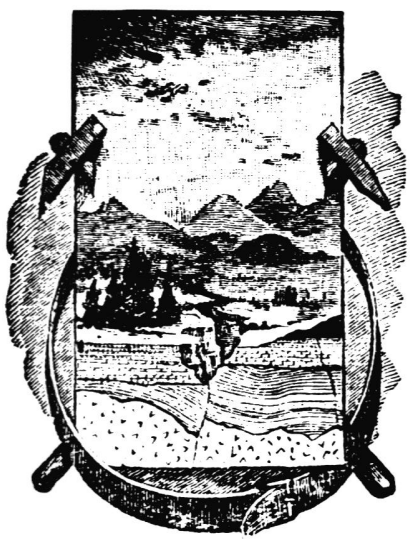
The United States Geological Survey:

1879-1989



U.S. GEOLOGICAL SURVEY CIRCULAR 1050

Front cover. The logos are taken from early and present-day annual reports

Inside front cover. The national domain in 1879

The United States Geological Survey: 1879 - 1989

By Mary C. Rabbitt

A history of the relation of geology during the first 110 years of the U.S. Geological Survey to the development of public-land, Federal-science, and mapping policies and the development of mineral resources in the United States

U.S. GEOLOGICAL SURVEY CIRCULAR 1050

DEPARTMENT OF THE INTERIOR

MANUEL LUJAN, Jr., Secretary

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, Director

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The United States Geological Survey: 1879-1989

By Mary C. Rabbitt

INTRODUCTION

The United States Geological Survey was established on March 3, 1879, just a few hours before the mandatory close of the final session of the 45th Congress, when President Rutherford B. Hayes signed the bill appropriating money for sundry civil expenses of the Federal Government for the fiscal year beginning July 1, 1879. The sundry civil expenses bill included a brief section establishing a new agency, the United States Geological Survey, placing it in the Department of the Interior, and charging it with a unique combination of responsibilities: "classification of the public lands, and examination of the geological structure, mineral resources, and products of the national domain."[1] The legislation stemmed from a report of the National Academy of Sciences, which in June 1878 had been asked by Congress to provide a plan for surveying the Territories of the United States that would secure the best possible results at the least possible cost. Its roots, however, went far back into the Nation's history.

The first duty enjoined upon the Geological Survey by the Congress, the classification of the public lands, originated in the Land Ordinance of 1785. The original public lands were the lands west of the Allegheny Mountains claimed by some of the colonies, which became a source of contention in writing the Articles of Confederation until 1781 when the States agreed to cede their western lands to Congress. The extent of the public lands was enormously increased by the Louisiana Purchase in 1803 and later territorial acquisitions.

At the beginning of Confederation, the decision was made not to hold the public lands as a capital asset, but to dispose of them for revenue and to encourage settlement. The Land Ordinance of 1785 provided the method of surveying and a plan for disposal of the lands, but also reserved "one-third part of all gold, silver, lead, and copper mines to be sold or otherwise disposed of, as Congress shall thereafter direct,"[2] thus implicitly requiring classification of the lands into mineral and nonmineral. Mapping of the public lands was begun under the direction of the Surveyor-General, but no special provision was made for classification of the public lands, and it thus became the responsibility of the surveyor. There was,of course, no thought in 1785 or for many years thereafter of employing geologists to make the classification of the mineral lands, for geology was then only in its infancy.

By 1879, eight classes of public lands had been recognized, each of which had separate regulations for disposition, but, except in a few cases, no special provision had been made to secure an accurate classification in advance of disposition. Of the mineral lands listed in the 1785 Ordinance, lead lands had been leased for a time and later sold, and copper lands had been sold, but no regulations were made about the lands bearing precious metals until 1866 when they were declared free and open to exploration and purchase. Iron lands, not mentioned in the 1785 Ordinance, were ruled "not mineral lands,"[3] and coal lands, also not mentioned, were offered for sale in 1863. The surveyors were still responsible for classification of the public lands, but, in actual practice, did not make the classification themselves but relied on affidavits from the interested parties.

Neither the public lands nor scientific investigations of any kind were mentioned in the Constitution of the United States, which superseded the Articles of Confederation in 1788. Scientific investigations and the construction of public works were both considered the prerogative or responsibility of the States or private institutions rather than the Federal Government. Of necessity, the Federal viewpoint changed in later years, but even so, the two were frequently treated alike.

Although the military engaged in some scientific activities, Congress did not authorize civilian scientific activities in the Federal Government until 1807 when it established the Coast Survey for the practical purpose of providing better charts of coastal waters and navigational aids for commercial interests. The Coast Survey, however, was unable to get underway until after the end of the War of 1812 and then had only a brief independent life before being transferred to the jurisdiction of the Navy.

In 1810, only 3 years after the Coast Survey was established and long before it got underway, Benjamin Silliman, Professor of Chemistry, Mineralogy, and Natural History at Yale, proposed to the Connecticut Academy of

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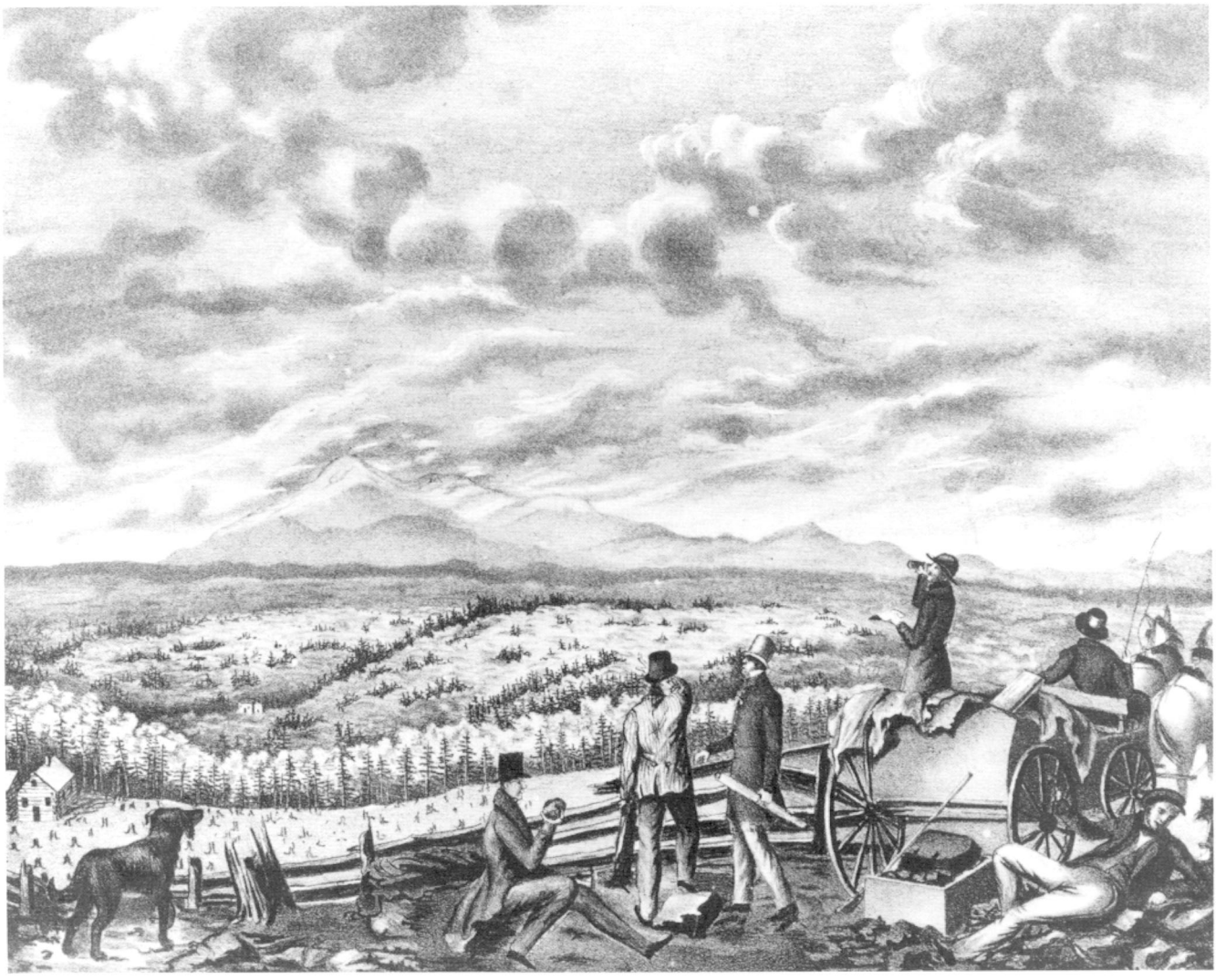

Figure 1. Gentlemen engaged in geological pursuits, 1836.

Sciences that a geological survey be undertaken of part of the national domain, the State of Connecticut. The academy approved the idea but had no funds to carry it out, and another decade passed before a publicly supported geological survey was made.

GEOLOGICAL SURVEYS BEFORE THE CIVIL WAR

The earliest geological surveys were made in support of agriculture, which was the basic occupation in the United States in the early 1800's. Manufacturing was then of importance only in a few areas, and mining was a quite insignificant part of the economy. Farmland in the Eastern and Southern States, however, was beginning to lose its fertility, and farmers were abandoning their holdings and moving westward. The westward migration increased to enormous proportions after the War of 1812. In the summer of 1820, Stephen Van Rensselaer, president of the Agricultural Society of New York, using funds appropriated by the State Legislature, employed Amos Eaton, who had studied under Silliman at Yale, to make a geological survey of Albany County to aid in the improvement of agriculture. In the following year, Eaton made a geological and agricultural survey of the neighboring Rensselaer County. After two surveys in aid of agriculture, Eaton proposed and obtained approval to make a survey of the district adjoining the Erie Canal, one of a vast number of internal improvements that had been begun to link eastern markets and the newly settled regions beyond the Allegheny Mountains. A year earlier, Denison Olmsted, Professor of Chemistry, Mineralogy, and Geology at the University of North Carolina, also a former student of Professor Silliman, had approached the North Carolina State Board of Internal Improvements with the idea of making a geological and

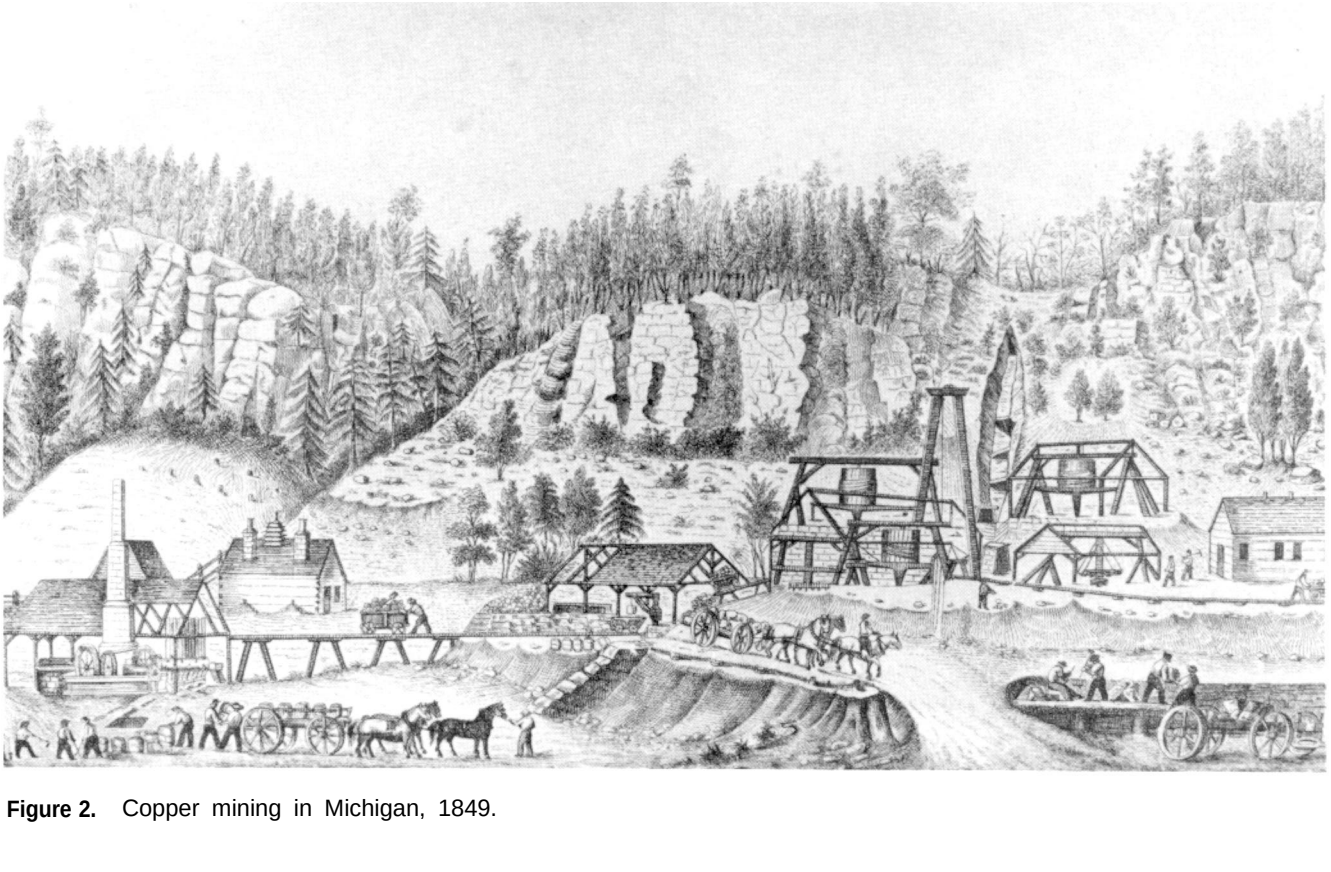

Figure 2. Copper mining in Michigan, 1849.

mineralogical survey of the State, but the General Assembly in North Carolina, to which the Board had referred Olmsted's request, had instead authorized the Board of Agriculture to make such a survey in 1823.

In 1824, as the number and scope of internal improvements increased, Federal policy was changed as a matter of practical necessity. Congress authorized the Army Engineers to make engineering surveys to prepare estimates for roads and canals for national military, commercial, or postal purposes. Science in general, and geology in particular, however, remained almost exclusively the province of the States or private individuals for another decade.

Olmsted's first report, published in 1824, provided the inspiration for establishment of geological surveys on another basis. Olmsted devoted several pages of his report to the gold mines of North Carolina and in 1825 published a paper on the gold deposits in Silliman's *American Journal of Science and Arts*. Gold-bearing rock in place was discovered in North Carolina that very year and later in Virginia, South Carolina, and Georgia as well. The more practical-minded geologists seized upon the gold discoveries in the Southeastern States as a better means of promoting the establishment of geological surveys than either the improvement of agriculture or the need for internal improvements. During the early 1830's, several of the Eastern and Central States established State surveys "to examine the geological structure, mineral resources, and products"[4] of their part of the national domain.

In 1834, just a year before the Geological Survey of Great Britain was established, Congress authorized the first Federal examination of the geological structure, mineral resources, and products of the public lands by permitting the Topographical Bureau of the U.S. Army to use $5,000 of its appropriation for geological investigations and the construction of a geological map of the United States. The head of the Bureau, Colonel J.J. Abert, had based his request for funds on the importance of mineral resources, stating that "few subjects connected with the duties of this bureau open so many and so important national advantages, or are adapted to redound more to internal commercial prosperity" as the "development of these great resources of wealth and commercial intercourse, which now lie inert and buried in the bowels of the earth"[5] The geologist employed, however, proved a little too impractical for the Engineers and the survey was discontinued after 2 years.

In 1839, the Federal Government for the first time called on a geologist to classify public lands as Congress made plans to authorize the sale of the mineral lands in the Upper Mississippi Valley. David Dale Owen organized a force that made a survey of 11,000 square miles in a little more than 2 months, which led the Commissioner of the General Land Office to propose that "an officer skilled in the sciences of geology and mineralogy"[6] be appointed to

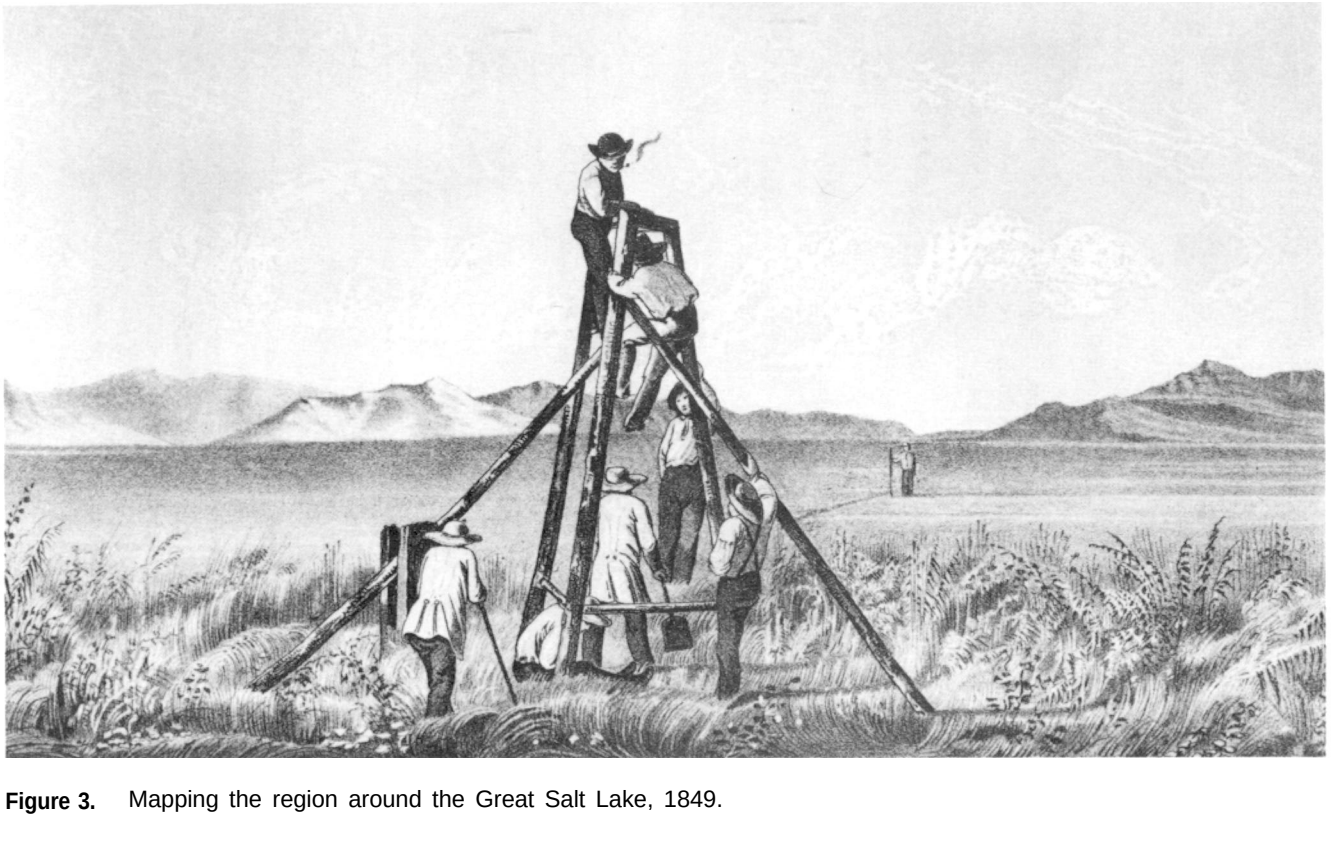

Figure 3. Mapping the region around the Great Salt Lake, 1849.

explore all the public lands and thus enable the Commissioner to discriminate between agricultural and mineral lands before putting them on the market. That idea came to nought, but in 1847, when Congress authorized the sale of mineral lands in the Lake Superior Land District in Michigan and the Chippewa Land District in the Territory of Wisconsin, it specified that geological examinations be made prior to the sale.

The change in the Federal attitude toward geology was part of a change in the Federal view of science in general. The Federal Government was not yet ready to accept science for its own sake but there was a growing realization that certain economic purposes could be aided by science, or, from the perspective of the first Commissioner of Patents in 1836, that the scientific activities of the Government should serve the great economic interests of the country. This same attitude was evident when Congress in 1836 authorized the United States Exploring Expedition, which had the backing of some of the country's most influential scientists, as an aid to commerce. Perhaps of even greater importance for the future of Federal geology was the establishment in 1838 of the Corps of Topographical Engineers to explore and map the continent. Americans were already beginning to feel it was their manifest destiny to overspread and possess the whole continent, and the Topographical Engineers for more than 2 decades provided geologists with opportunities to study the West.

America's manifest destiny was also to become a great industrial nation but that was not so apparent in the 1840's. Coal and iron were the basic elements of industrial development, but toward the end of that decade iron production had begun to decline and the mineral industry, except for coal, began to experience difficulties. The discovery of gold in California on January 24, 1848, altered the situation. In December 1848, President James Polk asked Congress to provide for a geological and mineralogical examination of the region where gold had been discovered and to take steps to preserve the mineral lands, especially those containing the precious metals, for the United States, or to dispose of them in such a manner as to secure a large return of money to the Treasury. The lameduck Congress took no action on these recommendations but in the closing days of the session established a new executive department, the Interior Department, which would include the General Land Office, the Pension Office, the Office of Indian Affairs, and the Census.

The discovery of gold gave great impetus to mining endeavors throughout the country, and this increased activity, combined with the prosperity after the Mexican War, interested several States in the South and the Midwest in establishing State geological surveys. It also made the development of better means of communication and transportation between the Eastern States and the western territories more urgent. In 1853, Congress appropriated $150,000 for surveys to ascertain the most practical and

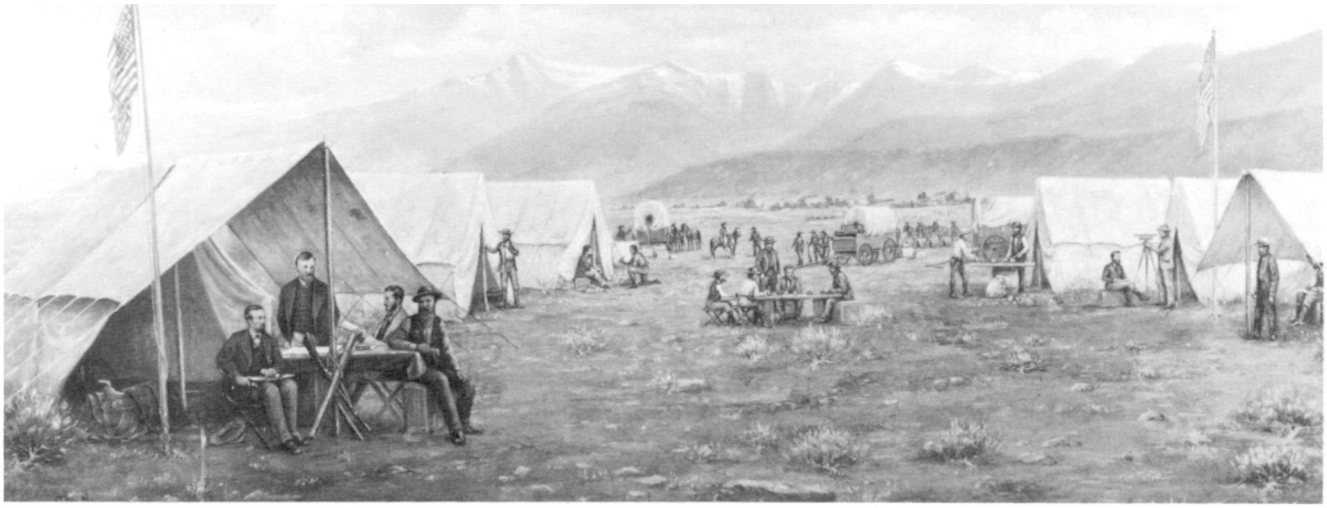

Figure 4. The Geological Exploration of the Fortieth Parallel (King survey), ca. 1869.

economical route for a railroad from the Mississippi River to the Pacific Ocean and authorized the Secretary of War to employ the Corps of Topographical Engineers to make the explorations and surveys. The Congress also took action on the mineral lands in California, excluding them from the General Land Office surveys, forbidding their preemption or selection by the State, and prohibiting settlement or location on them.

During the 1850's. while the Topographical Engineers explored four routes for the transcontinental railroad, the industrialization of the Nation quickened. In 1859, for the first time, the value of the products of U.S. industry exceeded the value of agricultural products. In that same year, gold was discovered in Colorado, silver was discovered at the Comstock lode in western Nevada to begin the era of silver mining in the West, and the first oil well in the United States was successfully drilled in northwestern Pennsylvania. By that time, the relationship between geological surveys and mineral resources was sufficiently clear that when gold mining in California became difficult and costly, the State Legislature established a Geological Survey, on April 21, 1860, to make an accurate and complete geological survey of the State.

The Civil War had a pronounced effect on science and on the industrial development. of the United States. It brought to an end the second era of State surveys--only the California Geological Survey survived. It checked or halted the western mining frontier in some areas but allowed continued expansion in others. The usefulness of science for economic purposes was recognized on May 15, 1862, when the 37th Congress established the Department of Agriculture "to acquire and diffuse * * * useful information on subjects connected with agriculture" and for the first time authorized "practical and scientific experiments"[7] to obtain this information. The industrialization advanced significantly during the war. At the start of the war, American iron fabrication was inferior to that of Europe, but A.S. Hewitt of Cooper Hewitt iron manufacturers went to England in 1862 and learned the secret of the British process so well that in 1863 the Secretary of War boasted that American iron was superior to that obtained abroad. Alexander Holley, an American metallurgist, also visited England in 1862 and obtained the American rights to the Bessemer process for making steel; in 1865, he began to produce steel by that process in the United States.

THE FOUR GREAT SURVEYS OF THE WEST

By 1867, the developing industries were making radical demands on the Nation’s natural resources. Joseph S. Wilson, the Commissioner of the General Land Office, in his annual report written in the fall of 1866, assessed at some length the mineral resources of the public domain, and afterward stated that the proper development of the geological characteristics and mineral wealth of the country was a matter of the highest concern to the American people. On March 2, 1867, Congress for the first time authorized western explorations in which geology would be the principal objective: a study of the geology and natural resources along the fortieth parallel route of the transcontinental

Figure 5. Clarence King exploring an active glacier on Mount Shasta, 1870.

railroad, under the Corps of Engineers. and a geological survey of the natural resources of the new State of Nebraska, under the direction of the General Land Office. Looking back at that day's work in 1880, Clarence King. Director of the U.S. Geological Survey, remarked that "Eighteen sixty-seven marks, in the history of national geological work, a turning point, when the science ceased to be dragged in the dust of rapid exploration and took a commanding position in the professional work of the country."[8]

King was only 25 and 5 years out of Yale, where he had been a member of the first class to graduate from the Sheffield Scientific School, when he was appointed Geologist in charge of the Geological Exploration of the Fortieth Parallel. He had been a member of the Geological Survey of California when he conceived the idea of a geological survey along the route of the railroad then being built, had then interested the Engineers in the plan and secured their endorsement and that of the War Department, exhibiting political as well as scientific acumen. The Chief of Engineers told King he could expect to receive $100,000 to finance the work for 3 years and was authorized to engage two assistant geologists. three topographic aides. two collectors, a photographer, and necessary camp men. King chose as assistants well-trained young men, the geologists with graduate education in Europe, and planned the work in detail before taking the field.

Ferdinand V. Hayden, M.D., who had already established a reputation as a master of reconnaissance in the Upper Missouri country, was placed in charge of the survey of Nebraska. for which only $5,000 was available. Hayden, 38, was a graduate of Oberlin College in Ohio and Albany Medical College. Except during the Civil War years, Hayden had been enthusiastically exploring the northern Great Plains region since 1853 when James Hall, the New York State Geologist, had sent him and Fielding B. Meek west to study the geology and collect fossils. In 1856 and 1857, Hayden had accompanied expeditions led by Lieutenant G.K. Warren and in 1859, the expedition led by Captain W.F. Raynolds, both of the Topographical Engineers.

Both the King and the Hayden surveys were successful. In 1870, the King survey, without solicitation, received additional funds for another 3 years in the field. The Hayden survey received additional appropriations in 1868 and 1869 for exploration in Wyoming and Colorado, and in

Figure 6. The Hayden survey in the Yellowstone area, 1871.

1869 was placed directly under the Secretary of the Interior. In 1870, Hayden presented to Congress a plan for the geological and geographical exploration of the Territories of the United States that looked forward to the gradual preparation of a series of geographical and geological maps of each of the territories on a uniform scale. With Congressional blessing the Hayden survey then became the Geological and Geographical Survey of the Territories under the Department of the Interior.

By that time two additional surveys had taken the field. On May 24, 1869, John Wesley Powell, Professor of Geology at Illinois State Normal University, and a party of nine men left Green River, Wyoming, in three small boats to explore the unknown canyonlands to the south and west. Powell's expedition was privately sponsored--its only public support an authorization to draw Army rations--and the members of the expedition were a mixed crew of nonprofessionals.

Powell, 35, was the son of an itinerant Methodist preacher. His formal schooling had ceased when he was 12, and his life thereafter had been spent in farming, studying, teaching, and exploring the Midwest until the outbreak of the Civil War. He enlisted in the Union Army in May 1861 and remained in the service until the war was over. After the war, Powell became professor of geology at Illinois Wesleyan University and then at Illinois State Normal University. In 1867 and 1868, he explored the Rocky Mountains in Colorado and eastern Utah and became convinced that the unknown canyonlands to the southwest could best be explored in boats. In a trip fraught with hardships, Powell and five of the nine original members of the crew completed a journey down the Green River to the Colorado and through the Grand Canyon on August 13, 1869. In 1870, Professor Powell received an appropriation of $10,000 from Congress to make a second trip down the Colorado, being required only to report his results to the Smithsonian Institution. On June 10, 1872, Congress appropriated another $20,000 for completion of the survey.

The second new exploration in 1869 was led by Lieutenant George Wheeler, Engineer Officer on the staff of the Commanding General of the Army's Department of California (which covered California, Nevada, and Arizona). Wheeler, not quite 27, was a graduate of West Point in 1866 where he had ranked sixth in his class and won a commission in the elite Corps of Engineers. By 1869, exploration of the Colorado River and location of north-south routes across the Great Basin had become the most important projects of the Division of the Pacific, but when the Army learned of Powell's planned expedition, exploration of the Colorado was postponed.

In early June 1869, Lieutenant Wheeler received orders to organize and equip a party to make a thorough and careful reconnaissance of the country south and east of White Pine, Nevada, as far as the head of navigation on the Colorado, to obtain data for a military map and to survey the possibility of a wagon road and select sites for military posts. In 1871, the Engineers sent Lt. Wheeler to explore and map the area south of the Central Pacific Railroad in eastern Nevada and Arizona.

Figure 7. The Powell survey on its second trip down the Colorado River, 1871.

On his return from the 1871 expedition, Wheeler, convinced that the day of the pathfinder had ended, proposed a plan for mapping the United States west of the 100th meridian on a scale of 8 miles to the inch, expected to cost $2.5 million and take 15 years. Congress authorized the program on June 10, 1872, the day on which funds were appropriated for completion of the Powell survey. Hayden that year was given $75,000 for his Geological and Geographical Survey of the Territories.

Inevitably, conflicts developed between the Hayden survey, mapping the Territories of the United States, and the Wheeler survey, mapping the areas west of the 100th meridian. In 1874, Congress was provoked to a thorough discussion of civilian versus military control of mapping. In the testimony heard by the Congressional committee, much of it on the purposes and efficiency of the mapping, Powell credited King's Fortieth Parallel survey with the most advanced techniques, which Hayden and he had later adopted. In the end Congress concluded that each survey had been doing excellent work for the benefit of the people and that there was sufficient work for both the Interior Department and the War Department for years to come. The Secretary of the Smithsonian Institution had requested an additional appropriation for the Powell survey, which Congress granted but transferred the survey to the Department of the Interior, where it was at first called the second division of the Geological and Geographical Survey of the Territories. Later, because of tension between Powell and Hayden, the Powell survey became known as the Geographical and Geological Survey of the Rocky Mountain Region.

ESTABLISHMENT OF THE U.S. GEOLOGICAL SURVEY

Deterioration of the economy led to another consideration of the problem of mapping the West in 1878. The King survey had by this time completed its reports, but the Hayden, Powell, and Wheeler surveys were still in the field. This time Congress turned to the National Academy of Sciences and asked it to recommend a plan for surveying and mapping the Territories of the United States that would secure the best possible results at the least possible cost. A committee of seven members appointed by the Academy recommended that the Coast and Geodetic Survey be transferred from the Department of the Treasury to the Department of the Interior, renamed the "Coast and Interior Survey," and be given responsibility for geodetic, topographic, and land-parceling surveys in addition to its existing work. The Academy committee also recommended that an independent organization, to be called the U.S. Geological Survey, be established in the Interior Department to study the geological structure and economic resources of the public domain.

Legislation to rename the Coast and Geodetic Survey and transfer it to the Department of the Interior and to establish the U.S. Geological Survey for "classification of the public lands, and examination of the geological structure, mineral resources, and products of the national domain"[9] was included in the bill appropriating funds for the legislative, executive, and judicial expenses of the Federal Government for the fiscal year beginning July 1,

18

Amendment numbered 90, 91, 92 & 93,

That the House recede from its disagreement to the amendments of the Senate numbered 90 - 91 - 92 - and 93,

and agree to the same with amendments, as follows

In lieu of the matter proposed insert the following:

For the salary of the Director of the Geological Survey, which office is hereby established, under the Interior Department, who shall be appointed by the President by and with the advice and consent of the Senate, six thousand dollars: *Provided*, That this officer shall have the direction of the Geological Survey, and the classification of the public lands and examination of the geological structure, mineral resources, and products of the national domain, and that the Director and members of the Geological Survey shall have no personal or private interests in the lands or mineral wealth of the region under survey, and shall execute no surveys or examinations for private parties or corporations; and the Geological and Geographical Survey of the Territories, and the Geographical and Geological Survey of the Rocky Mountain Region, under the Department of the Interior, and the Geographical Surveys West of the One hundredth Meridian, under the War Department, are hereby discontinued, to take effect on the thirtieth

Figure 8. The Conference Committee copy of the law establishing the U.S. Geological Survey, 1879.

1879. An appropriation for the expenses of the new national geological survey was included in the sundry civil expenses bill.

The transfer of the land-parceling surveys to a Coast and Interior Survey aroused strong opposition among Congressmen from Western States, and the bill was amended to exclude the public-land surveys from the work of the Coast and Interior Survey. There were few objections to the Geological Survey, and Congressman A.S. Hewitt of New York, who had initiated the Academy study, spoke most eloquently about the value of the study of mineral resources to the future development and prosperity of the Nation. The bill was then passed and sent to the Senate.

The Senate took up the sundry civil expenses bill first, and amended the item for the expenses of the geological survey so that it became $100,000 for the Geological and Geographical Survey of the Territories, in other words, the Hayden survey. The bill then went to a conference committee to iron out the differences between the two houses. The Senate voted to delete the entire section on the reorganization of the surveys from the legislative, executive, and judicial expenses bill, making the Senate action a clear triumph for Hayden, and sent it to conference.

The Democratic House and Republican Senate were far apart on some items in the bill, unrelated to the Survey legislation, and it became evident that agreement could not be reached before adjournment. The Senate and House conferees on the sundry civil bill, among them Hewitt, then agreed to combine into one item the sections in the House version of the legislative bill establishing the geological survey and the House version of the appropriation for the expenses of the U.S. Geological Survey. Thus the U.S. Geological Survey was established, by a last-minute amendment, to classify the public lands--94 years after the Land Ordinance of 1785 first directed their surveying and classification--and to examine the geological structure, mineral resources, and products of the national domain. The legislation also provided that the Hayden, Powell, and Wheeler surveys be discontinued as of June 30, 1879. Congress also established a public lands commission, of which the Director of the U. S. Geological Survey would be a member, to prepare a codification of laws relating to the survey and disposition of the public domain, a system and standard of classification of public lands, a system of land-parceling surveys adapted to the economic use of the several classes of lands, and recommendations for disposal of the public lands in the western portion of the United States to actual settlers.

ORGANIZING THE U.S. GEOLOGICAL SURVEY

Hayden, who had been directing geological surveys in the Department of the Interior for a dozen years, was the obvious candidate to be director of the new national survey, but a small group that considered Clarence King better qualified undertook to secure the appointment for him. On March 20, 1879, President Hayes sent to the Senate the nomination of Clarence King to be the first Director of the U.S. Geological Survey. The Senate confirmed the nomination on April 3, and King took the oath of office on May 24. The Fortieth Parallel Exploration under King's direction had led the way in converting western exploration to an exact science. His new position gave him a unique opportunity to influence the development of Federal geology.

The first duty enjoined on the Geological Survey was the "classification of the public lands."[10] In the year that the Geological Survey was established, the Federal Government still held title to more than 1.2 billion acres of land, nearly all of it west of the Mississippi River, of which only 200 million had been surveyed. The edge of settlement was at about 102° West; beyond the frontier were only isolated pockets or belts of settlement, and in vast areas beyond the frontier, the population was officially less than 1 per square mile.

Nearly all the public lands were within the arid region as defined by John Wesley Powell in his 1878 "Report on the Lands of the Arid Region of the United States." Water was the region's most precious resource, but Powell had pointed out that very little of the remaining public land was suitable for conventional farming and that only a small

Figure 9. Clarence King, Director of the U.S. Geological Survey, 1879-1881.

fraction of the arid land was irrigable. He then proposed radical changes in the land system, including organization of irrigation and pasturage districts, which suggested that water was more of a sociopolitical than a scientific problem.

Many of the isolated small pockets or belts west of the frontier owed their initial and some their continued existence to miners or prospectors, but the larger and more profitable mining industry was in the States east of the 100th meridian--Pennsylvania was the leading mining State in the Nation. Just eight commodities--gold, silver, iron, coal, copper, lead, zinc, and petroleum--accounted for nearly 99 percent of the value of the mineral production in the United States; the greater part of the precious metals and lead came from the area west of the 100th meridian, but the rest came from the States east of that line.

The very brief enabling legislation did not define in detail the duties of the new organization, thus leaving much to the Director's judgment. King concluded that the Geological Survey's classification of the public lands, especially as Congress had made no change in the General Land Office, was not meant to supersede the classification made by the Land Office as a basis for granting title, and the Public Lands Commission agreed. To meet the requirement for classification, King therefore planned a series of land maps to provide information for agriculturists, miners, engineers, timbermen, and political economists.

The duty of examining the geologic structure, mineral resources, and products of the national domain offered many possibilities. The year in which the Survey was established, however, was one of great monetary uncertainty, when knowledge of precious-metal resources was vital, and one in which the iron and steel industry faced problems in obtaining suitable raw materials, while information about the Nation's mineral wealth, mining and metallurgical techniques, and production statistics was meager. For the Survey's initial program of work, therefore, King chose to emphasize mining geology, to devote but a small effort to general geology, and to confine paleontology and topographic mapping to what was necessary to support the geologic studies. Although King in so doing emphasized practical studies at the expense of basic studies, he nonetheless expected that the facts gathered in the mining-geology studies would lead to advances in basic science.

The term "national domain" in the organic act provided a problem. The framers of the law had used the term to mean all lands within the national boundaries without having to name all the States and Territories, but an Interior Department attorney ruled that it meant the lands to which the Government had not parted title, that is, the public lands. The literal interpretation of that ruling would preclude work in a mining district where most of the land had become private property. King asked Congress to clarify the meaning, and the House promptly extended the field of the Geological Survey to the entire Nation but Congress adjourned before the Senate acted. For the first year, therefore, King decided to confine operations to the public-land regions though not to the public lands.

THE FIRST QUARTER-CENTURY

King, in consultation with Secretary of the Interior Carl Schurz, established the qualifications for appointment to the new Survey and the salaries. Applicants for appointment to the Division of Mining Geology were expected to have a good working knowledge of mathematics, mechanics, mining geology, chemistry, metallurgy, and the mineralogy of economic products, evidence of which could be furnished by university degrees, the testimony of experts in the required branches, or a written examination. For appointment to the Division of General Geology, applicants were expected to furnish equivalent evidence of a working knowledge of mathematics, physics, chemistry, geology, and mineralogy. In July 1879, S.F. Emmons and Arnold Hague of the King survey, G.K. Gilbert of the Wheeler and later the Powell survey, F.V. Hayden, and Raphael Pumpelly, who had been Sturgis-Hooper Professor of Geology at Harvard and State Geologist of Michigan and Missouri, were appointed geologists at $4,000 a year. George F. Becker, instructor in mining and metallurgy at the University of California, was appointed a geologist at $2,500 a year. Appointed as topographers were A.D. Wilson and F.A. Clark of the King survey, and Sumner Bodfish and John H. Renshawe of the Powell survey. Pumpelly headed the Mining Geology Division, and John Wesley Powell served informally as head of the General Geology Division but drew his salary from the Bureau of Ethnology of the Smithsonian Institution.

The mining geology program began in 1879 with comprehensive studies of the geology and technology of three great mining districts--Leadville in Colorado and the Comstock and Eureka in Nevada--and the collection of mineral statistics in the Western States. In addition, through a cooperative arrangement with the Tenth Census, mineral statistics were collected in the Eastern States, iron resources in all parts of the country were systematically studied in the field and in the laboratory by a variety of techniques, including microscopic analysis, chemical analysis, and magnetic observations, and an effort was made to trace the continuation of the copper-bearing rocks of Michigan and Wisconsin through northeast Minnesota to the Canadian boundary. The investigations in general geology included the unfinished studies of the earlier surveys in the Colorado Plateau region, on the Quaternary history of valleys in Utah, and on the geology of the Rocky Mountain region north of New Mexico and west of the 94th meridian.

In his first annual report, King promised 12 volumes on "practical and general geology and paleontology."[11] Some were published as part of the Tenth Census reports,

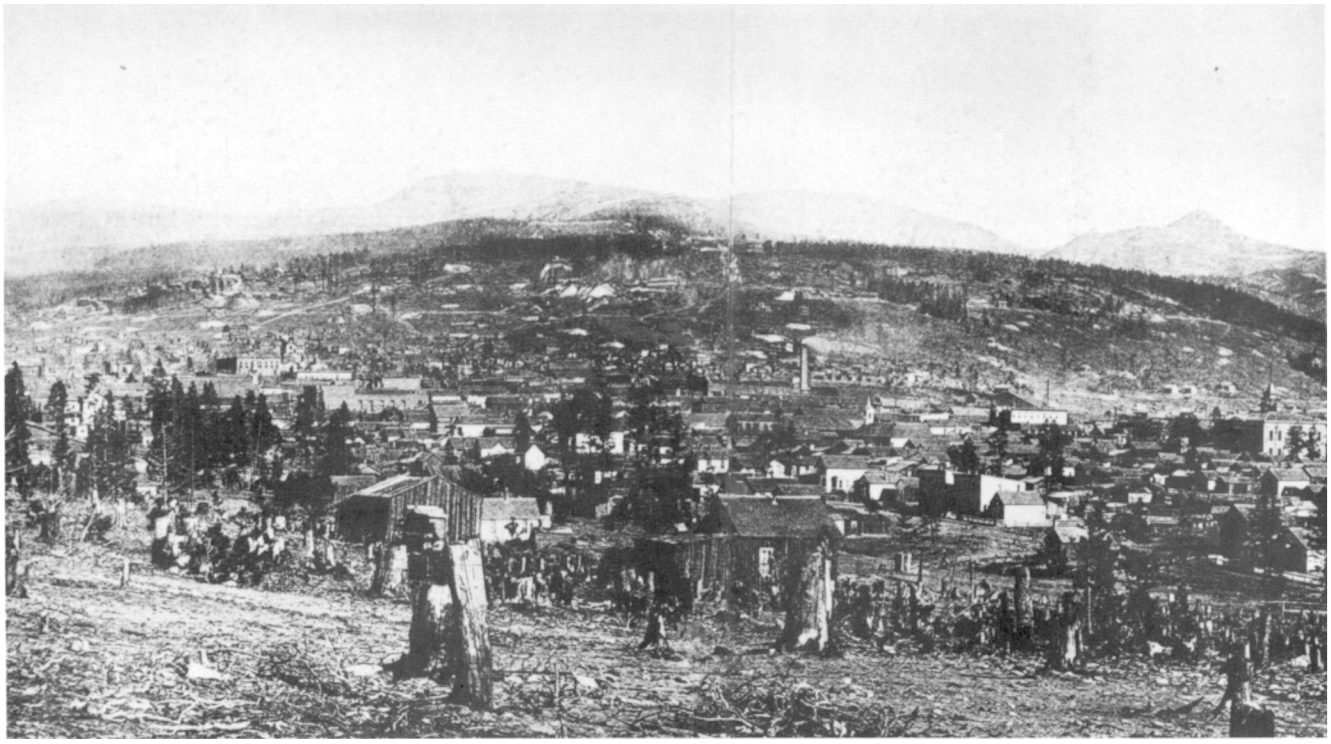

Figure 10. Leadville, Colorado, mining district, subject of an early mining-geology study, 1879

including the mineral statistics that provided the first comprehensive study of the Nation's mineral resources, others as monographs of the U. S. Geological Survey.

King resigned as Director in March 1881. He had not planned to stay beyond the time necessary to organize the work, and when James Garfield became President King realized that he would no longer have the support of his good friend, Secretary of the Interior Carl Schurz, whose views on political reform, including a merit-based civil service system, he shared. Despite his short tenure, King had such a profound influence on the organization and mode of operation of the Survey that decades later his imprint was still clearly evident and can be recognized even to this day.

King's choice to succeed him was John Wesley Powell, who was almost King's antithesis in background, education, and experience. Both men had wide-ranging scientific interests but King's centered on mathematics and geophysics, and Powell's tended toward natural history and anthropology. In geology, which Powell considered part of geography, he was primarily concerned with landforms and land use.

King and Powell also differed greatly in their philosophies of administration, which King apparently did not realize when he resigned. King had given the work of the Geological Survey a mission orientation, planned the goals, and selected the staff, but given them freedom to choose their methods of work in order to achieve the goals. Powell allowed the staff to choose not only their methods of work but the subjects they would investigate as well. That alone meant an immediate change in the Geological Survey's program. In addition, because Powell looked on geology and topography as independent although closely related parts of the greater field of geography, he made the topographic work of the Geological Survey independent of geologic studies as soon as he became Director. Powell also retained direction of the Bureau of Ethnology and simply merged the work of the two organizations.

In 1882, Powell obtained authorization from Congress "to continue the preparation of a geologic map of the United States,"[12] which implicitly extended the work of the Survey to the Eastern States without explicitly clarifying the public lands-national domain question. Powell then redirected all topographic work toward preparation of the geologic map and began topographic mapping to provide a base for the geologic map in Eastern as well as Western States. Topographic mapping became the largest part of the Geological Survey program. Paleontologic and stratigraphic studies to support the geologic mapping program were also begun throughout the country. Mining geology, however, was restricted to the Western States-Powell insisted that

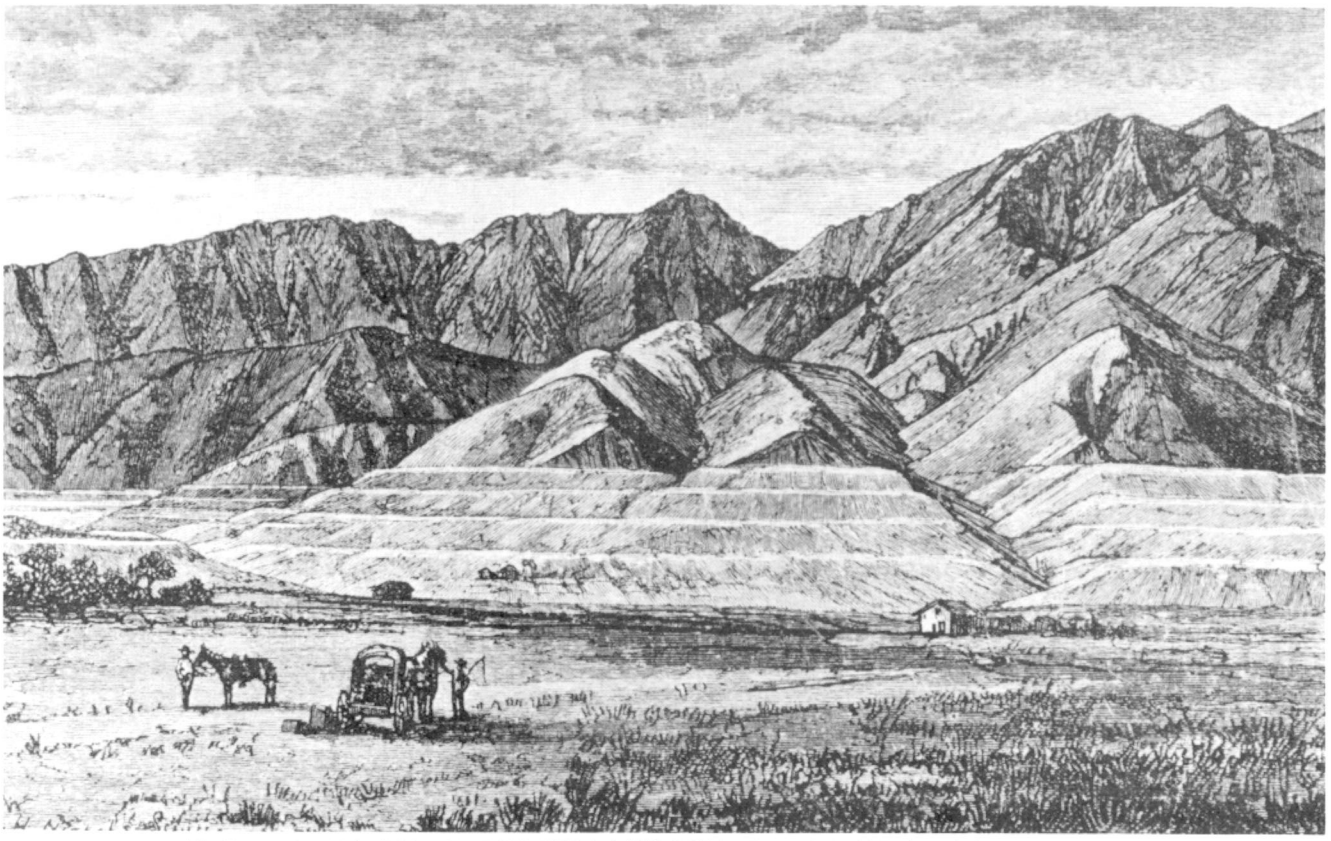

Figure 11. Shorelines of ancient Lake Bonneville, subject of an early general-geology study, 1879.

no authorization had been obtained for mining geology in the Eastern States--and had insufficient funds for field work.

During Powell's first 3 years as Director, the Survey prospered, and its appropriations grew steadily, amounting to $386,000 for the fiscal year beginning July 1, 1884. By that time, King's simple organization of the Survey into Mining Geology and General Geology had been transformed. General geology, initially described by Powell as structural geology and paleontology, became five divisions of geology and five of paleontology. The chemical laboratory, mining statistics, preparation of illustrations, and the library were "accessory"[13] divisions. Without benefit of formal organization, the Geological Survey was also investigating the irrigation of the arid lands, the relief from floods that would be afforded the lower valley of the Mississippi by utilizing waters from the Rocky Mountains for irrigation, and the geographic distribution of the great forest areas.

The appropriations act for the fiscal year beginning July 1, 1884, however, also included provisions for two Congressional investigations: one by the Joint Committee on Public Printing aimed at reducing the cost of public printing, especially the cost of scientific publications, which had become a matter of some concern; the other an investigation of the organizations of the Signal Service, Geological Survey, Coast and Geodetic Survey, and the Hydrographic Office of the Navy, to secure greater efficiency and economy of administration of the public service among them. The latter investigation was ostensibly a general one but was actually a combination of two investigations, one of the Signal Service and the other an attempt to save the Coast and Geodetic Survey from the encroachment on its functions by the Geological Survey, with its newly extended topographic mapping program, and the Hydrographic Office. Common to both was the old argument of civilian versus military control of science.

The National Academy of Sciences, again called on for advice, recommended that all the scientific work of the Government be concentrated in four bureaus, organized on the basis of scientific discipline, and that the four should preferably form a separate Department of Science or at least be in one executive department. Others expressed the opinion that scientific work should be conducted in and directed by the department that needed scientific assistance, and still others held that the scientific work of the Federal Government should be severely limited in scope.

The lameduck Congress that met in December 1884 had to face serious economic problems and a mandatory close on March 4, 1885. The Joint Committee on Public

Figure 12. John Wesley Powell, Director of the U.S. Geological Survey, 1881-1894.

Printing decided to leave to the new Congress the task of drafting a bill to reduce the cost of public printing. The Commission on the Organization of the Scientific Work of the Government held hearings, then obtained authorization to continue the hearings when the new Congress convened, and in 1886, presented a divided report. The majority recommended no changes in the organization of the existing bureaus and, with respect to the Survey, noted that on the basis of the current annual appropriation it would require 30 years to complete the geological survey of the whole country but thought the rapidity with which the work was done could be left to Congress to determine through the amount of the appropriation. The minority called for restriction of paleontology to the collection, classification, and proper care of fossils, and for prohibition of general discussions of geologic theories and of the publication of anything except an annual report of operations. In the next session of Congress, the Geological Survey was directed henceforth to present itemized estimates in requesting funds so Congress could control expenditures, and the amount the Public Printer was authorized to spend on Geological Survey publications was drastically reduced.

More trouble for the Geological Survey was already developing on another front. A few months after becoming Director, Powell had submitted a report to the second session of the International Congress of Geologists in which he attempted to establish rules "adopted"[14] in the Geological Survey as the American norm for stratigraphic nomenclature and cartographic representation. Only one American geologist attended the Congress, which voted to adopt other terms largely of European derivation. Following the 1885 Congress, however, the American Committee met and voted to adopt the decisions of the International Congress and to recommend their acceptance by American geologists. American opinion on stratigraphic nomenclature was divided, as became clear in meetings held in 1887, but the American Committee sent its reports to the 1888 International Congress without prior distribution in the United States, arousing considerable protest. In August 1888, American geologists voted to form an American geological society and the first meeting of the Geological Society of America was held on December 27, 1888. Three weeks before the Geological Society held its initial meeting, Powell convened a conference of Federal geologists on "geologic taxonomy and nomenclature" with the claim that "the range of conception concerning geologic principles and methods among the Federal geologists has become an epitome of the geologic opinion of the earth."[15]

Powell was temporarily diverted from the geologic map and stratigraphic nomenclature by a change in climate in 1886. During the 1870's and early 1880's, great numbers of people had settled on the Great Plains, and would-be farmers came into competition with cattlemen for water and land. The drought of 1886 and the severe winter that followed compounded the difficulties. In October 1888, Congress authorized a survey to investigate the extent to which the arid region of the United States could be redeemed by irrigation, to segregate the irrigable lands, and to select sites for reservoirs and other hydraulic works for the dual purpose of storage and utilization of water for irrigation and prevention of floods and overflows. To prevent speculation, Congress then stipulated that all lands that might be irrigated by the reservoirs and canals to be located by the surveys be withdrawn from entry.

In his arid lands report of 1878, Powell had defined the arid region as the region where rainfall was less than 20 inches a year, and so most of the area west of the 100th meridian was in his arid region. Between the arid region of the West and the humid region of the East was a region, which Powell called the subhumid region, where rainfall was 20 to 28 inches a year. Most of the farmers who had been hurt by the change in the weather were in the subhumid region or the eastern edge of the arid region.

Given the opportunity he had so long awaited to attack the problem of the arid lands, Powell planned first topographic surveys to plot catchment basins, then a hydrographic survey to measure streamflow, and finally an engineering survey to determine the feasibility of construction. The topographic mapping was begun in October 1888, immediately after passage of the Appropriation Act, as an

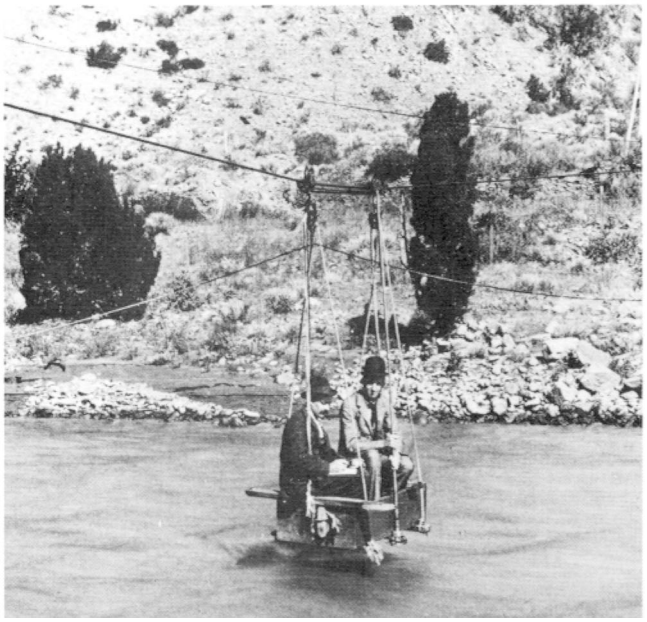

Figure 13. An early method of stream gaging, 1890.

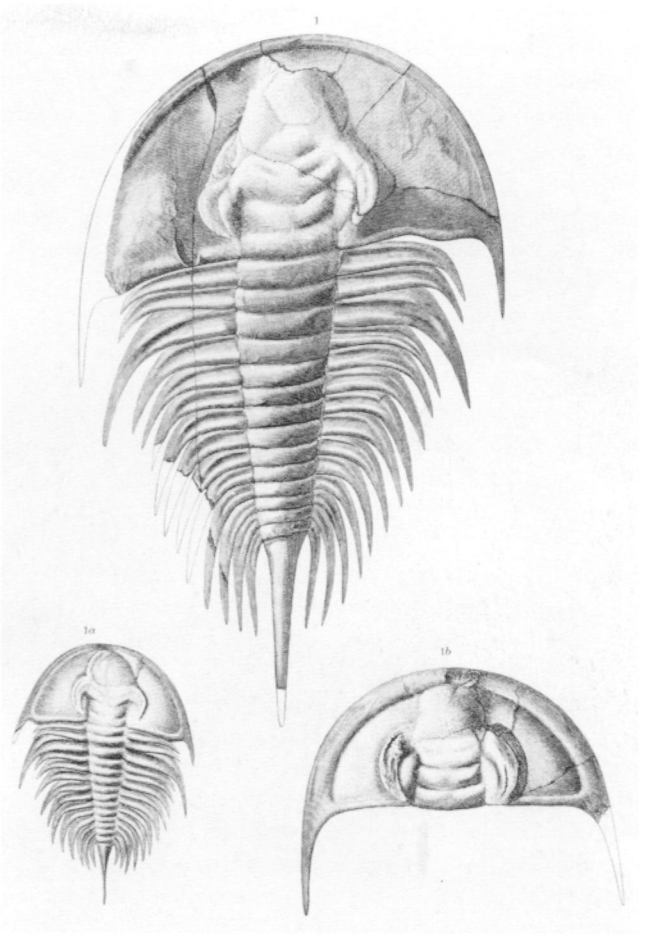

Figure 14. *Olenellus,* a genus of trilobites that C.D. Walcott found marked the lowest zone of the Cambrian, **1890.**

expansion of the regular topographic mapping program in Colorado and areas to the west. The stream-gaging and engineering surveys had to wait upon the training of hydrographers and the recruitment of engineering personnel and did not get underway until 1889. Men experienced in stream-gaging methods and instruments were scarce, so 14 young men were chosen and placed in an instruction camp at Embudo, New Mexico, under the direction of F.H. Newell, a 26-year-old engineer who had graduated from the Massachusetts Institute of Technology in 1885.

The Irrigation Survey was discontinued in 1890. Congress was impatient for results, but Powell insisted that all the facts had to be determined before any recommendations could be made. In May 1890, the Acting Attorney General ruled that all irrigable lands had been withdrawn from entry on October 2, 1888, and as no one knew which lands were irrigable until the Survey certified them, all claims filed after that date had to be invalidated. The public domain was in fact closed to entry, a situation which advocates of western development did not want at any cost. To complicate the situation, six new States had been admitted in 1889 and 1890, some wholly, some partly in the arid region, and their dowry lands, the public lands ceded by Congress to new States from which they would derive their taxes, were also withheld. In the summer of 1890, Congress repealed the provision for withdrawal of lands except those selected as reservoir sites and provided no further funds for the Irrigation Survey.

The demise of the Irrigation Survey was the first serious setback; another followed 2 years later. The year in which the Irrigation Survey was discontinued was one of almost universal national discontent in the United States. Farmer and labor organizations began to join together with other protest groups to achieve their common objectives. The monetary situation was precarious. Production of gold had been declining for many years while the production of silver had steadily increased and its market price as steadily declined. In 1890, the silver and inflationist forces in the Senate, reinforced by the Senators from the recently admitted States of North and South Dakota, Montana, Washington, Idaho, and Wyoming, succeeded in passing a bill for free and unlimited coinage of silver. The House blocked that bill, but a compromise bill passed in July 1890 required the Treasury to purchase 4,500,000 ounces of silver each month (the estimated total U.S. production) at the prevailing market price and to issue in payment legal-tender Treasury notes redeemable in gold or silver at the option of the Treasury. The effect was an increase in the circulation of redeemable paper currency and a weakening of the Federal gold reserve, creating a fear that the silver inflation might take the country off the gold standard. A new

downward spiral of commodity prices began in 1891 and for the first time in 20 years the Treasury announced an impending deficit.

At this critical point in its history, the Geological Survey was out of favor with Congress, with many American geologists, who felt that it had too often acted unilaterally, and with some elements of the mining industry, who felt that economic geology was being neglected. In a mood for economy, Congress in 1892 slashed appropriations for scientific agencies, especially those items which seemed to have little immediate practical purpose. The Geological Survey's appropriations for geologic surveys, paleontology, and chemistry and physics were drastically reduced, and several statutory positions were eliminated. Only the appropriation for the report on mineral resources went unscathed, although the appropriation for topographic surveys was cut only a little. The Senate then appointed a Select Committee to "investigate the operations of the United States Geological Survey, the efficiency and utility of such a survey, together with the progress made and economy observed in this work."[16]

The congressional action was clearly aimed at Powell and his administration of the Geological Survey, and the reasons for it were equally clear. The principal reason was that Survey science was not serving the great economic interests of the country although the all-encompassing nature of the Survey work or resentment of Powell's ideas of land reform and the closing of the public domain during the Irrigation Survey, to which some historians have attributed the action, may have played a part. In particular, Senators from the mining States in the West, which were also States in the arid region, wanted economic geology restored to the preeminent position it had had under King, and members of Congress in the South and East wanted economic geology investigations in their region. A few powerful Senators in fact wanted to force Powell's resignation and to restore King to the directorship.

Powell continued to occupy the position of Director until June 30, 1894, but his control of the Survey's geologic work came to an end in August 1892. Charles D. Walcott gradually took charge, first on an emergency basis when Powell was absent from the office for several months, then with administrative responsibilities delegated by Powell. On July 1, 1893, the Secretary of the Interior appointed Walcott Geologist-in-Charge of Geology and Paleontology. In the spring of 1894, Powell told the House Committee on Agriculture, then considering legislation to transfer the Geological Survey from the Department of the Interior to the Department of Agriculture, that although the Geological Survey when it was organized was supposed to be concerned principally with mines and mining, the bulk of its operations were now concerned with agriculture. The Secretary of the Interior requested a cut in Powell's salary, a device used by the administration to embarrass officials and force their resignation, and Powell submitted his resignation in May 1894. The Secretary of the Interior promptly recommended to President Grover Cleveland the appointment of Walcott as the third Director of the U. S. Geological Survey.

Walcott was not an obvious choice for the position in view of the congressional desire for more emphasis on economic geology. He was a man of unusual administrative and scientific ability, but, although he had already established an international reputation in what he chose to call paleontologic geology, as late as 1890 he was one of the lower paid paleontologists and in 1892 had been on the verge of leaving the Survey to become a professor at the University of Chicago. Walcott, however, had been one of King's early appointees, as an assistant geologist at $600 a year, and had been part of the group that worked with King in New York after King's resignation as Director. Walcott understood the difficulties the Geological Survey faced and the steps that had to be taken. In fact, in the request for funds that was sent to Congress in December 1892, the purpose for which the geologic surveys were to be made was changed from "preparation of the geologic map"[17] to "locating and representing by maps, sections, and reports,"[18] the various mineral resources known or believed to exist in 17 different areas, including those in the Eastern States.

Walcott's appointment was greeted with cautious approval by geologists but more or less ignored by the mining fraternity, although King assured them of his administrative ability. Walcott revived the mission orientation of the Geological Survey as outlined by King in 1879 but broadened the mission beyond that envisioned by King. The Survey would aid not just the mineral industry but all industries--in fact any practical objective that could be aided by a knowledge of geology. It would not, however, be limited to practical geology but would undertake basic research whenever research was necessary in the solution of a geologic problem.

Walcott abolished all organizational units within the Geologic Branch and assumed direct control of the work. Mining geology studies were resumed and extended into the Eastern States, and in view of the gold crisis, an intensive study of gold deposits, including exploration for new sources, was begun. The deposits at Cripple Creek, Colorado, a little-understood telluride ore, were studied, as were those at Mercur, Utah, which had become usable through development of the cyanidation process. Studies of gold deposits in Alaska began in 1895. By 1900, the value of gold produced annually in the United States was more than twice what it had been in 1890, and the United States adopted the gold standard as its monetary base. The mining-district studies were not restricted to gold but were also undertaken in the iron districts of Michigan and Minnesota and the copper districts of Montana, Utah, and Arizona. Nor were they held to practical matters only. By 1900, the ideas on the classification and genesis of ores,

Figure 15. A geological party on its way to map the Cripple Creek mining district, Colorado, 1893.

Figure 16. Charles Doolittle Walcott, Director of the U.S. Geological Survey, 1894-1907.

which King had hoped would come from the mining-geology program, were matters of intense discussion; papers on these topics at the meeting of the American Institute of Mining Engineers in 1901 became landmarks in the history of geology.

Basic science was an integral part of the Geologic Branch program. Fundamental studies were made in the genesis of ore deposits, in paleontology and stratigraphy, in glacial geology, and in petrography. The geologic time scale was revised, new definitions for rock classes were developed, and the first geologic folios were published.

Geology was also extended to include the study of water. In 1894, a small appropriation was obtained for the purpose of "gauging the streams and determining the water supply of the United States."[19] Streamflow measurements begun during the Irrigation Survey had been continued in a modest way as part of the topographic mapping program after the Irrigation Survey was discontinued in 1890. With the new appropriation, work was expanded. In 1895, the work was transferred to the Geologic Branch, and studies of underground water and water utilization were gradually added to the stream gaging. Appropriations were increased regularly, and in 1896 a new series of publications was inaugurated to make available the ever-increasing volume of information. The Irrigation Congress that met in Phoenix in December 1896 reversed the opinions of earlier congresses with regard to the Geological Survey's role in public-land management by recommending establishment of a Public Lands Commission, including the Director of the Geological Survey as a member, to be responsible for

Figure 17. Bench marks, showing elevations above sea level, greatly enhanced the value of topographic maps, 1896.

Figure 18. Pollution of the Potomac River by industrial wastes such as sawdust and tannery products was recognized by Survey hydrographers, 1897.

Figure 19. A geologist examining an asphalt well in Cuba after the Spanish-American War, 1900.

preparing a topographic map, determining the water supply, ascertaining the character and value of the timber, and making regulations for the occupation and utilization of the public lands.

The development of the topographic work followed a similar pattern. Before Walcott became Director, the work of the Topographic Branch of the Survey had been criticized by many who considered the extensive program inappropriate for a geological survey and more properly part of another organization, but at the beginning of his directorate Walcott simply announced that topographic map quality would be improved. Within a few months, the topographic corps was placed under Civil Service, thus eliminating some of the difficulties of the Powell era when many with inadequate or no training, including congressional relatives, had been employed. A practical demonstration was made of the advantages of combining topographic surveys and the subdivisional surveys of the General Land Office in Indian Territory. The value of topographic maps for practical purposes was greatly increased by the placement of permanent bench marks showing the exact location and elevation of fixed points.

By 1897, Walcott had regained the confidence of Congress. The Forest Management Act that year placed management of the forest reserves in the Department of the Interior and required that surveys of the "public lands that have been or may be designated forest reserves"[20] be made under the supervision of the Director of the Geological Survey. Survey topographers within the next 3 years mapped more than 32,000 square miles in and adjacent to the reserves, even though most were in wilderness areas. At the same time, a program of topographic mapping on the larger scales needed for more urbanized areas was steadily growing in cooperation with the Eastern States.

In the late 1890's, geologic work was extended into new fields and went beyond the national domain. In 1897, a Survey geologist and a hydrographer were detailed to the Nicaraguan Canal Commission to study the proposed canal route between the Atlantic and Pacific Oceans. The Commission made extensive use of their findings, marking perhaps the first time on this continent that geological evidence provided support for a great engineering project. After the Spanish-American War in 1898, Survey geologists were sent to investigate the mineral resources of Cuba and the Philippine Islands.

In 1897, a Senate resolution called for a three-man commission, including the Director of the Geological Survey, "to determine the best method of ascertaining all the facts of general importance relating to mines and mining within the United States, whether by a mining bureau, a Secretary of Mines and Mining, a Commissioner of Mines, or a commission."[21] In December 1898, a Senate resolution called for a Division of Mines and Mining in the Geological

Survey to gather statistics on mineral resources and mineral production and to make investigations related to mines and mining. Walcott agreed that the mining interests should be represented in the organization of the Government and that establishing such a division would care for the interests of the mining industry. He added that, in addition to precious-metal investigations, studies should be undertaken of coal, coke, petroleum, asphalts, building stones, and clays.

In 1900, a bill for establishment of a Department of Mines with the Survey as a nucleus was tiled but not acted on. However, when Congress appropriated for the Survey 110 percent of the amount it had requested, the Geologic Branch was reorganized, and a Division of Mining and Mineral Resources was established.

The reorganization of the Geologic Branch on July 1, 1900, was an experiment designed to separate scientific and administrative control. Seven divisions were established, covering specified subject areas, each in charge of a specialist who would prepare plans of work, establish priorities, recommend geologists to undertake particular projects, and review manuscripts. Party chiefs would plan the conduct of the work. The Director would approve plans and make allotments. In essence, it was King's plan of 1879 adapted to a larger organization.

In his presidential address to the Geological Society of America in December 1900, Walcott foresaw that the "standards of the future will be progressively higher and higher, and the scope of routine investigations will become broader. As geologic science progresses, and as new uses are discovered for mineral resources, it will become necessary to increase the number of classes of facts to be covered by area1 surveys. * * * Every investigation undertaken to solve some geologic problem, whether it prove successful or not, is sure to develop other problems, and the geologic Alexander will never lack worlds to conquer."[22]

At the time, Federal science was clearly enjoying a new but somewhat hazardous status. While becoming more involved in the economic life of the Nation, it was at the same time tending more and more toward the practical, so Washington scientists were seeking private funds to support basic research. In May 1901, the Board of Trustees of the Washington Memorial Association, of which Walcott was president, was incorporated "to promote science and literature; to provide opportunities and facilities for higher learning, and to facilitate the utilization of the scientific and other resources of the government for purposes of research and higher education,"[23] and a plan for a nongovernmental institution to promote the study of science and liberal arts in Washington was developed. The trustees conferred with Andrew Carnegie, who agreed to endow the Carnegie Institution of Washington for the purpose of "extending human knowledge by original investigations and research."[24] The trustees of the new institution, of which Walcott was Secretary, defined the limits of research as the limits of the knowable, and concluded that the function of

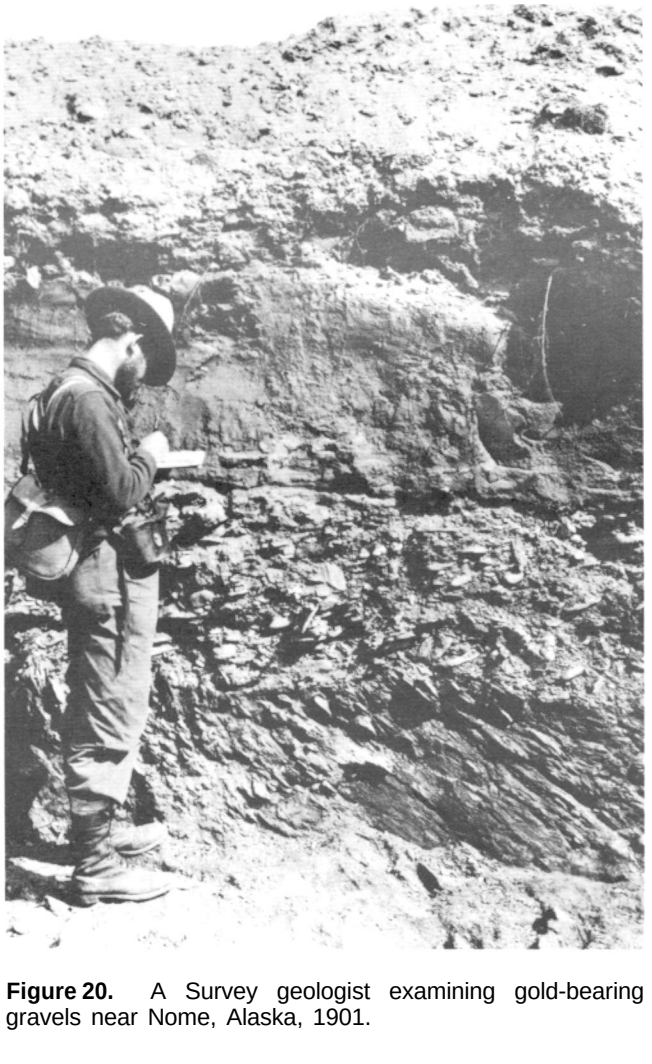

Figure 20. A Survey geologist examining gold-bearing gravels near Nome, Alaska, 1901.

the institution should be the substitution of organized for unorganized effort whenever it promised the best results, and the prevention of needless duplication of work, pointing out that no investigator, working alone, could approach the largest problems in the broadest way thoroughly and systematically.

The accession of Theodore Roosevelt to the Presidency in September 1901, after the assassination of President William McKinley, very quickly had an effect on the Survey program. By inclination and training, Roosevelt was in full sympathy with the movement for scientific management of the Nation's resources, and in his first State of the Union message, in December 1901, outlined a national forest and water policy. The long effort to promote reclamation of the arid lands, with which both Walcott and F.H. Newell were associated, culminated in passage of the Newlands Act in June 1902 and the establishment of the Reclamation Service. At the same time, the appropriation for the Geological Survey's water-resources investigations was increased and the total appropriation for the Geological Survey for the first time was more than $1 million. At the

direction of President Roosevelt, the Reclamation Service became an adjunct of the Geological Survey, and Walcott served as director of both agencies.

The organization of the Geologic Branch was again altered when Walcott assumed additional duties as Director of the Reclamation Service and Secretary of the Carnegie Institution of Washington in 1902. Administrative control of five divisions was transferred from the Director to the Geologist-in-charge of Geology and Paleontology, and those five divisions became sections in the Division of Geology and Paleontology. The Division of Physical and Chemical Research and the Division of Mining and Mineral Resources remained under the administrative control of the Director. The Hydrographic Division was separated from the Geologic Branch and became the Hydrographic Branch. In 1903, the Division of Alaskan Mineral Resources, in effect an Alaskan geological survey because it included topographic mapping, was established in the Geologic Branch.

Federal science had then become so involved in the economic life of the Nation that inevitably it also became caught up in the making of national policy. The Geological Survey through its Director had had a hand in the passage of the Forest Management Act in 1897 and the establishment of the Reclamation Service in 1902. Shortly thereafter the Geological Survey also became involved in the regulation of industry. When the coal resources of the Nation became a matter of public interest because of the hardships endured during the prolonged anthracite coal strike in 1902, President Roosevelt appointed a commission, including among its members the Survey's coal statistician, to arbitrate the dispute. The commission in its report was critical of the rivalry between railroads, which owned or controlled more than 96 percent of the anthracite deposits, of wasteful methods of mining, and of mining safety practices, and the Commissioner of Corporations in the newly established Department of Commerce and Labor promptly began an investigation of some of these problems.

Early in 1903, President Roosevelt also appointed the Director of the Geological Survey chairman of a committee to investigate the scientific work of the Government to increase its usefulness, efficiency, and economy. The committee concluded that, in general, the work of scientific research on the part of the Government should be limited primarily to utilitarian purposes and that research in pure science on broad and general grounds should be within the scope of private institutions. The committee favored organization of research around a problem rather than a discipline, and recommended the transfer of several bureaus, including the Geological Survey, to the Department of Agriculture, which already included one-third of all Federal scientific bureaus, received three-fifths of all appropriations for scientific work, and employed two-thirds of all Federal scientists. No action was taken on these recommendations but at the time President Roosevelt was much involved in foreign affairs, including negotiations for the isthmian canal and Alaskan boundary problems.

In 1904, the U.S. Geological Survey celebrated the 25th anniversary of its establishment. It had grown from an organization of 38 employees at the end of its first year to one with 491 employees (and another 187 in the adjunct Reclamation Service) in 1904. Its first appropriation had been $106,000; the appropriation for the fiscal year that ended on June 30, 1904, was $1.4 million. It had become the leading geologic institution in the United States in the view of "American Men of Science," and many of the 100 geologists whose work was considered most significant by their peers, including the first five ranked numerically, were associated with the Survey. To mark the anniversary, a bulletin describing the Survey and its operations during the 25 years was published. Among the achievements noted were preparation of topographic maps of 929,850 square miles of the United States (26 percent of the country including Alaska) published as 1,327 atlas sheets; geologic mapping of 171,000 square miles and publication of 106 geologic folios; experimental and theoretical investigations of the physical characteristics of rocks in various processes of formation, of volcanic and geyser action, and of rock composition and structure; paleontologic and stratigraphic studies; streamflow measurements and their analysis, which, among other things, had stimulated the development of water power, especially in the Southern States; and studies of irrigable lands and detailed examination and classification of 110,000 square miles of the forest reserves.

Of all the work of the Geological Survey, the bulletin concluded, its immediate value to the people was best shown by the aid extended in developing the mineral resources and in forwarding important engineering projects in which the people, as well as Federal and State Governments, were interested. Singled out for special mention were the investigations of the mining geology of Leadville, of the Lake Superior iron ores, and of the Appalachian coal field.

The mining geology program had, in fact, been a major factor in the development of economic geology as a distinct field in geology, composed of both theoretical and practical aspects. The 25th anniversary of the Survey coincided with the beginning of a new journal *Economic Geology*, and with a call from the American Mining Congress for establishment of a Department of Mines and a counter statement from the *Engineering and Mining Journal* that a bureau of mining should be established under the Director of the Geological Survey because "in no other country--we say it advisedly--has economic geology been applied to the development of industry with such beneficent results as in the United States, and no geological survey has contributed so much to the practical application of the science of geology in mining operations as has the organization in whose behalf we bespeak the earnest interest of our readers ."[25] What the Survey needed, the *Journal*

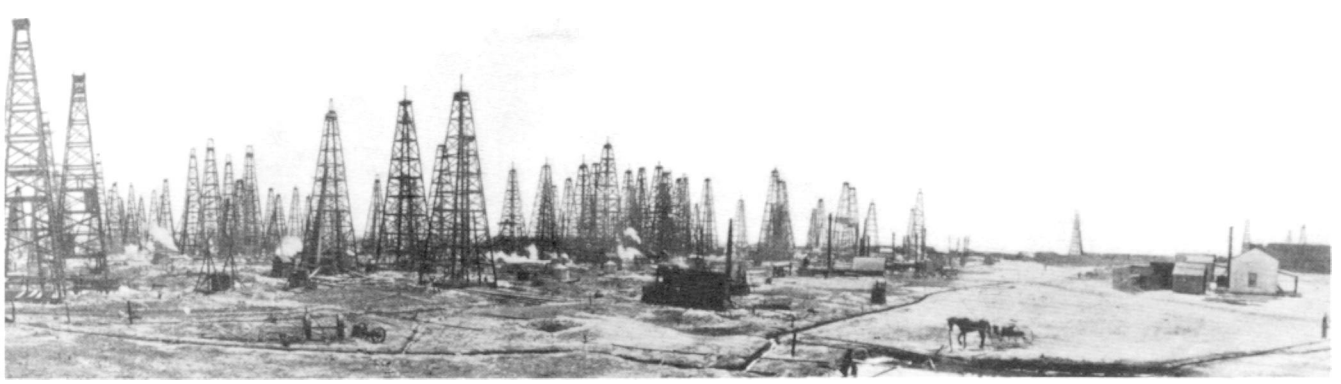

Figure 21. Spindletop oil field, near Beaumont, Texas, discovered in 1901, inaugurated a new era in the use of energy resources.

said, was greater scope for economic geology and "freedom from the encroachments of the wood and water departments."[26]

BEGINNING THE SECOND QUARTER-CENTURY

In 1904, as the U.S. Geological Survey began its second quarter-century, the United States was in the early stages of a period of profound change just as it had been when the Survey began in 1879, but many of the problems facing the Nation in 1904 were very different from those of 1879. During the Survey's first 25 years, the United States had become an urban industrial world power. The population had increased from 48.9 million in 1879 to 81.8 million in 1904. The number of manufacturing establishments and the value of manufactured products had more than doubled during this period, and the value of the mineral products had increased from $365 million in 1879 to more than $1 billion in 1904. At the same time, settlement of the West had proceeded so rapidly that by 1890 the frontier had disappeared.

During this age of change, which began in the early years of the century, national policies that had prevailed in the late 19th century were abandoned, social and economic reforms were enacted, and the role of the Federal Government was developed. In fact, the whole fabric of American life was altered. More than one historian has noted the correlation between this period and changes in the use of energy. Whether or not changes in the use of energy affected American mores, clearly they affected the development of natural resources, especially the fossil fuels and water, and these in turn resulted in changes in the geological sciences.

The most obvious change was the increased interest in nonmetalliferous resources, including the fossil fuels. For several years, the Geological Survey had been reporting that an increasing proportion of the value of the annual mineral production of the United States was being contributed by the nonmetalliferous resources. In 1898, when problems began to develop in the coal industry that caused consumers to turn to other kinds of fuel, Director Walcott had suggested to Congress that a thorough investigation, including practical tests, be made of the coals and cokes of the United States so they might be used to the best advantage, in his own way echoing King's statement in 1880 that mineral resources should be used with the utmost scientific economy. In 1901, oil became a major Survey interest after the successful drilling of a well at Spindletop, 20 miles southeast of Beaumont, Texas, inaugurated a new era in the oil industry.

At the World's Fair in St. Louis in 1904, celebrating the centennial of the Nation's first great acquisition of western territory, the Geological Survey was given an opportunity to demonstrate the value of the more comprehensive investigations of coal and coke, which it had been proposing for many years. For the department of mining and metallurgy at the exposition, which the Survey had agreed to organize, appropriations totaling $60,000 were obtained for analyzing and testing coals and lignites "to determine their fuel values and the most economic method for their utilization for different purposes."[27] The coal-testing program almost immediately began to produce significant results, and after the fair was over, it was extended and became part of the regular Survey program. At the same time, a similar program for the testing of structural materials was begun. Construction of large public works by the Reclamation Service and the Panama Canal Commission, among others, made the program Walcott had proposed in 1898 of immediate value.

In 1905, the Survey also obtained additional funds to increase its field investigations of iron and coal, the staples of industry, about which there was some concern, and a new program of mapping western coal deposits was started. As the emphasis in the Survey's program in economic

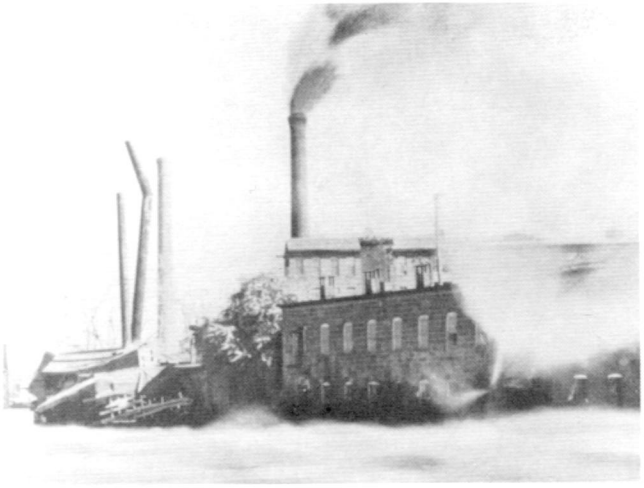

Figure 22. Floods in the Passaic River basin, northern New Jersey, 1902-1903, were among the earliest studied by the Survey.

geology shifted to nonmetallic resources, specifically fuel resources, a new Section of the Geology of Fuels was set up in the Geologic Branch.

On March 7, 1904, just 4 days after the Survey celebrated its silver anniversary, the Second Public Lands Commission, appointed in October 1903, submitted its preliminary report. The Federal Government, 118 years after the Land Ordinance of 1785, still held title to 1 billion acres of public lands, most of which, as in 1879, were west of the Mississippi River. President Roosevelt had asked the Commission to report on the condition, operation, and effect of the land laws and to recommend such changes as were needed to effect the largest practicable disposition of the public lands to actual settlers, requests not unlike those Congress had made of the Commission of 1879, but he had also asked that the Commission recommend changes in the public-land laws "to secure in permanence the fullest and most effective use of the resources of the public lands."[28] The recommendations in the preliminary report bore chiefly on the control, use, and disposal of forest lands and the control of water, and no consideration was given to the mining laws even in the final report although the Commission recognized that changes were necessary. In the spring of 1905, Congress transferred the management of the forest reserves from the Department of the Interior to the Department of Agriculture. The classification of the forest reserves was then transferred from the Geological Survey to the newly renamed Forest Service. As the Reclamation Service was becoming less dependent on the Geological Survey and would become independent in 2 years, by the middle of 1905, most of the public-land management responsibilities had been shifted from the Geological Survey.

In 1906, unexpected problems forced a change in the Geological Survey program. When the appropriations bill came up in the House, a Representative from Iowa challenged the authority in law for the Survey to make a map or gage streams except in the national domain, which he clearly believed to be the public lands, and precipitated a 2-day debate. In the end, only the appropriation for water-resources investigations was greatly reduced, but on the day that the appropriations bill was passed, President Roosevelt ordered the Secretary of the Interior to report as soon as possible the coal lands where the coal deposits were believed to be of such value that the lands should be withdrawn from entry. Evidence had been uncovered that much coal land had been fraudulently acquired, and the Roosevelt administration was about to embark on the conservation of mineral resources in dramatic fashion. A month later, some 66 million acres of potential coal-bearing lands were withdrawn from entry until the Survey could determine their extent, location, and value. The "classification of the public lands" in the organic act took on new meaning.

In the spring of 1907, Walcott left the Geological Survey to become Secretary of the Smithsonian Institution. Before he left, there was a reprise of the 1906 appropriations debate in Congress and several organizational changes within the Survey. The Reclamation Service became an independent agency, and F.H. Newell left the Survey to become its Director. The fuel-testing and structural-materials-testing programs were combined as the Technologic Branch under Joseph A. Holmes. C.W. Hayes, the Geologist-in-charge of Geology and Paleontology, was given a new title and commensurate responsibilities as Chief Geologist of the Survey, in charge of divisions of Geology and Paleontology, Chemical and Physical Research, Mining and Mineral Resources, and Alaskan Mineral Resources.

George Otis Smith, the Geologist-in-charge of the Section of Petrography of the Geologic Branch, succeeded Walcott as Director in May 1907 and continued as Director until December 1930. Smith had joined the Survey after receiving his doctorate from Johns Hopkins University in 1896, and he was barely 36 years old when he was appointed Director. His Survey career had not been particularly distinguished, but he had come to the attention of the new Secretary of the Interior, James R. Garfield, in 1906 when Smith had served as chairman of one of the subcommittees of a Presidential commission that sought to put the operation of Government agencies on a modern businesslike basis. Smith was particularly interested in a business policy for the public domain. He also believed that the work of the Survey should be primarily although not exclusively practical.

A combination of circumstances ensured that the work of the Survey for many years did indeed become primarily practical. For the first 20 years of Smith's directorate, appropriations were essentially static while funds from outside sources steadily increased, especially for

the topographic mapping and water-resources program. which were largely practical in nature. The classification program was extended as the Roosevelt conservation program developed but Congress steadfastly refused to appropriate additional funds for the new form of classification. It was necessary to divert personnel from research programs to the classification program, and an exodus of geologists from the Survey for more challenging positions in industry, which began in the first year of Smith's directorate, resulted in residual impoverishment. Within a few years, the profession began to look down on the Survey as a "department of practical geology."[29]

The extension of the classification program began at the behest of geologists working in the California oil fields who urged the Director to act to safeguard oil development on the public lands. At the time, title to oil-bearing lands could be obtained only under the Mining Act of 1872, which required that a discovery be made before the land could be acquired, discoveries required drilling, which cannot be done in secret, and potential oil lands were being obtained fraudulently under other laws to take advantage of

‹ **Figure 23.** George Otis Smith, Director of the U.S. Geological Survey, 1907-1930.

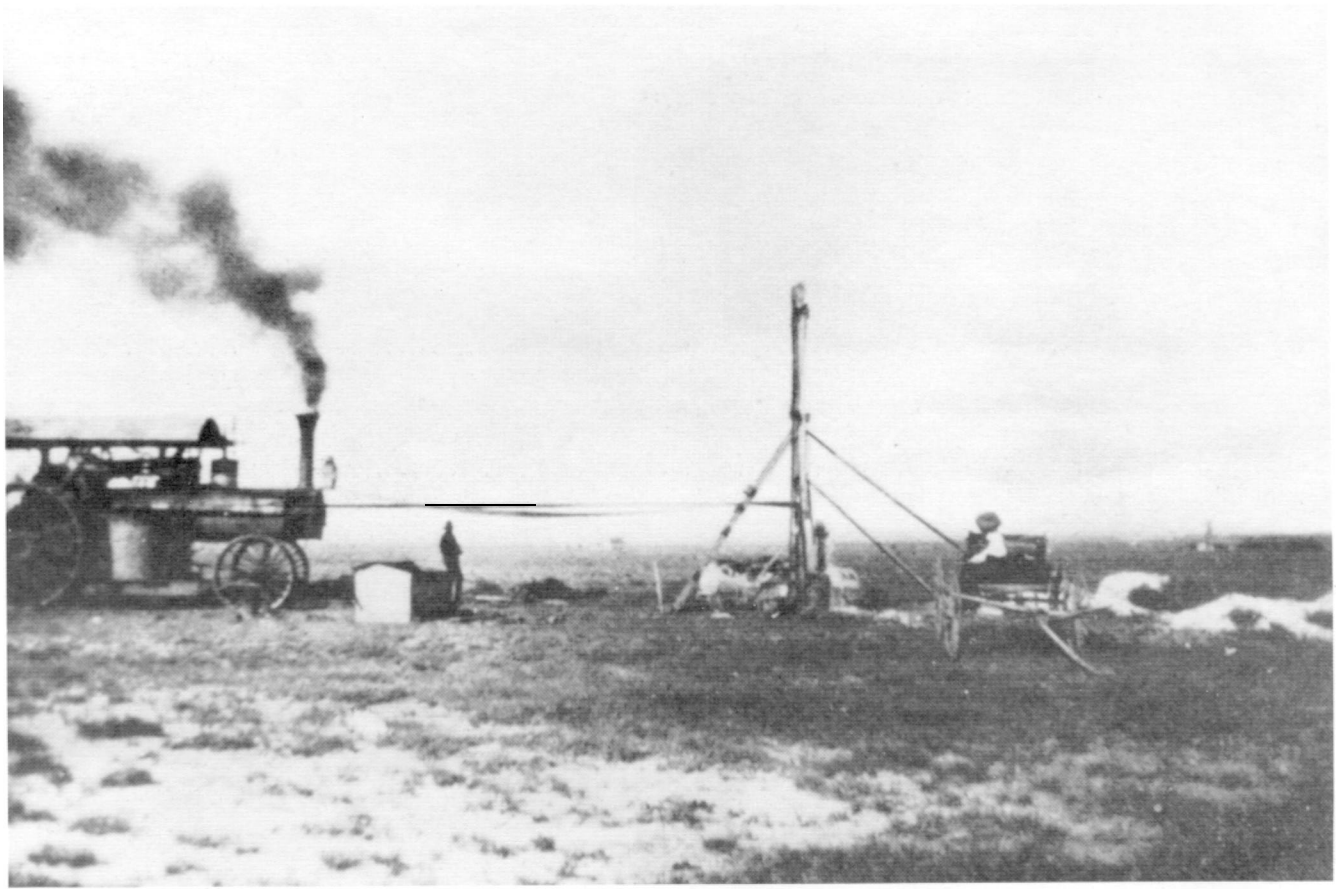

Figure 24. Land-classification and ground-water studies were combined in New Mexico, 1909.

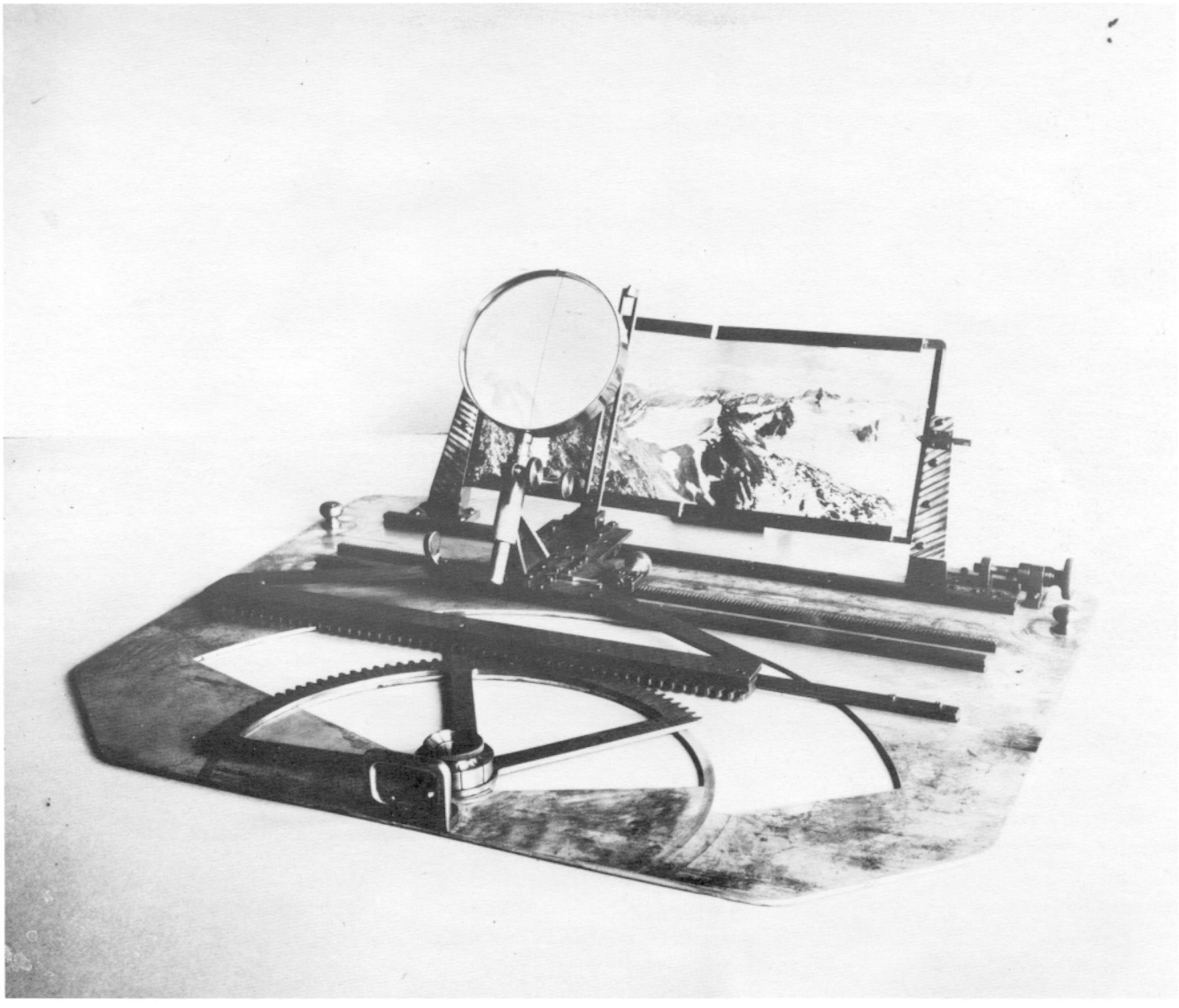

Figure 25. The panoramic camera, used in the early 1900's in Alaska, marked the beginning of photogrammetric methods of mapping by the Survey.

the oil companies' work. On Smith's recommendation. the Secretary of the Interior in August 1907 withdrew some potential oil-bearing lands in California from agricultural entry, pending classification. In December 1908, newly discovered western phosphate lands were withdrawn from entry, and the Land Classification Board was established in the Geologic Branch to administer the new responsibilities for classification. Within a few months of the Board's formation, the Survey was assigned responsibility for classification of lands under the Enlarged Homestead Act, and a program of hydrographic classification was added to that of mineral-land classification.

The classification program was only part of the Survey's involvement in the rapidly developing Roosevelt conservation program. An Inland Waterways Commission, appointed in March 1907 to prepare a comprehensive plan for use of inland waters, in the fall of 1907 suggested a Conference of Governors at the White House to dramatize the need for conservation. From the Governors Conference in May 1908 came the National Conservation Commission that in the record time of 5 months, with the aid of Government scientific agencies including the Geological Survey, prepared an inventory of natural resources, containing not only estimates but predictions of times of exhaustion of various mineral resources.

Conservation, however, became a controversial issue, politically and scientifically. Originally, conservation had referred primarily to the prevention of waste or destruction of resources and was thus considered a scientific or technological problem. In Europe, however, where natural

Figure 26. Coal-land classification and geologic mapping were combined in North Park, Colorado, 1911.

resources had long been used with the utmost care, it was natural for the government to exert some control, and there conservation was part of political economy. The conservation inaugurated under Roosevelt differed from European conservation in being almost completely restricted to the public domain and, by the withdrawal from entry of millions of acres of public land, locking up the resources rather than regulating their use. Politically, it arrayed East against West and progressive against conservative; paradoxically, the progressives rather than the conservatives favored conservation. Scientists were also divided; while some stressed the need for research, others urged government control.

Under William Howard Taft, who succeeded Roosevelt as President in March 1909, the conservation movement provided the setting for a battle between progressives and conservatives. Taft was as committed to conservation as Roosevelt but, being a strict constructionist of the law, believed it to be his role to give the Roosevelt program the force of law. His Secretary of the Interior, Richard A. Ballinger, was of like mind. In 1910, Congress undertook an investigation, ostensibly of the Forest Service and the Department of the Interior with regard to certain land claims in Alaska but in reality of loose construction of the law as typified by Gifford Pinchot, the Chief Forester and Roosevelt confidant, and of strict construction as typified by the Secretary of the Interior. The Director of the Survey strongly supported the Secretary, cheerfully accepted greatly increased responsibilities for classification of the public lands, including evaluations of waterpower sites, and sought and eventually obtained the withdrawal of oil-bearing lands in California and Wyoming, Although Secretary Ballinger was exonerated by Congress, he was condemned by the public and resigned in 1911. Congress, however, had resolved the question of the legality of the withdrawals by passing the Pickett Act in 1910. Thereafter, the resources of all withdrawn lands except the coal lands, which could be sold after being classified and appraised by the Geological Survey, became unavailable.

In May 1910, while the Ballinger-Pinchot investigation was still underway, Congress established a new agency, the Bureau of Mines, designating the Technologic Branch of the Geological Survey as its nucleus, a designation later changed to require the transfer of the structural-materials testing to the National Bureau of Standards and the mine-accidents and fuel-testing investigations to the Bureau of Mines. George Otis Smith served for a few months as Director of the Bureau of Mines as well as of the Geological Survey until Joseph A. Holmes, who had been head of the Technologic Branch in the Survey, was made Director of the Bureau of Mines. Unlike the spinoff of the Reclamation Service in 1902, which had been accompanied by an increase in the Survey appropriation, this second spinoff from the Geological Survey resulted in a decrease in

the appropriation and a greater loss of personnel than the transferred elements of the Technologic Branch.

The Geologic Branch by this time was making an effort to combine some fundamental research with the classification studies. When Chief Geologist Hayes resigned to become the vice president of an oil company in 1911, his successor, Waldemar Lindgren, insisted on the opportunity for research and a reduction in the administrative burden of the office. In 1912, the Land Classification Board was separated from the Geologic Branch and made an independent branch. It had no funds of its own, however, and had to subsist on assessments on the the funds of the other branches. When Lindgren left in 1912 to become a professor at the Massachusetts Institute of Technology, paleobotanist David White, even more committed to research, became Chief Geologist. In 1913, to draw attention to the research aspects of the branch's work, a new Professional Paper series, "Shorter Contributions to General Geology," was begun.

In 1914, the Survey faced a new problem. Congressmen from Eastern, Midwestern, and Southern States, reacting to the concentration of Survey work in the public-land States--much as Congressmen 2 decades earlier had reacted to the emphasis on general geology--filed bills to require a more equitable distribution of work, especially of the topographic mapping and water-resources investigations. In retaliation, a Congressman from California proposed an amendment to the appropriations bill to restrict the geologic work of the Survey to the public lands. The House passed the amendment but, fortunately, the Senate and the Conference Committee rejected it.

WORLD WAR I

World War I reoriented conventional views on mineral resources. When the war began in August 1914, it was assumed that the conflict would last but a short time. The United States was believed to lack a known supply commensurate with its needs of only five minerals of first rank--tin, nickel, platinum, nitrates, and potash. On the other hand, the reserves of mineral fuels and iron were regarded as so enormous that no problems would arise. The Geological Survey, however, immediately increased its geologic mapping to aid the discovery of new oil fields or extension of known fields, but of the five scarce minerals actively sought only potash. The war at first disrupted normal trade relations, but before long, Europe was in urgent need of American agricultural products and then in still more urgent need of American steel, copper, and explosives. Within 2 years, some minerals became difficult to obtain, and the Survey reoriented its work to aid the search for both metals and fuels.

When the United States entered the war in April 1917, the Geological Survey was almost wholly on a war basis. Earlier in the year, a Division of Military Surveys had been formed, and plans for topographic work were adjusted to conform with a program drawn up by the Army's General Staff. The majority of the technical personnel of the Topographic Branch were commissioned in the Army's Corps of Engineers, as were many scientists from the other branches, including the Chief of the Alaskan Division, who became the Chief Geologist of the American Expeditionary Force.

Figure 27. Geologist searching for nitrates in World War I, 1917.

The strategic-minerals concept was born at this time when it became clear that domestic supplies of a dozen minerals were inadequate in quantity or quality or both, another half dozen adequate for peace but insufficient for war, and petroleum production barely sufficient to meet the Nation's normal demand and much too small for the abnormal demands of war. In August 1917, Congress passed the Lever Act empowering the President to make regulations and issue orders to stimulate and conserve the production and control the distribution of fuels necessary to the war effort. A similar bill for the control of other mineral commodities was passed shortly before the war ended but never put into effect.

During the war years, the Survey sought intensively for deposits of war minerals at home and, in time, extended the search to Central and South America and the West Indies. The results were highly successful; adequate supplies of all essential materials were found before the war's end. The Geological Survey also became the main source of information on mineral production, both domestic and foreign, and its data were used to solve a variety of industrial and transportation problems. Personnel from the Survey's Division of Mineral Resources worked in close cooperation with statisticians of the Fuel Administration established after passage of the Lever Act. Geological Survey engineers also undertook a nationwide survey to determine where waterpower could be substituted for

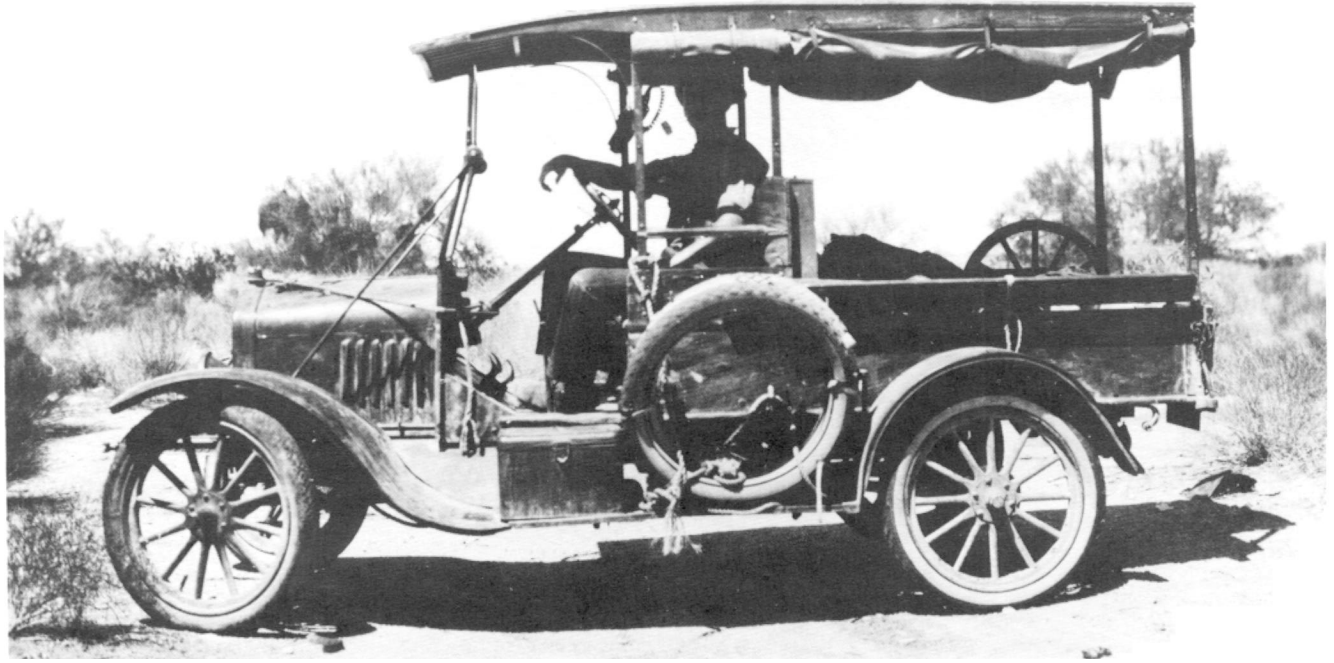

Figure 28. Automobiles were used in field work by the time of World War I, 1917.

steam-generated power or where coal could be saved by interconnecting electric plants or systems.

THE 1920'S

World War I had a pronounced effect on American science; it convinced industry of the value of research, accustomed scientists to work together on the solution of problems, and acquainted scientists in both the public and private sectors with disciplines other than their own. Once the war was over, however, Congress stressed economy, and Federal science suffered for lack of support. So great was the demand for economy that only 1 percent of the budget for the fiscal year beginning July 1, 1919, was earmarked for education and scientific research and development. Industrial research, on the other hand, flourished and created a second industrial revolution based on chemistry. Many scientists left the Government at this time to accept more remunerative positions in industry or in the academic world.

The apparent insufficiency of energy resources was one of the postwar problems calling for immediate attention. Oil shortages in 1919 and 1920 gave credibility to predictions of the exhaustion of domestic supplies within a decade. At the same time, so many Survey scientists were leaving for positions in the oil industry that in some sections there were too few scientists left to train newcomers, and the Survey had to face the long slow process of rebuilding its geologic staff. Many who left the Survey at this time later became chief geologists of leading oil companies, and thus, during the 1930's, a significant proportion of oil-company chief geologists were men who had begun their training under David White.

The postwar shortages convinced Congress that it was necessary to open up the public mineral lands to development. In February 1920, the Mineral Leasing Act was passed. Under the terms of that act, mineral lands were to be leased by competitive bidding, and royalties and other income were to be divided between the Federal Government and the States. The Survey's responsibility for classification of mineral lands was again changed; its major task became

Figure 29. San Juan Canyon, southeastern Utah, explored by geologists, topographers, and hydrographers in connection with proposed power and storage projects, 1921.

the determination of the known geological structure of producing oil or gas fields within which oil and gas leases would be issued. Congress then for the first time appropriated funds for the classification of public lands, which in turn were allotted to the field branches.

Waterpower as an alternative source of energy was given new status by passage of the Federal Water Power Act in June 1920, establishing the Federal Power Commission to issue licenses for development of waterpower on Federal lands. Under the Water Power Act, the Survey took responsibility for the necessary streamflow records and for examination of proposed projects on the public lands outside the National Forests. In 1921, Congress authorized a superpower survey to investigate if economy in fuel, labor, and material could be gained by a comprehensive system for generation and distribution of electric power in the region between Boston and Washington. The study was made under the direction of the Geological Survey by independent engineers who proposed a power grid that anticipated the present northeast power network.

Another postwar problem that demanded action was the lack of maps, which had become evident even before war was declared when the Army had found itself without maps upon which to base its defense of the border areas. Industrial development, land reclamation, power-generation projects, and highway construction were also creating a demand for topographic data. Nearly 60 percent of the country was still totally unmapped, and much that had been mapped was in need of resurvey. Professional organizations urged the President and Congress to make provision for completing the topographic map of the United States in the shortest possible time compatible with requisite accuracy. The Survey proposed a plan whereby the mapping could be effectively and economically completed by 1932, but no funds were made available to inaugurate the plan. Meanwhile, several West Indian republics sought the assistance of the Geological Survey in both topographic and geologic mapping, and Survey scientists and engineers were given leave to supervise their mapping programs. Topographic Branch engineers used the tri-lens aerial camera and related equipment that they had developed in 1916-17 for a systematic aerial survey of parts of Santo Domingo and Haiti. In 1921, a Section of Photographic Mapping was established in the Topographic Branch.

Despite the loss of scientists to industry, the Survey under Chief Geologists David White and Walter C. Mendenhall, who succeeded him in 1922, devoted a major effort to energy minerals. Research was begun on the source materials of petroleum, the physical properties of reservoir rocks, microfaunas as aids to the identification and corre-

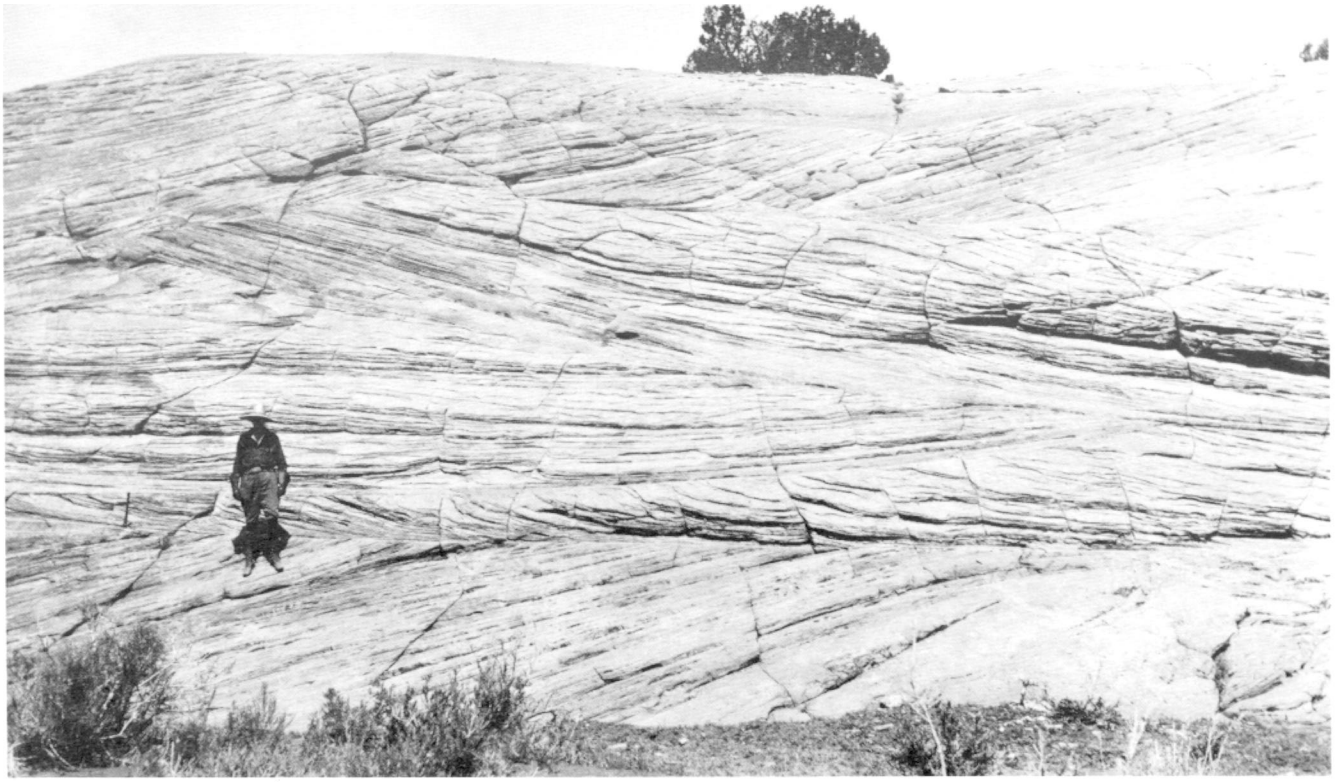

Figure 30. Stratigraphic studies in the 1920's supported public-land classification, the search for new oil fields, and the development of a new stratigraphic code.

lations of beds, and salt-dome caprocks. Survey physicists and chemists joined the effort by developing improved recovery techniques and by laboratory and field tests of geophysical methods of exploration. In addition, geologic mapping for classification purposes and mapping of potential oil areas was continued, especially in Wyoming, where there was some oil company interest, and in Montana, where only the Survey had done any detailed work. In 1923, the Survey extended its intensive study of possible oil-bearing areas to Naval Petroleum Reserve No. 4 on the Arctic Coast of Alaska. The Survey's long-range stratigraphic correlation studies also became a contribution valued by industry in its exploration for petroleum.

By the mid-1920's, new discoveries in the midcontinent region, the Gulf Coast, and California resulted in an oil surplus, and overproduction and competition leading to reckless waste became a major public concern. This postwar expansion of the oil industry from famine to glut was in part the result of the striking developments in the geological sciences in the industry, as well as Government surveys and the academic world. Two new professional societies, the Society of Economic Paleontologists and Mineralogists, of which Chief Geologist David White was a founder, and the Society of Exploration Geophysicists, attested to the coming of age of new branches of the geological sciences.

Chief Geologist Mendenhall, who became known for his frequently repeated aphorism "There can be no applied science unless there is science to apply,"[30] strengthened the research aspects of the geologic program during this period even though the size of the staff continued to decrease. By 1925, when the rate of exodus of staff had been slowed or even reversed in some sections, nearly all the geologic work was reoriented toward research.

The Survey, through the Director, also became involved in energy policy. After the great coal strike in 1922, a Coal Commission was established to study the problems of the industry and to aid Congress on legislation that would ensure the Nation of an adequate supply of coal. Director Smith was a member of the Commission, and the Geological Survey's resource data provided the basis for much of the Commission's report. In 1924, Smith unsuccessfully urged resumption of coal research in much the same terms as Walcott had used in 1898. Director Smith also served as Chairman of a three-man commission appointed by President Calvin Coolidge in March 1924, after the Teapot Dome scandal, to study the efficient

management of the naval petroleum reserves, and as Chairman of the Advisory Committee to the Cabinet-level Federal Oil Conservation Board established in December 1924 to reappraise Federal oil policies.

The Survey once more became involved in regulatory functions in 1925, when the Bureau of Mines, which had had responsibility for supervising mineral lease operations on the public lands since passage of the Mineral Leasing Act in 1920, was transferred to the Department of Commerce, and the Department of the Interior delegated that responsibility to the Geological Survey. The Land Classification Branch was renamed the Conservation Branch and its responsibilities were described as classification of lands according to their highest use; the protection of the public interest in undeveloped mineral, waterpower, and agricultural resources; and the promotion of economical and efficient development of mineral deposits on public and Indian lands. The regulatory functions, which were quite different from any previous Geological Survey responsibilities, required a large force of mining and petroleum engineers who increased the Geological Survey staff to more than 1,000 employees, of whom only 126 were geologists.

The topographic-mapping and water-resources programs by this time were heavily dependent on cooperative and transferred funds. In February 1925, Congress passed the Temple bill which called for completion of a topographic map of the United States within 20 years and authorized both an appropriation of $950,000 for the first year and cooperative arrangements with States and other civic subdivisions to expedite the mapping. Congress, however, did not increase the appropriation to the authorized level but instead made it evident that it expected the States to bear most of the cost. In 1927, Congress appropriated additional funds for topographic mapping with the proviso that they be available only to match cooperative funds from States or municipalities. Under these circumstances, the topographic-mapping program was controlled by the cooperators and could not be a truly national program.

A similar situation existed in the Water Resources Branch, where directly appropriated funds were less than 30 percent of the total. Congress, in 1928, increased the funds for water-resources investigations, again with the proviso that the additional funds be available only to match cooperative funds. The bulk of the work was stream gaging, much of it in connection with flood-control investigations of the Corps of Engineers or international problems for the Department of State. Waterpower investigations were often made in conjunction with engineers of the Topographic Branch. Demands for quantitative information on the availability and most efficient methods of utilizing ground water became increasingly urgent; in some parts of the country, the demand for ground water for municipal supplies or irrigation had become so great that there was danger of overdevelopment. In much the same manner that the mining-geology investigations of the Survey's first quarter-century led to the development of general principles and the emergence of economic geology, in the latter part of the second quarter-century ground-water investigations progressed to a quantitative stage, and a major report on the occurrence of ground water in the United States with a discussion of the principles of hydrology was published. As a new stage in the professionalization of the science was reached, Survey scientists took an active role in the organization of the Section of Hydrology of the American Geophysical Union.

For its 50th year, the Survey had an appropriation of $2 million and available total funds of $3.4 million. It had 998 permanent employees and was conducting mapping and investigations in 45 States, Alaska, Hawaii, and the District of Columbia. Nearly 44 percent of the continental United States exclusive of Alaska had been topographically mapped. Streamflow was being measured at 2,238 gaging stations; income from mineral leases, licenses, and prospecting permits on the public lands under Survey supervision was $4.1 million. As part of the 50th anniversary celebration, Survey alumnus President Herbert Hoover and Mrs. Hoover received members of the Survey at the White House on March 21, 1929, the 50th anniversary of the appointment of Clarence King as the first Director.

THE DEPRESSION YEARS

The Great Depression began only 7 months after Hoover's inauguration, and efforts to combat it dominated the next decade. Before it began, however, Hoover's interest in science and conservation brought about a change in the Survey's work in several respects, first in conservation activities and then in basic research. In the conservation of the public lands, Hoover recognized three urgent problems: overgrazing, which diminished the value of the lands and imperiled the water supply through destruction of the natural cover; the best method of applying reclamation in order to gain real and enlarged conservation of water resources; and the conservation of oil and gas resources. He took action first on the third problem, announcing on March 12, 1929, that henceforth there would be the greatest possible conservation of Government oil, thereby changing the work of the Conservation Branch with respect to oil and gas leases. The importance given to the conservation of water resources led to a still greater expansion of the Water Resources Branch.

In the fall of 1929, the first Hoover budget called for increased funds for scientific agencies, including $100,000 for fundamental research in geologic sciences, the first substantial increase in Federal funds for geologic investigations since 1915. In the spring of 1930, Congress appropriated $2.87 million for the Geological Survey and also

Figure 31. Walter Curran Mendenhall, Director of the U.S. Geological Survey, 1930-1943.

appropriated funds for the expenses of a commission on the conservation and administration of the public domain.

In December 1930, Hoover appointed George Otis Smith to the newly reorganized Federal Power Commission and then appointed Walter C. Mendenhall to succeed Smith as Director of the Geological Survey, honoring not only a commitment to appoint the heads of scientific agencies from within the civil service but also a commitment to support basic research. Mendenhall was 59, the same age as Smith. He had joined the Survey in 1894, fresh from Ohio Normal University, and had mapped in the Appalachian coal fields. In 1898, he had been one of the pioneer geologists in Alaska, and in 1903 he had become one of the first ground-water specialists in the Water Resources Branch. An early member of the Land Classification Board, he became its chairman in 1911 and in 1912 the first Chief of the Land Classification Branch. For 8 years before becoming Director, Mendenhall had been the Chief Geologist. Although more than half his Survey career had been in administrative work, he had made notable contributions to the geology of Alaska, and his study of the principles in ground-water hydrology had helped to establish it as a field of scientific endeavor. Like King, Powell, and Walcott, Mendenhall became a member of the National Academy of Sciences.

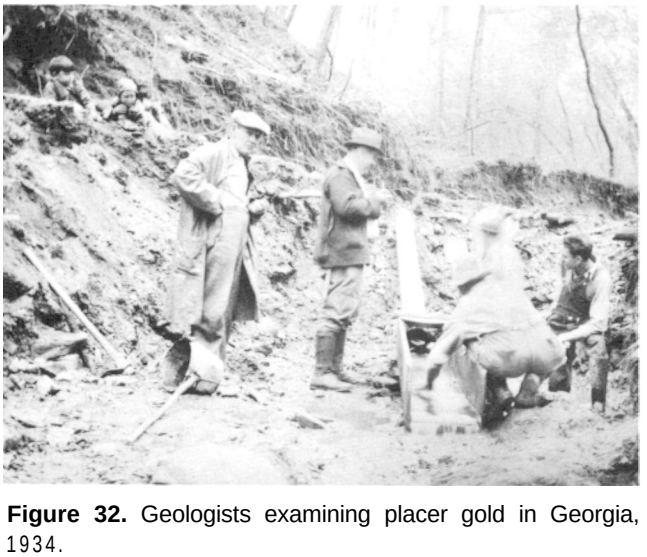

Figure 32. Geologists examining placer gold in Georgia, 1934.

Mendenhall's directorate was pivotal in the history of the Geological Survey. In spite of the difficult times, the depression years, and the beginning of World War II, he encouraged the Survey, as he had the Geologic Branch, to emphasize the necessity of basic research and created an environment in which, in the words of the *Engineering and Mining Journal,* "scientific research, technical integrity, and practical skill could flourish."[31]

A year after Mendenhall became Director, the Federal budget was sharply cut as the effects of the depression began to be felt. The appropriations were not restored to earlier levels until the late 1930's, shortly before the outbreak of World War II, but the Survey subsisted, even grew, on funds transferred from agencies formed to combat the depression by the Franklin D. Roosevelt administration. The Tennessee Valley Authority, established in May 1933, turned to the Survey to meet its need for maps of the entire valley and for a much expanded program of stream gaging throughout the basin. Time constraints on the mapping assignment provided the Survey with an opportunity for a full-scale test of the use of aerial photography, with which it had been experimenting since 1904, and ultimately, with the aid of newly developed photogrammetric equipment and techniques, led to a complete revolution in mapmaking procedures. The Public Works Administration, established in June 1933, began allocating funds in August for topographic mapping, water-resources projects, and much-needed safety work on the public lands that by November 1 amounted to more than $3.7 million, more than the total of all funds for the Survey's 50th year. By the end of the fiscal year, the funds from other Federal agencies and cooperative funds were four times the Federal appropriation. The grants from the Public Works Administration and the Tennessee Valley Authority could be and were used in part to extend Survey investigations and mapping into new areas and to

Figure 33. A Survey topographer using multiplex equipment to prepare a topographic map, 1936.

support research studies. Mineral-resource investigations were made in Eastern and Southern States, extensive studies of the relation of rainfall to runoff and of the magnitude and frequency of floods were undertaken, gaging-station networks with improved structures and instruments were expanded, the topographic-mapping program became a national program, and most of the mapping was done at the needed larger scales.

The Roosevelt administration made extensive use of boards and commissions for planning purposes, including both science and conservation. The Science Advisory Board, established by President Roosevelt in July 1933 and placed under the jurisdiction of the National Academy of Sciences and the National Research Council, reported to Secretary of the Interior Harold Ickes that the organization of the Survey was well designed, and its scientific and technical standards high, but its work was inadequately supported and conditions under which its scientists worked were intolerable. The National Planning Board, established at about the same time by Secretary Ickes to aid him in formulating a comprehensive plan of public works, evolved into a National Resources Board or Committee that attempted to develop policies for minerals, mapping, water, and land use. Survey scientists and engineers contributed to these planning groups. Although Americans in general and Congress in particular were suspicious of governmental planning, the idea was eventually accepted.

In June 1934, the Taylor Act was passed, providing for organization of the public grasslands into grazing districts under the control of the Secretary of the Interior. By the following March, the President withdrew all remaining public lands, used primarily for grazing, to determine the most useful purpose for which they might be used. The work of agricultural and grazing classification, which the Survey had begun in 1909, was transferred to the new Grazing Service as the third spinoff from the Survey.

The Federal appropriation for the Geological Survey was restored to its 1931 level for the fiscal year beginning

Figure 34. William Embry Wrather, Director of the U.S. Geological Survey, 1943-1956.

Figure 35. Military geologists opening a box of soil samples from the Southwest Pacific, 1945.

July 1, 1938. No longer dependent on uncertain emergency funds, the Survey hoped to resume its long-term research and mapping projects. By that time, however, Germany, Italy, and Japan were already perceived to he aggressor nations. Beginning in the mid-1930's. both the Survey and the Bureau of Mines had called attention to the need for strategic-mineral investigations. The need for a national mapping program had been outlined as early as 1934. Strategic-mineral investigations were begun in 1938 with funds from the Public Works Administration. Congress passed the Strategic Materials Act in June 1939 and appropriated funds for strategic-mineral studies in August, only days before Hitler's armies marched into Poland to begin World War II.

WORLD WAR II

Topographic mapping of strategic areas in accordance with military priorities was begun in 1940. In 1940 also, the State Department allotted funds to the Geological Survey to begin investigations in cooperation with other American republics to identify mineral deposits of potential importance in hemisphere trade.

The Japanese attack on Pearl Harbor on December 7, 1941, abruptly ushered the United States from defense to war and united Americans in a determination to defeat the Axis powers. For the next several years, the Geological Survey bent its entire energies to the war effort. The Geologic, Topographic, Water Resources, and Conservation Branches each made its own special contribution.

Production, the keystone of the American effort, was based on metals and other raw materials, which were the province of the Geologic Branch. The strategic-minerals program begun in 1939 as an adjunct to the geologic program was gradually extended from seven strategic minerals to base metals to nonmetallic resources, especially oil, and to rare metals. Geologists, geophysicists, chemists, physicists, petrologists, and paleontologists were all drawn into service, and the Geological Survey reached out to universities and industry to recruit others. The search for needed resources covered not only the United States but also, under the auspices of the State Department or the Board of Economic Warfare, Latin America and other foreign areas. New methods were devised to aid in the search, among them airborne magnetic surveying, which the Survey developed in cooperation with the Navy, and geochemical prospecting. In addition to its work with raw materials, the Geologic Branch formed a group that used the

Figure 36. Geologist operating airborne magnetic equipment, 1945.

extensive library resources to prepare terrain reports on strategic areas for military engineers. Eventually several members of the group joined the engineers in the war theaters. The Topographic Branch continued the strategic mapping program on behalf of the War Department until the threat of invasion passed and then became deeply involved in the production of maps of foreign areas for the military. The trimetrogon mapping program was developed for rapid production of aeronautical charts, at first of Alaska and then of other areas of the world as well. The Water Resources Branch supplied information on the quantity, quality, and availability of surface and ground water needed for cantonments, naval stations, military hospitals, training fields, airfields, manufacturing plants, and a host of other purposes in more than 15,000 special reports. The Conservation Branch was stretched to cover the greatly expanded production of mineral resources from the public lands.

In 1943, as the Federal Government began planning for the postwar era, Director Mendenhall, who had served 2 years beyond then mandatory retirement age by Presidential exemption, was succeeded by William Embry Wrather. For most of his life, Wrather, a graduate of the University of Chicago who had been a Survey field assistant in 1907, had been an eminently successful consulting petroleum geologist, but when he was named Director he was Associate Chief of the Metals and Minerals Division of the Board of Economic Warfare. In the fall of 1943, Wrather was a member of the small mission sent by the Petroleum Administrator for War, Harold Ickes, to appraise the petroleum resources of the Middle East, and Thomas B. Nolan, a geologist in the Metals Section who had played a leading role in the strategic-minerals program, became Acting Director. A year later, in December 1944, Nolan became the Survey's first Assistant Director. Nolan, like Clarence King, the first Director, was a graduate of the Sheffield Scientific School at Yale and also had a strong interest in research to aid the mineral industry. Nolan had joined the Survey in 1924, after receiving his doctorate from Yale, and his abilities had been quickly recognized. While still only an Assistant Geologist, he was made chief of the Gold Hill project in Utah, and his study of the Tonopah mining district in Nevada helped to revitalize the district. In 1933, the International Geological Congress had awarded him its Spendiarov Prize as a particularly promising young geologist. The Assistant Director was expected to be the principal assistant and deputy to the Director in the general administration of the Survey and representative and deputy of the Director on official or technical committees or in conferences with the officers of the Department, other Federal agencies, and cooperating agencies. In corporate terms, Nolan was the Chief Executive Officer of the Survey and Wrather the Chairman of the Board in the effort to ensure full use of Survey resources in winning the war and in the postwar world.

POSTWAR AND COLD WAR

World War II was a watershed in the history of the U.S. Geological Survey. Wartime developments in science and technology provided new tools for the solution of prewar problems that had been put aside and new ones created by the exigencies of the war. The contribution of science to the security and prosperity of the Nation was more widely recognized than ever before, and greater demands were made for both traditional and innovative research in solving postwar problems. The growth of the Geological Survey, begun under the spur of war needs, continued after 1945, and thus within only a few years, the Survey had become a very different organization than the prewar Survey.

Some of the postwar problems faced by the Survey at the end of the war were reminiscent of those after World War I. Half the Nation, including a large part of the public lands, was still without topographic maps, and many of the available maps were inadequate to meet the needs of the postwar world. Geologic mapping of the country was even less complete. Less than 10 percent of the country had been mapped geologically on scales suitable for an appraisal of natural resources and land potential to meet modem needs,

and the rate of mapping possible with funds available was only one-sixth of that needed to complete the job by 1980. Base-metal reserves had been greatly depleted during the war, the limit of the Nation's capacity to produce efficiently from known oil fields had been reached, and appraisal of coal reserves and the search for new supplies was considered urgent.

The Geological Survey prepared a plan to provide adequate topographic maps for the entire Nation within 20 years, needing only funds to implement it, planned major studies on copper, lead, zinc, iron, and the ferroalloy metals, and the continuation or expansion of regional studies to aid the search for new petroleum supplies.

There were new problems as well. The United States was accounted a have-not nation in radioactive raw materials, and wartime technological developments had created needs for many other rare elements, such as beryllium and tungsten, Development of the Missouri River Basin by coordinated projects of the Bureau of Reclamation and the Corps of Engineers, authorized by Congress in December 1944, would begin as soon as the war was over. The Survey would be called on to conduct an extensive topographic-mapping program, an intensive multiyear program of hydrologic data collection and investigations, and geologic investigations to help determine the availability of construction materials, suitability for irrigation, susceptibility to landslides, and water-holding capacity of various sites. Survey scientists and engineers also continued to serve in foreign areas. Under the auspices of the State Department, cooperative projects were continued in several Latin American countries. Several members of the Military Geology Section were assigned to the Natural Resources Section, General Headquarters, Supreme Allied Powers, in Tokyo, where they formed the main part of the Mining and Geology Division. Geologic and hydrologic studies were also made in Korea, and two geologists were assigned to the general engineer district in Manila to make surveys of construction materials to aid in the rebuilding of Manila and to cooperate in a program designed to develop the valuable mineral deposits of the Philippine Islands.

Both the Geologic and the Topographic Branches reorganized to cope better with postwar problems. The Geologic Branch was divided in the fall of 1945 into two groups of sections, one of economic geology, the other of basic and engineering sciences. Included were sections for new specialties in foreign geology, engineering geology, military geology, and geophysics. The Topographic Branch established two staff divisions, Plans and Coordination, and Research and Technical Control, on January 2, 1946, to prepare for an immense mapping effort with new mapping techniques. In a major change, on July 1, 1946, the topographic mapping facilities and commitments of the Alaskan Branch were transferred to the Topographic Branch. In October, the Alaskan Branch was dissolved as a major organizational unit and its geologic staff transferred to the Geologic Branch. The Water Resources Branch had an almost complete change of management in 1946 with a new Chief Hydraulic Engineer, new chiefs of the Surface Water, Ground Water, and Quality of Water Divisions, and a great increase in the number and size of State-level district offices. Then on January 1, 1949, as the Survey approached its 70th birthday, its time-honored nomenclature for organizational units was changed to conform to usage in other parts of the Federal Government. The Branches became Divisions, the Sections became Branches, and the former Divisions lost any distinguishing title.

Science and the management of natural resources received increased attention in both the domestic and foreign policy of the administration. In September 1945, President Harry Truman, concerned about petroleum resources, claimed Federal authority over the Continental Shelf and provoked a legislative and judicial battle, eventually settled in 1953 when the coastal States were given authority over submerged lands to a maximum distance of 3 geographical miles. In 1946, the Atomic Energy Commission and the Bureau of Land Management were established. In 1947, the President's Scientific Research Board called for an increase in annual expenditures for research and development and an increased emphasis on basic research. In his inaugural address in 1949, President Truman called for U.S. capital and technical assistance to underdeveloped areas of the world. In 1949, also, the Hoover Commission on the Reorganization of the Federal Government proposed a new role for the Department of the Interior in the development of subsoil and water resources, and the Senate and House held joint hearings in search of an improved policy for the conservation, development, and administration of the natural resources. In January 1950, the President appointed a Water Resources Policy Commission to recommend a comprehensive policy for water resources and related land-use development; in May 1950, the National Science Foundation was established and a new office, of the Assistant Secretary for Mineral Resources, was established in the Department of the Interior.

The scientific programs were expanded as increased funds became available. At first, Congress was amazed at the amounts the Survey requested in its first postwar budgets, and appropriations were far less than was requested, but transfers of funds from other Federal agencies, notably the Department of Defense, the Atomic Energy Commission, and the Bureau of Reclamation, together with cooperative funds from the States, made the total available about twice the appropriation. After the initial shock, Congress increased appropriations to more than $15 million for the fiscal year beginning July 1, 1949, and more than $19 million for the fiscal year beginning July 1, 1950.

By 1950, the Geological Survey began undertaking investigations in new areas to meet the demand for current information. Geologic mapping was needed in fast-growing

industrial areas to provide geologic data for the many types of engineering construction. The demand for construction of large dams to impound water for irrigation, power development, flood control, and industrial use focused attention on the need for information on the effect of waterloss by evaporation and the limitation of the useful life of reservoirs by deposition of sediment as well as on stream flow and sediment load. The heavy drain on ground-water resources during the war had resulted in critical conditions in many areas; saltwater encroachment was a subject of special concern in some coastal areas. Efforts to upgrade the Nation's highways required hydrologic data and flood studies to aid highway drainage design. When funds were appropriated for technical assistance programs, Survey scientists and engineers took on assignments in the Eastern Hemisphere, and the Survey extended its in-service training program in geology and the administration of research organizations for promising young scientists of Latin American countries to scientists of the Eastern Hemisphere countries.

THE KOREAN WAR

In late June 1950, the uneasy peace that followed World War II was shattered by the outbreak of hostilities in Korea, and defense again became the underlying theme of national policy. The Geological Survey made an effort to continue the regular program, but of necessity the staffing of defense activities caused delays or interruptions in other programs. About three-fourths of the mineral-deposits investigations were focused on strategic minerals. The military geology program was expanded, as was the search for radioactive raw materials. The new program of urban geology was accelerated to aid in civil defense. In response to a request from the Army's Corps of Engineers, the topographic mapping program was expanded in an effort to complete mapping of about 600,000 square miles of strategic importance in 6 years. A unit newly established to investigate the quantity and quality of water required to produce various manufactured products began with an investigation of the needs of the steel industry. The Geological Survey was also given new responsibilities under the Defense Production Act of 1950, which provided for stockpiling of critical materials, including, for the Defense Minerals Administration, the evaluation of applications for loans and the preparation and enforcement of contracts for the loans. The Petroleum Administration for Defense called on the Survey to make a special geologic investigation of the newly discovered Scurry Reef in Texas to aid in planning its development. At the same time, activities in foreign geology increased in scope and tempo under the Mutual Security Act of 1951.

The Korean War heightened concern about long-term materials supply in a world that felt threatened by Soviet expansionism. In January 1951, President Truman established a Presidential Commission to make an objective inquiry into the major aspects of the problem. The Survey furnished a full-time liaison and consultant and made studies of marginal ore reserves of several mineral commodities and of exploration and discovery practices for several important minerals for the Commission. The Commission in its report in June 1952 concluded that both the Government and private citizens must be involved in ensuring a long-term supply and that the effort should be carried on "not periodically at wide-spaced intervals, but day by day and year by year."[32]

A cease-fire and armistice in Korea had been proposed in June 1951, 6 months after the Commission was appointed and a year before it issued its report, but the truce talks were stalemated for 2 years so there could be no complete return to peacetime conditions. When the armistice was finally concluded in the summer of 1953, a new Republican administration with a different perspective and the avowed purpose of reducing Government spending, balancing the budget, and reducing taxes had taken over in Washington. President Dwight Eisenhower called for a cooperative effort in resource development to "level off peaks and valleys"[33] in the economy, but the Appropriations Committee concluded that the Interior Department should be concerned only with functions or activities that private enterprise could not or would not undertake. Progress in the development of a minerals policy was suspended.

THE SURVEY AT 75

For its 75th year, beginning July 1, 1954, the Survey had 7,000 employees, appropriated funds of $27,750,000, and total funds, including those from other Federal agencies and the States, of nearly $48.5 million. Its methods of work had changed markedly in the decade since the end of World War II. The Survey had been given responsibility by the Bureau of the Budget for the National Topographic Map Series of the United States and for exercising government-wide leadership in coordinated planning and execution of mapping activities of the Federal Government. Although only 33 percent of the topographic mapping of the Nation met modem standards, the use of aerial photographs and photogrammetric methods for production of most topographic maps, the continuing development of more accurate instruments and methods, and the use of helicopters to transport topographic engineers to mountaintops and other remote spots to obtain survey control measurements resulted in a significant increase in the amount of mapping accomplished each year. Data on streamflow were being obtained at some 6,400 gaging stations, about 500 ground-water investigations were in progress, and the chemical quality of more than 85,000 samples of water was being

Figure 37. A helicopter landing topographic engineers and equipment for triangulation, 1953.

Figure 38. Thomas Brennan Nolan, Director of the U.S. Geological Survey, 1956-1965.

determined in Survey laboratories. In addition, studies of the water requirements of industry, of flood frequency and low flow, of sedimentation, and of flow in open channels and through constrictions were underway. Geologic mapping and mineral-resources investigations were still being carried on, but geologists were adapting photogrammetric methods to their mapping, making use of physics and chemistry in their studies, and applying modem statistical methods to problems of field geology. Geophysicists were keeping two aircraft busy making airborne magnetic and radioactivity surveys, chemists were devising faster and more accurate analytical methods, and the Survey acquired an electron microscope, a mass spectrometer, and an electronic computer. The Survey had responsibility for supervising more than 100,000 lessee operations on mining or oil-and-gas properties on public, acquired, or Indian lands and, since 1953, of oil-and-gas lease operations on the Outer Continental Shelf. Rent and royalty income from supervised operations was $73.5 million.

A NEW AGE BEGINS

In January 1956, after Director Wrather retired because of illness and age, Assistant Director Thomas B. Nolan became the Survey's seventh Director. During his 11 years as Assistant Director, Nolan had many times and for extended periods served as Acting Director so no transition period was needed. Nolan believed that geologists, because of the unique requirements imposed on them by their science, should expand their fields of interest from individual problems and "participate actively and authoritatively in the matters affecting the whole country."[34] Until September 1965, when he resumed his research in Great Basin geology, Nolan pushed, prodded, and led the Survey to a broadened and intensified commitment to basic research, to the advancement of geology in the public service, and to the prompt publication of Survey results. As Assistant Director, he had also served as the Interior Department representative on the Interdepartmental Committee on Scientific Research and Development, on the Scientific Advisory Committee on Specialized Personnel to the Selective Service Committee, and on the Advisory Board on Education of the National Academy of Sciences, and had been president of the Society of Economic Geologists. As Director, his professional responsibilities outside the Survey were still further extended to service as vice president and president of the Geological Society of America, as vice president of the International Union of Geological Sciences, and on committees advisory to university geology departments.

Science and technology by this time were helping the Nation to meet many of its increasing demands for raw materials through improved methods of exploration, the ability to exploit lower-grade sources, and the substitution of common for less common materials, but new dimensions were added to the problem. Overspecialized exploitation of mineral resources in some areas caused economic problems; competition for resources, where development of one pre-

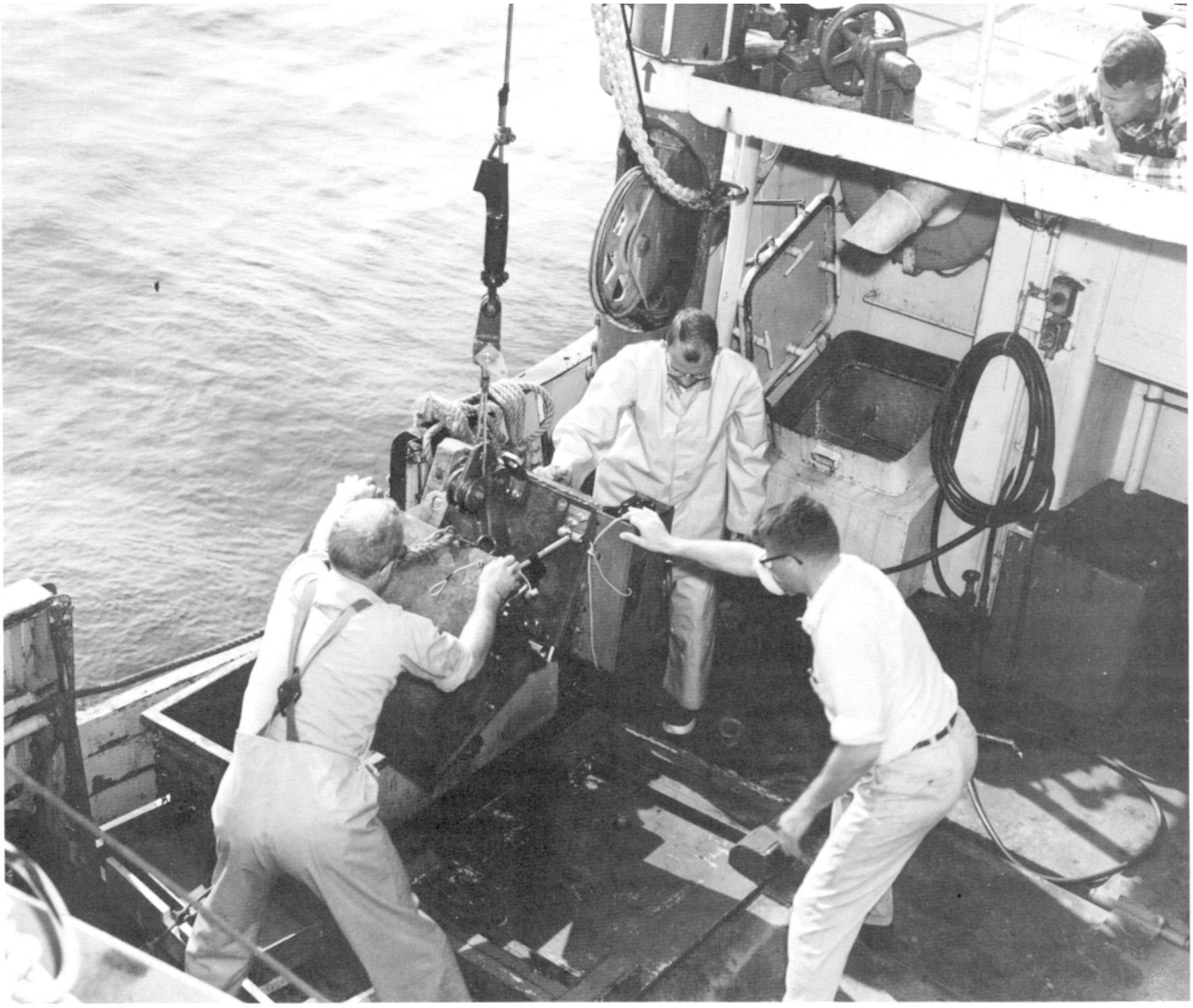

Figure 39. Marine geologists preparing sampling buckets to study the sea floor, 1962.

cluded use of others, created resource-management problems; the increasing industrial development and urbanization were creating wastes that caused health hazards and heightened vulnerability to damage by natural geologic processes. The Geological Survey in turn added new dimensions to its own investigations. In 1956, the Geological Survey began an evaluation of the effects of underground nuclear explosions at the Atomic Energy Commission's Nevada Test Site; that program was expanded to study the geologic and hydrologic conditions affecting the peaceful uses of atomic energy and the disposal of radioactive wastes. Geochemical exploration techniques, developed to aid the search for mineral resources, were adapted to investigate subtle differences in the natural distribution of chemical elements that might have a bearing on public health. Studies of geologic processes led to measures to protect the public from natural disasters; for example, research at the Hawaiian Volcano Observatory not only provided new understanding of the formation of ore deposits but also aided in the prediction of volcanic eruptions.

On October 4, 1957, Soviet scientists, investigating upper atmosphere conditions as part of the International Geophysical Year program, launched a rocket-powered artificial satellite "Sputnik" into orbit, astonishing the world and ushering in a new era in the sciences. The United States joined the race to explore space by putting Explorer I into orbit on January 31, 1958, and Vanguard I on March 17, 1958. In December 1958, Director Nolan, speaking at the meeting of the American Association for the Advancement of Science, remarked that the early work of the Geological Survey had been characterized by a transition from exploration of a geographical to an intellectual frontier, but

Figure 40. An astronaut in the Survey training program for geologic investigations of the Moon, 1963.

demands by younger scientists for studies of the geography of outer space might soon inaugurate a new cycle in the history of the Geological Survey. In 1959, the Survey compiled a photogeologic map of the Earth's satellite, the Moon, and began studies of tektites and impact craters. On May 25, 1961, President John F. Kennedy proposed as a goal "landing a man on the moon and returning him safely to earth"[35] before the end of the decade, and in 1963, the Geological Survey, in cooperation with the National Aeronautics and Space Administration, began to train astronauts in geology and to investigate and evaluate methods and equipment for geological and geophysical exploration of the Moon.

Congress had by that time already expanded the Survey's Earth-bound investigations, to Antarctica and the Trust Territory of the Pacific Islands in 1958, and to "outside the national domain"[36] in 1962. In 1962, the Geological Survey began a program of marine studies to identify and evaluate potential mineral resources on or beneath the sea floor and to aid in solving the problems caused by rapid population growth, urbanization, and industrial expansion in coastal areas. Both the Geologic and Water Resources Divisions modified their internal organizations to deal more effectively with multidisciplinary investigations and research.

Under the Kennedy-Johnson administration in the early 1960's, appropriations were increased significantly, and total funds available for the fiscal year beginning July 1, 1964, for the first time exceeded $100 million, more than double the amount available just a decade earlier. In 1964, the Geological Survey again prepared a long-range plan for its future. Research functions were obviously not susceptible to a definite schedule, but some phases of the work, such as the topographic mapping of the Nation, were planned for orderly progression toward completion. Standard 7.5- and 15-minute quadrangle maps had been published for approximately 60 percent of the total area of the United States, and advance prints were available for another 9 percent. The long-range plan called for completing the topographic maps of the United States and outlying areas in either 7.5- or 15-minute series by fiscal year 1976 and the 7.5-minute series for all areas of the United States except Alaska by fiscal year 1981. Research would be continued in mapping systems and cartography, and the applications of electronic measuring systems and data-processing systems investigated. An increase of approximately 50 percent in the collection of basic water data was planned for the decade 1964-1973, as well as the development and testing of digital recording equipment and processing of water data by automation by 1968. Generalized or detailed ground-water information would be available for 75 percent of the country and reconnaissance information for the remainder by the end of 1974. Research would be increased to approximately 25 percent of the water-resources program. Research in economic geology, engineering geology, regional geology, and experimental geology would be doubled to meet the accelerating needs for resources and to provide the basic geologic data for urban expansion, engineering construction, and other purposes. The marine program would map and evaluate the composition, structure, and resources of the ocean floor and study geologic and hydrologic processes that operate within the oceans to understand better the conditions under which ancient sediments and ore deposits were formed. For the attainment of these goals, the Geological Survey recognized that the cooperative relations with States and other Federal agencies which it had long enjoyed were essential.

In 1964, however, new responsibilities were thrust upon the Geological Survey. One of the greatest earthquakes of all time struck south-central Alaska on March 27. Within a few hours, the Survey began a scientific and engineering study that extended through several field seasons and provided a very thorough documentation of a natural disaster. Survey geologists were also assigned to the Task Force of the Federal Reconstruction and Development Planning Commission and helped select sites for rebuilding the devastated area. In October 1965, following public release of a report by an Ad Hoc Panel of the President's Office of Science and Technology, the National Center for Earthquake Research was established in Menlo Park, Cali-

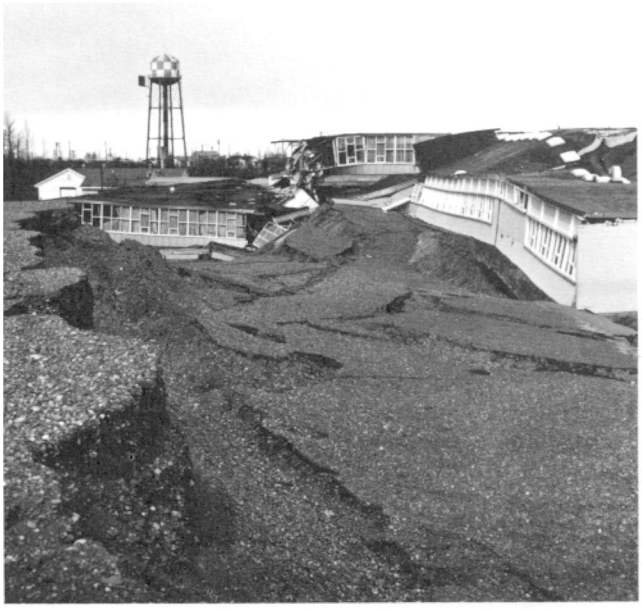

Figure 41. A major earthquake in 1964, which destroyed this elementary school in Anchorage, Alaska, spurred efforts to predict earthquakes.

fornia, to provide a focus for research on the causes, mechanics, and effects of earthquakes and on the development of methods for predicting the time, location, and destructive effects of earthquakes to reduce the loss of life and property.

On August 28, 1964, the Bureau of the Budget gave the Department of the Interior responsibility, which the Department then delegated to the Geological Survey, for the design and operation of the national network for collection of water data so that water information needed for effective development and management of water resources would be collected in a timely, effective, and economical fashion, and would be readily accessible at a single focal point. The Geological Survey in turn established an Office of Water Data Coordination. The new organization of the Water Resources Division made it possible for the Division to deal more effectively with multidisciplinary hydrologic studies and research needed for better water-resources and environmental management. The Division had also instituted intensive programs in hydrologic training and aided in establishing curricula in hydrology in leading universities.

On September 3, 1964, Congress passed the Wilderness Act, by which 9.1 million acres of national forest lands were made part of the National Wilderness Preservation System to be safeguarded permanently against commercial use and construction of permanent roads and buildings. New mining claims and mineral leases would be allowed only until December 31, 1983. The Geological Survey and the Bureau of Mines were authorized to assess the mineral resources of each area proposed or established as wilderness if no prior mineral survey had been made, and a new program of geologic mapping and mineral-resource assessment was begun.

In June 1964, President Lyndon Johnson, in proclaiming U.S. participation in the International Cooperation Year, said "I propose to dedicate this year to finding new techniques for making man's knowledge serve man's welfare. Let this be the year of science."[37] In January 1965, he proposed a vast program to build a "Great Society," which he assumed could be financed without additional taxation. Among the measures passed by Congress in 1965 were such conservation measures as the Water Quality, Highway Beautification, Clean Air, and Solid Waste Disposal Acts. In the spring of 1965, however, the United States began to increase its commitment to support the anti-Communist regime in Vietnam, begun in the Eisenhower administration, and in his budget message in January 1966, President Johnson acknowledged that the appropriation of funds for increased commitments in Vietnam would hinder domestic programs.

In late September 1965, Chief Geologist William T. Pecora succeeded Thomas B. Nolan as Director. Pecora, who received his bachelor's degree from Princeton in 1933 and his doctorate from Harvard in 1940, joined the Geological Survey in 1939. For several years, he investigated strategic-mineral deposits in the United States and Latin

Figure 42. William Thomas Pecora, Director of the U.S. Geological Survey, 1965-1971.

America and then engaged in a long-range study of rare mineral deposits in volcanic rocks and carbonatite complexes in Montana. He was elected to the National Academy of Sciences in 1965. He had also had administrative experience as Chairman of the Civil Service Board of Examiners and Chief of the Geochemistry and Petrology Branch before becoming Chief Geologist. Pecora was Director for only a few years; in April 1971, he left the Geological Survey to become Under Secretary of the Interior.

The late 1960's were troubled times in the United States, marked by student unrest, racial demonstrations, racial violence, and increasing opposition to the war in Vietnam. Survey appropriations were not decreased, but the rate of increase was considerably less than it had been. Pecora's administration became an interesting blend of old and new problems and solutions. The Geological Survey had been established in an era of monetary uncertainty, in its first year it had concentrated on a study of some of the great precious-metal mining districts, and it had responded to other monetary crises in the 1890's and 1930's. In 1965, the U.S. gold stock, which had been steadily declining since 1949 despite government efforts to stem the deficit in balance of payments, was a matter of concern. In April 1966, the Geological Survey and the Bureau of Mines began a joint program to stimulate domestic production of a group of metals that were in short supply, about 90 percent of the program effort at the start being on gold because of its international monetary importance. On the basis of the Geological Survey mapping, a mining company located by drilling a major gold mine, the first major gold discovery for several decades. Another major project in the Survey's first year had been a study of the iron-ore resources of the United States. In the early 1900's, it had begun studies of western iron ores in an effort to meet industrial demands. After World Wars I and II there had been major studies of iron districts, and in the late 1960's, appraisals of the iron-ore resources of the United States were again prepared, this time for inclusion in a United Nations survey of the world's iron-ore resources.

Sixty years earlier, the Geological Survey had made its first appraisal of the petroleum resources of the Nation. Periods of oil shortages and oil gluts had followed, but World War II had seriously depleted domestic petroleum resources. The continuing concern over energy resources gave rise to a study of world resources of oil, gas, natural-gas liquids, oil shale, and coal. In the ongoing search for domestic resources, new sources were discovered, but their exploitation was not simple. In 1968, for example, a giant oil field was found in Alaska's Arctic Slope, near where the Survey had first made reconnaissance studies in 1923. The oil would help ease impending shortages but transportation of that oil, whether by tanker or pipeline, posed the possibility of damage to the environment. More than 100 billion tons of coal were estimated to be potentially recoverable by open-pit mining techniques, but plans had to be developed to restore and utilize the strip-mined lands. About 1.8 million acres of land in the Western States were classified as potential sources of geothermal energy, but a new industry would be required to exploit them. At the same time, new studies and investigations in space, under the sea, and on land were expanded.

The space program was centered in the Astrogeologic Laboratory established in October 1965 in Flagstaff, Arizona. In July 1969, two astronauts, trained by the Survey, walked on the Moon as the program called for by President Kennedy in 1961 met his objective of landing men on the Moon before the end of the decade. A Survey geologist turned astronaut also walked on the Moon in one of the later missions. Director Pecora took a personal interest in a program aimed at gathering facts about the Earth's resources from orbiting satellites carrying sophisticated remote-sensing instruments, and the Geological Survey was given direction and management of an Interior Department program to achieve this goal.

The marine program led to a report on resources of the sea beyond the Continental Shelf, summarizing the potential and known mineral resources and the technology for their exploration and exploitation, presented to the U.S. Economic and Social Council in 1968.

In January 1969, as the Nixon administration took office, oil leaking from a well on a Federal Outer Continental Shelf lease in the Santa Barbara Channel off California blackened nearby beaches and threatened marine life. Studies by a task force including Survey geologists and engineers led to new and more stringent operating regulations to prevent or control such incidents in the future. The Santa Barbara oil spill was a catalyst in the passage of the National Environmental Protection Act in January 1970.

In 1970, the Geological Survey published the "National Atlas of the United States of America," a reference tool comprising more than 700 physical, historical, economic, sociocultural, and administrative maps compiled through the combined efforts of more than 80 Federal agencies and a score of specialists and consultants over a period of several years. In cooperation with the Department of Housing and Urban Development, the Survey began a pilot study in the San Francisco Bay region of the application of geology, geophysics, hydrology, and topography in improving regional urban planning and decisionmaking. The Survey also played a major role in representing the United States at meetings of the United Nations Committee on the Peaceful Uses of the Seabeds and Ocean Floors Beyond the Limits of National Jurisdiction.

In 1971, after Pecora became Under Secretary of the Interior, Chief Geologist Vincent E. McKelvey, a career scientist with the Survey since 1941, became Director. McKelvey, a graduate of Syracuse University with a doctorate from the University of Wisconsin, had served in several research and administrative capacities in the Geo-

Figure 43. An oil spill off Santa Barbara, California, in 1969 was a catalyst in the passage of the Environmental Protection Act of 1970.

logical Survey. He was internationally known for his studies of phosphates, had headed the Survey's program of exploration and research for the Atomic Energy Commission for several years, had been deeply involved in sometimes controversial estimates of long-range energy and mineral-resource needs, and had most recently been engaged in studies of seabed resources.

In the year that McKelvey became Director, the Geological Survey had an operating budget of $173 million and 9,200 employees. Investigations and mapping were underway in all 50 States, Antarctica, and the Trust Territories, and technical-assistance programs were being carried out in Latin America, Africa, and Asia. Great strides had been made toward accomplishing the goals set forth in 1964. General-purpose topographic maps were available for 84 percent of the total area of the 50 States, Puerto Rico, the Virgin Islands, Guam, and American Samoa. Streamflow data were being collected at more than 11,000 gaging stations, water quality was being measured at 4,000 stations, and several hundred ground-water investigations were underway. Mineral production from lands supervised by the Survey was valued at more than $3 billion, and annual royalties were approaching $0.5 billion.

McKelvey's term as Director was marked by an increase in multidisciplinary studies and in the diversity and complexity of Geological Survey operations, as well as an increased effort to make scientific information acquired through years of research available in a form most easily used in the solution of such contemporary problems. The pilot study of the San Francisco Bay region was followed by several similar studies of other urban areas. The marine program assumed new significance, for many regions of the oceans were less well known than the surfaces of the planets. Subsea mineral deposits might be resources for the future, but an understanding of the behavior of marine geologic processes was also of importance if people were to

Figure 44. Vincent Ellis McKelvey, Director of the U.S. Geological Survey, 1971-1978.

live and build along coasts and out into the sea. The marine-geology investigations included oil-and-gas resource appraisal, environmental investigations assessing the potential impacts of geologic hazards on the development of offshore oil and gas resources, geochemical studies of deep-sea deposits and engineering studies of deep-sea sediments, and the development of deep-ocean remote-sensing instruments. Major efforts were made to delineate the hazards associated with earthquakes, volcanic eruptions, landslides, mudflows, ground subsidence, and floods, and advances were made toward a capability of predicting some of these disasters.

Planetary studies were extended to Mars and other planets. A program to map the geology of Mars systematically, managed by the Geological Survey but involving both Survey and university geologists, was formalized with the National Aeronautics and Space Administration in 1971. A shaded-relief map of Mars was published in 1973, and by the time two Viking spacecraft landed on the surface of Mars in the summer of 1976, at sites selected by scientists at the Survey's Flagstaff, Arizona, office, the Survey had prepared more than 100 maps of Mars, Mercury, Venus, and the Moon in support of space exploration.

The first Earth Resources Technology Satellite (ERTS-1, now Landsat-1) was launched in July 1972, beginning a new era in the acquisition and management of data. The Geological Survey established a data center at Sioux Falls, South Dakota, to handle distribution of satellite and other remotely sensed data. Investigations of the applicability of the data to geologic, hydrologic, geographic, and cartographic studies were begun.

In 1973, the Geological Survey moved its National Headquarters from downtown Washington to a new building designed expressly for its needs in Reston, Virginia. It took on primary responsibility for operational research in seismology and geomagnetism by agreement with the National Oceanic and Atmospheric Administration, and 10 units of NOAA were transferred to the Geological Survey. It also began a Land Resource Analysis program in response to the need for earth-science data in land-use planning and resource management, primarily of nonurban areas not yet critically affected by growth and development but which existing trends indicated were in danger of being seriously impacted in the future.

The long-anticipated energy crisis developed after the Arab-Israeli War in October 1973, when Arab nations embargoed oil shipments to the United States. On November 7, 1973, President Richard Nixon announced measures to address the energy crisis, including increased production from naval oil reserves, approval of the Alaska pipeline, and greater energy research and development efforts designed to make the United States self-sufficient in energy resources by 1980. In 1974, Congress directed the Geological Survey to provide a schedule and objectives for inventorying geothermal energy resources.

In 1974, the National Topographic Mapping Program became the National Mapping Program to meet the increasing demand for basic cartographic data in all forms including digital cartographic data. The National Cartographic Information Center was established to provide a focal point for information on U.S. maps and charts, aerial photographs and space imagery, geodetic control, and related cartographic data. The Geological Survey and the National Oceanic and Atmospheric Administration agreed on a program to produce topographic-bathymetric editions of the 1:250,000-scale maps for the coastal zones of the United States, including those of the Great Lakes.

In April 1975, the Land Information and Analysis Office was established to consolidate several multidisciplinary land-resource and environmental programs. One of its main objectives was to interpret and display land-resource information collected within the Department of the Interior in ways that were readily accessible and understandable to a wide range of users.

In 1976, Congress transferred jurisdiction of the Petroleum Reserve in Alaska from the Department of the Navy to the Department of the Interior, effective June 1, 1977. Responsibility for administration of the continuing petroleum exploration program on the Reserve and operation of the South Barrow Gas Field was delegated to the

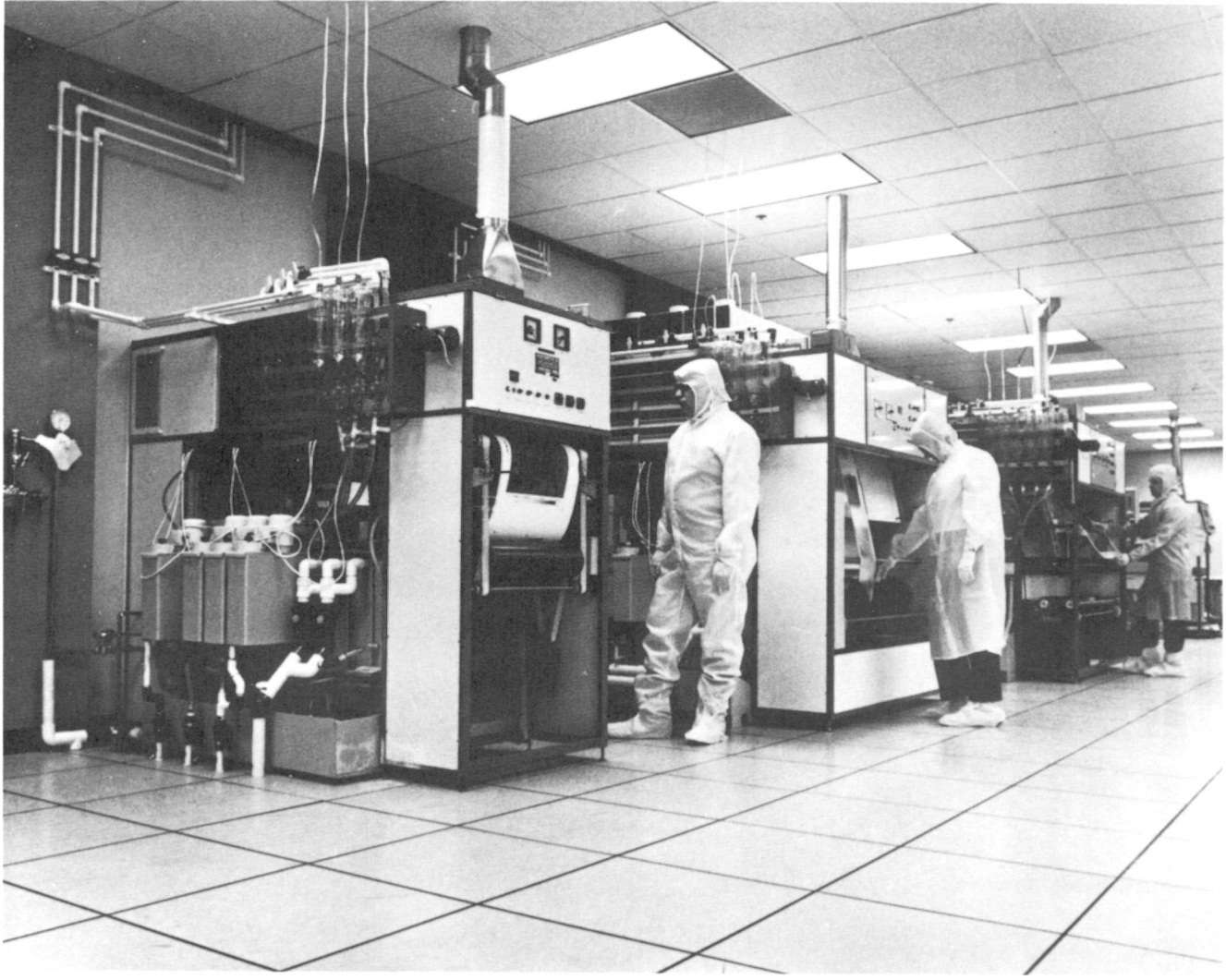

Figure 45. The photographic processing laboratory at the EROS Data Center, Sioux Falls, South Dakota, 1975.

Director of the Survey. The new activity brought with it a 50-percent increase in funds, but most of the increase was for contractual services.

In 1977, Congress directed the Survey to establish a national water-use information program. It became part of the Federal-State cooperative program and by the late 1980's, 49 States and Puerto Rico were participating in it.

In September 1977, Secretary of the Interior Cecil Andrus announced that he had accepted McKelvey's resignation as Director but that McKelvey would remain with the Survey as a research scientist. In April 1978, H. William Menard became the Survey's tenth Director but remained only through the balance of the Carter administration. Menard, who had graduated from the California Institute of Technology in 1942 and received a doctorate from Harvard in 1949, had been a marine geologist with the Naval Electronics Laboratory in San Diego for several years and then had become a member of the faculty of the Scripps Institution of Oceanography. In 1965-66, he was associated with the Office of Science and Technology in the White House. A member of the National Academy of Sciences, Menard was a recognized worldwide authority in marine geology and oceanography and had discovered notable topographic and structural features of the sea floor that laid much of the foundation of the plate-tectonics revolution in geology.

THE SURVEY AT 100

For Menard's first full fiscal year in office, a year that included the centennial of the establishment of the U.S. Geological Survey, the Survey's appropriation was about $640 million, augmented to 3.7 times the appropriation for the fiscal year 1972 for contractual services in connection with the operation of the National Petroleum Reserve and

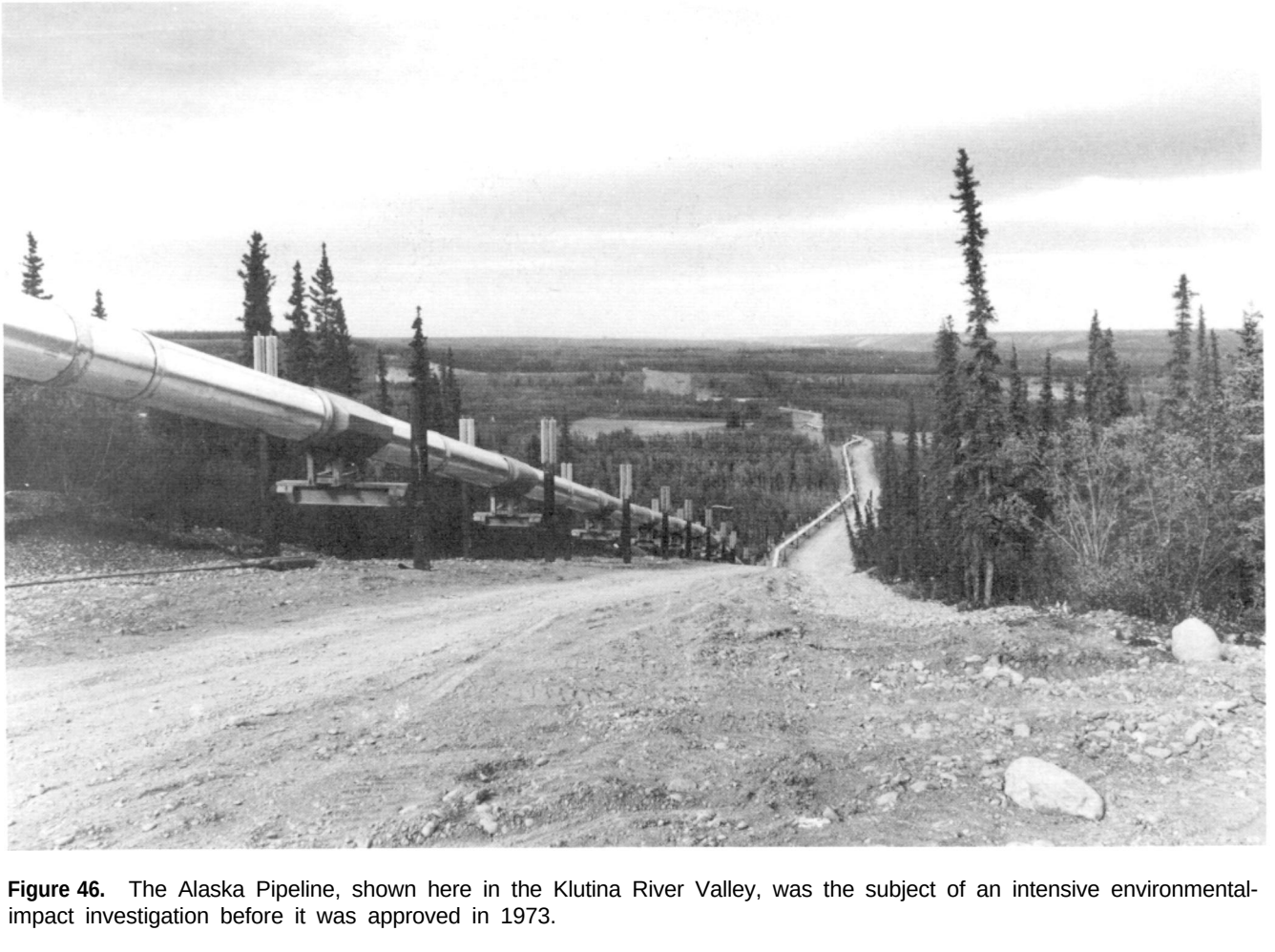

Figure 46. The Alaska Pipeline, shown here in the Klutina River Valley, was the subject of an intensive environmental-impact investigation before it was approved in 1973.

by the persistent inflation of the 1970's. The total funds available were about $765 million. The Survey staff numbered more than 12,000 scientists, engineers, technicians, and administrative and support personnel, about three-fourths of them full-time employees.

The 100th anniversary of the establishment of the Survey, one of only a very few Federal agencies to survive for 100 years with its original name and mission unchanged, was celebrated in ceremonies at the National Center and other major facilities on March 2 and 3, an international symposium in the fall of 1979 on resources for the 21st century, in symposia or technical sessions at meetings of the Geological Society of America, the American Association for the Advancement of Science, the American Chemical Society, the American Association of Petroleum Geologists, the National Academy of Sciences, the American Congress on Surveying and Mapping, and the American Society of Photogrammetry, and in articles in newspapers and magazines. The Survey itself issued two special publications--"Maps for America," covering the cartographic products of the Survey and other agencies, and "Minerals, Lands, and Geology for the Common Defence and General Welfare * * * Before 1879," the first of several volumes on the history of geology in relation to the development of public-land, Federal-science, and mapping policies and the development of mineral resources in the United States.

INTO THE SECOND CENTURY

Advanced age did not bring about any diminution of activity and change in the Survey, but rather the reverse. The truth of Director Walcott's statement in 1900, "Every investigation undertaken to solve some geologic problem, whether it prove successful or not, is sure to develop other problems, and the geologic Alexander will never lack worlds to conquer,"[38] was never more evident. The Survey's 101st year was marked by the largest earthquake in California in 25 years and the disastrous volcanic explosion of Mount St. Helens. In both areas, geologic-hazards investigations had previously been underway.

The earthquake, on the Imperial fault near the international boundary between the United States and Mexico, on October 18, 1979, caused $30 million in damage and generated the most comprehensive set of data on ground

Figure 47. Henry William Menard, Director of the U.S. Geological Survey, 1978-1981.

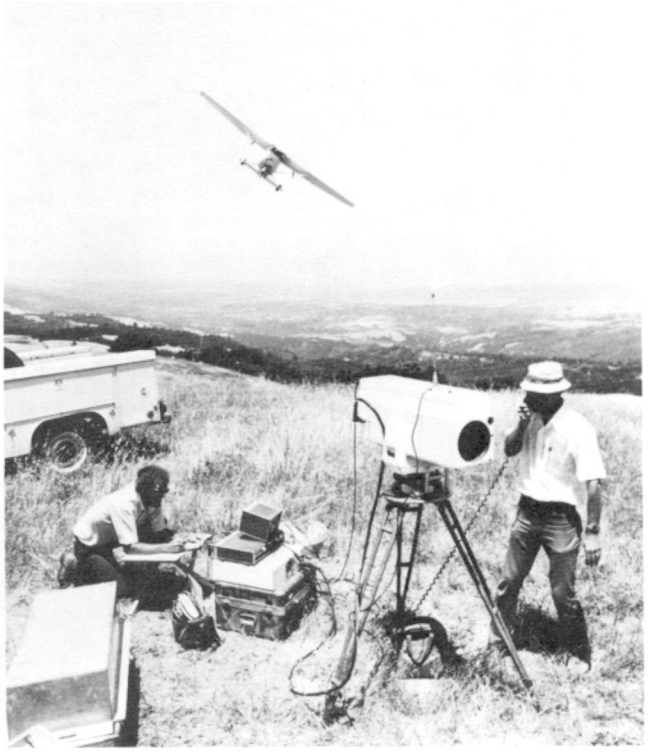

Figure 48. A geodolite survey for monitoring motion along a fault in southern California, 1978.

shaking and structural response recorded from a damaging earthquake anywhere in the world. The region had been under intensive study by scientists and engineers of the Geological Survey and other institutions because of the frequent seismic activity and the possibility of a repetition of the Imperial Valley earthquake in 1940, and the shock was thus the first damaging earthquake in California's history for which the actual surface rupture zones had been defined by careful mapping before the event.

The eruption at Mount St. Helens, in the Cascade Range of Washington, on May 18, 1980, removed about 1,300 feet of the mountaintop and filled the valley of the North Fork Toutle River with a massive debris avalanche for a distance of about 17 miles downstream. Survey geologists had pointed out in 1978 that Mount St. Helens, which had a long history of spasmodic explosive activity, would probably erupt violently in the future and that such eruptions would "affect human life and health, property, agriculture, and general economic welfare over a broad area."[39] An earthquake on March 20, 1980, immediately northwest of the summit, followed by a swarm of earthquakes directly beneath the volcano, was recognized as possible symptoms of an impending eruption by University of Washington scientists working in cooperation with the Survey in a study of the geothermal potential of the region. The Geologic and Water Resources Divisions began collecting and assessing data and, with the Office of Earth Science Applications, determined that the possibility of an eruption was great enough to issue a hazard warning. On March 27, the Geological Survey issued a Hazards Watch summarizing the potential hazards from an eruption. That same day, the volcano began to erupt steam and ash. On April 3, and again on April 30, the Survey updated its Hazards Watch, and the Governor of the State established two "hazard zones" into which access was limited. Loss of life on May 18 was thus minimized. Following the first eruption, the Geologic and Water Resources Divisions continued monitoring the volcano, and the National Mapping Division, which had compiled special maps to record preeruption changes, prepared several new special maps to aid general planning by scientists, land managers, law-enforcement officers, and emergency support personnel in the devastated area and for recording scientific and resource data.

Several changes in the Geological Survey's organization were made in fiscal year 1980. In the Office of the Director, the Land Information and Analysis Office was renamed the Office of Earth Science Applications, given more specific responsibilities to coordinate multidisciplinary multidivision programs, and strengthened by the transfer of some elements of the former Publications Division. The National Mapping Division was formed from the

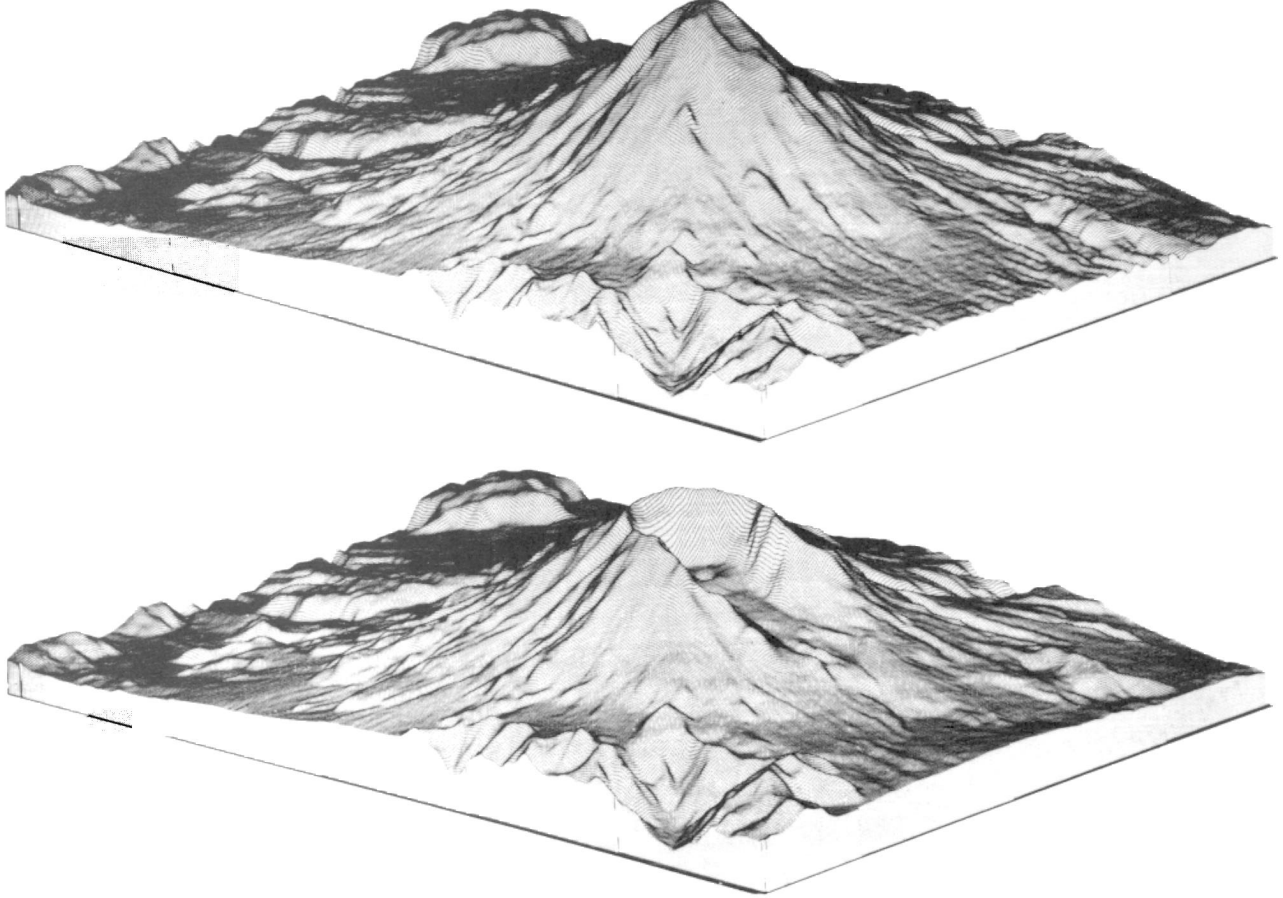

Figure 49. Digital maps of Mount St. Helens before and after the eruption of May 18, 1980.

Topographic Division, parts of the Publications Division, and the Geography Program of the former Land Information and Analysis Office. The organization of the Conservation Division was modified to separate onshore from offshore program management, increase the number of geographic service areas, and separate royalty management from field operations.

In January 1981, as the Reagan administration took office, H. William Menard submitted his resignation in order to return to research at the Scripps Institution of Oceanography in California. On September 30, 1981, Dallas L. Peck was sworn in as the eleventh Director of the Geological Survey. Peck, like Menard, was a graduate of the California Institute of Technology, in 1951, and had received his doctorate from Harvard, in 1960. He had spent his entire professional career with the Geological Survey, starting as a field assistant in 1951. Peck had been a research geologist at the Hawaiian Volcano Observatory and had made extensive petrologic studies in the Sierra Nevada, but for 4 years before becoming Director he had been the Survey's Chief Geologist.

The new administration came to Washington with a promise to increase private access to Federal lands for mineral and energy development, reduce the regulatory role of the Federal Government, accelerate and expand domestic energy and mineral production, and in general to reduce funding and staffing of Federal activities other than those related to national defense and a few other specified areas. For the Geological Survey, there were new responsibilities to replace or merge with ongoing responsibilities. In Alaska, the oil-and-gas assessment program in the National Petroleum Reserve was phased out, but the Alaska Mineral Resources Assessment Program was continued and expanded under the terms of the Alaska National Interest Lands Conservation Act of December 2, 1980.

In January 1982, part of the Survey staff and operating budget were once again split off from the Survey as Secretary of the Interior James Watt announced the formation of the Minerals Management Service. The Conserva-

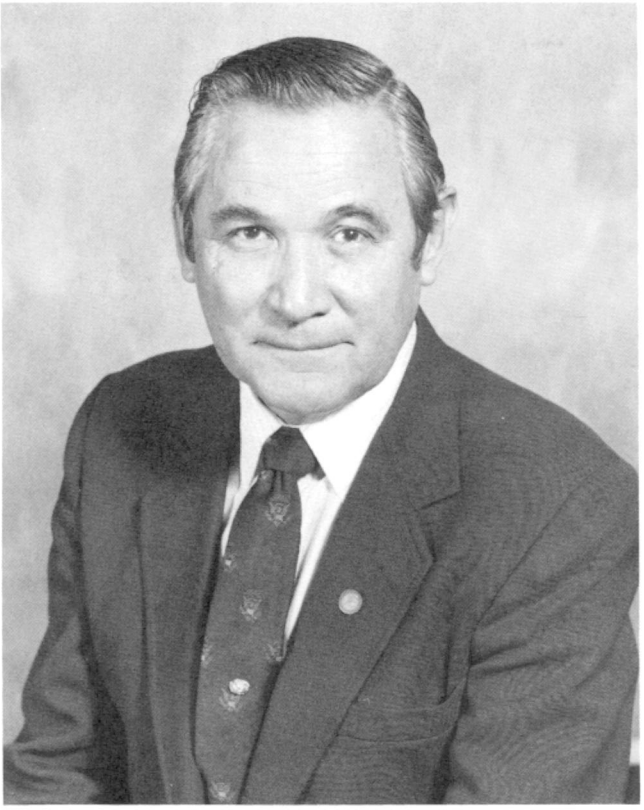

Figure 50. Dallas Lynn Peck, Director of the U.S. Geological Survey, 1981-.

tion Division and part of the marine geology program, some 23 percent of the personnel and 29 percent of the operating budget of the Geological Survey, were reassigned to the new agency, and the Survey reverted to its initial responsibilities to classify the public lands, and examine the geologic structure, mineral resources, and products of the national domain as they had developed in the years since 1879. These were organized in three major programs: the evaluation of the Nation's geologic structure and the geologic processes that have shaped it, the assessment of its mineral and energy resources, and the identification and investigation of geologic hazards; the conduct of the National Mapping Program, involving the collection of cartographic, geographic, and remotely sensed data and production of maps and related cartographic information in graphic and digital form; and the provision of the hydrologic information and understanding needed by others to achieve the best use and management of the Nation's water resources.

New challenges were not long in forthcoming. On March 10, 1983, President Ronald Reagan proclaimed an Exclusive Economic Zone (EEZ), which extended jurisdiction of the United States for a distance of 200 nautical miles seaward of the Nation's shorelines and thereby more than doubled the area of the national domain to be mapped and within which mineral and energy resources must be assessed. EEZ-SCAN, a reconnaissance survey that uses long-range side-scan sonar to map the 3 million square nautical miles in the zone, began in 1984. The initial atlas of computer-enhanced mosaics, covering the Western Conterminous U.S. portion of the EEZ at a scale of 1:500,000, was published with preliminary geological interpretations and bathymetry in 1986. Other studies provided geologic information on the nature, extent, and cause of coastal erosion for use by various Federal and State agencies in mitigating coastal retreat and land loss.

The National Mapping Division continued the quiet revolution in mapping. The development and application of advanced cartographic techniques and systems to geographic information systems was continued, a National Digital Cartographic Data Base was established, and standards of digital cartographic data were developed for the U.S. mapping community. Primary map coverage for the United States was 97 percent complete in early 1989. In 1988, in cooperation with the Bureau of the Census, the Division completed a 1:100,000-scale digital data base of the transportation and hydrology features of the conterminous United States, which the Bureau of the Census will use to generate more than 500,000 different maps needed to take the 1990 census and which will also be used for many other applications. A major new program was begun in close cooperation with the Defense Mapping Agency to develop, install, and operate new mapping technology using automated computer methods, the goal being to have data for all maps in digitized form so that the maps can be updated easily and graphic products printed on demand. The National Mapping Division was also responsible for all functions that relate to domestic geographic names, and continued to compile, publish, and maintain the "National Gazetteer of the United States of America" and to manage the National Geographic Names Data Base.

Early in 1984, the Water Resources Division published the first "National Water Summary," the product of the national water-use information program, describing hydrologic events and water conditions for the water year, providing a State-by-State overview of specific water-related issues, and identifying ground-water contamination and acid rain as two pressing water-resources issues. To improve the scientific understanding of acid rain, the Geological Survey began a study of the effects of acid deposition on lakes, streams, and aquifers as part of a program coordinated through the Interagency Task Force on Acid Precipitation.

Also published in 1984 were the first six studies of major regional aquifer systems, begun in response to the intense droughts in the late 1970's, to assess the discharge-recharge dynamics, hydrogeologic and chemical controls governing response of aquifer systems to stress, and to develop computer simulation models. Congress authorized

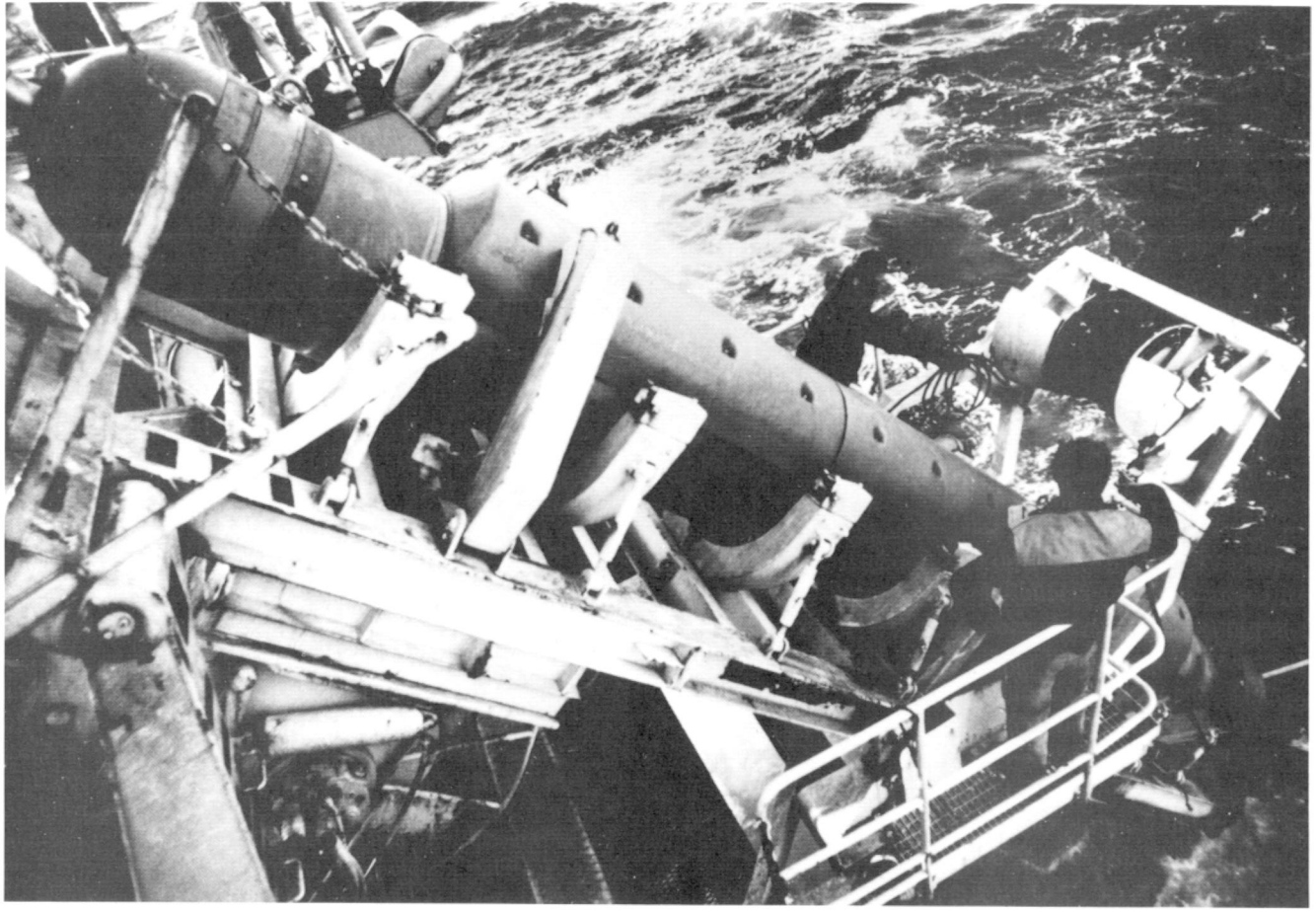

Figure 51. Launching the side-scan sonar "fish" during reconnaissance mapping of the U.S. Exclusive Economic Zone off California, 1984.

the Bureau of Reclamation to establish demonstration projects for ground-water recharge of aquifers in the High Plains States.

The disposal and release of hazardous chemical and radioactive wastes and ground-water contamination problems were also under investigation to provide data to help alleviate their effects on the Nation's water resources, some of them to assist the Department of Energy in developing procedures and guidelines for identifying suitable waste disposal sites.

Now several years into its second century, the Geological Survey continues to fulfill its original mission of classification of the public lands and examination of the geological structure, mineral resources, and products of the national domain. It continues to conduct research both on the cutting edge of science and with reference to economic and other issues of national concern, to develop and apply innovative means of solving problems in resource management. It looks forward to a continuing challenge to advance the earth sciences in the service of the public.

NOTES

1. "classification of the public lands * * *": The phrase is taken from the Organic Act of the U.S. Geological Survey, U.S. Statutes at Large, v. 20, p. 394 [The Statutes at Large are ordinarily cited in abbreviated form as 20 Stat. L., 3941.
2. "one-third part of all gold * * *": Ordinance of 1785.
3. "not mineral lands": Opinion of the Attorney General, August 28, 1850.
4. "to examine the geological structure * * *": the phrase is taken from the Organic Act of the U.S. Geological Survey.
5. "few subjects connected with the duties * * *" and "development of these great resources * * *": Lt. Col. John J. Abert, Report of the Chief of the Topographical Bureau, *in* Report of the Secretary of War: U.S. Congress, 23d, 1st session, House Executive Document 2, 1833, p. 182.
6. "an officer skilled in the sciences * * *": James Whitcomb, Commissioner of the General Land Office, *in* House Executive Document 239, 26th Congress, 1st session, 1840, p. 7.

7."to acquire and diffuse * * *" and "practical and scientific experiments * * *": An Act to establish a Department of Agriculture, 12 Stat. L., 387.
8. "Eighteen sixty-seven marks * * *": Clarence King, *in* U.S. Geological Survey 1st Annual Report, 1880, p. 4.
9. "classification of the public lands * * *": Organic Act of the U.S. Geological Survey.
10. "classification of the public lands * * *": Organic Act of the U.S. Geological Survey.
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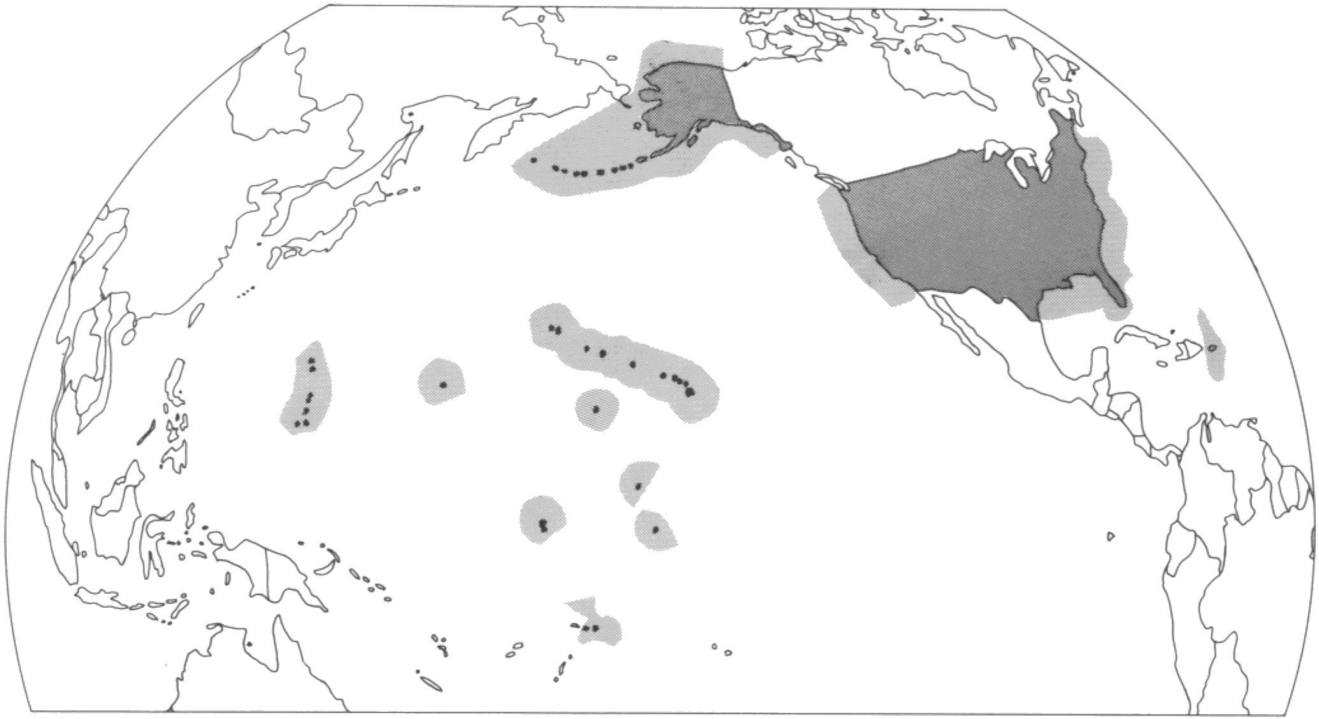

Inside back cover. The national domain, including the Exclusive Economic Zone, in 1989