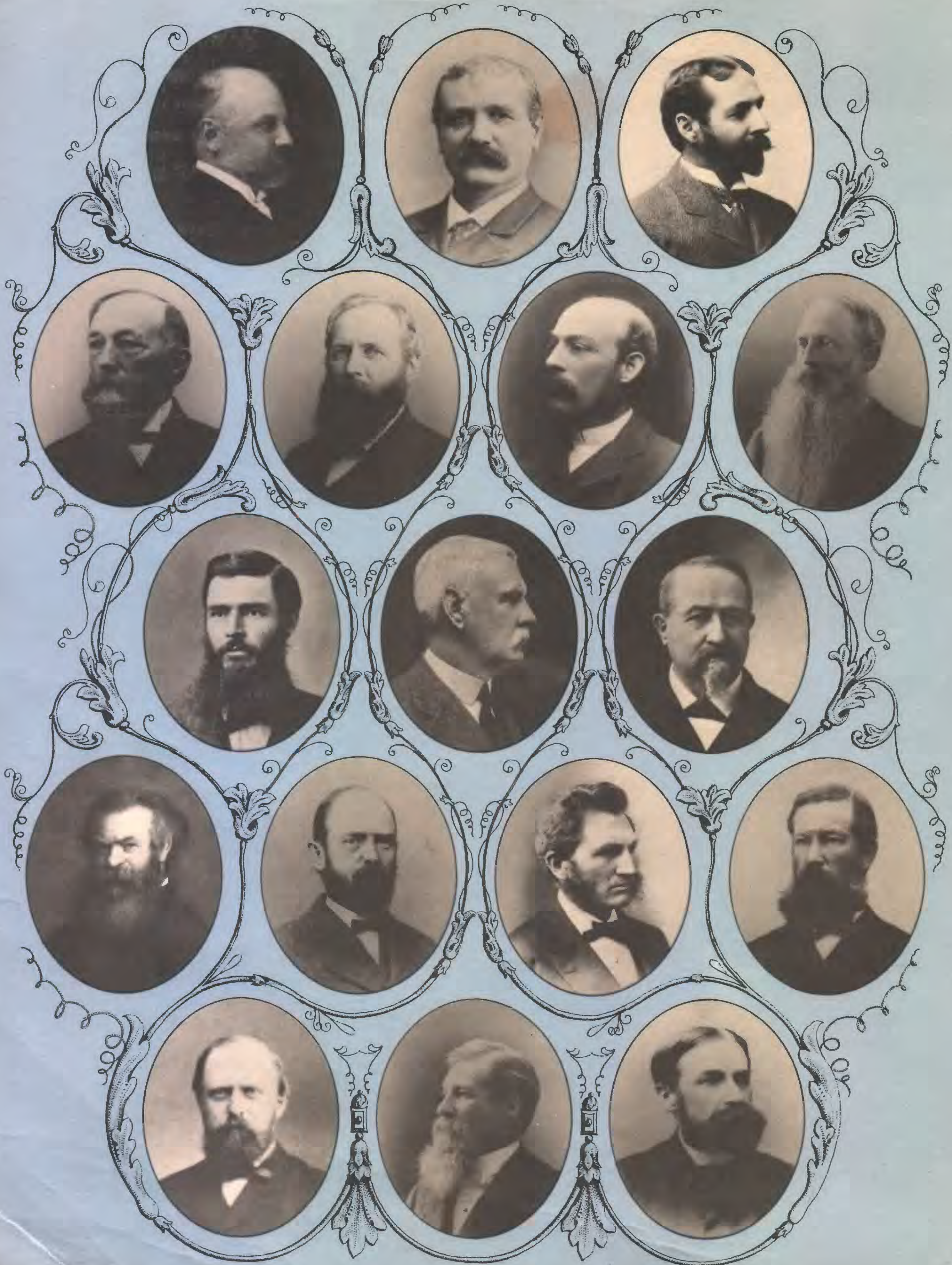
Minerals, Lands, and Geology for the Common Defence and General Welfare

Volume 2, 1879–1904

UNITED STATES GEOLOGICAL SURVEY



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U.S. Geological Survey party on the way to study the gold deposits at Cripple Creek, Colorado, in 1893. (Photograph by Whitman Cross ▶ from the files of the U.S. Geological Survey.)

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Minerals, Lands, and Geology for the Common Defence and General Welfare Volume 2, 1879–1904

By Mary C. Rabbitt

UNITED STATES GEOLOGICAL SURVEY

A History of Geology in Relation to the Development of Public-Land, Federal-Science, and Mapping Policies and the Development of Mineral Resources in the United States During the First 25 Years of the U.S. Geological Survey

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GEOLOGICAL SURVEY
H. William Menard, Director

Preface

John Wesley Powell told the Allison Commission in 1885 that "Sound geologic conclusions cannot be reached by following a few narrow lines of investigation, but all such lines of research must be followed that each may shed light upon the other. Unless this principle is fully recognized, a geologic survey might lead to conclusions of no value to the people at large, or conclusions might be reached so erroneous as to be misleading." The principle is sound, but Powell, like many others of his time, did not fully comprehend the magnitude of the task that he proposed of encompassing all knowledge of a given science before applying any part of it.

The same principle may be applied to history but would obviously produce the same impossible task, and therefore, it is customary to deal with limited portions of history or with a particular aspect. Nonetheless, as explained in Volume 1, it was decided not to treat Survey history from a thematic point of view, although it would have been possible to consider the Survey in that way, as a Government agency, as a research institution, in terms of its contribution to the industrial development of the country, or to the conservation of its natural resources and preservation of its environment. All of these are only facets of the total Survey, and rather early in the study of Survey history it was discovered that focusing on a particular aspect could easily, and in fact has, led to conclusions far different from those drawn from consideration of the whole.

In the traditional view of the Survey's first 25 years, which are the subject of much of this volume, John Wesley Powell, with his broad view of science and advanced ideas of land and water in the West, is the heroic figure. Clarence King is dismissed as brilliant but with a limited view of science as mining geology, and Charles D. Walcott is regarded primarily as a brilliant paleontologist chosen by Powell to succeed him. The Survey's first quarter century, however, spanned a watershed in American history that separated a primarily rural and agrarian nation and a primarily urban and industrial nation, a nation intent on conquering the continent and isolated from the Old World and a nation involved in world politics, a nation that believed in the virtues of competition and limited government and a nation that saw the virtue of cooperation and insisted on reform and regulation to ensure equal opportunities to all. Science itself changed during this period. The age of instruments was just beginning when the Survey was established; by the turn of the century, instruments had almost revolutionized science and the era of the lone investigator had to give way to an era of organized effort in the solution of problems.

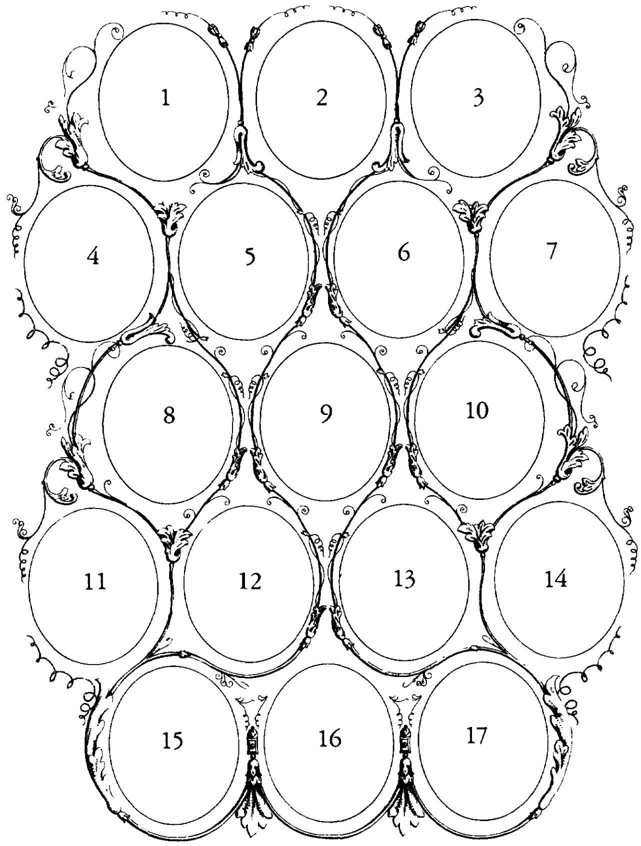
When these facts are taken into consideration, it can be concluded that the importance the Geological Survey achieved in its first 25 years, in fact its longevity, should be attributed not to the broad view of science taken by John Wesley Powell, but to the foresight of Clarence King in organizing the Survey's research to aid in the industrial progress of the country while seeking ultimately the advancement of science and to the perspicacity, administrative skill, and seemingly limitless energy of Charles D. Walcott, who held that the Survey's field was geology and not all science, who directed its research toward the aid of not just the mineral industry, as envisioned by King, but of all industries and practical undertakings that would benefit from a knowledge of the Earth and its resources, and who insisted that basic research and applied science cannot be separated. The development of economic geology as a science and not just applied geology must be considered one of the achievements of this era, and to this development, the Geological Survey was a major contributor.

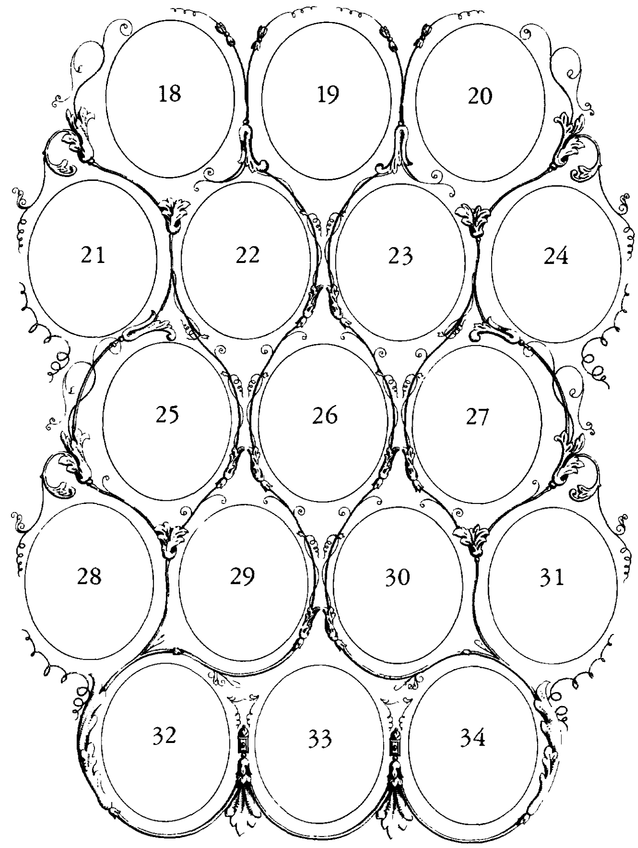
Economic geology, however, was not the sole achievement. There were advances in other fields, sometimes as part of economic geology, sometimes apart from it, to name but a few: the growth of petrography and petrology, the development of glacial geology, the definition of mapping units, stratigraphic classification, and geologic time divisions, the conservation of water, changing standards of topographic mapping, the emergence of geophysics and geochemistry. Each of these could fill a separate book. The detailed indexes will help those who wish to follow a particular development or to obtain a bird's-eye view of the variety.

Basic to all, however, is the idea that Federal science must respond to national needs as perceived at the time in order to remain healthy. And so the presentation must be chronological rather than thematic. In time-honored Survey fashion, the facts are presented and a conclusion drawn, but acceptance of the conclusion must rest of the facts, not on any special pleading.

I should like to acknowledge my indebtedness to many members of the Geological Survey for their help in preparation of this volume. In particular, I wish to thank Thomas B. Nolan, Director, 1956–1965, for his interest, encouragement, advice, and many useful discussions; Arthur A. Baker, former Associate Director, Vincent E. McKelvey, Director, 1971–1978, and Clifford M. Nelson, Associate Historian, 1976–1980, for thorough and detailed reviews of the manuscript; and other reviewers, including R. H. Lyddan, R. P. Southard, Morris Thompson, George H. Brett, G. D. Robinson, and E. Roy Hendricks for valuable suggestions.

Keys to portraits on end Papers





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Chapter 1. A New Order

> **There is nothing more difficult to take in hand, more perilous to conduct, or more uncertain in its success, than to take the lead in the introduction of a new order of things.**
>
> **—Niccolo Machiavelli**

On March 3, 1879, the U.S. Congress established the U.S. Geological Survey, placing it in the Department of the Interior and charging it with responsibility for the classification of the public lands and examination of the geological structure and mineral resources and products of the national domain. In the same act, Congress created a public lands commission and asked it to provide a codification of laws relating to the survey and disposition of the public lands, a system of land-parcelling surveys, and recommendations in relation to the best method of disposing of the public lands to actual settlers.

The United States was then a primarily rural and agrarian nation, consisting of 38 States, 8 Territories, the District of Columbia, Indian Territory, Alaska, and a piece known as Public Land or Land Strip southwest of Kansas and north of Texas, unattached to any State or Territory. The edge of settlement, or frontier, was at about longitude 102° West; beyond the frontier were only isolated pockets or belts of settlement, many of which owed their initial existence and some their continued existence to miners and prospectors. In vast areas beyond the frontier, the population was officially less than 1 per square mile. The Federal Government still held title to more than 1.2 billion acres of land, only 200 million of which had been surveyed. Nearly all the public lands were in the Territories and States west of the Mississippi River; only 26 million acres in Florida, Alabama, Mississippi, Arkansas, and Louisiana were still part of the public domain.

Agriculture was the principal occupation of nearly half the working force. Thirteen States—Delaware, Virginia, North and South Carolina, Georgia, Alabama, Mississippi, Tennessee, Kentucky, Illinois, Missouri, Iowa, and Wisconsin—were classed as successful agricultural regions by the Census of 1880. About half as many people were employed in the manufacturing, mechanical, and mining industries combined as in agriculture. Only two States—Rhode Island and New Jersey—were regarded as industrialized, although eight others—Massachusetts, Connecticut, New York, Pennsylvania, Maryland, Ohio, Indiana, and Michigan—were more industrialized than agricultural.

There were very few Federal scientific and mapping agencies when the U.S. Geological Survey was established in 1879. The oldest were the mapping agencies. The Office of the Surveyor General had been established in 1796 to map the public lands, but since 1836, it had been part of the General Land Office, which came under the Department of the Interior in 1849. The Coast and Geodetic Survey in the Treasury Department had been authorized in 1807 to chart the coasts in aid of commerce. In 1832, it had acquired responsibility for standardization of weights and measures, and under its second and third superintendents, Alexander Dallas Bache and Benjamin Peirce, it had begun various scientific studies as well. In 1871, the Coast Survey was authorized to make a coast-to-coast triangulation, and in 1878, its name had been changed to Coast and Geodetic Survey. The U.S. Army Corps of Engineers had been responsible for mapping the western Territories. The Naval Observatory had been established in the early 1840s, and the Naval Hydrographic Office had been set up during the Civil War.

The Department of Agriculture had been established in 1862 and authorized to make practical and scientific experiments in order to acquire and diffuse useful information on subjects connected with agriculture. In establishing the department, Congress acknowledged that its power to provide for "the common defence and general welfare" warranted sponsorship of continuing scientific research in the older of the two basic industries. In 1869, Congress authorized the Army Signal Corps, which had collected meterological information during the Civil War, to continue the service, again sanctioning continuing scientific investigations. Then in 1871, as a conservation measure, Congress established the Fish Commission to study the diminishing fish population in the Atlantic.

In addition to these continuing organizations, Congress had in earlier years also ordered commissions or surveys to perform certain tasks, such as the surveys of mineral lands or various exploring and mapping expeditions. In 1867, two surveys had been authorized: the Geological Exploration of the Fortieth Parallel, administratively under the War Department but directed by a civilian, Clarence King, and a survey under the General Land Office of the resources of the new State of Nebraska. The latter, headed by Ferdinand V. Hayden, had developed into the Geological and Geographical Survey of the Territories. In 1871, two other western surveys were authorized. One was the outgrowth of the daring exploration of the Colorado River by Major John Wesley Powell in 1869; it was at first under the Smithsonian Institution but in 1874 was transferred to the Department of the Interior where it was first the second division of the Geological and Geographical Survey of the Territories and later the Geographical and Geological Survey of the Rocky Mountain Region. The second survey authorized in 1871 was the Geographical Surveys West of the One Hundredth Meridian, directed by Lieutenant George M. Wheeler of the Corps of Engineers. None of these surveys was regarded as permanent; they had been established to accomplish certain tasks. The Geological Exploration of the Fortieth Parallel had in fact completed its fieldwork in 1872 and its reports in 1878.

Rivalries among the remaining surveys had led Congress to ask the National Academy of Sciences in June 1878 to consider all surveys of a scientific character under the War or Interior Departments and to report to Congress a plan for surveying and mapping the Territories of the United States on a system that would secure the best possible results at the least possible cost. A committee of the National Academy of Sciences concluded that it was absolutely essential that there be only one geodetic system, one topographic system, and one land-parceling system, all under one head, and had recommended that the Coast and Geodetic Survey be transferred from the Treasury Department to the Interior Department, renamed the "Coast and Interior Survey," and given responsibility for all mapping and surveying. The committee also recommended that a second survey, the United States Geological Survey, be established to obtain a thorough knowledge of the geological structure, natural resources, and products of the public domain to meet the requirements of existing law on the disposition of the public lands, and that a public lands commission be formed. The committee noted:

By far the larger part of the public domain lies in the region where, from geological and climatic causes, the lands are for the most part not valuable for field culture, and where the system of homestead pre-emption and sale in accordance with existing laws is both impracticable and undesirable.

The prairies and Rocky Mountain country had been passed over in early westward migrations, as farmers sought new land to replace land that had lost its fertility, but by the end of the Civil War, suitable new land was becoming difficult to find. During the 1870's, therefore, farmers had settled large areas in Dakota, Nebraska, Kansas, and Texas, moving the frontier westward scores of miles. The plains and prairies country into which they were moving was especially suited to the growing of grains and cereals, a type of agriculture that had begun to change from a subsistence to a commercial operation with the introduction of farm machinery in the 1850's. To be successful, however, such agriculture required large farms and many workers, and therefore a substantial investment in lands, buildings, and equipment. As early as 1875, the Commissioner of the General Land Office reported that the lands most desirable for homestead settlement, because of the fertility of the soil and the presence of conditions necessary for honest observance of the requirements of the homestead law, had already passed into private ownership.

Farmers who had to borrow money were at a disadvantage, for farm prices had been declining since 1869. Although the principal crops were produced in ever-increasing quantities, the total value of farm products in 1879 was less than it had been a decade earlier. Farmers in two sections of the country were especially affected by the problem of credit: those in the South, who lacked both land and capital, and those moving into the Great Plains, who needed large amounts of capital.

The farmers had begun to organize shortly after the end of the Civil War, at first simply to promote agricultural interests, but when prices began to decline, some of the farmers' associations, particularly the Patrons of Husbandry, more commonly known as the Grangers, began to lobby politically against monopolies, especially the railroads, and for farm credit.

The farmers tended to look toward politics rather than science for aid, for agriculture had not as yet greatly benefited from science. Although scientists in the private sector had made studies of soil chemistry, fertilizers, plant nutrition, diseases, and pests, their work had not had any great impact on farming practices. The Department of Agriculture had been authorized to conduct scientific experiments, but the first commissioner had organized the scientific work along the lines of the scientific disciplines. Appropriations lagged, and by 1879, many despaired of any useful scientific contributions from that department.

Crop yields were more dependent on weather conditions than any other factor, and that was a matter of particular importance to those moving into the Great Plains area. Cyrus Thomas of the Interior Department's Geological and Geographical Survey of the Territories had pointed out early in the 1870's that the 100th meridian was a dividing line between two regions of very different climate, and he urged that climatological studies be undertaken. It was well known, he said, that on the eastern side of the plains, the average rainfall was sufficient to supply the moisture necessary for growing grains; it was almost as well known that irrigation was necessary at all points on the plains along the east base of the Rocky Mountains, and it was very important to determine the exact boundary between the two regions.

In 1878, John Wesley Powell of the Interior Department's Geographical and Geological Survey of the Rocky Mountains had pointed out in his *Report on the Lands of the Arid Region* that two regions were involved: The Arid

Region proper, where the mean annual rainfall was less than 20 inches and therefore insufficient for agriculture on the basis of the traditional patterns of the Humid Region; and a Subhumid Region, where the mean annual rainfall was 20 to 28 inches. Most of the region west of the 100th meridian was part of the Arid Region proper. The Subhumid Region extended eastward from that meridian to about the 97th meridian. Powell pointed out that droughts would be frequent in the western part of the Subhumid Region and that irrigation would be undertaken at an early stage, whereas in the eastern part of the region, droughts would be less frequent and farming could be undertaken for long periods without irrigation.

A slightly different definition of the Arid Region was given by Henry Gannett, geographer for the Tenth Census. Gannett said that irrigation was necessary for cereal crops where rainfall was less than 20 inches annually or less than 12½ inches during the growing season. This limit was reached along a line described as running approximately along a meridian passing through the middle of Dakota, western Nebraska, western Kansas, and central Texas, or presumably between longitude 100° and 101° West. Near this line and perhaps a degree on either side of it, according to Gannett, was debatable ground—Powell's Subhumid Region.

In the plains country where influx of people had been heaviest, rainfall had been sufficient for successful agriculture for several years, and there was a widespread belief that the Timber Culture Act, which encouraged the cultivation of trees, had actually changed the climate. However, in Kansas and Nebraska, ribbons of settlement progressing toward the western boundaries of the States clung to the South Platte, Republican, Kansas, and Arkansas Rivers where water would be available for irrigation.

In most of the belts and pockets of settlement west of the frontier where agriculture was practiced, irrigation was already a recognized necessity. The Mormons of Utah had developed a highly successful agriculture based on irrigation. Many settlements in Colorado, Idaho, and Montana followed the streams. In California and Nevada, where mining had ceased to flourish and agriculture had become more important, the problem of irrigation had been recognized early. In 1873, Congress had appointed a commission to investigate the possibilities of irrigation in the San Joaquin, Tulare, and Sacramento Valleys in California. The commissioners concluded that extensive systems of irrigation could be built only by the State or by private capital and could be built only after a complete instrumental survey had been made to determine the location of dams, canals, and ditches and to divide the country into different irrigation districts.

Major Powell in his 1878 report on the Arid Region went beyond the commissioners. He included drafts of two bills for the organization of irrigation and pasturage districts by homestead settlements, following classification of the lands. Major Powell's proposal, like that of the commissioners in 1874, was essentially a political solution of the problem.

The farmers' groups had some success in securing enactment of State legislation controlling railroad freight rates, but the problem of money and credit was more intractable. At first, the farmers favored the continued use of greenbacks. During the Civil War, the Government had issued about $450 million in paper currency, greenbacks, not redeemable in gold or silver. After the war, public opinion had been almost unanimously in favor of retiring the greenbacks from circulation until the postwar depression caused a decline in prices.

Eventually sentiment changed from support of greenbacks to support of silver-based money. Monetary legislation had undervalued silver for many years. Silver prices had remained high; silver dollars, being worth more than gold dollars, had gone out of circulation, and the Coinage Act of 1873 had dropped silver dollars from the list of coins. Silver production had begun to rise, however, with the discovery of the Comstock in 1859; the price of silver had begun to drop, and in 1873, gold and silver reached parity. A month after silver dollars were dropped, a new bonanza was discovered at the Comstock, production soared, and silver prices declined still more, so that by 1876 the bullion in a silver dollar was worth less than 90 cents on the market. Several European governments had by this time adopted the gold standard, but American currency was still on a bimetallic standard. Silver money would satisfy the demand that the currency have a metallic base, coining silver at the ratio of 16:1 would expand the money supply, so a combination of silver interests, inflationists, and farmers brought about passage of the Bland-Allison Silver Purchase Act in February 1878, directing the Secretary of the Treasury to purchase not less than $2 million nor more than $4 million worth of silver bullion each month at market value.

The West was particularly interested in silver legislation, for almost all the precious metal resources came from the Western States and Territories, whereas almost all the minerals needed by industry, then chiefly coal and iron, were mined in States east of the 100th meridian. There were, in effect, two distinct mining industries, separated geographically and by product. Mining laws were also different. In the Eastern States, English common law was the rule for transfer of property, and surface rights carried with them the minerals vertically below. In the public-land States and Territories, mineral land could be obtained from the Federal Government under the Mining Law of 1866 and the Mining Law of 1872, which recognized local customs and regulations and other relations between surface and mineral rights.

The larger and more profitable mining industry was in the States east of the 100th meridian; of the top 10 mining States and Territories in 1880, 6 were east of that line. Pennsylvania was the leading mining State of the Union, the value of its mineral products more than three times that of the second State, Colorado, and more than that of the next three States, Colorado, California, and Nevada, combined. In the census year of 1880, when 28.6 million tons of anthracite and 42.7 million tons of bituminous coal were mined, nearly all the anthracite and 45 percent of the bituminous coal came from Pennsylvania, and nearly 70 percent of the bituminous coal came from the Appalachian fields. Nearly 8 million tons of iron ore were produced in 1880, about half of it in Pennsylvania and Michigan. New York and New Jersey ranked third and fourth, and these four States produced more than 75 percent of all the iron ore produced in the United States.

Copper, lead, zinc, and petroleum were then of far less importance in industry, but of these, copper, zinc, and petroleum also came chiefly from States east of the 100th meridian. More than 90 percent of the 55.8 million pounds of copper mined in 1880 came from the eastern part of the country; more than 90 percent of eastern copper came from the Lake Superior district and more than 50 percent, from the Calumet and Hecla mines alone. Nearly half the zinc came from New Jersey and Pennsylvania, most of the rest from the Mississippi Valley. Nearly all the petroleum came from northwestern Pennsylvania, only small amounts being obtained elsewhere in Ohio, West Virginia, and Kentucky. Petroleum production in 1880 was only about 7 million barrels, but petroleum was the subject of a special report by the Tenth Census. It was then used chiefly for illumination, lubrication, and medicinal purposes. S. F. Peckham reported, however, that there had been some theoretical consideration of its use as a fuel and that a "novel application" had been made by exploding petroleum vapor behind the piston of an engine and that the expansive force had been made available as a motor. Such uses, if developed, could affect future production.

Lead was the only one of the nonprecious minerals that came chiefly from west of the 100th meridian, and the lead industry was troubled by overproduction. After 1849, the United States had been a lead-importing nation until 1877, when the large new production from the silver-lead industry of Nevada and Utah once more made it independent. The new production, however, brought about a decline in the price of the metal, and in 1878, the American Pig Lead Association had been organized in an effort to hold the price at not less than 4 cents a pound. The effort was unsuccessful. Toward the end of the year, an increase in domestic consumption coupled with a falling off in production and the shipment of Nevada's surplus to China gave rise to optimism until reports began coming in of the developments at Leadville, Colorado.

Gold and silver, iron, coal, copper, lead, zinc, and petroleum were the only minerals given special consideration by the Tenth Census of 1880. Lumped together, and valued at little more than 1 percent of the total mineral production of that year, were asbestos, asphaltum, barytes, chromic iron, cobalt, corundum, garnet, glass sand, graphite, hydraulic cement, hydraulic lime, infusorial earth, kaolin, magnesian limestone, manganese, mica, mineral soap, nickel, nickel and cobalt matter, ocher oilstone, pyrite, quartz and feldspar, scythestones, shoemakers' sandstones, soapstone, talc, and whetstone.

The mineral industry, unlike agriculture, had had a long and close relationship with science. The study of minerals was the oldest phase of the earth sciences. Chemistry had its beginnings in the alchemists attempts to transmute base metals into precious metals. Geology began to separate from natural history as a distinct science in the mining school at Freiberg in Saxony. Government geological surveys, which began in the eastern part of the United States, were first inaugurated to aid agriculture but very quickly shifted to investigations of mineral resources. The Federal Government also employed geologists in the evaluation of mineral resources, particularly in the classification of mineral lands. These surveys in turn led to advancements in the science of geology. Thus Josiah Dwight Whitney was led to say in 1875:

> **It is chiefly through its intimate connection with the art of mining and the development of the mineral resources of the country that geology has acquired the importance it now has.**

The mineral industry of the United States had not neglected political action. Some of the earliest efforts to establish the protective tariff system originated in the iron industry. The copper industry had also resorted to the tariff. However, the American Institute of Mining Engineers was established in 1871 because, in the words of one of its first members:

> **The time has come when scientific research is to assume its true position—the day of 'sheer force and blind stupidity,' whose only protection was a high tariff, has gone by forever. *** the physicist, the geologist and mineralogist, the chemist, the engineer and mechanic, are as essential to success as the furnace itself, or the labor that works it.**

Congress did not follow all the recommendations of the National Academy of Sciences in the legislation of March 3, 1879. The Coast and Geodetic Survey was not transferred to the Interior Department. The West was opposed to any change in the public-land surveys that might hinder development. A decision on national-mapping policy was thus postponed, and the hope of the Eastern States for Federal assistance in topographic mapping to aid in the development of natural resources was left unfulfilled. The Coast and Geodetic Survey would continue to survey the coasts and to extend triangulation from the Atlantic to the Pacific, but for the time being, the States would have to do the mapping within their own boundaries.

In establishing a public lands commission, Congress acknowledged that the public lands of 1879 were very different from those of the early years of the Republic and that it was time for a new look at public-land law. The inclusion of the Director of the Geological Survey as one of the commission of experts conceded the usefulness of science in the formulation of public-land policy.

Federal geologic work was given an entirely new status, for Congress went beyond the recommendations of the National Academy of Sciences when it established the U.S. Geological Survey. The Academy had recommended that the Survey be established to obtain a thorough knowledge of the geological structure, natural resources, and products of the public domain; Congress required the Survey to classify the public lands but to examine the geological structure, mineral resources, and products of the national domain. The change was significant. Congressman A. S. Hewitt of New York, author of the legislation and a well-known ironmaster and former president of the American Institute of Mining Engineers, told Congress in February 1879 that the Geological Survey was needed to determine,

> **What is there in this richly endowed land of ours which may be dug, or gathered, or harvested, and made part of the wealth of America and of the world, and how and where does it lie?**

His friend, Clarence King, said that 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 production of the United States" was the "step necessary to give the highest efficiency and the most harmonious balance to the National geological work." The Organic Act of the U.S. Geological Survey in 1879 thus acknowledged the increasing importance of the second basic industry in the national economy and so marked the beginning of a new era.

Within the next 25 years, the United States was transformed from an isolated, rural, and agrarian nation into an urban industrial world power. The population increased from 48.9 million in 1879 to 81.8 million in 1904; settlement of the West proceeded so rapidly that by 1890 the frontier had disappeared. The number of manufacturing establishments and the value of manufactured products more than doubled in the period. Money in circulation per capita increased from $16.75 on July 1, 1879, to $30.77 on July 1, 1904.

Transportation was an important factor in the change. There were 35,000 miles of steam railroads in the United States and more than five times as much at the turn of the century. The first transcontinental railroad was completed in 1869, and only 15 years later, three other lines had been completed to the west coast. Railroads were especially important in developing the West, increasing its population and transporting its products, both mineral and agricultural, to eastern centers.

A second factor in the transformation was the development of science and technology. The use of electricity, improvements in the quality of steel, and new metallurgical processes that made available the ores of precious and industrial metals previously considered intractable, all aided in the industrial revolution. An agricultural revolution during this same period was similarly aided by science. Federal scientific bureaus in the Departments of Agriculture and the Interior contributed to both revolutions.

Political and economic conditions were also important. Laissez faire—which has been described "as a shorthand abbreviation for a whole complex of economic and social thought, economic organization, political policy, judicial theory and decisions, and popular belief"—was then at its height. As first formulated in Europe, laissez faire was a reaction against mercantilism and its strict governmental regulation of the economy. Laissez faire promoted the interests of a rising class of farmers and business entrepreneurs by stressing the virtues of competition in the economic well being of the community. Implicit in the system was the idea that the State should not interfere with the economic life of the community. After the Civil War, laissez faire came to have a new meaning in the United States. Charles Darwin's *Origin of Species* had been a major revolution in scientific thought when it was published in 1859. By 1879, the theory of natural selection had been translated into other spheres of thought, notably into what has been called Social Darwinism, the idea that the evolution of society and social institutions also came about by competitive struggle and survival of the fittest exactly as did biological evolution. Social Darwinism originated with Herbert Spencer in England but was widely accepted in the United States, where it reinforced an old American belief that that government governed best that governed least and also justified the actions of the captains of industry. By the tenets of Social Darwinism, the rich achieved their wealth because they were superior, more industrious, or more virtuous, and the poor were poor because they were inferior, lazy, or evil. If the most fit survived in the struggle for business success, their methods were sanctioned and the Government should in no way interfere. Thus, businessmen used ruthless tactics to destroy competition and establish monopoly, and bankers, to extend control over railroads and industries and build up interlocking financial empires. Thus, also, the railroads and the large industrial combinations were able to acquire vast holdings in land, timber, and mineral resources.

There were dissenters to the theory from the 1870's on. On the intellectual level, one of the most eloquent was Lester Ward, pioneer sociologist and paleobotanist of the U.S. Geological Survey, who pointed out that competition in the economic sphere did not assure survival of the fittest and often had the opposite effect. Ward was a firm advocate of economic planning. So were Richard T. Ely and other young economists critical of orthodox economics, who formed the American Economic Association in 1885 with a declaration that the positive assistance of the State was one of the indispensable conditions for human progress. The popular revolt against the philosophy of laissez faire began with the farmers, in the Granger movement of the 1870's, and with industrial workers, in the formation of labor unions. Others, mostly Easterners, were concerned with tariff reform, the merit system in government, and later with anti-imperialism. The philosophic response to the ferment was a distinctly American system of philosophy, pragmatism, which regards truth as not absolute but relative and tested by its consequences. After 1890, nearly all aspects of American life—political practices, economic institutions and practices, social relationships—were examined and changed. Not even science was exempt.

Science, which was the root cause of much of the change, was itself in a transitional state in 1879. Many scientists still reflected the influence of the naturalists of earlier decades, who collected and classified objects by collecting and classifying facts, sometimes only to add to the sum of human knowledge without further synthesis and application. There were scientists who believed it possible to learn everything about a particular subject; there were even those who thought that everything had already been learned about some subjects except, perhaps, a few details. The use of tools, such as petrographic microscopes and cameras, which added new dimensions, was then in its early stages.

Scientists themselves, consciously or unconsciously, often subscribed to the current philosophy. Most scientists in 1879, in a sort of scientific laissez faire, cherished the right to select and pursue their own interests in investigations and resisted direction and standardization. Scientists who accepted the Darwinian theory for biological evolution were among the most critical of Social Darwinism. Curiously, however, some of them, bureau chiefs not excepted, in their enthusiasm for science and its potential for contributing to human welfare, accepted a role as superior products of evolution, and like their business counterparts attempted to establish scientific monopolies. Progress in science, however, was so great and so rapid that organization and cooperation became necessary and accepted.

Clarence King, who became the U.S. Geological Survey's first Director, organized the Survey into two independent divisions, Mining Geology and General Geology, and then into geographic divisions after the fashion of the Coast and Geodetic Survey. Conceiving it to be his duty to obtain immediate results of strictly practical value, he allotted most of the funds to mining geology and planned a two-fold program: a study of mining districts and the collection of mineral statistics. Although general geology had the lesser role, basic research was not neglected. In addition to the work of the General Geology Division, some of the earliest geophysical and geochemical studies were undertaken in support of mining geology. The Survey was thus mission oriented in its first years.

King remained Director of the Geological Survey for only 2 years, and in 1881, John Wesley Powell succeeded him. Powell, who had favored a single survey for topographic and geologic mapping in 1878, immediately initiated an independent topographic-mapping program. In 1882, he obtained from Congress authorization to continue preparation of the geologic map of the United States and took that as authorization to prepare a topographic map of the United States as well. This brought about some overlap with the work of the Coast and Geodetic Survey. In that same year, the Treasury Department fought off an attempt by the Navy Department to take over the Coast Survey.

With the authorization to prepare a geologic map of the United States, the Geological Survey reverted to an older tradition of science. The geologic map was a task that could be completed; it would develop the science, add to human knowledge, and ultimately provide the basis for application to practical problems. Stratigraphic and paleontologic studies were expanded, and mining geology investigations were limited. Coincidentally, there was a return to individualism, most scientists being allowed to choose their own investigations if such investigations fitted into the overall plan for a geologic map.

In 1884, Congress called for a joint commission of the Senate and House of Representatives to consider the organizations of the Signal Service, Geological Survey, Coast and Geodetic Survey, and the Hydrographic Office of the Navy Department to secure greater efficiency and economy of administration of these scientific bureaus. The proposed investigation, ostensibly a general one, was actually a combination of two investigations. One was an attempt to save the Coast and Geodetic Survey from the encroachment on its functions by the Geological Survey and from another attempt by the Navy to take it over; the other investigation was the Signal Service, in particular of the meteorological investigations. Many people questioned whether a weather bureau was properly a military function. The Naval

Observatory was not included in the investigation, but the struggle to make that agency a civilian one was an internal affair.

The National Academy of Sciences was called on for advice and suggested that the topographic work of the Coast and Geodetic Survey and the Geological Survey be combined under one executive department and that the civilian and military functions of the Signal Service be divided. The Academy went on to suggest that the scientific functions of the Federal Government be divided among four bureaus: the Coast and Interior Survey, concerned chiefly with geodesy and hydrography; the Geological Survey; the Meteorological Bureau; and a physical laboratory, which would include the Office of Weights and Measures, then part of the Coast Survey. The Academy also suggested that a Department of Science be established, or alternatively, that all scientific bureaus be transferred to one executive department.

The congressional investigation spanned two sessions of Congress and a change of administration. The majority report in 1886 did not recommend any immediate changes in the organization of any of the bureaus and specifically accepted the wisdom of a geological survey of the entire country. Publication funds, however, were thereafter restricted. The minority report, signed by two members of Congress from the newly industrializing Southeast, attempted to restrict research in general geology and paleontology.

The congressional committee made no investigation of the scientific work of the Department of Agriculture. That Department had begun to develop as a scientific organization when it became more mission oriented, after the Entomological Commission, which had investigated the locust plagues of the Great Plains in the 1870s, became its Division of Entomology in 1880. A Bureau of Animal Husbandry was established in 1884 to study a specific problem of animal diseases, and a Division of Mycology the following year to study the problem of plant fungi. All three divisions aimed investigations at the solution of a practical problem, using whatever means were necessary or practicable. As the prestige of the Department grew, farmers demanded that it be raised to Cabinet status, and in February 1889, Congress passed the necessary legislation.

During the early part of the 1800's, agricultural production continued to increase. Prices, however, did not, and agriculture on the whole lagged behind other segments of the national economy. The portion of the national income earned by farmers and their share of the national wealth declined. Then in 1886, for the first time in several years, rainfall on the Great Plains was inadequate for farming and crops were a failure. During the following winter, blizzards and ice storms devastated the cattle ranches. The drought continued, and a series of crop failures together with declining prices dealt the farmers west of the 97th meridian crushing blows. Many soon realized that their land was worth less than the mortgages and let the loan companies foreclose, and large areas of the plains from Kansas northward became almost depopulated as farm families moved back east. Protest movements that had declined at the end of the 1870's again became important.

Irrigation of the arid lands, especially of the Great Plains, became a matter of importance. Congress at first turned to the Department of Agriculture for information, and that Department submitted a lengthy report in December 1886, stating that the area of irreclaimable arid land was quite moderate in extent, but in a large part of it, the water supply was both inadequate and irregular. In 1888, Congress turned to the Department of the Interior. Major Powell proposed that a topographic map be made of the arid region to determine the hydrographic basins and that this map be supplemented by stream-gaging and engineering surveys to designate reservoir sites, irrigable lands, and canal lines. Congress authorized the U.S.

Geological Survey to make such a survey and, to prevent speculation, withdrew all irrigable lands from entry until the survey could be completed.

In the spring of 1890, officials of the Department of Agriculture questioned the concentration of the Survey's work in the area west of the Rocky Mountain front rather than in the Great Plains area. In the summer of 1890, the Department of Agriculture issued a report on the water problems of the Great Plains that suggested geologic studies, rather than topographic maps, were needed and that underground water resources should be investigated. Many of the engineers of the Irrigation Survey had already discounted the usefulness of topographic mapping for designating reservoir sites or laying out canal lines. The Attorney General also ruled that the entire public domain had been closed to entry by the reservation clause in the 1888 legislation because no one knew which lands were irrigable until the Geological Survey designated them. Western interests raised a storm of protest, and Congress discontinued the Irrigation Survey and amended the 1888 legislation to reserve only the reservoir sites. Two months later, Congress separated the civilian and military functions of the Signal Corps, as the National Academy of Sciences had recommended in 1884. The civilian functions were transferred to the Department of Agriculture, there to become the Weather Bureau, with responsibility, among other duties, for climatological studies and for gaging streams.

In the following spring, Congress made major revisions in the public-land laws, in accordance with the recommendations of the Public Lands Commission of 1879, bringing to an end most cash sales of public lands, repealing the Preemption and Timber Culture Acts, and providing more stringent conditions for entries under the Desert Land Act. In a major step toward the conservation of natural resources, the President was authorized to create forest reserves. Mineral-land laws, which had been a major concern of the Public Lands Commission, were unchanged.

Industrial progress had continued unimpeded, and therefore, most of the mineral industry in the Eastern States had prospered during the decade. In 1890, the value of the nonprecious minerals produced was nearly double that of 1880. The United States had become the world's leading iron- and steel-making country. In fact, the United States in 1890 produced more than 34 percent of all the pig iron produced in the world and more than 35 percent of all the steel; it mined more than 28 percent of the iron ore and nearly 28 percent of the coal. James M. Swank of the American Iron and Steel Institute said proudly:

> **Such industrial progress in a brief time as is here illustrated the world has never before known.**

Mining of iron and coal remained very much an eastern affair, although a shift westward and southward from the original centers had taken place. Pennsylvania was still the leading mining State in 1890; the value of its mineral product more than double that of the second-ranking State, Michigan. Pennsylvania and the Appalachian fields in general dominated the coal industry, producing all the anthracite and 65 percent of the bituminous coal. The Central coalfield of Illinois, Indiana, and Kentucky produced another 18 percent of the bituminous coal. Only 17 percent came from west of the Mississippi. Michigan had become the leading iron-producing State, by itself producing nearly 45 percent of all the iron ore mined in the United States in 1890. Owing to the rapid industrial progress in the Southeast, Alabama had outstripped Pennsylvania and was the second-ranking iron-producing State. Wisconsin and Minnesota had also made rapid strides in iron mining and ranked fifth and sixth.

Copper had become important because of the rapid progress of the electrical industry. Copper production had more than quadrupled during the decade, and the United States had become the world's leading copper producer. The Lake Superior mines had produced more copper in 1890 than the whole country had produced in 1880 but had yielded first place to the Montana mines, which produced more than 43 percent of the copper mined that year. Arizona was a distant third. As the West for the first time became an important producer of an industrial mineral, so industry became involved in western mining law, resulting in epoch-making litigation with the war of the copper kings.

Among the other minerals, lead and zinc were still of less importance. Aluminum was produced commercially for the first time in 1882, and the newspapers had written glowingly of the advent of the age of aluminum. Its future, however, was still uncertain, for although 61,000 pounds were produced in 1890, aluminum was not being used as widely as expected.

The future of petroleum was also still uncertain. Production had more than doubled in the decade, and petroleum was being found in nearly every State and Territory, but it was being produced in quantity only in western Pennsylvania, West Virginia, and Ohio and in small amounts in Colorado and southern California. A leading observer thought it highly unlikely that any other State, with the possible exception of Wyoming, would ever become a large producer, but took the precaution of adding that there had been so many surprises in petroleum that his statement should be regarded as only setting forth current indications.

The production of gold had continued to decline during the 1880's and the value of gold mined in 1890 was only $32.8 million. California's annual production had declined to only $12.5 million chiefly because of the prohibition of hydraulic mining, and the other leading gold-producing States produced at the most $3 to $4 million each. Silver production, on the other hand, had increased to $70.5 million, about 1.7 times that of 1880. The monetary situation was thus even more precarious than it had been in 1879.

The year 1890 was a turbulent one in American politics. The increasing agrarian unrest organized itself into powerful farmers' alliances, which plunged into politics with a vigor that alarmed business and industrial interests. The farmers' parties opposed the moneyed interests of the East and again joined with western silver interests who were pressing for silver coinage.

The protective tariff had become a partisan issue after President Cleveland called for lowering of duties in his annual message to Congress in 1887. The Democratic party was thereafter opposed to the existing system, and the Republicans felt constrained not only to support the protective tariff but to advocate its extension.

When the Republicans regained control of Congress after the elections of 1888, they felt compelled to propose new tariff legislation; to make the measure more palatable to the agrarian West, Republican leaders decided first to accede to western desires for antitrust and silver legislation. The Sherman Antitrust Act and the Sherman Silver Purchase Act were passed in July 1890, the latter requiring the Treasury to purchase 4.5 million ounces of silver, the estimated total production, each month at the prevailing-market price and to issue in payment legal tender Treasury notes redeemable in gold or silver. The McKinley Tariff Act was then passed in September.

In 1892, a Presidential election year, Congress again took a hard look at the scientific agencies. Passage of the Silver Purchase Act of 1890 had not provided the ample money supply that the farmers demanded, and a new downward spiral of commodity prices began. There was a drain on the gold reserve, and the Treasury announced, for the first time in 20 years, an impending deficit. In a mood for economy, Congress slashed appropriations for scientific agencies, especially items that seemed to have little immediate practical purpose. The Geological Survey's appropriations for geologic surveys, for paleontology, and for chemistry and physics were drastically reduced; only the appropriation for the report on mineral resources went unscathed. The Survey became principally a mapping agency. Appropriations for the Coast and Geodetic Survey, the Fish Commission, and the Smithsonian Institution were cut, and the Bureau of American Ethnology came close to being eliminated altogether. Appropriations for the Department of Agriculture, then even more mission oriented, were unchanged.

In 1893, Grover Cleveland succeeded Benjamin Harrison as President as the worst depression of the 19th century was beginning. Scientific bureaus, remembering the difficulties of the first Cleveland administration, were fearful, and at first, their fears seemed justified. The Secretary of the Navy and the Secretary of the Treasury came to an early agreement on a dismemberment of the Coast and Geodetic Survey, part of its mapping functions to go to the Hydrographic Office, part to the Geological Survey. In the Department of Agriculture, Secretary J. Sterling Morton announced that he would drop all "useless scientists" from the Department. There were, however, no drastic changes. Congress refused to go along with the proposed changes in the Coast and Geodetic Survey. Secretary Morton chose as his Assistant Secretary a German-trained chemist, Charles Dabney, who, as head of the North Carolina agricultural experiment station, had discovered the phosphate deposits of eastern North Carolina and tin deposits of the western part of the State and had helped to revitalize the economy of North Carolina. Dabney directed an expansion of the scientific work of the Department. In the Geological Survey, Powell remained nominally Director until 1894, but Secretary of the Interior Hoke Smith named Charles D. Walcott geologist in charge of geology and paleontology on July 1, 1893. In the field season of 1893, the geologic-mapping program was related to economic problems. Walcott became Director of the Geological Survey a year later. He revived the mission orientation of the Survey's work as outlined by King in 1879, but at the same time, he broadened the mission. The Survey would aid not just the mineral industry, but any industry, in fact any practical object that could be aided by a knowledge of geology. Both Walcott and Dabney succeeded in placing the scientists in their agencies under civil service, thus removing the threat of patronage.

Walcott emphasized at first that the principal work of the Geological Survey was geology, and although he stressed the practical aspects, he made it clear that basic and applied science could not be separated, that basic science would be undertaken when and where it was needed in the solution of a problem. Mining geology studies were resumed and extended into the Eastern States, and in view of the gold crisis, an intensive study of gold deposits, including exploration for new sources, was begun. An appropriation for gaging streams and determining the water supply of the United States was obtained, and the importance of the geologic aspects of water was indicated by assigning some of the most experienced geologists to water-resources investigations. When a congressional commission recommended transfer of the Geological Survey's topographic-mapping program to the Coast and Geodetic Survey, the move was forestalled when Congress accepted instead the Geological Survey's proposal to map Indian Territory, including the subdivisional surveys, and to make a geological survey at the same time.

With an upturn in the economy in 1896, Federal science and mapping programs were able to expand. In both the water-resources investigations and the topographic-mapping programs of the Geological Survey, cooperation with the States and with the Department of Agriculture was extensive. In 1895, an interdepartmental committee on irrigation was formed. In 1897, the Geological Survey was given responsibility for surveying, mapping, and classifying the forest reserves of the United States; for the work of classification, there was close cooperation with Agriculture's Forestry Division. When James Wilson of Iowa became Secretary of Agriculture in 1897, he took for himself the role of its chief scientific officer. Under Wilson's guidance, the Department quadrupled in size in the next dozen years. Studies of soils, grass and forage plants, and the use of fertilizers, and investigations of dry-land farming were begun. In the Coast and Geodetic Survey, the new Superintendent, Henry Pritchett, made plans for increasing the scope and the support of the work of the Office of Weights and Measures.

Although general geology was not neglected, it was the Geological Survey's work in economic geology that won for it increasing recognition. The production of precious metals increased dramatically during the 1890's. The deposits at Cripple Creek in Colorado, first recognized in 1891, were studied by the Geological Survey in 1893–1894. By 1900, the value of annual production there was $18 million. The gold ores at Mercur, Utah, were investigated in 1894, just about the time development of the cyanidation process made its ores practicable. Investigations of the gold resources of Alaska began in 1895, a year before the big strikes. By 1900, the value of gold produced annually in the United States had reached a record $79.2 million, and the United States adopted the gold standard as its monetary base. The silver yield in 1900 was one of the largest in history, but two-thirds of it was a byproduct of mines that would be operated regardless of the price of silver, so the currency issue ceased to be controversial.

Copper production in 1900 was 600 million pounds, more than 10 times what it had been in 1880, but it still could not meet the demands. The Geological Survey began a study of the Montana mines in 1896 and of Utah copper in 1897; as the decade ended, it began studies of eastern copper deposits and the Arizona deposits. Aluminum was replacing copper in the electrical industry and also replacing iron and steel in parts of industrial machinery, as well as being used for such diverse purposes as railway cars and household utensils. As a result, production had increased nearly 1,000-fold in just 10 years. In 1893, the Geological Survey had begun a study of the aluminum ores of Georgia and Alabama, which were the major source of the metal, and in the spring of 1900, it began a study of the Arkansas deposits, which had just begun to produce.

The metal-mining industry called for greater support of the Geological Survey, and there was a move to establish a Cabinet-level Department of Mines with the Survey as a nucleus. The gold discoveries spurred congressional interest in additional studies of the precious metals, but the Survey took a broader view and suggested that studies of coal, coke, petroleum and asphalts, building stones and clay be undertaken as well.

Walcott said that the work of the Geological Survey had just begun and that the task would take decades if no changes were made in either the scope of the work or the size of the working force. He predicted, moreover, that the standards of the future would be progressively higher, that the scope of investigations would become broader, and that as the science progressed and new uses were found for mineral resources, the number of facts to be determined would increase. Geologists would never lack worlds to conquer.

By the turn of the century, however, Federal science was more and more oriented toward the utilitarian. In 1901, the National Bureau of Standards replaced the Office of Weights and Measures, which had been part of the Coast Survey since 1832. The new bureau was not modeled after the national physical laboratory of Germany, as Pritchett had hoped, but was an American model drawn up on the basis of consultation with both scientists and manufacturers. A Bureau of Plant Industry was established in the Department of Agriculture, and the Divisions of Chemistry, Soils, and Forestry were raised to the status of bureaus. The Department of Agriculture and the Department of the Interior, largely through the Geological Survey, were by that time cooperating in the effort to preserve forests on watersheds and to develop waterpower. In 1902, when the Federal Government assumed responsibility for construction of irrigation works to water the lands of the arid West, the Reclamation Service was made an adjunct of the Geological Survey. In 1903, when the Department of Commerce and Labor was formed to foster and promote industry, the Bureau of Standards, the Coast and Geodetic Survey, and the Fish Commission were all made part of the new Department. Recognizing that the trend was not easily reversed, Walcott and several other scientists persuaded Andrew Carnegie to donate $10 million as an endowment for an institution for the promotion of pure research.

In 1903, a committee on the organization of the scientific work of the Government appointed by President Theodore Roosevelt concluded that in general the work of scientific research on the part of the Government should be limited nearly to utilitarian purposes and that research in pure science on broad and general grounds should be within the scope of private institutions. As a basic principle, the committee stated that the scientific work of the Government should be organized so that an administrative unit comprised all the elements necessary for the solution of a distinct scientific problem or group of closely related problems, and that, in general, individual sciences should not be segregated in separate bureaus or offices. The committee also recommended that several bureaus be transferred to the Department of Agriculture, which already included one-third of all Federal scientific bureaus, received three-fifths of all appropriations for scientific work, and employed two-thirds of all Federal scientific investigators. The transfers would have concentrated the scientific bureaus in one department and in effect would achieve the recommendation of the National Academy of Sciences in 1884, but few of them were ever made.

The second Public Lands Commission, appointed later that year, more effectively altered the relations of the scientific agencies. President Roosevelt asked it to report on the condition, operation, and effect of the land laws and to recommend such changes as were needed to effect the largest practicable disposition of the public lands to actual settlers, requests not unlike those Congress had made of the Commission of 1879. To them he added a further charge, to recommend changes in the public-land laws "to secure in permanence the fullest and most effective use of the resources of the public lands."

As in 1879, most of the public lands were west of the Mississippi River; the Federal Government still held title to 1 billion acres. The West, however, was no longer a thinly populated little-known area. The Reclamation Act had dramatically increased the availability of western lands for agriculture by irrigation. The vast wealth of western mineral resources was better known, not only the precious metals but other metalliferous and nonmetalliferous minerals as well. The mineral industry began looking toward its iron and coal resources. In 1904, the West produced more petroleum than the East. Steps had already been taken to conserve the forests and to make the best use of water and land. Classification of the public lands in advance of disposition before long became an important element of the Geological Survey program for the first time, and research and mapping programs were altered accordingly. The shift in priorities in accord with national policy brought about a new order within the Geological Survey and among the Federal scientific agencies that lasted for many years.

Chapter 2.
The Most Ancient Art, 1879–1881

> **Indeed, the subject of mining is a very extensive one, and one very difficult to explain; no part of it is fully dealt with by the Greek and Latin authors whose works survive; and since the art is one of the most ancient, the most necessary, and the most profitable to mankind, I considered that I ought not to neglect it.**
> **—Georgius Agricola**

The appointment of the first Director of the new U.S. Geological Survey was critical to the success of the new agency, for the first director would create as well as direct the organization. Ferdinand V. Hayden, director of the older of the two Interior surveys discontinued by the legislation establishing the U.S. Geological Survey, was at first considered the leading candidate; however, a small group considered Clarence King, who had directed the Exploration of the Fortieth Parallel, better qualified for the position and worked to obtain his appointment. On March 20, 1879, President Hayes sent to the Senate the nomination of Clarence Rivers King as first Director of the U.S. Geological Survey. The nomination was confirmed by the Senate on April 3, and King took the oath of office on May 24, 1879, although no funds would be available for the new agency until July 1.

King represented a new professionalism in American geology. He had studied under James Dwight Dana and George Brush at Yale's Sheffield Scientific School as a member of the first class to receive the degree of bachelor of science. He had studied briefly under Louis Agassiz and had spent 3 years with the California Geological Survey under Josiah Dwight Whitney before undertaking the Exploration of the Fortieth Parallel in 1867. The King survey had completed its fieldwork in 1872, and the last of its reports, King's *Systematic Geology*, had been published in 1878. King had been only 25 when placed in charge of the Exploration of the Fortieth Parallel; in the dozen years since, he had achieved an extraordinary position for a young man. Acclaimed for his literary as well as his scientific talents, he was the youngest member of the National Academy of Sciences, and had a wide circle of friends in positions of influence in political, educational, and literary circles as well as among scientists.

Although the Organic Act of the Geological Survey assigned what seemed to be very specific duties to the new agency, the brevity of the legislation actually left much to the judgment of the Director. King decided that the initial work of the Survey should be directed toward production of immediate results of strictly practical value. His own experience in the Fortieth Parallel Exploration had shown the wisdom of early publication of a volume on the mining industry and engagement in pure science in later years. He laid out the work of the Geological Survey on the same basis.

Almost immediately, however, he was confronted with problems in interpretation of the Organic Act. The first duty enjoined on the new bureau was the classification of the public lands, but Congress had at the same time asked the Public Lands Commission to determine a system and standard of classification and had not made any changes in the General Land Office, which had for more than 90 years made the classification of the land in advance of disposition. Moreover, the National Academy of Sciences committee in its 1878 report had stated that investigation and classification of the public domain was needed to meet the requirements of existing law but had proposed only that the Geological Survey be responsible for investigation of the public domain. King therefore decided that the Survey's classification was not meant to supersede that of the General Land Office but was to be a scientific one that would provide information for all the people. He planned a series of land maps which would show "all those features upon which intelligent agriculturists, miners, engineers, and timbermen might hereafter base their operations," and which would also be of value for "students of the political economy and resources of the United States." That decision was later confirmed by the Public Lands Commission, which concluded after careful study that it would be impracticable for the Survey or any other branch of the Interior Department to classify the lands in advance of sale without seriously impeding settlement.

The remaining tasks were the examination of the geological structure, mineral resources, and products of the national domain; of these, King chose to emphasize first the examination of mineral resources. Americans could take pride in the development of their natural resources, he said, but the methods of the past were no longer enough, and only the Federal Government could do what was needed. Because of the size of the country, information was lacking on the primary industries—those that yielded the raw materials, mineral, vegetable, and animal. The Agriculture Department had begun the systematic collection of information on crops, but the only efforts to acquire knowledge of mineral production were the "highly useful but feebly endowed" mining commissions, and those had been ended in 1874 for lack of appropriations.

There were at the time some outstanding problems. The year 1878 had been one of great monetary uncertainty. The Secretary of the Treasury had to buy silver each month as required by the Bland-Allison Act. At the same time he had to accumulate a gold reserve of about $200 million in anticipation of the resumption of specie payments for greenbacks on January 1, 1879. The gold product of the United States had been as high as $53 million in 1853 but had been steadily declining; in 1878, it was less than $39 million. The silver product, on the other hand, had been increasing since 1859 and in 1878 had a coining value of almost $41 million. Knowledge of the precious-metal resources of the Nation could clearly be of great value at such a time.

At the same time, industry was growing at a phenomenal rate. Since the Civil War. the natural resources most in demand for industry had been iron and coal. Although there was general optimism that these resources were well nigh inexhaustible, certain problems were becoming evident. Steelmaking processes in common use required a low-phosphorus, low-sulfur pig iron, and pig iron was being imported because steelmakers were finding it difficult to obtain sufficient American iron of suitable composition.

In King's mind:

> **In the history of the United States, whatever may be the final adjustment of the machinery of National government—upon one great field of American activity, the pride of to-day and the judgment of the future will agree. That field is the development of our material resources. In the industrial conquest of a continent the tide of victory has never ebbed.**
>
> **In possessing ourselves of this broad, virgin area, we have shown a power unprecedented in the slower past—to discern, to seize, and to utilize the national wealth with which the United States is so liberally endowed. With an energy never relaxed, with an originality which has revolutionized and improved nearly all industrial methods, we grasp the problem of material development, and grasping, solve it.**

He went on

> **Every intelligent student of the country knows that we are yet at the very threshold of the industrial life of the Republic.*** The modern method of distributing population by means of the network of railroads which is rapidly threading the last remaining wilderness, greatly accelerates the progress of the industries.*** Our fifty millions will equalize its grasp on the different sections by rapid migration, till the population finds an equilibrium with the local resources. That equilibrium will soon be attained. Our real industrial problem is then to utilize with the highest technical skill and with the utmost scientific economy, all elements of national wealth.**

The decision about program having been made, King organized the Survey first into two independent divisions, Mining Geology and General Geology, and then into geographic divisions, after the fashion of the Army and the Coast Survey. In each geographic division, there would be a permanent corps under a geologist whose personal experience and background fitted him to undertake the chief problems of that division.

The region west on the 101st meridian was divided into four districts on geological, rather than political, lines. The Rocky Mountain District, with its headquarters at Denver, Colorado, included Colorado, New Mexico, Wyoming, Montana, and a small part of Dakota, "an area enclosing the whole great chain of the Rocky Mountains, whose geographical function is the dividing of the watershed of the Atlantic from that of the Pacific." The Division of the Colorado, embracing the plateau and canyon country between the Rocky Mountains and the Great Basin, was a temporary one until such time as the extensive work that Major Powell had been carrying on could be completed. Its headquarters were at Salt Lake City, Utah. The Division of the Great Basin, which also had headquarters in Salt Lake City, included the region of primarily interior drainage between the Rocky Mountains and the Colorado Plateau on the east and the Sierra Nevada, Cascade, and Pacific Coast Ranges on the west, a region of great importance because of its abundant silver districts. The Division of the Pacific included all of Washington Territory, Oregon west of the Blue Mountains, and all of California, except the desert region east of the Sierra Nevada and south of the 38th parallel, which belonged to the arid region of the Great Basin. Pacific Division headquarters were in San Francisco.

King also planned four divisions east of the Rocky Mountains. The Appalachian Region would be divided into two districts, one embracing Maryland, Delaware, Pennsylvania, New Jersey, New York, and New England, and the other, West Virginia, Virginia, North and South Carolina, Georgia, Florida, Alabama, Tennessee, and Kentucky. The Mississippi Basin, although geologically, he said, but one field and one problem, would also be divided into two districts. The boundary line between the two would be the Ohio River east of the Mississippi and the southern boundaries of Missouri and Kansas west of the river.

A problem arose, however, about the meaning of the term "national domain" in the Organic Act. The Academy committee had consistently used the term "public domain"—it considered its field of inquiry limited to the surveys that pertained to the public domain, concluded that a thorough investigation and classification of the of the public domain was needed, and recommended the establishment of a survey to study the geological structure and economic resources of the public domain. The law as passed by Congress, however, had used two different terms, charging the Geological Survey with classification of the "public lands" and examination of the geological structure, mineral resources and products of the "national domain." The latter term, King said, was "supposed by the first framers of the law to cover the entire United States." That language was chosen, according to Dutton, to "authorize by a reasonable construction the survey of the states without making it obligatory upon the Survey to go into each and every one of them." Opponents of the Survey took advantage of the ambiguity to incite the fears of several State geologists and other leading scientists that the national survey would override the State surveys. The Attorney General was asked for an opinion and ruled that the term "national domain" meant the public lands to which the United States had not parted title. If the Director had to use that opinion as his guide, Dutton said, "he might as well 'shut up shop & take in his sign' at once. It puts him in the position of the little girl who asked

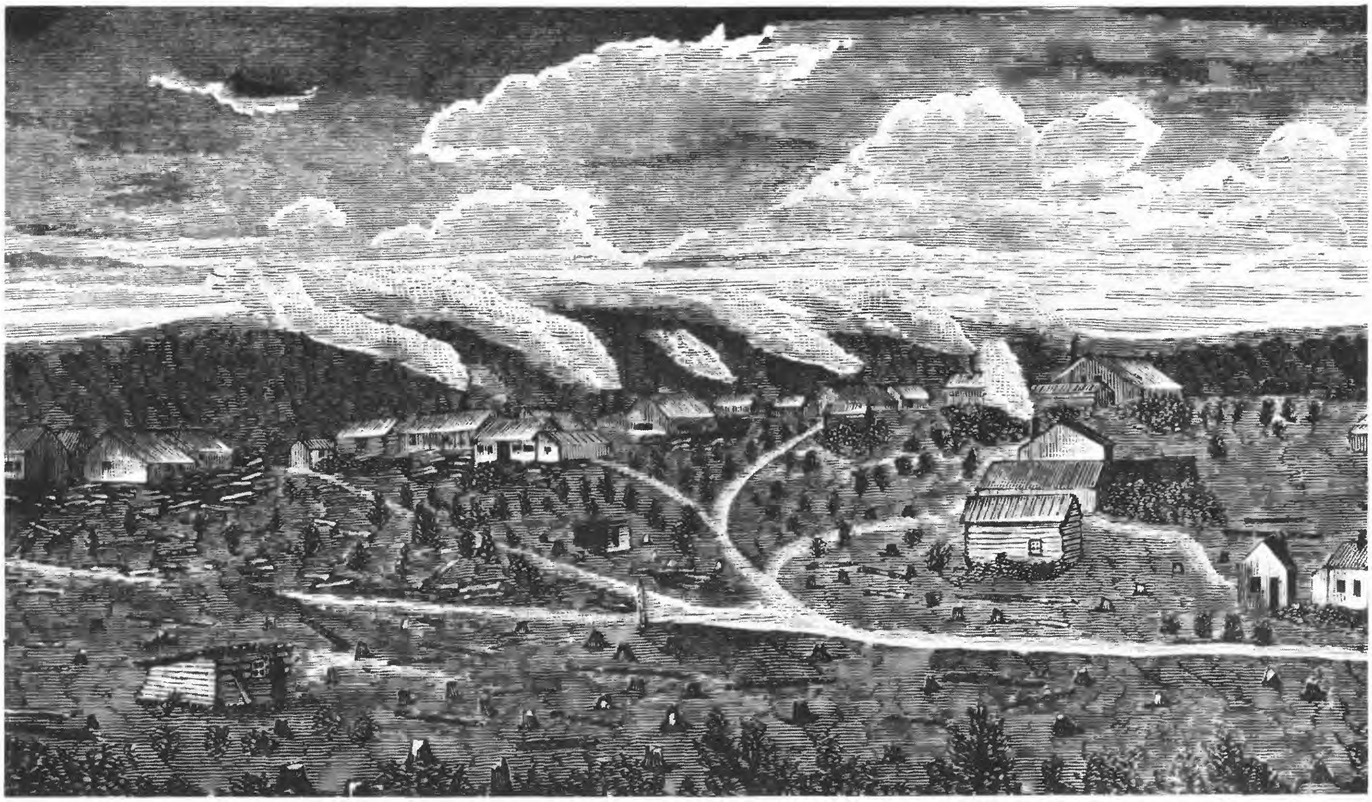
Mother may I go out to swim?
O? Yes my darling daughter
Hang your clothes on a hickory limb
But don't go near the water."

King turned to Congress for clarification. On June 28, Congressman J. D. C. Atkins introduced a joint resolution to amend the Sundry Civil Expenses Act by adding after "national domain" the three words "and the States," explaining that "the Geological Director desires to make surveys of the mineral resources of the entire country, not only in the Territories and in the States where there are public lands." "And," Congressman Joseph Hawley of Connecticut added, "to collect what the States have already done for themselves.* * * In order to make a correct estimate of the mineral resources of the country, it is necessary that the information which has already been collected by the States be secured." Congressman A. J. Warner of Ohio wanted reassurance on the intent. "We should know before acting on this measure whether or not it is a proposition for a general geological survey of the States." "Not at all," Atkins insisted, "the object I had in offering this joint resolution was simply to enable the Geological Director to make in his next report a practical presentation of the mineral resources of the entire country." The problem of Federal-State relations and the possible trespass of State rights by a national survey was thoroughly aired, and the amendment was changed before being passed, first to "and he may extend his examination into the States," and finally to "and he may extend his examination into the States, not to interfere, however, with any geological survey now being made by the State." In the Senate the resolution was referred to the Committee on Appropriations, but Congress adjourned on July 1 before it was acted upon.

King deemed it wise to choose the conservative course and to restrict the first year's operations to the public-land States. In any event, the size of the appropriation would not permit any extensive operations. He still felt that it "was his duty to bend the energies of the Bureau first of all to the production of immediate results of strictly practical value," the emphasis would be on mining geology and only "a very small proportion" of the funds and force would be "diverted" to pure geology. The mining geology program would be twofold; a study of mining districts and the collection of mineral statistics.

With regard to mining district studies, King wrote:

> **There can hardly be two opinions on the desirableness of immediately working out such problems in these great districts which in their past and present history offer examples of instructive geological structure and great bullion yield, and which have required of mining men special mechanical skill and large outlay of capital. Proper scientific reports on such typical districts become records of remarkable phenomena in the field of industrial geology, and chronicles of distinguished success in the department of mining engineering.**



The first three great mining districts investigated by the U.S. Geological Survey included Leadville, Colorado, which had sprung from a comparatively unknown mining camp to a great mining center with almost unexampled rapidity in the late 1870's. Its annual production in 1879 was probably greater than that of any other single district in the West with the exception of the Comstock. Fryer Hill was the site of some of the richest mines. (From Frank Fossett, 1879.)

Restriction to the public-land States would not be a handicap to the mining-district studies, for among the districts that deserved study, he was able to choose three in public-land States that "more than others seemed to offer harvests of technical information, of which the mining population stands in immediate need." The first districts to be studied were: "Leadville, that extraordinary district in middle Colorado, Eureka, Nevada, which for fifteen years has been the most productive silver-lead district in America, and the incomparable Comstock Lode."

Of the three districts, Leadville was new. Eureka was in its prime, and the Comstock was apparently declining. Leadville was just coming into production—its first big year was 1878—but the excitement engendered by the discoveries there was reminiscent of the early days of the Comstock. Almost overnight it seemed, an abandoned gold camp had been transformed into a roaring mining town. The Leadville discovery was the beginning of the Colorado era of western mining.

The ore causing all the excitement was a silver-lead ore. Miners in the early gold-mining days at Leadville had been troubled by a heavy gray rock that had to be picked out of the sluices by hand, but not until long after the camp had been abandoned was it recognized. In 1874, A. B. Wood of Detroit identified this heavy rock as a lead ore and made a quiet search for its source. When the titles to abandoned placer claims expired in 1875, he and his associates located claims on Iron Hill. In 1876, ore was shipped to St. Louis for smelting and yielded a profit in spite of high transportation costs. Thereupon prospectors, miners, promoters, and the usual camp followers rushed to Leadville.

The richest orebodies on Fryer Hill were discovered by somewhat less scientific methods. S. F. Emmons, who, in his precise way, called the discovery "a singular accident," said: "At this point there is no outcrop, the whole surface of the hill being covered to an average depth of 100 feet

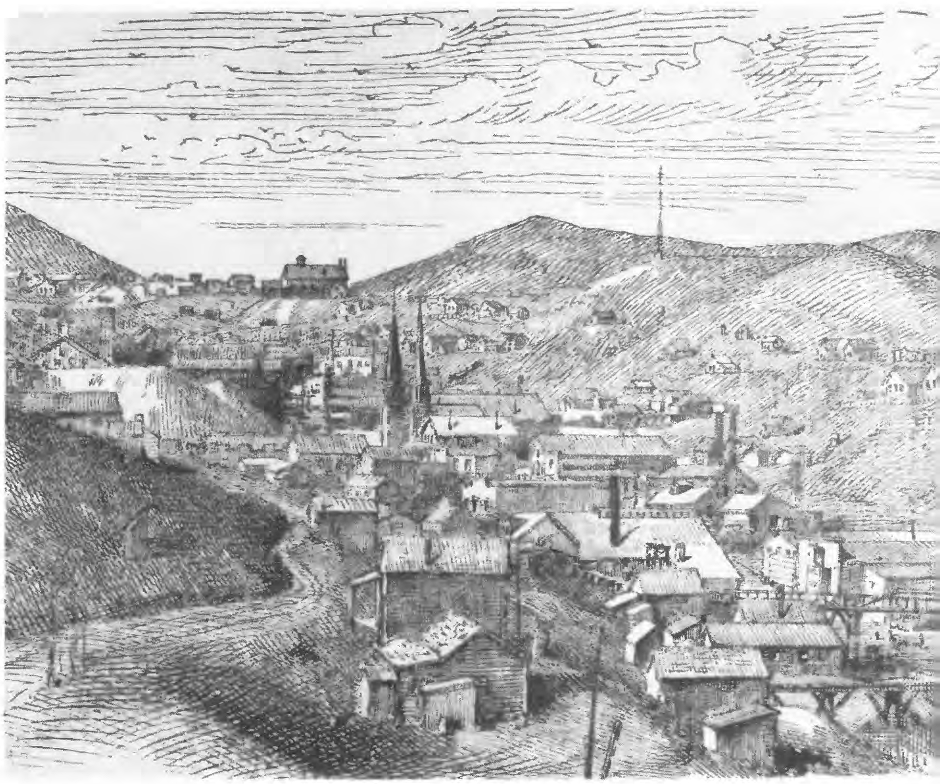
The lead-silver ores at Eureka, Nevada, had been discovered in 1864, but the mining did not become profitable until 1869 when smelting methods were introduced. The silver-lead deposits at Eureka were found in limestone, and the question of whether limestone formed a lode, in terms of mining law, had been the subject of litigation that was carried all the way to the U.S. Supreme Court. (Photograph of Eureka about 1880, courtesy of Thomas B. Nolan.)

by detrital material. Tradition has it that two prospectors were 'grubstaked,' or fitted out with a supply of provisions, by Tabor [H.A.W. Tabor, later Lieutenant Governor and briefly Senator], half of all they discovered to belong to him. Among the provisions was a jug of whiskey, which proved so strong a temptation to the prospectors that they stopped to discuss its contents before they had gone a mile from town. When the whiskey had disappeared, though its influence might probably still have been felt, they concluded that the spot on which they had thus prematurely camped was as good a one to sink a prospecting hole on as any other. At a depth of 25 to 30 feet their shaft struck the famous ore body of the Little Pittsburg mine, the only point on the whole area of the hill where rock in place comes so near the surface." The era of discovery of ore deposits by scientific methods was still somewhat in the future.

The Eureka district had been more completely developed than any of the other silver-lead deposits and offered an opportunity for a complete investigation of such deposits. The litigation at Eureka also was undoubtedly a factor in the selection. The question was whether or not the Ruby Hill deposits formed a lode, in terms of mining law, and on this, there had been a great difference of opinion. The lawsuit between the Eureka and Richmond mining companies had been argued in July 1877, celebrated geologists testifying for both sides. The crux of the matter was the continuity of a particular limestone zone between levels in an area where there was faulting. T. Sterry Hunt, W. S. Keyes, R. W. Raymond, T. J. Reid, and I. E. James testified in favor of the Eureka Company that the zone in question was a lode in the miner's sense of the term; however, King, J. D. Hague, J. D. Whitney, William Ashburner, and N. Wescoatt had all declared that in their opinion, the limestone could not be regarded as a lode either from a practical or a scientific point of view.

At the "incomparable" Comstock, the problems were primarily scientific. The mines were the deepest in North America, and they contained about 185 miles of galleries, offering an unparalleled opportunity for scientific study. The origin of the deposits, from which more than $300 million of bullion had been extracted since their discovery, was of course the principal subject of investigation, but there were other features of interest. The nature of some of the rocks associated with the ores was still a moot point. Baron Ferdinand von Richthofen had examined the deposit in 1865 for the Sutro Tunnel Company and had identified one of the enclosing rocks, a fine-grained greenish rock containing crystals of feldspar and hornblende, as propylite. King had studied the deposit in 1867–1868 and had accepted von Richthofen's designation, although he distinguished two forms of propylite, one of which he called quartz propylite. He noted an affinity between certain propyite and andesites and said that it would not be at all surprising if the propylite should finally prove to be chemically identical with, and in reality only a different form of, andesite. Zirkel had also accepted the term propylite and had confirmed the independence of quartz and hornblende propylite. Church had accepted the lithology of his predecessors with minor modifications. The nature of propylite was, however, unknown. Propylite resembled ancient rocks but was apparently of very recent origin. Another subject of interest was the cause of the high temperature observed in the mines, which some had attributed to extensive kaolinization.

The mineral statistics that King planned to collect were more than production data. Geographical, geological, mineralogical, and chemical data were needed on ores, fuels, and fluxes; not even an accurate knowledge of the mineral resources of a given State was enough, for "the mechanical arts in a multitude of instances depend on an artificial association of mineral products from widely separated regions." The iron industry of Michigan and Wisconsin, for example, depended on the utilization of its ores in distant States, in combination with ores of other States, and the coal and flux of still others. Silver ores, "valueless from their rebellious nature at the mines which yield them," could be taken to a neighboring State, mixed with others of different chemical composition, and profitably worked. Clos-



The incomparable Comstock, as King referred to it, had been discovered in 1859 at a point north of the town of Gold Hill. By 1879, more than $300 million worth of bullion had been extracted from Comstock mines. (From Dan DeQuille, 1876.)

ing the quicksilver mines of California would close a greater number of gold mines in Georgia. In a few instances, he said, minerals occurred in such restricted areas that private or State enterprises might ascertain all the needed information.

> **But as a whole it is true, and can never be refuted, that the Federal Government alone can successfully prosecute the noble work of investigating and making known the natural mineral wealth of the country, current modes of mining and metallurgy, and the industrial statistics of production.**

Until Congress authorized the Survey to conduct investigations in the region east of the 100th meridian, the Survey could collect mineral statistics only in the Western States. King, however, was able to make the study of mineral statistics national through the cooperation of the Tenth Census, authorized on the day the Survey was established. The Tenth Census legislation provided that the data were to be collected by a field force supervised by the Superintendent, rather than by Federal marshals and their assistants as in earlier censuses, and also greatly extended the scope of the census. The Superintendent, moreover, was authorized to withdraw certain classes of statistical inquiry from the ordinary enumerators and place them in the hands of experts and special agents who would be permitted to investigate "in their economic relations" the industries on which they were to collect

Clarence King

Director of the U.S. Geological Survey, 1879–1881. King's administration was brief, but his influence, exercised at a critical period of the Survey's existence, left a lasting impression upon it. The broad general principles he outlined for its work anticipated the mission orientation that guides most federal scientific agencies today. Though some latter-day historians have tended to be critical of King, his contemporaries held him in great esteem. (Photograph of oil portrait by George Howland in the Directors' Conference Room, U.S. Geological Survey, National Center, Reston, Virginia)

Francis A. Walker

As superintendent of the Tenth Census, Walker made it possible for the Survey to make a complete appraisal of the Nation's mineral resources during its first year. Walker succeeded William B. Rogers as president of the Massachusetts Institute of Technology in 1881. In 1884 he was a member of the Commission that supervised the cooperative arrangement for topographic mapping of the Commonwealth of Massachusetts. (Courtesy of the Massachusetts Institute of Technology Historical Collections.)

information. Francis A. Walker was appointed Superintendent of the Tenth Census in April 1879. Walker, who had been among the group pressing for King's nomination as Director of the Geological Survey and who, like King, was a member of the National Academy of Sciences, arranged with several fellow members of the Academy to undertake these special studies: Spencer Baird, the Secretary of the Smithsonian Institution, a census of the fisheries; Professor John S. Newberry, a report on the building-stone and quarry industry; Professor W. P. Trowbridge, a survey of power and machinery; and Professor C. S. Sargent of Harvard, a study of forestry and the lumbering industry. For the collection of mineral statistics, Walker observed, the creation by the act of Congress at the same session of the Geological Survey seemed to offer a most fortunate opportunity. The collection of the statistics and studies of the economic relations of the precious metals, iron, coal, petroleum, copper, lead, quicksilver, and zinc be entrusted to Clarence King.

The census inquiry offered an opportunity to appraise the character, extent, and influence of the entire mining industry in a way that had never been done before, and King proposed to make full use of it. West of the 100th meridian, the investigation could be organized as part of the regular Survey program in mining geology, but in the Eastern States, the investigation had to be organized in a different fashion. On July 1, 1879, the first day of the fiscal year, Director King was appointed expert special agent of the census, to serve without pay from the Tenth Census appropriation. Arrangements were made whereby other geologists of the Survey would be similarly appointed as unsalaried special agents, and still others would be appointed, paid from census funds, and detailed to the "Geological Director." East of the 100th meridian, only census agents would be employed; west of that line both Survey and census employees would engage in the investigation.

The program having been determined, the staff was then recruited. The qualifications for appointment to the staff and the salaries were established by Director King in consultation with Secretary of the Interior, Carl Schurz. Their standards were high. Applicants for appointment to the Division of Mining Geology were expected to have a good working knowledge of mathematics, mechanics, mining geology, chemistry, metallurgy, and the mineralogy of economic mineral products, evidence of which could be furnished by university degrees, the testimony of experts in the required branches, or a written examination. For appointment under the Division of General Geology, applicants were expected to furnish equivalent evidence of a working knowledge of mathematics, physics, chemistry, geology, and mineralogy.

The first appointments were made on July 8, 1879; as geologists at $4,000 a year, S. F. Emmons, Arnold Hague, Grove Karl Gilbert, and F. V. Hayden; and as geologist at $2,500 a year, George F. Becker. A few days later Raphael Pumpelly was appointed geologist at $4,000 a year and Charles D. Walcott as assistant geologist at $600 a year. To the topographic staff were appointed Allen Wilson at $3,000 a year; Frederick A. Clark at $2,500; Sumner Bodfish and John H. Renshawe at $1,800 and $1,700 respectively; Richard U. Goode at $1,200; and Philo B. Wright at $800. A clerical staff of four and two messengers completed the first list. In September, Andrew A. Blair was appointed chemist at $3,000.

Most of those appointed had been associated with one or another of the predecessor surveys. Of the geologists, Emmons and Hague had been with King's Fortieth Parallel Exploration, Gilbert with the Wheeley and Powell surveys, and Hayden had been geologist in charge of the Geological and Geographical Survey of the Territories. Allen Wilson had been a valued

S. F. Emmons

Geologist of the U.S. Geological Survey, 1879–1911. Emmons, who had been a member of the King survey, shared with King an interest in mining geology and became the leading economic geologist of his day. His contributions to economic geology have been likened to those of Charles Lyell in general geology. When Emmons died in 1911, George Becker said there was not a geological society or even a mining camp from Arctic Finland to the Transvaal, or from Alaska to Australia, where his name was not known and his authority recognized. (Photograph courtesy of the Smithsonian Institution Archives.)

member of the Exploration of the Fortieth Parallel group and later a member and then chief topographer of the Hayden survey. F. A. Clark had also been with both the Fortieth Parallel and Hayden surveys; Sumner Bodfish, John H. Renshawe, and Philo Wright had been with the Powell survey; and R. U. Goode had been an aide in the Engineer Corps.

Of those who had not been members of predecessor surveys, both Becker and Pumpelly were clearly experienced in mining geology. Becker was 32, born in New York City. When he was still very young, his family had moved to Cambridge, Massachusetts. There, a preference for science rather than sports had brought him into contact with such scientific luminaries as Benjamin Gould, Jeffries Wyman, Benjamin Peirce, and the elder Agassiz. He was graduated from Harvard in 1868 and went abroad at once to continue his education, taking advanced degrees at Heidelberg and the Royal School of Mines in Berlin. On his return to the United States, he became an engineer at the Joliet steelworks, and from there moved to California, where he became an instructor in mining and metallurgy at the University of California. In 1878, Becker had accompanied James Hague, the U.S. Commissioner to the Paris Exposition, and had contributed extensively to Hague's report on the mining industry of the world.

Pumpelly had been born in Owego, New York, in 1847. At 17, after graduating from General Russell's school in New Haven, he chose not to

Arnold Hague

Geologist of the U.S. Geological Survey, 1879–1917. Hague, who began as a mining geologist, later turned to general geology and devoted many years to study of the Yellowstone area. He also took an active role in the forest conservation movement. J. P. Iddings who was his assistant for several years, noted that "Hague took a lively interest in discovery, whether a bit of geological structure or the lay of new or little-known country. He delighted to follow an elk trail through a difficult region as well as to unravel a complex piece of stratigraphy, but when he had solved the riddle his interest in it ceased." Hague's publication record is consequently short. (Photograph courtesy of the Smithsonian Institution Archives.)

go to Yale with the rest of his classmates but went instead to Europe. After a period of travel, he entered the Bergakademie at Freiberg and studied there from 1856 to 1860 at the same time as James Hague. After returning to the United States, he had been in charge of the Santa Rita mine in Arizona for a year and then had spent 3 years as adviser to the Japanese and Chinese Governments on the development of natural resources. He later became closely associated with Josiah Dwight Whitney and through his influence was invited to become Sturgis-Hooper Professor of Mining at Harvard University, a position that he accepted because the endowment was not sufficient to pay a professor's salary and therefore the duties were light. For several years he had been engaged in studies of the iron and copper deposits of Michigan, for private industry and for the Michigan Geological Survey after its reestablishment. In 1871, he had become State Geologist of Missouri and directed a study of the iron and coal resources of that State before resigning in 1873.

Blair's experience was also valuable in the Mining Geology Division. He had been born in Kentucky in 1848 and had graduated from the Naval Academy at 18 but had later turned to chemistry. Since 1875, he had been the Chief Chemist of the U.S. Commission for Testing Iron, Steel, and Other Metals, at the Watertown Arsenal, New York.

Grove Karl Gilbert

Geologist of the U.S. Geological Survey, 1879–1918. Gilbert, who had been a member of both the Wheeler and Powell surveys, was a close friend and adviser to John Wesley Powell. Gilbert served as Chief Geologist from 1889 to 1892. Gilbert was described as "An authority in many fields and yet one who never assumed authority; a leader in science and yet one who never assumed leadership; neither power nor glory did he seek, but the satisfaction of contributing his share to the sum of human knowledge." (Photograph courtesy of the Smithsonian Institution Archives.)

Charles Doolittle Walcott, the lowly assistant geologist, came to the U.S. Geological Survey on the recommendation of James Hall. Walcott was born in 1850, the youngest child of a wealthy millowner near Utica,New York. He had become interested in fossils at the age of 11, and by the time he was 17, he was determined to become a geologist, despite family opposition. His spectacular collection of fossils brought him to Louis Agassiz's attention, and he planned to study at Harvard, but Agassiz's death in December 1873 put an end to that plan. In 1876, he became James Hall's assistant at the New York State Museum, and when he joined the Survey in 1879 he had already published several important papers on the details of the appendages of trilobites.

Pumpelly was placed in charge of the Mining Geology Division, the collection of mineral statistics east of the 100th meridian, and the discussion, for the census, of the statistics of all mining industries except the precious metals. King retained for himself the collection and discussion of the precious-metal statistics. Major Powell acted as head of the General Geology Division, or Geologic Map Division, although he did not then receive a formal Survey appointment. In the Sundry Civil Expenses Act, $20,000 had been appropriated "for completing and preparing for publication the contributions to North American ethnology, under the Smithsonian Institution" in addition to the appropriation for completion of the reports of the Geographical and Geological Survey of the Rocky Mountain Region; Major Powell preferred an appointment under the Smithsonian Institution to direct the ethnologic work.

Emmons was named geologist in charge of the Rocky Mountain Division, G. K. Gilbert, geologist in charge of the Division of the Great Basin, and Arnold Hague, geologist in charge of the Pacific Division. Captain C. E. Dutton, whose detail from the Army to the Interior Department had been continued, was placed in charge of the Colorado Division. Becker was assigned to the Division of the Great Basin for studies in mining geology. Allen Wilson was named Chief Topographer of the Department of Topographic Engineering, and F. A. Clark, the Chief Topographer of the Division of the Pacific. Blair became Pumpelly's chief assistant in the Mining Geology Division.

Andrew A. Blair

First Chief Chemist of the U.S. Geological Survey. Blair later became a member of the firm of Booth, Garrett & Blair, analytical chemists, which had been founded by James C. Booth, of the First Pennsylvania Survey and the first Geological Survey of Delaware. Blair developed many new methods for analysis of iron and steel, and published a text on the chemical analysis of iron which was a classic in its day. (Photograph courtesy of Booth, Garrett & Blair, Inc., Philadelphia.)

Although it is nowhere spelled out, it is evident that there were various grades in the service, and terms had been carefully chosen. Pumpelly, Emmons, Gilbert, and Hague were all heads of divisions, and all received salaries of $4,000 a year. Wilson was head of a department, which was evidently of lesser status than a division, and received a salary of $3,000 a year, as did Blair, who was the chief chemist. Becker and Clark, assigned to geographic divisions, were somewhat lower in the scale than department heads and received salaries of only $2,500.

Pumpelly was give a free hand by the Director and the Superintendent of the Census when he agreed to undertake the Census work, and he had concluded that in the time and with the means available it was not possible to make a special study of each of the mineral industries for which the Survey was to be responsible. Coal and iron were the most important in the industrial development of the country; of the two, Pumpelly decided to concentrate on a study of the iron ores because of the rapid advances in iron manufacture during the preceding decade, especially the new steelmaking processes. In the original Bessemer process, only pig iron that was practically free from phosphorus could be used, and there had been many failures when domestic pig iron was used. Large quantities of Bessemer pig iron were being imported, and American manufacturers were uncertain whether American iron ores could ever make good Bessemer pig iron. A thorough knowledge of the chemical composition of iron ores was therefore most important, and Pumpelly planned that "every mine and known outcrop of iron ore from Canada to the Gulf of Mexico and from the Atlantic to the Pacific" would be examined geologically and systematically sampled and that the samples would be chemically analyzed and studied under the microscope. The headquarters of the Mining Geology Division were set up in Newport, Rhode Island, where "work could be carried on without the necessity of long summer vacation" and where several Government offices were already located. A chemical laboratory was equipped with provision for mechanical preparation of samples, including the crushing and grinding of ores, and everything necessary for rapid and careful chemical analysis.

Several appointments were made to the census staff so that work on the iron project could begin. First on the list was Bailey Willis, appointed a special agent on July 10. Willis was fresh out of the Columbia School of Mines, and Professor Newberry had sent him to Washington to look for a job with the newly established U.S. Geological Survey. While Willis was waiting to see the Director one day, Pumpelly breezed by and into the

Director's office unannounced. Willis, who did not recognize the "red-bearded giant," was astonished that anyone would so unceremoniously approach the Director of the United States Geological Survey. King and Pumpelly discussed plans for sampling iron ores. "You will want young men," said King. "There is Willis, you can have him." In this offhand manner began the long association of Willis and Pumpelly and of Willis and the Geological Survey. In August, Major T. B. Brooks, who had been a pioneer in the geologic study of the Michigan iron districts, and Charles F. Johnson were added to the census staff. Johnson was to be responsible for the statistical work. F. A. Gooch, who had a Yale Ph.D. in chemistry, became Blair's principal assistant in October; later, Captain J. Pitman of the Ordnance Corps, J. F. White, Edward Whitfield, W. R. Richmond, and C. F. King joined the chemistry staff. Bayard T. Putnam and E. R. Benton, both Harvard graduates, and William Chauvenet, an 1879 graduate of Washington University, were added to the staff to collect iron-ore samples along with Bailey Willis.

Pumpelly's objective in the iron-ore investigation was to determine the classification, geographic and geologic distribution, manner of oc urrence, and chemical character of the different varieties of iron ores. The yo ıng men

Raphael Pumpelly

Pumpelly was head of the Mining Geology Division of the U.S. Geological Survey from 1879 to 1881 and of its Archean Division from 1884 to 1892. From 1881 to 1884, he headed the Northern Transcontinental Survey. Pumpelly was primarily a mining engineer (King accounted him the best of his day), but Bailey Willis placed him among the great explorers. "He used his profession of mining engineer but never devoted himself to it. He served his adopted science, geology, but not exclusively. He cherished for forty years a dream of carrying out investigations in archeology and ethnology of the Asiatic and European races and at the age of three score and ten realized it with the same thoroughness and devotion to truth which characterized all his scientific studies." (Photograph courtesy of the Smithsonian Institution Archives.)

Allen D. Wilson

First Chief Topographical Engineer of the U.S. Geological Survey. The unequaled accuracy and rapidity of his work, according to S. F. Emmons, could be adequately appreciated only by those who put it to the test of actual instrumental verification. Wilson left the Survey in 1881 to join the Northern Transcontinental Survey. (Photograph from the files of the U.S. Geological Survey.)

were sent out to collect hand samples and commercial samples, the latter consisting of 10 to 20 pounds of small chippings from the mines and from the stockpiles, a method of sampling proposed and used by Brooks in Michigan and by Pumpelly in Missouri. After detailed information about each sample was recorded, they were then to send the samples to Newport for chemical analysis and microscopic study. Putnam visited the iron mines in Massachusetts, Connecticut, New York, New Jersey, part of Pennsylvania, Michigan, and northern Wisconsin. Benton visited the mines in Maine, New Hampshire, Vermont, Maryland, and Virginia. Chauvenet collected samples in Kentucky, Tennessee, Alabama, and Missouri. Willis was sent to eastern Pennsylvania, Ohio, North Carolina, Tennessee, Georgia, and Alabama, where with some ingenuity, he obtained the aid of mountaineers and moonshiners to find the ore banks from which the Confederates had made iron. Willis was also sent to run down reports of iron ore north of Lake Superior, a trip that was made under exceptionally difficult circumstances, beginning in canoes and ending on snowshoes. One party spent the autumn of 1879 and the following winter making geologic and magnetic observations in an attempt to trace the connection between the iron-bearing formation of the Marquette district in Michigan and the new iron fields on the Menominee River, and in tracing the continuation of the Menominee iron ore range eastward under the overlying rocks. A steady stream of samples was shipped to the laboratory, by mail under Government penalty label for postage. The samples caused great consternation to some of the postmasters of small country offices who supposed them to be precious metals and kept them guarded overnight.

Emmons, on the other hand, was given detailed instructions by King:

1. "You will devote the first years of the administration of your division exclusively to a study of mineral wealth of the Rocky Mountains.
2. "Personally you will confine your investigations, till further orders, to the metallic minerals of Colorado, their geological connection, mode of occurrence and association. District by district you will acquaint yourself with the minutest features of lodes, with the legal aspect of mining, and you will prepare to furnish for the year 1880 such statistical tables as may be necessary to show, as far as practicable, gross and net product of each district and region, summing up in one general table and entire precious-metal product of Colorado.

   "As far as possible you will check mine, mill, and furnace returns by the receipts of the various transportation companies, and, in general, trace the metals into actual market. In the case of base bullion, refining returns should be obtained, if the process is completed in America; if not, note to that effect should be made.
3. "You will prepare to execute, and, if possible, within two years complete, under your own personal supervision, monographs of the Leadville region, of the mining districts on the waters of Clear Creek and the West Mountain Valley group of districts. You will accompany your reports on these districts with topographical, geological, and mine maps, with full diagrams and sections illustrating all interesting points of lode structure. You will carefully describe all methods of mining, and make full reports of all metallurgical processes, with plans and working drawings of all establishments which present peculiar interest."

Leadville, which was Emmons' first assignment, was about 75 miles from Denver, on the foot of one of the western spurs of the Mosquito Range at an altitude of 10,000 feet. The mines were between the city and the crest of the range, a few hundred to two to three thousand feet higher. The season for fieldwork was therefore very short. Moreover, the position of Leadville,

George F. Becker

Geologist of the U.S. Geological Survey, 1879–1919. Becker early established himself among the front rank of mining geologists, but his interests lay more in abstruse physical and chemical problems. He himself said that next to being a student of the interior of the Earth, he would choose to be an army officer in the field. Arthur Day said that "with the possible exception of Gilbert, there was no man of his time in the Washington geological world who possessed greater versatility in discussion and such breadth of view." (Photograph courtesy of the Smithsonian Institution Archives.)

Emmons said, was one that presented many difficulties in the way of geological research. The spur on which the mines were situated was traversed in every direction by a perfect network of folds and faults. Since the folding and faulting, long ages of erosion had passed, the upper beds had been worn away, and glaciers had carved out deep ravines and deposited debris on the intervening spurs so as to practically hide the effects of all previous action. No wonder mining men were puzzled to know the right place to look for minerals, and that courts, in endeavoring to decide the rights of the many claimants to one piece of valuable ground by the rules of mining law which never contemplated such a class of deposits, should give decisions that, from a geological standpoint, were utterly without reason.

Emmons had his own ideas as to how a mining-district study should be conducted. The first requisite was an accurate map. A comprehensive view of the larger features of the geology of the whole region was also essential. Then a systematic examination should be made of all the deposits, tracing them step-by-step in the mines so that the position, form, and relation of the deposits to the enclosing rock could be accurately determined, their horizontal extent and shape delineated on maps, and their positions in the rock masses represented on cross sections and profiles. Then the question could be asked, "Whence did they come?"

Emmons said:

> **The study of the origin of ore deposits is one upon which comparatively little systematic scientific work has been done; and which presents peculiar difficulties in its prosecution. Its results may not be of immediate practical value for any particular district, but for the advancement of the interests of mining, in general, they are of the utmost importance.**

It was his wish "not to content (himself) with the simple expression of an opinion that the ore came from below or from above, but by patient research and investigation to prove definitely that it could or could not have proceeded from this or that source." For such a study, chemical investigations and microscopic examinations would be necessary.

King approved his plans. Allen D. Wilson, the Chief Topographer, was dispatched to Denver and spent the remaining summer and fall months in making a detailed map of the region covered by the Leadville mines. While he was so engaged, Emmons made a trip from the Laramie Plains through North and Mineral Parks studying the general geology; then during the winter he began a study of the underground workings at Leadville.

Becker was instructed to make a reconnaissance of the San Francisco district in southern Utah, the Eureka district in Nevada, and the Bodie district in California to lay plans for the comprehensive studies of each and then to make a detailed investigation of the geology of the Comstock Lode. He went into the field in October visiting first the San Francisco district, spending November in Eureka, and moving on to an examination of the principal mines of the Bodie district in December.

Clarence E. Dutton

Captain Dutton, Ordnance Corps, U.S. Army, was detailed to the Public Lands Commission in 1879 and to the U.S. Geological Survey from 1880 to 1890. Dutton, who had been detailed to the Powell survey in 1875, shared Major Powell's interest in the Canyon country, and also had a long-standing interest in volcanism and earthquakes. He differed with Major Powell on the administration of the Irrigation Survey, and was recalled to the Army just before the Irrigation Survey was discontinued in 1890. Dutton was one of the clearest, most impressive, and entertaining of writers. (Courtesy of the Library of Congress.)

Before geologic work could begin at Eureka, where the third of the three principal mining district studies that King had proposed would be undertaken, a topographic map was needed. As Hague, the geologist in charge of the Division of the Pacific, was still in China and not expected to report for some months, Frederick A. Clark, the Chief Topographer of that division, was sent to Eureka with a small party to make a survey of a 20-square mile area.

Gilbert was allowed to choose his own field of investigation in the Division of the Great Basin. With the limited means at the Survey's disposal, he said,

> it was manifestly impossible to occupy the entire field at once and carry on the work in a way that would be both geologically and geographically symmetric. It was necessary to restrict attention, and the question arose whether this should be done by selecting a limited district for initial work and beginning in it the study of every topic to which it might contribute, or by choosing a specific line of inquiry and carrying it through the entire area. The latter course was decided on, and the theme of study selected was the Quaternary history of the valleys of the Great Basin.

He already had on hand a considerable body of unpublished material on Lake Bonneville, the Pleistocene ancestor of Great Salt Lake; the history of Lake Bonneville would be nearly identical with the Quaternary history of the valleys around Salt Lake City, and thus the choice was made. Gilbert's study, however, was much broader than the Quaternary history of valleys in Utah. He believed the history of Lake Bonneville to be the history of the ancient climate of Utah and thereby closely linked to the material interests of the territory. He said:

> The secular cycles of climate, whereby the water-level was raised and lowered a thousand feet, and the water surface increased and diminished, as compared to the present surface, a thousand per cent, finds its modern counterpart in oscillations whereby the level of Great Salt Lake has recently varied through a range of twelve feet, and its area through a range of fifteen per cent. Whatever we can learn as to the character and cause of the greater change will contribute directly to an understanding of the lesser, and the public domain presents no more important problem to the Survey. In a dozen States and territories, agriculture is restricted by the insufficiency of the water supply, and in half of them, it is only here and there that a spot can be found to repay cultivation. The supply of water for a few years shows a flattering increase, and then for a like period discourages by its decrease. It is a matter of the utmost importance to determine what, on the whole, is the tendency of the climate. Is it growing moist or dry? And are there any means by which precipitation can be increased? Upon the solution to these problems will ultimately depend the population of a great district, and if the logic of events can be anticipated, and the conditions of the future told or modified, the immigration that has begun can be duly stimulated or discouraged, and the investment of the great capital which appears to be demanded for works of irrigation can be wisely directed or wisely limited. It is partly by the study of causes and effects in meteorology, and partly by the empirical study of the history of storms, that the scientific weather prediction of the day has been achieved. It may fairly be hoped that a critical investigation of the secular oscillations of climate in the past will help to solve the problems of secular change which is of such vital importance to the agriculture of an arid domain.

Hayden was asked, as his contribution to the Geological Survey, to prepare a digest of the results of the fieldwork and of the geological reports of the Hayden survey. The area to be considered was that part of the Rocky Mountain region north of New Mexico and west of the 94th meridian; an historical account of earlier work and the general geography of the areas were to be included along with the discussion of the stratigraphy and the igneous and metamorphic rocks.

Investigations in general geology were not pressed with such vigor as those in mining geology. Gilbert spent the summer of 1879 in Washington, somewhat to King's dismay, and did not get into the field until October. His report on the Henry Mountains was finally published. (Although the report bears the date 1877, in the spring of 1878, Powell said it was in the hands of the binder, and Dana, in the January 1880 issue of the *American Journal of Science*, stated that despite the date it had only been issued within the preceding 3 months.) Gilbert proposed for the Henry Mountains, to use his own word, a novel structure. "It is usual," he wrote, "for igneous rocks to ascend to the surface of the earth, and there issue forth and build up mountains or hills by successive eruptions. The molten matter starting from some region of unknown depth passes through all superincumbent rock-beds and piles itself up on the upper most bed. The lava of the Henry Mountains behaved differently. Instead of rising through all the beds of the earth's crust, it stopped at a lower horizon, insinuated itself between two strata, and opened for itself a chamber by lifting all the superior beds. In this chamber it congealed, forming a massive body of trap. For this body, the name laccolite (λακκοϛ cistern, and λιθοϛ stone) will be used."

Dana said that "Mr. Gilbert presents much that is new to Geology in his account of the Henry Mountains." He allowed that "The quaquaversal dip in the strata appears to indicate, as Mr. Gilbert states, that the dome-like elevations were produced through force acting directly beneath each, and

The Survey's Division of the Colorado embraced the plateau and canyon country which had been the field of exploration of the Powell survey. Powell had called it the "Plateau Province," a land of nearly or quite horizontal platforms and terraces abruptly terminated by long lines of cliffs. The Land of the Standing Rocks is in the very heart of the plateau country. (From C. E. Dutton, 1882.)

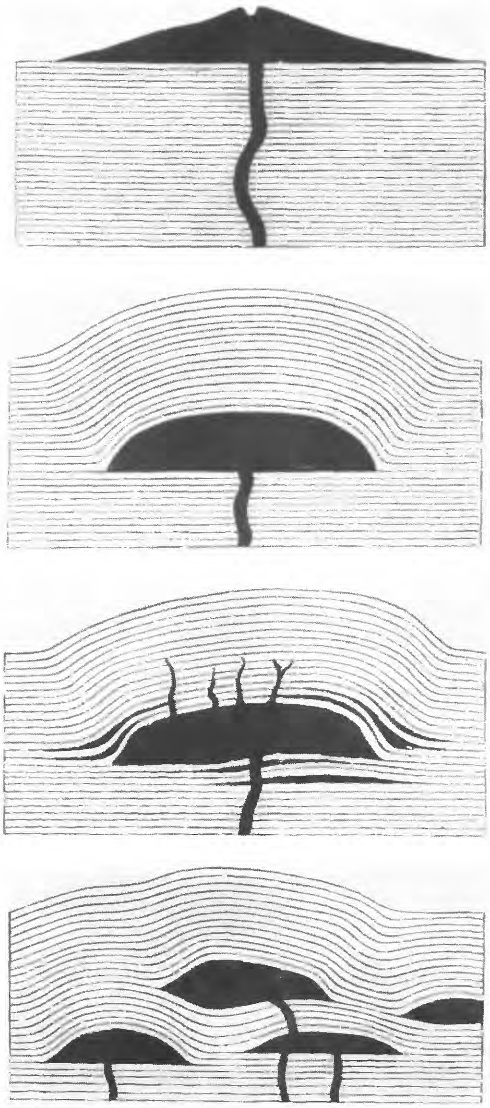
The Division of the Great Basin included, in addition to rich silver districts, the remnants of ancient lakes, the largest of them ancient Lake Bonneville, of which Great Salt Lake is the shrunken remnant. The history of Lake Bonneville was linked to the material interests of the region because it was the history of the ancient climate. The outlet of the ancient lake, source of long-standing interest to geologists and explorers, Gilbert found at Red Rock Pass. (From G. K. Gilbert, 1890.)

from the position of the trachyte, the natural inference is drawn that the force was connected with the eruption of this igneous rock," and that "The facts appear to sustain Gilbert's conclusion that the mountains were made such, out of horizontal strata, by the ascending trachyte, which 'insinuated itself between the strata* * *'," but that the explanation "appears to be complete without reference to this difference in density" which Gilbert had invoked to explain the action. Privately, Professor Dana wrote to Professor Geikie that the report contained an "account of queer facts—which although I appear to accept them all in the notice, I confess I accept only with questionings."

Dutton was fully occupied during the year with the work of the Public Lands Commission and did not do any geologic fieldwork. To complete the reports on the Colorado Plateau region, maps of the Uinkaret Mountains and a portion of the Grand Canyon and its subsidiary canyons were needed, so a topographic party was sent into the field. S. H. Bodfish made the survey of the Grand Canyon district, and J. H. Renshawe, the survey of the Uinkaret district. In addition to this work, C. D. Walcott was sent out, instructed to make a stratigraphic section from the summit of the Pink Cliffs, at the source of the Kanab along its course through canyons to the junction with the Colorado River. The section was supposed to contain a nearly unbroken series from the Eocene to the base of the Carboniferous, with Devonian and Silurian rocks lying unconformably below the latter. The detailed section would be used as a standard of comparison for various other subordinate sections that had been made in adjacent country.

Hayden retired to Philadelphia to work. However, the first manifestations of the illness that eventually caused his death appeared, and by midwinter, he was nearly blind and brooding on the injustice that had been done him.

After completing his plans for the Geological Survey, King turned his attention to the Public Lands Commission, which began its work early in July also. The Commission, consisting of the Commissioners of the General Land Office and the Director of the Geological Survey, ex officio, and three



Several reports of the predecessor surveys were published during the Survey's first year. In his report on the Henry Mountains, which he had investigated for the Powell survey in 1875 and 1876, G. K. Gilbert gave the first explanation of laccoliths, formed when lava instead of rising to the surface stopped at a lower layer, insinuated itself between two strata, and opened for itself a chamber by lifting all superior beds. Laccoliths were later found to be fairly common in the West although almost unknown elsewhere. (From G. K. Gilbert, 1877 [1879].)

civilians to be appointed by the President, was charged with reporting to Congress: "first, a codification of the present laws relating to the survey and disposition of the public domain; second, a system and standard of classification of public lands as arable, irrigable, timber, pasturage, swamp, coal, mineral lands and such other classes as may be deemed proper, having due regard to humidity of climate, supply of water for irrigation, and other physical characteristics; third, a system of land parcelling surveys adapted to the economic uses of the several classes of lands; and fourth, such recommendations as they may deem wise in relation to the best method of disposing of the public lands of the western portion of the United States to actual settlers." King asked that Major Powell be appointed one of the three civilian commissioners, "because he is the originator of the reform and has more facts than any one else" and President Hayes appointed him along with Thomas Donaldson of Philadelphia and Alexander T. Britton, a former clerk in the Land Office and a member of an influential law firm then practicing before the Land Office.

The Commission met on July 8, chose Commissioner James A. Williamson, Commissioner of the General Land Office, as chairman, and divided its work into two principal parts—the codification of laws and an investigation looking to recommendation of new legislation. Captain Dutton joined the Commission as secretary and disbursing agent on July 22. In the performance of its first duty, the Commission found it necessary to collate all the laws relating to the disposition of public lands, about 3,500 in all, to digest the land decisions of all the Federal courts, the supreme courts of the several States, and the Interior Department. To ascertain the practical working of the existing laws and their adaptation to settlement of the public domain and to learn the views thereon of the people of the West, the Commission spent from August 18 to December 1 visiting all the States and Territories west of Kansas and Nebraska except Washington Territory. The chairman of the House Committee on Public Lands, George Converse, accompanied them. The Commissioners conducted some personal interviews, but relied greatly on printed questionnaires widely distributed with the aid of State and Territorial Governors, congressional delegations, and land officers. A comprehensive preliminary report was submitted in late February with recommendations in the form of a land bill covering the entire public land system in its permanent and general features, which would take the place of all of Title 32 of the Revised Statutes and so much of Title 11 as applied to the General Land Office.

In determining its recommendations, the Commission said it gave controlling weight to the following considerations: (1) The existing land system had been tried for many years, on the whole was believed to be sound in principle, and was based on a wise and beneficent policy; (2) Government policy had been to devote the public lands to settlement by industrious citizens; and (3) Government policy limited the amount of land that one person could acquire directly from the Government. The laws and the machinery of their execution, however, had not been constructed in all respects to attain these ends, and the people in the western regions had "to a certain extent framed customs which take the place of laws" or had taken the law unto themselves. Laws had also been passed to meet special necessities or to counteract special abuses and had not been coordinated to the general system.

The Commission recommended that the staff of the General Land Office be increased (except the office of receiver, which should be abolished), and that the salaries of the Commissioner and certain other officials be increased.

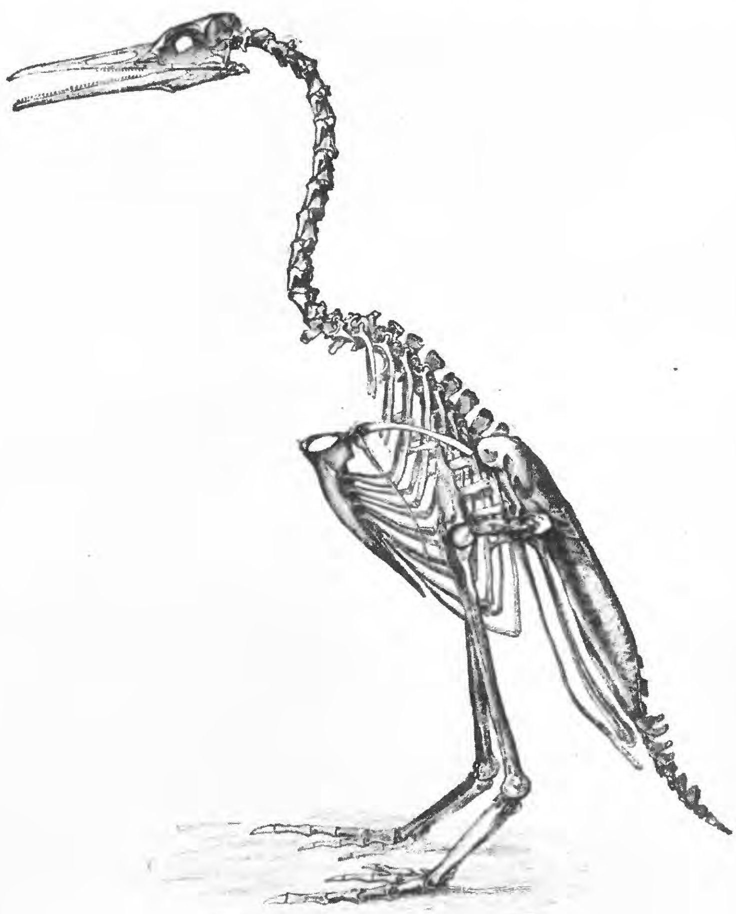
C. E. Dutton's report on the geology of the High Plateaus of Utah, which he studied for the Powell survey during the summers of 1875–1877, was published in 1880. The principal subject of his investigation had been the volcanic phenomena, which he said was the most difficult of all geological investigations. The Markagunt Plateau, the southernmost of the High Plateaus, was bounded by the Hurricane fault, which separates the Plateau Province from the Great Basin. The tufa forming the Markagunt Plateau Dutton described as material derived from the complete decay of lavas accumulated as a deposit in the bed of a small lake, consolidated, and subsequently eroded. (From C. E. Dutton, 1880.)

The machinery of the land system lies at the threshold of the successful administration of the law. If defective and incomplete in its organization, it will not be operative from inherent weakness, and the law will, in the ratio of such weakness, remain a dead letter upon the statute book. If cumbersome and complicated it will, by cumulative delays and excessive cost, impair and retard the operation of the law it was intended to execute. The commission has sought to put the officers of the land system on such footing in point of numbers and powers as would, at a minimum expenditure, secure a maximum efficiency.

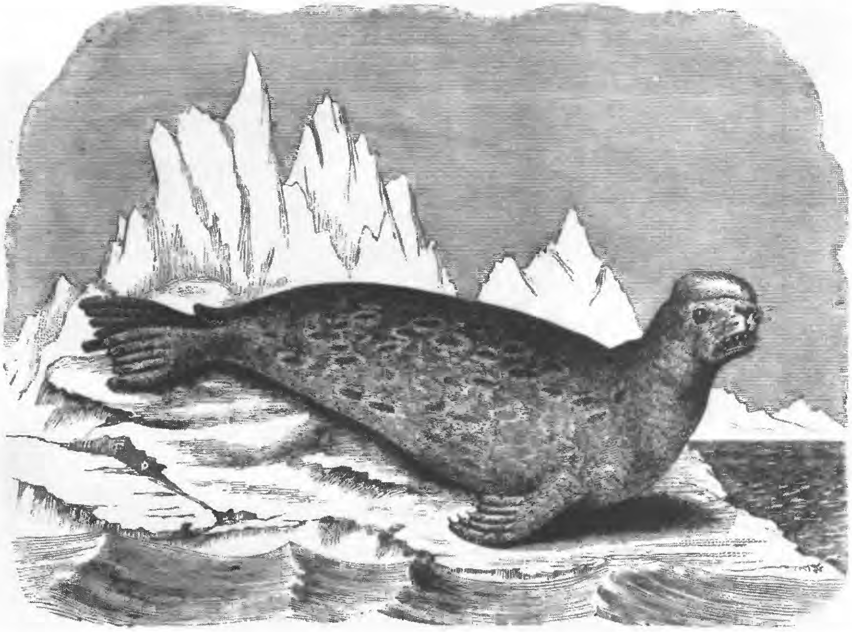
The land-parceling system was also satisfactory, but there were objections to the manner in which it had been executed: surveying swamp and arid lands into small subdivisions which might not soon or ever by used in tracts less than a township; surveying areas long before settlement, without adequate monumentation, so corners could not be found and lines had to be retraced; and letting contracts for surveys without providing for an adequate system of inspection, so that inaccuracies resulted. The Commission recommended that lands that were notoriously swamp, which had been granted to the States, and pasturage lands be surveyed and patented by townships; that a proper system of monumentation be prescribed by the Commissioner of the General Land Office; and that all surveys of public lands be made by salaried deputies except in such places where it would be manifestly in the interest of the Government to have the work performed under contract. It also recommended that thereafter, all boundary lines of States and Territories that remained to be surveyed, and corrections of those already surveyed, be surveyed under the direction of the Superintendent of the Coast and Geodetic Survey.

With regard to the classification of lands, the Commission proposed that there be only five classes: arable, mineral, irrigable, pasturage, and timber lands. Primacy, however, was given to mineral lands, which were defined as "all lands which contain veins or lodes of quartz or other rock in place bearing gold, silver, cinnabar, lead, tin, copper, coal, iron, or other valuable deposit (and which are rendered thereby more valuable for mineral than for agricultural purposes)." Timberlands were defined as "all lands, excepting mineral, which are chiefly valuable for timber of commercial value, for sawed or hewed timber." Arable lands were all nonmineral lands that would produce agricultural crops without irrigation and that were not chiefly valuable for timber for commercial purposes. Irrigable lands were all lands, excepting mineral lands, and excepting lands chiefly valuable for timber of commercial value, that could not, without irrigation, produce some agricultural crop, except grass, for the reclamation of which sufficient water could be obtained. Pasturage lands were all lands, excepting mineral lands, and lands chiefly valuable for timber, that could not produce crops without irrigation, and that were chiefly valuable for pasturage. The practical application of this system was left to the surveyors.

With regard to the disposal of the public lands, the Commission recommended that all the arable lands of the western part of the United States be held for the benefit of actual settlers under the Homestead Act but recommended that the Preemption Act be stricken from the statutes. Irrigable lands should be sold in unlimited quantities, subject only to the condition that the purchasers actually redeem the lands by constructing the hydraulic works necessary thereto. As an alternative, the Commission noted that the general Government or State goverments might construct the necessary hydraulic works, although such a method was not "in consonance with the traditions of the American people." Pasturage lands should be sold in quantities large enough to establish a home and at prices low enough that men could afford to take them solely for pasturage purposes. The Commission concluded that the farm unit should not be less than 4 square miles and recommended a graduation in the price with time. Timberlands



The last of the reports of the King survey was Professor O. C. Marsh's volume on Odontornithes. Its 34 plates included a magnificent one, at half size, of a restoration of *Hesperornis regalis*, a Middle Cretaceous toothed bird, whose skeleton, if extended, would measure about 6 feet from the point of its bill to the tip of its toes. The figure shown here is a smaller version from the third annual report of the U.S. Geological Survey. (From O. C. Marsh, 1883.)



The Hayden survey published in 1880 a monograph on the walruses, sea lions, sea bears, and seals of North America, the second volume in a systematic *History of North American Mammals*. Among the illustrations was one of *Cystophora cristata* by H. H. Nichols, who also made many illustrations for the Geological Survey. (From J. A. Allen, 1880.)

as defined by the Commission covered only a small area; the Commission recommended that they be retained by the Government and that the standing timber be sold. Timber on arable or pasturage lands could be taken with the land.

The mineral-land laws were subjected to critical attention, and King's experience and pen are clearly evident in the report. The "early Californian" theory that a mining claim consisted of a certain number of running feet of vein, with a strip of land covering the surface length of the claim, was the obvious foundation of the Mining Laws of 1866 and 1872. East of the Mississippi River, common law had been the only rule, and there the surface tract always carried with it all minerals vertically below it. California was "one of those extraordinary historic exceptions that defy precedent and create original modes of life and law. And since the developers of the great precious metal mining of the far West have for the most part swarmed out of the California hive, California ideas have not only been everywhere dominant over the field of industry, but have stemmed the tide of Federal-land policy and given us a statute-book with English common law in force over half the land, and California common law ruling in the other."

As a result, there was a characteristic difference between mineral development east and west of the Missouri. East of the Missouri, almost no litigation grew out of the conditions of Government conveyance; west of it, litigation was frequent, vexatious, and costly. The two features that caused the most litigation were the recognition by the law of local customs and regulations, and the "attempted conveyance of a lode, ledge, or deposit of rock in place bearing mineral, as a thing separate from and independent of the surface tract of ground." The net result was that the law "might be fitly entitled 'An act to cause the government to join, upon unknown terms, with an unknown second party, to convey to a third party an illusory title to an indefinite thing, and encourage the subsequent robbery thereof.'" The Commission suggested that the time had come when Congress should formulate legislation to govern the changed conditions of an occupation that had passed from a frontier experiment into a national industry.

> **If mining is to be continued as an experiment, or for speculative purposes alone, an adherence to the existing customs is desirable. If it is to be continued**

as a business, upon settled principles and with expectation of legitimate returns, it should be governed by the same rules which the wisdom of centuries has formulated for the definition of all real property titles.

The Commission also recommended that the mineral lands include subclasses of coal and iron lands. Coal did not occur in the same manner as gold, silver, and similar minerals; iron sometimes occurred in the same way as coal and sometimes in the same way as gold. Coal and iron lands should be sold in larger tracts than gold and silver lands and without the conditions and restrictions imposed on the latter.

The Commission noted that there was a serious and increasing conflict in California between miners and farmers on mining debris. Facilities for running off tailings were indispensable to the successful working of the mines, but it was claimed that agricultural lands on the lower parts of the streams were being destroyed and that the shoaling of rivers and bays was destroying navigation and restricting commerce. The Commission recommended that another commission be created to ascertain the facts and to propose a remedy to Congress.

The report was signed by all five members of the Commission, but Major Powell qualified his endorsement of the report with a letter to the Secretary in which he suggested amendments to two sections of the proposed new law to prevent the severance of water property from land property and to provide that the right to use the water for irrigation purposes would inhere in the land and pass with the title to the land; he also proposed amendments to sever the mineral rights from surface rights in pasturage lands.

H. H. Dunham, later a Commissioner of the General Land Office, said of the report, "It is impossible to compute the benefits which prompt adoption of wise laws and suggestions for efficient machinery would have created for purposes of distribution in the land rush of subsequent decades." President Hayes sent the report to Congress on February 25, 1880, with a message commending it to "the prompt and earnest consideration" of Congress. For several years, however, little was done except for printing the report.

King had hoped to supervise the collection of statistics of precious metals for the Tenth Census himself, but he found that the work of the Public Lands Commission and direction of the Survey would not allow him sufficient time. Emmons and Becker were therefore summoned to Washington in January 1880 to begin the preparations. The two met for the first time while waiting outside King's office, and by the time he was ready to introduce them, they had already become firm friends. For a time they were in almost daily consultation with King and also had many conferences with the Superintendent of the Census, but in the end, their plans were accepted almost without change. Emmons took responsibility for the State of Colorado and the Territories of Dakota, Montana, New Mexico, and Wyoming, and Becker, for the States of California, Oregon, and Nevada and the Territories of Idaho, Utah, Arizona, and Washington. Precious-metal statistics for the area east of the 100th meridian would be gathered by Professor Shaler and his assistants in the New England States and by George H. Eldridge, a former student of Professor Shaler and recommended by him, in the Southern States.

The objective of the survey of precious metals for the Tenth Census was to obtain a complete picture of the industry, not only an estimate of the actual product that was more accurate than any previously obtained but also data on the occurrence of the ores and the processes by which the ores were made to yield their metals. It was well understood that it would be difficult. Precious-metal mining was usually carried on in regions that were remote

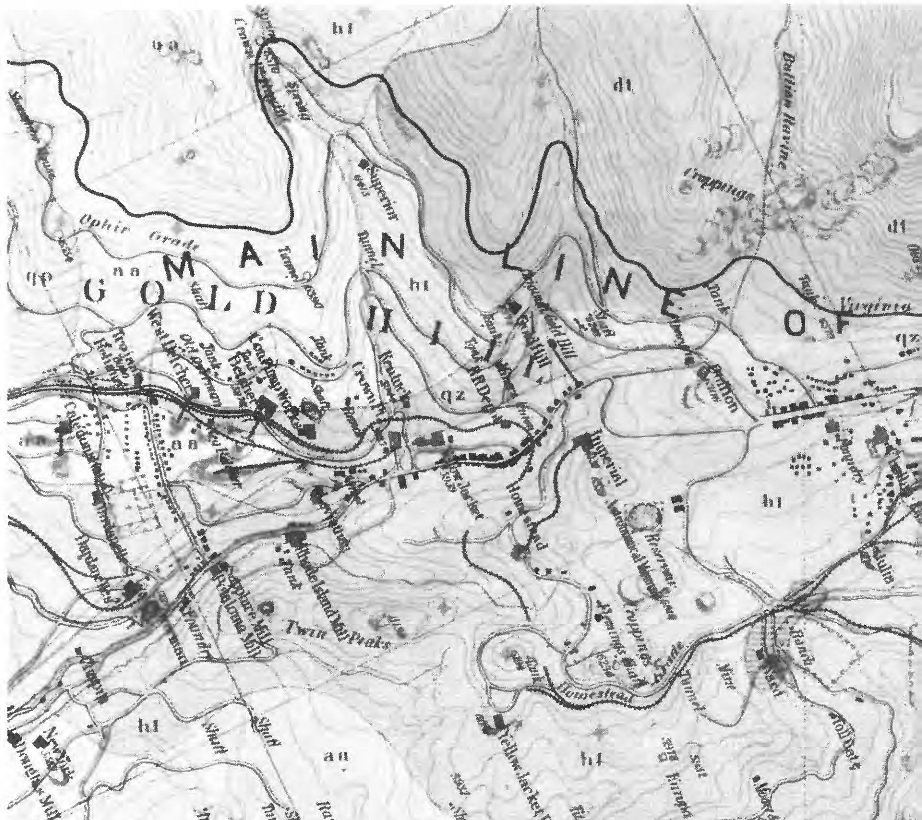
The first reports of the infant U.S. Geological Survey were published in its second annual report. Emmons' first geologic map of Leadville and vicinity, on a scale of 2 inches to the mile, covered an area of about 27 square miles. The part shown includes some of the richest mines. Ore was found on the contact of the White porphyry (s) and the Blue limestone (e). (From S. F. Emmons, 1882.)

and difficult of access, and by business methods that were not probably systematic, and precious-metal mining tended to make those engaged in it somewhat uncommunicative.

As the Geological Survey approached the last quarter of its first year, all seemed well. Dutton wrote to Sir Archibald Gelkie: "I cherish the belief that the Survey in the course of a few years will accomplish much for geology. The spirit which has been infused into it is most gratifying. There is a disposition to sink all personalities & to subordinate all efforts to the single end—the benefit of science. No man seems to desire anything more than to promote that one object. Mr. King is more than justifying all the high expectations which attended his appointment & his skill & ability to organize & administer have proved to be of the highest order. He succeeds in everything—his influence in Congress is adequate to the magnificent plans he has conceived—& he is enthusiastically loved by everybody. He has drawn into the survey the best geological talent of the country; he gives to every assistant the fullest latitude & discretion which is admissible & judges them by the results they furnish. A man who does not return handsome dividends may be sure of being put into bankruptcy. I think the whole tone & temper of the Survey augurs well for the future. The contrast with the state of affairs which prevailed a little more than a year ago when the rule was every man to gain what notoriety he could (as distinct from honest fame) & to repress all honest rivalry is most complete."

However, there were personnel problems and financial worries. Hague returned from China and entered on duty on April 1, 1880, but instead of becoming geologist in charge of the Pacific Division as originally planned, he went to the Division of the Great Basin to begin the Eureka district study. Though Gilbert was geologist in charge of the Division, he was completely occupied with his Lake Bonneville study. Becker, who had been expected to take charge of mining geology in the division, was just beginning the Comstock project and would be thoroughly busy with that and the census investigation. Gilbert, more accustomed to the freedom of the Powell survey than the highly organized ways of King, had assumed that the work in the Great Basin had been divided between him and Becker, and the decision to divide it three ways, he said, was "partly in accord with his request and wholly in accord with his desire."

Powell had just about decided to withdraw from geology and concentrate wholly on ethnology. During the summer of 1879, James Stevenson had made an extraordinary collection of Pueblo Indian material, and Powell wanted to undertake fieldwork in the area. The appropriation on March 3, 1879, had been for completion of the ethnological research begun under the Geographical and Geological Survey of the Rocky Mountain Region, and there was a question about who would support the fieldwork. King wrote to A. S. Bickmore, the director of the American Museum of Natural History in New York, suggesting that there ought to be enough public-spirited men in New York to contribute the $30,000 a year he would require. Powell prepared a plan for continued ethnologic research, which Secretary Baird of the Smithsonian Institution endorsed and submitted to Congress, recommending an appropriation of $50,000.



Becker's first geologic map of Virginia, Nevada, and immediate vicinity covered an area of only 8 square miles on a scale of 1 inch to 1,500 feet. The part shown includes the site of the original discovery. The symbol qz is used for quartz vein, hl, the earlier hornblended andesite, aa, augite andesite, qp, quartz porphyry, and dt, diorite. (From G. F. Becker, 1882.)

Professor James Dwight Dana, apparently under the impression that the original version of the extension resolution proposed by Mr. Atkins had been passed, and admitting that he did not know the nature of the discussion in the House, complained in an editorial in the *American Journal of Science* that the National Academy of Sciences committee's plan "had in view the economy of expenditure, suggested in the act of Congress; while the new scheme with the proposed enlargement of its scope, would involve—as State geological surveys have shown—millions of outlay for the strictly geological party and indefinite millions besides for the economical branch.* * *A change so great in the administration of the affairs of the government should have a full discussion before it is accepted. It will appear to many that the Constitution has left to the States the making of their own geological surveys and the study of their own economical resources—as past history seems to attest—and that such an infringement on State rights and assumption of State responsibilities would be politically wrong."

Dana also took Congress to task for not providing for topographic surveys as proposed by the Academy committee.

> **Topographical surveys are needed in every State as well as Territory; and for this purpose there is manifestly required the establishment of a Department of Mensuration Surveys under the General Government, whose geodetic work over the breadth of the country shall, in accordance with some well devised plan, be supplemented by topographical work at the expense, and under the united superivison, of the State and General Government. This done, the States could easily carry forward their own scientific and economical surveys.**

Then he added candidly that he was a member of a committee that had petitioned the Connecticut State legislature for a scientific survey of the State but urged that a topographic survey be made first so that a satisfactory geological survey could be made.

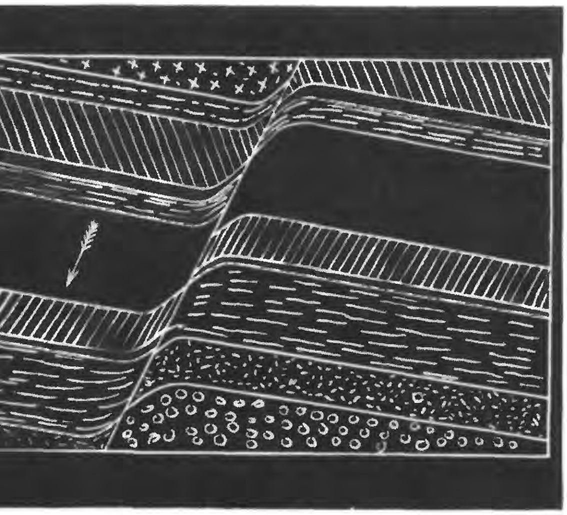
The extension resolution passed by the House in June 1879 did not come up for discussion in the Senate until May 10, 1880. It had been amended by the Committee on Appropriations so that it now read "and he may extend his examination of the geological structure, mineral resources, and products into the respective States when requested by the authorities thereof." In general, the Republicans seemed opposed to the measure. Senator Henry L. Dawes of Massachusetts thought it would be very convenient for the States to be able to invite the bureau in to carry on work; it would save the States a lot of money. Senator W. B. Allison of Iowa, the chairman of the Senate Appropriations Committee, said it meant the Director could organize a force and go into a State to examine its mineral resources. Then Senator Dawes concluded they were amending the original act to permit private surveys at public expense. Senator William Eaton of Connecticut protested that it merely meant that when the Director thought it necessary to go into the State, he first had to get permission from State authorities. It was a matter of States' rights. At that point, Senator Roscoe Conkling of New York, leader of the Senate oligarchy, announced that if that were what was meant, he for one was opposed and would not vote for it. And there the matter ended.

The appropriation for Survey expenses in the Sundry Civil Expenses bill came up for floor debate on May 28. The Department had requested $354,000, but the Appropriations Committee had approved only $150,000. Mr. A. H. Buckner of Missouri moved that the amount be increased. The Survey was meant for scientific investigation of the great iron and coal fields of the Appalachians, the salt of West Virginia and Ohio, the phosphates of the South. . . "wherever else there was mineral deposit—wherever, in fine, in behalf of the interests and welfare of the people and the Government, our country required examination and scientific development at the hands

Becker's monograph on the Comstock was published in 1882. From a petrographic study of Comstock rocks, he concluded that the so-called propylite of earlier investigators was actually several Tertiary and pre-Tertiary rocks that had been reduced to a nearly uniform appearance by decomposition. The erroneous determination of these rocks as an independent species was mainly due to confusion between green and fibrous hornblende and chlorite. Sections of minerals shown here are magnified 170, 48, and 50 diameters respectively, and show hornblende passing into chlorite, a pseudomorph of chlorite after hornblende with epidote being developed from five distinct centers, and a pseudomorph of epidote after hornblende. (From G. F. Becker, 1882a.)

of these scientists, there it was intended this Geological Survey should operate and submit reports for the information of Congress and the people." Mr. James Chalmers of Mississippi thought the Survey should be given all it asked for. Unless it was given the full amount, it might as well be struck out all together. It was a waste of money to leave it as it stood, for the Survey could not do justice to the work on that amount. The Territorial delegate from Montana, Martin Maginnis, however, announced that he was happy to pay tribute to the character and ability of the eminent gentleman at the head of this survey but that "Geology never has discovered mines or profitably worked them in the Territories, nor will it do so in Mississippi, West Virginia, or Missouri." Mr. Maginnis was very disturbed by the report of the Public Lands Commission on mining laws. Eventually, Buckner's motion was defeated by a vote of 84–72. Then, Eppa Hunton of Virginia moved that the appropriation be increased to $200,000, but that, too, was rejected 62–57.

The House Appropriations Committee proposed an appropriation of $20,000 "for the purpose of continuing ethnologic researches among the North American Indians, under the direction of the Secretary of the Smithsonian Institution." Mr. Adlai Stevenson of Illinois made a long speech on behalf of the work and proposed that the appropriation be increased to $40,000, but others complained that the ethnologic work of the great surveys had been done by using money appropriated for other purposes and the appropriation in March 1879 was to complete such work. In the end, $20,000 was appropriated for ethnologic research. The Senate made no change in either the appropriation for the Geological Survey or for ethnologic research, and so for fiscal year 1881, the Survey's appropriation for expenses was $150,000.



Because of the importance of faulting in the Comstock area, Becker also made a mathematical study of strain in a sheet or plate of rock under the influence of friction of a relatively opposite character on its two faces. Strain in faulted sedimentary rocks, indicated by a permanent flexure of the ends of strata shown here, is a phenomenon long known to miners. In massive rocks, the strain will cause a shearing off of one or more sheets. Becker concluded that the sheeted structure of the Washoe country was due to faulting rather than eruptive bedding and on the basis of this conclusion proposed rules for prospecting. (From G. F. Becker 1882a.)

President Hayes had announced at the start of his term that he would not seek reelection, and as convention time drew near in 1880, there was no obvious choice of a successor. The Democrats controlled the solid South, and 135 of the 185 electoral votes needed to win. The Republicans had to hold nearly all the Northern and Western States in order to win, and the loss of even one or two of the bigger States would mean the loss of the election. The electoral votes of New York and the Midwestern States of Ohio, Indiana, and Illinois were critical to both parties. The Republicans were divided, the Stalwarts under Senator Conkling of New York supported a third term for General Grant; Senator Blaine and his Half Breeds favored John Sherman of Ohio, Secretary of the Treasury. So evenly balanced were the two forces that the convention was deadlocked for 33 ballots. Finally, on June 8, on the 36th ballot, James A. Garfield of Ohio, who had been floor manager for Sherman, was nominated for President. The ticket was then balanced by the nomination of Chester A. Arthur, Conkling's lieutenant, as the Vice Presidential candidate. The Democrats had almost as much difficulty in nominating a candidate but finally settled on General Winfield Scott Hancock, a military hero with no political experience.

King thus had a double disappointment in the first 10 days of June. Not only was the appropriation less than half what he had hoped for, but it was also clear that there would soon be a new Secretary of the Interior. It was no secret that Schurz did not approve of Garfield and would not be a member of the Cabinet even if the Republicans won the election. Schurz himself made it certain by his letter early in July to Garfield on the subject of civil service reform.

King apparently at this time decided to resign but, when he told Schurz of his desire, was persuaded to stay on. It might have been difficult to forestall the appointment of Hayden as his successor if Hayes were to make the appointment, but Garfield would surely appoint Powell who was on very friendly terms with him, so friendly in fact that he had just released his stenographer, Joseph Stanley-Brown, to be Garfield's secretary during the campaign. The plan was supposed to be kept quiet so that Hayden would not find out about it. Hayden did, however, and early in August wrote to Geikie: "I understand that the defeat of King's great plans has so disgusted him that he will resign soon and place Powell in the chair. Powell has been his devoted parasite, but I cannot hold any position. King, although he knows he has lost ground, is a man of ability and the opposition he has encountered made him disgusted. He intends to put Powell in his place. I could not serve under such a fraud."

On the 1st of July 1880, the first day of the Survey's second year, four additions were made to the Survey staff: William R. Eckart, civil engineer, at $4,000 a year; and 3 young men, still in their 20's: William F. Hillebrand, Chemist, at $2,000 a year; Ernest Jacob, assistant geologist, at $1,200 a year; and Carl Barus, physicist, at $1,200 a year. Hillebrand had studied at Cornell, Heidelberg (from which he received the Ph.D. in 1875), Freiberg, and Strasbourg. Jacob, who had been a volunteer assistant to Emmons, was a graduate of the Royal School of Mines in London. Barus had studied at the Columbia School of Mines and Würzburg from which he received the Ph.D. in 1879. He had then spent a year as assistant to Professor Kohlrausch.

Jacob and Hillebrand joined Emmons in the Leadville project. In October, Whitman Cross was appointed as assistant geologist at $1,200 a year and also joined the Leadville project. Cross had studied under B. K. Emerson at Amherst, who had awakened his interest in microscopic petrography, and then had gone to Göttingen and Leipzig where he had received a Ph. D. in 1880. The season at Leadville was very short that year, snow having covered the ground before October 1. Some of the map work had been entrusted to private engineers because of the lack of appropriation, and that caused delays; the laboratory had to be built before Hillebrand could get to work, and the draftsmen were leaving regularly for higher salaries elsewhere. Despite all these frustrating causes of delay, however, Emmons managed to complete the fieldwork so that the Leadville office could be discontinued on April 1, 1881.

King was so pleased with Becker's work that on July 1 his salary was raised to $4,000, and Eckart and Barus were both assigned to work with him. Eckart was instructed to prepare a report on the mechanical appliances used in mining and milling on the Comstock lode, designed to present to the general mining world an insight into the magnitude, cost, and extent of the machinery that was used only there in all the world. Eckart divided his work into two parts: one, accurate drawings and descriptions of the appliances; the other, experimental determinations of the work accomplished by the various appliances, which Eckart himself thought would form a sound basis from which engineers and mining men might understand the limit of their expectations in the mechanical and practical accomplishment of large mining undertakings. Barus, under Becker's supervision, was to make experimental determination of electric currents around ore bodies.

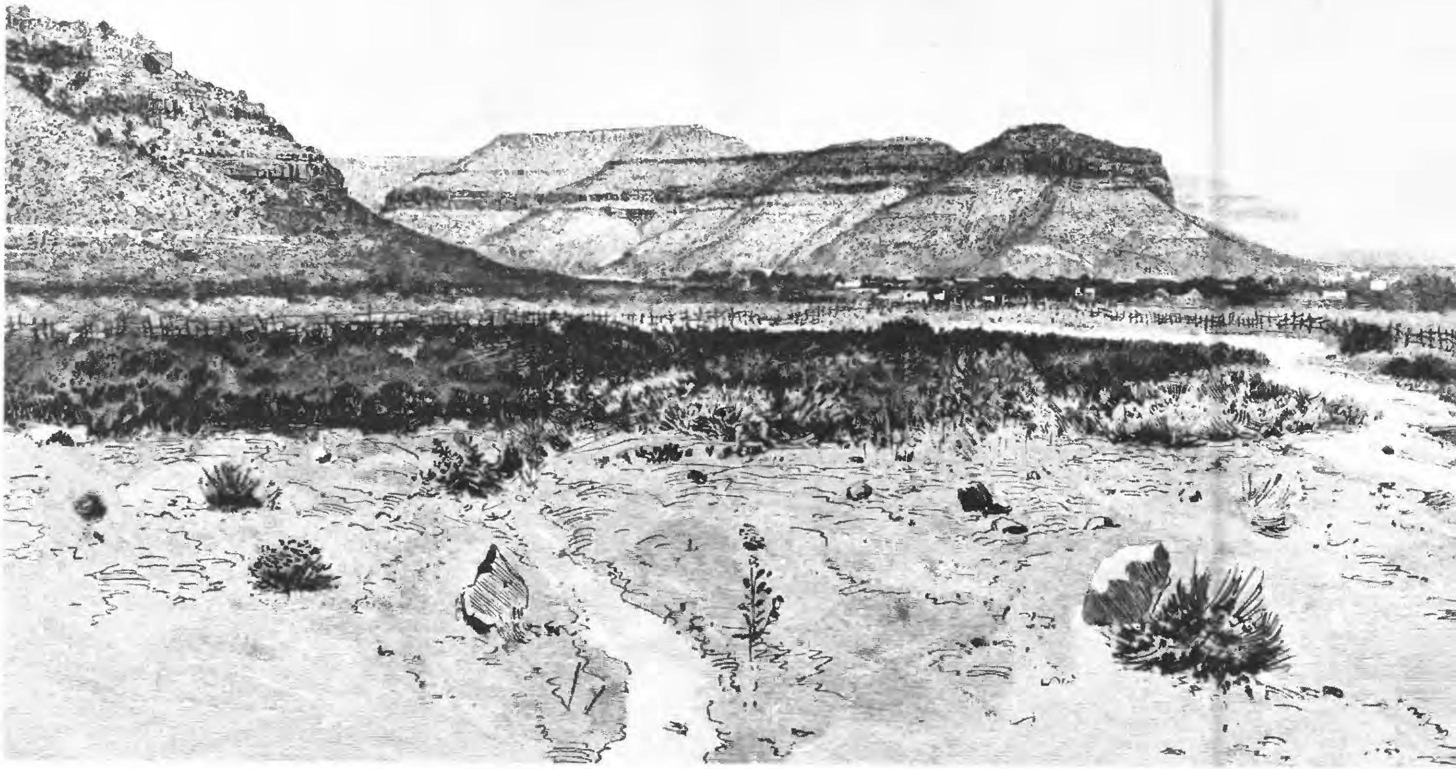
Hague began work at Eureka in July with C. D. Walcott and Joseph P. Iddings as assistant geologists. Walcott had done so well in the first year that King had doubled his salary. Iddings was appointed assistant geologist at $75 a month in July 1880. He had graduated from Yale at the age of 20 and had then studied at Yale, the Columbia School of Mines, and Heidelberg. He was especially interested in the new art of microscopic petrography, an interest which he attributed to a lecture King had given at Yale. Hague was instructed to make a geologic survey of a tract of country embracing not only the productive mines of the Eureka mining district but all those in the same broad mass of mountains, including the Secret Cañon district to the south and the Silverado district to the southwest. Clark had mapped only about half the area during the preceding season, so the topographers continued while the geologic mapping got underway. Like Emmons, Hague began with a rapid survey of the entire region to determine the nature of the country, but Hague had an additional objective: to determine the best way to accomplish the survey with the least loss of time and the least labor. Hague was never one to waste effort. He stayed in the field until December 5 and then sent Iddings off to work briefly with Becker at Virginia City and Walcott to New Mexico to collect some plant material, while he went to New York to get the office work underway.

A new project was begun under Pumpelly's direction. Professor Roland D. Irving of the University of Wisconsin was appointed to trace a continuation of the copper-bearing rocks of Michigan and Wisconsin through northeast Minnesota to the British boundary. The formations had been studied on the American side by both the Michigan and Wisconsin surveys and on the north shore by the Geological Survey of Canada, and it was thought desirable to trace the formations through the little-studied region of Minnesota to a point where the results obtained by the American and Canadian Surveys could be compared intelligently. Because of the interpretation of national domain, Irving was appointed as a census expert, although Pumpelly, in what was apparently a Freudian slip, referred to his assignment as being the work of the Geological Survey (proper).

The survey of the minerals industry for the Tenth Census got underway in the spring of 1880. It was deemed impracticable to obtain information on the precious metals by mailing lists of questions to those in charge of mining operations, because of the difficulty of obtaining all addresses and because many questions would probably be overlooked or incorrectly answered. Therefore, it was decided to send technically trained men to all mines and reduction works to gather the necessary information personally. Ideally, these expert special agents would be men of considerable experience, thorough training, and recognized ability. Unfortunately, the census could offer only a small salary, so they had to settle for gentlemen who were "honest, faithful, well educated, and able," a few of whom had had some experience.

To help the agents prepare the best possible report in the shortest possible time, schedules of questions, as many as 150, were prepared for each branch of mining and reduction works. The questions were arranged under the general headings of position, ownership, geology, development, system of working, accidents, plant consumption of labor, power, and material, production, and disposition of product; they were framed so that the more important data were involved in the answers to several of them in order to guard against errors in recording and mistakes in statement as well as intentional misrepresentation. The agents were also instructed to obtain from each mine, specimens of the ore, gangue, and country rock on both hanging and footwalls of the vein or deposit and to obtain full and accurate copies of all State and district mining laws and regulations.

Emmons and Becker were themselves unable to take much part in the collection of data. They found that in addition to their regular duties "much time and labor were involved in advice to the experts as to routes, in the decision of doubts* * *, the approval of expenditures, and the multifarious matters of administration implied in keeping twenty men ((all of them unfamiliar with the conditions and restrictions of government work) moving



without delay and performing their duties to the advantage of the service." The "honest, faithful, well educated, and able" gentlemen recruited as experts included several who later became successful or well-known mining engineers. Perhaps best known was John Hays Hammond, Yale '76, and Freiberg, who had just been appointed superintendent of the Homestake mine when he was offered the position. George Hearst advised him to take it and complete his education at Government expense.

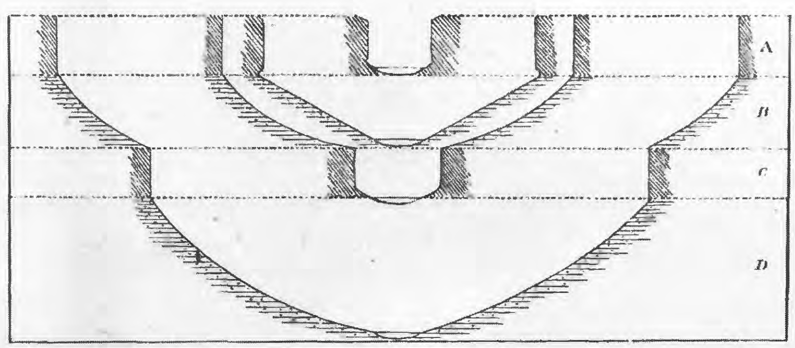
As it happened, there were more difficulties in the field examinations than Emmons and Becker had anticipated. When John Hays Hammond arrived at Bodie, California, which was the center for 40 or more mines, he was greeted as he walked down the street by a sudden blaze of gunfire. In the exchange of shots a bystander was inadvertently killed. A brief trial was held immediately by the vigilance committee, the killer was severely reprimanded for his poor markmanship, and without further formality swung from a nearby tree. Hammond reported that during his first week on the job, there were eight murders.

Hammond completed his mine examinations within 6 months by working at a terrific speed, but he had an incentive. The sooner he finished, the sooner he could get married. Charles Potter was not so fortunate. Potter was assigned to gather information on the mines in New Mexico. On October 14, he left Tejera, in Bernalillo County, for Santa Fe, but never arrived there. His fate was disclosed a few months later. The *Daily New Mexican* for February 2 reported that "as the sun came up from behind the peaks of

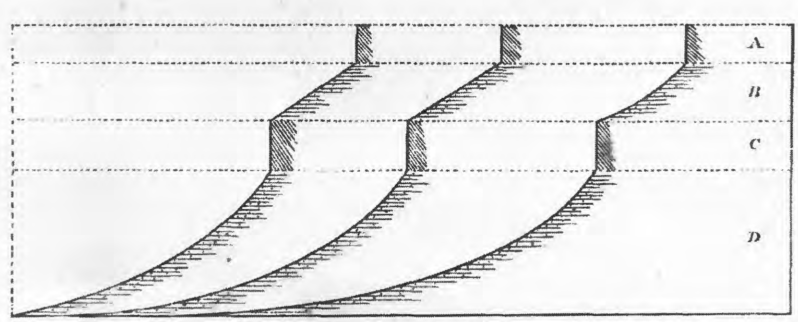
Dutton said the Plateau province is characterized by long lines of lofty and brilliantly colored cliffs, each marking the boundary of a geographical terrace and the termination of a geological series. Each sedimentary group has its own style of sculpture and architecture. The profile of the Vermilion Cliffs that terminates the Triassic terrace consists of a series of vertical ledges and intervening slopes covered with talus. (From C. E. Dutton, 1882.)

the Sandias and shed its bright rays over the roofs of the flat topped adobe buildings, they fell on three human forms, stark and stiff, dangling from a wooden beam in front of the county jail. They were those of the three prisoners brought in last evening by Sheriff Armijo and placed in jail to await trial for the murder of Col. Chas. Potter, of which they had confessed themselves guilty."

Pumpelly was able to organize the collection of statistics on a different basis because of the availability of so many professors, mining engineers, and State employees on a part-time basis. Most of them were paid $5 a day for their services, although Professor Edward Orton of the University of Ohio and the Ohio Geological Survey was paid $6 a day, and some received as little as $1 a day. Among those assisting Pumpelly were Professors N. S. Shaler of Harvard, John C. Smock of Rutgers, L. B. Hall of Johns Hopkins, N. W. Lord and A. G. Wetherby of the University of Ohio, and W. B. Potter of Washington University, St. Louis; State Geologists Eugene A. Smith of Alabama, George A. Little of Georgia, John R. Proctor of Kentucky, and T. C. Chamberlin of Wisconsin; and Andrew Roy, Ohio State Inspector of Mines.



Development of Cañon Profiles.



Development of Profiles by Recession—Upper and Lower Aubrey

In Dutton's monograph published in 1882, he discussed the development of the architectural forms displayed in the cliffs. The key to the development was in the formation and functions of the talus. A hard rock (A) yields little fragmental material, which is quickly removed, and the canyon is narrow with vertical or nearly vertical walls. A soft rock (B) yields more debris, which accumulates at the base, but overlying hard rocks are undermined, and as the talus mounts higher the rate of recession in the softer beds is checked. As the river cuts through lower layers, the profiles are more complicated because all layers above furnish debris, but as soon as the talus is established on the lowest slope, the cliff may be said to have attained its normal profile. (From C. E. Dutton, 1882.)

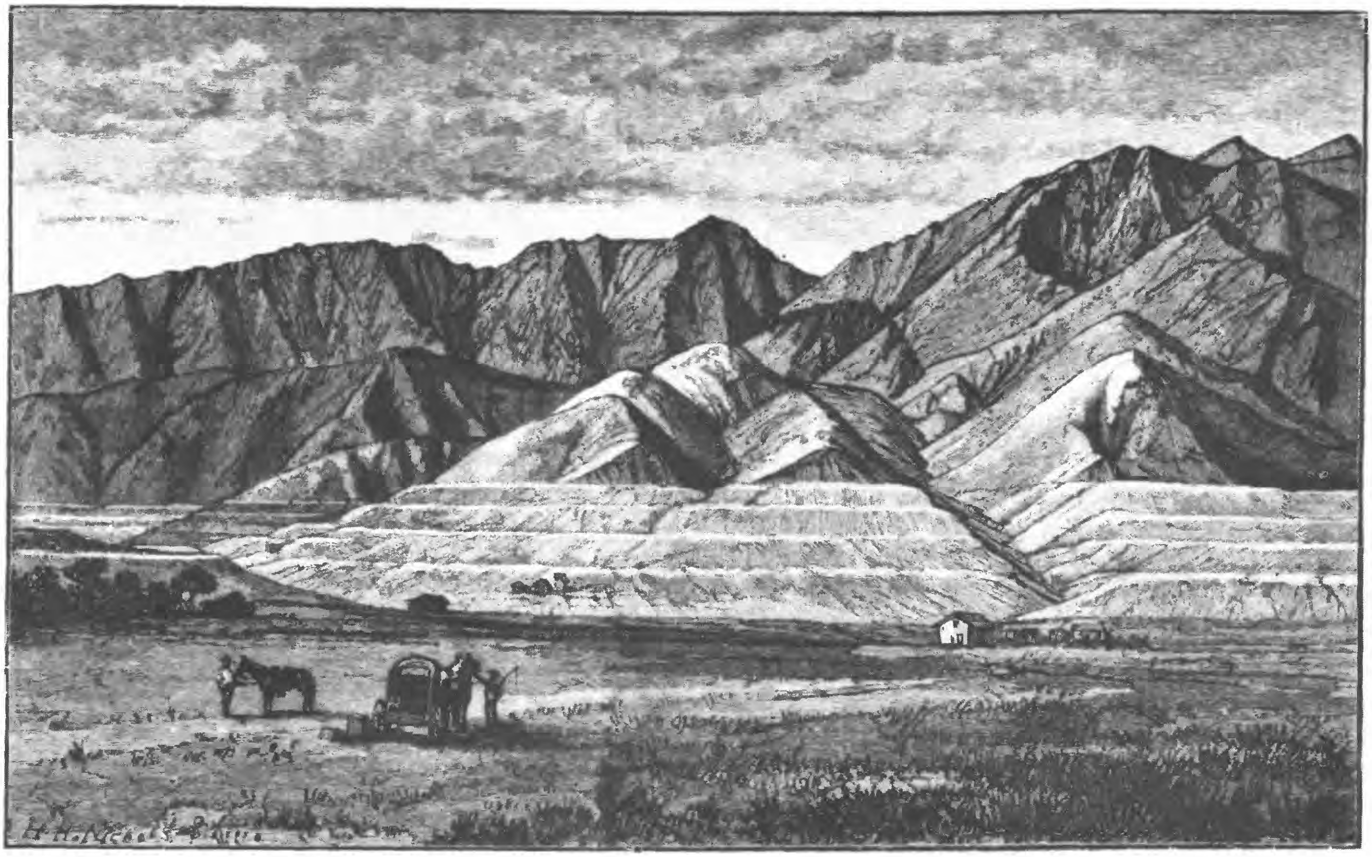
In the East, the schedules were distributed to the mines in each State by the special census agents, and when they were returned, properly filled in, they were sent on to Newport, Rhode Island. When the schedules were incorrectly filled in, which was more common, they were returned to the mines, and after sufficient time had passed, the agents then traveled through the State, visiting the delinquent mines, and filling in the schedules. The statistics on the coalfields of Missouri, Kansas, Arkansas, and Texas were gathered by the regular census enumerators, and those on the nonprecious metals west of the 100th meridian were collected by the western divisions of the Geological Survey, but all schedules were sent to Pumpelly's office to be tabulated.

The census investigation ran into problems despite all the careful planning. Becker and Emmons had underestimated the time necessary to collect the census data, and the fieldwork had to be discontinued before it was completed because of lack of funds. The compilation of the data was put in charge of Albert Williams, Jr., who had shown special ability in his examinations in Idaho and northern Nevada. The compilation was also hampered by lack of census funds, and King advanced the necessary money so that time would not be lost.

Pumpelly too had difficulty in carrying out the iron-ore investigation. When the fieldwork was nearly finished and more than 1,300 samples had been collected from all except the carbonate ores of West Virginia, Pennsylvania, and Ohio, it became apparent that the census appropriation was inadequate to carry out the complete plan. Only a few more complete chemical analyses could be made, partial analyses were limited to iron and phosphorus determinations, and the microscopic study was abandoned. In all, 93 complete and 1,157 partial analyses, embracing more than 4,400 determinations were made, and, in addition, through the courtesy of Director Lesley of the Pennsylvania Survey, several analyses of Pennsylvania ores were obtained. Despite the curtailment, enough data had been gathered, together with the material from the statistical canvass proper, to prepare a classification of the iron-ore fields and an analysis of the broader economic aspects of the industry.

Gilbert went back into the field in mid-July of 1880 with instructions from the Director to continue the investigations of Lake Bonneville and stayed until mid-November. With him were I. C. Russell and H. A. Wheeler as geological assistants, F. D. Owen, an artist, and a topographic party with Gilbert Thompson in charge, assisted by Albert Webster. Russell was a well-educated but restless man. He had graduated from New York University in 1872, studied photography in order to qualify for a place on the Transit of Venus expedition to New Zealand, and had spent 2 years as professor of geology at Columbia and 1 year with the Wheeler survey. Thompson was also new to the Survey, appointed in May as topographer at $2,500 a year, on the same rank as Clark. Thompson had also been with the Wheeler survey.

Gilbert planned that the geological party would trace the outline of Lake Bonneville in southern Utah more carefully than had been done before and would also make special studies of the interrelations of the various shorelines and of the relation of the lake phenomena to glacial phenomena of the lake to the volcanism of the region. Climatic considerations of a very general character had given rise to a belief that the ancient lake was coincident in time with the system of glaciers in the Wasatch and other mountains of the western territories, but up to that time no geologist had been able to study the phenomena produced by the lake and glaciers in juxtaposition. However, Emmons had told him that at least one glacier, that of Little Cottonwood



In the first annual report of the Survey, Gilbert explained in classic prose "There is a topography of the land and a topography of the water. The forms of the land are sculptured by the beating of rain and by the flow of rills, and creeks, and rivers, and they have peculiar characters accordant with their origin. The forms of the beds of lakes and oceans, and especially the forms of shores, are sculptured by the sway of waves and currents, and are distinguished by characters equally peculiar. All the hills and mountains above the shore line of Lake Bonneville bear witness of the play of subaerial agents, while below that line the slopes betray their subaqueous shaping." The contrast is shown along the mountain front near Wellsville, Utah. (From G. K. Gilbert, 1890.)

Canyon, had extended as far as the shore of the lake, and the relation of its moraines to the lake formations might confirm or controvert the age equivalence of Bonneville and the glacial epochs. The work of the topographic party was partly topography and partly geology. Thompson and his assistants first made a triangulation from points established, completed the necessary topographic work in the Escalante Desert area, and then occupied themselves in tracing the ancient shoreline of the lake.

In the summer of 1880, Dutton went back into the field to continue the investigation of the Plateau Province in the area to the south of that covered in his years with the Powell survey. From Kanab, which Dutton, Sumner Bodfish, R. U. Goode, and two assistant topographers reached on July 29, Bodfish set out to complete the survey of the part of the Grand Canyon that extends through the Kaibab Plateau, and the Plateau itself, and Goode to make a survey of the San Francisco Mountains and their vicinity. Dutton himself studied the Uinkaret and Kaibab Plateaus and traveled along the front of the Vermilion Cliffs and the Hurricane fault. W. H. Holmes who had distinguished himself as a geologist-illustrator with the Hayden survey, was given a temporary appointment as assistant geologist on August 1 and joined him in the field.

Dutton's purpose was simple: in his own words to study the geology of as much of the district as he could cover, seeking evidence of its geological history. "As for problems to be solved, " he wrote, "I went there to find them as well as to solve them. The great chasm, the faults and flexures of the strata, the vast erosion of the region, its cliffs and canyons, its strata and extravasated rocks, surely would furnish problems enough. But it seemed to me that whatever question they might bring up and whatever answers they might suggest were merely subsidiary to one comprehensive inquiry: what have been the stages, the chief successive steps and the physical causes of the evolution of this strange region?" Dutton, who had a flair for words that complemented Holmes' ability as an artist, drew inspiration from the mining-geology studies when he said that the geologist "picks up his facts much as the vagabond prospector picks up float ore or pans for a few colors in every gulch and when he finds them seeks to trace them back to their sources, dreaming always of bonanzas. Every accessible feature, therefore, was studied and pondered in the hope that it might be traced back to its origin."

The first annual report was prepared in the fall of 1880 to accompany the Secretary's annual report. In it, King recounted the beginning of the Survey, its organization, and appointments; he included reports of the work done and a list of expenditures from fuel and forage to horses and mules,the bulk of expenditures, of course, being for the services of assistants and employees.

He promised a series of publications. The first field season had been short, and at the end of the 1880 season, there would be only 1½ seasons—a very short time to complete special work. "Realizing very fully, however," he wrote, "the natural desire of Congress and the Administration to see actual results and apply the test of a critical examination to the fruits of the new Bureau, I have called upon the members of the corps for an energy and intensity of labor which should not be greatly prolonged, and which affords no measure of the rate of progress on small appropriations hereafter. The gentlemen of the corps have responded with such cheerfulness and enthusiasm, that I am able to promise, between the close of field-work this autumn and the opening of next spring's campaign, the completion of twelve volumes of practical and general geology and palaeontology."

The 12 would be:

Geology and mining industry of Leadville, Colorado, by S. F. Emmons.
Geology of Eureka mining district, Nevada, by Arnold Hague.
The copper rocks of Lake Superior and their continuation through Minnesota, by Professor Roland D. Irving.
The Comstock lode, by George F. Becker.
Mechanical appliances used in mining and milling on the Comstock lode, 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 Capt. C. E. Dutton.
Lake Bonneville, by G. K. Gilbert.
Dinocerata, by Professor O. C. Marsh.

In addition, he promised a volume on the history of the Comstock mines by Eliot Lord, one of the series of three he had planned on the Comstock lode, and he stated that the statistical parts of the four volumes on coal, iron, the precious metals, and the lesser metals would be combined in one volume on the mineral resources of the United States, the first of an annual series.

There was still a possibility that the extension resolution might be passed by the Senate in the last session of the 46th Congress and that the appropriation requested might be made, so he added a plea for the future of the Survey.

> **Provided Congress extends the field of the Geological Survey over the whole national territory, and appropriates the comparatively small amounts necessary for the maintenance of the organization, it will be entirely practicable to carry**

forward this work and contribute powerful aid to the mineral industries. Of the desirableness from every point of view of the results of a general geological survey, I conceive there can not be two opinions. That these results can only be attained by an organization under federal patronage, is, in my opinion, scientifically certain.

Granting these two propositions, which the foes of progress may vainly strive to disprove, and there remain but two questions worthy of serious consideration regarding the future policy of this Bureau. These are, first, Has the Federal government the constitutional authority to make a Geological Survey over the State? and, secondly, Can this nation afford the money to maintain such a Survey?

In regard to the question of authority, it may be said that the Federal right derived from the Constitution to regulate internal commerce could hardly fail to carry with it the correlative right to gain a knowledge of those commodities and products which are the very material and basis of commerce: without this knowledge, commerce is mere *transportation*.

From every analogy of past legislation, Congress has clearly assumed to possess the requisite authority. If it can investigate agricultural industry and maintain a Department to execute that branch of inquiry, why not investigate mineral industry? If it can make a Coast and Geodetic Survey over the whole United States, why not a Geological Survey?

Since the Constitution empowers the Federal government to levy taxes upon the industries of the nation, there would seem to be a failure in the logic which should deny to it the implied power of informing itself as to the nature and extent of those industries.

King promised that if the Geological Survey were organized upon a permanent basis, with its jurisdiction extended over the entire United States, there need be no apprehension of the necessity for extravagant amounts. Five hundred thousand dollars a year, the sum that had been a long time annually appropriated for the Coast and Geodetic Survey for many years, would be sufficient to carry on all the work that was either necessary or desirable over the whole United States.

He predicted that "the mineral industries of the United States would soon reach an annual money yield of a thousand million dollars of value. The small Federal appropriation of half a million a year toward the development of this great field of American enterprise would certainly not be an excessive contribution."

The Secretary supported the plea. In his report, Schurz called the "especial attention of Congress to the remarks made by the Director on the important benefits which the extension of the Geological Survey over the whole area of the United States would confer on the industrial interests of the American people." Schurz added: "The importance of the results of the collection and dissemination of such information as the geological survey would gather can scarcely be overestimated. Being now so fortunate as to have in the service of the government a corps of scientific men of signal ability and energy to undertake this important work, under a direction eminently capable to give system of action and harmony of purpose to their operations, there is but little doubt that the American people would willingly approve an expenditure small in proportion to the general benefit to be expected." It was a forlorn hope, however, Congress had other things on its mind as it prepared for the inauguration of a new President.

The election campaign of 1880 had not been one of the most edifying on record. Garfield and Hancock were both plagued by intrigues within their own parties, charges and countercharges of fraud and deceit filled the air, and great efforts were made by both parties to arouse ethnic or religious prejudices. The election was close; Garfield had a plurality of less than 10,000 out of more than 9 million votes, but he carried New York with its 35 electoral votes, and all the Northern and Western States except New Jersey, Nevada, and California.

Garfield had difficulty in forming a Cabinet because of the demands made by Senator Conkling and the New York machine and turned more and more to the Blaine faction, even to the extent of appointing Blaine as Secretary of State. For Secretary of the Interior, he chose Senator S. J. Kirkwood of Iowa, a former Ohioan who had served as Civil War Governor of Iowa and who in private life had had a variety of occupations, including farmer, teacher, miller, lawyer, banker, and railroad president.

Senator Henry G. Davis, Democrat of West Virginia, tried several times to bring up the extension resolution, but the Republicans were preoccupied with other matters. Once it lost place to a discussion of applying part of the proceeds of the sale of public lands to educational purposes, and another time, to a discussion of placing General Grant on the retired list of the Army; the session ended before the resolution was voted on.

The Sundry Civil Expenses bill was introduced on February 16, 1881, and the Committee on Appropriations recommended for the Survey the same amount as in the current fiscal year. The House passed the bill on February 28 without any floor discussion of the Survey appropriation. It was not for lack of time but lack of interest. The appropriations of $25,000 for continuing ethnological research, $150,000 for continuation of the Washington Monument, and $60,000 for cases, furniture, and fixtures to display collections of geology and mineralogy at the National Museum were all subject to caustic comments although all were passed. The Senate took up the bill on March 2 and passed it on March 3, again without any discussion of the Survey appropriation. For the fiscal year beginning July 1, 1881, the Survey would receive the same amount—$150,000 for expenses, $6,000 for salary of the Director.

King had said little about resigning for some months, and some members of the Survey hoped that he had changed his mind. However, early in January 1881, James Stevenson, who was Powell's right hand in the ethnoloical work, was appointed Executive Officer of the Survey at a salary of $250 a month. On Monday, March 7, the first business day of the new administration, the temporary appointments of Stevenson and Holmes were made permanent by the Secretary, and on Friday, March 11, 1881, King submitted his formal resignation:

"To the President of the United States.
Executive Mansion, Washington, D.C.
Sir: Finding that the administration of my office leaves me no time for personal geological labors, and believing that I can render more important service to science as an investigator than as the head of an executive bureau, I have the honor herewith to offer my resignation as Director of the Geological Survey

Very respectfully, your obedient servant,
CLARENCE KING"

The President did not delay in accepting the resignation. On March 12, he wrote in reply, thriftily using up his Congressional stationery on which he carefully marked out House of Representatives and substituted Executive Mansion:

"Dear Sir: In accepting your resignation, which I do with reluctance, permit me to express my appreciation of your efficient services to the government during your term of office, and my regret that you do not find it possible to longer remain in charge of the Geological Bureau."

King served such a short time as Director that his contribution to the Geological Survey has sometimes been minimized or overlooked entirely. The tangible results of his 2 years may perhaps be measured in terms of the six reports in the second annual report, four of which were abstracts of monographic treatments which appeared later, part of the report of the Public Lands Commmission, and the Tenth Census reports. Both Emmons' report on the Leadville district and Becker's report on the Comstock demonstrated a concept that is sometimes forgotten, that a single paper can contribute both to the advancement of science and the solution of practical problems. Emmons' report included some general conclusions on the origin of the ore deposits and the beginning of the development of the theory of secondary enrichment and pointed out that the ore was localized along the contact of the Blue limestone and the White porphyry. Becker based his report on a study of nearly 2,500 samples and 500 microscope slides of Comstock rocks, identified the propylite as a decomposed form of previously known rocks, concluded that the immediate neighborhood of the Comstock was an almost extinct solfatara and suggested that the ore was deposited by lateral secretion at or near the contact between the diorite of the footwall and the diabase of the hanging wall. King's own paper compressed a large amount of statistics on the precious metals into 68 pages and demonstrated the importance of a knowledge of geology in the analysis of such statistics.

King's contribution, however, was greater than these papers. As Rossiter Raymond had remarked in 1879, the manner in which the Survey was conducted for its first 2 years would either establish it as a recognized and esteemed branch of the public service or expose it to utter overthrow. King, during his 2-year tenure, set standards and goals for the Survey that are still valid. Several years before the Civil Service law was passed, he and Secretary Schurz established educational and professional requirements for appointment to the Survey that differ only in detail from those that are in effect today. As chief of the Geological Exploration of the Fortieth Parallel, King had set standards for geologic work that profoundly influenced the work of others. As Director of the U.S. Geological Survey, his goal was to continue to raise standards and at the same time to apply known principles in the survey and service of the country. That is still a Survey goal. The realization of the importance of mineral resources in the national economy and the initiation of systematic work in economic geology, as well as the beginning of work in experimental geophysics, were part of the King years. In the opinion of S. F. Emmons:

> **It was not until the truth that geological studies could not be profitably confined within State lines or other artificial boundaries had been proved by practical demonstration that the aid of the general government was freely and permanently enlisted and thereby geological science in America raised to its present high position.**
>
> **To the accomplishment of this result the late Clarence King was the foremost and one of the most active contributors. His influence on the development of geological science in this country was exercised at a critical point in its history, when the personality of the man, aside from his purely scientific ability, played a much greater part than it would at the present day, when the labors of men of his type have already borne abundant fruit in impressing upon the people at large the practical importance of a scientific guidance in the development of their material resources.**

Another contribution to the Survey was the spirit instilled in the organization; a spirit sometimes subdued but never overwhelmed. King was a man of administrative ability, but much of his success as an administrator was due to the fact that he was "enthusiastically loved by everyone" and so each one did his best. King put it somewhat more diffidently; he had made the corps uniformly "harmonious and patient" by a "natural spirit of command and personal sympathy with all hands and conditions, from geologists to mules."

King's greatest legacy to the Survey was undoubtedly the staff—not only Emmons, Gilbert, Hague, Pumpelly, and Dutton, all of whom had established reputations by 1879, but also the younger men who were beginning their careers, among others, Becker, Walcott, Hillebrand, Barus, Iddings, and Cross, all of whom were later elected to the National Academy of Sciences. In a very special way, King's influence persisted for the next 30 years or more through Emmons and Becker and their work in the development of economic geology and geophysics.

Chapter 3.
The Broad View, 1881–1884

> **It is not local work which demands the attention or should command the endowment of the nation. The study of the individual mine may safely be intrusted to the interests of the mine owner and the study of the structure of a restricted locality may be left to the zeal and enterprise of the private geologist; but the higher walks of science and all the great economic interests of the country are replete with problems which can only be comprehended through the broad view.**
>
> **—S. J. Kirkwood**

On March 12, 1881, President Garfield accepted King's resignation and nominated John Wesley Powell to be the second Director of the U.S. Geological Survey. The Senate spent 45 minutes in executive session on Friday, March 18, during which it officially received from the President a great number of nominations, including that of Powell. The Senate had been unable to organize itself as there were 37 Democrats and 37 Republicans; consequently, no committees had been appointed. Most of the nominations were carried over, but on the motion of individual Senators, a few were confirmed without being referred to committees for evaluation. Among them, on the motion of Senator John Logan of Illinois, was that of John Wesley Powell of Illinois. On the following day, Saturday, March 19, Powell took the oath of office as the second Director of the Survey.

The editor of the *Engineering and Mining Journal*, disappointed at King's resignation, qualified its endorsement of his successor. "The principal doubt is simply whether Major Powell will receive a hearty support from the scientific public. Personally he is not merely unobjectionable, but, as far as we know, generally acceptable. We hope and believe that his appointment will not revive any of the jealousies which were laid to rest by that of Mr. King. Professionally, he has had, like his predecessor, long experience in the direction of field-work, and possesses an extensive knowledge of the public domain in the West. His report on the exploration of the Colorado River, which appeared some years ago, contained much interesting topographical and geological material, clothed in somewhat superabundant rhetoric. His paper on the Arid Lands of the West was able and effective. His assistants have done excellent work, and bear strong testimony to his good judgment and executive skill as a Director."

The notice in the *American Journal of Science* was short but pointed. "Major J. W. Powell has been appointed Director of the Geological Survey of the National Domain in place of Clarence King resigned. His various reports on the Rocky Mountain region, geological, ethnographic, and economical, show that he is well fitted for the position." Apparently Dana had not yet accepted the idea of a geological survey of the United States, although he no longer insisted that it was a survey of the public domain.

Powell's background, education, and scientific interests were so different from King's that it was inevitable that there would be a change in the Survey, although probably no one expected either a rapid or radical change. Within 3 years, however, King's original plans and organization were completely altered; mining geology and mineral statistics became minor appen-

John Wesley Powell

Director of the U.S. Geological Survey, 1881–1894. Under Powell, general geologic research was emphasized, the topographic-mapping program was expanded, and investigations of forests and of irrigation were carried on. Opinions were divided in his own time—Powell was the subject of extravagant praise and strong opposition, but opinions since his rediscovery by Walter Prescott Webb in 1930 have generally been favorable. (Photograph of an oil painting by Edmund C. Messer, 1889, courtesy of the National Portrait Gallery, Smithsonian Institution.)

dages in an organization that concentrated on topographic and geologic mapping and paleontology and also on problems related to the irrigation of the arid lands, the relief that would be afforded the lower valley of the Mississippi by utilizing the waters from the Rocky Mountains in irrigation, and the distribution of forests—problems of more interest to agriculture than to the mineral industry.

A few days before Powell became Director, President Garfield in his inaugural address had said,

> **The interests of agriculture deserve more attention from the Government than they have yet received. The farms of the United States afford homes and employment for more than one half our people, and furnish much the largest part of all our exports. As the Government lights the coast for the protection of mariners and for the benefit of commerce, so it should give to the tillers of the soil the best lights of practical science and experience.**

The sentiment was one to which John Wesley Powell thoroughly subscribed. In his own survey work in the 1870's, he had shown only slight interest in mineral resources and had stressed the plight of settlers in the arid lands.

The farming community needed scientific help, to be sure. Agriculture was far less prosperous than other sectors of the economy, and the Department of Agriculture, though established in 1862, had not yet made any significant contribution to its advancement through scientific means. In an editorial in one of its early issues in 1881, *Science* complained that the results obtained by the Department of Agriculture had been small in proportion to the expenditure and doubted that the Department was competent to carry on continuous scientific research. The Department of Agriculture, however, was the bureau designated by Congress to carry on research in aid of agriculture.

The development of general geology at the expense of mining geology was not, as might appear at first glance, an emphasis on pure rather than applied science, for the experimental work in geophysics, which was surely pure science, received the same treatment as mining geology. Powell, like King, realized the importance of an economic basis to the work; in 1878, he had said, "a geographical and geological survey divorced from economic considerations and devoted to research valuable for abstract science would always be weak and have an uncertain tenure of existence."

The change may have been more the result of a difference in his practice than in his theory of the administration of science. Major Powell believed in the cherished right of the individual scientist to choose his own field of work. King, on the other hand, believed that the Director should establish the program and that the individual scientists should then plan and conduct their own work. Because of economic conditions, King had chosen to emphasize a few lines of investigations in mining geology, where the Survey could make an immediate contribution and solidify its position.

There was another notable difference. Although he found little time for his own research, King himself did engage in the work of the Survey as well as in its administration. When Powell became Director, however, he had all but abandoned geologic work. Although he maintained an interest in the Southwest and talked occasionally of going back into the field, he was personally involved only in ethnologic research and in the attempt to develop a philosophy of science. He was active in the Anthropological Society of Washington and the Biological Society of Washington, both of which he had helped found. His program for ethnologic research under the Smithsonian Institution had been tacitly approved by Congress by the appropriation of funds, and he continued to direct and engage actively in that work. In the Geological Survey, he would have to depend largely on others. G. K. Gilbert and C. E. Dutton, who had been members of the Powell survey, became his closest advisors. Emmons and Becker, who had been closest to King, Hague and the others, who were stationed outside in Washington, had less influence.

A change in the composition of the staff, prelude to a change in the program, began very soon after Major Powell became Director. He retained direction of the Bureau of Ethnology, although he drew no salary from the Smithsonian Institution, and simply merged the administrative staffs and, to a degree, the work of the two bureaus. On July 1, 1881, James C. Pilling, clerk of the Bureau of Ethnology and former clerk of the Powell survey, became Chief Clerk of the Survey at $2,400 a year; George Shutt was named general assistant at $200 a month; Jack Hillers was appointed photographer at $1,800 a year with an assistant at $720 a year; Clay MacCauley was appointed editor at $1,800 a year. Women also joined the Survey for the first time, Julia McCord as clerk and Georgie Marvine, Gilbert's sister-in-law and the widow of Archie Marvine, as librarian. The appointments of an Executive Officer (Stevenson), general assistant (Shutt), and Chief Clerk (Pilling) in addition to the existing clerical staff of the Survey might seem excessive unless it is understood that all three were engaged for part of the year in ethnological work.

The appointments to the scientific staff included some planned during King's term of office: Joseph S. Curtis as geologist at $3,000 a year on March 21, 1881, to work with Becker; and T. C. Chamberlin, Tenth Census "expert" and also professor of geology at Beloit College and chief geologist of the Wisconsin State Survey, on July 1 as geologist at $2,500 a year. On July 1, 1881, also, C. A. White, curator at the National Museum, former State Geologist of Iowa and paleontologist with both the Powell and Hayden surveys, was appointed geologist at $2,000 a year, Lester Frank Ward as paleobotanist at $1,800 a year, and Vincent Strouhal, as geologist at $1,200 a year. There were also departures from the scientific staff. Pumpelly left to become director of the Northern Transcontinental Survey, and Allen Wilson, the Chief Topographical Engineer, joined him, as did several members of Pumpelly's census staff, including Bailey Willis, George Eldridge, and F. A. Gooch. Andrew Blair left to become a consulting chemist. The Mining Geology Division was thus dismembered, and no one was appointed to succeed Pumpelly as head of the division. Gilbert Thompson, however, became Acting Chief Topographer at the end of the field season.

Of the new appointments, that of Lester Frank Ward is especially interesting. Ward was then a clerk in the Treasury Department, although he held three degrees, including one in law, from Columbian University (now George Washington University). He had been briefly a member of the Powell survey, and his report on timber and grasses was incorporated in Powell's *Report on the Lands of the Arid Region.* Major Powell was greatly interested in Ward's sociological and philosophical writing, wished to encourage him, and so offered him his choice of a position in either the Bureau of Ethnology or the Geological Survey. Ward was one of the first critics of Social Darwinism proposed by Herbert Spencer and developed by Yale's Professor William Graham Sumner; Spencer had applied the Darwinian theory of evolution to men and concluded that competition led to the survival of the fittest, a theory that appealed to those who wished to preserve the status quo. Ward argued that the struggle for existence inhibited full development, that human beings had shown that competitive forces could be constructively manipulated, and that civilization was the result of man's not leaving things alone. Government, which was an invention of the human mind, could be made to help mankind, and the key to good government was knowledge.

The allotment of funds altered the program. King had set up headquarters at the American Museum of Natural History in New York after leaving Washington, and Becker and Emmons joined him there for several months to work on the statistics of the precious metals. Barus also came east to work with King, and together they were planning extensive research on the effect of heat and pressure on the materials of the Earth. The newly appointed geologist Vincent Strouhal was given responsibility for testing and purchasing equipment for the new laboratory, most of which had to come from Europe and most of which was paid for from King's personal funds as Powell could spare little more than Strouhal's salary from Survey funds.

In Emmons' division, the only fieldwork undertaken was an examination of the Tenmile district in Summit County, Colorado, and a study of the region around the basaltic mesas at Golden, chosen, Emmons said, "more because, being within easy reach of the Denver office, and a portion of the necessary topography being already prepared, they could be carried on by

Charles Abiathar White

Paleontologist of the U.S. Geological Survey from 1881 to 1892. White had been State Geologist of Iowa, 1866–67, and had served as paleontologist for the Wheeler, Powell, and Hayden surveys. Much of his work was pioneer descriptive work, and the mass of his publication is very considerable. (Courtesy of the Smithsonian Institution Archives.)

Lester Frank Ward

Paleobotanist of the U.S. Geological Survey, 1881–1907. Ward, a close associate of Major Powell, was an ardent advocate of the evolutionary hypothesis and enlisted with enthusiasm in the conflict between science and theology. He became the great pioneer of modern and evolutionary sociology in the United States. Ward argued that the human mind is a factor in evolution, that the intellect, when rightly informed with scientific truth, enables the individual to plan intelligently for future development, and that this ability would usher in an age of systematic planning for human progress. (Courtesy of the John Hay Library Archives, Brown University.)

my present corps of assistants with but little additional expense over and above their regular salaries, than because of their intrinsic interest." In Becker's division, only Joseph S. Curtis was sent into the field, to begin the long-planned study of the ore deposits at Eureka.

Hague, Iddings, and Walcott also spent most of the year in New York. Hague worked on the Eureka monograph, making only one short trip to examine some disputed points. Iddings completed his monograph on the microscopic petrography of the crystalline rocks, including six plates of microphotographs, which had required months of experimentation. Thereafter, he took up a study of the Fortieth Parallel rocks that had been stored at the American Museum. Walcott completed his monograph on the paleontology of the Eureka district.

Gilbert did not go into the field but spent the summer of 1881 in Washington in administrative matters concerned with the central office, to no small degree the preparation of reports that bore the Director's name. In the Great Basin region, however, I. C. Russell completed the reconnaissance of the basin of ancient Lake Lahontan.

Chamberlin was instructed to devote himself principally to the part of the terminal moraine in Dakota Territory and other parts that had not been previously traced. During the summer of 1881, he and Professor J. E. Todd worked in the Dakota area while Professor L. C. Wooster studied the moraine in Michigan. In September, Chamberlin began a study of the moraine in New York and eastern Ohio.

Lester Ward spent most of his first month on the Survey writing a sketch of Powell, which was published in the *Popular Science Monthly* for January 1882. He then went west to learn something about paleobotany, or vegetable paleontology, as it was more commonly known. C. A. White was expected to work with him, but early in August 1881, White was given an appointment in the Department of Agriculture as commissioner for the location of artesian wells, so Ward arranged with Lawrence Bruner, an assistant entomologist of the Department of Agriculture, to accompany him.

The largest project undertaken in the summer of 1881 was in the Colorado Plateau region, and it was not geologic but topographic. King had announced his intention of discontinuing the Colorado Division as a separate organization once Dutton finished the report, but Powell reversed that plan. Two reasons were given—that the Survey had "inherited from its predecessors a large amount of good topographic material" and "for the study of certain important geologic problems this region is unrivaled." An unmentioned factor was Powell's plan for continuing the ethnologic work in the area.

Relations were also more cordial with the Coast and Geodetic Survey since Julius Hilgard had been appointed Superintendent. Hilgard and Powell had become friends during the campaign to consolidate the surveys, and Hilgard had been one of Powell's sponsors when he was elected to the National Academy of Sciences in 1880. Professor J. Howard Gore of Columbian University was sent to Fort Wingate, New Mexico, to measure a base line and determine its geographical position with equipment borrowed from the Coast and Geodetic Survey. Gilbert Thompson received orders to organize and outfit a party in Salt Lake City and report to the Director at Fort Wingate. Gore had planned to leave Washington on July 5, and apparently Powell with him, but plans were changed when President Garfield was shot. Gore finally left Washington on July 25, but Powell did not go into the field at all. After many difficulties Thompson arrived at Fort Wingate on August 27 with a party consisting of A. L. Webster, assistant topographer, J. K. Hillers, G. W. Shutt, 4 teamsters, 2 cooks, a helper, 4 wagons, and 34 animals. James Stevenson was already in the field for ethnologic work, and Webster spent 3 weeks with him mapping the Moko towns. The topographic fieldwork continued until late December 1881.

Major Powell submitted a report on geologic nomenclature and cartography, for most of which Gilbert was probably responsible, to the second session of the International Congress of Geologists at Bologna, Italy, in September 1881. In April 1880, J. P. Lesley, who was the U.S. member of the committee on maps appointed at the first session of the congress in 1878, had asked King to undertake some work on map colors, but King wrote that he was personally unable to begin, being fully engaged in the census work as well as the Survey. Powell, in his 1877 report of the Geographic and Geological Survey of the Rocky Mountain Region, had stated that a special investigation of geologic cartography was underway; presumably, the work continued in the General Geology Division of the Geological Survey. The formal statement sent to the International Congress in 1881 referred to rules relating to general geologic nomenclature and cartography "adopted" in the U.S. Geological Survey. A large body of material was ready for publication, he said, and it was "unfortunate that advantage cannot be taken of the deliberations of so great a body of savants in the publication of these monographs, but the exigencies of the work will not permit of longer delay even for so important a purpose."

ERA OR SYSTEM.	*Period or Group.*	Epoch or Formation.
of Man	Quaternary	To be formulated in various districts as the facts demand.
ozoic or Tertiary	Pliocene	
	Miocene	
	Eocene	
ozoic	Cretaceous	
	Jurassic	
	Triassic	
eozoic	Permian	
	Carboniferous	
	Devonian	
	Silurian	
	Cambrian	
hæan	Huronian ?	
	Laurentian ?	

In a report submitted to the second session of the International Congress of Geologists in 1881, Major Powell attempted to establish an American norm for stratigraphic nomenclature and cartographic representation. The geologic time scale proposed was based on that adopted by King in his *Systematic Geology* (1878). It followed Dana (1863) in the use of Archean divided into Huronian and Laurentian but departed from his terminology in recognizing the Cambrian in place of Lower Silurian and in dividing the Cenozoic into Eocene, Miocene, and Pliocene. (From the second annual report of the U.S. Geological Survey.)

The statement was prefaced with a warning:

> **The adoption of a nomenclature is to an important extent an attempt to establish the categories of classification; but every stage in the progress of knowledge is marked by a stage in the progress of classification, and any attempt to fix permanently the categories for a nascent science must be futile. Insofar, then, as proposed uniform methods of nomenclature and representation are designed to establish the fundamental categories, no good can be accomplished.**

On the other hand, useful results could be obtained by the use of a uniform nomenclature and system of representation in the preservation of like facts.

In general geologic nomenclature, American practice was substantially uniform, at least with respect to the major divisions of time—the eras and periods. Dana had divided periods into epochs and subepochs, but American practice in that regard was widely divergent, and in the present state of knowledge, such refined distinctions could not be made or correlated throughout an area as vast as America. The New York section had been established first, but attempts to correlate the formations of other areas with those of New York had in general not been successful, "and the assumption that such correlation should be made" had"led to unnecessary and unseemly controversy," and finally, the attempt had been virtually abandoned. In the various districts, various schemes of formations had been made to present the facts discovered. So there were a number of series of names for geologic formations, each representing a special district.

This state of affairs represented the logical and necessary growth of the science. From district to district, a typical series would not be reproduced, but new series, having new structural, lithologic, and biologic characteristics would be discovered, and these facts should be represented in the nomenclature.

> **Such being the state of affairs in the districts most thoroughly studied, it seems especially unwise for the exploring geologist to commit himself in early stages of investigation to refined and exact correlations, *** until further research demonstrates approximate identity or establishes diversity. Thus the names of formations are ultimately fixed by a process of selection.**

The terms used for rock masses were also in a state of confusion. The term "system" was generally used for the series of formations included in an "era," but sometimes for the series included in an "age." The terms "epoch," "formation," and "group" were used synonymously, but sometimes the term "group" included the series of formations of a "period," and sometimes the term "formation" was synonymous with the term "series." "Perhaps it would be well," Powell said, "if Era, Period, and Epoch could be used in speaking from the standpoint of history, and System, Group, and Formation as their synonyms, severally, from the standpoint of structural geology; Time to be used as a general historic, Series as a general structural term." The general scheme adopted by the Survey recognized 5 Eras or Systems: Archean, Paleozoic, Mesozoic, Cenozoic or Tertiary, and Era of Man; and 14 periods or groups; in the Archean, the Laurentian and Huronian; in the Paleozoic, the Cambrian, Silurian, Devonian, Carboniferous, Permian; in the Mesozoic, the Triassic, Jurassic, and Cretaceous; in the Cenozoic, the Eocene, Miocene and Pliocene; and in the Era of Man, the Quaternary.

American practice, the report said, had also been diverse as regards colors for geologic cartography. The Survey's color scheme was planned to represent common usage as far as possible but not to force the geologist to make distinctions and correlations not warranted by the facts at his command. The colors were chosen to be easily distinguished on the maps but at the same time printed with the greatest economy. Grays were selected to represent the Quaternary; variations of yellow for the Cenozoic; green for the Mesozoic; blue for the Permian and Carboniferous; and purple for the Devonian, Silurian, and Cambrian. Browns were reserved for the Archean, and reds for the igneous rocks. By using three tones of gray, yellow, green, purple, red, and brown, and two of blue, and two tints of each, one dark and the other light, many distinctions could be made. Further distinctions could be made by using the light tint as a base and the dark tint as an overprint in patterns of lines and dots.

Professor C. H. Hitchcock of Dartmouth, State Geologist of New Hampshire and a member of the American Committee for the International Congress of Geologists, had published a geological map that had an entirely different color scheme earlier in the year. Hitchcock used lemon-yellow for Quaternary, yellows for Tertiary, yellow-green for the Laramie, blue-green for Cretaceous, burnt siena for Jura and Trias, medium blue for Permian, two shades of sepia for Coal Measures, light blue for the lower Carboniferous, light purple for Devonian, cobalt blue for Upper Silurian, reddish-purple for Cambrian, shades of pink and red for Archean, bright carmine for granite, and vermillion for volcanic rocks.

The Bologna meeting of the International Congress of Geologists considered proposals from several sources and voted to use as time terms "Era," "Period," "Epoch," and "Age" and for rock masses, the corresponding terms "Group," "System," "Series," and "Étage." Below the rank of Étage was assise, several of which constituted a sub-étage. For colors, they voted to use rose-carmine for crystalline schists, violet for the Triassic, blue for the Jurassic, deep blue for Lias, green for Cretaceous, and yellow for Tertiary. Other decisions were left to a committee on the map of Europe, which met subsequently and decided to use gray for the Permo-Carboniferous, brown for the Devonian, greenish-gray for the Silurian, and seven tints of red for eruptive rocks. James Hall was the only American present, and the terms chosen were largely of European derivation.

In his annual report to Congress in November 1881, Secretary of the Interior S. U. Kirkwood urged the new Congress to extend the domain of the Survey to the entire area of the United States so that the most valuable contributions could be made to geology, both pure and applied. The Survey, he said, was "unable to carry on work simultaneously in the several districts where important mining industries are prosecuted, and at the same time maintain such a standard of excellence as shall give a true and permanent value to its results." Senator Henry Davis of West Virginia promptly filed a bill to provide for extending the Survey into the States. It was referred to the Committee on Mines and Mining and was not heard of again.

Within the Survey, a new view of mining geology was already developing. When the American Institute of Mining Engineers met in Washington in February 1882, Major Powell told them that the work of the Survey was intimately related to mining engineering but that geologists and mining engineers (whom he called "scientific artisans") complemented each other. Mining engineering must have a sound basis in structural geology, which could only be discovered and delineated by the great agencies of Government. In the work of mining geology, the Geological Survey sought to discover:

> First. The geological structure of the country.
>
> Second. The geological relations and palingenesis of ores and other mineral deposits, and to discover the laws and modes of their occurrence. Here the work of the official geologist ends, and here the work of the mining engineer begins. It is for him to develop individual mines and to discover the sites of

ore-bodies and other valuable deposits, and to develop the machinery for the working of mines, and metallurgical processes by which crude materials may be wrought into forms best adapted to the wants of man.

Major Powell held that progress in mining had been made by industrial corporations rather than by Government agencies. In the growth of civilization, corporations had been the most important element, and technology had done more for mankind than sociology, institutions of art more than institutions of government. "Technology," he concluded, "is the father of science, and science is again the father of technology. Arts give birth to sciences and sciences give birth to arts, and thus in alternating generations they multiply to bless mankind."

S. F. Emmons took issue with the Major in a paper on *The mining work of the United States Geological Survey* published in the AIME Transactions. Emmons said:

the duty of the mining engineer toward his employer, the actual or prospective owner of a mining property, is to place before him in an intelligible manner the character, mode of occurrence, and probably quantity and value of the mineral deposits which his property may contain, and the best method of utilizing them. The duty of the government mining geologist, whose field of observation is wider, and whose facilities for carrying on work are greater, differs only in this, that his views should be more comprehensive and his study should take in the general interests of a group of mines or of a whole mining region, rather than a single mine.

He agreed that trustworthy results could not be obtained "except they be founded on a sound and accurate knowledge of the geological structure of the region in which the deposits are found," but also said that while the geological branch of mining engineering occupied a prominent place in the work of the Survey, the more technical branches would by no means be neglected. The monograph on Leadville would be accompanied by an elaborate discussion of the processes of lead smelting. W. R. Eckart was at work on a report on the mechanical appliances used in mining and milling on the Comstock. "Such papers," he said, "prepared by specialists best fitted for the particular work, should accompany every monograph, whenever there is any particular process or mechanical appliance in the district examined of sufficient importance to justify the labor and expense."

By March 1882, when Major Powell testified before the House Committee on Mines and Mining, which was considering bills for the establishment of a bureau of mines, mining geology had already lost precedence. He told them that the work of the Survey was "1st. Topography; 2d. Structural Geology; 3d. Mining Geology," although in describing the results of the Survey's work, he spoke only of the Leadville, Comstock, and census reports. A bureau of mines, he suggested, would only duplicate Survey work, and he proposed instead that for an appropriation of $50,000 a year the Survey could continue the statistical work that had begun under the census. The committee, impressed, reported to the House that in their opinion "the geological survey is, to all intents and purposes, practically a bureau of mines and mining, and that all the legislation that is needed is to enlarge somewhat its jurisdiction." The Committee on Mines and Mining recommended to the Committee on Appropriations that the $50,000 be appropriated.

In mid-April, Major Powell submitted his estimate for the regular expenses of the Survey for the coming year. It was similar to King's budget for the Survey's second year, and like it, included funds to begin work in the States east of the Mississippi River even though the resolution to extend the work into the Eastern States had not been passed. The total was $350,000: $150,000 to continue the work underway; an additional $100,000 to begin work in Minnesota, Dakota Territory, Wisconsin, and Arkansas; and the $100,000 for the Eastern States. To the House Committee on Appropriations, he stated that the work of the Survey was geography, general geology, and economic geology, in that order, and that the appropriation would be divided four ways with approximately equal amounts for general geography, the topography of mining districts, general geology, and economic geology. On that basis, mining geology and general geology would receive the same amounts, and mining geology would not fare too badly if the full amount were received. As the Treasury had a large surplus at the time, there was reason to hope that the increased appropriation might be granted. In every year since 1875, revenue had exceeded expenditures, and by 1882, the Treasury surplus was becoming something of a political issue.

Rather than reduce income, or increase the size of Government operations, to use the surplus, Congress had begun to appropriate larger sums for such items as pensions and rivers-and-harbors bills. In fact, Congress was so intent on limiting Government operations that the House Committee on Appropriations wanted to appropriate a specific salary for each and every employee and to prohibit the employment of anyone for whom an appropriation had not been made. For fiscal years 1881 and 1882, the $6,000 for the salary of the Director had been included in the Legislative, Executive, and Judicial Expenses bill. When the House Committee on Appropriations prepared the bills for fiscal year 1883, they transferred the salaries of the Executive Officer, Chief Clerk, Chief Disbursing Clerk, four photographers, six clerks, four copyists, five watchmen, one janitor, and four messengers to the Legislative bill, making a total of $34,540 with the Director's salary, and in the Sundry Civil Expenses bill instructed the Secretary of the Interior to

> **organize the force for which this appropriation is to be expended and to fix the salaries and compensation to be paid to the members thereof, and to make his estimate for the fiscal year commencing July 1, 1881, in detail, in reference to the force to be employed with its grades and compensation in the respective grades, and specifying the branches of work in which it should be employed and the amount to be expended in each branch.**

The Committee on Appropriations recommended for the expenses of the Survey only $122,000 ($150,000, the amount appropriated for the preceding year less the salaries transferred to the Legislative bill). The extension into the Eastern States was clearly not approved.

When the Sundry Civil Expenses bill came up in the House, Mr. Atkins, no longer chairman but the ranking Democrat on the Appropriations Committee, moved to amend the item for the Geological Survey by adding "and to continue preparation of the geological map of the United States." It was immediately recognized for what it was, an attempt to extend the operations of the Survey into the Eastern States. Congressman Frank Hiscock of New York, chairman of the Appropriations Committee, made a point of order against it as changing existing legislation, saying, "This amendment, couched in so few words, is most pregnant with meaning." There was an immediate protest that no point of order had been made against a provision in the same bill for the Coast and Geodetic Survey to make a map of the Eastern United States, and the chairman explained that as that provision did not change existing legislation, the Coast and Geodetic Survey having previously been authorized to do mapping on land, no point of order could be made. Several of the representatives from Eastern States were quite outspoken about their desire for economic geology studies and about the fact that the Eastern States paid most of the taxes. Congressman Joseph G. Cannon of Illinois pointed out that the Survey could, under the existing legislation, go into Alabama, Mississippi, Missouri, and Arkansas, where there were public lands, and probably would if the money were available, and that moreover the Survey could go outside the public lands where it was necessary to complete mapping of a geologic structure. With that, Mr. Atkins amended his motion to read "and complete preparation of a geologic map of the national domain," Congressman E. C. Willits of Michigan moved to increase the appropriation from $122,000 to $222,000, and both motions were approved.

The Senate, as had the House, took up the Legislative Expenses bill first. The Senate Appropriations Committee recommended that the Director's salary be reduced from $6,000 to $5,000 and that the salaries of the Chief Clerk and the Chief Disbursing Clerk, which the House had set at $2,000, be increased to the $2,400 they were currently receiving. Senatorial opinion on the merits of the Director was divided. There was a long discussion whether he should receive more than Senators, or the Assistant Fish Commissioner, all of whom received $5,000; although there seemed little question that he deserved more than the Assistant Fish Commissioner, there was considerable doubt that he was worth more than Senators. Both Senator John Logan of Illinois, who reminded the Senate that Powell was his friend, and Senator James Beck stated that the salary had been set at $6,000 to obtain the services of Clarence King, and both Senators thought the ends of justice would be better served by reducing the Director's salary and restoring those of the two clerks. Senator W. B. Allison reported that the committee had been dismayed to learn, when the Executive Officer, James Stevenson, came to them seeking a salary of $4,000 for himself, that several, including Professor Hayden, were receiving that amount. They had concluded that they could not reduce the subordinates' salaries without reducing the Director's also. The Senate then agreed to the changes.

The Senate Appropriations Committee recommended two changes in the Survey appropriation in the Sundry Civil Expenses bill: to use "United States" rather than "national domain" in the clause about preparation of the geologic map, and to add that not more than $20,000 of the total could be spent for "procuring of statistics in relation to mines and mining, and in making chemical analyses of iron, coal, and oil." The Senate itself passed the measure without discussion of the Survey appropriation.

The Senate and House conferees on the Legislative bill compromised, leaving the Director's salary at $6,000 and raising the clerks' salaries to $2,200. The House debated both Senate amendments in the Sundry Civil Expenses bill before accepting one and compromising on the other. Appropriations Committee Chairman Hiscock said that he understood from the highest authority that the clause authorizing completion of the geologic map of the United States would not be taken to mean authorization of surveys of lands outside the Government domain but would permit utilization of maps prepared by the States. If the House desired to authorize the compilation of maps depending on geological surveys other than those of the national domain, it would concur in the Senate amendment, but if it did not desire surveys of private property, it would nonconcur. Congressman John E. Kenna of West Virginia said that the friends of the measure knew what they intended it to mean and what it did mean, and the amendment was accepted. The amendment to permit collection of mineral statistics was more extensively debated and amended to exclude collection of statistics on gold and silver, for which the Mint was responsible, and to reduce the amount to $10,000. No geographic restriction was placed on the collection of mineral statistics.

Whatever the intent of those who voted for the amendment on the geologic map, it was interpreted to mean that the Survey's field as regards geologic mapping was national in scope. The Sundry Civil Expenses bill authorizing (or, as Powell preferred to say, "requiring") the geologic map was approved on Monday, August 7, 1882. The Director's plans had been well laid in advance. A topographic map must be made before the geologic map, so a few topographers had been added to the staff in July, among them Congressman Atkins' son. By the close of business on Friday of the week following passage of the bill, 78 topographers of various grades had been added to the staff, and the appointments of Henry Gannett, as Chief Geographer at $2,700 a year, and Almon H. Thompson, Powell's brother-in-law, as geographer at $2,500 a year, had been approved by the Secretary. By the first of September, the topographic staff of the Survey outnumbered the geologic staff.

All the topographic work was placed under the supervision of the Chief Geographer. A scale of 1:250,000, or 4 miles to the inch, was decided on as "necessary for the intelligent presentation of the principal facts of struc-

Henry Gannett

Until 1879 a member of the Hayden Survey, Gannett was appointed Chief Geographer of the U.S. Geological Survey in 1882 and remained with the Survey in various capacities until his death in 1914. He was Chairman of the U.S. Board of Geographic Names from 1894 to 1914 and also supervised the forest investigations of the Geological Survey from 1897 to 1905. Gannett was geographer of the 10th, 11th, and 12th Censuses, assistant director and statistician of the Philippine Census of 1903, a founder of the National Geographic Society and its President from 1910 to 1914. (Photograph courtesy Smithsonian Institution Archives.)

Othniel C. Marsh

Marsh, a professor at Yale University, had been acting president of the National Academy of Sciences in 1878 and chairman of the committee that recommended the establishment of the Geological Survey. He became the Survey's vertebrate paleontologist in 1882, and remained associated with the Survey until his death in 1899, serving after 1892 without compensation. (Photograph courtesy of the Smithsonian Institution Archives.)

tural geology." Vertical relief would be shown by contours drawn at intervals of 200 feet in mountainous country down to 25 feet as the topographic features became more plain (The pun is Powell's.). The map would be published in atlas sheets, each 1° of longitude by 1° of latitude, in areas bounded by parallels and meridians. The sheets were to be designated by the number of the parallel and meridian west of Greenwich intersecting at the southeast corner of the sheet.

For convenience of administration, the United States was divided into seven districts, essentially those outlined by King in the first annual report; centers were chosen from which the work could be expanded outward, and fieldwork was begun in five of the seven districts. There were three parties in the southern Appalachians under W. C. Kerr, who had been appointed as a geologist on August 18, 1882, two in western North Carolina and eastern Tennessee, and one in southwestern Virginia and eastern Kentucky. Professor Gore was sent to measure a base line and begin a reconnaissance survey near Hot Springs, Arkansas, in the South Central district. A. H. Thompson was placed in charge of the work in the southern part of the Rocky Mountain district and instructed to complete the map of the Plateau region, and work was begun in the northern part of the Rocky Mountain district near Bozeman, Montana, J. H. Renshawe in charge. Albert Webster headed a geographic party in the Great Basin. Gilbert Thompson was placed in charge of work in the district of the Pacific and began mapping in the southern Cascades.

To complete the topographic map in the shortest possible time, others were set to work compiling and adjusting the results of previous surveys by the "general government, by the several states, counties, townships, by industrial corporations and individuals." Useful information was obtained even from the parceling surveys of the General Land Office that Powell had described in 1878 as "absolutely valueless for scientific purposes."

Several new appointments were made in 1882 to the scientific staff; the principal ones were Professor O. C. Marsh of Yale as paleontologist at $4,000 a year and Professor Roland D. Irving of the University of Wisconsin as geologist at $2,700 a year. Marsh's appointment added vertebrate paleontology to the Survey's capabilities. Professor Irving was to continue studies of Archean rocks begun under the Tenth Census program.

The lateness of the appropriation made a distinct difference in some plans for fieldwork, none at all in others. Marsh's appointment was dated August 18, but he had a full field season. Under instructions dated July 1, he organized five parties for the collection of fossils: one in the Tertiary of Oregon, two in the Eocene of western Wyoming, and two in the Jurassic of Wyoming. Irving's appointment was also made in mid-August, but, unlike Marsh, he was unable to begin work before that time for lack of funds. He proposed to make a comprehensive study of the Archean rocks that extended from the northern end of Lake Huron westward across Wisconsin and around Lake Superior to the southeastern part of Dakota Territory, including microscopic examination of specimens, in which he would be assisted by C. R. Van Hise, one of his students.

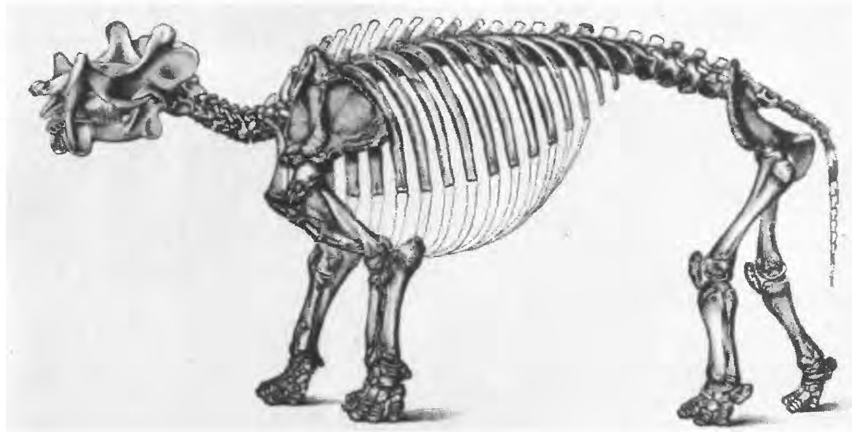
Gilbert did not go into the field in the summer of 1882, his time again being taken up with administrative work in the Washington office. However, two parties began work in the Great Basin at the beginning of the season: a geologic party under I. C. Russell with Willard D. Johnson as topographer, and the geographic party under Albert Webster. Early in July they were joined by W J McGee, geologist, and Eugene Ricksacker, topographer. In the latter part of August, after the appropriations became available, Russell's force was increased by the arrival of yet another geologic assistant. The chief subjects of investigation were the Quaternary history of the western part of the Great Basin as revealed by the vestiges of Lake Lahontan and the history of the ancient lake and glaciers of the Mono Basin.

Dutton spent several months in the Hawaiian Islands in preparation for a study of the Cascade Range in northern California and Oregon. Work could not begin until the topographic mapping under Gilbert Thompson made some progress. Dutton's monograph on the Tertiary history of the Grand Canyon district had been completed, and finding himself with about a year's time on his hands, he concluded that it would be "a well-founded criticism" to entrust the Cascade study to "one who had never seen a live volcano." The Hawaiian Islands were not U.S. territory, so Major Powell obtained funds from the Smithsonian Institution to pay for Dutton's travel.

Professor Chamberlin continued the investigation of glacial moraines and associated deposits with the aid of several assistants, including Professor Todd, F. H. King, and Professor Wooster. Chamberlin himself, with the assistance of R. D. Salisbury, continued the study of the moraines of southern and south-central New York State, a study that he had begun the previous season.

C. A. White, having completed his report as artesian-well commissioner, left on July 1, 1882, for Montana Territory to make geological and paleontological investigations in the valleys of the Yellowstone and Missouri

When Marsh joined the Survey, he had in preparation his second great monograph on the extinct higher vertebrates, the Dinocerata, which King had planned for Survey publication. He had found the first remains of the Dinocerata in an Eocene lake basin in Wyoming in 1870 and had begun a systematic investigation in 1872. In this restoration of the skeleton, the animal is represented as walking. (From O. C. Marsh, 1884.)

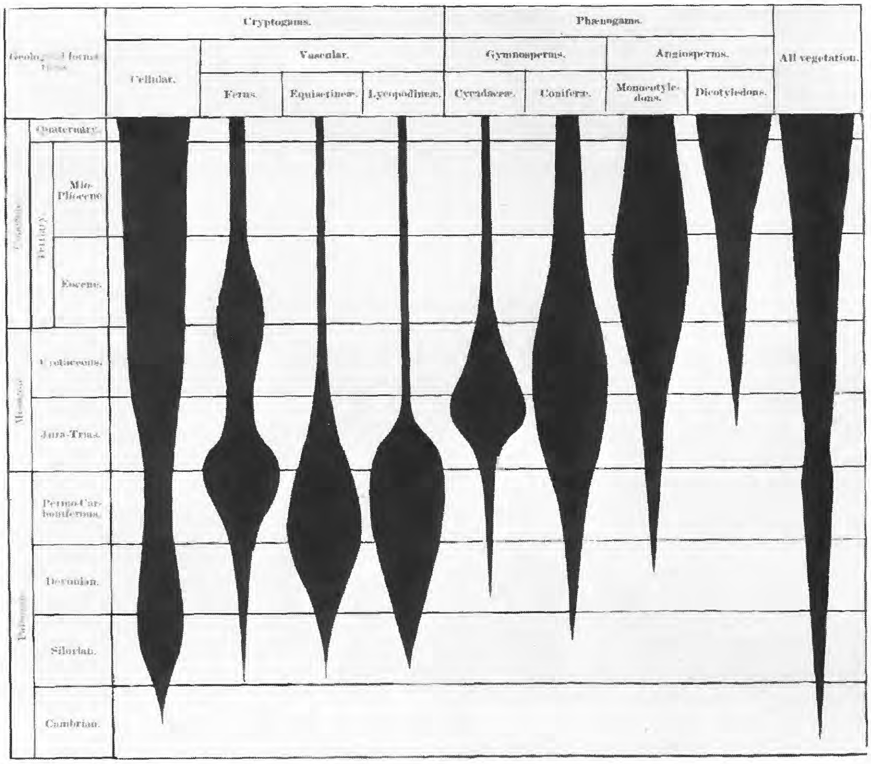


Rivers, where the only sedimentary formation was believed to be the Laramie group, the age of which was a matter of controversy. King had given the name Laramie to a series of shales, sandstones, and coal beds lying conformably over the Fox Hills strata and widely present in Colorado, Utah, and Wyoming. He considered it to be Cretaceous, and the last deposit of that age. Hayden accepted the name for his Lignitic group, which he considered as a transitional formation between Cretaceous and Tertiary. White had worked in northwestern Colorado in his first season with the Hayden survey in 1877 and had committed himself to a post-Cretaceous age for the beds. However, he had suggested that as none of the American Cretaceous could be considered as equivalent to the Lower Cretaceous of other parts of the world but must be considered Upper Cretaceous, the Laramie rocks must represent a great and important period wholly unrepresented in any other part of the world.

Ward did not go into the field, being fully occupied with the study of the Laramie flora, serving as honorary curator of the Department of Fossil Plants in the National Museum, beginning a catalogue of American fossil plants, and publishing his first book, "Dynamic Sociology," which was dedicated to Major Powell.

One of the busiest members of the Survey staff that year was Charles D. Walcott, who was released from New York exile on July 1, 1882. He went first to Nevada, to make observations and collections at Eureka and White Pine, requested by Hague. At the end of August he went to Kanab, and early in September, with the necessary camp outfit, he moved out to study the stratigraphy of the Permian and to collect fossils. Snow drove them from the field in late October. Early in November, instructions arrived from the Director to accumulate supplies and a force of men for work in the Grand Canyon. A trail ("a perfectly frightful trail," according to Dutton) was built down into the canyon at the head of Nunkoweap Valley, and on November 26, Walcott was left at the trail camp, with instructions to study the pre-Carboniferous strata as far south in the canyon as possible, provisions for 3 months, 9 saddle and pack mules, and 3 assistants, one of whom soon succumbed to depression from living in the depths of the canyon and had to be sent home. Walcott and the others, however, stayed in the canyon until February 5.

In the Grand Canyon, above the great unconformity between Precambrian and Paleozoic rocks, is some 4,500 feet of conformable beds, the upper part of which is Carboniferous. Dutton thought that the lowermost beds just above the unconformity were Silurian. Some years before, however, Gilbert had inferred that they were Cambrian, basing his inference on a single



Paleobotany in the early 1880's was in an infantile state according to Lester Ward. The term "paleobotany" he thought was preferable to "vegetable paleontology" or "phytopaleontology," being shorter, and equally legitimate, being derived from two Greek words. In this diagram, he attempted to show the origin or geologic age of the first appearance of each type of vegetation, the period of its maximum development, and the rank it occupies in the living flora relative to its maximum. (From L. F. Ward, 1884.)

specimen of a very uncertain fossil, and had given the name Tonto group to the lower part of the horizontal beds. If Gilbert was right, then the Silurian and Devonian were missing in the series, even though just west of the canyon they were present in great thickness, and the rocks below the unconformity, which appeared fresh and unmetamorphosed, were Precambrian. Powell and Dutton found this a bit too much to believe, but Gilbert was right. Above the unconformity for several hundred feet, Walcott found an abundant fauna, unquestionably Cambrian, and of many types. Below the unconformity, he found only a thin layer containing *Stromatopora*, on which no age determination could be based.

Hague and Iddings spent the entire year in the office in New York. Hague continued to work on the Eureka report, and he and Iddings continued their investigation of the Fortieth Parallel rocks. A good deal of time was given to the nature of the pyroxene in the andesitic rocks, and Hague reported that their results tended to confirm those reached by Cross in Colorado.

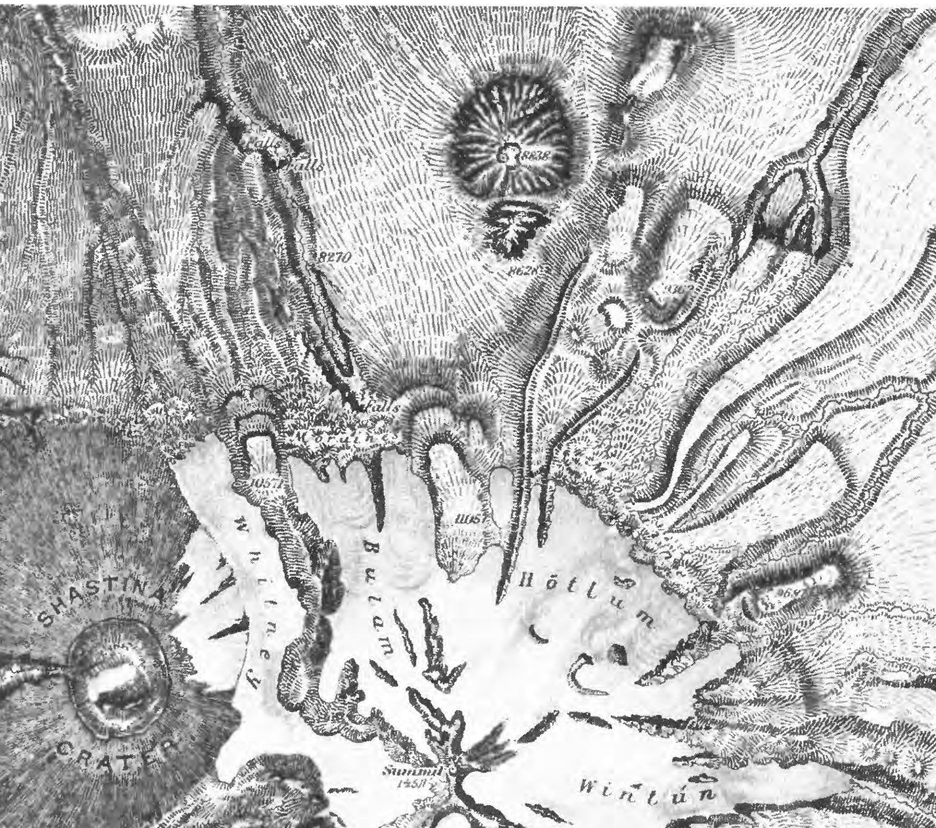
Emmons had only a brief field season. At the beginning of the year, he had said that the possible fields of work in the Rocky Mountain division were "almost bewildering from the multitude of points of scientific interest and economical importance" but had chosen the silver deposits of the Silver Cliff region as the next investigation. As soon as the appropriations became available, he laid out the work for the topographers there, then joined Jacob and Cross in the Tenmile district. The geology there had turned out to be unexpectedly complicated, and the topographic map that Bien had completed after Wilson's resignation was inadequate, so time was lost in improving it. Emmons also spent several days at Crested Buttes in the Gunnison region. The valuable coalbeds there he thought would make that region in the future the center of the mining industry on the west slope of the Rockies, so he decided that that would be the next area of investigation. At the end of August, he returned to New York to assist Becker in completing the compilation of the census material. King had settled most of the major problems but had resigned from the Tenth Census in May 1882. Because of the wealth of material available, they found it difficult to restrict the volume to the thousand pages that the Superintendent of the Tenth Census insisted was the absolute limit; they finally transmitted the manuscript on February 1, 1883.

The volume included approximately 100 pages describing the geology of the mining regions of the Rocky Mountain and Pacific regions, statistics on the products of deep mines and placer, amalgamating mills, smelting works, bullion production, mints, and a directory of mines. King contributed an introductory statement on the peculiar conditions affecting American mining, in which he stressed the originality and ingenuity of many of the methods adopted, which those trained in Europe tended to look askance at as crude and wasteful. The *Engineering and Mining Journal* took more note of his introduction and the geological sketches than of the statistics, commenting that King was "right in his main contention, the rapidity and apparent wastefulness of American mining are not altogether bad economy. No one can lightly judge in any such case without taking into account the elements of transportation and wages, which so greatly affect the problem." King had also completed a compilation of the mining laws of the United States, which was published as volume 14 of the Tenth Census reports.

Barus spent most of the year finding a new site for the laboratory, moving it to New Haven, and getting the new laboratory set up. There had been indications that newly approved projects of the American Museum of Natural History would in time crowd out his operations in New York, and on the advice of Becker and Hague, who maintained an interest in his work after King left, the move was made before work progressed to the stage at which such a disruption would be serious.

Becker left for the West when the census manuscript was completed. Curtis had been in the field at Eureka, and his work on the ore deposits there was well advanced. Becker noted that one of the most important conclusions

When T. C. Chamberlin joined the Survey in 1882, he was instructed to begin a study of the terminal moraines that stretch from Dakota to the Atlantic. It soon became apparent that the moraines and associated glacial deposits were more complicated than anticipated. The terminal moraine of the second glacial epoch, for example, consists of a series of 12 great loops, each of which embraces a broad valley-basin formed by the ice tongue that occupied it. The moraine near Eagle, Wisconsin, was left by the Green Bay glacier, one of the smaller ice tongues. (From T. C. Chamberlin, 1883.)



The glaciers on Mount Shasta in northern California, which had been discovered by Clarence King in 1870 (see volume 1, p. 190), were investigated by Gilbert Thompson who began a topographic survey of the region in 1882. Thompson made a large-scale topographic map of the summit area, using hachures to denote differences in elevation, and also several sketches. Thompson concluded after examining the photographs taken by C. E. Watkins at the time of King's visit that there had been more snow on the mountain in 1870 than there was in 1883. (Both illustrations from I. C. Russell, 1885.)

to be drawn from Curtis' work was "the hopelessness of defining ore deposits of various classes in such a manner as to render the terms employed convenient or suitable as a basis for legislative enactment." Once back in California, he began an investigation of the geology of quicksilver, which was becoming increasingly important in the reduction of ores. His first step was to establish a chemical laboratory in San Francisco, where W. H. Melville, who had been an instructor in chemistry and mineralogy at Harvard, would assist him.

Albert Williams assumed charge of the collection of mineral statistics for the Survey in late December, 1882. With only $10,000, he could not build a staff of the size needed to collect the statistics, so he made arrangements with members of State surveys, universities, the American Institute of Mining Engineers, and the staff of the technical journals to provide him with material at a few dollars a page. Emmons had suggested that preliminary reports be prepared from time to time with the aid of material gathered by those engaged in the statistical work and published in relatively cheap form as bulletins of the Survey. Williams arranged for papers on the metallurgy of copper, lead, zinc, and iron, the geology of the coalfields of Pennsylvania, and the iron ores of Alabama. They were published, however, not as separate bulletins but as part of the report on "Mineral Resources of the United States, 1882" that was submitted to the Director on July 2, 1883.

A Bulletin series was established to include papers to the general purpose of Survey work that could not properly be published in the annual reports or as monographs. Each bulletin was to contain but one paper and be complete in itself. They were, however, to be numbered in a continuous series and in time united into volumes of convenient size. The bulletin series thus would be not unlike the bulletins of the Hayden survey. Bulletin No. 1 of the U.S. Geological Survey came from the Rocky Mountain division; it was submitted on October 1, 1882, and published on March 1, 1883: "*On Hypersthene Andesite and on Triclinic Pyroxene in Augitic Rocks*," by Whitman Cross, *With a Geological Sketch of Buffalo Peaks, Colorado*, by S. F. Emmons. It was not the first publication of the Division. Emmons had already instituted a series of "Communications from the U.S. Geological Survey, Rocky Mountain Division" as "preliminary notices of interesting facts, in cases where the publication of the report which would embrace them is necessarily delayed for a considerable length of time." Whitman Cross and W. F. Hillebrand had analyzed and identified several zeolitic minerals in the basalt of Table Mountain, near Golden, Colorado, and their paper had been published in the June 1882 issue of the *American Journal of Science*.

For the fiscal year beginning July 1, 1883, the Sundry Civil Expenses bill passed in March 1883 provided a substantial increase in funds: $64,700 for "salaries of scientific assistants" in addition to $240,000 for expenses. The scientific assistants composed the force organized in accordance with the requirements of the act of August 7, 1882. When Congress had instructed the Secretary to organize the force and fix the salaries, it was with the limitation of Government operations in mind rather than civil service reform. In the Senate, as well, there had been an evident desire to reduce the $4,000 salaries, and Senator Allison had reported that the Director was content with the proposed reduction in his own salary, which was a prerequisite to the other reductions. When it came time to organize the force, however, the salaries were not reduced. The Director explained to the Appropriations Committees that for the position of "chief geologists," men of outstanding ability for original research were needed, the Survey had to compete with universities and industry for their services, and Survey employees were, by the Organic Act, prevented from undertaking private work to supplement their income.

The civil service, however, had been patently in need of reform. Politicians in both parties clung to the patronage system, but it was no longer practical to try to operate the Federal Government, which had more than 100,000 employees, with a system that resulted in a complete turnover every few years. The assassination of President Garfield in 1881 by a demented would-be officeholder aroused a public clamor for civil service reform, but Congress still procrastinated. President Arthur said that he favored a civil service law, but he questioned the practical proposals and opposed competitive examinations. Congress debated but passed no bills. Public irritation mounted when the Republicans levied assessments against office-holders during the campaign of 1882. When the votes were counted, the Democrats outnumbered the Republicans in the House 197 to 118. The handwriting was on the wall. When Congress returned in December, President Arthur urged it to take prompt action on the civil service problem, and the Pendleton Act was passed and approved on January 16, 1883. It provided for a bipartisan three-man Civil Service Commission to draw up and administer competitive examinations to determine the fitness of appointees to Federal office on the basis of merit. A limited civil service list was set up, and the President was empowered to extend it at his discretion. The act affected immediately only about one-tenth of the total number of Federal employees and governed only future appointments.

The Survey's scientific staff, as specified in the Sundry Civil Expenses Act of 1883, included 23 positions: 5 geologists at $4,000 a year; 2 geologists at $3,000; 1 geologist at $2,700; 2 geologists at $2,400; 2 geologists at $2,000; 1 paleontologist at $4,000; 1 paleontologist at $2,000; 1 chemist at $3,000; 1 chemist at $2,000; 1 Chief Geographer at $2,700; 3 geographers at $2,500; and 3 topographers at $2,000. In addition to these scientific officers, the Director told the Appropriations Committees, the Survey had four kinds of temporary employees who were paid from the appropration for expenses: (1) packers, cooks, teamsters, and others employed in fieldwork; (2) copyists and other assistants for the scientific officers when they were in the office; (3) college professors who were specialists in particular fields and worked for the Survey for short periods; and (4) young men on trial until they could demonstrate their ability to do scientific work.

The new civil service law did not apply to the scientific assistants of the Survey, and there were a few unexpected appointments to the statutory positions. Emmons, Hague, Gilbert, Hayden, and Becker were the five chief geologists at $4,000, Curtis and Chamberlin the two at $3,000, Irving the one at $2,700 and Williams one of the two at $2,400; all were simply reappointed to the positions they had been holding. The other position as geologist at $2,400 went to W. H. Holmes, who had been a geologist-illustrator for Hayden but was now in charge of illustrations, and those as geologist at $2,000 went to Joseph Stanley-Brown, who was serving as the Director's secretary, and Washington Kerr, the State Geologist of North Carolina, who was making topographic surveys in the southern Appalachians. Joseph P. Iddings, C. Whitman Cross, and I. C. Russell, all of whom had been with the Survey longer and presumably had demonstrated ability to do geologic work, were left in the category of temporary employees, or young men on trial. The two positions as paleontologists went to O. C. Marsh and C. D. Walcott. C. A. White and Lester Ward were therefore also still on trial, not yet having demonstrated ability to do scientific work, but were nonetheless given increases in salary. F. W. Clarke and W. F. Hillebrand were appointed to the statutory positions as chemists. Clarke was then a professor at the University of Cincinnati and had not previously been employed by the Survey. Becker's chemist, W. H. Melville, was retained as a temporary employee, as were the two physicists, Carl Barus and William Hallock.

Henry Gannett was named Chief Geographer, Gilbert Thompson, J. H. Renshawe, and A. H. Thompson the geographers at $2,500, and Sumner Bodfish, Anton Karl, and Henry Walling, topographers at $2,000. All but Walling, who had been employed by the Coast and Geodetic Survey, were confirmed in the position that they had been holding. Several of the topographic staff thus remained in temporary status, including Powell's nephew, Arthur Powell Davis.

The reasons for the choices of those to occupy the statutory positions were not stated, but personal and(or) program factors evidently entered into the selection. During the House's consideration of the appropriation, Congressman John A. Anderson of Kansas had suggested that the Survey's functions of "examination of the geological structure, mineral resources, and products of the national domain" should be changed to "examination of the geological structure, mineral, agricultural and other industrial resources, and products of the national domain," saying that, if his amendment was out of order, then the Survey was also out of order because they were making reports on arable land and the flow of rivers. It is not clear what reports Congressman Anderson had in mind, but clearly a change in program was underway. With the increase in funds, many new temporary appointments were made: 27 topographers of various grades, 20 geologists of various grades, 6 paleontologists, and 2 chemists. The programs in topographic mapping and general geology were then expanded.

Topographic work began in the North Atlantic district with H. F. Walling in charge and W. T. Griswold, recently graduated from the Columbia School of Mines, his principal assistant. Fieldwork began in the northwestern part of Berkshire County, Massachusetts, and proceeded southward. In the South Atlantic district (or Appalachian division), there were parties in western Maryland, West Virginia, Virginia, North Carolina, and Tennessee. In the Rocky Mountain district, three parties began work in the Wingate division at the start of the season, and a fourth was organized early in July with Arthur Powell Davis in charge. Davis' party, which was sent to map an area north of the San Juan and east of the Colorado, had to be recalled because of threatened difficulties with the Navajo Indians. In the Montana division, a survey of Yellowstone National Park was begun at a mile-to-the-inch scale. In the Great Basin district, Willard Johnson mapped under the supervision of the geologist in charge of the field party, and in the Pacific district, work continued under Gilbert Thompson, although hampered by haze, smoke, and stormy weather.

Nineteen of the new geologists were assigned to general geology, and that work was greatly expanded. A very large project, expected to last several years, was organized in Yellowstone Park and the adjacent regions of Wyoming and Montana. The annual report of the Hayden survey for its last year of 1878 had finally been completed and printed. It was a two-volume affair, one volume devoted entirely to the work in Yellowstone, but there still remained much to be done. The topographic survey of the western and northwestern parts of the park had not been completed, and much was yet to be learned about the volcanic rocks, hot springs, and geysers. The park was already attracting large numbers of tourists, and access to it and accommodations therein were much less difficult than in Hayden's day.

Hague was selected to take charge of the project. With him was a large field party, consisting of Iddings; newly appointed assistant geologists W. H. Weed, J. M. Wright, and C. D. Davis; William Hallock, who had been working with Barus; W. H. Jackson, the photographer, who had been associated with the Hayden survey; as well as an assistant photographer and a volunteer assistant. Nearly all of Iddings' time, and much of Wright's, was spent in determining the varieties of volcanic rock present and their areal relations. Hague himself studied the phenomena connected with geysers and hot springs and the relation of the rhyolite extrusions to the centers of thermal activity. Weed was occupied in a careful examination of the thermal springs and geysers and in collecting a complete suite of specimens illustrating the form of deposition and mode of occurrence of the travertine and geyserite. Hallock spent most of his time determining subterranean temperatures in geyser pipes and reservoirs, using both maximum thermometers and thermoelectric methods.

The organization of a central chemical laboratory that would make routine analyses for other divisions of the Survey and also conduct scientific research in geological chemistry and mineralogy was begun when F. W. Clarke entered on duty on July 1, 1883. Clarke was then 36, a graduate of the Lawrence Scientific School at Harvard in 1867. He had stayed on at Harvard for another year and published his first paper in March 1868 on *A New Process of Mineral Analysis*, had been an instructor at Cornell for a year, a professor of chemistry at Howard University, and, from 1874 until his appointment to the Survey, professor of chemistry at the University of Cincinnati.

A good chemical laboratory had already been established at the National Museum, so Director Powell and Secretary Baird made arrangements to start the new division of chemistry on a cooperative basis. Clarke was appointed honorary curator of minerals of the U.S. National Museum, the existing laboratory was placed in his "custody," and additional apparatus and supplies were imported so that regular chemical work could begin in December. In January 1884, Dr. Thomas M. Chatard, who had a Ph.D. from Heidelberg and several years' experience as a mine and mill manager, was added to the staff. F. A. Gooch returned to the Survey from the Northern Transcontinental Survey in April 1884.

Compilation of the geologic map of the United States was begun in earnest under the Director's supervision by W J McGee, who had been appointed assistant geologist at $1,200 a year on July 1, 1883. McGee's geologic experience was confined to a study of the glacial deposits of Iowa, which he had worked out on his own initiative, and as a field assistant to Russell in the Great Basin. When not engaged in compiling the map, he was to study the surface deposits of the District of Columbia and contiguous territory. McGee began a study of American geologic publications, as a necessary preliminary to the compilation of the map, and spent intervals of leisure in fieldwork around Washington. The Director was impatient, however. The next session of the International Congress of Geologists was scheduled to meet in Berlin in the summer of 1884, at which time he wanted to present the claims of American geology for consideration, especially as represented by the Geological Survey. So on November 20, 1883, McGee was given instructions to prepare a hand-colored map at the earliest possible date, and Professor C. H. Hitchcock, whose geologic map of the United States had been published in 1881, was employed to assist him. The hand-colored map, on a double-atlas sheet at a scale of 1:7,115,000, was completed in January 1884, largely, McGee confessed, because of Hitchcock's "energy, his experience and skill in geologic cartography, his extended personal knowledge of American terranes, and his familiarity with American geologic literature." The map was colored in 11 age groups: Archean (all nonvolcanic crystalline rocks) and Volcanic (all eruptive rocks) of the Azoic Era; Cambrian, Silurian, Devonian, and Carboniferous of the Paleozoic Era; Jurasso-Triassic and Cretaceous of the Mesozoic Era; and Eocene, Neocene, and Quaternary of the Cenozoic Era. The colors were extended over nearly the entire United States, although McGee said the "coloration was to an extent hypothetic."

Powell immediately ordered McGee to recompile the data in a form suitable for publication, and this task was completed in April, although on this

W J McGee

Geologist of the U.S. Geological Survey, 1883–1893. McGee, a protégé of Major Powell, was a largely self-educated Iowan. He was only 30 when appointed to the Survey and given the task of compiling the geologic map of the United States. After leaving the Survey, McGee was a member of the Bureau of American Ethnology while Major Powell was its Director. He was later active in the conservation movement under Theodore Roosevelt. (Courtesy of the Smithsonian Institution Archives.)

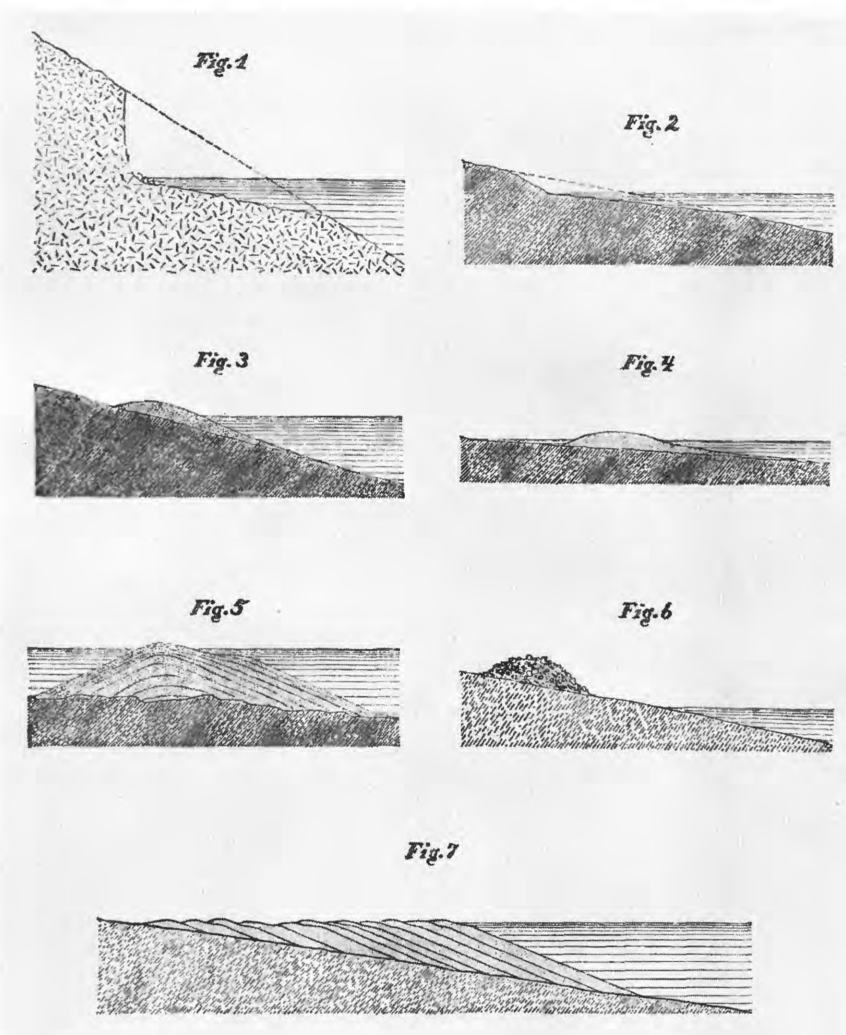
McGee's geologic map for the third International Geological Congress used a different and less sophisticated time scale than that proposed to the 1881 Congress. The term "Azoic" had been revived to include the Archean and Volcanic rocks, the Carboniferous included the Sub-Carboniferous, Coal Measures, and Permian, the Triassic and Jurassic were combined as the Jurasso-Triassic, and the Cenozoic comprised the Eocene, Neocene, and Quaternary. (From W J McGee, 1884.)

map, Arizona, California, Idaho, Montana, Nevada, New Mexico, Oregon, Texas, Utah, and Washington were left either partially or wholly uncolored. The map was published as plate II of the fifth annual report. McGee said it represented "perhaps an ultra expression of the conviction of the author that the scale commonly adopted for maps printed in colors is too large, and that geologic maps and atlases are in consequence unnecessarily cumbrous and expensive." He also reported that the cartography was so fine that the lithographer had great difficulty in transferring it, and six successive proofs required revision. The congress for which it was prepared was postponed because of an outbreak of cholera in Europe.

Even before the recompilation was finished, the Director gave McGee instructions to invite the cooperation of the State Geologists of New York, Pennsylvania, and New Jersey in compiling a local map to test the suitability of the Survey system for larger scale maps. James Hall, J. P. Lesley, and George H. Cook met with McGee on April 14, 1884 to devise a uniform stratigraphic scheme, and Gannett supervised preparation of a base map of the region on a scale of 6 miles to the inch.

McGee found that the records of his study of geologic publications naturally assumed a form readily expansible into a thesaurus of American formations. He sorted his material into four categories, relating respectively "to the phenomena classified, the method of classification, the terms used in classification, and the bibliothecal place of classification." He then began four treatises, which he referred to as a compend, a conspectus of classification, a dictionary, and a bibliography of American formations. The Survey's librarian, C. C. Darwin, also began preparation of a catalogue of publications on North American geology, and a series of topical bibliographies was proposed. A comprehensive plan seemed desirable, so a scheme of topics was devised to cover the field of geology.

At the June 7, 1884, meeting of the Philosophical Society of Washington, G. K. Gilbert presented a plan for the subject bibliography of North American geologic literature, and Major Powell presented a slightly different



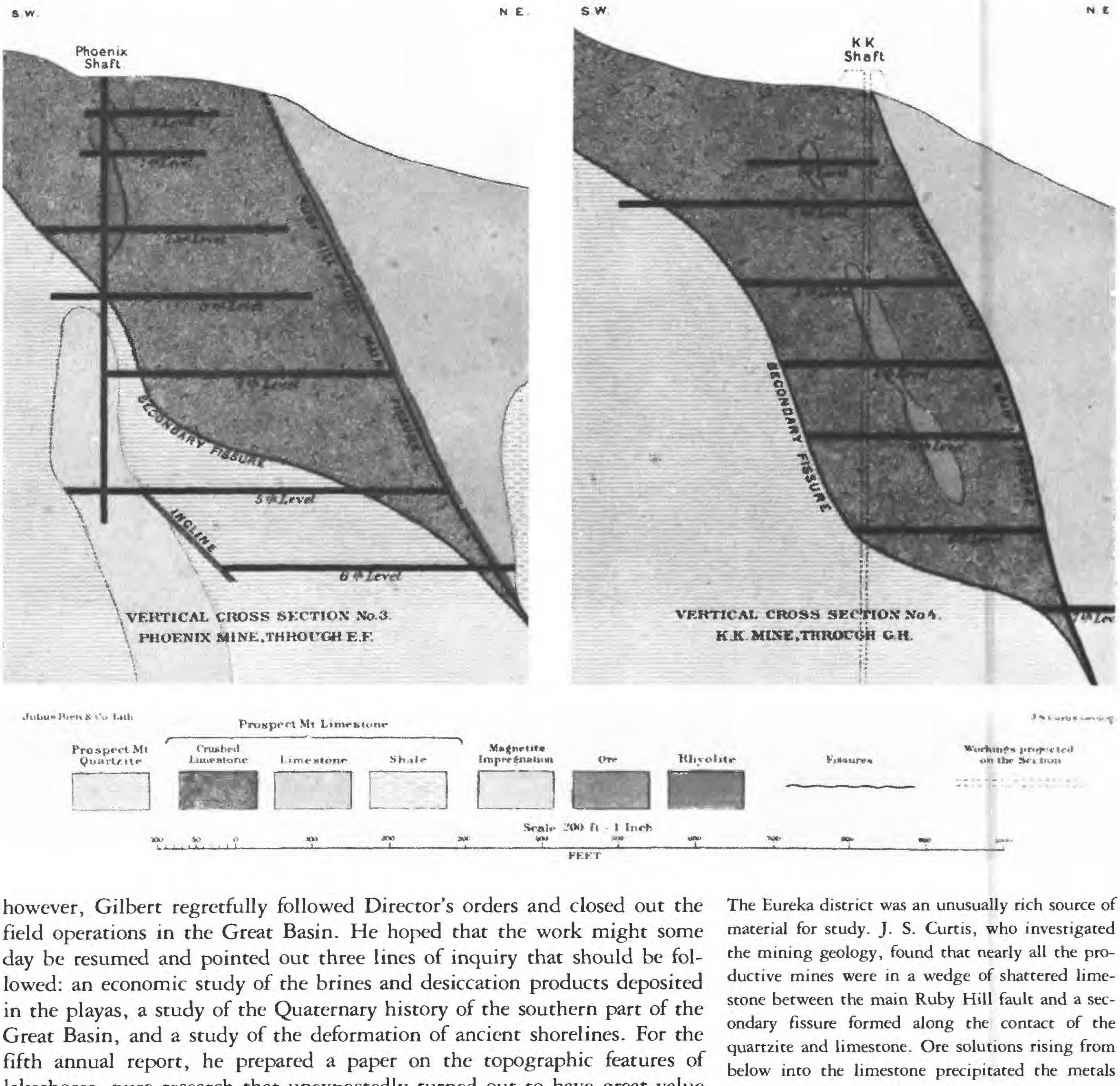
G. K. Gilbert, in studying the shorelines of ancient Lake Bonneville, investigated not only surface forms, (in which civil engineers engaged in construction of engineering works along shorelines were interested) but the internal structure of the various features as well. In the modeling of shore features, waves were the agent of erosion, waves and currents acting together provided transportation, and deposition was the result of increasing depth. The results shown in the illustration are, in order, a wave-cut cliff and terrace in hard and in soft material, a beach, a barrier at two stages in its development, and wave-built terraces. (From G. K. Gilbert, 1885.)

I. C. Russell, who had been Gilbert's assistant, made a special study of Lahontan Lake, the ancient lake that was the complement of Lake Bonneville; Lahontan filled a depression along the western border of the Great Basin as Bonneville occupied the depression on the eastern side. Lahontan Lake was smaller and more shallow than Bonneville but, unlike Bonneville, did not overflow. Thus, all the mineral matter supplied by tributary streams and springs remained in the lake and the deposits of lacustrine sediments and calcareous tufa,or the desiccation products formed when the lake evaporated, could be studied. The tufa crag at Allen's Ranch, Nevada, shows the successive deposits of mineral matter. (From I. C. Russell, 1885.)

plan. Both plans proposed to establish at the outset a limited number of divisions of the subject matter of the literature. A long discussion ensued, in the course of which the plans were vigorously criticized by Dr. John Shaw Billings, who had prepared the index catalogue of the library of the Surgeon General's office. Dr. Billings maintained that any classification would be found to require continual modification and would be ultimately unsatisfactory. He advocated adoption of the subject index method and the accumulation of a large body of references before classification was attempted. The fifth annual report nonetheless contained a list of 14 proposed subject categories, all of which reflect Powell's preference for the shorter "-ic" ending of words, and many of which showed Gilbert's training in Greek and propensity to coin terms on a Greek derivation. The 14 categories into which it was proposed that all geology be divided were: Volcanic, Diastrophic, Hydric, Glacic, Eolic, Biotic, Anthropic, Lithic, Petromorphic, Geochronic, Choric, Geomorphic, and Economic Geology and Geologic Technology.

Another project undertaken was the collection of an "Educational Series of Rocks," a collection of type specimens that would be valuable to educational institutions for teaching purposes. The first plan was to collect 200 suites of 100 specimens each, belonging about equally to the 2 great groups, sedimentary and igneous. Becker, Hague, and Emmons were to collect the crystalline rocks and Gilbert, Powell, Chamberlin, Hague, and Kerr, the sedimentary rocks.

Gilbert was able to spend a few weeks in the field in the summer of 1883, and I. C. Russell and Willard Johnson spent full field seasons mapping in the Lahontan and Mono Basins. At the close of the field season,

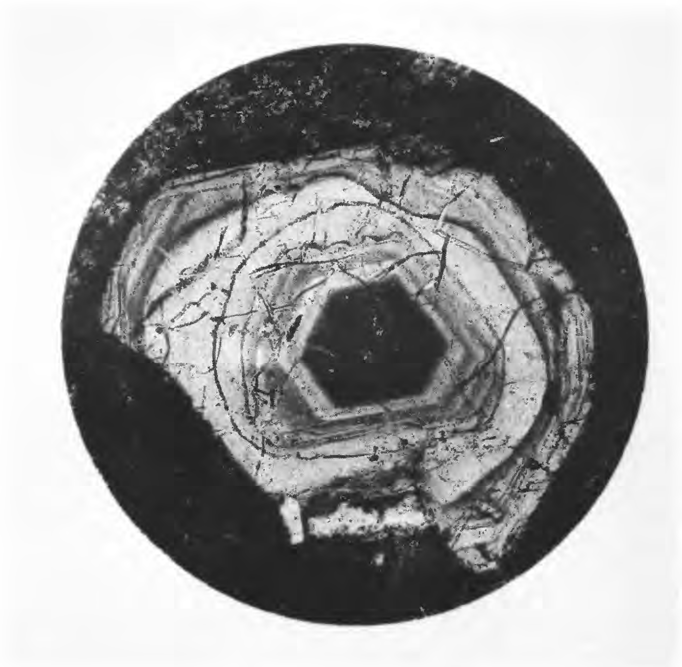


The Eureka district was an unusually rich source of material for study. J. S. Curtis, who investigated the mining geology, found that nearly all the productive mines were in a wedge of shattered limestone between the main Ruby Hill fault and a secondary fissure formed along the contact of the quartzite and limestone. Ore solutions rising from below into the limestone precipitated the metals because of the changed conditions of temperature and pressure. Curtis thought that the ores were substituted for country rock rather than deposited in preexisting cavities. (From J. S. Curtis, 1884.)

however, Gilbert regretfully followed Director's orders and closed out the field operations in the Great Basin. He hoped that the work might some day be resumed and pointed out three lines of inquiry that should be followed: an economic study of the brines and desiccation products deposited in the playas, a study of the Quaternary history of the southern part of the Great Basin, and a study of the deformation of ancient shorelines. For the fifth annual report, he prepared a paper on the topographic features of lakeshores, pure research that unexpectedly turned out to have great value in the planning of engineering works.

Dutton remained in Washington to write a memoir on his trip to the Hawaiian Islands. J. S. Diller, one of the new assistant geologists, was sent out to begin the study of the Cascade Range by making a preliminary reconaissance between the head of the Sacramento Valley and the Columbia River.

Chamberlin had three parties in the field. He and Professor Todd continued their work on moraines, and R. D. Salisbury, one of his students who had been appointed an assistant geologist, began an investigation of the driftless area in the upper Mississippi Valley. Chamberlin had intended to use the Missouri River as a base of operations and to extend lines of observation westward, but the Sioux were restless and on the advice of the



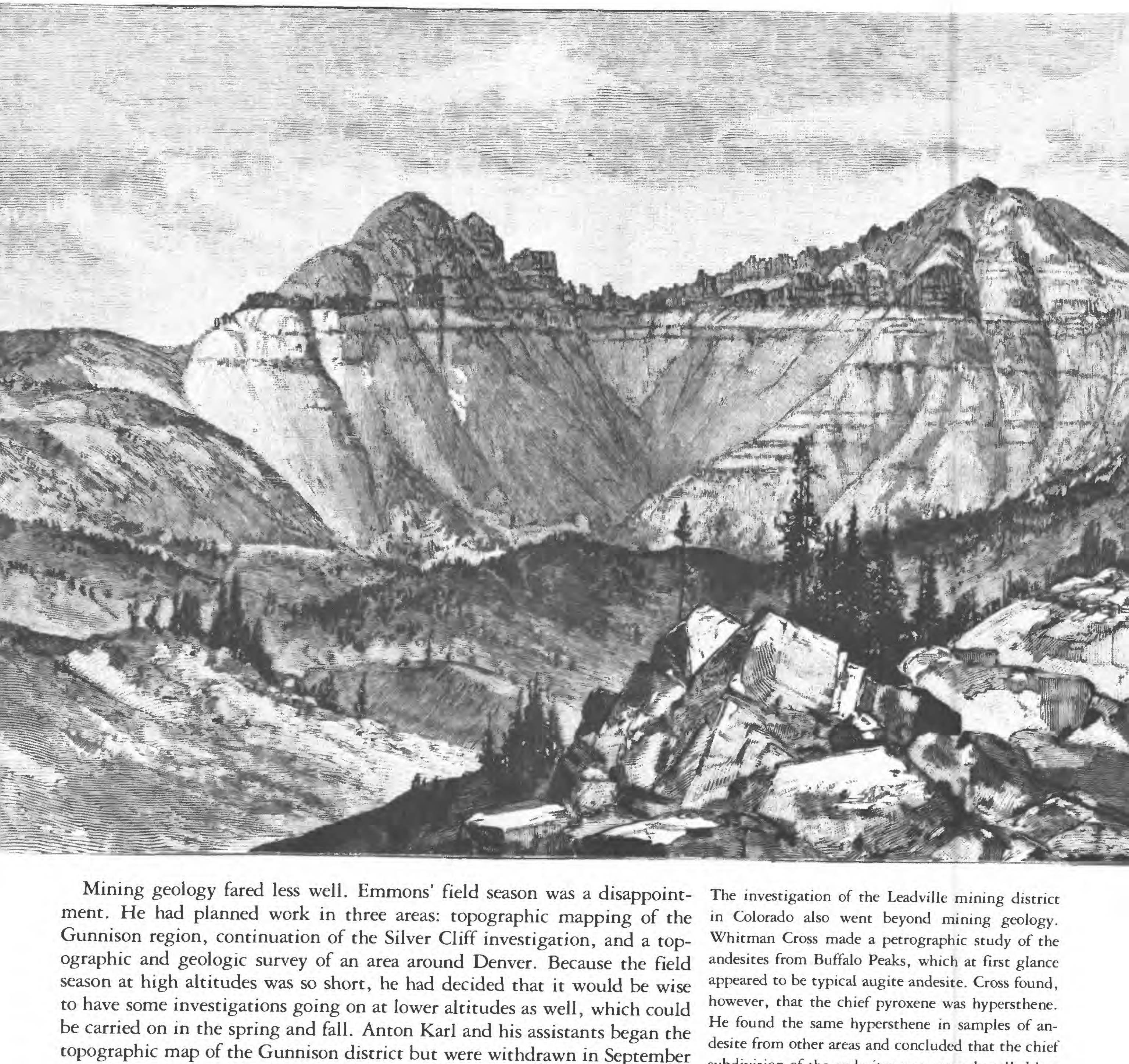
J. P. Iddings studied several hundred thin sections of rocks from the Eureka district. Although the variety of volcanic rocks was great, there was a marked similarity between the individual crystals of a given mineral species wherever they occurred with but a few exceptions. This similarity linked together the various kinds of rocks and suggested to Iddings the possibility of a common source. The thin section shown is of a feldspar crystal in a hornblende-mica-andesite magnified 45 times. (From Arnold Hague, 1892.)

C. D. Walcott identified more than 500 fossil species, many of them new to science, in the rocks of the Eureka district. In the lowest fossiliferous stratum of the Cambrian, he found a species of the trilobite genus *Olenellus, O. howelli,* which had several unusual features and certain embryonic characters that showed the relation of *Olenellus* to the genus *Paradoxides*. The specific identity of two of the three species of *Olenellus* with *O. gilberti* and *O. howelli* from Pioche, Nevada, and their close resemblance to species of *Olenellus* found in Vermont and Newfoundland suggested that *Olenellus* might provide a basis for correlation of the different parts of the Cambrian system on the North American continent. (From C. D. Walcott, 1884.)

Indian agents, the excursions were confined to routes and methods least likely to excite attention, and after mid-July all work was moved eastward.

The Laramie problem received a great deal of attention in the summer of 1883. Hayden was able to go back into the field and, with A. C. Peale as his assistant, made a reconnaissance along the line of the Northern Pacific Railway from Bismarck, Dakota, to Helena, Montana, studying the relations of the Laramie and the immediately underlying Cretaceous. C. A. White, with John B. Marcou and Melvin Wade as assistants, started from Fort Benton, Montana, crossed the Missouri and traveled southward to the Judith River and then northward to the point where the Judith empties into the Missouri, also studying the Laramie and its relation to the underlying Cretaceous. White made excursions to the Bear Paw Mountains and to the Great Falls of the Missouri for the same purpose. Lester Ward went to Glendive and spent some time investigating the localities from which fossil plants belonging to the Fort Union had been obtained; then in mid-August, he joined White at Fort Benton. Together, they descended the Missouri from Fort Benton to Bismarck in an open boat, making the journey of 1,059 miles in 30 days.

Professor Marsh had several parties collecting in Oregon, Wyoming, Colorado, Kansas, and Nebraska. Paleontologic work began in earnest in the East under Walcott's direction. Walcott himself began a study of the Cambrian of New York, and Professor H. S. Williams of Cornell, of the Devonian sections of New York. H. R. Geiger, Ira Sayles, and A. M. Gibson made paleontologic studies in the Appalachian area in preparation for geologic work in the area.



Mining geology fared less well. Emmons' field season was a disappointment. He had planned work in three areas: topographic mapping of the Gunnison region, continuation of the Silver Cliff investigation, and a topographic and geologic survey of an area around Denver. Because the field season at high altitudes was so short, he had decided that it would be wise to have some investigations going on at lower altitudes as well, which could be carried on in the spring and fall. Anton Karl and his assistants began the topographic map of the Gunnison district but were withdrawn in September to assist in the Land Office survey of the Maxwell grant in New Mexico, leaving the Gunnison map incomplete and the Denver map not begun; Jacob had had to resign because of ill health brought on by hard work at high altitudes and was not replaced; and, as a result of the depression in mining interests, many of the mines at Silver Cliff were abandoned or inaccessible.

Becker had one new assistant, H. W. Turner, to aid in the field investigation of the quicksilver deposits while Melville concentrated on the chemical work. Curtis, however, had no funds for fieldwork, and once he finished his monograph on the Eureka silver-lead deposits, he occupied himself with making a model of the Eureka mines for the National Museum.

The investigation of the Leadville mining district in Colorado also went beyond mining geology. Whitman Cross made a petrographic study of the andesites from Buffalo Peaks, which at first glance appeared to be typical augite andesite. Cross found, however, that the chief pyroxene was hypersthene. He found the same hypersthene in samples of andesite from other areas and concluded that the chief subdivision of the andesites was properly called hypersthene andesite. The illustration is the frontispiece of Bulletin 1 of the U.S. Geological Survey. (From C. W. Cross, 1883.)

The appropriations act had made no specific mention of the statistical work, and no funds were allotted. The volume on mineral resources for 1882 was issued on October 15, 1883, and 527 copies were sold before the end of the fiscal year, in addition to the official distribution; however, no volume was prepared for 1883.

During Major Powell's first 3 years as Director, the Survey prospered. Its field had been extended to the entire United States, and its appropriation had grown steadily. In the appropriations bills carrying funds for the fiscal year beginning July 1, 1884, there was no separate appropriation for expenses of the Geological Survey in the Sundry Civil Expenses bill. The appropriations for "Surveying the public lands, geological survey, and Yellowstone National Park" were lumped together as one item, and from this appropriation, the Survey received $386,000, an increase of more than 60 percent over the previous year.

In October 1884, the Survey moved into a new headquarters in the new Hooe Building at 1310 F Street Northwest. The Survey had first been quartered in a house on the northwest corner of 8th and G Streets Northwest, near the Interior Department Building (now the National Collection of Fine Arts). In 1881, the Smithsonian Institution had provided space in its new National Museum. The move to the Hooe Building permitted a consolidation of offices in Washington and the transfer of Hague's division from New York and Barus' laboratory from New Haven to Washington. The 12 rooms in the northeast pavilion of the National Museum that became vacant when the Survey moved were placed at the service of the Chemistry Division; 9 were fitted up for laboratory purposes, permitting an expansion of the chemical work, and 3 were assigned to the physical laboratory. Becker and Emmons, however, retained their offices in San Francisco and Denver.

Chapter 4.
Measures of Reform, 1884–1886

> **Each head of a scientific organization is now, practically, absolutely independent, and in his individual judgment of what his organization shall do is controlled only by Congress itself acting only through its annual appropriations bills. We conceive that this state of things calls for measures of reform.**
>
> **—National Academy of Sciences**

The Sundry Civil Expenses Act of July 7, 1884, included two items, in addition to the appropriation of funds, that would profoundly affect the Survey and its future. In the section pertaining to the Public Printer, there was a provision "that it shall not be lawful for the head of any Executive Department or of any Bureau, branch, or office of the Government, to cause to be printed, nor shall the Public Printer print, any document or matter of any character whatever except that which is authorized by law and necessary to administer the public business, nor shall any Bureau officer embrace in his annual or other report to be printed any matter not directly pertaining to the duties of his office as prescribed by law." The Joint Committee on Public Printing was directed to look into the numbers of the various Congressional documents printed and also to investigate the printing and binding for the Executive Departments and to report bills in the following December to reduce the cost of public printing.

The second provision, under the appropriation for the Signal Service, called for a Joint Commission of the Senate and House of Representatives to

> **consider the present organizations of the Signal Service, Geological Survey, Coast and Geodetic Survey, and the Hydrographic Office of the Navy Department, with a view to secure greater efficiency and economy of administration of the public service in the said Bureaus.**

The Commission was directed to report on or before the third Monday in December.

Named to the Joint Commission were Senators W. B. Allison, Eugene Hale, and George Pendleton, and Representatives Hilary Herbert, Robert Lowry, and Theodore Lyman. Senators Allison and Hale were members of the Senate Appropriations Committee, Senator Allison its chairman and Senator Hale a specialist in naval affairs. Senator Pendleton was an advocate of civil service reform and had sponsored the act passed in January 1883 that established the Civil Service Commission. Representatives Herbert and Lowry were members of the House Appropriations Committee, Mr. Herbert specializing in naval affairs and Mr. Lowry in the expenditures of the Treasury Department of which the Coast and Geodetic Survey was then part. Mr. Lyman had been elected to Congress as an advocate of civil service reform, but his selection was understood to be due to his membership in the National Academy of Sciences. Mr. Lyman was a graduate of the Lawrence Scientific School at Harvard, where he had studied under Louis Agassiz. He had helped establish the Museum of Comparative Zoology at Harvard, served as its treasurer, secretary of its faculty, and instructor. He was

Thomas Chrowder Chamberlin

Chamberlin first worked for the Survey as an expert special agent of the Tenth Census and in 1882 was appointed a geologist. He worked only part of the year for the Survey, being also a professor at the University of Wisconsin, president of the University from 1887 to 1892, and founding chairman of the Department of Geology at the University of Chicago after 1892. His work greatly stimulated the development of glacial geology in the United States and led him to investigate some of the most fundamental problems in geology. (Courtesy of the Smithsonian Institution Archives.)

The driftless area of the Upper Mississippi basin, Chamberlin and Salisbury pointed out, provides a standard of comparison and contrast between glaciated and unglaciated areas. For example, as the result of glaciation the drift-covered region has renewed its youth, and streams that cross it tumble in cascades and falls, whereas the driftless area has passed beyond youth and the streams move placidly. The driftless area also provides a means of estimating the amount of glacial planation and the quantity of glacial drift. (From T. C. Chamberlin and R. D. Salisbury, 1885.)

a close friend as well as associate of Alexander Agassiz, the president of the museum, and he and Agassiz had married sisters. Mr. Lyman also claimed the credit for the provision in the Sundry Civil Expenses bill calling for the investigation.

The proposed investigation was ostensibly a general one but was actually a combination of two investigations, one of the Signal Service and the other an attempt to save the Coast and Geodetic Survey from the encroachment on its functions by the Geological Survey and the Hydrographic Office. Common to both was the old argument of civilian versus military control of science.

The Signal Service was then the target of much unfavorable publicity. During the Polar Year 1882–1883, it had been responsible for manning two stations—at Point Barrow and Ellesmere Island. Supporting expeditions did not reach Ellesmere Island in 1883, and a Navy rescue mission sent out in the spring of 1884 found only seven weak survivors. The Signal Service, though bearing the military name, was actually a weather bureau, as the meterological observations for military purposes authorized in 1869 had expanded into research. In 1881, a departmental task force had concluded that there was no natural connection between the military and the weather bureau, but a bill to transfer the function to the Interior Department had never emerged from committee.

The Coast and Geodetic Survey, which was the oldest of the bureaus, had taken on several functions in addition to its original one of a survey of the coast, including the supervision of weights and measures, magnetic and

Roland D. Irving

Irving also began his career with the U.S. Geological Survey as an expert special agent for the Tenth Census and later served as geologist until his untimely death at 41 in 1888. Irving also combined a career of teaching at the University of Wisconsin and research for the U.S. Geological Survey in the difficult and controversial areas of Lake Superior geology. (Courtesy of the Smithsonian Institution Archives.)

hydrographic studies, and geodetic surveys and mapping. The Navy had been collecting hydrographic information since the 1840's and had had a separate Hydrographic Office since 1865. Though a division of work had been made, the Coast and Geodetic Survey being responsible for domestic waters and the Navy for foreign waters, in actual practice naval officers were detailed to the Coast Survey for hydrographic work. An aggressive Secretary of the Navy, intent on modernizing his department, thought that the Coast Survey's hydrographic work should be under the Navy. The Geological Survey and the Coast Survey were apparently in competition in mapping the interior. In 1882, the Geological Survey had begun an extensive topographic mapping program in preparation for the geological map of the United States. In that same year, the Coast Survey had received Congressional authorization to make the map of the Eastern United States, and in 1884, it had been given authorization to make the map of the whole country.

Before going home for the summer, Mr. Lyman began the investigation by asking the National Academy of Sciences for advice, suggesting that it consider: (1) the organization of the government surveys and signal services in the chief countries of Europe and whether any parts thereof could be adopted in this country; (2) in what way the scientific branches could be best coordinated; and (3) what changes in or additions to these branches were desirable.

The Survey's work in the summer of 1884 was not affected by the proposed investigation. Topographic surveys were continued in all areas where they had been underway in the preceding year; new surveys were begun in Missouri, Kansas, and Texas; and the field of operations in the southwest was extended into southeastern Utah and southern Nevada. On

The most ancient rocks, which contained no fossils, were classified only with difficulty by structure or lithology. Irving studied the ancient rocks between Lake Huron and the Dakotas by petrographic methods and found that all quartzites provisionally considered Huronian, including the type Huronian, are sandstones that have received various degrees of induration by interstitial deposition of a siliceous cement, generally in the form of enlargements of the original quartz fragments. The quartzite at Sioux Falls, South Dakota, had been given various ages from Huronian to Cretaceous, but Irving concluded that it was Huronian. (From R. D. Irving, 1885.)

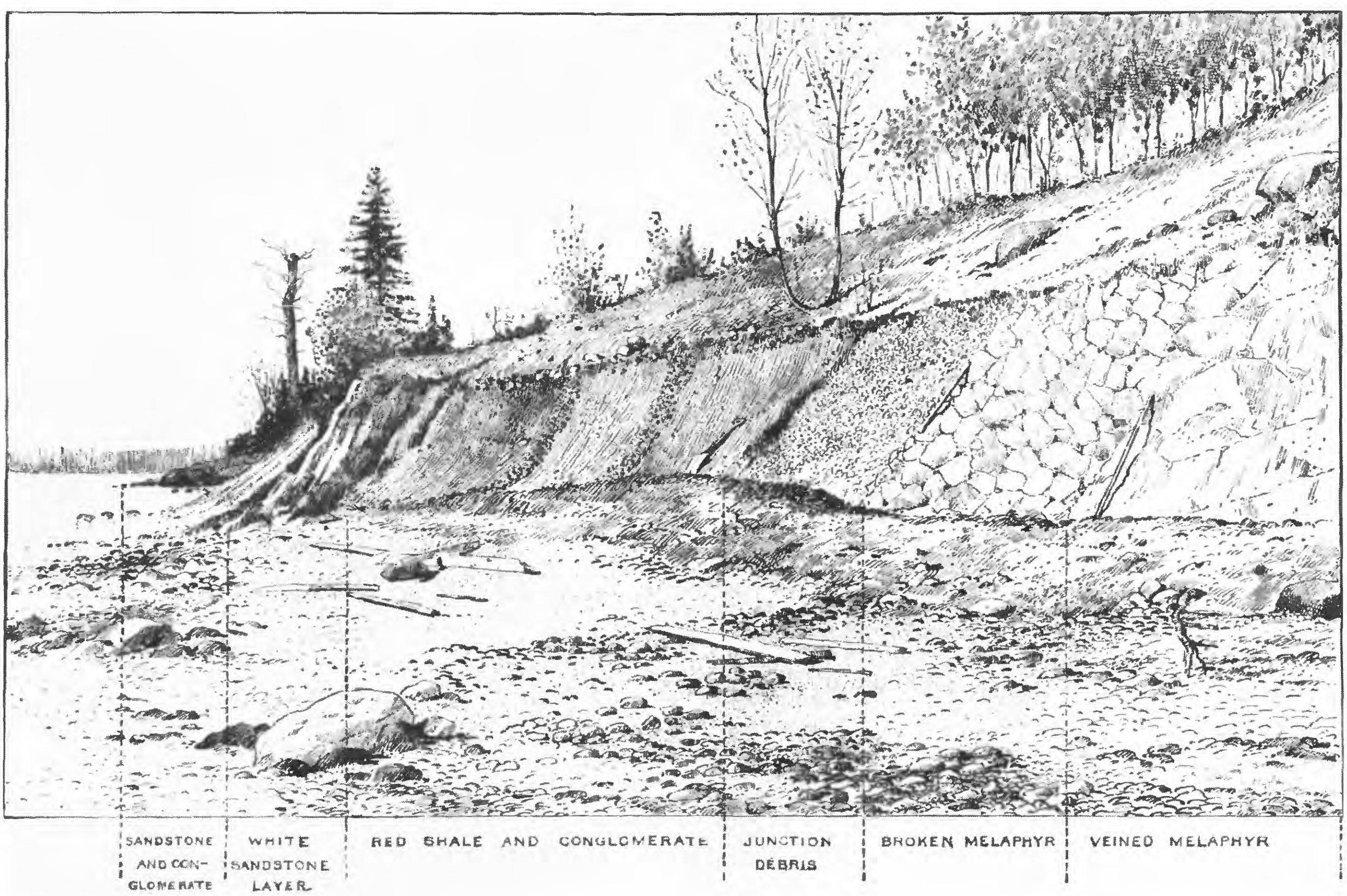
July 16, the topographic work of the State survey in New Jersey was taken over by the Federal survey and its personnel transferred to the Federal payroll.

The Massachusetts survey became a cooperative enterprise. During the spring, the State legislature appropriated $40,000, which was estimated to be half the necessary amount, to make a map of the State for publication on the mile-to-the-inch scale, on condition that the U.S. Geological Survey pay the other half. The interests of the State were placed in the hands of a commission consisting of Francis A. Walker, president of the Massachusetts Institute of Technology, Professor N. S. Shaler of Harvard University, and H. L. Whiting of the Coast and Geodetic Survey. Under a proposition made by the Director and accepted by the commission, work was begun by the Survey and carried on for 2 months, the results to be accepted or rejected by the commission. The work was accepted in October, and was thereafter carried on with financial support from both the State and the Survey.

Gilbert Thompson came east to take charge of the work in the southern Appalachians. Gannett said that this region was perhaps the most difficult for the surveyor to be found upon the continent, and the work called forth "all of a man's best qualities" and required "most unwearied energy and activity" to make even a fair rate of progress. Because of the prospective development of the region and the intricacy of the geology, the mapping would henceforth be at a scale of 1:125,000 and a contour interval of 100 feet.

A. H. Thompson was placed in charge of the work in Kansas, Missouri, and Texas as well as that in the plateau country. For Missouri and Kansas,

The nature of the contact between the Keweenawan Series and the Eastern Sandstone in northern Michigan had various interpretations by different geologists. Alexander Agassiz and M. E. Wadsworth of Harvard said that the Eastern Sandstone and the detrital rocks in the Keweenawan were the same formation but R. D. Irving and T. C. Chamberlin concluded from a detailed structural study that the Keweenawan was much older than the Eastern Sandstone. They held that the latter had been laid down in Potsdam seas unconformably against a fault line which developed during a long period of erosion following deposition of the Keweenawan. (From R. D. Irving and T. C. Chamberlin, 1885.)



it was concluded that the work could be expedited greatly without sacrificing accuracy by a proper use of the plats of the General Land Office—the "proper use" to include a system of correction, supplying the missing drainage wherever it appeared to be necessary, and adding the vertical element. R. U. Goode was directed to take charge of the work in Missouri and Kansas. E. M. Douglas was put in charge of the projected work in Texas.

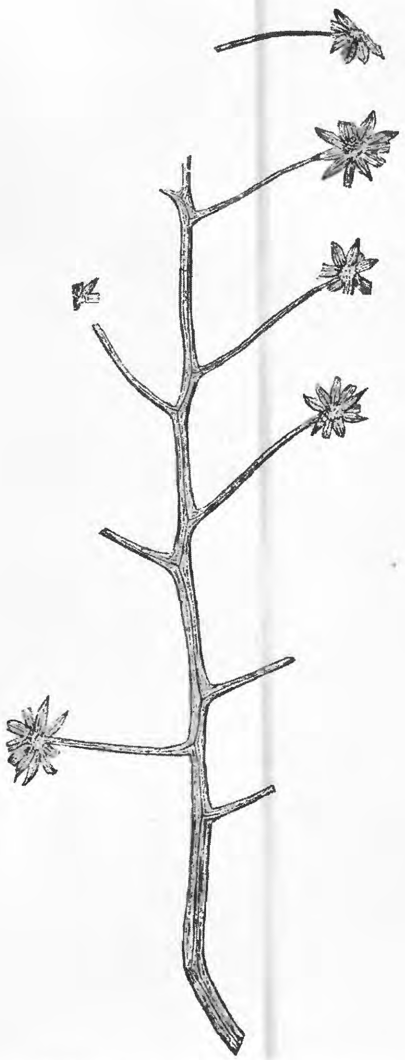
Major Powell explained to the National Academy of Sciences that,

> **Sound geologic research is based on geography. Without a good topographic map geology cannot even be thoroughly studied, and the publication of the results of geologic investigation is very imperfect without a good map; but with a good map thorough investigation and simple, intelligible publication is possible. Impelled by these considerations the Survey is making a topographic map of the United States.**

Because geologic work could not be done successfully until the maps were made, Powell said, the Survey was "necessarily diverting much of its force to the construction of maps, and cannot with present appropriations expand the geologic corps so as to extend systematic work in the field over the entire country," especially into areas where the terranes were composed of fossiliferous formations. Nonetheless, the work in general geology, previously defined as structural geology and paleontology, had so increased by 1884 that it became necessary to organize it into several divisions.

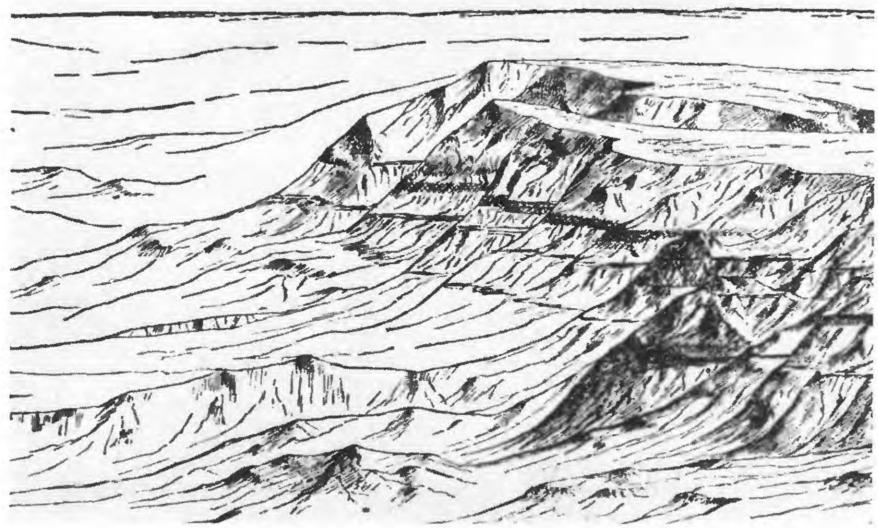
The Director explained that in organizing the general geologic work, it was necessary: "first to consider what had already been done in various portions of the United States; and for this purpose, compilation of a general geologic map of the United States was begun, together with a thesaurus of American formations;" and then to consider the best method of apportioning the work. The strictly geographic apportionment of work on the geologic map was "not deemed wise, from the fact that an unscientific division of labor would result and the same classes of problems would to a large extent be relegated to the several corps operating in field and in the laboratory." Instead the Director thought it best to divide the work as far as possible by subject matter, although he acknowledged that to some extent the two methods of division coincided.

In practice, however, the division of work seems to have been dictated by personnel more than by any other factor. The new organization simply made several geologists "chief geologists" who would originate the plans for work. At first, five divisions were established: glacial geology, under T. C. Chamberlin; volcanic geology, under Captain Dutton; a division to work on the Archean rocks and metamorphic crystalline schists of the Lake Superior region under Professor Irving; a division to study the areal, structural, and historical geology of the Appalachian region under G. K. Gilbert; and a topographic and geologic survey of Yellowstone National Park under Arnold Hague. The Appalachian Division, as originally defined, extended "from the Atlantic westward to the zone which separates the mountain region from the great valley of the Mississippi." Shortly afterward, two new divisions were created in the same area. When Pumpelly returned to the Survey after the Northern Transcontinental Survey was discontinued in 1884, he began a study of the geology of New England, and a new division was created for study of the "crystalline schists and associated rocks of the Appalachian region from New England to Georgia." Matters were further confused when Pumpelly adopted the term "Archean Division," and Professor Irving used the name "Lake Superior Division." Later, when Professor Shaler began work on the Atlantic Coastal Plain, also within the Appalachian Division as originally defined, he used the term "Atlantic Coast Division." On the other hand, no provision was made for Hayden in the table of

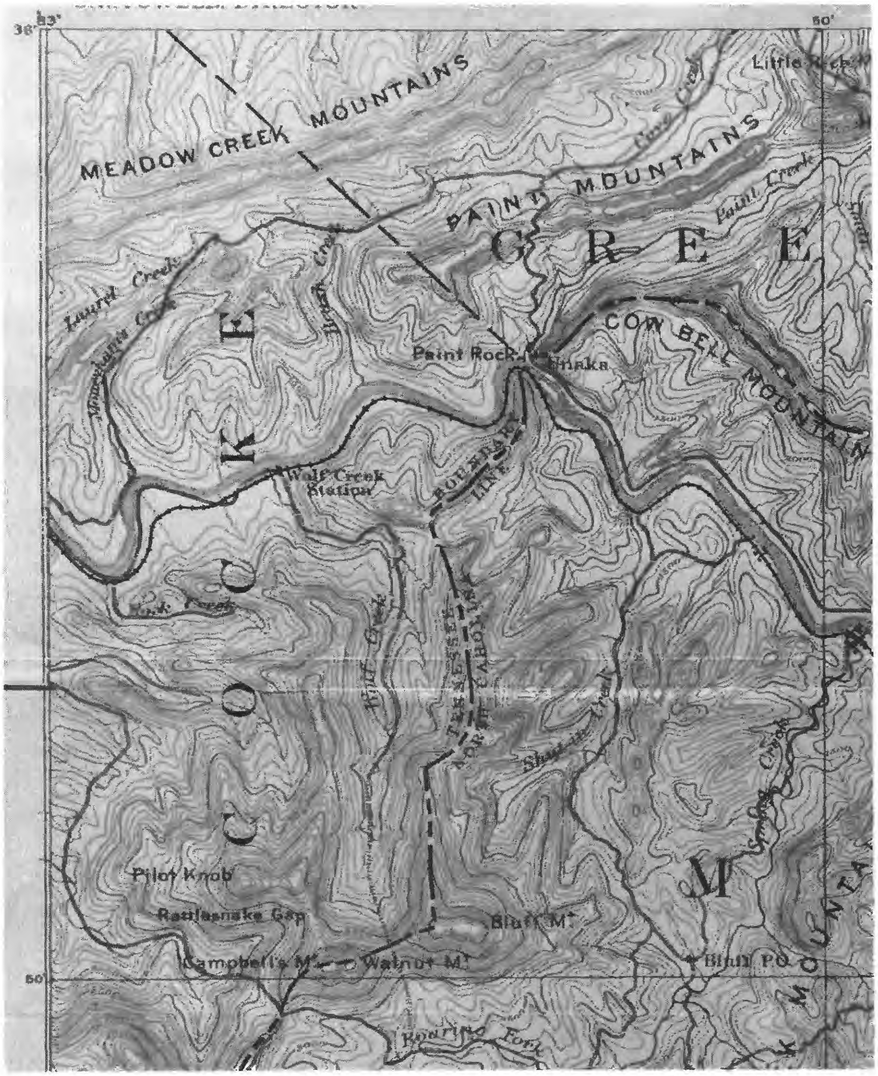


The age of the Laramie Group, which King had called the last great formation of the Cretaceous, was also a subject of controversy. Lester Ward agreed with those who said it was impossible to assign the group either to the Cretaceous or to the Tertiary, although he conceded that its geological age could not be proved by its flora alone. The *Sparganium* shown was collected from the Fort Union beds, which Ward considered part of the Laramie, near Seven Mile Creek, Montana. (From L. F. Ward, 1885.)

Secretary of the Interior Henry Teller and Major Powell shared an interest in improving the conditions under which the Indians lived. In the summer of 1884, a field party led by Bailey Willis attempted to determine whether coalbeds of economic value existed within the Great Sioux Reservation, ▶ but they searched in vain for fuel. They found that the valleys of Cottonwood Creek and the Moreau slope directly south of it were of badland character but that the remainder of the region was grass-covered and seemed favorable for stock-raising. (From Bailey Willis, 1885.)



In 1884, Dutton was sent to investigate the striking features near Mount Taylor in northwestern New Mexico that the topographic mapping parties had reported. Dutton was less excited than the topographers had been. From the edge of the Mount Taylor mesa could be seen a broad valley, a confused patchwork of bright colors representing the lower and middle Cretaceous rocks, out of which rose several inaccessible eyries of black rock, easily recognizable by the experienced geologist as volcanic necks. (From C. E. Dutton, 1885.) ▼



The Asheville, North Carolina-Tennessee, sheet was one of the first in the Eastern United States mapped by the U.S. Geological Survey. (From Bailey Willis, 1888.)

organization announced by the Director, who also said that no provision had been made for studying the crystalline schists of the Rocky Mountains. Hayden and Peale, working in an area where "presumably Archean gneisses" existed, adopted the name "Montana Division."

The organization of the work in paleontology was an extreme case of organization by personnel. The paleontological divisions obviously represented different areas of specialization and each had its own corps, but they were distinguished in the table of organization by the name of the head of the divisions: O. C. Marsh, C. A. White, C. D. Walcott, L. F. Ward, and W. H. Dall.

Mining geology, now the lesser part of the Survey's work was organized into two divisions. The Director said that "under the organic law of the Geological Survey, investigations in economic geology are restricted to those States and Territories in which there are public lands; the extension of the work into the eastern portion of the United States included only that part relating to general geology." Emmons, who had been named geologist in charge of the Rocky Mountain Division by King, would henceforth be in charge of a small division of mining geology in Denver. Similarly, Becker, who had been promoted by King to be geologist in charge of the Pacific Division, found himself in charge of a small division of mining geology in San Francisco.

There were, in addition, several "accessory divisions." Included among them were the five paleontological divisions, the Chemic Laboratory under F. W. Clarke, the Division of Illustrations under W. H. Holmes, the Division of Mining Statistics under Albert Williams, Jr., and the Library under C. C. Darwin. The physical laboratory under Barus was in an anomalous unmentioned position.

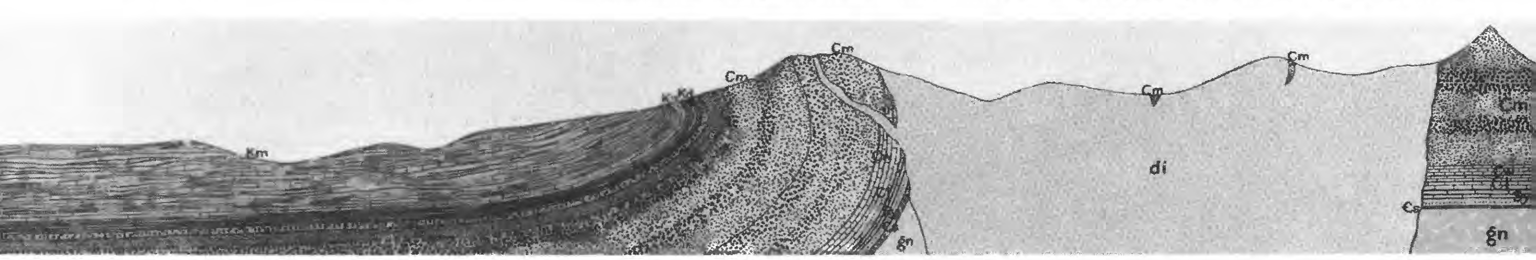
In the Annual Report of the Secretary of the Interior to Congress in the fall of 1884, the economic basis of all the work was stressed in describing the new organization. The explanations were obviously oversimplified: Captain Dutton's division had been organized "for the study of the volcanic rocks of the United States, especially in relation to the occurrence of gold and silver ores;" Professor Irving's division had been organized "for the study of metamorphic rocks, in which a large part of the iron and copper ores of the United States are found;" and another division, presumably the Appalachian Division, had been organized "for the general study of the sedimentary rocks, embracing the great coal-fields of the country."

In the summer of 1884, Dutton sent Diller off to the Cascades to begin a detailed study of Mount Shasta and the surrounding area, while he himself went to New Mexico. The topographic parties that had been mapping in northwestern New Mexico had brought back such tales of the wonderful things to be seen near Mount Taylor that Powell, who shared with Gilbert and Dutton a never-ending enthusiasm for the "geologic wonderland" of the Southwest, sent Dutton off to investigate. At the end of the season, Dutton reported that "if the cone of Mount Taylor were all that this locality [had] to present for study it would hardly have repaid the trouble of a visit. But the volcanic district of which it is the culminating point presents matter of great interest and instruction when viewed as a whole, for it discloses clearly the origin of the great lava caps which form such a conspicuous feature in many parts of the West, and offers a wide range of information concerning the modes of accumulation of lavas in the basic group."

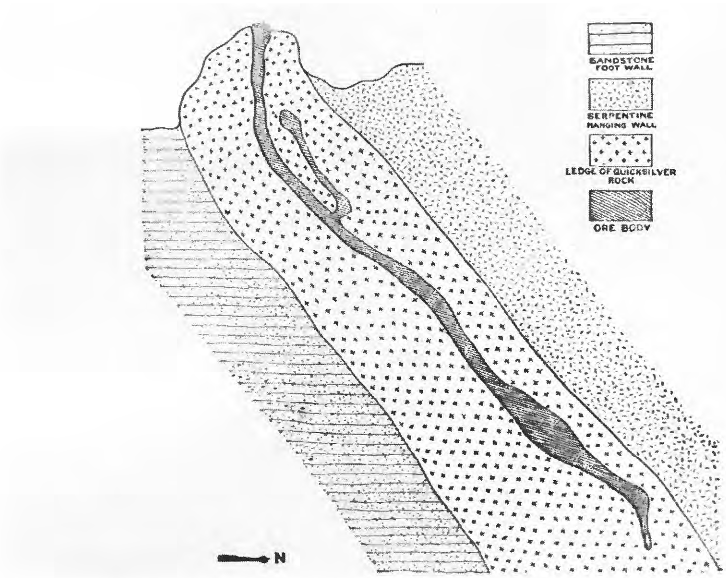
Professor Irving had four parties in the field, in addition to his own in northeastern Minnesota and the Upper Peninsula of Michigan, in work that he described as "a general investigation of those formations of the Northwestern States which underlie the basal fossiliferous sandstones of the Mississippi Valley."

Gilbert again spent most of the year in Washington. He proposed to make use of the copious literature on the Appalachian area and to do no unnecessary fieldwork. The only geologists of the Appalachian Division in the field that summer were H. R. Geiger, studying the section near White Sulphur Springs, West Virginia, and Ira Sayles, in east Tennessee. Professor I. C. White of the University of West Virginia spent the summer studying the stratigraphy of the coal measures in the valley of the great Kanawha River in West Virginia.

The work in glacial geology was expanded. Professor Chamberlin added several lines of investigation to those already underway, among them monographic studies of drumlins, osars (now called eskers), boulder trains, the chemical composition of the drift, and the petrographic study of glacial



The mapping by Emmons and his party in the Crested Butte region of Colorado confirmed the substantial accuracy of Holmes' description of the great fault fold of the Elk Mountains after his reconnaissance in 1873, but added many details and complexities in the structure. The section shown is close to Holmes' Section I shown on page 227 of volume 1. (From S. F. Emmons, 1894.)



Becker found in his study of the quicksilver deposits of the Pacific slope that the cinnabar was deposited in preexisting openings in the rocks, probably from hot sulfur springs. Before the ore bodies were deposited, silica, in part amorphous, replaced some of the country rocks; the miners recognized the clue by referring to silicified serpentine as "quicksilver rock." (From G. F. Becker, 1888.)

deposits. Professor G. F. Wright joined the division to study the southern limit of the drift in Illinois, Ohio, and western Pennsylvania; Professor George H. Stone began a study of the osar systems of Maine; and William Morris Davis, an instructor at Harvard, began the study of drumlins.

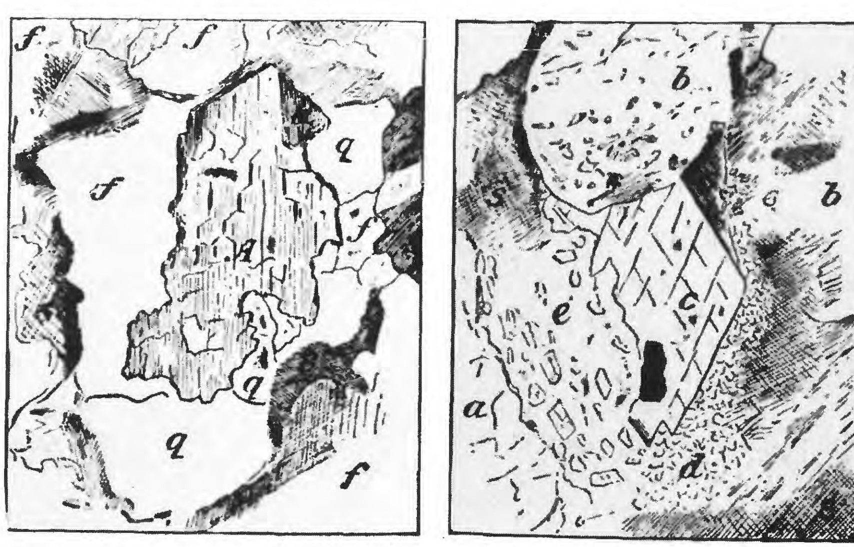
Hague, along with Iddings, Weed, Wright, Davis, Gooch, Hallock, and W. E. Sanders, a student at the Columbia School of Mines and volunteer assistant, spent the summer of 1884 in and around Yellowstone Park. Gooch collected water samples while Hallock continued his investigations of the physics of geyser action and Hague made a general reconnaissance of the Gallatin Range for indications of mineral deposits "in order that, if the boundaries of the Park were to be defined anew by law of Congress, the propriety of still including the range within the reservation might be fully understood." Hague then made a reconnaissance of the area between the southern boundary of the park and the 44th parallel to examine the country with reference to the advisability of extending the area of the park to that line. Hague thought that valuable as the park undoubtedly was as a place of recreation and desirable as it was that the incrustations and sediments around the geysers and hot springs and other objects of scientific interest should be preserved, there were other very important reasons why the park should be maintained—the protection of the forests and the preservation of game. The Yellowstone region contained many natural reservoirs that would vanish if the forests did not restrain the runoff and protect the water supply. And if the Yellowstone River valley was ever to support any considerable population, it could stand no diminution of its water supply.

Hayden and Peale worked in the area between the Bridger or East Gallatin Range and the Three Forks of the Missouri River, north of Yellowstone Park, continuing the work begun by the Hayden survey. The area was selected "because it contained within its limits probably some of the best exposures of the rocks of the Northwest, representing the entire geologic scale extending from the presumably Archean gneisses to the sands and loose superficial deposits of the Quaternary, thus affording one of the best opportunities for the study of the formations of the Upper Missouri region, and facilitating the making of the most complete section of the various beds." Hayden and Peale could thus make their own geologic column. Among the fossils that they collected that summer, Walcott identified 12 species identical with those in the Upper Devonian of the Eureka district and two similar to Upper Devonian species in New York State. Hayden and Peale were thus able to make the first positive identification of the Devonian in the Rocky Mountains of Montana.

Pumpelly did no fieldwork in the summer of 1884 beyond a reconnaissance in the Monadnock and Kearsage districts of southern New Hampshire. Most of his year was spent, with Bayard Putnam as his assistant, in completing the volume on the mining industries for the Tenth Census, which he had left unfinished when he resigned in 1881.

Becker had reached a point in his studies of the quicksilver deposits at which it became absolutely necessary to determine the age of the metamorphic rocks of the Coast Ranges and the time relations of the epoch of metamorphism. C. A. White joined Becker and corroborated on paleontological grounds the tentative conclusions that Becker had reached on the basis of structure. Together, Becker and White made some studies in Oregon, and they then prepared two bulletins with their conclusion that the first uplift of the Coast Ranges dated at least as far back as the great uplift to which an important part of the Sierra Nevada was due. Becker believed that the Cascades must be regarded as a continuation of the united Sierra Nevada and Coast Ranges to the north, structurally as well as topographically.

Curtis was unable to get into the field in 1884. He spent the first part of the year on the proofs of the Eureka report and on the construction of a glass model of the mines for an exposition in New Orleans; he then occupied himself in the laboratory preparing a method for the determination of minute quantities of silver. Emmons finally got the Gunnison project underway, and a mixed party of topographers and geologists began work in the Crested Butte region. Emmons said that the reconnaissance observations made by Holmes in 1874 were in themselves sufficient to show the necessity of a detailed study of the region from a purely structural point of view; in addition, he said that the great number of intrusive masses older than the Tertiary volcanic rocks and their relation to the formation of ore deposits had great importance from the purely scientific as well as economic point of view and that the many ore deposits and coal beds in the region made its examination of the greatest importance. The work would take considerable time because the geology was complex and only a short field season was possible at such high altitudes. George Eldridge had been assigned to Emmons' division after his return from the Northern Transcontinental Sur-



Becker found that the study of the quicksilver deposits of the Pacific slope also afforded an opportunity for the investigation of the metamorphism of Mesozoic rocks. A sandstone from near Knoxville, seen under a high-power microscope, had numerous unaltered grains of granitic quartz and feldspar but some of the minerals had been converted into aggregates of new minerals, especially important among them augite and hornblende. The augite in the left-hand figure is marked *A*, the hornblende in the right-hand figure is marked *c*. (From G. F. Becker, 1888.)

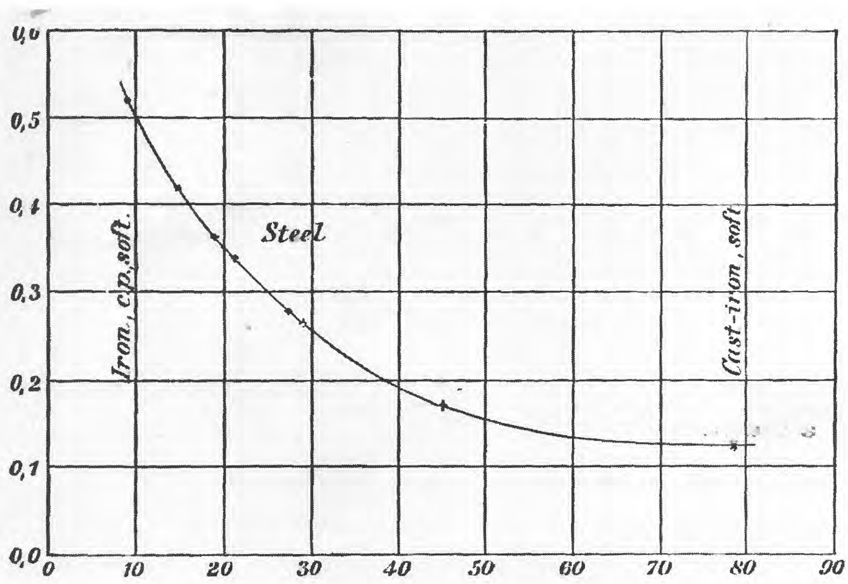
vey, and Emmons planned to have him study the stratified rocks while Whitman Cross studied the eruptive rocks. However, when the topographic work was finished early in September, Anton Karl was recalled and assigned to work in Massachusetts rather than on the Denver Basin map, and when the geologists came in from the field after the first snowfall, Eldridge was sent to make sections of the Paleozoic formations in the Arkansas River valley to establish a geological connection between the eastern and western slopes of the Rockies. Whitman Cross had to go to the Leucite Hills of Wyoming to collect specimens for the Educational Series of Rocks. Albert Williams, however, was given a small allotment so that a volume of *Mineral Resources of the United States* for 1883 and 1884 could be prepared.

During the summer of 1884, Professor Marsh had two parties collecting in the Jurassic of Wyoming and a third in the Jurassic of southern Colorado. Another party spent most of the year collecting in the Pliocene of Kansas and Nebraska, and during the winter months, a party began collecting in the Permian of Texas. Dall and Ward spent most of the year in the office, busy with the study of previous collections. From the Paleozoic group, Professor Williams investigated sections of Devonian strata in western New York, northwestern Pennsylvania, and eastern Ohio, and Cooper Curtice made collections of Cambrian fossils in Wisconsin, Minnesota, Alabama, and Texas. Walcott himself began a study of the Cambrian in Vermont but was recalled to examine a coalfield in the San Carlos Indian Reservation in Arizona for the Secretary of the Interior.

In the fall of 1884, another field of investigation was added to the Survey program. Two light but widely felt earthquakes in the Eastern States in 1884 had called attention to the lack of any organized attempt to observe them in this country. *Science*, in its issue of October 3, 1884, suggested that the U.S. Geological Survey provide instruments and observers and that students of "this branch of physical geography" form an earthquake club. In November the Director, with Gilbert and Dutton, met in conference with Professor C. C. Rockwood of Princeton, who had been collecting accidental records of earthquakes, Professor W. M. Davis of Harvard, Cleveland Abbe and C. F. Marvin of the Signal Service, and H. M. Paul of the Naval Observatory to consider the best way to arrange for systematic observations. They agreed that the only practicable scheme was to rely on voluntary cooperation and to work toward collection of noninstrumental observations by distributing circulars and blanks to be filled in and toward the establishment of stations for instrumental observations. Marvin undertook to design an instrument that would be simple and inexpensive and that would require a minimum of care and attention. Rockwood and Davis, and Abbe were constituted a committee to determine the best geographic distribution of stations. The Geological Survey was to furnish the instruments to observers and receive reports. The seismological investigations were made part of the work of the Division of Volcanic Geology under Captain Dutton.

A petrographic laboratory was also set up as part of the Division of Volcanic Geology. Petrographic studies were part of the investigations underway in several divisions, notably by Cross, Iddings, and Irving and Van Hise. Captain Dutton had also had a long-standing interest in petrography, and at the end of the field season, when Diller returned to Washington, the petrographic laboratory was fitted up under his direction. The laboratory consisted of two rooms, one solely for mineral analyses by heavy solutions, chemical reagents, or similar techniques, and another for microscope work. During the remainder of the year, Diller identified and described rocks for various geologists of the Survey.

The electrical researches which King had permitted Carl Barus to undertake, provided that they did not take too much of his time, disclosed information of interest to metallurgists. After five years of experiment and analysis, Barus and Vincent Strouhal found a relation between electrical conductivity and temperature of steels in different states of hardness, of wrought iron, and of cast iron. This relationship permitted a classification of these substances and enabled Major Powell to report to the Allison Commission that the difference between iron and steel, a matter of debate at the time, had been determined in the laboratories of the U.S. Geological Survey. (From Carl Barus and Vincent Strouhal, 1885.)



Without benefit of formal organization, certain other problems were also being investigated, as the Director told the National Academy of Sciences in the fall of 1884. The most important related to the irrigation of the arid lands; the second to the relief from floods that would be afforded the lower valley of the Mississippi by utilizing the waters from the Rocky Mountains for irrigation; and the third, the geographic distribution of the great forest areas. No reason was given for not according these investigations formal status, nor was any detailed explanation of the work given. The forestry investigations were the work of George Shutt, the general assistant. At least in the beginning, these studies were made in the southern Appalachians, but no report on them was ever published, although Shutt continued to work for the Survey until 1890.

The irrigation investigations, Major Powell later said, were, from the beginning, part of the topographic work of the Survey. Survey geologists, however, were also interested in water supply and irrigation. Emmons had said that the geologic survey of the Denver region would provide information on the water supply for Denver and vicinity, but its practical hearing would extend far beyond Denver to the whole plains region.

> **While the existence of a synclinal basin has long been known to us from the hasty observations one makes in simply passing over the country, accurate and reliable maps and profiles are an indispensable basis for the observations which shall determine the true source of the water supply, the amount and quality that may be expected from different geological horizons, and the most favorable points for sinking artesian wells; it is in large degree owing to the want of this accurate preliminary knowledge that the money already appropriated by Congress and spent in sinking artesian wells upon the plains of Colorado has been so barren of practical and definite results.**

Chamberlin took time from his glacial studies to refurbish a paper on artesian wells, which he had prepared for the Wisconsin Survey, for publication in the fifth annual report of the U.S. Geological Survey. Its aim was "to gather into a simple and convenient form such information relative to the necessary and qualifying conditions of artesian wells as may be capable of brief, general statement, and may seem to be serviceable alike to citizen, driller, and geologist." The seven essential features of artesian wells, he said, were: (1) A pervious stratum to permit the entrance and passage of water; (2) a watertight bed below to prevent the escape of the water down-

Grover Cleveland

President of the United States, 1885–1889 and 1893–1897. In his first inaugural address, Cleveland put himself on record as in favor of strict economy, protection of the Indians and security of freedmen, and the value of civil service reform. Reputed to be opposed to science, his attitude was probably colored by his interest in economy and in civil service reform. He went against the advice of some of his Cabinet in promoting the status of the Department of the Agriculture. (Courtesy of the Library of Congress.)

ward; (3) a similar impervious bed above to prevent escape upward; (4) an inclination of the beds so that the edge at which the waters entered would be higher than the surface of the well; (5) a suitable exposure of the edge of the porous stratum so that it might take in a sufficient supply of water; (6) adequate rainfall to furnish this supply; and (7) absence of any escape for the water at a lower level than the surface of the well.

He was constrained to point out,

> **Artesian wells do not manufacture water. They do not even bring to the surface more than goes down from the surface. The total water supply of any given region is not, therefore, increased by them. They merely pour out at one point what had fallen and sunk elsewhere. If the total fall is inadequate to the agricultural wants of the total region, artesian wells cannot make it adequate. They may concentrate a sufficient supply upon a part but cannot supply the whole.**

Still, he thought it wise to "urge as large a development of artesian wells in arid regions as practicable. While it is useless to think of them as a resource competent to restore productiveness to the total dry area, or even any great percentage of it, they form one of several means for its amelioration.

"If the great volumes of water which the Colorado, Columbia, Missouri, and other streams, above and below ground, bear away from the arid provinces could be led out upon the thirsty plains, absorbed, and given again to the atmosphere, very notable direct and indirect benefits would follow." And more than that, "Professor Powell has suggested that the utilization of the Missouri and other detritus-laden streams in irrigation would furnish at least a partial solution of the serious engineering problems they present."

Paleobotanist Lester Ward had also been giving thought to the problems of irrigation but from a sociological rather than a scientific point of view, and Ward differed with Major Powell on how irrigation should be accomplished. For the lower parts of the Missouri River region, irrigation was essential to successful agriculture, and agriculture was the only permanent and reliable basis of population. An extensive system of irrigation would require an immense outlay of capital, which the settlers themselves could not provide. Private enterprise might, but that would lead to monopoly. State action would be better, but again the means would not be available until the territory was well peopled. The only unobjectionable plan was national action. Ward said:

> **If we could obtain the same degree of collective foresight in the general government as exists in the average capitalist, nothing could be easier than for the United States, acting as a corporation that seeks only its own interest, not only to secure the particular end of which we are now speaking, but to develop its own resources and increase its own wealth and prosperity.**

William B. Allison

Senator from Iowa, 1873–1908; Chairman of the Senate Appropriations Committee, 1881–1908; and chairman of the joint commission to investigate the scientific bureaus of the Government, 1884–1886. Allison, although from the farming state of Iowa, was identified with the nationwide expansive business urge of the time, and one of the few western Congressmen popular with eastern financiers. One of his most notable characteristics was his mastery of the arts of conciliation. (Courtesy of the Library of Congress.)

In the national elections in November 1884, a Democrat was elected President for the first time since 1856. There had been a resurgence of agrarian discontent during the year as the prices of agricultural commodities began to decline. The farmers began to band together in State or regional organizations and aimed their attack against the eastern moneyed interests, the middlemen, the railroads, and the advocates of the gold standard. The nomination by the Republicans of James G. Blaine for President alienated the independent Republicans, among them Carl Schurz, who regarded Blaine as inimical to the cause of good government. Grover Cleveland, Governor of New York, was nominated by the Democrats, and he was elected with the aid of the independents. The Republicans gained in both houses of Congress, but they did not win control of the House from the Democrats.

The lameduck Congress that met in December 1884 had to face serious economic problems. Under the Bland-Allison Act of 1878, the Government had minted nearly $200 million in silver dollars, and much of it had gone into circulation. During the depression in 1884, the silver began to come back to the Treasury as obligations due the Government were paid. The Government, however, had to pay out gold to its creditors, so the gold reserve was threatened. Congressman A. S. Hewitt, chairman of the House Ways and Means Committee, and other sound money men thought legislation to stop the coinage of silver would solve the problem, and an amendment to the Sundry Civil Expenses bill was drafted. Silver men from the West and South protested, and though President-elect Cleveland endorsed the proposal, the House with its Democratic majority defeated the amendment by a decisive margin.

The Joint Committee on Public Printing did not submit a bill to reduce the cost of public printing, as required by the act of July 7, 1884, but left it for the new Congress which had been elected in November. The Public Printer, in his report for the fiscal year ending June 30, 1884, refrained from comment on a subject under congressional study but clearly felt that some measures were necessary. The most expensive reports were the scientific reports. The total spent for Geological Survey reports that year had been close to $100,000, and another $41,000 had been spent for the Bureau of Ethnology. At the end of the year, the Printer had on hand seven volumes on ethnology that he estimated would cost $104,000 to print and bind, and five volumes of the Hayden survey reports that he estimated would cost more than $110,000.

By the end of 1884, the Survey had published—in addition to the annual reports, each of which since Powell became Director had been several hundred pages long—7 monographs and 12 bulletins. Dutton's monograph on the Grand Canyon district and Becker's on the geology of the Comstock lode had been published in 1882. Eliot Lord's report on Comstock mining and miners, part of the Tenth Census investigations, Irving's report on the copper-bearing rocks of Lake Superior, and a *Contribution to the Knowledge of the Older Mesozoic Flora of Virginia* by Professor W. M. Fontaine of the University of Virginia had been published in 1883. In 1884, Curtis' report on the silver-lead deposits of Eureka and Walcott's on the paleontology of the Eureka district were published. The 12 bulletins included papers by Whitman Cross, Albert Williams, H. S. Williams, C. A. White, Henry Gannett, R. D. Irving and C. R. Van Hise, C. D. Walcott, a report of work done in the Washington laboratory, a catalogue of geological maps of North and South America by the Marcou brothers, a compilation of *Elevations in the Dominion of Canada*, by Professor J. W. Spencer of the University of Missouri, a report *On the Quaternary and Recent Mollusca of the Great Basin*, by R. E. Call, and *A Crystallographic Study of the Thinolite of Lake Lahontan*, by Professor E. S. Dana of Yale.

Another of the quarto volumes of the Hayden survey reports was also published in 1884—Cope's report on *The Vertebrata of the Tertiary Formations of the West.* It was a volume of 1,009 pages, which soon became known as "Cope's Bible" or, in some circles, as "Cope's Primer." Cope still had more to say, but the appropriation for completion of Hayden Survey reports was long since exhausted.

The Joint Commission on the Organization of the Scientific Work of the Government, informally known as the Allison Commission from the name of its chairman, convened knowing that two of its members, Senator Pendleton and Congressman Lyman, had not been reelected. The report from the National Academy of Sciences, which Mr. Lyman had requested, had been submitted in mid-October. Professor O. C. Marsh, who had been elected president of the Academy in 1883, appointed a committee consisting of General M. C. Meigs, recently retired as Quartermaster General, chairman; Simon Newcomb and W. P. Trowbridge, who had been members of the 1878 Academy committee whose report led to the establishment of the U.S. Geological Survey; Francis A. Walker, president of the Massachusetts Institute of Technology and chairman of the Massachusetts Commission for the Topographic Map; Colonel Cyrus Comstock of the Army Engineers; Professor William Brewer of Yale; and three astronomers—S. P. Langley, E. C. Pickering of Harvard, and C. A. Young of Princeton. Although the military had complained that they had not been represented on the Academy committee in 1878, the War and Navy Departments refused to allow Comstock and Newcomb to serve to avoid the possibility of requiring them to comment on the policy of their superiors.

The National Academy of Sciences Committee found that the land maps of European countries were, as a rule, made under the direction of the war departments and that the hydrographic surveys of the coasts of Europe appeared in every country to be the work of the naval establishment, but the committee did not find that the European surveys offered anything to im-

Hilary A. Herbert

Congressman from Alabama, 1877–1893, Secretary of the Navy, 1893–1897. Herbert was three times chairman of the House Committee on Naval Affairs and was largely responsible for the increased appropriations which led to the revival of the American Navy. Herbert was identified with those promoting the industrialization of the South following the Reconstruction period, and was also a determined advocate of economy in government. (Courtesy of the Library of Congress.)

prove those of the United States except, perhaps, the economy in time and money to be achieved by greater use of photography and zincography in printing maps.

Rather tartly, the committee called attention to the recommendation of the Academy Committee in 1878 for two surveys, a coast and interior survey and a geological survey. Congress had not provided for the transfer of the Coast and Geodetic Survey nor had it made any other provision for the topographic work necessary for the Geological Survey. Consequently, under different provisions in appropriations acts, both the Coast and Geodetic Survey and the Geological Survey were making trigonometric surveys of the whole United States. The committee was not entirely confident that just placing the two surveys under either one of the executive departments would, without other measures, lead to the unity of work that was desirable, but the members were entirely clear in the opinion that one executive department should control both. The Signal Service, they thought, could be divided between its civil and military functions. The Coast and Geodetic Survey and the Hydrographic Office might well remain separate until the survey of the coast was completed at which time the consolidation of the hydrographic work might be reconsidered.

The Academy Committee then sought to establish some general principles. First, the Government should not undertake any work that could be equally well done by the enterprise of individual investigators, and it should confine itself to the increase and systematization of knowledge tending "to promote the general welfare" of the country. Secondly, the scientific bureaus should be under one authority. Administration of a scientific bureau or department involved greater difficulties than those of a purely business department. The connection between the work done and the results ultimately to be attained were not at all obvious to the people and the press, and thus the "great benefit of vigilant watching and constant criticism" was wanting. Moreover, administration of a scientific bureau required a combination of scientific knowledge and administrative ability that was more difficult to command than either of those qualities separately. These difficulties were intensified by the absence of any central authority to control the work of a Government scientific organization. Thus, the head of each scientific organization became almost completely independent, and his individual judgment of what his organization should do was controlled only by Congress acting through the annual appropriation bills. The committee proposed a Department of Science, but realizing that Congress was unlikely to act on such a proposal, suggested as an alternative that all scientific bureaus be transferred to one executive department and that the work be coordinated by a permanent commission attached to the office of the secretary of that department and with the secretary as president ex officio.

The Academy Committee also recommended that the scientific functions of the Federal Government be divided among four bureaus: the Coast and Interior Survey, to be concerned principally with geodesy and hydrography; the Geological Survey; the Meteorological Bureau; and a physical laboratory to investigate the laws of solar and terrestrial radiation and their application to meteorology along with other investigations in the exact sciences. The functions of the bureau of weights and measures, performed by the Coast and Geodetic Survey, would be transferred to the physical laboratory and extended to include electrical measurements.

Dutton wrote to Sir Archibald Geikie that there was no probability that the Academy's plan would be carried out at any early date, although it might be some years in the future. Dutton did not believe in much organization for scientific work. Some was necessary, but it ought to be a min-

The Geological Survey under Powell maintained an interest in irrigation. Although the drilling of wells for water had benefited from improved methods developed by the petroleum industry, drilling of wells for artesian supplies was not always successful. The requisite geologic conditions, Chamberlain explained, included a porous stratum, inclined so that the edge at which water entered would be higher than the surface at which the well was drilled, and impervious beds above and below to contain the water. The diagram shown was one of the most frequently repeated illustrations in Survey reports. (From T. C. Chamberlin, 1884.)

imum. "The scientific worker must be as untrammeled as possible. Any scientific results depend upon the efficiency of the man who does the scientific work & all that an organization *ought* to do for him is to give him men, money & room and let him alone otherwise." Dutton was pessimistic about the future. "Gov't scientific work always has & always must grow more & more perfunctory. It must grow more expensive & less efficient & that continuously. Our Survey is now at its zenith & I prophesy its decline. The 'organization' is rapidly 'perfecting,' i.e. more clerks, more rules, more red tape, less freedom of movement, less discretion on the part of the geologists & less outturn of scientific product. This is inevitable. It is the law of nature & can no more be stopped than the growth & decadence of the human body."

Powell was the first witness when the commission began hearings on December 4. He was questioned on the Survey's authority to do geodetic work and to extend its work into the "old" States, the nature of topographic maps, and even the necessity of topographic maps as the basis of geologic maps and the relation of the Survey maps to those of the land surveys. Powell explained that the Geological Survey made use of the Coast and Geodetic Survey's work wherever possible, but that the Coast Survey work would have to be greatly extended in order to serve the purposes of the geologist. The Geological Survey, he said, expected to complete its geologic map in about 24 years.

Powell was invited back the next day to present his views on the organization of the scientific work of the Government. There were two guiding principles to its proper organization, he said. The first was that all the scientific bureaus should be under one general management. Scientific investigations were by their nature interrelated and interdependent, and the official organizations should be coordinated so that they might work together and aid each other, but not in such a way that one would be compelled to do what was the proper function of another, nor should one be permitted to encroach on the functions of another. His second guiding principle was that the bureaus engaged in research should be free of dictation from superior authority regarding the methods of research. Scientific investigations had to be controlled by the facts discovered; therefore, the investigations could only be controlled by the men doing the work. The Director of the Geological Survey, for example, could not lay out the work for his assistants in detail; he could only set forth in a general way the object to be reached and the general methods to be pursued. The most important function a director had to perform was to select the proper men, those with a genius for research.

Major Powell objected to the National Academy of Sciences committee's proposed board of commissioners as the alternative to a Department of Science. Such a board would be composed of incongruous elements, for civil and military officials had diametrically opposing views of administration. Apparently, he overlooked the proviso that all the scientific bureaus be transferred to one executive department, whose Secretary would preside over the board, for he complained that the relations to the various departments would be impracticable, that officers subordinate to the Secretaries would control the work and transmit instructions to the bureaus through the Secretaries, and that, he feared, would be irksome to the members of the President's Cabinet. He suggested instead that the bureaus be placed under the Regents of the Smithsonian Institution.

He thought too that instead of establishing a new bureau, the Coast and Geodetic Survey could take on the electrical researches and those relating to solar and terrestrial radiation. When the survey of the coast was completed, the Coast and Geodetic Survey's hydrographic work should be transferred to the Hydrographic Office. Then the Coast and Geodetic Survey would have for its functions investigations relating to geodesy, gravity, solar and terrestrial radiation, magnetism, and electricity. As for the Signal Service, it should not be associated with the other bureaus unless it was reorganized on a civil basis.

Secretary of the Navy William Chandler had a different view. He told the Allison Commission that all the scientific work that was necessary or convenient to carry on the Government should be conducted within and under the direction of the Department that needed the scientific assistance. On that basis, he said, the Navy claimed everything belonging to the water (although they had no desire for the Fish Commission.) The Coast and Geodetic Survey's hydrographic work belonged in the Navy; the land part should be placed under the Interior Department.

Secretary of War Robert Lincoln, on the contrary, said he entirely agreed with the Academy's recommendation that the Meteorological Service be transferred to a civil bureau. Military signaling, he said, was now being done by the Army without the slightest assistance from the Signal Corps.

Superintendent Hilgard of the Coast and Geodetic Survey testified that the existing relations between the Coast Survey and the Navy were working smoothly, efficiently, and economically, and he saw no reason for a change. The plan had satisfactorily stood the test of time. There was no lack of coordination between the work of the Geological Survey and that of the Coast Survey in the interior of the country, nor was there duplication of work or useless expenditure, because of the willing cooperation of the two chiefs. However, he said, it was obvious that the functions of the two organizations should be clearly defined and that the mode in which their operations were to be coordinated should be firmly established.

Hilgard told the Allison Commission: "I do not like to have the work of the Coast and Geodetic Survey considered in the light of what you properly call scientific. I consider that it is economic, of practical value. I consider that we are not fomenting science, but that we are doing practical work for practical purposes, though some science comes of it. A great deal of high science comes into requisition and is incidentally advanced by it, such as the general figure and size of the earth, its density, magnetism, tides, and so on, but I expect to follow out our work in a way that will tend to public usefulness. That is what I take as the reasons for its existence. I consider the Coast and Geodetic Survey instituted to meet a public want and not as work so strictly scientific as paleontology or something of that kind."

Hilgard said:

> To this end, I am now, as I have always been, frankly in favor of the plan submitted by the Academy to Congress in 1878, according to which the Coast and Geodetic Survey should be transferred to the Interior Department, 'retaining its original field of operations, and assuming also, the entire mensuration of the public domain,' and to be known hereafter as the Coast and Interior Survey. I see no objection on the part of the Coast and Geodetic Survey to such transfer to another civil department, provided its present scope is preserved, and there is added to its functions the gradual execution of a trigonometrical network over the whole country (as a basis for all economic or property surveys and maps), and likewise all accurate topographic surveys.

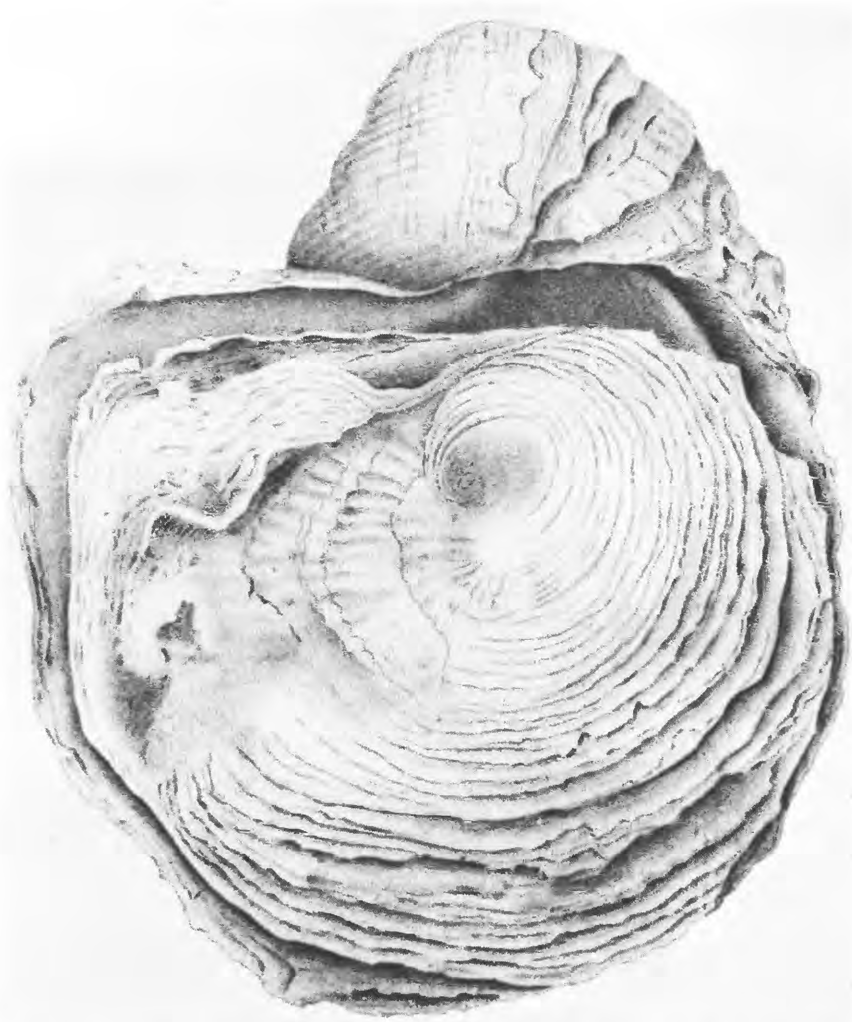
Powell came back to argue against the transfer of the Geological Survey's topographic work to the Coast and Geodetic Survey. The maps of the Coast Survey were very elaborate and represented a vast system of cultural details; they were very expensive, and they were also difficult to understand. The geological organizations of the Government had invented new methods of surveying and new methods of presenting the results on maps, so that now the maps could be more easily understood by geologists, engineers, and the common people. He said,

> The experience in the United States, up to the present time, warrants this statement, that if the topography is kept under the control of geologists it will be executed better and at less expense than if placed under some other organization.

Moreover, geologic problems did not appear in some systematic geographic order, as from east to west or north to south, but in a geologic order, and geologic problems had to be taken up in the order demanded by that science. Unless the Geological Survey could conduct its topographic work according to its own needs, its work would be greatly hampered.

F. V. Hayden and A. C. Peale returned to the Three Forks region of Montana in 1884, where Peale and W. H. Holmes had made a reconnaissance as members of the Hayden survey in 1871 and 1872. The area was believed to contain Archean rocks, but Hayden and Peale found many fossils, which C. D. Walcott identified as Upper Devonian, in shaly beds, which are easily eroded and usually marked by a ravine between two belts of limestone. (From A. C. Peale, 1893.)

Powell was called back early in January 1885 to elaborate on this testimony, and told the Allison Commission that he was unable to state any useful purpose which the cadastral or artificial element in the coast charts subserved first because it was not executed so as to form a complete cadastral map and second because the artificial topographic features were ephemeral and changed from year to year in such a manner that the charts speedily became misleading. The topographic maps made by the Geological Survey, on the other hand, represented natural features, such as streams and bodies of water, valleys, hills, and mountains and showed only certain cultural features such as important highways, canals, railroads, and wagonroads, the sites of cities, towns, villages, and railway stations. The purposes served by such topographic maps were many. They were used first of all as bases for geologic maps. They could be used for the purposes of the Signal Service and for all purposes of military maps except battle maps. They were valuable to cities and towns in securing a proper supply of water. As the maps were constructed with grade curves and every elevation and depression was represented "with mathematic accuracy," they could be used in laying out the courses of aqueducts and in planning and protecting waterworks so that the catchment areas would not be "corrupted by foul and pestilential agencies." The maps showed the relative levels of all parts of the country to each other and to the level of mean tide, so they could be used to determine the possibility and practicability of draining marsh- and swamplands. They were useful in planning and laying out highways, such as wagonroads, canals, and railroads. In conjunction with geologic maps, they could be used for determining the sites of artesian wells. The topographic maps were of the highest importance in areas where agriculture was dependent on artificial irrigation and streams had to be conducted from their natural channels by canals. As an illustration, he said that every town in Utah had been moved, perhaps twice on an average, after it had been built, when it was found that the water could not be economically brought to it or economically controlled. The studies that he had made of topographic methods and of the economics of topographic surveys grew out of his interest in these arid lands,



While the Allison Commission was in progress, the Geological Survey published 2 annual reports, 3 monographs, and 17 bulletins, a total of more than 3,500 pages on scientific and technical subjects. Monograph 9 on the fossil Brachiopoda and Lamellibranchiata of the Raritan clays and greensand marls of New Jersey was a reprint of a New Jersey Survey publication. The fossils came from a limited district in the United States, but one that had been studied longer than any other so that it was a classic ground for all American geologists. (From R. P. Whitfield, 1885.)

for he found in traveling through that region the people were searching for an economic but simple and practical means of learning how the streams could be utilized. The topographic map would have a high value in furnishing data to engineers to make plans for protecting the flood plains, the parts of the country that were annually or occasionally inundated by the great rivers. The flood plain of the Mississippi, could it be properly protected from inundation, would be one of the most fertile districts in the United States. The great floods of the lower Mississippi had their chief, though not their whole, origin in the Missouri River and its western tributaries, and the floods of these streams came from the melting of the snow in the Rocky Mountains in the spring and early summer. If the waters that resulted therefrom could be taken out of their natural channels and poured out on the arid plains and used in the irrigation of lands that were practically deserts, the relief from floods thus afforded to the lower valley of the Mississippi would in large part redeem these valuable lands, and at the same time, would redeem twice as large an area in the great plains. The maps were also used by local surveyors, for general information, in the schools and for a variety of scientific purposes by naturalists, ethnologists, and archeologists. In fact, it was impossible in a reasonable space to set forth all the purposes subserved by the maps made by the Geological Survey. The coast charts of the Coast and Geodetic Survey did not subserve these purposes because they were constructed on another plan and for another purpose.

Powell's final statement to the Allison Commission was "that the map can be completed on the present plan, with the present organization, within twenty-four years, but the demands for such a map are so urgent that the work ought properly to be completed in a shorter period. Since the organization of the Geological Survey, Congress has, by increased appropriations, expanded its work from year to year, and the Director has earnestly desired and hoped that this growth would continue, so that a map of the whole country could be completed by the year 1900, and he has steadily and vigorously worked to that end. He has tried hard to develop a plan which should not be impracticable on account of excessive cost and which should not be without substantial value by reason of imperfect methods and results. He has also endeavored to develop the plan in such a manner that no work would be lost, even though the needs of the distant future should demand more elaborate work than the wants of the present time, and that all work done should have enduring value."

The Allison Commission did not complete its investigation in the short session that ended on March 4, 1885, so permission was sought and obtained to continue the hearings in the new Congress. By his testimony in the first year, Major Powell had established himself as one of the leading scientists in Washington, and his testimony was reprinted in *Science* and given wide circulation.

The plan for the topographic surveying and cartographic systems described to the Allison Commission was formally announced in the Survey's next annual report. Map sheets would be published at three scales, 1:62,500, 1:125,000, and 1:250,000, the choice of scale depending on the present or prospective density of settlement, the economic importance of the area, the complexity of the geology, and the degree of detail in the topography. Relief would be shown in contours with vertical intervals of 10, 20, 50, 100, or 200 feet, depending on the scale of the map and the magnitude of the relief. On the 1:250,000 scale, the maps would be engraved in sheets, 1° square, designated by the latitude and longitude of the southeast corner, as, for example, 40–100. On the 1:62,500 scale, 16 sheets would be required for the same area and the designation then became a bit complex, as, for example, 40–100 SE¼ of the SE¼. The sheets were to be engraved on copper, with three plates for each—the hydrography in blue, the hypsography in brown, and the projection lines, lettering, and culture in black. A prime consideration in developing the systems, the Director said in the announcement, was that "the map once constructed should be enduring, that the expense of frequent resurveys may be avoided."

The topographic work had been reorganized into three divisions: an astronomic and computing division, a triangulation division, and a topographic division; in turn the topographic division was organized into parties that worked in various parts of the United States. During the summer of 1885, mapping continued in Massachusetts, New Jersey, the southern Appalachians, Kansas, Missouri, Texas, Arizona, the Cascade Range, and Yellowstone National Park. Work was begun in the area around the District of Columbia and in the Gold Belt of California where Becker planned to work next.

In the Division of Volcanic Geology, Dutton and Diller hoped to be able to put most of the geology of the Lassen Peak area on photographic copies of the topographic maps that included Lassen Peak and the area immediately to the west. The maps, however, were found to be wholly unsuited for geologic work, so Dutton left Diller to make the best of it and went off to make a reconnaissance of the Cascade Range and its relation to the Sierra Nevada and Coast Ranges in the light of Becker's conclusions.

Gilbert had divided the work in the Appalachian Division into three parts: an investigation of the structure and stratigraphy of the folded Paleozoic rocks immediately west of the Archean belt, a study of the Triassic formations, and a study of the Tertiary and Quaternary history of the district. The last he reserved for himself, and during the summer of 1885, he spent 6 weeks investigating the former extent of Lake Ontario and then joined Professor Chamberlin in a study of the terrace system of the Monongahela, Allegheny, and Ohio Rivers, covering much of the ground over which McGee had traveled the summer before.

The study of the Triassic was assigned to I. C. Russell, but one season in the field convinced Russell that the work could not be done until better maps were available, so the Triassic work was temporarily discontinued. For the Paleozoic work, Gilbert planned that four sections crossing the Appalachians at right angles would be studied: one within the basin of the Potomac; one including portions of the Greenbrier and New Rivers in West Virginia and Virginia; the third in eastern Tennessee, crossing the Holston and including part of the French Broad River; and the fourth in Alabama, crossing Coosa Valley at latitude 34°. During the summer of 1885, Geiger was assigned to the Potomac section and Bailey Willis, to the French Broad, but work was not begun in the other sections. In addition to these studies, Professor I. C. White was asked to prepare a comprehensive review of the sedimentary structure of the Appalachian coalfield in West Virginia, western Pennsylvania, and eastern Ohio, which he had been studying for several years both as professor at the University of West Virginia and assistant on the Pennsylvania Survey.

In the Archean Division, Pumpelly and his assistants spent most of the 1885 field season studying the structure of the Green Mountains, which, Pumpelly was convinced, contained the key to the geology of New England. Irving and the Lake Superior Division were occupied with petrographic studies. Professor G. H. Williams of Johns Hopkins had been added to the staff on a part-time basis, and he and Van Hise were tracing the development of the chloritic and mica schists by metasomatic alteration. Although a large part of the records and samples had been lost in a disastrous fire in December 1884, the work was beginning to produce results. The studies of the Penokee-Gogebic region were essentially complete, and the general geological structure of northern and northeastern Minnesota had been satisfactorily determined. The ferruginous schists of the Lake Superior region and their accompanying iron ores were reported with some confidence "to have arisen in the main from the silicification of ferruginous carbonates, which were, in some measure, analogous to those of the Coal Measures." The conclusion that the Archean formations were divisible into two discordant members was confirmed.

The work in glacial geology in 1885 was described as related to the classification of soils with respect to their agricultural capabilities. The principal project was a reconnaissance of the drift margin from near Bismarck in Dakota Territory through largely unsettled territory to the international boundary line at the foot of the Rocky Mountains by Professors Chamberlin and Salisbury. At the end of the season, Chamberlin continued on to study glacial phenomena in western Montana, northern Idaho, and northern Washington. During part of the year, Warren Upham of the Minnesota Survey also joined the U.S. Survey to continue a study of former Lake Agassiz, which was practically equivalent to the basin of the Red River of the North.

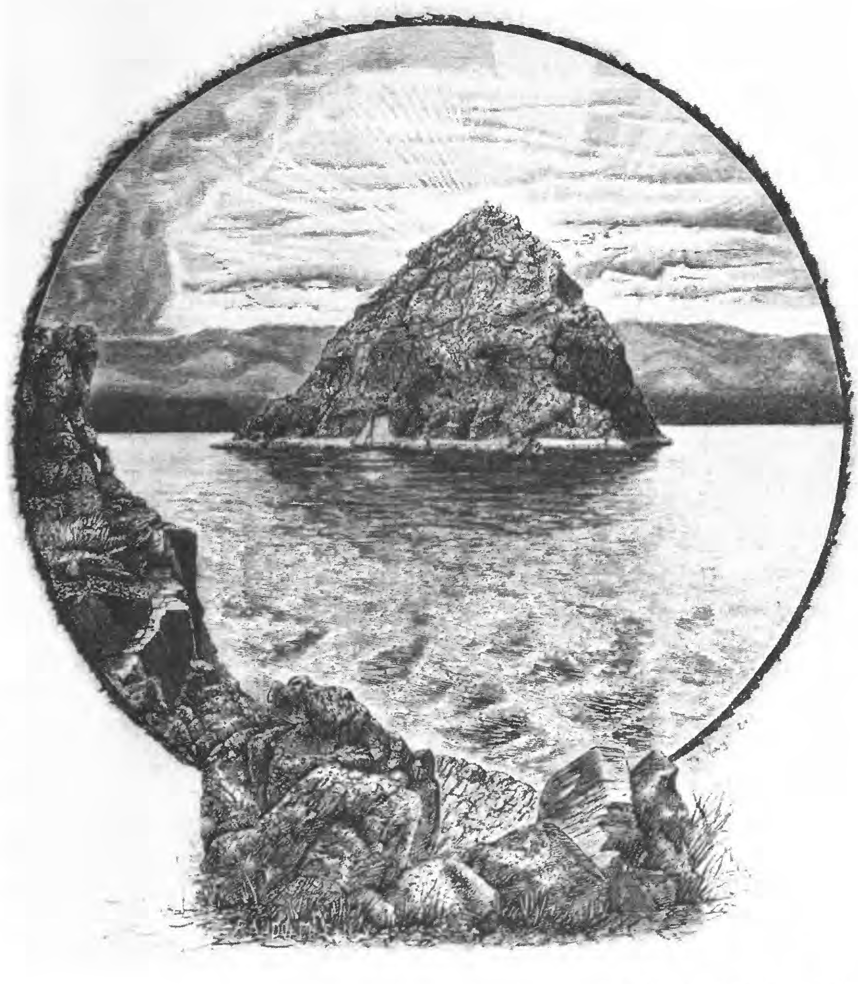
Professor Shaler's investigations in the Atlantic Coastal Plain Division were described as being made to guide engineering operations for the reclamation of what might be the most valuable of all agricultural lands, the

Monograph 10 was Professor Marsh's long-awaited report on Dinocerata. Among the many extinct animals discovered in the Tertiary of the Rocky Mountain region, none, said Professor Marsh, were more remarkable than the huge mammals of the order Dinocerata, whose remains had been found in the single Eocene lake basin in Wyoming and nowhere else. The skull of *Dinoceras mirabile*, the type of the genus *Dinoceras* on which the order was based, was exceptionally well preserved. (From O. C. Marsh, 1886.)

inundated lands along the coast. Shaler mapped glacial deposits and studied changes of sea level on the islands of Nantucket and Marthas Vineyard and in Maine and found that the front of the ice during the last glacial advance had remained for some time over Nantucket; the region had been suddenly elevated above sea level after the disappearance of the ice but had since been depressed 20 feet or more.

Hague and a large entourage, including Iddings, Weed, Wright, Davis, and S. L. Penfield of the Sheffield Scientific School as a volunteer assistant, spent the summer in Yellowstone National Park. A committee of the House of Representatives visited the park to investigate its condition and to consider what legislation was needed; Hague presented to them his views on the necessity for enlarging the park and on the great importance of the region as a forest reservation. Hague also advised the special agent sent by the Secretary to examine the park on the changes necessary to ensure its efficient administration. Hayden and Peale again worked in the area north of the park, extending their previous season's work in the Gallatin Valley.

In the paleontologic divisions, Professor Marsh continued the systematic collection of vertebrate fossils in the West. Walcott's division had several studies of the Paleozoic underway, and C. A. White with R. T. Hill as his assistant was studying the stratigraphy and paleontology of the later Cretaceous and earlier Tertiary formations of Utah. Dall did not go into the field, being busy with referred collections. Lester Ward accompanied two expeditions, both of which had for their object the study of the Potomac



Monograph 11 recorded the geological history of an ancient water body in northwestern Nevada, Lake Lahontan. Pyramid Lake is a recent freshwater lake that covers part of the site of the ancient lake. Pyramid Island in that lake has fascinated all explorers since Frémont who named it for its resemblance to the pyramids of Egypt. This romantic sketch was made by adding the sailboat and the setting sun to a photograph by I. C. Russell. (From I. C. Russell, 1885.)

formation. One new man, constituting a new division, was added to the organization: S. H. Scudder, the editor of *Science*, began a study of insects from the peat deposits of Nantucket, and the Division of Fossil Insects was thereby established.

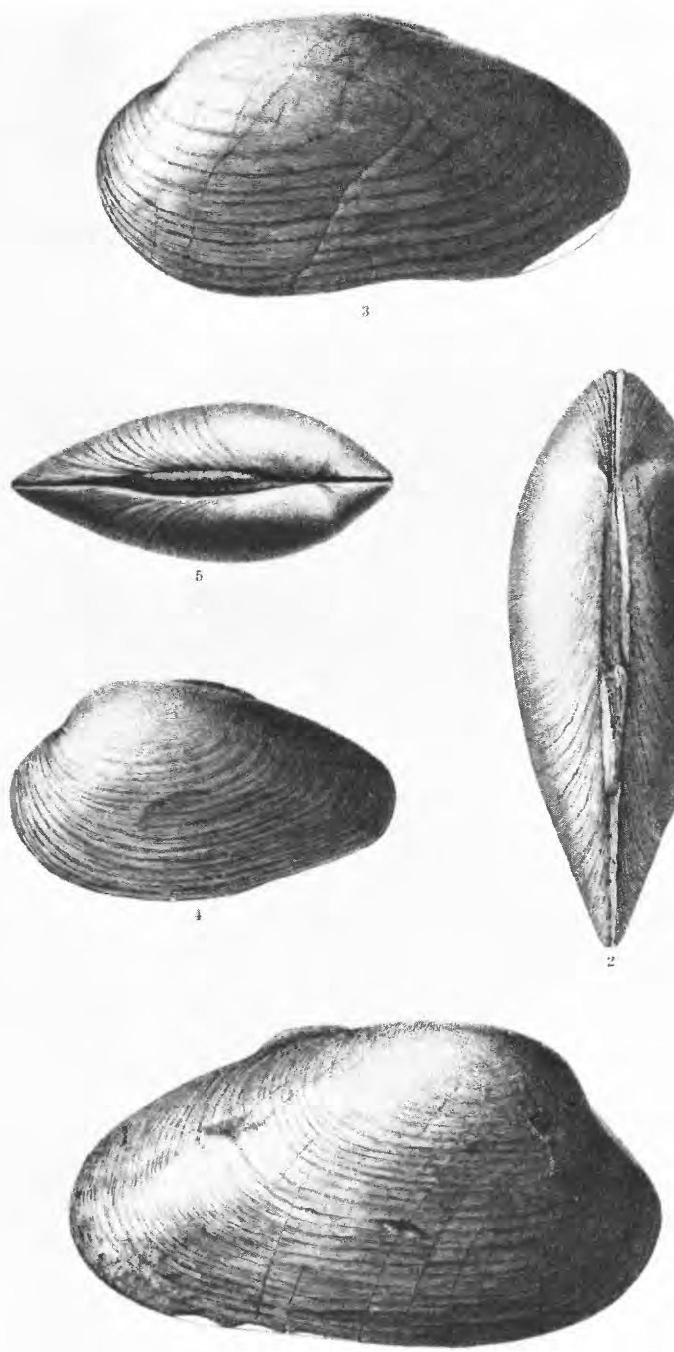
Another new division was added to the table of organization, the Geologic Map Division, and McGee and Stanley-Brown were assigned to it in the plan of operations. McGee, however, spent comparatively little time on the map, and Stanley-Brown left in September to begin the study of geology at Yale. McGee was sent to Berlin in September to present a discussion to the International Geological Congress of the principles of geologic taxonomy and cartography as developed in the Survey; unfortunately he arrived late and was unable to present the paper, as it was written in English rather than French, the official language of the congress.

McGee's geologic investigation of the District of Columbia was still awaiting completion of the topographic map, but he continued to collect photographs and specimens and to examine "evanescent exposures." During part of the summer, he accompanied Lester Ward and Professor W. M. Fontaine in a study of the Potomac formation in eastern Virginia and central Maryland, where it was practically destitute of organic remains. Even though the formation had a unique flora in the area north and south of Washington, its correlation with formations elsewhere had so far been found impossible. McGee, however, had come to the conclusion that it was Cretaceous in age, basing his conclusion on an investigation of physical relations of land and sea when the formation was deposited.

McGee also spent part of the year revising a manuscript by E. A. Smith, the State Geologist of Alabama, and L. C. Johnson on the Tertiary and Cretaceous strata of the Tuscaloosa, Tombigbee, and Alabama Rivers. One of the formations described in their report was a series of peculiar sands, clays, and gravels, in which no fossils had been found, typically exposed on the Tuscaloosa River near the city of Tuscaloosa. McGee suggested that it be named the Tuscaloosa formation and stated that the description corresponded so closely to that of the Potomac formation "as to suggest like conditions of genesis and (the stratigraphic relations being identical) presumptive chronologic equivalence of these formations." He therefore elaborated the portion of Smith and Johnson's report relating to the Tuscaloosa formation in accordance with his hypothesis on the Potomac formation and returned the manuscript to the senior author with directions to test the hypothesis in the field and either disprove or corroborate it by additional observation and study. Smith was a dozen years older than young McGee. He had a Ph.D. from Heidelberg, and he had been State Geologist of Alabama since 1873. He was also one of the more sensitive State Geologists. Less than 2 years before, he had protested that the Federal survey was intruding upon the work of the State survey, and it had taken a personal letter and a meeting with the Director to soothe his feelings. McGee's review of his work did not improve matters.

The work in mining geology in California was very different from that in Colorado as Becker's mathematical bent led him into new areas of investigation. He completed the field studies for the quicksilver investigation and began preparation of a monograph with the assistance of Melville, Turner, and Waldemar Lindgren, a young graduate of Freiberg who had joined his staff in November 1884. His notes on the stratigraphy of California led him to consider the fundamental shape of volcanic cones; on the premise that additions were made at or near the top and that the cone would constantly tend to the loftiest form that the amount of material it contained could assume consistent with stability, he found that he could determine

Among the bulletins were several on paleontology. C. A. White prepared a general discussion of all freshwater invertebrates yet discovered in North American Jurassic strata. All specimens of *Unio* found, including that of *Unio felchii,* belonged to the simpler types, which had unornamented surfaces and departed but little from the transversely oval shape common among both living and fossil species in other parts of the world. A considerable part of the Laramie species, however, were of distinctively North American types. (From C. A. White, 1886.)



mathematically the form that would coincide with surveys and photographs of actual cones in America and Japan. He also investigated the mechanical conditions of faulting, showing that the results he reached in an analysis of the faulting of the Comstock were necessary deductions from the nature of friction, and that frictional problems were part of the general problem of elasticity. Chemical questions involved in the quicksilver investigation led him to a new law of mechanics, which he called a "theorem of maximum dissipativity." The chemical interpretation of the law, Becker said, meant that chemical energy would be degraded at the highest possible rate, and this would affect the order of succession of minerals in volcanic rocks.

Emmons was allowed no fieldwork in the summer of 1885, being instructed to remain in the office to attend to the preparation of reports.

Eldridge and Cross were able to work in the Crested Butte region of Colorado until late October when snow made the work impracticable. Eldridge then began mapping the Denver Basin while Cross, Hillebrand, and Eakins carried on several interesting mineral investigations, the results of which were published in scientific periodicals. On November 1, however, Hillebrand was transferred to Washington, and he was thereafter occupied chiefly in routine work in the chemical laboratory.

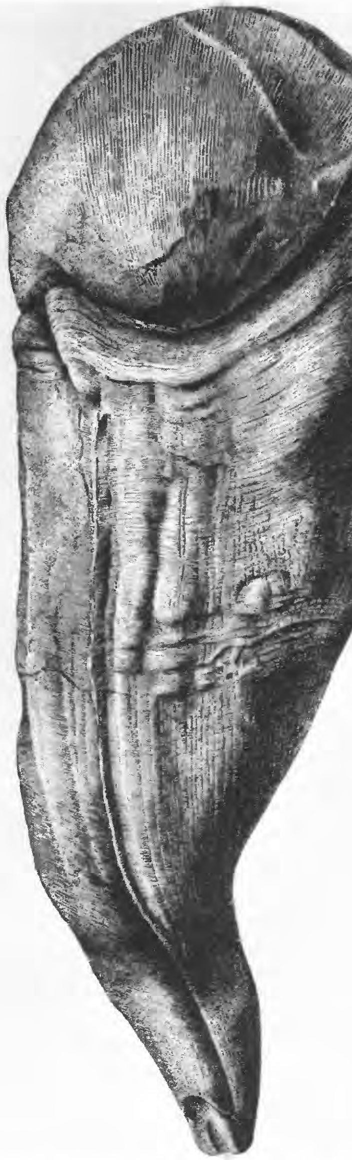
Williams completed the volume *Mineral resources of the United States 1883–1884* which was finally published in December 1885. The *Engineering and Mining Journal* complained that,

> Anything that is worth doing at all is worth doing well, and every intelligent man must recognize the immense importance and value to the country of full and accurate reports of our mineral production. That the report is disappointing, both in the date of its issue and in the incompleteness of the information it gives, is painfully apparent, and it must be especially discouraging to Mr. Williams, whose herculean efforts, though they have accomplished much, have not been able to effect the impossible. That this most important department, whose work has perhaps a more immediate measurable commercial value than that of any other portion of our Geological or Scientific Survey, should be so neglected and starved, is a blunder that has not been explained, and as far as we know can not be justified.

This was a direct challenge to Major Powell's direction of the Survey, but it was not the first, for both the political and scientific climates had changed markedly since the inauguration of Grover Cleveland on March 4, 1885.

Cleveland had faced special problems in forming his Cabinet. The only Democrats with political experience, except a few Governors, were in Congress, and he could not afford to weaken the party in Congress by removing too many. Yet he was determined to have the Cabinet represent all sections of the country and all factions of the party. In the end, he chose three conservatives, two Southerners, and two from the reform wing of the party. Senator Lucius Quintus Cincinnatus Lamar of Mississippi, one of the two Southerners, became the Secretary of the Interior. Lamar was a scholar and had been at various times professor of mathematics, political economy, and law in the University of Mississippi. He had drafted Mississippi's ordinance of secession and had served in the Confederate Army, but after the war had distinguished himself as a champion of reconciliation. From the reform wing of the party, Cleveland chose William F. Vilas of Wisconsin for Postmaster General. Vilas had a distinguished war record, on the Union side, and had been a professor of law at the University of Wisconsin. Before the end of Cleveland's first Administration, he succeeded Lamar as Secretary of the Interior.

Cleveland was also faced with the problem of patronage. He had been backed by the Independent Republicans, including Carl Schurz, who valued civil service reform above party loyalty. In response to a letter from the National Civil Service Reform League, he issued a public reply in December that he believed in the new Civil Service law and had repeatedly promised to enforce it. He would not only enforce the terms of the law but would observe its spirit in dealing with employees who were not within the letter of the statute but so far removed from the policy of the Administration that they should not be replaced on partisan grounds. Efficient employees would be kept and only inefficient employees, offensive partisans, and unscrupulous manipulators of local politics would be removed. Of the approximately 126,000 Federal employees, however, only 16,000 were as yet under Civil Service, and there was a horde of hungry officeseekers. Despite Cleveland's statement on civil service, the demands for offices persisted, and in the spring, there were rumors of many changes. Among the rumors were several



C. A. White also found that some fossils collected by C. R. Orcutt of San Diego at Todos Santos Bay, 60 miles south of the southern boundary of the State of California, indicated a fauna of decidedly Cretaceous character but quite different from any other Cretaceous fauna known on the Pacific coast. Among them, he identified a new species, *Coralliochama orcutti*. (From C. A. White, 1885.)

stories that Powell would be replaced. Once such even named Shaler as his successor. Shaler, however, wrote to his sister that "Nothing could induce me to take the place of Director U.S. Geological Survey. As Hosea Bigelow says, 'Taint a knowin' kind of cattle that is ketched with mouldy corn.' "

The first great task that Cleveland wanted to undertake was the reform of the executive departments, which he believed had grown lax and inefficient under a quarter of a century of uninterrupted Republican administrations. Cleveland thought that general administrative reform was more important than civil service reform. Good government was the main object, civil service reform a means to that end. The first meetings of the Cabinet were devoted almost entirely to departmental reform. The Treasury and Navy Departments seemed particularly open to reform, but the Interior Department, with its responsibility for the public domain and the Indians, was not far behind.

Within 3 weeks after entering office, the Secretary of the Treasury appointed a commission under the Assistant Secretary to investigate the whole Department and recommend means of placing it on a business basis. The greatest public attention was given to the Navy Department which was in the midst of a transition from old to new methods and equipment, and a complete reorganization was undertaken.

In the Interior Department, Secretary Lamar was not overly fond of administration but was aided by very capable assistants. His First Assistant Secretary was Henry L. Muldrow, whose committee assignments in Congress had given him an insight into Interior affairs. The new Commissioner of the General Land Office was William Andrew Jackson Sparks, also a former member of Congress and a born crusader. Former Congressman John D. C. Atkins of Tennessee became the new head of the Indian Bureau. Within 60 days after the new team took over, orders disposing of public or Indian lands issued in the last days of the Arthur Administration were countermanded, and in midsummer, cattlemen were ordered to remove their cattle from Indian Territory.

Early in August, 1885, the Treasury investigators appointed under Cleveland's plan for departmental reform released their report. Some irregularities had been found in the Coast and Geodetic Survey, and Superintendent Hilgard had been dismissed. The report was critical of the work of this Survey, much of which it considered expensive and of little value. The August 14 issue of *Science* contained a three-page editorial that was, in turn, highly critical of the contents of the report and the manner in which the news of it was released. It might have been more reasonable, *Science* suggested, to allow Hilgard to retire, inasmuch as he was ill, in pain, and had served faithfully and well for more than 40 years. C. S. Peirce, whose work on gravity was one of the projects the Treasury investigators deemed of meager value and too expensive, promptly resigned with less temperate remarks for all to read.

The American Association for the Advancement of Science at its August 1885 meeting passed a resolution that although it was "in earnest sympathy" with the Government in its intent to secure the greatest possible efficiency of the public service, the value of scientific work could be best judged by scientific men. The AAAS expressed its "earnest approval" of the extent and high character of the work of the Coast Survey and stated that the head of the Coast Survey should have the highest possible standing among scientific men and should command their entire confidence.

Early in September, Professor Alexander Agassiz of Harvard, in a long comment on an article in the *New York Evening Post* on "political scientists," said that "a committee of treasury experts, however competent to judge business methods, cannot be expected to know the value of the scientific work upon which, from their point of view, money has been squandered." Professor Agassiz further complained that men of science were being left out of the decisionmaking. The National Academy of Sciences had tried to reorganize the scientific bureaus so that the evils of the system might be remedied, but the Academy had been largely ignored, and officials had been appointed without their advice. The Allison Commission had accomplished nothing.

Professor Agassiz concluded by saying, "While criticizing the article of the Evening Post, so far as it related to the Coast-Survey, let me express my complete agreement with its condemnation of the 'political scientist.' It is time that the system thus attacked should be abandoned, and that indiscriminate scientific assistance given by the heads of bureaus to institutions and individuals, and never contemplated or sanctioned by Congress, should be discontinued. It has brought nothing but discredit upon the official science of the country. Let the most liberal appropriations be made for the work of our scientific bureaus, but let the requisition be so complete and detailed as to invite a fair and open criticism."

The last undoubtedly referred to the Geological Survey and its lump-sum appropriation, which the Director could spend as he chose. Professor Agassiz, who had personal and family interest in mining enterprises and the Museum of Comparative Zoology at Harvard University, knew as well as anyone that while the Secretary of the Interior was emphasizing mining geology in his reports to Congress on the Geological Survey, most of the funds were being spent on general geology, paleontology, and topography and that the work of several professors, Harvard professors included, was being aided by the Geological Survey.

The *Boston Advertiser* on September 25, 1885, published a story that a report had been issued on the mismanagement of the Geological Survey, but the Department of the Interior denied that any such report existed. The stories persisted, however, and Powell was accused of extravagance, of unduly influencing the National Academy of Sciences, and of patronage of favored members of the scientific community. In October, Fred Endlich, formerly a member of the Hayden survey and one of Professor Cope's associates wrote to former members of the Hayden survey asking for information to add fuel to the fire, and early in November, Major Powell wrote a long denial of the various charges for Secretary Lamar.

The grounds on which some of the inferences had been drawn were easily determined. It was clearly an exaggeration to say that Powell had packed the National Academy of Sciences with his own supporters when only three members of the Survey had been elected, but two of the three were those closest to him, Gilbert in 1883, and Dutton in 1884. The charge of patronage of favored members of the scientific community stemmed from the employment of professors during part of the year, although a ruling by the Treasury Department required that they be rated in terms of an annual salary.

In 1883, after the force had been organized in accordance with the requirements of the Sundry Civil Expenses Act, the Survey had two classes of employees, permanent, or those in the statutory positions, and temporary. The temporary employees included young men on trial, as well as professors who worked for the Survey for short periods, those who worked during the field season as cooks, teamsters, and so on, and copyists and others who assisted the scientists during the office season. By 1885, however, three types of appointments were in use. Scientific employees were selected by the Director, subject only to approval of the Secretary of the Interior, exclusively

Much attention had been given to the finer subdivision of the Devonian on strictly paleontological evidence. John M. Clarke of New York had had an unusual opportunity to study the Devonian fauna of Ontario Country, New York, the results of which the Survey published. The figure shown is a reproduction of the lower right mandible of *Dinicthys newberryi*, which he described as a sort of monstrous fish. (From J. M. Clarke, 1885.)

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for their professional qualifications, if these scientists had established a reputation. In asking for their appointment, the Director stated his reasons, the work in which the person was to be employed, together with his qualifications, especially his published works, and the Secretary invariably made the appointment. Young men who had not established a reputation in scientific research were selected through the agency of the Civil Service Commission by special examination, the papers for which were prepared in the Survey. The remaining employees, about half of the staff, were temporary, being engaged for services lasting for a few days or a few months only, largely in the field, and coming under two classes: skilled laborers and common laborers. The temporary employees were employed by the Director or by the heads of divisions and discharged when no longer needed.

When the new Congress met in December 1885 and the Allison Commission reconvened, Senator John T. Morgan, Democrat of Alabama, and Representative John T. Wait, Republican of Connecticut, replaced Senator Pendleton and Congressman Lyman, who had not been reelected. Attention was focused on the Coast and Geodetic Survey. President Cleveland in his state of the Union message alluded to the "irregularities" which had been found and said: "This service has never been regulated by anything but the most indefinite legal enactments and the most unsatisfactory rules. It was many years ago sanctioned apparently for a purpose regarded as temporary and related to a survey of our coast. Having gained a place in the appropriations made by Congress, it has gradually taken to itself powers and objects not contemplated in its creation, and extended its operations, until it sadly needs legislative attention. So far as a further survey of our coast is concerned, there seems to be a propriety in transferring it to the Navy Department. The other duties now in charge of this establishment, if they cannot be profitably be attached to some existing Department or other bureau, should be prosecuted under a law exactly defining their scope and purpose, and with a careful discrimination between the scientific inquiries which may properly be assumed by the Government and those which should be undertaken by State authority or by individual enterprise."

President Cleveland had offered the position of Superintendent of the Coast and Geodetic Survey to Professor Agassiz, who had declined for reasons of health and also because he believed the Superintendent should be not just a scientist but one expert in the Survey's field. The head of the Treasury team that investigated the Coast Survey was then placed in charge. The Coast Survey assistants held a meeting, and a committee of three was appointed to protest the transfer or dismemberment of the service. Before Congress convened, Professor Agassiz with Messrs. B. A. Colonna, Boutelle, and Hergesheimer of the Coast Survey met with Congressman Herbert for a discussion of the Coast Survey's position and its work and scientific accomplishments. The discussion prompted Mr. Herbert to write to Professor Agassiz on November 27, 1885, asking about the work of the Geological Survey. It seemed to him that Major Powell was transcending the rule that Agassiz had laid down about the Government's role in science, and he asked specifically about the various studies of the Comstock lode, about paleontology, and about topography. Mr. Herbert's interest may have been aroused by the many newspaper stories, but the specific nature of his inquiries suggests a more authoritative source, and it must be noted that the State Geologist of Alabama was no friend of the Geological Survey and was associated with Professor Cope, a member of the American Committee of the International Congress of Geologists.

Professor Agassiz replied promptly on December 2; he was getting ready to leave for Egypt for the winter. Private individuals had learned nothing from the works on the Comstock, and the scope of the investigations on the mining industries of Comstock, Eureka, and Leadville were all such as seemed to him to fall within the limits of individual investigation. There was no more reason why the Government should publish a history of the mining enterprises of the country than that they should publish a history of manufacturing processes. All that was in the province of private historians. The methods of publication adopted by the various bureaus, the mode of distribution, and the size of the editions were all wasteful and extravagant. Paleontology was one of those things that private individuals and learned societies could do just as well as the Government. They would, in fact, do it more cheaply. There were people in the universities who would do it and get the gist of their results published by scientific societies to which they belonged. As for topography, a geologic map without it was impossible, but if the States did not want a topographic map enough to pay for it, it seemed plain that they did not want the Government to pay for it either.

Agassiz was more concerned about the Coast and Geodetic Survey, and on the next day dashed off another letter about its contributions to zoology, which had begun in 1849 when Superintendent Bache had invited his father, Louis Agassiz, to join the Coast Survey schooner and make some dredgings off Cape Cod. His own work, beginning in 1877 when Superintendent Patterson asked him to take charge of some oceanographic work, had also produced valuable results. Professor Agassiz's reply taken at face value was the quintessence of laissez faire—the Government should in no way do any scientific work that could be done by individuals except when it provides aid to my work.

On December 16, there appeared before the Allison Commission four gentlemen from the Coast and Geodetic Survey to present their case against its dismemberment. On the morning of the 19th, B. A. Colonna, the Assistant in Charge of Office of the Coast Survey, and Director Powell argued the merits of the topographic work of the respective surveys. Mr. Colonna said that the topographic work of the Geological Survey cost little, and its worth was commensurate with its cost. Major Powell countered that the work of the Coast Survey was so expensive and its maps on such a large scale and so detailed that they would have to be done over every few years.

On the afternoon of the 19th, without making any reference to the Agassiz letter, Congressman Herbert questioned Director Powell about the various reports on the Comstock. Powell answered that Becker's work could not have been done by a private individual because no private individual could have afforded the expense of the paleontologic and chemical laboratories and the various experts. His answer applied to Becker's later work on the quicksilver deposits of the Pacific slope but not to his report on the Comstock, which was based chiefly on microscopic petrography. Pressed about Eliot Lord's report on *Comstock mining and miners*, Powell reluctantly admitted, "I should not have inaugurated the work." Lord's work, of course, had been done under the Tenth Census appropriation. The Geological Survey had been responsible only for its publication.

Mr. Herbert was curious about a recent publication on copper metallurgy in *Mineral Resources of the United States.* Could not that work have been done just as well by individuals as by the Government? And what relation did it have to geology? Major Powell explained that the publication was intended to add to the general knowledge, and that copper ores throughout the country might be better utilized if the information were available. Mr. Herbert did not doubt the usefulness of the information, but he wondered why the Geological Survey should do such work and if that might be one reason why the appropriations had increased so rapidly. Major Powell explained that the short papers on metallurgy were part of the investigations on mineral resources and cost perhaps $1,500 to $2,000 a year. In fact, in the tabulated account of Survey expenses which the Allison Commission had before them, James Douglas, the leading copper metallurgist in the country, was recorded as having received $86.40 for preparation of the article.

Senator Morgan took over the questioning and led the Director to say that there were large copper ore bodies in the Territories and that the information on metallurgy would be for the benefit of the public. He asked about work on iron metallurgy and learned about chemical analyses of iron ores to determine their availability for steel manufacture. He asked about discoveries on borax, soda, and petroleum. The Director said that the quantities of petroleum in the United States were enormous, with no possibility of exhaustion within any reasonable length of time, but the difficulty was that only a very small percent of the petroleum could be used. Senator Morgan asked, "Suppose you could use it as economically as coal or other fuel, would that be important to this country?" The Director replied, "It would be of the utmost importance." Senator Morgan asked about fertilizers, about the usefulness of topography in forest conservation and flood prevention. He was interested in Major Powell's idea that floods on the lower Mississippi could be relieved by diverting the water in the upper streams, and the Director was given a chance to expatiate on a subject in which he was deeply interested. There was a lively exchange about the cost of dams for such purposes, a subject which the Director thought would most likely be found in the reports of the Engineers.

Finally, Mr. Herbert broke in: "You have spoken, in reply to Senator Morgan, of the usefulness of the work under you, which, of course, is not denied. I think nobody denies the usefulness of geological investigations." However, he went on to ask whether these discoveries had not been made by parties in the field, aided by the work in the laboratories, and had not all the topographic work, map making, and bookmaking been simply to illustrate and locate the discoveries? Would not the geologic work and the laboratory work be sufficient?

The Director explained that the maps were necessary. The facts discovered could not be conveyed to the public without the maps, and the maps were necessary to the geologist as part of his means of investigation. Then he asked permission to go on to say a word about the practical economic results that flowed from scientific research.

> There are many investigations that may not at first seem to lead to economic results, but ultimately and indirectly are of importance even for economic purposes. The scientific man, especially the geologist has to do with a vast complexity of problems. To select a part of these problems and work upon them may not lead to substantial results when other problems are neglected that have relation to the first. The whole body of research in geology has a very important practical value, because geologic investigation reveals the wealth buried beneath the surface of the earth. Sound geologic conclusions cannot be reached by following a few narrow lines of investigation, but all such lines of research must be followed that each may shed light upon the other. Unless this principle is fully recognized, a geologic survey might lead to conclusions of no value to the people at large, or conclusions might be reached so erroneous as to be misleading. It, therefore, often happens that in determining to inaugurate investigations in a particular line the one question asked is 'Are we likely thereby to discover facts that will shed light upon the general problems of geology?' feeling assured that ultimately all such research will be of economic value.

Before adjourning for Christmas, the Commission addressed some inquiries to the Director regarding the scientists who received salaries of $4,000, those who worked part time, and the general assistants. Senator

Allison read the replies into the record when they reconvened on January 2. Major Powell stated that the scientists who received salaries of $4,000 were all in charge of important divisions, all had a full corps of assistants, and all devoted their full time to the work of the Survey. A list of 69 who worked part time for the Survey was supplied, together with the amounts paid to them. Powell called attention to the fact that in accordance with Treasury regulations, persons employed by the month were rated by annual salaries. There were actually two general assistants, he said. One was called the Executive Officer. Their duties were the same. They simply divided the country between them.

Mr. Herbert then questioned the Director about the work in ethnology. Major Powell answered that, "The ethnologic work of which I have charge is not part of the work of the Geological Survey, but a part of the work of the Smithsonian Institution." However, he went on to explain that the clerical work was done by the Geological Survey, that the topographers of the Geological Survey mapped the archeological data, and that the geologists collected archeological material. The salaries of the specialists in ethnology and their field expenses were paid from the appropriation for ethnology, although the ethnologists sometimes traveled with the geological parties to keep their expenses down.

The investigation continued on into January but was concerned almost entirely with the Signal Service. Major Powell made only one brief appearance, to supply information on expenditures for topographic work in New England. As the hearings were drawing to a close, Senator Allison sought the views of Simon Newcomb, who had not been permitted to serve on the National Academy of Sciences committee in 1884. Newcomb wrote that it appeared to him "that the evils in the scientific bureaus of the Government, the correction of which is your main object, have their origin in the want of adequate administrative supervision of these bureaus." There was only one remedy, which the Academy had proposed, that they all be under one head. The heads of the bureaus must be scientists, but the head of the whole department would represent the public, see to it that the work was conducted economically, and that no work was undertaken of which the value could not be made evident. He did not think that the Navy by itself could do the hydrographic work of the Coast and Geodetic Survey as economically and effectively as they were doing it with the guidance and control of the civilian organization. Nor did he think the successful management of the land work of the Coast Survey by the Geological Survey was practicable. The head of the Geological Survey had to be a geologist, but no geologist was qualified to conduct the work of the Coast and Geodetic Survey, which was mainly geodetic and astronomical.

Newcomb's letter was read to the Commission on January 21 and inserted in the record. Mr. Herbert also presented for the Commission's record a memorandum of the conversation between himself, Alexander Agassiz, and Messrs. Colonna, Boutelle, and Hergesheimer of the Coast and Geodetic Survey, and his correspondence with Professor Agassiz.

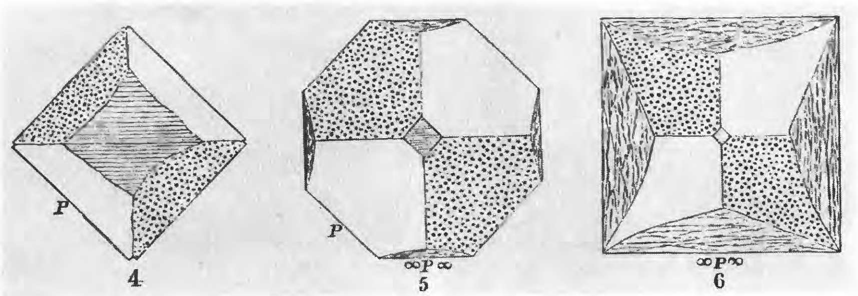
Major Powell felt that he could not let the Agassiz letter go unchallenged—it was a "censure of the administration" of the Geological Survey and "a condemnation of its existence as a governmental institution." He therefore sent Senator Allison a criticism of the Agassiz statements and asked that it too be placed on record. The criticism was 25 times as long as the letter that provoked it, and it was written not to convince the sinner of the error of his ways but to demolish him. The Agassiz charges were not "clearly and specifically formulated"; they seemed to "condemn the entire work of the Survey as being of a character which should not be prosecuted by the

General Government, but only by private individuals and institutions" but the letter was not entirely clear. Perhaps Mr. Agassiz meant to condemn geologic investigation "when it had for its ultimate purpose the development of industrial utilities," or perhaps he meant to condemn "that part of the investigation by which it was sought to apply the facts and principles discovered to economic purposes."

He asked, "Did the general work of the Geological Survey fall within the limits of individual investigation as its exclusive province?", and answered that topographic surveying had been recognized as the proper work of the General Government ever since the adoption of the Constitution and geologic surveying, ever since the development of the science. Powell's claim was clearly an exaggeration. Surveying, but not topographic surveying, had been the work of the Federal Government since the adoption of the Constitution. Federal work in geology, as Powell knew full well, was much more recent. Powell added that many states had provided for topographic and geologic surveys, but he knew of no private institutions that had undertaken to do fieldwork in topography and geology. Some individuals, notably college professors, had done geologic work in the field and had made important contributions, but they were small in proportion to the great works of the official surveys. The principal geologic publications were all official, and had to be, because proper publication called for illustrations, maps, and diagrams too expensive for private publication.

Powell asked, were the Comstock, Eureka, and Leadville districts unwisely selected as the subjects for thorough investigation? He defended the choice and said that the publications on them were great contributions to geologic science.

Professor George Huntington Williams of the Johns Hopkins University, one of the pioneers in microscopic petrography, undertook a study of the metamorphism of igneous rocks. Near Baltimore, he found a hypersthene gabbro metamorphosed to a gabbro diorite by secondary alteration of its pyroxene constituents to fibrous hornblende. The section shown is of a rock in the transitional zone between the gabbro and the diorite. (From G. H. Williams, 1886.)



Whitman Cross and W. F. Hillebrand, at intervals of leisure from their regular duties, made studies of minerals from the Rocky Mountain region, including optical studies and very careful chemical analyses. The figures show optical anomalies in apophyllite from Table Mountain, Colorado. (From C. W. Cross and W. F. Hillebrand, 1885.)

Was economic geology unworthy of the patronage of the Federal Government? The organic act of the Geological Survey required it to do economic geology."The purpose for which the Geological Survey is organized is not to develop science at large, but to develop that branch of science which relates to one class of the great industries of the country in order that industry may be the gainer thereby." Yet Powell had made it clear that investigations were undertaken not for immediate practical results but to shed light on the general problems of geology, feeling assured that ultimately they would be of economic value.

Then Powell counterattacked:

> **It is hardly appropriate to present to statesmen an argument in favor of the importance of directing scientific research to purposes of industrial utility. There is a sentiment current among ignorant men that profound science is incompatible with practical business, and this arises from the fact that it is difficult to demonstrate the immediate and direct utilitarian purpose of scientific investigation. It is often that such results are not proximate, but only ultimate. When the ignorant challenge the learned for the 'practical,' or 'economic,' or 'utilitarian' value of their knowledge, the answer is not always rendered in terms within the comprehension of the questioner, and he scoffs at all answers that he cannot understand. Now, there are narrow and dilettant scientists who retort that science is too exalted to be in any manner interested in utilitarian results, and sometimes these wiseacres boast of their devotion to 'pure science.' But great scientific men, like great statesmen and great men in all departments of society, clearly recognize the fact that knowledge is a boon in itself and in its utilitarian consequences alike—that wisdom is exalting and knowledge is power.**

Specific allegations were taken up, and the sarcasm grew more cutting with each. "Mr. Agassiz says: It is an impossible thing to make a good geologic map of the country without having as a groundwork a good topographical map of the country. In this statement Mr. Agassiz exhibits a knowledge of the subject under consideration not manifest in his other statements, and hence he occupies high ground; but on that pinnacle of truth he becomes vertiginous and falls into the error of saying that 'if the States are not willing to go to that expense, it seems plain that they do not wish the Government to go to that expense for them,' thus by implication asserting that the people do not want a topographic map of the country. The representatives of the people in Congress assembled have provided for a topographic map of the United States, and it is reasonable to suppose that the statesmen of the country fairly represent public opinion." Mr. Agassiz's statement that the publications of the Survey were worthless implied that eminent scholars were but pretenders and the Director the chief of pretenders. It was not fitting that the name of "Agassiz the Great" be appended to the defamation of such men. The charge that editions of reports were too great smacked of the Eurpean idea, rarely found in America, that the people at large should be excluded from a knowledge of the progress of scientific research.

Mr. Agassiz has devoted many years to the accumulation of a great fortune, and it had been his ambition to make the museum over which he presided the American center of scientific research, and the agency that should "create, control, and diffuse the increase of knowledge of the New World." Due honor should be accorded him for the brilliancy of his scheme, but a hundred millionaires could not do the work of scientific research now being done by the General Government. Should the work of scientific research and the progress of American civilization wait until the contagion of his example inspired a hundred millionaires to engage in like good works?

In conclusion, Powell restated his principles of scientific work to be pursued by the Government and asked consideration of three important questions:

"The first is this, Are the relations of the Geological Survey to the other scientific institutions of the Government such as will best subserve their interests? Of this you are now to judge.

"The second is, Is the Survey now wisely organized so that there may be reasonable assurance that the appropriations made by the General Government are honestly and economically applied to the work in hand? Of this also you are now to judge.

"The third question of importance to statesmen is this: Has the Survey reached its proper limit in magnitude so as to fully supply the wants of the country for the work which it is doing? I think that a fair examination of this question will reveal the fact that the wants are great and that the agencies for the supply are inadequate, and that the Survey itself should have a slow, normal, and healthy growth from year to year until the reasonable demands of the people in all portions of the country, now so urgent, shall be met in a manner worthy of the General Government, by which so great a people are organized into one body politic."

For 2 months, the Survey and the other bureaus under investigation awaited the Allison Commission report. Then on April 26, Mr. Herbert filed a bill in the House. After June 30, 1886, the Geological Survey shall not expend any money for paleontology except for the collection, classification, and proper care of fossils, nor for general discussion of geologic theories, nor for the compilation and publication of monographs or bulletins or other books except the annual report, and that was to be a report of operations only. Authors might publish at their own expense and copyright their publications. All printing and engraving for the Geological Survey, and for the other bureaus as well, was to be estimated separately and appropriated in detail. The Secretary of the Interior was to dispose of in accordance with law the laboratories of the Geological Survey that would no longer be needed.

The bill was, naturally, looked on as disastrous. Major Powell wrote a letter to the Commission, which was somehow published in the *New York Tribune* of May 3. The principal properties to be sold in accordance with the bill were portions of the buildings of the Smithsonian Institution, the National Museum, a rented building used as headquarters and office, and the Peabody Museum of Yale College. Such a sale was impossible and the provision was "nugatory." On May 5, Mr. Herbert quietly submitted an amended bill, omitting the provision for the sale of the laboratories.

The report accompanying the bill, signed by Mr. Herbert and Senator Morgan, dealt at length with the expenditures of the Survey, and especially the expenditures for printing. The total cost of engraving and printing Survey reports to March 24, 1886, had been $289,732.76, and the estimated cost of printing the material in the hands of the printer on that date was another $177,550. The cost of printing was thus another 20 percent over and above the total that had been appropriated for the Survey to that time. But no geologic quadrangle maps had yet been published. "It is the intention of the Commission," the report said, "to allow the Survey to continue the collection of material but to inhibit it from paleontological discussion and also from discussing the general principles of geologic science. These the Commission believes may be well left as in England to private enterprise. This will result in a large saving to the Government, and it is hoped will tend to expedite the preparation of the geologic map of the United States." Then Mr. Herbert felt free to wax a little sarcastic. "It would appear to us, however, that if the map we have appropriated so much money for is to be of any practical value, it should make its appearance in a reasonable time. But come when it may, it will have its uses. Should it continue its present progress toward completion, then, although geology may perhaps keep pace in improvement with other sciences, and although it may become antiquated before it is published, yet we can console ourselves with the thought that our map when finished will be of value to those who wish to study the archeology of geologic research."

The report concluded with a quotation from the historian Buckle on the stifling of independent thought and the repression of the spirit of individual enterprise through patronage by Louis XIV. The Director of the Geological Survey had a corps of more than 150, all of whom were no doubt loyal to their chief. There were, in addition, 69 scientists scattered over the country who were also on the Survey payroll. When so many geologists were sustained by the Government treasury, was there any room in the field for individual enterprise? If not, then "all American geology must be under one man, whose favor must be retained, whose theories must be sustained, and so there can be no independent thought. Monopoly that gives absolute control, that puts in the hands of one the power to say who and who only shall pursue geology profitably, will most assuredly put science in bondage, and its votaries, in the language of Buckle, to 'scrambling in miserable rivalry for the sordid favors of a court.' "

So loud was the outcry of protest from scientists throughout the country (*Science* was particularly outraged) that the Allison Commission held another session, and in the full Commission report, filed in the Senate on June 8, 1886, a substitute bill was recommended, one that would limit the cost of printing and engraving and enable Congress from year to year to judge the amount and character of printing and illustration work to be done on the basis of estimates prepared in advance of publication. "It is not the purpose of the Commission," the majority report said, "to recommend the withholding of the publication of the full results of the Survey, as it is plain that if it is wise to make the survey it is not unwise to provide for the fullest publication of its results."

The Commission did not present a unanimous report. A majority report, signed by Senators Allison and Hale and Mesrs. Lowry and Wait leaned heavily on efficiency and economy as the reasons guiding their deliberations and decisions. The majority concluded that nothing in the testimony indicated that the work of the Coast and Geodetic Survey could be more efficiently or economically done if transferred to the Navy, so there was no reason for making the change. The majority was of the opinion that the administrative part of the work of the Geological Survey was well conducted; they expressed no opinion on the plan of the survey. They had no doubt of the wisdom of the geological survey of the whole country, noted that on the basis of the current annual appropriations it would require 30 years to complete this survey but thought that the rapidity with which the work was done could "wisely be left to Congress from year to year, depending upon the condition of the country and the necessities of the Treasury for the amount to be appropriated each year."

Still, Mr. Herbert managed to have the last word. Major Powell had filed a rebuttal to the minority report, taking up 18 specific points. Major Powell's letter and Mr. Herbert's comments thereon concluded the Commission's report. For the most part, Mr. Herbert simply quoted the testimony from which he had drawn his conclusions. Major Powell said that when the report complained of the expense of the geological survey, it had not considered the amount that was spent for topography, but Mr. Herbert said that if all the topographic work was in preparation for the geologic map, then its cost was properly part of the cost of the geologic survey. Major Powell said that the report complained that economic geology was not being done in the Survey, whereas all the work was directly or indirectly of economic value, and Mr. Herbert quoted the Director's testimony that the States were organizing to do the economic work that was not being done as part of the general survey. Major Powell said that the report complained of geologic dictatorship, whereas there was no class of men so independent and self-poised as those engaged in original research. Mr. Herbert blandly replied that there was no purpose to show that the Director was personally dictatorial, and he had not used the word. His objection was to the system. There was a tendency of those supported by the Government to defend the Survey against all critics and to maintain its infallibility. There were many able men in the corps, capable of independent thought, whose views might have been of great value to the Commission, whose views might have been different on some points, but during nearly 2 years of hearings, only one man had been heard from. Every inquiry had been answered by him, every thought had come from him. "Who can say," he concluded, "that the views of that chief who thinks and speaks for all before a Commission of Congress will not unduly preponderate in the consideration of scientific questions?"

Mr. Herbert tried to have the last word in Congress, too. On June 29, when the Sundry Civil Expenses bill was being considered, he spoke at length against the extravagant spending in the Survey. "The difficulty seems to be right here. Professor Powell deems this to be a strictly scientific institution, 'organized for,' as he says, 'and strictly comprehending original research,' the searching for new principles to enlarge the field of science. This seems to him to be one of the prime objects of the institution and the law of its being, as he understands it.* * *Is it not true that Congress when it established this survey intended it to be a bureau of applied science?" Mr. Hewitt did not deny it.

Representative Symes of Colorado, the chairman of the House Committee on Mines and Mining, had demanded, and been granted, equal time to speak for the Survey. Mr. Symes' committee had been considering another bill to establish a bureau of mines and mining, but had proposed instead, in a report dated April 22, 1886, that certain duties be added to the Geological Survey's work. Mr. Symes spoke in glowing terms of the mining geology work of the Survey and the great value of the reports on mineral resources. When the Sundry Civil Expenses bill was passed, the Survey received the same appropriation, $67,700 for scientific assistants and $400,000 for expenses. The Survey's operations were seemingly approved by the Congress.

There was, however, one person still dissatisfied. Professor Cope had been seeking a special appropriation to pay for publication of the rest of his report. He obviously was privy to the discussions of the Allison Commission, for on April 15, or 11 days before Mr. Herbert filed his bill, Cope had written to his daughter that, "Paleontology is of course killed for the present, but I hope by the aid of Secretary Lamar to get all straightened in time." A month later, he saw the Secretary, but the meeting was unsatisfactory. He continued to visit the Secretary's office, waiting to be seen, and finally had another meeting on June 29, but all the Secretary did was dictate a letter to the Secretary of the Smithsonian Institution asking for information and advice. Professor Cope then transferred his attention to the House Appropriations Committee, but they had already completed the bill. From the House he went to the Senate, and finally an amendment was inserted in the Senate bill. A few days later it was thrown out on a technicality.

The full effect of the Allison Commission investigations was felt when the appropriations for fiscal year 1888 were considered. The House Committee on Appropriations, in making up the Sundry Civil Expenses bill, allowed the usual $400,000 for Survey expenses, but when that item came up for discussion in the House itself in December 1886, Mr. Herbert inquired why it was not itemized as was that of the Coast and Geodetic Survey.

> **Here are $400,000 in a lump sum for what, in my opinion, is a very extravagant bureau extravagantly conducted. Unless there is itemizing it is absolutely impossible, if it is desired to make an amendment, to know how to get at it.**

The chairman of the Appropriations Committee agreed that itemization would be desirable, said he would gladly support anyone who wanted to make the effort to obtain such estimates, but, recalling the long battle with the Coast Survey on that score, was pessimistic about the outcome. Mr. Herbert solved that problem simply by an amendment to the item for the Survey, adding the clause

> **and hereafter the estimates for all moneys wanted by the Geological Survey shall be itemized.**

And so it was passed by both the House and Senate. Until 1950, Congress continued to appropriate funds for the Survey item by item.

In the same bill, the Public Printer was authorized to spend $54,000 for the engraving of geologic maps but only $68,000 for engraving illustrations, printing, and binding Survey reports. As the latter amount was little more than a third of the amount reported necessary to publish the reports in the hands of the Public Printer in March 1886, a drastic change in the publication program would be necessary, particularly in the preparation of illustrations other than maps. Congress continued to control publication by appropriating specific amounts for printing and binding reports annually until 1949.

Chapter 5.
Civilized Competition, 1886–1888

In civilization man does not struggle with man for existence, but by the invention of institutions he emancipates himself from the reign of terror inherent in brutal competition, and transfers the struggle from himself to the institutions of his creation

—John Wesley Powell

The summer of 1886 was a relatively peaceful one for the Geological Survey after the tension of the Allison Commission investigation, but new tensions soon developed. In January 1886, while the Allison Commission was in session, the American Committee on the International Congress of Geologists had met in New York and decided to prepare a report on the Berlin Congress of 1885 and to seek the cooperation of the scientific societies of the country in securing a meeting of the International Congress in the United States. W J McGee represented the Director, who was held in Washington by the congressional hearings. The Committee had met again in May without Survey representation, and at that time, set up subcommittees on the Archean, Lower Paleozoic, Upper Paleozoic, Mesozoic, Cenozoic (marine), Cenozoic (interior), and Quaternary, Recent, and Archeology. Then on August 4, 1886, as Congress was about to adjourn, the Senate passed a resolution proposed by Senator Preston B. Plumb of Kansas directing the Commissioner of Agriculture to furnish to the Senate early at its next session such information on the subject of irrigation as he might have gathered and prepared for publication. In both instances the Survey had knowledge and strong interest, but others were taking the lead. Within the Survey, tension developed between the mining geologists and general geologists.

The topographic work that summer was again for the most part simply a continuation of the work of the preceding year. A few changes in organization were made. Marcus Baker, who had spent 12 of his 13 years at the Coast and Geodetic Survey as a subassistant, chiefly in hydrographic and coast-pilot work in Alaska, joined the Geological Survey as a geographer and was placed in charge of the Northeastern Section. The mapping on the mile-to-the-inch scale in the District of Columbia area for McGee's project was transferred from the Appalachian Section to the Northeastern Section. A new section, the Central Section, was established to include the work in Kansas and Missouri and such other work as might be done thereafter in the Mississippi Valley States; John H. Renshawe was placed in charge.

Gilbert resumed his studies of the shorelines of the Great Lakes and continued work on his still-unfinished report on Lake Bonneville. Dutton spent the summer in the Cascade Mountains, most of it investigating Crater Lake, which had been proposed for a national reservation, while Diller continued the detailed geologic study of Lassen Peak. For the examination of Crater Lake, Dutton arranged for the construction of a boat to be used for sounding and two small skiffs; he obtained sounding apparatus that was fitted to the larger boat as well as a tackle for lowering the boats into the water from the cliffs, which rose sheerly from the water's edge. He needed also "a number of stalwart men, who could lower the boats, row them, and do the hard labor connected with the examination of the Lake." General Gibbon, commanding the Military Department of the Columbia, obliged a fellow officer by placing 10 men from the Vancouver barracks at his service. Some 168 soundings were made, and the depth of the floor was found to be 1,600 to 2,000 feet below the surface, making Crater Lake the deepest freshwater lake known to Dutton.

McGee was sent off to make such examinations as were necessary in order to reply to inquiries that had been received about the possibility of an artesian water supply at the head of Chesapeake Bay. He established a center of operations at the Fishing Battery Station near Havre de Grace, Maryland, and made extended studies along both shores of the bay, traveling either in a steam launch belonging to the Fish Commission or on foot. McGee's report was equivocal: "The favorable probabilities are such as to warrant the risk of boring provided it can be done at small cost, but not such as to warrant costly operations; while the unfavorable probabilities are such that a successful issue cannot be confidently predicted." The data collected proved to be of unusual scientific interest, however, and McGee later revisited the area to make a thorough study of the Potomac formation and Coastal Plain geology and topography.

McGee was also pressed into service to begin the investigation of the earthquake in South Carolina that occurred on Tuesday, the 31st of August, 1886, at 9:50 in the evening, while Dutton was somewhere in the Cascade Mountains. Communication between the Charleston area and the outside world was cut, the railways were made impassable, and the telegraph lines were down, so that word of the disaster was not spread until late Wednesday when a brief telegraphic despatch was sent out. The *Charleston News Courier* sent an account to Summerville, whence it was telegraphed to Washington for publication on Thursday. McGee and a photographer arrived on Friday, September 3, and spent a week making observations in the most seriously shaken area. A more extensive study was reserved for Dutton's return in the fall.

Professor Shaler pursued the matter of the reclamation of swamplands. He spent the month of July preparing a plan for the study of the freshwater swamps of the country that had been added to the work of the Atlantic Coast Division. The novelty of the inquiry, together with the probability that it would in time call for a considerable expenditure of money, made it desirable that the character of the work to be done be carefully determined, so Shaler visited several swamp areas in New England and New York, although his funds were insufficient for any extensive work. Meanwhile, Chamberlin, Salisbury, Leverett, and Wooster began a detailed study of the region about the head of Lake Michigan and between it and the Erie Basin, where the glacial phenomena were exceptionally complicated because of the successive ice invasions.

In the Appalachian Division, Bailey Willis mapped along the French Broad River, I. C. Russell was in Alabama, and H. R. Geiger continued along the Potomac section. Willis had developed a method of using the stadia transit as his principal instrument, and Russell used essentially the same method, but Geiger clung to the use of an odometer for distances on wagonroads and a tapeline where the wagon would not go.

Hague went back to the Yellowstone region, this time accompanied by Iddings, Hallock, Weed, and S. L. Penfield, who had volunteered for a second summer. The fieldwork was confined to the park and adjacent country, the area being determined in part by the geological problems and in part by the boundaries proposed in the bill for the enlargement and maintenance of the park at the preceding session of Congress. Hague was accom-

Although by the 1880's most geologists had accepted the fact that the great mantle of drift that covers much of the Northern States is the product of ice action, they still differed on whether, as T. C. Chamberlin put it, the ice invasion had been by land or by sea, or whether the drift came primarily from glaciers creeping over the face of the country or from icebergs and ice floes sailing over submerging waters. Chamberlin's own investigation of rock scorings, which he called the trails left by the invader, was convincing evidence that the icy visitor was a glacier. (From T. C. Chamberlin, 1888.)

panied for part of the summer by Congressman Charles H. Allen of Massachusetts, who was examining the park as a forest reservation and studying its importance to the Government from an economic standpoint. A special agent of the Secretary of Interior, investigating the management of the park, was also given aid and sustenance.

In the two Archean divisions, Pumpelly and Irving were ready to begin mapping atlas sheets but also continued their special studies. Professor B. K. Emerson of Amherst, who had previously done extensive work in central Massachusetts, was added to the staff of Pumpelly's division part time to map east of the Hoosac Range. In the Lake Superior Division, Merriam and W. S. Bayley, who had just received his Ph.D. from Hopkins, began the mapping. Florence Bascom, daughter of the President of the University of Wisconsin and a student there, assisted Irving, Van Hise, and G. H. Williams in the special studies. Irving was now convinced that the older crystalline schists, gneisses, and granites were entirely separate from the clastic series which he called the Huronian, and he advocated reserving the name Archean for the pre-Huronian crystalline rocks.

Hayden spent his last summer in the field. He and Peale spent about a month reexamining localities near Fort Ellis, Montana, while G. P. Merrill of the National Museum studied the field relations of some of the eruptive rocks they had observed the year before. Because of a recurrence of his illness, Hayden was unable to continue work, and in December, he resigned from the Survey.

Professor Marsh's monograph on Dinocerata, which King had promised in the first annual report, was published. It was an impressive volume of

243 pages, larger than quarto, but the illustrations were its main glory. Marsh himself said: "The text of such a Memoir may soon lose its interest, and belong to the past, but good figures are of permanent value in all departments of Natural Science. What is now especially needed in Palaeontology is, not long descriptions of fragmentary fossils, but accurate illustrations of characteristic type specimens. In the fifty-six lithographic plates and nearly two hundred original woodcuts in the present volume, it is believed that this requirement is fairly met."

Emmons had presented a major paper on *The Genesis of Certain Ore-Deposits* at the Bethlehem meeting of the American Institute of Mining Engineers in May 1886. His conclusions on the Leadville deposits, published in the second annual report, had been widely criticized as if he had intended them as a general theory. On the basis of further work, he was then ready to

C. E. Dutton investigated the major earthquake that had occurred in South Carolina on August 31, 1886. Seismology was then in its infancy, but Dutton investigated not only the effects of the earthquake on buildings and railroads but also the nature of the motion and the depth of the shock. Unlike most pictures showing the effects of earthquakes on railroads, there are no twisted tracks in this scene, which was captioned "Disaster on the Railroad." (From C. E. Dutton, 1889.)

present some generalizations to his audience "as suggestive, that their own observations may further prove or disprove them." Emmons stated:

> **That many deposits have been formed under conditions of great heat and pressure is most probable; that heat and pressure greatly increase the solvent power of percolating waters is evident; but that heat and pressure are an absolutely essential condition of mineral solution cannot be maintained, since we see in nature many instances of mineral solution and deposition under ordinary pressure and by comparatively cold waters.**

His own work, he thought demonstrated "increasing applicability" of the following conditions; that ores "are deposited from solutions made by percolating waters. That the deposition takes place very rarely in actually open cavities, but most frequently by a metasomatic interchange, or by replacement of the more soluble or more accessible portions of a rock or members of a rock-series. That these solutions do not necessarily come directly upward, but simply follow the easiest channels of approach. That these materials are not immediately derived from sources at some unknown depth, but from neighboring bodies of rock within and conceivable distance. That where, as is so often the case, ore-deposits are associated with, or in the vicinity of, bodies of eruptive rock, especially the older intrusive rocks, there is a reasonable probability that their materials have been derived from these rocks."

Emmons' fieldwork in the 1886 field season was limited to short visits to mining districts for comparative studies of the conditions of ore deposition after he finished the final proof corrections and indexing of the Leadville monograph in late August. Cross was deeply involved in lithologic studies in Denver, and Eldridge continued the fieldwork in the Denver area, although he was unable to complete it as planned because the geology was far more complicated than had been anticipated.

Becker spent several months resolving the remaining chemical problems for the quicksilver monography, while Turner and Lindgren began mapping the California gold belt. Becker's plan for that work called for a preliminary survey in which only the simplest features would be mapped but extensive notes taken so that appropriate localities could be selected for more detailed studies of the structure of the range, the age of the gravels, the metamorphism, and the genesis of the ore.

Albert Williams completed the volume on mineral resources for 1885 and resigned at the end of August to become Dean of the new Michigan College of Mines at Houghton. David T. Day, who had graduated from the John Hopkins University in 1881 and received a Ph.D. in chemistry in 1883, succeeded him. Day had contributed to all three volumes on mineral resources of the United States, on miscellaneous metals, fertilizers, and certain nonmetals, and he was Williams' own choice to carry on the work.

The Survey's position on stratigraphic nomenclature and cartographic representation was challenged in October 1886 when C. H. Hitchcock presented a communication to the American Institute of Mining Engineers on the geologic map of the United States. Hitchcock used McGee's map as the base for his map, which he colored in accordance with the color scheme of the International Geological Congress. He explained that, "The color scheme of the International Congress agrees in many respects with the usage of American geologists prior to 1875. The latter commonly used yellow for Tertiary, green for Cretaceous, dark gray or sepia for Carboniferous, rose or carmine for the crystalline, vermillion for the volcanic, and the former propose to continue to use these. Usage has varied for the other systems."

He added:

> **In regard to nomenclature, the value and order of time-words and stratigraphic designations have never been based upon any natural relations. Consequently great relief is afforded by a majority vote of the geologists of all countries.**

He then outlined for the AIME the general conclusions of the Berlin Congress on the use of terms. "The word Formation conveys the idea of origin rather than of time, and is not used in a stratigaphic sense. In its stead, the French word Terrain, anglicised to Terrane, is regarded as more definitive. The most general stratigraphic division will be designated as group, of which there are four, Archean, Paleozoic, Mesozoic, and Cenozoic. The groups are divided into Systems, which are Tertiary, Cretaceous, Jurassic, Triassic, Carboniferous, Devonian, Silurian, Cambrian, Huronian, and Laurentian. The systems are divided into series, the series into Etages, or Stages, and the stages into Assises or Rocks. Any further subdivision receives the name of beds. The chronological divisions corresponding to these terms are Era, Period, Epoch, Age, and Phase. The Committee upon the European map have suggested the need of distinguishing the different orders of division by homophonous terminations, that is, possessing the same sound. They propose the termination -ary for the groups, -ic for the systems, and -ian for the series. To carry out this suggestion it would be needful to restore such words as Secondary, and to change Cretaceous, Carboniferous, Devonian, and Silurian to Cretacic, Carbonic, Devonic, and Siluric."

The American Committee on the International Congress met again in December 1886, voted to adopt the decisions of the International Congress and to recommend their acceptance by American geologists. Persifor Frazer was named to prepare a report on the Archean, N. H. Winchell on the Lower Paleozoic, J. J. Stevenson and H. S. Williams on the Upper Paleozoic, G. H. Cook on the Mesozoic, E. D. Cope on the interior Cenozoic, E. A. Smith on the Marine Cenozoic, and Major Powell on the Quaternary, Recent, and Archeology. Circular letters were sent out and notices were published in the *American Journal of Science* and in *Science* inviting American geologists to submit opinions. The reporters, as they were designated, were expected only to obtain and synthesize American opinion or usage; there were, however, some strong-minded geologists serving as reporters, and it might be surmised that their own opinions would carry great weight.

On December 17, 1886, just 2 days after the House had passed Mr. Herbert's resolution calling for itemization of the Survey's budget request, the Commissioner of Agriculture submitted to the Senate a 240-page report on irrigation prepared by Richard J. Hinton in response to Senator Plumb's resolution of August 4. In his report, Hinton did not so much as acknowledge the existence of Major Powell's 1878 report on the arid lands, even in the list of references, although he covered some of the same ground. He considered the extent and character of the area in which the annual rainfall was insufficient, the extent of the fall of rain or snow in the area, the evidence as to increase or decrease of precipitation resulting from agricultural settlement or pastoral occupation, the increase of humidity of earth or air, the destruction of timber, the effect of the destruction of native grasses, and what had been accomplished in the way of artificial methods of water distribution and economy.He concluded that the area of irreclaimable arid lands in the United States was "comparatively speaking, quite moderate in its extent," but that there was a very large area, at least one-third of the total land surface, wherein the water supply was both inadequate and irregular. He estimated that the area reclaimable by irrigation was 245 million

Topographic mapping was the largest single element in the Survey's program. The work involved location of mapped area on the Earth's surface by astronomic observation, the horizontal location of points by triangulation or traverse, the measurement of heights, and the sketching of the map. In the sketch shown, a signal has been set up for use in triangulation. (From Henry Gannett, 1893.)

acres, if water could be obtained, but that the known water resources were sufficient to irrigate only 147 million acres. The last session of the 49th Congress ordered the report printed but took no further action.

Irrigation in the arid region was not the most urgent problem with which farmers were concerned in 1886. Farm prices were low, the middlemen who handled the crops and the railroads that transported them were making charges that the farmers thought exorbitant, and operating capital was perennially short because banking facilities were scarce and interest rates were high. An investigating committee headed by Senator Cullom of Illinois had concluded that the railroads had indulged in "unjust discrimination between places, persons, commodities, or particular descriptions of traffic" and recommended that a rigorous pattern of regulation be adopted. On February 4, 1887, the Interstate Commerce Act was passed, forbidding discrimination, prohibiting pooling, rate agreements, excessive rates and rebates, and restricting charging more for a short than a long haul.

The American Committee on the International Congress met again in April 1887, and to this meeting a general invitation to attend had been extended to all American geologists. The committee seemed still intent on conforming to the decisions of the International Congress. Professor H. S. Williams, however, suggested that there should really be a dual set of designations: one referring to the lithologic character of rock masses and based on geographic names, which would tend to vary from place to place; and the other based on some great and persistent fauna that would be substantially constant over large areas and perhaps over the world. The stratigrapher, he pointed out, takes account of the great physical changes to which the Earth's surface had been subjected, and the paleontologist tries to delineate the organic changes that the surface of the Earth has witnessed. These changes were supposed to be coeval and coextensive, and, so long as the geology of the United States was known accurately only in New York State, the relation seemed to hold. Since other areas of the United States had been carefully examined, however, divergences had been found in various places and in various ways. Unless great freedom to diverge from the scheme adopted for stratigraphic designations was allowed, he said, any nomenclature adopted by the American Committee on the International Congress would be a short-lived experiment.

Gilbert had held aloof, all this while believing that the Congress was trying to regulate something that could not be regulated by legislation. At first he had thought that the International Congress would accomplish little, but was finally convinced that,

> **Unless the conservatives make themselves heard, geology may be saddled with a tyranny of authoritative classification that will seriously hamper its development.**

At the meeting of the AAAS in August 1887, at which he was vice president for Section E, he opened the session with an address on "The Work of the International Congress of Geologists." He expressed approval of the action of the International Congress in selecting names to show the taxonomic rank of stratigraphic divisions and chronologic divisions. There was "a manifest advantage in bringing order out of this chaos." The order or rank was strange to most English readers and writers, and so was one of the terms—stage—but the strangeness was only a temporary disadvantage, for experience had shown that the connotations of a word transferred from one use to another quickly disappeared from consciousness, leaving it purely denotative. He did not like the propositions before the International Congress to distinguish the names of individual groups, systems, series, and stages by means of homophonous terminations. Although the adoption of such a plan would enable a writer or speaker to indicate the taxonomic rank of a terrane without adding a word for that purpose, it would become impossible to allude to a terrane without declaring its rank, and this would contravene one of the most important rights of opinion, the right to reserve opinion. It would also introduce a needless synonymy when geologists differed as to the rank of a terrane, and the necessity for taxonomic discrimination on all occasions would lead many a geologist to conceive of taxonomy as an end instead of a means.

The problem in stratigraphic classification was one of the true concept of a system. "There does not exist," Gilbert said, "a world-wide system nor a world-wide group, but every system and every group is local. The classification developed in one place is perfectly applicable only there. At a short distance away some of its beds disappear and others are introduced; farther on its stages cannot be recognized; then its series fail and finally its systems and its groups.

"If I have properly characterized stratigraphic systems—if they are both natural and local—it goes without saying that the classification of the strata of all countries in a dozen or so systems, as proposed by some of the members of the congress, is impossible."

Or rather, he said, it was not impossible from their point of view, because they had a different concept of a system. A universal system, however, would be artificial in all except the geologic province in which it was developed, and Gilbert was opposed to any attempt to coerce the geology of one country in a rigid matrix formed over and shaped by the geology of

Survey topographers needed a plane table that had the utmost stability consistent with lightness and portability for traverse work. Both forms used by the Coast and Geodetic Survey—a very stable but heavy and cumbersome movement and a light but unstable movement—were tried, but one invented by W. D. Johnson of the Survey that had a movement based on the ball-and-socket principle, proved more suitable. (From Henry Gannett, 1893.)

another country. The time scale was another matter. The time scale was arbitrary and a matter of convenience, so it was legitimate to modify it and fix it by formal convention, but it should be recognized that such a scale was arbitrary and that a scale once adopted would not continue to be the best possible indefinitely.

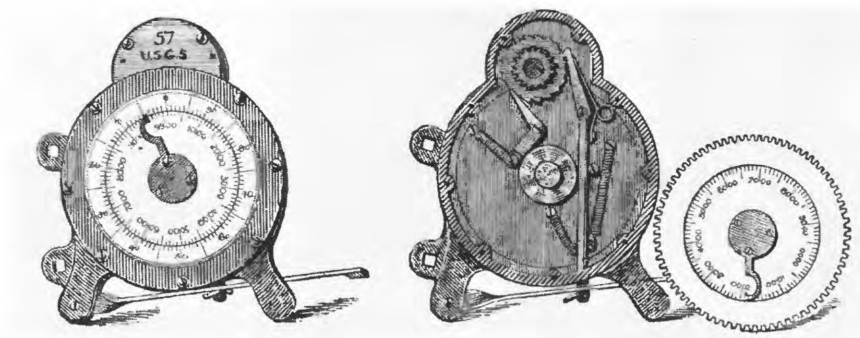
As for map colors, it would be better to adopt no convention at all than to adopt one carrying with it and promulgating a vicious classification. Uniformity was not worth purchasing at the price of falsification. Gilbert proposed that the continuous prismatic spectrum be adopted as the standard universal for continuous geologic time, that the conventional time scale, based on the geologic history of Europe, be complemented by a prismatic but discontinuous color scale, each period being assigned a specific color defined by its position in the spectrum, and that students in each geologic district then assign to the stratigraphic systems of that district a set of prismatic colors so selected from the spectrum as to properly represent the relation of each system to the time scale.

In conclusion, Gilbert pointed out that science established its fundamental data by observation and that it was not only illogical but suicidal for science to establish facts in any other way. No vote of the most august body could possibly establish a fact, and no geologic results could be made more true or be prevented from yielding to contrary facts by agreement. Classification was the generalized expression of observed facts and outside the dominion of the voter. The proper function of the International Congress was

> **the establishment of common means of expressing the facts of geology. It should not meddle with the facts themselves. It may regulate the art of the geologist, but it must not attempt to regulate his science. Its proper field of work lies in the determination of questions of technology; it is a trespasser if it undertakes the determination of questions of science. It may decree terms, but it must not decree opinions.**

The American Committee had met a week beforehand to hear the papers prepared by the reporters. Major Powell opposed any formal vote of acceptance of the reports by the Committee, and in deference to him, no vote was taken, but it was decided to present the reports in summary at the Section E meeting. Walcott was hastily summoned to meet the Director "for consultation and to be present at the meeting of the Geologic Section." When Persifor Frazer presented the summary, those present, well prepared by Gilbert's talk, began a point-by-point discussion, but little progress was made. Gilbert had announced at the outset that a vote would not be in order as the reports had not been adopted by the American Committee and were merely expressions of individual opinion. He did, however, permit a resolution approving the work of the Committee, to which Powell added an amendment increasing the membership of the Committee to 75. When considerable opposition to the amendment developed, Gilbert hastily declared the meeting adjourned to take part in an excursion. At the next session, Powell withdrew his amendment, and the resolution was passed, although only a few bothered to vote.

During the summer of 1887, much of the Geological Survey work was concentrated on the stratigraphic column. One of the principal questions was related to the Archean and its relationship to the Paleozoic, with which both Irving and Pumpelly were concerned. Pumpelly continued to concentrate on the geology of western New England, in particular the Green Mountains, but spent some time with Irving. Irving spent the summer visiting points that could throw light on the relations of the iron-bearing series and the green crystalline schists, gneisses, and granites with which



E. M. Douglas devised a new form of odometer, the device used to measure distances by counting the revolutions of a wheel, usually one of the front wheels of a buggy or buckboard. Althouth it was the most trustworthy yet devised, it was not wholly satisfactory and many topographers preferred to count the revolutions of the wheel, using an arrangement by which a bell was rung at each revolution. (From Henry Gannett, 1893.)

they were associated. Peale also worked in an area of supposed Archean rocks, completing the geologic mapping of the northern part of the Three Forks sheet.

Most of Walcott's fieldwork was an investigation of the Cambrian and Lower Silurian strata of the Hudson River valley and of Vermont and western Massachusetts, to determine the true position, extent, and significance of the Taconic system of Ebenezer Emmons in the localities where Emmons had originally studied it, and in the Green Mountains to the north. Walcott found the stratigraphy of the eastern part of the area essentially as described by Emmons, but fossils found in the quartzite to the east and also in the overlying limestone indicated that the age of the greater part of the original Taconic system had been misinterpreted and that its rocks belonged to several intervals of geologic time.

Four parties were in the field in the Appalachian Division: I. C. Russell, assisted by C. W. Hayes, a recent Ph.D. from Hopkins, in Alabama; Bailey Willis, assisted by Arthur Keith, who had just received an M.A. from Harvard, in Tennessee; H. R. Geiger on the line of the Potomac; and N. H. Darton, who had been employed to compile a bibliography on Appalachian geology, was given a chance to get into the field and spent 2½ months in a reconnaissance of the headwaters of the Greenbrier, New, and James Rivers in Virginia and West Virginia.

C. A. White continued his examinations of the Lower Cretaceous strata of Texas and made progress in correlating them with formations to the east in the lower Mississippi Valley. Professor Marsh and his assistants made further collections in the Jurassic of Wyoming and southern Colorado and also in the Miocene of Dakota. Dall directed and conducted fieldwork in the Cenozoic of northern California, Florida, and New Jersey, and Lester Ward made extensive collections in the coal-bearing strata in the vicinity of Bozeman, Montana, and in the fossil forests of the Yellowstone with the assistance of F. H. Knowlton.

Gilbert continued his investigation of postglacial changes of level in the Northern and Northeastern States. Dutton was fully occupied with his study of the Charleston earthquake, and Diller completed the survey of Lassen Peak and the northern part of the Sacramento Valley. The field of the Division of Volcanic Geology was extended to include all the region between the Great Basin and the Pacific Ocean north of the 40th parallel, that is, north of the area where Becker was working. The plan had been to cover only the area between the 121st and 123d meridians until Becker and White reported that the Coast Range and the Cascade Range had a common and interdependent history and could not properly be dissociated.

In the California Division of Mining Geology, Becker continued serenely on his own way. He spent most of the year in a microscopic study of the ores and rocks of Almadén, Spain, which he had visited in the spring of

1887, in order to compare the geology of the Almadén and California quicksilver deposits. Turner and Lindgren continued to make steady progress in mapping the gold belt.

Emmons, Cross, and Eakins spent the field season of 1887 in the Crested Butte region, while Eldridge worked on the Denver Basin report, no small part of his time being taken up with corrections to the topographic base. Emmons was not too happy about the Crested Butte project. When he selected the area for study, it had promised to be the scene of the most important economic development on the western slope of the mountains, but industrial development had followed the railroads on the northern rather than the southern slope of the Elk Mountains. Large and valuable coalbeds had been opened, iron ores discovered, and above all, extremely rich silver deposits were being developed in Aspen, only 15 to 20 miles north of the area covered by their maps. A quick trip to Aspen showed that the structure there was too complicated to study without a topographic base, and Emmons' allotment was too small to have one made.

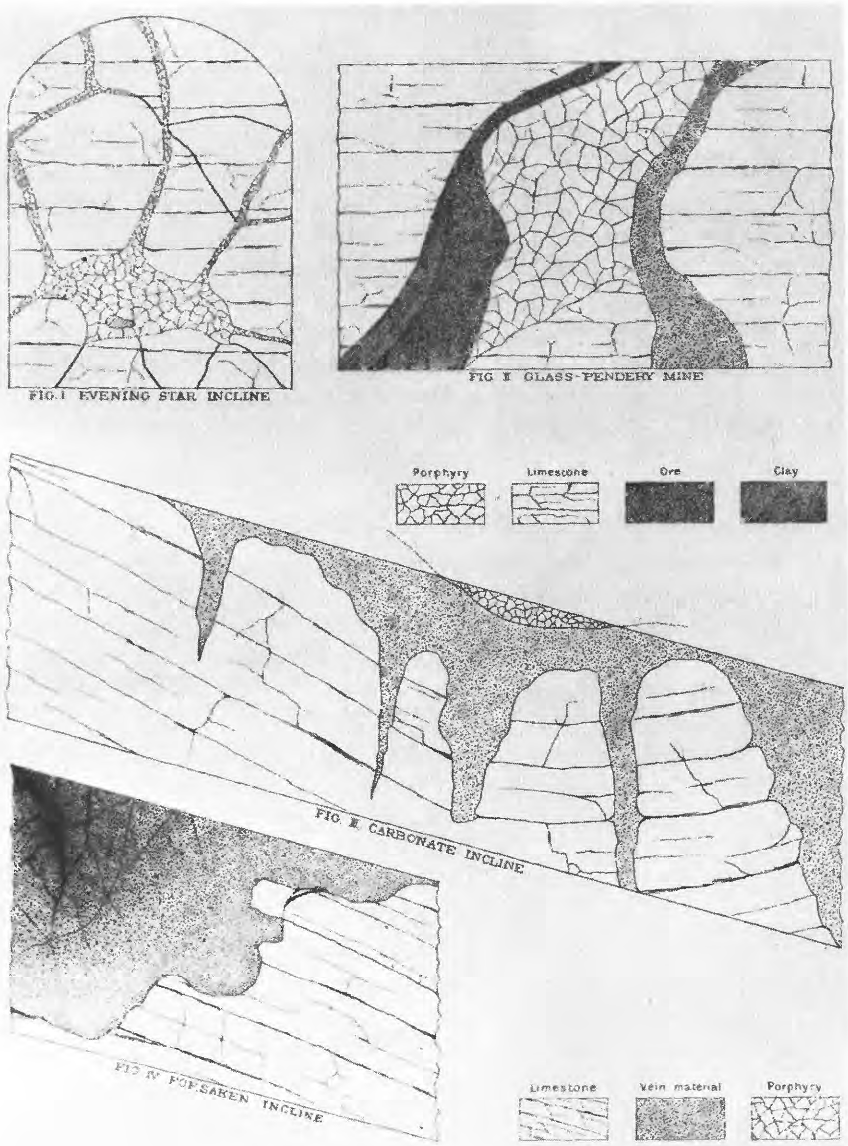
Almost all the topographic fieldwork in the summer of 1887 was simply a continuation of previous work. Gannett reported that the improvements in instruments and methods of work had kept pace with the extension of the topographic surveys. Graphic methods had been found to be the most economical and rapid and also to yield the best results. The plane table and alidade were being used for nearly all surveying. There had, in fact, been such great improvements, not only in the instruments and methods but in the skill and efficiency of the topographers, that the cost of work per unit area had greatly diminished, the quality and accuracy of the work had improved, and a given grade of work could be accomplished more rapidly. At the same time, the demand for maps of greater detail and on a larger scale had been growing. As a result, the original 4-mile scale was being abandoned in all but high mountain areas and the arid plains and plateaus.

Emmons' Leadville monograph was finally issued in September 1887. The *American Journal of Science* said the work was "grandly prepared in all respects" and a "very important contribution to geology and the science of mines and mining." *Science* called the volume and accompanying atlas magnificent. T. A. Rickard called the monograph "epoch making," and said,

> gave the mining community a series of maps that to the mining engineer were as charts whereby he steered the course of his exploration; it is not too much to say that, measured even in so commercial a unit as the dollar they were worth many millions to the operators at Leadville. Moreover, the report *** taught those engaged in mining throughout the Rocky Mountain region, and elsewhere, how great was the immediate and practical usefulness of a correct geologic diagnosis of a mining district, quite apart from its obvious value in presenting scientific conclusions and its general educational effect.

In the following month, the Director ordered Emmons to close the Denver office and transfer the collections to Washington, thereby provoking yet another source of tension. The Colorado Scientific Society protested, and the Denver Chamber of Commerce sent a petition to Washington. Congressman Symes, long a supporter of the Survey, had second thoughts and said the people of Colorado might turn their backs on the Survey if the Denver office were closed. For a while the Director hesitated, but finally, at the beginning of 1888, the decision was made. The collections and materials were shipped to Washington.

In February 1888, Emmons presented another major paper on the origin of ore deposits at the meeting of the American Institute of Mining Engineers in Boston, this one entitled *The Structural Relations of Orebodies*. Modest



Emmons' monograph on the Leadville mining district was perhaps the most important Survey publication in its first quarter century. Emmons found that the principal deposits at Leadville were in the Blue limestone at or near its contact with overlying bodies of porphyry. He concluded that the material was derived from the porphyry and deposited from descending currents by metasomatic interchange with the country rock. In the four examples shown: The limestone has remained barren although the porphyry has been intruded into it; ore is found along the contact of the porphyry and the limestone; ore has replaced the limestone in thin sheet-like bodies following a cleavage or fracture plan; and ore has replaced a large mass of limestone. (From S. F. Emmons, 1886 [1887].)

as always, he claimed no originality for his work; he gave credit to King for the generosity that had enabled him to make an elaborate and detailed study of the geology, not only in the immediate vicinity of the Leadville mines but of the adjacent mountain regions as well, so that the structural relations were determined with an exceptional degree of detail and accuracy. The inductions based on those structural relations had now borne the test of 7 years of exploration, and their substantial accuracy had been so abundantly proved that they afforded an excellent practical illustration of the importance of the structural study. Now Emmons was ready to extend his ideas to other types of deposits and present some preliminary generalizations that might furnish the basis for a general classification of ore deposits. He stated that: Deposits were formed from aqueous solutions; under given conditions of heat and pressure, all substances were more or less permeable to water, but water tended to concentrate where there was more ready passage or flow; and during such passage or flow, it might come into different conditions that might favor deposition, precipitation, or chemical interchange. Natural water channels might be formed by sedimentation or bedding by intrusion of eruptive masses or by dynamic movements producing fractures across rock masses of differing origin or composition.

Emmons "main proposition," as he put it, was

> **that careful structural study of the district in which a mine occurs and of the manner in which the water-passages were formed, which originally gave access to the mineral-bearing solutions, is of the greatest importance to the mining engineer in his determination of the probable extent and value of a deposit and of the best method of exploiting it.**

Despite the modest disclaimer, this paper was of fundamental significance in its claim for the structural control of ore deposits, and it, like the 1886 paper on the genesis of ore deposits, is considered one of the dozen most influential papers on mining geology in the first 75 years of the American Institute of Mining Engineers. Moreover, it clearly established Emmons as one of the top-ranking economic geologists in the Nation.

Meanwhile, the debate on stratigraphic nomenclature continued. Persifor Frazer, the secretary of the American Committee on the International Geological Congress replied to Gilbert's AAAS critique with a paper in the *American Naturalist*. The American Committee then met in December 1887 and approved and ordered printed its reports on the Archean, Devonic, Carbonic, Mesozoic, Marine Cenozoic, and Quaternary, Recent, and Archeology. Major Powell initiated a series of conferences in the Survey on stratigraphic nomenclature; as a result of these conferences, it was decided that a series of essays would be prepared in which existing data affecting the problems of American geologic nomenclature would be collected and discussed. Specialists would prepare essays on each of the following systems: Quaternary, Newer Tertiary, Older Tertiary, Cretaceous, Jura-Trias, Carboniferous, Devonian, Silurian, Cambrian, Eparchean, and Archean. Survey nomenclature was both different from, and more detailed than, that of the American Committee. The series of essays would also include discussion of the evidence from fossil vertebrates and fossil plants, and a thesaurus of North American stratigraphic terminology would be prepared. Gilbert was placed in general charge.

In January 1888, opposition to the Federal survey took a new form. Several American geologists, including Professors Alexander Winchell, N. H. Winchell, Samuel Calvin, Edward W. Claypole, and L. E. Hicks, along with Persifor Frazer of the Franklin Institute and E. O. Ulrich of the Illinois Survey, published the first issue of a new American journal, *The American Geologist*. They stated,

> **The promoters of The American Geologist have been satisfied for several years past that the interests of the science of geology in America have been jeopardized, and sometimes have suffered, because of the lack of cooperation among American geologists, and of a ready means of expression through a sympathetic medium of communication. Many of them have had serious misgivings as to the result of the influence of the national geological survey in extending its operation into the settled states of the Union, and especially into the states in which official geological surveys are in progress, fearing that by the concentration of all authority and control at the national capital, and by the extensive accumulation at one centre of all the material illustrating the state and local geology of the country, the local interest and effort may die out, and that ultimately the weight of public sentiment favorable to geologic investigation may suffer diminution.**

The American Geologist would serve as a medium of intelligence to the stratigrapher, the petrographer, the paleontologist, the mineralogist, the "fossil botanist," the climatologist, the chemist, the physicist, the seismologist, the glacialist, the anthropologist, and the astronomer in all the directions where their special investigations bore directly on the constitution and history of the Earth. "Geology," said the editors, "includes them all, and is built on them as cornerstones."

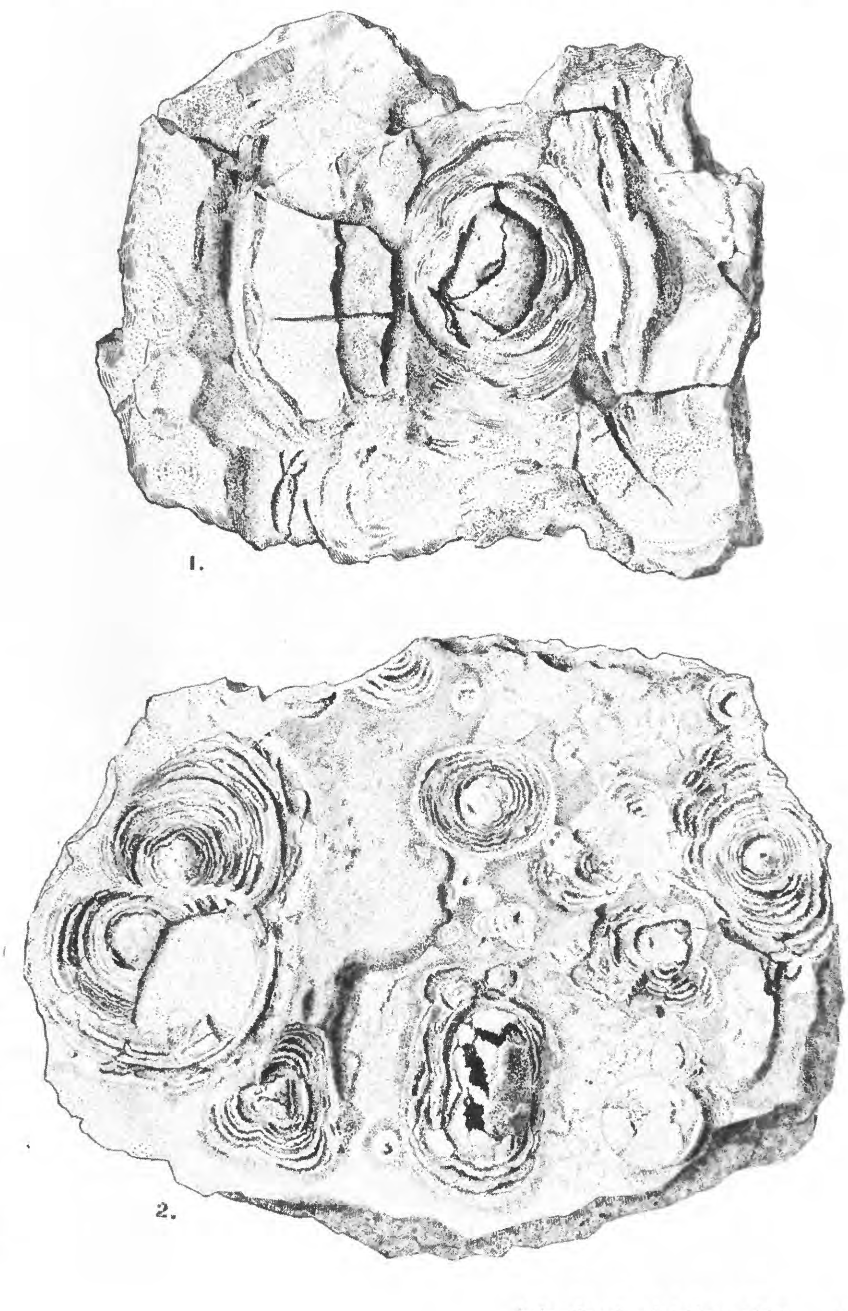
Major Powell's view of the place of geology in the scheme of knowledge was somewhat different. In the same month, January 1888, he had a hand in establishing the National Geographic Society, not as one of the signers of the original note calling for the organizational meeting but as one of the 15 incorporators of the society. The purpose of the new organization was to increase and diffuse geographical knowledge, and at the outset, five areas of geographic knowledge were recognized: land, sea, air, distribution of life, and what Gardiner G. Hubbard, one of the founders, called the abstract science of geographic art, or mapmaking. In Germany, where the great development of geography as a science had taken place during the 19th century, geology was considered part of geography. The National Geographic Society, quite possibly because of Major Powell's influence, went still further. It included not only geology but anthropology as part of geography. Major Powell did not hold office in the new society, but Henry Gannett was the first recording secretary and A. H. Thompson, the vice president for the Section of Cartography.

All these matters, however, took second rank to an opportunity, which Major Powell had long sought, to do something about the irrigation question. When the 50th Congress convened in December 1887, Senator William Stewart of Nevada was back, after an absence of 12 years, with two strong interests—irrigation and silver. The session was only a few days old when Senator Stewart filed a bill to encourage irrigation by the segregation of irrigable lands and reservation of places for reservoirs and rights of way for ditches and canals. The bill was referred to the Committee on Public Lands, of which Senator Plumb, who had requested the report from the Department of Agriculture, was chairman.

President Cleveland devoted his entire state of the Union message in December 1887 to tariff reform. A surplus in the Treasury at the time was proving to be somewhat of an embarrassment. With money locked up in the Treasury instead of circulating, there was the possibility of an economic crisis. The surplus funds could not be used to reduce the national debt except by buying bonds in the open market at a premium, so congressional extravagance was encouraged. As the tariff provided the major part of Federal income, Cleveland deemed a lowering of the tariff the best method of dealing with the surplus. The House Ways and Means Committee began preparation of a bill to incorporate the President's recommendations, and the stage was set for a major tariff battle. With the Republicans, nominally the high tariff party, in the majority in the Senate, and the Democrats, nominally the low-tariff party, controlling the House, tariff reform would be difficult if not impossible.

Senator Stewart was not a patient man. When action of his irrigation bill was not forthcoming from the Committee on Public Lands by February 13, 1888, he proposed a resolution, to which the Senate agreed, "That the Secretary of the Interior be requested to inform the Senate if in his opinion it is desirable to authorize the organization in his Department known as the Geological Survey to segregate lands of the public domain capable of irrigation, in the section of the United States where irrigation is required, from other lands, and to lay out suitable places to be reserved for reservoirs and rights of way for ditches and canals for the purpose of irrigation."

The Secretary of the Interior was newly arrived on the job. Secretary Lamar had been nominated for the Supreme Court and confirmed by the Senate on January 16, 1888, and the Postmaster General, William F. Vilas, had then moved to Interior. Secretary Vilas had become Cleveland's closest friend in the Cabinet, and Cleveland considered him "one of the most complete men, mentally, morally, and politically" he had ever met. Secretary Vilas, unlike Secretary Lamar, became actively involved in the administration of the Department. He did not reply immediately to the Stewart resolution because he had conflicting advice from within the Department which he wished to consider. The Acting Commissioner of the General Land Office said, "whilst it may be desirable that legislation of the character contemplated by the resolution should be had in the future, at the present I am unable to see any urgent necessity for it."The Director of the Geological Survey, however, reported that "The topographic work of the Geological Survey has from the first been executed with a view to the problems of irrigation, and if such authority as is contemplated by the resolution shall be given the Survey the maps now completed and in preparation will serve



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Studies at Yellowstone National Park yielded information on the origin of igneous rocks. At Obsidian Cliff, the rock in the lower part of the column is a dense black obsidian containing thin layers of small rounded masses called spherulites; higher up it is less massive and contains large hollow spherulites; and still higher it is honeycombed with large cavities. Although the distribution suggested the bursting bubbles that rise to the top of boiling muds in Yellowstone, Iddings found that the spherulites acutally represent primary crystallization from a molten glass. (From J. P. Iddings, 1888.)

as a basis for the special work required in respect to irrigation." The fundamental topographic work had already been done for about 10 percent of the arid region, but "in extending the geographic work of the Geological survey over the portion of the arid region not yet covered by it, it will be economic to give the topographic work a special adjustment in the interest of irrigation." In addition, it would be necessary to make "local surveys for the selection of sites for reservoirs, canals, etc., and of irrigation areas" and "to gauge a certain number of representative streams at all seasons of the year, so as to ascertain their total discharge and its seasonal distribution, and also to gauge a greater number of streams at certain seasons determined to be critical."

Major Powell still held that 20 inches a year was the minimum amount of precipitation necessary for successful agriculture, but others disagreed. Cereals were then being cultivated in western Kansas, a region which it had been supposed could be made productive only by irrigation. Many believed that settlement and tree-planting had caused greater rainfall, but Henry Gannett's research indicated that the increase, if there were one, was only a fraction of an inch. Gannett pointed out that there was no doubt that cultivation added to the economy of the rainfall because cultivated soil retained most of the rainfall whereas the rain flowed off freely from hard bare ground. General A. W. Greeley of the Signal Service, who also disagreed with Major Powell, told the Philosophical Society at its February 18, 1888, meeting that there had been many misconceptions about the amount of rainfall in western areas because of the scarcity of observations. More numerous observations in the preceding decade had reduced to almost nothing the area in which annual precipitation was less than 5 inches a year and had reduced by a quarter of a million square miles the area in which precipitation was less than 15 inches a year. In the discussion following the meeting, G. K. Gilbert said that it was not safe to fix any given amount of rainfall as the minimum necessary without qualifications as much depended on the season when the rain fell and the rapidity with which evaporation took place.

While Secretary Vilas pondered his decision, Senator Teller of Colorado, who had been President Arthur's Secretary of the Interior, introduced a joint resolution on March 6, 1888: "That the Secretary of the Interior, by means of the Director of the Geological Survey, be, and he is hereby directed to make an examination of that portion of the arid regions of the United States where agriculture is carried on by means of irrigation, as to the natural advantages for the storage of water for irrigation purposes with the practicability of constructing the reservoirs, together with the capacity of the streams and the cost of construction and capacity of reservoirs, and such other facts as bear on the question of storage of water for irrigating purposes; and that he be further directed to report to Congress as soon as practicable the results of such investigation." The joint resolution was passed by both houses and approved by the President on March 20, 1888. It enlarged the functions of the Geological Survey to include irrigation investigations.

Funds were needed for the irrigation investigations, and in accordance with the requirements of the preceding Congress, the estimates for appropriations had to be itemized. On March 27, therefore, Senator Stewart introduced a resolution: "That the Secretary of the Interior is hereby directed to report to the Senate what appropriation is necessary to enable the United States Geological Survey to carry into effect the joint resolution, directing the Secretary of the Interior, by means of the Geological Survey, to investigate the practicability of constructing reservoirs for the storage of water in the arid region of the United States, and to report to Congress, approved March 20, 1888, and the several acts of Congress requiring such Geological Survey, under the direction of the Secretary of the Interior, to classify the public lands and to furnish a map or maps showing the various divisions of the public domain suitable for agriculture, minerals, and other purposes, and particularly to segregate the lands susceptible of irrigation, where irrigation is required, from other lands, and designating places for reservoirs, canals, and other hydraulic works." The language of the resolution is tortured, but it is reasonably clear that the Senate, or Senator Stewart at least, regarded the resolution of March 20 as directing an investigation of the practicability of constructing reservoirs, segregating lands susceptible of irrigation, and designating places for reservoirs, canals, and other hydraulic works.

At this point, Secretary Vilas gave up and on March 31 replied to the resolution of February 13. He begged to be excused from expressing an opinion; he had not had sufficient opportunity to examine and study the question. However, he did sound a note of caution: "The subject involves vast areas of territory, manifold public and private interests, and far-reaching considerations touching results and cost,"and "each separate instance of contemplated action involves peculiar and special inquiries and determinations, so that although the general desirability of so comprehensive and effective a system of irrigation as Government alone can institute and carry to completion may be readily affirmed, a particular designation of what lands may be segregated and what means may be employed to accomplish any result must be the fruit of distinct and particular inquiry in each case." With his letter, he forwarded the letters from the Acting Commissioner of the General Land Office and the Director of the Geological Survey containing their conflicting advice. The letter from the Secretary was referred to the Committee on Public Lands where it would not receive any prompt consideration, but it mattered little because the Congress had already committed itself to a course of action by the joint resolution of March 20.

Mr. Symes of Colorado submitted a bill to the House on April 2, 1888, for the investigation and development of the water resources of the arid regions, and the utilization thereof for irrigation, providing an appropriation of $500,000 to be expended under the direction of the Director of the Geological Survey for topographic and hydrographic surveys. The Symes bill was referred to the Committee on Agriculture.

It was May 11 before Secretary Vilas replied to the resolution of March 27, and then the Secretary merely forwarded Major Powell's estimate, dated May 3, with the comment, "I have no means to make any estimate other than the considerations presented by the Director." The Director asked for an appropriation of $250,000 and suggested that the clause in the appropriation bill be:

"For the purpose of investigating the extent to which the arid region of the United States can be redeemed by irrigation, and the segregation of the irrigable lands in such arid region, and for the selection of sites for reservoirs and other hydraulic works necessary for the storage and utilization of water for irrigation, and to make the necessary maps, including the pay of employees in field and in office, the cost of all instruments, apparatus, and materials, and all necessary expenses connected therewith, the work to be performed by the Geological Survey, under the direction of the Secretary of the Interior."

When the Secretary's reply was received on May 14, Senator Stewart thought it should be referred to the Committee on Appropriations, but the Chair ruled that it too should go to the Committee on Public Lands. Later that same day, Senator Paddock of Nebraska, chairman of the Committee on the Improvement of the Mississippi River, reported favorably on an amendment to the Rivers and Harbors bill proposed by Senator Bowen of Colorado on May 9 and moved that it go to the Committee on Appropriations. The amendment as reported on May 14 provided $25,000 to the Geological Survey, "For the purpose of investigating the extent to which the arid region of the United States can be redeemed by irrigation* * *" as in the Powell formula, but concluded, "for the storage and utilization of water for irrigation, and the prevention of floods and overflows." It is possible that the Bowen amendment may originally have included both purposes, but it is equally possible and perhaps more probable that the Powell clause had been added to an amendment calling for an investigation aimed at preventing flood and overflows of the Mississippi River. The $25,000 could be a misprint for $250,000, or the amount specified in the original amendment. What is sure is that the Governor of Nebraska had written to the Nebraska congressional delegation urging that some action be taken on the irrigation problem, that Senator Paddock zealously watched out for the interests of Nebraskans whenever national policies that would touch them were up for consideration, and that the matter of the irrigation survey had at last been placed in the hands of the Senate Appropriations Committee.

During all this time, there had been no report on the Survey's regular appropriation. The Sundry Civil Expenses bill was always one of the last to come in a session, as it was meant to gather together all items not provided for in other appropriations, but in 1888, it was later than usual because of the great tariff debate that occupied the House from mid-April to early June.

The Survey's budget request for fiscal year 1889 was $500,000; it was itemized for the first time, the funds being apportioned among eight items: topographic surveys, geologic surveys, paleontologic research, chemistry and physics, preparation of a report on mineral resources, skilled laborers, preparation of illustrations, and books for the library. Major Powell told the House Appropriations Committee that three methods of itemizing had been considered: by districts or regions to be surveyed, by personnel, and by classes of work to be performed; the last had been chosen (Two of the eight items "skilled laborers" and "books" were obviously exceptions.). Itemization by districts was not chosen because the paleontologic work was in no proper sense local. The paleontologists studied type localities and established sections in order that the geologist could have facts available when mapping formations, but their results were applicable over far greater areas. Similar considerations applied to the work in chemistry and petrography. Moreover, the Survey had been established to do general work which could not be economically or successfully accomplished under State auspices, and the Organic Act "practically prohibit[ed] the Government survey from engaging in local economic problems." The objection to the second scheme was that by establishing a schedule of salaries a list of offices was created, and incumbents of offices were prone to magnify their rights as officers, whereas persons employed to do a specific work magnified their duties as employees.

The Appropriation Committee accepted the itemization but arbitrarily reduced all items by the same percentage so the total appropriation would be $402,000, approximately the same as the appropriations had been for the past few years. The largest amount was for topographic surveys, $199,000. The other recommendations were: for geologic surveys, $100,000; for paleontologic research, $40,000; for chemistry and physics, $17,000;

for preparation of a report on mineral resources, $10,000; for skilled laborers, $15,000; for preparation of illustrations, $16,000; and for books for the library, $5,000.

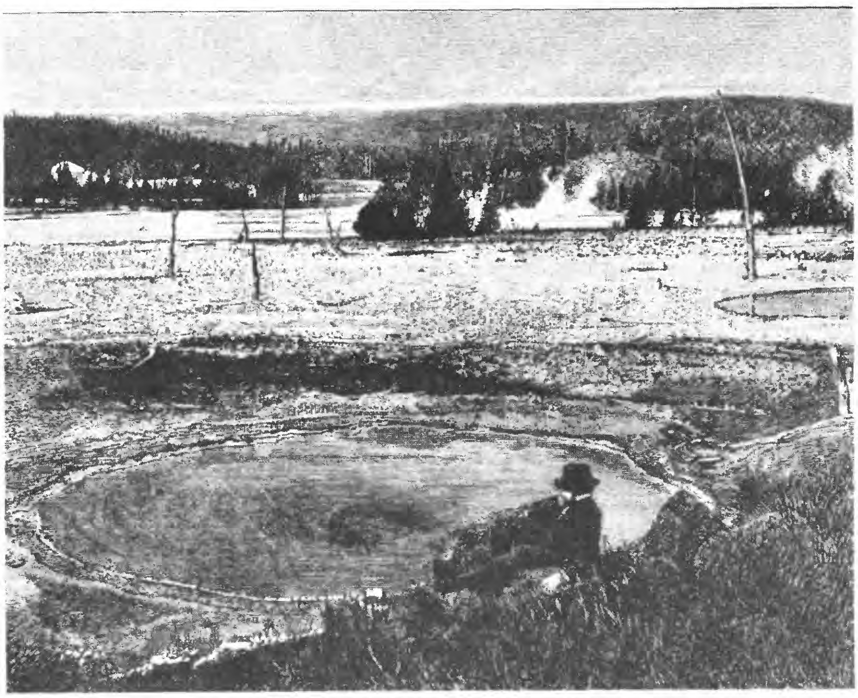
When the bill came before the House, motions were made to increase the appropriations for topographic surveys and for geologic surveys, but both were defeated. So was an amendment to appropriate $25,000 for the classification of public lands, which William W. Morrow of California said was called for in the law creating the Survey but "had been a dead letter so far as agriculturists were concerned." Joseph Toole of Montana proposed an amendment, the clause proposed by Major Powell for the irrigation survey in its original form without reference to the prevention of floods and overflows. The chairman of the Appropriations Committee immediately made a point of order against it, and the Sundry Civil Expenses bill was passed by the House on June 21 with approximately the same funds as the year before and no appropriation for irrigation investigations.

Most of the regular work of the Survey got underway in July even though the appropriation bill had been passed only by the House. Most of the topographic work in the summer of 1888 was either a continuation or an exension of earlier work. The Massachusetts and New Jersey surveys had been completed, but work was extended north of Massachusetts into New Hampshire and southwestern Maine and west into New York State. Several sheets (now called quadrangles) projecting northward and westward from New Jersey into adjoining States were completed. In the spring, the legislature of Rhode Island appropriated $5,000 for a survey of that State in cooperation with the Geological Survey under an agreement similar to that made with Massachusetts, and the entire State was mapped during the summer. Ten sheets comprising New York City and its suburbs were also mapped, "probably the most important group of sheets in the United States, and in many respects the most difficult to survey, owing to the complex culture," according to Gannett. In the southern Appalachians, work continued in both the Virginia-West Virginia-Kentucky area and the Georgia-Alabama area. In the Mississippi Valley, surveys were made in Kansas, Iowa, and southern Wisconsin and the two sheets comprising St. Louis and its suburbs. The surveyed area in Arkansas was extended eastward and that in Texas northward. In the far West, work was done in New Mexico, California, Oregon, and Montana.

A plane table suitable for traverse work was devised and introduced into general use. It relieved the topographer of the labor of platting traverses in the field or office and provided a correct skeleton upon which to sketch. The table was also simple and light, and less accuracy was required in its use. It was even being used by geologists.

At the beginning of fiscal year, a Division of Geologic Correlation was established, and Gilbert was placed in charge. For the time being, he also retained direction of the Appalachian Division, but the Director was turning to him increasingly for advice and the Bonneville monograph was still unfinished, so Willis was entrusted with some of the administrative duties of the Appalachian Division. Captain Dutton was placed in charge of the irrigation investigations under the authorization of the joint resolution of March 20, so the field of the Division of Volcanic Geology was modified, the division was renamed the Cascade Division, and Diller was placed in charge. On July 25, James Stevenson died after a long illness, and a new Executive Officer was appointed—a gentleman of the press, W. A. Croffut, who had been in newspaper work, except for th period of his Civil War service, since 1852 and was then on the staff of the *Washington Post*.

At Mammoth Hot Springs, Walter Weed found that the deposits are calcium carbonate (travertine) because the hot waters rise through a Mesozoic limestone. Silica deposits at the Geyser basin are largely due to the growth and life of a brilliantly colored algal vegetation living in the hot mineral waters. (From W. Weed, 1889.)



Work began in earnest on the geologic atlas. In New England, Shaler began the task of mapping the surface deposits of the area included in the 56 atlas sheets prepared by the Survey in cooperation with the Commonwealth of Massachusetts. He had so many volunteer assistants that the mapping was nearly completed in one summer. Pumpelly's division also began "coloring the geological map of New England." Although the investigation of the Green Mountain structure was still incomplete, the mapping had shown that the mountains consisted of long folds that extended in the direction, and were apparently a continuation, of those of the Appalachian system; the range had a generally hidden Precambrian crystalline core and surface rocks of Early Cambrian to Early Silurian age.

In the Appalachian region, Arthur Keith and C. Willard Hayes began work on atlas sheets—Keith in east Tennessee, where Willis' work on the French Broad section had prepared the way, and Hayes in the Alabama-Georgia section, which Russell, who did not enjoy the work in the Appalachians, cheerfully relinquished. I. C. White, who had nearly completed a monograph on the comparative stratigraphy of the bituminous coal rocks, took up the Lewisburg, West Virginia, atlas sheet, and N. H. Darton began a survey of the Staunton, Virginia, sheet. The earlier work by Willis, Russell, and Geiger had made it evident that a uniform scheme of stratigraphic classification could not be carried throughout the Appalachian province, and Gilbert therefore gave instructions that,

Formations rather than names should be mapped; that is to say, the actual distributions afforded by the stratigraphy of the given area are to be represented on the map in preference to distinctions belong to the stratigraphic classification of other areas.

This meant that the stratigraphic subdivisions on adjacent sheets would often fail to correspond in minor features, but it was concluded that as the atlas sheet was a small unit of area, the stratigraphic variations would be noted at frequent intervals, and the many small changes at the boundaries of atlas sheets would conform to the gradual passage of lithologic characters from one phase to another.

In the West, Hague's party began work in Yellowstone Park and in the Absaroka Range east of the park in July, and Peale continued mapping in the Three Forks area, although he was unable to get into the field until mid-August. Diller did a little mapping in northern California but spent most of the season collecting specimens for the Educational Series of Rocks.

In the summer of 1888, Professor Marsh began a systematic investigation of the Laramie formation, which held the key to the location of the Cretaceous-Tertiary boundary in the Rocky Mountains. A stratum was discovered in the typical Laramie of Wyoming that yielded more than 100 specimens of mammalian remains, including many new genera and species. Until this discovery, no mammalian remains had been known with certainty from the Cretaceous. In the same bed with the mammals, a new family of gigantic horned dinosaurs was found, which Marsh said were "by far the strangest reptiles yet discovered."

C. A. White spent most of the summer on the Cretaceous memoir, but in September, he went to Texas to investigate some Permian strata in the northern part of the State that were reported to contain a commingling of Paleozoic and Mesozoic fossils. His observations there confirmed his long-held view that the Permian of North American was closely related to the Carboniferous and should be assigned to the Paleozoic rather than to the Mesozoic.

Dall and Ward were both busy with manuscripts. During the summer, while Williams continued his study of the Devonian, Walcott was in northern Vermont studying the stratigraphy and fauna of a series of Cambrian limestones on the Canadian border. On his return to Washington, he began preparation of a major paper on the fauna of the *Olenellus* zone.

With the Director so involved in irrigation, McGee was now clearly out of the center of things. He spent the early summer months in northeastern Iowa, reviewing his earlier work in the light of recent advances in glacial geology. He also made a study of the "memorable freshet" in the Potomac River on June 1 and 2, 1888, which was, he reported, an opportunity without precedent to study the departure of the Potomac from the "well known law of river deportment, established by Powell and Gilbert, that streams of high declivity tend to corrade vertically and thus to flow in deep and narrow channels." He was also exercising at least nominal supervision of a variety of projects, including A. J. Phinney's work on the rock-gas field of Indiana, Professor George H. Williams' study of the crystalline rocks of the Piedmont region in Maryland, Hay's survey of the Fort Riley Military Reservation in Kansas, and Professor J. A. Holmes' study of the correlation of formations of the middle Atlantic slope with those of the southern Atlantic and Gulf regions.

In the summer of 1888, Emmons was told that his division was to undertake no new work but to devote all its energies to completing and preparing for publication the work already undertaken, chiefly the quadrangles in the southern Elk Mountains. Eldridge took charge of a combined geologic and topographic party and completed the survey of the Elk Mountains, and Emmons, for once, was pleased with a topographic map. Emmons and Cross spent the summer making isolated investigations in parts of Colorado, Montana, and Wyoming to verify, elaborate, or complete observations and to gather new data that might furnish correlative evidence for generalizations on ore deposits.

Becker completed work on the proof of the quicksilver monograph and then went to California to start on the gold-belt study. Nearly half the topographic maps had been completed, and Turner and Lindgren were well along in their preliminary geologic mapping, although they had not subdivided the sedimentary rocks of Paleozoic and early Mesozoic age and had grouped together all the eruptive rocks. The massive rocks were much more complex than had been anticipated, and their representation at the 2-mile scale was very difficult. The rocks had been so profoundly modified by dynamic and chemical action that it was not easy to identify them, let alone determine their relations to one another. Becker thought the map might be completed by the end of 1893.

Although Major Powell had been diverted from problems of stratigraphic nomenclature by his work on irrigation, others continued to press for consideration of the American viewpoint. The State Geologist of New Jersey, George H. Cook, and a member of the American Committee on the International Geological Congress, had succeeded Gilbert as vice president for Section E of the AAAS, but continued Gilbert's theme of the International Congress and its relation to American geologists in his principal address. Cook said, "a meeting of the congress must be held in this country and America must be fully represented before any conclusions can be reached which will be accepted by the scientific world." Geology, he said, was first systematized from a limited part of the globe, and it was not surprising that a system arranged consistently with the facts in a single country should not be comprehensive enough to meet the circumstances of all others. American geologists had begun by transferring the German, English, and French systems to this country, and even after they found that these systems did not fit, reverence for authority, which is due from the younger to the older, led to an attempt to make our geology conform with that of Europe. Now geologists had to admit that something larger and more far reaching must be devised before the science could be called a general one, applicable in all places.

Geologists attending the AAAS meetings assembled on August 14, 1888, and unanimously resolved that an American geological society was desirable. They agreed that until January 1, 1889, members of the geological society must be active workers or teachers of geology who were either members or fellows of the AAAS, but that thereafter, others would be eligible.

Gilbert, Walcott, and Marsh attended the International Geological Congress in London in mid-September 1888. The Congress, however, took no formal votes on the various questions at issue. As one American who attended observed, the Congress provided an opportunity to make acquaintances and to compare views and modes of studying problems, but the general agreement was that votes could settle few of the questions. Philadelphia was selected as the next place of meeting, and a Provisional Committee of Messrs. James Hall, James D. Dana, John S. Newberry, Persifor Frazer, G. K. Gilbert, T. Sterry Hunt, O. C. Marsh, and C. D. Walcott was appointed to make the arrangements.

The American Committee had had its reports printed and sent to the International Congress but withheld distribution in the United States before the opening date of the Congress. The reports were then published in full in *The American Geologist.* Professor Dana let everyone know what he thought of them in the next issue of the *American Journal of Science:* The American report was "a 'majority' report of the Committe and of its several Subcommittees, and a minority report as regards American geologists." He thought that "its right to appear in the volume of the Congress for 1888 should be seriously considered if it is not already too late." Major Powell also objected, especially to the use of his name as if he supported the Committee and had not resigned in protest. Powell said:

> **There is no body of men so wise or so powerful that it can establish the science of geology by authority, and it is pretentious and unseemly to make the attempt; and to authoritatively announce a fact or generalization in science and ask its acceptance is an absurdity.**

The members of the Provisional Committee, with the exception of T. Sterry Hunt, met at New Haven on November 15 and elected a 24-member Permanent or Organizing Committee for the Philadelphia Congress. The Permanent Committee was a judicious mixture of American geologists, both the young and older, and all warring elements. John Strong Newbery was appointed temporary chairman, and the first meeting of the Permanent Committee was scheduled for Washington in April 1889. The Provisional Committee thereupon ended its duties. With malicious satisfaction, Professor Dana wrote to Professor Geikie that 20 good men had been elected and three obnoxious ones left out. "Frazer, who was present and secretary as the votes were read off looked desperate but said nothing. T. S. H. who was put to bed the day before in New York City by his physician there has not since been heard from." The third obnoxious one was presumably E. D. Cope. Marsh was a member of the Permanent Committee.

James Hall was elected the first president of the Geological Society of America at its first meeting in Ithaca on December 27, 1888, with Dana and Alexander Winchell as vice presidents, J. J. Stevenson, secretary, H. S. Williams, treasurer, and Powell, Newberry, and C. H. Hitchcock the first members at large of the council. Again the offices seem to have been divided up judiciously. Professor Hall addressed the society informally and counseled harmony and mutual forbearance. He hoped that every American geologist would be mentally prepared to pursue a course of justice, and, if need be, of forbearance and conciliation, in order that peace and harmony might reign.

From the Survey, only W J McGee attended. The Director was then thoroughly occupied in the affairs of the Irrigation Survey, but preparations were also underway for a conference in the Survey on geologic nomenclature and map notation.

On December 7, 1888, a circular letter was addressed to "heads of geologic divisions and some other specialists" in the Survey on the cartographic system. Since the first system had been announced in the second annual report, the science had developed, geologic nomenclature and map notation had been under investigation both in the United States and abroad, and the operations of the Survey had been extended over many parts of the country. It was time for a reconsideration. The circular said:

> **It was long ago well shown by Dana and is now recognized by geologists everywhere, that the North American continent represents in itself an epitome of the geologic development—that every important event in world growth, every great rock group, every class of minerals, every type of fossils, every order of the superficial deposits formed by air, water, ice and the decay of older rocks, every kind of normal and deformed rock structure and every grade of surface configuration formed by geologic agencies found in any part of the earth is**

here well represented. During the decade all of these classes of phenomena have been under investigation by officers of the Geological Survey, and in the progress of the work it has been found that many of them are susceptible of delineation upon maps. In the course of their work upon different phenomena in the various parts of the country the collaborators of the Survey have devised methods of mapping well suited to their respective areas and to the classes of phenomena with which they respectively deal.

So within the Geological Survey, there has been wide differentiation of ideas concerning geologic taxonomy and nomenclature and concerning their application in geologic mapping; within the Geological Survey there has grown up as great need for diverse systems of map publication as was ever felt during the days of numerous State surveys; within the Geological Survey, indeed, the range of thought and work concerning these matters has become practically as wide as the range of thought and work among the geologists of the world, and just as the North American continent represents an epitome of the geologic development of the earth, so the range of conception concerning geologic principles and methods among the Federal geologists has become an epitome of the geologic opinion of the earth.

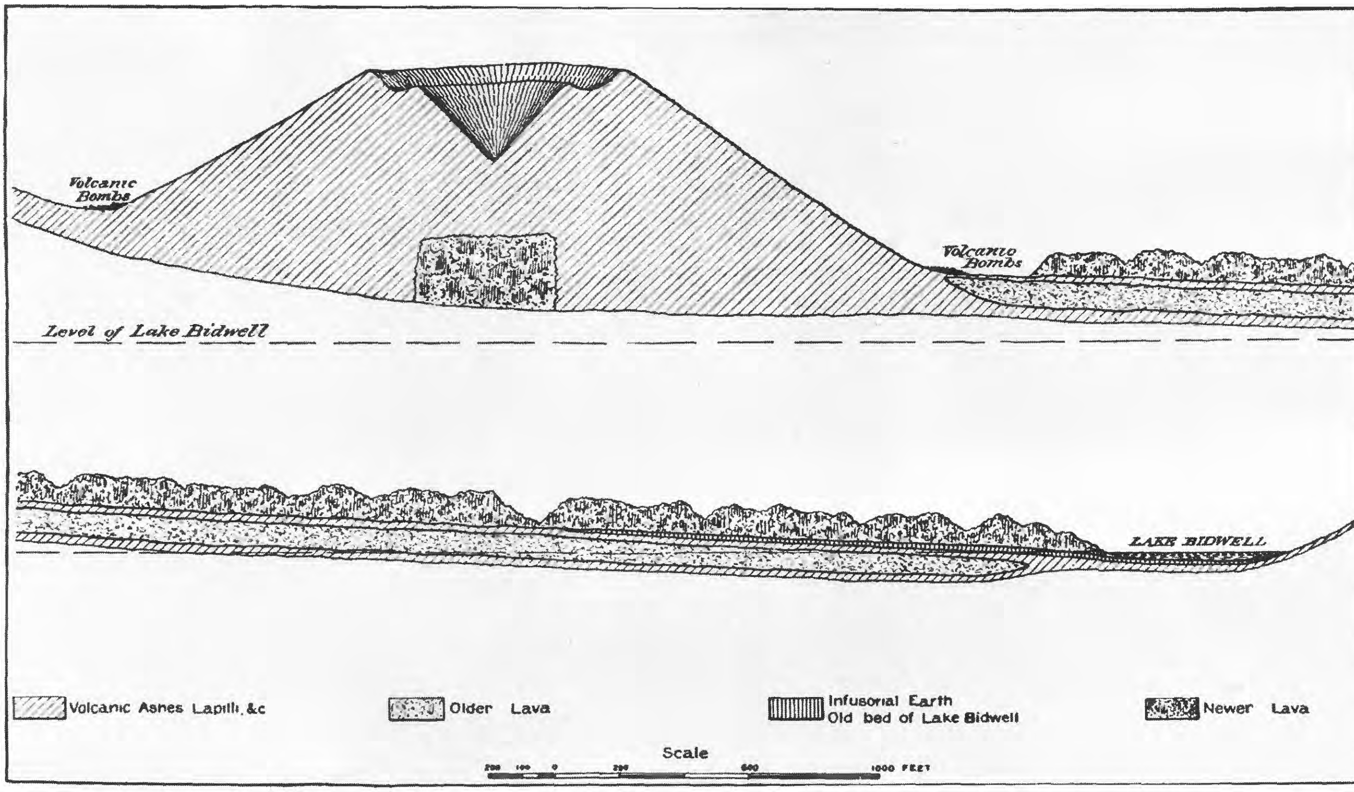
The conference of Federal geologists was therefore arranged to devise a cartographic system applicable throughout the country, and at the same time, to allow geologists employed in each region to form and express convictions as to local needs. C. W. Cross, J. S. Diller, C. E. Dutton, G. H. Eldridge, B. K. Emerson, S. F. Emmons, G. K. Gilbert, Arnold Hague, W. H. Holmes, J. P. Iddings, W J McGee, A. C. Peale, Raphael Pumpelly, C. R. Van Hise, W. H. Weed, C. H. Williams, Bailey Willis, and C. D. Walcott met in conference with the Director January 28–31, 1889, to consider the 32 questions posed in the circular on the unit of publication, nomenclature, map notation, map colors, and notation for sections.

There was general and ready agreement to the plan that the unit of publication be an atlas sheet, with legend on the margin, accompanied by a full sheet of description so prepared as to be intelligible to users who were not trained geologists, a sheet of sections when necessary, and sometimes a soil map or map of Pleistocene deposits, the whole to be arranged under a folio cover.

After prolonged consideration of the subject of nomenclature, the geologists finally agreed that it was desirable, and in fact necessary, to establish certain rules regarding the nomenclature to be used on the Survey's geologic maps. They agreed that for cartographic purposes and for use in the maps published by the Survey, four great classes of rocks should be recognized: fossiliferous clastic rocks, superficial deposits, ancient crystalline rocks, and volcanic rocks. Among the clastic rocks, two classes of division should be recognized—structural and time—and all other taxonomic divisions should be excluded from the atlas sheets.

The structural divisions should be the units of cartography and should be designated formations, and formations should be distinguished on the basis of lithology. Formations should receive distinctive designations, the most desirable being binomial—the first member geographic and the other lithologic, as Trenton Limestone. The geographic term should be the name of a river, town, or other natural or artificial feature at or near which the formation is typically exposed. These rules of nomenclature were to be used, as far as applicable, to all classes of rocks.

The time divisions were to be defined primarily by paleontology and secondarily by structure and were to be called periods. Eleven periods were recognized. For the first, the term "Quaternary" was rejected on the ground that it was the vestige of a primitive and otherwise obsolete classification, and the term "Pleistocene" was substituted. The second period, including the time divisions sometimes called Pliocene and Miocene, was designated



Evidence of one of the latest volcanic eruptions in the United States was discovered by J. S. Diller at Cinder Cone, northeast of Lassen Peak in California. Diller estimated from the trees that had grown on the volcanic sand near the Cone since it was formed that the first eruption probably occurred about a century before the American Revolution and that a second eruption had occurred later, but before 1840. (From J. S. Diller, 1891.)

the "Neocene." The third was the Eocene, including the subdivision sometimes called Oligocene. The fourth period was the Cretaceous and the fifth, the Jura-Trias. The sixth period was the Carboniferous, including the Permian. The seventh was the Devonian. The eigth included the time divisions sometimes called Upper and Lower Silurian and sometimes Silurian and Ordovician, and it was called "Silurian." The ninth period was designated the "Cambrian." The tenth period was the time of deposition of clastic rocks older than the Cambrian. For this the terms "Eparchean" and "Huronian" were rejected, and the term "Algonkian" was agreed to. The oldest time division, covering the time of formation of the ancient crystalline rocks, was designated the "Archean."

In the superficial deposits, the primary classification should be genetic rather than chronologic, though the secondary classification could be structural. Among the ancient crystalline rocks, the division would be chiefly petrographic, though genetic and chronologic divisions might be used as more knowledge was acquired. Among the volcanic rocks, the primary divisions were to be chronologic when possible and adjusted to the historic divisions of the fossiliferous clastic rocks; minor divisions might be petrographic, genetic, or structural, at the convenience of the geologist.

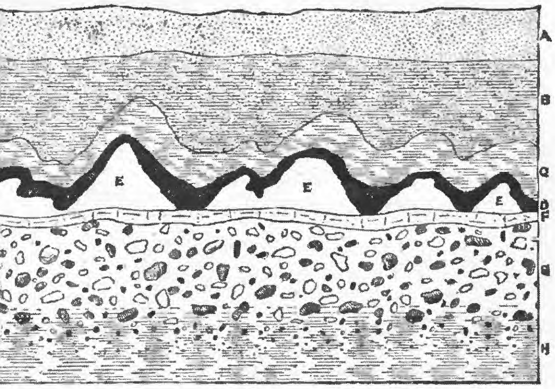
There was less unanimity of opinion on the subject of geologic cartography, and the final decisions were made by the Director. The general plan was as follows: To each of the four great classes of rocks there was assigned a group of patterns, parallel straight lines for clastic rocks, dots and circles for superficial deposits, hachures for the ancient crystallines, and triangles and rhombs for volcanic rocks; within each class, subdivisions were to be represented by colors and specific patterns, the two ordinarily being used in combination, and identified by letter symbols. The colors and letter symbols for the periods were as follows: Neocene, orange, N; Eocene, yellow; E; Cretaceous, yellow-green, K; Jura-Trias, blue-green, J; Carboniferous, blue, C; Devonian, violet, D; Silurian, purple, S; Cambrian, pink, Ꞓ;

Algonkian, red, A. The arrangement of the color series was essentially prismatic, as suggested by Gilbert, the chromatic circle completed by the addition of the extraprismatic colors purple and pink. The Pleistocene and other superficial deposits would be indicated by the pattern in pale colors over the period color of the subsurface when it was known, otherwise on a white ground. Archean rocks were to be indicated by the hachure pattern over a ground color of pale brown.

In accordance with the decisions made at the conference, it was concluded that the correlation essays should be concerned with formations belonging to a time division rather than formations belonging to a structure division. The essays would have a threefold purpose: To summarize the existing state of knowledge of North American geologic systems; to formulate the principles of geologic correlation and taxonomy; and to set forth from the American standpoint the possibility or impossibility of using in all countries the same set of names for stratigraphic divisions smaller than these systems. The essay on the Pleistocene was assigned to T. C. Chamberlin, that on the Neocene to W. H. Dall, the Eocene to W. B. Clark, the Cretaceous (including the Laramie) to C. A. White, the Jura-Trias to I. C. Russell, the Carboniferous and the Devonian to H. S. Williams, the Silurian and Cambrian to C. D. Walcott, and the Algonkian and Archean to C. R. Van Hise. An additional essay would be prepared by D. C. Marsh on correlation by vertebrate paleontology and one by Lester Ward on correlation by paleobotany. McGee would prepare a resumé of North American stratigraphy, and Gilbert, a discussion of the principles of correlation. McGee's work on the thesaurus of North American stratigraphy, the bibliography, index, and discussion, was transferred to the Division of Geologic Correlation.

The Irrigation Survey, which required more of the Director's attention, had finally been authorized on October 2, 1888. The Senate took up the Sundry Civil Expense bill in late July. The Appropriations Committee had not included the Bowen amendment, so on July 30 he offered it again for consideration by the whole Senate. It had acquired an additional sentence: "All titles to the public lands hereafter acquired shall be subject to the right of the United States to make reservations for reservoirs for storing water and for rights of way for ditches and canals for the purposes of irrigation." Senator Allison, the chairman of the Appropriations Committee, immediately made a point of order against the amendment; it was new legislation, or at least the last part was new legislation, and therefore should not be part of an appropriations bill. Senator Stewart appealed to him to withdraw the point of order, and he agreed, saying that if the amendment was to pass it would be better to have the reservation clause in rather than out. He then explained that the Appropriations Committee had not approved the amendment because further consideration should be given to the methods and cost of irrigation and proper legislation prepared for segregation of lands. Major Powell had told them that 80 percent of the appropriation would be used for topographic surveys, and the Senate might therefore increase the appropriation for topographic surveys as a preliminary measure until these other matters could be resolved.

The ensuing discussion showed a certain amount of confusion. Senator Teller said that $250,000 would not commit the Government to anything; it was just to get information. Senator Allison replied that $250,000 was only the beginning, that Powell had said it would take $4 million or $5 million. Teller thought that the $4 million or $5 million was to finish all the topographic surveys, but Allison said, no, only of the mountainous region; it will take $20 million or $30 million to do all the United States. Teller though that *that* amount included geologic surveys as well. Finally,



One of the best selling Survey publications at this time was R. A. F. Penrose's doctoral dissertation on the nature and origin of deposits of phosphates of lime, a continuation and extension of the work Professor Shaler had begun for the Coast Survey in 1870. The illustration shows the strata overlying the phosphate bed at Castle Hayne, New Hanover County, North Carolina: **A**, sand; **B**, ferruginous sandy clay; **C**, green clay; **D**, indurated peat; **E**, calcareous marl; **F**, white shell rock; **G**, phosphate conglomerate; **H**, marl containing smaller nodules. Scale: 1 inch=5 feet. (From R. A. F. Penrose, 1888.)

they read from Powell's statement: He could locate all the reservoirs and so on in 6 years if appropriations were available. He estimated the total cost at $5,125,000, and the additional cost over and above the regular topographic surveys would be $1,250,000.

That settled, objections were made to the Survey's doing the work. Senator Manderson of Nebraska preferred the Army Engineers. Senator Plumb had long had reservations about Major Powell. When Senator Stewart insisted that the idea of the Irrigation Survey had not originated with Powell but with the Senators from Colorado and himself, Senator Plumb retorted, "You didn't think of it, Powell did, twelve years ago. It originated in the scheming brain of the head of the Geological Survey. He expects some day to be incorporated into the Constitution of the United States as an amendment."

Senator Allison kept urging that the amount for topographic surveys be increased, that it be specified that the additional money was for surveys in the high mountainous regions and the Territories, and that if any part of the work underway was postponed it should be that in the older States. Several agreed, but no one offered a motion.

The discussion then turned to the land laws, and finally Senator Reagan of Texas offered as a substitute for the last sentence: "And all the lands which may be designated for reservoirs, canals, and ditches for irrigation, shall be reserved as the property of the United States, and shall not be subjected to entry or settlement until hereafter provided for by laws." And so the amendment was passed.

The Sundry Civil Expenses bill was returned to the House in mid-August, and the House at first refused to concur in the amendment. On September 1, however, Congressman William C. Breckenridge of Kentucky moved that the House accept the amendment but add, "And the Director of the Geological Survey under the supervision of the Secretary of the Interior shall make a report to Congress on the first Monday in December of each year, showing in detail how the said money has been expended." Said Mr. Breckenridge, "I think this is in many ways the most important item in the present bill. I presume two of the most difficult problems with which we have to deal in America are two connected with this enterprise—the proper treatment of the Mississippi River and the irrigation of the arid lands in the Territories. * * * It seems to be possible that the solution of both these questions is in the scientific survey of the waters of the Rocky Mountains and the utilization of those waters after that survey to the irrigation of those arid regions, by which these waters, which defy our efforts as yet to control them in the Mississippi, may be directed from ruin to fruitfulness by means of canals in irrigating the arid regions of the Territories."

There was considerable discussion in the House whether the two purposes of irrigation and flood control could be served by one survey. Hilary Herbert said that more water went into the Mississippi from the Ohio than from the Missouri, so controlling the Missouri would not stop the floods; Major Powell had said so. Congressman James Morgan of Mississippi agreed that Major Powell had told the Committee on Agriculture that he could not say that stopping floods on the Missouri would affect the floods on the Mississippi. When several insisted that Major Powell must be wrong, the undaunted Mr. Herbert called on the Signal Service for information on high water on the two rivers, which he then presented to the House to prove his point.

Mr. Herbert also charged that the irrigation survey was a "scheme hatched in the brain of the Director of the Geological Survey," and refused to back down when told that demands had been coming from various western groups for 5 or 6 years. The Director, he said, had thought it up long before that: "I do not want to make a personal attack on him and I shall not do it. I have great respect for his ability. He has great knowledge; he is a great talker; he is a man of great power, even, as I think, over Congress. But I submit that this House ought not to enter upon a scheme involving so large an expenditure on the unsupported opinion of one man. * * * It may be a grand scheme, but is it feasible? And if it is feasible, who is to accomplish it?"

Several thought that irrigation should not come up in an appropriation bill, but that it should be considered by the Committee on Public Lands, not the Committee on Appropriations. Mr. Symes of Colorado spoke up; the appropriation must be passed. The Committee on Public Lands had not and could not provide legislation in that session. If this appropriation was not made, the Committee on Agriculture would make a favorable report on his bill to appropriate $500,000. Mr. Symes insisted that the money would be used for additional local surveys to locate reservoirs and for classifying public lands susceptible to irrigation, and that the amendment would not commit the Government to conducting the irrigation. Congressman W. H. Forney saw no reason to spend so much money for information. The Director said that the survey would be finished in 30 years, and the Senate wanted to give him money to finish in 6 years, but actually the information would not be needed for 30 years. Mr. Herbert was a persistent refrain in the background, asking who would undertake the irrigation. Private industry would not, because it was not profitable. Only the Government could do it, and in the end it would cost the Government more than $1 billion. And, he wondered, if all the irrigated land were put to growing grain, what would be done with all the grain?

Congressman Richard A. Bland of Missouri moved to cut the appropriation to $50,000, but the motion was rejected. The motion was then changed to "$100,000 or so much thereof as may be necessary" and was passed on September 12. Mr. William Holman of the Public Lands Committee proposed a substitute amendment that the money appropriated for topographic surveys or any part thereof might be used by the Director with the approval of the Secretary to ascertain the feasibility of establishing reservoirs and report to Congress and that until the public-land issue was settled all desert-land entries should be suspended. His motion, however, was not agreed to. On September 14, 1888, the Senate and House conferees agreed to the House version with an additional proviso, that the President might at any time in his discretion by a proclamation open any part or all the lands reserved to settlement under the homestead laws.

The bill as finally passed and approved on October 2, 1888,

"For the purpose of investigating the extent to which the arid region of the United States can be redeemed by irrigation, and the segregation of the irrigable lands in such arid region, and for the selection of sites for reservoirs and other hydraulic works necessary for the storage and utilization of water for irrigation and the prevention of floods and overflows, and to make the necessary maps, including the pay of employees in field and in office, the cost of all instruments, apparatus, and materials, and all other necessary expenses connected therewith, the work to be performed by the Geological Survey, under the direction of the Secretary of the Interior, the sum of one hundred thousand dollars or so much thereof as may be necessary. And the Director of the Geological Survey under the supervision of the Secretary of the Interior shall make a report to Congress on the first Monday in December of each year, showing in detail how the said money has been expended, the amount used for actual survey and engineer work in the field in locating sites for reservoirs and an itemized account of the expenditures under this appropriation. And all the lands which may hereafter be designated or selected by such United States surveys for sites for reservoirs, ditches, or canals for irrigation purposes and all the lands made susceptible of irrigation by such reservoirs, ditches or canals are from this time henceforth hereby reserved from sale as the property of the United States, and shall not be subject after the passage of this act, to entry, settlement, or occupation until further provided by law:

"*Provided,* That the President may at any time in his discretion by proclamation open any portion or all of the lands reserved by this provision to settlement under the homestead laws."

Chapter 6.
The First Great Problem, 1888–1890

> **Hydraulic engineering is the oldest scientific art.*** Everywhere throughout the world civilization began in arid lands and hydraulic engineering was the first great problem to be solved; and for this reason it was solved at an early time, and well solved. Something has been added through the years, but not much.**
>
> **—John Wesley Powell**

Only a month after the Irrigation Survey was authorized, Benjamin Harrison was elected President of the United States. The protective tariff had been the principal campaign issue, the Democrats calling for revision, the Republicans for continuation. The election was a close one. Cleveland actually received the majority of the popular vote, but Harrison carried the key States of New York and Indiana and with them the electoral vote.

Cleveland's annual message to Congress in December 1888 was forthright. He again reminded Congress of the repeated recommendations for changes in public-land laws:

> **I cannot too strenuously insist on the importance of proper measures to insure a right disposition of our public lands, not only as a matter of present justice, but in forecast of the consequences to future generation. *** We have no excuse for the violation of principles, cogently taught by reason and example, nor for the allowance of pretexts which have sometimes exposed our lands to colossal greed. Laws which open a door to fraudulent acquisition, or administration which permits favor to rapacious seizure by a favored few of expanded areas that many should enjoy, are accessory to offenses against our national welfare and humanity, not to be too severely condemned or punished.**

Reflecting on the approaching centennial of the Constitution, he observed "Our survival for one hundred years is not sufficient to assure us that we no longer have dangers to fear in the maintenance, with all its promised blessings, of a government founded upon the freedom of the people." Equal and exact justice, he said, should not be confined to the relations of citizens to each other. The Government itself should deal with citizens in a manner scrupulously honest and fair and absolutely just. "He mocks the people who proposes that the Government shall protect the rich and that they in turn will care for the laboring poor. Any intermediary between the people and their Government, or the least delegation of the care and protection the Government owes to the humblest citizen in the land, makes the boast of free institutions a glittering delusion and the pretended boon of American citizenship a shameless imposition."

Cleveland took particular notice of the irrigation legislation. The arid lands, he said, should not "be yielded up to the monopoly of corporations or grasping individuals.* * * Already steps have been taken to secure accurate and scientific information of the conditions, which is the prime basis of intelligent action. Until this shall be gained, the course of wisdom appears clearly to lie in the suspension of further disposal. * * * No harm can follow this cautionary conduct. The land will remain, and the public good presents no demand for hasty dispossesion of national ownership and control."

Congress in that short session made no changes in the public-land laws. It did, however, take actions that affected greatly the Irrigation Survey and the disposition of the arid lands. On February 11, 1889, the Department of Agriculture was raised to Cabinet status to indicate the importance of the agricultural industries. On February 22, Congress provided for the admission of four new States: North Dakota, South Dakota, Montana, and Washington. All four had large agricultural interests, and all four were at least partly in the arid region. Washington had been a Territory since 1853, Dakota since 1861, and Montana since 1864, but the population had increased slowly until after completion of the northern railroads. Dakota Territory was divided into two States because there were two widely separated centers of population. Both were primarily agricultural, but in South Dakota the Homestake mine was also an important factor. Montana was one State, but its eastern and western parts were entirely different. The first population boom had been the result of the discovery of gold in its western mountains; there, gold and silver mining were still important, and the great era of copper mining was just getting underway. Stock raising was the principal occupation in the eastern part. Washington had large agricultural and lumbering interests, and there had been some mining activity in the interior.

The appropriations for the coming year were passed in the final days of the session. Those for the Geological Survey proper were the same as the year before except that the appropriation for topographic surveys was rounded off to $200,000, and the appropriation for engraving and printing maps, previously under the control of the Public Printer, was made part of the Survey appropriation. The Public Printer had let contracts to private firms for engraving and printing maps, but the system had not been entirely satisfactory because the work of revising sheets to bring them up to date and experimental work for the development of more economical methods of printing could not advantageously be made the subject of a contract. The organization of a division of engraving and printing in the Survey would place it on the same footing as the Coast and Geodetic Survey and the Hydrographic Office, both of which already had their own divisions of engraving.

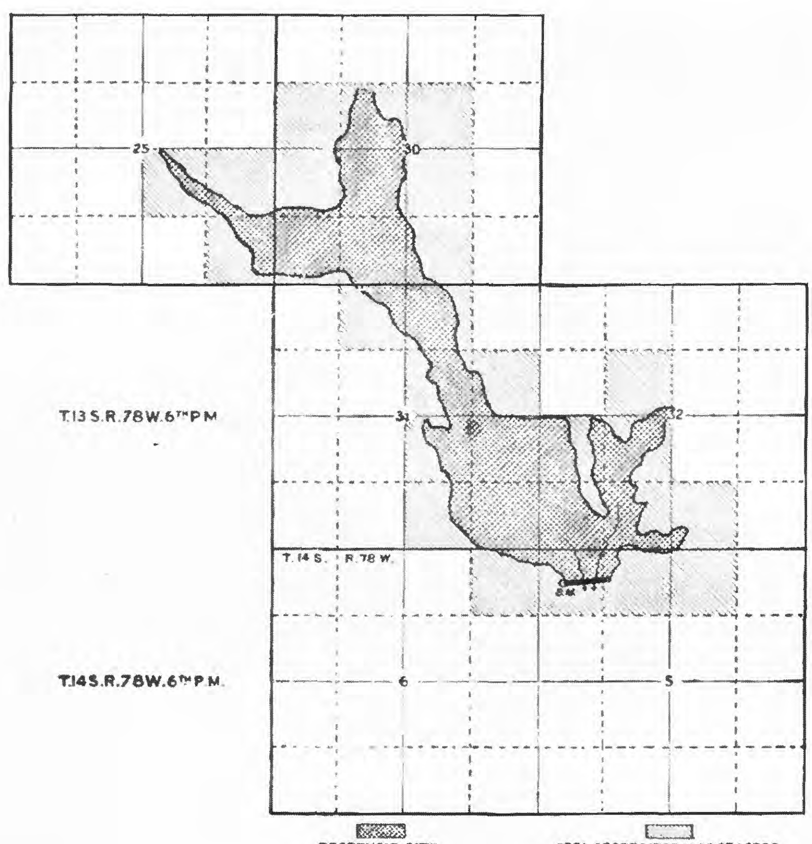
For the Irrigation Survey, the new appropriation was $250,000. The budget request had been $350,000, and the House Committee on Appropriations had recommended only $150,000. When the item came up for discussion on the floor, Congressman Symes of Colorado made a long speech in support of the Irrigation Survey, detailing its accomplishments since October and explaining Major Powell's invention of a unit of measurement of water, the acre-foot. Symes thought that the appropriation should be increased to $250,000; if $40,000 could be appropriated for ethnology and $40,000 for Professor Marsh to determine whether a fossil bird had one or two teeth, more money could be appropriated for something useful like the Irrigation Survey. Hilary Herbert of Alabama objected to taxing the East to fertilize the lands of the West, and he complained again that the Geological Survey was established as an economy measure, but its funds had been increased year by year, and now the bureau was so big it was looking for a building all its own. Many agreed that the officer in charge had too much discretion, but no one was disposed to take any action against him. Congressman Holman urged that the land laws be amended first, but his advice was largely ignored. On January 28, 1889, the House voted to raise the appropriation to $250,000, and the Senate accepted the figure.

Almon Harry Thompson

Major Powell's brother-in-law, close friend, and associate in western exploration and the U.S. Geological Survey. To him Major Powell entrusted direction of the topographic mapping for the Irrigation Survey. (Photograph courtesy of Utah State Historical Society.)

A bill to appropriate $600,000 for erection of a building for the Geological Survey, to which Mr. Herbert had made reference, was submitted in the final session of the 50th Congress. The plan called for a rectangular building, 100 by 300 feet, five stories high, with a hipped roof, which would be built on the public reservation near the Smithsonian Institution. Alhough *Science* reported that Congress was considering the bill favorably, the short session ended before it was passed.

On March 4, 1889, Benjamin Harrison was inaugurated as the 23d President of the United States. Harrison came from a family long active in politics, but his own previous experience was limited to one term in the Senate, from 1880 to 1886. Harrison was not a strong executive. He was content to let Congress assert supremacy and the members of his Cabinet run the Government. The Cabinet included several capable lawyers, among them his own law partner W. H. H. Miller as Attorney General, but the best known lawyer was undoubtedly the Secretary of the Interior, John W. Noble of St. Louis, a graduate of Yale in 1851, who had a distinguished Civil War record and a national reputation for legal triumphs in difficult cases, some of them argued before the Supreme Court. Among the cases on which his reputation rested were several involving land and mining law. The Secretary of Agriculture in the Harrison Cabinet, the first to hold the office for more than a few days, was Jeremiah M. Rusk. Secretary Rusk was even more widely known. He, too, was a Civil War veteran and had previously been a member of Congress, where he had served on the Public Lands and Agriculture Committees. He had been Governor of Wisconsin from 1882 to 1889, and had been especially active there in promoting the agricultural and dairy interests of the State and in forming farmers' institutes.



The topographers also selected the reservoir sites, such as this one at the junction of the Arkansas River and Seven Mile Creek in Chaffee County, Colorado. Here, at an altitude of 8,000 feet, a dam 120 feet high was proposed to impound water for irrigation of lands in the lower part of the Arkansas Valley. (From A. H. Thompson, 1891.)

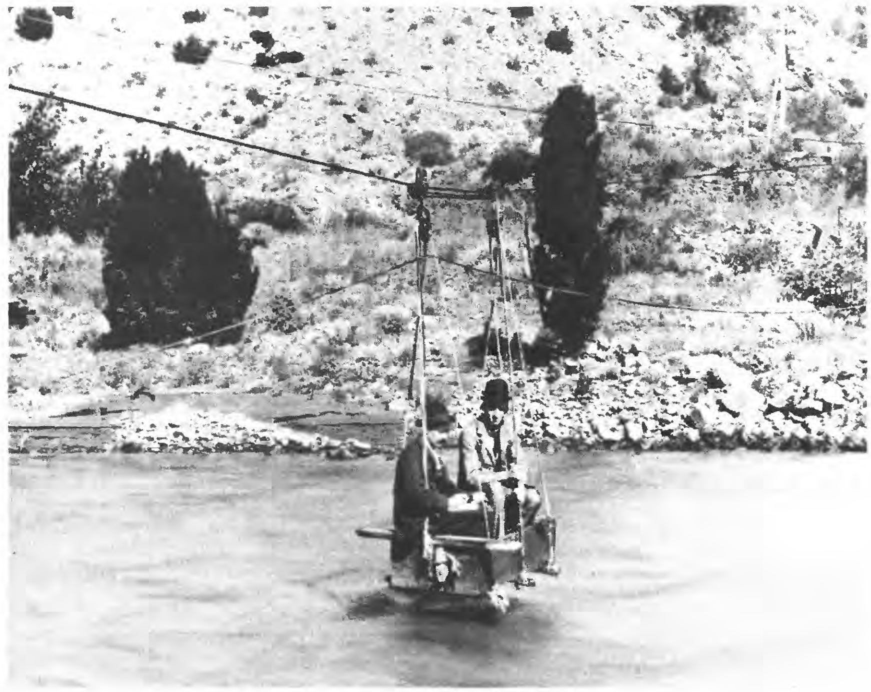
Secretary Rusk immediately began a sweeping reorganization of the Department of Agriculture to make it of more service to the agricultural community. He was particularly anxious to provide scientific assistance and prompt publication of results. Congress had established the office of Assistant Secretary in the legislation creating the Department and the first incumbent of that position, Edwin Willits, former Congressman from Michigan and president of Michigan Agricultural College, was given responsibility for all purely scientific investigations.

Secretary Noble plunged immediately into the problems involved in the opening up of Indian Territory to settlers. The Dawes General Allotment Act had been passed in 1887 to break up the Indian reservations by allotting land to individual Indians and providing for the sale of the surplus lands. In the last days of the Cleveland Administration, Congress had approved the acquisition of land in the central part of Oklahoma. President Harrison issued a proclamation on March 23, 1889, and on April 22 at noon, the Oklahoma district was opened to homesteaders. Within a few hours, 1,920,000 acres were claimed, the towns of Guthrie and Oklahoma City were organized, and preparations were begun for establishment of a Territorial government. Meanwhile, several of the established Territories were preparing to form State governments and adopt constitutions, and a treaty was being negotiated with the Sioux Indians of Dakota Territory. There was little time in the first few months for Noble to give to the smaller bureaus in Interior such as the Geological Survey.

The Irrigation Survey got fully underway in the spring of 1889. When the Sundry Civil Expenses bill was approved on October 2, 1888, making available money for the Irrigation Survey, extensive changes were made in the Geological Survey's Geographic Branch. All those engaged in work in New Mexico, California, and Montana were constituted a division of the Irrigation Survey, with A. H. Thompson in charge; the Geographic Branch of the Geological Survey, which remained under Gannett, was limited to the country east of the Rocky Mountains and one party in western Oregon. It was, however, already late in the field season, and little could be accomplished until spring.

The stream gaging and engineering surveys which would make up the rest of the Irrigation Survey waited upon the recruitment of personnel and the training of hydrographers. Stream gaging was then not a widely practiced art, and experienced men and instruments were both scarce. It was thought best therefore "to select a small body of men of good education and high general intelligence and establish them at some advantageous situation where they could, in the course of the winter months, acquire a knowledge of the methods and instruments they would have to employ." Fourteen young men were chosen and placed in a camp of instruction at Embudo, on the Río Grande about 50 miles north of Santa Fe, New Mexico. F. H. Newell, a young engineer who had graduated from the Massachusetts Institute of Technology in 1885, was in charge of the camp.

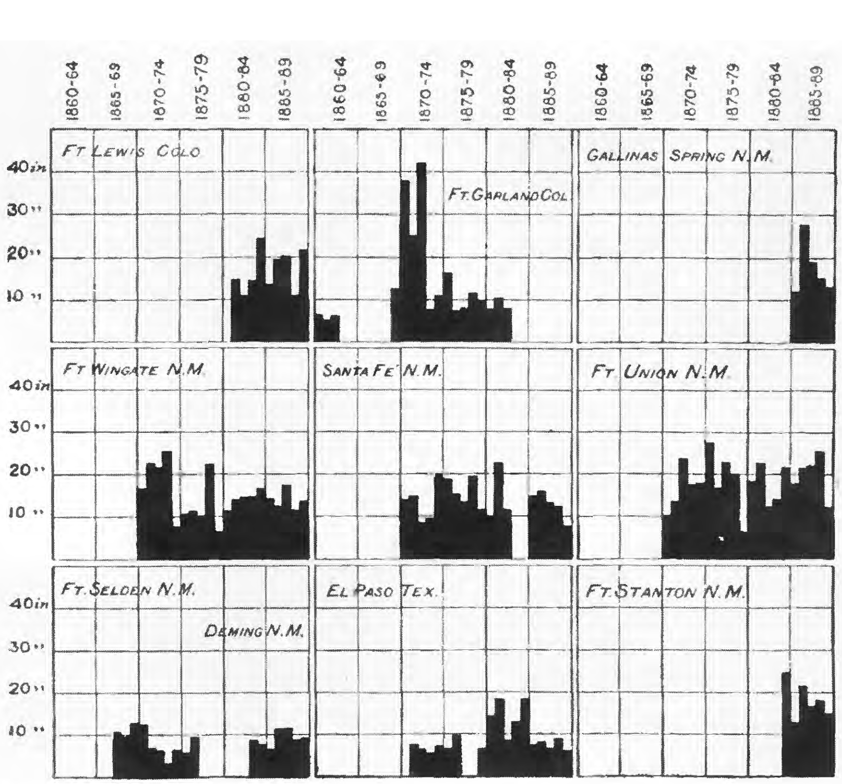
The topographic, hydrographic, and engineering surveys of the Irrigation Survey were almost completely independent of each other. Nearly all the topographic mapping was done by atlas sheets, at a mile-to-the-inch scale with contour intervals of 25, 50, or 100 feet. Survey parties worked in New Mexico, Colorado, Idaho, Montana, and the Lake Tahoe region of California and Nevada. In addition to their topographic mapping, the topographers selected possible reservoir sites, marked out the areas of irrigable lands, and mapped the forests. All the parties found reservoir sites, some only a few, Stream-gaging methods were primitive. In some places, a stout box, about 3 feet wide and 5 feet long, was hung from pulleys running on a wire cable across the stream. The hydrographer moved himself from side to side of the river, lowering and raising the current meter by hand or by a rope and pulley. Photograph taken on the Arkansas River near Canon City, Fremont County, Colorado, 1890. (From J. W. Powell, 1891.)



but an enthusiastic Willard Johnson found 110 possible reservoir sites at elevations of 4,500 to 11,000 feet in the Arkansas River drainage basin. Those that reported irrigable land, and not all of them did, made their findings contingent on the adequacy of the water supply.

Hydrographic measurements were made on streams in the upper Missouri River and Yellowstone River basins in Montana, in the Snake River basin in Idaho and Oregon, in the South Platte River and Arkansas River basins in Colorado, the Truckee River and Carson River basins in California and Nevada, and in the Río Grande basin in Colorado, New Mexico, and Texas. The field parties moved from point to point on the various rivers and attempted to measure some of the more important streams at various stages from low to high water. The hydrographers also tried to determine the evaporation from water surfaces, the rainfall in certain areas, the amount of sediment carried by running water, and other data required by the engineers making preliminary estimates for irrigation systems. The year 1889, however, was one of great drought, and the investigations indicated what might be expected during conditions of maximum aridity rather than average conditions on which the plans for irrigation construction should be based.

The engineering surveys began in the summer of 1889. E. S. Nettleton of Colorado, a civil engineer with many years experience in irrigation work, was appointed as supervising engineer, Sumner Bodfish and H. M. Wilson transferred from the topographic staff, and several other assistant engineers were appointed. Engineering surveys were made along the Sun River in Montana, the Snake River in Idaho, around Clear Lake and in the Sierra Nevada in California, on the Truckee and Carson Rivers in Nevada, around Utah Lake in Utah, along the headwaters of the Arkansas River in Colorado and farther downstream in Kansas, and on the Río Grande in Texas, principally in the vicinity of El Paso. The El Paso situation was politically hazardous as it involved international water rights. The city council of El Paso sought the Survey's help in connection with a plan for the erection of a dam to impound the Río Grande waters during the flood season. After the engineering survey was made, a decision was made to construct a dam



The difficulties of dryfarming in the arid and semi-arid regions, as well as the difficulties of drawing valid conclusions from inadequate data, are shown in these records of rainfall in the Rio Grande Basin. Note particularly the rainfall at Fort Wingate, one of the longest series of measurements, where in two instances years of great rainfall were followed immediately by years of drought. (From F. H. Newell, 1891.)

about 3 miles above El Paso. When an irrigation company secured a license to construct a canal and charge the farmers water rent, the Mexican farmers protested. After long hearings, the charter for construction of the dam was revoked. Early in December, H. M. Wilson was despatched to India to study irrigation practices there, and he returned in March via Cairo, Rome, and Paris.

The Topographic Branch of the Geological Survey mapped 12 sheets in southern Kansas that were selected because of their importance to agriculture. They were in the subhumid region, where agriculture without irrigation was successful in some years, in others not. The people were beginning to turn to irrigation, which would depend chiefly on the storage of storm waters. A topographic map would be useful, but the region was not included in the Irrigation Survey because the law had been construed as covering only regions where irrigation depended on use of perennial streams.

The Topographic Branch mapped, all told, 46,807 square miles in 20 States, about one-fourth of it at 1:62,500 and the remainder for publication at 1:250,000. A cooperative survey was begun in Connecticut, and other surveys were made in Maine and Vermont. Mapping started in the anthracite region of Pennsylvania in response to a request from the State Geologist; mapping was also underway in the coal and iron areas of the Southern Appalachians. A survey was begun of the iron region of the Upper Peninsula of Michigan; three atlas sheets were surveyed in the moraine region of southern Wisconsin; work was begun in Illinois, with Chicago as the initial point, because of the plans then being considered for connecting the Great Lakes and the Mississippi River by ship canal; and areas encompassing nine map sheets were surveyed in Iowa. Work continued in the Ozark Hills of Arkansas and in Texas, and during the winter, mapping began in the alluvial region of the lower Mississippi and in the Florida phosphate region.

Major Powell had become so deeply involved in the irrigation work that he was unable to continue directing the Geological Survey and the Bureau of American Ethnology along with it, so with the concurrence of the Secretary of the Interior, part of the administrative supervision of the Geological Survey was shifted to a Chief Geologist. On July 1, 1889, all the geologic divisions were combined as the Geologic Branch and placed in charge of G. K. Gilbert. Because Powell had relied heavily on Gilbert for several years, the appointment did not mean any marked change in philosophy and no modification in the internal organization of any of the divisions or of the general plan of work was involved.

Most of the divisions in the Geologic Branch began mapping for the geologic atlas in the field season of 1889. Problems remained in the study of rocks at the two ends of the geologic column. The crystalline schists could not be discriminated by means of fossils, and as the evidence of their original sequence was obscured by metamorphism and complicated displacements, the determination of their structure was slow and difficult. Pumpelly, Van Hise, and Willis began a series of joint field excursions to unify their work. The glacial formations could not be correlated by means of fossils either, and a study of the stratigraphic sequence alone was insufficient. The glacial geologists were therefore studying external forms and internal constitution to establish a primary classification on the basis of origin, but they were far from ready to present results on atlas sheets.

Powell's protégé, W J McGee, was, as usual, unrestrained by organization. As topographic maps were not yet available for most of the area covered by the Potomac Division, McGee spent some time on the Iowa report, examined exposures as streets were extended in northwest Washington, checked Darton's mapping of the East Washington sheet, continued his studies of the "deportment" of the Potomac River, and critically examined W. H. Holmes' work for the Bureau of Ethnology. L. C. Johnson, J. A. Holmes, and N. H. Darton, all nominally under McGee's supervision, were studying the stratigraphy of the Coastal Plain; George Williams, also under McGee's supervision, was investigating the petrography and geologic structure of the Piedmont crystalline rocks. As part of their work, Johnson and Darton spent several months in Florida where they distinguished three classes of phosphate deposits and determined roughly the distribution of each and its economic importance.

Gilbert's associate, I. C. Russell, spent the summer in Alaska. In May 1889, the Superintendent of the Coast and Geodetic Survey had invited the Director of the Geological Survey to send a Survey geologist along with the Coast Survey party organized to survey the boundary of Alaska in the vicinity of the Yukon and Porcupine Rivers. Russell, who endured rather than enjoyed the comforts of civilization was selected; he was to make collections and observations in zoology and ethnology as well as geology.

Little fieldwork was done in economic geology in 1889. The Colorado Division of Mining Geology was again required to devote itself exclusively to the preparation of reports. In the California Division of Mining Geology, Turner and Lindgren continued to map atlas sheets while Becker was engaged in a study of the dynamic history of the Sierra Nevada. One new project began under instructions from Secretary Noble. The Missouri Geological Survey was then being reactivated, and Arthur Winslow, who had spent 3 years on the Arkansas Survey under J. C. Branner, had been appointed as State Geologist. Walter P. Jenney, a mining engineer for the Union Pacific Railway, was engaged to begin an investigation of the zinc deposits of Missouri in cooperation with the State survey. Organizationally, this became the Division of Zinc.

The paleontological work was extended even more in the summer of 1889. Alpheus Hyatt was added to the staff to undertake a study of lower

Mesozoic paleontology. T. W. Stanton, recently appointed assistant paleontologist, spent the summer with C. A. White in a study of the Lower Cretaceous in Texas, New Mexico, and Colorado. The Division of Paleobotany did a large amount of fieldwork, and S. H. Scudder spent 3 months in the field studying fossil insects. Professor Marsh continued the work of trying to determine more accurately the relation between the Cretaceous and Tertiary formations of the West. The break between the Laramie vertebrates and the corresponding fauna of the early Eocene was profound, but the transition series had not been discovered.

At the Geological Society of America meeting in December 1889, stratigraphic nomenclature was again at issue. Professor Newberry said that no part of the geological column had given rise to a greater amount of literature or a greater diversity of opinion than the Laramie problem, but it was all because many people had combined two distinct formations and called them one and thereby provoked one of the minor battles to which paleontologists were prone. Newberry said the confusion started with Hayden, who had accepted King's term "Laramie" but had applied it differently. Many had accepted Cope's conclusion of 1874 as evidence that paleobotanical evidence was unreliable, and Ward, who had collected his own material, had compounded the confusion by calling the Laramie formation Eocene, whereas most of his material came from the Fort Union formation. In Newberry's mind, the floras of the Laramie and Fort Union were totally distinct and distinguishable at a glance; the Laramie was Cretaceous, and the Fort Union, Tertiary. Ward retorted that C. A. White was responsible for the error, if indeed there was one, and that Newberry had misremembered his conclusion because his only conclusion was that the whole thing was a war of words.

A few weeks later, a more publicized paleontological war was renewed. A reporter for the *New York Herald* assembled a story from interviews with Professor Cope, T. Sterry Hunt, Persifor Frazer, and others, and on Sunday, January 12, 1890, his story appeared under the headline: "SCIENTISTS WAGE BITTER WARFARE. PROF. COPE, OF THE UNIVERSITY OF PENNSYLVANIA, BRINGS SERIOUS CHARGES AGAINST DIRECTOR POWELL AND PROF. MARSH OF THE GEOLOGICAL SURVEY." Despite the headline, Marsh was the principal target of Cope's attack. Cope charged that Marsh was incompetent, that he published the work of his assistants as his own, destroyed fossils in the field so no one else could study them, kept enormous collections belonging to the Geological Survey in his Yale laboratory under lock and key and refused other scientists access to them, and mixed Survey collections with the Yale collections so no one could ever sort them out. Cope charged that Powell had blocked publication of his paleontological work for the Hayden survey and had insulted him by suggesting that some of his collections belonged to the Government.

Among the unrelated charges against Powell, some were an echo of the Allison Commission days—that he had gained control of the National Academy of Sciences and had made himself head of a great scientific monopoly—and others, that he had stolen or duplicated the work of State geological surveys, had obstructed geological work that contradicted his own, had attempted to dominate scientific meetings, and had neglected mining geology in his conduct of the Survey. Powell's dignified denial of all charges against him was published in the same issue. Marsh's more vigorous defense of himself appeared a week later. The matter was soon dropped; the general public found national politics of far more interest.

The 51st Congress elected in 1888, convened for its first session in December 1889 with the Republicans in control of both Houses by slim majorities. The Republican victory at the polls was taken as a mandate to provide new tariff legislation. The situation was difficult, however, for the western wing of the Republican party could not be counted on on this issue. Western farmers at the best of times did not feel that the protective tariff served their interests, and 1889 was close to the worst of times. Farm prices had been declining since 1884, and the drought of 1887 and later years had caused great losses. The farmers had begun to organize, aiming their attack at the eastern moneyed interests and trusts. Fourteen States had already forbidden trusts and monopolies in their constitutions, at least thirteen had prohibited them by statute, and six to be on the safe side, had enacted both constitutional and statutory prohibitions. State action alone, however, was ineffectual, because the most notorious monopolies operated across State lines. At the same time, western silver men, troubled by the steady decline in the price of silver, were more vigorous than ever in their demands for silver coinage. The Secretary of the Treasury had been purchasing and coining $2 million of silver each month, the minimum required under the Bland-Allison Act of 1878, but silver men were pressing for the Treasury to coin the entire national output of silver. Hoping to make the tariff more palatable to the West, Republican leaders prepared to act first on the trust and silver issues. The antitrust bill was introduced in the Senate by Senator Sherman of Ohio as S. 1. The House Committee on Coinage began consideration of a new silver purchase plan. The House Ways and Means Committee began preparation of the new tariff bill, euphemistically entitled, "A bill to reduce the revenue."

Both Houses of Congress at the time were rather inefficient legislative bodies. The House, Woodrow Wilson wrote in his doctoral thesis on congressional government, "has as many leaders as there are subjects of legislation." The Senate prided itself on its independence, and Wilson said that although it contained "the best men that the system calls into politics," the Senate itself was "merely a body of individual critics."

The problem in the House was compounded by cumbersome and archaic rules. In 1889, however, when Thomas B. Reed of Maine was elected Speaker, he appointed the two unsuccessful candidates for that office, William McKinley and Joseph G. Cannon, chairmen of the powerful Ways and Means and Appropriations Committees, respectively. These three then devised a new set of rules for "the more expeditious handling of House business." The most significant changes were the redefinition of quorum as members present rather than members voting, and the grant to the Speaker of discretionary power in entertaining dilatory motions. The Reed tactics in pushing the new rules through earned him the title of "Czar" Reed, but their adoption smoothed the way for the passage of Republican legislation.

The Republican majority in the Senate was a precarious two at the start of the session, but during the next few months, eight new Senators arrived from the States admitted in November. Gilbert A. Pierce and Lyman R. Casey, the first Senators from North Dakota, Gideon Moody and Richard Pettigrew, the first Senators from South Dakota, and John B. Allen and Watson C. Squire, the first Senators from Washington, were all sworn in in January 1890. Two sets of Senators presented credentials from Montana, Republicans Thomas C. Power and Wilbur Sanders and Democrats William A. Clark and Martin Maginnis. In April, the Senate ruled in favor of the Republicans Power and Sanders. As all 8 new Senators were Republicans, the majority was raised to 10, but the new Senators were more concerned with problems within the new States than with the tariff. Irrigation had not been regarded by Senate leaders as of the same importance as the silver and trust questions at the beginning of the session, but it was of great importance to the new States, and as the months went by, it became a highly explosive issue. By midsummer, Senator Gorman called it "the most important question which has come before the Senate during the entire session."

The Senate Select Committee on Irrigation had made a fact-finding trip through the arid region in the summer of 1889. Major Powell had joined them at the invitation of the chairman, Senator Stewart, during most of the trip, and he addressed two of the constitutional conventions meeting in preparation for admission of territories to statehood. To the North Dakota convention, Powell made a plea for State control of water rights. In the eastern part of the State, he reminded them, there was sufficient rainfall and in the western, a permanent dependence on irrigation. The danger was in the middle region, where there would be years of abundance and years of disaster. "There are waters rolling by you which are quite ample to redeem your land and you must save these waters," he said. "Don't let these streams get out of the possession of the people.* * * Fix it in your constitution that no corporation—no body of men—no capital can get possession of the right of your waters."

To the Montana Constitutional Convention, Powell made a still more radical proposal, that the county boundaries be drawn on the basis of geography. "In the western half of America, the local, the state, the territorial governments, and the regulations and the national government are in no sense adapted to the physical conditions of the country." Thirty-five million acres of land in Montana could be redeemed by irrigation, but only if every drop of water falling on the land remained in the State. A man in any given drainage basin must be interested in every part of the basin because the entire basin gathers the water he needs. Therefore, the primary unit of organization in the arid lands should be the drainage basin.

The Idaho Constitutional Convention complained to the General Land Office early in July that speculators had followed the Survey crews and staked out claims within the supposedly reserved reservoir site of Bear Lake, and on August 2, 1889, followed it with a resolution asking the Department of the Interior to retain Bear Lake as a public reservoir. Secretary Noble was then drawn into the irrigation question.

On August 2, Noble sent a telegram to the Governor of Idaho Territory, pointing out the extent of the law of October 2, 1888. He said,

> **It follows necessarily that the speculators, corporations, or other persons referred to in the resolution, are under the effect of this law and unable to obtain the advantages that you say they are seeking. Unless the law is repealed or the President opens the lands to settlement under the homestead laws, the Government must have and will take eventually absolute control of every acre of arid land that may be redeemed by the system of reservoirs, canals, and ditches, as provided in the appropriations act mentioned. * * ***

He then directed the Commissioner of the General Land Office to notify local-land offices to cancel all claims filed after October 2, 1888, on reservoir, ditch, or canal sites. On August 5, this was done and, in effect, all land offices in the arid region were closed, for no one knew where the reservoir, ditch, or canal sites were. There was, of course, an immediate uproar from those who had filed claims in good faith or otherwise and from their Congressmen, and a new order was issued, that patents could be issued with the proviso that they might later be found invalid.

In his annual report to Congress in November 1889, Secretary Noble pointed out another problem:

John W. Noble

Secretary of the Interior in the Harrison Administration, 1889–1893. A distinguished and successful lawyer, Noble early perceived some of the problems of the irrigation law, and encouraged work in economic geology. (Courtesy of the Library of Congress.)

in those States and Territories where irrigation must be resorted to and where the same stream runs through different States or different Territories, unless some control is kept by the National Government, the streams may be exhausted or greatly depleted by those nearest its source, and that those below, who have already made every preparation and calculation dependent on the particular water supply, may be brought to great loss, if not destitution * * * The present statute should be supplemented by some general law, with such other provisions as will meet the different difficulties apt to arise from any national system of irrigation intended.

A national system of irrigation, however, was not what Congress had had in mind. Bills were filed almost as soon as Congress convened, but they were to cede public land in aid of irrigation, to promote irrigation, or provide for irrigation, or to grant right of way through public lands for irrigation. The Senate Select Committee on Irrigation came back from its western trip with masses of testimony to guide its deliberations.

On January 16, 1890, while the Cope-Marsh fracas was making headlines, Senator Plumb, who had opposed the Irrigation Survey in 1888, filed a bill "to provide for the conservation and use of natural water supplies upon certain portions of the public lands of the United States," and three times in the next 8 days Major Powell appeared before the Senate Committee on Irrigation. On January 21, he proposed to them a bill of his own, the "theory" of which, he said, was that "there are natural hydrographic basins or drainage areas; that the people of each of these districts should be organized into bodies corporate and politic and constitute commonwealths for the regulation of irrigation, the division of waters, the protection of forests, the protection of the pasturage lands, and for the utilization of all of these values." When Senator Moody asked him on what principle of constitutional power he attributed to Congress the authority to make such regulations and divide up the water, Major Powell answered, "I provide for it in my theory, not on a principle of law but on a principle of policy."

In the other two sessions, Major Powell displayed maps of the arid region and discussed the work of the Irrigation Survey. The area where irrigation was necessary, he said, covered some 1,340,000 square miles between the 100th meridian, or close to it, and the Pacific. The new map was modified slightly from that of 1878, but chiefly on the Pacific side. About 8 million acres, scattered throughout the States and Territories, were already being irrigated, and he thought that about 100 million acres could be irrigated. The work of the Survey had been begun, he said, in the most densely peopled regions where the scarcity of water was most keenly felt, the Arkansas Valley in Colorado, the Río Grande in New Mexico, the Truckee and Carson Valleys in California and Nevada, and the Snake River valley in Idaho.

The questioning, on the face of it, was not unfriendly. Senator Stewart asked how long it would take to do the engineering work so that the people might know where to locate reservoirs and how long it would take to do sufficient work in each State so that they could have it in hand. Major Powell finally said that it would take a long term of years at the rate at

William Morris Stewart

Senator from Nevada, 1864–1875 and 1887–1905. In 1873, he introduced the legislation establishing the Irrigation Commission and in 1888, the legislation that led to the Irrigation Survey. Stewart, however, was more interested in mining and monetary legislation. He had helped legally in the development of the Comstock Lode and had been largely responsible for the Mining Act of 1866. In his later years in the Senate, he tried to promote the Survey's work in economic geology. (Courtesy of the Library of Congress.)

which they were going—15 to 20 years. To get it done in 6 or 7 years as originally planned, he would need $1 million a year. Senator Stewart pressed him as to how long it would take to locate the reservoirs and the points at which the ditches were to be taken out, but Major Powell objected that the work could not be done piecemeal. Nothing could be made known until all the facts in a given basin were determined, and the topographic survey was the cheapest way of getting the facts. But, Senator Stewart said, there are a number of localities where people are anxious to get to work and are pressing us for information. How can we relieve the pressure? Senator Reagan especially wanted to know what was being done for the new States.

During this round of questions, it came out that the Irrigation Survey was concerned only with stream waters and not with artesian or storm waters. Senator Stewart thought people boring artesian wells should be helped, but Major Powell dismissed artesian waters as not important in irrigation. He agreed to the undertaking of an experimental investigation if it were properly financed but concluded his testimony with the question, "Is it wise to encourage the people to gamble for water with the dice loaded against them?"

The situation was radically different at the next session of the Committee a week later. When Senator Stewart called for testimony from "any person present who had practical ideas as to what can and ought to be done to facilitate irrigation; how it can be directly got at; what aid the Government can give most advantageously and with the least expense," there were several on hand with ideas. Richard J. Hinton, who had prepared the 1886 report on irrigation for the Senate, thought that the work should have been begun in the region between the 97th and 104th meridians, where the most people had settled and that the chief objects of the survey should be to delimit the drainage areas, to define the available reservoir sites within those areas, and to indicate the channels by which they could be distributed. The work of the irrigation survey was not dependent on the progress of the topographic and geologic surveys, and competent engineers could begin work at once without waiting for the topographic survey. Mr. Hinton thought that if $350,000 were spent for the development of ground water east of the mountains, $400,000 for engineering surveys, and a small amount on climatology, the survey could be completed in 3 to 4 years.

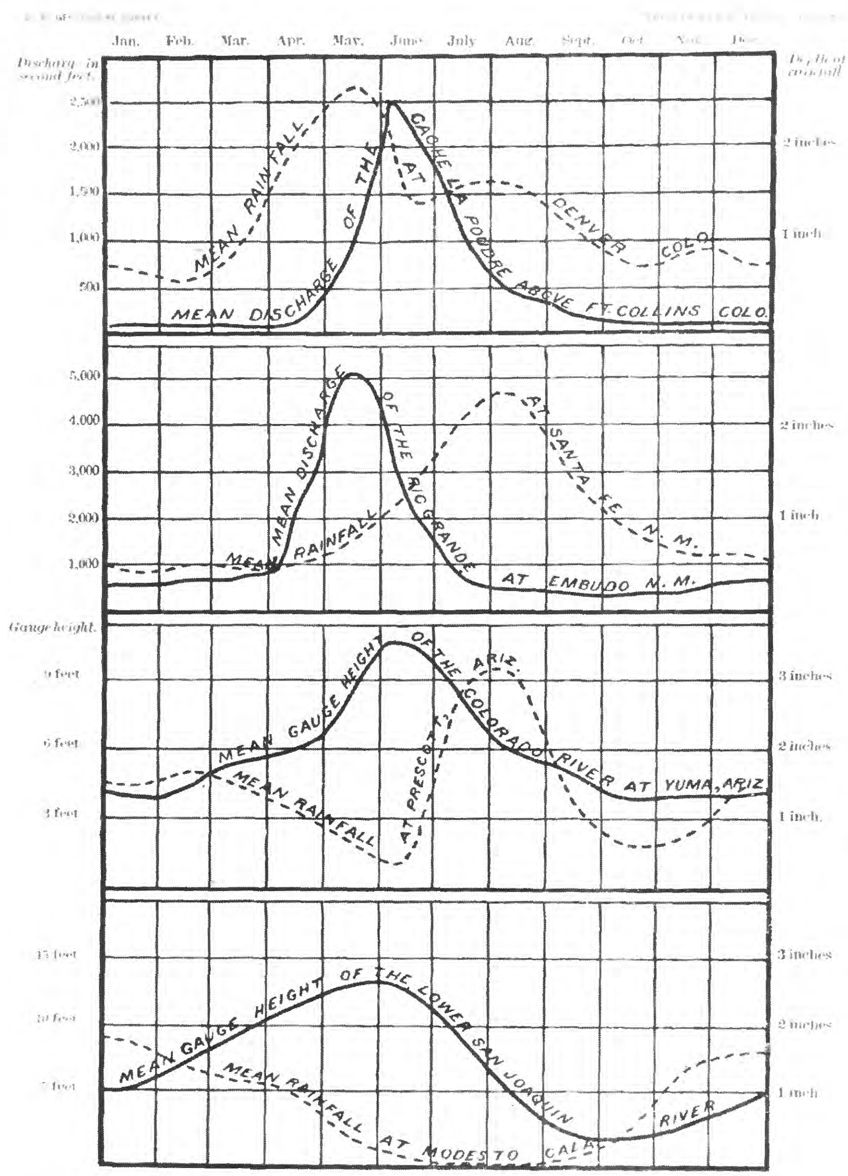
E. S. Nettleton, who was second in command to Captain Dutton, also questioned the need for the topographic surveys. Nettleton, who claimed 45 years of experience in civil engineering, 20 of them in irrigation work, said, "The whole of this work can be accomplished by what I call an irrigation engineering survey—including sufficient topographical work and sufficient hydrographical work." The "sufficient topographical" work would be surveys in the immediate vicinity of irrigation works, not of mining sites or pasturelands.

Assistant Secretary of Agriculture Edwin C. Willits was on hand to express the great interest of that Department in the whole subject of irrigation, accompanied by experts who had prepared papers to show the relation of irrigation to agricultural interests, the forests, control of insect pests, and selection of crops. Assistant Secretary Willits also pointed out the importance of climatology. The Department of Agriculture was waiting to see whether the Weather Service would be transferred to it, as was then being discussed. If it were not, the Department would ask an appropriation to begin its own work in climatology.

Major Powell was also invited to appear before the House Committee on Irrigation to discuss the problems of irrigation and his ideas on the subject. There he seemed to win the interest of all, even the redoubtable Mr. Herbert who answered Major Powell's diffident, "I am afraid that I have wearied you gentlemen already" with "You are not wearying me, for I feel a very great interest in it." During a session on Saturday morning, March 15, Major Powell attacked the Plumb bill as impracticable and proposed his own bill. He began by discussing the problem of water rights. There was a general theory of law which provided for priority of right, but it did not apply to questions of water right between different districts and different States. He stressed the fact that not all the land in the arid region could be irrigated; it would be "a large estimate" to say that one-tenth of it could be irrigated by perennial streams. For that reason, it was an important problem to determine which lands could be served. It was possible to select the lands so that good lands could be irrigated or poor lands. It was possible to select the lands in such a way that ultimately less than one-tenth of the arid region could be irrigated. Finally, he said, "I do not know whether it is modest for me to suggest a solution of the problem, but if you will hear me on the subject I would like to speak a few minutes upon what I think is the solution."

Invited to proceed he said, "It takes me out of my proper function as an executive officer of the Government to suggest legislative measures, but I think there are three methods by which it can be solved, two of which I deem impracticable under our form of government." The first was that the General Government take control of the waters, construct the irrigating works, and charge the people for the water. That could be dismissed without further discussion, for Congress was clearly opposed to such a proposition. The second was that the General Government authorize the people to construct the works by granting charters for them. The Government could institute a commission with an organization to make surveys to examine the streams and lands and could authorize that commission to charter private bodies, corporations, or individuals to do the work. That was the substance of Senator Plumb's bill, which the Senate Committee was studying. That scheme, the Major said, would need a great central commission and local and State commissions, and a vast body of marshals and U. S. courts. It would result in piling up against the Government the most enormous claims. Corporations would control the water, farmers the lands, and the farmers would be supplied with water by the corporations instead of controlling it themselves. The preferred solution, the one in harmony with the institutions of this country, was the bill Powell had outlined to the Senate on January 21 and described then to the House Committee.

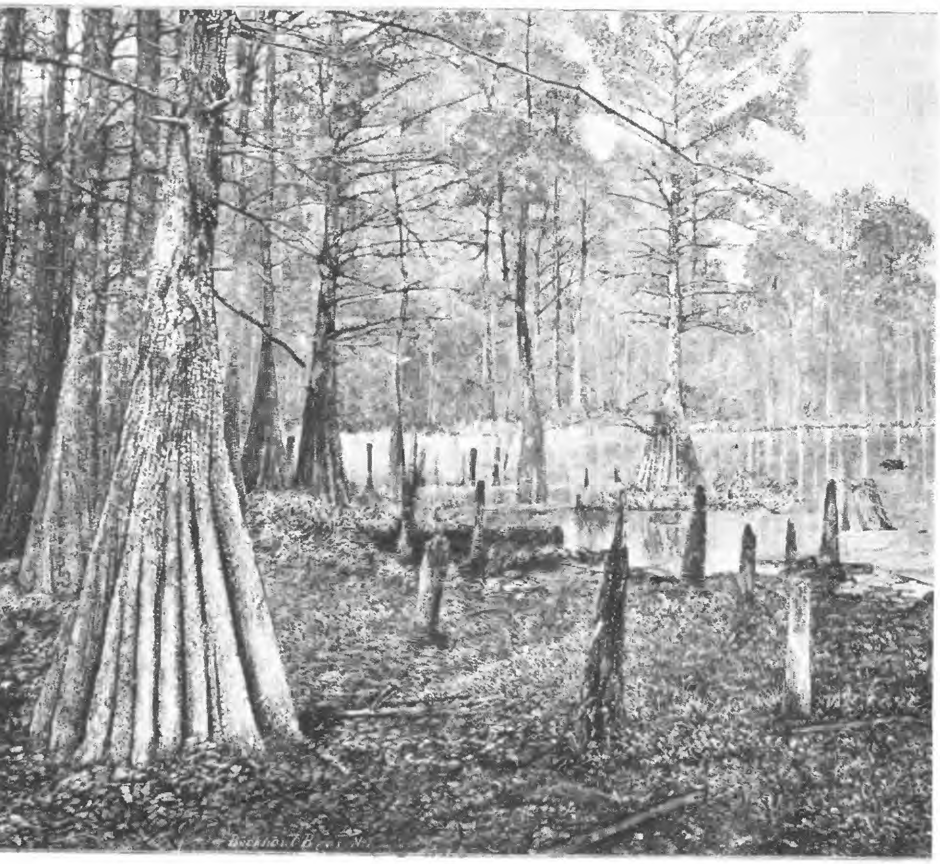
On March 13, while Major Powell had met with the House Committee on Irrigation, Captain Dutton appeared before the Senate Committee. He was questioned on two points: the division of the appropriation between the topographic surveys and the engineering work; and the connection, in practical operations, between the two. Dutton replied that of the first appropriation of $100,000, only $36,000 had been allocated for hydrographic and engineering surveys; of the second appropriation of $250,000, only $100,000. As to the connection between the topographic and engineering surveys, Dutton said that there was some general usefulness in a good topographic survey in an engineering or hydrographic project but they could get along without it. The topographic surveys needed in irrigation work were never on a scale of less than 1,000 feet to the inch and more frequently on a scale of 100 to 200 feet to the inch. The vertical element was even more important, and the contour interval in the general survey was simply too large. "It would be impracticable," he said, "to construct a topographic map, at a reasonable cost, with a degree of accuracy at all commensurate with the accuracy which is demanded by the engineering surveys of a canal,



Quantity, distribution, and fluctuations of rainfall, F. H. Newell pointed out, are not directly related to the amount of water flowing in a stream and available for storage and use in irrigation. Snow is more important than rain, and the time of year when snow falls and the temperature in early spring have great influence on the quantity and intensity of floods. (From F. H. Newell, 1891.)

or even a reservoir." Major Powell, Captain Dutton thought, was under some misapprehension as to the degree of accuracy attainable by the mapping methods in use. He did not believe that the accuracy needed by the engineer was at all attainable by the methods used by the topographers, and, furthermore, none of the topographers, with the possible exception of A. H. Thompson, thought so either.

On March 14 and again on the 18th, Major Powell was called before the Senate Committee and grilled on the necessity of the topographic surveys. He protested that he had said from the beginning that the topographic maps must come first. Senator Stewart insisted that they were not complaining about what had been done; they merely wanted to know how much had been spent on each. Faced with the fact that his engineers disagreed with him, Major Powell said that he, who had overall charge of the work, was a better judge of what was necessary than the head of any part of the program who would obviously be convinced that his own work was the most important, and he asked permission to bring in members of the Survey who agreed



As a corollary to the investigation of the arid lands, Professor Shaler investigated the inundated lands. The development of swamps was controlled by relations among the shape of the land, the rainfall, and the annual temperature. He found that in the swamp near Corapeake, North Carolina, only slight differences in altitude had resulted in differences in physical conditions to which different types of trees had become adapted. (N. S. Shaler, 1890.)

with him rather than Dutton and Nettleton, mentioning specifically G. K. Gilbert, A. H. Thompson, Henry Gannett, and Willard Johnson. The funds, Major Powell insisted, had been nearly equally divided, a little less than one-half for the topographic surveys, a little more for engineering work.

Major Powell was by then making a serious effort with a series of speeches and magazine articles to explain his position to the public. The best and safest agriculture, and the oldest, was irrigation agriculture. Perhaps 20 percent of the western lands could be reclaimed by irrigation, but that 20 percent added up to more land than had been tilled so far in the Nation. The water to reclaim that 20 percent would have to come from the large rivers. Dams on the large rivers, if properly engineered, would provide protection from floods and permit a controlled flow that would prevent wasteful runoff and allow both the reclamation of arid lands at the headwaters and swamplands near the river mouths. Laws governing the ownership or use of interstate or international rivers must be worked out and a plan devised to obtain means to construct the enormous engineering works necessary.

Powell estimated that $1 billion would be required but said that the Government should not engage in the work. "So dreamers may dream, and so ambition may dictate, but in the name of the men who labor I demand that the laborers shall employ themselves; that the enterprise shall be controlled by the men who have the genius to organize, and whose homes are in the lands developed, and that the money shall be furnished by the people; and I say to the Government: Hands off!" The solution that he proposed was that the entire arid region be organized into natural hydrographic districts and that each one make laws for the division of waters, protection and use of the forests (a forestry organization under the hands of the General Government, he said, would become a hotbed of corruption), for the protection of the pasturage on the hills, and for the use of power.

Powell said:

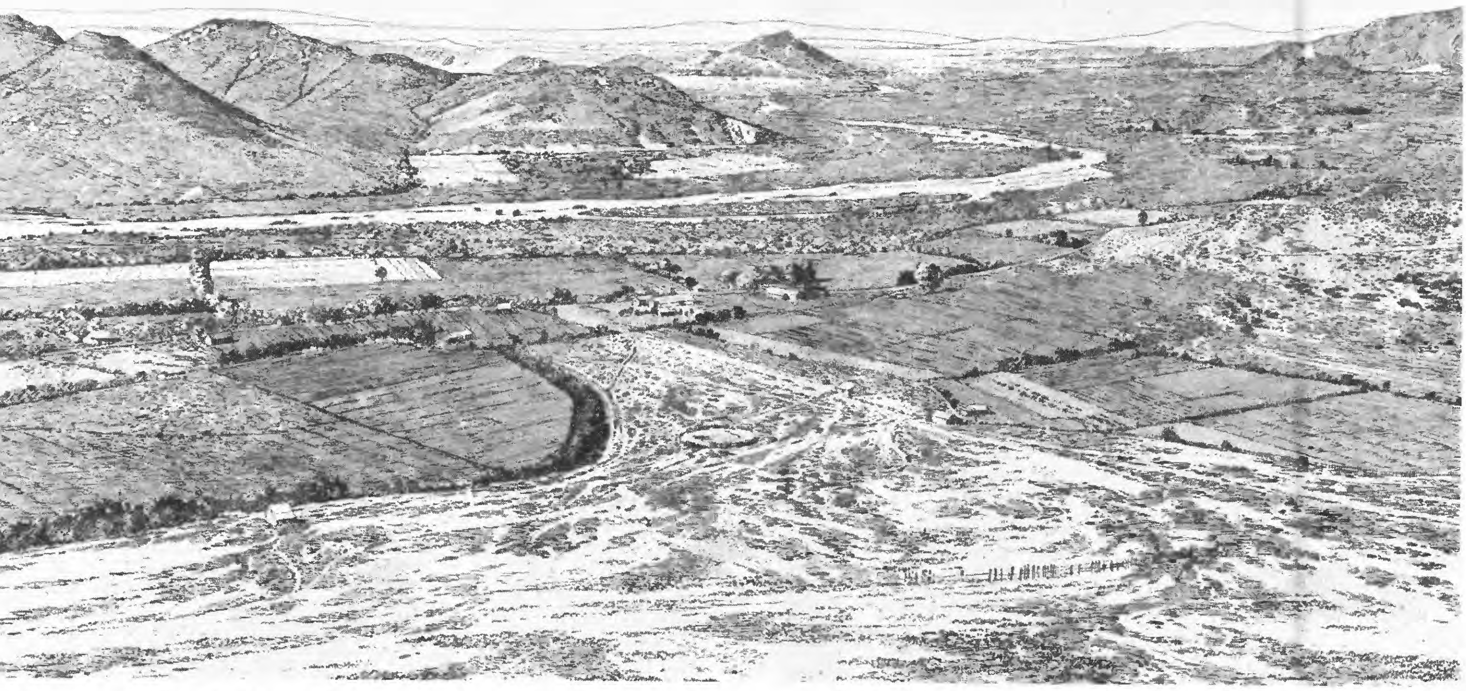
> **Let the General Government make a survey of the lands, segregating and designating the irrigable lands, the timber lands, the pasturage lands, and the mining lands; let the General Government retain possession of all except the irrigable lands, but give these to the people in severalty as homesteads. Then let the General Government declare and provide by statute that the people of each district may control and use the timber, the pasturage, and water powers, under specific laws enacted by themselves and by the States to which they belong. Then let the General Government further declare and establish by statute how the waters are to be divided among the districts and used on the lands segregated as irrigable lands, and then provide that the waters of each district may be distributed among the people by the authorities of each district under State and national laws.**

(Only undeveloped mining lands were to remain in the possession of the General Government; titles should pass to individuals under the provisions of existing statutes, where such lands were obtained by actual occupation and development, but only in quantities sufficient for mining purposes.)

The capital, Powell thought, should not and could not come from great corporations that had done much to accomplish the works necessary to modern civilization. Agriculture had not come under the domination of these "modern rulers." Throughout the humid regions the farmer was independent, and corporations that had sought to take control of agriculture in the arid region had "often failed to secure brilliant financial results, and many have been almost destroyed."There was a war between capital and labor in the West, but Powell's plan would permit individual farmers to exploit the land and at the same time open to capital a field for safe investment and remunerative return.

On March 21, Major Powell returned to the Senate Committee accompanied by G. K. Gilbert and A. H. Thompson. Neither, in the end, proved of much help. Gilbert tended to give long technical replies, but he finally admitted that the topographic survey had to be done over on a different scale for the practical work. Thompson thought that topographic surveys preceded the engineering work in India and southern California. He didn't have any reports from India that insisted on topography first, but he thought that there were some in the Survey library. When pressed for examples from southern California, he recalled once discussing a survey of a 10-square-mile area with a gentleman in San Francisco. Certainly, he admitted, the engineers of the Irrigation Survey could get along without having the topographic maps in hand; none of the maps were finished yet. As the session ended, Major Powell said, "I would like to have five minutes time. Neither of the gentlemen who have been speaking has seemed to fully comprehend what the committee desires, and I would like to have five minutes of your time." Senator Stewart promised, "There will be another meeting and you shall be heard."

The next day was little better. Willard Johnson did his best, citing the constant demands from the engineer in the Arkansas Valley for maps, but he too admitted that the engineering survey had been able to start without the topographic maps. Then A. H. Thompon volunteered the information that the topographic maps for the irrigation survey were made in exactly the same way as the topographic maps for the geologic survey, and the committee had a whole new line of attack, for in 1888 Powell had suggested that the topographic work be given "a special adjustment in the interest of irrigation."



While the Senate Committee was grilling Major Powell about the topographic mapping, the Senate itself had already, on March 18, 1890, agreed without discussion to an amendment to the Urgent Deficiency bill proposed by its Committee on Appropriations that provided $20,000 for "the Secretary of Agriculture to make such preliminary investigations of an engineering and other character as will, so far as practicable, determine the proper location for artesian wells for irrigation purposes within the area west of the ninety-seventh meridian and east of the foothills of the Rocky Mountains."

On the 27th, while the bill was still in conference, Major Powell appeared before the House Committee on Irrigation with a prepared statement on artesian waters. The supply of water from artesian sources, he said, "is always limited, is always very small," and he concluded that "if all the artesian wells in the world which are used for irrigation were assembled in one county of Dakota they would not irrigate that county." The chairman thought that the statement would not be borne out by the facts, but Major Powell insisted, "Though irrigation has aided agriculture from the earliest times and though artesian wells have long been understood, the world has succeeded in using artesian water for agriculture in but a few exceptional spots. The Great Plains may become one of these exceptional localities, but the conditions do not warrant great expectations."

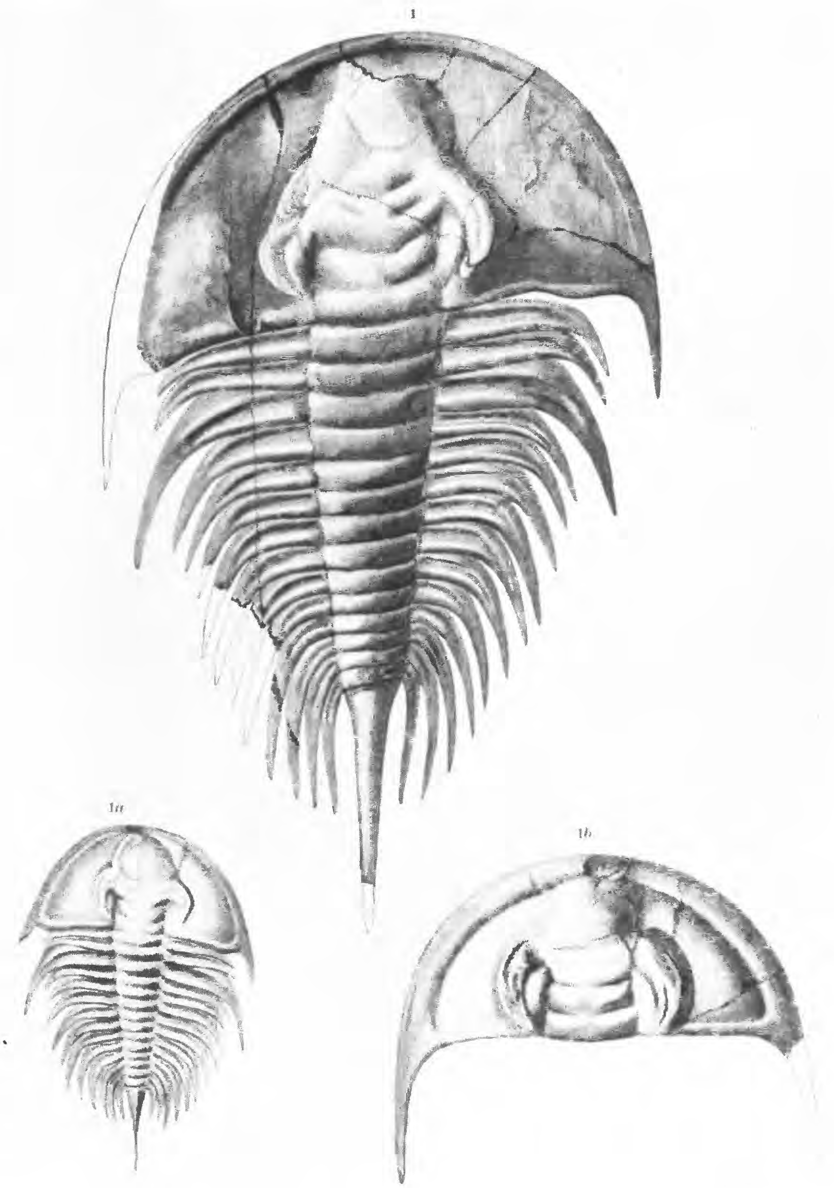
He said:

> **Owing to the cost of well boring, it is not economic to bore wells for the purpose of reclaiming land by artesian water unless the flow obtained exceeds a certain minimum. The economic limit is quickly reached in any district upon the multiplication of wells, and unless well systems are wisely planned there is a great**

As part of the Survey's effort to educate the public, Professor Shaler also prepared a wide-ranging popular account of the origin and nature of soils, which he said were a far more precious inheritance than mineral resources. Because civilization rests on the food-giving capacities of the soil and because all future advances depended on the preservation and enhancement of its fertility, the soil must be nurtured and cared for with an exceeding tenderness and affection. (From N. S. Shaler, 1891.)

danger that the economic limit will be exceeded, and especially that new wells at lower levels will have the effect of destroying wells previously sunk at higher levels. Disappointment is also incurred when the temporary flow resulting from antecedent storage is mistaken for permanent flow. For these reasons exploitation with a drill should be guided by the results of surveys—geologic surveys to determine the stratigraphy and geologic structure, and engineering surveys to determine the limitation of discovered reservoirs. While the Dakota sandstone is one of the most important of the known artesian reservoirs, the amount of land which can be redeemed to agriculture through its aid is yet so small that disastrous results might follow if great expectations were aroused in regard to it.

The subject demanded, he said, "the most skillful investigation which can be bestowed," but there were other sources that were vastly more important. The House nonetheless agreed to the Senate amendment, and the Urgent Deficiency bill became law on April 4, 1890. Senator Moody of South Dakota had already filed a bill to authorize and direct the Department of Agriculture to make investigations of the underflow waters between the 97th meridian and the foothills of the Rocky Mountains.



In the work of the Survey proper, while the Irrigation Survey was underway, much effort went into locating the boundary between the Paleozoic and the Precambrian. In nearly all localities where the lowest zone of the Cambrian was recognized, C. D. Walcott found a peculiar genus of trilobites, and the term *"Olenellus* zone" then came into general use to designate the base of the Cambrian. (From C. D. Walcott, 1890.)

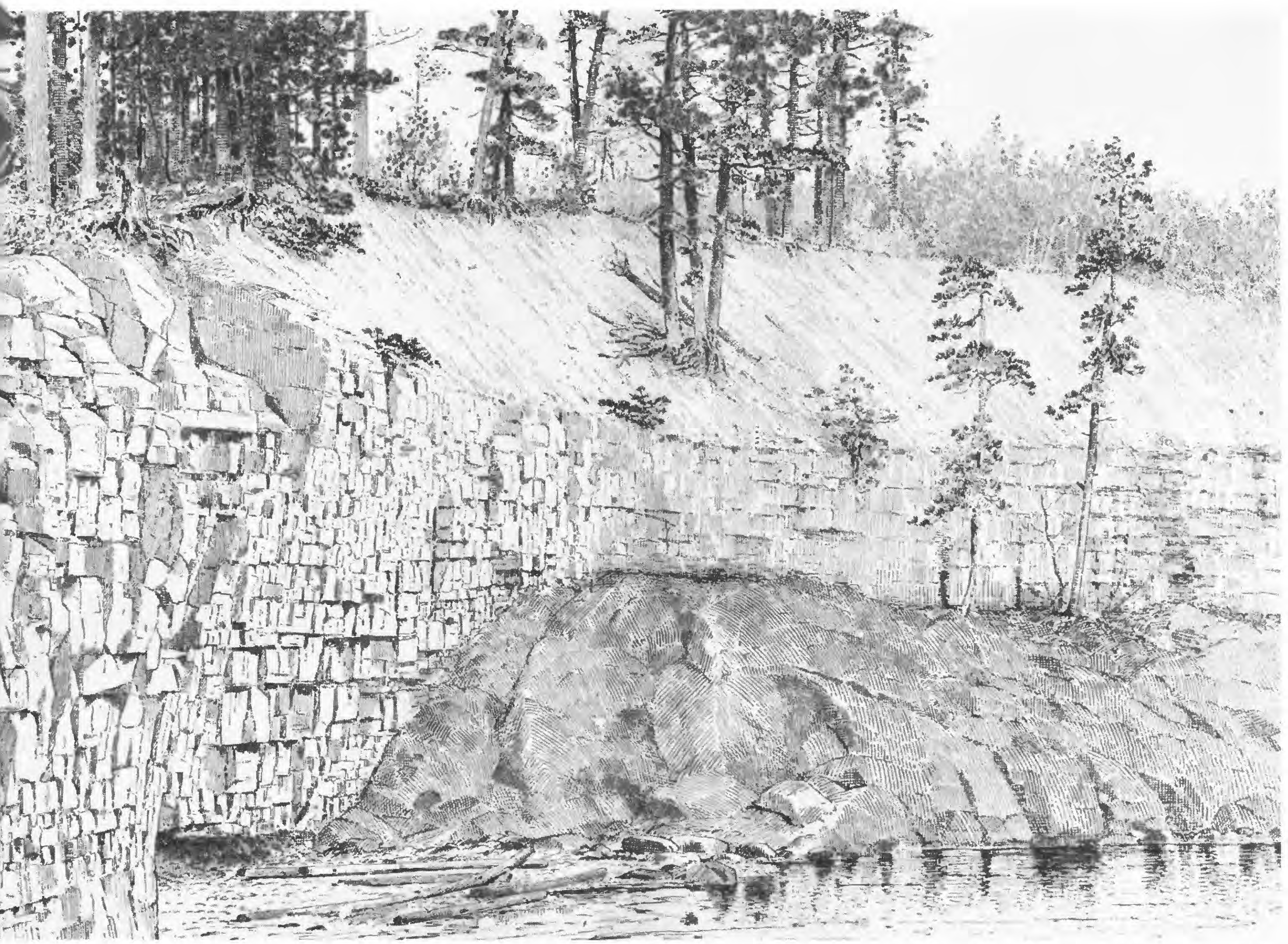
Commissioner Lewis A. Groff of the Land Office was by this time sufficiently troubled about the exact meaning of the reservation clause to ask guidance of the Secretary of the Interior "whether, under the act of October 2, 1888, the reservation extends to such tracts as may be actually selected as sites, etc., becoming operative only after such selection, or whether the reservation from disposal extends from the data of the act to the entire expanse of the arid region." The Secretary on April 21 referred the question to the Attorney General, and the Commissioner issued instructions to hold up patents on lands in the arid region until further notice.

On April 17, Major Powell had appeared before the more sympathetic House Committee on Irrigation with a prepared statement on the operations of the Irrigation Survey, to set before them "the plans of the survey, the methods of the survey, and the underlying principles which have guided me in the administrative of the trust." It seemed to him, he said that the provisions of the law were wise, but wise or not, as an administrative officer he was bound to carry them out. The law was manifestly in the interest of homestead settlers. Individuals and companies had applied to him to have surveys made for plans and schemes that they had devised, but he had concluded that his duty was to enter into each basin and make a complete examination of it, report the best system of works for that basin, and reserve the sites and lands for homestead settlers. The promoters were disappointed and raised a hue and cry that the survey did not aid the development of the country and was not practical. "And that is true," he concluded, "so far as development and such practical benefit are to come from the advancement of irrigation schemes by which lands and waters are aggregated in the possession of individuals and corporations. If this is a fault it is a fault of the law itself, as I act only in harmony with the statute."

On the 24th, Major Powell again appeared before the House Committee on Irrigation to alert them to a problem regarding the segregation of lands made susceptible of irrigation. The law, he said, had an uncertainty in it but would be construed in a few weeks. He thought that the survey should be directed to segregate these lands in such a way as to secure: (1) the greatest area of irrigable land, (2) the most valuable lands for agricultural purposes by reason of climate, (3) the most valuable lands for agriculture by reason of soil and subsoil, and (4) the lands that could be irrigated and cultivated with the greatest economy. All these provisions had in fact been incorporated in Mr. Reagan's bill. But he wanted to warn them that unless something was done to provide that specific lands be irrigated, capitalists and corporations would acquire larger quantities of lands under the Desert Land and Timber Culture Acts, and these poorer lands would be the ones to be irrigated.

Commissioner Groff was already hearing from Senators and Congressmen dismayed by his instructions to hold up patents. On May 3, 1890, Senator Teller offered a formal resolution "that the Secretary of the Interior be requested to inform the Senate what construction is placed by his Department upon the scope and effect of the reservation from sale and disposal of the arid lands under the provisions of the act of October 2, 1888 * * * and what instructions or orders, if any, have been issued or made thereunder, whether general or special, with respect to the suspension of the arid lands from entry under the public land laws, or the suspension of entries thereof heretofore made, or affecting the rights of citizens to construct canals and ditches for irrigating purposes on the public domain."

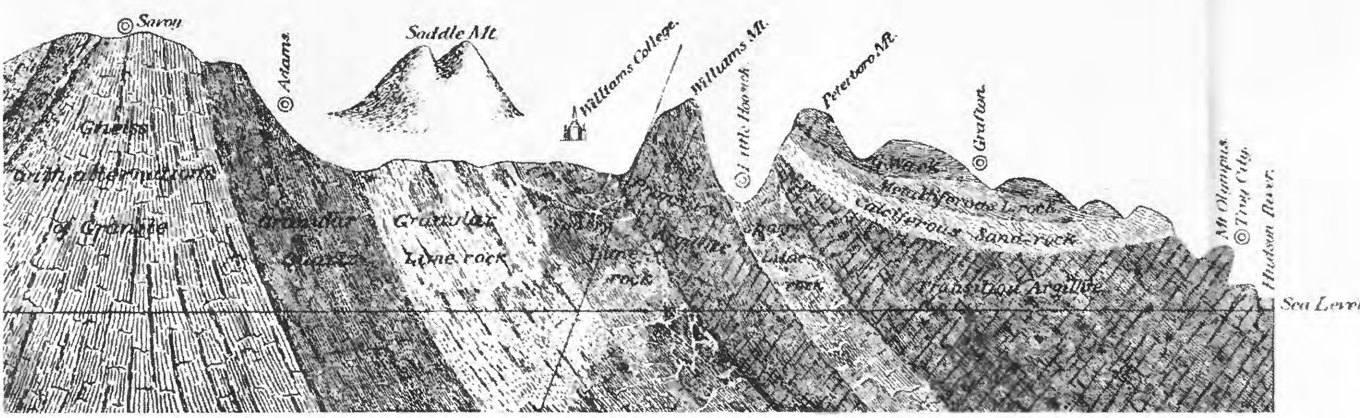
On May 8, the Senate Select Committee on Irrigation filed its report. The majority, Senators Stewart, Plumb, Casey, and Moody, endorsed Senator Plumb's bill, which reserved all unappropriated waters of lakes and



Locating the Paleozoic-Precambrian boundary had been difficult because in some areas the *Olenellus* zone was missing and the Upper Cambrian, the Potsdam, rested directly on the Precambrian. (From C. D. Walcott, 1890.)

rivers and placed them under the control of the States or Territories. The bill also called for the appointment of a Commissioner of Irrigation in the Department of Agriculture and the transfer of the Irrigation Survey to that Department. A minority report, signed by the three Democratic members of the committee, Senators Reagan, Gorman, and Jones, offered as an alternative to the majority bill a new bill based on the proposals of Major Powell.

A large part of the majority report was devoted to the charge that the Director had illegally transferred money appropriated for the irrigation survey to topography. The Director claimed that the term "necessary maps" in the legislation meant the topographic maps, that in fact the topographic maps were necessary to the irrigation survey. The committee thought that the maps were useful and convenient for minor purposes but reported that the engineers said that maps were not necessary in any "imperative" sense, that they would not save any important amount of labor or expense. The Director said that the maps made trial lines unnecessary; the engineers said that trial lines were seldom necessary, and when they were needed it was to settle questions that the topographic maps couldn't answer. The Director said that the maps showed whether the slopes would lead water to benchland, saving the engineers an expensive survey; the engineers said that a simple inspection would show that. The big questions were the amount and



Amos Eaton had made the first attempt in the United States to assign strata known to be Lower Cambrian to a definite position in a series of stratified rocks. C. D. Walcott reproduced Eaton's 1824 section because of its great historic interest and identified Eaton's Granular Quartz as Cambrian, his Transition Argillite as nearly all Cambrian, and the Greywacke of Peterboro Mountain as Upper Cambrian. (From C. D. Walcott, 1890.)

cost of construction, and as they depended on the quality of the ground, a topographic map could not supply the information. The Director said that the topographers discovered the reservoir sites; the engineers said that they had to see the district for themselves. The Director said that the amount of runoff could be computed using information from the topographic maps; the engineers said that computations were no better than guesswork. The minority report defended the Director's use of topographic mapping.

On May 26, Senator Stewart moved to discredit Major Powell's direction of the Irrigation Survey by proposing a resolution, which the Senate adopted:

"Whereas by the act of October 2, 1888, an appropriation of $199,000 was made for topographic surveys and $100,000 for investigations and surveys for the purpose of irrigation and

"Whereas by the act of March 2, 1889, an appropriation of $200,000 was made for topographic surveys and $250,000 for irrigation investigations and surveys: Therefore

"Be it resolved, That the Secretary of the Interior be directed to inform the Senate how much, if any of the money appropriated for irrigation investigations and surveys has been diverted and used for topographic surveys and matters connected therewith; and, if any such money has been so diverted and used, to inform the Senate by what authority of law, where appropriations are made by Congress for several purposes, the money appropriated for one purpose can be diverted and used for another purpose for which an appropriation is also made in the same statute."

On May 28, the *Washington Star* published an interview with Major Powell. "The struggle that I am at present engaged in with relation to the irrigation question," he was quoted as telling the *Star* writer, "is a fight against the speculators pure and simple. I am doing what I can to prevent moneyed sharks from gobbling up the irrigable lands of the great arid belt, together with the waters upon which they will depend for fruitfulness, and so establishing a sort of hydraulic feudal system, to which the American farmers would be helplessly subject." The wisdom of the provision for withdrawal of the land, he said, was "even now being shown by the tremendous efforts which the speculators, with $500,000 to back them, are making to secure the repeal of the law by Congress, in order that they may rush in and gobble these areas and supply waters, which the Geological

Survey has recently declared to be so valuable." He was doing his best to defeat the speculators, but they wielded great influence and had even misled some members of Congress. Attacks were made on the Survey, they were trying to turn the irrigation business over to the Department of Agriculture and the hydrographic survey to the Signal Service, and he personally had been accused of misuse of funds. "But how on earth," he concluded, "the survey was to ascertain the manner in which irrigation was to be successfully accomplished without preliminary mapping of the regions exhibiting the problem to be solved goodness only knows."

When the Senate convened the next morning, an irate Senator Stewart rose to a question of privilege and asked that the article be read to the Senate. As soon as the clerk finished reading, he launched into an attack on Major Powell, calling the Geological Survey "a political hospital where no civil service rules apply, and where members of Congress who will serve his schemes find places for their relatives and dependents." Senator Gorman tried to defend the Director, but he had to admit that his statement to the paper was "unfortunate, probably, and should not have been made by him."

On June 3, Secretary Noble sent to the Senate his reply to Senator Teller's resolution of May 3.

On May 24, William Howard Taft, Solicitor General and Acting Attorney General, had replied to the Secretary's inquiry of April 21 about reservation of lands and had sustained the Secretary's interpretation. It was the purpose of Congress to suspend all rights of entry upon any lands which might possibly come within the scope of the law of 1888. The entire arid region was in fact closed to entry on October 2, 1888. The Secretary added that, while he was not called on to express his views further than upon the construction he had placed on the act, he asked the privilege to say that he deemed the matter

> one of such magnitude and of such vital interest to the people inhabiting or who may hereafter inhabit these vast regions, that if the Senate and House of Representatives do not as a body fully concur in the purpose of this law they should take the business in hand without delay, to so modify it as they may deem the public interests require, as otherwise there may be the greatest losses on the one hand to persons who, ignorant of the law or disregarding the same, settle upon these land, or upon the vast and valuable properties that should be controlled by the Government for reservoirs, ditches, etc.

On June 4, the Secretary replied to the Senate resolution of May 26 and upheld the Director's use of funds for topographic mapping: "The statute directs that the expense of making the topographic maps for the Geological Survey shall be defrayed from the appropriations made for the Geological Survey, and that the expense of making the topographic maps for the Irrigation Survey shall be defrayed from the appropriation for the irrigation survey. It appears from the report of the Director of the Geological Survey, in my judgment, that the appropriations for the Geological Survey have not been diverted from their purpose, but have been strictly used as contemplated in the act, and that the appropriations for the irrigation survey have not been diverted from their purpose but strictly used for the irrigation survey as required by law." Senator Stewart, however, thought that the Director had hoodwinked the Secretary. "What the Director of the Geological Survey has done was to take over $200,000 of the irrigation money and use it for topography. That is the fact; and when it is stated that because he was to make maps for the irrigation survey he should therefore take the money for the irrigation survey and use it for another purpose, when it was directly approriated for that purpose, with all due respect to the Secretary of the Interior, it is in direct violation of the law. * * * I say the money has been squarely misappropriated. The language of the statute has not been observed, and the whole legislation, which I was guilty of inaugurating to some extent myself, has been an unmitigated evil to the people of my part of the country."

That same day the House Committee on Appropriations was to consider the appropriations for the Irrigation Survey, and both Senator Stewart and Senator Moody of South Dakota attended. The budget request was for a total of $777,500–$720,000 for the Irrigation Survey itself, $50,000 for engraving maps, and $7,500 for rent. Major Powell wanted the $720,000 divided among the States and Territories, including those in the subhumid region. Congressman Joseph Sayers of Texas asked if the topographic maps for the Geological Survey and for the Irrigation Survey were really the same, and Major Powell assured him that they were made in the same way but that the entire $200,000 for topographic surveys under the Geological Survey had been spent in mining regions, leaving nothing for the Irrigation Survey.

Senator Stewart told the House Committee that "every representative of the arid region—I think there is no exception—would prefer that there would be no appropriation to having it continued under Major Powell" and tried to explain to the committee "what kind of investigation we want and what kind of invesigation we do not want." Senator Moody questioned Major Powell in great detail about his knowledge of South Dakota. Senator Moody "deprecated" the unfortunate controversy that had arisen, but complained that the Major had given the artesian project a "black eye." The House Committee, despite the Senators' presence, approved the full amount for the Irrigation Survey.

The Sundry Civil Expenses bill was brought before the House in mid-June 1890 under the 5-minute rule which limited discussion of amendments. Provision was made, however, for full debate on the irrigation survey. The new chairman of the House Appropriations Committee, Joseph G. Cannon of Illinois, insisted that the surveys were for information only. "There is no proposition to do otherwise than comply with the law, and no intention or desire on the part of the committee to recommend appropriations that will commit the Government to the improvement of arid lands or any other lands anywhere." The committee had viewed the Survey's work as designating irrigable lands so the President could open them to settlement under the homestead laws and had allowed the full amount of the budget so the work could be prosecuted with dispatch. The House itself was divided. Mr. Sayers said the legislation also aimed at preventing syndicates and corporations from obtaining control of reservoir sites, but Congressman William Oates of Alabama allowed that that could be done more cheaply by changing the land laws. Isaac Goodnight of Kentucky wanted to eliminate the entire appropriation, but Alexander Dockery of Missouri said it would be necessary either to repeal the law or to appropriate the money to designate the irrigable lands. Both Edward P. Allen of Michigan and Benton McMillin of Tennessee objected to putting more lands in competition with existing agricultural lands since farms all over the country were in bad shape. The motion to eliminate the appropriation was defeated, and a motion to repeal the joint resolution of March 20, 1888, went out on a point of order.

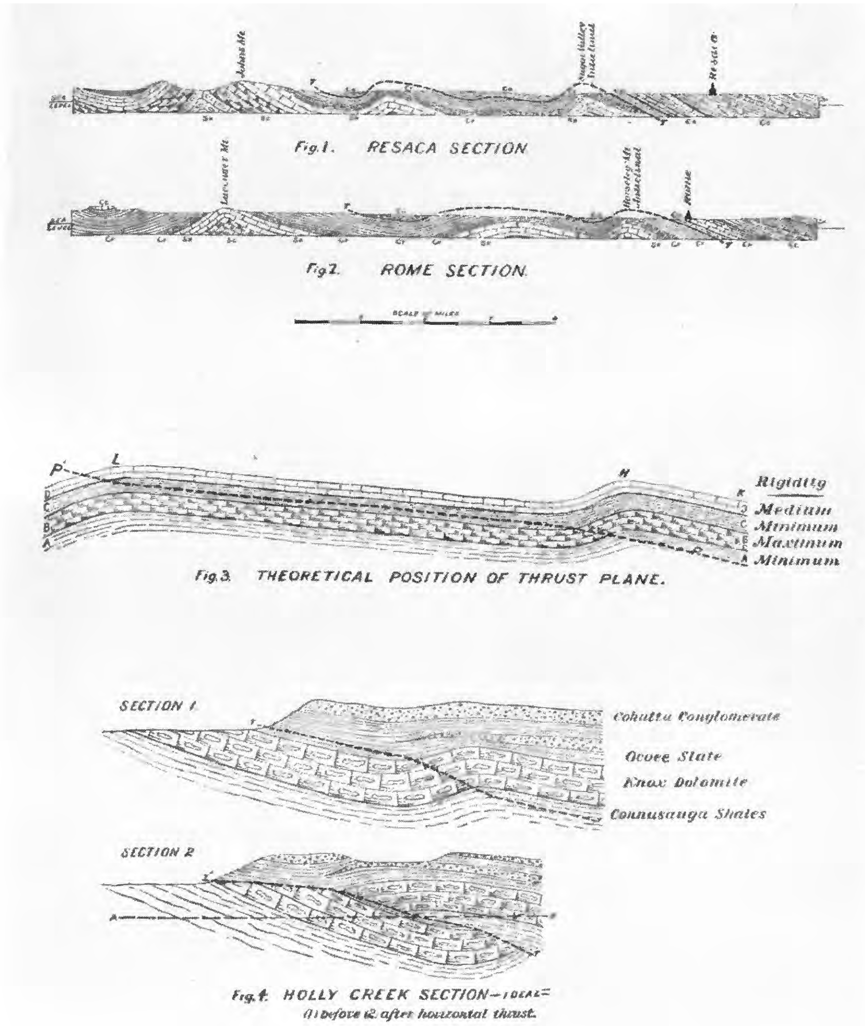
The House Committee on Appropriations had recommended the same amount as the previous year, $515,700, for the Geological Survey proper, and there was no discussion of that appropriation as the Sundry Civil Expenses bill was passed by the House on June 17, 1890.

Chief Geologist Gilbert wrote to Professor Alpheus Hyatt: "The attack on the Survey by Senator Stewart seems quite as likely to react on him as to impede our work. His late efforts have seemed quite abortive. He made an argument before the Committee on Appropriations of the House against the appropriation for the irrigation investigation, but the appropriation was, nevertheless, voted unanimously by the Committee, the full amount of the estimate being given—$750,000—and Powell's administration being practically sustained. The resolution introduced by him to ascertain on what authority Powell had used certain moneys in certain ways elicited a reply from the Secretary of the Interior, which fully sustained Powell's administration, and that reply was submitted by the Secretary to the Cabinet before sending it to the Senate. The Major has had a hard winter but the brunt of the battle seems to be over and he has turned his attention once more to the scientific work." Gilbert was wrong. The worst of the battle was yet to come.

On June 20, Senator Stewart again attacked the direction of the Survey, this time while the Senate was considering the Legislative, Executive, and Judicial Expenses bill. He asked Senator Allison to explain the duties of the Executive Officer of the Survey, and when Senator Allison replied that he understood them to be to take charge of the surveying parties in the field and arrange their accounts, he then moved to strike out the appropriation for the Executive Officer's salary. "I think it is an entirely useless office. The person who fills it has the reputation of being an executive officer of a literary bureau that runs newspapers," and further, Mr. Croffut had been frequently seen in the halls of Congress attempting to influence legislation. Several voices said, "Let it go!"so he subsided, but only briefly. His next charge was that Powell had "susperseded men as much superior to him as he is superior to the veriest clodhopper in the country. He took the place of Wheeler, he took the place of Hayden, who was a real geologist, who died of grief by being crowded out. He has by his wily arts superseded many men who were his superiors. But there is no man in this country who is his superior as a lobbyist or who can better organize and control Congress."

Senator Gorman again tried to defend the Director, but the defense was halfhearted. He agreed that the office had grown without supervision, but he saw no hope of changing things until there was a problem raising money by taxation. Powell was surrounded by influences that could not be resisted until Congress determined the number of Survey employees. The Survey, the Senator said, was "the asylum of all the scientists in the country who have nothing else to do," and "the final step of the young men who are graduating at the colleges of the country." Gorman added, "I have never yet heard even his bitterest enemy charge him with being derelict in his duty, or incompetent, or dishonest. He has been, in my judgment, extravagant," but "I have no word of excuse to offer for the head of this department who, I think, has improperly and unwisely criticized gentlemen in the Senate and elsewhere because they have different views from his. * * * There is no excuse, in my judgment, for his criticisms of individuals and charging them with a desire to defraud and rob the government."

The Senate Appropriations Committee had not yet completed its work on the Sundry Civil Expenses bill. On July 1, 1890, while the appropriation for the General Land Office was under review, Commissioner Groff was asked if the public-land surveys would be held up materially by the "irrigation feature." He agreed they would be unless there was legislation on the arid lands. Involved was the allocation of land to the new States, the four admitted in November 1889 and two more to be admitted within the



In his mapping in the southern Appalachians, C. W. Hayes found broad overthrust faults comparable in magnitude to those of the Scottish Highlands. A simple broad gently undulating syncline near the Tennessee-Georgia line was terminated on both sides by thrust faults, the Rome fault on the west, the Cartersville fault on the east. In the sections shown here, Hayes demonstrated the development of the structure. (From C. W. Hayes, 1890.)

next 10 days. Without the allocation of lands, the new States had no base for taxation. The Commissioner was then asked what he considered the arid region, and he replied that the only light on the matter the General Land Office had was the map that the Director of the Geological Survey had given him. "Until this morning," he reported, "the arid region, as we have understood, was embraced within the red lines on this map; but the director sent in this morning this map, and he admits that this white portion of the map is not within the arid region and is subject to entry under the settlement laws of the United States." All the land west of the 101st meridian was withdrawn except a portion of Washington, a small portion of Montana, a portion of Oregon, and a portion of California, but the eastern half of North Dakota, South Dakota, and Nebraska, all but the westernmost part of Kansas, and the western half of Oklahoma, areas where settlement was proceeding most rapidly, were open.

Major Powell appeared before the Senate Appropriations Committee on the following day; five of the eight Senators from the new States were present as well as Senators Stewart, Paddock, and Reagan of the Senate Committee on Irrigation. The Director admitted that of the 100 million acres that could be irrigated, 45 million were already in private hands. Moreover, irrigable lands should be consolidated as much as possible to use water to the best advantage, so the lands adjacent to those already under cultivation should be segregated. Once the reservoir site was determined and canal lines laid out, he would make a topographic survey to determine which lands most deserved irrigation and would recommend to the President which lands should be opened to homesteading. He agreed with Senator Hale that there was really little left for the General Land Office to do.

It was a foregone conclusion that the Senate Committee on Appropriations would not go along with the Irrigation Survey. Senator Allison had been opposed in 1888, and 1890 was not the year to oppose western demands. The Sherman Antitrust Act had just been passed, the Sherman Silver Purchase Act was in its final stages, but debate on the tariff measure was about to begin. The Senate Appropriations Committee filed its report on the Sundry Civil Expenses bill on July 9, recommending an increase of $100,000 for topographic surveys by the Geological Survey, elimination of the entire appropriation for the Irrigation Survey, and an increase of $400,000 for the public-land surveys of the General Land Office. When the bill was introduced on the floor of the Senate, Senator Gorman made it very clear that the elimination of the appropriation for the Irrigation Survey and the increase in appropriation to the General Land Office were linked. The crucial point was that until the public-land surveys were made, the lands were not subject to taxation, a matter of great importance to the new States.

On July 10, the Senate passed Senator Stewart's resolution directing the Secretary of the Interior to inform it if the Director of the Geological Survey, in selecting sites for reservoirs and designating lands susceptible to irrigation, had actually surveyed and marked the boundaries of the areas so they could be distinguished on the ground from other land and also be officially delineated on the Land Office maps and whether or not the Director had included in these selections land not intended for the storage of water or land that was not susceptible to irrigation.

It had been his intention, Senator Stewart said, when he proposed his first bill in 1887, that the General Land Office segregate the lands. "I had no conception that the survey of reservoir sites involved topography, or geology, or any other scientific performance. People were doing it every day in my country, the engineers understood it perfectly well. * * * If it is necessary to do all that is proposed in order to secure the simple thing of surveying these reservoir sites and changing the usual mode of surveying the public lands, then we had better leave it under the rectangular form and make no change."

The Director's reply was forwarded, without comment, by the Secretary on July 21 and with it a statement from the Commissioner of the General Land Office. Major Powell said that he had indeed actually surveyed the land selected for reservoir sites and lands designated as susceptible to irrigation. The boundary of the reservoir sites had not been marked out by stones on the ground, but a single stone had been set showing the height to which the water was expected to rise. The lands susceptible to irrigation had been designated by Land Office subdivisions. The lands designated as reservoir sites were all to be used for reservoirs, but since Land Office subdivisions had been used to designate the lands susceptible to irrigation, some nonirrigable lands might be included. The Commissioner of the General Land Office said that to his knowledge, all selections were made by designating lands by proper legal subdivisions and were not accompanied by any evidence that the boundaries had been actually surveyed and marked out. He further had no way of knowing whether the reservoir sites included any land not intended for the storage of water or whether the lands susceptible to irrigation included any land that could not be irrigated.

By the time the reply was received, the Senate had already sealed the fate of the Irrigation Survey. The Senate began consideration of the Survey appropriation on July 16, 1890 but spent most of its time on the irrigation question. The Appropriation Committee's increase for topographic surveys was accompanied by a proviso that one-half be expended west of the 101st meridian and also that so much of the Sundry Civil Expenses Act of October 2, 1888, "as provides for the selection and location of reservoirs upon the public lands, and the reservation of irrigable lands, is hereby repealed; Provided, That reservoir and canal sites heretofore located or selected shall remain segregated and reserved from entry or settlement until otherwise provided by law." The purpose of the first proviso was, as Senator Allison admitted on questioning, to require the Director to do the topographic work for location of reservoirs under the regular appropriation.

Senator Stewart, however, said, "I wish to say there is not an experienced engineer in America I have met with who agrees with the Director of the Geological Survey that a topographic survey is any material aid to irrigation, but in order to locate reservoir and ditch lines there must be a particular survey of the ditch lines and there must be an examination of the ground to see where reservoirs can be made. A general topography of the country is but a general map to direct you where the rivers are." Senator Stewart did not object to the topographic survey for a general map of the country. He merely wanted to make it clear that it was not for the benefit of irrigation.

Senator Wilkinson Call of Florida, who opposed repeal of the reservation clause, introduced another element into the discussion. The question of practicable irrigation had to be determined by the principles of applied science, he said, and Senator Stewart might as well argue that two and two did not make four as to argue that the problems of irrigation could be solved by anything but the application of geologic principles and topographic and engineering surveys. To prove his point, the Senator read a statement that had been furnished him "by an eminently scientific man, a practical man,a man who has acquaintance with this country and with its public lands, but his modesty prevents him from desiring or allowing me to mention his name."

The statement made no reference to irrigation investigations and was, in fact, an explanation of the relation of pure and applied science, and, in particular, of the relation of pure and applied science in the Geological Survey. The statement strongly supported research, but research related to economic problems. The unknown author said:

> When a need is felt and the means of satisfying it are not known, search for the means may be at random or it may be by aid of general facts previously known. In the main random search is unprofitable, and needs are not satisfied until the necessary general facts are discovered. It is economically advantageous to mankind to expend a considerable portion of its energies in the discovery of general facts of nature, in order that these may become available for application as need arises. The work of discovery of general facts is called 'scientific research.' The recognition of the function of research in human economy marks the change from the slow progress of barbarism to the rapid progress of civilization.
>
> In the method of progress in civilization not only are general facts discovered before they are applied, but they are sought without knowledge of all the needs, and frequently without knowledge of any needs, to which they may be applied. Research is largely the sowing of seed by one generation that the next may gather fruit.
>
> The United States Geological Survey is an institution for research. Its function is to discover two classes of general facts about rocks: First, the facts of distribution in space * * *; Second, the general facts of sequence in time or the laws under which they change. Out of these laws grow certain laws of asso-

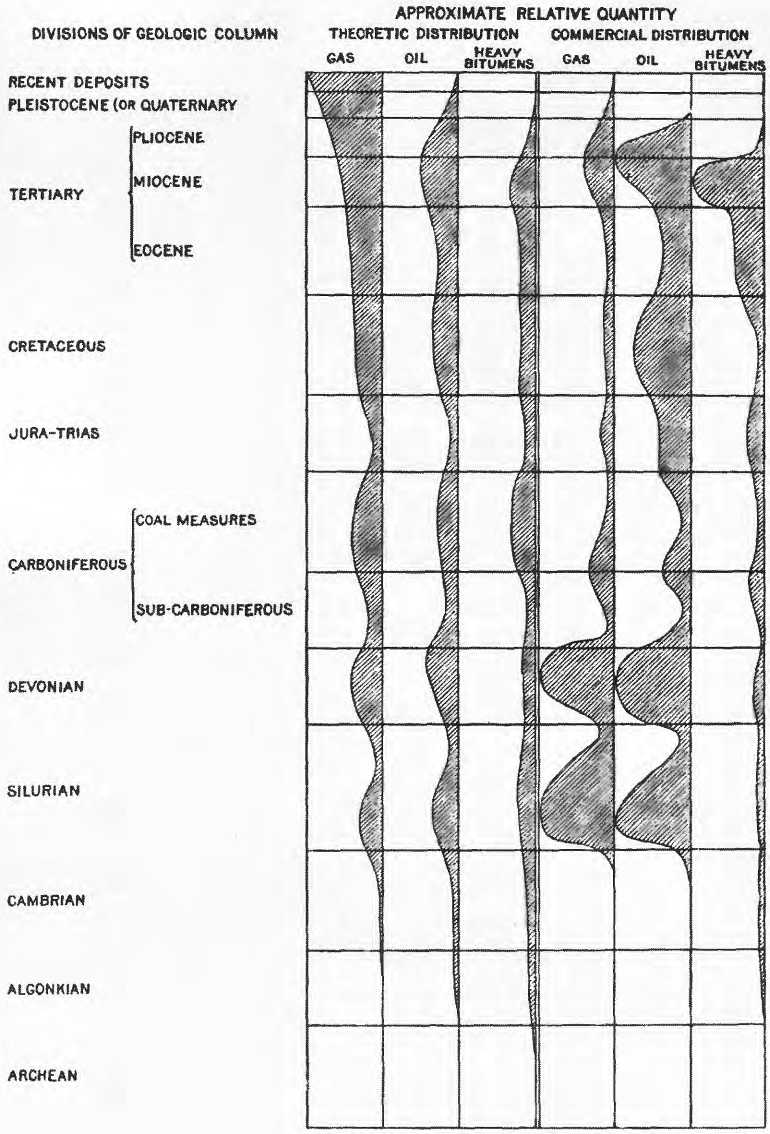
ciation among rocks, and it is through these that most of the economic results are reached. General geologic research discovers with what rocks the economic minerals are associated, and records the horizontal and vertical distribution of the rocks. In its economic application specific search for desired minerals is made in the areas of the rocks with which they are associated, and is restricted to those areas. Instead of being random search it is search with the aid of general facts of association and distribution.

The United States Geological Survey, however, was not primarily organized for general geological research but for the study of the extent, character, and relations of the geological formations of the country and the attainment of a knowledge of its mineral resources. * * * Along with this work of economic significance, much in the way of purely scientific investigation is done. In order to have applied science we must have science to apply; and no economic problem can be long studied without reaching the boundary between the known and the unknown. To answer the economic questions, unsolved problems must be solved; and to do this is the function of pure science. Pure science is the foundation upon which applied science rests.

This was not the official Survey position as is clear from the annual report of progress which Chief Geologist Gilbert was preparing even as Senator Call was reading his statement to the Senate. Gilbert said that geologic investigations might be broadly grouped as local and general. The local work was areal geology, the general work, the development of the philosophy of the science. The local work resulted in geologic maps and structure sections; the general work provided classifications of rocks according to their manner of formation and alteration, classifications of topographic forms and explanations of their origin. The two classes of work were interdependent; the philosophy could not be developed without observation of local phenomena, and maps and structure sections could not be prepared without the aid of geologic philosophy, for the field geologist could never hope to see all points of a formation.

Both local and general work Gilbert said, had economic "implications." Rare substances, such as the ores of metals, were associated with certain formations or structures, and one of the chief functions of the Geological Survey was to indicate on maps the areas occupied by the various formations and thus to guide and aid the search for minerals. The successful search for rare substances was also dependent on correct theories of the manner in which they originated and accumulated, and the economic function of geologic science was to discover true theories and substitute them for the false.

To some extent this sounds like another statement of the relation of pure and applied science. Gilbert went on, however, to say that when the Survey was established, the existing body of geologic theories offered sufficient basis for good areal work. If this had been the sole requirement, the general plan would have given great prominence to the areal work until the geologic atlas was well advanced, then general inquiries could have been added as their results were needed to guide the local work, and finally a system of general discussions would be undertaken when the accumulation of local data gave broad basis for generalization. In actual practice, the areal work could not be carried on until the topographic maps were ready. The principal resources of the organization had therefore been devoted to making topographic maps, and a number of researches promising broad generalizations and other contributions to geologic philosophy were begun instead of areal surveys. The topographic work was now advanced enough so that a readjustment between local and general work could be made. Thus, the geologic investigations being conducted by the Geological Survey were not designed to meet an existing problem or need, although they might do so ultimately, but to develop the science of geology. This was exactly the philosophy expressed by Major Powell to the Allison Commission in 1885.



Until the mid-1880's, known petroleum fields were almost exclusively in Pennsylvania and West Virginia. Discovery of natural gas at that time gave a decided impetus to prospecting in the interior States. The Geological Survey itself made no investigation but published a report by A. J. Phinney, an amateur geologist, who observed the results of drilling in Indiana. Phinney concluded from a study of the literature that bitumens are found in quantity throughout nearly the whole of the geologic column and in nearly every country. (From A. J. Phinney, 1891.)

The same philosophy was evident in the Irrigation Survey, as was clearly brought out by Senator Moody of South Dakota who dominated the Senate discussion on July 17. Senator Moody quoted "one of the ablest engineers in the United States Army" that,

"the position taken by the Director that a topographic survey of the entire arid country is a necessary precursor of an irrigation survey is disputed by the unamimous voice of all experienced engineers.* * * He has repeatedly insisted that it is necessary in order to discover reservoir sites, routes for canals and irrigable lands. He says 'We can not commence at the wrong end and plan backwards. We can not plan a reservoir and then afterwards discover its site; we must know its site first.' The answer to this is plain enough. Three things are necessary to constitute a practical reservoir site—first, a water supply; second, a dam which can be constructed at practicable cost and with safety; third, good cultivable land to which the water can be conducted at a practicable cost. Until these three facts are ascertained no practicable reservoir site has been or can be discovered. It is the Director himself who proposes to begin at the wrong end. He proposes to discover reservoir sites first; that is, he has determined that water is to be had; that safe dams can be constructed at practicable cost, and that irrigable lands exist to which the water can be taken, and then these sites are to be surveyed to ascertain the same facts again."

Another engineer had told Senator Casey that some of the dams being proposed by the topographers could never be constructed at practicable cost. A system of dams proposed by Willard Johnson for Colorado would, he estimated, cost several million to the fourth or fifth power.

The Senate expressed no opposition to the geologic work of the Survey. Senator John C. Spooner of Wisconsin said, "There is no man who reads much of exploration and geological research but has had occasion many times to be grateful that the genius and enthusiasm of Major Powell have been employed in the service of the Government. I am certainly not disposed to vote against the continuance of the Geological Survey, but I am opposed to embarking in the vast work of attempting now to reclaim at the public expense the vast empire known as the 'arid region.'" Even Senator Stewart was not opposed to the geologic work although he suggested that economic geology was the only geology worth studying. Stewart told the Senate that he did not think the geological survey of any section of the country had been completed or would be completed for the next 500 years. "New excavations are made which change theories and develop new facts, and any scientific man will tell you that there have been more developments in the United States in the last forty years by miners than all the knowledge they had before on the subject. The principal explorations came from mining for the various metals, and the real geological surveys going on in the United States are made by those who excavate the earth, and the scientists follow and see what they have done, and record it. That is about all that is necessary. Tramping over the earth and pretending to make a geological survey of it is an impossible thing." When Senator John R. McPherson, Democrat of New Jersey, proposed an additional $15,000 be added to the appropriation for geologic surveys to enable the Survey to aid the States in geologic work, the amendment was passed without question.

One of the most elaborate reports published by the Geological Survey during these 2 years was W J McGee's *Pleistocene History of Northeastern Iowa*, a study he had begun as a personal venture in 1876. Under Survey auspices, McGee progressed from an investigation of glacial deposits to a study of topographic form and rock structure. As McGee described it, "the trail of the ice monster has been traced, his magnitude measured, his form and even his features figured forth, and all from the slime of his body alone, where even his characteristic tracks fail." (From W J McGee, 1891.)

On July 19, there was a telling blow against the Irrigation Survey when Senator Cockrell of Missouri read a letter from Secretary Rusk of the Agriculture Department with a synopsis of the forthcoming report on artesian wells prepared in response to the appropriation of April 4, 1890. The report itself, submitted in mid-August, was a 398-page document on artesian wells between the 97th meridian and the foothills of the Rockies, which Secretary Rusk emphasized was for information only. Richard Hinton had been in charge of the work, and the entire investigation had cost less than $15,000. The report stated that there was a large artesian basin in the Dakotas, that it probably extended westward a considerable distance from the James River developments, that there was probably a basin in Texas, and that there might be several small basins elsewhere. However, artesian wells, even within the limits of recognized basins were not always succussful and sometimes had to be pumped in order to obtain sufficient water. Only in a few places were artesian wells a cheaper means of irrigation than laterals from ditches. The report repeated Major Powell's statement that geologic examination was needed to define areas where water might or might not be obtained from artesian wells, but the report also suggested that the utilization of ground water for irrigation be investigated.

The Senate passed the Sundry Civil Expenses bill on July 19, adopting the recommendations of the Appropriations Committee with regard to the Irrigation Survey and the Geological Survey except for the increase of the appropriation for geologic survey. All told, however, the Senate made 202 amendments to the House bill, so the House and Senate had difficulty in reaching agreement; full agreement was not reached until August 25, 1890. Among the most controversial items were the Senate amendments of the Survey appropriations which the full House debated for several days before calling for a conference. In the end, the House accepted the elimination of the Irrigation Survey, and in its final form, the Sundry Civil Expenses bill provided "For topographic surveys in various portions of the United States, three hundred and twenty-five thousand dollars, one-half of which shall be expended west of the one hundredth meridian, and so much of the act of October second, eighteen hundred and eighty-eight * * * as provides for the withdrawal of public lands from entry, occupation, or settlement is hereby repealed, and all entries made or claims initiated in good faith and valid but for said act shall be recognized and may be perfected in the same manner as if said law had not been enacted, except that reservoir sites heretofore located or selected shall remain segregated and reserved from entry or settlement as provided by said act, until otherwise provided by law, and reservoir sites hereafter located or selected on public lands shall in like manner be reserved from the date of location or segregation thereof." The $325,000 for topographic surveys, more than either the House or Senate version of the bill, was a compromise proposed by the ConferenceCommittee, which also added an additional $25,000 for engraving maps and $3,200 for rent in lieu of the appropriation for the Irrigation Survey.

Before adjourning, Congress also established a new bureau in the Department of Agriculture, to be known as the Weather Bureau. The civilian functions of the Signal Service were transfered to the new bureau, which was made responsible for forecasting the weather, for issuing storm warnings, and for the gauging of rivers. The Department of Agriculture, with its more practical point of view, was thus in a position to undertake the irrigation investigations that Assistant Secretary Willit had proposed.

Chapter 7.
A Weedy Harvest, 1890–1892

And thus of all my harvest hope I have
Nought reaped but a weedye crop of care.

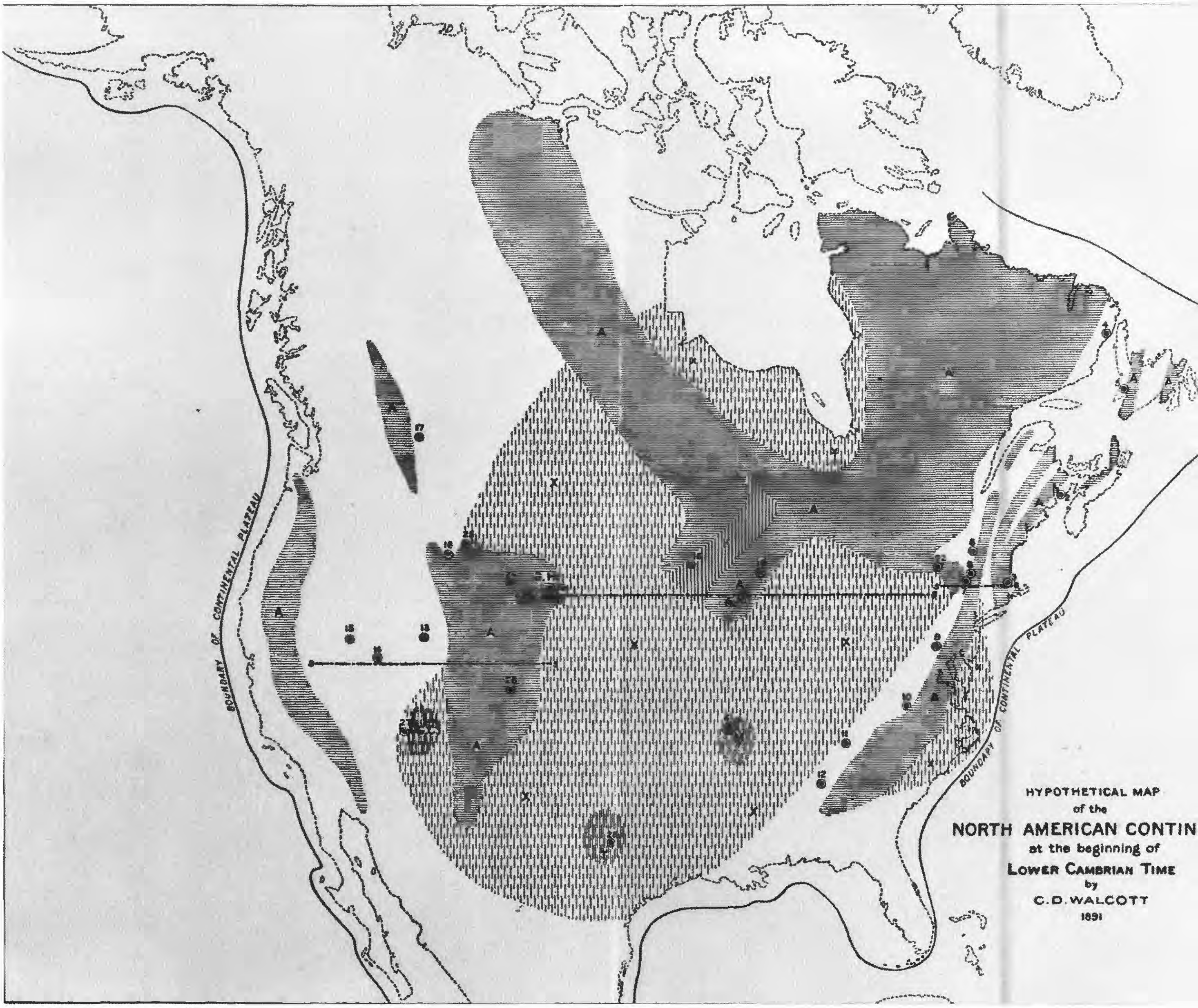
—Edmund Spenser

During the summer of 1890, while the fate of the Irrigation Survey was in the balance, most of the Geologic Branch had been mapping for the geologic atlas. Apart from that program, Bailey Willis was making structural experiments, and Van Hise began a study of the Precambrian of North America, in pursuit of which he visited several Precambrian areas with Pumpelly, C. D. Walcott, and G. H. Williams. Becker devoted his efforts to the dynamic history of the Sierra Nevada and problems of correlation while Turner and Lindgren continued mapping the gold belt in California. In the Division of Glacial Geology, Warren Upham was studying ancient Lake Agassiz; Professor Salisbury, the glacial deposits in the vicinity of the Mississippi and Ohio Rivers; and Frank Leverett, the moraines in northeastern Ohio, northwestern Pennsylvania, and the southwestern corner of New York. McGee was attempting to correlate the formations on the Potomac River with those in the Mississippi Valley on the basis of physical characteristics and was also making a comparative study of the prevailing earth forms of the Pacific coast and those of the Eastern United States to correlate "later earth-forming episodes on opposite sides of the continent." I. C. Russell and Mark Kerr, Survey topographer, spent the summer in Alaska exploring a district that extended from Disenchantment Bay to Mount St. Elias under the joint sponsorship of the National Geographic Society and the Survey.

Little work was underway in economic geology. Emmons had an allotment for fieldwork, but it was so small that little work could be done because, as he complained, the investigation of the underground geology of mining districts was, by its nature, much more expensive than other geological investigations. Whitman Cross spent the season gathering additional data for the Tenmile, Silver Cliff, and Elk Mountain reports while George Eldridge continued work on the Denver Basin report. Jenney continued his investigations of the zinc deposits of southwestern Missouri; his theory of their origin and distribution was so different from previous theories that it was thought wise to withhold publication for further work.

The Topographic Branch of the Geological Survey, under Henry Gannett, had mapping underway in 19 States east of the 97th meridian during the early part of the season. Somewhat less than 40 percent of the area under survey was being mapped at the mile-to-the-inch scale, an increase of 50 percent over the preceding year.

Gannett himself had been actively involved in the newly established Board on Geographic Names. Several Bureaus were engaged in the production of maps and charts, and although it was conceded that the duplication of surveys was sometimes necessary because of the different purposes involved, no purpose was served by differences in geographic nomenclature. After a



As C. D. Walcott continued to study Cambrian faunas and formations, he prepared this hypothetical map of the North American continent to show the areas (shaded) that were supposed to have been above the ocean during later Algonkian and Lower Cambrian time. The area marked with X's was hypothetical as it is now covered with sediments of later age than Cambrian and there was thus no absolute proof of its existence. James Dwight Dana's map for the same period is shown in Volume 1, page 144. (From C. D. Walcott, 1891.)

conference of a few of those most closely interested, in the winter of 1889–1890, the Superintendent of the Coast and Geodetic Survey proposed organization of a board consisting of representatives from the Departments and Bureaus concerned, to which might be referred all questions arising in any of them relating to geographic names. Such a board was organized in April 1890 and was promptly inundated with questions for consideration and determination. Six months later, because of the importance of the work and the difficulties involved, the board was given executive authority by Executive order of the President on September 4, 1890. Although the Superintendent of the Coast and Geodetic Survey was designated chairman, the investigation of questions and recommendations devolved on an executive committee of three: Henry Gannett of the Geological Survey, Lieutenant Richardson Clover of the Navy Department, and Herbert G. Ogden of the Coast and Geodetic Survey.

Congress remained in session until October 1, 1890, an unusually late date in an election year, delayed in large part by the debate on irrigation and on the McKinley tariff bill. The House had passed the tariff bill on May 21, but the Senate debated it off and on all summer long before finally passing it in September. The metals schedules, which had formerly been an important part of the protective system, were supplanted by the wool and woolens schedule as the most sharply debated part of the tariff. Duties on iron and steel were unchanged because foreign competition was no longer a threat to domestic production. The rate on copper was actually reduced because copper was not being imported. However, as a concession to the silver Republicans, a duty was imposed on lead to impede importation of foreign silver-bearing lead ores. On the whole, however, the Tariff Act of 1890 proposed a radical extension of the protective system, and F. W. Taussig said that it presented the question of this extension to the American people "without disguise."

While the Senate debated the merits of the Irrigation Survey and the tariff bill, the House took up other matters. A bill to repeal the Timber Culture Act was passed and sent to the Senate but failed to be enacted when the session ended before the conference committee could settle the difference between House and Senate bills. In the spring, the House also considered but did not act on memorials from the American Forestry Association on the preservation of forests and from the American Association for the Advancement of Science on the preservation of forests in watershed areas on the public domain. The latter suggested that a commission be appointed, including officers of the Geological Survey and the Forestry Bureau of the Department of Agriculture, both of which were concerned with aspects of the problem, and President Harrison in a message on January 20, 1890, had recommended that legislation be provided.

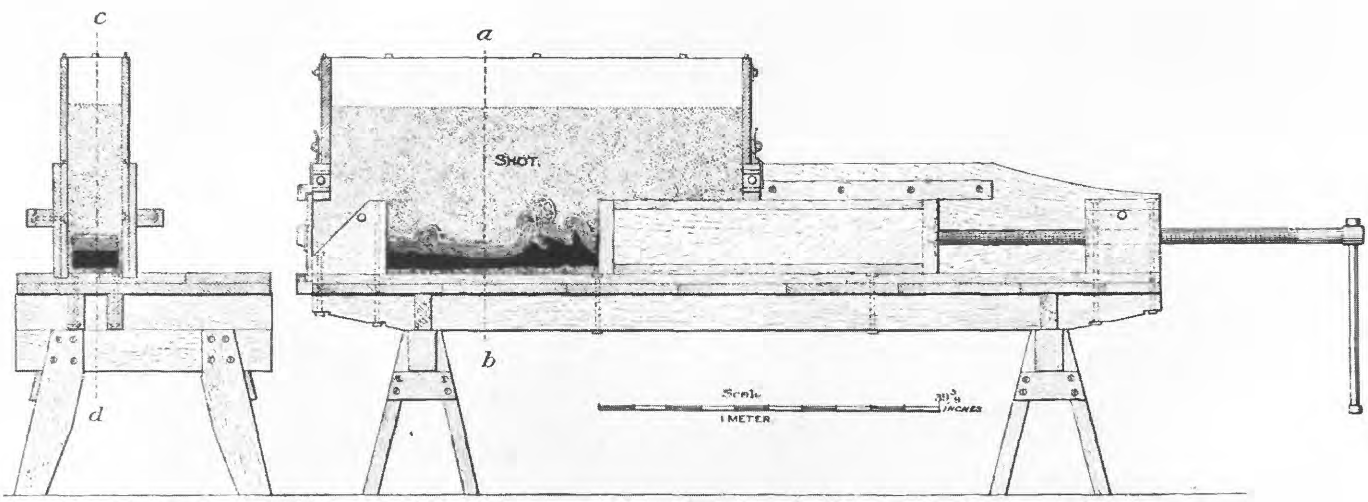
Both Houses agreed, however, to the reservation of some special forests and an extension of the national park system presented in two bills that were passed with remarkable celerity and almost no opposition in the closing days of the session. Both bills were introduced by Congressman William Vandever, who, by coincidence, had been commanding officer of the Iowa regiment in which Secretary of the Interior Noble had been lieutenant during Civil War days. The first bill, introduced in the House, endorsed by the Department of the Interior, and passed on August 23, passed by the Senate without discussion on September 8, and approved by President Harrison on September 25, 1890, established Sequoia National Park in California. The second bill, introduced in the House, amended, and passed on September 30, and then passed by the Senate and approved by the President on October 1, more than doubled the size of the reservation stated in the first bill. The Act of October 1 also reserved forest lands surrounding Yosemite State Park in California and placed them under the control of the Secretary of the Interior who was authorized to make regulations for the preservation from injury of "all timber, mineral resources, natural curiosities or wonders, and their retention in their natural condition." Yosemite National Park, thus established in 1890, was increased in size by the cession of the State park in 1906. Another provision of the Act of October 1 reserved an area of 4 square miles, not contiguous to the other two, which was named General Grant Park, now part of Kings Canyon National Park.

During the summer of 1890, it became evident that the dissatisfaction of Congress with the Survey extended to more than its conduct of the Irrigation Survey. The House at first refused to go along with the Senate amendment to add $15,000 to the appropriation for geologic surveys. Benton McMillin of Tennessee, for one, was vociferously unhappy about the lack of information in the Survey about the mineral resources of the great State of Tennessee. He had asked for a report and had been given extracts from an old report by Professor Safford, the State Geologist of Tennessee. Others pointed out that geological surveys were important in the development of mineral resources but that results were obtained slowly, and the House then agreed to the amendment.

Senator Power of Montana raised questions about personnel practices and duplication of work in a Senate resolution passed on July 16, 1890. The resolution directed the Secretary of the Interior to furnish information about the Geological Survey and the Bureau of Ethnology, although the latter was part of the Smithsonian Institution: A complete list of persons employed by the Survey on June 30, 1890, their grades, salaries, whence appointed, where employed, and, for persons employed by the day, the nature of their duties, where performed, and the number of days employed in the previous fiscal year; the nature of the duties performed by the executive officer (a question that Senator Stewart had already posed) and by the general assistant, where performed, and the relation of their duties to the scientific work of the Survey; by what authority the Bureau of Ethnology was established, by whom J. W. Powell was appointed Director, by whom the subordinates were appointed, their names, whence appointed, and their compensation on June 30, 1890; the amount expended from Survey appropriations during fiscal years 1880 to 1890 exclusively for photographs, transparencies, and other photographic objects outside the reproduction of maps, sketches and so on required in connection with fieldwork pertaining to geology, geography, and topography; what persons, if any, on Survey rolls were also employed in another branch of the public service, and their compensation from each branch; and finally, what contracts had been made for engraving Survey maps, and were they made after competitive offers.

Almost 2 months were required to prepare the reply, and in compiling the list of employees, a great many inequities were uncovered. The list sent to the Senate on September 11 included the names of 53 permanent employees, those in the positions specified in the appropriations acts, 397 temporary employees, and 23 employees paid by the day. The 420 employees listed as temporary or paid by the day included, in addition to teamsters, cooks, field assistants, and river-gauge observers, such employees of long standing as G. K. Gilbert, T. C. Chamberlin, N. S. Shaler, Bailey Willis, and David T. Day in the Geologic Branch; paleontologists C. D. Walcott and W. H. Dall; and among the topographers, Henry Gannett, A. H. Thompson, Marcus Baker, Arthur Powell Davis, E. M. Douglas, and H. M. Wilson. It was evident that as the Survey's program had grown, so had the need for additional personnel and for promotion of those on the staff. The number of statutory positions established in 1883 was too small, and the problem had been solved by creating temporary positions. There had been, however, no uniformity in salary scales, and an effort was made to adjust appointments and salaries to a more equitable basis. The Secretary's report in November 1890 credited the Survey with 124 permanent and 20 temporary employees.

A few Survey employees were also employed in other branches of the Federal service, but no one was drawing two salaries. Major Powell, Chief Clerk Pilling, Chief Disbursing Clerk McChesney, and Executive Officer Croffut were also employees of the Bureau of Ethnology but received no compensation from that Bureau. In effect, the Geological Survey appropriation was being used to supplement that of the Bureau of Ethnology. David T. Day and Henry Gannett were both working for the Eleventh Census, but both the Eleventh Census and the Survey were in the Department of the Interior. Captain Dutton had been with the Survey for 10 years by authority of an Act of Congress approved June 16, 1880, which authorized the Sec-



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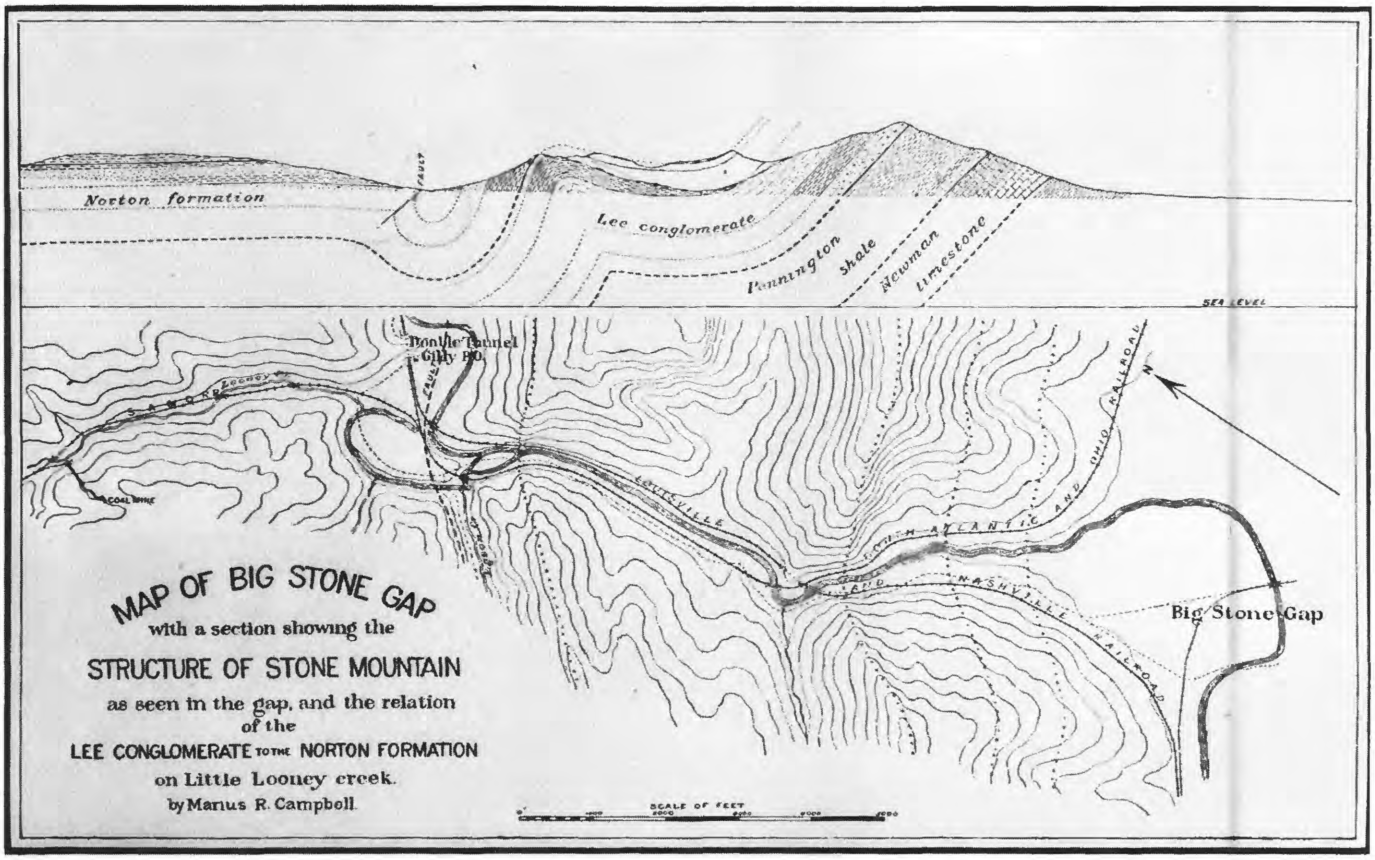
In an effort to understand the complexities of the structure in the Appalachian Mountains, Bailey Willis made a series of experiments in which he attempted to use forces and resistances proportional to those in the Earth's crust. Willis used an oak box, 1 meter long, provided with a piston that could be advanced by a screw, to compress strata, simulated by beeswax containing different amounts of plaster of paris or Venice turpentine. (From Bailey Willis, 1893.)

retary of War to detail not more than two officers of the Ordnance Corps to the Survey. E. S. Nettleton had been detailed briefly from the Survey to the Department of Agriculture for the artesian-well investigation.

The duties of the executive officer (which was a temporary position) and the general assistant (a statutory position) were explained as being similar as far as field duties were concerned, a matter of service and supply of field parties. They simply divided the country between them. In addition, each undertook some special work—Croffut was handling publications and Shutt was studying the distribution of forests. It was admitted, however, that General Assistant Shutt had been ill and had been unable to come to the office for several months. Shortly after the reply was sent to Congress, Marcus Baker replaced him as general assistant.

The last inquiry about contracts for engraving evidently referred to the appointment in February 1890 of S. J. Kübel as chief engraver at $2,400 a year. For 3 years prior to that, he had worked independently, receiving contracts and employing his own force of engravers and printers, and had done satisfactory work for the Survey, the Coast and Geodetic Survey, and the Hydrographic Office. The contracts, however, had all been let by the Public Printer, not the Survey.

Dissatisfaction with the Survey was not confined to Congress. Some of the State Geologists were also unhappy. Several States had recently reestablished surveys, and at the meeting of the American Association for the Advancement of Science in August 1890, John C. Branner, the State Geologist of Arkansas, chided the Survey for its attitude. More cooperation was needed among geologists, whether associated with national or State surveys, educational institutions, scientific societies, or commercial corporations. The success of commercial and industrial enterprises, Branner said, had been due to concerted action, and geologists who disregarded the advantages to be derived from cooperation did so at their own expense and the expense of science. There were certain classes of work that, of necessity, fell upon the national Survey rather than State surveys: triangulation, precise leveling, topography, paleontology, almost all investigations falling under the head of pure science, all investigations that required much time, labor,



Minor folds were the chief source of difficulty in recognizing and correlating coal seams by the aid of key beds in the Big Stone Gap coal field in the central Appalachian Mountains. The Lee Conglomerate is the great mountain-making formation in this area, but the Norton formation, above the conglomerate, is the most important, because it contained the great bulk of the workable coals, and, according to M. R. Campbell, was the least understood. (From M. R. Campbell, 1893.)

and money and many specialists, even economic problems that required study over a wide area, although economic problems in general should be left to the States. All these investigations, he said, could be undertaken so that they aided the work of others rather than unilaterally, and the national Survey could be much more effective than it had been in helping the State surveys.

Parts of the mining industry were also unhappy with the Survey's meager support of economic geology. In August 1890, the mineowners and operators of Leadville held a testimonial dinner in Emmons' honor and, at the suggestion of one of the mine managers, proposed to give him "every and all facilities in our power" to aid his work. Emmons accepted the offer and spent 2 months examining the new underground workings. Two mining engineers, who volunteered their services, were put to work compiling maps.

The year 1890 might be described as one of almost universal national discontent as all the various protest movements since the Civil War seemed to coalesce into one great protest. Although industry was prospering, farmers and laborers were not, and the various farmers' alliances and workers' groups became political forces. In the South and the West, where the farmers were at a particular disadvantage, the discontent was most evident, and in both sections, financial reform was demanded.
Samuel Eliot Morison said:

> **In 1890, American politics lost their equilibrium and began to pitch and toss in an effort to reach stability among wild currents of protest that issued from caverns of dissent.**

A People's Party was organized which met at Topeka, Kansas, and demanded, among other reforms: Free and unlimited coinage of silver; Government ownership of railroads, telegraphs, and telephones; a graduated income tax; restriction of immigration; an 8-hour day; and popular election of U.S. Senators. The Democratic party was divided by the demands for reform, southern Democrats in favor and midwestern Democrats opposed. When a group of fanatical temperance advocates attached themselves to the People's Party, Democrats William F. Vilas of Wisconsin and J. Sterling Morton of Nebraska hit upon the strategy of diverting attention from the Topeka platform to the prohibition issue; and as a result, the Democratic candidates were elected in the urbanized States. The Populists, however, cut deeply into Republican majorities, and ten Populists were elected to the House and two to the Senate. The Democrats gained control of the House

By identifying flora in samples collected by W. P. Jenney in his study of the zinc and lead deposits of southwestern Missouri, paleobotanist David White determined a date for the earliest limit of the period during which the ores were deposited. White also described what he considered to be the first flora sufficient for correlation of Carboniferous strata within the trans-Mississippi region. (From David White, 1893.)

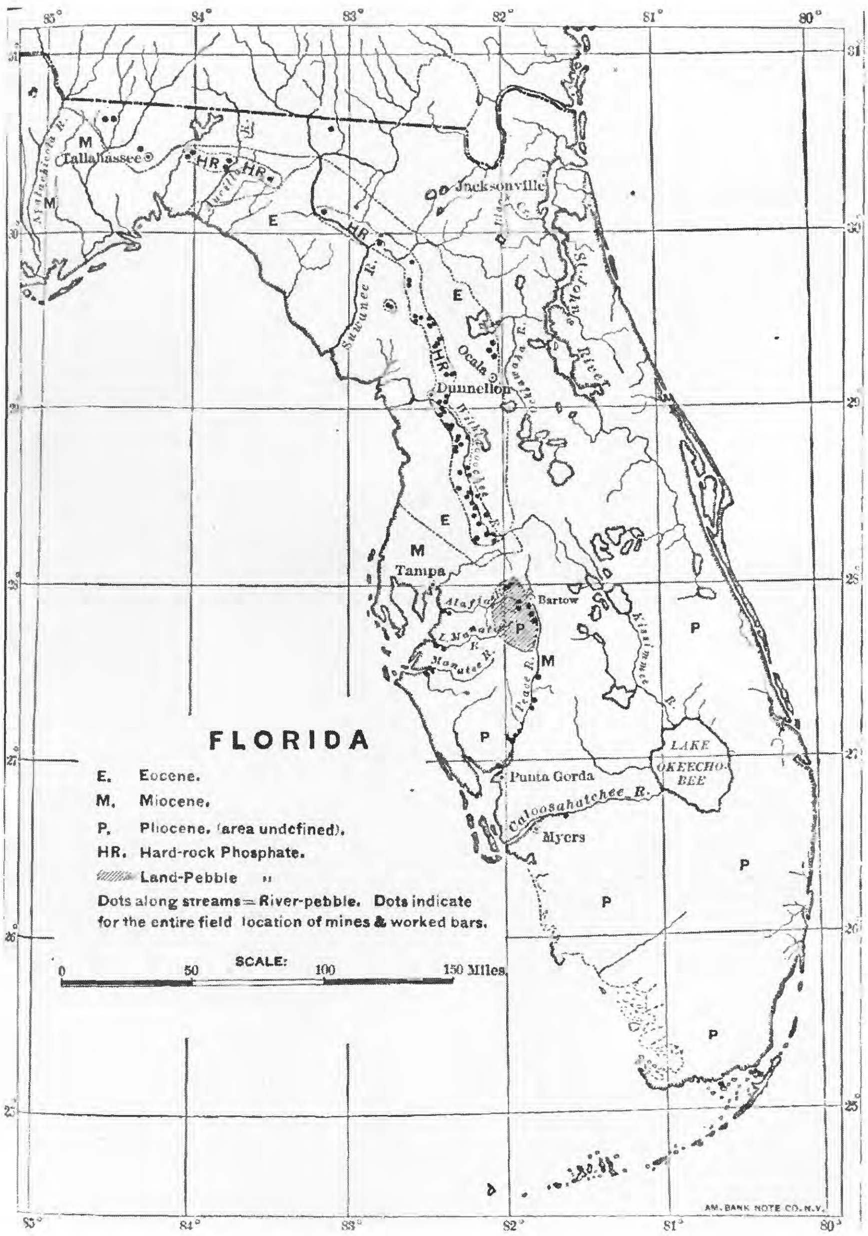
by a substantial majority; the Republicans, however, retained control of the Senate as four Republicans were elected as the first Senators from the new States of Idaho and Wyoming, admitted in July 1890.

In the last short session of the 51st Congress that convened in December 1890, the Senate and the House came to an agreement on a law making several changes in public-land laws. The General Revision Act, which was signed by President Harrison on March 3, 1891, ended cash sales of public lands with a few minor exceptions, repealed the Preemption and Timber Culture Acts, and provided new and stringent conditions for entries under the Desert Land Act, including the filing of a map and plan showing the mode of contemplated irrigation sufficient to irrigate the land and the source of water. The law restricted the reservoir sites located or selected by the Survey under the act of October 2, 1888, to the amount of land necessary for construction and maintenance of reservoirs and also granted rights-of-way to canal and ditch companies organized under the laws of a State or Territory, thus giving the field of water supply to private corporations and associations.

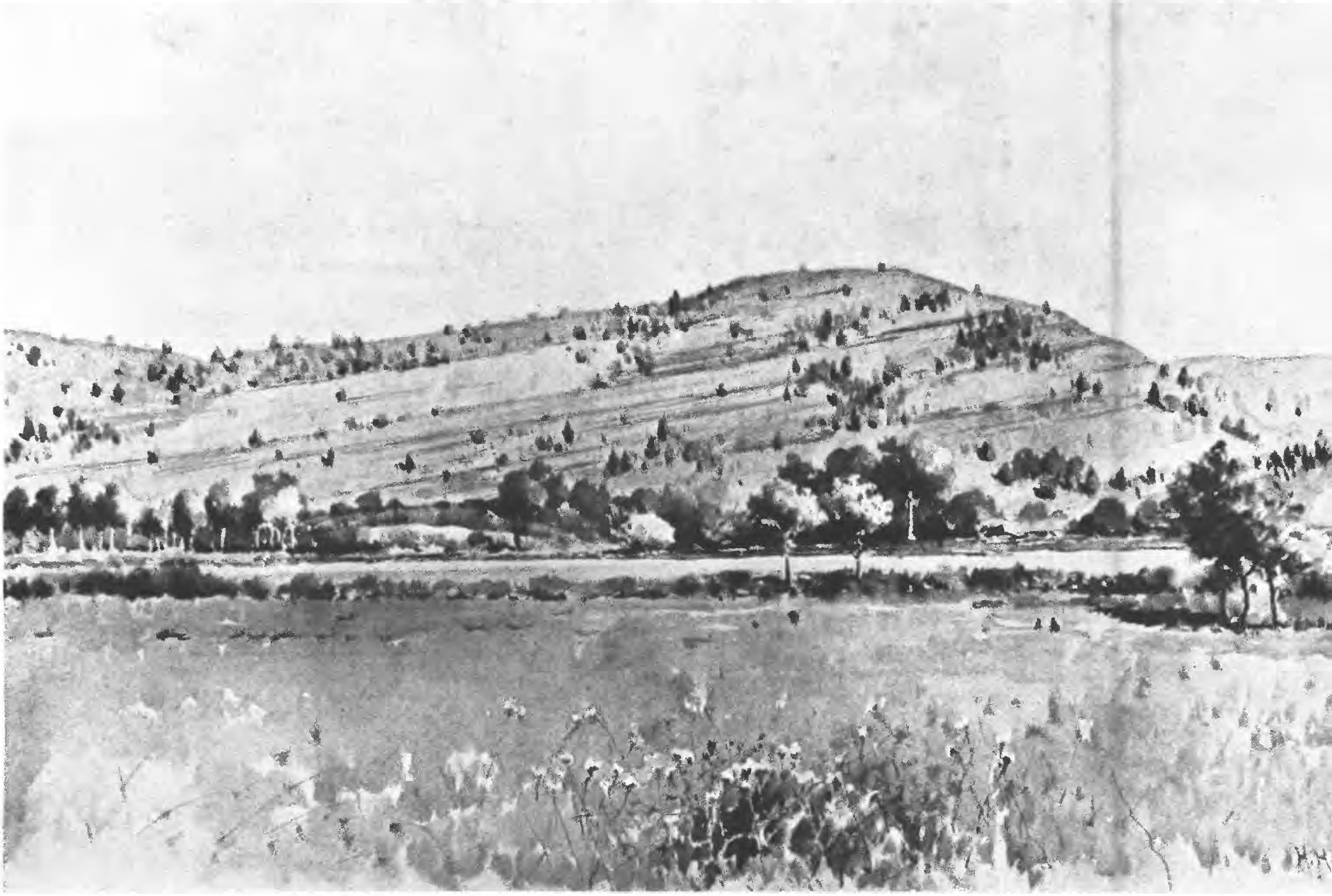
A final section of the act authorized the President to create forest reserves "wholly or in part covered with timber or undergrowth, whether of commercial value or not." At the same time, Congress authorized the cutting of timber for specified purposes but without means of enforcing regulations, so that to some extent the purpose of reserving the forests was nullified. The first forest reserve, more than 1 million acres south and east of Yellowstone Park, was created only 4 weeks later on March 30, 1891. Arnold Hague, who had been calling attention to the need for forest preservation in that area for several years, prepared the statement defining the boundaries and justifying the withdrawal which Secretary Noble relayed to President Harrison.

Survey funds for fiscal year 1892 were included in the Sundry Civil Expenses bill, which was also enacted on March 3, 1891. The House Committee on Appropriations recommended the same appropriation as for the preceding year for all items except preparation of the annual report on mineral resources, for which it recommended $50,000 instead of $10,000. The House passed the bill on February 9 without any discussion of the Survey appropriation. The Senate Committee on Appropriations proposed to return to the pre-1891 figures of $200,000 for topographic surveys, $45,000 for engraving maps, and recommended only $10,000 for the report on mineral resources. Only the last provoked any discussion on the Senate floor. Senator James Wilson of Iowa was the first to object: "It is seldom that we have more intelligent and comprehensive work done than we find in this volume." Senator Stewart defended the reports—they were "very intelligent, very conservative, and useful" and Professor Day was doing good work. Senator Call said that the small amount of money involved was a matter of no consequence compared with the practical investigation and communication to the people of the country of the extent of its mineral resources and its mining industries. The Senate Appropriations Committee, however, deemed it unnecessay to prepare another comprehensive report so soon after the 1890 census, and the Senate adopted the committee's recommendations. In the conference between the two Houses, the House yielded to the Senate on the report on mineral resources, and a compromise was worked out for the other amendments: $250,000 (a decrease of $75,000) for topographic surveys and $60,000 (a decrease of $10,000) for engraving geologic maps.

Senator Stewart had said little about the Survey as the two appropriations bills went through, but when the Deficiency bill came up on March 2, George Eldridge's study of the Florida phosphates was one of the first true economic-geology studies in the East. The Peace River pebble-phosphates had been discovered in 1887 and the hard-rock deposits in 1889; thereafter the phosphate industry became an important factor in the Florida economy. (From G. H. Eldridge, 1893.)



1891, he opened fire. In a discussion of the increase of expenses in the Senate, he suddenly announced that the Senate was not the only expensive department of the Government—Major Powell's department had kept pace. "It may be a more useful institution than the Senate, but I doubt it." He hadn't intended to say anything, he said, but the Committee on Irrigation had asked for an appropriation of $20,000 to provide information on irrigation, and no appropriation had been made. He held the Survey responsible for what had happened to the irrigation investigation; the Survey's "face is set against anything useful, anything that will do the people any good." On the last day of the session, he planted a seed by asking Senator Allison how the Survey had been organized, or had it simply grown from year to year in appropriation bills? Senator Allison replied that Senator Stewart knew very well that it had never been organized as a distinct and separate bureau except in appropriations bills, to which Senator Stewart replied that he just wanted it in the record, and there, seemingly, the matter was dropped.



While mapping in the Yellowstone Valley, between the Bridger, Snowy, and Crazy Mountains, Walter Weed found evidence to support King's conclusion that the Laramie was the last great deposit of the Cretaceous. A series of water-laid sediments containing intercalated volcanic agglomerates, such as those near Springdale, Montana, which he named the Livingston formation, rested on the Laramie in apparent conformity, but the profound change in composition indicated that the Laramie epoch had been followed by uplift and a period of erosion, accompanied by volcanic eruptions. Overlying the Livingston was a formation identified as the Fort Union, which the fossil flora indicated to be Eocene. (From W. H. Weed, 1893.)

After the appropriations bill had been passed in August 1890, eliminating the Irrigation Survey, the hydrographic parties had been disbanded and the property turned over to the Topographic Branch. Newell was detailed to the Eleventh Census as a special agent for the investigation of irrigation, and the accumulation of hydrographic information on hand and the reports on heights of rivers that continued to come in were turned over to Cyrus Babb. Dutton had been recalled by the War Department in July, Nettleton resigned on August 12, and the other engineers were dismissed or reassigned.

To meet the requirements of the appropriations act regarding topographic surveys, several changes in organization were made on October 1, 1890. Two topographic divisions were established: an Eastern Division in the charge of Henry Gannett and a Western Division under A. H. Thompson. The mapping in Texas and part of the mapping in Kansas were moved west of the 100th meridian; the mapping in Iowa was transferred to western North Dakota; and several men were transferred from the Eastern to the Western Division. Only one mapping project in Arkansas remained in the Northern and Southern Central Divisions, which were then combined as the Central Section. In the Eastern Division, H. M. Wilson replaced Marcus Baker as head of the Northeastern Section, and Baker replaced Shutt as general assistant. R. S. Woodward resigned as head of the Astronomic and Computing Section, and S. S. Gannett succeeded him. In the Western Division, two new sections were established under R. U. Goode, who supervised the work in Kansas, and Arthur Powell Davis, who was given charge of the work in New Mexico.

The field season of 1891 was the first opportunity for the Survey to respond to the criticisms leveled against it in the summer of 1890. The appropriation for topographic surveys was again divided equally between the Eastern and Western Divisions. Despite the second cut in funds, the Eastern Division under Gannett mapped 25,000 square miles in 15 States, including a considerable amount of revision in the southern Appalachians, where geologists had been complaining about the maps. The work in Kansas was pushed so that 8,000 square miles were mapped in the northern part of the State between the 98th and 100th meridians. The Western Division under A. H. Thompson mapped nearly 29,000 square miles in eight States and continued surveying for reservoir sites. A small allotment was given to F. H. Newell to continue the work of stream gaging in the arid region. However, the party under Morris Bien that began the season surveying reservoir sites in Idaho and Utah was moved to Colorado to begin the topographic survey of the Aspen mining district in response to the petition of 51 mineowners for a geologic investigation such as Emmons had made at Leadville.

The Geologic Branch again devoted most of its efforts to mapping for the geologic atlas, Gilbert's "local geology," in connection with which some special investigations with economic implications were made. It had been too late in the season when the additional appropriation for geologic surveys had been voted in August 1890 to begin new work. Plans were made, however, to begin work in the spring of 1891 in New Jersey and Florida, the home States of Senator McPherson, who had proposed the amendment, and of Senator Call, who had valiantly defended the work of the Survey. The New Jersey work was placed under the direction of Raphael Pumpelly and that in Florida under George Eldridge. The annual report emphasized that in connection with the areal surveys examinations were made of

> **nearly all of our more important natural resources, including the metals used in manufacture and construction, the various mineral fuels and illuminants, building materials of all kinds, artesian waters, the precious metals, materials for the manufacture of household and ornamental wares, gems and precious stones, and the substances yielding most other industrial and domestic commodities.**

During the field season of 1891, the Atlantic Coast Division did a certain amount of work in the delineation of drumlins, and the Archean Division, which had found that, generally speaking, the degree of metamorphism and consequently the difficulty of classifying formations increased from west to east, undertook elaborate studies along the intermediate zones in order to extend the correlation from the fossiliferous formations of New York to more crystalline formations in central Massachusetts, eastern Vermont, and New Hampshire. In New Jersey, J. E. Wolff began mapping the crystalline formation, in which magnetites are interbedded, under Pumpelly's direction.

The Lake Superior Division divided its work into three categories: detailed studies of regions of exceptional scientific interest or economic importance, areal mapping for atlas sheets, and a general study of the Precambrian rocks of North America. Van Hise himself was responsible for the last, and W. S. Bayley was in charge of the special study of the Marquette iron-bearing district.

In the Appalachian Division, Arthur Keith worked in the Great Smoky Mountains of North Carolina and Tennessee, and M. R. Campbell was assigned to map the Estilville sheet, where Kentucky, Tennessee, and Virginia meet. The rapid increase in the consumption of fuel in the United

States had stimulated the search for coal in the central part of the Appalachian coal basin, and there was urgent need for geologic information regarding the structure and stratigraphy of that field as a basis for future operations.

McGee's Potomac Division was extended from Sandy Hook to the Río Grande. Topographic sheets were not yet available, but stratigraphic studies were made in several States, and evidently an effort was being made to enlist the cooperation of the various State Geologists. W. B. Clark began the mapping in the New Jersey Coastal Plain, and State Geologists J. A. Holmes of North Carolina, E. A. Smith of Alabama, and E. W. Hilgard, formerly State Geologist of Mississippi and Louisiana, were all engaged in various phases of the program. A special investigation of the Eocene formations of Arkansas was also begun in cooperation with the Arkansas State Survey.

In the Division of Florida, which was established on January 1, 1891, Eldridge began a systematic study of the mineral phosphates. His plan of work included mapping, a study of the origin and distribution of the different kinds of phosphates, and a study of the methods of mining, handling, and treating ore—a plan that corresponded exactly with the plans for mining-geology investigations announced by Clarence King. It was perhaps not a coincidence that King, as a consulting geologist, was then interested in the Florida phosphates.

King had a hand in another Survey investigation in the spring of 1891. He had arranged with the Standard Oil Company for an opportunity to measure temperatures in a 4,500-foot dry well near Wheeling, West Virginia. William Hallock made two series of measurements from top-to-bottom of the well, which were believed to be because of the conditions of measurement, the best determinations yet obtained of underground temperature. The results were surprising; they indicated that the rate of increase of temperature with depth was not uniform but increased with depth. It was therefore necessary to determine whether this was a local or general phenomenon. Some of the citizens of Wheeling, thoroughly intrigued with the work, agreed to pay for continuing the well to 6,000 feet if the apparatus could be furnished. When that proved impossible, a second deep well at Radford, West Virginia was placed at the service of the Survey, but unfortunately it was full of water, and few measurements could be made.

In the Yellowstone Division, Weed was despatched to Montana to examine the coal fields before beginning work in the region between the Snowy, Gallatin, and Bridger Ranges, and the Crazy Mountains. Iddings continued his study of igneous rocks in the same area. The Cascade Division continued general mapping but gave much time to an elaborate study in the vicinity of Taylorsville, California, to facilitate the correlation of formations of that district with those of other areas. Plans were made, however, for a study of the artesian and mineral resources of Washington.

Economic importance was even ascribed to the work of the Glacial Geology Division, which continued to make progress in mapping moraines in Ohio, Indiana, Illinois, and Wisconsin. The glacial drift, the Geological Survey annual report states, was "not only one of paramount interest to the science of geology but a storehouse of important resources. It comprises a variety of soils and is a source of building material in the form of bowlders, sand and brick clays; it sometimes yields artesian water, and occasionally carries gold, iron, and other useful minerals."

I. C. Russell again went to Alaska, heading an expedition sponsored by the National Geographic Society, to continue his study of the Malaspina Glacier. Willard Hayes also spent the season in Alaska. Frederick Schwatka, whose trip down the Yukon River from the Chilkat Pass to the sea in 1883 had excited much interest in Alaska, had applied to the Survey for a scientific

Joseph P. Iddings

Geologist of the U.S. Geological Survey, 1880–1892, thereafter with the University of Chicago and part time with the Survey. Iddings had turned to geology from mining engineering as the result of the influence of Clarence King. From his field studies in the Eureka district and in Yellowstone National Park, he began the development of theories of magmatic differentiation and a classification of igneous rocks that had a profound influence on the science of petrology. (Courtesy of the Smithsonian Institution Archives.)

assistant to accompany him on a new expedition to explore an unknown part of Alaska between the Yukon and Copper Rivers. Hayes, who had found Russell's enthusiasm contagious, had applied for the assignment.

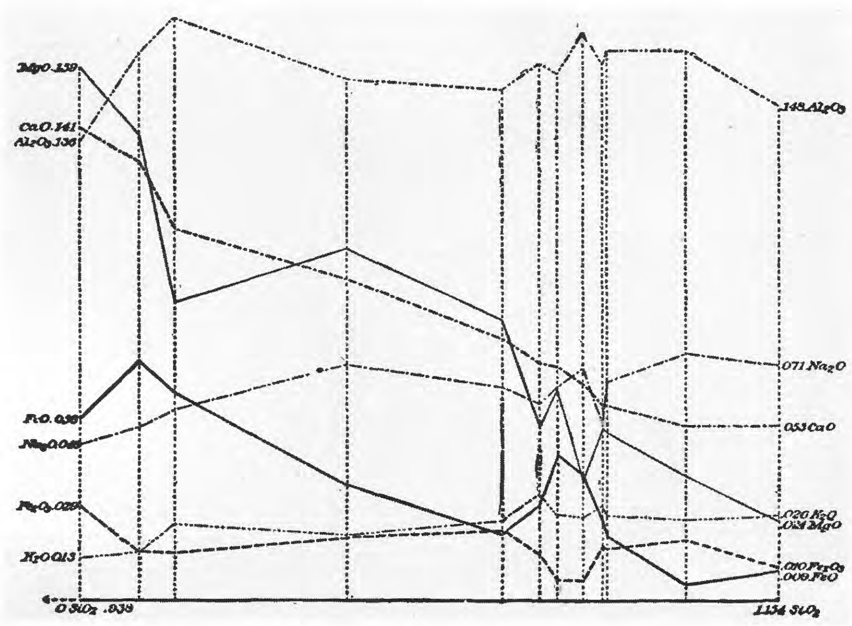
In the California Division of Mining Geology, Becker had expanded beyond mining geology. Turner and Lindgren were still mapping atlas sheets in the gold belt, but Becker had also obtained the services of Professor Andrew Lawson of the University of California to begin mapping in the San Francisco Bay area. Becker himself was becoming more deeply involved in mathematical geophysics and began a study of strain, flow, and rupture in rocks.

Emmons was thoroughly busy in the early part of the summer with preparations for the 1891 International Geological Congress, but in the fall, he revisited the Leadville district, made a reconnaissance examination of the Butte district in Montana, and planned a systematic investigation of the Aspen district in Colorado. Cross visited the new mining district at Creede, which Emmons thought was likely to prove of economic importance. Cross found that large rich deposits had already been opened in decomposed eruptive rocks, but he concluded that a detailed study would be needed to determine the structure and furnish data of practical value.

Emmons, it seemed, had been accorded new standing in the Geologic Branch. On November 13, 1890, he had been elected to fill a vacancy in the Organizing Committee for the International Geological Congress and was also named as its secretary and acting treasurer. Professor Newberry and G. K. Gilbert had already been named chairman and vice chairman, but after the organization of the Committee in 1888, no further plans had been made for the 1891 meeting beyond a request to the Bureau of the International Congress in London to change the place of meeting from Philadelphia to Washington, D.C. At the meeting of the Organizing Committee in November 1890, Major Powell was elected chairman of the Program Committee and Clarence Dutton, the chairman of the Committee on Excursions. Because French was the official language of the Congress, although it had been agreed that English would be permitted at the sessions in Washington, much of the correspondence and the preparation of announcements fell to Emmons, who had become fluent in French as a student in Paris. Much of the work of program preparation and plans for excursions also devolved upon him, and for the excursions, he prepared a 150-page guidebook for the use of the visitors.

The Fifth International Geological Congress met at Columbian University in Washington, D.C., from August 26 to September 4, 1891. Professor Joseph LeConte presided in the absence of Professor Newberry, who was ill, and Emmons was secretary-general. To the great disappointment of many American geologists, only 73 of the 240 in attendance came from outside the United States, and of those from the United States, fully one-third were from the Survey.

Most of the formal papers presented had been prepared in connection with the Survey's program in geologic correlation. The first scientific session was devoted to the Glacial Period and the classification of Pleistocene formations, with Professor Chamberlin as the leadoff speaker. The Friday session was devoted to the correlation of European and American geologic formations and was opened by Gilbert, who presented a paper on the problems of stratigraphic correlation. The first of the correlation papers, that by H. S. Williams on the Devonian and Carboniferous, was published in time for the meeting and distributed to those present. The value of the effects



Iddings found that the intricate relations between the various kinds of coarse-grained and glassy rocks were at the foundation of any system of classification and indeed affected comprehension of the real nature of the rocks. The seemingly irregular molecular variations in the diagram shown here he found were actually in accord with the order of crystallization of the minerals. (From J. P. Iddings, 1891.)

of physical events or conditions and of the relations of flora, fauna, invertebrates, and vertebrates in correlation was discussed, and the weight of opinion was that vertebrates if present were the best biological tools for correlation.

At the session on Monday, August 31, Major Powell exhibited the proposed color scheme for Survey maps. Objections were made to the changes in traditional usage—such as black for coal and red for volcanic rocks, to the lack of differentiation in the Mesozoic, to the unequal division of colors of the spectrum among the different stratigraphic divisions, but most of all to the overprinting of symbols on the base colors. The Survey scheme was especially adapted to chromolithography but would be almost impossible for hand coloring, which was still practiced to a large extent abroad. However, not all the objections came from abroad; several members of the Survey also disapproved. The foreign visitors were, however, much impressed with the Survey building, its printing plant, telephones, and elevators.

During the excursions that followed the Congress, Hague and Iddings led a party of 80 through Yellowstone National Park, and Major Powell led a trip to the Grand Canyon. The Committee of the Congress appointed to organize information on geological bibliographies held its first meeting in one of the cars of the special excursion train and elected G. K. Gilbert president of the committee.

There were some lingering evidences of the preceding year's problems. While the International Congress was in session, an attempt was made to form a "National Association of Government Geologists." Major Powell presided at the meeting, and Arthur Winslow, State Geologist of Missouri, acted as secretary. A committee of six was appointed to continue the work of organization, the members in addition to Powell and Winslow being E. A. Smith of Alabama, J. A. Holmes of North Carolina, J. C. Branner of Arkansas, and N. H. Winchell of Minnesota.

The First Irrigation Congress had met in September 1891 at Salt Lake City, while the International Geological Congress was on its western excursion. The Irrigation Congress was called by Governor Thomas of Utah

> **for the purpose of hastening the reclamation of the arable land, so far as possible, and for the purpose of petitioning Congress to cede to the States and**

Territories the arid lands within their borders, for the purpose, first, of reclaiming the same; second, in aid of public schools; and third, for such other public purposes as the Legislative Assemblies of the States and Territories may respectively determine.

Senator Stewart had presided over most of the sessions, and Francis Newlands, then a Nevada lawyer but later a U.S. Congressman and Senator and author of the Reclamation Act of 1902, in a keynote speech commended Senator Stewart for inaugurating Federal interest in irrigation in his first tour of duty in the Senate, for challenging the hold of Director Powell on the U.S. Congress and denying the Irrigation Survey appropriation to the Geological Survey in the preceding year, and for securing an appropriation instead to the Department of Agriculture. The Irrigation Congress voted to ask the U.S. Congress to grant in trust to the States and Territories needful of irrigation all public lands except mineral lands within their borders and to "heartily endorse" the irrigation work of the Agriculture Department and to recommend large appropriations for it. The U.S. Congress, however, was still unwilling to engage the Federal Government in any irrigation scheme and had put an end to the investigations of the Agriculture Department that threatened to involve the Government in such.

In December 1891, however, the work of the Survey was recognized by the Academy of Sciences of the Institute of France which awarded it its Cuvier prize. In making the award, the Academy said:

It will be impossible to give in this report even a summary idea of the most remarkable discoveries which are due to the Geological Survey. They belong to branches very diverse: regional geology, monographs concerning metalliferous deposits, general and comparative stratigraphy, mineral and petrography, volcanic phenomena, glacial phenomena, ancient Quaternary lakes, history of the Atlantic littoral. Among the most considerable results must be mentioned the paleontological discoveries made in the Rocky Mountains. * The monographs of the lamented Leidy, of Cope, and of Prof. Marsh are among the most beautiful paleontologic works accomplished since Cuvier. Magnificent researches have also been made concerning the invertebrates and the fossil vegetables. *** The work of the Geological Survey, with the magnificent collection of results that it comprises, merits then that we should render to it a striking homage for the light so vivid and so unhoped for that it has thrown upon the geologic history and the mineral riches of North America.**

Israel Cook Russell

Geologist of the U.S. Geological Survey, 1880–1892, thereafter with the University of Michigan and part-time with the Survey. Russell was closely associated with G. K. Gilbert in the Great Basin and in the Appalachian investigations but greatly preferred to work in wilderness areas. He was the first member of the Geological Survey to undertake work in Alaska. (Courtesy of the Smithsonian Institution Archives.)

In the spring of 1892, two Survey scientists were elected to membership in the National Academy of Sciences, Samuel Franklin Emmons and Carl Barus. The two represented opposite poles of Survey work, Emmons, preeminently the economic geologist, Barus an outstanding experimental physicist. They had in common a close relationship to Clarence King.

By the spring of 1892, the national economy had taken a turn for the worse. There was a drain on the gold reserve during the first few months of 1892, and the Secretary of the Treasury announced that a deficit was in the offing, the first in 20 years. Congress made a few desultory attempts to modify the tariff, which had been a big issue in the 1890 elections, but with the House and Senate divided, there was little hope of reform. Under the circumstances, especially in a Presidential election year, the Democrats were in a mood to economize.

When Mr. Holman, chairman of the House Appropriations Committee, introduced the Sundry Civil Expenses bill in May 1892, he announced that it provided $10 million less than the estimates, $13 million less than the bill for the current year, but that further reductions were possible without injury to the public service. Appropriations for soldiers' homes, the Light House Service, and the Life Saving Service could not well be reduced, but other appropriations, such as those for the Coast and Geodetic Survey and similar bureaus, could be. In the discussion of the bill that followed, the appropriations for the Coast Survey, the Fish Commission, and the Smithsonian Institution were cut, and the Bureau of American Ethnology came close to being eliminated altogether.

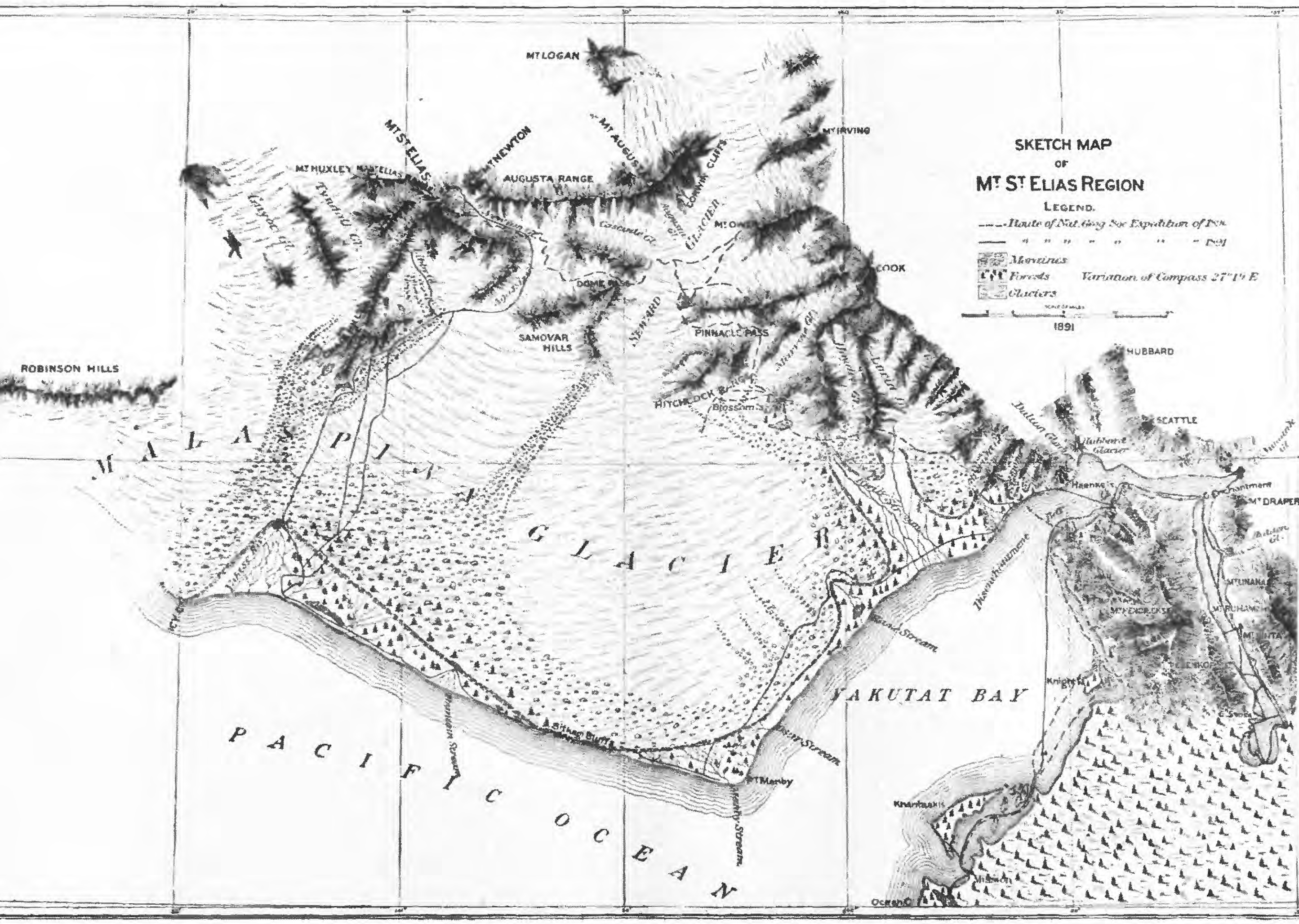
When the appropriation for the Survey came up for consideration, Congressman Hilary Herbert proposed amendments to eliminate the position of paleontologist at $4,000 and paleontologist at $2,000, to eliminate the appropriation of $30,000 for paleontological research, and to insert a provision that after July 1, 1892, no paleontological work could be carried on. He said:

> **If this House is bound at all by its repeated promises to reduce expenditures, we ought to begin on this Geological Survey. *** We ought to repeal or modify those laws that provide for expenditures of money not needed for any government purposes, and especially ought we to put in the knife where moneys are expended that are not necessary to carry on the government, not necessary for the preservation of order, or for the protection of life or liberty or property.**

He went to say, "Major Powell will tell you there is no such thing as abstract science. In my younger days I was taught that there was, and if there is on this earth an abstract science, it is paleontology. What practical use has the Government for paleontology? What function of the Government is carried on by means of paleontology? Not only has the Government no use for it as government, but paleontological work is not even necessary to the proper construction of a geological map." He brought out Alexander Agassiz's letter of 1885 saying that private individuals and learned societies could do paleontology as well as and more cheaply than the Government, and he read pertinent parts of the minority report of the Allison Commission into the record. The House agreed to Mr. Herbert's amendments, which called for a total cut of $36,000.

Congressman Jeremiah Simpson of Nebraska proposed a change in the appropriation for topographic surveys: to strike out "one-half of which shall be expended west of the one hundredth meridian" and substitute "$60,000 of which shall be expended west of the ninety-seventh meridian, in the States of North Dakota, South Dakota, Nebraska, Kansas, and the Territory of Oklahoma for the purpose of locating and developing subterranean and surface waters." Mr. Simpson said the water was to be located "in order to apply it to irrigation," and he understood that the chairman of the Appropriations Committee did not object to the amendment. A letter from Major Powell was read which said, "The people are petitioning and urging in every way possible for such a survey of the region as will exhibit the possibility of its redemption by irrigation, and it seems to me that it would be wise and just to grant their cries; but it should be distinctly understood that to do it by the method proposed is to suspend operations in other regions where urgent demands are made by the work." Mr. Pickler of South Dakota said that the survey was to enable people to know where to make artesian wells and that the $60,000 would permit an investigation for water and its storage. Mr. Holman promptly moved to strike out everything after "Oklahoma." It was only 2 months since Congress had ordered an end to similar investigations by the Agriculture Department that had come close to involving the Government in an irrigation scheme. Mr. Simpson protested that Major Powell said those words were necessary, but Mr. Holman prevailed. The amendment was adopted specifying where but not why the $60,000 was to be spent.

Other amendments were offered: To strike out the entire appropriation for topographic surveys; to cut it, to raise it, to strike out the appropriation for chemistry and physics; to strike out the appropriation for preparation of



On his expeditions to Alaska, Russell found glaciers flowing from the great névé fields of the mountains of the St. Elias system for fully 100 miles west of Yakutat Bay. These glaciers expand on reaching the flatlands between the base of the mountains and the sea, and unite to form a vast lake of ice which he named the Malaspina Glacier and identified as a new form, the piedmont glacier. (From I. C. Russell, 1893.)

illustrations; to increase the appropriation for the report on mineral resources; but all were defeated. Congressman Willis Sweet said that it was conceded throughout the West that Major Powell was doing a splendid work, but to illustrate it, he mentioned mining litigation in Idaho where expert witnesses had cited Survey work on mineral resources. Mr. Herbert, apparently thoroughly convinced that the work of the Survey was to prepare the geologic map of the United States, was against everything that he thought did not contribute to the making of the map, and he quoted Major Powell as saying it was not the business of the Survey to point out mines or minerals or to make discoveries of that kind, it was only to make a general geologic map. "I repeat what I said the other day, that this work, if ever completed, will cost the Government, over $20,000,000. But for myself I am very sure that I shall not live and no man here will ever live to see the day when these scientists will be willing to stop spending the Government money. There is no end to paleontology, there is no end to geology; and when the morning of resurrection shall come, some paleontologist will be searching for some previously undiscovered species of extinct beings, and some geologist will be pecking away at the rocks to find some characteristics which have never before been ascertained. There is no end to it." Before the debate ended, a letter from Major Powell was read, saying that paleontologic researches were "imperatively necessary," that making geologic investigations without palentology could be compared to

One of the few field projects that was completed in 1892 before fieldwork was suspended because of the cut in appropriations was Russell's investigation of the possibility of artesian-water resources near Yakima, Washington. He found the geological structure to be unfavorable in most of the area. (From I. C. Russell, 1893.)

excluding evidence and using only legal arguments in a trial, but Mr. Herbert again quoted Mr. Agassiz, and the bill was passed by the House on May 27 with the Herbert amendments intact.

The Senate did not take up the part of the Sundry Civil Expenses bill that concerned the Survey until July 8, 1892. In the meantime, the Republican National Convention met and nominated President Harrison for a second term, the Democratic National Convention met and nominated former President Grover Cleveland for a second term, and the People's Party held its first national convention and nominated James B. Weaver for President. New political alinements began to develop. The Republican platform had defended the high protective tariff, whereas the Democratic platform stressed tariff for revenue only. Both platforms straddled the money issue, although the Democratic platform called the Sherman Silver Purchase Act a makeshift. The People's Party demanded a variety of reforms, including free and unlimited coinage of silver at 16 to 1 and an increase in the circulating medium of not less than $50 per capita. Harrison was suspected of leaning toward the silver men, whereas Cleveland had in January 1891 taken a strong stand against the "dangerous and reckless experiment of free, unlimited, and independent silver coinage." There was no great enthusiasm for Harrison in his own party, and conservative eastern financial and business interests tended to support Cleveland.

In the interval, also, labor problems had been developing. The price of steel had been falling for about 2 years, and the agreement between the skilled workers and management at the Homestead Works of the Carnegie Steel Company, in which wages were tied to the price of steel, was due to expire on June 30. The company employed 300 Pinkerton detectives to guard the plant, and several were killed in a pitched battle with the workers. Labor problems developed in the western silver mines also.

When the Senate took up the Sundry Civil Expenses bill on July 8, Senator Allison for the Committee on Appropriations offered three amendments to restore the cuts made in the House and thereby provoked an immediate eruption of strong and conflicting opinions on the Survey program and the Survey's Director. Senator George Vest of Missouri began by asking if Senator Allison thought in the present condition of the Treasury that there was any burning necessity for paleontological work, and Senator Allison in his mild way replied "I don't think the necessity is very burning although the Director of the Geological Survey states that paleontology is the foundation of all geological surveying and without this provision the work will be inoperative." Senator Vest thought the Survey was "ornamental," and said he would take great pleasure in striking out a good deal of its appropriation. Senator Wilbur Sanders of Montana supported the restoration of funds, but only because he objected to abolishing part of the Survey. He thought a committee should be established to prepare a bill "to create this Bureau, define its functions, name its officers * * * so we can legislate intelligently." Senator Orville H. Platt of Connecticut suggested that if the Senators who did not like the Survey or its head thought something was wrong, they should introduce a resolution for an investigation. Senator Edward Wolcott of Colorado thought the cuts should stand, that this was the Senate's only chance to strike at the Survey. "This Geological Survey comes to this body in some way, the Lord only knows how, and we hear nothing about it until the appropriation bills come in providing about a million dollars every year to be expended by this survey." It was one of the measures supposed to be for the benefit of the West but the West got little from it. "As a matter of scientific research we rejoice in it. * * * But nobody seems to have any direction or control over it." Senator Joseph Hawley of Connecticut, who in general thought highly of the Survey, said the appropriation might well be reduced but not by picking on a particular item. Rather it should be done under a system of inquiry into the various branches and the usefulness and necessity of each. Senator Stewart made a long and vitriolic speech against the Survey and its Director, but the reaction of his listeners showed that Senator's Stewart's bias was well understood. The three amendments, to restore the two positions, restore paleontological work, and provide $30,000 for paleontological research, were passed, 31–21, 29–18, and 27–21. In all three votes, the majority of Republicans present and voting followed the committee lead, voting 20–7, 20–5, and 19–9 to restore the cuts, but the Democrats were almost evenly divided, 11–12, 9–10, and 8–10. Six western Republican Senators, Joseph Carey of Wyoming, Henry Hansbrough of North Dakota, Thomas Power of Montana, Charles Felton of California, W. M. Stewart of Nevada, and Edward Wolcott of Colorado, voted against all three amendments, as did Senators William Peffer and James Kyle, the two Farmers' Alliance Senators.

On the following day, Senator Wolcott, following suggestions of Senators Platt and Hawley, submitted a resolution that the Committee on Civil Service Reform and Retrenchment, of which he was chairman, be directed to investigate "the workings of the Geological Survey, the usefulness of said Survey, and the necessity for its continuance, as to whether the work of said Survey is conducted with economy, the value of said work to the country, the progress made by said Survey, and the probable time of completion of its work." The resolution was referred to the Committee to Audit and Control the Contingent Expenses of the Senate.

Nearly a week passed before the Senate resumed consideration of the Survey appropriation. The State militia had in the meantime taken over at the Carnegie Homestead Works after several days of open warfare, and violence had become so extreme at the Coeur d'Alene silver camp that martial law had been declared there and Federal troops dispatched to the scene. Officially, the Senate had been considering many matters related to the Columbian Exposition to be held in Chicago in 1893; a bipartisan majority voted for Sunday closing, and a Republican-Farmers Alliance co-

Edward O. Wolcott

Senator from Colorado 1889–1901, educated at Yale College and Harvard Law School and briefly editor of the *Georgetown Miner* before being elected to the U.S. Senate at the age of 40. He was noted for his oratory and for his advocacy of the free coinage of silver. Wolcott played a leading role in the attack on the Survey in 1892 and was a determined critic of the Survey for many years thereafter. (Courtesy of the Colorado Historical Society.)

alition prohibited the sale of intoxicating liquors on the exposition grounds. Off the Senate floor, certain other activity had been underway.

Senator Wolcott offered an amendment to cut the total appropriation for the Survey to the old figure of $400,000, saying that when he spoke about the amendments on paleontology he had met with just criticism by the Senator from Connecticut. Senator Wolcott was a Yale man, and he wanted it clearly understood that his objection to paleontology was not a criticism of Professor Marsh for whom he had great admiration. His real objection was to appropriating $562,000, the spending of which "nobody on earth directs but the Director of the Geological Survey, accountable to no man and no men, accountable only to the scientific bodies of the United States, who may criticize the wisdom or unwisdom of the work." He went on, "I do not question Major Powell's ability nor do I discuss his extreme fitness for securing from Congress an immense appropriation, but I do say that the work up to this time does not bear out the fruits that were promised nor has it borne out his promise made in 1886." In 1886, the Senator said, Powell had assured the Allison Joint Commission that he would complete the geologic map in 20 years at a cost of $18 million; his 1890 report, the latest available, showed that would take more than 100 years and cost more than $100 million. The amendment was defeated, but the vote was closer, 28–24. The Republicans still opposed the cut 17–12, and the Democrats were still split 10–11, but such stalwart eastern Republicans as Senators Eugene Hale of Maine, William Chandler and Jacob Gallinger of New Hampshire, and Matthew Quay of Pennsylvania had been persuaded to join the opposition along with Senators John B. Allen of Washington and Richard Pettigrew of South Dakota. Senators Frank Hiscock of New York and Fred Dubois of Idaho, on the other hand, joined the Survey supporters. On the Democratic side, five new votes for the Survey were canceled by five new votes against. Senators Peffer and Kyle continued to vote against the Survey.

The coup de grace was delivered by the two freshman Senators from Wyoming. Senator Joseph Carey offered an amendment to cut the appropriation on what he called a sliding scale, eliminating some of the statutory positions as scientific assistants and reducing other items by specific amounts. The total proposed was $336,100. The amendment, Senator Carey

Joseph M. Carey

Delegate from the Territory of Wyoming and its U.S. Senator, 1890–1894. Carey served only 4 years, losing his chance for reelection by supporting repeal of the Silver Purchase Act. His name is associated with the legislation granting lands to States for purposes of irrigation. He also proposed the amendment that cut the Geological Survey's appropriation in 1892. (Courtesy of the Library of Congress.)

said, would not destroy any part of the Survey but would cut it down. Senator Wolcott thereupon observed that cutting the appropriation might "awaken" those who were left "to an impression that they should investigate the needs of today" rather than "hunt for the remains of the paleozoic age." the Carey amendment was passed 26–23, and this time 17 Republicans favored the cut and only 9 were opposed; 7 Democrats favored the cut but 14 were opposed.

Senator Francis Warren then moved to add $40,000 to the appropriation for topographic surveys. He had earlier indicated that some adjustment of the Carey amendment would be needed, either an increase in the total or a reduction in the amount to be spent west of the 97th meridian so that one-quarter would be spent in the Dakotas, Nebraska, Kansas, and Oklahoma for the unmentionable purpose of locating and developing water resources. The Warren amendment was passed 28–25, and there were no significant changes in the voting pattern. Twenty Republicans, six Democrats, and two Farmers' Alliance Senators voted for it, and eight Republicans and seventeen Democrats against it.

The Carey-Warren amendments eliminated three of the five positions as geologist at $4,000, one of two positions as geologist at $3,000, both positions as geologist at $2,400, both positions as geologist at $2,000, the paleontologist at $4,000 (allowing instead 2 paleontologists at $2,000), two geographers at $2,500, the topographer at $2,000, and the general assistant. The appropriation for topographic surveys was reduced from $250,000 to $240,000, for geologic surveys from $115,000 to $50,000, for paleontological research from $40,000 to $10,000, and for chemistry and physics from $17,000 to $5,000. Only the appropriation for preparation of a report on mineral resources went unscathed.

When the bill was returned to the House, the Committee of the Whole at first refused to concur in the Senate amendment. Congressman Joseph Wheeler of Alabama pleaded for an increase in the appropriation, read long extracts from an article in the Leadville paper praising Emmons' work, cited the value of the Eldridge's work in Florida, and said that Professor Agassiz in his annual report for 1891 had announced abandonment of his attempt to establish a museum at Cambridge, devoted to original investigations, which had been the reason for Agassiz's objection to Government paleontology. But on the 19th, when the amendment came up in the House, John Bankhead, also of Alabama, moved to concur in the Senate amendment, the Speaker ruled that the motion was not debatable, and it was passed 94–25. The Survey appropriation was therefore not subject to negotiation in conference and remained $376,100 as the Senate had passed it. The bill was finally passed and approved on August 5.

Meanwhile on July 28, Senator Wolcott's resolution was reported out with the recommendation that instead of an investigation by the Committee on Civil Service Reform and Retrenchment, a select committee of five Senators be appointed by the president of the Senate to "investigate the operations of the United States Geological Survey, the efficiency and utility of such a survey, together with the progress made and economy observed in this work." The resolution was adopted, and the Vice President appointed Senators Wolcott, Carey, Gallinger, Arthur Gorman, and James K. Jones of Arkansas.

The effect of the cut in appropriations was less severe in the topographic divisions than in geology. The total appropriation for topographic surveys was only $10,000 less than the year before, even though it had to be divided three ways: $90,000 for work east of the 97th meridian, $90,000 for work west of the 103rd meridian, and $60,000 for work west of the 97th meridian in the States of North Dakota, South Dakota, Nebraska, Kansas, and the Territory of Oklahoma. The $60,000 was divided equally between the Eastern and Western Divisions, and each division kept two sets of books.

Henry Gannett as chief topographer and A. H. Thompson as geographer in charge of the Western Division were not in statutory positions and were therefore not affected by the elimination of statutory positions. The statutory positions of Gilbert Thompson, E. M. Douglas, H. M. Wilson, and S. S. Gannett were not affected. Geographers Renshawe and Goode, who occupied the two positions as geographer at $2,500 that had been eliminated, were moved into temporary positions at slight reductions in salary. Marcus Baker, whose position as general assistant had been eliminated, was appointed topographer at no reduction in salary.

Most of the topographic parties had waited until passage of the appropriations act before leaving for the field, so it meant a very short season for those working in the mountain States. Thompson organized the Western Division into eight topographic sections and a hydrographic section under F. H. Newell. A. P. Davis and Willard Johnson supervised mapping in California; E. M. Douglas had five parties mapping in Colorado, Montana, Nebraska, and South Dakota; W. T. Griswold continued mapping in Idaho, Frank Tweedy supervised the mapping of three atlas sheets in Wyoming; and R. U. Goode continued mapping in the Arkansas Valley in Kansas, as well as in New Mexico and trans-Pecos Texas. Morris Bien continued the special survey of the Aspen, Colorado, area at a scale of 800 feet to the inch. In September, R. H. McKee was sent to Washington to begin mapping. In the Eastern Division under Gannett, mapping was continued in New England, New York (where the State made a small appropriation to begin cooperative work with the Survey), Pennsylvania, and the southern Appalachians. In the central section under Renshawe, six parties were sent into the field in the James River valley of North and South Dakota, where artesian wells had been so successful, and into Nebraska, Kansas, and Oklahoma.

The effect of the cut in appropriations in the Geologic Branch was traumatic. During the first half of July, 13 geologic parties were in the field, but on the 14th, when the Carey and Warren amendments were passed, telegraphic orders were issued to avoid all expenses that would not be necessary if fieldwork should soon be stopped. On the 19th, when the House concurred, all fieldwork was stopped.

Several of the statutory positions had been eliminated and the great reduction in funds made it necessary to discontinue some of the salaries paid from expenses as well. Of the five positions as geologist at $4,000—those occupied by Becker, Emmons, Hague, Pumpelly, and Van Hise—three were eliminated; the Director chose to dispense with the services of Becker, Emmons, and Pumpelly. Van Hise, who spent only part of the year with the Survey, resigned, and Gilbert was then demoted from a temporary position as chief geologist at $4,250 to fill Van Hise's position. Gilbert was so glad to retire from administrative work that he moved to an office on another floor. Of the two positions as geologist at $3,000, held by Major Powell's close friends, Lester Ward and W J McGee, one was eliminated. Lester Ward was dropped as geologist and immediately reappointed to one of the two positions as paleontologist at $2,000. Bailey Willis, who had been holding a temporary position as geologist at $3,000, was demoted to fill the vacancy as geologist at $2,700 when C. A. White resigned. Diller and I. C. Russell held the two positions as geologist at $2,000, both of which were eliminated. Diller was moved into a temporary position at no change in salary; Russell left to become a professor at the University of

Michigan. Peale and Iddings held the positions as geologist at $2,000 which were eliminated. Peale was dropped; Iddings, whose paper on the origin of igneous rocks was acclaimed by both the American Journal of Science and the American Geologist, resigned to become professor at the University of Chicago.

The reduction in the appropriation for paleontology meant a reorganization and a large reduction in force. The several divisions were consolidated into one under a chief paleontologist, C. D. Walcott, who was also responsible for the Paleozoic work. T. W. Stanton was the sole survivor of the Mesozoic division, and W. H. Dall, of the Cenozoic division. Marsh's position had been eliminated, but he volunteered to continue his work on vertebrate paleontology without compensation and was given an honorary appointment. Lester Ward worked out an arrangement with the Smithsonian Institution's National Museum, which had accepted the gift of the Lacoe collection of Paleozoic plants but had no one to put it in order for shipment, whereby David White would undertake the task and the museum would provide for Frank Knowlton so he could continue his work on Laramie and post-Laramie plants.

The Division of Chemistry and Physics was reduced from 12 to 4 employees; F. W. Clarke, W. F. Hillebrand, George Steiger, and one laborer remained. Carl Barus, elected to the National Academy of Science in April, was dismissed in August and the pioneering work in geophysics was discontinued. The rooms at the National Museum were given up, and a new three-room laboratory was set up on the fifth floor of the Hooe Building.

The Division of Mining Statistics received its usual appropriation and alone among the various divisions of the Survey was unaffected by the cut in appropriations.

The Congressional action was clearly aimed at the Director and his administration of the Survey. Jules Marcou claimed credit for instigating the action with a privately printed pamphlet critical of the expense and all-encompassing nature of the Survey work, and the *American Geologist* said that it was one of the factors. Marcou, however, thought it imperative that the topographic mapping and the irrigations investigations be transferred from the Survey, and the American Geologist also called it a serious and far-reaching mistake when the Survey began topographic mapping of the United States. Congress, however, took care to see that topographic surveys were adequately funded. More recently, Wallace Stegner and W. C. Darrah, among others, have attributed the attack to resentment of Powell's ideas of land reform and the closing of the public domain during the Irrigation Survey. Stegner says that the only way Congress could get at Powell was through the research aspects of the Survey. Such resentment may have played a part in the action, but the principal reason was exactly what it appeared to be—an expression of dissatisfaction with the emphasis on pure science and the lack of immediate practical results.

According to S. F. Emmons, it was begun by those who felt themselves injured by the irrigation investigation, but directed by those who hoped to help the economic branch of the Survey. The voting pattern is consistent with this view. Hilary Herbert, who initiated the action in the House, attacked only the appropriations for paleontology, which was abstract science in his view. Herbert was not opposed to basic research; he simply thought it should be done in private institutions because he firmly believed in limited government and government that was economical and efficient. Herbert was also a staunch advocate of the industrial development of the South, a movement which the Survey had been conspicuously slow to aid.

The Senators who followed Herbert's lead in voting against paleontology were a mixed group. Stewart was clearly associated with the irrigation interests but he also represented a mining State, as did several others, and no single interest was clearly paramount in the voting. During the 6 days that the Sundry Civil Expenses bill was laid aside, two other plans to cut the Survey appropriation were devised, the one presented by Senator Wolcott, the other by Senator Carey and amended by his colleague, Senator Warren. Seantor Wolcott represented a mining State, a State in which mining operators had voted to extend aid to Emmons in his investigations and had sent a petition to Washington requesting additional investigations in economic geology. Senator Carey was interested in the irrigation issue, as was his colleague, but Senator Warren was also a member of the Committee on Mines and Mining. Joining those who voted against the Survey when the Wolcott amendment was proposed were Senator Matthew Quay of Pennsylvania, the leading mining State in the Nation, and Senator Richard Pettigrew of South Dakota, where the Homestake Mining Company was important. When the Carey amendment was proposed, Senator Francis Stockbridge of Michigan, the second-ranking mining State of the Nation, Senator Philetus Sawyer of Wisconsin, where iron mining was newly important, and Senator Warren all voted for the cut. In the end, all the western members of the Committee on Mines and Mining voted for the cuts in geology, chemistry and physics, and paleontology.

Behind the effort to reduce general geology and to restore economic geology to a preeminent position in the Survey was a move to force Powell's resignation and to restore King to the directorship. C. D. Walcott told Professor Chamberlin that "There is a powerful party in both the House and in the Senate who appear to be determined that there shall be a change in the Directorship and, if this is not done, to cut off the appropriation" and "the western mining men who are fighting Powell have confidence in King." King had been approached about returning and had agreed to do so on condition that it could be arranged without a struggle. Powell was at first believed to be willing to resign, and Walcott said that "King is probably the man who will be chosen by the Major" to succeed him. He found it "a curious state of affairs that the Senators who are attacking the Major desire that King shall be appointed in his place, and that King should be in accord with them and also with the Major."

Major Powell told several of his friends that he wished to retire from the Survey and devote his time to ethnology, and most of his friends felt that it would be the wisest thing for him to do. The Smithsonian Institution, however, was unwilling to make the provisions for the work that he wished, although Secretary Langley and the Trustees were willing to have the Bureau of Ethnology transferred to either the Department of Agriculture or the Department of the Interior. Other friends, notably McGee, urged Major Powell "to die in his tracks," and he did not proffer the expected resignation. Instead, he left town—his health, according to Walcott, in a "very precarious condition"—leaving McGee and Walcott to carry on. Walcott, who understood far better than McGee the difficulties the Survey faced, regretfully gave up the opportunity to become Professor of Paleontologic Geology at the University of Chicago. Major Powell, he wrote to Professor Chamberlin, "likes strong personal loyalty from those nearest to him. This with me is secondary to loyalty to the Survey & its work." Professor Chamberlin advised Walcott that if King did not take the directorship "it should go to you or Van Hise. * * * If it seems to be drifting in any other direction I would advise the bringing about of delay and some arrangement by which it can be kept in good hands."

Walcott planned a reorganization of the geologic work that began with the request for funds submitted to the Secretary in September and to Congress in December 1892. For many years, funds had been requested for "geologic surveys in various parts of the United States for preparation of the geologic map." In 1892, funds were requested for geologic surveys in 17 geologic provinces into which the United States had been divided, the surveys to be made "for the purpose of locating and representing by maps, sections, and reports" the various mineral resources known or believed to exist in that area. (Walcott's original plan contained only ten divisions; the number was raised by the Director "for political reasons.") The new organization not only brought economic geology to the fore; to Walcott it was the rational method of dealing with the geology of the country.

> I do not think of any better method by which to secure larger and quicker returns for the money expended, than to divide the country up into divisions containing essentially the same geologic problems and the same series of geologic formations and to place each district in the charge of one man to direct the work.

Walcott's plan was approved by King, Emmons, Becker, and Hague; it was only a slight modification of the original plan of organization of the Survey. The immediate development of a program in economic geology was made difficult by the elimination of the positions of the Nation's leading economic geologists, Emmons, Becker, and Pumpelly. Emmons and Becker, however, volunteered to continue to serve without pay. The wisdom of "the production of immediate results of strictly practical value" in King's program had been affirmed; the orientation of the Survey's work was changed.

Chapter 8.
The Utilization of Neglected Resources, 1892–1894

The material progress of the nation now depends upon the development of new industries and upon the utilization of resources hitherto neglected.
—John W. Noble.

Major Powell continued to occupy the position of Director until mid-1894, but his control of the Survey's geologic work came to an end in August 1892. Charles D. Walcott gradually took charge, first on an emergency basis when Powell left the office for several months, then with administrative responsibilities delegated to him by Powell, and on July 1, 1893, as Chief Geologist and Paleontologist appointed by the Secretary of the Interior. Finally, on June 11, 1894, he became Director. These were difficult years, as the Survey struggled to adjust to new conditions and make plans for the future in a rapidly deteriorating economic situation.

Walcott was not an obvious choice for the position, particularly in view of the congressional desire for more emphasis on economic geology. He was a man of unusual administrative ability, as he very shortly demonstrated, but as late as 1890 he had been one of the lower paid paleontologists. The choice, however, was limited. Emmons, Becker, and Pumpelly had been dismissed, Chamberlin and Van Hise spent only part of the year with the Survey, and Gilbert's plan of geologic work had been discredited by the congressional action. McGee was closer to Powell, but McGee resisted the idea of change. Walcott, however, had been one of King's early appointees and had been part of the group that later worked with him in New York headquarters. Walcott understood the difficulties the Survey faced and the essential steps that had to be taken. Regretfully, he gave up the idea of the Chicago professorship to devote his efforts to strengthening the Survey to withstand the coming trial.

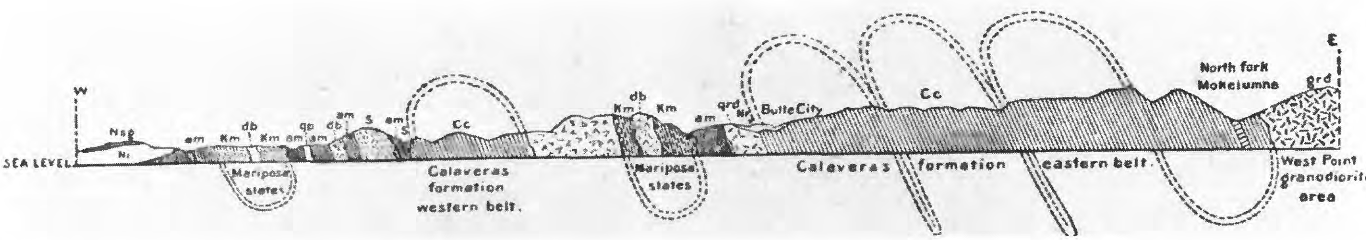
That the Survey had a future was somewhat uncertain in the fall of 1892, and the leaderless group reacted in various ways. McGee rushed to the defense of the Survey. He told the Schuylkill Valley meeting of the American Institute of Mining Engineers in October 1892 that preparation of the geologic map was taking a long time because of the necessity of preparing the topographic map and of research in systems of mapping and cartography. The cost was not excessive. The average cost of topographic surveys was only $4 a square mile, and the average cost of geologic surveys "since the establishment of the Bureau, computed on the moderate estimate that the final geologic surveys completed up to June 30, 1892, represent one-fourth of the total sum of geological work, and on the basis of appropriations for all other purposes than topographical work (including paleontological study, researches in glacial geology, work in chemistry and physics, hydrographic measurements and surveys, the acquisition of a library of 100,000 titles, the installation and maintenance of laboratories, the publication of more than one hundred volumes or reports, mostly illustrated and sometimes accompanied with large atlases, the cost of apparatus, stock and materials of various kinds, office-rent and all other expenditures), approaches $9 per square mile." But McGee also said that as far as the commoner resources were concerned, an official geological survey followed rather than preceded exploration and so "aided the miner and quarryman only by fixing the limits of productive areas and pointing out the unproductive areas, thereby reducing the final cost of minerals by curtailing bootless prospecting" although he conceded that the geologist's "laws of mineral association and his geological maps" would be "useful aids in the exploitation of the new mineral products brought into use as the years go on."

McGee, unfortunately, managed to become thoroughly embroiled in controversies which served to focus an unfavorable light on the organization. They began at the mid-August 1892 meetings of the American Association for the Advancement of Science and Geological Society of America at Rochester, New York. McGee presented a paper on comparative geological chronology in which he used erosion as a measure of time to fix the length of recent geological epochs and then extrapolated, using Dana's ratios of the lengths of the different eras, to fix the age of the earth at 15,000 million years, of which 7,000 million had elapsed since the beginning of the Paleozoic. McGee's paper provoked a lively discussion, but not so much as the discussions on glacial geology and glacial man. Professor G. Frederick Wright's book on *Man and the Glacial Period* had been published in June, but W. H. Holmes told the AAAS meeting that the "paleolithic implements" that were being cited as evidence for glacial man were very like the unfinished and rejected material at aboriginal quarries, and he questioned their great age.

The controversy continued thereafter in the pages of *Science* and other journals, and at one point Holmes said, "it is patent that until geologists take hold of the problem and prosecute the work not as a side issue but as a great and leading question germane to the field of geologic research, little true progress will be made." McGee leaped into the fray with the statement that Wright was not among the leading glacialists in the country, that he had no claim to the title of assistant to the Survey cited on the title page of his book, that he had in fact been temporarily employed by the Survey several years before and dismissed as incompetent. (McGee was wrong. Wright remained on the Survey rolls until July 1892, a good 2 years after completion of his report on the glacial boundary in Pennsylvania, Ohio, Kentucky, Indiana, and Illinois.) McGee's chief complaint, however, was that Wright was completely unaware of the "new Geology," or "geomorphy," whose function it was "to read geologic history from earth-forms, as the older geology read history from deposits and their fossils."

C. C. Abbott, who had supplied some of the material on which Wright based his conclusions, was inclined to take a humorous view of the situation. "The ghost of paleolithic man has arisen to plague the geologists at Washington. * * * The recent appearance of Wright's book * * * has set their pens and tongues wagging, but paleolithic man is not to be downed even by such an array of notables marshalled to defeat him. Salisbury's cunning argumentation, McGee's shaggy front, Holmes' imperious "begone!" and Brinton's persuasive smile do not make him afraid." Abbott in fact was moved to describe the controversy to the readers of *Science* in a bit of doggerel suggesting that McGee believed that all truth resided in himself—or Holmes.

Professor Wright preserved a dignified front in the face of all the assaults, although at one point he was provoked to say, "Geology is not an exact science. There is no infallible court of appeal for the settlement of theories.



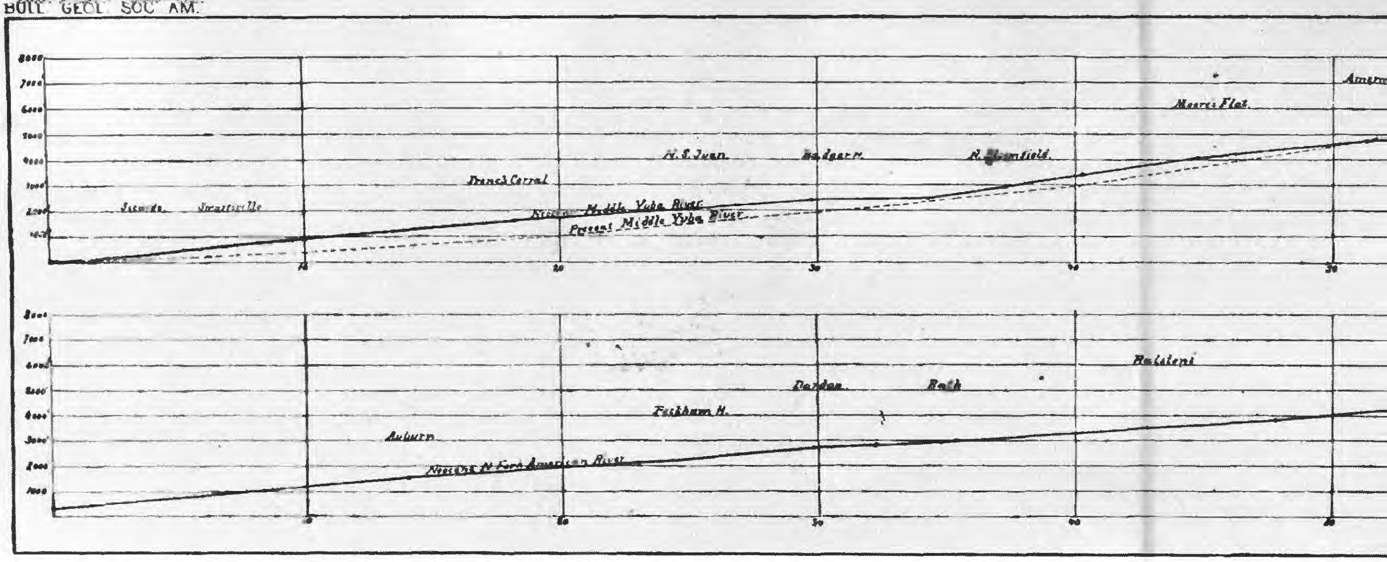
Investigations of the gold deposits of the Sierra Nevada were among those discontinued in 1892. The deposits had been formed at various times in the history of the range. Auriferous quartz veins were associated with highly compressed schists, slates, and associated igneous rocks. The Sierra was first formed as a mountain range after the deposition of the Mariposa slates, then reduced to an approximate peneplain. Still later, a large part of the western slope was covered with volcanic materials that preserved beneath them the auriferous river gravels of the drainage system of the old peneplain. (From H. W. Turner, 1894.)

Observers and students of the facts may widely differ for a long time in their conclusions without discredit to either part. I can only ask for freedom of opinion and freedom of utterance." The editors of the *American Geologist* and *Popular Science Monthly*, among others, took the Survey to task for the unseemly goings-on. Major Powell replied with an article in the *Popular Science Monthly*, saying plaintively that he was away from home and an invalid when the controversy started and that only one of those engaged in the controversy was a permanent member of the Survey. However, he failed to satisfy the *American Geologist*, which said, "a word from him even implying disapprobation of so unusual and unbecoming a mode of conducting a scientific controversy would have been of great weight and significance."

Another controversy involved Henry Gannett and the *American Geologist*, which in its November 1892 issue suggested that it was a "serious and far-reaching mistake" when the Survey, "in addition to the great work it had on hand in the examination of the geological structure and the natural mineral resources of the country, entered upon the geodetic and topographical surveying of the national domain." There was already in existence an efficient organization engaged in such work, and the country demanded more accurate geodetic measurements and more accurate mapping than the Geological Survey performed. The editorialist urged that the Academy of Sciences' original plan be implemented, and that the entire topographic branch be transferred to the "Coast and Interior Survey," leaving the Geological Survey to concern itself with the myriad scientific and economic problems offered by the geology of the country. Gannett objected immediately, but after an exchange of letters and editorials, the question resolved itself into one of whether the quality of mapping would be improved, the time shortened, and the expense lessened by such a change, and Gannett conceded that there could be different opinions but said that "the present status is producing, on the whole, satisfactory results, while the results of the change are uncertain."

By November, the role of the Geological Survey in the investigation of mineral resources was again given prominence. Secretary Noble in his report to Congress said that the function of the Geological Survey was "to discover and diffuse information concerning little known resources and thus to aid in the multiplication of industries." The budget for the fiscal year beginning July 1, 1893, called for appropriations of $145,000 for geologic surveys in 17 different areas in which mapping would be done in the search for various mineral deposits and $30,000 for preparation of the report on mineral resources. Both requests were much larger than any appropriation previously received. Then in December, McGee read a paper to the Geological Society of America which stated that "the purpose of our statesmen in instituting the Geological Survey was to exploit our mineral resources safely and economically."

The GSA paper was yet another explanation of the scientific work of the Geological Survey. Major Powell was listed as the author, but the paper was not written by Powell or by McGee, both of whom had a rather florid style.



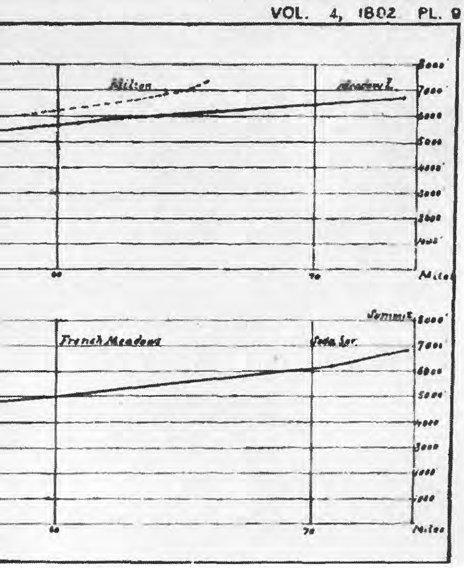
Lindgren found that the auriferous gravel deposits in the watersheds of the Yuba and American Rivers were part of two river systems which in general corresponded to the modern rivers. From the grades of the channels, however, he concluded that the slope of the Sierra Nevada had been increased considerably since the Neocene rivers flowed over its surface. (From W. Lindgren, 1893.)

The author was clearly familiar with the statement read to the Senate by Senator Call in 1890 with its felicitous description of research as the sowing of seed by one generation that the next may gather fruit, and, inspired perhaps by the Biblical seedtime and harvest which shall not cease, described the work of a scientific institution as consisting of a "preliminary, or experimental, or preparatory stage" which represented the seed time and a "final or effective stage" which represented the harvesttime of science. The seedtimes of the different phases of the Survey's work had been different. No research and little experiment was necessary for the collection of information about mineral resources. Considerable preparatory work had been desirable for topographic mapping because old methods and apparatus were expensive and dilatory. Geologic mapping required a vast amount of research and experiment to develop a satisfactory classification of rocks and a satisfactory system of mapping. Some mistakes had been made, the author acknowledged, but it was believed that the topographic methods and apparatus were now thoroughly effective and that the topographic survey could be carried forward more expeditiously and economically than before; the geologic mapping also was rapidly passing from the preliminary stage of research to the effective stage of applied science. The author also believed that the mineral statistics work could be carried on more expeditiously and economically and stated that that work would be expanded. The author may have been C. D. Walcott.

There was no unanimity of opinion in the Survey, however. In February, C. W. Hayes read a paper, again listing Major Powell as author but again clearly not written by him, to the American Institute of Mining Engineers, in which the Survey was referred to as "the Federal bureau created to prepare the geologic map." Nothing was said of mineral resources, and the only work discussed was that of developing a philosophic classification of rocks and a system of geologic cartography. Gilbert was more than likely the author.

The investigation of the Survey by the Senate Select Committee under Senator Wolcott was not made. Gilbert said that the committee found the idea unpopular with their constituents, but Senator Wolcott told the Senate on February 20, 1893, that the Committee had been too involved in politics during the recess and had been unable to get together in the short session. The inquiry, he felt, should still be made, but with the end of the session approaching on March 4, it would have to be done by the new Congress.

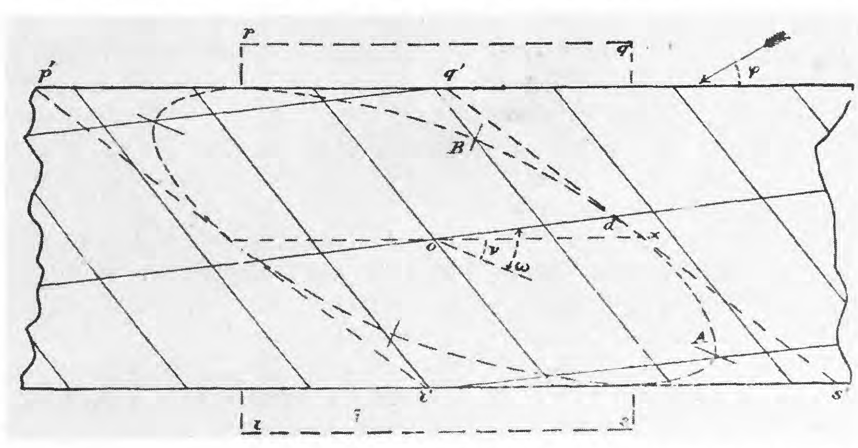
In the November 1892 elections, Grover Cleveland had won a second term in the White House, receiving a popular vote of more than 5.5 million to Harrison's somewhat less than 5.2 million. Weaver, the Populist candidate, received more than a million votes. The tariff was the leading issue,



but voter resentment over the lavish expenditures of the "Billion-Dollar Congress" and the Sherman Silver Purchase Act, and concern over labor disputes all contributed to the Republican defeat. The Democrats retained control of the House and gained control of the Senate for the first time since 1881.

The economic situation was also precarious. In December 1892, Harrison in his last message to Congress said, "There has never been a time in our history when work was so abundant or when wages were as high, whether measured by the currency in which they are paid, or by their power to supply the necessaries and comforts of life." He ignored the storm signals of impending financial disaster that were already evident. The balance of trade was becoming unfavorable. For months the prices of most staples had been falling. Violent fluctuations in the prices of securities indicated a growing uneasiness over the condition of business. European governments and banks were searching the world over for gold, and the U.S. Treasury was concerned about its $100 million gold reserve. Gold had been going steadily out of the country—the loss for 1892 was more than $50 million—and the amount of both gold and silver mined in the United States in 1892 had declined.

The question of the relative output of gold and silver in the future was one of great importance, and the Senate Committee on Mines and Mining thought the prospects for the future were very gloomy. On July 16, 1892, the Senate had directed it "to investigate and report the cost of the production of gold and silver bullion in the United States." In its report on February 18, 1893, the Committee said that it was generally conceded that the production of both gold and silver had cost more than their value repaid in the past, but many were under the impression that silver mining was then a very profitable business. Modern machinery and modern methods had made it possible to work silver ores that were formerly too refractory and to work mines at greater depths, but these modern methods and modern machinery entailed great expenditures. During the preceding 30 years, since the flush time of gold mining in California, the cost of producing gold and silver had been about the same; that is, it cost on the average just about as much to produce 25.8 grains of standard gold as it did to produce 412½ grains of standard silver, and the cost of producing either of them was far in excess of the coining value. In fact, the Committee report stated: "it may be safely stated that if all the necessary expenditure of prospecting, developing, extracting and reducing gold and silver ore are taken into consideration, excluding foolish or wildcat speculations, mining for the precious metals is prosecuted at a greater loss than is suffered by any other business



As an outgrowth of his fieldwork in the Sierra Nevada, Becker made a mathematical analysis of uniform or homogeneous finite strain in rock masses regarded as isotropic, exhibiting viscosity, and capable of flow. One conclusion was that simple irrotational pressure will produce two sets of fissures crossing one another at angles approaching 90° if the rock is brittle and two sets of schistose cleavages if the rock is plastic. (From G. F. Becker, 1893.)

in the United States, and that it would not be prosecuted at all if it were not for the occasional discoveries from which large fortunes are rapidly acquired."

The low price of silver had closed many mines that might be worked at a small profit if silver were advanced to par with gold at 16:1, "but a large increase in the production of silver in the United States is impossible from any mines now known to exist, and the chance of finding other mines that will keep up the present output, whatever may be the price of silver, is very remote." The outlook for gold was worse. "The largest supplies of gold have been obtained from the great placer fields found at long intervals. * * * California and Australia were the last which have been discovered and exhausted, and they are probably the last of any considerable magnitude that will be discovered, unless the regions of the interior of Africa may duplicate in richness California and Australia."

Emmons disagreed. He acknowledged that

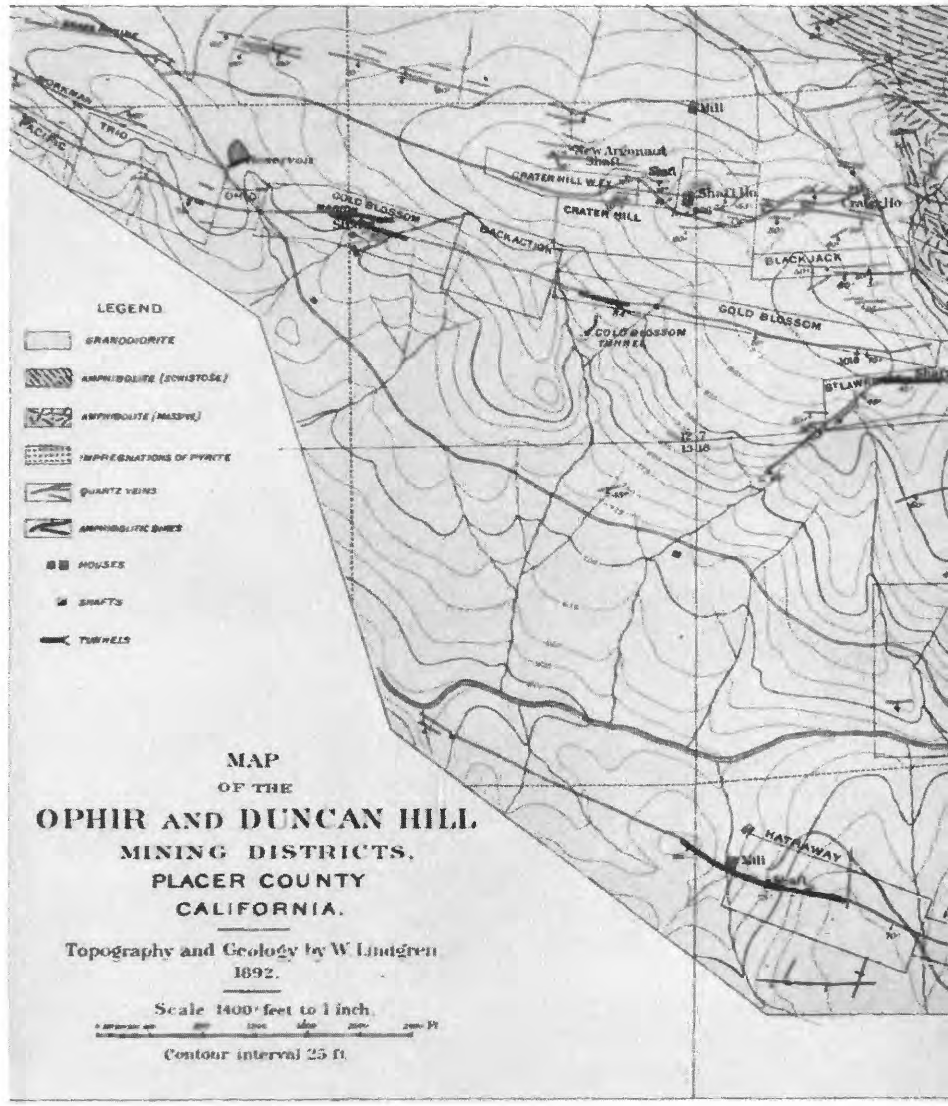
> general industrial conditions have been such as to stimulate mining enterprises during the decade, especially such as require large capital. Besides these broad general causes, there are in the physical and geological conditions of our various mining regions other causes which have influenced locally the relative production of these metals, and which, if accurately known, might aid in foretelling to a certain degree the probable future of either.

On the basis of his own knowledge of the various mining districts, Emmons thought that the gold industry was in a normal and healthy state, ready for a permanent though not necessarily rapid increase as more capital was directed toward its development. The gold product of the United States, he thought, was likely to show a moderate and steady increase, and the gold product of the world might increase to $150 million within a few years and possibly to $200 million before the close of the decade.

Silver production, he found, had increased phenomenally because of favorable industrial conditions. Discovery of the great ore bodies in limestone, such as those at Leadville and Aspen, the ores of which had to be reduced by smelting, brought about the development of a great smelting industry in the West and an immense increase in railroad facilities, and these in turn, encouraged the investment of capital in other mining enterprises. If capital had not been invested in railroad and reduction plants, mining would have been confined to the richer near-surface ores and would probably have been abandoned when these were exhausted. The industry had progressed in spite of a continuous fall in the value of silver because improvement in methods had reduced costs. If the larger reduction works were obliged to close, silver mining would be abandoned throughout the greater part of the western region.

Emmons doubted that the wisest course had been followed in attempting to sustain the price of silver by legislation. It seemed probable to him that if the price of silver had been left to follow the natural course and respond to the laws of supply and demand, the silver industry would be in a more healthy state, although its growth would have been less rapid. He foresaw a considerable decrease in the silver production of the United States during the next few years and thought it reasonable to look for a very decided decrease in the world's production of silver. It was only a question of time, he said, and probably not a very long time, before the production of gold and silver would be about equal. When in the downward course of the one metal and the upward course of the other, the line was crossed and the relation between the two reversed, a decided rise in the price of silver could be looked for, which would restore prosperity to the silver industry.

As concern about the economic situation increased throughout the winter of 1892-1893, Cleveland was urged to call a special session of Congress



Lindgren found that the quartz veins in the Ophir mining district in California belonged to two systems, one trending west-northwest and the other northeast. The fissure systems, he suggested, in all probability were formed simultaneously by a compressive stress acting in a direction parallel to the trend of the Sierra. The silica and ore were then deposited in the largely open fissures by ascending hot solutions. (From W. Lindgren, 1893.)

immediately after Inauguration Day to repeal the Sherman Silver Purchase Act. Senator John B. Carlisle, who was slated to be the new Secretary of the Treasury, proposed to Congress that it be repealed during the short session, but the Republican-controlled Senate took no action.

It was in this context that Senator Wolcott made a long speech in February 1893 about the role of the Geological Survey. The Survey, he claimed, had not been making a geologic map but a topographic map, completely independent of geology, and in many instances in places where it would be of no use in investigations in economic geology. "Topography has not been the handmaid of geology as the law contemplated and in its terms required. Topography has been the sop which has been thrown to the representatives of different sections of the country in order to induce them to vote for these great items of appropriations."

Senator Wolcott suggested that the true scope of the geological survey should be

> **the examination of the geological structure and mineral resources of the country, in order that the Government for its purposes and people for theirs may know with general accuracy and with such detail as is desirable and practicable the extent, the distribution, and the particular mode of occurrence of all useful minerals within the boundary of the national domain.**

He complained that the Survey ignored economic occurrences; nothing had been written on those in the Appalachian Mountains, one brief paper on the phosphate deposits of the Atlantic Coastal Plain, and in the Lake Superior region, "the greatest iron field yet developed," the glacial and general geology had been studied, but not the iron. There had been only one piece of economic work underway, the gold fields of California, and that had been suddenly stopped the preceding summer. The topography went on, but the geology was stopped. He thought that "geology should be limited to economic geology" and "topography should be limited to those fields which are soon to be followed by a careful and full geological survey."

He did not want to criticize Major Powell, whom he understood to be "a most distinguished ethnologist" and "a man of highest character." However, he understood that he spent nearly all his time in ethnological studies, which were not part of the Geological Survey, and was "wholly lacking in ability as an executive director for the Geological Survey." Wolcott quoted a "gentleman familiar with the Survey" as saying, "his great staff of officers have been driven as if they were loose stock; they have not been harnessed and driven together for the one purpose of developing the economic geology of the United States." Parties were sent west when only a few week's fieldwork was possible before snowfall, the Chief Geologist spent his time studying the moon, and the Survey published material on Hawaiian volcanoes, elevations in Canada, and the living oyster that contributed little to a geologic survey. Wolcott concluded, "I am not an enemy of this Survey; I am its friend. I come from a section where we need all the scientific help we can get. * * * We need the help of this Survey; we need it intelligently directed."

Congress had had second thoughts about the hasty action in the summer of 1892. The House Committee on Appropriations proposed to cut the appropriation for topographic surveys by $40,000 and offset it by an increase of $20,000 in the amount for geologic surveys and smaller increases for the report on mineral resources, skilled laborers, preparation of illustrations, and engraving of geologic maps. Only one change was made on the House floor. The gentlemen from Texas complained that the wording of the appropriation for topographic surveys made it impossible to make a survey in Texas, so Texas was added to the list of States west of the 97th meridian where $60,000 was to be spent. The Senate Committee on Appropriations proposed to add four "scientific assistants" to the list, two geologists at $4,000 and two at $2,000. Senator Hale said the committee had found that some eminent men were continuing to work without pay and felt some adjustment should be made. The Senate agreed as long as back pay was not included.

Senator Wolcott proposed an amendment to cut the appropriation for topographic surveys still more, to $100,000, and to increase the appropriation for geologic surveys to $100,000. Senator Allison was moved by the argument to suggest increasing the amount for geology by $30,000 and decreasing that for topography a like amount, even though Major Powell had not asked for a change in the House figures. Senator Call, however, was horrified at the idea of treating in such fashion "a one-armed Union soldier who gave his time and the risk of his life for his convictions of right, coming back into civil life, shattered in health but devoting himself with the enthusiasm of youth to science" and thought "we the people's representatives should respect him and furnish the necessary money to continue the valuable work in which he is engaged." Others had no objection to increasing the amount for geology but did not want to cut the amount for topography. Senator Charles Manderson of Nebraska for one was impressed with the potential usefulness of topographic maps in the construction of roads, and Senator A. S. Paddock, also of Nebraska thought that topography was more important in Nebraska than geology. Senator Power of Montana, however, said all the topographic work in his State had been wasted; the public land surveys had not been made; and the topography could not be tied to anything. Senator Stewart apparently sat quietly all this time but finally offered the opinion that the Survey was the "loosest and most unbusinesslike establishment ever organized in any government" and that it was "a disgrace that we have not examined it and organized it so that Senators voting for an appropriation might know what they were doing."

Senator Wolcott insisted on testing the sentiment of the Senate with his amendment to cut topography to $100,000, and the amendment lost, 37–18. He therefore withdrew the rest of the amendment to increase the amount for geology, and the House figures were approved. The Senate also voted to purchase the building at Third and G Streets Northwest for the Survey. Major Powell had inspected the building and was pleased with it. The House, however, refused to go along with the building or with the addition of the four geologists to the list of scientific assistants, and both were dropped from the final version of the bill.

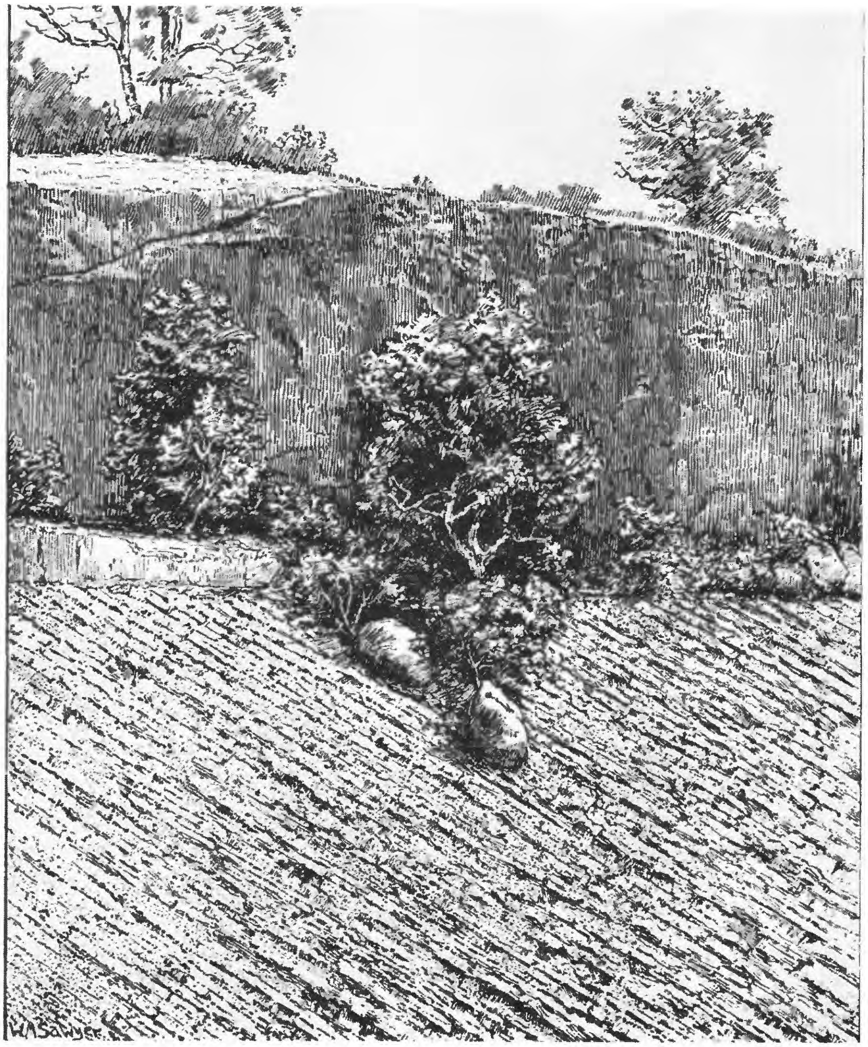
No provision was made for a special investigation of the Survey in the new Congress as Senator Wolcott urged. However, the Legislative, Executive, and Judicial bill approved March 3, 1893, provided that a Joint Commission of three Senators from the 53d Congress and three members-elect of the House be appointed to

> **inquire into and examine the status of the laws organizing the Executive Departments, bureaus, divisions, and other Government establishments at the National Capital; the rules, regulations, and methods for the conduct of same; the time and attention devoted to the operations thereof by the persons employed therein, and the degree of efficiency of all such employees; whether any modification of these laws can be made to secure greater efficiency and economy, and whether a reduction in the number or compensation of the persons authorized to be employed in said Executive Departments or bureaus can be made without injury to the public service.**

Appointed as members of the Commission were Senators Francis Cockrell, James K. Jones of Arkansas (who had been a member of the Select Committee to investigate the Survey), and S. B. Cullom, and Representatives Alexander Dockery, James Richardson, and Nelson Dingley. Congressman Dockery became chairman so the Joint Commission became known as the Dockery Commission.

That was the week that the Philadelphia and Reading Railroad Company, one of the giants of the business world, failed. The New York Central and the Lehigh Valley Railroads as well as other railroad and coal companies that were part of the combine of which the Reading was the center were all affected. During March and April an unprecedented amount of gold was exported, and on April 21, 1893, the Treasury's gold reserve fell below $100 million, the accepted level of minimum safety. In May, the National Cordage Company was taken over by its creditors, and the stock market dropped abruptly. In June, the British closed the Indian mint to silver coinage, and the world price of silver fell. The stock market collapsed. Banks recalled loans, businesses failed daily, and the panic was on.

Although it is now recognized that the overexpansion of industry in the 1880's, the agricultural depression, and the weakness of the banking system all contributed to the depression, in 1893 the monetary situation was regarded as the chief culprit. Gold was being hoarded, and there was increased demand for silver redemption or a bimetallic standard. Cleveland



Diller's study of ancient topographic features on the borders of the Sacramento, in the Klamath Mountains, and on the western slope of the Sierra Nevada confirmed the conclusions drawn by the mining geologists in the Sierra. Northern California had been reduced approximately to base level, truncating the Chico series. Volcanic rocks were later deposited on this surface, and since that time, the northern end of the Sierra Nevada has been raised at least 4,000 and possibly as much as 7,000 feet. (From J. S. Diller, 1894.)

blamed the whole "unfortunate plight" of the Nation on the Sherman Silver Purchase Act when on June 20 he finally called a special session of Congress to meet on August 7.

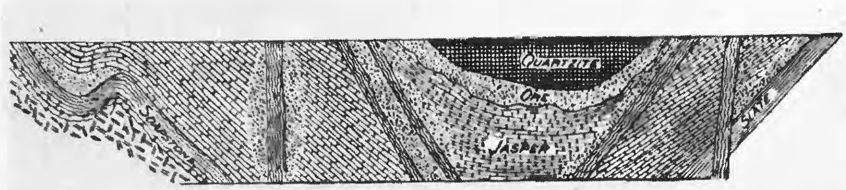
Cleveland again had difficulty in forming a Cabinet. Most of its members were chosen for their stand on the monetary situation. In addition to Senator Carlisle as Secretary of the Treasury, he chose as Secretary of the Navy, Hilary A. Herbert of Alabama, who had been chairman of the House Naval Appropriations Committee as well as critic of the Survey, J. Sterling Morton of Nebraska, who had resisted the efforts of the free silver Democrats to effect an alliance with the Populists in Nebraska, was named Secretary of Agriculture. The youngest, and most obscure, member of the Cabinet was the new Secretary of the Interior, Hoke Smith of Georgia, who was known in the South as a leading lawyer and owner and editor of the *Atlanta Journal*, a paper devoted to tariff reform and sound money. Smith had no particular qualifications for the Interior post, and his selection for the Cabinet was ascribed to the fact that he had rallied Georgians to vote for Cleveland rather than David Hill in the battle for the nomination.

During the early months of Cleveland's second administration, economic conditions intensified the usual pressure from would-be officeholders. Not only the President but every Cabinet member was almost in a state of siege. To alleviate the problem, the President issued a series of "rules": no one who held office in his first administration would be appointed, no newspaperman would be appointed, and finally, a reminder, that extreme partisan activity was not a recommendation for office. Secretary of the Interior Smith issued a statement that "Public offices should be created and conducted exclusively for the benefit of those who do not fill them." At the beginning, however, he was no advocate of civil service reform and happily engaged in the dispensing of patronage, even to strengthen his own faction in Georgia.

Those in the scientific bureaus who had lived through the beginning of the earlier Cleveland Administration might well be excused for any uneasiness. The Survey, in particular, was vulnerable. According to the Dockery Commission report, the Survey on June 30, 1893, had 17 employees in the Geologic Branch, 6 in Paleontology, 3 in Chemistry, and 3 in Mining Statistics. The Geographic Branch had 60 employees, 46 in the Eastern Division and 14 in the Western. (The scientists and engineers were almost equaled in numbers by 76 clerks, accountants, editors, illustrators, photographers, engravers, printers, watchmen, messengers, and janitors, and Dutton's pessimistic prediction of 1884 seemed borne out.) Only 23 employees had civil service status although the Civil Service law had been passed more than 10 years before, and 134 of its 165 employees on June 30, 1893, had been appointed within those 10 years. Fortunately, for the Survey, President Cleveland was genuinely interested in civil service reform and for that reason retained Theodore Roosevelt as a member of the Civil Service Commission and appointed as its chairman John R. Proctor, formerly State Geologist of Kentucky, who had resigned that post rather than yield to pressure for political appointments. Before many months had passed, Secretary Smith also was persuaded of the need for civil service regulations.

The Survey was still troubled by internal disagreements. In February 1893, a geological society was established in Washington to give geologists of the area an adequate outlet for full discussion of their various studies, which the Philosophical Society did not provide. Presumably, it would also provide an opportunity for the airing of differences within the "family circle." With whom the idea originated no one knows, and it was not unique, for under similar circumstances the Canadian Survey had done almost the same thing in 1887. A group of 23 met in the Director's office of the Survey on February 21, 1893, and decided unanimously to form the Geological Society of Washington. A committee of C. D. Walcott, chairman, J. S. Diller, secretary, S. F. Emmons, W. H. Holmes, and G. P. Merrill was appointed to prepare a constitution and bylaws, and at the organizational meeting of February 25, C. D. Walcott was elected president, S. F. Emmons and W. H. Holmes, vice presidents; Whitman Cross and J. S. Diller, secretaries; and Arnold Hague, treasurer. The selection of officers suggested a definite attempt to bring the various factions together.

The beginning of GSW, however, did not contain the disagreements, and McGee was still the leading dissenter. In the January 1893 issue of the *American Journal of Science*, there appeared Clarence King's first scientific paper in several years, on the age of the Earth. "Among the various attempts



The work in Michigan was also suspended for a time when C. R. Van Hise resigned in 1892. Van Hise had found that the ore deposits in the Marquette district were at the bottom of the iron-bearing formation, within the iron-bearing formation but at the top as now exposed, and at the true top of the formation or immediately below the Goodrich quartzite. The first two were generally "soft ore" or hematite; those at the top were hard specular ores or magnetite. The figure is a generalized section showing soft ore at the right, lower center, and left, and hard ore in the upper center. (From C. R. Van Hise and W. S. Bayley, 1895.)

Carl Barus

Geologist and physicist, U.S. Geological Survey, 1880–1892. Barus began studies of the behavior of rocks and minerals under high temperatures and pressures in 1880 with the guidance and encouragement of Clarence King. In the spring of 1892, Barus was elected to the National Academy of Sciences, at the early age of 36. In August 1892, he was dismissed from the Survey as the result of the reduced appropriation, and the pioneering work in geophysics was discontinued for almost a decade. (Courtesy of the John Hay Library Archives, Brown University.)

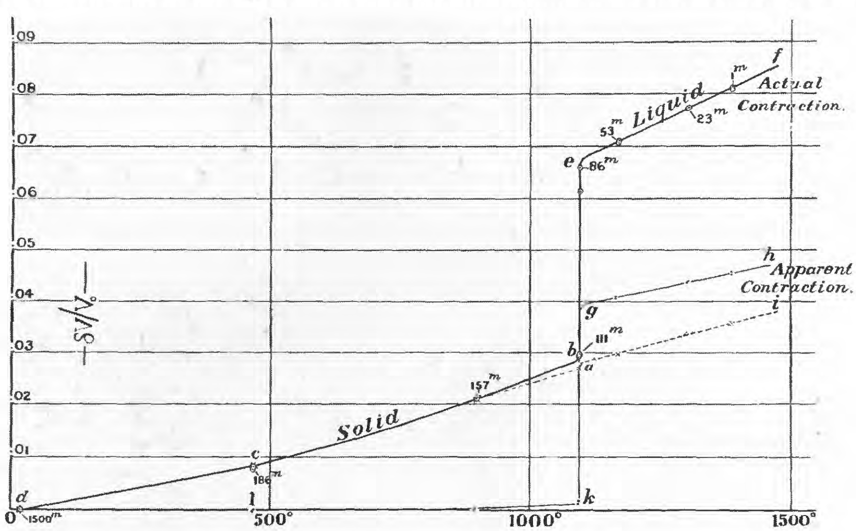
to estimate geological time," he began, "none has offered a more attractive field for further development than Lord Kelvin's mode of limiting the earth's age from consideration of its probable rate of refrigeration, published in 1862. At that time the consequences of his physical reasoning could not be fully applied to the conditions within the earth, so as to test the probability of his hypothetical case, for want of positive knowledge of certain properties of rocks, particularly the volume changes of melted rock in approaching and experiencing congelation, and the qualitative and quantitative effects of pressure upon the fusion and freezing points." Data were now, however, available from the work that Barus had been doing in the Survey's physical laboratory. King, who had inaugurated Barus' work and who had been helping to direct it since his resignation from the Survey had an agreement with Barus about publication, reserving for himself the geological application of the data, but Barus' three important bulletins were now in print.

If the Earth were rigid, King reasoned, and he accepted the results of Kelvin, G. H. Darwin, and Newcomb as warranting a firm belief in a rigid Earth, then it followed that there was no liquid layer in the outermost part of the Earth and the curve expressing the temperature gradient could not intersect the curve expressing the relation between the fusibility of igneous rock and pressure at corresponding depths. He used Hallock's temperature measurements and Barus' data on diabase and concluded that the Earth was 24 million years old, qualifying his result "to the extent that solidity is a valid criterion and so far as the melting temperature of diabase may be supposed to apply to the depth examined." Iddings, who reviewed the paper for the *Journal of Geology*, thought the estimate reasonable in view of Helmholtz' and Kelvin's estimates of the age of the sun as 15 and 20 million years. Osmond Fisher, the British physicist, said it was "impossible not to admire" King's "ingenious argument," although he questioned the result as he did not believe that the rigidity of the Earth had been clearly established. Lord Kelvin quoted King's results with the statement that there was no reason to make further calculations until new data were available.

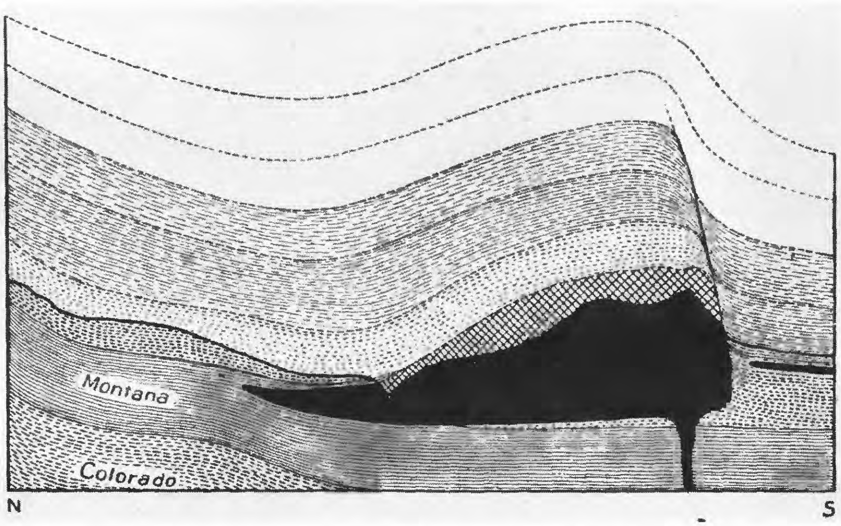
One of the April meetings of the new Geological Society of Washington was devoted to a discussion of King's paper, which inspired McGee to rush his views to *Science* for publication. "Factors involved in the non-geologic estimates [of the age of the earth]—surface and subsurface temperatures, thickness of the earth-crust, properties and conditions of rocks, etc.—must be furnished by the geologist, so that, at the best, such estimates represent nothing more than the grist ground from the mathematical mill; and, moreover, it usually happens that unknown factors are introduced to give texture to the product, but which, at the same time, so far adulterate the grist as seriously to affect its value." He complained that

> **the student of the 'exact' sciences is seldom willing to grant so high a degree of mobility in the terrestrial crust as is required by the geologist to explain current continent movements, and is given to rejecting or ignoring the evidence of such movements; while, on the other hand, he is the first to reject as excessive the time-estimates of the geologist based in part on, and in complete harmony with, other observed movements. This mental habit, growing out of the methods and postulates employed in certain lines of study, is constantly to be borne in mind in weighing non-geologic opinion concerning the rate of geologic process.**

(Apparently he saw nothing incongruous in adding a footnote to correct his own estimate of the age of the Earth from 15,000 million to 6,000 million



Barus' experiments on a sample of diabase furnished by King showed that in the fusion of basic magma, the passage from liquid to solid is one of contraction. King used Barus' results in his paper on the age of the Earth. (From C. Barus, 1893.)



Advances in petrology were made through study of laccoliths. Whitman Cross recognized several laccolithic intrusions in Colorado that departed from the theoretical dome shape postulated by Gilbert. At Mount Marcellina, a line of weakness in the strata above the developing laccolith resulted in a fault and an asymmetric form. Cross also found that the rock types produced by consolidation of magmas in laccoliths were similar as a result of the conditions of consolidation. (From C. W. Cross, 1894.)

years, and of the time since the Paleozoic from 7,000 million to 2,400 million years. He had found a mistake in his arithmetic.)

Barus, who had transferred to the Weather Bureau after being dismissed in 1892, almost immediately rose to King's defense and retorted that it was "curious, and certainly contrary to scientific usage," that King's own statements on the limitations of his work were ignored. He concluded, a little sourly, and with a glancing blow at Willis' experiments,

> perhaps it is heresy to state that an immense future awaits laboratory research in physical geology; but stating it, one would like to refer not so much to the punching of clay or the pulling of taffy candy as to legitimate physical measurements.

Walcott took the middle ground. He began his vice-presidential address at the August 1893 meeting of the American Association for the Advancement of Science by saying,

> Of all subjects of speculative geology few are more attractive or more uncertain in positive results than geologic time. The physicists have drawn the lines closer and closer until the geologist is told that he must bring his estimates of the age of the earth within a limit of from ten to thirty millions of years. The geologist masses his observations and replies that more time is required, and suggests to the physicist that there may be an error somewhere in his data or the method of his treatment.

Walcott's own analysis, based on a study of the sedimentary rocks of the Cordilleran area, led him to conclude that the minimum post-Archean time was 25–30 million years and the maximum 60–70 million years. Thus "geologic time is of great but not of indefinite duration. I believe it can be measured by tens of millions, but not by single millions or hundreds of millions of years." It would be another 4 years before Madame Curie would discover radioactivity and add another element to the problem.

McGee and Emmons disagreed, indirectly, on progress in science, especially in the Geological Survey. The annual report for fiscal year 1893 contained a summary of the Survey's work for which McGee wrote a preface as Major Powell still had not returned to duty. The preface was a philosophical discussion of the manner in which progress in science is achieved, in which the seed and fruit of 1890, which became the seedtime and harvesttime of 1892, was elaborated into a more geological "intellectual magma" of observed facts from which science, or as "organized knowledge", was segregated.

"The basis of knowledge is found in the facts of nature, and science always begins with the systematic observation of these facts. Through continued observation knowledge is accumulated and its field widens until a large body of the facts of nature are brought into view. Thus the facts observed, or the conceptions standing for them, increase in quantity and grow in volume and eventually form an intellectual magma representing a certain plane of knowledge.

"When the body of isolated facts grows large it becomes cumbrous, and the active mind seeks to group the conceptions standing for the facts either by artificial devices or in natural order, either by adventive features or essential relations; and from time to time some mind, supported by the intellectual magma of accumulated knowledge and inspired by genius, perceives relations previously unknown. Then the facts, or the conceptions standing for them, are grouped in a new way in accordance with the newly discovered relations, and thereby knowledge is raised to a higher plane.

"Thus science advances by distinct yet correlative alternate steps, of which the first is aggregation in a magma on a given plane, and the second segregation from the magma and elevation to a higher plane; the first is quantitative extension, and the second is qualitative enhancement. These alternating steps or stages have marked intellectual progress from the beginning, and thus the course of increasing knowledge is not a rising plain but a stair. * * *

"Now there are two stages in the development of scientific work by individuals and institutions, coinciding with the primary steps in the growth of knowledge, i.e., there is a preliminary or observational or experimental stage in which facts are gathered, not solely for immediate use, but as a foundation for a superstructure of science which it may not be possible even to foreshadow; and there is a constructive or creative period, in which the magma is crystallized and reared into the final superstructure, reaching to a higher plane of science.

"In like manner there are two stages in classification corresponding to the primary stages in the growth of knowledge. The classification employed in the primitive stage of extension is commonly designed to facilitate recording or finding, and is frequently based on external or artificial or adventive classification and characters; moreover, the process of adventive classification is usually one of successive division, in which the facts classified are successively separated by real or fancied differences. The classification employed in the stage of segregation and elevation of knowledge, on the contrary, is commonly designed to express natural relation, and is usually based on essential and inherent characters; and moreover, throughout the entire domain of modern science the classific process is one of successive grouping by resemblance—the antithesis of the primitive process of dividing by difference. Accordingly the scientific classification is an interpretation of nature, and is designed simply to express natural relation, and the more closely this end is approached the more perfect is the taxonomy.

"These stages in the progress of knowledge, of scientific work, and of classification, have been recognized in the organization of the work of the Geological Survey."

A definite statement of the actual scientific progress made by the Geological Survey as a body could not be made, for from the beginning the Survey had enlisted the services of the ablest men in the country, and it had encouraged them to associate with the ablest investigators in the world engaged in similar work. Thus the knowledge of geology had been widely diffused, and the science had been raised to a higher plane. During the 14 years since the establishment of the Survey, exact knowledge concerning the earth and its resources had "progressed apace"; it had "advanced far more than during any other equal period, perhaps more than during its entire previous history."

Little was said in the annual report about advances in economic geology. Emmons summarized them in a paper on the geological distribution of the deposits of useful metals that he had been invited to present at the International Engineering Congress held in August 1893 in connection with the Columbian Exposition at Chicago. The Emmons paper was based partly on his own firsthand knowledge and partly on an examination of the literature. Predictably, the paper began on a somewhat plaintive note: "Had the geological investigations undertaken by the Tenth Census been continued systematically by the United States Geological Survey or by the Eleventh Census, it might have been possible to make a fairly complete review of the subject. As it is, the principal result of my examination has been to show how very unequal and in many directions extremely meagre are the data of any kind that are available, and to demonstrate the great need that exists for a systematic investigation of this important subject by some scientific organization, for its field is too vast to be covered by any single individual, and will be of little permanent value unless carried out on some uniform plan by which the relative accuracy of its results may be assured."

Equally predictably, Emmons thought any statements about great progress in science a bit questionable. In the past 22 years, he said,

> many important contributions have been made to our knowledge of the geological structure of the continent, but a great part of these contributions, especially in late years, have been rather in the line of modifications and reversals of preconceived theories, than in the firm establishment of new ones. We seem now to have removed most of the unstable stones from the foundation of our geological knowledge, and to be nearly ready to build up a permanent structure in the immensely enlarged field that progress in various lines has opened to us. In like manner the special study of ore-deposits and of their relations to geological structure which had hitherto been rather neglected by field geologists, has in the last decade received more attention, though perhaps not as much as it deserves; many false conceptions have been cleared away, and important progress has been made toward a more rational method of correlating their phenomena.

He concluded that "Unfortunately, our knowledge of the geological relations of the ore-deposits of our country is as yet too incomplete to afford material for any exhaustive generalizations on the geologic relations of the useful metals as a whole, or the underlying genetic cause of such relations. The fissure systems, or the natural waterchannels which have admitted of the concentration of the metals into workable deposits, have, as pointed out by King, Becker, and others, certain definite relations with the great orographic movements, and these relations admit of our forming an idea of the relative age of the deposits. They do not, however, afford any reason why certain minerals are more prevalent in one district and certain others in another; nor do they necessarily afford any clue to the original source of the metals. A certain amount of systematic geological work has already been done by our Geological Surveys towards the solution of these important problems, which are of practical, as well as scientific, importance, but a vast amount remains yet to be done, and many large fields are still practically untouched."

Preparation of the preface to the annual report was McGee's last work for the Geological Survey. On June 30, 1893, he resigned from the Survey to devote his entire efforts to the Bureau of Ethnology. On July 1, Charles D. Walcott was appointed Geologist in Charge of Geology and Paleontology by Secretary Smith. The various geologic divisions were abolished, as the paleontologic divisions had been the year before, and the entire geologic and paleontologic force was organized as a single unit. Walcott had evidently seriously considered all the charges that had been made about the Survey, both in Congress and in the scientific press, including those that the chiefs of departments were staying home and sending the younger men into the field. Each geologist and assistant geologist, each paleontologist and assistant paleontologist, was made a chief of party, to work either alone or with the assistance of a relatively inexperienced man, classed as a field assistant or geologic aid, and fieldwork was resumed in all parts of the country.

Although the appropriation for geologic surveys was only half the amount requested, allotments were made by geographic areas, and an attempt was made to serve all sections of the country equally. Most of the work had for its stated purpose the preparation of the geologic atlas, but wherever possible it was also related directly to "useful minerals." In New England, for example, Professor Shaler's assistants completed work on several atlas sheets, but Shaler himself prepared a report on the geology of common roads. In New Jersey, J. E. Wolff continued to map in the Archean highlands but took care to note all information that would aid the development of the iron mines and also investigated construction materials. C. W. Hayes, Arthur Keith, and M. R. Campbell all returned to the southern Appalachians. Campbell worked in southwestern Virginia in the transition zone between the northern and southern phases of certain formations, an area where the coal deposits were expected to become particularly valuable. Campbell was assisted by Walter C. Mendenhall, the son of a childhood neighbor, whom he had invited to spend his summer vacation from Ohio Normal University with him, and David White, who had confided to Lester Ward that after working on the Lacoe collection he could name every species of coal measures plant remains on sight. Ward had asked Campbell to test the young man's boast. Both Hayes and Keith worked in Tennessee, whose Congressman had been so distressed that the Survey knew so little about its mineral resources. Hayes began a study of the coal measures but also spent part of the season investigating the iron and aluminum ores in Georgia and Alabama. Keith worked in eastern Tennessee and North Carolina, examining large numbers of iron and corundum deposits as well as a coal area.

Professor Van Hise centered the areal mapping in the Lake Superior region in the country adjacent to the Marquette iron district of Michigan. Walter Weed, accompanied by Professor L. V. Pirsson of Yale as a volunteer assistant, mapped the northern part of the Little Belt Mountain sheet in Montana and examined several mining districts. From Emmon's old division, Whitman Cross, with E. B. Mathews of Johns Hopkins as assistant, mapped the Pikes Peak sheet, near the center of which was the Cripple Creek mining district, the most important of the newer gold fields. George Eldridge made a reconnaissance of the Big Horn and Wind River basins in Wyoming, the home State of Senators Carey and Warren, to determine the extent and value of workable coals and to obtain information on other economic resources, as time and route permitted. In Becker's old division in California, Waldemar Lindgren spent almost the entire year in the field in the Sierra Nevada, mapping first the Truckee sheet, and then making a detailed study of the underground and surface geology of the gold-mining districts of Nevada City and Grass Valley, while Turner mapped the Downieville and Bidwell Bar sheets. The revival of gravel mining in the area lent special significance to the mapping of the auriferous gravels in the Sierra Nevada. Diller completed mapping the Lassen Peak sheet and worked in several of the bordering areas. He discovered that all the mines of the Greenville

region were on contacts bordering masses of ancient eruptive rocks, so that his maps became of considerable interest to prospectors and mine operators.

To G. K. Gilbert was assigned the task of mapping the areal geology of the Pueblo sheet, in the Great Plains east of the Rocky Mountain front in Colorado. R. T. Hill, who was already engaged in a study of a Great Plains area, spent 7 weeks with Gilbert at the beginning of the field season so that their work could be coordinated; later in the season, F. H. Newell also spent time with him in a study of artesian conditions.

Hague also went back into the field, this time accompanied only by T. A. Jaggar, Jr., a recent graduate of Harvard University, who came highly recommended, to extend his mapping into the forest area east of Yellowstone Park and begin a study of the north end of the Absaroka Range.

Joseph Stanley Brown was given the assignment of continuing McGee's work on Coastal Plain formations. He and W. H. Dall spent some time making a careful instrumental survey of the section between Bainbridge, Georgia, and the marshes of the Gulf Coast, as some doubt had been cast on the accuracy of the standard section of Florida and adjacent States adopted by the Survey. N. H. Darton was given the assignment of completing McGee's long unfinished work on the New York State map.

A mapping project in the Puget Sound area of Washington had been planned for Bailey Willis, but he was unable to get into the field because of the problems with finally getting some of the folios of the geologic atlas published. The format of the folio, as finally determined, consisted of a topographic and geologic map and descriptive text bound in a heavy cover, as a minimum, to which might be added, as circumstances warranted, maps of economic geology, surficial geology, artesian water supply, and structure

Walter Weed and L. V. Pirsson of Yale recognized in Square Butte in the Highwood Mountains of Montana a laccolith stripped of its cover. The lower slopes are dark and fantastically eroded into jutting towers and spires, the upper slopes are light colored and often a glaring white. The liquid mass forming the laccolith was differentiated after intrusion, and the inner kernel crystallized into a sodalite syenite while the outer mass formed a basic granular rock composed essentially of augite and orthoclase to which the name shonkinite was given. (From W. H. Weed and L. V. Pirsson, 1895.)

sections, columnar section, and other special illustrations. Three were published during the year: Livingston, Montana, by Iddings and Weed; Ringgold, Georgia, by Hayes; and Placerville, California, by Lindgren. At the end of the year, four more were in press: Hayes' Kingston and Chattanooga, Tennessee; Lindgren's Sacramento, California; and Arthur Keith's Harpers Ferry, West Virginia.

Walcott was fully occupied with administrative work during the summer (Major Powell was again absent for several months), but in October he made a reconnaissance of the Green Pond Mountain district in New Jersey with the State Geologist, then examined the lower Paleozoic rocks in Pennsylvania. In November, he spent time with Arthur Keith on the Ocoee problem in Tennessee and Georgia and also made arrangements with the State Geologist of Georgia for cooperative work on the phosphate deposits and for preparation of topographic maps in the gold belt of the northeastern part of the State.

Walcott's authority did not extend to topographic mapping, and no changes were made in the two topographic divisions, which continued under Gannett and Thompson. In the Eastern Division, under Gannett, some 26,060 square miles were mapped in 14 States, most of it at 1:62,500, while Gannett himself completed a manual of surveying and geographic dictionaries of Massachusetts, Rhode Island, Connecticut, and New Jersey. The cooperative survey in New York was greatly enlarged, mapping continued in New Hampshire and Vermont, and both mapping and revision in the southern Appalachians. In the central section, 75 atlas sheets, some 16,000 square miles, were surveyed in North and South Dakota, Nebraska, Kansas, and Oklahoma.

The Western Division under Thompson did fieldwork in eight States and mapped a total of 11,630 square miles. In California, mapping proceeded in the Los Angeles and San Francisco areas and in the gold belt, and a party under R. B. Marshall began mapping in the Yosemite. Douglas again had five parties at work in Colorado and South Dakota, completing the special survey of the Aspen mining district and beginning revisions of the Pueblo and Platte Canyon sheets in addition to new work. Tweedy began mapping in the area immediately east of Yellowstone Park, while his assistant continued the mapping in southern Wyoming. Under Griswold's direction, two parties worked in Idaho and Oregon, Goode had four parties at work in Texas, and R. H. McKee began mapping near Seattle, Washington.

Newell returned to the Survey after completing the census report on irrigation and during the fall made a personal inspection of the gaging stations in several Western States and spent time with Gilbert making a study of the water flowing in the St. Charles River and its possible increase or diminution while it flowed across the outcropping edges of the Dakota sandstone.

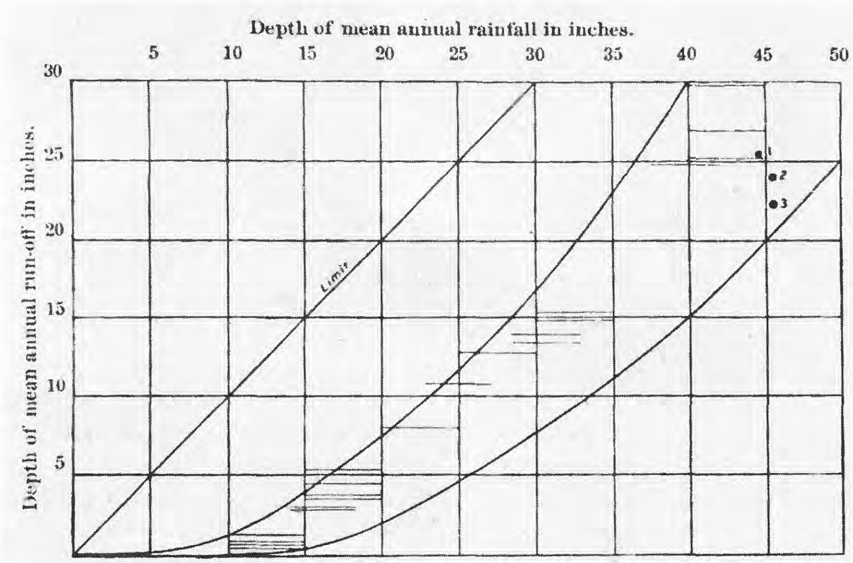
Newell's analysis of the census data had disclosed some rather startling information about irrigation. The area irrigated within the arid and subhumid regions during the census year ending May 31, 1890, was not 8 million acres, as Major Powell had estimated, but only 3,631,381 acres, approximately 0.4 percent of the total land area west of the 100th meridian. The water supply was not enough for 100 million acres to be irrigated, because the greater part, if not all, of the easily available water supply had already been utilized. Less than half the farms in the arid region contained irrigated areas, and only one-fifth of the area of these was successfully irrigated. Therefore, all the water supply of the arid region was needed to irrigate the lands already owned and not fully utilized. To increase the area under irrigation, the water would either have to be used more economically so that it would cover larger areas, or the flood and waste waters of the nonirrigation season would have to be stored. Some increase in acreage cultivated could be achieved by the construction of expensive works to divert the water of large rivers upon land, but in very few localities, if any, could a farmer divert water unclaimed by others and by means of a simple ditch bring his farm under irrigation.

"The simple fact," said Newell, "that the area which can be irrigated is dependent upon the amount of water flowing in the streams is often ignored in general discussions of irrigation and its possibilities. It is often taken for granted that because along some river there are vast areas of fertile land, some of which has been irrigated profitably, larger and larger areas will, with the progress of settlement, be brought under cultivation to an indefinite extent, the assumption being tacitly made that since a river drains a large area its waters must be proportionately abundant. It is unfortunately the case that many of the rivers of the arid region occupying a prominent place upon the map carry a very small amount of water for a part of the year, and this water is all utilized or needed for the land now wholly or in part under cultivation."

In some parts of the country attempts had been made to increase the amount of water available during the irrigating season by means of storage works. Unfortunately, there were few places where the storage capacity would be sufficient and a safe dam could be constructed with a reasonable outlay.

Artesian areas were widely scattered and individually of small size except in the Dakotas and in California. Comparatively few artesian wells had been put down for irrigation alone, and because other purposes were served, irrigation by this method was profitable. There were advantages in the matter of convenience and independence, but these were offset by the small amount of the water and its low temperature, which could damage crops when applied on a hot day.

Newell was the official representative of the Department of the Interior at the Second Irrigation Congress, which was held in Los Angeles in October 1893. He addressed the meeting on the investigations and surveys carried on by the Department, principally the work of the Geological Survey and the Census, and he stressed the need for data on water supply in the arid lands. "I confess that men making a specialty of one subject are prone to



F. H. Newell, who continued the hydrographic investigations of the Geological Survey after the Irrigation Survey was discontinued, found that although runoff is not immediately dependent on the quantity of rainfall but is a function of rainfall and topography modified by such conditions as climate, geologic structure, and vegetation, it was possible to make broad approximations of the quantity of runoff corresponding to certain depths of rainfall. In the diagram shown, the upper curve represents the relation under "average conditions of mountain topography" and the lower curve, conditions in a catchment basin of broad valleys and gentle slopes. (From F. H. Newell, 1894.)

overestimate its importance," he said, "but in this matter I thoroughly believe is to be found the key to the whole situation."

> **It is generally acknowledged that there is more land than can be irrigated by making use of the water available and employing it according to our present knowledge and resources. There are still great tracts of land to be brought under irrigation, and usually choice can be made among these as to the best or the most valuable, but, in nearly every instance, there is only one source of water supply, and this, to be thoroughly utilized, should be carefully studied and so well known that every drop of water can be accounted for.**

Newell thought that little could be learned from experience abroad, for American rivers were very different from the Nile or the great rivers of India. Methods of controlling the water must be worked out in America. For his part, he thought that any great increase in the area irrigated had to come in two ways: "by the development of all the small streams, greater economy in the use of water, and the employment of every wall and spring, no matter how small, and second, by the utilization of storage reservoirs and of great rivers which now flow to waste."

Davis spoke on the "economy of water." When water was stored at the most advantageous points and the maximum quantity applied to the best lands, the problem was only half solved. The elimination of waste in its use was of no less importance. To promote economy, he suggested that irrigators be educated in the intelligent use of water and be charged for water in proportion to the amount used rather than the amount of land irrigated.

Major Powell also attended the Irrigation Congress, making his first appearance as Director of the Survey in many months. When he spoke on Friday, October 13, he threw aside his prepared paper to devote himself "to an explanation of the detailment of certain facts relating to the condition of the public lands and to irrigation." In his effort to make it clear to the delegates that they were overoptimistic about what irrigation could accomplish in the arid region, he overlooked or at least omitted any reference to the points made by Newell and Davis. He told the delegates,

"Now what I wish to make clear to you * * * is this—there is not water enough—run-off water enough to irrigate all the lands; that when all the rivers are used, when all the creeks in the ravines, when all the brooks, when all the springs are used, when all the reservoirs along the streams are used, when all the canyon waters are taken up, when all the artesian waters are taken up, when all the wells are sunk or dug that can be dug in all this arid region, there is still not sufficient water to irrigate all this arid region; there is still not sufficient water to irrigate all the land. There is not sufficient water to irrigate all the land which could be irrigated—all the irrigable land—only a small portion can be irrigated.

"Therefore, it is not right to speak about the area of the public domain in terms of acres that extend over the land, but in terms of acres that can be supplied with water. Do I make that clear? There is but a small portion of the irrigable land which can be irrigated when all the water—every drop of water—is utilized, only a small portion of it can be irrigated. * * * The next thing which I want * * * to impress upon you, is one great fact: That * * * if all of the waters of the arid region were taken upon the land owned by private individuals and not one drop used here after on any arid land which now belongs to the General Government, there would not be enough to irrigate the private land. * * * There is not water enough and can never be conserved sufficient to irrigate more than one-third of the land already owned by private individuals. * * * Not one more acre of land should be granted to individuals for irrigation purposes; there is not water enough. * * * The land now remaining in the hands of the Government has three values: * * * some [are] valuable for mining purposes. * * * They are also valuable * * * for * * * ranges for stock. Many of them * * * are valuable for the cultivation and growth of forests. And, in my judgment * * * they should be dedicated to those purposes. * * * There is no more land, owned by the Government in the arid regions, that ought to be used for irrigation, except in about half a dozen little places."

Challenged on several sides, he resorted to a practical example: "Supposing you could put a roof over all the land in Arizona, or in Idaho, or in Nevada or California; suppose you could have a roof over all the land and gather all the rain which falls from the heavens, could you gather enough water to irrigate the land? * * * In the Yuma Valley, in the Colorado River, down below in Arizona, you have three, four or five inches of rainfall. Save it all; save every drop of it and put a roof over all, and put it all into the canals, and what would three or four, or five inches of rainfall do toward irrigating all that land? You want twenty-four inches * * * You are now putting twenty-four inches of water upon the land, and if the land don't receive that much from the heavens, even if you could gather it all, it would not irrigate it all."

Later in the day he tried to clarify his remarks. He had not said that the irrigable lands could not be increased. He had been speaking of percentages. The percentage of the land that could be irrigated was comparatively small, although in terms of acres or square miles it might seem very large. The next day, Newell tried to retrieve the situation by moving that papers be referred back to authors before publication "in order that corrections [may be] made of any grammatical statements, figures, and other scientific facts which might need to be looked over." One of the delegates said: " I supposed that Maj. Powell knew what he was talking about when he came before this Congress. * * * I don't see why gentlemen should be concerned at this crisis in helping him out by adopting a motion of this kind, and to print something that he did not utter, or something wiping out, to a certain extent, his utterances on the floor of this Congress." Another said: "I came to this Congress as a listener to learn what I could from the distinguished men; and I have not found any man here, excepting, perhaps, Maj. Powell, of the Government, that cares to modify his views. * * * While I would be glad to have Maj. Powell and also the financial part of this Government, take back some of the things they have done, and I think they will be glad to do so before we get through, still we want them to stand by the record."

In the end, the Congress adopted a carefully worded statement that enough of the remaining public domain was arable "to provide homes and farms for millions of people. The portion which can never be cultivated is valuable for range purposes or for forest reservations." The Congress favored the limitation of the amount of land that might be taken up by settlers under systems of irrigation to 40 acres, demanded rigid national and State supervision of dams and other works in order to protect life and property, stressed the importance of a national policy for the care and preservation of forests, and asked that "in simple justice" the Government devote part of the money received from the sale of lands in the semiarid region to the practical investigation of means for their reclamation.

The economic situation continued to deteriorate during 1893. The House, where the power of the industrial East was most evident, had voted to repeal the Sherman Silver Purchase Act on August 28. The Senate, however, was still the stronghold of western influence, and there it took until late October to get the measure through. Repeal of the Sherman Silver Purchase Act did not halt depletion of the Treasury's gold reserve. On

November 1, the gold bullion in the Treasury was $96.7 million, but because of declining revenues, the Treasury had to use the gold to meet operating expenses, and by the end of the year the reserve was down to $80 million. Shortly after the first of the year, the Treasury offered a bond issue of $50 million, but the public did not respond, and the loan had to be placed with New York bankers.

By this time, almost 600 banks had failed, 15,000 businesses had failed, and one-third the Nation's railroads were bankrupt. Unemployment rose to a level previously unknown in the United States, perhaps as high as 4 million. Reflecting the general economic conditions, the total value of the mineral products for 1893 was the smallest since 1889, the decline being most conspicuous in pig iron and structural materials. Silver production was down, especially in the latter part of the year. The gold product, however, bearing out Emmons' prediction, increased, chiefly owing to the new mines in Colorado, and was the largest since 1886.

The spring of 1894 was one of the grimmest in United States history. The coal miners went on strike in April. Many of the western metal miners were also on strike, and violence was commonplace. The new mining camp at Cripple Creek was said to be on a war footing. As economic conditions rapidly worsened, no fewer than 17 armies of the discontented formed and marched on Washington to present their grievances in person. The most famous, that led by Jacob S. Coxey of Ohio, arrived on April 30, and its leaders were arrested for trespassing or walking on the Capitol grass.

The House, contrary to its usual custom, took up the Sundry Civil Expenses bill in March 1894 even though other appropriations bills were yet to be introduced. The bill proposed by the Appropriations Committee gave the Survey the full amount of the budget request, or the same funds as the year before. During the debate, the Bureau of Ethnology came close to being completely eliminated, and the appropriation for the Coast and Geodetic Survey was slashed. An effort was made to abolish the Coast Survey—the new Secretary of the Navy, Hilary Herbert and the new Secretary of the Treasury, John Carlisle, had agreed that it should be abolished and its functions transferred to the Hydrographic Office and the Geological Survey—but the motion to accomplish this went out on a point of order. The Sundry Civil Expenses bill was passed by the House on March 20 and sent to the Senate with only a slight reduction in Survey funds.

Congress had before it several other bills that affected the future of the Survey. In the first session, which repealed the Sherman Silver Purchase Act, Congressman William Breckenridge of Kentucky had filed a bill to transfer the Survey to the Department of Agriculture, and this bill was still pending. On March 13, Congressman Eugene Hainer of Nebraska had filed another bill to transfer the Survey to the Department of Agriculture, and on March 28, Senator Thomas Power of Montana had filed a similar bill in the Senate. The House Committee on Agriculture held hearings on the House bills, and Major Powell testified before the committee in favor of the Hainer bill, which was then reported favorably by the Committee. The Committee report stated that geology dealt directly with the soil and its formation, that the study of the structure of the Earth and soil had a bearing on the success of agriculture; therefore, geological investigations should be intimately connected with and essential to the development of the science of husbandry. Questions of proper water supply, irrigation, and drainage also affected agriculture and should be studied by the Department of Agriculture.

The report went on to say: "Being in harmony with the characteristic work of the Department of Agriculture and its various divisions, the Bureau of the Geological Survey will readily cooperate with that Department and will have the immense advantage of a supervisory administration in full sympathy with general scientific work and especially that which can naturally be coordinated with its own. While in its first organization, it was supposed this Bureau would have to do principally with mines and mining, yet the subsequent tendency and work has been in the direction of Agriculture until now the bulk of its operations affect most intimately the great farming interests. This necessary tendency was admitted by the efficient head of the Bureau, Major Powell, in his testimony before the committee and was urged by him as one of the great reasons for transferring the Bureau to the Department of Agriculture."

The recommendation was not one to be welcomed by the Secretary of the Interior. However, on May 4, 1894, 10 days before the committee filed its report, Major Powell had submitted his resignation to the President:

"I have the honor to tender my resignation as Director of the U.S. Geological Survey, to take effect on the 30th day of June proximo.

"I am impelled to this course by reason of wounds that require surgical operation.

"With deep gratitude for the confidence you have imposed in me,

"I am, with respect,

Your obedient servant,
J. W. POWELL"

It was, needless to say, unnecessary for Major Powell to resign solely because of the impending surgery. He was admitted to Johns Hopkins Hospital on May 13, but the surgery was successfully accomplished on the 14th, and he returned home after about a week. During that week, his effects were moved from the Survey office to the Bureau of Ethnology, which he continued to direct until his death in 1902.

When the Appropriations Committee filed its report on the Legislative, Executive, and Judicial Expenses bill on May 9, it was discovered that the Secretary of the Interior had requested a reduction of $1,000 in the salary of the Director, a device used by the administration to embarrass officials and force their resignation. When the bill came up for discussion in the House on May 24, Joseph G. Cannon, the ranking minority member of the Committee, asked the House to restore the Director's salary to $6,000 because Major Powell had already resigned and had been succeeded "by a gentleman from New York, Mr. Walcott."

On May 11, exactly 1 week after Major Powell submitted his resignation and 7 weeks before its effective date, President Cleveland had sent the nomination of Charles Doolittle Walcott as third Director of the U.S. Geological Survey to the Senate, and the Senate was ready to confirm the appointment at its session on May 28. The cut in the salary of the Director was not restored for several years, but none of the bills to transfer the Survey to the Department of Agriculture were passed.

Major Powell had lost support for himself and for the Geological Survey by antagonizing many members of the Congress, by leading the Survey in directions that they and others questioned or found inadequate, and by attempting to interject his own ideas into national policymaking—even lawmaking. His personal integrity and scientific abilities were never questioned, but his record as an administrator was not impressive. He pressed topographic mapping vigorously, recognizing that it provided a base not only for geologic and other kinds of mapping but for guiding and planning many activities having to do with the use of the land. However, though he

Hoke Smith

Secretary of the Interior in the second Cleveland administration, 1893–1896. Smith, only 37 when he became Secretary, was one of the foremost lawyers in Georgia, one of its largest real estate owners, and head of the Atlanta *Evening Journal,* then the leading afternoon paper in the South. Smith appointed Charles D. Walcott Chief Geologist and Paleontologist of the Geological Survey in 1893 and chose him as Director to succeed Major Powell in 1894. (Courtesy of the Library of Congress.)

Charles D. Walcott

Walcott began his career with the Geological Survey as an assistant geologist at $600 a year in 1879 and rose through the ranks to become its Director in 1894. A leading American paleontologist when appointed Director, Walcott demonstrated that a rare individual can successfully combine scientific research and the administration of science. (Courtesy of the Smithsonian Institution Archives.)

had long argued the importance of scientific and engineering management of mapping, in practice, he employed many with inadequate or no training, including congressional relatives, and some of his arguments for his approach to the Irrigation Survey merited the opposition they received. He built up an organization that did much to develop and expand knowledge and understanding of the geology of the United States, as the Academy of Sciences of France recognized in awarding its Cuvier Prize in 1891 to the collective work of the Geological Survey. Again, however, although he had stated in 1878 that a geological survey divorced from economic considerations and devoted to research chiefly for abstract science would have an uncertain tenure, he did not direct the Survey toward meeting the economic needs it was uniquely qualified to aid—those of the mineral industry. It remained to his successor, Charles D. Walcott, to combine the best of the King and Powell administrations into an organization that fulfilled the promise of 1879.

Chapter 9
In Aid of All Industry, 1894–1897

> **The survey should be carried on as a strictly scientific investigation, with the view of aiding in every possible manner the development of such material industries as are affected by it.**
>
> **—Charles Doolittle Walcott**

Walcott's appointment was greeted with cautious approval by geologists. The *American Geologist,* which had been so critical of Powell, said:

> **We trust that this change will augur the reorganization of the work on an efficient and economic footing, and that the Survey will, under Mr. Walcott's management, stand as high in the esteem of the scientific world and the general public as befits so important a department of government.**

The *American Journal of Science* hoped "that the selection of one of our ablest paleontologists to be Director will result in the application of the thorough methods of research, used by Mr. Walcott in his interpretation of the Cambrian, to all the departments of the United States Geological Survey." The Royal Geological Society of London awarded him the Bigsby Medal, saying in the citation, "Few men have attained to a more distinguished position in Geology, or have achieved a larger share of original work in twenty years, than Mr. Walcott." The Bigsby Medal is given "for eminent services" to a geologist "not more than 45 years old at his last birthday [Walcott was 44] thus probably not too old for further deeds, and not too young to have done much."

The mining fraternity more or less ignored the appointment; however, Clarence King, who had selected Walcott as one of the first Survey employees and had been so pleased with his work that he had doubled his salary the first year, issued a statement saying,

> **Walcott is a man of remarkable executive ability and the mining interests may rest assured that he appreciates the national importance of the Geological Survey and will use his best efforts to carry out the work to the advantage of all the mining communities in the country.**

Walcott's concept of the Survey and its role was more like King's than Powell's. Its function was not primarily to aid the development of science but to make strictly scientific investigations to aid the development of industries affected by its operations and, in fact, any practical object that could be advanced by a knowledge of the surface and interior of the Earth and its resources. The ends toward which the investigations might be directed were more extensive than those envisioned by King; on the other hand, the work of the Survey was geologic and topographic mapping, and aid to agriculture was limited to investigating the distribution and supply of mineral manures and to mapping the distribution of soils, (which were decayed rocks) and the distribution of artesian water and water supply in relation to geologic structure. Moreover, basic and applied science could not be separated. Critics who said that abstract studies should be left to the universities and the technical schools failed to recognize that

scientific or technical knowledge is necessary to the solution of any geologic problem, and that, if it is not already in existence, investigations must be made in order to obtain it for the purpose.

He said, tactfully, that the policy and administration of the Bureau under his predecessors had been "in the main, wise and efficient," but he planned certain readjustments designed to meet new conditions and to bring the Survey more in touch with the economic and educational interests of the country. These included an upgrading of the topographic maps and methods of mapping, placing the topographic mapping force under Civil Service, and a renewed emphasis on investigations in economic geology. Moreover, he planned to begin reconnaissance surveys immediately in areas of economic interest without waiting for the completion of topographic maps.

He planned no radical changes in personnel, but one thing he would insist upon, and that was an end to the factions and divisions that had rent the Survey. "Under the statutes the function of the Geological Survey is to make a topographic and geologic map of the United States, and to continue the examination of its geologic structure and mineral resources and products. To accomplish this successfully," he said, "unity of thought and purpose is essential among those engaged in the work."

The times were not auspicious for a renascence of the Survey, but in 3 years it was accomplished. Economic conditions improved during those 3 years, but the renascence of the Survey was accomplished not so much by additional funds as by taking advantage of every opportunity to engage the Survey in work that aided development of all industries affected by its operations and by a restoration of confidence.

During May and June, before Walcott became Director, economic conditions became worse. On May 11, 1894, the day that Walcott's nomination went to the Senate, workers at the Pullman Palace Car Company went on strike in protest against wage reductions, and railroad cars were looted and burned amid scenes of violence and bloodshed. On June 26, the head of the American Railway Union called its members out in sympathy with Pullman strikers, and railroads in the Middle West were paralyzed. On July 2, the U.S. Court issued an injunction against the railroad strikers, and Federal troops were sent to Chicago. Free-silver agitation increased, and on June 21 the Democratic Silver Convention met in Omaha, Nebraska. Led by William Jennings Bryan, a young Nebraska Congressman, the convention adopted a platform demanding a 16:1 silver-gold ratio.

Congress was again struggling with a new tariff bill. The problem was the reverse of that in 1890. The Democrats had promised tariff reform, but Democrats from the industrial East were as interested in protection as were their Republican counterparts. The appropriations bills had not been passed by the Senate, but Secretary Hoke Smith approved a plan of operations based on the amount in the House bills so that the Survey could begin work at the start of the fiscal year.

At the beginning of the fiscal year, as soon as Major Powell's resignation became effective, the two indpendent topographic divisions were consolidated under the name of the Topographic Branch and placed in charge of Henry Gannett. The Branch was then organized by class of work into the Division of Triangulation and the Division of Topography, and by locality of work into four sections. (This was similar to the organization King had established for geology at the beginning of the Survey.) The Atlantic Section, which included the Appalachian Mountain region and the Atlantic Coastal Plain, was placed under H. M. Wilson. The Central Section, which remained under J. H. Renshawe, was enlarged to include the States of the

Mississippi Valley, Minnesota, the Dakotas, Nebraska, and eastern Wyoming. The Rocky Mountain Section, covering the Rocky Mountain States and Territories and Texas, was placed in charge of E. M. Douglas. The Pacific Section, including California, Oregon, Washington, and Idaho, was placed under R. U. Goode.

Gilbert Thompson, the former chief of the Southeastern Section, was demoted and assigned to map the Bristol, Virginia, sheet. A. H. Thompson, the former head of the Western Division, was also demoted and instructed to extend triangulation from the transcontinental belt of the Coast and Geodetic Survey over the Colorado plains where primary control had been found "insufficient in accuracy." Marcus Baker, who had been serving without portfolio since the position of general assistant was abolished, was assigned to a new position as editor of topographic maps and charged with responsibility for establishing some uniformity in the character and quality of the maps and in the use of geographic names. Finally, on December 4, 1894, topographers were placed under Civil Service. After that date, appointments were limited to men whose qualifications had been tested by impartial examination.

Mapping was done in 21 States, more than a third of it in the Central Section. The number of square miles mapped was considerably less than in 1893—23,562 for the first time and 6,850 revised—but about one-quarter of it was done at the scale of 1:62,500, and no mapping was done at 1:250,000. Other changes had to wait until the following year.

The geologic work was organized, as in the preceding year, into 26 independent field parties, but now each party reported to the Director. Economic applications were again stressed, and the gold crisis obviously influenced the Survey's work. Becker and Emmons were quietly reinstated and given substantial allotments of funds. Becker undertook a reconnaissance of the gold areas of the southern Appalachians. Emmons went back to Leadville to reexamine the underground workings. The discovery of gold at Breece Hill had given new life to the district, but Emmons found that the deposits there were not essentially different in origin or manner of formation from previously opened deposits that had been mined principally for silver. The gold ores carried a considerable amount of silver; Emmons thought that their greater gold content was due to their proximity to a great mass of pyritiferous porphyry, and he predicted that other gold deposits would be found along the contacts between the porphyry and adjoining limestones. Whitman Cross made a reconnaissance of the gold belt in the western San Juan Mountains and the La Plata Mountains to determine the best order in which to take up the study of mining districts there before proceeding to Cripple Creek. George Eldridge was despatched to investigate extravagant tales of gold coming from the Snake River region of Idaho. Eldridge made a reconnaissance of the Snake and Salmon River basins, visited eight or nine mining districts, covered some 850 miles, 750 of them by pack train, and brought back information on the possibilities for grazing and agriculture as well as mining. Turner and Lindgren continued their mapping in the Gold Belt of California.

Four parties were assigned to investigate the mineral deposits in the Appalachian Mountains. Willard Hayes was assisted by A. H. Brooks, whom Professor Shaler had recommended as one of the most promising young men to graduate from Harvard that year. Hayes and Brooks mapped in the coalfields of Tennessee. Hayes studied the coal seams in detail and measured sections so that he could estimate the amount of coal available, and then moved on to Georgia and Alabama to examine the bauxite and phosphate deposits. Keith completed some mapping in the coal areas of

Charles Whitman Cross

Geologist of the U.S. Geological Survey 1880–1925. Cross was associated with Emmons in work in the Rocky Mountains for several years, and later undertook detailed field investigations in the rugged volcanic country of southwestern Colorado. He was one of the leaders in the development of petrography and petrology, and collaborated with Joseph P. Iddings, Louis V. Pirsson, and Henry S. Washington in proposing a quantitative chemico-mineralogical classification and nomenclature of igneous rocks. (Courtesy of the Smithsonian Institution Archives.)

Tennessee and then moved eastward to the area in Tennessee and North Carolina where iron deposits had been reported. M. R. Campbell again had Walter Mendenhall with him as he mapped in the coalfields of southern West Virginia, and Bailey Willis, assisted by J. A. Taff, late of the Texas survey, and N. H. Darton, mapped the Elk Garden coalfield of western Maryland and West Virginia.

David White, who was made a party chief for the first time, began the field season with Campbell, collecting and studying plant remains to correlate coal beds that were interrupted by faults or erosion. In October, he joined Bailey Willis to make similar collections in an attempt to correlate the coalbeds of Maryland and northern West Virginia with those of southern West Virginia and Tennessee. Young Mr. White suggested that the coal miners at New River in southern West Virginia were working two seams rather than four or five as had been generally believed. This was completely contrary to the accepted views of eminent authorities that the Coal Measures sequence of Pennsylvania extended unchanged along the entire Appalachian trough.

Professor Van Hise had several parties working in the Marquette and Michigamme iron districts in the Lake Superior region, tracing the iron-bearing formations by use of the magnetic needle where outcrops were few.

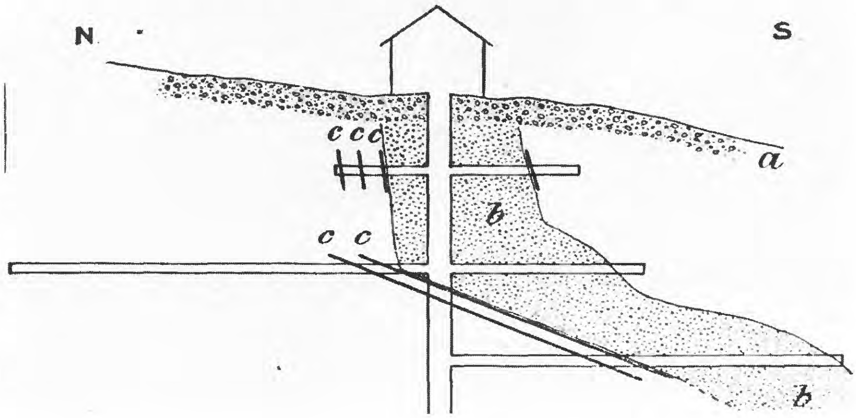
Walter Weed, again assisted by Professor Pirsson, continued mapping in Montana but also made reconnaissance investigations of the mineral deposits of the Little Belt Mountains. New economic projects were begun in Colorado and Texas. R. C. Hills, a geologist for the Colorado Fuel and Iron Company, and a former president of the Colorado Scientific Society, was engaged (at $8 a day) to make a study of the iron and coal region of south-central Colorado. R. T. Hill, assisted by T. Wayland Vaughan, who had just received his A.M. from Harvard, made a careful areal survey of the Austin sheet in western Texas, mapping both soil and bedrock in detail and studying the building stones, roadmaking material, rocks adapted to making water-lime cement, and artesian conditions as well as the fossil remains.

Even glacial geology turned out to have economic implications. Frank Leverett continued his study of the glacial deposits in Indiana, Illinois, Iowa, and Wisconsin, but two special problems engaged his attention: the possibility of a water supply in the drift, and the source and abundance of the natural gas which was being found in many places. Most important of all, Gilbert's mapping on the plains east of the Rocky Mountains continued to show the artesian-well districts and the regions in which water reached by the drill might flow out at the surface.

Neither Hague nor Diller did any fieldwork in the summer of 1894. As soon as he became Director, Walcott made it clear that he expected investigations that had been in progress for several years to be completed and the results published. Hague spent the summer working on the Yellowstone report, and Diller, on the bulletin on the educational series of rocks.

A great many bills in aid of irrigation had been filed in the House and Senate—to provide for irrigation surveys of the Great Plains and the semi-arid belt of country between the 97th meridian and the eastern foothills of the Rockies, to provide for irrigation surveys of various States, to provide for reclamation of the arid lands, to provide for the appointment of a commission to examine and classify the lands west of the 98th meridian with regard to their practical irrigation and use, and a host of others—but almost without exception, they had not been reported out by the committees to which they were assigned.

The Senate took up the Sundry Civil Expenses bill on July 31, 1894. In accordance with a recommendation from the Secretary of the Interior, the Committee on Appropriations proposed a reduction of $5,000 in the amount for topographic surveys, which would be offset by the new item of $5,000 for "gauging the streams and determining the water supply of the United



In 1894, Whitman Cross and R. A. F. Penrose investigated the Cripple Creek district southwest of Pikes Peak, where gold had been discovered in 1891. The hills containing the mines were almost entirely made up of volcanic rocks and Cross found a small vent in and about which there was a remarkably complete sequence of deposits typical of a true volcano. The gold occurred as free gold and calaverite, the telluride of gold, chiefly in vein deposits that filled fissures and fault planes around the volcanic vent and also blended laterally into the country rock, replacing it. (From C. W. Cross and R. A. F. Penrose, 1895.)

States," and also increases of $30,000 for geology, $2,000 for chemistry and physics, $3,000 for the report on mineral resources, and $10,000 for engraving and printing geologic maps.

On the following day, Senator William V. Allen of Nebraska proposed another item: "For the purpose of making an irrigation survey of the arid and semiarid lands of the United States, to be expended under the directon of the Secretary of the Interior, the sum of $100,000, or so much thereof as may be necessary." The Senate did not act on the amendment, and on August 2 he withdrew it, moving instead to increase the amount for gaging streams and determining the water supply to $25,000. He had in the meantime consulted the "experts at the Geological Survey" and was assured that the money would be judiciously spent. Senator Charles Manderson wanted to add "including the investigation of underground currents and artesian wells in arid and semiarid sections," which would make the amendment the same as one he had proposed on July 12, which was still bottled up in committee. Senator James Kyle of South Dakota spoke up. He too had been consulting the experts at the Geological Survey. They expected to include artesian wells in their studies, but it might be well to add the words to the amendment. The amendment was agreed to, the total for the Survey was raised to $434,100, and the bill passed the Senate on August 2.

The House's only objection to the changes made by the Senate was to the item for gaging streams, and in the conference, a compromise was reached whereby the item stayed in but the amount was reduced to $12,500. Enactment of the bill on August 18, 1894, provided authorization for

> **gauging the streams and determining the water supply of the United States, including the investigation of underground currents and artesian wells in arid and semiarid section**

as a function of the Geological Survey.

Once the appropriations bill had been passed, the Director headed west and met Emmons in Denver, where he consulted with a large number of mining engineers and others interested in geologic work in Colorado, and with Emmons he inspected the work in Cripple Creek. Walcott then went on to the West coast for 2 week's fieldwork on his beloved Cambrian and for further conferences with mining engineers and geologists in California, Oregon, Washington, and Idaho. Emmons took J. E. Spurr, a new assistant geologist, to the Marcur district in Utah, which had excited much interest because of the peculiar character and association of its gold-bearing ores, and left him to map the district.

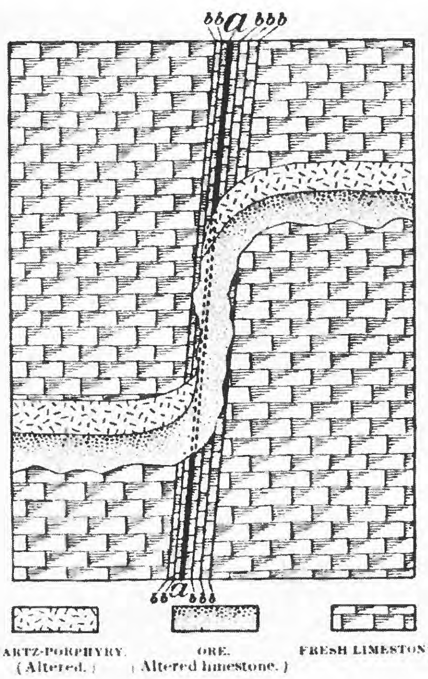
Newell chose Arthur Powell Davis as his principal assistant for the hydrographic work, and they both attended the sessions of the Irrigation Congress during the week of September 3, where Newell presented a paper on the water supply of the public lands. On his return to Washington after the Irrigation Congress of 1893, Newell had resumed the compilation of data on water supply. During the winter, several assistant topographers had aided him in assembling data showing the relative area and position of the vacant public lands and the relation of these lands to the water supply. Maps showing the mean annual runoff and the distribution of wooded areas in the Western United States were also compiled to illustrate in a broad way the relation of topography and runoff to vegetation.

At the conclusions of the sessions, the Irrigation Congress voted to ask "that sufficient appropriation be secured from the General Government for carrying out the work of discovering waters, applicable to the reclamation of the arid lands, and for the prosecution of surveys necessary to determine the location of lands susceptible of irrigation, and the selection and segregation of reservoir sites." The first Irrigation Congress, in 1891, had endorsed the work in the Department of Agriculture, but this Congress chose not to make any recommendation. Secretary of Agriculture Morton declined to send a representative to the Irrigation Congress, stating bluntly that the questions the Congress considered had nothing to do with practical irrigation and that the Congress met simply to petition for grants of lands and a cession of whatever control of ownership the General Government had of the waters of the arid region. The delegates to the Denver Congress were offended by Secretary Morton's remarks but were not quite ready to endorse the work of the Geological Survey, so they voted to "let Congress, in its wisdom, decide" which agency should do the work.

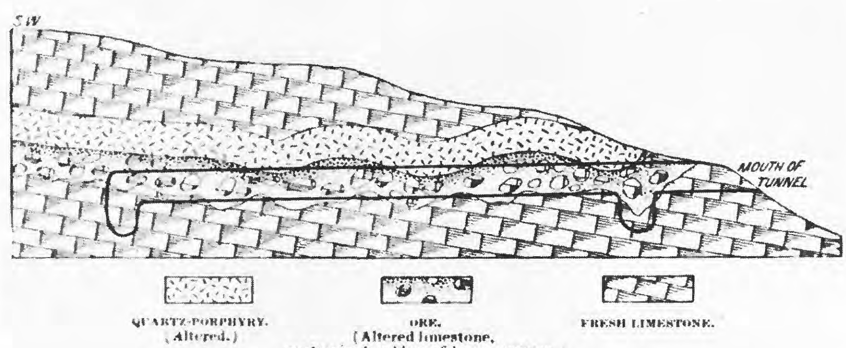
Newell and Davis began fieldwork as soon as possible after the Congress, making river measurements and reestablishing stations in Colorado. After visiting several river stations together and arriving at an understanding of methods and results desired, they separated. Davis headed west to spend 5 months visiting Utah, Idaho, Washington, Oregon, California, Arizona, and New Mexico, where the Irrigation Survey had undertaken work, before taking up work in Kansas. Newell, however, proceeded east and north to obtain general information on local conditions and to start fieldwork in the subhumid States. The services of Robert Hay were secured to make a general reconnaissance of the country along the 102d meridian from a point near the North Platte River in Nebraska through eastern Colorado and western Kansas to a point on the headwaters of the Smoky Hill River. Newell then went to the James River Valley in South and North Dakota, visiting artesian wells, then to Minnesota, where he measured the flow of the St. Louis River at Cloquet; he then proceeded southward through Kansas and Oklahoma to Texas, where he spent some time with R. T. Hill examining springs and artesian conditions.

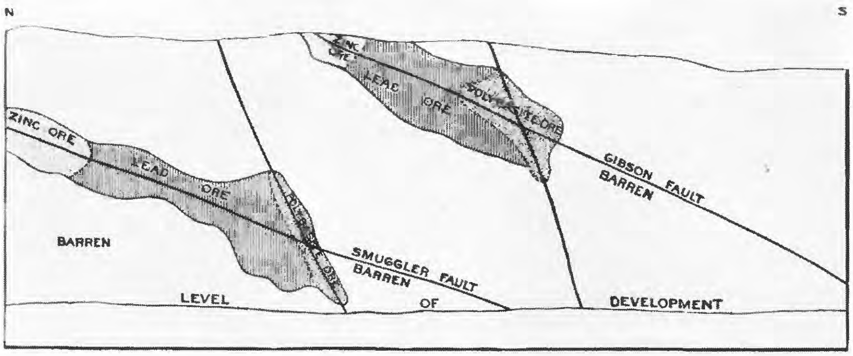
Congress had included in the Sundry Civil Expenses bill a provision, which became known as the Carey Act, authorizing the President to grant to each public land State a maximum of 1 million acres within its boundaries to aid in their reclamation. The States were required to file maps showing their plans for irrigation and the sources of water in much the same way that individuals had been required to do under the General Revision Act of 1891. The grants were somewhat less than the Irrigation Congress had wanted, but perhaps more than they expected.

Congress finally adjourned on August 28, after passing the Wilson-Gorman Tariff Act, which made only a nominal dent in the protective system and which Cleveland denounced as "party perfidy and party dishonor" although he let it become law without his signature. Among the bills that were not passed was one introduced on July 26 by Senator Watson Squire of Washington, largely written by Emmons and Willis, to make the western

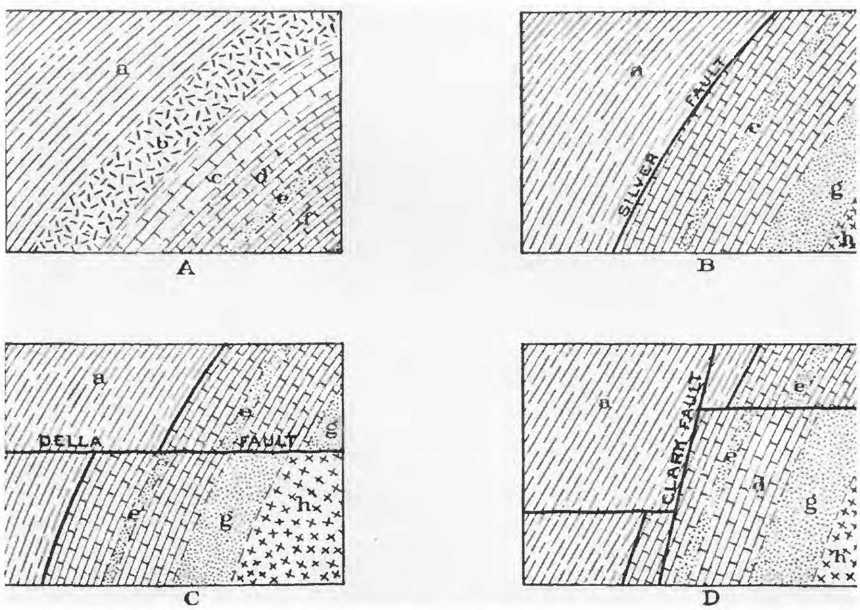


▲ J. E. Spurr, who studied the Mercur district of Utah in 1894, found that there had been two periods of mineralization, in each of which the ore minerals were deposited mainly along the lower contact of a porphyry sheet. The intrusion of the igneous materials produced a somewhat porous or brecciated zone in limestone which the mineralizing solutions ▶ reached through fractures or fissures extending downward from the respective sheets. The minerals of the earlier period, Spurr theorized, were pressed out of the cooling body of porphyry with the included water and brought to their present position in aqueous solution; the later minerals came from fumarolic vapors from an unknown body. (From J. E. Spurr, 1895.)





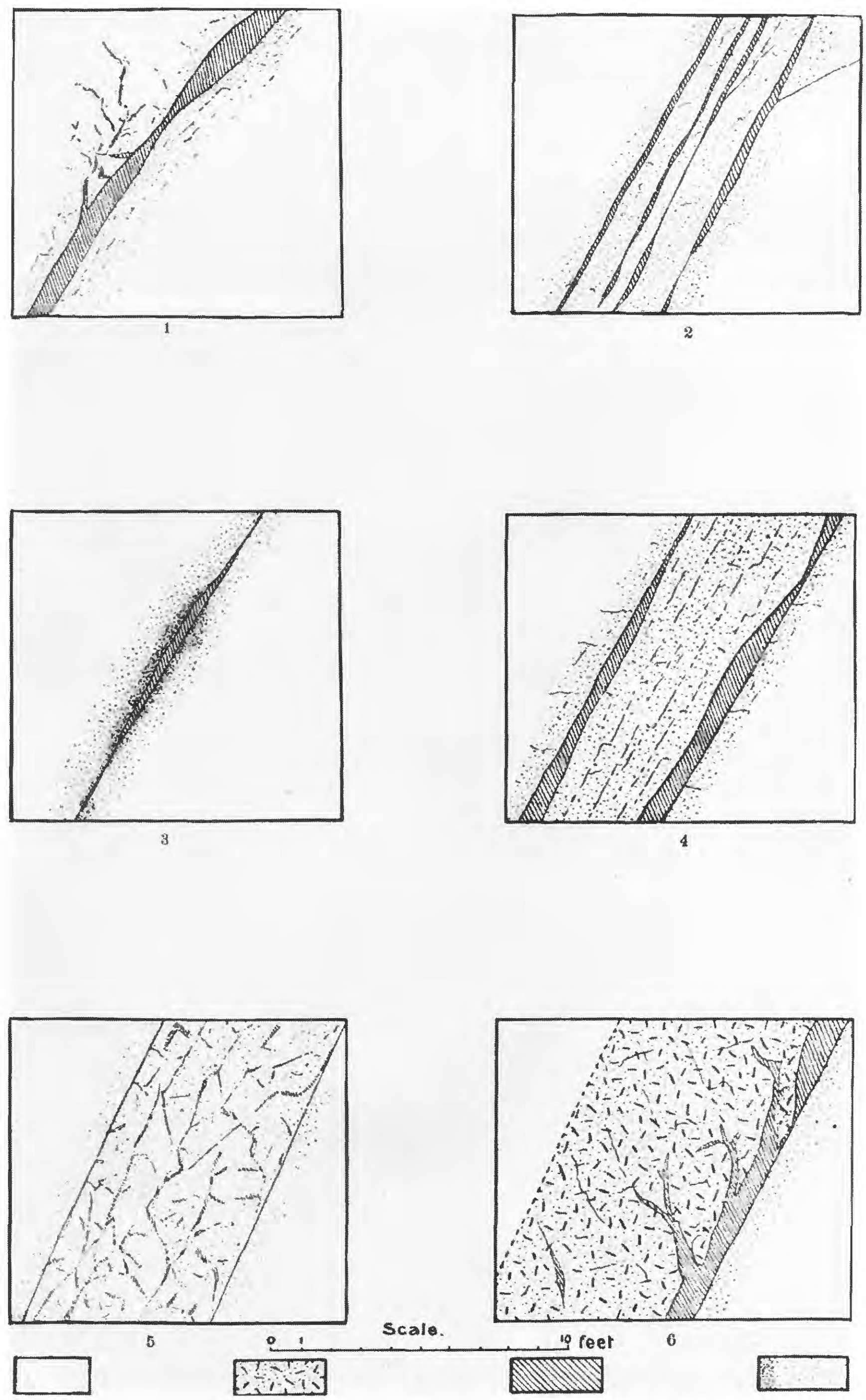
Spurr's investigation at Aspen, Colorado, in 1895 confirmed Emmons' conclusion, after a hasty reconnaissance in 1887, that the ore had been deposited along fault planes. The mines, however, were mostly discovered and opened by men who had been at Leadville and who expected the ore to be at or near the contact of limestone with porphyry. Spurr found that ore was deposited during formation of the Della fault system, to which the Gibson and Smuggler faults belong, and that later faulting produced two ore bodies where there had been but one. (From J. E. Spurr, 1898.)



part of the Pacific Forest Reserve Mount Rainier National Park. Emmons and Willis were members of a committee appointed by the Geological Society of America to memorialize Congress on the subject. Committees had also been appointed by the American Association for the Advancement of Science, the National Geographic Society, the Sierra Club, and the Appalachian Club, but most of the work devolved on Emmons and Willis because of their location in Washington. Congress was reluctant at the time to create new parks because of the expense involved and because of the opposition of those who had other plans for the land, and so the bill was not passed.

The economic situation was still precarious, and the electorate expressed its feelings in the midterm elections in November 1894. The Democrats were swept out of office, and the Republicans gained 117 seats in the House so they would control the new Congress by a large majority. In the Senate, six Populists held the balance of power between Republicans and Democrats. The gold drain continued, and in November it was necessary to place a new loan. Early in 1895, the gold reserve dropped to $41 million. President Cleveland then called in J. P. Morgan, and a third loan was placed with a banking syndicate, arousing the ire of both Populists and bimetallists. Under such circumstances, economy was the order of the day in Congress.

The new Commissioner of the General Land Office, S. W. Lamoureux, in his report written in the fall of 1894, suggested that changes were necessary in the system of surveying the public lands, and that there would be possible advantage in having the Geological Survey supervise the public land surveys. Secretary Smith agreed with the Commissioner, and the President endorsed the change in his state of the Union message. At the request of the Interior Department, an amendment was added to the Sundry Civil Expenses bill "that such portions of the public lands as may from time to time be designated by the Commissioner of the General Land Office shall, upon the order of the Secretary of the Interior so directing, be surveyed under the supervision of the Director of the Geological Survey, by such persons as may be employed by or under him for that purpose. * * *" The Secretary explained that "By this amendment it was intended that an op-



Lindgren pointed out that Emmons' theory of the deposition of ores by replacement had been extended beyond its proper bounds by many geologists and mining engineers. A solution of silica might simply deposit silica as a cement or might fill interstices of porous rocks as well as replace other minerals. There might be only minor alteration of surrounding rock with quartz filled open spaces in fissure veins, or there might be a wide belt of altered rock where the country rock was cut by several fault planes along which only small open spaces formed, or areas of country rock altered if there were a shattered zone. (From W. Lindgren, 1898.)

portunity should be given to try the experiment of executing surveys through the Geological Survey. If it proved satisfactory and economical it could then be enlarged until it included the entire work and dispensed with the offices of surveyor-general."

On December 17, 1894, shortly after the 53d Congress had convened for its final session, Messrs. C. W. Haskins and E. W. Sells, accountants employed by the Dockery Commission on efficiency and economy in the Government, submitted a report on the surveying and mapping activities of the Government. It was their recommendation that all surveying and mapping activities be combined in two bureaus, a U.S. Survey for all land surveys, including geologic and scientific investigations, and a Hydrographic Survey for mapping and investigations at sea. The office of Surveyor-General in the Land Office could then be abolished. The Haskins-Sells report leaned heavily on Powell's 1878 report on "Methods of Surveying the Public Domain" to justify and explain its conclusions. Only one more recent opinion was cited, a short memorandum identified only as "recently prepared in the office of the Director of the Geological Survey," which stated that the topographic and General Land Office surveys could be combined with certain advantages and economies in each bureau.

Secretary Smith, in transmitting the proposed amendment to the Sundry Civil Expenses bill, had pointed out that if the policy were adopted it should also be applied to the surveying of the Indian lands, and Congress chose to apply it there first. The Indian bill was reported out on January 12, with a statement that is apparently the memorandum referred to by Messrs. Haskins and Sells. The statement was unsigned, but the Director of the Geological Survey was clearly responsible. There would be a saving in time, the memorandum said, by having the Geological Survey do the work, the maps would be more complete because they would include topography, they would be correctly located by latitude and longitude, and they would be made more economically. Moreover, the author of the memorandum promised, "If this work is assigned to the Geological Survey, both the land parcelling surveys and the topographic surveys will be made, and in addition I shall have made at the same time by a geologist a geologic reconnaissance that would furnish information in relation to mineral and agricultural lands and the natural resources of the areas surveyed."

On January 14, Congressman Dockery filed a bill in the House to consolidate the Geological Survey and the Coast and Geodetic Survey. It was referred to the Committee on the Status of Laws Organizing Executive Departments and was reported back favorably on February 28 with the Haskins-Sells report as the Committee report. As the 53d Congress was due to expire on March 4, there was no time to act on the bill. By that time, however, the Indian bill had already been passed by both houses. Congress had been attracted by the bargain offered, and in the Indian bill, $200,000 was appropriated for the subdivision of lands in the Indian Territory that were to be thrown open to settlement, with the proviso that the Secretary of the Interior could, if he chose, have the surveys made under the supervision of the Director of the Geological Survey.

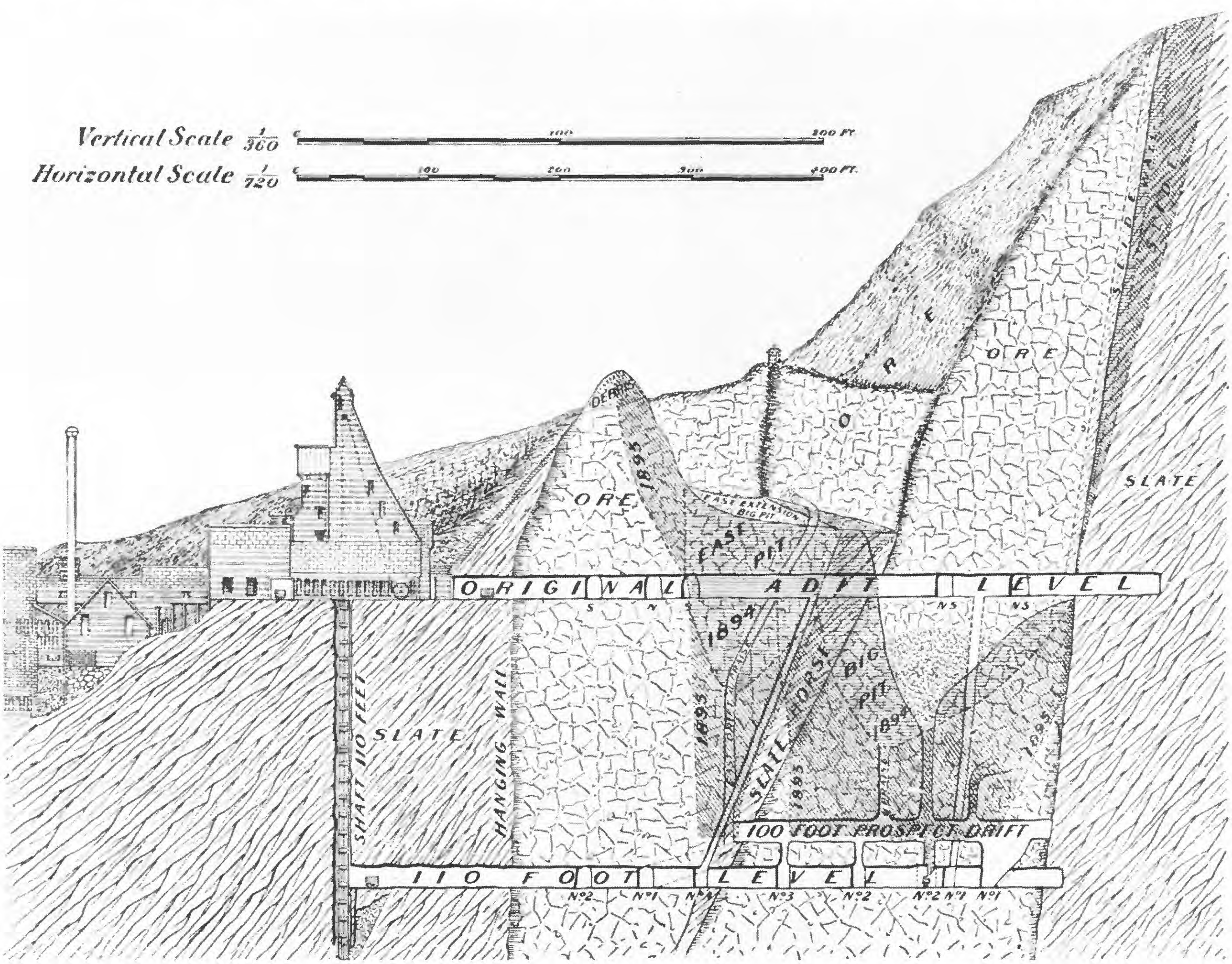
The conduct of the Indian Territory surveys was important to the future of the Survey. On March 13, 1895, under instructions from the Secretary, the Director assumed charge of the Indian Territory surveys and submitted a plan of operations which called for the Survey itself to survey all township exterior and standard lines and for the subdivision of townships to be done by experienced men hired temporarily for the purpose. The total area to be surveyed was estimated as 23,850 square miles, and the appropriation was sufficient for the survey of half the area. The plan was approved on March

21, and Charles H. Fitch was placed in direct charge of the work. The requisite animals and camp equipment were purchased and shipped to South McAlester in the Choctaw Nation, and by the end of March, two parties under G. T. Hawkins and W. J. Peters were in the field ready to begin running standard lines. Two more parties were placed in the field early in April to run township exteriors, and shortly thereafter, eight more parties were ready for running subdivision lines.

The regular appropriation for Survey expenses was included in the Sundry Civil Expenses bill which was passed on March 3. While most of the items were the same as for the preceding year, those for stream gaging and the report on mineral resources were increased by $7,500 and $3,000 respectively, and a new item provided $5,000 for an investigation of the coal and gold resources of Alaska. The appropriation for work in Alaska was the result of a last-minute amendment by Senator Squire of Washington, who quoted large parts of the annual report on mineral resources in support and insisted that the appropriation for geologic surveys was already too small and that this must be an addition.

The appropriation of $5,000 for work in Alaska was given the same treatment as the $200,000 for Indian Territory surveys. Becker was despatched to Alaska with Chester Purington as his assistant to make the gold investigations, W. H. Dall was to examine the coal deposits. They were

George F. Becker made the Survey's first investigation of Alaska's gold resources in 1895. The Alaska-Treadwell mine near Juneau was famous for its large yield and economical working. The ore ran only $3.20 a ton, but the total expense of treatment was only $1.35 so the profit was high. These results were obtained because of the situation of the mine—coal, machinery, and other supplies could be procured with ease and waterpower was available for part of the year. (From G. F. Becker, 1898.)

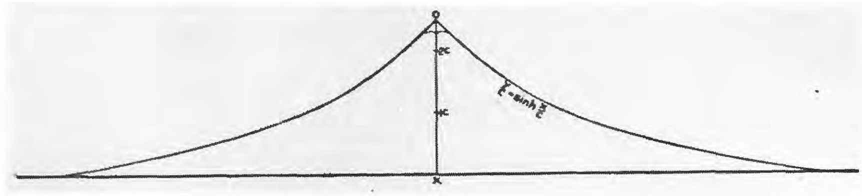


instructed to examine the deposits in the vicinity of the shoreline and islands along the coast of the Territory but not to attempt to penetrate into the interior. The Navy made the U.S.S. *Pinta* available for the investigations in the Alexander Archipelago. Then Dall went on his way in the Coast and Geodetic Survey steamer *Patterson* to study the coalfield near Kaotznahoo Inlet, after which he coasted along the south side of the Alaska Peninsula to the head of Cook Inlet, thence to Kachemak Bay, and finally to Unalaksa by way of the Shumagin Islands. Becker and Purington took the sail steamer to St. Paul, on Kodiak Island, and there secured a small tugboat of 24 tons, gross, in which they made a cruise of more than 1,300 miles. They then took the mail steamer to Unalaska and at Dutch Harbor chartered a steamer for a visit to Bogoslof and Grewingk. The party returned from Dutch Harbor to San Francisco on the *Bertha* with its cargo of sealskins.

Dall established the fact that large fields of fairly good quality brown coal existed on the eastern shore of Cook Inlet, that the coals of Alaska were all brown coals, and suggested that with the use of sufficient capital and proper business methods, a California market for the coals should be found. Becker and Purington recorded a considerable number of gold-bearing veins, found the beach mining attractive because of the ease of working but uncertain of success because of the "capriciousness" of the distribution of pay streaks. Becker reported that "The physical conditions of the Alaska coast can not be said to be unfavorable to mining. In spite of the high latitude, the winter is not severe. The summer is never hot. The precipitation, however, is great. In the region eastward of the center of Kadiak, timber is extremely abundant, so much so as to make prospecting laborious where it is not fairly impracticable. West of the line indicated there is no timber. The sea, of course, affords ready means of transportation for the entire coast, but navigation is often somewhat perilous." Becker took advantage of the opportunity to make other observations. His report contained as much if not more information on volcanoes as it did on gold.

The regular topographic work of the Survey in 1895 was carried on by 3 triangulation parties and 33 topographic parties. The topographic parties worked in 24 States, in most of them in close relation to the needs of the geologic parties, and altogether, 48,066 square miles was surveyed, nearly 1.6 times as much as had been mapped in the preceding year. The three triangulation parties were headed by A. H. Thompson, who continued work on the plains of southern Colorado, S. S. Gannett, who began triangulation in the Cascade region of Washington, and W. T. Griswold. Griswold began work in the Coast Ranges of Oregon, but forest fires made it impossible for him to continue, so rather than waste time, he shifted to Washington, ran primary traverse lines for control of the Tacoma and Seattle sheets, and then returned to Oregon in October after the early rains cleared the smoke.

Early in July 1895, Walcott met in conference with T. C. Chamberlin, S. F. Emmons, C. R. Van Hise, Arnold Hague, G. K. Gilbert, Henry Gannett, and Bailey Willis to consider changes in the explanatory text printed on the inside covers of the folios of the Geologic Atlas. The important advances that had been and were being made in petrography and in geologic nomenclature are shown by comparison of the 1889 and 1895 texts. In 1889, "surficial" rocks were defined as "composed chiefly of clay, sand and gravel, disposed in heaps and irregular beds, usually unconsolidated;" in 1895, "superficial" rocks "embrace the soils, clays, sands, gravels, and bowlders that cover the surface, whether derived from the breaking up or disintegration of the underlying rocks by atmospheric agencies or from glacial action." In 1889, sedimentary rocks were "conglomerate, sandstone, shale, and limestone, which have been deposited beneath



Becker observed that the volcanic belt of Alaska included both symmetrical cones and irregular masses and thus that similar lavas could produce mountains of very regular or very irregular geometry. He determined mathematically the loftiest figure of given volume and continuous curvature that could be built of successive showers of ash and found that the curve shown agreed remarkably well with the form of volcanic cones shown in photographs. (From G. F. Becker, 1898.)

seas or other large bodies of water and have usually become hard;" in 1895, sedimentary rocks were "all rocks which have been deposited under water, whether in sea, lake, or stream" and which usually hardened into conglomerate, sandstone, shale, or limestone but might remain unconsolidated. In 1889, a class of rocks was recognized and called "Altered rocks of crystalline texture;" these were "rocks which have been so changed by pressure, movement and chemical action that the mineral particles have recrystallized." In 1895, metamorphic rocks were treated as igneous or sedimentary rocks altered under the influence of dynamic and chemical forces, the alteration involving a rearrangement of particles, a change in chemical or mineralogic composition, or a change in structure.

The geologic time scale was also revised. Archean was again used to designate the oldest rocks, below the Algonkian, which had been defined as the oldest in 1889. At the other end of the scale, Pleistocene was again adopted instead of Neocene to designate the youngest rocks. No changes were made in the Cambrian, Devonian, or Cretaceous designations, but the Silurian became Silurian including Ordovician, the Carboniferous, the Carboniferous including Permian, Juratrias or Triassic and Jurassic might be used, the Eocene became Eocene including Oligocene, and the Neocene, Neocene including Miocene and Pliocene.

At the conclusion of the conference, it was agreed that the new text would be used in Folio 21 and subsequent folios, and that, although no folios had been issued while Major Powell was Director, his name would be placed on the first 20 in recognition of the long-continued and important preliminary work done under his direction.

Geologic fieldwork in the summer of 1895 was carried on by 28 parties. Most of the work was geologic mapping, stress again being placed on areas of economic interest. The geologic work at Aspen, Colorado, for which the mineowners had petitioned the Survey in 1891, got underway with J. E. Spurr, assisted by G. W. Tower, doing the mapping. Emmons had been ill in the spring and was unable to start fieldwork at the beginning of the season but arrived later in the summer to make the underground exploration. Whitman Cross began the mapping of the Telluride district in Colorado. Cross' work was purely areal geology, but it was anticipated that the geologic map would be of service in the development of the gold and silver mines in the area. George Eldridge had another special assignment—an examination of the mineral resources of the Uncompahgre and Uinta Indian Reservations, with special reference to the deposits of hydrocarbon compounds of the asphalt series. R. C. Hills continued mapping the coal and iron areas of south-central Colorado. In California, Turner and Lindgren continued mapping the areal geology of the Sierra Nevada. Turner, who was assisted by F. L. Ransome, was mapping in the heart of the gold belt. Lindgren, assisted by Herbert C. Hoover, a young mining engineer recently graduated from Stanford, mapped the eastern slope where two distinct dislocations were recognized, one corresponding to the Neocene base level and the other probably to the Cretaceous base level.

To serve the economic interests of the Pacific Northwest, two new investigations were begun. Bailey Willis, with George Otis Smith, a graduate student from Johns Hopkins, as his assistant, began reconnaissance work in northwestern Washington, visiting Mount Rainier, the Wilkeson and Green River coalfields, the Snoqualmie section of the Cascade Range, the Silver Creek and Monte Cristo mining districts, and the iron and coal deposits along the Skagit River. Diller spent a busy summer in northwestern Oregon, making reconnaissance surveys, even though no topographic maps were available, of the coalfields of the Coast Range as well as other economic deposits. He reported that the black sands along the coast contained not only gold but silver, nickel, platinum, and other precious metals and that a new machine, the Rossman concentrator, was being used to recover the gold with some success.

After Emmons completed his work at Aspen, he visited the Silver Cliff and Breckenridge districts to prepare for future detailed work, then joined the Director in an examination of the Butte, Montana, district to arrange for a geological survey there in 1896, and then with the Director and Walter Weed visited the Coeur d'Alene district of northern Idaho. They decided the Coeur d'Alene and Lake McDonald districts would have to be mapped with great care before any reliable data could be secured that would be of value in the further development of their mining industries. The Director concluded that a base line should be established near Spokane, Washington and that the mapping should be pushed eastward across northern Idaho and northward up the Columbia River valley to the Canadian boundary.

Weed was being drawn into economic work. He spent most of the summer in reconnaissance in northern Montana, Idaho, and northeastern Washington, and for a time was detailed to a Presidential Commission to help negotiate with the Blackfoot and Fort Belknap Indian tribes. He also made a reconnaissance of the Bear Paw Mountains and their rare types and unusual associations of rocks, and he examined the coalfields of Chinook and Havre.

Van Hise mapped chiefly in Michigan's Upper Peninsula and Wisconsin. He outlined three Huronian troughs, but apparently none of them contained members as high as the iron-bearing formation, so the principal economic result was negative.

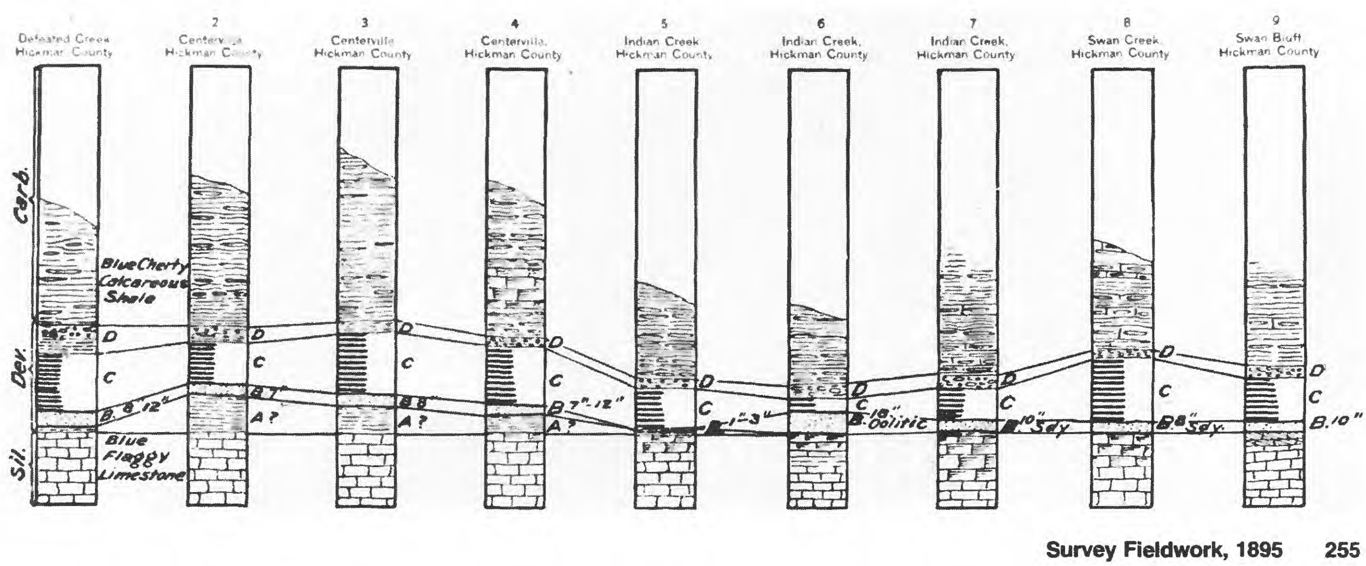
In the eastern coal areas, Taff was given charge of a party, and with Brooks to help him, mapped the Buckhannon sheet in West Virginia. Campbell, again assisted by Mendenhall, continued the survey in the area immediately southwest of where Taff was working; they found that David White's claim that the Quinnemont and Fire Creek coals were one and the same was fully borne out by the structural evidence. White himself was again instructed to cooperate with those mapping on the line of the Appalachian coalfields; he spent the early part of the season with Taff, then worked with Campbell, and finally mapped on the southwestern border of the Tennessee coalfield, all for the purpose of correlating the various coal horizons. In New England, Professor Shaler completed a survey of the Narragansett coalfield.

Hayes, accompanied by two, for part of the season three, assistants, went back to the southern Appalachians and mapped or remapped more than 3,000 square miles, about one-third in reconnaissance, in Georgia, Alabama, and Tennessee. Special attention was given to the gold belts, the extensive limonite deposits, most of which Hayes found were at the top of the Knox and base of the Chickamauga, at the top of the Weisner, and along fault lines. He also collected all available data on the thickness and quality of the bedded phosphate and the extent of nonbedded phosphate in Tennessee so that he could represent graphically, with a fair degree of accuracy, the extent of workable phosphate.

There were more mapping projects in which economic interest was not stressed than in the preceding year, in part because several professors joined the staff during their summer vacations. In New England, T. Nelson Dale continued the mapping of the slate belt, and Professors Emerson and Hobbs resumed the mapping in central Massachusetts. Professor Clark continued areal mapping in central New Jersey. Arthur Keith began mapping the Frederick, Maryland, sheet and made a special study of the crystalline rocks from the vicinity of Washington southeast across Virginia into North Carolina. N. H. Darton began mapping in Virginia just southeast of the coalfields. The State map of New York had been completed, and an edition of 1,000 copies was published in January 1896, concluding the cooperative work begun by McGee in 1884. In Texas, R. T. Hill, with T. W. Vaughan and T. W. Stanton as assistants, completed the long studies of the Cretaceous formations that had been begun by C. A. White. Incidentally, they also obtained information on the asphaltum beds of southwest Texas and the new and commercially valuable coalfields of trans-Pecos Texas, which Vaughan and Stanton said belonged to a new coal horizon.

In California, Professor Lawson continued the study of the geology of the San Francisco Bay area, and Professor John C. Branner of Stanford University, the former State Geologist of Arkansas, began a reconnaissance preparatory to a survey of the Palo Alto sheet. Only Hague stayed home, working on the data and material collected during his 9 years' work on Yellowstone National Park.

The Hydrographic Section was transferred from the Topographic Branch to the Geologic Branch, with which its work was more naturally associated. The field operations were gradually differentiated into three classes of work: The first, of a somewhat strictly engineering character, having to do with the measurement of surface streams and the consideration of water supply through storage of flood waters in reservoirs; the second, of a geologic nature, consisting of detailed examination of the underground structure and permeability of water-bearing rocks; and the third, for which Newell himself was chiefly responsible, a general reconnaissance to obtain information on methods of utilizing water supply for power, irrigation, or domestic purposes.



C. W. Hayes made some of the earliest Survey investigations of nonmetallic mineral resources. He divided the phosphates of Tennessee into two groups, a black phosphate deposited in its present position and a white phosphate composed of material moved from its original position and redeposited in another form. Hayes used sections such as these to show the variation of the phosphate beds in relation to adjacent formations. **B** is a bedded phosphate 0 to 40 inches thick. (From C. W. Hayes, 1898.)

As soon as its appropriation was assured, hydrographic work had been resumed in the East with Cyrus Babb in charge. The Potomac stations were renewed and extended, work was started in Virginia and North Carolina as the beginning of a systematic examination of waterpower in the Appalachian area, and preliminary work was begun in anticipation of an investigation of rivers in the New England States. Resident hydrographers were employed for some of the river gaging, and much of it in the East was placed in charge of Professor D. C. Humphreys of Lexington, Virginia, and Professor J. A. Holmes, the State Geologist of North Carolina.

Several geologists contributed to the second class of investigations—Frank Leverett, N. H. Darton, R. T. Hill, and especially G. K. Gilbert. Hill, as part of his studies of the Cretaceous in Texas, obtained data on the occurrence of underground water. Darton spent 2 months in North and South Dakota obtaining data on artesian-well prospects. Leverett, who was preparing a voluminous report on the Illinois glacial lobe, used his data to prepare a special report on the water resources of Illinois. Gilbert spent most of the 1895 field season in reconnaissance in Colorado and Kansas on water-related problems. He found that the artesian water of the Arkansas Basin

Frederick Haynes Newell

Newell was largely responsible for the early development of water-resource investigations in the Survey. He joined the Geological Survey when the Irrigation Survey was authorized in 1888, and was placed in charge of hydrography in 1894. Newell played an active role in the enactment of the Reclamation Act of 1902 and was the first Chief Engineer of the Reclamation Service. He left the Survey in 1907 to become Director of the Reclamation Service when it became an independent bureau. (Courtesy of the Library of Congress.)

was obtained from sandstones of the Dakota formation and that, although the Dakota was variable in thickness and arrangement, the overlying shales and limestones of the Benton, Niobrara, and Pierre were remarkably uniform in thickness and character. Thus, when the geology was mapped in detail, the depth to which it would be necessary to drill at any point in order to reach water-bearing rocks could be indicated with considerable precision, and the regions in which the water might be expected to rise to the surface could be approximately located. (In so doing, he confirmed what Emmons had predicted in 1883.) He also found that the extensive gravel and sand deposits of the uplands on both sides of the Arkansas Valley formed a reservoir in which part of the scant rainfall of the plains was stored, and that this body of water, popularly known as the underflow, did not have an inexhaustible source in the Rocky Mountains as many believed.

Arthur Powell Davis

Topographer and hydrographer of the U.S. Geological Survey 1882–1907, a nephew of Major Powell, Davis became Newell's chief assistant in hydrography and in the Reclamation Service. He succeeded Newell as Chief Engineer of the Reclamation Service in 1907 and as its Director in 1913. One of his great achievements was the conception and development of the plan to harness the waters of the Colorado River by erecting a dam in Boulder Canyon. (Courtesy of the Library of Congress.)

The Hydrographic Section also undertook a special assignment for the Secretary, and the first step was taken toward the direct involvement of the Federal Government in irrigation projects. The Indians at the Gila River Indian Reservation had been self-supporting and had carried on irrigation for centuries by means of water drawn from the Gila River. However, that river flowed for several hundred miles through arid lands susceptible to cultivation by irrigation, and those lands were being disposed of by the Federal Government. As the amount of water in the river was not enough to supply lands all along its course, the Indians on its lower reaches were being deprived of their only means of support. The Secretary directed that $3,500 of the Indian Act appropriation be spent to investigate conditions, and Arthur Davis was despatched to see what could be done.

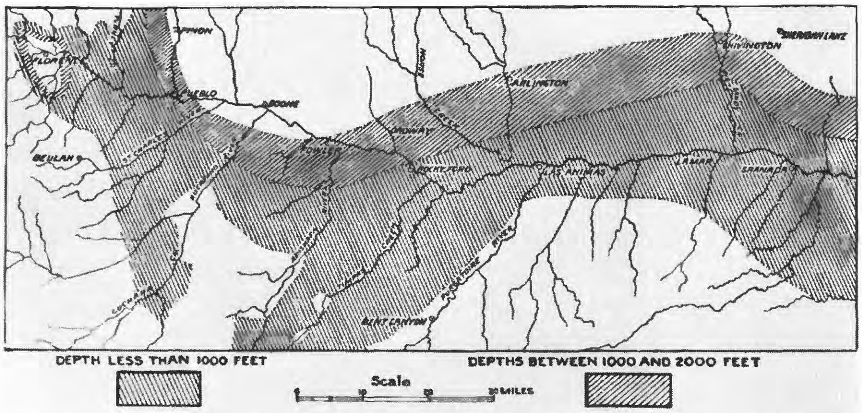
The Fourth Irrigation Congress, which met at Albuquerque in September 1895, did a complete turnabout from the first Congress and resolved

> **That [the U.S.] Congress, at its next session, be most earnestly requested to appropriate $250,000 for the continuation of the Irrigation Survey as heretofore carried on under the direction of the Department of the Interior.**

The Congress also asked that laws be enacted so that people could obtain title to the arid public lands without being subject to excessive charges for water for irrigation, declared that irrigation works should be supervised by public authority so that only works of a proper engineering character were constructed and life and property conserved, asked for appointment of an international commission to act in conjunction with the Mexican and Canadian authorities in adjudicating conflicting rights on international streams, and demanded an extension of the policy of forest reservations because

> **The issue of a proclamation neither prevents nor quenches forest fires, nor stays the ax of those who plunder the public domain.**

Economic conditions improved somewhat during 1895. Although the wholesale price index of farm products was still declining, the mineral industry had made a long step toward recovery from the depression. The total value of mineral products was nearly $100 million more than in 1894 and only slightly less than in the record year of 1892. In terms of quantities produced, 1895 actually exceeded 1892, but prices were lower. The increase in pig-iron production was a remarkable one, about 42 percent. Coal production was also up, and there was a notable increase in the production of petroleum, especially in Ohio, Indiana, and California and from the southward extension of producing districts in the Appalachian area. The United States shared in a general world increase in gold production—nearly all gold-producing States produced more gold but the largest amount came



G. K. Gilbert, who began a study of the geology of the Great Plains east of the Rocky Mountain front in 1893, was able to draw an economically valuable map showing areas in which artesian water might be obtained. Gilbert confessed, however, that he drew the map with much reluctance because it was impossible to give adequate expression to doubt and the data were too imperfect to fix the lines definitely. (From G. K. Gilbert, 1896.)

from Cripple Creek and other new camps in Colorado. The value of the gold product was $39,500,000 in 1894 and $46,610,000 in 1895. The Treasury's gold reserve dipped to $79 million in December 1895, and another loan had to be undertaken, but this time it was not necessary to resort to the bankers. The loan was thrown open to the public and quickly subscribed.

The estimate of funds needed for the next fiscal year submitted to Congress was only $2,000 more than the appropriation for 1895–1896. An increase of $2,000 was requested for the report on mineral resources, and some minor adjustments were made in other items. It happened, however, that the 16th annual report, for Walcott's first year as Director, was in press when Congress convened in December, 1895, and the 16th annual report differed in several important respects from its predecessors, being published in four parts, of which Part II consisted of "Papers of an economic character," and Parts III and IV the reports on *Mineral resources of the United States, 1894*. The papers of an economic character were on the Cripple Creek district by Whitman Cross and R. A. F. Penrose, Jr.; on the Mercur district, by J. E. Spurr; on the reconnaissance across Idaho, by George Eldridge; on road-building stones, by Professor Shaler; on the public lands and their water supply by F. H. Newell; and on the water resources of a portion of the Great Plains, by Robert Hay. The session was only a few days old when on December 9, Senator Henry M. Teller, a Silver Republican but from Colorado, submitted a resolution that there be printed "at the earliest day practicable" 5,000 copies of the Cripple Creek report, 2,000 for the Senate, 2,500 for the House, and 500 for the Geological Survey. The House agreed after amending the resolution to provide 1,500 for the Senate and 3,000 for the House.

Just a week after Senator Teller asked for additional copies of the Cripple Creek report, Senator Arthur Gorman submitted a resolution that 6,000 copies of Newell's report on the public lands and their water supplies, also in the 16th annual report, be printed—1,500 for the Senate, 3,000 for the House, and 1,500 for the Survey. When the resolution was presented to the House for consideration, Congressman George D. Perkins told how it came about: "It has been presented to our committee by the Director of the Geological Survey and by others interested in the matter that there is a great demand for this portion of the Report for circulation among the people." The House readily agreed to the resolution. Then, soon after Utah was admitted as a State and Senator Arthur Brown had taken the oath of office, another resolution was passed to provide extra copies of the Mercur report.

The Senate had great difficulty in getting organized because the balance of power was with the Populist Senators, who refused to vote on organization. Finally on December 30, the committees were appointed in a test vote, which gave the Republicans the majority. The Committee to Investigate the Geological Survey, which had been inactive in the 53d Congress, was renamed the Select Committee on the Geological Survey, and a freshman Senator from West Virginia, Stephen B. Elkins, was appointed chairman, with Senators Allison, chairman of the Appropriations Committee, Edward Walthall of Mississippi, and Roger Mills of Texas as the other members. The functions of the newly renamed committee were not indicated in the resolution appointing it. In the next few years, however, it acted as an adjunct to the Appropriations Committee to investigate or sponsor appropriations for the Survey. Senator Elkins, who had become involved in national politics in 1884 as an adviser to Senator Blaine and had served as Secretary of War in the Harrison Cabinet, was in a sense carrying on a family tradition for he was the son-in-law of former Senator Henry G. David, who had tried so valiantly when King was Director to get the extension resolution passed. He had been a large landowner in New Mexico and had also had extensive mine holdings in Colorado but had recently established the town of Elkins, West Virginia, where he made his home, and had acquired a considerable interest in Appalachian coal lands.

On February 19, 1896, the Director asked for a deficiency appropriation for gaging streams. The appropriation for 1895–1896 had already been expended, and the work would stop unless more money were made available. The previous year had been unusually dry, and attempts were made to obtain data in various parts of the country to supply urgent demands. "The conditions being to a large extent new, and the various local assistants enthusiastic and active," he wrote, "it has resulted in the expending of larger sums than was anticipated. * * * The demand for the work has pressed in from all quarters, and the attempt to meet it during the season of the year which is of vital importance to all industries, whether they relate to irrigation, water power, or municipal supply, has led to expenditures that could not be anticipated. We are now brought face to face with the problem of gauging the flow of all streams during the high-water stage of spring and early summer. This is of great importance, especially with reference to the storage of storm waters, in order to keep up an average supply, both for

The value of the Survey's topographic maps for geologists, mining engineers, and irrigation engineers, was greatly enhanced by the authorization in 1896 to place bench marks showing elevations above base level. For central datum points and in places that called for an attractive bench mark, the Survey chose a circular bronze tablet, 3½ inches in diameter and ¼-inch thick, with a 3-inch stem that could be cemented into a drill hole in the vertical walls of public buildings, bridge abutments, and other substantial masonry structures. (From the 18th annual report of the U.S. Geological Survey.)

power and irrigation, during the low-water period." His argument was persuasive, and when the House Appropriations Committee reported out the Sundry Civil Expense bill on March 26, it recommended an appropriation of $35,000 for gaging streams, $15,000 more than the original budget estimate. The Committee had not allowed the requested increase for the report on mineral resources, but the House itself voted unanimously to provide the increase.

The Senate Committee on Appropriations recommended an additional increase of $25,000 for topographic surveys to $175,000. An amendment proposed by Senator Warren on April 9 was attached to the appropriation for gaging streams as a proviso

> **That hereafter the reports of the Geological Survey in relation to the gaging of streams and the methods of utilizing the water resources may be printed in octavo form, not to exceed one hundred pages in length and five thousand copies in number; one thousand copies of which shall be for the official use of the Geological Survey, one thousand five hundred copies shall be delivered to the Senate, and two thousand five hundred copies shall be delivered to the House of Representatives for distribution.**

Senator Allison asked that the appropriation for gaging streams be increased to $50,000. The Senate passed the bill on April 25, providing a total appropriation of $489,100, $50,000 more than the budget estimate submitted by the Secretary, and the Senate figure was accepted by the House.

The Sundry Civil Expenses bill for fiscal year 1897 also included a requirement for the monumenting of the topographic surveys: "That hereafter in such surveys west of the ninety-fifty meridian elevations above a base level located in each area under survey shall be determined and marked on the ground by iron or stone posts or permanent bench marks, at least two such posts or bench marks to be established in each township or equivalent area, except in the forest-clad and mountain areas, where at least one shall be established, and these shall be placed, whenever practicable, near the township corners of the public-land surveys."

In proposing the legislation, the Director stated that in his opinion

> **the maps of the Survey would be enhanced in value fully 100 per cent if permanent records were left on the ground, in the form of monuments, to show the position of triangulation points and township corners, and their true elevation above sea level at some fixed point.**

The original object of the topographic map had been to serve as a basis for the geologic map of the United States, but the maps were now for sale separately. As the public became acquainted with them, a strong demand for them had grown up, and he thought it was time that the topographic surveys be connected directly to the land surveys.

Establishment of the monuments, he said, would benefit "the geologists of the Survey, the mining interests, and all engineers engaged in irrigation work." With regard to the irrigation work, he made a careful distinction between Major Powell's broad claim that topographic maps were a necessary precursor to an irrigation survey and his own recommendation. "The relative elevations of land and water, and of different bodies or streams of water, are shown in a broad way on the present topographic maps; but the information is not sufficiently accurate or detailed, especially where matters of practical application depend upon differences in elevation of a few feet, or even inches. The value of the topographic maps, as far as the utilization of the water resources is concerned, would be increased many-fold if, along the principal streams and the broad nearly level valleys, accurate level lines were run and occasional monuments or bench marks were located at distances of 5 or 6 miles, these being shown upon the map. Then when a question as to diverting water from a stream or from wells on the low land is brought up, it will be possible for any person of fair intelligence to take these maps and determine in a general way, from inspection, the feasibility of the project, or to go upon the ground and settle at a small outley of time and money any doubt as to the difference of elevation. In this way many projects which are impossible would at the outset be condemned, and on the other hand attention would be drawn to feasible schemes for the development of the natural resources of the country. As the matter now stands, an engineer, having determined upon the water supply and noted the general location upon the request topographic maps, must rerun many of the lines if he would know the exact elevation of any point."

Then Walcott added a practical note: "Many thousands of dollars expended in such work could be saved by the simple provision of placing a few permanent marks at the time the topographic surveys and the precise level lines are being run."

When the provision came up for discussion in the House, some of the members were concerned that the surveys in the East were not to be similarly monumented, so an amendment proposed by Mr. Wheeler of Alabama was added: "and in the areas east of the ninety-fifth meridian at least one such post or bench mark shall be similarly established in each area equivalent to the area of a township of the public-land surveys."

A similar provision was included in the Indian Appropriation Act covering the surveys of the Indian lands being opened for settlement. That bill also provided for a maximum fine of $250 or a maximum sentence of 100 days in prison for defacing, changing, or removing any monument or bench mark. The Indian Act also included another $200,000 for the Indian Territory surveys. The work had not progressed as rapidly as expected. The Land Office had estimated that one-fourth of the country was timber and three-fourths open, whereas the reverse was true. It would take $300,000 to complete the work, the Director said, and it could be done in 1 year or 2, as desired. Congress chose 2 years.

The requirement for monumenting did not necessitate any change in the organization of the Topographic Branch, although it became necessary to do spirit leveling of a higher order of accuracy than before. However, in April, the Director assumed immediate charge of the topographic work, and Henry Gannett was transferred to other duties.

Nearly 11,000 miles of spirit levels were run during the year, and 1,820 bench marks were established. The levels, whenever practicable, were run in circuits, a limiting error of closure being established, so as to eliminate any possibility of error beyond the very small limit allowed. The results of the level lines were permanently stamped to the nearest foot on bench marks. Three forms were used: wrought-iron posts 4 feet long surmounted by a brass cap in soil, about two-thirds being sunk into the ground; bronze tablets that could be cemented in holes drilled in dressed-stone surfaces; and copper plugs for insertion into rock surfaces when it was not practicable to use the posts or tablets.

In the Atlantic, Central, Rocky Mountain, and Pacific Sections, 19,743 square miles were mapped, although nearly 45 percent of the mapping in the Atlantic and Rocky Mountain Sections was revision. Nearly three-quarters of the mapping was done on the scale of 1:125,000. Cooperative arrangements continued with the State of New York, which contributed the rather substantial sum of $15,000, and were also begun with the States of Maryland and North Carolina.

The Indian Territory surveys had become so large and complex an operation that South McAlester was made sole headquarters, all work formerly done in Washington was transferred to that point, and Van H. Manning, who had had charge of a subdivision party, was assigned to assist Fitch. A total of 16,079 square miles was surveyed, and 7,678 square miles were also mapped topographically.

The geologic program in the summer of 1896 was more diversified, although mineral-resources investigations were still stressed. Emmons and Weed cooperated in fieldwork in Montana, principally the economic survey of the Butte mining district. It was thought that the investigation had been begun too late in the history of the district to be of practical advantage to the mineowners but that the knowledge of ore deposition to be gained would be of economic importance. Weed was responsible for the areal survey of the district, while Emmons, assisted by G. W. Tower, made the observations underground in the various mines.

Becker had expected to resume his work in California, but in April he had been given an unusually fine opportunity to examine the gold fields of South Africa and spent the summer there. Turner continued the mapping in the gold belt of the Sierra Nevada, but Lindgren was moved to Idaho where he mapped the Boise quadrangle on the northern side of the Snake River valley and part of the Idaho Basin quadrangle. In the Boise region, the ore deposits were as a rule gold-bearing fissure veins, and Lindgren examined especially the alteration to which the rocks adjoining these deposits had been subjected.

Spurr was sent to Alaska early in June to make a reconnaissance of the gold district of the Yukon region with the assistance of H. B. Goodrich and F. C. Schrader, who had been an instructor of Harvard. They were in Alaska when the first big strikes were made in the Yukon Territory and the rush to the Klondike began. Spurr and his companions reconnoitered some 30,000 square miles of territory along the Yukon River from Fortymile Creek down to Nulato. In the districts where there was actual production, more careful work was done, the locations of placer gold approximately determined, some idea of its probable value obtained, and the source traced to bedrock. Veins of argentiferous galena were also found, and several previously unknown coal-bearing localities were visited.

Whitman Cross, who had been associated with Emmons for so long, pursued his own special investigation of volcanic rocks in the San Juan region of southwestern Colorado, where past explorations had not shown the existence of any large or valuable ore deposits. Cross had two assistants, however—A. C. Spencer and C. W. Purington—and Purington made a special study of the mineral prospects in each area. Diller's work was also divided between economic geology and geologic mapping. He made complete surveys of the Roseburg and Crater Lake quadrangles in Oregon. In the former, coal, gold, copper, mercury, marble, and cement rock and a variety of building stones were investigated. The mineral resources of the Crater Lake region, it was conceded, were of little value, but it was agreed that the area would be economically important "when a proper appreciation of this remarkable locality as a resort for pleasure, health, and instruction is aroused among the people." Similarly, Bailey Willis made an 8-day reconnaissance of the glaciers of Mount Rainier in association with Professor Russell, and then, with the assistance of George Otis Smith, who had joined the Survey after receiving his Ph.D. from Johns Hopkins, began an areal survey of the Tacoma, Washington, quadrangle which contained a number of working coal mines.

In the Eastern States, George Eldridge, at long last, was able to go back to his studies of the Florida phosphate region and continued there almost without interruption during the entire field season. M. R. Campbell, with J. A. Taff and W. C. Mendenhall as assistants, mapped the areal geology along the western margin of the Appalachian coalfield in Kentucky and Tennessee. The party procured important evidence of a great time break at the base of the Pottsville, which was substantiated by David White's work in the same region. Much of the area was barren of workable coal, but petroleum as being found in many places. Campbell was unable to find any relation between the surface geology and the oil deposits, so refused to make any prediction until the supply was tested by drilling. White, meanwhile, continuing his study of the Pottsville series, found that the Pennsylvania survey had drawn the boundary some 15 miles too far north, and several of the lower workable coals could therefore be found farther south than expected in the upturned edge of the basin. C. W. Hayes and A. H. Brooks mapped areas in Georgia and Alabama, giving special attention to the structure of the metamorphic rocks of the Ocoee series. Hayes continued his study of the gold resources, mapping the auriferous belts as accurately as possible, and because of the active development of the gold deposits at the time, he found unusual opportunities for underground examination.

The promised reconnaissance of Indian Territory was made even though R. T. Hill, who had been scheduled to make it and to extend the work southward and westward into Texas, became ill and was unable to go into the field. The work was carried forward by young T. Wayland Vaughan, beginning his second year with the Survey, in addition to the work assigned to him in the original plan. Vaughan's chief work was mapping the areal geology of the Uvalde quadrangle in Texas, with special reference to the water supply. His studies indicated that conditions were almost hopeless for artesian water but that a permanent supply of water could be obtained from wells sunk in the gravel deposits along the streams.

Areal mapping in which the economic implications were less evident was continued in New England by Dale and by Professors B. K. Emerson and W. H. Hobbs; Professor Shaler began a study of the geology of Cape Cod. In New York State, Professor J. Kemp of Columbia began mapping in the Adirondack Mountains and also mapped an area in southeastern New York for inclusion in the proposed New York City special folio. In New Jersey, Professor J. E. Wolff completed the survey of the Franklin quadrangle. Professor W. B. Clark, who had become State Geologist of Maryland, moved his mapping project from New Jersey to Maryland and Delaware. Darton worked sporadically on the geology of the region around the District of Columbia. Areal work in the Lake Superior region was confined to the Menominee district. Professor Pirsson made a detailed survey of the Judith Mountains in Montana. On the west coast, Professors A. C. Lawson and J. C. Branner continued their work in the Coast Ranges.

G. K. Gilbert began a highly specialized study of the history of Niagara River. From a comparison of data from water-gage stations on the Great Lakes with earlier observations of the United States Lake Survey, he found that the land in the Great Lakes region was tilting toward the south-southwest. Even as fundamental an investigation as this, it turned out, had economic importance; the study indicated that the land near Chicago was being submerged at the rate of about 9 inches a century.

As increasing attention was given to certain fundamental investigations, several committees were appointed to advise the Director on some of the more highly specialized fields. Professors Van Hise and Iddings, Cross, Diller, Turner, and Weed were appointed a committee to consider the classification of igneous rocks, and Messrs. Cross, Clarke, Diller, Lindgren, and Willis, a committee to which all matters pertaining to petrography might be referred. Appointments of these two committees reflected the great development of the science of petrography. During the 1880's, the problems of geologic nomenclature had been largely with the stratified rocks, but more than 50 new names of igneous rocks had been proposed since 1890. That, Van Hise said, was more than young petrographers were obliged to learn before 1890. Two schools of thought on the naming of igneous rocks had come into being—one calling for names based on geologic relations, the other, on the inherent characteristics of the rocks. Igneous rocks, however, were so complex and had so many and such varied geologic relations that one systematic classification seemed impossible. Both Cross and Iddings pointed out that geologic factors, such as age or form or place of occurrence, were not the causes of systematic differences in the rocks and said that the classification must be based on chemical composition, mineral composition, texture, and physical aspect, among other factors, and must come from the science of petrography.

The Division of Hydrography increased its permanent staff to five by the transfer of Willard Johnson from the Topographic Branch and E. G. Paul from the Petrographic Laboratory to take charge of equipment. The fieldwork was similar to that of the preceding year—measurement of streams, to which nearly half the appropriation was allotted, studies of underground water, and studies of the utilization of water. In connection with the stream measurements, occasional examinations were made of reservoir sites, looking toward a determination of possible water supply under conditions of storage, and Davis prepared the results for publication in the annual report. Most of the ground-water investigations were carried on as part of geologic studies, but extensive special investigations were made in the Great Plains region. Willard Johnson spent the greater part of the year in western Kansas bringing together information on the behavior of water underground. N. H. Darton made a systematic study of the country from near Lincoln, Nebraska, westward along the Platte Valley to the vicinity of Lexington. In Kansas, Professor E. C. Murphy of Lawrence conducted a series of experiments on the efficiency of windmills in raising water for irrigation, while Professor O. P. Hood of Manhattan carried on a similar investigation of the efficiency of pumps. Professor Thomas U. Taylor of Austin, Texas, made a special investigation of the rate of silting of Lake McDonald, data of this character being of great importance in estimates of available water from storage projects.

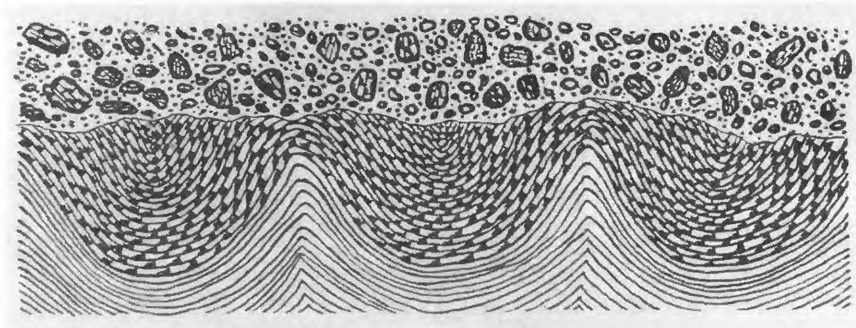
In preparing his estimates for 1897–1898, Walcott asked for a sizeable increase of $117,500 in the Survey appropriation, including $50,000 each for geologic surveys and topographic surveys. Only $100,000 was being asked for the Indian Territory surveys, not $200,000 as had been appropriated in the preceding 2 years, and he asked that the other $100,000 be transferred to the regular Survey base. Appropriations for geologic surveys and topographic surveys, he pointed out, were less than before the cut of 1892, and those surveys were the essential feature of the Geological Survey.

Only $2,500 was asked for completion of the work in Alaska, but when Spurr returned in the fall, the request was changed to $25,000 to prepare a reconnaissance map and to send five parties to Alaska in the spring. The Director reported that the Survey had been led to believe by the stories from the Yukon River region that there were large placer deposits along the streambeds but that the country was generally covered with a heavy growth of moss, bushes, and forest that made geological exploration very difficult, if not impossible. However, Spurr in his reconnaissance had secured suffi-

Charles Richard Van Hise

Van Hise assisted R. D. Irving while still a graduate student at the University of Wisconsin and succeeded him as geologist in charge of the Lake Superior Division in 1888. He spent part of each year with the Survey and part with the University of Wisconsin until 1903 when he became president of the University. Van Hise was noted for his work in metamorphic and Precambrian geology and later for his leadership in the conservation movement. He, Chamberlin, and Emmons were Walcott's closest advisers in the work of the Geological Survey. (Courtesy of the Smithsonian Institution Archives.)

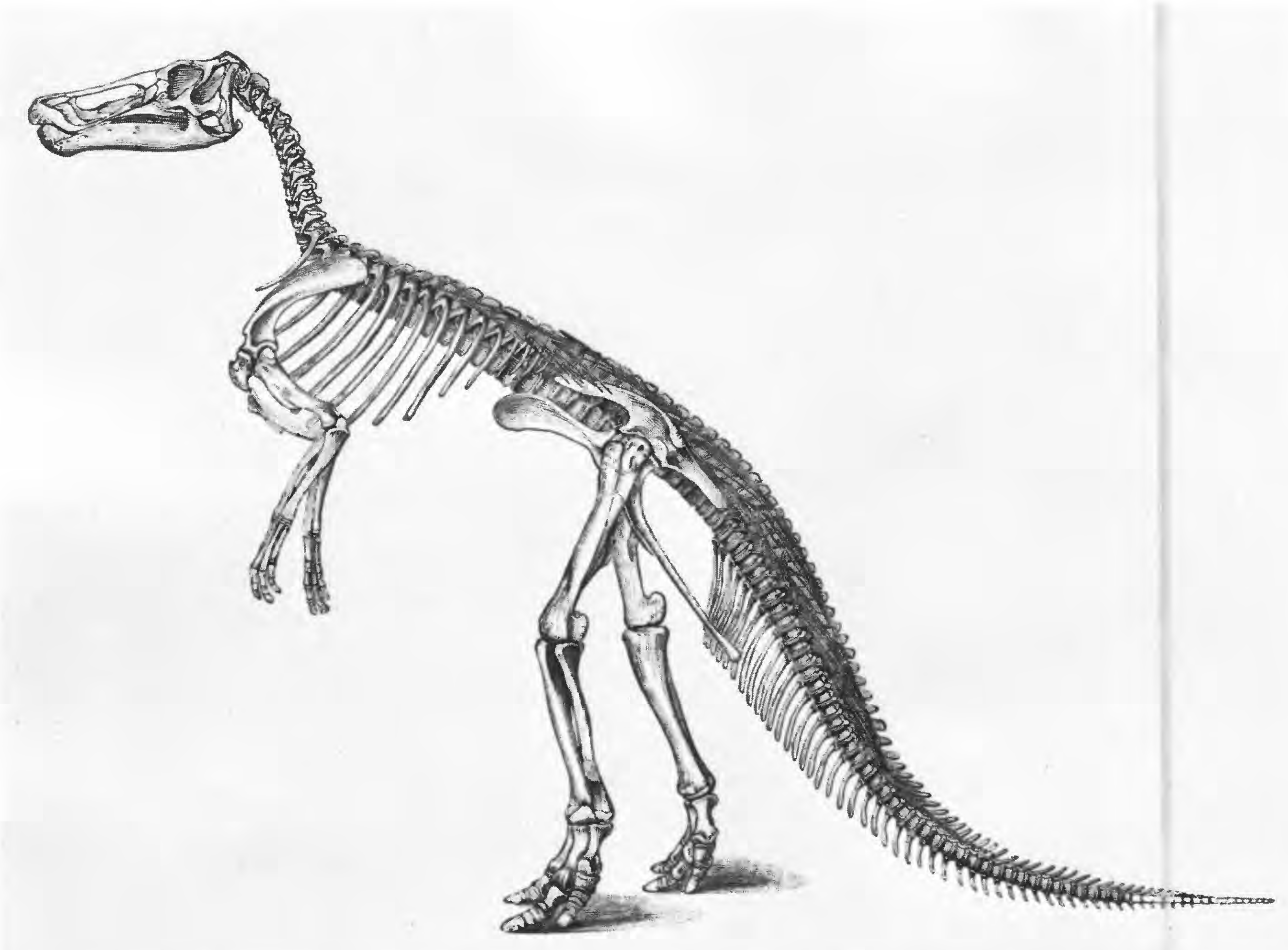
Despite the prominence given economic geology in the Walcott survey, pure science was not neglected. By 1895, Van Hise had developed a set of criteria for determining the stratigraphy of pre-Cambrian rocks. The first and most important criterion was the unconformity, which gave a common horizon from which to work in comparison. Sequence of beds, folding, faulting, jointing, cleavage, and fissility were also useful. (From C. R. Van Hise, 1896.)



cient data "to establish the presence of a gold belt 300 miles in length in Alaska, which enters the Territory near the mouth of Forty-mile Creek and extends westward across the Yukon Valley at the lower Ramparts. Its further extent is unknown. It is the opinion of the geologist-in-charge of the expedition that it is entirely practicable to prosecute quartz mining throughout the year in this region. He also discovered along the river areas of considerable extent of rocks containing hard bituminous coal. In view of these facts, I think it is desirable that a reconnaissance should be made of the gold and coal areas in order to secure an intelligent conception of the resources of the interior of Alaska."

Then on January 13, 1897, the Senate agreed to a resolution proposed by Senator Stewart "that the Committee on Mines and Mining be instructed to examine and report as to the best method of gathering statistics on the product of the mines of the United States." A week later, Senator George Perkins of California proposed an alternative, that a commission be appointed, consisting of the Commissioner of the General Land Office, the Commissioner of Labor, and the Director of the Geological Survey, "to determine the best method of ascertaining all the facts of general importance relating to mines and mining within the United States, whether by a mining bureau, a Secretary of Mines and Mining, a Commissioner of Mines, or a commission, and to report to the Secretary of the Interior for his examination and approval a bill providing means for securing all necessary information concerning mining and related industries within the United States." The *Mining and Scientific Press* endorsed the Perkins proposal. It doubted that the Commissioner of the General Land Office would be of much help but said, "much may be expected from the Director of the Geological Survey. The exceptionally good work that he has done while in that office, in making the survey of value, from an economic standpoint, to the mining industry, gives promise that his suggestions would be of value."

Senator Perkins' resolution was referred to the Senate committee on Mines and Mining and was not reported out. The Committee, however, called before it in connection with Senator Stewart's resolution, the Director of the Mint, the Director of the Survey, and the Commissioner of Labor, and concluded that the Survey's appropriation should be increased so that the Survey could collect information on precious metal mines and mining. "In the former reports of the Survey," the Committee said, "the statistics with regard to the production of gold and silver from the mines have not been included in the general mining statistics reported. The reports as to mines of the baser metals already made by the Survey are very exhaustive, interesting, and valuable, and the committee are of the opinion that a like report with regard to the mines of gold and silver, would be of great value to miners, business men and the country generally. To extend the researchers and reports of the mines of the precious metals will require an additional appropriation of $20,000, making in all $45,000." The Commissioner of



The first annual report of the U.S. Geological Survey published after Walcott became Director included an almost monographic treatment of the dinosaurs of North America by O. C. Marsh. The remains of *Claosaurus annectens* Marsh, a large herbivorous dinosaur with a very small brain, were obtained in the Ceratops beds of the Laramie in Wyoming. The reptile was nearly 30 feet long when alive and about 15 feet high in the position shown. (From O. C. Marsh, 1895.)

Labor supported the proposition, stating that by making an appropriation annually to the Survey, it would be unnecessary for the Twelfth Census to take up the question of mines and mining, there would be a saving of probably $200,000, in the Twelfth Census, and the work itself would be of more value to those interested in mining.

In a formal statement submitted to the Committee, which clearly reflects Emmons' way of thinking and the need to return to the Tenth Census type of investigation, Walcott pointed out that

> No division of the gold product into placer gold and vein gold has been attempted for years, yet the demand for this information during the past year indicates the advisability of publishing it. Placer gold has in history been the source from which sensationally large supplies of gold have come at short notice and with marked effect upon the gold market, while vein gold has been the product of slow development, with the investment of much capital and the establishment of contributory industries. The intelligent investment of capital in precious-metal mines, on business rules and without especial speculative excitement, depends essentially upon information impartially collected and widely distributed as to the characteristics of the ores which furnish most gold and silver in each district. The adaptability of these ores to various methods of treatment must be simply but clearly set forth. This can best be done by a few general statements concerning each camp, showing what processes have been most successful for each kind of ore.
>
> The information demanded from the statistics of gold and silver points us to the mines themselves as the necessary source. It will constantly become more difficult to collect the statistics by the present method alone. To collect them

from the mines will be difficult at first, but will steadily grow easier as the mining interests organize and consolidate, and the proportion furnished by wandering prospectors and other small operators grows smaller.

When Congress passed the appropriations bill with an increase of only $5,000 in the Survey appropriation, the *Mining and Scientific Press* took it to task: "The geological survey of the United States is at present under the direction of a man who appreciates the value of the work that can be done to aid mining, but is hampered for want of means. Less than half a million dollars a year is spent and much of that, perforce, is spent in purely scientific work. It is to be hoped that Congress will soon be impressed with the idea that no money spent can bring larger returns, nor add more to the wealth of the country, than upon the economic work of the geological survey." Senator Wolcott and Congressman John Shafroth of Colorado presented a memorial from the Colorado State legislature asking for a "generous provision for that branch of the United States Geological Survey which is engaged directly in examining the metalliferous districts of the States and Territories to the end that needed surveys may be commenced or completed and the results published at the end of each session in pamphlet form, as much of the value of the informtion thus received depends upon its speedy publication." The memorial went on to say,

It is not expected that the specialists of the survey will take the place now occupied by the prospector or the mining engineer. They should, however, understand the work of either or both of these classes of men, and should furnish an accurate basis upon which that work may be founded. Let the survey stand between them and nature, demonstrating, as well as may be in the absence of development, where the prospector may and where he may not prospect to advantage for this or that valuable mineral. In the absence of a Government department of mining, your memorialists believe that Congress should strengthen the mining department of the Geological Survey and provide for the more timely publication of its preliminary and final reports.

Economic geology had made great strides since Walcott became Director in 1894, but it was clear that the groundwork was being laid for even greater advances.

Chapter 10.
The Nearest Attainable Approximation, 1897–1900

In government organizations depending upon the will of so complex a body as Congress, it is often difficult to carry out a policy outlined in advance. Usually the policy is modified by considerations, not of what it is abstractly best to do, but of what it is possible to do. This compels the administrative officer to aim at the nearest attainable approximation to the desired object.

—Charles Doolittle Walcott

By 1896 economic conditions were distinctly better. The value of the gold product continued to increase as further developments were made at Cripple Creek, Mercur, and Deadwood, South Dakota, and for 1896, it was more than $53 million. Public confidence was sufficiently restored that when the Treasury reserve dropped to $90 million in July, no loan was required.

The monetary situation was, however, the main issue in the Presidential campaign. The Republican National Convention met in June and nominated William McKinley for President on a platform upholding the single gold standard, the high protective tariff, and a vigorous foreign policy, including U.S. control of the Hawaiian Islands. The Democratic National Convention met in July with the free-silver faction in control. Their platform called for free and unlimited coinage of silver and condemned trusts, monopolies, the high protective tariff, the use of injunctions against labor, and the Supreme Court, for declaring the income tax unconstitutional. William Jennings Bryan was nominated for President after delivering his Cross-of-Gold speech, and 2 weeks later the People's Party, and the Silver Republicans who had bolted the party under the leadership of Senator Teller, endorsed Bryan's candidacy. The Gold Democrats withdrew from the Democratic Party and nominated Senator Palmer for President. Although Bryan waged a vigorous campaign, far more strenuous than was customary for Presidential candidates, the Republican Party had the larger campaign fund and McKinley was elected.

By the winter of 1896–1897, Walcott's executive ability was widely recognized, and not only by the mining industry. When George Brown Goode, the Assistant Secretary of the Smithsonian Institution died in September 1896, Walcott had been offered the position. He declined, preferring to remain with the Survey, but was persuaded to accept it temporarily, in addition to his Survey responsibilities, with the understanding that his work would be concerned exclusively with the National Museum. The appointment was announced in late January 1897, and Bailey Willis was then appointed Assistant to the Director in Geology to relieve Walcott of some of the administrative details of the Geologic Branch.

The Fifth Irrigation Congress, which met in Phoenix in December 1896, also recognized the abilities of the Director of the Geological Survey. The Congress somehow looked on the hydrographic work of the Survey as one of its own substantial accomplishments, even though it was not entirely devoted to irrigation, and approved the requested increase for topographic

Bailey Willis

Geologist, U.S. Geological Survey, 1884–1915. Willis had taken part in the Tenth Census investigations under Pumpelly and had joined him in the Northern Transcontinental Survey from 1881 to 1884. In 1884, he rejoined the Survey and remained with it until 1915. In 1897, he was made Assistant to the Director for Geology and in 1900 geologist in charge of Areal Geology. (Courtesy of the Smithsonian Institution Archives.)

surveys because "general topography" was an "indispensable requisite in an intelligent study of the reclamation problem." The Congress went so far as to recommend establishment of a Public Lands Commission, composed of the Commissioner of the General Land Office, the Director of the Geological Survey, and three other persons appointed by the President and confirmed by the Senate, to be responsible for preparing a topographic map, determining the water supply, ascertaining the character and value of the timber, and making regulations for the occupation and utilization of the public lands. Thus in only 5 years, there had been a complete reversal of opinion on the role of the Survey and the Survey's Director in public-land management.

Although the recommendation regarding timber on the public lands was strictly limited, the forestry movement, was beginning to gather strength, and the Survey was again involved in a small way. The forest reserves had been established in 1891; no provision had been made for managing them, and there was danger that the reserves would be lost for lack of care. On February 15, 1896, Secretary Hoke Smith addressed a letter to Wolcott Gibbs, the president of the National Academy of Sciences, asking the Academy to answer three questions: (1) Is it desirable and practicable to preserve from fire and to maintain permanently as forested lands those portions of the public domain now bearing wood growth for the supply of timber? (2) How far does the influence of the forest upon climate, soil, and water conditions make desirable a policy of forest conservation in regions where the public domain is principally situated? (3) What specific legislation should be enacted to remedy the evils now confessedly existing? Gibbs was expecting the letter. He had, in fact, suggested that it be written. On March 2, he accepted the assignment for the Academy, stating in his reply, "it is the opinion of thoughtful men that no other economic problem confronting the government of the United States equals in importance that offered by the present conditions and future fate of the forests of western North America." Gibbs appointed a commission consisting of Professor Charles H. Sargent of Harvard, as chairman, General Henry L. Abbott, Professor Alexander Agassiz of Harvard's Museum of Comparative Zoology, Professor William Brewer of Yale, Arnold Hague of the Survey, and Gifford Pinchot, the youngest member of the commission, a Yale graduate of 1889 who had studied forestry in Europe. Gibbs himself was a member ex officio. At the first meeting of the commission, Pinchot was elected secretary, and Hague and Pinchot were designated a subcommittee to prepare a preliminary report and recommendations for the consideration of the full committee. Office space for the commission was supplied by the Survey, and Hague was relieved of Survey duties to devote full time to the forestry study.

The Academy commission on forests made a trip through the Western States and at a meeting in October agreed to recommend the creation of new reserves and also of Mount Rainier and Grand Canyon National Parks. The commission, it was understood, fully realized that the reserves could not be maintained unless some plan were adopted under which the arable and mineral lands included in them could be thrown open to settlement, and provision made for supplying timber from them for the needs of the settlers. The commission also believed that a great extension of the reserves would arouse a protest and a demand on Congress to enact laws for proper administration of the forest reserves. On February 22, 1897, with only 10 days of his term remaining, President Cleveland accepted a recommendation and issued an Executive order establishing 13 additional forest reserves containing an aggregate area of more than 21 million acres.

As was anticipated, there was a strong protest from the Western States. Six days after the Executive order was issued, Senator Clarence D. Clark of Wyoming offered an amendment to the Sundry Civil Expenses bill then under consideration to nullify the order and restore the reserves to the public domain. Senator Allison at first opposed the motion—it was not pertinent to the bill under consideration—but Western feelings were too strong. Senator Stewart said that the President had been misled by enthusiasts who wanted to protect all the forests in the United States, but others were not so kind. The reserves, it was charged, had been selected by a touring group of eastern scientists, without any reference to local interests and sometimes without even visiting the area; they were of unsurveyed lands, in places including scantily timbered areas and in other, settled areas. Memories were still vivid of the closing of the public domain by the Irrigation Survey legislation, and Senator Clark's amendment was agreed to in the Senate. The House, however, refused to accept the Senate amendment, countered with another permitting the use of timber for mining purposes and giving the President authority to abolish any or all reserves. The Senate agreed reluctantly, even though assured by one militant Senator that the new administration would be an "American Administration" that would undo the mischief. President Cleveland reaffirmed his action by a pocket veto of the whole Sundry Civil Expenses bill.

Congress was called into special session on March 15 by President McKinley because there was need of more revenue, and the country in his view had expressed its preference for the tariff as the means of obtaining it. The attack on the reserves continued in the special session, and for a time it seemed that the forest reserve section of the Revision Act of 1891 might also be endangered, so bitter was the feeling. At this point, the Director of the Geological Survey quietly provided a means of resolving the difficulties. Pinchot said he did it "partly because he believed in the Reserve policy, partly because of what there was in it for the Geological Survey (no one could blame him for that)."

As it happened, the Director and Senator Richard F. Pettigraw, who had made one of the most violent attacks on the Cleveland proclamation, were nextdoor neighbors on Q Street. The Homestake Mining Company, which was not only the greatest gold mine but also the greatest political power in Senator Pittigrew's home State of South Dakota, had sent its counsel to see the new Secretary of the Interior, Cornelius Bliss, and Secretary Bliss had assured him that Homestake could continue cutting mining timber in the new Black Hills Forest Reserve. Homestake thereupon withdrew its opposition to the reserves. Walcott knew this and was thus able to convert Senator Pettigrew to the idea that the forest reserves were good for the West, and at the end of March, the Senator asked Walcott to draft legislation to continue the reserves and to provide for their administration.

The bill suggested by the Director was essentially the McRae bill, which had been under fire in Congress for several years, giving the Secretary of the Interior the power to administer the forest reserves. To it, he added two simple provisions. Much of the dismay and anger of the Western interests was directed not at the idea of protection of forests, for it was realized that the forests in turn protected water sources, but at the selection of huge areas for reservation without regard to those already occupying the land or the nature of the forests included in the reservations. The Director suggested that the Cleveland reserves be suspended until March 1, 1898, thus giving time to make adjustments, and that the Geological Survey make an examination and survey of the reserves to obtain the information needed to revise the boundaries and subtract from the reserves the areas found to be more valuable for agriculture or mining than for timber, or, in other words, that the Survey classify the land.

When President McKinley met with his Cabinet on April 2, 1897, to consider what to do with the Cleveland reserves, Walcott was summoned to the White House. He explained the proposed legislation and was assured of McKinley's approval. The President did more than approve, he called in Senator Allison and explained to him the importance of the forestry legislation. Senator Pettigrew introduced the legislation as an amendment to the Sundry Civil Expenses bill early in April, and it was rather readily accepted. The House at first refused to accept the amendment, but the conference committee worked out a minor change which made it acceptable, and the bill passed both Houses and was signed by the President on June 4, 1897.

The Topographic Branch, with appropriations of $175,000 for topographic surveys, $150,000 for examination and mapping of the forest reserves, $100,000 for Indian Territoy surveys, $41,500 for mapping the Chickasaw Nation, and $7,650 for surveying the Idaho-Montana boundary, The Geological Survey expanded its special investigations in 1897. The surveying of the Idaho-Montana boundary line was not an assignment for the timid. The transit used was provided with a compass attachment, fixed stadia wires, and a tripod with extensions legs. The last, R. U. Goode noted laconically, were at times very necessary, as may be seen from the plate. (From R. U. Goode, 1900.)

once again became the largest branch of the Survey. Walcott retained control of the branch, and no change was made in the general organization, although the staff was increased by the addition of five assistant topographers through certification by the Civil Service Commission. Two of the five, F. E. Matthes and Glenn S. Smith, had long and distinguished careers in the Survey.

The survey of the northern part of the Idaho-Montana boundary was placed under the supervision of R. U. Goode, although the actual work was assigned to E. T. Perkins, Jr. This was the first such work delegated to the Survey. The law provided that points of the meridian defining the boundary should be located by triangulation from the Spokane base of the Survey, and it would be necessary to extend a belt of triangulation over a longitudinal distance of about 70 miles before the line could be located and marked. The work was begun late in June but was hampered by the alternation of storms and smoke from forest fires all through the field season.

The plan for the forest surveys called for preparation of topographic maps on a scale of 2 miles to the inch with contour intervals of 100 feet that would serve as base maps for representation of forest details, agricultural and mineral lands, and also for future geologic surveys; establishment of bench marks for vertical control; subdivision of the reserves by running township lines where necessary; demarcation of tracts more valuable for agricultural and mineral development than for timber; and the outlining of all wooded and forest areas. Experts would then classify and map the area occupied by timber suitable for various purposes, map the distribution of leading species of economic value individually, make note of the size and density of distribution of valuable timber, and the character and density of the undergrowth, map the area from which timber had been removed for whatever reason, the extent to which the forests had been culled and the species culled, and also be prepared to report on the extent and character of the demand for timber and the means for getting it out.

The topographic surveys were assigned to the Pacific and Rocky Mountain Sections of the Topographic Branch. Henry Gannett was placed in charge of the forestry survey and was authorized to employ experts in the examination of forests as assistants, at salaries not to exceed $125 a month and expenses. He was warned that great care should be exercised in the selection of the expert to examine the Black Hills Reserve "owing to the character of the country and the importance of the interests dependent upon it." It was anticipated that the 60,000 square miles of forests in the reserves could be thoroughly and economically surveyed within 5 years, provided appropriations were adequate. The first surveys would be made in parts of the suspended reserves in which there were large interests that might be adversely affected by inclusion of those areas within the reserves. Before the end of June, topographic-surveying parties left Washington to begin work in the Black Hills Reserve of South Dakota, the Teton and Bighorn Reserves of Wyoming, the Bitterroot and Priest River Reserves of Montana and Idaho, and the Washington Reserve in Washington.

The forest survey was organized early in July. Gannett chose 26-year-old Henry Graves, graduate of Yale with advanced work at Harvard and Munich, for the Black Hills survey and F. E. Town, T. S. Brandegee, J. E. Leiberg, W. G. Steele, N. W. Gorman, and H. B. Ayres for study of the other reserves. He himself then took off to familiarize himself as far as possible with the areas and forest conditions under examination.

Early in August, the Director, accompanied by F. B. Weeks, doubling as secretary and field assistant, set out for the West to inspect the forest reserves for himself and on behalf of the Secretary, some of the national parks as well. He first made a thorough examination of the area included in the Black Hills Reserve, a study of the geology in the immediate vicinity of Deadwood, visited the Homestake mine, and then inspected the Bighorn Reserve. From there, he went on to Yellowstone National Park where, under instructions from Secretary Bliss, he made an examination of the parts of the park usually visited by tourists. He reported that the most serious annoyance was dust, which rose from the roads as an impalpable powder, both stifling and blinding (The second most serious annoyance was the lack of a hotel in the Upper Geyser Basin.). Walcott recommended proper surfacing of the roads, an improvement in grading, and construction of a new road from Inspiration Point to Deer Creek to permit tourists to pass through one of the most interesting parts of the park, giving exact details as to where it should be located and why; the assignment of more soldiers be assigned to guard the park during the summer months; and the removal of the dead trees piled upon along the roads. His trip to the Washington Forest Reserve had to be abandoned owing to heavy and continuous storms, but he made a trip through Yosemite National Park (again under instructions from the Secretary to examine the roads, trails, patrol forces, and similar matters), to the Inyo Range for a bit of geology, and to the San Bernardino Forest Reserve.

In the Geologic Branch, which now had a certain measure of autonomy, the rudiments of a new organization were becoming apparent as special lines of investigation came to be pursued. Willis assumed many of the administrative tasks, and Emmons, Van Hise, and Chamberlin took responsibility for segments of the work. A new ruling was issued: Henceforth, all quadrilateral land units of the topographic and geologic surveys would be called "quadrangles," and where there was no such definite demarcation, the word "district" was to be used. Use of these terms in other connotations was to be avoided. Implicit in the announcement was the admission that geologic mapping need not be restricted to quadrangles, although in fact much of it continued to be.

The program in economic geology was perhaps better formulated than the other developing programs because Emmons had persistently worked toward the objectives set down in 1879, but even within economic geology, specialization was beginning. In the summer of 1897, under Emmons' direction, G. W. Tower and George Otis Smith began a survey of the Tintic

One of the first forest reserves examined by the Geological Survey in 1897, the Bighorn Forest Reserve in Wyoming, was found in general to be only lightly forested. Nearly all of it had been burned, much of it recently; a large part of it had been subjected to repeated fires set by Indians to drive out game or improve the pasturage. Fire had destroyed the soil as well as the timber, thus hindering future growth of seedlings. Near Little Goose Creek Canyon, the forest fires had stopped at the drainage line. (From F. E. Town, 1899.)

district, the most important mining district in Utah, Weed continued fieldwork near Butte, and Lindgren mapped the Silver City and Nampa quadrangles in Idaho. Spurr was kept at home completing the unfinished Aspen report. Emmons did little fieldwork but spent several months in Europe where he represented the U.S. Government at the Seventh International Geological Congress in Russia and took part in the extended excursions made by members of the Congress as guests of the Russian Government.

W. F. Hillebrand, who had first been associated with Emmons in the Denver office, worked out new methods for the quantitative determination of chromium and vanadium, which were then becoming of interest in steel metallurgy. He extended his investigation to a study of the occurrence of vanadium in rocks generally and found that instead of being rare, as was commonly supposed, vanadium is widely distributed—examination of 70 different rock specimens showed it is almost universally present in measurable quantities, chiefly in the dark silicates.

Geologic work in California reflected Becker's twofold interest in economic geology and geophysics. Becker himself, assisted by F. L. Ransome, visited most of the mines of the Mother Lode southeast of Plymouth, study-

In 1897, Sir Archibald Geikie delivered a series of lectures on the history of geology at The Johns Hopkins University. During his visit, about 50 geologists accompanied him on an excursion to the falls of the Potomac. Among those easily recognized in this photograph by J. S. Diller of the Survey are Major Powell (lower center, hatless), C. D. Walcott (at peak, in bowler), Sir Archibald (to Walcott's right, in light suit and cap), C. W. Hayes (front row, light fedora), C. R. Van Hise, at extreme right, and S. F. Emmons, at left, with back to group. (From the files of the U.S. Geological Survey.)

ing the character and origin of the fissures in which the gold deposits occurred. H. W. Turner mapped the Yosemite quadrangle, making a special study of the jointing of massive rocks. Turner also made special observations of glacial phenomena and concluded that there probably had been two periods of ice expansion and an interglacial period.

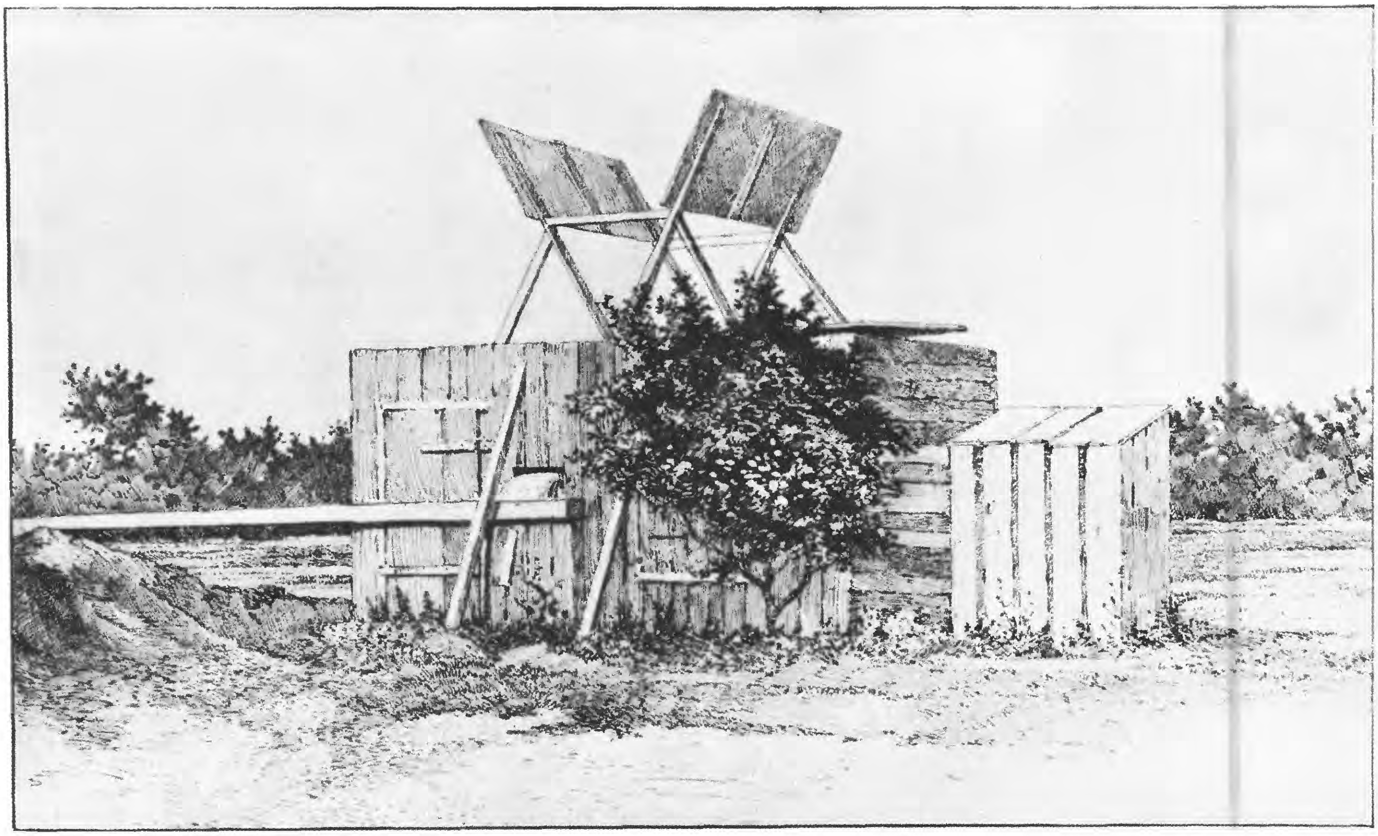
Van Hise continued to supervise the detailed surveys of the iron districts in the Lake Superior region being made by Professors W. S. Bayley and J. M. Clements and young C. K. Leith, who had just been graduated from the University of Wisconsin. His own personal investigations had now broadened into a general study of structural and metamorphic geology. In that connection, he made an extended trip through the Western United States, observing sections across the Cascade Range in Washington, the Coast Range in Oregon and California, the Sierra Nevada, and the Grand Canyon district. He also spent time with Arthur Keith studying the Ocoee series in Virginia and Georgia; with Florence Bascom, who was mapping the crystalline rocks in the vicinity of Philadelphia; and with Professors Emerson, Dale, and Hobbs in New England. He then began preparation of a treatise on metamorphism. The Committee on the Nomenclature of Igneous Rocks, under his chairmanship, submitted a report "for the information and guidance of the geologists of the Survey" containing rules of petrographic terminology and suggestions for the use of rock names. The report contained one authoritarian note. It directed geologists working in adjacent districts to agree on a legend designation for each rock occurring in both areas.

A few other investigations of iron ores were made in conjunction with areal mapping projects. Professor J. F. Kemp spent some time studying the magnetic ores while mapping in the Adirondacks, and C. W. Hayes investigated the iron deposits of the southern Appalachians while awaiting a decision on the age and relations of the Ocoee series so that his reports could be completed.

Investigations of nonmetallic deposits were chiefly related to coal, although George Eldridge, having completed his study of the Florida phosphates, began, by special order of the Secretary, an investigation of the asphaltic minerals in the Uinta and Uncompahgre Indian Reservations in Utah, and M. R. Campbell, who continued the work in the Appalachian coal fields, assisted by W. C. Mendenhall and L. C. Glenn, also investigated the occurrence of oil-bearing strata in relation to the geologic structure in Johnson and Floyd Counties, Kentucky. J. A. Taff was transferred to independent work on the coalfield in Indian Territory and mapped the McAlester and Atoka quadrangles with the assistance of George B. Richardson. David White continued his investigation of the flora of the coal measures in the Appalachian region and also studied the fossil plants collected in Indian Territory to make an approximate correlation between the formations of the McAlester field and those of other coalfields of the country. The first investigations of western coalfields were made by J. S. Diller, assisted by A. J. Collier and James Storrs, in the Coos Bay coalfield, Oregon.

Chamberlin, like Van Hise, continued to supervise the work of assistants while pursuing his own special investigations. From the discrimination of glacial deposits he had been led to study the causes of glaciation; that study led in turn to a consideration of the cause of climatic changes, and thence to the ultimate basis of time divisions in geologic history.

Most of the fieldwork of the Division of Hydrography in 1897 was done in the arid region. More than half the appropriation was allotted to stream gaging, and more than half the remainder to the study of underground



waters. Darton continued his investigation of underground water in Nebraska and pushed north into South Dakota with the idea of making a thorough study of artesian conditions east and south of the Black Hills. Johnson made his headquarters in Kansas and continued his study of the water supply of the High Plains. However, the unusual drought in the Potomac River basin during the fall of 1897 caused such low flow that an investigation of the basin was made, measuring the various tributaries and obtaining samples of water for sanitary analysis.

The new series of water-supply papers authorized in 1896 enabled the Geological Survey to inform the public on water resources in a somewhat popular vein. The homemade wind engine shown was the frontispiece for Water-Supply Paper No. 1, which described the various devices used for pumping water for irrigation. (From H. M. Wilson, 1896.)

Newell fully subscribed to Walcott's insistence on prompt publication. The first of the water-supply papers authorized in June was in print by the end of the year, and others were ready to go to the printer. Arthur Powell Davis' report on what could be done for the Pima Indians was published as a congressional document and as a water-supply paper. Davis suggested several possibilities, most of which he deemed impractical, including having the people upstream return to the river the amount of water needed by the Indians for irrigation. The best solution, it seemed to Davis, was a dam, which he estimated could be built for $2¼ million, that would provide enough water for the Indians and excess that could be sold. In transmitting the report, Newell wrote:

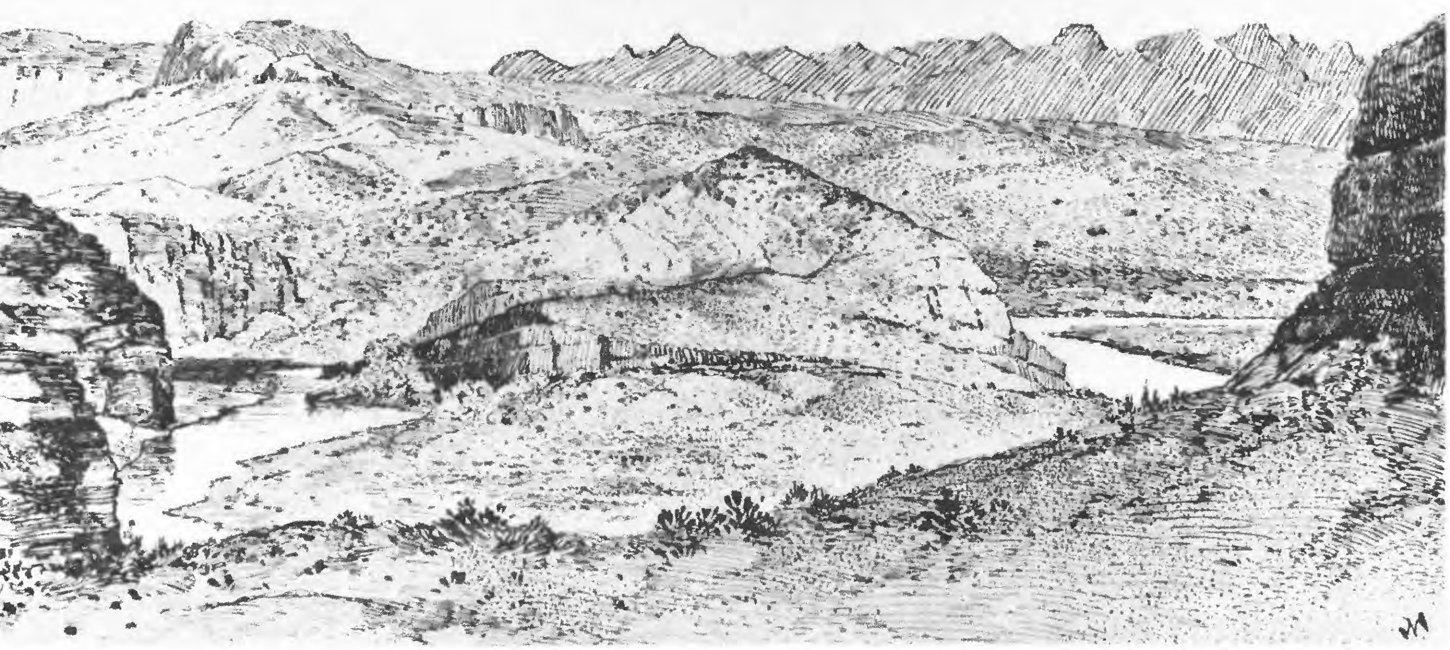
> This report brings matters to the point where some decisive step must be taken unless the policy of procrastination is to be continued. The facts are now before the Department and can be presented to Congress with recommendations through the proper channels. It is highly important, however, that the observations of river flow be maintained through a considerable period in order that more reliable estimates may be made of the amount of water available for storage. These observations should be maintained continuously up to the time a final decision is reached or until construction is begun.

The Fifth Irrigation Congress went on record as favoring construction of the reservoir as planned in the Survey and also as favoring construction of storage reservoirs in general by the Federal Government. The Irrigation Congress also asked that the U.S. Congress provide for hydrographic surveys for the location and construction of reservoirs for the storage of water and appropriate $100,000 for the preliminary location, construction, and operation of test wells for obtaining water.

The drought had created a problem in the water supply of the District of Columbia, and on January 14, 1897, Congress' attention was called to another phase of the Survey's work. Senator Jacob Gallinger introduced a resolution directing the Secretary of the Interior "to transmit to the Senate any information which may be in the possession of the Director of the Geological Survey regarding the hydrography of the drainage basin of the Potomac, with particular reference to the source of pollution and the effect of such pollution upon the water supply of the city of Washington." The reply to that resolution was forwarded 6 days later, a 60-page report complete with illustrations. In the letter of transmittal, Walcott stressed the usefulness of information on water resources in the more settled parts of the country:

> **This reconnaissance of the Potomac basin is similar in form to others made and planned for streams in various parts of the United States, the systematic measurements of discharge made at certain points being supplemented by a thorough examination intended to ascertain geologic or topographic conditions modifying the quantity and quality of the water and influencing the opportunities for industrial development.**

In areas where further development of irrigation by diversion of water from streams was impossible because the dry-weather flow was already appropriated, the actual water supply for irrigation could be increased by storage of storm waters or development of underground sources. A. P. Davis made a detailed survey of a proposed dam site on the Gila River in Arizona in connection with assuring a water supply for the Pima Indian Reservation, determining the best point for a dam as well as the dimensions of the dam and its cubical contents. (From A. P. Davis, 1897.)



In accordance with Senator Gallinger's request, the report was printed to serve as a guide to the committee that had the Washington water supply under its charge.

The mineral industry had had a very profitable year in 1897. The total value of mineral products was the greatest in history, $632 million. All previous records for pig-iron production were broken; copper, lead, and zinc also set new records. The gold product in 1897 was valued at more than $64 million, nearly twice what it had been in 1892, confounding the critics who had foreseen an end to the discovery of gold. The great mining excitement had been in Alaska and Canada. For several years, prospectors had been mining placers on tributaries of the Yukon, but in the autumn of 1896, still richer discoveries were made along the Klondike River, a short distance east of the Canadian boundary. Within a single year, the yield from that region exceeded in amount the purchase money for the entire Territory of Alaska, and although a large part of the gold came from Canada, most of it was taken out by American miners.

In preparing the budget request for fiscal year 1899, Walcott pointed out that the Survey had grown in various directions, but the appropriations for the essential features, topographic and geologic surveys, were less than before the cut of 1892. He thought at least $50,000 should be added to each to enable the Survey to meet the demands being made upon it. He also made a plea for more space, which could be obtained by securing two additional floors in the annex building. He suggested, however, that it would be economical on the part of the Government to provide a permanent building for the Survey. The annual rental of space then in use equaled the interest on more than $500,000 at 3 percent! The estimate submitted to Congress by the Department included an increase of $2,000 for rent, no increase for topographic or geologic surveys. Deficiency appropriations were approved, however, for funds to permit publication of 6 monographs and 23 bulletins for which no printing funds were available, and for completion of the Indian Territory surveys because of the added expense resulting from the necessity of reorganizing parties after the spring suspension.

Survey hydrographers were also concerned with water resources in the Eastern States, and as early as 1897, they pointed out that industrial wastes were polluting some of the streams. The North Branch of the Potomac River was so polluted by sawdust from 14 sawmills and waste products from 2 tanneries that the river had a foul appearance, especially in the dry season, in spite of its dashing course over boulders, which should have given it a picturesque appearance. (From F. H. Newell, 1898.)

On January 13, 1898, one year after Senator Stewart's resolution that the Committee on Mines and Mining be asked to report on the best method of gathering statistics on the product of the mines of the United States, Senator Perkins introduced another resolution, this time asking the Secretary of the Interior whether it would be "consistent with public interest for the Government to collect and publish" additional information "on localities from which the precious metals are produced, including Alaska, showing the exact amount, proportion which comes from placer mines and deep mines, and conditions of occurrence of gold in the United States" and "a plan therefore and estimate of cost." Walcott in his reply repeated much of what he had said the year before. In his opinion, the Geological Survey should collect the statistics of gold and silver production from their sources. He added, however, that the Survey should cooperate with the Director of the Mint in collecting statistics; thus, each would supplement the other. He estimated that the cost exclusive of Alaska would be $20,000 a year; Alaska would require an additional $5,000. However, some of the experts would be collecting statistics on other minerals as well, so he suggested that the appropriation, if it should be made, be for preparation of a report on the mineral resources of the United States, including the collection of statistics on gold and silver.

Senator Elkins, of the Committee on the Geological Survey, had already introduced a joint resolution authorizing the Survey to prepare and print a map of Alaska showing all known topographic and geologic features, including what was known of the gold-bearing rocks and an explanation of the best known routes and methods of reaching the goldfields. When the resolution came up in the House, George Perkins, chairman of the Committee on Printing, explained that the map was already prepared and ready for printing, but Congress could get copies cheaply by ordering immediately 30,000 copies for its own distribution. On January 28, 1898, Congress appropriated $20,000 for the Survey to make geological and topographical surveys in Alaska.

For the Alaska program, two types of work were considered necessary—exploratory surveys, including geologic reconnaissance, into regions about which there was little or no satisfactory geographic information, and detailed topographic surveys in areas whose general geographic features were fairly well known but which were of importance from a geologic or economic standpoint. The work promised to be of unusual severity and to involve many hardships, so a call was issued for volunteers. From the geologic corps, two of Emmons' protégés, George H. Eldridge and Josiah E. Spurr, were chosen; Alfred H. Brooks, whose interest in Alaska had been fired by Hayes, was the third. For Brooks, this was the beginning of a long association with Alaska. From the topographers, E. C. Barnard, W. J. Peters, W. S. Post, and Robert Muldrow were selected. Eldridge was placed in charge.

George H. Eldridge

Geologist of the U.S. Geological Survey, 1884–1905. Before joining the Survey, Eldridge was associated with Pumpelly in the Tenth Census mineral investigations and the Northern Transcontinental Survey. Eldridge worked with Emmons in the Rocky Mountains for several years, then began the study of the Florida phosphates, and in 1898 was sent to Alaska. He later undertook some of the earliest Survey investigations of petroleum and petroleum products. (Courtesy of the Smithsonian Institution Archives.)

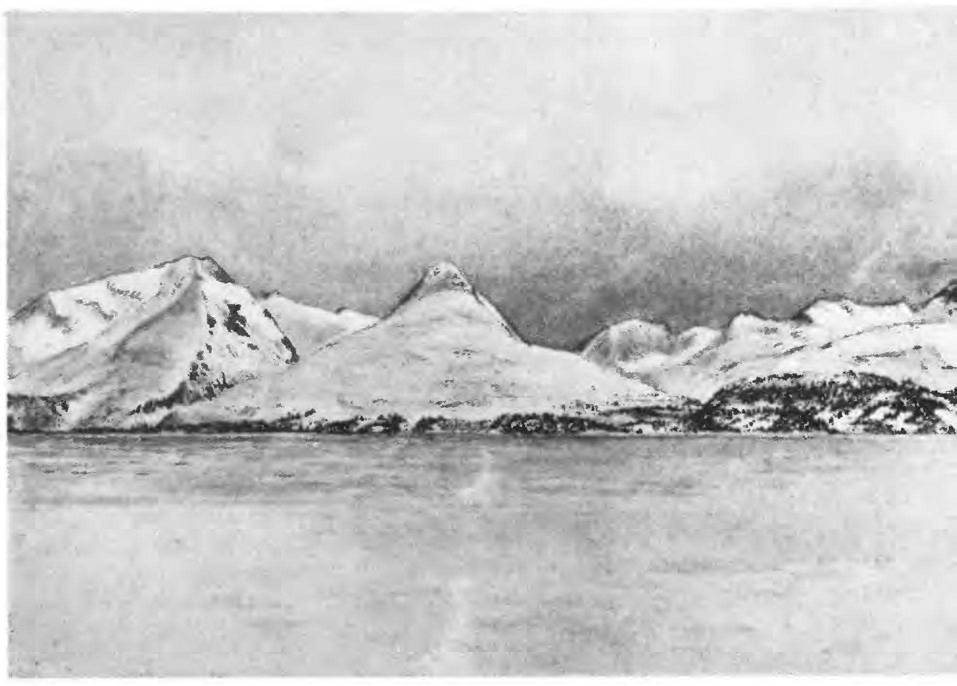
Provisions and equipment—22,000 pounds of it—were assembled at Seattle, and on April 5, the U.S.S. *Wheeling,* which had been made available for the transportation of the parties and their outfit, sailed with all except Barnard aboard. Barnard had gone on ahead to investigate the practicability of using reindeer in transporting his outfit to the upper Yukon.

The Barnard and Peters parties were discharged at Skagway on April 11, and from there traveled by wagon, sleigh, packhorse, dog team, and canoe to the mouth of the White River. The Barnard party was assigned to survey an area in the Klondike region, and the Peters party, to which Brooks was attached, to the survey and examination of the White and Tanana Rivers.

Survey geologists and topographers sent to Alaska in 1898 to explore for routes inland visited many previously unexplored areas. Eldridge's party explored the Sushitna (modern spelling Susitna) River system and beyond to the Yukon to locate a route to the Tanana. The Susitna-Tanana divide is the lofty and rugged Alaskan Range which carries the highest peak on the North American continent, Mount McKinley. (From G. H. Eldridge, 1900.)

Vague reports from traders who had obtained the information from Alaskan natives indicated that the divide between the Susitna and Kuskokwim Rivers was in low flat country but Spurr's party found it to be a high range of mountains on whose summits lay snow and whose sides bore glaciers. The pass over the mountains was about 4,400 feet above sea level. (From J. E. Spurr, 1900.)

Mendenhall photographed the Matanuska Glacier with its well-defined medial moraine. (From W. C. Mendenhall, 1900.)



Schrader noted that Port Valdes (now Port Valdez) seemed to be the best gateway from the coast into the Copper River country but was enclosed by mountains which rose steeply from the shore to a height of about 5,000 feet. (From F. C. Schrader, 1900.)

The *Wheeling* continued to Cook Inlet and discharged the rest of the party at Tyonek on April 27. Eldridge and the remaining corps traveled together up the Susitna River to about 60°40′ N. where several forks of the river combine. Then Eldridge, with Muldrow as topographer, began an exploration of the northeastern part of the Susitna drainage basin, and Spurr, with Post as topographer, proceeded westward across the divide to survey the headwaters of the Kuskokwim River and determine the navigability of the stream.

The services of Survey scientists and engineers were also made available to other Federal agencies. In December 1897, Willard Hayes and Arthur P. Davis were sent to Nicaragua with the Nicaraguan Canal Commission, for which Congress had provided in the Sundry Civil Expenses Act of June 4. There had been two reconnaissance surveys of a canal route from the Atlantic to the Pacific, and then a third had located a route and drawn plans on which construction had begun. Financial difficulties brought construction to a halt, so Congress appointed a commission, which examined the plans, doubled the estimates, and recommended further investigation of the route, in particular of the geology and hydrography of the area.

The War Department also requested the services of geologists to accompany exploring expeditions to Alaska. F. C. Schrader accompanied a party that made a reconnaissance of the Copper River district to find an all-American route from the coast into the gold districts of the upper Yukon. W. C. Mendenhall accompanied a party that made a reconnaissance from Resurrection Bay on the southeastern shore of the Kenai Peninsula to the Tanana River at the mouth of the Delta River, one of its southern tributaries, through a region previously almost unknown. A third expedition, planned by the War Department, had to be canceled because of the outbreak of the Spanish-American War.

The Spanish-American War was brief, and there was no need to adjust Survey programs to meet war needs. Between the sinking of the battleship *Maine* in Havana Harbor on February 15, 1898, and the declaration of war on April 25, both the House and Senate passed the appropriations bill. The conference report was held up, however, until June 6, and by the time the bill was signed on July 1, 1898, the war was all but over. The Survey appropriation was increased by token amounts: $1,000 for preparation of illustrations, $5,000 for topographic surveys, and $10,000 for geologic surveys.

The war created no strain on the mineral supplies in the United States but did create an immediate interest in the mineral resources of the occupied areas. Early in July, Becker sailed from San Francisco, under orders from the War Department, to investigate and report on the mineral resources of the Philippine Islands. He compiled a summary of the geology of the islands as known at the time, but despite the surrender of Manila on August 13, he was unable to do much fieldwork because of continuing native hostility.

U.S. Geological Survey scientists and engineers were sent beyond national boundaries. C. W. Hayes and A. P. Davis investigated the geology, topography, and hydrography of Nicaragua where a set of unusual conditions held promise of a practicable route for a large ship canal between the Atlantic and Pacific. Lake Nicaragua is separated from the Pacific Ocean by a narrow strip of land containing the lowest depression in the continental divide between the Arctic Ocean and the Strait of Magellan. It is a natural reservoir that could be used for storing water for operating the locks of a canal and also as a regulator for the control of floods. Lake Managua, northwest of Lake Nicaragua, was suggested as a storage reservoir for supplying water to Lake Nicaragua during the dry season. (From A. P. Davis, 1900.)

George F. Becker was sent to the Philippine Islands in 1898 to investigate the geology and mineral resources of the islands but could accomplish little because of the continuing insurrection. Geologizing under arms with a military escort, he noted, was more exciting than profitable. He found, however, that Mayon Volcano confirmed some of his earlier studies of the shape of volcanoes. (From G. F. Becker, 1901.)

Becker, who is reported to have said that if he could not have been a geologist he would have been a soldier, attached himself to the Bureau of Military Information of the Eighth Army Corps, and on invitation from General MacArthur, went to the front and participated in several engagements.

While Becker was in the Philippines, Emmons moved into Becker's territory and made an extended reconnaissance of mining districts in California as well as Washington, Arizona, New Mexico, Colorado, and Montana in order to arrive at a better understanding of the relative importance of the different mining districts and thus be able to advise the Director on future economic work. Ransome continued the surveys of the Mother Lode district begun under Becker's direction. Under Emmons' direction, Tower, assisted part of the time by Arthur Spencer, investigated the underground workings near Rico, Colorado, and T. A. Jaggar, who had been working with Hague, joined J. M. Boutwell, a graduate student at Harvard, in mapping in the northern part of the Black Hills of South Dakota. Weed completed the general geologic investigations in the Boulder quadrangle in Montana but was unable to complete the economic survey because some of the mines were shut down. Lindgren continued his detailed mapping in Idaho, concentrating on the mining district near Hailey.

The iron-ore investigations in the Lake Superior region and the Adirondacks were continued, and Professor J. E. Wolff began an investigation in the Franklin Furnace area in New Jersey. Nonmetallic investigations were more limited. Marius Campbell mapped about 1,000 square miles in the West Virginia coalfields, then moved on into Kentucky to make a physiographic study of the valleys of the Kentucky and Licking Rivers, part of an investigation of the Ohio River drainage basin. J. A. Taff began a very detailed and accurate survey of the coalfields in Indian Territory.

A Mining Congress, mostly metal-mining men, met in Salt Lake City in July 1898, primarily concerned with a revision of mining laws and the establishment of a Federal Department of Mines. However, it also adopted a resolution calling for a liberal increase in the Survey's appropriation. "The United States Geological Survey, as conducted at the present time under Director Walcott," the resolution said, "has been and is doing splendid work in bringing to the notice of the mining world and investors the mineral resources of the United States," and went on to say that "the amount of money appropriated for this survey is entirely insufficient," and even to suggest that "State surveys now in progress or in contemplation should co-operate with the United States Geological Survey, and be made co-ordinate to and a part of that work," as a means of lessening costs and at the same time adding to the value of the work done.

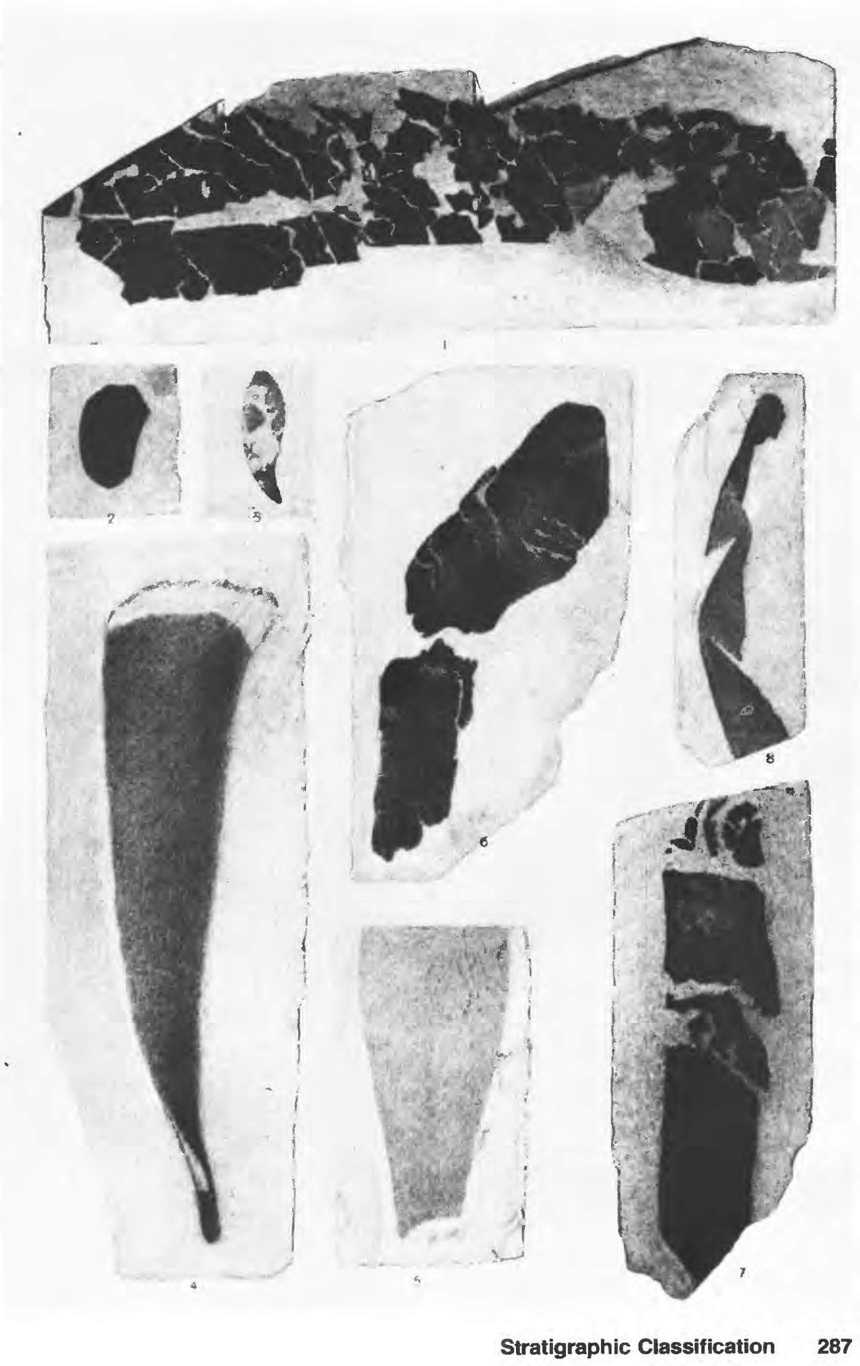
Areal geologic mapping was continued in all parts of the country, much of it being done by professors who were able to devote part of their year to the work of the Survey. Paleontologic work was concentrated on two time periods—late Paleozoic and late Mesozoic. The late Paleozoic problem was attacked by geologists of Yale University. Professor H. S. Williams continued his general study of Devonian rocks and faunas, sent one of his graduate students, E. M. Kindle, to southern Kentucky, Virginia, and West Virginia to study and collect Silurian to Carboniferous fossils for comparison, and sent another graduate student, H. E. Gregory, to Aroostook County, Maine, to enlarge the collections of the previous year. George Girty, who had joined the Survey in 1895 after receiving his doctorate from Yale, studied early Carboniferous fossils in Ohio, Michigan, and in Indian Territory. The Survey staff concentrated on the late Mesozoic problem. T. W. Stanton studied the Cretaceous in Texas, Ward studied the relations of the Comanche and Dakota formations, and Knowlton studied the Cretaceous of the State of Washington. Professor Van Hise spent some time in the southern Appalachians, where the Ocoee series was the big problem, working with Arthur Keith, George W. Stose, and Cooper Curtice in an attempt to determine its relations to the Paleozoic rocks of the Great Valley. A detailed report was submitted to the Director, which served as a basis for discussion among geologists familiar with the problem, but no conclusion was reached.

The time was propitious for another effort to establish some uniformity in stratigraphic classification and nomenclature. In the spring of 1898, the *Journal of Geology*, of which T. C. Chamberlin was editor and C. D. Walcott an associate editor, took a poll of several American geologists on the subject. The importance of a more systematic classification of time divisions and rock series had been recognized by the international congresses, the editors said, but the limited results attained indicated that the problem must be worked out gradually, perhaps in the great provinces or in individual continents first. Many geologists who sympathized with the effort to secure a more uniform practice were unwilling to have a rigid system imposed on them by the vote of a body such as an international congress. There were also those who questioned whether the science had reached a stage of development that warranted the formal adoption of a universal system of classification and nomenclature. The editors sympathized with these views but felt nonetheless that some effort should be made toward development of a system appropriate to North America as a preliminary to the establishment of an intercontinental system.

Gilbert, who was one of those polled, had mellowed a bit in the decade since he had thrown down the gauntlet to the International Congress of Geologists in 1887. He said:

> **So long as historical geology continues to be a living science, no definite system of nomenclature can hope to be permanent, nor even, perhaps, to give temporary satisfaction to a majority of geologists. Nevertheless *** teachers and geological surveys must have definite systems, and so the task of making and remaking them is a sort of necessary evil.**

Gilbert preferred Eon, Period, Epoch, and Stage for time terms, System or Series, Series or System, Group, and Formation for the corresponding rock terms. Bailey Willis, however, voted for Era, Period, Age, and Epoch, as time terms with System, Group, Series, and Formation as corresponding rock terms. Others preferred different combinations, and Samuel Calvin,



C. D. Walcott continued his scientific work, on a somewhat reduced scale, while he was Director. In 1898 when he visited the Belt Mountains, he discovered a great unconformity between the Cambrian and the Belt series, considered Algonkian in age, and found fossils in shales nearly 7,000 feet below the highest beds of the Belt series. This was only the third area of which it could be said with certainty that the strata were Precambrian and the fossils of organic origin. (From C. D. Walcott, 1899.)

the State Geologist of Iowa and one of the editors of the *American Geologist*, said that the terms suggested by the Journal as a basis for discussion—Group, System, Series, Stage, and the correlative time divisions, Era, Period, Epoch, Age were to his mind very satisfactory, but "Of course any other terms would answer equally well provided geologists were agreed to use them." There was no more unanimity on other questions proposed, such as dividing the Carboniferous, the Cretaceous, or the Cenozoic.

The *Journal of Geology* poll had not disclosed any uniformity of opinion on geologic nomenclature, but the Survey decided to take a step toward systemization. On February 17, 1899, a Committee on Geologic Formation Names was established, with Philip C. Warman, Chief of the Editorial Division, as chairman and G. W. Stose and F. B. Weeks as the other members. By that time, the custom of giving a local geographic name to geologic subdivisions had become so universal in the United States that names were being duplicated because the geologic literature was too vast for the working geologist to determine whether or not the names he proposed to use had been preoccupied. The Committee was "to consider all names of geologic formations or other divisions of rock classifications with a view to determining whether they comply with the rules of nomenclature adopted for the Survey publications and to recommend such action as may be advisable in any individual case to secure unity of nomenclature under the rules." No attempt was made to impose Survey rules on others, but Weeks, who had been compiling a card catalogue of formation names in his spare time between fieldwork and preparation of the *Bibliography of North American Geology,* volunteered in the April–May 1899 issue of the *Journal of Geology* to furnish information to anyone who wrote asking about names until such time as the catalogue could be completed and published.

In the Hydrographic Division, the usual stream measurements were continued in all parts of the country, although most of the work was in the arid region. In California, the drought was the most severe on record, and J. B. Lippincott and his assistants made a large number of low-water measurements. Willard Johnson continued his studies of the Great Plains area, and N. H. Darton, his examination of the region east of the Black Hills. Darton mapped the Hermosa quadrangle, South Dakota, with the object of ultimately preparing a folio for the geologic atlas, thus placing the groundwater investigations on a new footing. The construction of reservoirs as a means of providing a water supply for the Indians being forced to live on reservations became an established part of the program. In the Indian Appropriations Act, Congress authorized $20,000 for a study of the Gila River and Queen Creek in Arizona. As soon as he returned from Nicaragua, Arthur Davis took charge of the Gila River investigation, and Cyrus Babb made a general reconnaissance of the Gila River to determine the feasibility of constructing a dam at the Buttes. Under instructions from the Secretary, Newell directed Gerard Matthes in a detailed survey of reservoir sites in southwestern Colorado by means of which it was thought to be practicable to supply water to the southern Utes.

The Topographic Branch completed the field surveys of Indian Territory and continued the work on the Idaho-Montana and other boundary lines and the surveys of forest reserves in addition to the regular topographic-mapping program. In the standard mapping program, surveys were made in 31 States and Territories, including Alaska. The bulk of the mapping was for publication at 1:125,000, but more than 20 percent of the area was mapped for publication at 1:62,500. Both New York and Maryland contributed increased funds for cooperative mapping to expand the program in those States, and West Virginia also began cooperative work.

S. S. Gannett and D. L. Reaburn continued the the work on the Idaho-Montana line and completed the survey of the random line on October 31 in snow 2½ feet deep, narrowly missing being snowed in without provisions. The Secretary ordered an examination of the existing boundary line of the Yakima Indian Reservation to determine whether it conformed to the provisions of the treaty under which the land was set aside for the use of the Indians. When E. C. Barnard returned from Alaska in October, he was sent to make the examination but was unable to accomplish much because of the deep snow.

The field surveys of the Indian Territory, including the resurvey of the lands of the Chickasaw Nation, were completed in the latter part of June 1898. The subdivision parties were therefore disbanded at the begining of the year, and some of the men transferred to the Central, Rocky Mountain, and Pacific Sections of the Topographic Branch. Authorization had been given to use the unexpended money from the Chickasaw Nation resurveys to extend the mapping into Texas. These were completed at the end of December 1898, and in March 1899, all office work having been completed, the Indian Territory Section was discontinued. C. H. Fitch was then assigned to the survey of the forest reserves, and several topographers were added to the Survey staff.

During the Indian Territory surveys, 63,881 miles of lines and 9,303 miles of spirit levels had been run, 138 triangulation stations located, and 30,885 square miles mapped topographically in addition to the subdivisional surveys. The work demonstrated that it was more economical to survey areas of 1,000 square miles or more in this manner than under the contract system previously used, although smaller areas might be surveyed under the contract system at lower cost than by the Geological Survey if the contracts were let to local surveyors who would not incur traveling expenses. It was 20 years since Powell had told Congress that the surveys as then carried on were "unnecessarily expensive" and that "surveying is properly a question of scientific engineering, and some man thus qualified should have charge of the work, alike to protect the interests of the government and of the people settling on the public lands." He had been proved right, and the contract system was shortly thereafter abandoned.

The surveys of the forest reserves were advanced as rapidly as possible in the short time available for work at high altitudes and were extended into the older reserves. Topographic or subdivisional surveys were made in 13 reserves, and 5,314 square miles were mapped on the 2-mile scale, 708 square miles on the 1-mile scale. The forestry experts completed their examinations of seven reserves. Both the mapping and examination of the Black Hills Reserve was completed so that the U.S. Surveyor could begin marking the 217 miles of boundary on July 1, 1899.

For fiscal year 1900, Walcott asked for increases of $40,000 in the appropriation for geological surveys and $45,000 for topographic surveys, but the estimate submitted to Congress by Secretary Bliss was simply the amount appropriated for 1899. Walcott therefore took his case to Congress. The House Appropriations Committee added $20,000 to the Secretary's estimate for topographic surveys, making it $200,000, but then subtracted $20,000 from the appropriation for mapping forest reserves. No other changes were made.

The Sundry Civil Expenses bill reached the floor in February 1899 and brought on an eruption of oratory on the Spanish-American War, the acquisition of the Philippine Islands, and the Nicaraguan Canal before the Congressmen finally settled down to the details of the appropriations. As soon as the appropriation for topographic surveys was read out, George Stone of Pennsylvania moved to increase it from $200,000 to $250,000, because the requirements for work in the semiarid and arid regions left insufficient funds for the Survey to carry on cooperative work with half a dozen States in the East. George Ray of New York also favored the amendment; he had been assured by gentlemen connected with the Survey that the work would be seriously crippled and its efficiency impaired if the appropriation was not granted. Oscar Underwood of Alabama agreed, and then Alston Dayton of West Virginia offered the opinion that "There is no Government work in which our people are more deeply interested than that of the Geological Survey—and there is no branch of it that is of deeper interest in our people * * * than the topographical part of it." Charles Grosvenor of Ohio endorsed that sentiment. Of the five speakers, four, it should be noted, came from States where there had been a concentration of mapping activities for several years past, and the fifth, from a State that was about to begin cooperative work.

When he got the chance, Joseph Cannon, the chairman of the Appropriations Committee, said, "If the friends of this amendment are through, I'll tell the consideration given by the Committee and am content to abide by the decision of the Committee of the Whole." He then explained that the committee had raised the Secretary's estimate by $20,000 and added that if the Director of the Geological Survey had spent half as much time convincing the Secretary as he had evidently done elsewhere, the Secretary's estimate might have been larger. Mr. Stone's amendment was then defeated, 36–28, and the House passed the bill following the recommendations of its Appropriation Committee.

The Senate Appropriations Committee recommended the full amount originally requested by the Director, $225,000. When the bill reached the floor of the Senate, Senator Mathew Butler of North Carolina, which was also about to enter into a cooperative agreement, proposed an additional increase to $250,000. Senator Allison tried to sidetrack the issue, but Butler was persistent, and in the end the Senate voted to appropriate $250,000 for topographic surveys. In the compromise between Senate and House versions of the bill, $240,000 was appropriated for topographic surveys. An appropriation of $6,300 was also approved for surveying and marking the 98th meridian between the Red and Canadian Rivers.

There were no increases for geologic work although an effort was made by Senator Stewart, former archcritic of the Survey. In December 1898, Senator Stewart, still pursuing the matter of mineral statistics, introduced a resolution calling for a Division of Mines and Mining in the U.S. Geological Survey "for the purpose of gathering and publishing statistics of the mineral resources of the United States, including the products of gold and silver, based upon the actual mined product of each State, and statistics of labor employed and wages earned in mining operations, and making investigations in relation to mines and mining generally, and publishing the results thereof, and for the purpose of compiling and publishing the laws relating to prospecting, prospectors, and mining, and recommending revisions of the same and that there be appropriated for the purposes of this division one hundred and fifty thousand dollars." The stated purposes for the Division harkened back to those of the combined Mining Geology-Tenth Census investigations of 1880. The suggested appropriation was equal to the total Survey appropriation for that year, 1881.

The Director of the Geological Survey by now had something a little broader in mind. He wrote to Senator Stewart on December 21, that he believed "that the mining interests should have a clearly defined representation in the organization of the Government, and that either this proposed division or a bureau of mines should be established," but he suggested mildly that, instead of "investigations in relation to mines and mining generally," the resolution should read "investigations and surveys in relation to mines and mining generally."

In a more formal statement, he said, "There has been a sentiment growing among the mineral producers throughout the United States that the Government has not given as much attention to mining as the importance of that industry demands; that inasmuch as there is a Department of Agriculture, there should also be a department of mines, or at least a bureau in which mines and mining should form a part of the title. There does not seem to be any well-defined idea of what the scope or duty of such a bureau should be or what relations it should have to the existing bureaus of the Government dealing more or less indirectly with statistics and matters relating to mines and mining. It appears that many advocates of the establishment of a department of mines and mining have lost sight of the fact that an existing organization, the Geological Survey, includes among its duties many that could be done by such a department; that by the establishment of a division of mines and mining within the Geological Survey the mining interests of the country would have a clearly defined representation in the organization of the Government; that if properly provided with means for the collection of statistics and investigation of all matters pertaining to mines and mining, the publication of the statistics and information thus gathered, the interests of the mining industry would be properly cared for."

In listing the investigations that might appropriately be undertaken, Walcott first repeated earlier statements about precious-metal investigations but added that studies of coal, coke, petroleum, and asphalts, building stones, and clays should also be undertaken. Problems were by that time developing in the coal industry. The artificially maintained high prices for anthracite had caused consumers to turn to other kinds of fuel. Bituminous coal, with the use of smoke-consuming furnaces, was superseding anthracite for steam raising, and coke, or a mixture of bituminous coal and coke, was being used in iron furnaces. Coke was also being used in kitchen ranges and domestic furnaces, and natural gas was also increasingly being used for domestic purposes. Walcott pointed out that

> **The coals and cokes of the United States have so far been studied mainly on the empirical side, each by itself, or at best in small series and with reference to immediate purposes. Most of the analyses have been partial only, and there have been very few complete and ultimate analyses, particularly when we consider the extent of our resources. Then, coupled with the chemical investigation, there should be a thorough study of the calorific value of the various coals, not only as shown by the analyses, but through the medium of thorough and systematic practical tests. * * * The coke-making industry, closely allied to that of coal mining, could also be much benefited by a study of the best methods of coke making. Th prevalent method heretofore in use in this country has been an exceedingly wasteful one, in that valuable by-products generated in the coking process have been lost, and it is only within very recent years that the problem of saving and utilizing these by-products has been seriously considered.**

With regard to the building stones, Walcott reported that the Supervising Architect had requested information on a granite that was to be used in construction of public buildings and said that in his opinion "every variety of granite, sandstone, limestone, and slate, and every other stone entering into the construction of a public building, should be examined and its qualities determined before a contract is entered into for its use."

The Director's statement was printed as a Senate document, but the resolution to establish a Division of Mines and Mining in the Survey was not passed.

Walcott also tried to interest Congress in the establishment of a new national park. He had spent part of the summer of 1898 inspecting the Teton Forest Reserve, which was adjacent to and south of the Yellowstone Reserve. A bill recommending an extension of Yellowstone National Park to embrace the Yellowstone Reserve, the Teton Reserve east of the summit of the Teton Range, and two small unreserved areas at the southwest and northwest corners of the park had been sent to Congress on February 1, 1898. The Interior Department had also received petitions from Wyoming residents who favored instead the inclusion of the part of the forest reserve abutting Yellowstone Park on the south within the Teton Reserve, adding to the latter certain public lands on the south frequented largely by game, and the creating therefrom of a new national park, to be managed separately from Yellowstone National Park.

Congress had hardly convened in December 1898 before the Director's neighbor, Senator Pettigrew, introduced a resolution asking the Secretary of the Interior to send the Senate "all the information in the possession of his Department in relation to the region south of and adjoining the Yellowstone National Park; also, what steps should be taken to preserve the game in the park, and whether the region south of the park should not be put under the same control as the national park, in order to prevent the extinction of the herds of wild game roaming therein."

Walcott's report was forwarded to Congress promptly. As far as the wild game were concerned, the Director said, their winter pasture was being crowded northward by settlement, and unless something was done to protect what remained, it was only a question of time before the game, like the buffalo, would become extinct. However, rifle and shotgun would as surely exterminate the game as would destruction of their winter pasture, unless the Government did something to prevent the shooting of game. The Teton Reserve might be kept as a forest reserve although there was very little commercial timber because in the past it had persistently been burned by the Indians. However, young pines were springing up, and in a few years, there would be a heavy forest growth, provided fires were kept out. Extension of the reserve to the south would secure natural fire limits and would provide winter range for the elk, antelope, and deer that had their summer range in Yellowstone National Park.

A Teton National Park, comprising the Teton Reserve and that part of the Yellowstone Reserve south of the Park, would be even better than a forest reserve. Walcott's enthusiasm for the area was evident: "I have personally visited most of the points and regions in the United States noted for their scenery, but in my judgment, there is nothing that excels in natural beauty the valley of Jackson Lake and the Teton Mountains. * * * It may be more truly called the Switzerland of America than can any other spot known to me." Walcott even added a bit of practical advice, "If it were practicable to obtain railroad facilities to the foot of Jackson Lake and thus enable the tourist to see that beautiful region and then go north by stage to the Yellowstone Lake and through the park it would be the grandest trip, for one of limited extent, to be found anywhere in the world."

Teton National Park was eventually established, but not until 1931. However, Congress on March 2, 1899, created another national park, Mount Rainier National Park, for which geologists, especially Willis and Emmons, had been lobbying. Mount Rainier was the fourth national park, following Yellowstone, Sequoia and Yosemite.

In the field season of 1899, the Topographic Branch, its Federal appropriation of $180,000 supplemented by contributions of $43,000 from five States for cooperative mapping, mapped nearly 37,000 square miles in 29 States and Territories and ran about 1,600 miles of reconnaissance traverse in Alaska. Topographic maps were made of about 6,000 square miles of forest reserves, and the forestry experts completed their examinations of seven reserves. The survey of the Idaho-Montana boundary was completed, and the survey of the Oklahoma-Indian Territory boundary was begun. Barnard completed the survey of the boundary of the Yakima Indian Reservation and concluded that the Indians had indeed been deprived of land that was rightfully theirs.

Though no additional funds were available for geologic surveys, the metals investigations were extended in the summer of 1899. Emmons was personally engaged in an investigation of the Black Hills of South Dakota, which King while he was Director had suggested should follow his work in Colorado. The areal and economic survey of the Spearfish quadrangle, which included the most important and actively exploited ore-bearing areas, was completed, and observations were extended into the adjacent Sundance quadrangle. Tower had resigned to engage in private work but J. D. Irving made the economic study under Emmons' direction, while T. A. Jaggar and J. M. Boutwell did the general mapping. In other precious-metal investigations, F. L. Ransome came east from California to work under Emmons'

In March 1899, part of the Pacific Forest Reserve including Mount Rainier with its extensive glacier systems was made a national park. Both S. F. Emmons, who had been the second person to climb Mount Rainier and who had discovered the glaciers there in 1871, and Bailey Willis of the U.S. Geological Survey had been active in promoting establishment of the park.(The view shown is from the same point as that shown in volume 1, page 108.) (From I. C. Russell, 1898.)

direction, making first the economic study of the Silverton quadrangle in Colorado, which Cross and Spencer had mapped. Lindgren completed his report on the Silver City, DeLamar, and other mining districts of Idaho and then began a reconnaissance of the Bitterroot Range in Montana.

In October, Ransome and Spencer were sent off together to make a reconnaissance examination of the copper and uranium deposits of the Uncompahgre Plateau in western Colorado that Emmons had decided were worth investigating. A new mineral containing vanadium and uranium had been discovered earlier in the year and named "carnotite." It was found in commercial quantities and offered a new source of the rare metals for which there was some economic demand. Hillebrand had made a study of the mineral and the associated vanadiferous sandstone in which relatively large quantities of the rare vanadium mica, roscoelite, also occurred.

Weed was by now well on his way to becoming the Survey's copper expert. He spent 3 months in Butte, Montana, where new and extensive development work in the mines made it imperative that additional data be secured. He continued work on the Helena Special quadrangle, and with the assistance of Joseph Barrell, a graduate student at Yale, he made a special study of the ore deposits and intricate geology of the region near Elkhorn, Montana. Then in the winter, he made a reconnaissance trip to Ducktown, Tennessee, copper mines and examined the newly opened copper properties at Goldhill, North Carolina, and the copper districts of Person County, North Carolina, and Halifax, Virginia.

Only two geologists with experience in Alaska were available to continue the work there. Eldridge was again in demand for a new assignment and began a study of the asphaltum deposits of the United States under the auspices of the Division of Mineral Resources. Spurr had been married early in the year and declined to head up the work. Instead he was sent to make a reconnaissance of the lesser known parts of the Great Basin region of Nevada and California with a view to filling in gaps in the geologic map of the United States and ascertaining whatever might be of interest from a scientific or economic standpoint. Mendenhall was planning to go to Germany for study. So Frank Schrader took charge of a party that explored the Chandlar and Koyukuk Rivers, and A. H. Brooks accompanied W. J. Peters in an exploration along the upper Alsek River and aross the White River to the Tanana Valley and Eagle City.

At the same time, areal geologic mapping and stratigraphic studies were continued in various parts of the country, and a committee, under the chairmanship of Arnold Hague, was established to consider the scope of a proposed "9-sheet" geologic map of the United States. Three of the senior scientists of the Survey, W. H. Dall, Henry Gannett, and G. K. Gilbert, accompanied the Harriman Expedition to Alaska.

There was another reminder of times past in renewed controversy on the age of the Earth. In May 1899, *Science* had printed Lord Kelvin's paper, *The Age of the Earth as an Abode Fitted for Life*—the annual address of the Victoria Institute in 1897, with additions to May 1898. The paper was, of course, mathematical, drew heavily on the Barus experiments, and Lord Kelvin concluded that he was "not led to differ much" from Clarence King's estimate of 24 million years. Professor Chamberlin followed with a paper of the same title in which he differed from the mathematical-physical approach, as had McGee in 1893, but on somewhat different grounds.

Professor Chamberlin began very diplomatically:

> In the early half of the century, when the more sober modes of interpreting geological data were struggling to displace the cataclysmic extravagances of more primitive times, it is not strange that there should have arisen, as a natural

outgrowth of the contest, an ultra-uniformitarianism which demanded for the evolution an immeasurable lapse of time. It is not remarkable that individual geologists here and there, reacting impatiently against the restraints of stinted time-limits imposed on traditional grounds, should have inconsiderately cast aside all time limitations. It was not unnatural that the earlier uniformitarians, not yet fully emancipated from inherited impressions regarding the endurance of rocks and the immutability of the 'everlasting hills' should have entertained extreme notions of the slowness of geological processes and have sought compensation in excessive postulates of time. Natural as these reactions from primitive restrictions were, a reaction from them in turn was inevitable. This reaction must have ensued, in the nature of the case, whensoever geologists came seriously to consider those special phenomena which point to limitations of time. But in the earlier part of the century geological attention was absorbed in the great phenomena that testify to the vastness of the earth's history. The time for the study of limitations had not come.

Chamberlin went on to point out that Kelvin was right in attacking the ultrauniformitarians, but there were also ultracatastrophists, and the "great body of serious geologists have moved forward neither by the right flank nor by the left, but on median lines." These lines, he thought, were in the field of qualified uniformitarianism. The real problem, as Chamberlin saw it, was that Kelvin's determination was based on the assumption (very sure assumption, in Kelvin's words) that the material of the present solid Earth all around its surface was at one time a white-hot liquid. There was an alternative, which Chamberlin had proposed, that the Earth grew by meteoric accretion with sufficient slowness to remain essentially solid at all stages. He suggested that if astronomers, physicists, and mathematicians jointly attacked the formational history of the solar system, stage by stage, it might be possible to come to some conclusion, but he wondered "whether there is at present a solid basis for any 'sure assumption' with reference to the earth's early thermal conditions, either internal or external, of such a determinate nature as to place any strict limitations upon the duration of life."

The Division of Hydrography, in addition to gaging streams, surveyed several reservoir sites, and prepared estimates of their capacity and cost, examined canal lines conducting the water from these reservoirs to the irrigable lands, and ascertained the cost of construction chiefly in connection with the Indian reservations but also in California. The investigation of the practicability of storing water along the Gila River to irrigate the Gila Indian Reservation was completed by J. B. Lippincott and Cyrus Babb after Davis took leave of absence to continue investigations in Central America for the Isthmian Canal Commission similar to those he had begun for the Nicaraguan Commission. Babb then began a survey and examination of the Uinta Indian Reservation in northeastern Utah to ascertain the water supply and practicability of irrigating the agricultural lands of that reservation, while Gerard Matthes made a detailed survey of the Riverside reservoir site in Arizona and then a reconnaissance of Mancos Canyon in southeastern Colorado to determine the cost and capacity of small reservoir sites near the Southern Ute Indian Reservation. Lippincott was put in charge of fieldwork in California, where the continuing drought had made the necessity for water storage apparent. The California Water and Forest Society raised a fund of several thousand dollars, part of which was intended for use in cooperation with the Survey for examination of reservoir sites and the determination of available water supply. The principal reservoir survey was the Hetch Hetchy, near the headwaters of the Tuolumne, but systematic measurements were also begun on the San Joaquin, Kings, Salinas, and other streams.

The mineral industry had another very profitable year in 1899. The total value of mineral products was more than 40 percent over that in 1898 and was already close to the $1 billion that King had predicted as its ultimate value. The gold mined that year was valued at more than $71 million, just about twice what it had been only 5 years earlier.

In his state of the Union message, President McKinley reported that on December 1, 1899, there was a cash balance of $278 million in the Treasury, of which $239.7 million was in gold coin and bullion, and that the "widespread confidence" that prevailed throughout the country had brought gold into more general use. In fact, gold was seeking the Treasury demanding paper money in exchange. It was therefore "the most fitting time to make adequate provision to ensure the continuance of the gold standard and of public confidence in the ability and purpose of the Government to meet all its obligations in the money which the civilized world recognizes as the best." On March 14, 1900, the United States adopted the gold standard.

Several bills were filed in aid of the mineral industry, and the House Committee on Mines and Mining reported favorably on two of them, one to establish mining experiment stations and the other to establish a Department of Mines with the Survey as its nucleus "to acquire by examination, practical and scientific experiments, geologic research and otherwise, useful information on the subject of mining in the comprehensive sense of the word," including among a long list of minerals, "mineral waters, as well as waters used in mining, manufacturing, or developing electric power." None was passed.

Walcott took advantage of the American Institute of Mining Engineers meeting in February 1900 to deliver a statement of policy on the role of the Survey in relation to the mining industry. The Survey, he said,

> should endeavor to accomplish for the mining industry, as a whole, what the individual mining engineer or mine-owner cannot succeed by his unaided exertions in doing; *** should not undertake to do what could be done as well, if not better, by individual exertion; *** [and] should not interfere either favorably or unfavorably, with the private business of individuals or corporations, or enter into competition in their legitimate occupations with professional men, such as mining engineers.

The way was clear for Survey involvement in more than strictly geological investigations in connection with mining, and Walcott urged those in the mining industries who wished government recognition to "first secure legislative provision for a division of mines and mining in the Geological Survey, and later, if it is found desirable, ask for the establishment of a Department of Mines and Mining."

Walcott went on to say that the means for economic work in the Survey were limited, so the energies of Survey scientists were devoted to those branches of investigation that were of immediate use to the greatest number, and these were chiefly investigations leading to broad general deductions. He quoted Emmons as saying that the Survey's relations to the mining industry could be viewed from three standpoints: purely scientific, technical, and commercial. In the field of purely scientific investigations, the general object had been to determine the laws that govern the formation of deposits of the useful minerals and of the rock formations in which they are most likely to be found. The objective could be attained only by long and careful study of many and varied deposits, and the most intensive studies had to be made in old districts where the mining development had been greatest. From a partly developed district, only superficial facts could be learned, and such districts were the province of the mining engineer rather than that of the Government geologist.

The same general principle held for technical and commercial studies. There was more danger of encroaching on the legitimate field of the mining engineer or metallurgist in technical studies than in geologic studies, and the Survey should confine itself to investigations that it was better fitted to make than was an individual.

The principle was easy of application in relation to commercial studies. The collection of accurate statistics of the mineral production of the country was a prime duty of the Survey. No branch of statistical science was in greater need of technical knowledge and thorough system than that which dealt with mineral production, and none was more liable to be led into error, if the collector's opinions were in any way biased by his interest. There was no body of men more absolutely disinterested than the employees of the Survey because, under the law, they could have no commercial interest in the subjects they treated. The statement called to mind J. D. Whitney's requirements, as outlined in 1878, and the words of the first Director on the importance of mineral statistics. The cycle had once more run full course.

More important than the Director's statement were the papers prepared by Survey geologists for the meeting, which gave a broad view of the work of the Survey in economic geology. The papers ranged from major discussions of principles, the distillation of the study of many years, to short descriptions of recent work. The major papers by C. R. Van Hise, S. F. Emmons, W. H. Weed, and Waldemar Lindgren presented a broad range of thought on the origin of ore deposits. Van Hise held one extreme—that the deposition of most ores was a special case of the general work of ground waters and that ores of direct igneous origin or the direct result of processes of sedimentation were of limited extent. Lindgren tended toward the other. He was not prepared to deny that some classes of veins might be due to circulating surface waters alone, but he did not believe that their dissolving power was sufficient to account for all classes, or even the majority of fissure veins. Lindgren pointed out that important changes in the rocks adjacent to ore deposits had been overlooked and proposed an attempt at classifying veins according to the different phases of alteration accompanying them. Emmons held the middle ground. He did not deny the importance of the formation of ore deposits exclusively by magmatic differentiation as a possible first cause, but in his 20 years of study, he had not yet seen any of which the present condition was not due to further concentration. Emmons and Weed presented an explanation of the occurrence of bonanzas by secondary enrichment. The papers did not present any definitive explanation of the origin of ore deposits but laid solid groundwork for the advancement of the science. Thus, the meeting was described in later years as having established "a veritable milestone in the study of ore deposits."

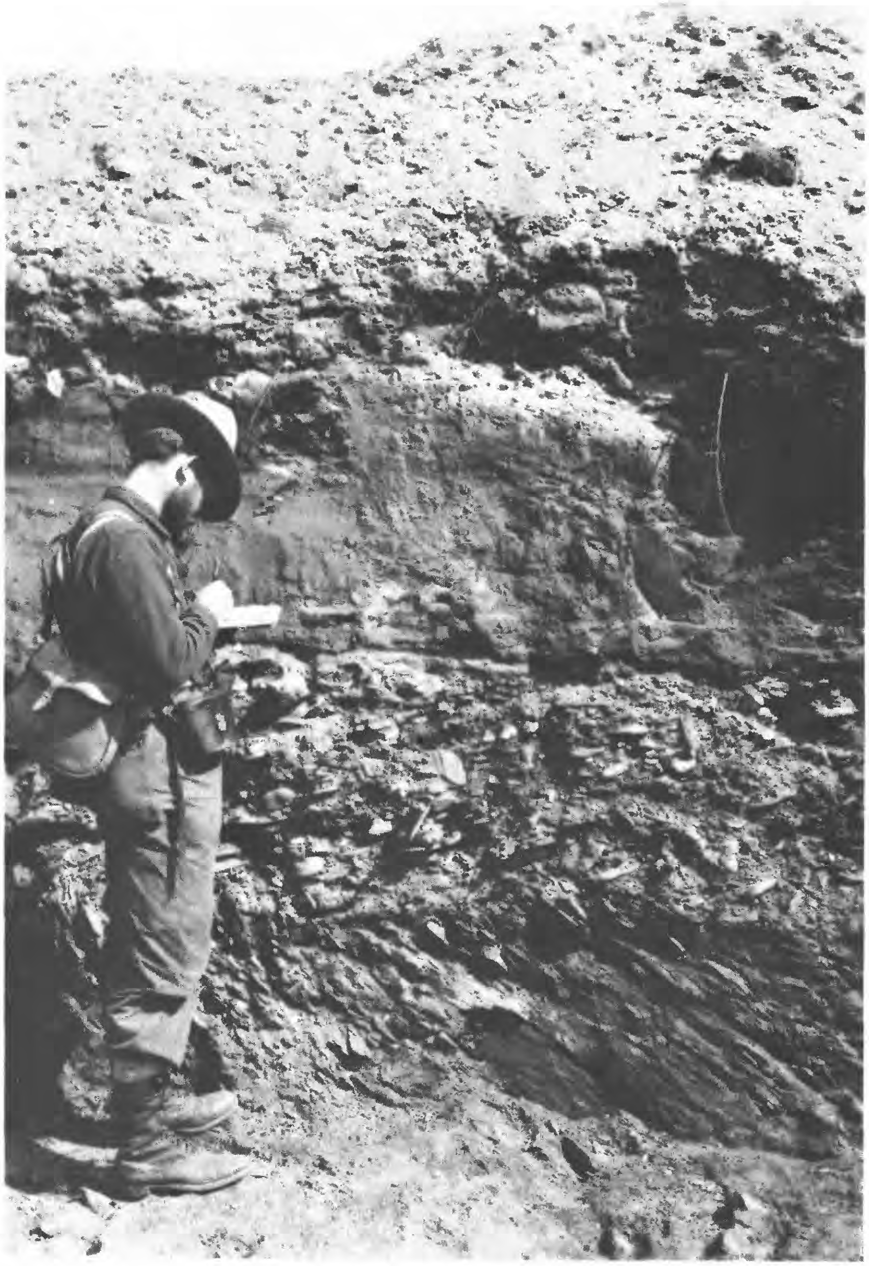
Chapter 11.
The Best Geological Survey in Christendom, 1900–1902

> **Proper regard for truth compels me to say that the Geological Survey of the United States, by common consent of well informed men, is the best Geological Survey conducted by any government in Christendom.**
>
> **—Senator Thomas H. Carter**

On February 20, 1899, Ethan Allen Hitchcock became Secretary of the Interior, succeeding Cornelius Bliss who retired for personal reasons. Hitchcock had amassed a fortune in the China trade and had retired in 1872, at the early age of 37, thereafter being occupied as a successful man of affairs in St. Louis, where his brother Henry was a distinguished lawyer and founder of the Washington University Law School. Secretary Hitchcock was aware of the needs of the mineral industry. He had established the first successful American plate-glass factory, which had been sold to the Pittsburgh Plate Glass Company a few years before he became Secretary. He also had extensive interests in iron and steel. Hitchcock was a personal as well as political friend of President McKinley and had prepared the plate-glass schedule for him in the 1890 tariff bill. When McKinley became President, he sent Hitchcock as minister to Russia in 1897 to advance the interests of American trade and in December 1898 recalled him to become Secretary of the Interior. Hitchcock was reported to be cold and formal in manner, collected in speech, and utterly impervious to the persuasions and influence of hard-headed men of affairs or of genial politicians. Secretary Hitchcock and the Director of the Geological Survey, however, soon established a very cordial working relationship.

The first budget estimate submitted to Congress by Secretary Hitchcock included a substantial increase for the Geological Survey to a total of $778,100. The House Appropriations Committee did not file its report on the Sundry Civil Expenses bill until May 2, 1900, but in a complete reversal of form, it recommended an appropriation for the Survey of $802,100, or $24,000 more than the estimate. The appropriation for geological surveys was increased to $150,000, and for the report on mineral resources, to $50,000.

On April 30, 3 days before the House Committee filed its report, Senator Thomas Carter of Montana had asked for a report on the Survey's water-resources investigations. The request was detailed: expenditures in the year ending June 30, 1900, character of the information obtained, steps being taken to make specific statements of the possibility and cost of the reclamation of certain tracts, specific localities under consideration for surveys, amount of money required for the year ending June 30, 1901. The Director replied on May 2. The amount of money available for fiscal year 1900 was about $90,000—$50,000 from the regular appropriation, $20,000 from a supplemental appropriation on March 30, and the balance from the Office of Indian Affairs. The information obtained related largely to the flow of streams and the possibility of regulating this flow by means of reservoirs.



After news of the discovery of gold on the Klondike in 1896 reached the United States, prospectors swarmed into all accessible parts of Alaska. Gold was found in commercial quantities on Ophir Creek in the Seward Peninsula in the spring of 1898, and in the beach deposits near Nome in July 1898. Alfred H. Brooks is shown here examining the auriferous gravels on a tributary of Ophir Creek. (From A. H. Brooks, 1901.)

In a few instances, detailed estimates of various storage propositions had been made, but for the most part, only a general knowledge of the fluctuations of streamflow had been obtained. The measurements of rivers and examinations of underground waters were laying the foundation for detailed estimates of possibilities of further reclamation or the development of resources not now utilized. The river measurements should be followed by specific examinations of the possibilities and cost of the reclamation of certain tracts. Then it would be "possible to discuss intelligently the probable cost and benefits of certain lines of development and to draw conclusions whether such work can best be carried on by individuals or by governmental agencies, whether State or national." The "resources not now utilized" to which he referred were then explained as the undeveloped waterpower in the Eastern and Southern States that could be utilized when the volume of water was known. That work, Walcott said, should be undertaken by the National Government rather than the States or private industry. A list of

40 localities at which surveys were desirable, each of which would cost $5,000 to $25,000, was provided. Altogether, an appropriation of $250,000 was needed, $38,000 for investigations in the Eastern and Southern States, the remainder for the West. On May 11, Senator Carter submitted a proposed amendment to the Sundry Civil Expenses bill to increase the appropriation for gaging streams to $250,000. It was referred to the Committee on Irrigation, which reported it favorably 4 days later and sent it to the Appropriations Committee.

As was common during an election year, much of the discussion of the Sundry Civil Expenses bill in the House Committee of the Whole was campaign oratory. The bill was passed on May 5 without any special notice of the Survey appropriation. The Senate Appropriations Committee recommended an increase of $63,000 for the Survey over the House bill but only $100,000 for gaging streams. The other increases were $10,000 for topographic surveys and $3,000 for research in physics and chemistry.

The Senate itself was in a mellow frame of mind when the Survey appropriation came up for consideration. Senator Henry Cabot Lodge of Massachusetts did complain that there were too many departments involved in surveys and said they should be concentrated in one department, but his colleague from New Hampshire, Senator William E. Chandler, took the stand that it was better to scatter the work because competition made for better results. Senator Chandler said, perhaps facetiously, perhaps seriously, that he regretted that the Geological Survey seemed to be the only one of these surveys that did not have any ships, and he hoped that Senator Allison would propose an amendment to give them all the ships, all the officers, and all the seamen they needed for their business. Senator Lodge then prophesied that in time, as the Coast Survey had extended onto the land and become geodetic, the Geological Survey would extend into the water and get a navy (His prophesy was fulfilled in 1947.).

The appropriation for stream gaging was the only item in the Survey appropriation to call forth much serious discussion. Senator Carter proposed that it be increased to $250,000, saying as he did so that the Geological Survey of the United States was the best geological survey conducted by any

By 1900, Butte, Montana, had become the most important mining center in the United States, producing 54,552 ounces of gold and 9,454,279 ounces of silver as by-products of copper that amounted to 270,738,489 pounds in that year. The veins in the Anaconda system were of remarkable width and mineralogic uniformity; some of them, stoped for thousands of feet along their courses, had only local variations in richness and no well-formed ore shoots. (From W. H. Weed, 1912.)

government, its publications the most enlightened, and its researches conducted by the most thoroughly equipped men of any like institution anywhere. Senator Stewart agreed: "I must say that the Geological Survey is now in good hands—that it is working legitimately and accomplishing great good. * * * I was opposed to this Survey when it did extravagant things, but now that it is engaged in legitimate business, which is benefitting the country, I hope the Senate will take a rational and sensible view of it and give us a larger appropriation, which the Department wants." Senator Wolcott of Colorado remained unconverted. He thought the former chief of the Survey "was but an infant compared with the present head," and warned the "trustful and unsuspicious Southern Senators" that it was not gaging streams but gouging people that the Survey planned. Senator Butler of North Carolina assured him that he was wrong, and that if his State had "as efficient, as intelligent, and as valuable a State geologist as North Carolina," he too would appreciate the Geological Survey. Senator Butler then read a communication from the State Geologist, Joseph A. Holmes, on the reasons why the hydrographic appropriation should be increased, and the Senate voted an appropriation of $250,000. The other increases proposed by the Appropriations Committee were also approved.

The House and Senate conferees agreed quickly on the House figure of $240,000 for topographic surveys and the Senate figure of $10,000 for chemical and physical research, but it took two conference reports before a compromise was reached on an appropriation of $100,000 for stream gaging, less than desired but double that of the year before. The total for the Survey was $855,100, the greatest amount that had ever been appropriated for the Survey and almost as much as had been appropriated for the Geological Survey and the Irrigation Survey combined in 1891. In the 8 years since that bleak August of 1892, the total appropriation had more than doubled, water-resources investigations were firmly established as part of the Survey work, funds for work in Alaska had increased twelvefold in 5 years. Only paleontology remained at the 1892 level.

On July 1, 1900, the Geologic Branch was reorganized in an experiment designed to separate scientific and administrative control of the work. Scientific control was vested in a group of specialists while administrative control was retained by the Director. Scientific control was discussed by the Director with Chamberlin, Van Hise, Emmons, and Willis, and they jointly prepared the statement on the new organization. Seven divisions were set up, covering specified subject areas, and each was placed in charge of a specialist. For each subject area, or division, the field of supervision of the specialist in charge, or division chief, was Survey-wide and his opinion was considered authoritative. He was expected to prepare plans of work within his division, recommend that which was especially desirable, establish priorities, and recommend geologists to undertake particular projects. He was to confer with the other division chiefs to adjust plans, call attention to opportunities in other areas, and promote cooperation. Division chiefs would also review manuscripts, and no manuscript would be accepted for publication without a favorable recommendation from the division chief concerned. Party chiefs would plan the conduct of the work, the Director would approve plans and make allotments, and the party chief would be responsible to the Director for the execution of the work and disbursement of funds unless the Director delegated that responsibility to a division chief. The new organization was tacit recognition that, in the Geological Survey at least, the day of the individual investigator, free to pursue his own interests, was past. It was also explicit recognition of the intimate relations of economic and general geology.

Charles Willard Hayes

Geologist, U.S. Geological Survey, 1886–1911. Hayes was the first geologist in charge of the Nonmetals Section, established in 1900. He became geologist in charge of the Division of Geology and Paleontology in 1902 and Chief Geologist in 1907. Hayes was trained as a chemist but became interested in geology as a graduate student at The Johns Hopkins University. His training in the exact sciences led him to make more detailed and accurate investigations than were common at the time and led to advances in structural geology, physiography, and economic and engineering geology. (From the files of the U.S. Geological Survey.)

The areas of specialization or divisions established were Areal Geology, Pleistocene Geology, Pre-Cambrian and Metamorphic Geology, Paleontology, Economic Geology, Physical and Chemical Research, and Mining and Mineral Resources. Bailey Willis was placed in charge of Areal Geology, which included stratigraphy, structure, and pre-Pleistocene physiography; T. C. Chamberlin, of Pleistocene Geology, which included glacial and nonglacial formations and Pleistocene physiography; C. R. Van Hise, of Pre-Cambrian and Metamorphic Geology, which included structure, metamorphism, and the genesis of crystalline schists and associated rocks, including the metamorphic iron ores; and T. W. Stanton, of Paleontology. S. F. Emmons and C. W. Hayes shared responsibility for Economic Geology, Emmons being responsible for metalliferous ores and Hayes for practically everything else (officially for "nonmetalliferous economic deposits and nonmetamorphic iron ores, bauxite, etc."). George F. Becker was named head of the Division of Physical and Chemical Research in which research in physics would once more get underway. David T. Day retained charge of the statistical work on mineral resources, but the renaming of the division indicated an extension of the work and its identification with the interests of the mining industry.

These eight division chiefs would set the scientific tone of Survey geology for the next few years. There were no new faces in the group—Emmons, Becker, and Willis had all joined the Survey in 1879, Willis as part of the Tenth Census, and Chamberlin had been with the Survey since 1881; all the others had been on the staff for a dozen years or so. All were college trained, and all but Willis had advanced degrees. The eight, however, were of two different generations. Emmons and Chamberlin were approaching 60, Becker was 53; the other five were all younger, barely into their forties. Francis Bacon observed that "Young men are fitter to invent than to judge, fitter for execution than for counsel, and fitter for new projects than for settled business." The division chiefs might almost have been chosen with this observation in mind. The oldest, Emmons and Chamberlin, were responsible for fields in which a solid groundwork had already been established, largely through their efforts. The younger men were in fields in which there were many opportunities for innovative work and in which they later made substantial contributions.

Most of the younger men had begun to specialize, but Hayes had shown a broad range of competence. His training had been primarily in chemistry until Professor G. H. Williams had stimulated his interest in geology, and because of his background in mathematics and the physical sciences he set higher standards of accuracy in fieldwork than were in general use at the time. Finding the topographic maps in the southern Appalachians inadequate for his work, he prepared his own bases, and his method of working had a marked influence on the improvement of topographic maps. His careful mapping led to the recognition of the broad overthrust faults that were the key to understanding the structure of the southern Appalachians, but his contribution to structural geology was matched by his careful analysis of the geomorphology of the area. In 1893, when Survey interest in mineral deposits was revived, Hayes was assigned to study the Tennessee phosphate and bauxite deposits, and he began to make quantitative estimates of reserves as well as to study the occurrence and origin of the deposits. In 1897, he had made the first large-scale engineering geology study in connection with the construction of a Nicaraguan canal. Hayes was also a natural leader. Alfred H. Brooks, whose first assignment on the Survey was with Hayes and who remained his close friend for the rest of his life, said that one of the reasons for Hayes' success in fieldwork, and later as an administrator, was the admiration he inspired in his assistants. They all became his devoted followers, but they became independent thinkers rather than disciples. All of these characteristics enabled Hayes to exert a major influence in the development of petroleum geology in the next decade.

Only a few nonmetalliferous investigations were made in the summer of 1900. Hayes spent 2 months in Tennessee, mapping the Columbia quadrangle and studying the phosphate and clay resources, then went south to visit the salt and sulfur deposits of northwestern Louisiana, some of the oilfields of Texas, and the bauxite district of Arkansas. He thought that there was little possibility of oil being found where drilling was going on in the southeastern coastal region of Texas. M. R. Campbell, with whom he had made the physiographic study of the southern Appalachians, began a cooperative geological survey in Pennsylvania with the assistance of John D. Irving and Myron L. Fuller, who had been an instructor at the Massachusetts Institute of Technology. Areal mapping was begun in the Uniontown and Masontown quadrangles, which included the southern end of the Connellsville coalfield and the eastern edge of the coalfield underlying Greene and Washington Counties. The plan of work called for very careful mapping of the Pittsburgh coal in order to show not only its outcrop but also its attitude beneath the surface by means of contour lines.

In the Metals Section in the summer of 1900, copper superseded gold and silver as the metal of greatest interest. Emmons himself began the summer with a reconnaissance of the copper district of the Grand Encampment Mountains in Wyoming where he had first worked in 1872, spent a few weeks with Boutwell in the Bingham area, went on to Butte, Montana, to consult with Weed on the work there, then to Spokane via the Great Northern Railroad to examine the cross section of the Rocky Mountains, and back to Butte for a conference with the Director. The apex law suits were underway, with distinguished geologists testifying on both sides, and the Director and Emmons decided that a district where ownership of ore bodies depended on geologic structure should be given monographic treatment. Weed was instructed to complete his unfinished work and then devote his entire time to study of the mines in the Butte district. Emmons then went back to Bingham for a time, then to southwestern Utah and southeastern Nevada to examine the deposits of the Horn Silver and Delamar mines, and finally to Leadville, Colorado.

Lindgren spent about 4 months in a reconnaissance of the mining regions of eastern Oregon, covering an area of about 6,000 square miles from the Snake River westward to the John Day Valley that included all the mining districts that had recently come into prominence. Ransome spent the season in Colorado, in an economic survey of the Rico district, the Silverton quadrangle, and a reconnaissance of the mining regions of Clear Creek and Gilpin Counties to plan future work.

In the fall, the Metals Section took over supervision of lead and zinc projects. H. F. Bain and G. I. Adams had been examining the lead and zinc deposits of the Joplin district, Missouri, under the joint supervision of Van Hise and Willis, neither of whom had had much experience with deposits of the Joplin type. Emmons went to Missouri for a conference with Bain, adopted the work, and ended the season with Bain in an examination of the zinc, antimony, and gold deposits of west central Arkansas.

Precious metals were still of greatest interest in Alaska. A. H. Brooks, with George B. Richardson and A. J. Collier as geologic assistants, made a reconnaissance of an area of about 6,000 square miles in the Nome region and studied the occurrence of placer gold on nearly 100 different creeks in nine different gold districts. Brooks concluded that there was a second belt of gold-bearing rocks about 30 miles north of the Nome region proper and that the gold-bearing region of the Seward Peninsula was much larger than at first supposed. The discovery of stream tin at York was of scientific interest and of possible commercial interest. W. C. Mendenhall was assigned to work in the Seward Peninsula as a member of the party under W. J. Peters. The original plan of operations had contemplated the ascent of Koyuk River, portage over it to some stream flowing northward to Kotzebue Sound, and return to Golofnin Sound over an unspecified route; the plan was modified, however, when the party reached the field in order to make the mapping more continuous and valuable over an area that promised to develop economically within the near future. The Fish, Tubutulik, and Koyuk Rivers were ascended in order, and topographic and geologic maps of the basins were made in as much detail as was possible. F. C. Schrader directed the third party and was assisted by T. G. Gerdine and Arthur Spencer in mapping the Chitina copper district in the Copper River region.

C. K. Leith became Van Hise's principal assistant in the Division of Pre-Cambrian and Metamorphic Geology. Leith began mapping in the Mesabi district of Minnesota with the assistance of some excellent private maps that

By 1900, Minnesota was crowding Michigan for first place in iron production. The Mesabi ores were soft, for the most part slightly hydrated hematites, and at shallow depths, under an overburden that ranged in thickness from only a few feet to as much as 85 feet. Stripping the overburden from the ore with steam shovels and loading the ore directly on railway cars in open cuts proved to be an economical method of mining. By 1902, about 47 percent of the Mesabi ore was mined in this way. (From C. K. Leith, 1903.)

were placed at his disposal and the cooperation of the mining men of the area, while Professors W. S. Bayley and J. M. Clements continued mapping in the iron districts of Michigan. Van Hise himself spent the greater part of his time in studying the structure of the Lake Superior basin and preparing his treatise on metamorphism.

The increased appropriation for the report on mineral resources made it possible for the Division of Mining and Mineral Resources to begin an examination of the conditions of occurrence of the precious metals, as discussed by Congress, to prepare a report on the coalfields of the United States from the commercial standpoint and to sponsor some field studies, such as M. R. Campbell's investigation of the distribution of borax and salt in southern California, and George Eldridge's investigation of the petroleum resources of the Pacific slope. Oil had been discovered near Coalinga in Fresno County, California, in 1890, and in 1892, E. L. Doheny drilled the first successful well in Los Angeles. Well drilling thereafter proceeded so rapidly that a problem was created in the General Land Office. In 1896, Secretary Hoke Smith had ruled that land that contained oil could not be patented under the Placer Mining Act, which had been the practice when patents were few in number, but Congress overruled him in February 1897 and made the Placer Act applicable to petroleum lands, thereby creating a problem for the oil drillers. Under the Placer Act, land could not be patented until a discovery was made, but drilling cannot be done in secret. Others therefore tried to capitalize on the oil companies' work by patenting land under other laws. Eldridge's investigation was an attempt to determine the general conditions under which petroleum occurred in that region.

Bailey Willis did no fieldwork, being thoroughly occupied with his duties as head of Areal Geology, chairman of the Committees on Geologic Names and Illustrations, member of the Building, Records, and Publications Committees, custodian of property for the Geologic Branch, and Geologic Map Editor. Early in the year he began, at the Director's charge, a study of current practices in mapping units and the use of such terms as "formation," "series," "system," and related terms. For a decade or so, the Survey had been mapping formations by lithology, following the plan laid down in 1889, but not infrequently geologists of the Survey and others had correlated these local formations by their contained fossils. A certain amount of confusion and controversy resulted when the criteria used were not specified, because a stratigraphic series may be divided in one way by lithologic character and another by its fossils. The report on the Willis study was sent to several Survey geologists for comment and was also the subject of a lively discussion at a meeting of the Geological Society of Washington. Willis believed that the cartographic unit should be defined purely on the basis of lithology and that there should be uniformity in usage of terms for the units of lithologic, faunal, and chronological scale. The question was whether to fix the usage of such English substantives as series, formation, system, period, and so on or to adopt entirely new terms from some foreign, preferably dead, language. Major Powell, who was present at the GSW discussion, strongly favored new terms, saying that he had attempted to redefine old words in devising a scientific nomenclature for psychology and found that people tended to forget his definitions and use the terms in their own way. Both Whitman Cross and H. S. Williams thought that fossils and lithology should both be considered in defining the unit, and the matter remained unresolved.

In the Division of Pleistocene Geology, R. D. Salisbury became Chamberlin's principal assistant, and Chamberlin confined his Survey activities chiefly to the direction of field operations and the examination of manuscripts. Salisbury studied the glacial deposits of New Jersey and also examined critical points in the District of Columbia, Maryland, and New Jersey so that the Maryland and U.S. surveys would agree on interpretation. Other projects were underway in Michigan, Pennsylvania, Ohio and adjacent parts of West Virginia and Kentucky, New York, and New England.

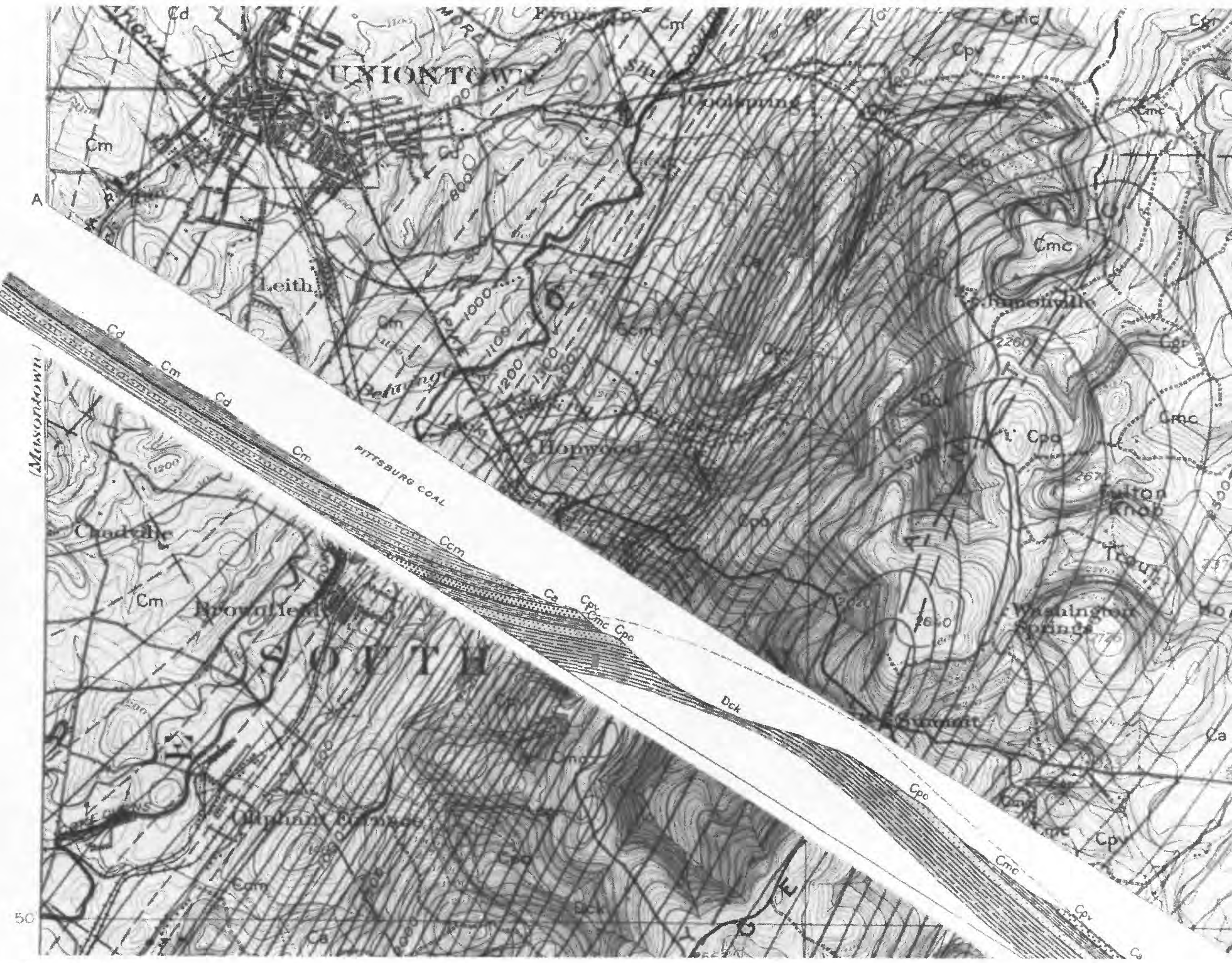
The paleontologists worked closely with geologists in determining and correlating various formations but also undertook special investigations: Girty, of the Carboniferous; Stanton, of the Cretaceous; Knowlton, of the Cretaceous and Tertiary; Dall, of the Tertiary; and Vaughan, of fossil corals. Lester Ward continued work on his *Compendium of Paleobotany*, and Henry Fairfield Osborn continued work on the monograph on Sauropoda and began preparation of the monograph on Titanotheres.

The establishment of the Division of Physical and Chemical Research in July 1900 took the Survey back into work that had been instituted by King but abandoned in 1892. In the meantime, field geologists had been bringing together vast amounts of data, and laboratory studies in both chemistry and physics were vitally needed. The organization of the new physical laboratory was begun in October 1900 with the appointment of Dr. Arthur L. Day to the Survey staff. Day was another Yale man, with an A.B. in 1892 and Ph.D. in 1894. He had spent 3 years as instructor in physics at Yale and had then gone to Germany, where he was first a volunteer assistant and then a regularly appointed member of the scientific staff of the Physikalische Technische Reichanstalt, a rare honor for one of non-German citizenship. In August 1900, he married the daughter of the president of the Reichanstalt. Day was at first occupied in procuring new equipment, some of it being especially made for the Survey at the Reichanstalt, for most of the equipment from the earlier laboratory was either obsolete or unfit for further use. In the chemical laboratory, H. W. Stokes was assigned to an investigation of the secondary enrichment of ores at a moderate distance beneath the Earth's surface, a subject of particular interest to the Metals Section.

Topographic mapping also achieved a new status in 1900. In the 20th annual report, Walcott stated that topographic work had been extended into all the States and Territories, but only 27 percent of the entire area exclusive of Alaska had been surveyed. Moreover, more than 200,000 square miles that had been mapped in early years on the scale of 1:250,000 was in need of resurvey, so that only 19 percent of the total area had been adequately covered. Major Powell had told the Allison Commission in 1885 that the topographic map could be completed in 24 years, and that statement had been used to measure progress, to the misfortune of the Survey. Walcott stated frankly that, at the then current rate of progress, somewhat more than 100 years would be required to complete the map exclusive of Alaska, and more than 110 years would be required if provision were made for resurvey of the 1:250,000-scale work. The statement caused no raising of eyebrows in Congress. The Senate, in fact, was willing to consider the possibility of extending topographic mapping to the islands acquired after the Spanish-American War. In answer to a Senate resolution of January 9, 1900, Walcott stated that although the Survey could now legally undertake surveys in Puerto Rico and Hawaii, the exhaustion of the appropriation by established work in the United States made it inexpedient, and that surveys in Cuba and the Philippines would require special authorization. He was clearly willing to undertake such surveys and submitted an estimate of $124,000 for topographic surveys in Puerto Rico, Hawaii, the Philippines, and Cuba. If cadastral surveys were also desired, additional funds would be needed.

Congress made no additional appropriations for topographic surveys that year, and on February 23, 1900, the Director relinquished administrative control of the Topographic Branch to the Topographic Committee, at the same time appointing R. U. Goode its chairman. Henry Gannett was on loan to the Department of the Interior to serve as Chief Geographer of the

Central Arizona ranked third in copper production in the United States in 1900. Ransome reported that the more important copper ore there was found in large masses in limestone and in irregular mineralization of shattered or permeable rocks rather than in lodes or fissure veins. The Old Dominion mine, just north of the town of Globe, had been the first mining location staked in the district. After being worked sporadically for silver first, it later became the largest and steadiest producer of copper in the region. (From F. L. Ransome, 1903.)



Under Hayes' direction, areal mapping in the Pennsylvania coalfields was done so carefully that structure contours could be drawn on the top of the Pottsville sandstone and the base of the Pittsburg coal and overprinted on the geologic map to show the horizontal contours of troughs and arches, the dip of the beds, and the height of the reference surface above sea level at any point. Such structure contours were invaluable to the coal operators. (From M. R. Campbell, 1902.)

Twelfth Census, so the other members of the Committee were Messrs. Wilson, Renshawe, and Douglas.

Detailed topographic mapping was done in 1900 in 32 States and Territories. The total area mapped was 35,123 square miles, nearly 38 percent of it at the mile-to-the-inch scale. In connection with the Alaskan investigations, about 6,500 square miles were mapped, and as part of the forestry program, 132 miles of boundary were marked and 6,543 square miles were mapped topographically. Cooperative surveys were made with five States, and the State of Ohio also appropriated funds to begin cooperative work in the next year.

The increased appropriation for hydrography was allotted three ways: to measurements of streams, surveys of reservoir sites and preparation of land-classification maps, and preparation of reports on the best methods of utilizing the water supply and investigation of underground currents and artesian wells. Newell himself took charge of the collection of statistics on irrigation for the Twelfth Census. The largest amount of fieldwork was done in California, where the operations were under the direction of J. B. Lippincott. The California investigations included stream measurements, investigations of waterpower, the transmission of power by electricity, and the utilization of power in pumping water from underground for lands beyond the reach of gravity canals. Arthur Powell Davis was on leave in the early part of the year to continue investigations in Central America for the Isthmian Canal Commission, but on his return to the United States, he began the investigation of the cost of water storage on the Salt and Verde Rivers east of Phoenix, Arizona. Charles H. Fitch was mainly occupied in a determination of the feasibility of diverting the waters of the St. Mary River eastward into the drainage basin of the Milk River so that the waters flowing across the International boundary would be available instead for use in northern Montana. Fitch also made a reconnaissance to determine conditions for diverting the waters of the upper Green River in western Wyoming, the North Platte River in southern Wyoming, and the Madison River in southwestern Montana. N. H. Darton continued his field investigations in the vicinity of the Black Hills and began preparation of a map of the Central Plains region on which all available information could be compiled of the geologic conditions governing the occurrence of water in that drought-stricken region.

In the East, H. A. Pressey was mainly occupied with the examination of streams in the southern Appalachian Mountains, including the localities where it was proposed to establish a national forest reserve or park. That idea had originated with the State Geologist of North Carolina, Joseph A. Holmes, and Gifford Pinchot when Pinchot was practicing forestry in the Vanderbilt Forest, and was brought to the attention of Congress in 1900 by a memorial from the Appalachian Mountain Club of New England and the Appalachian National Park Association of the South Atlantic States. Congress had authorized the Secretary of Agriculture to use not more than $5,000 of appropriated funds for the fiscal year beginning July 1, 1900, to investigate the forest conditions, and the Survey had cooperated in the examination of a 6,000-square-mile area in the mountain region of North Carolina and adjacent parts of South Carolina, Georgia, and Tennessee, studying not only water supply and forest conditions but geology and topography as well.

Secretary Hitchcock in his annual report to Congress in November 1900, stressed the need for action on a reclamation law.

> **Developments of irrigation have proceeded almost wholly along the line of building small individual or cooperative ditches. The opportunities for extending and multiplying these are, however, limited, as the lands most easily accessible for water supply have already passed into the possession of individuals. There remain large bodies of public land for which water can be obtained only at great expense, although the cost per acre may not exceed that of the small systems. Further extension of the irrigable area depends on the building of great storage reservoirs and of canals to take water from the larger rivers. Progress in the construction of these large works of reclamation has come practically to a standstill, as it has been found by experience and shown by statistics that these reclamation works are not a source of individual profit.**

The argument was not new. Major Powell had favored construction of irrigation works by the cooperative effort of farmers, but as early as 1874, the irrigation commissioners appointed by Congress had said that irrigating works involving large expenditures could not be built by cooperation but must be built by the state or by private capital. The Public Lands Commission in 1880 suggested that the General Government might construct the necessary works but reflected Powell's view in its further statement that this was not consonant with the American system. In 1888, when the Irrigation Survey was under discussion in the House, Hilary Herbert had said over and over again that private capital would not construct irrigation works because it was not profitable and that if it was to be done, only the Government could do it. By 1900, that fact was generally accepted. Colonel

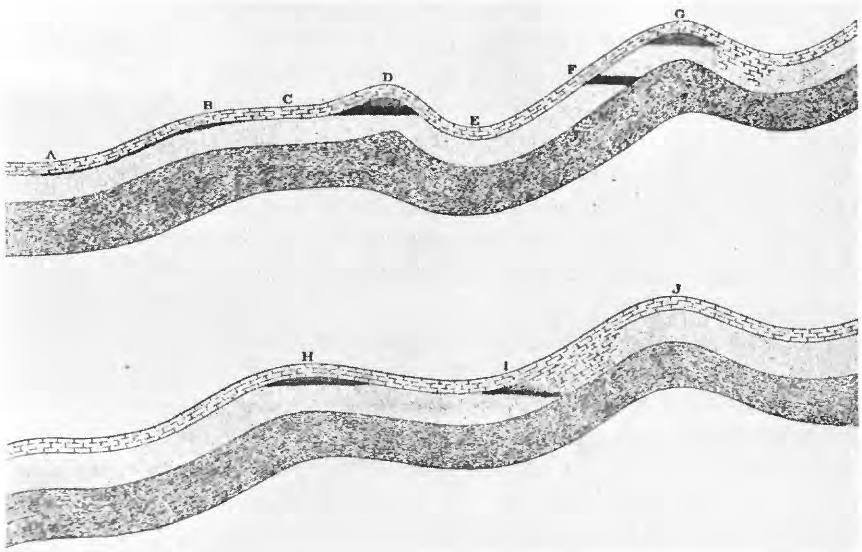
Chittenden of the Army Engineers pointed out to the Ninth Irrigation Congress that the opposition to an amendment in the River and Harbors bill providing for construction of two reservoirs was based on interference with existing State systems and not either the principle of the National Government's doing it or the cost. The question was no longer should the Federal Government construct the necessary irrigation works, but how.

Reclamation was not an issue in the Presidential campaign of 1900, as both the Republican and Democratic Party platforms favored reclamation of the arid lands by the Federal Government. The Republicans had nominated President McKinley for a second term and Governor Theodore Roosevelt of New York for Vice President on a platform upholding the gold standard, the Administration's foreign policy, and a U.S.-built and -controlled isthmian canal. The Democrats again nominated William Jennings Bryan for President on a platform condemning imperialism and calling for free coinage of silver. The Democrats made imperialism the prime issue in the campaign, and the Republicans countered with the "full dinner pail" as the hallmark of Republican success. President McKinley was easily reelected, and the Republicans retained control of both Houses of Congress.

More than a dozen bills to promote irrigation of the arid lands were filed in the House when Congress convened in December 1900. In the Senate, Senator Carter introduced a resolution of inquiry which was passed on January 9, 1901, directing the Secretary of the Interior to transmit to the Senate an abstract of the petitions, memorials, requests, and estimates relating to the operations of the hydrographic branch of the U.S. Geological Survey. The reply, dated February 5, contained some 57 printed pages of petitions, memorials, and requests. It also included an estimate of funds needed for fiscal year 1902, again $250,000.

The budget estimate submitted by the Department had called for only $173,160 for "gauging streams." The odd amount was the result of a change in presentation. The salaries of the Director and "Office of the Survey had been included in the Legislative, Executive, and Judicial bill, and since 1894, when the Director's salary was cut, had amounted to $31,390. The new budget estimate called for $72,670, the increase being composed of $1,000 for restoration of the Director's salary to $6,000 and the transfer of $40,280 in salaries being paid from the appropriations for expenses in the Sundry Civil Expenses bill. In addition to the increase in the appropriation for stream gaging, increases were also requested for chemical and physical research, investigation of Alaskan mineral resources, skilled laborers, and the preparation of illustrations.

The House Appropriations Committee reported out the Sundry Civil Expenses bill on February 4, 1901, with a total appropriation of $926,490, and only $100,000 for stream gaging. Much like the 47th Congress in 1882, it added a proviso that specific estimates for all personnel services, including those of a technical or scientific character, necessary for the office of the Geological Survey at Washington be submitted annually thereafter. Congressman Cannon prefaced the discussion of the Survey appropriation in the Committee of the Whole with a lecture on economy and the propensity of the Senate to increase appropriations. He asked the assembled representatives to give "careful, patriotic, business-like attention" to the bill. Most of the discussion was on the appropriation fo stream gaging. The House debated at length the need for further hydrographic investigations versus moving ahead to a comprehensive plan for actual irrigation, but in the end voted only the $100,000.



Very careful mapping in eastern Ohio, disclosed that an anticline or flexure of strata was only one of the conditions essential for a productive oil or gas well, the others being porosity of the reservoir rock and degree of water saturation. In the ideal section shown, both oil and gas work their way to the roof at A, but oil is trapped at the crest of the terrace at B while the more buoyant gas moves on. The dome at D completely captures both gas and oil. Between E and G the higher portion of the rock is not completely saturated with water, so the oil can move only to the upper surface of the water at F but the gas passes on to G. Similarly, both oil and gas accumulate at H, but at I, the sand rock becomes impervious and oil and gas accumulate at the bottom of the barrier. (From W. T. Griswold, 1902.)

The House Committee on Irrigation of the Arid Lands, which had been considering the various bills in aid of irrigation, made its report on February 20 and filed a substitute bill that it recommended be passed: That all moneys received from the sale and disposal of public lands in Arizona, California, Colorado, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, Oregon, South Dakota, Utah, Washington, and Wyoming, except the moneys set aside for educational purposes, be set aside as an arid land reclamation fund for the examination, survey, construction, and maintenance of reservoirs and other hydraulic works for the storage and diversion of water for the irrigation and reclamation of arid lands. The bill further provided that "the Secretary of the Interior, by means of the Director of the Geological Survey, be, and hereby is directed to make examinations and surveys of the arid region of the United States as to the advantages of the storage of water for irrigating purposes, the practicability of constructing reservoirs, together with the capacity of the streams, the quantity of water unused and unappropriated, and the cost of construction and capacity of reservoirs * * * as required by the act approved March 20, 1888." The provision with respect to the Geological Survey added to the 1888 resolution the determination of the quantity of unused and unappropriated water but was otherwise almost identical. The bill was filed too late in the session to be passed, but it contained the formula that proved successful in the next Congress.

On February 25, the Senate Committee on the Geological Survey proposed three amendments to the Survey appropriation: to increase the appropriation for topographic surveys to $260,000, to add "examination of the forested regions of the United States" to the item for mapping forest reserves, and to increase that appropriation to $180,000. These were read to the full Senate before being referred to the Committee on Appropriations. They brought on another display of Senatorial bonhomie:

Senator Wolcott, long-time critic of the Survey, in real or pretended amazement: "That is a proposed increase of only $70,000."

Senator Hale, of the Appropriations Committee: "I suggest to the Senator that before the bill is brought before the Senate he accept these amendments at once. Otherwise, in the end the amounts would be doubled rather than what is asked for now given."

Senator Wolcott: "I have not a question of it. This report from the Committee on the Geological Survey is but the first step in the triumphal progress of the Geological Survey through the Senate. It will be added to by the Committee on Appropriations."

Senator Hale: "And by the Senate."

Senator Wolcott: "It will be increased by the Senate. It will be increased in the Committee of the Whole."

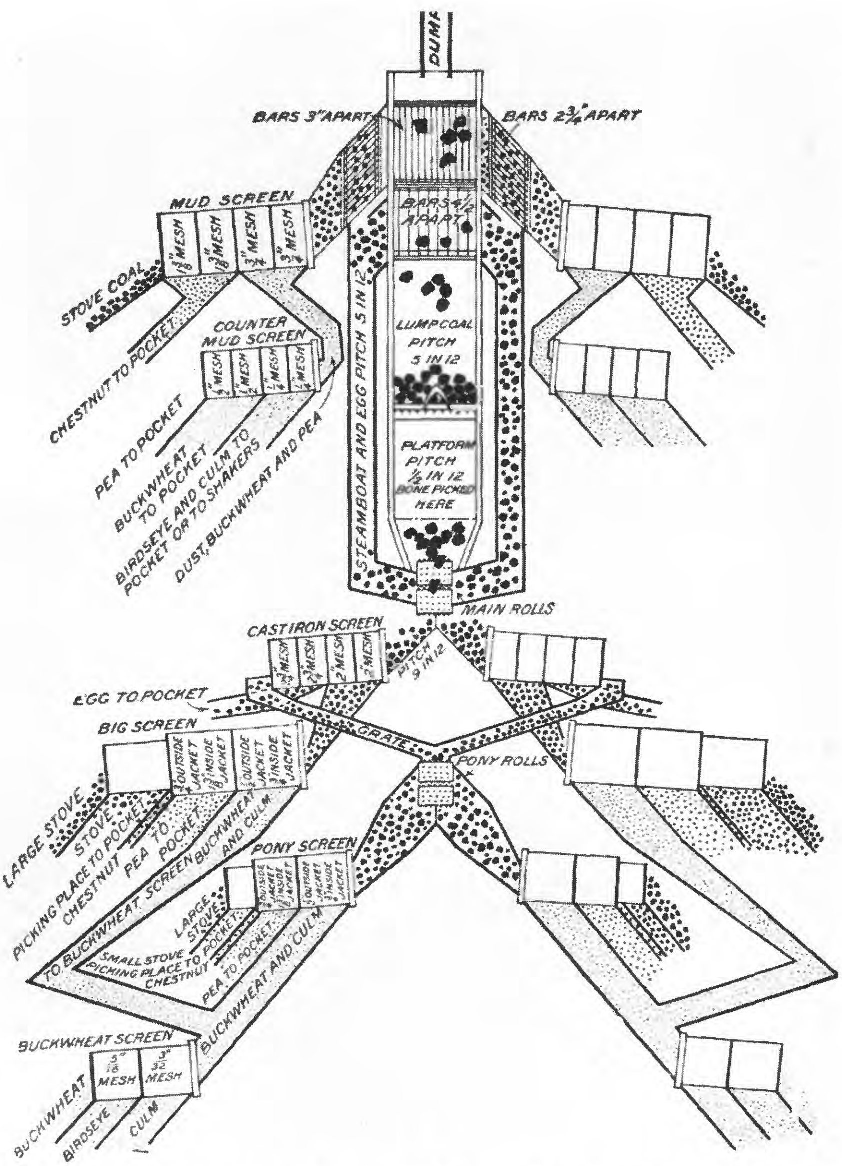
Senator Hale: "And in conference."

Senator Wolcott: "And if the committee of conference can increase it they will do so."

The two subsided when Senator Elkins asked plaintively if debate were in order.

The Senate Appropriations Committee reported the bill out with three amendments proposed by the Committee on the Geological Survey and several other small increases over the House bill, but they recommended only $150,000 for stream gaging, which was to be extended to Puerto Rico. Again, only the appropriation for stream gaging was cause for debate. Senator Carter proposed that it be increased to $250,000. Then Senator Hansbrough of North Dakota offered a substitute amendment, similar to the proposal in the House report on the reclamation bill, that moneys from the sale and disposal of public lands, except moneys already set aside by law for educational purposes, be set aside in a fund to be at the disposal of the Secretary of the Interior for examinations and surveys for and construction of reservoirs and other irrigation works, adding another provision that, until further provided by Congress, not to exceed 10 percent of the fund be available for examinations and surveys, for gaging the streams, determining the water supply of the United States, and investigating the underflow and artesian wells of the arid and semiarid regions of the United States. A point of order was made against the Hansbrough amendment and sustained, and the Carter amendment was passed instead. The conference committee, however, agreed on the House figure of $100,000 and struck out extension of the work to Puerto Rico, compromised on $250,000 for topographic surveys, which were to include an examination of and report on the topography and geology of the territory adjacent to the 49th parallel west of the 120th meridian, and agreed on other Senate increases. The total appropriated for the Survey was $950,770. The Director's salary was increased, and the stage was set for a reclamation law.

On the same day, March 3, 1901, the closing day of the session, the National Bureau of Standards was established, and the Division of Forestry in the Department of Agriculture was given the status of a full bureau. Both actions were recognition of the importance and necessity of Federal science, but both suggested the stress being placed on applied science in an industrial era. The Bureau of Standards replaced the Office of Weights and Measures, which had been part of the Coast Survey since 1832. In 1897, Henry S. Pritchett, the new Superintendent of the Coast and Geodetic Survey, hired Professor S. W. Stratton of the University of Chicago to be Director of the Office of Weights and Measures; his first order of business was to be a plan for enlargement of the office to cope with the increasing work. Pritchett had the Reichanstalt in mind as a model, but after Stratton consulted with other scientists in both public and private sectors and with manufacturers, he drew up a plan for a bureau adapted to American science and American manufacturing. The plan was cleared with the established Federal bureaus before being sent to Congress and was endorsed by the National Academy of Sciences, the American Association for the Advancement of Science, the American Physical Society, the American Chemical



A major report on the coalfields of the United States covered all phases of the coal industry, not only the geology and methods of mining but preparation for marketing as well. Anthracite, for example, was prepared for market in a coal breaker, first broken by toothed rolls and then screened in circular revolving screens or in shaking horizontal screens. The slate was picked out by hand, by automatic slate pickers, or separated from the coal by jigging. From 2,000 to 3,000 tons of coal could be prepared in a day. (From H. H. Stoek, 1902.)

Society, and the American Institute of Electrical Engineers. The responsibilities of the new bureau were "custody of standards; comparison of standards * * *; construction, when necessary, of standards * * *; testing and calibration of standard-measuring apparatus; solution of problems which arise in connection with standards; the determination of physical constants of materials, when such data are of great importance to scientific or manufacturing interests and are not to be obtained of sufficient accuracy elsewhere." The bounds were carefully drawn, and there was no conflict of interest between the new bureau and the Survey laboratory at the time, although within a few years, with the growth of science and industry, both agencies would claim as their prerogative other work which neither had yet begun.

By March 1901, Survey work had been extended into new areas by other developments. Hayes had been wrong when he thought there was little possibility of obtaining oil in the southeastern coastal region of Texas. On January 10, 1901, a gusher was struck at Spindletop, about 20 miles southeast of Beaumont, inaugurating a new era in the oil industry. The Spindletop crude was heavy but suitable for fuel, and the market for fuel oil was beginning to grow. The discovery well was also in new territory, so that pipelines, refineries, and marketing organizations were all needed. Hayes immediately arranged with William Kennedy of Texas to prepare a report for the Survey on the new developments. Hayes himself had been detailed to the War Department. Congress had not appropriated funds for insular surveys, but Major General Leonard Wood, military governor of Cuba, had requested the Survey to make a reconnaissance of the economic geology of that island, and Hayes, along with Arthur Spencer and T. Wayland Vaughan, left Washington on March 19, 1901, for the Caribbean.

By the summer of 1901, the Nonmetals Section was almost wholly engaged in fuels investigations, and oil was a major interest. As soon as Hayes completed his report on Cuba, which he did with even more than his usual celerity, he became deeply involved in oil. He had made arrangements with the Topographic Branch to obtain the services of W. T. Griswold for part of the year to investigate the structure of the Berea grit oil sand in the Cadiz quadrangle, Ohio, and Hayes spent part of September working with him. Griswold's work in applying exact instrumental measurements to the determination of structure was looked on as a distinct advance in the study of oilfields. Hayes then spent October with Kennedy, who had been working in the Texas-Louisiana fields since spring, and part of December with Eldridge, who had begun a stratigraphic, structural, and economic investigation of the petroleum fields of California. In January 1902, Hayes again spent time with Kennedy and, on his way home from Texas, examined the oil and asphalt prospects in Arkansas.

M. R. Campbell had immediate supervision of the areal and economic work in New York, Pennsylvania, and Indiana. In Pennsylvania, where the work was carried on under a cooperative agreement between the Survey and the State, he was assisted by Myron L. Fuller, George S. Richardson, Charles Butts, L. C. Glenn, and Lester Woolsey. George Ashley began the areal mapping in Indiana. In Indian Territory, J. A. Taff completed areal and economic surveys of the Tahlequah and Sallisaw quadrangles and began a special reconnaissance of the Arbuckle and Wichita Mountains.

The Metals Section in the summer of 1901 concentrated on copper. Weed was at Butte, California, Ransome began a study of the copper deposits of the Globe district in Arizona, and Lindgren divided his time between the Bingham district in Utah and the Clifton-Morenci district in Arizona. Emmons himself began a resurvey of the Leadville, Colorado, district, with the assistance of J. D. Irving. Although he had recognized the extreme complexity of the geologic structure in the area in his earlier work, the drifts of the many mines exploited in the 20 years since that investigation offered the possibility of details that might contribute to knowledge on the laws of ore deposition. Another precious metal study was underway in Montana where Professor Joseph Barrell and R. W. Stone mapped the Marysville quadrangle which contained some of the State's largest gold mines.

Metals remained of primary interest in Alaska, although some attention was also given to coal. Four parties were in the field because of the increased appropriation, two in the region north of the Yukon engaged in reconnaissance and exploratory work, one in the Seward Peninsula engaged in areal mapping and an investigation of placer deposits, and one making an examination of the Ketchikan mining district and a reconnaissance of southeastern Alaska. The Peters-Schrader party exploring the Colville River area traveled in the winter to reach the area while frozen streams permitted rapid travel. By contrast, the Brooks party brought a gasoline launch from Seattle and used it for living quarters and travel.

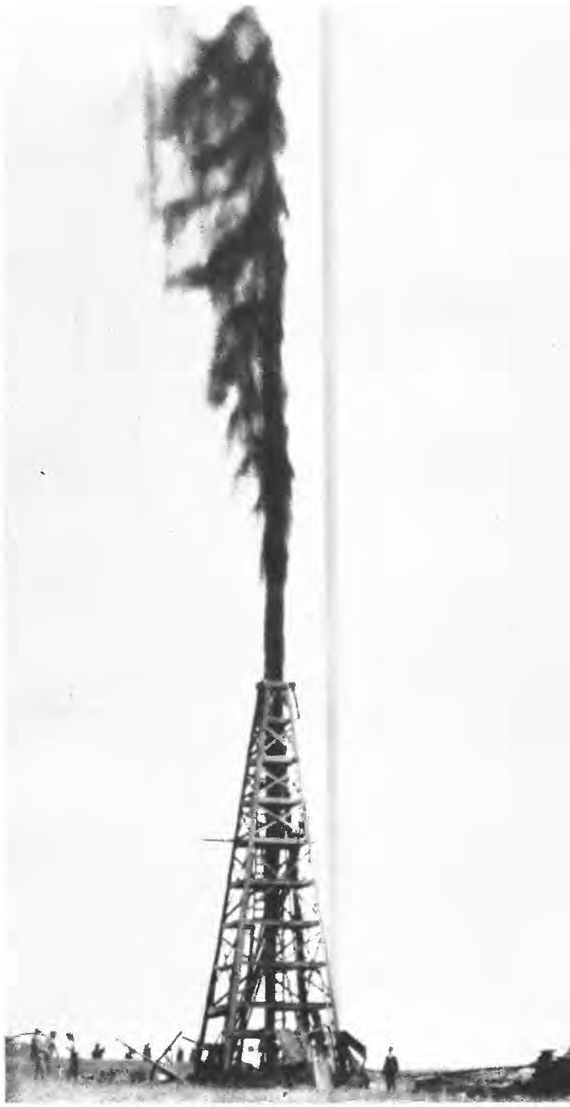
The work of the Pre-Cambrian Division on iron ores was drawing to an end, although Leith and Bayley continued mapping in the Lake Superior region. Clements, however, joined Whitman Cross in the San Juan region of Colorado.

Research in physics was delayed by difficulties in procuring equipment, but C. E. Van Orstrand joined the staff as an assistant physicist and began work on the linear force exerted on growing crystals and the elastic properties of solids. Most of the work in chemistry was routine analyses. Hillebrand, however, identified and named a new mineral. His work of developing methods of analysis was extended to new fields, and at the request of the New York section of the Society for Chemical Industry, he began studying methods of analyzing portland cement and copper slag.

The areal work was again largely a continuation of previous work. Dale was assisted by F. H. Moffit in mapping in New York and Vermont. Professor Emerson began a reexamination of rocks in Worcester County, Massachusetts, in the light of new information. Professor Hobbs and H. E. Gregory mapped in Connecticut, and Professor Kemp again worked in New York State. Professor Clark continued his study of Coastal Plain formations of Maryland and adjacent States, and Professor Bascom, having completed her study of the crystalline rocks of Cecil County, Maryland, began a study of the continuation of that belt in Pennsylvania. Arthur Keith completed work for folio publication on areas already surveyed in North Carolina and studied the age and stratigraphic equivalence of the Ocoee formations in North Carolina and Tennessee. Professor Wilbur C. Knight began mapping the Laramie, Wyoming, quadrangle. Hill continued mapping in trans-Pecos, Texas and New Mexico. Diller spent July in the vicinity of Crater Lake, then began a study of the Redding quadrangle, California.

After the field season, Cross devoted most of his time to special work in petrography, a review of the development of systematic petrography during the 19th century, and the formulation of a new classification of igneous rocks in collaboration with J. P. Iddings, L. V. Pirsson, and H. S. Washington.

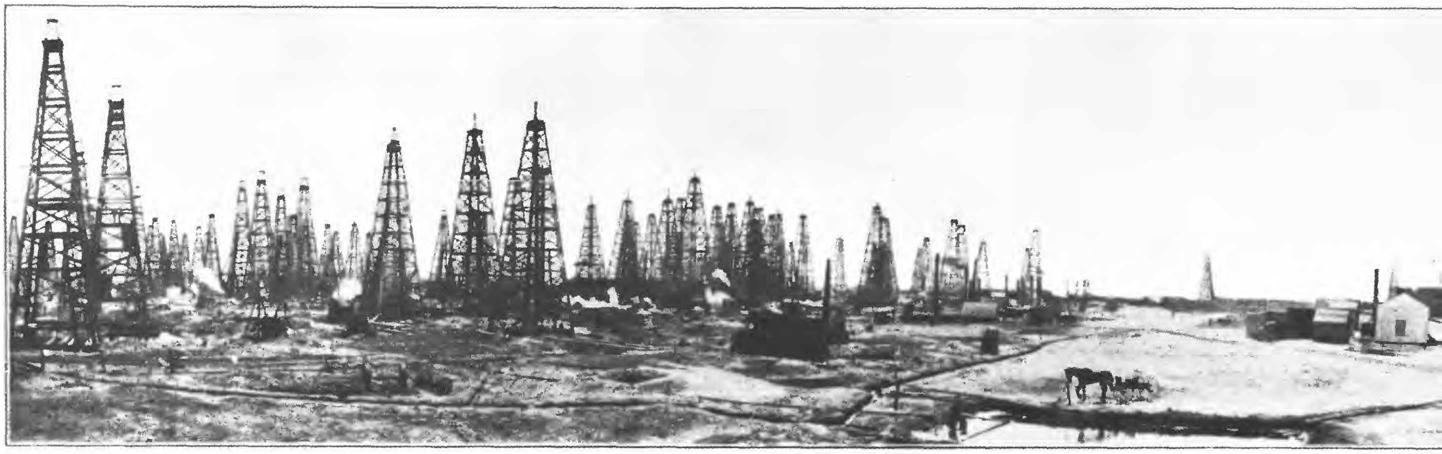
From the Division of Pleistocene Geology, F. B. Taylor mapped in the Housatonic and Taconic quadrangles in Massachusetts, New Hampshire, and New York; Frank Leverett in the Lower Peninsula of Michigan; and W. C. Alden mapped in southeastern Wisconsin. Professor Salisbury supervised the work of assistants in Montana, Wyoming, and Utah and began work himself in the mountains near Santa Fe, New Mexico. W. W. Atwood, now an assistant at the University of Chicago, mapped in the Wasatch Mountains of Utah; F. H. Calhoun, also an assistant at Chicago, mapped in northern Montana; and George Garrey and Eliot Blackwelder, who had just received his B.S. from Chicago, worked in northwestern Montana, northern Idaho, and northeastern Washington.



The first oil well in southeast Texas, a new area for petroleum production, was struck unexpectedly on January 10, 1901. The casing began to rise out of the well with a force too great for the drillers to control, shot up through the derrick, followed by a stream of oil which rose to a height of about 160 feet before the men on the derrick had time to descend. (From G. I. Adams, 1901.)

In the topographic program, cooperative agreements were made with 10 States that contributed a total of $96,500, or 38.6 percent of the direct appropriation. Detailed topographic surveys were made of 31,798 square miles in 28 States and Territories. In the forestry program, 117 miles of boundary of the Bighorn Reserve were surveyed and marked.

The Topographic and Geologic Branches joined forces in the summer of 1901 to survey the land portion of the boundary between the United States and Canada extending westward from the summit of the Rocky Mountains. Some of the monuments had been torn down, and parts of the line had never been surveyed. E. C. Barnard of the Topographic Branch in cooperation with C. H. Sinclair of the Coast and Geodetic Survey defined and marked temporarily the boundary line in three localities where there was



About a year after the first successful well was drilled in the Gulf Coastal Plain of Texas, the area looked like this. (From C. W. Hayes and William Kennedy, 1903.)

considerable uncertainty, and three geologic parties, under Bailey Willis, F. L. Ransome, and George Otis Smith, examined the whole line to report on existing conditions. During the 3 months that Bailey Willis spent in reconnaissance in northwest Montana, he discovered a great overthrust fault by which Algonkian rocks had been shoved northeastward at least 7 miles over the Cretaceous of the plains area—a major discovery made during the course of practical work.

In the Division of Hydrography, Newell moved ahead in his planning, despite the failure to get an increased appropriation. A reclamation law was only a matter of time, so funds were allotted in new ways: to reservoir surveys and gaging, diversion surveys and gaging, artesian surveys and gaging, waterpower surveys and gaging, and sanitary surveys. Arthur Davis completed investigations of the storage of water on the Verde and Salt Rivers in Arizona, including preparation of plans for the construction of dams, and then began a reconnaissance investigation of the lower Colorado River. Fitch supervised work in Colorado, including plans for the diversion of the Gunnison River by tunnel to the Uncompahgre Valley, as well as the surveys for the storage and diversion of the St. Mary River in Montana, the diversion of the upper Snake River in Idaho, and the storage of water on Crow Creek in Wyoming. Hydrographic investigations in California were again under the general direction of J. B. Lippincott; there, special studies were made of storage possibilities in the Salinas Valley. The problem was difficult, as conditions for water storage were unfavorable and the cost of fuel for pumping was high. A new inventory was made of the vacant public lands, and maps of the Western States showing land in private ownership were brought up to date through the cooperation of the General Land Office.

Although ground-water surveys were given less prominence, Professor Charles Slichter of the University of Wisconsin, who was employed by the Survey as a consulting engineer, advanced the work notably when he succeeded in making an apparatus to measure the movement of water beneath the surface. His method involved the introduction of an easily soluble electrolyte, such as ammonium chloride, into a well and measuring the resistance between this well and another sunk to the same level, which would decrease as the salt in solution reached the second well.

Only a small amount was alloted to the sanitary surveys. There had been a demand for more information on the quality of natural waters, because for many industrial purposes, it was necessary to know what foreign substances were carried in suspension or solution. Complete chemical and bacteriological analyses would be very expensive and time consuming, so an effort was made in the beginning to select a few important determinations that could be done quickly and inexpensively, preferably in the field. Measurements of color and turbidity were made at a few river stations in the East, enough to show the general relation between riverflow and quality of water at certain places, and then the work was extended to other parts of the country. For the complete analyses, it was necessary to rely on individual chemists, State boards of health, universities, and similar institutions. To secure approximate uniformity in methods and statements of results, Marshall O. Leighton, the Superintendent of Health at Montclair, New Jersey, was employed as a consulting engineer to prepare a circular for this purpose in conformity with the recommendations of the committee on standard methods of water analysis of the American Public Health Association.

A Pan-American Exposition was held in Buffalo in the summer of 1901, and F. W. Clarke who had become somewhat of an expert on expositions since joining the Survey was in charge of the Interior Department's exhibit. S. J. Kübel prepared a special exhibit, at the request of the department of graphic arts, to show the Survey's methods of collecting data for drafting, printing, and distributing topographic and geologic maps. David T. Day aided in preparing the general exhibit of minerals and mining. As part of the exhibit, Day arranged a display of samples from all deposits in which osmium was found, together with statements concerning the conditions of occurrence that had proved significant. Osmium was then of some interest in metallurgy, and the exhibit proved to be helpful in a more intelligent search for sources. The exhibit was, in fact, so successful that the Survey was asked to take full responsibility for the exhibit of mines and minerals at the Louisiana Purchase Exposition, which was being planned for 1904.

On September 6, 1901, President McKinley visited the Pan-American Exposition and while there was shot by an anarchist. A week later he died, and on September 14, Theodore Roosevelt, a month short of 43 and already a thorn in the side of the established hierarchy of the Republican Party, became President of the United States. In his first official statement, Roosevelt said that he would continue absolutely unbroken the policies of his predecessor, but Mark Hanna prophesied that practically anything could happen with Roosevelt in the White House, and Hanna was right. In the words of two noted American historians, with the accession of Theodore Roosevelt, "the comfortable world of William McKinley evaporated as a morning mist" and a revolution was ushered in.

As an undergraduate at Harvard, Roosevelt had considered becoming a scientist, although he eventually abandoned that idea in favor of becoming a politician. He had lived in the West and had developed a great enthusiasm for the area. He had also come to realize the importance of the forests, the need for protection of wildlife, and the requirement of irrigation. While he was Governor of New York he had succeeded in having legislation passed for forest preservation and protection of wildlife and had consulted both Gifford Pinchot and F. H. Newell while in pursuit of that objective.

It was not his interest in science and conservation, however, that caused the revolution so much as his concept of executive power. President McKinley had served in Congress and respected its prerogatives, but President Roosevelt elected to follow Andrew Jackson and Abraham Lincoln in "regarding the executive as subject only to the people, and, under the Constitution, bound to serve the people affirmatively in cases where the Constitution did not explicitly forbid him to render the service." The view that the President was "the servant of Congress" and could do nothing "unless the Constitution explicity commands the action" he rejected as a view taken by "most able lawyers who are past middle age."

The Director of the Geological Survey, who had declared not too many years earlier that the field of the Geological Survey was to aid any object that could be advanced by a knowledge of the Earth and its resources, was one to sympathize with such a view. In his presidential address to the Geological Society of America, in December 1901, Walcott reminisced that on becoming Director he had outlined what seemed to him the proper policy to be followed by the Survey, and "a kindly critic" had said: "There will not be much left for others to do if all that you have planned is carried out." The work of the Survey had progressed steadily along the lines then laid down, except for the study of the geology of public roads, but State surveys still flourished, and any active capable student or professor could find more geologic problems close at hand than he could possibly investigate.

> **The areal work and other labors constituting the geologic survey of the country are but begun, and the task would require decades for its completion if no changes were made either in the scope of the work or in the size of the working force. *** But experience warrants the prediction that the standards of the**

Theodore Roosevelt

President of the United States, 1901–1909. Roosevelt wrote in his autobiography that when he became President, "the idea that our natural resources were inexhaustible still obtained, and there was as yet no real knowledge of their extent and condition. The relation of the conservation of natural resources to the problems of National welfare and National efficiency had not yet dawned on the public mind." Roosevelt considered the inauguration of the conservation era the proudest achievement of his Administration. (Courtesy of the Library of Congress.)

Ethan Allen Hitchcock

Secretary of the Interior 1899–1907. Hitchcock had been a successful business man, but during his term of office, he successfully prosecuted many public-land frauds, fought to preserve for the Indians of the Five Nations their inheritance in oil and gas lands, and wholeheartedly supported the conservation program. (Courtesy of the Library of Congress.)

future will be progressively higher and higher, and that the scope of routine investigations will become broader. As geologic science progresses, and as new uses are discovered for mineral resources, it will become necessary to increase the number of classes of facts to be covered by areal surveys. In the field of pure science there is even less suggestion of the approaching completion of the work. Every investigation undertaken to solve some geologic problem, whether it prove successful or not, is sure to develop other problems, and the geologic Alexander will never lack worlds to conquer.

Newell and Pinchot, both of them younger than the new President, had already moved with young men's impetuosity and called on him when he returned to Washington after President McKinley's funeral, even before he had a chance to move into the White House. Newell hoped his first message to Congress would help along his dream of a reclamation service. Pinchot was equally keen that it say the right thing on forestry. Their conference was more than satisfactory: they were authorized to draft what they thought the message should say on the twin subjects.

In the 57th Congress, which met for the first time on December 2, the majorities in each House were solidly Republican but almost totally conservative. The Speaker of the House, under the Reed rules, could be the most powerful man in the Government, next to the President, but Speaker David Henderson was content to follow the lead of the Senate, then dominated by Nelson W. Aldrich of Rhode Island, John C. Spooner of Wisconsin, Orville H. Platt of Connecticut, and William B. Allison of Iowa. Roosevelt had had little experience in national politics, but he had a native shrewdness about its practice. No legislation could be passed without the cooperation of these powerful Senators, so they had been invited to go over the chief issues with Roosevelt before he wrote his first message to Congress.

Much of the message followed the orthodox Republican position, especially on economic matters, but it also broke ground in proposing a national reclamation program and measures for the protection of forests. The President asked for authority to transfer management of the forest reserves to the Department of Agriculture. "At present," he said, "the protection of the forest reserves rests with the General Land Office; the mapping and description of their timber with the United States Geological Survey; and the preparation of plans for their conservative use with the Bureau of Forestry, which is also charged with the general advancement of practical forestry in the United States. These various functions should be united in the Bureau of Forestry to which they properly belong."

The message also endorsed Federal construction of storage works:

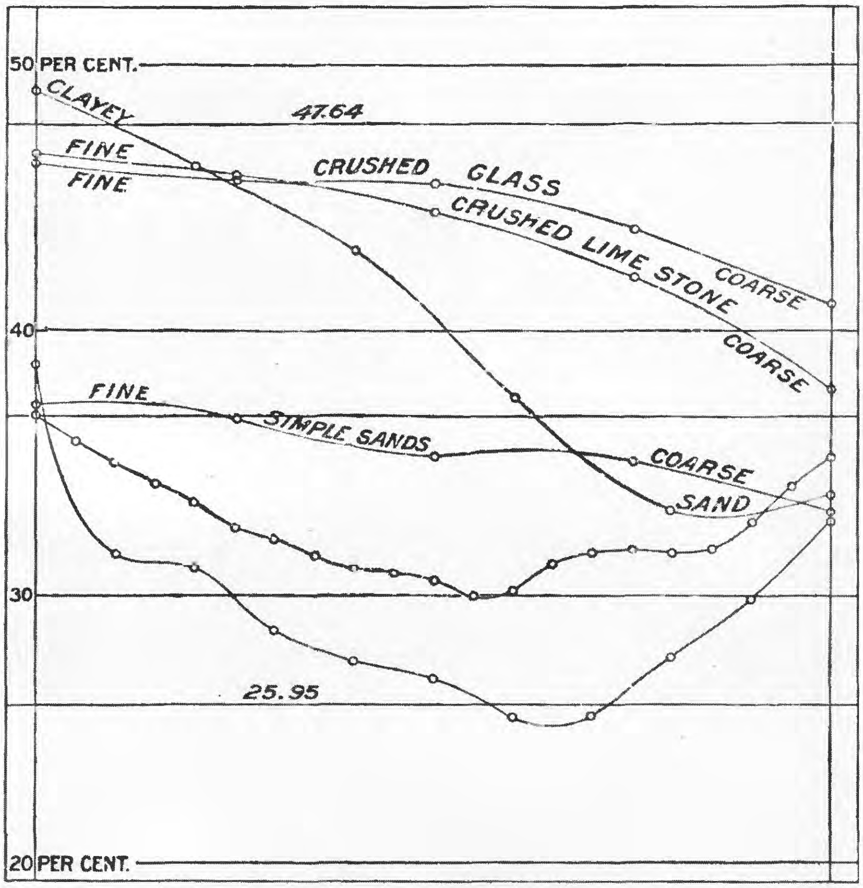
> **The forests are natural reservoirs. By restraining the streams in flood and replenishing them in drought they make possible the use of waters otherwise wasted. They prevent the soil from washing, and so protect the storage reservoirs from filling up with silt. Forest conservation is therefore an essential condition of water conservation.**
>
> **The forests alone cannot, however, fully regulate and conserve the waters of the arid region. Great storage works are necessary to equalize the flow of streams and save the flood waters. Their construction has been conclusively shown to be an undertaking too vast for private effort. Nor can it be best accomplished by the individual States acting alone. Far-reaching interstate problems are involved; and the resources of single States would often be inadequate. It is properly a national function, at least in some of its features. It is right for the National Government to make the streams and rivers of the arid region useful by engineering works for water storage as to make useful the rivers and harbors of the humid region by engineering works of another kind.**

In the densely populated agricultural area of southern California, water had enormous value for irrigation. Thus, every possible expedient was used for economizing or increasing the supply: tunnels into the hills, dams in the canyons, wells in the valleys, and almost every conceivable device for pumping to bring the water to the orchards and more valuable crops. What had been done in southern California, F. H. Newell pointed out, might be done for the arid lands as well where climate and soil conditions were favorable. (From J. B. Lippincott, 1902.)

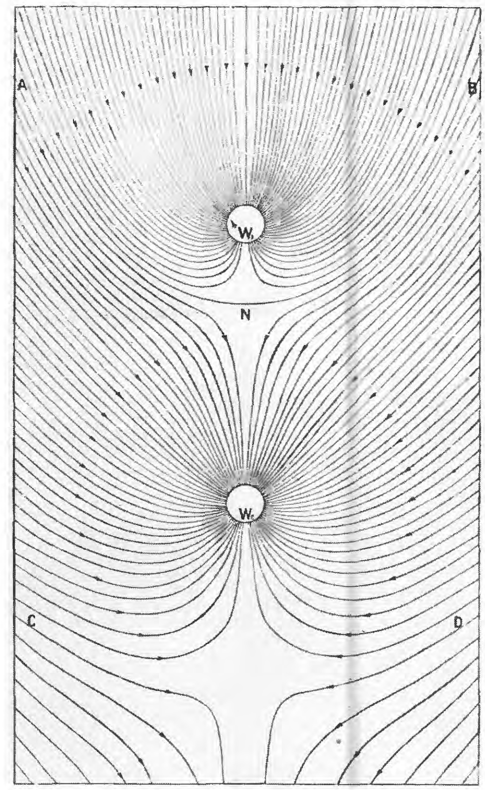
The groundwork for a reclamation law had already been painstakingly laid. A committee of Senators and Representative from the Western States and Territories drew up a bill with substantially the same provisions as the one that had failed to pass in the last Congress. To indicate its nonpartisan character, it was introduced in the Senate by Senator Hansbrough of North Dakota, a Republican, and in the House by Mr. Newlands of Nevada, a Democrat. The Senate Committee reported the bill out first, including with its recommendation a comprehensive statement from the Geological Survey on irrigation. The Senate passed the bill, unanimously, on March 1.

The House did not take up the reclamation bill until June 12, but spent only one day on it. Congressman T. W. Mondell of Wyoming introduced it with an eloquent speech in which he pointed out that the first century of United States history had seen the solution of the problems of transportation and intercommunication, the second presented for solution the problem of making available for human use and occupancy the vast areas that had been acquired. There was some opposition, but the bill was passed by a vote of 146 to 55 on June 13. The Senate speedily concurred in House amendments which had been made to safeguard the interests of homeseekers, and on June 17, 1902, President Roosevelt signed the bill into law.

The Newlands Act, as it became known, provided that essentially all moneys from the sale and disposal of public lands in sixteen Western States and Territories that had more or less arid or semiarid land were to be credited



Professors F. H. King and C. S. Slichter of the University of Wisconsin undertook experimental and mathematical studies in an effort to determine the principles and conditions of the movements of ground water. King determined the variations in the percentage of pore space in samples of various materials. (The two lowermost curves in the upper diagram are of mixtures of rounded sand grains of dissimilar diameters.) Professor Slichter calculated the motion of a fluid in soil made up of grains of nearly uniform size and approximately spherical form. The lower diagram shows the lines of flow into two interfering wells. (From F. H. King, 1899; C. S. Slichter, 1899.)



to a Reclamation Fund and used for planning, construction, and maintenance of dams and other irrigation works. The fund was placed under the direction of the Secretary of the Interior.

Congress was not so thoroughly prepared to act on the forest reserves. Despite the endorsement of the President and the Secretary of the Interior, the bill to transfer their administration to the Department of Agriculture failed. The majority of the House Committee on Public Lands endorsed the measure because once the formative stage of the reserves had passed and the boundaries were definitely determined, it would be necessary either to organize a bureau similar to the Bureau of Forestry in the Interior Department or to transfer the permanent reserves to the Agriculture Department, and one bureau would be better and more economical than two. The minority, however, led by the same F. W. Mondell who helped push the reclamation law through, considered the transfer "impracticable, unwise, and exceedingly expensive" and foresaw great friction between the two Departments. The minority held that the field for the Bureau of Forestry was properly the study of problems in forestry on both private and public lands, and that such studies "need not and should not interfere with the policing and administration of the forest reserves by the Interior Department," and saw

> **no reason why a scientific bureau should absorb a practical and administrative one. No reason why a bureau of the Agricultural Department, presumably established for the purpose of exploiting theories, should be allowed to supersede a division of the Interior Department organized for and carrying on an intensely practical work.**

The bill was brought up for consideration in the House but failed to pass, one of its opponents being the chairman of the Appropriations Committee, Joseph Cannon.

The Senate took up and passed a bill recommended by the Secretary of Agriculture and endorsed by the Secretary of the Interior, that lands be purchased and a forest reserve be established in the southern Appalachians, but the House did not act on it. In the report to Congress on the investigations in 1900, the Director of the Geological Survey emphasized the importance of the measure:

> **The destruction of the mountain forests now in progress there is being followed by a consequent erosion of the mountain slopes and valleys, an increasing irregularity in the flow of streams, and a silting up of the river channels across the lowlands of the bordering States, which if continued will seriously and permanently injure the industrial conditions over considerable portions of these States.**

Comparatively little difficulty was experienced in passing the bill to establish Crater Lake National Park, although the two preceding Congresses had failed to pass similar bills. For the bill proposed in the 57th Congress, J. S. Diller had been asked to draw the boundaries so no land valuable for other purposes would be included. Before passing the bill on April 19, the House indulged in some discussion as to what would happen if valuable minerals should be found in the Park even though geologists said they would not. The Senate was more concerned about the possibility of railroad grants within the proposed tract which might create a problem of forest lieu lands, but having determined that there were none, it passed the bill on May 9, 1902.

The Survey itself fared well in the appropriations bills. The budget estimate for fiscal year 1903 was prepared in accordance with the instructions of the preceding Congress that specific estimates for all personnel services be submitted. It asked for $492,915 in salaries and $531,292 in expenses, a total of $1,024,207, or $73,437 more than the current year. The salaries were divided into groups: the Director's Office proper of 13 people; a general clerical force of 44; a technical force of 26 statisticians, draftsmen,

Crater Lake National Park in Oregon was established in 1902. The lake, 2,000 feet deep, fills the crater of an extinct volcano to which the name "Mount Mazama" has been given. J. S. Diller called the wreck of Mount Mazama, which resulted in the formation of a great pit or caldera, the culminating event in the volcanic history of the Cascade Range. The lake which now fills the caldera is unrivaled for grandeur and beauty anywhere in the world. (From J. S. Diller and H. B. Patton, 1902.)

and photographers; a force of 65 printers and engravers; and a scientific force of 151 geographers, cartographers, topographers, triangulators, geologists, paleontologists, chemists, and hydrographers. The list included new positions being submitted, those that had previously been paid from expenses, and those that had been paid from specific salary items, as well as a list of previously authorized positions that were to be discontinued. The total staff was 299, slightly more than half being professional and scientific. The items for expenses were almost without exception less than those of the previous year because of the transfer of salaries, but not by any fixed percentage, so that it was not readily apparent how much would be spent on each activity.

The House Appropriations Committee concluded that it was not practical for the Secretary to estimate or the committee to recommend specifically for the entire scientific corps and simply recommended for the Survey a total appropriation of $880,570, or $70,200 less than in the Sundry Civil Expenses bill for the current year. The committee said that the reduction, however, was apparent, not real, because $60,000 for investigations in Alaska had been transferred to the deficiency bill and $11,200 for rent, to the legislative bill. There was, in fact, a net increase of $1,000 in the appropriation for the expenses of transmitting documents through the Smithsonian Exchange. The Senate, meanwhile, had had its attention drawn to the need for more funds for topographic surveys. On January 13, Senator John Kean, the new chairman of the Committee on the Geological Survey, had asked for a report on the demands for topographic work and had promptly been given a list of 196 petitions, memorials, and requests together with an estimate that $250,000 was needed for the work.

When the Sundry Civil Expenses bill came up for consideration in the House Committee of the Whole in late March, the apparent reduction for the Survey was promptly challenged by James Lloyd, Democrat of Missouri, and explained by Mr. Cannon, the chairman of the Appropriations Committee, as apparent but not real. Mr. Lloyd, however, was persistent. The Department had estimated $1,024,207, the committee allowed $880,000. What was left out? Mr. Cannon said that part of the reduction came about from the return to the old form of appropriations and part from a reduction of $30,000 for printing maps. Mr. Cannon then added:

> I want to say, touching this service, that it is a great service, a growing service. It has got about legs enough to crawl itself. It has a wonderfully bright head and a wonderfully meritorious one, I will frankly say, in my judgment.

Mr. Lloyd interrupted to agree with that, and then Mr. Cannon continued:

> It grows, you know, like a green bay tree. I think we have fairly well cared for it. I trust it may always remain as efficient as it is now and may always keep out of the rut in which much of the public service is apt and to contract the disease of dry rot.

Mr. Lloyd was not to be deterred. "Is it not true that a considerable sum was asked as an additional appropriation for topographic surveys?" "$50,000." "Was any necessity shown for that $50,000?" "That was for additional work, as we understood. The truth is there would be a demand for $1,000,000, if we could give it. They would like the amount and would do the work. But this service had grown quite rapidly, and after investigating your committee is of opinion that the amount received is sufficient. My friend knows that we must have something for future generations to do." The colloquy continued, and finally Mr. Cannon admitted that the Survey had also wanted another $20,000 to send another party to Alaska, but the committee thought it could wait. On the next day, John Small, Democrat of North Carolina, moved an increase for topographic surveys

The Department of the Interior and the Department of Agriculture cooperated in an effort to save the forests of the southern Appalachians, which were rapidly disappearing because of the industrial development of the South. Not only was the beauty of the area being destroyed; but when the forest cover was removed, the soil was washed from the mountain sides and deposited on the cultivated lands along the rivers below, making future tilling impossible and ruining immense areas of arable lands. (From H. A. Pressey, 1902.)

from $250,000 to $300,000. Eight States were contributing $101,000 toward topographic mapping in their States, which the Survey had to match. Therefore, unless the appropriation were increased, the other States would suffer. Mr. Small was followed by Alston Dayton, Republican of West Virginia, who stressed the importance of topographic mapping in expediting industrial development. John Shafroth of Colorado thought the fact that so many States were willing to cooperate was conclusive evidence that the surveys were urgently needed. Mr. Lloyd thought it was the duty of Congress to increase the appropriation, because otherwise the States that cooperated would get most of the work. Congress had a responsibility to look at it from a national standpoint.

Mr. Cannon listened patiently and finally said:

> The appropriation for this service for the current year is $950,000 in round numbers *** a large appropriation for geology, if you stop to think a minute. This is a growing service. That is true. It is a live service—no doubt about it. It is a hustling service—no doubt about that. It is true, now, that a portion of this money for topography is spent in States that make appropriations from

State treasuries, and my observation is that this Bureau is quite lively in suggesting to States that that is a wise thing to do * Now, we recommend the same amount for the coming year as there is for this year—$250,000 for topography and between 9 hundred and 10 hundred thousand dollars for the whole service. Your committee thought that we had better leave something for posterity in topography.**

But Mr. Dayton thought the topographic maps were of greater value than all other Government publications put together. Though it was clearly established that the dollar-for-dollar cooperation was the Survey's idea and not a requirement of law, it was also admitted that that was the way the Survey would operate, and so the House voted 58 to 24 to increase the appropriation for topographic surveys to $300,000. Mr. Small then moved to increase the amount for printing maps to $100,000, and Mr. Cannon agreed that this was logical, considering the increase for mapping. The total for Survey expenses passed by the House was $960,570.

The Senate had already passed the reclamation law when the appropriation bill reached it, so the Senate Committee on Appropriations revised the item for water-resources investigations to avoid any semblance of the problem that had arisen with respect to topographic surveys during the Irrigation Survey. The reference to arid and semiarid regions was removed, so the entire program became national, and the appropriation was doubled. The Senate committee also proposed some minor increases and an appropriation of $5,000 for topographic surveys in Puerto Rico. The full Senate accepted all the committee's recommendations. However, the Conference Committee eliminated the appropriation for topographic surveys in Puerto Rico. The total appropriation for the Geological Survey was $1,066,570, somewhat more than the Department had asked.

The appropriation of more than $1 million for the Survey was approved on June 20, only 3 days after the reclamation law had been approved. In a letter to Secretary Hitchcock on the day that he signed the reclamation law, President Roosevelt specified that the work of reclamation was to be delegated to the Geological Survey because Walcott and Newell "have been tested and tried and we know how well they will do the work." The Reclamation Service, however, did not become an integral part of the Survey but was administered by the Survey officers, Walcott as the Director and Newell as the Chief Engineer. Then on July 1, 1902, in recognition of the increased scope of the Survey's hydrographic work, the Hydrographic Division of the Geologic Branch was given new status, becoming the Hydrographic Branch, coordinate in rank with the Geologic and Topographic Branches. F. H. Newell became the first Chief Hydrographer.

The Reclamation Service, when it began in 1902, had a little more than $3 million available for expenditure because the revenue from disposal of the public lands in fiscal years 1901 and 1902 formed its "dowry." From the Survey, Newell chose as his principal assistants, Arthur Powell Davis, to supervise work related to engineering estimates and operations, and Charles H. Fitch, to supervise field parties making preliminary surveys for diversion lines, reservoirs, and other irrigation works, and to outline irrigable lands. Plans were made to employ consulting engineers and boards of review to consider the results of the various surveys and examinations and report to the Chief Engineer. Expansion of the hydrographic work of the Survey, Walcott and Newell agreed, would have to wait until the Reclamation Service got underway.

In the general celebration at the Tenth Irrigation Congress in the fall of 1902, Newell explained that he became the Chief Engineer of the Reclamation Service because the Secretary of the Interior and the Director of the

I. C. Russell made a reconnaissance of the Snake River plains of southern Idaho to determine whether geologic conditions there were such that flowing water might be obtained by drilling wells. Russell held out little hope that water could be obtained; however, he called attention to the almost unlimited and unutilized waterpower available along the Snake River. (From I. C. Russell, 1902.)

Geological Survey were both very busy men. The Secretary had charge of the largest department in the Government and irrigation, important as it was, was only one of the many subjects before him. The Director of the Geological Survey was busy because he had more than $1 million to spend that year. Newell's modesty was unconvincing. Certainly many people had worked hard and long for the passage of the reclamation law, but it is doubtful if any one had worked harder and longer than Newell. Moreover, he has been credited with the suggestion that proved to be the keystone to success, that the public-land moneys be used for the reclamation fund. Walcott's contribution is harder to assess, because, in characteristic Walcott fashion, most of it was behind the scenes. It was, however, acknowledged as indispensable by those who were familiar with the many details involved in maneuvering the bill through Congress.

Chapter 12.
Bewitching Prosperity, 1902–1904

Prosperity doth bewitch men, seeming clear;
As seas do laugh, show white, when rocks are near.

—John Webster

When Charles D. Walcott, the Director of the Geological Survey, assumed direction of the Reclamation Service in the summer of 1902, he was clearly one of the most, if not the most, influential Federal scientists in Washington. Not only did he direct two Federal bureaus, one engaged in the very practical work of reclaiming the arid lands of the West, the other a full spectrum of practical and theoretical studies in the Earth sciences, but he was also involved in promoting the cause of pure science in his position as secretary of the newly established Carnegie Institution of Washington.

As Federal science tended more and more toward the practical, Washington scientists looked for opportunities to improve the facilities for basic research, and in 1901 they achieved a measure of success, working through the George Washington Memorial Association. The Association had been founded in 1898 by a group of women with the aim of securing the establishment of a national university in Washington to honor the first President. A committee of the National Education Association Council, however, composed chiefly of college presidents, deans, and professors, however, had declared that the Federal Government should encourage and aid education instrumentalities but not control them. On March 3, 1901, Congress had extended the research facilities of Federal agencies (which in 1892, it had made accessible to students of institutions of higher education in the Nation's Capital) to duly qualified students or graduates of institutions of learning anywhere in the United States. The George Washington Memorial Association then reorganized to reflect a new purpose, to aid in securing an increase of opportunities for higher education in Washington. Two months later, the president of the George Washington Memorial Association joined Daniel C. Gilman, about to retire as president of The Johns Hopkins University, C. Hart Merriam, Director of the U.S. Biological Survey, George M. Sternberg, the Surgeon General of the United States, Charles D. Walcott, Director of the U.S. Geological Survey, and Carroll D. Wright, the Commissioner of Labor, in incorporating the Washington Memorial Institution "to promote science and literature; to provide opportunities and facilities for higher learning, and to facilitate the utilization of the scientific and other resources of the government for purposes of research and higher education."

Walcott became president of the Board of Trustees of the Washington Memorial Institution which began development of a plan for a nongovernmental institution to promote the study of science and liberal arts at Washington and to exercise systematic oversight of advanced study and investigation in government laboratories. The plan was promptly endorsed by the National Educational Association Council.

The Trustees then conferred with Andrew Carnegie, who agreed to endow an institution "to extend human knowledge by original investigations and research," to be known as the Carnegie Institution of Washington. A Board of Trustees of the Carnegie Institution was formed and elected A. S. Hewitt as chairman, then selected Daniel C. Gilman as first president of the Institution and C. D. Walcott as first secretary.

The Trustees concluded that

> **Research may be defined as original investigation in any field whether in science, literature, or art. Its limits coincide with the limits of the knowable. In the field of research the function of the Institution should be organization, the substitution of organized for unorganized effort wherever such combination of effort promises the best results; and the prevention, as far as possible, of needless duplication of work. Hitherto, with few exceptions, research has been a matter of individual enterprise, each worker taking up the special problem which chance or taste led him to and treating it in his own way. No investigator, working single handed, can at present approach the largest problems in the broadest way thoroughly and systematically.**

The charter of the Carnegie Institution clearly reflected the experience of the Director of the Geological Survey, the necessity for promoting basic research, the need to prevent duplication as wasted effort, and the advantages of organized effort.

Walcott had already relinquished administrative control of much of the geologic work of the Survey to C. W. Hayes. On March 1, 1902, while the reclamation law was being maneuvered through Congress and the Carnegie Institution was being established and organized, the five divisions: Areal Geology, Pleistocene Geology, Economic Geology of Metalliferous Deposits, Economic Geology of Nonmetalliferous Deposits, and Paleontology were united as the Division of Geology and Paleontology under Hayes, who was given the title geologist-in-charge of geology and paleontology. The former divisions retained their individual identities as sections in the new division, and the section chiefs retained full-scientific authority in their respective fields. Hayes had scientific authority only for nonmetallic investigations, and, in theory at least, was only one among equals in establishing the scientific program of the division. Nonetheless, the designation of Hayes, rather than Bailey Willis, who had been Assistant to the Director for Geology, to take administrative charge of the work emphasized the importance of economic geology, and the revival of the title used by Walcott in the year before he became Director suggested that perhaps Hayes was being groomed for the future.

Only the Division of Geology and Paleontology became independent in 1902. The Director retained administrative control of the Divisions of Chemical and Physical Research under Becker, Mining and Mineral Resources under David T. Day, and of Hydrography under F. H. Newell. The Alaskan program was given special status, neither a section in the Division of Geology and Paleontology nor yet a separate division. Alfred H. Brooks was appointed geologist in charge of geologic work in Alaska and together with R. U. Goode constituted a committee to consider and submit plans for work in Alaska.

In the work of the Metals Section, copper retained its primary importance as it did in the industrial world. Weed spent a short field season at Butte, Montana, chiefly in underground work, and also made brief visits to various copper mines in New Jersey and North Carolina to obtain data for a report on the copper deposits of the Eastern United States. Ransome began a study of the geologic relations and origin of the copper ore bodies near Bisbee, Arizona. Arthur Spencer was in charge of a party studying the copper de-

The Silver King mine, one of the bonanza silver-lead mines in the Park City district in Utah, first began to produce in 1893 and for several years was the largest dividend payer in the State and among the largest in the country. The general geology of the area had been mapped by the Fortieth Parallel survey in 1869, and the mining geology investigation was begun more than 30 years later. (From J. M. Boutwell, 1912.)

posits in the Encampment Mountains of Wyoming, and Emmons spent some time with him and with Professor J. F. Kemp at the New Rambler mine in the Medicine Bow Range. The platinum-bearing copper ore there was unusual, but because the deeper workings of the mine were inaccessible, they could not make a satisfactory study of it.

Precious-metal investigations included Lindgren's field study of the auriferous gravels of Placer County, California, and Spurr's work in the new gold district at Tonopah, Nevada. Irving and Boutwell began an economic study of the Park City district in Utah, the first detailed geologic work in the Wasatch Mountains undertaken by the Metals Section. It involved, as did all economic work under Emmons' direction, a study of the general structure of the range as well as a very detailed study of the silver-lead ore deposits. Emmons was more or less familiar with the structure of the range from his work there in 1869, but the study of the ore deposits was especially difficult because of their relation to the long and complicated history of the range. He had, therefore, decided that the preliminary mapping of the district should be done with great deliberation and detail and no attempt made to complete the work in one summer. Emmons himself continued the restudy of the Leadville, Colorado, district, examining in particular the recent underground workings in the Downtown district whose future constituted one of the most important problems. In December, 1902, Emmons was elected president of the Geological Society of America, the first economic geologist to be so honored.

As most nations had, by this time, either adopted the gold standard or seemed ready to do so before long, the question of the available supply of gold for the future was a matter of some interest. Lindgren, following in the tradition of Emmons, studied the geological features of the gold product of North America and concluded that the great increase of the preceding 10 years would probably not continue at the same rate. He thought it likely that the placer fields of Alaska and the Northwest Territories would gradually decrease their output, that districts producing gold from copper ores and other working bonanzas of the Tertiary veins would also probably lessen their output, and that reserves of old mill-tailings and dredging-grounds to which new processes had been applied were being exhausted. However, new discoveries and the introduction of improved processes of extraction were always possible, so he concluded, "Tentatively striking a balance, a small decrease of the gold production of North America would seem more likely, for the next few years, than an increase."

The lead and zinc investigations of the Metals Section included a study of the lead, zinc, and fluorite deposits of western Kentucky by W. S. Tangier Smith and E. O. Ulrich, carried out under a cooperative arrangement between the U.S. Geological Survey and the Kentucky Geological Survey. Smith also completed the investigation of the lead and zinc deposits of the Joplin district, Missouri-Kansas, with the assistance of C. E. Siebenthal.

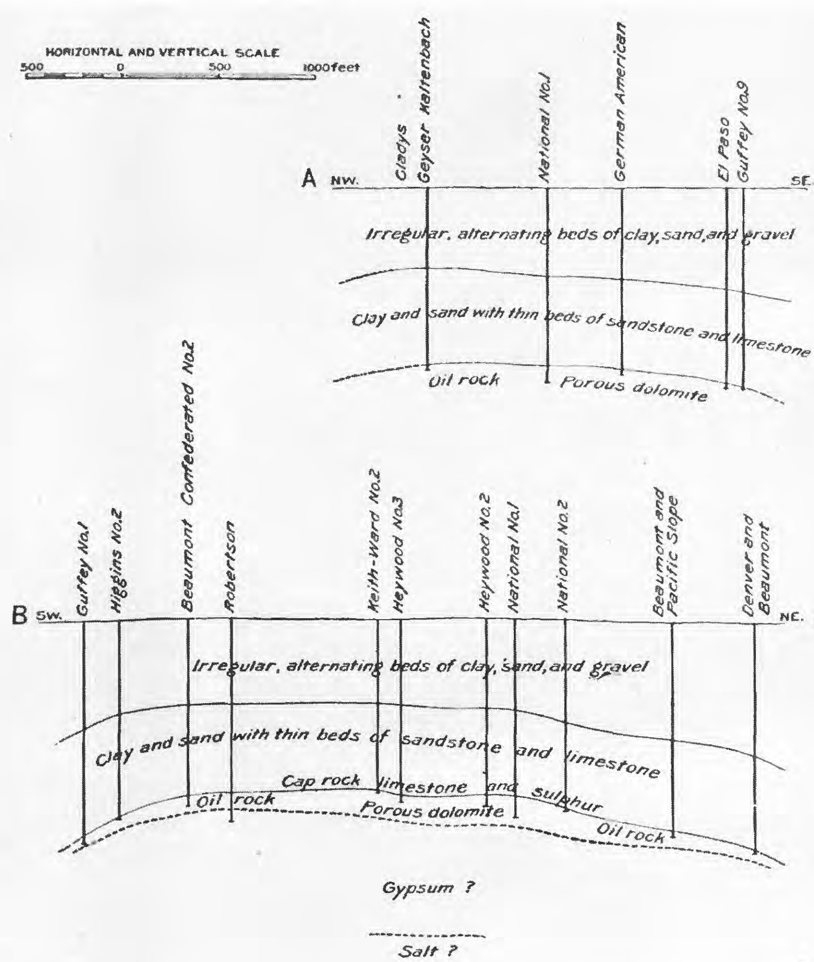
The Metals Section came closer to achieving one of its long-term goals—a genetic classification of ore deposits—as both Weed and Spurr presented tentative classifications at meetings of the Geological Society of Washington in January 1903. Weed divided all economic geologists into two schools: descensionists, who maintained that all ore deposits were the work of underground meteoric waters, which had derived their mineral contents from the rocks traversed; and ascensionists, or the igneous school to which he belonged, who believed that igneous intrusions had furnished not only the heat for most hot waters but also the mineral contents, either directly as differentiations or emanations, or through the leaching of rocks by vapors and heated waters. Weed's classification was sixfold: I. Igneous (magmatic segregations); II. Pneumatolytic (deposited by igneous emanations); III. Fumarolic; IV. Gas-Aqueous (deposits from igneous emanations mingled with ground waters); V. Meteoric; and VI. Sedimentary, such as gold placers. Spurr's classification was simpler, with only three classes: Original, or formed during the cooling processes of igneous rocks; Subsequent, or formed from cold rocks, either sedimentary or igneous, by atmospheric waters; and Transitional, somewhere between or a combination of the first two.

Lindgren stated that he doubted that the time had yet come for a genetic classification, although he agreed with the general plan of Weed's scheme. Ransome pointed out that those who were inclined to assign to meteoric waters a large share in ore deposition did not necessarily maintain that the ores were concentrated by cold descending waters from cold rocks or that igneous intrusions had no part in the process. For his part, he wished to be described as occupying intermediate ground in substantial accord with Emmons. The discussion was so prolonged that it was continued at a February meeting to which non-Washington geologists were invited. Emmons, always cautious, led off by stating that deposits that are probably the result of direct emanations from cooling igneous rocks or actual segregations in an igneous rock, had been held previously on almost a theoretical basis but now had been observed. As far as he was concerned, the big problem was whether igneous magmas as they came from the interior of the Earth contained sufficient water to produce the phenomena observed in ore deposits. Professor Kemp put it in a slightly different fashion: there were deposits at each end of Weed's classification that were certain, but in between the extremes there were many deposits about which the interpretation was doubtful. Emmons, referring directly to some of Spurr's work, cautioned,

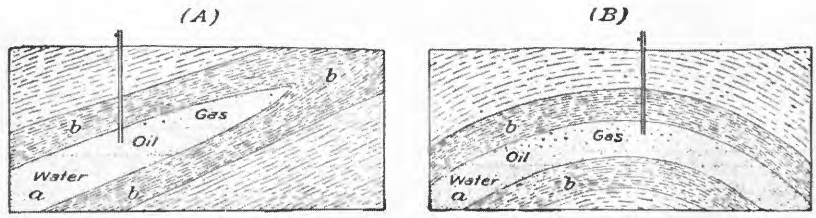
> **it is wise to guard oneself against the attractiveness of what appears to be novel, and hence presumably an advance on previously conceived ideas, and not to confound speculative assumptions with demonstrations.**

The discussions were of wide interest to both geologists and mining engineers, and both *Science* and the *Engineering and Mining Journal* carried full reports.

In the nonmetallic investigations, which were Hayes' primary scientific responsibility, several innovations were made in both methods of work and applications. Hayes again borrowed W. T. Griswold from the Topographic Branch to continue a very careful plotting of the geologic structure in an oil-producing area in eastern Ohio to study the effect of small changes in the dip of formations on the accumulation of petroleum. M. R. Campbell was again in charge of several parties engaged in areal and economic work in bituminous coal areas. Most of the work was in western and southwestern



The discovery of petroleum in east Texas was the beginning of a new era in geology. Hayes and Kennedy found that the oil structure at Spindletop did not fit previous theories. The only horizon that they could identify with any degree of certainty in the record of wells was the oil rock itself; the structure appeared to be a "dome or quaquaversal with steep sides and a rather flat summit." The two sections, at right angles to each other, show the structure as far as it had been made out in 1902. It was later identified as a salt dome. (From C. W. Hayes and William Kennedy, 1903.)



Oil and gas reservoirs in the Kansas field were found associated with sandstone lenses interbedded in shales, most commonly at the upper margin of an inclined or dipping sandstone. (From G. I. Adams and others, 1904.)

Pennsylvania, but George Ashley and L. C. Glenn began a study of the coal resources near the headwaters of the Cumberland River in Kentucky, and M. L. Fuller worked in Indiana and Illinois.

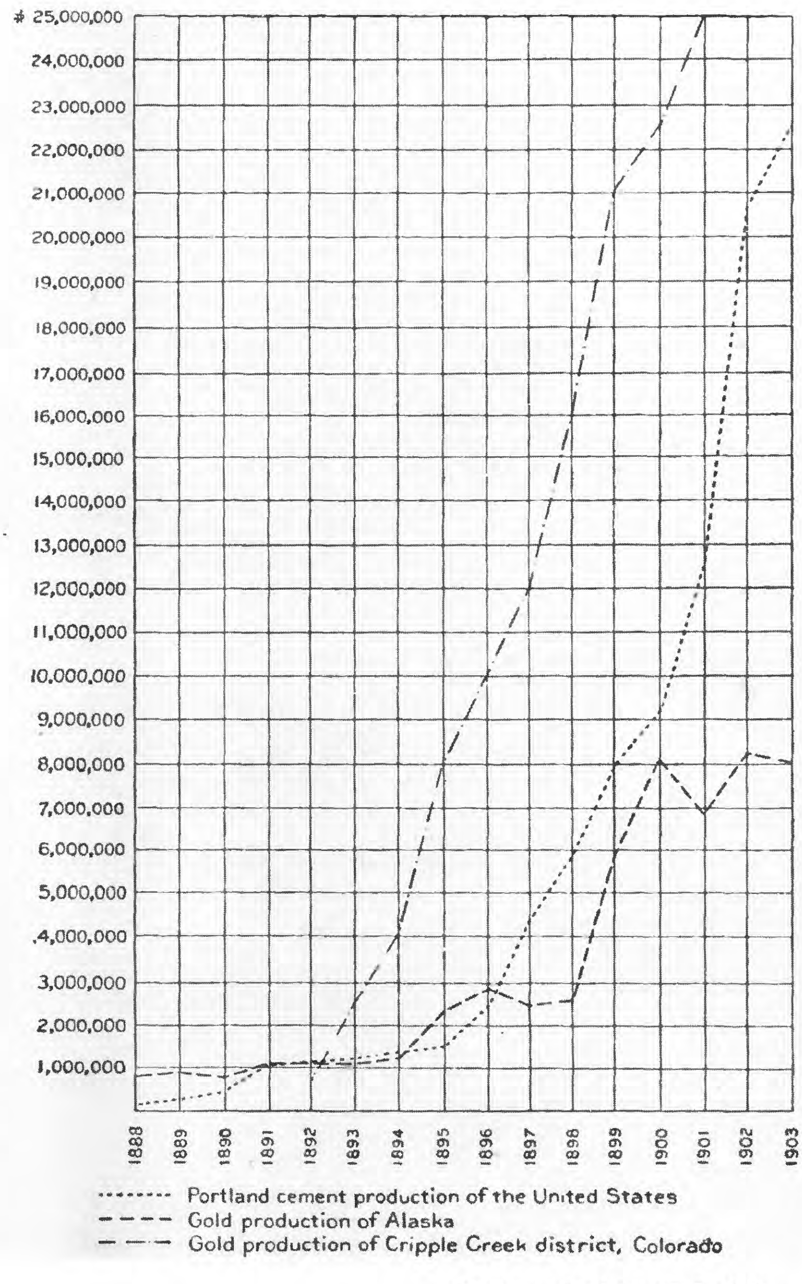
At Campbell's request, Fuller prepared a plan for the systematic collection of well data, which several individual geologists had used in determining details of structure and stratigraphy. The data proved so valuable, especially in the study of oil and gas fields, that it was thought a section might advantageously be organized to collect them systematically. In some localities, particularly in Pennsylvania, such records had been preserved, but in general, only the larger operators kept permanent records of their wells, so it was essential in most places to obtain the information when the well was being sunk if it was to be had at all. Fuller's plan included the collection of rock samples as well as records, compilation of a catalogue of well records, preparation of a bibliography of oil and gas papers, compilation of correlation tables of the various producing sands, and preparation of statistics on production.

Emmons and Hayes combined efforts to produce a bulletin entitled *Contributions to Economic Geology 1902,* the first of a new series designed to meet the growing demand from the mineral industry for prompt publication of Survey work. The bulletin, published early in calendar year and, under the new rules, distributed free of charge, included in its 449 pages 59 contributions from 33 geologists in addition to summary statements by Emmons and Hayes and lists of Survey publications on various mineral commodities. Some of the papers were preliminary statements of the results of extended investigations, which would later be described in more detail; some were descriptions of phenomena of economic interest not of sufficient importance to warrant separate publication; and some were abstracts of the more important papers that had appeared during the year. All told there were 10 reports on the precious metals, 9 on copper, 4 on lead and zinc, 2 each on tin and tungsten, 1 on platinum, 7 on iron and manganese, 7 on oil and gas, 4 on coal, and 13 on other nonmetals. More commodities were discussed in *Mineral Resources of the United States,* but the Survey's interests were expanding.

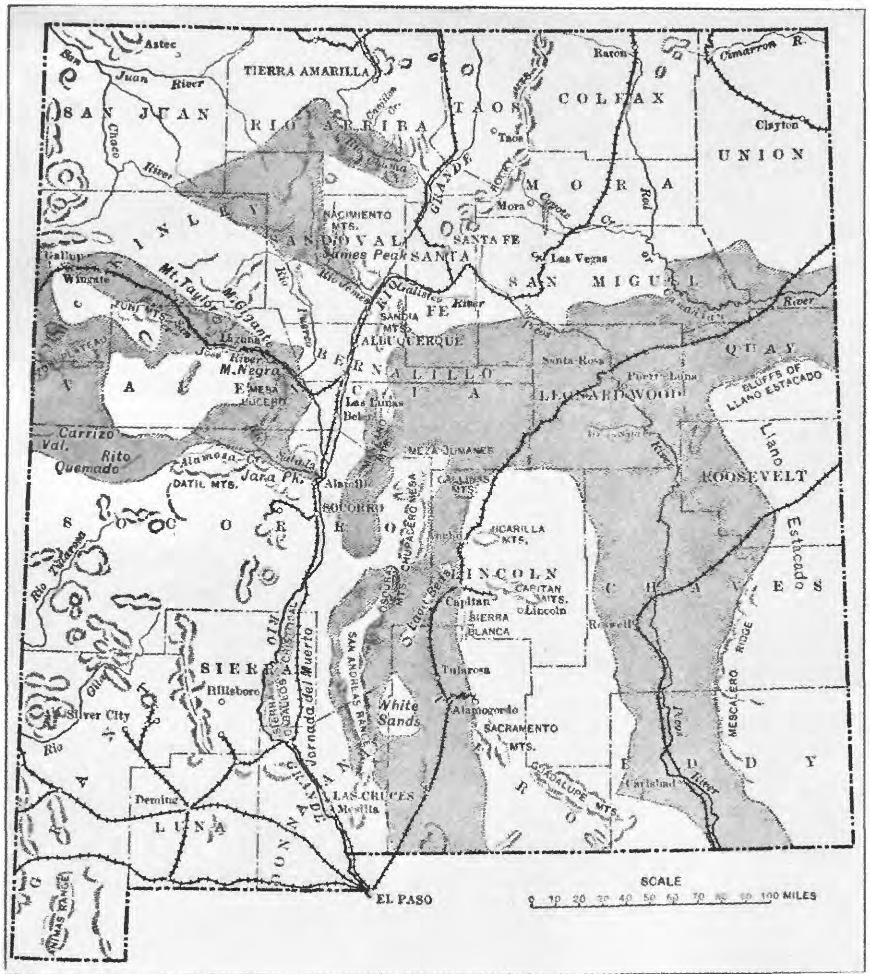
J. A. Taff extended the Survey's work into classification of mineral lands in advance of their disposition by the Government for the first time since 1879. Taff was detailed to the Secretary's office to select the commercially valuable coal and asphalt lands in Indian Territory so they could be segregated and sold, rather than allotted to the Indians, with the proceeds being distributed instead. With the assistance of M. K. Shaler, Carl D. Smith, and R. D. Mesler, Taff spent 3 months in the field and selected nearly half a million acres of coal and asphalt lands for segregation and sale.

Hayes also arranged for the preparaion of summary reports on other nonmetallic resources: a report on the clay resources of the United States east of the Mississippi River by Professor Heinrich Ries of Cornell University and a report on the gypsum deposits of the United States by a Survey geologist, G. I. Adams. E. C. Eckel, who had been graduated from New York State University in 1895, was appointed in August 1902 and assigned to work under Hayes' immediate supervision. After a few months' indoctrination, Eckel was put to work collecting data for a report on the portland and natural cement industries of the United States. The new methods of construction with steel-reinforced concrete had brought about an extraordinary increase in the quantity of cement being produced in the United States.

The Alaskan program was a miniature version of that in the Division of Geology and Palentology in the summer of 1902. Most of it was concerned with metals, but A. J. Collier, accompanied only by two camp hands, made a reconnaissance for some 1,300 miles down the Yukon River from Dawson to investigate the coal resources, study the stratigraphy, and make paleontologic collections. Brooks, accompanied by D. L. Reaburn, topographer, and L. M. Prindle, geologic assistant, made a reconnaissance of a previously unexplored area, traveling from Cook Inlet to the Yukon River through the Alaska Range and along the northwestern base of Mount McKinley. For



Investigations of structural materials were begun shortly after the great change in construction methods near the turn of the century. The great gold strikes at Cripple Creek and in Alaska had attracted everyone's attention, but the tremendous growth of the portland cement industry was achieved in comparative obscurity, added almost as much to national wealth. (From E. C. Eckel, 1905.)



Gypsum became one of the most important structural materials in the early 1900's. Its most extensive use was as wall plaster, and it had largely displaced lime and sand mortar as a wall finish. The Red Beds of New Mexico were an important source of gypsum. Some years later, these same Red Beds became the focus of the search for another needed mineral, potash. Areas of Red Beds are shown by shading. (From G. I. Adams, 1904.)

Reaburn and Prindle, this trip was the first experience in Alaska, and it was an exceedingly difficult one. In places, almost constant trail chopping was necessary, horses and riders were sometimes swept downstream by the rushing current as they tried to cross a river, and they were harassed by Alaska's legendary mosquitoes. Brooks, however, was able to climb Mount McKinley to the snowline and to obtain some idea of its geologic structure.

As geologic mapping and stratigraphic studies continued in all parts of the country, yet another effort was made to establish new rules for geologic nomenclature. A circular letter was sent to all Survey geologists and paleontologists in January 1902 asking them to examine the published rules and submit suggestions for amendment. Gilbert agreed to act as chairman of the committee reviewing the rules and serving with him were Whitman Cross, Bailey Willis, and C. R. Van Hise, who had taken part in the 1889 conference, and W. B. Clark, C. W. Hayes, T. W. Stanton, and H. S. Williams. F. B. Weeks, who had been compiling the bibliography of North American geology for several years and whose bulletin on North American geologic formation names had just been completed, served as secretary. The new rules were promulgated in March 1903, after revision by the Director, as a code of regulations for making the Geologic Atlas of the United States. A permanent board, the Committee on Geologic Names, was then established with G. K. Gilbert as its first chairman. The committee was charged with scrutiny of all formation, group, and series names used in publications in connection with Survey work. One of the most important functions of the committee was to guard against duplication of formation names.

Under the new rules, rocks were grouped into only three classes: sedimentary, igneous, and metamorphic; sedimentary was used in a broad sense to include rocks formed by aqueous, organic, glacial, and eolian agencies. The word "formation," which under the old rules had been restricted to structural divisions of the fossiliferous clastic rocks, was applied to rocks of all classes, as the cartographic unit, ordinarily the smallest rock body separately named and mapped. Under the old rules, the sedimentary formation had been defined by its physical characters alone, but under the new rules, its definition might depend largely on contained fossils. The new rules substituted the rock term "system" for the time term "period" in the atlas, and they gave definite rank to member, formation, group, series, and system. Members, formations, and groups were local or provincial, series either provincial or broader, and systems were worldwide. Algonkian and Archean were redefined in such a way as to recognize the presence of metamorphic clastic rocks among the dominantly igneous rocks of the Archean. Ordovician was finally accepted in place of Lower Silurian and given rank as a system. Permian, Pennsylvanian, and Mississippian were recognized as series of the Carboniferous. The compound "Jura-Trias" was abandoned and Triassic and Jurassic adopted. The terms "Pleistocene," "Neocene," and "Eocene" were abandoned as primary terms, and "Quaternary" and "Tertiary" were reestablished. Pleistocene was given series rank to include all deposits of the glacial period, and the Lyellian divisions of the Tertiary—Eocene, Oligocene, Miocene, and Pliocene—were adopted.

Arthur L. Day

Physical Geologist U.S. Geological Survey 1900–1907. Under Day's direction, the work in geophysics, abandoned in 1892, was resumed. The great promise of the work led to the establishment of the Geophysical Laboratory of the Carnegie Institution of Washington. During a distinguished career, Day made notable contributions to geophysical chemistry, volcanology, seismology, and ceramic research. (Courtesy of the Geophysical Laboratory of the Carnegie Institution of Washington.)

An entirely new system of classification of igneous rocks, the distillation of many years of study, was proposed by C. Whitman Cross, Joseph P. Iddings, L. V. Pirsson, and H. S. Washington in their *Quantitative Classification of Igneous Rocks* published in 1903. All igneous rocks were classified in a hierarchical system on the basis of their chemical composition, and the chemical composition and the unit of classification were defined in terms of certain minerals capable of crystallizing from a magma of given chemical composition. Cross, who had spent several months in the Hawaiian Islands to compare the volcanic masses there with those of the older volcanic region of the San Juan Mountains of Colorado where he had been mapping, was designated as geologist in charge of a new section of petrology, and thus the Survey's scientific authority in petrology, when he returned to the United States in December 1902.

In the Division of Chemical and Physical Research, Arthur L. Day, with the assistance of E. T. Allen, was engaged in an experimental investigation of the behavior of rock-forming minerals and analogous, but somewhat simpler, chemical compounds at high temperatures. The melting temperatures of the principal rock-forming minerals were determined, beginning with representative feldspars, by a very sensitive method, at the point where the absorption of heat showed a change of state was taking place so that minerals might be fitted into their proper place in modern physical chemistry.

Research, such as the investigations being undertaken by Day and Allen, was important for the development of the science, as most geologists knew. Van Hise believed that in order to go far in geology it had become necessary to have a fair knowledge of the basal sciences of physics, chemistry, mineralogy, and biology.

> **The domain of geology is so great, the portion of earth not geologically mapped and the structure worked out so vast, the ore and other valuable deposits which have received no study are so numerous, that there is an immense field for the application of well-established principles. In geology, as in engineering and other applied sciences, there is an opportunity for many honest, faithful men**

to perform useful service to the world even if their early training and capacity are not all that could be desired. But even the application of old principles will be well done in proportion as the geologist has training in the basal sciences; and to the man who combines with such training talent must necessarily be left the advancement of the philosophy of geology.

George Becker, who headed the Survey's Division of Chemical and Physical Research, acknowledged that "Geology has long, and with some justice, labored under the reproach of inexactitude. * * * The science is still in the qualitative stage and * * * even its most ardent students have seldom succeeded in ascertaining the quantitative relations between effects and operative causes and have been perforce content to indicate tendencies. Thus geological doctrine is far too much a matter of opinion, but this is hardly the fault of the areal geologist. The country must be mapped for economic reasons and to accumulate a knowledge of the facts to be explained. Working hypotheses the field geologist must have, or he could not prepare his map; and he is only responsible for living up to the standard of knowledge of his time. He is continually face to face with phenomena for which physics and chemistry should account, though they have not yet done so, and must accept seeming probabilities where certainty is unattainable."

Becker pointed out, however, that the problems that needed investigation offered very serious experimental and theoretical difficulties. If they had been easy, they might have been solved for many of them had been discussed for some time. Their difficulty, not lack of recognition of their importance, had postponed their solution. Moreover, the investigations could only be dealt with by a well-organized staff working on a definite plan. The tastes and convenience of individuals had to give way to "the methodical advancement of knowledge along such lines that the work of each investigator shall be of the utmost assistance to the progress of the rest."

Investigations such as those of Day and Allen, despite their importance to geology, were not likely to appeal to the very practical minded and unlikely to receive strong financial support in a Federal bureau. Moreover, the physical facilities available in the Survey headquarters were not suited to the nature of the experiments, which required delicate and accurate measurements. They were, however, research such as the Trustees of the Carnegie Institution wished to support. Not unexpectedly, the Advisory Committee on Geology of the Institution, T. C. Chamberlin, C. R. Van Hise, and C. D. Walcott, reported to the Trustees that research in geology was well covered in existing institutions but recommended that work in geophysics be undertaken, a recommendation that bore fruit within a few years when the Geophysical Laboratory was established.

The topographic-mapping program in the summer of 1902 was almost independent of the rest of the Survey. The choice of areas to be mapped in the East was largely controlled by the avalability of cooperative funds. In the Western States, much of the work was that required in the forest reserves and in aid of the Reclamation Service. In the States east of Mississippi River, 16,278 square miles were mapped, nearly 84 percent of it in the 11 States that had made cooperative agreements with the Survey, and roughly half of it in New York, Pennsylvania, Ohio, and Virginia. West of the Mississippi, 18,918 square miles were mapped, nearly 60 percent of it in California, Arizona, Washington, and Montana.

The doubling of the appropriation for stream gaging made possible a considerable expansion of the Survey's hydrographic work. The Reclamation Service continued most of the previous year's work in the Reclamation States and Territories and began new projects so that work was underway in all 16 States and Territories mentioned in the Reclamation Act. Stream gaging was continued in the nonreclamation States and plans were made to expand it, once the Reclamation Service was well underway. One exception was made. Newell was anxious to begin studies of water quality and had asked his alma mater, the Massachusetts Institute of Technology, to recommend a qualified engineer, specifying that he must also be good at making public contacts. MIT had recommended Marshall Ora Leighton, a graduate in 1896, who was serving as health officer at Montclair, New Jersey. Leighton was a classmate of M. L. Fuller, who had joined the Geologic Branch in 1900. Leighton was given a per diem appointment on July 1, 1902, pending qualification by civil service examination, and sent to begin the stream gaging in the upper Mississippi Valley which Newell was also anxious to get underway. N. C. Grover, professor of engineering at the University of Maine, carried on stream gaging in Maine, as the first of the projected operations in the New England area. R. E. Horton was similarly engaged in New York in cooperation with the State engineer and with officials of New York City. E. G. Paul was in charge of river stations within convenient reach of Washington, D.C. B.M. Hall and others were engaged in the work in the South Atlantic States. Leighton established an office at Chicago where he could conduct work on the quality of water as well as supervise the stream gaging in the upper Mississippi Valley. Professor T. U. Taylor took charge of the operations in Texas. In September, John C. Hoyt transferred from the Coast and Geodetic Survey to the Geological Survey and was put in charge of computing, which released Gerard Matthes for work with the Reclamation Service. In October, E. C. Murphy, who had been making special investigations for the Survey at the Cornell hydraulic laboratory, was appointed and, after a short period in the field, made inspector of stream gaging. In October, Henry Gannett left the Philippine Islands, as Assistant Director of the Census, and the forestry investigations were transferred from the Topographic Branch to the Hydrographic Branch.

Fuller's plan for collection of well data could not be started in the Geologic Branch because of lack of funds, but it served as the basis for a new division in the Hydrographic Branch proposed by Newell to the Director as a "well division." Newell simply added water wells to Fuller's oil and gas wells. The Director approved the plan, but the division was named "Hydro-Geology," which was promptly shortened to "Hydrology," when it was organized in January 1903. Two sections were planned, one for the Reclamation States and Territories, the other for the States east of the Mississippi River and bordering it on the west. Fuller was assigned to take charge of the work in the Eastern States, and he promptly made plans for collecting well records, beginning with water data. He also made arrangements with State geologists and other officials to begin work in 21 States and began compilation of statistical information and preparation of a bibliography of hydrology and hydrography. The Western Section was organized in May 1903, when N. H. Darton was transferred from the Geologic Branch to take charge of the work. W. C. Mendenhall, C. E. Siebenthal, and G. B. Richardson also transferred from the Geologic Branch to the new section, and Willis T. Lee and C. A. Fisher were added to the staff.

Because of the intimate relation of the work of the new division to that of the Geologic Branch from which it sprang, an arrangement for cooperation with that branch was approved by the Director on May 26, 1903, under the terms of which geologists in charge of the various sections of the Division of Geology would have the same authority with respect to scientific questions over geologists in the Division of Hydrology as they did over geologists in the Geologic Branch. Geologists in the Division of Hydrology were to collect and prepare for publication, incidental to their work on underground waters, as much purely geologic data as possible, particularly in little known regions where such data were needed for the preparation of the geologic map of the United States, and members of the Division of Geology were instructed to collect data relating to the occurrence of underground waters in the region where they were working and to prepare, for geologic folios, sheets showing the conditions of its occurrence in regions where the underground waters were of great importance.

The budget submitted to Congress for the fiscal year beginning July 1, 1903 called for an increase of $50,000, or one-third, in the appropriation for geologic surveys. Secretary of the Interior Hitchcock, in his annual report in the fall of 1902, pointed out that the mining industry had learned the value of geology, and that as the work of the Survey became more widely known, it became more largely economic. There was a growing demand for its extension into new regions. The demand far exceeded the ability of the Survey with its existing appropriation, and many meritorious requests had to be postponed.

The mineral industry as a whole had had an exceedingly profitable year in 1902. For the third time, the total value of the mineral products of the United States exceeded $1 billion, and the gain over 1901 was the second largest in 20 years. Iron and coal were most important, accounting for about 60 percent of the value. Crude petroleum increased by 27.4 percent over 1901, the greatest increases coming from Texas and California and from Louisiana, which produced for the first time. In fact, every variety of fuel increased in value except anthracite coal. Anthracite decreased in both quantity and value, although the average price at the mine increased from $2.05 to $2.50 a ton, because the total tonnage was decreased almost 40 percent by the strike that began on May 12, 1902, and lasted until October 21.

Between 70 and 80 percent of the anthracite fields were owned by six railroads, and for several years, the anthracite owners and operators had succeeded in maintaining a high price for their product while the price of bituminous coal declined and its use increased. Although the price of anthracite coal went up, miners' wages did not, and the United Mine Workers called the strike when the anthracite owners declined an offer of arbitration. For 5 months, 15,000 anthracite workers stayed out of the mines, and the industry was completely paralyzed. By September, most of the press was opposed to the stand of the mine operators, and some newspapers were advocating Government ownership of the mines. In October, the New York State Democratic Convention took a stand in favor of national ownership. With winter approaching and the Nation facing a serious coal famine, President Roosevelt decided the time had come for the Government to take a hand. Instead of calling out the troops, as Presidents Hayes and Cleveland had done when faced with crippling strikes, President Roosevelt called the operators and union leaders to Washington and asked them to agree to arbitration. The union leaders agreed immediately and the operators somewhat more reluctantly as soon as public opinion forced them to do so. On October 16, the President announced the formation of a commission to mediate the dispute, and 5 days later, the strike was called off. E. W. Parker, who had been the Survey's coal statistician since 1890, was one of the members of the commission.

The commission, in its report of March 1903, was critical of the manner in which the anthracite business had been conducted, noting that rivalry among railroads, which owned or controlled 96.29 percent of the anthracite deposits, had contributed to the unsettled conditions. The commission also commented that

Arthur L. Day said, "Geological field research, is essentially a study of natural end-phenomena, of completed reactions, with but a very imperfect record of the earlier intermediate steps in the earth-making process." To gain understanding of earth processes, he planned to study some of the simple rock-making minerals by the exact methods of physics and physical chemistry—first their thermal behavior and eventually their behavior under varying pressure and temperature. Photograph shows natural albite after heating to 1200°F. Melted areas are dark. (From A. L. Day and E. T. Allen, 1905.)

one can not but be struck by the thought that a commodity so valuable and indispensable, lying within a small area, limited in quantity, should not be wastefully mined, and that the needs of future generations should be considered and their interests conserved.

The commission also pointed out that in considering the compensation to be paid for any class of labor, the danger to life and limb to those engaged should be taken into account. All kinds of mining involved risk of accident considerably in excess of the average in manual labor, but coal mining was more hazardous than any other class of underground work, and anthracite coal mining was more dangerous than bituminous coal mining.

In his second state of the Union message in December 1902, President Roosevelt discussed at some length economic policies and the regulation of trusts. No country, he remarked, had ever occupied a higher plane of material well-being, and that well-being was not accidental but was due in large part to the phenomenal industrial development. Conditions that had favored the growth of so much good had of course also favored somewhat the growth of evil; it was necessary to try to cut out the evil, but a "due sense of proportion" should be maintained—"let us not in fixing our gaze upon the lesser evil forget the greater good." In correcting evils, industrial development must not be checked.

Congress, for the first time in several years, showed some reluctance to increase appropriations for the Survey and questioned some of the Survey's work. The House Committee on Appropriations did not recommend any increases and, in fact, recommended a reduction of the appropriation for stream gaging to $100,000 to test the sentiment of the full House on the previous year's increase to $200,000. The Committee of the Whole quickly restored the $200,000 but the bill passed by the House provided no increase in funds for the next fiscal year.

During the debate in the House, Congressman F. W. Mondell expressed some concern about the forestry program in the Survey. Mondell, who had been Assistant Commissioner of the General Land Office when the program began, thought that all public-land surveys, including those in the forest reserves, should be made under the supervision of the General Land Office. "I have no criticism to make of the surveys which the Geological Survey has executed under this provision, or of any of their work. They are doing a great work but their work is generally along other lines. It is along the line of scientific and practical investigation—topographic, geologic, and hydrographic surveys—and it is not along the line of ordinary public-land surveys."

Another familiar theme was given an airing by Congressman F. H. Gillett of Massachusetts. Mr. Gillett said it did not seem to him wise for the National Government to spend money simply for scientific researches that did not promise material advantage, and he thought that perhaps the Democratic members of the House might consider it unconstitutional. The National Museum, which attracted so many visitors in Washington, should be continued, he granted, but he did not see why it should cost $170,000 a year to take care of it. Research in ethnology, he thought, had been undertaken for the benefit of the Indian Affairs Committee but the state of that legislation showed how little effect it had had. As for paleontology, he said, "Why should we study that? How does paleontology interest the Government of the United States? It means, I believe, a study of fossils. Now, if they would study the numerous fossils connected with the Government and find out some way to eradicate them I would make no criticism. But to spend $10,000 supporting some learned and excellent men in the study of fossils out in our West seems to me wrong."

The Senate Committee on Appropriations, being more attuned to industry, approved the increase for geologic surveys and again suggested an appropriation of $5,000 for topographic surveys in Puerto Rico. Senator Perkins of California proposed an additional appropriation of $100,000 for investigations of mines and mining by the Survey, and the Senate agreed to $50,000. The House refused to yield, however, and in the end, the only increase in the Survey appropriation was an increase of $350 in the salary of John McChesney, the Chief Disbursing Clerk.

In the state of the Union message, the President repeated his recommendation that the administration of the forest reserves be transferred from the Department of the Interior to the Department of Agriculture, although in the face of the strong opposition of Congressman Cannon to the transfer there was little chance of its being approved during the short session. However, information had reached the Secretary of the Interior that frauds of a serious nature had been and were being perpetrated against the Government under the Forest Lieu Land Act, and he had already launched upon a thorough investigation of public-land administration. The first indictment was brought in December 1902 and several more followed in succeeding months. The Commissioner of the General Land Office, Binger Hermann, who was suspected of involvement, resigned, and the Assistant Commissioner, W.

A. Richards, was appointed in his place. The President had urged that a thorough revision of the public-land laws be made and suggested that if Congress felt unable to undertake the task, a commission of experts be set up to study the problem and advise them. Joint resolutions for the appointment of a public lands commission were proposed in both Houses, but were never acted on.

The state of the Union message also contained a recommendation for the establishment of a Department of Commerce. "The creation of such a department would in itself be an advance toward dealing with and exercising supervision over the whole subject of the great corporations doing an interstate business; and with this end in view, the Congress should endow the department with large powers, which could be increased as experience might show the need." The Department of Commerce and Labor was established by an act approved February 14, 1903, after a Presidential threat of a special session if it were not passed. The stated purpose of the new Department was "to foster, promote, and develop the foreign and domestic commerce, the mining, manufacturing, and transportation facilities of the United States." Transferred to the new Department were several bureaus from the Treasury Department, including the Coast and Geodetic Survey and the National Bureau of Standards, other bureaus from the Department of State dealing with foreign trade, and the Census Office from the Department of the Interior. The Office of Commissioner of Fish and Fisheries and the Fish Commission were also placed under the jurisdiction of the Department of Commerce and Labor. The Secretary was given control of gathering and distributing statistical information "naturally relating to the subjects confided to his department." Section 12 authorized the President to transfer "the whole or any part of any office, bureau, division or other branch of the public service engaged in statistical or scientific work" from the Departments of State, Treasury, War, Navy, or Interior to the Department of Commerce and Labor.

On March 13, 1903, 10 days after Congress adjourned, President Roosevelt appointed a committee to report directly to him "upon the organization, present condition, and needs of the Executive Government work wholly or partly scientific in character, and upon the steps which should be taken, if any, to prevent the duplication of such work, to coordinate its various branches, to increase its efficiency and economy, and to promote its usefulness to the Nation at large." Charles D. Walcott, Director of the Geological Survey, Director of the Reclamation Service, secretary of the Carnegie Institution of Washington, and president of the Washington Academy of Sciences, was named chairman of the committee. The other members were Brigadier General William Crozier, Chief of Ordnance; Rear Admiral Francis T. Bowles, Chief Constructor of the Navy; Gifford Pinchot; and James R. Garfield, Commissioner of Corporations in the newly established Department of Commerce and Labor.

In his autobiography, Pinchot claims that he proposed the plan to the President and that he was motivated at least in part by the idea that a strong recommendation from such a committee might help him achieve his objective of transferring management of the forest reserves from the Department of the Interior to the Department of Agriculture. President Roosevelt in his autobiography credits Pinchot with suggesting four later commissions but not this one, and in the letter of appointment stated that this was undertaken in view of the authority conferred in the act establishing the Department of Commerce and Labor enabling him to make certain transfers of the scientific work of the Government to that Department.

It is probable, however, that something more was involved. The National Academy of Sciences was concerned that it was seldom consulted by the Federal Government on science policy, and at the November 1900 meeting, Walcott had suggested that a committee of five be appointed to recommend suitable investigations and incorporate them in the annual report to Congress. When Alexander Agassiz, who still disapproved of the Washington influence in the Academy that was promoting science in the Government, was elected president of the Academy in April 1901, he recommended instead that an executive committee, with himself and home secretary Arnold Hague and three members resident in Washington, be appointed to represent the Academy in its relations with the Government. A year later, however, the council of the Academy decided that the Academy should have full and reliable information on the scientific work and needs of such bureaus as the Geological Survey, National Museum, Fish Commission, Bureau of Ethnology, Bureau of Forestry, Naval Observatory, Coast and Geodetic Survey, and National Bureau of Standards; and the Academy agreed to set up a committee to report to the Government on their work. The committee, however, had not progressed beyond the discussion stage.

In December 1902, President Roosevelt did as the advice and cooperation of the Academy in instituting scientific exploration of the natural resources of the Philippine Islands, and a committee under William H. Brewer of Yale reported in February 1903 that the exploration was of the greatest scientific and economic importance and proposed that a Board of Philippine Surveys be set up. A few days before appointing the Committee on the Organization of the Scientific Work of the Government, President Roosevelt had appointed a Board of Scientific Surveys of the Philippine Islands under the chairmanship of Charles D. Walcott. The Board prepared a bill which was transmitted to Congress but never acted upon.

The Committee on the Organization of the Scientific Work of the Government held 38 meetings between March and early July and then traveled to President Roosevelt's home at Oyster Bay, New York, to present its preliminary report. The committee had found that, considering the vast amount of work carried on by the Government, wholly or partly scientific in character, there was very little actual duplication and that such duplication as had existed had been magnified by being made the subject of controversy. Because of the growth of Federal science, however, there was a lack of efficiency and coordination of the work, and the committee suggested that the efficiency could be increased by subdivision and redistribution of some branches among the executive departments.

The basic principle upon which the scientific work of the Government should be organized, the committee concluded, was that the

> administrative unit should comprise all the elements necessary for the solution of a distinct scientific problem, or a group of closely related scientific problems, the investigation of which is for the benefit of the people in general. *** On the other hand, individual sciences and arts should not be segregated in the separate bureaus and offices, unless there exists such a large item or group of items in which a single branch of science or art predominates as to render such separation a matter of distinct economy. The committee is also of the opinion that research in pure science on broad and general grounds is more properly within the scope of private institutions and that in general the work of scientific research on the part of the Government should be limited nearly to utilitarian purposes.

Specific recommendations included the transfer of all general statistical work that was separate and distinct from particular scientific problems to the Department of Commerce and Labor; transfer of the Geological Survey, General Land Office, Office of Indian Affairs, and custody and care of the national forest reserves and national parks from the Department of the Interior to the Department of Agriculture; transfer of the geodetic and magnetic work of the Coast and Geodetic Survey to the Geological Survey; and transfer of the hydrographic work of the Coast and Geodetic Survey to the Hydrographic Office of the Navy with the formation of a Coast and Hydrographic Survey under the administrative and scientific control of civilians.

The rationale behind the proposed transfers to the Department of Agriculture appeared in a later report, which pointed out that in the 13 years since the Department of Agriculture had attained Cabinet status, the growth of scientific work in that Department had exceeded that of the entire Government in the preceding century; the Agriculture Department comprised one-third of the Federal scientific bureaus, received three-fifths of the appropriations for maintenance of scientific work, and employed fully two-thirds of the investigators engaged "in the promotion of knowledge for human welfare." What was left unsaid was perhaps more significant. The transfer of additional scientific bureaus to the Department of Agriculture would concentrate science in that Department to such an extent that the recommendation of the National Academy of Sciences in 1884 for establishment of a Department of Science might be more easily achieved. It must be noted also that the legislation establishing the Department of Agriculture specifically authorized "practical and scientific experiments," whereas the legislation establishing the Department of Commerce and Labor called for it to "foster, promote, and develop" commerce and industry, and authorized the transfer of scientific work from all other departments except the Department of Agriculture to the new department. The committee may have concluded that the scientific work of the Government should be limited to utilitarian purposes; it clearly wanted to ensure that the scientific work remain scientific.

On the basis of his detailed study of the rocks of Mount Ascutney (pictured), Vermont, R. A. Daly proposed a new and fundamental explanation of the mechanics of magmatic intrusion—that the chambers now occupied by igneous rocks were not opened by bodily movements of the crust but that the rocks made room for themselves by some kind of assimilation of the invaded formations. The Geological Survey's contribution to the work was an elaborate series of chemical analyses by W. F. Hillebrand. (From R. A. Daly, 1903.)

The Cripple Creek district of Colorado was restudied in 1903 at the request of the citizens of the State. The productive part of the district was then contained within a circle only 6 to 7 miles in diameter. More than 20 shafts had been sunk to depths greater than 1,000 feet; one of the important questions then was whether the veins persisted at depth. Lindgren and Ransome thought that the future of the district was in discovery of additional ore bodies within 1,000 feet of the surface. (From Waldemar Lindgren and F. L. Ransome, 1906.)

The Survey began its 25th year, still adapting its structure and procedures to changing conditions and responsibilities. Its senior branch, the Geologic Branch, was both successful and respected. The Topographic Branch, also successful, was troubled by organizational problems. The youngest branch, the Hydrographic Branch, was experiencing growing pains.

In the Geologic Branch, the economic geology of fuels received more attention than the economic geology of metals. Such emphasis was fitting in a year that saw the first flight of a heavier-than-air machine and the first transcontinental trip by an automobile under its own power, although it was probably not the result of prescience, and the Survey gave as much attention, if not more, to coal as it did to oil. M. R. Campbell and assistants continued the detailed mapping of the Appalachian coalfields and in the Ohio, West Virginia, and Pennsylvania oilfields. George Ashley spent most of the season in Pennsylvania but also made a resurvey of the Middlesboro region in Kentucky as soon as the new topographic base was completed. W. T. Griswold continued his very detailed surveys of the oilfield in eastern Ohio, and plans were made for a model to be displayed at the Louisiana Purchase Exposition showing the underlying structure. Oil investigations were extended to the midcontinent region by G. I. Adams who made a survey of the Iola quadrangle, Kansas, in the midst of a rapidly developing oil and gas district, in cooperation with the State Geologist. Professor Fenneman completed a study of the Boulder, Colorado, oilfield, finding that the

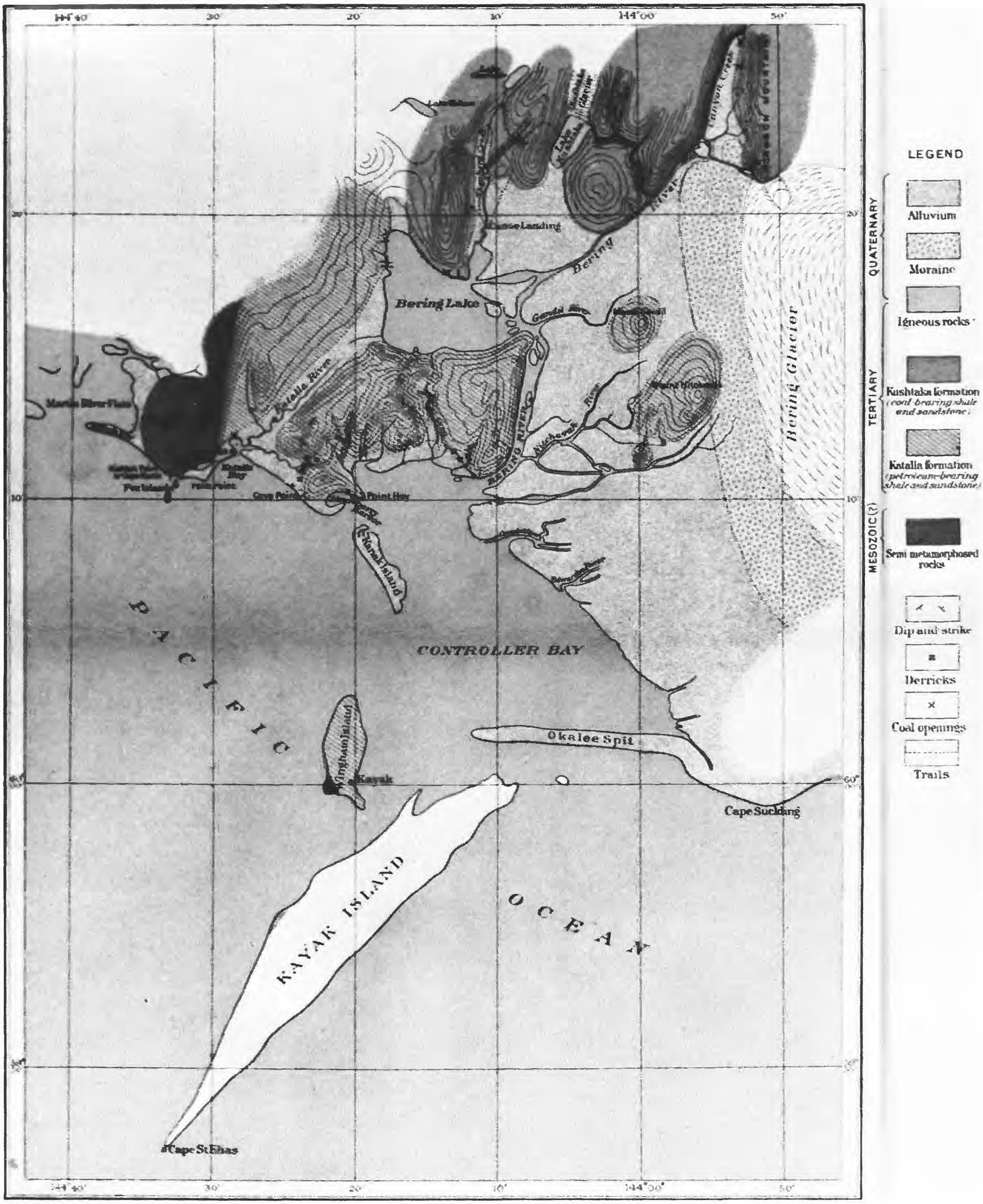
producing wells there were all on the east limbs of en echelon folds. The work of land classification was also continued as J. A. Taff was again detailed to the Department to prepare reports on the segregated coal and asphalt lands in Indian Territory. E. C. Eckel and T. Nelson Dale were responsible for most of the work on other nonmetalliferous deposits. Eckel visited the various cement-producing areas and typical plants to compile information for the report on the cement industry and with the assistance of Dale began collection of data for a report on the slate industry.

Nonmetamorphic iron ores, however, were also the responsibility of the Nonmetals Section. The enormous and rapidly increasing consumption of iron ore was becoming a matter of concern, and inventories of available supplies were being made to emphasize the limitation of known deposits and the necessity for early exploitation of new ones. Less than 2 percent of the iron ore mined annually had come from west of the Mississippi River, although it had long been known that there were large deposits there that had not been exploited because of lack of transportation or distance from consuming centers. C. K. Leith, who had studied both the Michigan and Minnesota iron deposits for the Precambrian Section, began a reconnaissance of the western iron deposits.

The major project in the Metals Section in the summer of 1903 was a resurvey of the Cripple Creek district in Colorado, which had been investigated by Cross and Penrose in 1894, in cooperation with the State of Colorado. The study was an important and a sensitive one. Not only were the underground workings far more extensive than they had been in 1894, but the district had had two serious conflicts between mineowners and miners, the cost of mining and treatment were high, there had been a tendency to capitalize companies for amounts greatly in excess of the probable value of the prospects to be developed, and few mines had yielded the amount of their capitalization in dividends. Both Lindgren and Ransome were assigned to the investigation. Ransome had been scheduled to begin the study of the Coeur d'Alene district in Idaho with F. C. Calkins as assistant. Calkins began the areal mapping, but the economic study was postponed until the following season. Boutwell continued the Park City study, and Spurr, the studies at Tonopah, but Irving left to join the faculty of the University of Wyoming, Spencer joined the Division of Alaskan Mineral Resources, and Weed was kept busy writing reports.

The Division of Alaskan Mineral Resources was established on July 1, 1903, of the same rank as the Divisions of Geology and Paleontology, Chemical and Physical Research, and Mining and Mineral Resources. Alfred H. Brooks was designated geologist in charge. Because of the reorganization in the Topographic Branch, topographers as well as geologists engaged in Alaskan surveys were transferred to the new Division. The Division of Alaskan Mineral Resources, although part of the Geologic Branch, became, in effect, an Alaskan geological survey; and it began, as had the U.S. Geological Survey in 1879, primarily to study economic geology and with topographic mapping subservient to that purpose.

Most of the Alaskan surveys were concerned with metals, but Brooks foresaw that coal and oil would be essential to the development of Alaska. Drilling had been going on since the summer of 1901, but only one well had struck oil. George C. Martin of the Maryland Geological Survey was selected to begin the oil investigations, and he began fieldwork near Controller Bay and Bering River and in Cook Inlet and Cold Bay. Arthur Spencer, assisted by C. W. Wright, studied the geology of a 200-mile strip along the southeastern mainland where the gold production was estimated as $2.4 million. In the Seward Peninsula area, A. J. Collier and F. L. Hess


LEGEND
QUATERNARY
Alluvium
Moraine
Igneous rocks
TERTIARY
Kushtaka formation
(coal-bearing shale and sandstone)
Katalla formation
(petroleum-bearing shale and sandstone)
MESOZOIC(?)
Semi metamorphosed rocks
Dip and strike
Derricks
Coal openings
Trails
144°40'
30'
20'
10'
144°00'
50'
60°
Canoe Landing
Bering Lake
Bering River
Bering Glacier
Katalla River
Nichawak River
Point Hey
Kanak Island
CONTROLLER BAY
PACIFIC
OCEAN
Wingham Island
Kayak
Okalee Spit
Cape Suckling
KAYAK ISLAND
Cape St Elias

In the summer of 1903, George C. Martin began a reconnaissance of the petroleum and coalfields in Alaska for the U.S. Geological Survey. Few wells had been drilled, and it was considered too soon to ◀ predict an important future for the region as a petroleum producer. He concluded, however, that the Bering River coal was the best yet found on the Pacific coast of North America. (From G. C. Martin, 1905.)

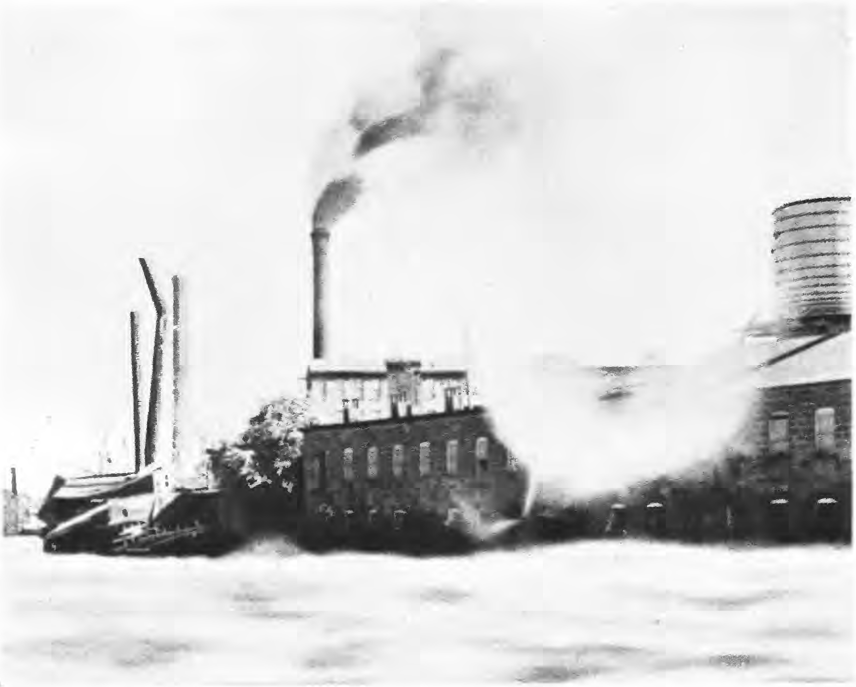
investigated tin deposits and gold placers, while a combined party under D. C. Witherspoon with Fred Moffit as geologist completed the reconnaissance mapping of the northeastern part and procured additional information on the placer gold deposits. L. M. Prindle and two assistants examined gold-producing placers and prospect areas near Fortymile, Birch Creek, and Fairbanks, while T. G. Gerdine was mapping 6,000 square miles topographically. Collier's reconnaissance of the previous year down the Yukon River had been of such interest that Arthur Hollick and Sidney Paige were dispatched to Alaska to travel down the Yukon by canoe and collect fossils to clear up doubtful points of Mesozoic and Tertiary stratigraphy and to determine the age of the coal-bearing rocks.

Perhaps by design but more certainly as the result of circumstance, especially the establishment of the Carnegie Institution, the noneconomic work of the Geologic Branch declined. Bailey Willis, the head of the Areal Geology Section, was on leave during the year on a mission in China for the Carnegie Institution. Areal mapping was continued but much of it was done by professors working part time for the Survey. Professor Chamberlin, the head of the Section of Pleistocene Geology, had been given a grant by the Carnegie Institution for investigation of fundamental problems in geology and consequently had very little time for the Survey. Some work in glacial geology was continued by Professor Salisbury, who took a large part of volunteers, many of them University of Chicago students, to the Bighorn Mountains of Wyoming. F. H. H. Calhoun and W. W. Atwood, who had been graduate students at Chicago, studied the geology and physiography of the Great Falls area in Montana and the Uinta Mountains, respectively. G. K. Gilbert spent part of the year investigating granite districts in Georgia on behalf of the Carnegie Institution, in search of a locality suitable for the investigation of subterranean temperature gradients by means of a deep boring.

The Pre-Cambrian Section to all intents and purposes ceased to exist. Professor Van Hise had been selected as president of the University of Wisconsin and the long-standing arrangement by which he had spent about half of each year with the Survey in Washington had to be discontinued. Professors Bayley and Bascom were winding up their mapping projects in the New Jersey Highlands and Philadelphia areas, and Professor Leith had begun the investigation of western iron ores.

The work of the paleontologists of the Survey was far more than "studying fossils out West," as Congressman Gillett supposed; much of it could be more properly described in Walcottian terms as paleontological geology, even paleontologic economic geology. E. O. Ulrich, for example, spent considerable time in the lead-zinc area of southern Illinois; George Girty studied the stratigraphic relations of the Devonian and Carboniferous rocks in the oil regions of northwestern Pennsylvania; and both T. Wayland Vaughan and Ralph Arnold, who had recently been appointed as W. H. Dall's assistant, were aiding investigations of water resources, particularly in southern California.

The work of the chemists was also closely allied to the interests of economic geology. H. W. Stokes, who had been engaged in the investigation of secondary enrichment, transferred to the Bureau of Standards but was succeeded by E. C. Sullivan, who held a Ph.D. from Leipzig and had been an instructor in analytical chemistry of the University of Michigan. Waldemar Schaller, a graduate of the University of California, joined the staff as assistant chemist and began a study of lithium minerals.



The Passaic River basin in northern New Jersey, a region limited in area but containing about one-third of the State's population, experienced two series of floods in 1902 and 1903. The large capital investment and community interests involved made it desirable that the occurrence and progress of floods in the area be thoroughly understood, and thus a new element was added to the water-resources program. (M. O. Leighton, 1904.)

The work in the physical laboratory was supported in part by a grant from the Carnegie Institution. Day and Allen completed their study of the thermal properties of the plagioclase feldspars at ordinary pressures, settling the question of the isomorphism of the series and giving for the first time an accurate series of melting points. Day and Van Orstrand also began an investigation of "black bodies" as efforts were being made in Europe to use their properties as the basis for measuring temperature at a distance.

Emmons, Becker, and Van Hise all attended the sessions of the International Geological Congress in Vienna in the summer of 1903. Both Becker and Van Hise investigated geophysical research in Europe and the possibility of a geophysical laboratory at the Carnegie Institution of Washington. Emmons, as one of the vice presidents of the Congress, won the endorsement of the Congress for such a venture.

The Topographic Branch, which since 1896 had been administered by a Topographic Committee with the Director or one of the section chiefs as chairman, was reorganized tentatively on May 1, 1903. Two divisions were set up, a Division of Topography, which remained under the Topographic Committee, of which R. U. Goode was then chairman, and a Division of Geography and Forestry under Henry Gannett, to include the forest investigations, which had never been formally organized, and certain special investigations. The Division of Topography included the four topographic sections, a Section of Triangulation and Computing under S. S. Gannett, and a Section of Inspection under John H. Renshawe. The Section of Inspection was charged with responsibility for eliminating as far as possible individual mannerisms in contour sketching in order to achieve uniformity of style, thus returning to the Branch the essential function of map editing. Early in June, the four topographic sections were consolidated into two; Goode took charge of the Western Section, which included all the United States west of the 100th meridian, and H. M. Wilson took charge of the Eastern Section. Goode, whom Walcott considered one of his right-hand men, was probably slated to become Chief of the Topographic Branch, but he died suddenly on June 9, unable to withstand pneumonia because of a rundown condition brought on by overwork. The Topographic Division remained under the Topographic Committee and E. M. Douglas was placed in charge of the Western Section.

The accomplishments of the two topographic mapping sections in the field season of 1903 were very different. In the Eastern Section, mapping was carried on in 24 States, in 10 of them under cooperative agreements, and of the 19,013 square miles mapped, more than 75 percent was for publication at 1:62,500. In the Western Section, which was responsible for mapping in the forest reserves, mapping was carried on in only 10 States and Territories and of the 15,127 square miles surveyed, 80 percent was for publication at 1:125,000. Only in California, where the State contributed funds for mapping at scales of 1:62,500 and 1:31,680 in the Sacramento Valley, was mapping done at larger scales. There, R. B. Marshall was given immediate supervision of all work in California, and a branch office was opened in Sacramento where all office work for the California sheets was completed.

The Reclamation Service under Newell was instructed to push its work as rapidly and economically as possible, and by the end of the year, it was ready to begin actual construction on the Salt River project in Arizona and the Truckee-Carson project in Nevada. The Survey's Hydrographic Branch had grown in a year until it had almost as many heads as the legendary Hydra. The Division of Hydrography had two sections, with five hydrographic districts in the Eastern Section and three in the Western Section. The Division of Hydrology was also divided into Eastern and Western Sections.

In the Division of Hydrography, N. C. Grover, R. E. Horton, and M. R. Hall had qualified for civil service appointments and were given full-time appointments as district hydrographers or engineers. Grover took charge of the New England district with headquarters at Bangor, Maine; Horton, of the New York-Michigan district with headquarters at Utica, New York; and Hall, of the Southern Atlantic and Eastern Gulf States district with headquarters at Atlanta, Georgia. E. G. Paul continued as district hydrographer for the Northern Atlantic States district with head-

quarters at Washington, D.C. Edward Johnson, who had been assisting Leighton, took charge of the work in the upper Mississippi Valley, which became known as the Chicago district. Only three districts were set up in the Western Section because so much work there was being carried on in connection with the irrigation investigations. The Central West district included all or part of Colorado, Kansas, Nebraska, South Dakota, Wyoming, Utah, New Mexico, and Oklahoma; work there was carried on under the general direction of A. L. Fellows. California and Texas each constituted a district, California under the general supervision of J. B. Lippincott, and Texas under Professor T. U. Taylor. By the end of the year, 619 river stations were being maintained in these districts.

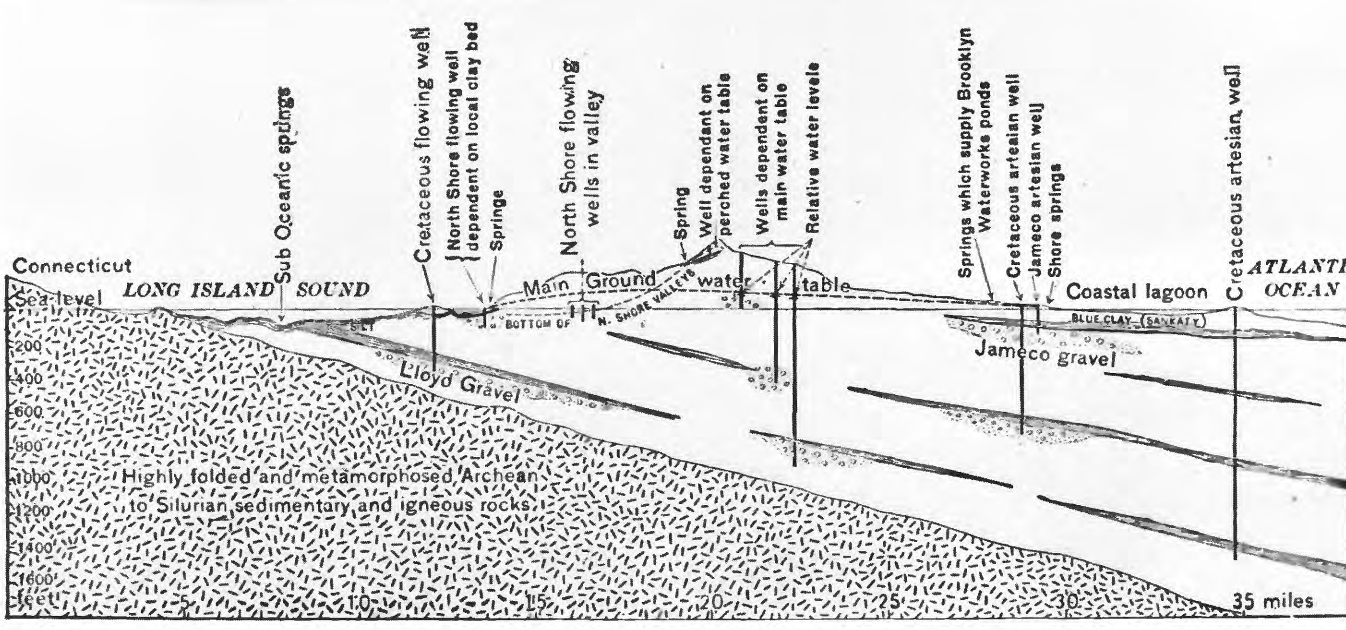
The island of Molokai in the Hawaiian Islands was built up of extremely porous rocks which seawater and rainwater penetrated freely. The rainwater sank into the rocks until it met the seawater and rested like a sheet on it. When Waldemar Lindgren visited the island in 1900, more than 1,000 of the island's total population of 2,400 lived in the leper settlement. The problems of water conservation were thus difficult and involved. (From Waldemar Lindgren, 1903.)

In the Division of Hydrology, the Eastern Section had work in progress in 21 States at the beginning of the fiscal year, for the most part the collection of well and spring data and surveys of ground-water supplies by university and State geologists. The Survey itself began an ambitious project to study the geology and water resources of Long Island, New York, with Fuller himself in charge and Arthur Veatch as his assistant. Professor Slichter, using the electrical apparatus he had invented, studied the movement of ground water on the island. From these studies, Fuller and Veatch were able to determine not only the disposition of the sand beds and clay masses beneath the island and their effect on the movement of ground water but also the amount of underflow available for municipal supplies in several localities. Veatch, who had collected samples from wells drilled on the island in order to make fine distinctions in the glacial materials, found the samples so valuable and the operators and drillers so willing to assist that he drew up a plan for a system of collecting and preserving well samples throughout the country.

Work in the Western Section was almost entirely a Survey effort. Darton completed his study of the geology and water supply of the central Great Plains. Mendenhall began a study of the underground water resources of southern California, while C. E. Siebenthal and G. B. Richardson studied the San Luis Valley of Colorado and El Paso County, Texas. Newcomers Willis T. Lee and C. A. Fisher studied underground water supplies in Arizona and the Arkansas Valley. In January, when Lippincott was claimed full time by the Reclamation Service, Mendenhall took on the work of mapping the irrigated lands and collecting well data in southern California.

In September, the Division of Hydro-economics was organized to investigate such features of economic value in the water supplies of the United States as quality of water, changes in composition, damage arising from abuse, and methods of making it commercially valuable. M. O. Leighton, who had been appointed in July 1902 with this goal in mind, moved to Washington to head the Division. He was assisted by Richard B. Dole, a graduate of Bowdoin College, who had some advanced study at the Massachusetts Institute of Technology. Leighton planned that some investigations would be made by the Survey staff, some in cooperation with State or private bodies under joint appropriations, and some in cooperation with laboratories, in which the Survey would collect and transport the samples; and, the laboratories would make the chemical analyses.

The Survey staff's investigations included the development of field methods of water assay for turbidity, color, total hardness, alkalinity or carbonates, total sulfate, chlorine, and iron; field determinations of the principal constituents of ground and surface waters in Georgia, Indiana, and Iowa; and an investigation of the effects of sewage and industrial pollution on Lake



A detailed study of the ground-water resources of Long Island showed that rainwater sank directly into the porous surface gravel and produced practically no runoff. Records of many deep wells combined with C. S. Slichter's experimental studies of the movement of ground water demonstrated that part of the ground water passed coastward in the upper gravels and another part sank into the Jameco gravels and Cretaceous sands and finally escaped in the form of suboceanic springs. (From A. C. Veatch and others, 1906.)

To understand the ground-water resources of the Great Plains, it was necessary to investigate the geology, especially the structure of the water-bearing and associated formations. N. H. Darton, who continued and extended the work begun by Gilbert in the 1890's, carried on an old tradition in presenting illustrations of striking scenery, such as this one of the Cathedral Spires in Colorado's Garden of the Gods, which he identified as vertical strata of the lower Wyoming red grits. A sketch of the same scene appeared in Hayden's 1874 report and is reproduced in volume 1 of this history, page 206. (From N. H. Darton, 1905.)

Champlain. In cooperation with the Minnesota State Board of Health, the ground and surface waters of Minnesota were studied. In the third class of investigations, periodic examinations were made of the character of river waters in Maine, New York, Pennsylvania, Indiana, Kentucky, and Kansas to determine the effects of industrial pollution or to determine the character of the water available for manufacturing or municipal use, and the samples were analyzed by cooperating laboratories.

March 3, 1904, marked the 25th anniversary of the legislation establishing the U.S. Geological Survey, and June 30, 1904, the completion of its first quarter-century of work. The anniversary was marked by appropriate festivities, and a bulletin describing the Survey and its operations for 25 years was published. From the viewpoint of 1904, the following achievements were considered noteworthy.

A topographic map of 929,850 square miles of the area of the United State, or 26 percent of the country including Alaska and 31 percent of the country excluding Alaska, had been prepared and published in the form of 1,327 atlas sheets. The topographic maps had expedited investigations of city water supplies, such as those by New York City and the New York State Barge Canal. They had also been of value to railway companies and State highway bureaus; the improvement of highways in New York, Maryland, Massachusetts and other States had been facilitated and the cost of work materially reduced.

Geologic mapping of the country had been extended over about 171,000 square miles; 106 geologic folios had already been published, and nearly as many more were in various stages of preparation. In addition to this geologic mapping, experimental and theoretical investigations of the physical characteristics of rocks in various processes of formation, of volcanic and geyser action, and of rock composition and structure had been undertaken, and the paleontologists had aided in the solution of stratigraphic and structural problems by classification and identification of fossil plants and animals.

The maximum, minimum, and mean discharge of all the more important rivers, had been recorded for 15 years, and of all the lesser tributaries of many hundreds of streams for shorter periods. These data had been assembled and studied, especially in relation to precipitation. The physical characteristics of river basins had been studied in respect to such factors as forestation and soil covering, so that the volume of runoff of each of the streams could be closely estimated. The development of the waterpower of the country, especially in the Southern States, had been stimulated by the facts brought to light in respect to the volume and regularity of the discharge of, and the fall in, the various streams of the country. Data had been gathered concerning the public lands which were irrigable an their relation to possible water supplies, a large number of reservoir sites had been examined and surveyed in a preliminary way and the lands withdrawn from sale or occupation pending more detailed studies. Several reservoir and irrigation projects had been studied in greater detail, surveys of irrigable lands and canal lines had been made, and some had been finally approved for construction by the Reclamation Service.

Detailed examinations had been made of 110,000 square miles, and the lands classified as forested, grazing, desert, or cultivable, and reports had been prepared on the forest reserves showing the character and amount of timber and other facts that would serve as a basis for forest management.

Of all the work of the Geological Survey, however, its immediate value to the people was best shown by the aid extended in developing the mineral resources and in forwarding important engineering projects in which the people, as well as Federal and State governments, were interested. The work of the Geologic Branch had had a wide educational influence on the public at large, but more directly on those in the mining industry. The investigation of the mining geology of Leadville had not only "guided exploration and secured economical mining in a district that has produced between $200,000,000 and $300,000,000" but had 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." Leadville was by no means all. The investigation of the origin and geologic relations of the Lake Superior iron ores had "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 determination of structure in the Appalachian coalfield were placing the development of the coal, petroleum, and gas on a scientific basis and relieving that part of the mineral industry of a large part of the hazard and uncertainty that had been associated with them. Finally, the collection and publication of reliable statistics of mineral production had furnished a sound basis for appraising the status and development of all branches of the mineral industry.

As the anniversary approached, the American Mining Congress was calling for establishment of a department of mines. The *Engineering and Mining Journal* preferred the establishment of a bureau of mining under the Director of the Geological Survey, saying

> **in no other country—we say it advisedly—has economic geology been applied to the development of industry with such beneficent results as in the United States, and no geological survey has contributed so much to the practical application of the science of geology in mining operations as has the organization in whose behalf we bespeak the earnest interest of our readers.**

What was needed, the editor said, was greater scope for economic geology and "freedom from the encroachments of the wood and water departments."

On March 7, 1904, the Public Lands Commission, which President Roosevelt had appointed in October 1903 when Congress failed to respond to his recommendation, submitted a partial report. The President forwarded it immediately to Congress with the recommendation that the suggestions therein be favorably considered. The commission had only three members, W. A. Richards, Commissioner of the General Land Office; F. H. Newell, Chief Hydrographer of the Survey and Chief Engineer of the Reclamation Service; and Gifford Pinchot, the Chief Forester. The changes proposed in their preliminary report reflected their principal interests and bore chiefly on the control, use, and disposal of forest lands and the control of water. No consideration was given to mining laws, with which the 1879 commission had been much concerned, and even in its final report in 1905, the second commission stated that it had not been possible to take up the subject, although it recognized that important changes were necessary in both the United States and Alaska.

It is impossible to define the end of an era exactly, but the coincidence of the 25th anniversary of the establishment of the U.S. Geological Survey and the submission of the preliminary report of the Second Public Lands Commission comes close to pinpointing one. Within a short time thereafter, the "wood and water departments" became not less but more influential, and the conservation of natural resources became of greater import than their development. For the conservation of both renewable and nonrenewable resources, large tracts of the public domain were withdrawn from entry. The reaction in the West, and in Congress, was not unlike that when lands had been withdrawn during the Irrigation Survey and for forest reserves. Classification of the public lands became an important element of the Survey's work for the first time, and, as appropriations were not increased, both research and mapping programs had to be altered to accommodate the new work. The separation of basic and applied science, already underway, was accelerated, and the Survey became essentially a department of practical science.

Notes and Bibliography

The chapter notes identify the sources of directly quoted material and a few indirect statements, some incidental biographical data, and give the reference to the U.S. Statutes at Large for all laws mentioned in the text. These have been related to the relevant page and either to the first few words of the quotation or to a significant phrase. Complete citations for most published material used as background, including the more extensive biographical works, and for quotation or illustration are given in the bibliography. Citations are arranged alphabetically by author, and include the Congressional documents (in parentheses at the end of the citation), the serial number of the volume in which the document appears. Annual reports of the Director of the U.S. Geological Survey and the Secretary of the Interior are cited in the notes.

To aid the reader in finding pertinent references in the bibliography or in seeking additional material on a particular topic, a simple index has been prepared, with references identified by author and date. Primary or contemporary documents are listed first, with but a few exceptions in chronological order, followed by more recent secondary sources, alphabetically by author. Biographical data not otherwise identified were obtained from the Dictionary of American Biography, National Cyclopedia of American Biography, Dictionary of Scientific Biography, Who Was Who in America, Who Was Who in American Politics by Dan and Inez Morris, or the Biographical Directory of the American Congress, 1774–1961.

Notes

Title.

"for the common defence and general welfare": Article I, Section 8 of the Constitution provides that "The Congress shall have Power To lay and collect Taxes, Duties, Imposts and Excises, to pay the Debts and provide for the common Defence and general Welfare of the United States;" This section is the authorization for appropriation and expenditure of public funds for scientific research.

Chapter 1. A New Order

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1. "There is nothing more difficult * * * ": Niccolo Machiavelli, The Prince, 1517, Chapter 6.

3. "By far the larger part * * * ": National Academy of Sciences, U.S. Congress, 45th, 3d session, House Miscellaneous Document 5, p. 5.

5. "novel application": S. F. Peckham, 1884, p. 251.

6. "It is chiefly * * * ": J. D. Whitney, *in* North American Review, 1875, v. 121, p. 274.
   "The time has come * * * ": E. C. Pechin, *in* Transactions of the American Institute of Mining Engineers, 1872, v. 1, p. 297.

7. "What is there * * * ": Congressman A. A. Hewitt, *in* Congressional Record, U.S. Congress, 45th, 3d session, p. 1203.
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8. "a shorthand abbreviation * * * ": Max Lerner, *in* A. M. Schlesinger, Jr., and Morton White, eds., 1963, p. 148.

11. "Such industrial progress * * * ": James M. Swank, *in* David T. Day, Mineral Resources of the United States calendar years 1889 and 1890, p. 22.

Chapter 2. The Most Ancient Art, 1879–1881

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17. "Indeed, the subject of mining * * * ": Georgius Agricola, Preface to De Re Metallica, 1550.

18. "all those features * * * " and "students of the political economy * * * ": Clarence King, 1880a, p. 335.
   "highly useful but feebly endowed": Ibid., p. 389.
   "In the history of the United States * * * ": Ibid.

19. "Every intelligent student * * * ": Ibid.
   "an area enclosing * * * ": Ibid., p. 339.
   "supposed by the first framers * * * ": Ibid., p. 335.

20. "authorize by a reasonable construction * * * " and "he might as well * * * ": C. E. Dutton to Archibald Geikie, June 21, 1880, *in* the manuscript collections, University of Edinburgh Library.
   The discussion of Joint Resolution 117 is on pages 2420–2424 of the Congressional Record of the 46th Congress, 1st session.
   "and the States" and "the Geological Director * * * ": Ibid., J. D. C. Atkins, p. 2420.
   "And to collect * * * ": Joseph Hawley, Ibid., p. 2421.
   "We should know * * * ": A. J. Warner, Ibid., p. 2421.
   "Not at all * * * ": J. D. C. Atkins, Ibid., p. 2421.
   "and he may extend * * * ": Ibid., p. 2422.
   "and he may extend * * * not to interfere * * * ": Ibid., p. 2422.
   "was his duty * * * ", "a very small proportion", and "diverted": Clarence King, 1880, p. 387.
   "There can hardly be * * * ": Ibid., p. 338.

21. "more than others * * * " and "Leadville, that extraordinary * * * ": Ibid.

23. "the mechanical arts * * * " and "valueless from their rebellious nature * * * ": Clarence King 1880a, p. 370.
24. "But as a whole * * * ": Ibid., p. 391.
"in their economic relations * * * ": 20 Stat. L., 475, Section 18 of the Act establishing the Tenth Census.
27. "took a lively interest * * * ": J. P. Iddings, 1918, p. 45.
28. "An authority in many fields * * * ": W. C. Mendenhall, 1920, p. 44. Mendenhall attributes the appraisal to C. Hart Merriam.
29. "every mine and known outcrop * * * ": Raphael Pumpelly, 1918, p. 618.
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30. "red-bearded giant" and "You will want young men * * * ": Bailey Willis, 1947, p. 5–6.
"He used his profession * * * ": Bailey Willis, 1925, p. 45.
32. "Whence did they come?": S. F. Emmons, U.S. Geological Survey 1st Annual Report, 1880, p. 348.
"with the possible exception * * * ":A. L. Day, 1920, p. 14.
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34. "it was manifestly impossible * * * ": G. K. Gilbert, U.S. Geological Survey 2d Annual Report, 1882, p. 170.
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"Mr. Gilbert presents * * * ": J. D. Dana, 1880, p. 17.
"The quaquaversal dip * * * ": Ibid., p. 18.
36. "The facts appear * * * " and "appears to be * * * ": Ibid., p. 22.
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Hayden's mental and physical condition are described in letters to Archibald Geikie, *in* the manuscript collections of the University of Edinburgh Library.
37. "first, a codification * * * ": 20 Stat. L., 39.
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38. "the machinery of the land system * * * ": Ibid.
"all lands which contain * * * " and "all lands, excepting mineral * * * ": Ibid., p. lxiii.
39. "in consonance with the traditions * * * ": Ibid., p. xxviii.
40. "one of those extraordinary * * * ": Ibid., p. xxxiv.
"attempted conveyance * * * ": Ibid., p. xxxv.
"might be fitly entitled * * * ": Ibid., p. xl.
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42. "I cherish the belief * * * ": C. E. Dutton to Archibald Geikie, April 1, 1880, *in* the manuscript collections, University of Edinburgh Library.
43. "partly in accord * * * ": G. K. Gilbert, U.S. Geological Survey 2d Annual Report, 1882, p. 11.
44. "had in view * * * " and "Topographical surveys * * * ": J. D. Dana, 1879, p. 495.
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45. "Geology never has discovered * * * ": Martin Maginnis, *in* Congressional Record, 46th Congress, 2d session, p. 3925.
"for the purpose of continuing ethnologic researches * * * ": Congressional Record, 46th Congress. 2d session, p. 3928.
46. "I understand * * * ": F. V. Hayden to Archibald Geikie, August 1, 1880, *in* the manuscript collections, University of Edinburgh Library.
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"much time and labor * * * ": Ibid., p. 3.
48. "as the sun came up * * * ": Daily New Mexican, February 2, 1881, clipping in Survey scrapbook.
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"There is a topography * * * ": G. K. Gilbert, *in* U.S. Geological Survey 1st Annual Report, 1880, p. 357.
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53. "the mineral industries * * * ": Ibid., p. 392.
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57. "It is not local work * * * ": S. J. Kirkwood, *in* Report of the Secretary of the Interior for the year ending June 30, 1881, p. xxxvii.
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59. "a geographical and geological survey * * * ": J. W. Powell, *in* U.S. Congress, 45th, 3d session, House Miscellaneous Document No. 5, p. 23.
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"Such papers * * * ": Ibid., p. 421–422.
"1st. Topography * * * ": U.S. Congress, 47th, 1st session, House Report 1065, p. 4.

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"and to continue preparation * * * ": Congressional Record, 47th Congress, 1st session, p. 5923.
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Chapter 4. Measures of Reform, 1884–1886

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"not deemed wise * * * ": Ibid.
"from the Atlantic * * * ": Ibid., p. xxiv.
"crystalline schists * * * ": Ibid.

94. "presumably Archean gneisses": F. V. Hayden, *in* U.S. Geological Survey 6th Annual Report, p. 49.
"under the organic law * * * ": Ibid., p. xxv.

95. "for the study of the volcanic rocks * * * ": H. W. Teller, 1885, p. xxxi.
"for the study of metamorphic rocks * * * ": Ibid.
"for the general study of the sedimentary rocks * * * ": Ibid.
"geologic wonderland": C. E. Dutton, 1885, p. 113.
"if the cone of Mount Taylor * * * ": Ibid., p. 116.
"a general investigation * * * ": R. D. Irving, *in* U.S. Geological Survey 6th Annual Report, p. 40.

96. "in order that * * * ": Arnold Hague, *in* U.S. Geological Survey 6th Annual Report, 1885, p. 55.
"because it contained * * * ": F. V. Hayden, *in* U.S. Geological 6th Annual Report, 1885, p. 49.

98. "this branch of physical geography": Science, 1884, v. 4, p. 334.

99. "While the existence * * * ": S. F. Emmons, *in* U.S. Geological Survey 5th Annual Report, 1885, p. 46.
"to gather into a simple and convenient form * * * ": T. C. Chamberlin, 1885, p. 132.

100. "Artesian wells * * * ": Ibid., p. 148.
"urge as large a development * * * ": Ibid., p. 150.

101. "If we could obtain * * * ": L. F. Ward, 1884, p. 168.

103. "to promote the general welfare": National Academy of Sciences, *in* U.S. Congress, 49th, 1st session, Senate Document 82, p. 7.
"great benefit * * * ": Ibid.

104. "The scientific worker * * * ": C. E. Dutton to Archibald Geikie, February 26, 1885, *in* the manuscript collections, University of Edinburgh Library.
"Gov't scientific work * * * ": Ibid.

106. I do not like to have * * * ": U.S. Congress, 48th, 1st session, Senate Miscellaneous Document 82, p. 150.
"The experience in the United States * * * ": Ibid., p. 169.

107. "with mathematic accuracy" and "corrupted by foul and pestilential agencies": Ibid., p. 198.

109. "that the map * * * ": Ibid., p. 208.
"the map once constructed * * * ": J. W. Powell, *in* U.S. Geological Survey 6th Annual Report, p. xvii.

110. "to have arisen in the main * * * ": R. D. Irving, *in* U.S. Geological Survey 7th Annual Report, 1888, p. 75.

112. "evanescent exposures * * * ": W J McGee, *in* U.S. Geological Survey 7th Annual Report, 1888, p. 109.
"as to suggest * * * ": Ibid., p. 107.

113. "theorem of maximum dissipativity": G. F. Becker, *in* U.S. Geological Survey 7th Annual Report, p. 96.

114. "Anything that is worth doing * * * ": Rossiter Raymond, *in* Engineering and Mining Journal, August 22, 1885.

115. "Nothing could induce me * * * ": N. S. Shaler, 1909, p. 328.
"in earnest sympathy" and "earnest approval": Science, 1885, v. 6, p. 204.
"political scientists" and "a committee of treasury experts * * * ": Alexander Agassiz, 1885, p. 253.

116. "While criticizing the article * * * ": Ibid., p. 255.

117. "irregularities" and "This service has never * * * ": Grover Cleveland, Annual message to Congress, 1885, *in* J. D. Richardson, Messages and Papers of the Presidents, v. 8, p. 347.

118. "I should not have inaugurated the work": J. W. Powell, *in* U.S. Congress, 49th, 1st session, Senate Miscellaneous Document 82, p. 690.

119. "Suppose you could use it * * * ": Senator John Morgan, Ibid., p. 696.
"It would be of the utmost importance * * * ": J. W. Powell, Ibid.
"You have spoken * * * ": Hilary Herbert, Ibid., p. 698.
"There are many investigations * * * ": J. W. Powell, Ibid., p. 700.

120. "The ethnologic work * * * ": J. W. Powell, Ibid., p. 191.
"that the evils in the scientific bureaus * * * ": Simon Newcomb, Ibid., p. 999.
"censure of the administration": Major Powell's letter in rebuttal of

the Agassiz testimony is on pages 1070–1084 of Senate Document 82.

124. "It is the intention of the Commission * * * ": U.S. Congress, 49th, 1st session, Senate Report 1285, p. 82 of minority report.
"It would appear to us * * * ": Ibid., p. 87.
"all American geology * * * ": Ibid., p. 95.
"It is not the purpose of the Commission * * * ": Ibid., p. 53 of majority report.

125. "wisely be left to Congress * * * ": Ibid.
"Who can say * * * ": Hilary Herbert, Ibid., p. 125.
"The difficulty seems to be * * * ": Hilary Herbert, *in* Congressional Record, 49th Congress, 1st session, p. 6298.

126. Paleontology is of course killed * * * ": E. D. Cope to his daughter, quoted *in* H. F. Osborn, 1931, p. 361.
"Here are $400,000 in a lump sum * * * ": Hilary Herbert, *in* Congressional Record, 49th Congress, 2d session, p. 197.
"and hereafter the estimates * * * ": Ibid.

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127. "In civilization man does not struggle * * * ": J. W. Powell, 1888a, p. 311.
"a number of stalwart men * * * ": C. E. Dutton, *in* U.S. Geological Survey 8th Annual Report, 1889, p. 156.

128. "The favorable probabilities * * * ": W J McGee, *in* U.S. Geological Survey 7th Annual Report, 1888, p. 644.

130. "The text of such a Memoir * * * ": O. C. Marsh, 1886, p. xvii.

131. "as suggestive * * * ": S. F. Emmons, 1886, p. 126.
"That many deposits * * * ": Ibid.
"Increasing applicability": Ibid., p. 146.
"are deposited * * * ": Ibid., p. 131.
"The color scheme * * * ": C. H. Hitchcock, 1887, p. 488.

132. "In regard to nomenclature * * * ": Ibid.
"The word Formation * * * ": Ibid.
"comparatively speaking, quite moderate * * * ": R. J. Hinton, 1887, p. 5.

133. "unjust discrimination * * * ": U.S. Congress, 49th, 1st session, Senate Report 46.

134. "unless the conservatives * * * ": G. K. Gilbert to Archibald Geikie, August 29, 1887, *in* the manuscript collections, University of Edinburgh Library.
"a manifest advantage * * * ": G. K. Gilbert, 1887, p. 432.
"There does not exist * * * ": Ibid.

135. "the establishment of means * * * ": Ibid., p. 451.
"for consultation and to be present * * * ": C. D. Walcott, *in* U.S. Geological Survey 9th Annual Report, 1889, p. 118.

137. "grandly prepared in all respects" and "very important contribution * * * ": American Journal of Science, 1888, 3d series, v. 35, p. 84.
"epoch making" and "gave the mining community * * * ": T. A. Rickard, 1932, p. 132.

139. "main proposition" and "that careful structural study * * * ": S. F. Emmons, 1888, p. 838.
"The promoters of the American Geologist * * * ": American Geologist, 1888, v. 1, no. 1, p. 1.

140. "Geology includes them all * * * ": Prospectus for The American Geologist, included in v. 1, no. 1.
"That the Secretary of the Interior * * * ": Congressional Record, 50th Congress, 1st session, p. 1137.

141. "one of the most complete men * * * ": Grover Cleveland to W. S. Bissell, August 14, 1886; quoted in Allan Nevins, 1832, p. 315.
"whilst it may be desirable * * * ": W. F. Vilas, *in* U.S. Congress, 1888, p. 3.
"The topographic work of the Geological Survey * * * ": J. W. Powell, *in* U.S. Congress 1888, p. 6.

142. "in extending * * * ", "local surveys * * * ", and "to gauge * * * ": Ibid.
"That the Secretary of the Interior * * * " (Resolution of March 6): Congressional Record, 50th Congress, 1st session, p. 1766.
"That the Secretary of the Interior * * * " (Resolution of March 27): Congressional Record, 50th Congress, 1st session, p. 2428.

143. "The subject involves * * * ": W. F. Vilas, *in* U.S. Congress, 1888, p. 1.
"I have no means to make any estimate * * * ": W. F. Vilas, *in* U.S. Congress, 1888a, p. 1.

144. "for the purpose of investigating * * * " and "for the storage * * * ": Congressional Record, 50th Congress, 1st session, p. 4087.
"practically prohibited the Government survey * * * ": J. W. Powell, *in* U.S. Congress, 50th, 1st session, House Report 2599, p. 78.

145. "had been a dead letter * * * ": Congressional Record, 50th Congress, 1st session, p. 5462, in resolutions adopted by California State Grange and read by William W. Morrow.
"probably the most important * * * ": Henry Gannett, *in* U.S. Geological Survey 10th Annual Report, 1890, p. 86.

146. "coloring the geological map of New England * * * ": Raphael Pumpelly, *in* U.S. Geological Survey 10th Annual Report, 1890, p. 114.

147. "formations rather than names should be mapped * * * ": Bailey Willis, *in* U.S. Geological Survey 10th Annual Report, 1890, p. 121.
"by far the strangest reptiles * * * ": O. C. Marsh, *in* U.S. Geological Survey 12th Annual Report, 1891, part 1, p. 118.
"memorable freshet" and "well known law * * * ": W J McGee, *in* U.S. Geological Survey 10th Annual Report, 1890, p. 150.

148. "a meeting of the congress * * * ": George H. Cook, 1889, p. 160.

149. "a 'majority' report * * * ": J. D. Dana, 1888a, p. 469.
"its right to appear * * * ": Ibid., p. 470.
"There is no body of men * * * ": J. W. Powell, 1888, p. 476b.
"Frazer, who was present * * * ": J. D. Dana to Archibald Geikie, January 4, 1889, *in* the manuscript collections University of Edinburgh Library.
"heads of geologic divisions * * * ": U.S. Geological Survey 10th Annual Report, 1890, p. 58.
"It was long ago well shown by Dana * * * ": Ibid., p. 57.

152. "All titles to the public lands * * * ": Congressional Record, 50th Congress, 1st session, p. 7012.

153. "You didn't think of it, * * * ": Senator Preston Plumb, *in* Congressional Record, 50th Congress, 1st session, p. 7023.
"And all the lands * * * ": Senator John Reagan, *in* Congressional Record, 50th Congress, 1st session, p. 7031.

154. "I do not want to make a personal attack * * * ": Hilary Herbert, *in* Congressional Record, 50th Congress, 1st session, p. 8469.
"$100,000 or so much thereof * * * ": Congressional Record, 50th Congress, 1st session, p. 8515.
"For the purpose of investigating * * * ": 25 Stat. L. 526.

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157. "Hydraulic engineering is the oldest * * * ": J. W. Powell, 1889b, p. 150.
"I cannot too strenuously insist * * * ": Grover Cleveland, *in* J. D. Richardson, Messages and Papers of the Presidents, v. 8, p. 794.
"Our survival for one hundred years * * * ": Ibid., p. 773.
"He mocks the people * * * ": Ibid., p. 776.
"be yielded up * * * ": Ibid., p. 795.

160. "to select a small body of men * * * ": U.S. Geological Survey 10th Annual Report, 1890, Part 2, p. 79.

165. "has as many leaders * * * ": Woodrow Wilson, 1885, p. 58.
"the best men * * * ": Ibid., p. 136.
"merely a body * * * ": Ibid., p. 147.
"the more expeditious handling * * * ": The Reed rules were adopted by the House after long debate on February 14, 1890.

166. "the most important question * * * ": Senator Arthur Gorman, *in* Congressional Record, 51st Congress, 1st session, p. 7941.
"There are waters rolling by you * * * ": J. W. Powell, *in* Debates, North Dakota Constitutional Convention, 1889.
"In the western half of America * * * ": J. W. Powell, *in* Proceedings and Debates, Montana Constitutional Convention, 1889.
"It follows necessarily * * * ": J. W. Noble to the Governor of Idaho, *in* U.S. Congress, 51st, 1st session, Senate Executive Document 136, p. 2.

167. "in those States and Territories * * * ": J. W. Noble, *in* Annual Report of the Secretary of the Interior for the year ending June 30, 1889, U.S. Congress, 51st, 1st session, House Executive Document No. 1, pt. 5, v. 1, p. xxv.
"to provide for the conservation * * * ": U.S. Congress, 51st, Senate Bill 2104.
"theory" and "there are natural hydrographic basins * * * ": J. W. Powell, *in* U.S. Congress, 51st, 1st session, Senate Report 928, pt. 5, p. 66.

168. "I provide for it * * * ": Ibid., p. 65.

169. "Is it wise * * * ": Ibid., p. 95.
"any person present * * * ": Senator Stewart, Ibid., p. 95.
"The whole of the work * * * ": E. S. Nettleton, Ibid., p. 106.

170. "I am afraid I have wearied * * * ": J. W. Powell, *in* Statement before the Committee on Irrigation of the House of Representatives in U.S. Geological Survey 11th Annual Report, pt. 2, p. 222.
"You are not wearying me * * * ": Hilary Herbert, Ibid.
"a large estimate": J. W. Powell, Ibid., p. 251.
"I do not know whether it is modest * * * ": Ibid., p. 254.
"It takes me out of my proper function * * * ": Ibid.
"It would be impracticable * * * ": C. E. Dutton, *in* U.S. Congress, 51st, 1st session, Senate Report 928, pt. 5, p. 106.

172. "So dreamers may dream * * * ": J. W. Powell, 1890, p. 113.

173. "Let the General Government * * * ": Ibid., p. 115.
"modern rulers": Ibid., p. 116.
"often failed to secure * * * ": Ibid.
"I would like to have five minutes * * * ": J. W. Powell, *in* U.S. Congress, 51st, 1st session, Senate Report 928, pt. 5, p. 182.
"There will be another meeting * * * ": Senator Stewart, Ibid.
"a special adjustment * * * ": J. W. Powell, *in* U.S. Congress 1888, p. 6.

174. "the Secretary of Agriculture * * * ": Congressional Record, 51st Congress, 1st session, March 18, 1890.
"is always limited * * * ": J. W. Powell, *in* Statement before the Committee on Irrigation of the House of Representatives, p. 260.
"if all the artesian wells * * * ": Ibid.
"Though irrigation has aided agriculture * * * ": Ibid.
"Owing to the cost * * * ": Ibid., p. 275.

175. "the most skillful investigation * * * ": Ibid.

176. "whether, under the act of October 2 * * * ": U.S. Congress, 51st, 1st session, Senate Executive Document 136, p. 5–8.
"the plans of the survey * * * ": J. W. Powell, *in* Statement before the Committee on Irrigation of the House of Representatives, p. 287.
"And that is true * * * ": Ibid.
"that the Secretary of the Interior * * * ": Congressional Record, 51st Congress, 1st session, p. 4177.

177. "necessary maps" and "imperative": U.S. Congress, 51st, 1st session, Senate Report 928, pt. 1, p. 9.

178. "Whereas by the act of October 2, 1888 * * * ": Congressional Record, 51st Congress, 1st session, p. 5273.
"The struggle that I am * * * ": Congressional Record, 51st Congress, 1st session, p. 5419.
"even now being shown * * * ": Ibid.

179. "But how on earth * * * ": Ibid.
"a political hospital * * * ": Senator Stewart, *in* Congressional Record, 51st Congress, 1st session, p. 5419.
"unfortunate, probably * * * ": Senator Gorman, Ibid., p. 5243.
"one of such magnitude * * * ": John W. Noble, *in* U.S. Congress, 51st, 1st session, Senate Executive Document 136, p. 3.
"The statute directs * * * ": John W. Noble, *in* U.S. Congress, 51st, 1st session, Senate Executive Document 141, p. 1.
"What the Director of the Geological Survey * * * ": Senator Stewart, *in* Congressional Record, 51st Congress, 1st session, p. 5590.

180. "every representative of the arid region * * * ": Senator Stewart, *in* U.S. Congress, 51st, 1st session, House Report 2407, p. 62.
"deprecated" and "black eye": Senator Moody, Ibid., p. 74.
"There is no proposition * * * ": Joseph G. Cannon, *in* Congressional Record, 51st Congress, 1st session, p. 6045.

181. "The attack on the Survey * * * ": G. K. Gilbert to Alpheus Hyatt, June 11, 1890, Gilbert Letterbooks, U.S. Geological Survey.
"I think it is an entirely useless office * * * ": Senator Stewart, *in* Congressional Record, 51st Congress, 1st session, p. 6301.
"Let it go!": Ibid.
"the asylum of all the scientists * * * ": Senator Gorman, Ibid. p. 6306.
"I have never yet heard * * * ": Ibid.
"I have no word of excuse * * * ": Ibid.
"irrigation feature": U.S. Congress, 51st, 1st session, Senate Report 1466, p. 31.

182. "Until this morning * * * ": Commissioner Grof, Ibid.

183. "I had no conception * * * ": Senator Stewart, *in* Congressional Record, 51st Congress, 1st session, p. 7405.
The reply to the Stewart resolution of July 10, 1890, is in U.S. Congress, 51st, 1st session, Senate Executive Document 199.

184. "as provides for the selection * * * ": Congressional Record, 51st Congress, 1st session, p. 7319.
"I wish to say * * * ": Senator Stewart, Ibid., p. 7320.
"by an eminently scientific man * * * ": Senator Wilkinson Call, *in* Congressional Record, 51st Congress, 1st session, p. 7324. The author of Senator Call's material has not been identified. He obviously subscribed more to the King theory of administration than Powell's. One intriguing possibility is that the author was King himself who had been interested in the development of the Florida phosphate deposits.
"When a need is felt * * * ": Congressional Record, 51st Congress, 1st session, p. 7320.

185. Gilbert's analysis of research is in U.S. Geological Survey 11th Annual Report, 1891, pt. 1, p. 49–51.

186. "one of the ablest engineers * * * " and "the position taken by the Director * * * ": Senator Moody, *in* Congressional Record, 51st Congress, 1st session, p. 7345.

187. "There is no man * * * ": Senator Spooner, Ibid., p. 7328.
"New excavations are made * * * ": Senator Stewart, Ibid., p. 7417.
"The trail of the ice monster * * * ": W J McGee, 1891, p. 200.

188. "For topographic surveys * * * ": 26 Stat. L., 391.

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189. "And thus of all my harvest hope * * * ": Edmond Spenser, The Shepheardes Calendar: December 1579.

"later earth-forming episodes * * * ": W J McGee, *in* U.S. Geological Survey 12th Annual Report, 1891, pt. 1, p. 72.

191. "without disguise": F. W. Taussig, 1931, p. 282.

"all timber * * * ": 26 Stat. L., 160.

194. "every and all facilities * * * ": Leadville Herald Democrat, August 9, 1890.

"In 1890 American politics * * * ": S. E. Morison, 1965, p. 789.

196. "wholly or in part * * * ": Section 24 of An Act to repeal timber culture laws, and for other purposes, 26 Stat. L., 1095.

"It is seldom * * * ": Senator James Wilson, *in* Congressional Record, 51st Congress, 2d session, p. 3297.

"very intelligent * * * ": Senator Stewart, Ibid.

197. "It may be a more useful institution * * * ": Senator Stewart, *in* Congressional Record, 51st Congress, 2d session, p. 3668.

"face is set * * * ": Ibid.

199. "nearly all of our more important * * * ": U.S. Geological Survey 13th Annual Report, 1893, pt. 1, p. 32.

200. "not only one of paramount interest * * * ": Ibid., p. 36.

202. "for the purpose of hastening the reclamation * * * ": Proceedings of the Irrigation Congress, Salt Lake City, 1891, p. 2.

203. "heartily endorse:" Ibid., The Salt Lake Platform, adopted at the Irrigation Congress, September 17, 1891.

"It will be impossible * * * ": U.S. Geological Survey 13th Annual Report, 1893, pt. 1, p. 65.

204. "If this House is bound * * * ": Hilary Herbert, *in* Congressional Record, 52d Congress, 1st session, p. 4389.

"Major Powell will tell you * * * ": Ibid., p. 4390.

"one-half of which shall be expended * * * ": Congressman Simpson, Ibid., p. 4396.

"in order to apply * * * ": Ibid.

"The people are petitioning * * * ": Ibid., p. 4397.

205. "I repeat what I said * * * ": Hilary Herbert, Ibid., p. 4361.

"imperatively necessary". Ibid., p. 4626.

206. "dangerous and reckless experiment * * * ": Grover Cleveland to E. Ellery Anderson, February 1891, quoted *in* Allan Nevins, 1932, p. 468.

207. "I don't think the necessity * * * ": Senator Allison, *in* Congressional Record, 52d Congress, 1st session, p. 5886.

"ornamental": Senator Vest, Ibid.

"to create this Bureau * * * ": Senator Sanders, Ibid., p. 5887.

This Geological Survey * * * " and "As a matter * * * ": Senator Wolcott, Ibid., p. 5887.

"the workings of the Geological Survey * * * ": Senator Wolcott, Ibid., p. 5932.

208. "nobody on earth directs * * * ": Senator Wolcott, Ibid., p. 6151.

"I do not question * * * ": Senator Wolcott, Ibid., p. 6152.

210. "awaken" and "to an impression * * * ": Senator Wolcott, Ibid., p. 6156.

"investigate the operations * * * ": Congressional Record, 52d Congress, 1st session, p. 6851.

213. "There is a powerful party * * * ": C. D. Walcott to T. C. Chamberlin, September 1, 1892, *in* the Walcott Papers, Smithsonian Institution Archives.

"the western mining men * * * ": C. D. Walcott to T. C. Chamberlin, September 23, 1892, *in* the Walcott Papers, Smithsonian Institution Archives.

"King is probably the man * * * ": C. D. Walcott to T. C. Chamberlin, October 13, 1892, *in* the Walcott Papers, Smithsonian Institution Archives.

"a curious state of affairs * * * ": Ibid.

"to die in his tracks": Ibid.

"very precarious condition": Ibid.

"likes strong personal loyalty * * * ": C. D. Walcott to T. C. Chamberlin, August 7, 1892, *in* the Walcott Papers, Smithsonian Institution Archives.

"it should go * * * ": T. C. Chamberlin to C. D. Walcott, October 13, 1892, *in* the Walcott Papers, Smithsonian Institution Archives.

214. "for the purpose of locating * * * ": Letter from the Secretary of the Treasury transmitting estimates of appropriations required for the service of the fiscal year ending June 30, 1894: U.S. Congress, 52d, 2d session, House Executive Document No. 5, p. 247–249.

"for political reasons": C. D. Walcott to T. C. Chamberlin, October 22, 1892, *in* the Walcott Papers, Smithsonian Institution Archives.

"I do not think * * * ": C. D. Walcott to T. C. Chamberlin, October 22, 1891, *in* the Walcott Papers, Smithsonian Institution Archives.

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215. "The material progress of the nation * * * ": John W. Noble, *in* Report of the Secretary of the Interior for the year ending June 30, 1893, p. xcviii.

"since the establishment of the Bureau * * * ": W J McGee, 1893, p. 617.

216. "aided the miner * * * ", "laws of mineral association * * * ", and "useful aids * * * ": Ibid., p. 609.

"it is patent * * * ": W. H. Holmes, 1892, p. 297.

"new Geology" and "to read geologic history * * * ": W J McGee, 1892a, p. 317.

"The ghost of paleolithic man * * * ": C. C. Abbott, 1892, p. 270.

"Geology is not an exact science * * * ": G. F. Wright, 1892, p. 361.

217. "a word from him * * * ": American Geologist, v. 12, p. 116.

"serious and far-reaching mistake" and "in addition * * * ": American Geologist, v. 10, p. 309.

"the present status * * * ": Henry Gannett, *in* American Geologist, v. 11, p. 128.

"to discover and diffuse * * * ": John W. Noble, *in* Report of the Secretary of the Interior for the year ending June 30, 1893, p. 102.

"the purpose of our statesmen * * * ": J. W. Powell, 1893a, p. 17.

218. "preliminary, or experimental * * * ": Ibid., p. 15.

"final or effective state": Ibid.

"the Federal bureau * * * ": J. W. Powell, 1893, p. 877.

219. "There has never been a time * * * ": Benjamin Harrison, Message to Congress, December 1892, *in* J. D. Richardson, Messages and Papers of the Presidents, v. 8, p. 309.

"to investigate and report the cost * * * ": Congressional Record, 52d Congress, 1st session, p. 6266.

"it may be safely stated * * * ": U.S. Congress, 52d, 2d session, Senate Report 1310, p. 4.

220. "but a large increase * * * ": Ibid., p. 6.

"The largest supplies of gold * * * ": Ibid., p. 4.

"general industrial conditions * * * ": S. F. Emmons, 1893, p. 49.

221. "Topography has not been the handmaid * * * ": Senator Wolcott, *in* Congressional Record, 52d Congress, 2d session, p. 1841.

"the examination of the geological structure * * * ": Ibid., p. 1842.

222. "the greatest iron field * * * ": Ibid., p. 1843.

"geology should be limited * * * ": Ibid.

"topography should be limited * * * ": Ibid.

"a most distinguished ethnologist", "a man of highest character", and "wholly lacking in ability * * * ": Ibid., p. 1843.

"This great staff of officers * * * ": Ibid.

The "gentleman familiar with the Survey" was not identified but the metaphor suggests someone familiar with cattle ranching, perhaps S. F. Emmons.

"I am not an enemy * * * ": Senator Wolcott, Ibid., p. 1844.

"a one-armed Union soldier * * * ": Senator Wilkinson Call, *in* Congressional Record, 52d Congress, 2d session, p. 1847.

"we the people's representatives * * * ": Ibid.

223. "the loosest and most unbusinesslike * * * ": Senator Stewart, Ibid., p. 1850.
"inquire into and examine * * * ": 27 Stat. L, 681.
224. "unfortunate plight": Grover Cleveland, *in* J. D. Richardson, Messages and Papers of the Presidents, v. 8, p. 402.
Cleveland's rules on civil service are described in Allan Nevins, 1932, p. 515.
225. "Public offices * * * ": Secretary Hoke Smith, *in* the Atlanta *Journal*, May 2, 1893, quoted *in* D. W. Grantham, 1958, p. 62.
The Dockery Commission report is U.S. Congress, 53d, 1st session, House Report 49.
"Among the various attempts * * * ": Clarence King, 1893, p. 1.
227. "to the extent that solidity * * * ": Ibid., p. 12.
"impossible not to admire" and "ingenious argument": Osmond Fisher, 1893, p. 464.
"Factors involved in non-geologic estimates * * * ": W J McGee, 1893a, p. 310.
"The student of the 'exact' sciences * * * ": Ibid., p. 310.
228. "curious, and certainly contrary * * * ": Carl Barus, 1893, p. 22.
"Perhaps it is heresy * * * ": Ibid., p. 23.
"Of all subjects * * * ": C. D. Walcott, 1893, p. 639.
"geologic time is of great * * * ": Ibid., p. 676.
"intellectual magma": U.S. Geological Survey 14th Annual Report, 1893, pt. 1, p. 65.
229. "The basis of knowledge * * * ": Ibid.
230. "progressed apace" and "advanced far more * * * ": Ibid., p. 68.
"Had the geological investigations * * * ": S. F. Emmons, 1894, p. 54.
"many important contributions * * * ": Ibid., p. 54.
"Unfortunately, our knowledge * * * ": Ibid., p. 94.
234. "The simple fact * * * ": F. H. Newell, 1894, p. 12.
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235. "but in this matter * * * " and "It is generally * * * ": Ibid.
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"economy of water": A. P. Davis, Ibid., p. 134.
"to an explanation of the detailment * * * ": J. W. Powell, Ibid., p. 108.
"Now what I wish to make clear * * * ": Ibid., p. 109.
236. "Supposing you could put a roof * * * ": Ibid., p. 110.
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238. "by a gentleman from New York * * * ": Joseph G. Cannon, *in* Congressional Record, 53d, 2d session, p. 5231.

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249. "that such portions * * * ": Report of the Secretary of the Interior for the fiscal year ending June 30, 1894: U.S. Congress, 53d, 3d session, House Executive Document 1, pt. 5, p. 8.
"By this amendment * * * ": Hoke Smith, U.S. Congress, 53d, 3d session House Document 12.
250. "recently prepared * * * ": U.S. Congress, 53d, 3d session, House Report 1954, p. 24.
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The comparisons are between the texts of Folios 1 and 21 of the geologic atlas of the United States.
257. "That Congress at its next session * * * ": Proceedings of the 4th Irrigation Congress, Albuquerque, 1895, p. 68.
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258. "at the earliest day practicable": Senator Teller, *in* Congressional Record, 54th Congress, 1st session, p. 62.
"It has been presented * * * ": Congressman G. D. Perkins, *in* Congressional Record, 54th Congress, 1st session, p. 800.
259. "The conditions being to a large extent * * * ": C. D. Walcott, *in* U.S. Congress, 54th, 1st session, House Document 257, p. 2.
260. "That hereafter the reports of the Geological Survey * * * ": 29 Stat. L., 453.
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265. "to establish the presence of a gold belt * * * ": C. D. Walcott, *in* U.S. Congress, 54th, 2d session, House Document 181, p. 2.
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274. "owing to the character * * * ": U.S. Geological Survey 19th Annual Report, pt. 1, p. 122.

275. "quadrangles" and "district": U.S. Geological Survey circular letter.

277. "for the information and guidance * * * ": U.S. Geological Survey 19th Annual Report, 1898, pt. 1, p. 22–23.

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287. "So long as historical geology * * * ": G. K. Gilbert, *in* Journal of Geology 1898, p. 338.

288. "Of course any other terms * * * ": Samuel Calvin, Ibid., p. 353.

289. "unnecessarily expensive" and "surveying is properly a question of scientific engineerings * * * ": J. W. Powell to Committee on Public Lands, U.S. Congress, 45th, 2d session, House Miscellaneous Document 55, p. 6.

290. "There is no Government work * * * ": Congressman Dayton, *in* Congressional Record, 55th Congress, 3d session, p. 1808.

"If the friends of this amendment * * * ": Joseph G. Cannon, Ibid., p. 1809.

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"The coals and cokes of the United States * * * ": Ibid.

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292. "all the information in the possession * * * ": Senator Pettigrew, *in* Congressional Record, 55th Congress, 3d session, p. 20.

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"If it were practicable * * * ": Ibid.

294. "not led to differ much": Lord Kelvin, 1898, p. 672.

"In the early half of the century * * * ": T. C. Chamberlin, 1899a, p. 889.

295. "great body of serious geologists * * * ": Ibid., p. 890.

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296. "widespread confidence": President McKinley's annual message to Congress, December 1899, Congressional Record, 56th Congress, 1st session, p. 24.

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297. "a veritable milestone * * * ": L. C. Graton, 1933, p. xvi.

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300. "possible to discuss intelligently * * * ": U.S. Congress, 56th, 1st session, Senate Document 338.

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302. "I must say * * * ": Senator Stewart, *in* Congressional Record, 56th Congress, 1st session, p. 6214.

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318. "the comfortable world * * * ": Henry S. Commager and Richard B. Morris, *in* Editors' introduction to George E. Mowry, 1958.

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319. "the idea that our natural resources * * * ": Ibid., p. 395.

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323. "The destruction of the mountain forests * * * ": U.S. Congress, 57th, 1st session, Senate Document 84.

324. "I want to say * * * ": Joseph G. Cannon, *in* Congressional Record, 57th Congress, 1st session, p. 3472.
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325. "The appropriation for this service * * * ": Congressman Cannon, Ibid., p. 3529.
326. "have been tested and tried * * * ": Theodore Roosevelt to Ethan Allen Hitchcock, June 17, 1902, p. 277, *in* Elting E. Morison, editor, The letters of Theodore Roosevelt, v. 3, 1951.

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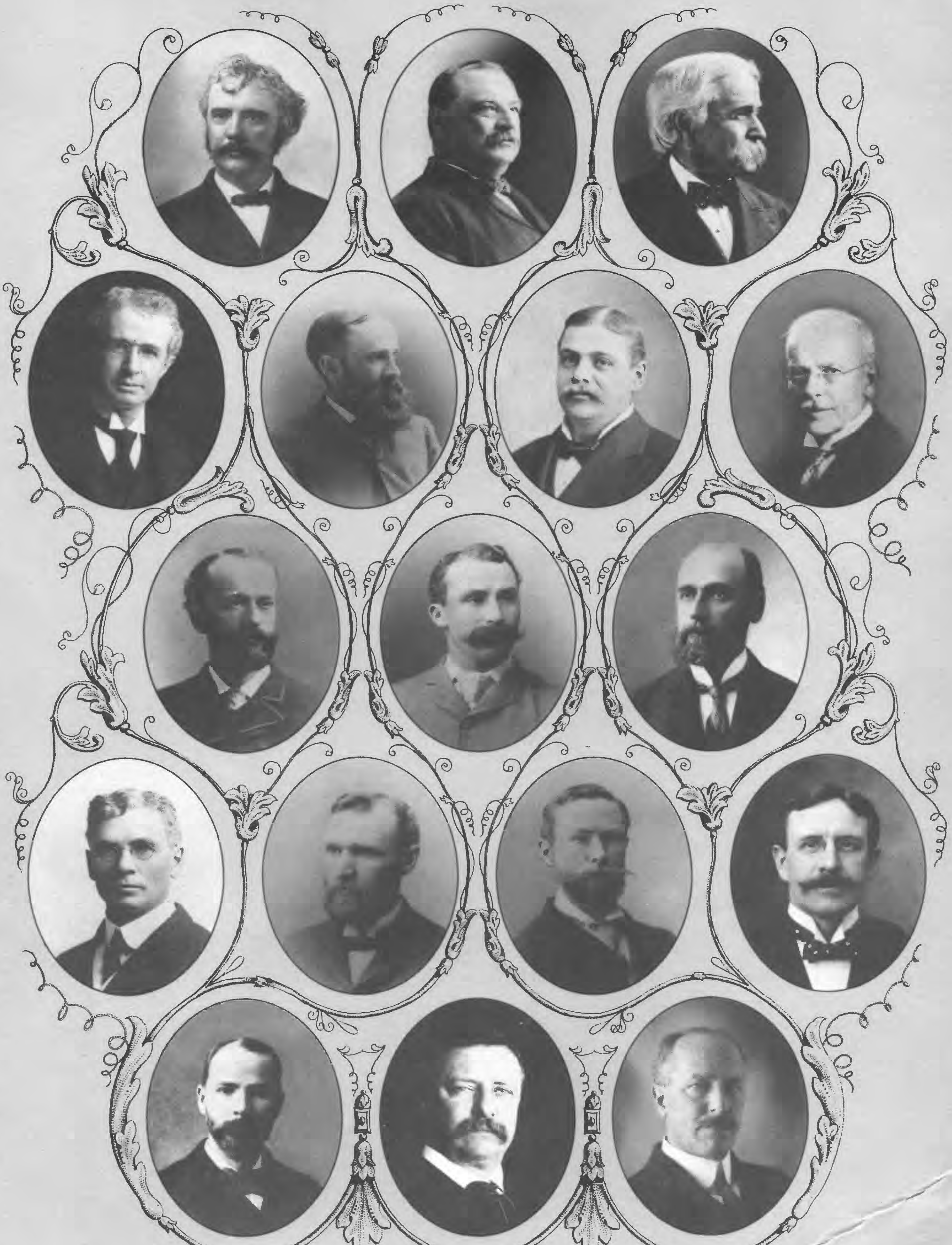

U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interest of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. Administration.