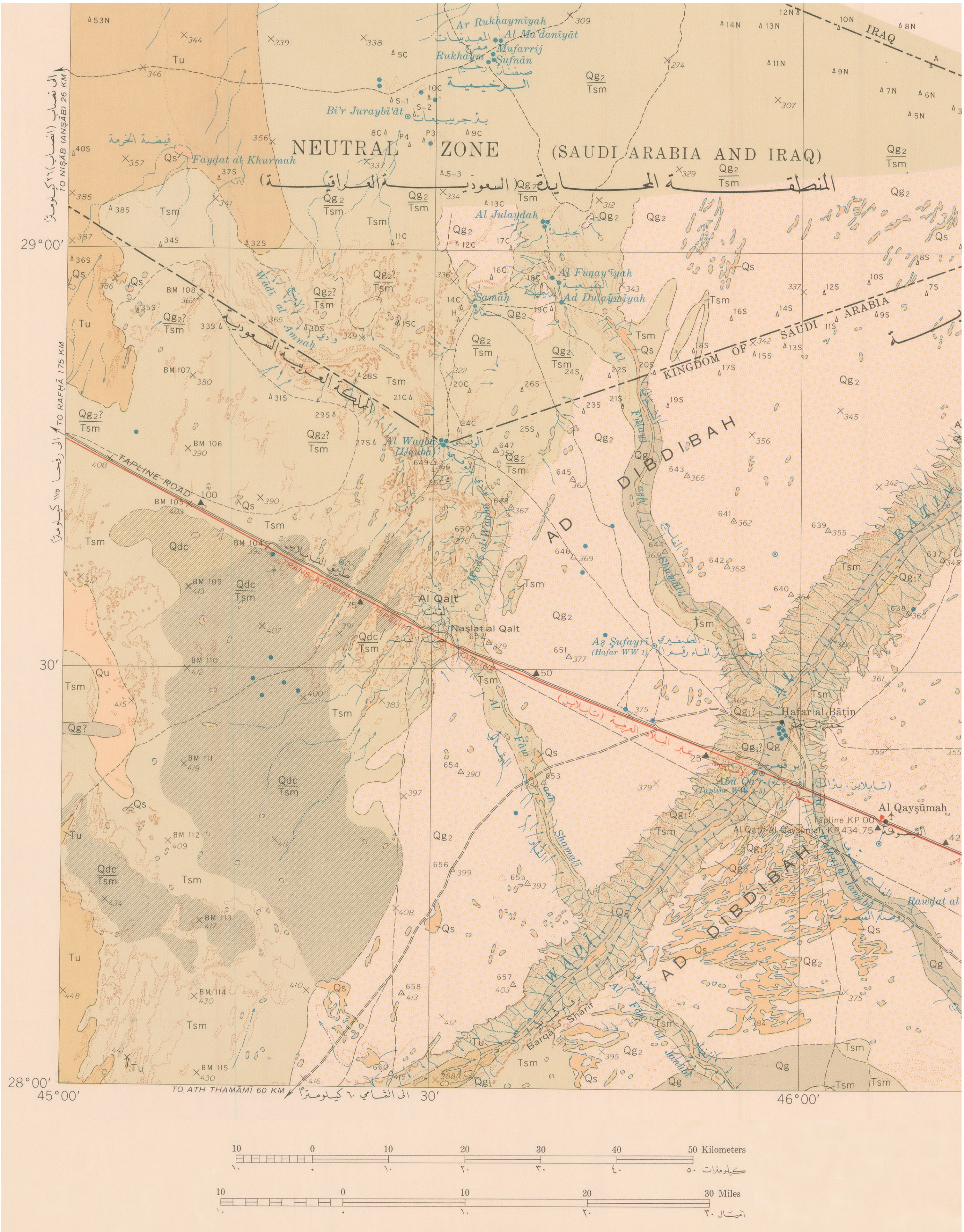
Members of William Johnston's Foreign Geology Branch continued during fiscal year 1959–60, with the ICA's financial aid, to provide technical assistance to mineral-resource and related investigations abroad and to train visitors at home, whose instruction (aided by Topographic Division personnel) included photogeologic techniques. Nearly 50 geologists in the Branch and the Division and at Interior worked with their colleagues in 13 countries and helped to train some 120 scientists and technicians from 30 countries. They continued cooperative geologic mapping and related studies, and (or) advised government agencies, in Bolivia, Brazil, Chile, the Republic of China, India, Indonesia, Libya, Mexico, Pakistan, Peru, the Philippines, Saudi Arabia, and Thailand. Thor Kiilsgaard finished his mineral investigation in southern Peru during September 1959 and then traveled to Bolivia for similar work and to aid the formation of a national geological survey; he returned to the United States in April 1960 and began a 3-year term as the Geologic Division's commodity geologist for lead and zinc. In Brazil, Robert Johnson completed his base-metals assignment in September 1959 and shifted to full-time work in Indonesia on that country's phosphate and bauxite deposits. Robert Reeves ended his service with John Dorr's Minas Gerais iron project in March 1960. In June, Mackenzie Gordon finished his geologic-education work in Brazil, 6 months after Russell Gibson began a similar assignment in January. Samuel Moore's association with George Ericksen in Chile ended in September 1959, and so Moore missed the magnitude 9.5 earthquake off the southern coast of Chile on May 22, 1960; the quake, named for Valdivia, was the strongest ever recorded and caused local tsunamis with wave heights of up to 80 feet that killed more than 500 people. The Valdivia quake also generated a Pacific-wide tsunami whose runups of heights to 35 feet in Hawaii devastated Hilo Bay and killed 60 people there before it reached and damaged areas in Japan and in the Philippines.[110] James Gualtieri finished his service in Libya during September 1959. Quentin Singewald joined the Branch's mineral-deposits studies in Turkey in January 1960. Paul Richards served with the Branch's mineral investigators in India during July 1959–March 1960, as John Albers completed his aid to the institutional development of that country's national geological survey. William Hemphill lent his photogeologic expertise to John Reinemund's project in Pakistan during September–December 1959. Roscoe M. Smith, who left industry to join the USGS in 1951 for DMEA-funded studies, began a multiyear assignment in October 1959 as a technical adviser on minerals to Thailand's Government. In Indonesia, Howard Weeks completed his investigations of mineral resources in September 1959; Howard Waldron arrived there in October for work in engineering geology until year's end.

Glen Brown, Chief of the Foreign Hydrology Section, remained in Washington overseeing the preparation and publication of the bilingual geographic and geologic maps of Saudi Arabia. Between July 1960 and October 1963, he also advised the International Bank for Reconstruction and Development (part of the World Bank Group) while reporting to the ICA's Harold Folk. During this interval, Brown also gave requested information about minerals, water, and maps to the World Bank for its mission to Saudi Arabia. By the end of calendar 1960, 24 of the 1:500,000 Saudi quadrangles were printed as I-Maps—10 geologic, labeled "A" after their three-digit I numbers, and 14 geographic, labeled "B" after those numbers. The maps were prepared by Brown, Richard Bogue, Richard Bramkamp, Gus Goudarzi, Roy Jackson, Leon F. Ramirez, Max Steineke, and their colleagues. Both geographic and geologic maps were now available for nine of these quadrangles. They included Wadi Al Batin in the north, which covered the Neutral Zones that Saudi Arabia shared with Iraq and Kuwait; an interior-to-Persian Gulf strip of six quadrangles between 20 and 28 degrees north latitude and 45 and 54 degrees east longitude, including Dammam, Riyadh, and the eastern coast; and the last two in the coastal southwest, extending coverage to the Kingdom's indefinite border with Yemen. Three other geographic quadrangles provided additional coverage to the northwest and completed that mapping of the entire Red Sea littoral and the areas around Mecca and Medina.

The NSF deployed nearly $6,180,000 of the $154,773,000 appropriated for fiscal year 1959–60 to support Antarctic research.[111] Rear Admiral David M. Tyree replaced George Dufek as the Navy's Antarctic Projects Officer in April 1959 and as commander of the Naval Support Force Antarctica for Operation Deep Freeze 60 during the austral summer of 1959–60. Edwin McDonald continued to lead TF 43, an eight-ship group that included icebreakers *Atka*, *Burton Island*, *Eastwind*, and *Glacier*.[112] The Air Force's logistical support increased when it made new transport aircraft available. On January 23, 1960, a four-turboprop C–130 Hercules landed at McMurdo; this transport, another product of Clarence ("Kelly") Johnson's Skunk Works at Lockheed, could carry up to 21 tons of cargo for as much as 8,500 miles and was modified for polar operations. USGS geologists and topographers again formed teams to conduct mapping and science surveys on the continent. William Chapman and geologist Eugene L. Boudette participated in a round-trip traverse across Marie Byrd Land from the Byrd Station to the Amundsen Sea, via the Executive Committee Range. Preliminary results of investigations on and over Marie Byrd Land suggested that it was a volcanic archipelago. Chapman and Boudette (who served with the Army Engineers before beginning work in economic and regional geology for the USGS in 1953) wintered over at the Byrd Station, where they continued map-control surveys and made stellar and other observations to fix geographic locations. Geologist Harold A. Hubbard and topographer Warren T. Borgeson sailed in *Burton Island* as part of the Navy's Bellingshausen Sea Expedition and fixed a number of geographic positions, including those on the coast of the Thurston "Peninsula," which the expedition decided was an island separated from Ellsworth Land by Peacock Sound. Geologist Alfred R. Taylor and topographer Louis J. Roberts completed a geological and map-control traverse across Victoria Land, during which they discovered the Outback Nunataks. Topographer Walter R. Seelig finished map-control surveys for McMurdo Station aerial photography and also the land-surveying and mapping to be used by the Topographic Division's Future Planning Team.[113] Members of the Topographic Division in Washington continued to prepare three 1:500,000 maps of areas along the Knox Coast, east of ice-free Cape Hordern, began compiling similar maps for the McMurdo Sound area, and added maps and aerial photographs to the Division's Antarctic library.

During November–December 1959, representatives of countries participating in the IGY and those with claims on territories on Antarctica met to assess scientific results and sign a treaty that continued that cooperative effort by determining the future of the continent in the coming decades. Attendees at the Antarctic Symposium, held at Buenos Aires during November 17–25, evaluated the achievements of the 2.5 years of scientific programs conducted under IGY auspices. In Washington, on December 1, following a year of negotiations, representatives of 12 counties—Argentina, Australia, Belgium, Britain, Chile, France, Japan, New Zealand, Norway, South Africa, the Soviet Union, and the United States—signed the Antarctic Treaty. The agreement, with equally authentic versions in English, French, Russian, and Spanish, declared that the area south of 60 degrees south latitude "shall continue forever to be used exclusively for peaceful purposes and shall not become the scene of international discord." The treaty required sharing all scientific information, giving free access to all scientific bases, and protecting the continent's living resources. The pact prohibited nuclear explosions, radioactive-waste disposal, and all military installations and activities (except those required to support scientific operations or other peaceful purposes); provided for international inspections and peaceful solutions of disputes; held in abeyance all territorial and sovereign claims south of 60 degrees; allowed no mining or other resource extraction until 2041; and provided for its own renewal. Representatives of the signatory countries would meet in Canberra within 2 months after the treaty became effective on June 23, 1961, "and thereafter at suitable intervals and places."[114]

To promote the Antarctic Treaty's requirements for continued free access to all areas for scientific investigation and the unrestricted exchange of information and personnel, organizations in some of the participating countries established new centers for polar investigations. In the United States, during February 1960, Ohio State University (OSU) founded an Institute for Polar Studies (later the Byrd Polar Research Center). Richard P. Goldthwait, a glaciologist-geomorphologist who joined OSU's faculty in 1946, directed the new center in Columbus. From there, Goldthwait also managed the reduction of the IGY's glaciological data, stored in


NEUTRAL ZONE (SAUDI ARABIA AND IRAQ)
المنطقة المحايدة (السعودية العراقية)
IRAQ
KINGDOM OF SAUDI ARABIA
AD DIBDIBAH
Ar Rukhaymiyah
Al Ma'daniyat
Mufarrij
Rukhaym
Sufnan
Bi'r Juraybi'at
Faydat al Khurmah
Al Julaydah
Al Fuqay'iyah
Ad Dulaymiyah
Samah
Al Waqba
Wadi al Amnah
Wadi al Waqba
TAPLINE ROAD
TRANS-ARABIAN PIPELINE
Al Qalt
Nash'at al Qalt
As Sufayri
(Hafar WW 1)
Hafar al Batin
Abu Qur
(Tapline WW A-5)
Al Qaysumah
Tapline KP 00
Al Qalt Al Qaysumah KP 434.75
Rawdat al
Shamali
WADI
Barqa Sharif
TO NISAB (ANSAB) 26 KM
TO RAFHA 175 KM
TO ATH THAMAMI 60 KM
29°00′
30′
28°00′
45°00′
30′
46°00′
10 0 10 20 30 40 50 Kilometers
10 0 10 20 30 Miles

This portion of the geologic map (originally at 1:500,000) of the Wadi al Batin quadrangle in the northeastern part of the Kingdom of Saudi Arabia was prepared by the USGS and the Arabian-American Oil Company (Aramco) and sponsored by the Saudi Government's Ministry of Petroleum and Mineral Resources and the U.S. Department of State. The USGS published the map in English and Arabic in "1960 A. D." (and "1379 A. H." in the Arabic calendar) as USGS Miscellaneous Geologic Investigations Map I–203 A. The map does not show geologic features north of the northern boundary of the Neutral Zone between Saudi Arabia and Iraq. The same-scale geographic (only) map of the Wadi al Batin quadrangle, also in English and Arabic, had appeared as I–203 B in "1959 A. D." ("1379 A. H."). Personnel from the USGS, Aramco, Saudi Arabia, and other countries used aerial photographs (1949–59) as base maps in compiling (1950–63) the Kingdom's geography and geology on 21 quadrangles. Members of this mapping project, directed by Glen Brown, completed the 1:500,000 depiction of the geology and geography of Saudi Arabia with the publication of the 21st quadrangle in 1964. The geologic maps were combined as a single geologic map of the Arabian Peninsula at 1:2,000,000 and published as I–270 A in 1963, the year the USGS began its continuing mission to Saudi Arabia. The geographic composite at 1:2,000,000 initially appeared as I–270 B–1 in 1958; a revised edition was issued as I–270 B–2 in 1963. (From Bramkamp and Ramirez, 1960.)

the World Data Center A's glaciology facility at the American Geographical Society in New York City. Goldthwait also completed a glacial map of Ohio at 1:500,000. Two collaborators aided the compilation—the Ohio Geological Survey's Jane L. Forsyth and George W. White, earlier a professor at OSU and State Geologist of Ohio. Since 1947, White had chaired the Department of Geology at the University of Illinois at Champaign-Urbana, where he continued part-time work with the USGS begun in 1942.

During fiscal year 1959–60, the Topographic Division drew on total funds of nearly $19,811,000, about $652,000 more than it received in 1958–59, for the salaries of and operations by its 2,450 permanent and seasonal employees, or 8 more than in the previous year. More Topographic Division personnel depended on reimbursable funds—523 of 2,135 permanent personnel and 79 of 315 seasonal workers—than did Geologic Division staff. SIR appropriations supplied some $14,715,000 of the new total, representing an increase of about $41,000 compared to the previous year's sum. Nonfederal sources provided nearly $2,904,000, a gain of more than $691,000. Most of the additional funds came from the States, counties, and municipalities, which contributed more than $2,731,000, an increase of more than $718,000. The State-supplied monies included $1 million from Ohio, which, if it continued its yearly and equally shared funding with the USGS, would have its 1:24,000 map coverage completed in 1962. Other Federal agencies provided nearly $2,192,000 in 1959–60, a loss of about $80,000 from the previous year. The USBR increased its transfers by nearly $104,000 to $908,000, but funds from the Army and its Engineers fell by almost $450,000 to about $785,000. The AEC provided $130,000, which was $30,000 less than the sum received from the NSF. In 1960, Chief Topographic Engineer George Whitmore appointed Russell Bean, then Chief of the Branch of Research and Design in Arlington, as Assistant CTE for Research and Technical Standards and Chief of the Office of Research and Technical Standards. William Radlinski became Bean's Deputy Assistant CTE. Radlinski, an Army Engineer officer in Europe during World War II, joined the USGS in 1949; he later served on Bean's photogrammetry staff and helped to develop the ER–55 projector and the Orthophotoscope. Radlinski traveled to Antarctica in 1960 to gain the on-site experience required to advance the Division's plans to map the continent.

During 1959–60, the Topographic Division continued its cooperative mapping in 32 States and Puerto Rico. Division personnel mapped 60,000 square miles at 1:24,000, including 15,100 in Ohio and Texas and 13,195 in Arizona, California, Indiana, and Nevada. They also mapped 18,000 square miles at 1:62,500 and another 18,000 at 1:63,360 in Alaska. Although maps of an additional 6,800 square miles were revised, the area depicted by 1:24,000 maps needing revision neared 250,000 square miles. Using data from the Defense Department and civilian agencies, Division members completed an additional 11,000 square miles of new quadrangle mapping and revised maps showing another 3,000 square miles. The Division published 1:62,500 maps for Oahu and Molokai in Hawaii, a new two-sheet, 1:2,500,000 map of the United States, and a new 1:500,000 map of Utah. Compilations continued for similar maps of Kansas, Maine, Montana, Nebraska, North Dakota, South Dakota, and Washington. Urban-area maps were published for Chattanooga, San Juan in Puerto Rico, and Washington (D.C.), while work continued on those for Albuquerque, Indianapolis, Madison in Wisconsin, and New York City. Following the priorities set by the NPS for the cooperative program, the Division published maps of Maine's Acadia National Park and New Mexico's Bandelier National Monument. Work continued on the prioritized maps requested for other national parks, including Olympic in Washington, Rocky Mountain in Colorado, Wind Cave in South Dakota, and Yellowstone in Wyoming, Montana, and Idaho. Division members also prepared maps to aid the USBM's studies of land subsidence in Arizona, maps of electric-powerplant locations for the Interior Secretary's Office, and base maps for the U.S. Study Commission-Southwest River Basins. They also continued work on the 1:1,000,000 series depicting North America for the Army Map Service.

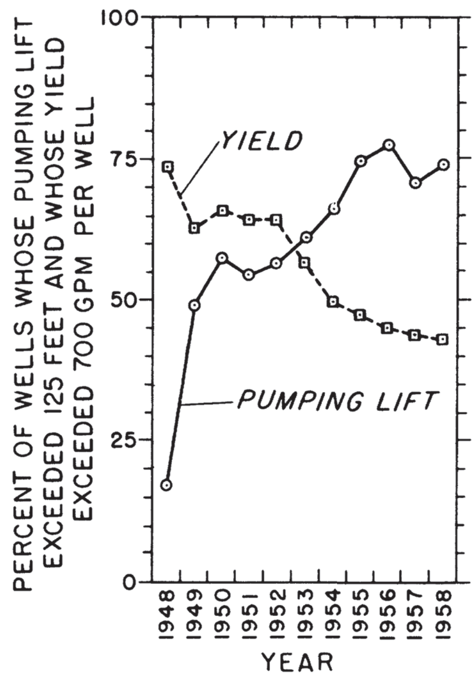
As part of the second pilot program for the comprehensive national atlas of the United States, directed by the NAS–NRC Interagency Committee, the cooperating Federal agencies produced nearly 80 thematic sheets by 1960 and deposited them in the Map Information Office. By then, Carleton Barnes and his Committee decided the project required "a more formal arrangement of the maps, more comprehensive scope of the subject matter, greater uniformity of quality, and centralized distribution of map sheets."[115] They recommended to the NAS' Detlev Bronk that he end their service and give the responsibility for completing the national atlas to a single Federal agency, preferably the USGS, and set a specific time limit. On June 22, 1960, Bronk endorsed that recommendation and sent it to Interior Secretary Seaton. In the fall, Seaton informed Bronk that the Department of the Interior (DoI) would study the project's feasibility. Bronk then again recommended the USGS as the principal agency for the national atlas, whose preparation would be funded by additional monies in its future appropriations or by a separate statute. Before the end of fiscal year 1959–60, the Topographic Division published two U.S. index maps in National Atlas format—the 9th edition of the Status of Topographic Mapping and the 10th edition of the Status of Aerial Photography. Both maps included data for all the States, Puerto Rico, and the Virgin Islands.

The Topographic Division's research and development efforts continued in fiscal year 1959–60 to center on improving the efficiency of mapping instruments and their supporting equipment. Division members began a project to empirically determine and analyze representative horizontal errors in all component phases of the mapping. They reorganized and revised the "Manual of Topographic Instructions" for publication as a sales item of 41 parts. Colleagues developed a lightweight surveying tower to facilitate theodolite observations and electronic-distance measurements over obstructions. Two people could erect the tower in about an hour, and it could be transported by helicopter without disassembly. The 50-foot and 500-pound tower, with welded one-piece horizontal triangular sections, could be modified by adding or omitting some of the 12-foot standard, tubular-aluminum sections. Division personnel installed collimator equipment to more rapidly, accurately, and completely test theodolites and levels. Experiments with a new, polyester-based aerial film proved its increased dimensional stability, but the USGS awaited the advent of commercially available quantities before the film could be used to increase horizontal and vertical accuracy in photogrammetrically compiled maps. Division members completed a study of visual factors in stereoplotting that included the effects of applying refractive correction and varying room illumination. They obtained for testing two new super-wide-angle (120-degree) cameras and devised a system to modify the camera calibrator to accept the wider angle coverage. The Orthophotography Use Study Group continued to aid planning for improving the Division's Universal Orthophotoscope, orthophotomosaics, and 1:24,000 and other orthophotomaps. The group expanded in March 1961 and was renamed the Working Group on Use of Orthophotography.

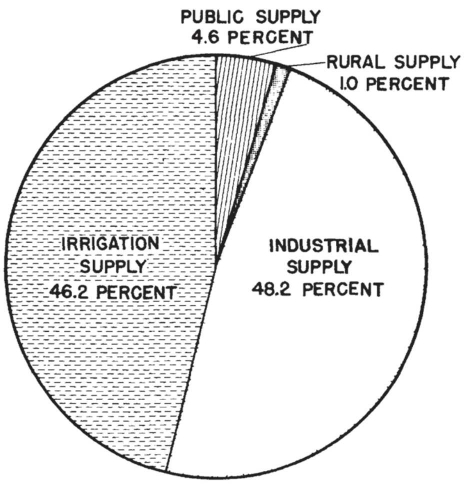
With the ICA's aid, the Topographic Division continued its program of technical assistance at home and abroad to colleagues in ICA-accredited nations. Division members trained in the United States technical personnel from Argentina, Brazil, Ceylon (Sri Lanka), Ethiopia, Nicaragua, and Pakistan. Gus Goudarzi returned to Libya to gain additional information needed for the 1:2,000,000 base map of that country. Other Division personnel spent 6 months training a photographic-laboratory staff and also provided advice to colleagues in Brazil for their national cartographic program and training their technicians in modern cartographic techniques.

In fiscal year 1959–60, the Water Resources Division accumulated total funds of almost $24,133,000, an increase of some $1,368,000 compared to the sum in 1958–59, for the salaries of and operations by its 2,572 employees, or 72 more than in the previous year. The numbers of the Division's permanent personnel—1,141 of 2,335—and seasonal employees—111 of 237—paid by reimbursable funds during the new fiscal year were the largest of the four program Divisions. The SIR appropriation provided more than $11,675,000, a gain of nearly $398,000. The statutory limitation on the use of the SIR funds for cooperative work with the States, counties, and municipalities increased by $500,000 to $7,450,000; although those nonfederal sources did not match this total, they did supply about $7,342,000 in reimbursements and direct payments or about $546,000 more than the Division received in 1958–59. California, the leading contributor, furnished more than $714,000, Texas contributed more than $432,00, Florida supplied nearly $338,000, and 9 other States each provided more than $200,000. Other Federal agencies transferred about $4,812,000, or $394,000 more than the total in 1958–59. The Army and its Engineers increased their transfers by $77,000 to a new total of about $1,837,000, the USBR's funds rose by $103,000 to more than $879,000, those from the AEC increased by nearly $167,000 to total $599,000, and the TVA added nearly $1,200 to raise its transfer to $97,000. Four other Federal organizations reduced their transfers by a total of about $72,000—the ICA supplied nearly $463,000, the Agriculture Department provided $227,000, the Air Force shifted $131,000, and the State Department transferred almost $115,000. In August 1959, Chief Hydraulic Engineer Luna Leopold detailed R. Hal Langford, whose water-quality studies in Great Plains and Rocky Mountain States began in 1949, as John Horton's successor as staff assistant to Assistant Director Robert Lyddan. Leopold's memorandum of July 12, 1960, confirmed the responsibilities for planning and scheduling programs assigned to the Division and those for scheduling and conducting operations, with Division review and approval, now assigned to the Branches. He continued the process of consolidating the Division's operations in each District under a single Chief, who reported to the Regional Hydrologist as well as to the Branch Chief.

In 1959 and 1960, Luna Leopold continued to promote basic research in the Division and to issue general but systematic discussions of water-related issues in the United States. His and Thomas Maddock, Jr.'s analysis of the hydraulic geometry of stream channels earned them the GSAm's Kirk Bryan Award. Leopold published brief contributions about probability analysis applied to water problems, conservation and protection, water management's challenges, conservation views, and the place of water resources in ecological systems. Leopold, with Ralph A. Bagnold, Gordon Wolman, and Lucien M. Brush, Jr., published an analysis of flow resistance in sinuous or irregular stream channels. Equally brief overviews included John A. Baker's on wetlands and water supply; Walter Langbein's on U.S. water yield and reservoir storage; Raymond Nace's on water management, agriculture, and groundwater supplies; Arthur Piper's on present and future concerns about water, and his interpretation of the current status of groundwater rights; and Ralph Bagnold's study of sediment discharge and stream power, and his analysis of river-meander shapes. Bagnold served with the British Army in France and Belgium during World War I, and then in Egypt, England, Hong Kong, and India before retiring in 1935. At the University of London's Imperial College, he conducted wind-tunnel and hydraulic experiments to add to his field observations on windblown desert sand and waterborne sediment. Major Bagnold, recalled to the colors in 1939, created and led the Long-Range Desert Group in daring and disruptive reconnaissance missions behind Italo-German lines in Egypt and Libya before being promoted to Colonel in 1941 and assigned to the staff in Cairo. The Royal Society of London elected Bagnold a member in 1944. In postwar years, he directed Shell's Research Center in Chester and helped to establish the Hydraulics Research Station at Wallingford.[116] Leopold invited Bagnold to spend a month each



This graph depicts the growth of pumping lift and the decline of water yield during 1948–58 in groundwater wells on the High Plains of Texas. Of the 8,356 such wells in 1948, "only 17.5 percent * * * lifted water more than 125 feet and 74 percent yielded more than 700 gallons per minute." As a measure of the subsequent significant drawdown on the aquifer, "[i]n 1958 the number [of wells] had increased to 45,522 and the percentages had changed to 74 and 43 respectively." (Quotation and graph from Nace, 1960, fig. 4 and caption.)



This chart shows the percentage of water supplied to irrigation, industrial, rural, and public users in the United States during 1958. Raymond Nace, in analyzing the use of water in the United States per day during that year, reported an estimated total of 240 billion gallons, not counting "conveyance losses in irrigation" of 32.4 billion gallons per day. That use represented an estimated increase since 1955 of 29.5 billion gallons, exclusive of the additional 3.5 billion gallons lost in conveyance. Nace called for "aggressive intelligent management" of the Nation's total water supplies, based on the results of "further scientific studies." (Quotations and chart from Nace, 1960, fig. 2's caption, p. 11, and fig. 2.)

year in the United States as a consultant to the Water Resources Division, thereby helping to "stir the pool of complaisant tradition with the stick of inquiry,"[117] and offered to publish the results of his water-sediment research in USGS serials.

During fiscal year 1959–60, the Water Resources Division continued to issue parts of its "Manual of Hydrology" in its series of Water-Supply Papers. Walter Langbein and Kathleen T. Iseri's "General Introduction and Hydrologic Definitions" prefaced the sections for "Part I. General Surface-Water Techniques" that included James K. Searcy's "Graphical Correlation of Gaging-Station Records." In the Manual's "Part 2. Low-Flow Techniques," Searcy presented "Flow-Duration Curves." Rolland W. Carter and Richard G. Godfrey's discussion of "Storage and Flood Routing" formed a section in the Manual's "Part 3. Flood-Flow Techniques." Norbert J. Lusczynski's description of the "Filter-Press Method of Extracting Water Samples for Chloride Analysis" and Solomon M. Lang's presentation of "Methods for Determining the Proper Spacing of Wells in Artesian Aquifers" were scheduled to be issued in 1961 as parts, respectively, of "General Ground-Water Techniques" and "Methods of Aquifer Tests."

Leopold announced on December 28, 1959, that Joseph Wells, the Chief of the Surface Water Branch since September 1946, would become the second Assistant Chief Hydrologist. Ernest L. Hendricks succeeded Wells as Branch Chief on March 6, 1960. Hendricks joined the Surface Water Branch in 1935. He worked mostly in Florida before being appointed Chief of the General Hydrology Branch's Research Section in September 1956. Hendricks and Robert Sigafoos subsequently studied the movement of glaciers on Mount Rainier during the past 1,000 years to interpret long-term climatic and water-supply trends.

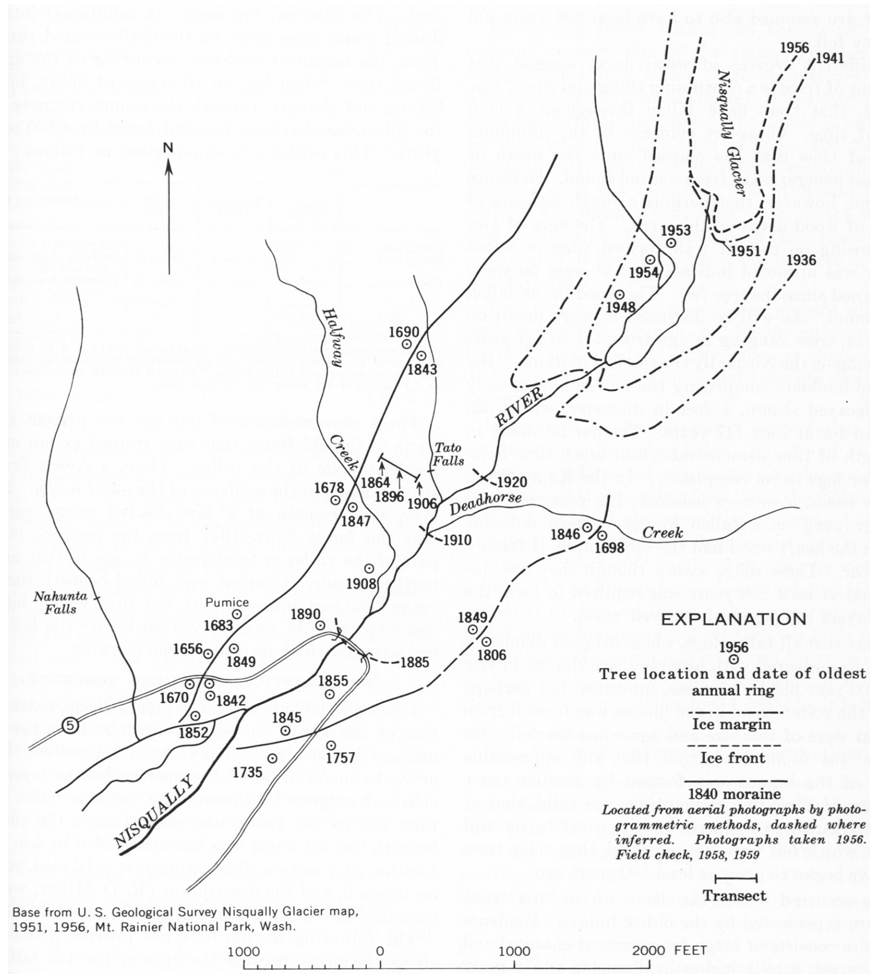
During fiscal year 1959–60, Branch members operated some 7,200 gaging stations in all of the States, Puerto Rico, Guam, and Samoa. They continued to revise and improve the long-range program established 3 years earlier to develop a coordinated streamgaging network consisting of (1) permanent hydrologic-base gaging stations; (2) temporary stations, operated long enough to define basic relations; and (3) permanent and temporary stations, intended to yield data for more efficient water management. The compilation of streamflow records for 1888–1950 reached virtual completion, summarizing nearly 142,500 station-years of records from almost 11,300 measuring stations. Branch members contributed streamflow data to aid the operations of the 19 ongoing interstate water compacts and the International Joint Commission that regulated U.S.-Canadian boundary waters. For the Soil Conservation Service, they also studied the runoff from maximum annual floods for 2,443 drainage areas of less than 400 acres each. Branch personnel published reports for the river basins of the Hudson, the Upper Mississippi, the Upper Missouri, California's Central Valley, and the Pacific Slope. They also published 22 reports on individual metropolitan areas, continued work on 10 others, and began investigations of 2 additional cities. The nationwide flood-frequency program issued analyses of the Pacific Slope basins and the basins of the Columbia and Snake Rivers and nationwide summaries of floods in 1953 and 1954. The Branch started a pilot project in the Western Gulf of Mexico Basin to study analytical methods in arid areas. Other efforts included a series of nontechnical reports on the water resources, water-supply demands, and potentials for further development in specific States. Additional work comprised special reports on the frequency and magnitude of floods in States and regions, the frequency of low streamflows, the surface-water resources of specific areas, and yearly reviews of the hydrography and hydrology of streams where they intersected roads, especially the interstate highways. The Branch also supplied hydraulic data for 78 drainage-structure sites to 14 State highway departments. The Branch's reports on Maryland and Washington brought to 41 those on statewide probability of floods. Bruce Colby and David W. Hubbell worked up simpler methods to use the modified Einstein procedure to compute total sediment discharge.

This photograph shows the lower part of the Nisqually Glacier and its valley on Washington's Mount Rainier. In the late 1950s, USGS scientists began extending Federal studies of glaciers in the Cascade Range, which began with those by Clarence King's U.S. Geological Exploration of the Fortieth Parallel in 1870, to try to determine modern and longer term changes in water supply and climate and the geologic and hydrologic hazards. USGS scientists Robert Sigafoos and Ernest Hendricks investigated the terminal moraines left by advances and retreats of three of Mount Rainier's glaciers—Emmons (east-northeast), Nisqually (south), and Tahoma (southwest). They also gathered data on the distribution, sizes, and ages of key trees and tree stands established since glacial recessions and of the 1,000-year-old stands. Their maps of these glaciers showed their advances and retreats since 1635. (Photograph, 1966, from the USGS Denver Library Photographic Collection as Sigafoos, R.S., srs00032, https://www.sciencebase.gov/catalog/item/51ddb1aee4b0f72b4471f648; published with colored lines added [to show past glacial widths and terminuses] in Sigafoos and Hendricks, 1972, as fig. 1 on pl. 2.)

The Ground Water Branch's specialists made periodic measurements at more than 25,000 sites during fiscal year 1959–60. Work continued on collecting basic records and studying areal hydrology and geology and the occurrence and movement of groundwater. Other research done in collaboration with surface-water specialists focused on the relations among surface water, groundwater, and land use; the water resources of areas; and water utilization. Branch members completed a map of the maximum-reported content of fluorine in groundwater as the initial contribution to a series of studies of iodine, selenium, and other elements whose concentrations in water might produce deleterious physiological effects. Earlier studies evaluated the groundwater conditions and storage capacity of California's San Joaquin and Sacramento Valleys. Joseph Poland and his colleagues used the actively subsiding San Joaquin Valley as a natural laboratory to investigate the processes involved in the strain, deformation, and compaction of water-bearing rocks that followed groundwater withdrawals. Poland's studies related subsidence to dewatering and compaction of artesian aquifers' confining beds rather than the dewatering of the aquifer itself. He demonstrated that dewatered and compacted confining beds lacked significant restorage capacity and so would not allow land surfaces to rebound in the subsiding areas.[118] The Branch's investigation of tritium, begun in 1957, continued with the hope of demonstrating its value as an indicator of groundwater recharge, movement, and discharge that could be used in quantitative evaluation through water-budget studies. Branch personnel continued their evaluations of water supplies in the volcanic terranes of the Columbia River Basalt and in a limestone terrane in the Central and Southeast United States. Eugene H. Herrick completed a 1:31,680 map of the groundwater resources and proposed enhancements in the headquarters area of New Mexico's White Sands Missile Range.

In April 1960, Stuart Schoff succeeded Alfred Clebsch as chief of the Ground Water Branch's project at the Nevada Test Site (NTS). Schoff moved the project's headquarters to Denver to coordinate efforts with the Geologic Division's planned Special Projects Branch, which, as of July 1, 1960, became responsible for all USGS operations in support of the NTS tests. John E. Moore, W. Arthur Beetem (who replaced Francis Barker), and others joined the project's staff. Schoff and "Ike" Winograd (who remained based at Las Vegas) supervised the drilling of six wells on Yucca, Frenchman, and Jackass Flats (basins connected by groundwater flow), which reached depths of 1,700 to 2,300 feet. Data from these wells

This map (originally at 1 inch = 1,000 feet) depicts the Nisqually Glacier's terminal moraine, which marks the glacier's maximum modern advance in 1885. The map also shows the locations and the ages of the oldest annual ring (between the years of 1656 and 1953) of the trees selected for dendrochronologic determinations. Arthur Johnson and Robert Sigafoos "located trees, road, and 1840 moraine by plane table survey, August 30, 1958." They fixed other features by photogrammetrically interpreting aerial photographs taken in 1956 and field checked their results during 1958–59. (Quotation and map from Sigafoos and Hendricks, 1961, fig. 6, and its caption.)



indicated that deeper drilling, hydraulic tests, and additional geologic mapping at 1:24,000 would be required in the search for thick nonporous strata and to achieve a more accurate estimate of potential groundwater contamination by the seepage of strontium-90 and other radioisotopes after underground nuclear tests. This and subsequent deeper drilling in the early 1960s confirmed interbasin flow through a major regional aquifer. Also in 1960, Gordon D. Bennett and Eugene P. Patten, Jr., presented their borehole geophysical methods for analyzing specific capacities of multiaquifer wells.

In January 1960, Charles McDonald left his post as Chief of the General Hydrology Branch to lead a hydrology project at Yuma, and the Branch Chief's position remained vacant until August 1961. Late in the 1950s, the Water Resources Division established a National Research Program that involved the Branch in investigations of low- and high-level radioactive and other hazardous wastes, their distribution, the effects of wastes, the paths taken by waste liquids, the length of time that wastes remained hazardous, artificial recharge, and the effects of urbanization on the hydrologic regime. From 1959, John Hem's primer guided Branch studies and interpretations of natural water's chemical characters and Joseph Huffty's residue method facilitated identifications of common minor elements. In 1960, Robert Garrels' analysis of mineral equilibria gave geohydrologists the tools of chemical thermodynamics.[119] Branch members also began studies of three small watersheds, two recently developed and the third as the control area, in the San Francisquito Basin near Menlo Park. Several other and similar-sized basins in California and Nevada were selected for additional investigations. During fiscal year

1959–60, the Branch obtained water-quality data at 907 sites, one-third of which were west of the Mississippi River, and investigated water quality in the basins of the Colorado, Columbia, Mississippi, and other rivers. Branch specialists also studied the factors controlling the solution and deposition of iron and manganese, the absorption of radioactive elements by water-sediment mixtures, and methods to distinguish waters of deep origin. Investigations of sediment loads and movement in streams continued in the Colorado, Missouri, and Middle Rio Grande Basins. Related work involved the mineralogy of river sediments, the effect of variations in roughness and other factors in bed-load transport, and the measurement and analysis of stream-sediment loads. For the Soil Conservation Service, Branch members looked at sediment yields and reservoir trap efficiency in the SCS small test basins. Reports by Branch personnel issued during the year treated flume studies that used medium-sized sand, sediment transport in alluvial channels, ultrasonic measurement of size distribution and concentration of water-suspended sediments, and the effect of fine-sized sediments on water-flow mechanics. Work continued on the comprehensive hydrological study of the Colorado River above Lees Ferry. Branch members planned, funds permitting, to begin comparable work on the river basin below Lees Ferry in July 1960. Studies of phreatophytic plants were extended to the Humboldt River Valley near Winnemucca, Nevada, where large water tanks were installed for controlled investigations of evapotranspiration to measure water use. Branch members continued or began soil and moisture studies of grazing areas, reservoirs, and streams in Arizona, California, Colorado, Idaho, Montana, Nebraska, Nevada, New Mexico, Oregon, Utah, and Wyoming.

The Water Resources Division, aided by the ICA's Technical Assistance Program, continued its long-term projects in Afghanistan, Chile, Iran, Libya, Pakistan, the Philippines, Saudi Arabia, Tunisia, and Turkey. Robert Schneider, who joined the USGS as a photogrammetrist in 1941 and then shifted to work in groundwater geology, advised the Brazilian Government on that country's water resources during November–December 1959. Wilbur T. Stuart served with Chase Tibbitts' team in Libya in January–March 1960. Edward Bradley's tour in Jordan ended in the following June. During September–December 1959, F.D. Bertleson and John B. Cooper completed their service in Pakistan; Eugene Patten, Jr., began work there in April 1960. Division personnel also were sent on short-term advisory assignments to Argentina, Egypt, Haiti, and Southern Rhodesia (Zimbabwe). They and their colleagues elsewhere in the Division also helped to train in the United States visiting hydrologists from 17 countries—Argentina, Brazil, Chile, Colombia, Egypt, Ethiopia, Ghana, India, Israel, Kenya, Libya, Pakistan, Peru, the Philippines, the Sudan, Turkey, and Uruguay.

During fiscal year 1959–60, the Conservation Division received nearly $2,797,000, a gain of nearly $101,000 from the previous year, for its 348 employees at year's end or 20 more than in 1958–59. Only seven of the Division's permanent employees depended on reimbursable funds for their salaries. Part of the appropriation from the Interior Department's Office of Oil and Gas passed to the Conservation Division's SIR appropriation, raising it to about $2,749,000 or $314,000 more than in 1958–59. Funds transferred to the Division from nonfederal sources increased by $800 to a total of about $1,800. Lacking any transfer monies from Interior's Office of Oil and Gas, the funds supplied by other Federal agencies declined by nearly $215,000 to a total of about $46,000. During the year, Emmett A. Finley summarized the procedures used by Division members in defining known geologic structures for leasing-law administration.

As before, the requirements of new statutes increased the Division's work. On August 18, 1959, a new law amended Alaska's admission statute by requiring the State to file, "within a period of five years after the date of admission of Alaska into the Union,"[120] an application with the Interior Secretary to select leased, permitted, licensed, or contracted lands covered by the Mineral Leasing Act of 1920 or the Alaska Coal Act of 1914; otherwise, the Federal Government would withdraw those lands. The Mineral Leasing Act was amended again on September 21, 1959, by inserting a provision that relieved persons, associations, or corporations holding valid leases, options, or interests on acreage from responsibility for cancellations or forfeitures, already completed or in process, and extending such interests "for a period of time equal to the period between the filing of the waiver or the order of suspension * * * and the final decision, without the payment of rental."[121] On March 18, 1960, another new statute amended the U.S. mining laws "to provide for the inclusion of certain nonmineral lands in patents to placer claims" for use in "mining, milling, processing, beneficiation, or other operations in connection with such claim." This law restricted these locations to five acres and required payment "at the rate applicable to placer claims which do not include a vein or lode."[122] The Phosphate Mining Act, also signed on March 18, further amended 1920's Mineral Leasing Act "to authorize the issuance of prospecting permits for phosphates in lands belonging to the United States"[123] for intervals of not more than 2 years and areas of 2,560 acres or less. An additional new statute, signed on June 29, authorized "an extension of time [of up to two 3-year periods] for final proof under the desert land laws under certain conditions" and limited its benefits to those persons who then held an uncanceled entry, under the desert land laws, "to reclaim public lands * * * located on the Lower Palo Verde Mesa in the Palo Verde Irrigation District in Riverside County, California,"[124] showing they were not liable for engineering or financial expenses due to the delay in constructing irrigation works.

During fiscal year 1959–60, members of the Mineral Classification Branch processed more than 30,700 cases (2,900 fewer than in the previous year); 7,000 of the cases involved the outright disposal of Federal lands without reserving any minerals or with reserving one or more specific minerals. Branch personnel also handled an additional 21,000 cases involving Federal mineral leases to private enterprises. They defined or revised definitions of 66 producing oil and gas fields on Federal lands, geologically appraised 358 unit-plan and participating-area proposals, fixed the productive limits of 63 producing oil and gas deposits, assessed and reported the geologic significance of 248 new discoveries of oil and gas on or affecting Federal-land leaseholds, reviewed competitive sales of oil and gas leases in 29 public-land parcels, reported 18 appeals from the Bureau of Land Management's disposal of public lands, and prepared for other Federal agencies nearly 200 reports on the mineral potential of specific public lands. Branch members also prepared geologic maps and reports on fields or areas before leasing or legislation: coal at Rifle Gap in Colorado; gas at Gragg and Booneville in Arkansas; helium in Pinta Dome in Arkansas; oil and gas at Soso in Mississippi and also in the San Juan Basin and at Bisti in New Mexico; phosphate in Florida; and potash in southeastern New Mexico. They also reported on the stratigraphy and structure of the Delaware Basin, the Sweetgrass Arch in Colorado, and four oil and gas fields in Montana, North Dakota, and Wyoming.

By the end of fiscal year 1959–60, the Mining Branch supervised almost 3,900 properties in 32 States, of which more than 2,700 were on public lands and the remainder on Indian or acquired lands. The estimated nearly 26 million tons, a decrease of more than 184,000 tons compared to the total in 1958–59, of minerals produced from these lands during the year were valued at more than $165 million, a decrease of nearly $5 million, and yielded royalties of about $7.7 million, or $113,000 less than in the previous year. Uranium production of almost 1.4 million tons was worth $20.3 million. Prospecting on lease and permit lands delineated a minable deposit of potash on and southeast of Utah's Cane Creek anticline and extended known trona deposits in Wyoming's Green River area. Mining companies also located additional lead-zinc deposits in sedimentary sequences and new copper-iron occurrences in basement rocks in southeastern Missouri and began operating a new lead mill near Viburnum in Iron County.

During fiscal year 1959–60, members of the Water and Power Branch worked in Alaska, Colorado, Montana, Oregon, and Washington mapping and examining the waterpower and storage potential of streams and dam sites. They published 18 map sets, completed 6 additional sets, and continued to prepare 8 others that covered 600 miles of stream channels and 40 dam sites. Streams and sites evaluated in these reports included those on the areas in Alaska around Bradley Lake, Lost Lake, Nellie Juan Lake, and the Snow River on the Kenai Peninsula; five lakes on Baranof Island; and an area on the mainland between Thomas Bay, near Petersburg, and Juneau. Other reports covered the Lower Flathead River in Idaho; the Nehalem, Siletz, and Trask Rivers in Oregon; and Dinwoody Creek in Wyoming. Branch members continued to systematically review all waterpower withdrawals. Sites reserved for power and reservoirs now totaled, respectively, more than 7.2 million acres and nearly 131,600 acres. They submitted more than 7,600 reports about waterpower value, acquisition, and withdrawal to the BLM and the Federal Power Commission, a reduction of about 1,000 compared to the total sent forward in 1958–59.

During fiscal year 1959–60, members of the Oil and Gas Leasing Branch supervised 159,000 properties (about 28,000 more than in 1958–59) totaling 125 million acres, or 17.7 million more than in the previous year. The work involved 139,000 properties on 113.6 million acres of public lands and 527 properties on 2.1 million acres of the Outer Continental Shelf. Petroleum companies completed more than 3,400 wells and produced oil and gas from about 2,300 of them. At year's end, nearly 27,700 of the more than 46,600 wells remained producers. These wells yielded almost 261.3 million barrels of oil, 898 million cubic feet of natural gas, and 451.3 million gallons of natural gas liquids. Their value neared $869.6 million, an increase of $409 million, and yielded royalties of $116.2 million, or $59 million more than in the previous year. Branch members approved 94 new unit plans on land and terminated 49 others, leaving 420 plans, a gain of 85, that covered 7.9 million acres, an increase of 1.8 million, operating at year's end. Four OCS plans were approved and 1 was canceled for a new total of 15 that covered 375,800 acres. They also approved 147 drilling units or communitization agreements and ended 2, leaving 1,021 operating on June 30; the 3 new development contracts approved raised the total to 14, covering more than 4.6 million acres. The nearly 1,700 wells on the OCS produced about 41 million barrels of petroleum and 234 billion cubic feet of natural gas. The Branch expected the termination of the interim Federal-Louisiana agreement of 1956 and the resumption of normal leasing to increase even further its workload, as would the growing activity in the Four Corners area and in Alaska. In administering the Connally Act, Branch members monitored more than 4,600 leases and visited nearly 1,200 of them, checked 50 pipelines, visited 411 oil fields, conducted about 1,550 interviews, and detected 12 alleged violations. To the 17 cases of alleged violations extant when the fiscal year began, they added 3 new ones; court action closed 7 cases and yielded fines of $52,900.

The U.S.-Soviet race in space continued during fiscal year 1959–60, as both countries strove to achieve impressive "firsts." The United States placed three Explorers in orbit, out of six launched; one of these satellites, whose apogee exceeded 26,000 miles, further defined the Earth's radiation belts. Two of four Vanguards reached orbit; one of them returned additional data on the Earth's magnetic field. Pioneer 4, launched on March 3, 1959, missed the Moon by some 37,000 miles, or more than twice the distance required to activate its photoelectric cells. Early on September 14 (Moscow time), Korolev's Soviet team won the contest to hard-land a vehicle on the Moon when Luna 2, after a flight of 33.5 hours, smashed into the lunar surface west of Mare Serenitatis and near Crater Autolycus. Luna 2 carried a scintillometer, a Geiger counter, a magnetometer, and a micrometeoroid detector; data from these instruments indicated only a weak lunar magnetic field and no radiation. Two additional U.S. Pioneers failed in September and November. In December, the JPL announced the start of NASA's Project Ranger that planned to use robotic spacecraft to photograph the Moon from increasingly close distances and return the images electronically before the probes crashed on its surface. On March 11, 1960, Pioneer 5 lifted off from Cape Canaveral and returned data about the solar wind's effect on the Earth's magnetic field and other interplanetary information through April 30; signals stopped on June 26 at a point 22.5 million miles from Earth. On April 1, NASA launched from the Cape and orbited its initial Television [and] Infrared Observation Satellite TIROS 1, a weather satellite with two television cameras. The satellite's cameras returned some 23,000 images, including many photographs of clouds, snow cover, and sea ice in areas between 50 degrees north latitude and 50 degrees south latitude. Two Transit satellites, in orbit on April 13 and June 22, aided navigation. The Missile Defense Alarm System satellite MIDAS 2, lofted on May 24, provided initial early warning capabilities to detect launches of Soviet intercontinental ballistic missiles (ICBMs). Explorer 6, launched into orbit on August 7, 1959, deployed solar panels and also returned images of the Earth, but not until November 23, 1960, did photographs from TIROS 2 distinguish ice from clouds.

Meanwhile, the United States and the Soviet Union continued their race to photograph the Moon. Another Soviet Luna failed on June 18, 1959, but on October 7, Luna 3 circled the Moon in polar orbit. The probe's 35-millimeter camera took 29 pictures of about 70 percent of the farside and scanned and transmitted 17 images used to make a photogrammetric map. The photographs confirmed the expected paucity of maria; one of the few discovered was Moscoviense. These images also recorded craters, one named for Konstantin Tsiolkovsky, and a mountain range, later identified as crater rays. Other features honored Giordano Bruno, Thomas Edison, Louis Pasteur, and Jules Verne.[125]

The United States continued to respond to politico-military challenges on the Earth's surface. At Eisenhower's invitation, Khrushchev arrived in the United States on September 15, 1959, for a visit that lasted until the 27th. On January 19, 1960, Japan and the United States signed a new mutual security treaty that extended the agreements of 1951 and 1954 to give the United States almost carte blanche in using its armed forces on and off the Japanese Islands. Amid significant opposition in Japan, both countries ratified the pact in June. On January 20, the multinational discussions designed to produce a test-ban treaty ended without agreement. Khrushchev conditionally approved on March 19 a ban on nuclear tests, except for the small-yield underground explosions that he wished to exclude from any agreement. Members of U.S. Project Vela-Uniform continued to work toward successfully distinguishing the blasts smaller than 5 kilotons from natural seismic events.

As calendar 1959 ended, the Department of Defense gained a new Secretary and a new weapons system. Neil McElroy resigned as Secretary of Defense on December 1 and Thomas S. Gates, Jr., succeeded him on the next day. Gates introduced a single operational plan that eliminated duplication of targets for the strategic nuclear weapons of the U.S. armed services. On December 30, the Navy commissioned *George Washington* as the lead boat in a planned series of nuclear-powered, ballistic-missile submarines. To build the new boat, a *Skipjack*-class submarine under construction was cut in half, and a center section was added to house 16 Polaris A–1 IRBMs, each with a range of 1,200 miles. On July 20, 1960, *George Washington* submerged and successfully launched two Polaris missiles. The new ballistic-missile submarine sortied from Charleston on its initial patrol on November 15 and spent 66 days submerged at sea.[126] *George Washington* and subsequent strategic submarines completed, with the Strategic Air Command's (SAC's) jet bombers and its ICBMs, the U.S. strategic-defense triad. The Navy retired its Regulus-carrying submarines, launched its nuclear-powered aircraft carrier *Enterprise,* and developed an advanced Polaris that extended the missile's reach to 1,500 miles. The Air Force readied its solid-fuel Minuteman ICBM for deployment in 1961, a year ahead of schedule.

In Southeast Asia, coeval developments in Laos threatened to expand the already growing conflict in the Republic of Vietnam. To counter the heightening insurgency in South Vietnam, encouraged and aided by Hõ Chí Minh's regular forces from the north, Eisenhower authorized an increase in U.S. military advisers to 700, more than twice the number allowed by the Geneva Accords in 1954.[127] On December 20, 1960, Vietnamese Communists (Vietcong) formed the National Front for the Liberation of South Vietnam, better known as the National Liberation Front (NLF), and increased their attacks. To the west, Laos and Cambodia separated the two Vietnams from Thailand, where the pro-Western dictatorship of Premier Sarit Thanarat, a former Field Marshal, staged a bloodless coup in September 1957. Both Cambodia and Laos, after many decades as French protectorates, gained their full independence from France in 1954. Cambodia remained reasonably stable under the alternating rule of King Norodom Suramarit, who died in April 1960, and his son Prince (later King) Norodom Sihanouk. When Sihanouk's People's Socialist Community won all the seats in the national assembly in March 1958, he returned as premier and extended diplomatic recognition to the Government of the People's Republic of China.

As Cambodia recognized the PRC, neighboring Laos remained in turmoil. There, the nationalist and pro-Communist Pathet Lao (State of Laos) received Viet Minh aid. The Pathet Lao, opposed since 1951 by the Royal Laotian Government, was aided by France and the United States in a conflict described and analyzed by Bernard B. Fall.[128] At the Bandung conference in 1955, representatives of Cambodia and Laos expressed their preference to remain independent and neutral. The Soviet Union recognized Laos in June 1956. Neutralist Prince Souvannaphouma saw Mao Zedong and Zhou Enlai in Beijing in August. The Laotian national assembly chose Souvannaphouma as premier in April 1957, and Souvannaphouma decided in November to add Pathet Lao representatives to his government and by doing so regained two northern provinces. In July 1958, members of the Pathet Lao, who looked to their own Prince Souvanophong, Souvannaphouma's half-brother, joined the cabinet. Souvannaphouma resigned and the premiership passed in August to Phoui Sananikone, who requested and received increased U.S. support. On February 11, 1959, Phoui renounced the 1954 Geneva agreement and asked the United Nations to intervene and resolve the Laos conflict. Representatives of the Southeast Asia Treaty Organization (SEATO) agreed to intervene only if the U.N.'s peacekeeping effort failed.

U.S. economic and military aid to the pro-Western but corrupt governments of Laos increased in 1959 and 1960, as American military trainers increasingly replaced their French counterparts and the American contribution to the Laotian military budget grew to 100 percent. With the approval of the French Military Mission, 100 men of the U.S. Army Special Forces began training the Royal Laotian Army and its allied tribes in 1959. The Central Intelligence Agency's (CIA's) Civil Air Transport (later Air America) continued to fly cargo and agents into Laos, as well as Cambodia and South Vietnam. Other Americans, some also CIA contractees, flew Royal Laotian aircraft on strike missions against the Pathet Lao's forces, as their colleagues in South Vietnam did against the insurgents there.

During December 1959–December 1960, Laos underwent a national election and a series of military coups and countercoups. During those 13 months, coups ended Phoui's regime, replaced it with one headed by Souvannaphouma, tossed out Souvannaphouma in favor of Phoui and strongman General Phoumi Nosavan, and finally drove Souvannaphouma into exile in Cambodia. Phoumi supported

Prince Boun Oum, the hereditary leader of the southern Laotian kingdom, who renounced his throne, as the new premier. Boun Oum asked for and received additional economic and military aid from the Eisenhower administration, but the Pathet Lao, backed by the Soviets and the Viet Minh, continued to gain territory, including the Hõ Chí Minh Trail to South Vietnam, which controlled or influenced more than two-thirds of Laos. The USGS Military Geology Branch helped the U.S. Army to prepare for possible military intervention. MGB members completed a Special Report, with maps at 1:100,000, in 1959 for the Office of the Chief of Army Engineers on the water supplies, construction materials, cross-country movement, and terrain suitability for constructing depots at the capital Vientiane, with its own airfield, and Savannakhét, another port on the Mekong River in the central part of Laos' panhandle, with its French airfield just to the east at Séno. Their MGB colleagues, supervised by Harold W. Hawkins, finished in 1960 for the Pacific Engineer Intelligence Program a terrain study, at 1:250,000, for airborne operations, airfield construction, construction materials, cross-country movement, roads, and water supplies for all of Laos. They also began a similar study of Thailand, the staging area for any additional U.S. troops, and planned those for Vietnam, Burma, the Malay Archipelago, and Indonesia. Laos would not fall to the Communists, Eisenhower warned on December 31, 1960, but he sent no U.S. Army conventional units there to build facilities and (or) to redress the military balance. The U.S. Air Force honed its plans to use nuclear weapons in Laos if ordered to do so.

Managers of U.S. aerial reconnaissance continued to focus their efforts on the Soviet Union. Since 1956, the CIA's U–2 overflights provided high-resolution photographs of the Soviet nuclear-test site at Semipalatinsk, the air-defense-missile test range at Saryshagan on the western shore of Lake Baikal (Balkash), the satellite-launch complex at Baikonur, the military-industrial complex at Sverdlovsk, the Strategic Rocket Forces' ICBM site at Plesetsk, operational since February 9, 1959, and other key military bases. Richard Bissell convinced Allen Dulles and President Eisenhower to authorize one additional U–2 flight of nearly 3,800 miles across the Soviet Union principally to check progress at Tyuratam, Sverdlovsk, and Plesetsk before the summit conference between the leaders of the United States, Britain, France, and the Soviet Union scheduled to open in Paris on May 15, 1960. Early on May 1, the Soviet national day of celebrations and parades, a U–2 piloted by Francis Gary ("Frank") Powers took off from Peshawar in Pakistan en route for Bodø, in northern Norway, by way of Dushambe, Tyuratam, Chelyabinsk, Sverdlovsk, Kirov, Plesetsk, Archangel, Kandalaksha, and Murmansk. As Michael R. Beschloss described in his book "May Day," Soviet MiG-19s and other aircraft failed to intercept Powers' U–2, flying at altitudes above 60,000 feet, but an antiaircraft battery at Sverdlovsk downed the aircraft with two of its SA–2 Guideline surface-to-air missiles. Powers could not issue a mayday distress call, but his nonarrival at Bodø generated the National Oceanic and Atmospheric Administration's cover story that the U–2, on a weather-research mission, strayed accidentally into Soviet airspace, went missing, and was presumed down.[129]

The U.S. lie exploded when Premier Khrushchev announced, on May 5, that the Soviets captured pilot Powers (a former USAF Lieutenant who had flown for the CIA since 1956), pieces of his aircraft, and some of his equipment, including film and containers. Khrushchev's disclosure forced President Eisenhower to admit 2 days later that he had approved this mission and the 23 earlier spy flights. At the Paris meeting on May 16, Khrushchev denounced the U.S. aerial espionage. When Eisenhower promised to end U–2 flights over the Soviet Union, but refused to apologize for them, Khrushchev walked out, and the meeting ended the next day. In a show trial, the Soviets convicted Powers on August 19 and sentenced him to 10-years' imprisonment, but they exchanged him for a convicted Soviet spy in 1962. The CIA, expecting eventually to lose a U–2 to improved Soviet aircraft or missiles, in 1959 authorized Clarence ("Kelly") Johnson's Skunk Works at Lockheed to develop a supersonic and higher flying successor to the U–2. Johnson's team worked on new reconnaissance aircraft whose engines, shape, titanium skin, and special paint would provide speeds of up to Mach 3, the ability to reach altitudes of more than 85,000 feet, and other capabilities that would make radar detection difficult and interception almost impossible when they began overflights.

Until then, the U–2 flights would continue over mainland China, Cuba, and other countries and areas where missiles or aircraft were (as yet) less dangerous or posed no threat at all to these reconnaissance planes. An agreement signed by Castro and Anastas I. Mikoyan on February 13, 1960, brought Cuba $100 million in Soviet credits in return for 5 million tons of sugar. Castro's Cuban Government began seizing U.S. vegetable and mineral assets on the island in January. On June 29, the Cubans expropriated three oil refineries owned by American and British companies when they refused to accept Soviet petroleum. In response, on July 6, Eisenhower reduced the U.S. quota for Cuban sugar by some 95 percent or 700,000 tons a year. After Khrushchev warned Eisenhower not to move militarily against Cuba on July 9, the President promptly reinforced the Monroe Doctrine. The United States, Eisenhower told Khrushchev, "in conformity with its treaty obligations," would not permit the establishment of "a regime dominated by international Communism in the Western Hemisphere."[130] Foreign ministers of the Organization of American States (OAS), while convened in San José, Costa Rica, on August 28, condemned Soviet and PRC efforts to spread their influence and system in the Western Hemisphere. Nineteen delegates to a meeting in Bogotá, Colombia, voted on September 13 to approve U.S. aid for social development in their countries. Cuban representatives opposed both measures. On October 14, Castro nationalized all banks and remaining industries.

Eisenhower responded to the Cuban Government's actions by quickly reducing the remaining imports of sugar in 1960 and eliminating them for 1961. The administration then embargoed all U.S. exports, except for medicines, to the island, vowed that the United States would defend its naval base at Guantanamo Bay, held under the 1903 treaty, told the OAS about Soviet arms reaching Cuba, promised to oppose by force any Soviet- or Cuban-led invasion of a Central American country, and vowed to devote $1 million to aid Cuban refugees. Eisenhower approved raising from Cuban refugees a brigade of all arms that was planned, recruited, aided, and directed by the CIA's Richard Bissell, with the help of other members of the CIA and the U.S. military. Castro's spies discovered the existence of the clandestine unit, based, with the approval of Nicaragua's president Luis Somoza, at Puerto Cabezas on the northeastern coast of Nicaragua, some 630 miles south of Havana. Eisenhower refused to authorize the carrying out of Operation Zapata, Brigade 2506's planned invasion of Cuba; after the Cuban Government drastically reduced the size of the staff it allowed the U.S. embassy in Havana, he broke diplomatic relations with Castro on January 3, 1961.

In Africa, the civil war in the Republic of Congo (Zaire) continued despite repeated efforts by the United Nations to achieve a peaceful solution.[131] On June 21, 1960, Joseph Kasavubu assumed the presidency and appointed as premier the leftist Patrice Lumumba, the leader of the National Congolese Movement. Nine days later, as promised in 1959, Belgium granted its former colony independence. The Congolese Army promptly mutinied and Moise Tshombe's Katanga Province seceded from the new republic. Katanga's cobalt, copper, diamonds, radium, tin, and uranium (produced by the Union Minière) were still vital to the West. In July, Lumumba appealed for U.N. aid, and the Security Council voted to send a peacekeeping force, eventually totaling 20,000 troops, to replace Belgian forces, end the violence, and restore order. Congo Army troops arrested Lumumba in Leopoldville (Kinshasa) in September. Colonel Joseph Mobutu, who commanded the Republic's army, took over its government after the legislature increased the deposed Lumumba's authority; Kasavubu responded by ordering Soviet diplomats, who supported

Lumumba, out of the country. In November, as the U.N. General Assembly seated Kasavubu's delegation and he tried to gather all Congolese leaders in a peace conference, Lumumba fled to Katanga. In December, the U.N. General Assembly overwhelmingly approved its Resolution 1514, which denounced colonialism and reasserted the rights of all people to independence and self-government. U.N. forces generally kept the peace in the Congo, even after the withdrawal in December of troops from five countries, but they could not save Lumumba, who was killed by Mobutu's soldiers, on Tshombe's order.

At home during fiscal year 1959–60, Congress and the President welcomed another new State into the Union, supported the Oil Import Administration, authorized continued disposals from the Nation's mineral stockpiles,[132] enacted measures designed to increase support for domestic mineral-mining industries, and passed a new civil rights act. Hawaii's voters had begun petitioning for statehood in 1903, bills for achieving that status dated from 1919, and the voters approved an earlier constitution in 1950. Eisenhower signed the congressional enabling act[133] on March 18, 1959; his proclamation[134] of August 21 admitted Hawaii into the Union as its 50th State. Hawaii's land, held mainly in private ownership, included no significant public acreage, but, as time passed, the new State added to its holdings as the Federal Government decided it no longer needed the lands it earlier reserved and returned them to the State. The Oil Import Administration and the Oil Import Appeals Board,[135] established within Interior by Eisenhower in March 1959, continued to implement and monitor the Federal program and handle appeals by those persons and corporations that it adversely affected. On May 6, 1960, a new Civil Rights Act[136] strengthened the 1957 law by providing for judicial enforcement of registration and voting rights, and for criminal penalties for those convicted of threatening or attacking voters and polling places.

The Eisenhower administration continued to sell off parts of U.S. mineral-commodity stockpiles to aid the Nation's economic recovery from the 1957–58 recession and to increase financial aid to education and technological developments in the wake of Sputnik 1. The Office of Defense Mobilization (ODM) established a Special Stockpile Advisory Committee, composed of civilians, including retirees General Walter Smith and Admiral Arthur Radford, to review existing policies and programs for stockpiles worth several billions of dollars. The Committee's report of January 28, 1958, as Alfred Eckes, Jr., later summarized,[137] recommended reducing the interval for emergency procurement from 5 to 3 years, on the basis of the assumed duration and nature of a war with the Soviet Union, giving the ODM's Director more flexible authority to decrease surplus commodities (while keeping those commercially usable), and shifting the stockpile effort's emphasis from raw materials to finished goods. On April 22, Eisenhower and his Cabinet agreed to implement carefully most of those suggestions so as not to disrupt the Nation's domestic economy or its international relations and commitments. Of the 75 items in the strategic-critical stockpiles, nearly 60 were now surplus, including large amounts of aluminum, chromite, rubber, and tin. On September 9, 1959, a congressional resolution authorized the disposal from the national stockpiles of fixed amounts of diamonds, osmium, rhodium, ruthenium, and zircon concentrates.[138] Diamonds could be spared now after being synthesized in a General Electric laboratory in December 1954; the company received in June 1960 a Federal patent for the new process. On September 10, 1959, a second resolution authorized the President to arrange for a review by each Federal department and agency to provide for "increased production and employment in critically depressed domestic mining and mineral industries."[139] This measure reflected the continuing problems in the lead-zinc industry that were partially solved when, on September 22, 1958, Eisenhower further limited the imports of some commodities, but this decision drew vociferous protests from Australia and Peru. The President pocket-vetoed the bill for the proposed Coal Research and Development Commission on September 16, 1959. Eisenhower, who viewed mineral self-sufficiency as a worthy but unrealistic policy, also vetoed, 2 weeks before the 1960 national elections, a measure that provided subsidies for the lead-zinc industry, claiming they would lead to increased taxes, more production problems, and greater free-market instability.

The Interior Department already administered conservation programs for mines but the second Hoover Commission recommended that the Federal Government link functions by its major departments and agencies by their purpose. The Senate held hearings in January 1960 on a bill designed to end restrictions on the U.S. Coast and Geodetic Survey's coverage of the coastlines and continental shelves of the United States and its Territories and possessions. That measure, the Navy protested, would compromise Defense Department surveying and charting. The Navy lost its bid to retain sole control of oceanic mapping and research when the legislators and their staffs found that the detail and accuracy of some of the Navy's ocean charts were as much as 2 centuries behind those of some land maps. Congress and the President authorized the U.S. Coast and Geodetic Survey and the U.S. Coast Guard to conduct oceanographic research whenever and wherever possible. In April, Senator Magnuson held hearings on another bill, for marine science and research, supported by resolutions from a wide group of public and private organizations both civilian and military, designed to advance oceanographic work by Federal and private agencies.

Secretary Seaton returned to Representative Kirwan's House subcommittee on January 13, 1960, an early start in that Presidential-election year, to defend the Interior Department's request for funds, not including those for the reclamation and waterpower agencies, for fiscal year 1960–61. Kirwan, also speaking for his colleagues Fenton, Jensen, and Norrell, welcomed Seaton by saying that they got along with the Secretary "as well as we have with any man I know and he is doing a good job."[140] Seaton thanked Kirwan and then reviewed for the subcommittee operations by Interior and its agencies for 1950–60. During that decade, Interior's funds, excluding those for reclamation and waterpower, increased by $160.5 million, but its staff decreased by 280 persons, not including the nearly 5,400 other positions already discontinued or transferred to other Departments. In the same interval, Interior, including reclamation and waterpower, received appropriations of nearly $6.5 billion and generated revenues of almost $3.2 billion.

Seaton then summarized the accomplishments of each of Interior's agencies during 1950–60. The USGS, he reported, increased its adequate map coverage of the United States from 22 to 45 percent, while reducing the cost of a topographic map sheet by 14 percent and the average cost of printing one map edition by 22 percent. The agency's supervision of operations on mining properties grew by 360 percent, and its supervision of oil and gas leases rose by 450 percent. USGS geological investigations "provided private industry with additional basic data to guide successful information for new mineral deposits," as exemplified by the recent discovery of extensive high-grade silver-lead ore in Utah. Seaton also pointed to the agency's "[s]ignificant advances in * * * the knowledge of the occurrence and availability of our water resources and in the identification of hydrologic principles involved in the utilization of water."[141] He asked the subcommittee to approve $43,365,000 for the USGS in fiscal year 1960–61, or $659,000 more than the adjusted SIR appropriation in 1959–60; most of the requested gain would support land classification and mineral-lease supervision. Seaton estimated that these operations would involve 346,000 cases relating to classification, leases, mines, and wells, whose production and royalty values would rise, respectively, to $1.08 billion and $125 million owing to "the unprecedented rate of development of the Nation's oil and gas resources."[142] In response to Keith Thomson's concern about rising personnel costs and falling program expenditures, Seaton later summarized for the record Interior's total number of paid employees by month between the 62,744 in July 1951 and the 50,471 in November 1959. The USGS hoped to increase its staff in 1960–61 by just 22 persons to a new authorized total of 7,622, including 6,928 permanent appointments and 694 full-time-equivalent positions.

Nolan appeared on January 14 before Kirwan's subcommittee to support the budget requested for the USGS in fiscal year 1960–61. Seaton's promotion of the agency's accomplishments should have made Nolan's task easier, but Kirwan was not in his usual friendly mood. He called the meeting to order and promptly asked Nolan for a statement. Nolan began his remarks by noting that the "nuclear and space age, which has come upon us so rapidly, has created new demands for mineral substances; for more water and better utilization of water resources; and for more maps that accurately depict the face of the Nation."[143] As before, he explained the USGS work in basic and applied science and engineering, pointing out their specific contributions to the common defense and general welfare. The fundamental studies and monitoring by personnel at the Hawaiian Volcano Observatory, Nolan emphasized, aimed at achieving more accurate predictions of volcanic eruptions. He stressed the hydrological investigations that aided the "improved design of river control works, bridges, and other structures." Nolan, like Seaton, also pointed out the studies in Utah's East Tintic District that led "to the recent discovery by a mining company of 'blind' ore bodies."[144] That find greatly increased East Tintic's known reserves of high-grade silver-lead ore in the primarily lead-zinc district, opened new areas to deep exploration, and again demonstrated the value of the agency's geochemical, geological, and geophysical techniques. The USGS, Nolan noted, was aiding the evaluation of problems of nuclear-waste disposal by measuring beta-gamma activity as well as the uranium-radium content in surface water and groundwater at several hundred sites nationwide. The Western Region's topographers now occupied Building 3 at Menlo Park. The topographic mapping of Kentucky at 1:24,000, newly revised in cooperation with that State to aid resource assessments and highway construction, and attract new industries, led to the new cooperative agreement with Ohio's Government to map at the same scale the remaining 75 percent of Ohio's surface within 3 years. The acquisition of new water-stage recorders and improved electronic-computer facilities enabled the more rapid and accurate gathering and processing of hydrologic data. The new Publications Division, now just 6 months old, and improved processing of reports by the program Divisions, Nolan claimed, would significantly speed the publication of the results of USGS operations. A committee, composed of one representative each from the General Accounting Office (GAO) and Interior's Administrative Assistant Secretariat, and the USGS Executive Officer, continued to evaluate the agency's accounting procedures. Walter F. Frese, Professor of Business Administration in Harvard's Graduate School, who earlier directed the GAO's Accounting and Auditing Policy Staff and led the Treasury Department's Fiscal Service Operations and Methods Staff, served as a consultant to the committee. Nolan closed his remarks by reminding the subcommittee that the Independent Offices Appropriation Act[145] for 1960 contained funds for a new headquarters building for the USGS. The General Services Administration would begin work as soon as Congress acted on the construction-project prospectus submitted in September 1959.

The USGS, Nolan reported, expected to receive an estimated total of $64,513,000 in fiscal year 1960–61, a loss of more than $243,000 from 1959–60 but one subject to review by the new administration and the new 87th Congress. Thirty-two States and Puerto Rico, counties, municipalities, and miscellaneous nonfederal sources would provide $11,298,000, a $361,000 gain; another nearly $11,060,000, an almost $1,304,000 decrease, would come from other Federal agencies. The $43,356,000 requested in the SIR appropriation included $14,810,000, an estimated $85,000 gain, for topographic surveys and mapping; $11,837,000, or $74,000 more, for geologic and mineral-resource surveys and mapping;

$12,044,000, a $69,000 increase, for water-resources investigations; $176,000, a gain of $1,000, for soil and moisture conservation; and $3,169,000, a $420,000 increase, for conservation of lands and minerals. The SIR increase included $265,000 of the $392,000 needed for medical insurance required by the Federal Employee Health Benefits Act[146] of September 28, 1959. Total sums, including other Federal and nonfederal sources, accrued for the program Divisions would rise for two of them—Conservation Division funds would increase to $3,217,000 and Water Resources Division funds, to $24,611,000. Total monies would fall for the other two program Divisions—Geologic Division funds to $16,467,000, and Topographic Division funds to nearly $19,489,000. The AEC's Research Division and the Geologic Division agreed to a change of base to the USGS of $337,000 for fundamental research on the crystallography, geochronology, infrared-ultraviolet radiation, stable isotopes, and thermoluminescence of radioactive minerals. Some of the 1960–61 appropriation, Nolan proposed, would fund several specific studies in geology. Those investigations included ore deposits in the older Precambrian rocks of southwestern Montana, the petroleum potential of Cambrian rocks in the northern Rocky Mountains, the 1959 earthquakes and landslides in southwestern Montana, uranium deposits in Wyoming's Shirley Basin, a mapping and mineral-resource evaluation of Nevada's Esmeralda County to be conducted in cooperation with that State, ore deposition in California's Merced Peak area, the geology of helium, increased geologic mapping at 1:250,000 of the 300,000 square miles to be completed in Alaska to assess its mineral potential, and oxygen-isotope measurements in mineral deposits as aids to an increased understanding of ore genesis. Nolan also reminded the subcommittee that only one-sixth of the conterminous States were covered by geologic maps of 1:62,500 or larger scales.

During Kirwan's mostly supportive review of funding requests for the USGS SIR programs, Nolan responded to the Chairman's additional queries about the agency's work for the AEC, the cost of the two USGS aircraft, and the discovery of the new lead-silver-zinc deposit in Utah. Nolan told Kirwan that the AEC increased its transfer by nearly $317,000 to cover additional work by the USGS related to the safety and the geologic and hydrologic environment of underground nuclear shots at the Nevada Test Site. The $130,000, for which the AEC transferred $105,000, for the two USGS aircraft covered the fuel, maintenance, salaries, and special equipment needed for the magnetic and radioactivity surveys, and this cost was not comparable to the money expended on the Bureau of Sport Fisheries' 22 aircraft. When Kirwan emphasized that U.S. stockpiles of lead and zinc were, respectively, four and eight times the maximum wartime requirements, Nolan hoped that the higher grade of the newly discovered deposit at East Tintic would, when eventually developed, enable the Nation to compete more effectively with foreign sources. The International Lead and Zinc Study Group, formed by the United Nations in 1959, held its first meeting in Geneva from January 27 to February 3, 1960, with members of Assistant Secretary Royce Hardy's office in attendance. Meeting participants agreed to continue curtailing shipments of lead by exporters and began new and similar restrictions on zinc; after the market improved, they terminated the latter in May. The Eisenhower administration estimated that expenditures for stockpiling and expanding domestic production for defense would fall below $70 million during fiscal year 1960–61 and would drop further to about $50 million in 1961–62, as materials deliveries were completed, contracts ended, and no new agreements were signed.

Kirwan then renewed a significant complaint about the adequacy and timeliness of USGS accounting methods in its supervision of oil and gas leases. He began by querying the $250,000, the major part of the additional $400,000 requested for the Conservation Division in fiscal year 1960–61, to fund 33 new employees to supervise the ever-growing number of oil and gas leases, especially those on the Outer Continental Shelf, where petroleum production exceeded

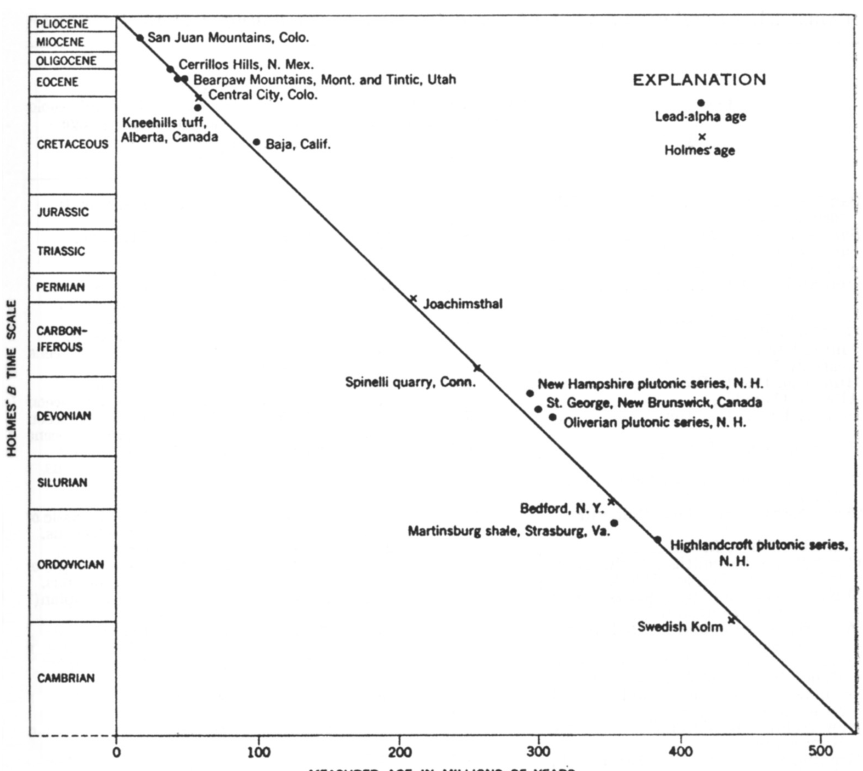
103,000 barrels daily in November 1959. The extra personnel, Nolan explained, would allow the Division to respond positively (by increased and improved efforts in field and office) to yet another critical report by the General Accounting Office in December 1959 of "serious deficiencies in royalty accounting" on the leased lands. "This is the third straight year," Kirwan reminded Nolan, "that we have taken up this General Accounting Office criticism." "One company," Kirwan continued, "had never been billed since 1949."[147] He pointed to "the inadequate procedures used in accounting for royalties in the audit reports issued to the Congress on the Bureau of Land Management, for fiscal years 1953 and 1954; to the Administrative Assistant Secretary [Beasley] in 1955; and to the Director of the Survey in 1956 and 1957." When Kirwan emphasized that "[t]here is something wrong in the method,"[148] Nolan said the review committee's preliminary evaluation of the most recent report by the GAO, which recommended transferring royalty accounting from the Conservation Division to the Administrative Division, yielded explanations of some comments and corrective action on other criticisms. Nolan emphasized that the delays, reflecting the divergence between the BLM and the USGS records, were in recording and did not represent any loss of Federal collections income. He anticipated that a system acceptable to the GAO would be completed within the next few months. The subcommittee, Kirwan responded, expected the USGS to resolve satisfactorily this problem before the appropriations hearing for fiscal 1961–62. If GAO complains to us again, Kirwan warned Nolan,

> **we are going to have to do something about it. I would like to see it corrected without our having to send somebody down there to straighten it out. Seven years is too long.[149]**

After this exchange, additional questions by Kirwan, Fenton, and Thomson proved something of an anticlimax. The three Representatives queried the funds for general administration, new housing for additional employees at the HVO, the new geologic mapping in Ohio, the progress since 1947 in mapping anthracite basins, the seemingly disproportionate increase since 1951 in USGS appropriations, the long-standing allegation of duplication in Federal mapping and possible consolidation of those functions in one agency, and the amounts spent to date on the USGS-State cooperative programs in topographic mapping and water-resources investigations. They also asked about the Nation's water-resources problems involving supply, variability, distribution, quality, pollution, and floods and the USGS responses to help resolve these problems that included collecting and analyzing basic facts about water, making interpretative reports on areas, and continuing research on processes and relationships. These questions and Nolan's answers yielded no surprises. The hearings closed with an exchange about the continuing search for a site for a USGS national center in the Washington metropolitan area. The General Services Administration, Nolan now reported, submitted to the House and the Senate Committees on Public Works on September 15, 1959, 6 days after the Public Buildings Act, the construction-project statement prepared jointly by the GSAd and the USGS. As soon as the committees approved the statement, Franklin G. Floete, the GSAd's Administrator since 1956, assured Seaton and Nolan that the GSAd would proceed with securing a site and preparing plans for the building, using the estimated $2,125,000 from fiscal year 1960–61's appropriation. Congressional approval also would enable the GSAd to confirm that construction was scheduled for fiscal 1962–63 and 1963–64.

On February 2, Secretary Seaton promised Senator Hayden's appropriations subcommittee that he would establish an office of coal research, supported by $1 million in contingency funds, if Congress and the President authorized the newly proposed program and its funds. Seaton also pledged to increase Interior's efforts to conserve and develop helium, as Eisenhower requested in his balanced-budget message of January 18 that contained expected revenues during fiscal year 1960–61 of $84 billion and expenditures of $79.8 billion.[150] Later in 1960, amendments[151] to the 1925 Helium Act, as amended in 1937, enabled, during the next 20–25 years, the Federal Government to contract with private firms to build another extraction plant. During these years, industry would deliver 62.5 billion cubic feet of helium, extracted from natural gas, beyond current needs and store the excess in the USBM's underground facility at Cliffside, just northwest of Amarillo, in Texas. As recommended by the NSF's Advisory Committee on Minerals Research, Seaton emphasized, the USGS proposed to expend a total of $500,000 on three projects—$200,000 on the first year of additional studies in geochronology, $100,000 on lead-isotope investigations, and $200,000 on geologic and topographic mapping related to understanding the occurrence and locating new supplies of the Nation's mineral commodities, especially in the Rocky Mountain area, and developing new exploratory methods and tools.

When the USGS contingent appeared before Senators Carl Hayden, Henry Dworshak, and Thomas Kuchel on February 9, Nolan began his statement by summarizing the requested SIR increase that included $400,000 for lease supervision and land classification and $265,000 for the Federal share of the medical-insurance program. Nolan called for additional SIR appropriations to support USGS studies related to safely disposing of the growing volume of radioactive wastes by investigating suitable underground sites for storage, the mechanisms and mineralogy of ion exchanges, the reactions of mixed electrolytes with rocks and other natural materials, and the dissipation of heat underground. The House and the Senate Committees on Appropriations agreed to add $285,000 to the agency's request for SIR funds for fiscal year 1960–61, $127,000 of which would go to medical insurance and relieve the USGS from absorbing that amount. On July 7, a new law established the Office of Coal Research (OCR) in the Interior Department, to "encourage and stimulate the production and conservation of coal in the United States through research and development by authorizing the Secretary of



This chart compares USGS lead-alpha ages from rocks of known geologic ages with those from the *B* time scale of British geologist and pioneering geochronologist Arthur Holmes (1890–1965). In the 1950s, USGS isotopic geochronologists used lead-alpha, lead-uranium, lead-thorium, and lead-lead methods of dating igneous rocks containing the minerals zircon, monazite, thorite, and xenotime. They compared the results of these techniques with other radiometric dates determined by the newer potassium-argon and strontium-rubidium methods. Dates were considered concordant if they varied within plus or minus 10 percent of each other. Partial or complete melting and recrystallization of minerals after their formation that led to the loss of lead isotopes were among the causes of discordant dates. (From Gottfried, Jaffe, and Senftle, 1959, fig. 6; for a biography of Holmes, see Lewis, Cherry, 2000.)

the Interior to contract for coal research."[152] Industry wanted less abstract research and the USBM wanted immediate practicable and applicable results. The new OCR received up to $2 million during fiscal 1960–61 from unappropriated funds in the Treasury.

On May 13, 1960, President Eisenhower signed his last bill that provided regular appropriations for the Interior Department. The Public Land Administration Act of July 14 authorized the Secretary of the Interior to conduct "investigations, studies, and experiments" and to accept "donations of money, services, and property" to facilitate "the improvement, management, use, and protection of the [public] lands."[153] The USGS, for its land-related and other operations during fiscal year 1960–61, received SIR funds of $43,650,000, of which $7,450,000 could be used only for the State-county-municipal cooperative studies of water resources.[154] A supplemental measure, strongly supported by Senator John S. Cooper (R–KY) as Alben Barkley's successor, and enacted on September 8, gave the USGS an additional $300,000,[155] to equal Kentucky's funds authorized in March for its initial year's contribution to the cooperative geologic mapping of that State. A second supplemental bill, signed on March 31, 1961, added $2,006,000[156] and brought the SIR funds available to the USGS for 1960–61 to $45,856,000, or nearly $3.8 million more than in 1959–60. Other Federal agencies would provide about $13,196,000; States, counties and municipalities would contribute some $11,641,500; and miscellaneous nonfederal sources would add nearly $610,800, to raise USGS funds for fiscal year 1960–61 to just over $71,349,000, an increase of some $6 million above the total for 1959–60.

The Eisenhower administration, while focusing on the coming Presidential election, the State and more local contests, and other significant developments at home, continued to experience successes and failures in dealing with the Soviet Union and in space. U.S.-Soviet relations deteriorated even further after July 1, 1960, when Soviet interceptors shot down an American RB–47 reconnaissance aircraft as it neared the Barents Sea and incarcerated the surviving crewmembers until 1961. In August 1960, Richard Bissell's Project Corona began paying off on its investment, and the Eisenhower administration established an initially civilian group to direct all U.S. aircraft and satellite reconnaissance. In the following year, that group was replaced by the National Reconnaissance Office, with its supporting and CIA-directed National Photographic Interpretation Center to handle the film records. On Aug. 11, Corona personnel successfully recovered from Pacific waters a capsule ejected from the Discoverer 13 satellite; the capsule contained damaged film. This action was the first recovery of a manmade object ejected from an orbiting satellite; several other capsules had sunk at sea, and one was lost on Spitsbergen (Svalbard). On August 19, the crew of American transport *Pelican 9*, one of six Fairchild EC–119J Flying Boxcars, recovered in midair over the Pacific a parachute-suspended capsule, with film intact, returned from Discoverer 14. The initial processed image, taken a day earlier, showed a 10-square-mile area, and within it a Soviet military airfield and other objects as small as 25 feet across, around Cape Schmidt on the northern coast of Chukotka, about 475 miles northwest of Nome, Alaska. The photograph also recorded patterns of vegetation, sediment transport, and waves and currents. On August 19, 1960, Soviet Sputnik 5, a Vostok spacecraft carrying canines "Belka" and "Strelka," achieved orbit; later the two dogs were recovered safely, unlike "Laika," as were three U.S. mice sent aloft aboard an Atlas on October 13. By then, another Pioneer and a Soviet probe to Mars both failed and U.S. Project Mercury continued to encounter difficulties in testing its spacecraft. After failures in July and November, a modified Redstone rocket, launched from Cape Canaveral on December 19, hurled an empty Mercury capsule 135 miles into space and 235 miles downrange in the Atlantic. A helicopter crew recovered the spacecraft and brought it safely aboard aircraft carrier *Valley Forge*.

As the space race continued in 1960, oil was discovered in the Neutral Zone between Kuwait and Saudi Arabia, and the West's petroleum policies gained it a new competitor. On March 10, 1959, Eisenhower moved to protect domestic producers by setting quotas on oil imported into the United States. Attendees at an Arab Oil Congress, held in Cairo in April, signed an informal agreement that Daniel Yergin later viewed as their effort to defend existing prices, nationalize more of their native industries, and increase their revenue shares.[157] Oil production from the Middle East, which held most of the world's reserves, continued to increase during the 1950s, as it did in the Soviet Union, but oil prices continued to fall as the West's major oil companies changed posted prices, as opposed to market values, without first consulting the producing countries. When Standard Oil of New Jersey increased oil prices by 14 cents, or about 7 percent, per barrel on August 9, 1960, the company's failure to obtain advance agreements with other oil-producing nations produced a significant change in Saudi Arabia and also led to the founding of a new international, potentially powerful, and certainly hostile cartel. Crown Prince Faisal promptly replaced Abdullah Tariki, the Saudi oil minister who signed the Cairo agreement in 1959, and appointed lawyer Ahmed Zaki Yamani to the Council of Ministers; during the past 4 years, Yamani, now 30, advised the Finance Ministry's Oil Department and then the Council. On September 8, 1960, Shell increased its price by 2 to 4 cents per barrel. Representatives of five major oil-producing nations—Iran, Iraq, Kuwait, Saudi Arabia, and Venezuela, who together produced 80 percent of the world's exports—met in Baghdad to try to control and stabilize petroleum prices. By September 14, they formed the Organization of the Petroleum Exporting Countries (OPEC), but the new organization received little attention in the CIA's November report on the Middle East. Eventually nine other countries—Algeria, Angola, Ecuador, Gabon, Indonesia, Libya, Nigeria, Qatar, and the United Arab Emirates—joined OPEC. The group's members often disagreed with each other and did not succeed in stabilizing oil prices. As Yergin recorded, they did begin to control production, increased their shares of the profits from a 50:50 split to as high as an 86:14 division, and required the global oil companies to negotiate their proposed changes in price. Policy in Saudi Arabia, the largest of OPEC's oil producers, changed again after Crown Prince Faisal resigned his two ministries at the request of King Saud on December 21, 1960. A week earlier, the Organization for European Economic Cooperation, founded to promote freer trade worldwide, added Canada, Japan, and the United States as member nations to become the Organization for Economic Cooperation and Development. When Faisal returned to power, Yamani became Minister of Petroleum and Mineral Resources and joined Aramco's Board of Directors in 1962.

The U.S. Presidential campaign began in earnest in late July 1960, after both major political parties held their conventions. The Democrats, meeting in Los Angeles on July 13, nominated Massachusetts' Senator John Kennedy, now 43, for President on the first ballot. Kennedy, educated at Harvard, served in Navy intelligence at home and in combat in Patrol Torpedo (PT) boats in the Pacific during World War II. Lieutenant Kennedy received wider attention in 1943, when the Japanese destroyer *Amagiri* rammed and sank his PT–109 during a night patrol in Blackett Strait off Kolombangara in the central Solomons. Two of the PT's crew died, but Kennedy helped to rescue the other survivors and was decorated. Despite continuing problems caused by a reinjured back and Addison's disease, Kennedy served his State as a Democrat in the House from 1947 before being elected to the Senate in 1952. His younger brother Robert F., who served after the war in destroyer *Joseph P. Kennedy, Jr.*, named for their deceased elder brother killed on an aerial-bombing mission in 1944, helped to counsel the second Hoover Commission and McCarthy's subcommittee, and campaigned for JFK, who announced his decision to seek the Presidency on January 1, 1960. Joseph Kennedy, Sr., who opposed his son's try for the Vice Presidential nomination in 1956, now provided funds and political influence. Hubert Humphrey, Jr., the Senate's Democratic whip, who also wanted the Vice Presidential nomination in 1956, now hoped to become the next President. The more liberal Humphrey lost key primary elections in 1960 to the more conservative Kennedy, whom Humphrey and Adlai Stevenson called the Democratic "Nixon," and withdrew from the contest. At the party's national convention, Kennedy achieved a more balanced ticket, especially in the South, by offering the Vice Presidential nomination to Lyndon Johnson, who took the post after running second to Kennedy in the only Presidential ballot. Kennedy and Johnson, rarely campaigning together, promised to get the United States moving again. They pledged to eliminate an alleged Soviet advantage in ICBMs (the so-called but nonexistent missile "gap"), end Soviet dominance in space, improve civil rights for minority citizens, place medical care for older persons under the Social Security system, and begin a policy of looser credit and money.

Republicans convened in Chicago and chose Vice President Richard Nixon as their nominee for President on the initial ballot on July 27, 1960, after Governor Nelson Rockefeller of New York declared that he would not be a candidate. "Prospect for America," the report[158] of Rockefeller's six panels established in 1956, would not appear until 1961. As Nixon's running mate, the delegates selected Henry Cabot Lodge, Jr., the U.S. Ambassador to the United Nations, whom Eisenhower had appointed and given Cabinet rank in 1953. Lt. Colonel Lodge, a Harvard graduate like Kennedy, led armored units in combat in North Africa and Europe during World War II. Lodge, like his grandfather, served Massachusetts as one of its Senators. Lodge served in the Senate during 1937–1944 and 1947–1953; he resigned in 1944 to return to active military duty. In November 1952, Lodge lost his seat to Kennedy after campaigning widely for Eisenhower. Nixon and Lodge pledged to continue Eisenhower's domestic and foreign policies, including establishing a fiscally sound but contributory health program, enforcing the civil rights of all citizens, and increasing funds for national defense. Eisenhower, Nixon, and Defense Secretary Gates denied a missile gap and emphasized the U.S. lead in the space race with the Soviet Union in the number of satellites and probes launched. In the ensuing campaign, Nixon, against Eisenhower's advice, debated Kennedy four times on radio and television, beginning on September 26; the results were mixed. Kennedy convinced additional voters that he was mature and experienced enough to be President and that his Catholic religion would not adversely influence his conduct while in office. Both parties issued policy statements on science and technology, and both candidates for the Presidency employed science advisers; George Kistiakowsky replaced James Killian as Eisenhower's adviser in mid-July 1959.[159] Nixon and his advisers kept Eisenhower on the shelf until the last weeks of the campaign; the President's active participation came too late to affect its result.

Kennedy won by an exceedingly slender margin on November 8, even though more than 8 million new Democrats registered during the campaign. The tally proved so close that recounts in four States, including Illinois, where Mayor Richard J. Daley of Chicago held his city's votes until he knew the downstate totals, delayed the Electoral College's official decision until December 19. Kennedy received just 118,574 popular votes more than Nixon, out of 68,508,943 cast, but he gained 303 electoral votes to Nixon's 219, an 84-vote margin that included Illinois' 27. None of the four minor-party candidates, including Governor Orval Faubus of Arkansas, drew more than 48,000 popular votes. Virginia Senator Harry Byrd, Sr., received the votes of 15 unpledged electors in Alabama (6), Mississippi (8), and Oklahoma (1). The Democrats held Texas (24) and the Old South, except for Florida, Kentucky, Tennessee, and Virginia. Republican electors from California (32), Indiana, Iowa, Ohio (25), Washington, many of the Great Plains and Rocky Mountain States, and a few in New England did not offset the Democrats' total. Nixon could have demanded a recount, but he decided not to contest his loss; he returned to

California, where he intended to run for Governor in 1962. In elections for the 87th Congress, the Democrats kept control of both houses; they led by the same 65–35 margin in the Senate, but the loss of 21 seats in the House reduced their edge there to 263–174.[160]

In response to Kirwan's remarks in January 1960, Nolan and his staff continued to consolidate and simplify USGS administrative services by using electronic data-processing equipment to improve financial-management reports, timely payment of rents under annual contracts, tracking of per diem payments for employees on continuous travel status, space-inventory records, accounting and property control for interdivision services, and cost controls by agency shops. Representatives of the Interior Department and the USGS continued to meet annually with the USGS Science Advisory Committee—Horace Albright, John Frye, William Heroy, Herbert Loper, Donald McLaughlin, George Gaylord Simpson, and Abel Wolman—to evaluate the agency's management and programs. As before, the external advisers also submitted a report of recommendations to the Secretary. The USGS, also as usual, then commented on each evaluated item for the Secretary and the House appropriations subcommittee. The agency's advisers planned to hold their next 2-day meeting in December 1960.

Kirwan's comments also led the USGS to speed the appearance of the results of its research. On June 30, Nolan introduced the initial compilation of "Geological Survey Research," published in two volumes (chapters A and B) as Professional Paper 400. In his foreword, Nolan wrote, "This report is frankly an experiment."[161] He hoped to reduce the interval between the completion and publication of the results of USGS research; perhaps he also wished to decrease the loss of articles to outside periodicals or at least to get brief versions of them earlier into print. Professional Paper 400 summarized the results of recent work by members of the Geologic Division. Chapter A, a "Synopsis of Geologic Results" prepared by Division members under Vincent McKelvey's direction, presented summaries of "important new findings, either as yet unpublished or published"[162] during fiscal year 1959–60. These brief synopses appeared in seven groups—mineral-resources investigations, development of exploration and mapping techniques, geology applied to problems in the fields of engineering and public health, regional geology, geologic investigations in foreign nations, investigations of geologic processes and principles, and analytical and other laboratory techniques. Chapter A also listed the Division's offices, its reports released during the fiscal year, and its in-progress investigations.

USGS Professional Paper 400's Chapter B, "Short Papers in the Geological Sciences," contained 232 articles, most shorter than 1,000 words. Some articles announced "new discoveries or observations on problems of limited scope" in advance of "more detailed and comprehensive reports" that might or might not "be published later." Other articles summarized the conclusions drawn from extensive and long-term investigations; Nolan's foreword said that the conclusions "in large part will be embodied in much longer reports that will be published later." Chapter B's articles were further divided among 13 categories: geology of metalliferous deposits (27 articles); geology of light metals and industrial minerals (8); geology of fuels (7); exploration and mapping techniques (20); geology applied to engineering and public health (11); geology of the Eastern United States (20); geology of the Western conterminous United States (58); geology of Alaska (11); geology of Hawaii, Puerto Rico, Pacific islands, and Antarctica (12); paleontology, geomorphology, and plant ecology (6); geophysics (14); mineralogy, geochemistry, and petrology (20), and analytical and petrographic methods (18). Nolan hoped to include in future annual issues the results of similar comprehensive work by the agency's other program Divisions. He sought "comments and suggestions from those who use the volume" to "help determine the content of the future ones."[163]

In 1961, the Menlo Park chapter of the USGS Pick and Hammer Club printed its program, subtitled "The Collapsis of Geologic Results,"[164] as a "facsimile" of Professional Paper 400. The players burlesqued that volume, especially the delay its preparation imposed on other Geologic Division publications, and the year-old reorganization of the Division.

Chapter B's short-paper potpourri contained reports by older and younger authors from the Geologic Division, and those in affiliated Federal, State, and academic organizations, that summarized on a few pages the results of their wide-ranging recent and ongoing basic and applied research. The AEC provided most of the transfer funds for publication, but support also came from the Arctic Institute of North America, the USAF's Cambridge Research Center, the Army Engineers, the USBM, the Bureau of Public Roads, the USBR, the GSAd, the NSF, the Navy's Bureau of Yards and Docks and its Office of Naval Research, and the Soil Conservation Service. Other organizations providing financial and other aid included State agencies in California, Colorado, Connecticut, Maryland, Nevada, Oregon, and Pennsylvania; Puerto Rico's Economic Development Administration; the University of California at La Jolla and at Riverside; and Caltech. The hypothesis proposed by J. Hoover Mackin (at the University of Washington-Seattle) and Earl Ingerson (at the University of Texas-Austin since 1958) for the origin of ore-forming fluids and a study by John N. Rosholt, Jr., of uranium migration in sandstone-type ore deposits were among the metalliferous-deposit papers. Isidore Zietz, Gordon E. Andreasen, and Arthur Grantz compiled regional aeromagnetic surveys of possible petroleum provinces in Alaska. Paul Averitt summarized U.S. coal reserves as of January 1, 1960. William Fischer evaluated spectral-reflectance measurements as bases for film-filter selection for differentiating rock units on aerial photographs. Articles about studies in Alaska included Robert Chapman's and Hansford T. Shacklette's summary of the results of geochemical exploration in Alaska; an assessment by Gordon W. Greene, Arthur Lachenbruch, and Max Brewer of the effects of Alaska's Richardson Highway, at mile 130, on permafrost; a 1:1,584,000 sketch map of the State's surficial deposits by Thor N.V. Karlstrom and his collaborators; and carbon-14 dates, reported by Henry Coulter, and his Iowa State University coauthors Keith M. Hussey and John B. O'Sullivan, of 38,000 to 9,100 years (before the present) for the upper part of the North Slope's Gubik Formation. Coulter and Karlstrom were part of the in-house group of geologists, including David Hopkins, Troy Péwé, Clyde Wahrhaftig, and James Williams, who planned a glacial map of Alaska.[165]

Chapter B also reported some results of the Geologic Division's work with electronic computers and its continuing efforts at the Nevada Test Site.[166] Martin F. Kane used the USGS Datron 205 to compute terrain corrections for gravity stations in moderately mountainous areas of southern Nevada; Kane expected the cost of the expensive but more rapid and consistent computations to be reduced by three-quarters when the new Datron 220 began operations. Results of work at the NTS included studies by V. Richard Wilmarth, Theodore Botinelly, and Ray Wilcox of how the Rainier nuclear test's explosion altered the containing tuffs. Carl M. Bunker, William Diment, and Wilmarth discussed the distribution of gamma radioactivity, radioactive gas, and temperatures generated by the same test. Diment, Don L. Healey, and Joe C. Roller related gravity and seismic exploration to understanding the geology of the NTS. George V. Keller described the physical properties of the test-containing Oak Spring Formation's tuffs. Francis A. McKeown and Dayton D. Dickey evaluated the effects of the NTS explosions on their geological environment. Wilmarth and McKeown reported the structural effects of the Rainier, Logan, and Blanca tests. Gene Shoemaker, who was acquiring the double-entendre nickname "Supergene," used data from the Rainier-test tuffs and the craters from the Jangle-U and Teapot-ESS nuclear tests in alluvium, his mineralogical and stratigraphic studies of Meteor Crater, and dynamite explosions in Colorado sandstones to develop a scaling law for domain of brecciated mixing of rock by strong shocks that included an equation between the mixing-domain's limit and the energy released.

Other parts of Chapter B extended the geologic-geographic coverage of the Geologic Division's current research. Bill Bromery presented his preliminary interpretation of aeromagnetic data in Pennsylvania's Allentown quadrangle. Samuel W. Stewart, Renner B. Hofmann, and William Diment analyzed some aftershocks of the Hebgen Lake, Montana, earthquake of August 1959, and Wayne H. Jackson reported a profile based on postquake soundings in Hebgen Lake. Henry Joesting and James E. Case assessed salt anticlines and deep-seated structures in the Paradox Basin of Colorado and Utah. Charles Hunt and hydrologist Thomas Robinson proposed possible interbasin circulation of groundwater in the southern Great Basin, and Don R. Mabey summarized regional gravity surveys in the Basin and Range Province. Three articles evaluated volcanism in the Cascade Range, studied by USGS geologists since Clarence E. Dutton began working there in the 1880s. Don R. Mullineaux and Dwight R. ("Rocky") Crandell, protégés of Ray Wilcox at Denver since 1950–51, fixed the age of Washington's Mount St. Helens as late Recent and suggested that its present cone might be less than 1,000 years old. Dallas Peck assessed volcanism and volcanic trends in Oregon's portion of the Cascades, and Louis Pakiser suggested an eruptive mechanism for the Cascade volcanoes within California. Frank Whitmore described fossil mammals collected by Helen Foster's field party on Ishigaki-shima in the Ryukyus. Six other articles represented research on topics of more recent interest to the Geologic Division—Robert Hackman's technique for stereoscopically viewing lunar photographs; Warren Hamilton's new interpretation of Antarctic tectonic features; Harry Ladd's view of the distribution of Cenozoic molluscan faunas in the Pacific, based on fossils from its islands; Donald White's summary of the chemical characteristics of some deep-origin waters; E-an Zen's analysis of the early stages of evaporite deposition; and Richard Doell's and Allan Cox's preliminary assessment of paleomagnetism's relation to polar wandering and continental drift.

Doell and Cox, who published elsewhere in 1960 an extensive review of paleomagnetism,[167] concluded in their brief article for Chapter B that "the paleomagnetic data now available," gathered since George Becker's prediction in 1904, indicated that "the earth's magnetic field had vastly different characteristics during the following periods: post-early Pleistocene, Oligocene to early Pleistocene, Mesozoic to early Tertiary, late Paleozoic, early Paleozoic, and Precambrian." The value of paleomagnetic evidence for or against continental drift, they asserted, required determining "the configuration of the earth's magnetic field during the time when contemporaneous rocks from different continents were magnetized." Only in a few of these six time intervals was the geomagnetic field's configuration "established with sufficient certainty to justify application to the problem of continental drift."[168] The late Pleistocene magnetization directions, all of the same polarity, often differed significantly from the present geomagnetic pole but rarely from the present geographic pole, data that supported the dynamo theory, a transient dipole field, and

> **a total absence of processes causing self-reversal of the remanent magnetization.[169]**

Magnetization directions of half of the Oligocene–lower Pleistocene rocks assessed were oriented nearly 180 degrees to the present field directions, indicating that at least a dozen field reversals occurred during this interval, in which polar wandering and continental displacement were less than 10 degrees. Not one of the more than 40 reported studies of Precambrian rocks showed a virtual geomagnetic pole near the present geographic pole; most of these poles were near the Equator and just east of the 180th meridian.

"Continental drift interpretations" based on the scattered virtual geomagnetic poles of lower Paleozoic rocks, Doell and Cox cautioned, were "extremely hazardous."[170] All but a few of the Permo-Carboniferous poles lay between 30 and 40 degrees of latitude, but those calculated from measurements on European and North American rocks occupied positions between 90 and 180 degrees east, while those from Australia were well to the west. An interpretation based on continental drift during this interval required "rather improbable relative movements between North America and Europe." All of the Permian virtual geomagnetic poles also had the same polarity, a fact that could not be explained by the self-reversing hypothesis. The 50-plus determinations of Mesozoic and lower Tertiary rocks showed no magnetic-field configuration consistent with those of the upper Paleozoic and upper Tertiary rocks; some calculated poles were near the present geographic poles, but many of the others were at low latitudes. Doell and Cox concluded that the Earth's magnetic field during these intervals was insufficiently well fixed "to justify interpretation of the paleomagnetic data as evidence either for or against continental displacement during this time."[171]

While the Geologic and Publications Divisions, and the Government Printing Office, prepared and processed Professional Paper 400, and the USGS began planning for a similar but larger volume in 1961, Anderson and Nolan completed planning late in May 1960 for their reorganization of the Geologic Division effective as of July 1. Their two principal goals reflected political realities and an increased emphasis on academic-style operations, as recommended in a report by an internal committee chaired by Harold James. First, Chief Geologist Anderson and Director Nolan designed the modifications "to bring the budget structure into accord with the organizational structure." The Division's three major subactivities—economic geology, geologic processes, and regional geology—would now be managed by three of the four new Assistant Chief Geologists. The fourth new ACG received "operational responsibility for programs conducted on behalf of other agencies." Second, Anderson and Nolan responded to congressional and other external critics who noted "a lack of supervision"[172] by planning to "facilitate better supervision of the technical operations"[173] by increasing the number of the Division's Branches from 10 to 27. In response to allegations by staff members of the House appropriations subcommittee that the Geologic Division's 27 new Branches led to supervisory duplication, Nolan responded at the hearings in March 1961 that the new Branches each held fewer scientists. Some of the older Branches "had included as many as 300 scientists"; the new ones contained only 20 to 50 scientists. "This rearrangement," Nolan claimed, "should provide much more effective supervision" by reducing "the number of levels of supervision, as well as the number of supervisory positions."[174]

How the Geologic Division's reorganization would reduce job and staff inflation, when each new Branch Chief would need a staff, remained to be demonstrated, but grade inflation could be controlled by giving the Branch Chiefs temporary promotions. No productive scientists would wish to be separated from their research for more than 5 years. If new Branch Chiefs were not already GS–15 scientists, they could become GM–15 managers as an inducement to leaving full-time scientific studies to fill these slots. Those GM–15s would be returned to their former GS rank at the conclusion of their managerial tour, unless during that interval they continued significant research and publication. The results of such work might earn them research appointments as permanent GS–15s. As part of the reorganization, Anderson and Nolan considered abolishing the Regional Geologists' positions at Denver and Menlo Park, reassigning their responsibilities, and replacing them with a committee of four part-time deputies at each locality. Some of these changes in the Geologic Division introduced a new generation of scientist-managers. Some of the new thematic Branches would prosper both financially and operationally; others would not, reflecting in part the loss of ties to mission-specific funding.

Those changes in the Geologic Division became effective on July 1, 1960, but the Pick and Hammer Club commented on them in "The Fox and the Goose or Anderson's Grimmest Fairy Tale," its annual show in May 1961, by suggesting that "Andy—go westward today."[175] At Division level, CG Andy Anderson retained Montis Klepper as Assistant Chief Geologist for Operations but Robert L. Boardman succeeded Harold Bannerman as ACG for Program, with the additional responsibility for Budget. Boardman, an economic geologist, served with the Trace Elements Planning and Coordination Office during 1948–51 and then the Mineral Deposits Branch before becoming a staff geologist with Bannerman in 1957. The three new operational Offices went to ACGs James Balsley, for Geologic Processes, where Edwin Roedder served as Staff Geologist; Warren Hobbs, for Economic Geology; and Walter White, for Regional Geology. White had been Anderson's Assistant Branch Chief during 1954–56. ACG Vincent McKelvey took over Interagency Programs and Special Services.[176]

The need for a fifth program office in the Geologic Division came under increased scrutiny after Preston Cloud, at Nolan's request, testified in May before the House Committee on Merchant Marine and Fisheries' Subcommittee on Oceanography. On March 9, 1959, newly seated Representative Hastings Keith (R–MA), a Colonel in the Army Reserve whose district included the Woods Hole Oceanographic Institution, placed in the *Congressional Record* a warning that "The United States is losing to the Soviet Union the biggest and most important sea battle in mankind's history—the contest to unlock the ocean's secrets for use in peace and war * * * Now that the United States has drawn alongside the Soviets in the race for outer space, it is essential that we concentrate as well on developing to the fullest our capacity for probing the oceans."[177] Cloud began a staff review to advise Anderson and Nolan about the advantages to be gained by establishing an office of marine geology.[178] In June, Cloud replaced William Thurston as the Director's representative to the NAS–NRC's Committee on Oceanography and at the first two meetings of the Interagency Committee on Oceanography and its Subcommittee on Ocean Surveys and Development. Thurston, who left the NAS in 1959 to return to the USGS as a member of the Director's staff, represented the agency on the NAS–NRC's U.S. National Committee on Geology. Nolan, like Cloud, thought research should be intensified on three topics—(1) identifying the Continental Shelf's minerals, rocks, and structure; (2) interpreting the geologic history of movement by the margins of the continents and ocean basins; and (3) developing instruments and rapid techniques for in-place analyses of the chemical and physical properties of sea-floor sediments, to supplement data from coring and dredging.

Warren Hobbs' Office of Economic Geology held five Branches. David Varnes replaced Edwin B. Eckel as Chief of Engineering Geology. Hobbs' four new Branches included Base and Ferrous Metals, led by Philip Guild; Exploration Research, managed by geochemist Garland B. Gott; Light Metals and Industrial Minerals, directed by James J. Norton; and Organic Fuels, under Thomas Hendricks. Norton, who joined the USGS in 1942, mapped chromite with Joe Peoples in Montana and Georgia, investigated mica and beryl pegmatites in the Black Hills and elsewhere in the West, and spent 3 years in Washington managing commodity studies for the DMEA.

James Balsley's Office of Geologic Processes contained six Branches, almost all with strong components in basic as well as applied research. The former Branch of Geochemistry and Petrology was divided into Experimental Geochemistry and Petrology, led by Charles L. Christ, and Field Geochemistry and Petrology, under Robert L. Smith and including the HVO. At the HVO, Jerry Eaton succeeded

Kiguma ("Jack") Murata for a second tour as the Scientist in Charge. Balsley's units also included four new Branches—Crustal Studies, managed by Louis Pakiser, with Charles Bates as head of Vela-Uniform; Geochemical Census, led by Wayne Hall; Isotope Geology, under Samuel Goldich; and Theoretical Geophysics, directed by William Diment. Project Chiefs in Diment's Branch included Richard A. Robie for calorimetry; George V. Keller for electrical sounding and telluric currents; Arthur Lachenbruch for heat flow and geothermal processes; Allan Cox, Richard Doell, and (later) Brent Dalrymple for paleomagnetism; King Hubbert,[179] after he retired from Shell, for petroleum analysis; Eugene C. Robertson for rock mechanics; and E-an Zen for structural-stratigraphic syntheses.

Walter White's new Office of Regional Geology included 11 geographic and programmatic Branches. Two Branches in Regional Geology—Alaskan, where Donald Eberlein succeeded George Gates, and Paleontology and Stratigraphy, under Charles Merriam—were held over without change, except for shortening the name "Alaskan Geology Branch" to "Alaskan Branch." The General Geology Branch was dissolved, and, in July 1960, its chief Fred Smith returned to his studies, begun in August 1955, of Nevada's Railroad district. Among White's new Branches, Regional Geophysics was led by Isidore Zietz. Beginning in September 1961, Lawrence Craig supervised Paleotectonic Maps' completion of the Mississippian and Pennsylvanian folios. The new regional Branches included New England, led by Lincoln Page; Eastern States, under Jarvis ("Jerry") Hadley; Kentucky, directed by Alfred Zapp to March 1961 and then by Paul Richards; Northern Rockies, managed by Gershon Robinson; Southern Rockies, led by Ogden Tweto; Southwestern, directed by Robert Wallace; and Pacific Coast, under Parke Snavely, Jr. Richards returned to the United States in 1960, after 2 years of providing advice on sedimentary geology to the Geological Survey of India's Director, and initially joined the geologic mapping in Kentucky as a regional manager. Snavely began studying the geology and mineral resources of the Coast Ranges and adjacent areas in western Oregon and Washington in 1942; he also supervised the Division's work in the Pacific Northwest Region during 1953–59. Tweto mapped and studied tungsten and other commodities in Colorado from 1940 for Foster Hewett, Thomas Lovering, and other project chiefs in the Metals Section and Mineral Deposits Branch before beginning his tour as a Branch Chief in September 1961.

McKelvey's Office of Interagency Programs and Special Services comprised five Branches. Foreign Geology, led by William Johnston; the Library; and Military Geology, under Donald Dow, continued as before, but Frederick Betz, Jr., left as head of the MGB's European Team to become Executive Secretary of the Geological Society of America in 1960. McKelvey's new Branches included Frank Grimaldi's Analytical Laboratories, enfolding the former TEPCO, and Frank Stead's Special Projects, a partial spinoff from Military Geology. With these and the other changes during the Geologic Division's reorganization in 1960, two additional Branches—Fuels and Mineral Deposits—disappeared from the Division's table of organization.

As fiscal year 1960–61 began, the Geologic Division continued to apply geology for the benefit of public health. Its scientists' studies of radioactivity and geochemistry, conducted with the cooperation of the National Cancer Institute, showed strong correlations between the occurrences of cancer and coronary disease and the composition of rocks and groundwater in the affected areas. Magnetic-balance studies revealed anomalous cell fluid in cancer tissue. Electron-microprobe investigations, now able to spectrographically analyze areas as small as 1 micrometer, disclosed abnormal concentrations of copper in the corneal tissue associated with Wilson's disease.

In other wide-ranging studies, members of the Geologic Division used neutron-activation detection and the sensitivity of analytical chemical procedures to aid searches to reduce the domestic shortage of beryllium and other rare elements.

The recognition of new mineralogical associations of beryllium and niobium, as those earlier with uranium, led to the discovery of new deposits that could be developed to increase the Nation's reserves. The Division published a new estimate of the Nation's coal reserves and a revised coal map of the United States. Division personnel continued geologic studies of major urban areas, including Anchorage in Alaska, Council Bluffs in Iowa and Great Falls in Montana, to determine the sensitivity of their terrain for housing and industrial development, dam-site selection, and highway routes. Landslide and earthquake hazards evaluated in Los Angeles resulted in the closing of a major highway before it was covered by debris.

Cressman and Noger recorded that Kentucky's new Governor Bert T. Combs, inaugurated in January 1960, added his support and that of Lt. Governor Wilson Wyatt, responsible for economic development,[180] to efforts by State Geologist Wallace Hagan and Assistant State Geologist Preston McGrain to finalize the cooperative arrangement by which the USGS would geologically map the Bluegrass State. On September 2, 1960, more than a month after fieldwork began, the USGS and the KGS signed the agreement for the Kentucky Cooperative Mapping Program (KCMP). The USGS and Kentucky's Government agreed to share equally the estimated $12 million required to geologically map the Bluegrass State at 1:24,000.[181] USGS geologists, aided by stratigraphic paleontologists, would use as bases the Topographic Division's newly completed series of 707 same-scale topographic maps of quadrangles that covered the State's 40,400 square miles, and the USGS would publish the resulting geologic maps that were expected to provide additional and needed economic benefits to Kentucky.[182] The KGS also would provide data about drill cores, economic geology, and stratigraphy of the State's mostly Paleozoic rocks, but KGS geologists would not map with USGS field parties. The KCMP enabled Chief Geologist Anderson to arrange for the transfer of USGS personnel, who otherwise might have been let go, from work no longer funded by the AEC to Regional Geology's Kentucky Branch and its KCMP. Additional USGS geologists also formerly paid with AEC funds went to the Engineering Geology Branch, and others returning from assignments abroad were shifted to join the mappers in Kentucky. Alfred Zapp, who cooperated with a program coordinator from the KGS, established his Branch's headquarters in Lexington on July 1, 1960; the first group of his field geologists arrived later that month. The Branch opened its initial field office at Princeton in August; additional offices began at Bowling Green and Pikeville in October, and at Ashland, Columbia, Corbin, and Paducah in November. By the end of November, many of the 30 geologists already assigned to these KCMP field offices were mapping the initial 31 quadrangles selected for priority coverage. The initial four quadrangles—Haldeman and Wrigley (both northeast of Morehead), Ewing (northeast of Middleboro), and Austin (southeast of Bowling Green)—edited in Zapp's new Technical Reports Unit at Lexington were scheduled for publication as numbered GQs during calendar 1961. The Geologic Division planned to add an additional 25–30 geological mappers and supporting personnel to the KCMP in fiscal year 1961–62.

The NSF and the Navy prepared for operations in Antarctica during 1960–61 as the Senate ratified the Antarctic Treaty on August 10, 1960, and Eisenhower signed it on August 18. The treaty was proclaimed on June 23, 1961, and it went into effect on that day. The NSF established a new Office of Antarctic (later Polar) Programs on May 26 to coordinate all U.S. research activities on and around the continent. Meanwhile, on September 2, 1960, the International Council of Scientific Unions' Special Committee for Antarctic Research convened its fourth meeting, in Cambridge, England, where the Scott Polar Research Institute (founded in 1920) had served as a formal subunit of Cambridge University's Department of Geography since January 1957. The NSF provided nearly $5,461,000 for Antarctic research during fiscal year 1960–61.[183] During the austral summer, U.S. operations in Antarctica continued under the direction of Thomas Jones, David Tyree, and Edwin McDonald. The Navy sent nine ships, including icebreakers *Eastwind*, *Edisto*, *Glacier*, and *Staten Island*, to participate as TF 43 in Operation Deep Freeze 61.[184] The Scripps Institution of Oceanography deployed its research vessel *Argo* in the Ross Sea in February 1961. USGS geologist Avery Drake, Jr., and USGS topographer Joel H. Langhofer sailed in *Glacier* to the Bellingshausen Sea to work on map control and the geology of Thurston Island and parts of Ellsworth Land's coast. The Geologic Division's Richard H. Evans, in *Staten Island*, participated in oceanographic studies during the second year of the Navy's Bellingshausen Sea Expedition.[185]

On the continent, Albert Crary led a party in tracked vehicles on a traverse from McMurdo to the South Pole, which the team reached on February 1. USGS topographer Peter M. Bermel, who joined the USGS at Rolla in 1948, and USGS geologist Arthur Ford co-led a geologic-topographic party that included geologists John M. Aaron and Harold Hubbard, glaciologist Bjorn G. Andersen, of the University of Oslo, and assistant David H. Green on map-control and science surveys of the Thiel (formerly Eastern Horlick) Mountains, part of the Transantarctic Range, and the Hudson Mountains in western Ellsworth Land. Bermel and Ford named for each of the seven USGS Directors one feature in a series of knobs, mounts, peaks, and pillars in the eastern part of the Thiel Mountains. Geophysicist John Behrendt, returned from teaching at Wisconsin and now with the Geologic Division, worked on the West Antarctic Ice Sheet and in Marie Byrd Land, and in the Transantarctic Range, from the Amundsen-Scott, Byrd, Hallett, and McMurdo Stations. Thomas E. Taylor's mapping and glaciological studies covered parts of the Ross Ice Shelf and the Beardmore, Mulock, and Shackleton Glaciers. William R. MacDonald served as photography liaison for the Division's aerial mapping. H. Richard Blank, of Victoria University in Wellington, New Zealand, studied the geology of the Royal Society Range on the west side of McMurdo Sound. USGS topographer Joe M. Anderson completed a map-control traverse from the Byrd Station to the Jones Mountains, named for the NSF's Thomas Jones, on the Eights Coast of Ellsworth Land. Leslie B. Robison and George R. Staeffler, also with the Topographic Division, continued map-control surveys in the McMurdo area, and Staeffler conducted similar work in Victoria Land's Willett Range.[186] Assistant Chief Topographic Engineer William Radlinski also came to McMurdo to oversee the ongoing map-control surveys as part of his responsibilities with the Topographic Division's Future Planning Team, as the Division continued its preparations to map the continent.[187]

Director Nolan led the USGS delegation to the 21st International Geological Congress (Norden), held at Copenhagen during August 15–25, 1960.[188] Andy Anderson, Alan Bateman, Frederick Betz, Bill Bradley, George Cohee, William Davies, Charles Erdmann, James Gilluly, William Johnston, Philip King, Konrad Krauskopf, Benjamin Leonard, Kiguma Murata, Joe Peoples, Joseph Poland, John Rodgers, and William Rubey represented the USGS or other U.S. organizations as official delegates, but they did not present papers at the meeting. In the 21st IGC's formal sessions, USGS geologists who were not organizational delegates presented the results of their recent research. They included Glen Brown, William Carter, Preston Cloud, Henry Faul, Michael Fleischer, Warren Hamilton, David Hopkins, Lincoln Page, Troy Péwé, Edwin Roedder, Kenneth Segerstrom, Gene Shoemaker, and E-an Zen. USGS hydrologists William Back, Luna Leopold, Charles McGuinness, and Harold Thomas also discussed the results of their recent work. Representatives of the Geological Surveys of Norway and Sweden told Nolan at Copenhagen that geological organizations in the Soviet Union were providing free geochronological determinations of submitted rock samples. Nolan used this information to support his request in February 1961 for increased funding for the USGS' own work in geochronology, following a recommendation by the President's Science Advisory Committee to the Secretary of the Interior to enhance this effort by the agency.

While USGS scientists participated in the IGC in Copenhagen, members of the Topographic and Water Resources Divisions continued to seek improvements in their equipment and operations. They also reviewed their emphasis on and relations between applied and basic research. The Topographic Division began looking at the possibilities of developing techniques for remote sensing from satellites. The Division also planned to combine online computers, interfacing-analog stereoplotters, and new sensing devices in automated photogrammetry for digital storage and retrieval of orthophotographic data.[189] Automated scanning and correlation of these images would facilitate the preparation of contour maps, profiles, terrain models, and other new products. The American Society of Photogrammetry published its "Manual of Photographic Interpretation," which included a chapter on photogeology written by USGS geologists William Fischer and Wilds W. Olive and their colleagues. James Lawson retired as Rocky Mountain Region Engineer in August. The Water Resources Division's overall program devoted to basic research rose from 1 to nearly 10 percent between 1955 and 1960. If future funding allowed, Luna Leopold hoped to increase his Division's basic-research component to 25 percent. By this change, he intended to stimulate the intellects of, encourage original thought by, promote the exchange of ideas between, sponsor the advanced education of, and recognize significant original achievements by its scientists and engineers. The Division also encouraged universities to develop graduate programs in scientific hydrology and hired in 1960 the initial graduate of the new curriculum. Geologic mapping continued on four areas with immediate water-resources problems—the Delaware River Basin, the South Platte drainage along the mountain-front recharge area in Colorado, the Rio Grande Valley near Del Rio in Texas, and the Carrizo-Corduroy area in Arizona. High-resolution seismic equipment was used to locate water-bearing strata. In September 1960, George C. Taylor, Jr., succeeded Thomas Eakin as Chief of the Office of International Activities, and Tyrus B. Dover, who joined the USGS in 1947, became the District Hydrologist at St. Louis.

The increase of $200,000 in the appropriation for mineral classification during fiscal year 1960–61 enabled the Conservation Division to begin an active classification of the approximately 50 million acres outside Alaska withdrawn for classification since 1900 that remained unclassified and the examination of another 18 million acres for their mineral-resource potential. The Division expected to classify some 750,000 acres during 1960–61. To support these classification activities aimed at aiding the reasoned conservation and development of the Nation's coal, gas, oil, oil shale, phosphate, potash, sodium, and other mineral-commodity resources, the USGS planned the long-range geologic mapping of about 68 million acres (16,400 square miles) on 3,500 multipurpose 1:24,000 quadrangles, mostly in the Western States and at a cost of about $74.7 million. On May 31, 1960, two Supreme Court decisions, *U.S.* v. *Louisiana et al.*[190] (Alabama, Mississippi, and Texas) and *U.S.* v. *Florida et al.*,[191] extended only the boundaries of Texas and Florida 3 leagues (9 statute miles) from the shoreline into the Gulf of Mexico according to their historic limits. On September 2, a new law amended the Mineral Leasing Act of 1920 to include oil and tar sands.[192] Up to 7,680 acres, for one person or corporation per State, could be leased for 5–10 years; the statute set the annual minimum rental at 25 cents to 50 cents per acre in areas lacking known deposits. Combined oil and gas lease options were limited to not more than 246,080 acres per person per State, except in Alaska. Alaska's previous limit was extended to 300,000 acres in both north and south halves of the State. To encourage prospecting, the new law raised the area limits on coal to 15,360 acres, on sodium to 15,360 acres, and phosphate to 10,240 acres. Twelve days later, two additional acts provided increased authority. One clarified the rights of States "to select certain public lands subject to any outstanding mineral lease or permit."[193] The other granted "mineral rights in certain homesteads in the State of Alaska."[194] Of the 7 million acres of public land still withdrawn for water-power or water-storage sites, the Division estimated that up to 2 million might have limited value for such uses and could, after review, be restored to entry for other purposes.

On January 3, 1961, as the 87th Congress convened and President Eisenhower prepared to leave office, an accident at the Federal nuclear plant at Idaho Falls killed three employees and reminded the Nation that it faced dangers from the nuclear industries other than weapons. Eisenhower, during his years as General and President, helped to end two major wars but started none, although he approved increased U.S. assistance and (or) deployment to several ongoing or potential conflicts, including those in Cuba, Guatemala, Iran, Laos, Lebanon, and South Vietnam. Peace came at the price of continued vigilance and the expenditure of natural as well as human resources and vast amounts of capital. In the 1950s, under the pressure of wars hot and cold, U.S. defense spending tripled, from $13 billion to $39 billion, and Eisenhower now projected an additional increase in fiscal year 1961–62 but one that would still leave an estimated surplus of $1.5 billion to be applied to the national debt.[195] In the 8 years between fiscal years 1952–53 and 1960–61, the NSF's appropriations grew from $4.75 million to $175.8 million.[196] During the same interval, the NSF's grants to support science (basic research and facilities, institutional grants, national research centers and programs, and disseminating scientific information) increased from $1.8 million to $102.8 million, and its support for scientific education, in the form of graduate fellowships, institutes, science education, and public understanding, rose from $1.4 million to $66.8 million. Meanwhile, Eisenhower also recalled, completion of the interstate-defense highway system reached 25 percent.

Domestic dangers, like those from abroad, continued to trouble Eisenhower. As "we can no longer risk emergency improvisation of national defense," he emphasized in his farewell address to the American people via radio and television on January 17, "we have been compelled to create a permanent armaments industry of vast proportions" that, including the funds for the 3.5 million men and women directly engaged in defending the Nation, increased these Federal expenditures beyond the level of all U.S. corporate profits. "We recognize the imperative need for this development," the President continued, "[y]et we must not fail to comprehend its grave implications." "In the councils of government," he warned, "we must guard against the acquisition of unwarranted influence, whether sought or unsought, by the military-industrial complex" in the power triangle it formed with Congress. "The potential for the disastrous rise of misplaced power exists and will persist."[197] "Yet," Eisenhower urged,

> **in holding scientific research and discovery in respect, as we should, we must also be alert to the equal and opposite danger that public policy could itself become the captive of a scientific-technological elite.[198]**

Future leaders, Eisenhower concluded in these farewell remarks, must "mold," "balance," and "integrate these and other forces, new and old, within the principles of our democratic system—ever aiming toward the supreme goals of our free society."[199]