The U.S. Geological Survey 75 Years of Service to the Nation, 1879–1954

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IN 75 years of professional scientific investigative work, the United States Geological Survey, Department of the Interior, has grown from an organization of 39 people to one of more than 6000. This growth has paralleled the development of the United States as a great industrial nation and has both resulted from and contributed to that development. The Survey's program, almost from the start, has been on a national scale, its activities being those that could be accomplished only by the Federal Government. Its growth, reflecting the confidence of Congress, state and other governmental units, industry, and the public in general, also indicates a continuing and vital need for its fact-finding work.

Many know something about the Survey, but the details of its history and functions are probably little known to those who are not in regular contact with it. In the words of Director W. E. Wrather, the Survey's work is seldom of a spectacular nature and does not usually produce startling headlines in the daily press.

It is our intent in this article to describe the origin, history, and work of the Survey. Such an account must necessarily be brief and sketchy; a full history of the Survey would fill many volumes. The origin and first years of the Survey are treated in some detail, as is its internal organization during those years. For later years, less detail is used and the internal organization is not described, in order to place greater emphasis on the broad results of its work. In the same way, the members of the Survey for the early years are treated at greater length than those of later years.

Published sources for this account are the annual reports of the director of the Survey, Congressional documents, biographic memoirs of the National Academy of Sciences, publications of the Geological Society of America, other scientific journals, the Institute for Government Research Service Monograph No. 1 of the United States Government, George P. Merrill's *Contributions to the History of American Geology,* and many other reports referred to in the text. In addition, unpublished administrative reports and manuscripts in the files of the Survey have been consulted. Finally, many members of the Survey have supplied material from their memories and opinions, and we are grateful for their help.

Origin of the Geological Survey

During the first four decades of the 19th century, the surveys conducted by the Federal Government were chiefly exploratory in character and were confined almost wholly to the western part of the country. Many surveys were made at an early date, most of them by the Army, partly for military use and partly to extend geographic knowledge. Among these early expeditions were the Lewis and Clark explorations of 1803–07, the Pike expedition to the Rocky Mountain area in 1805–07, the Long expedition to the Rocky Mountains in 1819–20, in which Edwin James served as geologist, the field trips of Featherstonhaugh (first man to bear the title of "U.S. geologist") to the Ozark Mountains in 1834, and the examination of the mineral lands of the upper Mississippi Valley for land-classification purposes by Owen in 1839–40 for President Van Buren.

Of these and later surveys, it was said by Clarence King (*1*), first director of the Geological Survey, that

> Up to 1867, geology was made to act as a sort of camp-follower to expeditions whose main object was topographical reconnaissance. Charged with definite objects and missions, the leaders of these corps have tolerated geology rather as a hindrance than a benefit. In consequence, such subsidiary geological work amounts to little more than a slight sketch of the character and distribution of formations, valuable chiefly as indicating the field for future inquiry.

In 1867, however, the picture changed. Between 1867 and 1869, Congress authorized three surveying expeditions in which geologic studies were the main or sole objects and a fourth in which they occupied a prominent place. The work of these surveys has been briefly and well described (*2*) as follows:

> 1) *Geological Exploration of the Fortieth Parallel.* The act of March 2, 1867 (14 Stat.L., 457) provided for "a geological and topographical exploration of the territory between the Rocky Mountains and the Sierra Nevada Mountains, including the route or routes of the Pacific Railroad." This survey was made under the jurisdiction of the War Department but its director, Clarence King, was a civilian, as were also his scientific assistants. The territory surveyed comprised a belt 105 miles in width extending from longitude 104°30′ to longitude 120°—that is, from Cheyenne, Wyoming, to the eastern border of California. The survey was primarily geological in character but included also the topography of the region. The results of the survey were published in 1870–1880 in seven volumes and an atlas. The total cost of the survey and its publications was $383,711.
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> 2) *Geological and Geographical Survey of the Territories.* The act of March 2, 1867 (14 Stat.L., 471, sec. 2) called for "a geological survey of Nebraska,

said survey to be prosecuted under the direction of the Commissioner of the General Land Office." F. V. Hayden was assigned to this work and was subsequently designated United States geologist for the territories of Colorado and New Mexico. As the work progressed, its scope was by the authority of Congress extended over all the territories and work was done in Wyoming, Idaho, Montana, New Mexico and Colorado, the total area embraced in systematic surveys reaching about 100,000 square miles. This survey was primarily geological, but its activities included work on topography, geology, paleontology, ethnology, philology, botany and kindred sciences. The results were published in a series of volumes which were issued from 1867 to 1883.

The original appropriation for this survey was only $5,000 but this was increased by successive annual appropriations of $10,000, $25,000, $50,000, $75,000, $115,000, $110,000, $95,000, $65,000, $75,000 and $75,000, as well as by a specific appropriation of $30,000 to complete maps and office work; so that the total cost of the survey amounted to $735,000 exclusive of the cost of printing and engraving and of the services of several officers detailed from the Army.

3) *Geographical and Geological Survey of the Rocky Mountain Region.* In 1867 the Smithsonian Institution began an exploration of the Colorado River. This survey was later recognized by Congress in a joint resolution, approved July 11, 1868 (15 Stat.L., 253), authorizing the Secretary of War "to issue rations for twenty-five men of the expedition engaged in the exploration of the river Colorado under direction of Professor Powell, while engaged in that work." Additional appropriations, $54,000 in all, were granted in 1870–73, the expedition still remaining under the control of the Smithsonian Institution. On the completion of the survey of the Colorado River, Powell was, by act of June 23, 1874 (18 Stat.L., 207) authorized to continue the survey in Utah under the direction of the Secretary of the Interior; and subsequent acts of appropriation authorized the extension of the field of survey to the "Rocky Mountain region." In all, the area surveyed was 67,000 square miles embracing southern Wyoming, central and southern Utah and adjacent portions of Nevada and Arizona. This survey was primarily exploratory and geographical but, in addition to the triangulation of the whole region and the establishment of the geodetic points, it included work in topography, ethnology, geology, botany, paleontology and kindred sciences.

The results of the survey were not published in full, the only printed documents produced being two brief reports in 1877 and 1878 by Powell.

Though the appropriations for the survey amounted only to $244,000, the total cost, not including engraving and printing, as stated by Powell in a letter to the Secretary of the Interior, was $279,000.

4) *Geographical Survey West of the One Hundreth Meridian.* An act approved June 10, 1872 (17 Stat.L., 367) authorized a "continuance of military and geographical surveys and explorations west of the one hundreth meridian of longitude." The survey was made under the jurisdiction of the War Department, Lieutenant George M. Wheeler, of the Engineer Corps, being placed in charge. This survey, as its name implies, covered all the territory west of the one hundreth meridian, which includes the western parts of the Dakotas, Nebraska, Kansas and Texas, the Rocky Mountain states, and the Pacific Coast states. This survey was primarily geographical or topographical, but, as was stated in the report of the Chief of Engineers to the Secretary of War on May 10, 1878 (House Executive Document No. 88, 45th Congress, 2d Session), was so made as to obtain "at the same time and as far as practicable without greatly increasing the cost, all the information necessary before the settlement of the country, concerning the branches of mineralogy and mining, geology, paleontology, zoology, botany, archaeology, ethnology, philology, and ruins."

The survey was brought to a close in 1879 and its results were published in 1875–1889 under varying titles.

The original appropriation for this survey was $75,000, but a series of additional appropriations for continuing the survey, for engraving and printing, and for completing the office work of the survey brought the total direct appropriations for the survey up to the sum of $618,644. If to this sum is added the value of the aid and supplies received from the War Department and the salaries of regular Army officers detailed to the survey, the cost of the survey appears to have been $805,340.

In writing of these surveys, King says (*1*):

> Eighteen sixty-seven, therefore, 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.
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> Congress, even then, hardly more than placed the Federal work on a par with that prosecuted by several of the wealthier States. During the years when the Federal geologists were following the hurried and often painful marches of the western explorers, many States inaugurated and brought to successful issue State surveys whose results are of dignity and value.
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> Since 1867 the Government work has been equal to the best State work, and in some important branches has taken the lead. The wisdom of the legislation which placed in the field those well organized, well equipped, and ably-manned corps is apparent in the improved and enlarged results obtained.
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> But there remained one more step necessary to give the highest efficiency and most harmonious balance to the National geological work. It was the discontinuance of the several Geological Surveys under personal leadership, and the foundation of a permanent Bureau charged with the investigation and elucidation of the geological structure and mineral resources and productions of the United States.

That there was need for such a step was beginning to be apparent in 1874. In the early 1870's, bitter rivalry had sprung up between Hayden and Wheeler. The rivalry was mainly a personal contest for prestige and appropriations, but it precipitated a hearing in the spring of 1874 before the House Committee on Public Lands. On April 15, the House adopted a resolution (*3*):

> *Resolved,* That the President of the United States

be requested to inform the House what geographical and geological surveys under different departments and branches of the Government are operating in the same and contiguous areas of territory west of the Mississippi River, and whether it be most practicable to consolidate them under one department, or to define the geographical limits to be embraced by each.

In answer to the resolution, President Grant sent a message (*3*) to the House on April 30. In this message, he transmitted the views of the War and Interior Departments and went on to say that

> Where surveys are made with the view of sectionizing the public lands, preparatory to opening them for settlement or entry, there is no question but such surveys, and all work connected therewith, should be under the direct control of the Interior Department, or the Commissioner of the General Land Office, subject to the supervision of the Secretary of the Interior. But where the object is to complete the map of the country; to determine the geographical, astronomical, geodetic, topographic, hydrographic, meteorological, geological, and mineralogical features of the country; in other words to collect full information of the unexplored, or but partially known, portions of the country, it seems to me a matter of no importance as to which Department of the Government should have control of the work. The conditions which should control this subject are, in my judgment, first, which Department is prepared to do the work best; second, which can do it the most expeditiously and economically.

He adds that he thinks the Army should do the job. The views of Hayden and Powell also accompanied the message; both men agreed that all scientific surveys should be in the Department of the Interior. The War Department recommended that all these surveys should be carried out by the Army.

Despite the hearings, no important changes were made in the surveys for 4 years. The situation changed, however, with the inauguration of Hayes to the Presidency in March 1877. Carl Schurz entered the Cabinet as Secretary of the Interior and immediately became active in efforts to reform the public-land system, a subject in which Powell took a deep interest. Reform of the public-land system and consolidation of the surveys became linked in a program fostered by Powell, which soon resulted in a struggle involving both political and scientific circles.

On March 8, 1878, John D. C. Atkins of Tennessee, Democratic chairman of the House Committee on Appropriations, had obtained passage of a resolution directing Schurz to supply information concerning possible consolidation of the surveys, and Schurz had replied with letters from Hayden and Powell which reiterated earlier discussion on a possible division of labor.

On the scientific front, new events were shaping partisanship. Joseph Henry, president of the National Academy of Sciences, died, and Othniel C. Marsh of Yale University became president. Marsh was a rival of Edward D. Cope for leadership in the field of vertebrate paleontology in America. There had been disagreements between Marsh and Hayden; Cope was an associate of Hayden as paleontologist of the Geological and Geographical Survey of the Territories. Marsh and King were in professional association, and King was in the Powell camp.

A group of Representatives associated with Abram Hewitt formed a plan to have the Academy back a reform of the land system and the geologic surveys. On June 20, 1878, Hewitt obtained passage of a clause in the appropriation act for sundry civil expenses of the Government, as follows (*4*):

> And the National Academy of Sciences is hereby required at their next meeting, to take into consideration the methods and expenses of conducting all surveys of a scientific character under the War or Interior Department, and the surveys of the Land Office, and to report to Congress, as soon thereafter as may be practicable, a plan for surveying and mapping the Territories of the United States on such general system as will, in their judgment, secure the best results at the least possible cost; and also to recommend to Congress a suitable plan for the publication and distribution of reports, maps, and documents, and other results of the said surveys.

Marsh appointed a committee consisting of James D. Dana, William B. Rogers, J. S. Newberry, W. P. Trowbridge, Simon Newcomb, and Alexander Agassiz. The committee report, which fully supported Powell's program, was submitted by Marsh to the House on November 26, 1878, after the Academy had adopted it on November 6. The report recommended (*4*):

> 1) In view of the paramount importance of the public lands, . . . that the coast and geodetic survey be transferred from the Treasury Department to the Department of the Interior, retaining its original field of operations, and assuming also the entire mensuration of the public domain, and that, so modified and extended, it hereafter be known as the United States Coast and Interior Survey. This organization would then embrace, in addition to its former work, a geodetic survey of the whole public domain, a topographical survey comprising detailed topographical work and rapid reconnaissance, and land-parceling surveys. The Superintendent of the Coast and Interior Survey should be appointed by the President, and should report directly to the Secretary of the Interior.
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> 2) The best interests of the public domain require, for the purposes of intelligent administration, a thorough knowledge of its geological structure, natural resources and products. The domain embraces a vast mineral wealth in its soils, metals, salines, stones, clays, &. To meet the requirements of existing laws in the disposition of the agricultural, mineral, pastoral, timber, desert, and swamp lands, a thorough investigation and classification of the acreage of the public domain is imperative. The committee, therefore, recommend that Congress establish, under the Department of the Interior, an independent organization to be known as the United States Geological Survey, to be charged with the study of the geological structure and economical resources of the public domain, such survey to be placed under a director,

who shall be appointed by the President, and who shall report directly to the Secretary of the Interior. It should be specially provided that the director and members of the geological survey, charged as they are with the investigation of the natural resources of the public domain, 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.

3) The publications of the Geological Survey should consist of an annual report of operations, geological and economic maps, illustrating the resources and classification of the land, reports upon general and economical geology in all its branches, with the necessarily connected paleontology.

All collections made by the Coast and Interior and Geological Surveys, when no longer needed for the investigations in progress, should be transferred to the National Museum.

The following recommendations were also offered:

4) Discontinuance of the Wheeler, Hayden, and Powell surveys.

5) Abolition of the offices of surveyors general and of the system of land-parceling surveys by private contractors.

6) Appointment of a public-lands commission to codify the land laws.

Debate on the report reached the floor of the House in February 1879. Hayden, in alliance with a large western bloc in Congress, opposed the Academy program. King gave effective support to Hewitt, and Powell campaigned to build up sentiment in favor of it. The program was not introduced to the House by the Committee on Public Lands. Instead, the new legislation was attached to the Legislative, Executive, and Judicial Appropriation Bill and to the Sundry Civil Expenses Bill, which would be reported by the Committee on Appropriations of which Atkins was chairman and Hewitt a member. Some have thought that the legislation was drafted by Powell or by a member of his staff under his direction.

Debate in the House was bitter and was mainly on a sectional basis, the western members being overwhelmingly against the proposal and many eastern members favoring it. Opposition in the Academy was claimed by Representative Dudley C. Haskell of Kansas by way of a letter from an anonymous member of the Academy which named Spencer Baird, Joseph Leidy, and Arnold Guyot.

After long debate, a compromise was proposed by Representative Horace F. Page of California on February 18 which called for consolidation of the scientific surveys and the appointment of a public-lands commission but which knocked out the provision for a change in the land system and the land-parceling surveys. This passed the House 98 to 79 but was dropped without debate in the Senate. The appropriation bill then went to a conference committee.

In conference, the provision for the consolidation of the scientific surveys into one organization, the United States Geological Survey, and for the appointment of a public-lands commission was inserted into the Sundry Civil Expenses Bill. In the closing rush of this third session of the 45th Congress, the conference report was accepted, 35 to 24 in the Senate and 148 to 107 in the House. The assumption is that, with the controversial reform of the land system reduced to a provision for an investigation, serious opposition to the consolidation of the surveys melted away. President Hayes signed the bill on March 3, and the Geological Survey came into being.

With the establishment of the Survey, the controversy shifted to the appointment of a director. Powell opposed the nomination of Hayden and asked Atkins to use his influence with Schurz and President Hayes to prevent it. Atkins did so and recommended Clarence King. Powell vigorously supported this recommendation and kept in touch with Marsh, who came to Washington to add his support.

Cope, on the other hand, supported Hayden and urged Schurz to recommend his appointment. King, however, was nominated March 20, and after a favorable report by the Senate Committee on Public Lands, the nomination was confirmed April 3. On April 6 Marsh wrote to Powell (*5*):

> Now that the battle is won we can go back to pure Science again. I therefore invite you and Mr. Gilbert to attend the coming meeting of the National Academy beginning April 15th and hope you both will have some papers to present.

With King director of the Survey, there was some question of Powell's relationship to the new organization. King invited him to become a member; Powell accepted, and King replied (*5*):

> Your welcome telegram came to me Saturday. I am more delighted than I can express. Hamlet with Hamlet left [out] is not to my taste.

Organizing the Survey, 1879–81

Clarence King took the oath of office May 24, 1879, as first director of the Survey. S. F. Emmons said (*6*) that King "accepted the appointment with the distinct understanding that he should remain its head only long enough to appoint its staff, organize its work, and guide its full activity." He was well fitted for these functions.

Born in Newport, Rhode Island, in 1842, King graduated in 1862 from the Sheffield Scientific School at Yale, where he studied geology and mineralogy under James D. Dana and George J. Brush. From 1863 to 1865, he was a volunteer assistant to J. D. Whitney of the Geological Survey of California. During the winter of 1865–66, he made an exploration of the desert regions of southern California and Arizona as scientific aide to General McDowell. The experience gained during this period developed latent powers of enterprise, energy, and scientific ability and leadership which characterized his career. In 1866–67, he organized the Geological Survey of the Fortieth Parallel, which he directed during the 7 years of its existence. The work of this survey under his direction was very important; Emmons said (*6*) that it was

> . . . the first government exploration primarily devoted to geological investigation, the first geological Survey in the country to make and publish topographical maps as a basis for its geology, the first to employ microscopical petrography in the study of its rocks, and the first to institute systematic geological examinations of mining districts with a view of establishing a more satisfactory theory of vein formation.

Thus King brought to the task of organizing the new Survey an array of scientific achievement and organizing ability that would assure its firm foundation.

The Act of March 3, 1879 (the organic act), creating the new agency, is remarkable for its brevity. It is as follows (*7*):

> 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 land 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-hundreth Meridian, under the War Department, are hereby discontinued, to take effect on the thirtieth day of June, eighteen hundred and seventy-nine. And all collections of rocks, minerals, soils, fossils, and objects of natural history, archaeology, and ethnology, made by the Coast and Interior Survey, the Geological Survey, or by any other parties for the Government of the United States, when no longer needed for investigations in progress, shall be deposited in the National Museum.
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> For the expenses 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, to be expended under the direction of the Secretary of the Interior, one hundred thousand dollars. . . .
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> The publications of the Geological Survey shall consist of the annual reports of operations, geological and economic maps illustrating the resources and classification of the lands, and reports upon general and economic geology and paleontology. The annual report of operations of the Geological Survey shall accompany the annual report of the Secretary of the Interior. All special memoirs and reports of said Survey shall be issued in uniform quarto series if deemed necessary by the Director, but otherwise in ordinary octavos.

King regarded this language as leaving some room for doubt as to the functions of the Survey and its field. He decided that Congress intended a rigid classification of the lands of the public domain (*1*),

> . . . for the general information of the people of the country, and to produce a series of land maps which should show all those features upon which intelligent agriculturists, miners, engineers, and timbermen might hereafter base their operations.

On the question of whether the term *national domain* meant the entire United States or merely the public lands, he decided that (*1*)

> With the small appropriation given to begin the vast work of this Bureau, I considered it best to confine the operations to the region of the Public Land, concerning which field there could be no question as to my legal authority.

On the question of organizing the new work, he noted that former surveys had operated by annual campaigns in the West and that the members returned to Washington in the winter and that this was wasteful of time and money. He therefore decided to divide the region of the 101st meridian into four geologic districts, which he called divisions.

These divisions were (i) the Rocky Mountain division, embracing generally the chain of the Rocky Mountains, S. F. Emmons, geologist-in-charge, with headquarters in Denver, Colorado; (ii) the division of the Great Basin, embracing the country between the Rockies and the Colorado Plateau on the east, and the Sierra Nevada and the Pacific Coast and Cascade Ranges to the west, G. K. Gilbert, geologist-in-charge, with headquarters at Salt Lake City, Utah; (iii) the division of the Pacific, covering all of Washington Territory, that part of Oregon west of the Blue Mountains, and all of California except the desert regions east of the Sierra Nevada and south of latitude 38°, Arnold Hague, geologist-in-charge, with headquarters in San Francisco; and (iv) the division of the Colorado, embracing the plateau and canyon country between the Rocky Mountains and the Great Basin, Captain C. E. Dutton, U.S. Ordnance Corps (detailed to the Survey), geologist-in-charge, with headquarters in Salt Lake City. One office and one laboratory were to serve both this and the Great Basin division.

In addition to these, King intended to set up four divisions east of the 102nd meridian if a pending House resolution extending the field of the Survey to the whole country were enacted. The resolution died in the Senate, and it was not until 1882 that the coverage was specifically extended by Congress in the words (*8*) "and to continue the preparation of a geologic map of the United States." Provision for further geographic expansion of the work of the Survey was made in 1888.

King reasoned that, by placing each division in charge of a competent geologist familiar with the problems of that division and assigning to him a corps of competent assistants, the work would be done better than by expeditionary corps moving from division to division.

Probably King's most important contribution to the successful organization of the Survey was the magnificent staff that he gathered to it. The staff was led by seven men who, individually and collectively, were

of the very highest geologic distinction. They were S. F. Emmons, Arnold Hague, G. K. Gilbert, F. V. Hayden, Raphael Pumpelly, George F. Becker, and Captain C. E. Dutton, detailed from the Ordnance Corps. Together with A. D. Wilson, chief topographer, Gilbert Thompson, topographer, W. F. Hillebrand, chemist, Joseph P. Iddings, assistant geologist, Charles D. Walcott, assistant geologist, with other young scientists, clerks, messengers, and watchmen, they formed a compact group of 39 people, the charter members of the Survey.

Of these, G. K. Gilbert attracts the most attention. Born in Rochester, New York, in 1843, he graduated from the University of Rochester in 1862. At that time he was mainly interested in mathematics and engineering, not particularly so in geology, and was well versed in Greek and Latin. After a short venture in teaching, he returned to Rochester where he entered Cosmos Hall, founded by Henry A. Ward, professor of geology and natural history. Cosmos Hall was described as a training school in the natural sciences, and Gilbert's association with it aroused his latent scientific interests and talents.

His next venture was as volunteer assistant under John S. Newberry on the Second Geological Survey of Ohio, which he joined in 1869. Here he gained geologic experiences and acquaintances, which prepared him for his first assignment, the Wheeler Survey, in 1871. His connection with the Wheeler Survey lasted until 1874. In the summer of 1872, he had his first introduction to Lake Bonneville and to northern Arizona. While in Washington in January 1872, he had met Powell, and they found that they had much in common. They were both geologic explorers; both had worked in the same or contiguous areas; both had the imagination to be stirred by the magnificence of the area; and both were intellectually enthusiastic about the many problems presented by the arid lands. They also complemented each other. Powell was aggressive, fertile in ideas, a great organizer and generalizer. Gilbert was steady in thought and accurate in observation, somewhat diffident and retiring in personality. Each tremendously admired the other, and they formed a close and lasting association.

It naturally followed that Gilbert joined the Powell survey in 1875, where he worked on the Aquarius Plateau, the Water Pocket fold, and the Henry Mountains. The following summer he worked entirely in the Henry Mountains and in 1877 worked with Powell on irrigation studies. In 1878 he spent the summer designing and executing a triangulation system in the Colorado Plateau Province as a base for topographic surveys.

Out of this work came Gilbert's Henry Mountains report (*9*), which defined the concept of laccolithic structure and which contains the celebrated chapter on "Land sculpture." Much of the material in this chapter had been published in a paper, "The Colorado Plateau Province as a field for geological study" (*10*), a model of clear, simple, logical scientific writing.

All this was a prologue to Gilbert's logical move to the new Survey. Thus began a career with that body of 40 years which raised Gilbert to a position as one of the most eminent scientists of his generation.

S. F. Emmons, a scientist of probably equal distinction, was born in Boston, Massachusetts, in 1841. He graduated from Harvard in 1861 and studied in Paris and at the Freiberg Mining School in 1862–65. At Freiberg, he had an unparalleled opportunity to associate with world-famous scientists in geology, mineralogy, and mining, and it was here that he laid the groundwork of his later fundamental contributions to mining geology.

In 1867 he joined King's Fortieth Parallel Survey along with J. D. Hague and Arnold Hague, all as assistant geologists. The winter of 1867–68 was spent at Virginia City, Nevada, in the study of the Comstock Lode, which by that time was being mined at depths of 1000 ft. Emmons remained with this survey throughout its life and participated in its publications which appeared in 1870–80.

Emmons brought to the new Survey an interest in and acquaintance with ore deposits which would prove immensely valuable in its work in mining geology.

F. V. Hayden's distinction in geology had been gained through the work of his survey which had a great following among many scientists and the public. He was born in Westfield, Massachusetts, in 1829 and graduated from Oberlin College in 1850. He was assistant to James Hall in 1853 and engaged in independent geologic work in the West in 1854–56. He was connected with a number of different expeditions and surveying parties until 1865, when he became professor of geology and mineralogy at the University of Pennsylvania. From 1869 to 1879 he was director of his celebrated survey.

Hayden brought to the new Survey a vast body of experience which added to the collective distinction of the staff.

Arnold Hague, born in Boston, Massachusetts, in 1840, entered the Sheffield Scientific School in 1861, where he became associated with King, Marsh, J. Willard Gibbs, and Ellsworth Daggett. On graduating in 1863, he went to Germany, spending a year in Göttingen and the next year in Bunsen's laboratory, where he devoted his time to chemistry and mineralogy. From Heidelberg he went to Freiberg, where he met S. F. Emmons, who had been there for a year. They began an intimate association which lasted a lifetime. It was then that Hague, as well as Emmons, became influenced by Bernhard von Cotta, author of a textbook on petrography, *Die Gesteinlehre,* which conditioned their interest in the petrography of igneous rocks.

On his return to the United States in 1866, Hague met King in New York and was offered a position as assistant geologist on King's proposed Fortieth Parallel Survey. He gladly accepted and a few weeks later introduced Emmons to King, which led to the appointment of Emmons.

The results of Hague's geologic work in connection with this survey contributed to the beginnings of

microscopical petrography in the United States, and Hague shares with Emmons the credit for visualizing the importance of this branch of science to American geology.

In 1877, Hague became government geologist of Guatemala, where he studied the mines and volcanic districts. In 1878 he went to China to study the gold, silver, and lead mines for the Chinese Government. From this assignment, he went to the new Survey.

Another who came to the Survey from the Fortieth Parallel group was George F. Becker. He was born in the City of New York in 1847, spent his early life in Cambridge, Massachusetts, and graduated from Harvard in 1868. He took advanced degrees at Heidelberg in 1869 and at the Royal School of Mines in Berlin in 1871. His major subjects of study were mining and metallurgy, and he became instructor in these subjects at the University of California. Having met King during this period, and being attracted strongly by Emmons and Hague, he became interested in the geologic problems developed during the King survey, especially those of the Comstock Lode. Geophysics became his chief interest.

Raphael Pumpelly, born in Oswego, New York, in 1837, had been employed in economic work by the Japanese and Chinese governments in 1862–63. In 1865 he was appointed professor of mining engineering at Harvard. He was state geologist of Michigan in 1869–71 and director of the state survey of Missouri in 1872–73. On joining the Geological Survey under King, he began the work in mineral statistics which was continued for many years.

Captain C. E. Dutton, born in Wallingford, Connecticut in 1841, graduated from Yale in 1860. He entered the United States Army in 1862 and, after the close of the Civil War, studied geology in his leisure. He joined the Powell survey on detail from the Army, which gave him an opportunity to gain professional standing. This detail was renewed in 1879 when he joined the Geological Survey and continued until 1891. Dutton's familiarity with the canyon country made him the logical man to be put in charge of the division of the Colorado to finish some of Powell's work.

Among this brilliant group of men, it is obvious that there was one missing. Where was the Hamlet of whom King had written in his letter to Powell? The appropriation act setting up the Geological Survey also created the Bureau of Ethnology in the Smithsonian Institution, and Powell, whose interest in ethnology equaled, if it did not exceed, his other scientific interests, became its director. He first joined the Survey when he became its director in 1881, retaining the direction of the Bureau of Ethnology without additional compensation. He continued this dual role until his resignation from the Survey in 1894 but continued as head of the Bureau until his death in 1902.

The Survey set to work. Washington headquarters were established in the National Museum. Emmons, in Denver, fitted up the first chemical laboratory, noting that chemical investigations would be a necessary part of his study of mining districts and the formation of ore deposits. To this laboratory, he brought W. F. Hillebrand and A. Guyard, who, he says, had made a specialty of this work, having studied under the best teachers in America and abroad. Hillebrand, of course, went on to become the foremost chemist of his time in inorganic chemical analysis, and it was through his work and his later associates that the Geological Survey became preeminent in the field of inorganic chemical analysis of rocks, minerals, ores, and other natural products, a place that it holds today.

C. W. Cross, who had just graduated from the University of Leipzig, where he had studied microscopical petrography, began, under Emmons' direction, a systematic examination of thin sections of 345 specimens of crystalline and eruptive rocks collected during Emmons' first summer's work.

Fred A. Clark, topographer, began making triangulation, leveling, and topographic surveys in the Eureka district, Nevada, under the general supervision of Arnold Hague.

G. F. Becker began his detailed study of the Comstock Lode. As a part of this work, he became interested in the relationship of electric currents in ore bodies and said that should this be worked out it would probably be adaptable to the discovery of new ore bodies. He also investigated temperatures and heat gradients in the Lode, noting, for instance, that on the 2700-ft level of the Yellow Jacket mine he found water at 153°F, with the air and rock temperatures at 125°F. He related this heat to remnants of volcanic action.

These studies, actively encouraged by King, can be said to be the first geophysical work in the Geological Survey.

In cooperation with the Census Bureau, the collection of statistics on yearly mineral production in the region west of the 100th meridian was begun under the direction of Raphael Pumpelly.

A survey of work in progress at the time King wrote the first annual report (*1*), November 1, 1880, is best illustrated by his list of "forthcoming publications":

Geology and mining industry of Leadville, Colorado, by S. F. Emmons.
Geology of Eureka mining district, Nevada, by Arnold Hague.
History of the Comstock mines, by Eliot Lord.
The Comstock Lode, by George F. Becker.
Mechanical appliances used in mining and milling on the Comstock Lode, by W. R. Eckart.
Coal of the United States, by Raphael Pumpelly.
Iron in the United States, by Raphael Pumpelly.
The precious metals, by Clarence King.
Lesser metals and general mineral resources, by Raphael Pumpelly.
Uinkaret Plateau, by C. E. Dutton.
Lake Bonneville, by G. K. Gilbert.
Dinocerata. A monograph on an extinct order of ungulates, by O. C. Marsh.

Thus the Survey was making investigations both practical and theoretical, or as we would label them today, applied science and basic research. King (*1*) could see the need for facts on a national scale to assure the development of our "material resources." To marshal these facts he saw

> . . . the necessity of a Government corps of geologists, topographers, mining engineers, metallurgists and chemists; . . . and this corps must be so directed . . . that the facts learned in one place may be made to throw light on all others.

The Survey was a going concern.

The Expanding Survey, 1881–94

Early in February 1881, King learned that Carl Schurz planned to resign as Secretary of the Department of the Interior as soon as Garfield assumed the Presidency in March, and he immediately tried to resign also. President Hayes persuaded him to wait. He did but submitted his resignation to President Garfield on March 11, having recommended John Wesley Powell as his successor. The resignation was accepted March 12. Powell was nominated March 14, was confirmed March 18, and was sworn into office March 19.

An admirer, Lester F. Ward, wrote on that occasion (*11*):

> John Wesley Powell is a pattern of the American self-made man, and well illustrates what may be accomplished with honest, steady adherence to a definite purpose.

Born in Mount Morris, New York, in 1834, Powell was largely self-taught. He attended Illinois College, Illinois Institute, and Oberlin in periods interspersed with intervals of teaching school in the years preceding the Civil War. He enlisted in the Union Army in 1861 and served throughout the war, reaching the rank of major, and lost his right arm from a wound received in the Battle of Shiloh. After the war, he became professor of geology at Illinois Wesleyan University and Illinois Normal University. His was the first party to explore the canyons of the Colorado River, in 1869. From 1871 to 1879, he was director of the Powell survey.

Powell was undoubtedly one of the great men of American history. He was one of the first to visualize the potentialities of the western lands in all their ramifications, and he has become a legendary figure in the history of the West. A recent biography by William Culp Darrah (*12*) provides a fuller account of his life.

Powell brought to the Survey experience and a keen interest in geology, topographic mapping, and irrigation. He was an able leader of men, resourceful, courageous, and persevering. He had that indispensable quality of a good administrator—the ability to surround himself with competent men and the wisdom to give them responsibility while holding in his own hands the policy-making functions. He had a goal for the Geological Survey from which he never deviated: to establish it as a great scientific and technical bureau with emphasis on research in all its functions. In this he succeeded, probably beyond his own expectations.

Powell had a concept different from that of King in the management of the Survey. He abolished the divisions as the somewhat autonomous bodies that they were and transformed the Survey's program into a truly national one with Washington as the nerve center. That this step may have involved other considerations is implied in a reputed statement in his diary that he did not so much mind each division lobbying in Congress for greater appropriations but when they lobbied against one another it was time for a change.

The change was illustrated in a communication by Powell to the October 1884 meeting of the National Academy of Sciences on the organization and plan of the Geological Survey (*13*). At this time the roster had grown to 135, and the appropriation (fiscal year 1885) to $504,000.

Five paleontological laboratories had been established under the supervision of O. C. Marsh. W. H. Dall, C. A. White, C. D. Walcott, and Lester F. Ward, respectively.

A physical laboratory had been established for researches related to the effect of temperature, pressures, and related phenomena on rocks. In 1882, these researches were under the direction of King as an outgrowth of the work of Becker on the Comstock Lode. This early work led to plans for the acquisition of suitable equipment for a physical laboratory. This equipment was constructed in Europe, and the expenses were met by King out of his own pocket. It was planned to set up the equipment in the American Museum of Natural History, but by the time it arrived the Museum had other plans for the space, and a house was rented for a laboratory in New Haven. However, in July 1883, Powell decided to consolidate all Survey laboratories in Washington under the direction of a chief chemist. The laboratory was therefore established in the Smithsonian Institution and, together with the chemical laboratory, was placed under the direction of F. W. Clarke, newly appointed chief chemist. The laboratory continued without serious interruption until 1892, when the annual appropriation for physical and chemical research was reduced from $17,000 to $5000 and all physical research was abandoned. During this period, G. F. Becker and Carl Barus made important contributions in the thermoelectric measurement of high temperatures.

A "chemic" (*14, 15*) laboratory had a large corps of chemists engaged in researches related to the constituents of waters, minerals, ores, and rocks. A part of the work was the study of metamorphism and paragenesis of minerals, and in these studies the chemists did fieldwork. At other times, they studied material collected by the field geologist.

A library had been established and it now had 25,000 volumes, of which the nucleus was 1000 volumes donated by Hayden. The librarian, C. C. Darwin, had a corps of assistants engaged in bibliographic work. Plans called for the preparation of a catalog of American and foreign publications on American

geology and for the publication of special bibliographies on various aspects of geology.

The publications of the Survey consisted of annual reports, bulletins, and monographs. By October 1884, nine bulletins had been published and seven were in press. Six monographs had been published and five were in press. Four annual reports had been published and the fifth was in press.

In economic geology, two so-called "mining divisions" had been organized, one in San Francisco under G. F. Becker, engaged in the study of quicksilver deposits in California, the other in Denver under S. F. Emmons, engaged in the study of the mining districts of Colorado. The lignite coals of the upper Missouri were also being studied by a party led by Bailey Willis.

In the field of general geology, the changes from the King system were most noticeable. The compilation of a general geologic map was in progress, together with a thesaurus of American formations. It then became necessary to consider the best division of the work, and it was decided to divide it, so far as possible, by subject matter rather than by territorial areas. There was therefore established a division of glacial geology under T. C. Chamberlin, with a plan for broadening the division to include the whole of Quaternary geology; a division of volcanic geology under Dutton; two divisions on Archean rocks, including all "metamorphic crystalline schists," one under Pumpelly concentrated in the Appalachian region, and one under Roland D. Irving in the Lake Superior region, with plans to cover the Rocky Mountains; a division for the study of areal, structural, and historical geology of the Appalachian region under Gilbert; and a division for a topographic and geologic survey of Yellowstone Park under Arnold Hague. Thus with the new congressional authority to prepare a geologic map of the United States, Powell was able to set up this broadly based work in general geology.

Finally, the Survey was making a topographic map of the United States. Powell said that sound geologic research is based on geography and, therefore, the topographic map comes first. First, the trigonometric survey was made, on a scale only sufficiently refined for map-making purposes, with the hypsometric work based on the network of railroad levels.

The topographic work was based largely on the use of the plane table, regarded not as a portable drafting table for field use but as a triangulation instrument.

Map scales were 1:250,000, 1:125,000, and 1:62,500, with larger scales being used in special districts. On this plan, Powell thought the country could be covered with 2600 sheets besides several hundred special large-scale maps. With his organization, he thought the topographic map of the United States could be completed in 24 years; one-fifth of the country had already been completed, inclusive of the work of the state governments.

The topographic work was divided into an astronomic and computing division, a triangulation corps, and a topographic corps organized in 27 parties scattered across the country. All the work was under the supervision of Henry Gannett, chief geographer.

In addition to these major work corps, there were a division of mining statistics and a division of illustrations for the preparation of illustrations for Survey reports, under W. H. Holmes. The mining statistics were published in an annual report entitled *Mineral Resources*. The illustrations were also preserved for use by the public.

This organization along functional lines has been modified repeatedly since Powell's time, but it is still basic to the Survey's work.

Powell also reported on the relationship of the Survey to state governments. In 1884, for instance, a cooperative agreement had been made with Massachusetts in the undertaking of a topographic survey by the state, the expense of fieldwork to be divided equally between the Survey and the state, the Survey to engrave the maps and give transfers of the plates to the state. This was the first of many such agreements made since that time.

By 1884, the rapidly expanding appropriations for the Survey, the Signal Service, and the Hydrographic Office had been under discussion in congressional circles, and the Sundry Civil Appropriation Act of 1884 (*16*) called for a joint congressional commission to investigate and attain greater efficiency and economy in the administration of these bureaus. Hearings were held in 1885 and 1886, with Powell appearing for the Survey. Questions raised related to the value of topographic maps prepared on a small scale, the rate of progress toward completion and publication of the Survey's geologic maps, and the propriety of the wide scope of the Survey's scientific investigations and publications.

Two of the six members of the commission submitted a minority report criticizing the Survey, but the majority report (*17*) found that the Survey was "well conducted, and with economy and care, and discloses excellent administrative and business ability on the part of its chief." The investigation resulted, however, in requiring the Survey to submit detailed and specific estimates of the cost of each future publication for which specific appropriations would be needed. This provision, for fiscal year 1887, was reenacted in 1895.

An additional restriction in the appropriation of 1887 was the requirement that estimates for Survey expenses be itemized. Of about $737,000 appropriated for Survey work, $40,000 was appropriated for paleontological researches and $17,000 for physical and chemical research. Thus, these research activities were specifically recognized and approved by Congress and they were itemized in Survey appropriations for many years.

In October 1888, Congress authorized the Survey to undertake a study of the arid regions of the United States where irrigation was necessary to agriculture; to investigate the storage of water in dams, the capacity of streams, and the cost and construction of

reservoirs; to designate all lands useful for sites for reservoirs, canals, or ditches for irrigation purposes and all the lands susceptible to such irrigation. It was provided that all such lands would be withdrawn from entry. This gave the Survey direct administrative powers in the public domain and was the start of the water resources investigations which are now such a large part of its work. It also marked the beginning of reclamation work by the Federal Government.

The investigation became known as the Powell Irrigation Survey and began in 1888 with the assembling of a party of 14 under a young Harvard graduate, F. H. Newell, at Embudo, New Mexico, to learn how to measure the flow of streams by experimenting on the Rio Grande. The whole survey, however, consisted of a large force, composed mainly of topographic engineers, and within little more than a year 127 reservoir sites were segregated, with an area of more than 2500 mi^2, and 30 million acres of irrigable land were located in five distinct basins.

This action of the Survey led to the appointment of a special committee of the Senate which, in a report in 1890 (*18*), severely criticized the Survey for the policy used in guiding the work. The whole of the authorization of 1888 was withdrawn except for reservoir sites, and the appropriations for the survey of the arid lands were discontinued. The work was of inestimable value, however, in the results achieved in stream measurements and topographic maps.

Following this setback for Powell and the Survey, the storm clouds gathered. Federal science, largely in the Survey, had gained a very commanding position but it had also gained many enemies both in governmental and scientific circles. Old rivalries, such as those between Cope and Marsh and Hayden and Powell, played their part. Powell's supporters in Congress were being replaced by neutral or hostile newcomers. The storm began to break on the Survey in 1892, when the previous year's appropriation of $843,000 was reduced to $705,000, and it came to a head in 1893 with a further reduction in appropriation to $488,000. The heaviest reductions, proportionately, fell on chemical and physical researches. For the former the reduction was from $40,000 in 1892 to $10,000 in 1893 and for the latter from $17,000 in 1892 to $5000 in 1893. As previously noted, the physical laboratory was discontinued and the chemistry force was drastically reduced. An old chestnut, repeated throughout the years by Survey men and attributed to George Steiger, later chief chemist, claimed that "Hillebrand was retained because he was the best chemist, Clarke because he was the chief chemist, and Steiger because he was the cheapest chemist."

Darrah (*12*) says that Powell was the real target of the blow at the Survey. In any case, perhaps seeing that his usefulness to the Survey was ended and wishing to spend more time with his Bureau of Ethnology, Powell submitted his resignation on May 4, 1894, to take effect June 30.

In the 15th Annual Report (*19*) Powell wrote of his men:

> In this severance of our relations, . . . I cannot refrain from an expression of profound gratitude for the loyal and loving aid which they have given me, ever working together with zeal and wisdom to add to the sum of human knowledge. The roster of these honored men is found in ten-score volumes of contributions to knowledge and fifty-score maps familiar to the scholars of the world, and their names need no repetition here. . . .

The work of the Survey during Powell's directorship produced a body of reports which has probably never been equaled for their profound contributions to geologic and topographic knowledge. Among these were S. F. Emmons' report on the geology and mining industry of Leadville, Colo. (*20*), by which he became the founder of mining geology in America; T. C. Chamberlin's report on the mechanics of glacial erosion (*21*); C. E. Dutton's report on isostasy (in which he introduced the term) (*22*); G. K. Gilbert's report on Lake Bonneville (*23*); G. F. Becker's report on the Comstock Lode (*24*); R. D. Irving's report on the copper deposits of Michigan (*25*); O. C. Marsh's report on the Dinocerata (*26*); Henry Gannett's manual on topographic methods (*27*), and many others. In addition, W J McGee produced the first Survey geologic map of the United States in 1884 (*28*) and followed it up with a second map in 1893 (*29*); and Powell and Gilbert devised a system of nomenclature, symbols, and colors for geologic cartography (*30*) that has remained the American standard with but few changes for nearly 70 years.

This is only a small sampling of these extraordinarily productive years. From the small but solid beginnings of King, the Survey had become an outstanding scientific body in the latter years of the Powell regime. This was a challenge to the next director to keep it so.

Widening Endeavor of the Survey, 1894–1907

W. C. Mendenhall says (*31*) that G. K. Gilbert probably could have been the next director had he so desired but that he decided he would be more useful in research than in administration. In any case, Charles D. Walcott was approved by Powell as his successor and he became director on July 1, 1894.

Born in New York Mills, New York, in 1850, Walcott was collecting natural objects when he was 7 years old and became interested in fossils and geology at the age of 13. He was trained in the public schools and at Utica Academy and at 23 had planned to study at Harvard under Agassiz but that teacher's death led him to abandon this idea.

Walcott was appointed an assistant to James Hall, state geologist of New York, in 1876 and joined the Geological Survey as an assistant geologist in July 1879. The next 10 years marked his great activity in paleontologic and stratigraphic researches in western and eastern United States and in the type district of Wales which brought him to his position of authority in Cambrian geology and paleontology, the study of which constituted his great contribution to science. He brought to the directorship talents as a leading

geologist and a skilled executive with a sound business sense and a marked ability to coordinate policies. He equated science to service and said that the advancement of science implied the physical, mental, and moral advancement of the human race.

During the Walcott regime, with the controversial figure of Powell off the stage, congressional appropriations for the Survey recovered, becoming $501,000 in 1894, going over the million mark for the first time in 1902 ($1,023,000), and reaching $1,757,000 in 1907. Chemical research was expanded; the physical laboratory was reestablished and, having produced notable work in the investigation of hydrothermal alteration and related studies, went off to the newly established Geophysical Laboratory of the Carnegie Institution in 1907.

Mining geology and mining technology became an important part of the Survey's work. Mining geology, which Emmons had shown to be of prime importance in the study of ore deposits and the exploration for new deposits, had been embraced wholeheartedly by the rapidly burgeoning mineral industry, and it came to magnificent achievement through the fundamental work of another extraordinary scientist of the Survey, Waldemar Lindgren, who had joined the Survey in 1884. His careful study of district after district in western mining regions led to a masterly synthesis of observation and speculation based on microscopical, chemical, and physical studies, and culminated in his concept of the hydrothermal depth zones and the role of metasomatism in ore formation. Lindgren's contributions to mining geology and geologic theory cannot be overestimated.

From the first years, the Survey had established a close relationship to the mineral industries of the country through its publication annually of the *Mineral Resources of the United States*. It had investigated technologic processes in mining. This activity was recognized and encouraged by a congressional resolution in 1898 calling for the creation of a separate division of mines and mining, but the resolution was not enacted. However, in 1904, $30,000 was appropriated for analyzing the coals and lignites of the United States, and this was increased to $227,000 in 1905 to cover all fuels and for studying structural materials. An appropriation was later made, under the directorship of George Otis Smith, in 1908 for the investigation of mine safety in the territories and for studying the causes of explosions in mines. These investigations led to the addition to the Survey roster of a large staff of mining technologists, and these were split off to form the Bureau of Mines in 1910.

Up to 1891, the Survey had gathered, in connection with its regular geologic and topographic surveys, data related to forests. In 1891, the President was empowered by Congress to create forest reserves on the public lands, and the Survey had aided in the determination of the boundaries of these reserves. However, there was little definite information on the resources of the lands included in the reserves, so Congress, in 1897, appropriated $150,000 for a survey of the public lands that had been or would be made forest reserves by Executive action and placed this survey under the supervision of the director of the Geological Survey.

The Survey began a thorough study of the forest reserves. The work continued for the next 8 years and covered 75 million acres. Forty atlas sheets of land classification maps were one of the results of this study. The data collected furnished the basis for the regulations governing the reserves, with administration vested in the General Land Office. The work was transferred to a new Bureau of Forestry in the Department of Agriculture in 1905. George Otis Smith says (*31*) that most of all this activity stemmed from Walcott's interest in forestry, that he drafted the relevant legislation, and that

> . . . it was only his influence with the leaders of Congress that made any stand successful against the anti-reserve agitation, so that the legislative beginning of a national forest policy may also be credited to him.

In the field of water resources investigations, the Survey received a specific appropriation in 1894 of $12,500 for gaging streams, and for determining the water supply of the United States, including studies of underground water and artesian wells in arid and semiarid regions. This appropriation, increased annually, had reached $100,000 in 1901, and authorization for the preparation of reports on water utilization was added. Thus, a large body of water data accumulated and, on the passage of the Reclamation Act in 1902, administration was entrusted by the Secretary of the Interior to the Survey. The resulting Reclamation Service remained in the Survey under the direction of F. H. Newell until it became an independent service in the Department in 1907, when the work had progressed from the planning to the construction stage. Newell continued as director in the independent service.

One of the functions cited in the organic act of the Survey was the "classification of the public lands." King had interpreted this to mean geologic and mineralogic examination of the public lands without reference to the public-land laws. Congress had silently acquiesced in this interpretation for some 20 years. Increasingly, the General Land Office and the Secretary of the Interior solicited Survey opinion, based on Survey data or calling for new investigations, regarding the applicability of specific provisions of the land laws to various tracts of public lands. Pursuant to these necessities, the Survey undertook in 1907, with the approval of the Secretary of the Interior, systematic evaluation of the public lands thought to contain coal, and later there was added the examination of oil, phosphate, potash, and mineral lands, and of lands suitable for water-power sites and for enlarged homesteads.

At the time that Powell resigned, topographic mapping had become by far the largest single activity of the Survey. The mapping had progressed, and continued to progress, beyond the needs of the Survey

itself for strictly geologic purposes. The maps were becoming basic and standard for all purposes. They were becoming useful to all governmental units, state, national, and local, for all varieties of public works and were being used for engineering works by private enterprise. Authority to sell the maps to the general public was granted by Congress in 1897 (*32*). In 1896 Congress had authorized the running of careful level lines and the establishment of bench marks; this contributed to increased detail and quality in the work. Another important event early in the Walcott regime was the placing of the topographic engineers in the classified service in order to get the best qualified men. In addition, an editor for topographic maps was appointed.

Data had been gathered informally by the Survey in Alaska as early as 1889, but its first formal work there was authorized by Congress in 1895 when an appropriation of $5000 was made for a study of the coal and gold resources; the amount was continued in 1896 and 1897. Because of the Klondike rush in 1898, the amount was increased to $25,000 in that year and the work was extended in 1901 to cover all mineral resources in Alaska, with an appropriation of $60,000, which was increased to $80,000 by 1905.

Similarly, the Survey had made investigations in Hawaii, Puerto Rico, and Cuba at an early date, and it continued to do so through Walcott's term.

This period marked the development of standardized geologic nomenclature with the organization of the Geologic Names Committee in 1899, with P. C. Warman as its first chairman. This important function of the Survey began in the Division of Geologic Correlation, established under Gilbert in 1888. Rules for geologic nomenclature and classification, published in 1890 (*33*), combined the minimum of regulation consistent with the orderly progress of geologic mapping and map publication. However, as mapping progressed and geologic folios were prepared, questions multiplied that were not covered by existing regulations, and decision on these, said Gilbert (*34*), "developed a system of precedents, analogous to the common law in distinction from statutory law." The regulations were therefore revised by the new committee, who took into account the opinions, suggestions, and criticisms of their colleagues, and were published in 1904 (*35*).

In 1904, the Survey celebrated its 25th anniversary by publishing a bulletin (*36*) describing its origin, development, organization, and operations. It gives a detailed picture of the Survey of that time. The permanent force had grown to 678 from 39 in 1879 and 135 in 1881. In a section of two and a half pages, the Survey evaluated the general results achieved in 25 years. It will be instructive to summarize them here.

Twenty-six percent of the area of the country including Alaska (31 percent excluding Alaska) had been topographically mapped and the results shown in 1327 atlas sheets printed in three colors from copperplate engraving.

Many of the broader problems whose solution was necessary to the "final geologic mapping of the country" had been solved. Geologic mapping of surface formations covered 171,000 mi², and 106 geologic folios had been published, with an equal number in preparation.

Important experiments and investigations into the physical characteristics of rocks in various processes of formation and of volcanic and geyser action had been conducted in the physical laboratory, and many important conclusions had been reached. The chemical and petrographic laboratories had been busy solving, chemically and microscopically, the more important problems connected with rock composition and structure, and the paleontologic section had done important work in solving stratigraphic and structural problems by the classification and identification of fossil plants and animals.

The engraving and printing division had engraved 1421 series of copperplates, each series consisting of three plates, one for each color. It had lithographed on stone the colors, ranging from 10 to nearly 30, necessary for distinguishing in each of about 100 folios the various formations and outcrops. It had printed several editions of most of the topographic maps and at least one edition of the geologic folios, and had engraved and printed miscellaneous state and United States maps.

In the preceding 15 years, the maximum, minimum, and mean discharges of all the important rivers of the United States had been recorded, together with those of the lesser tributaries for shorter periods. The physical characteristics of the river basins had been studied and a vast amount of data had been collected from which it was possible to estimate closely the volume of runoff of each stream. These data had contributed to the rapid development of water power. Data had been collected regarding irrigable lands and their relation to possible water supplies. Reservoir sites had been examined and surveyed, and the lands had been withdrawn from sale or occupation pending more detailed study.

Detailed examinations had been made of 110,000 mi², including classification of the lands, as forested (with the stand and kind of timber), grazing, desert, and cultivable, and final reports had been prepared on these reserves showing the kind and amount of timber and many other facts useful as a basis for future forest management.

Finally, the bulletin states (*36*):

> Perhaps the immediate value to the people of the work of the Geological Survey is best shown by the aid it extends in developing the mineral resources and in forwarding important engineering projects in which the people, as well as the State and Federal Governments, are interested. To instance a few cases: the work of the geologic branch has had a wide educational influence upon the public at large, but more directly upon those engaged in the mining industry. Among the many direct practical benefits which it has conferred upon this industry may be mentioned the investigation of the mining geology of Leadville, which has not only guided exploration and secured

economical mining in a district that has produced between $200,000,000 and $300,000,000, but has been of even more beneficial result in teaching the mining engineer and the miner the practical importance of geologic study in carrying on their work; in other words, it has greatly improved mining methods throughout the whole country. The investigation of the origin and geologic relations of the Lake Superior iron ores and the publication of numerous reports on that region have so effectively directed the prospector in the discovery of the deposits and the miner in economical methods of development that this region now leads the world in the production of iron ore. The detailed areal mapping and the determination of underground structure in the Appalachian coal field are placing the development of its coal, petroleum and gas resources upon a scientific basis and relieving those branches of the mineral industry of a large part of the hazard and uncertainty which has always hitherto been associated with them. The collection and publication of reliable statistics of mineral production have furnished a sound and commercial basis for all branches of the mineral industry.

Walcott had served as acting assistant secretary of the Smithsonian Institution in charge of the National Museum in 1906 while still director of the Survey, and in 1907 he was chosen to be secretary of the Institution, a position that he filled until his death in 1927. George Otis Smith (*31*) says:

> . . . he so administered that scientific bureau [the Survey], devoted to fact-finding and the coordination of facts and principles, as to serve both the Government and the people. "The public" as defined and served by Director Walcott included farmer, miner, landowner, and investor as well as student, teacher, and research specialist. He was prompt to see the need of research, both scientific and engineering, along varied lines and the growth in popular appreciation of the Geological Survey under Director Walcott is attested by the large increase in annual Congressional appropriations for the Survey work during his term of office.

Increased Usefulness of the Survey, 1907–30

On May 1, 1907, Secretary Garfield announced the selection of George Otis Smith to serve as the fourth director of the Survey. So, at the early age of 37, an able scientist and administrator was given the task of directing the organization that, in the words of Philip S. Smith in a memoir on George Otis Smith in 1944 (*37*), "had done so much to advance American science and that stood at the threshold of increased usefulness to the nation." Philip Smith's memoir is rich in details of George Otis Smith's activities and also those of the Survey during the period 1907–30, and we have relied heavily on his information in the material that follows.

George Otis Smith was born in Hodgdon, Maine, in 1871 and graduated from Colby College in 1894. He had been introduced to geology by Professor W. S. Bayley—it was probably at Bayley's suggestion that he went to Johns Hopkins University for graduate work in petrography and he received a Ph.D. degree there in 1896.

He immediately joined the Survey as an assistant geologist in a field assignment in the state of Washington under Bailey Willis. For the next 6 years he worked on assignments in various parts of the West and participated in the preparation of five geologic folios. In 1903 he was assigned to diverse investigations throughout New England, in much of which work he was assisted by E. S. Bastin.

By 1906 he had established himself as a geologist and a keen and well-balanced administrator and was selected to bear more and more details of office management and operation (for example, in 1906 he became geologist-in-charge of the section of petrography). When President Theodore Roosevelt appointed a commission to study Government administration and ways of improving procedures and reducing costs, Smith was made chairman of the special subcommittee on business methods of the Survey. Abolition of some old Survey practices and institution of new ones were a direct outcome of these studies which revealed Smith's ability to analyze problems and propose helpful solutions.

In the search for a successor to Walcott as director of the Survey, many geologists were considered and P. S. Smith (*37*) cites a letter on the subject from one of the deans of American geology in which George Otis Smith was characterized as

> . . . one of the ablest of the younger men but still too young for so great a responsibility. Ten or fifteen years hence he might be the best man but his appointment now would be regarded as premature by the great body of geologists.

Smith himself did not actively pursue the post and, indeed, is said to have been an ardent supporter of another man being seriously considered.

There were problems facing the new director. He was regarded as being among those who placed undue emphasis on so-called economic results as distinct from the theoretical aspects of geologic problems. P. S. Smith considered this a revolt against the leisurely way of some investigators in allowing their work to drag along for years without concrete results. The truth of the matter seems to be that George Otis Smith truly appreciated and encouraged basic research but sought to widen the Survey's usefulness in applied science. In fact, the Survey had come a long way on this path under its three preceding directors.

Under the new director, the Survey continued to grow, and a record of the next 23 years would be a long one. We have therefore chosen to describe only those events that seem to us to be of chief interest.

Early in this period, the conservation movement in the United States gained momentum, and it had its impact on the Survey. Smith and most of the Survey geologists took the middle ground that conservation meant wise use of the nation's natural resources without waste. President Roosevelt called a state governors' conference in Washington in 1908 to discuss conservation problems, and his successor, President

Taft, encouraged additional investigation. In these studies, the Survey played an important part in suggesting improvements in existing procedures, such as favoring the disposal of certain mineral lands through lease rather than by sale at nominal prices. In the ensuing controversies that developed between Gifford Pinchot and Secretary Ballinger, the Survey continued to support its own views, and improvements followed ultimately in the wiser disposal of public lands and in better leasing practices.

In 1908 a Land Classification Board was organized in the Survey, and the supervision of leasing operations was initiated in 1913 when the Bureau of Mines was charged with inspection of all mines belonging to Indians and Indian tribes. Passage of the Mineral Leasing Act in 1920 resulted in appropriations to the Bureau of Mines for public-land operations, and leasing supervision was transferred to the Survey in 1925.

Another expanded activity came to the Survey by congressional passage of the Potash Act, which directed the Survey to explore for deposits of potash. This act was in response to the monopoly that Germany had gained on the potash supply. In this program, Survey geologists studied many ancient salt deposits and modern-day saline playas and salt lakes. This led to the recognition of the importance of Searles Lake as a source of potash.

World War I brought new opportunities of service to the Survey. Most of the skilled topographers in the United States were members of the Survey, and many of them were commissioned for duty with the Topographic Corps of the Army or as artillery orientation officers. This led to increased interest of the Survey engineers in aerial photography and to rapid developments in photogrammetry, in which the Survey has played a leading part for 50 years.

Photogrammetry is defined in a recent Survey publication (*38*) as "the science or art of obtaining reliable measurements by means of photography," and is now used extensively for topographic mapping. It is an essential component of all large mapping operations.

Two members of the Survey, C. W. Wright and F. E. Wright, first used a panoramic camera for topographic surveys in 1904. C. W. Wright had a camera constructed especially for surveying purposes in 1907, and J. W. Bagley improved the camera for reconnaissance mapping in Alaska; he also designed a photoalidade. In 1916–17 he developed a tri-lens camera for aerial photography.

In the following year, the Survey cooperated with the Corps of Engineers and the Air Service in a program of photographing with the tri-lens camera strips of country between airfields for the purpose of making aeronautical charts. After the war, photogrammetry sparked revolutionary changes in surveying and mapping techniques under the leadership of C. H. Birdseye, J. G. Staack, and T. P. Pendleton.

World War I also saw the birth of the "strategic minerals" concept, which became important in World War II. Many of the Survey men made special investigations of certain mineral deposits, and exploration for new deposits was greatly increased. The backlog of scientific data in the Survey was essential to these activities. Domestic sources of mineral commodities were recanvassed, and information on the potential mineral and water resources of other countries was gathered. Much of this information was published in the Survey's *World Atlas of Commercial Geology* (*39*); it had originally been prepared in manuscript form for the use of the State Department and the Peace Commission.

Following the war, George Otis Smith took the Survey into areas of expanded service. An example of this activity was the Superpower Survey of the Boston-Washington area. N. C. Grover of the Survey contributed to the technical phases of this study. The inquiry stemmed from a proposal made to Secretary Lane by E. G. Buckland of the New York, New Haven, and Hartford Railroad for a survey of the sources of energy in New England and on the Atlantic seaboard as far south as Washington. The great development of war activities had increased the demand for power, and Lane was sympathetic to the proposal. He called on the Survey to investigate and report. Congress appropriated $125,000 for the work, which was completed in 1921 and published as *Professional Paper 123* (*40*). This paper is regarded as an important contribution to engineering literature related to power supply and was useful in the interconnection of power systems in the country.

This work led to an increased consideration of power sources in the United States and awakened interest in the need for facts regarding the production, distribution, and use of coal. As a result, Congress established the Federal Coal Commission in 1922, whose duties were strictly fact-finding. John Hays Hammond was appointed chairman, with George Otis Smith as one of four other members. The commission was set up for 1 year, and Smith, convinced of its worth and being advised by the Attorney General that he could not serve while director of the Survey, resigned as director October 31, 1922, and was reappointed August 24, 1923.

These activities brought the Survey, or at least its director, into an increased advisory capacity on many matters dealing with natural resources, and this trend is still going on. Its method of discharging such duties is described by P. S. Smith (*37*) as "the long-established record . . . of keeping free of partisan entanglements and attending strictly to those technical matters on which the Survey could speak with authoritative finality."

In the early 1920's, a group of Survey publications appeared that illustrates one of its most important functions. This is the dissemination of data in the form of bibliographies and useful compendiums. Among these are F. W. Clarke's fifth edition of his *Data of Geochemistry,* appearing in 1924, which, now under revision, has been the basic work in this field (*41*); J. M. Nickles' bibliography of North American geology, 1785–1918, which is one in a long

line of such works (*42*); the first edition of *Microscopic Determination of the Nonopaque Minerals* of E. S. Larsen, Jr., (*43*) which formed a systematic basis for the determination of nonopaque minerals under the microscope and which was enlarged in a second edition in 1934; O. E. Meinzer's report on the occurrence of ground water in the United States, with a discussion of principles, in 1923 (*44*); E. C. LaRue's work on water power and flood control of the Colorado River below Green River, Utah, in 1925 (*45*), prepared as a result of a Survey expedition through the canyons of the Colorado River in 1923; and E. M. Douglas' work on the boundaries, areas, geographic centers, and altitudes of the United States and the several states in 1923 (46), a publication which evolved from three earlier ones by Henry Gannett in 1885, 1900, and 1904, and which went into a second edition in 1930. The monumental earlier work of H. S. Washington, a compendium of the chemical analyses of igneous rocks published from 1884 to 1913, which appeared in 1917 (47) and is now under revision, should also be mentioned.

In 1929, when the Survey reached its first half-century, the occasion was marked in the 50th annual report of the director by a statement, under the heading "Fifty years of service," which reads, in part, as follows (*48*):

> In the first half century that has passed . . . the Geological Survey has grown in stature, widened its field of endeavor, and increased its usefulness, but it has not grown old. . . . The far-reaching outlook of specialized public service that is possessed by many men in high positions in this country is a by-product of the United States Geological Survey.
>
> During this half century the Federal funds made available for the work of the Geological Survey have increased from $100,000 to more than $2,000,000. The total expenditures for the 50 years have been $75,000,000 of which nearly $10,000,000 has been contributed by States for cooperative work. Most of the work on which these millions have been expended may be described by the simple term "fact finding." The Geological Survey has been continuously engaged in research—in bringing to light facts that have been of essential importance in the marvelous development of our country since 1879. When the Geological Survey made its first census of mineral production, the treasure house of the country had hardly been opened; since then the mineral industry has increased fifteenfold. The research work of the Geological Survey has not been confined to investigations whose immediate economic value is self-evident. Realizing that the pure science of today becomes the applied science of tomorrow, it has neglected no phase of the study of the earth. Its method of work and the men it has trained have powerfully shaped the course of development of the science of geology.
>
> The topographic maps that have been necessary to provide an accurate base upon which to represent the facts ascertained by the geologic work have now attained so high a degree of exactness that they are sought for themselves by all classes of the people—from engineer to vacation tourist. The investigations of water, our greatest mineral resource, have thrown light on the complex problems of public water supply, inland navigation, flood prevention, reclamation by both drainage and irrigation, and the development of power. The activities of the Geological Survey in respect to the vast mineral estate comprised in the public land, of which nearly 200,000,000 acres still remain unappropriated, have been based on the practical policy of planning for its future use without waste of the resources and for the intelligent distribution of that use as to time—between our day and our children's day.
>
> Not the least of the accomplishments of the Geological Survey during its first half century has been its service as the mother of other organizations that are playing essential parts in the study of our country and the development of its resources. The work that is being done by the Bureau of American Ethnology, the Forest Service, the Bureau of Reclamation, the Bureau of Mines, and the Geophysical Laboratory of the Carnegie Institution had its beginnings in the Geological Survey.
>
> The publications by which the results of the multiform investigations of the Geological Survey have been made available in permanent form now comprise more than 400,000 printed pages and occupy 120 feet of shelf room—twenty-four "5-foot shelves" of recorded facts and conclusions concerning the unequaled natural resources of the United States.

The Survey had grown to 998 permanent employees, and its annual expenditure, including state funds, for fiscal year 1929 was $3,875,000.

In 1930 George Otis Smith was asked by President Hoover to serve as chairman of the newly formed Federal Power Commission, and, after giving the matter considerable thought, he resigned the directorship of the Survey on December 22, 1930. His term as director was marked by unswerving official integrity and the practical application of science to the public welfare.

The Survey in Peace and War, 1930–43

W. C. Mendenhall became acting director of the Survey when George Otis Smith resigned and full director in 1931.

Born in Marlboro, Ohio, in 1871, Mendenhall graduated from Ohio Northern University in 1893. He studied at Harvard in 1896–97 and at Heidelberg in 1899–1900. He joined the Survey in 1894 as an assistant geologist, becoming geologist in 1901. His first work was in Alaska on a variety of assignments, and in 1903 he was placed in charge of the Los Angeles Basin ground water investigations. His work was the first application of stream flow records in the solution of ground water problems. In 1908 he became geologist-in-charge of the Ground Water Branch, continuing in this post until 1912, when he became chief of the Survey's Land Classification Board, a post he held until 1922. He became chief geologist in that year and acting director in 1930. He thus brought to the directorship sound scientific ability and wide administrative experience in a diversity of Survey activities.

The depression of the early 1930's was in full swing when Mendenhall took over. Painful adjustments be-

came necessary in fiscal year 1934, and many separations from the service were made with accompanying suspension of many projects. At the same time, however, the new agencies and services of the Government made so many and varied demands on the Survey that its specialists and their specialized knowledge were at a premium. The situation, however, was relieved by the allocation of funds from such agencies as the Public Works Administration that absorbed the available engineers and allowed the hiring of many hundreds of unemployed technical men, all on projects concerned with topographic mapping, suppression of mine fires, and plugging of abandoned oil wells in the public domain, as well as a survey of some of the more important mineral resources of the eastern and southern states. The pattern for the next few years was one of curtailed direct appropriations, but large allocations from other agencies made up the difference. However, in fiscal year 1936, the Survey was able to report that, because of a better fiscal situation, it was possible to resume more normal operations and to issue a large number of Survey products, as the publication of 50 reports and 281 topographic and other maps demonstrated. A similar number was issued in fiscal years 1937 and 1938.

When the Tennessee Valley Authority was established in 1933, it became immediately necessary to provide map coverage of the entire valley. In cooperation with TVA, the Survey agreed to prepare planimetric maps of the region and was able to do so by the application of photogrammetric methods. In 1935, the Survey bought its first multiplex equipment. The value of this method was successfully demonstrated, leading to the establishment of a fully equipped multiplex mapping office in Chattanooga, with a program of topographic mapping of the entire Tennessee River Valley in cooperation with the TVA. A variety of mapping work was done for other Federal agencies during these years.

In 1933, the XVI International Geological Congress was held in Washington and the Survey's new geologic map of the United States, in preparation for many years, was hastened to completion for the event (*49*). In four sheets, at a scale of 1:2,500,000, it has been in great demand, but such is the progress of geologic investigations that it is now in need of revision.

With the threat of approaching war, Congress appropriated $150,000 to the Survey in 1939 and authorized the same sum for the next 3 years to be used for strategic minerals investigations. When the war broke, however, these sums were greatly increased. Strategic minerals investigations had become a normal function of the Survey in World War I, and it was natural that the Survey should be called upon to provide its know-how in this highly critical field in World War II. Expansion of this work was limited only by the number of available qualified men. Almost the entire personnel of many of the Survey sections were shifted to this work.

In fiscal year 1941, the Survey was called upon by the Committee for Cooperation with American Republics to undertake examinations of certain strategic mineral deposits in a number of Latin American countries. This work assumed increasing importance during the war and was eventually sponsored by the Department of State.

In February 1942, a military geology group was formed in the Survey and grew very rapidly as its work became more and more useful to the Armed Services. Its function was to supply reports and maps on many areas in response to requests from the Intelligence Branch of the Army Engineer Corps, Air Forces, Naval Intelligence, Board of Economic Warfare, Engineer Board at Fort Belvoir, and Army and Navy Munitions Board.

Director Mendenhall had prepared the Survey for war service and, having passed the normal retirement age, was ready to retire after a long and distinguished career in the public service. He had steered the Survey through a most difficult period. The Survey and the nation owe him profound gratitude for his magnificent performance.

The Survey in War and Peace, 1943–

W. E. Wrather came to the directorship of the Survey from outside its ranks, although he was not entirely a stranger to its rolls, having worked for it as a field assistant in 1907.

Born in Brandenburg, Kentucky, in 1883, he graduated from the University of Chicago in 1908. He was a geologist with the Gulf Products Company and the J. M. Guffey Petroleum Company from 1908 to 1916. He was an independent consulting geologist from 1916 to 1942. He became associate chief of the Metals and Minerals Division, Board of Economic Warfare in 1942 and director of the Survey May 7, 1943.

When Wrather came to the Survey, it had begun a phenomenal growth which has continued to the present time. For fiscal year 1943, the expenditures of the Survey were more than $11,000,000, representing funds directly appropriated to it by Congress, supplied to it by cooperative agreement from various states and other governmental units, and transferred to it from other federal agencies. Every year since then these over-all funds have increased, and the resulting growth of the Survey has presented a variety of administrative problems. That the Survey has functioned well during this time is a tribute to Wrather's leadership.

During World War II, the Survey's resources were wholly devoted to the war effort. Military geology functions grew to great proportions. In addition to the work of this group, as previously described, it appraised the characteristics of enemy terrain for the Corps of Engineers from published geologic reports and maps. Soil scientists from the Department of Agriculture worked with the geologists in these appraisals, which were used for strategic planning. Later, Survey geologists went into the war theaters as civilian specialists and were able to aid in planning tactical operations. Since the war, the military geology group has remained an important part of the

Survey in continuing a variety of services for the Defense Department.

There was a tremendous expansion of mapping needs during World War II, and the Survey placed all of its map-making factilities and personnel at the disposal of the Armed Services. The period between the two world wars had been one of somewhat slow progress in mapping. The Temple Act passed by Congress in 1925 had called for a 20-year mapping program to finish the topographic map of the United States, but sufficient funds were not made available to carry out the schedule. At the end of World War I, it was considered that 45 percent of the United States was adequately mapped, but by World War II only about 20 percent met modern-day standards.

The impact of World War II stepped up the mapping program, more funds were made available, and map production has correspondingly increased. This is illustrated by the fact that 5000 separate topographic quadrangle maps were produced during the first 60 years of the Survey's existence and 8000 during the last 15 years. In fiscal year 1953, more than 1300 such maps were produced, and the present rate is 1500 a year. By the end of fiscal year 1953, about 30 percent of the United States was covered by maps of good quality. Much of the mapping in late years, because of the high priority of the defense mapping program, has been in areas of military needs, but more federal mapping can be started in areas of more general mapping needs when the military demands recede. Methods and techniques in use today are responsible for the production of maps that are better and less expensive and are appearing at a faster rate.

Under current mapping programs, new mapping or revision is going on in all the states, and in Alaska, Hawaii, Puerto Rico, and the Virgin Islands. The National Topographic Map Series consists of 7½-min quadrangle maps at a scale of 1:24,000, 15-min quadrangle maps at a scale of 1:62,500 and reconnaissance maps at a scale of 1:250,000.

The production of geologic maps should be materially increased by the use of photogrammetry in this type of mapping, and the Survey is actively pushing this application.

Water resources investigations have also increased and at present, for instance, the Survey is operating more than 6000 stream-gaging stations. A distinctive feature of these investigations is the extensive cooperation with federal and state agencies. The proportions of the total effort at present are 55 percent federal-state cooperation (on a 50-50 basis), 22 percent cooperation with other federal agencies, and 23 percent Survey. Data collected by the Survey are basic to the extensive federal interagency work in various river basins, and in this Survey effort the water resources investigations play a leading role. As water supplies for all purposes become increasingly critical in the United States, the systematic recording of water data of all kinds by the Survey insures that the basic facts are available when needed.

Conservation work in the Survey also has increased since 1943 and continues to increase. Since the beginning of mineral-leasing activities on public lands in 1920, up to 1952, the latest year for which complete figures are available, about $323,000,000 has accrued in royalties. By statute, 52½ percent of such royalties go to the Federal Reclamation Fund, 37½ percent go to the states where the minerals were produced, and the remaining 10 percent go to the United States Treasury. As of June 30, 1953, the Survey was supervising 1261 mining properties under leases, permits, and licenses in 27 states and Alaska. Annual production from such lands amounted to about $120,000,000. In addition, 78,785 oil and gas properties were under lease. These are examples of the extent of such work.

In its mineral classification work during the fiscal year 1953, the Survey handled 19,259 cases, and in its water and power classification work, it added 18,926 acres to power-site reserves and eliminated 2244 acres, increasing the outstanding reserves in 23 states and Alaska to a net total of nearly 7 million acres.

With the development of atomic energy, the Manhattan Engineers District Project and later the Atomic Energy Commission called on the Survey for a major effort in fissionable raw materials investigations. This has now become a large program in the Survey and has materially contributed to the nation's increasing inventory of such materials. The Stockpiling Act of 1950 has also involved the Survey in great responsibility for implementing the programs of the Defense Minerals Exploration Administration and the Defense Procurement Agency. The Survey in late years has also been called upon to undertake geologic investigations of mineral resources in underdeveloped countries under the Mutual Security Act and to serve as advisors and consultants to the National Security Resources Board, the National Science Foundation, and the Department of Defense. It is keenly aware of the need for continual improvement of techniques for exploration for mineral resources; and its development (in cooperation with the Navy) and successful use of the air-borne magnetometer, the development and successful use of air-borne radioactivity methods, the development and successful use of geochemical prospecting, and other related activities testify to its efforts in this field.

Today the Survey has more than 6000 permanent employees. It distributes nearly 2,500,000 maps and 225,000 book reports annually. It expends about $48,000,000 a year in funds from all sources, and in 75 years the grand total of such expenditures has been about $475,000,000. It has published about 3000 book reports and probably an equal or greater number of such reports in technical, scientific, and popular journals, and it has published about 15,000 different maps.

Its professional people through the years have won many honors in scientific circles and have served as officers in many scientific and technical societies. The whole Geological Survey is aware, with Director Wrather, of the great responsibility it bears in continuing to serve the nation in the years ahead. But there is much to be done and, as George Otis Smith

said at the beginning of the Survey's 51st year, "The one hundredth report of the Director of the United States Geological Survey may be expected to be simply a report of progress."

It seems appropriate to close this episodic history of the Geological Survey with the words of a dedication by Emmanuel de Margerie, which appeared in his *Etudes Americaines, Geologie et Geographie* (Librairie Armand Colin, Paris, 1952).

A LA GLOIRE DES MEMBRES DE
L'UNITED STATES GEOLOGICAL SURVEY
dont la féconde activité, au cours du dernier
siècle, a révélé,
dans l'Ouest du Territoire
tant de faits nouveaux et importants pour la Science

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News and Notes

Fourth Rochester High-Energy Physics Conference

The fourth in the annual series of conferences on high-energy nuclear physics initiated by R. E. Marshak, chairman of the Rochester physics department, and sponsored jointly by a group of local industries and the National Science Foundation, was held on Jan. 25–27. The conference chairman this year was J. B. Platt. About 75 representatives of American and European laboratories actively engaged in high-energy physics and cosmic-ray research attended the sessions. Attention was focused on the fundamental experimental and theoretical problems of nucleon-nucleon, meson-nucleon, and photon-nucleon interactions and the various unstable particles found in the cosmic radiation and now also produced artificially by the Brookhaven cosmotron.

J. R. Oppenheimer (Institute for Advanced Study) presided over the opening session on nucleon-nucleon scattering, polarization, and π-meson production. Ashkin (Carnegie Tech) reported on the differential p-p scattering cross section at 437 Mev measured by Sutton and Fox which shows a rise at small angles, in disagreement with results at Chicago; the discrepancy seems to arise from different methods of correcting for the process $p + p \rightarrow \pi^+ + d$. The n-p differential cross section at 400 Mev measured by Hartzler and Siegel at Carnegie Tech (reported by de Benedetti) shows the same asymmetry about 90° found at lower energies. Pickavance (Harwell) reported that R. Wilson's n-p measurement at 102 Mev confirmed the older symmetric results at 90 Mev, but by 133 Mev, this symmetry is disappearing.

Oxley (Rochester) summarized the original experiments showing strong polarization in 230-Mev proton scattering in hydrogen and several other elements. These are now confirmed at 150 Mev (Dickson and Salter, Harwell), 337 Mev (J. and L. Marshall, Chicago), 330 Mev (Chamberlain and Segrè, Berkeley).