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NATURAL RESOURCES AND GEOLOGICAL SURVEYS

BY

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NATURAL RESOURCES AND GEOLOGICAL SURVEYS.[1]

MORRIS M. LEIGHTON.

OUR natural resources deserve the highest and most devoted study. They constitute the foundation of our well being, the means for our protection, our hope for the future.

Man has always been dependent on Nature's storehouse. As he found more and more things which he could use, his desires increased, his own life changed. His consciousness, his awareness, his vision of a better life widened.

We have resources today that were not regarded as resources yesterday. It has been so throughout the ages. As science advances and we employ it to discover and disclose other useful substances, our inventory of resources will further grow.

The geological surveys of this country were born during the formative stages of our science, amid conditions different from the present. Their significance has changed. To that degree which our geological surveys have changed to embody this new significance, to that extent which they are able to command the powers of modern science, they fill their place in present-day society. It is this theme that I have chosen to emphasize.

As an approach to this subject, may we first recall the early period of science, the nature of the times when geological surveys were first established and how they came to be, and then review the transition leading to the present. As Aristotle once said: "He who sees things grow from the beginning will have the best view of them."

THE ROOTS OF MODERN SCIENCE.

The question of how deep into the past the roots of modern science go, is an engrossing one. Clarity changes to vagueness before we have penetrated very far into history. This is especially true when we pass the epoch-making date of the invention of printing, and again when the relics of handwritten manuscripts give way to the more limited records of archeology.

With assurance we can say that man had no knowledge of geology at the close of the Pliocene or at the beginning of the Pleistocene. The face of the

[1] Presidential Address, presented at the Annual Meeting of the Society of Economic Geologists, St. Louis, Missouri, February 20, 1951.

earth was then untouched except by the forces of nature. The landscape was the product of Nature's artistry. The oceans bore no ships and only birds claimed the air. Then, for the first time in the history of the earth, a single species of animal evolved—man—who was destined to dominate the globe. The knowledge he inherited or received from his antecedents was of no mean order insofar as his habitat was concerned, but his comprehension was without scientific quality as we use the term.

Man appeared in Asia at the beginning of an epoch of climatic changes. As a minor part of the terrestrial fauna, he slowly pushed his frontiers over adjacent lands until, later in the Pleistocene, he had spread over nearly all of the habitable portions of the globe. Gradually and with difficulty he rose above the level of the animal intelligence with which he was first endowed.

With each onset of a glacial climate, within the southward shifting zone of forced migration, further advancement came from differential reproduction which doubtless increased the mental quality of succeeding generations. By the time the fourth ice age arrived, man had an expressed talent for art which indicates the breaking of dawn for civilization.

The broad outlines of what happened in the millennia that follow, around the Mediterranean and along the northern shores of the Indian Ocean, may be conjectured. Regional commerce became interregional, wars united tribes into nations, population centers developed, and the stage was set for science. From now on we can expect evidence of the progress of *Homo sapiens* toward his crowning achievement—that of understanding the world in which he lives.

It is doubtful, however, if the progress of the historical period can be represented by a smooth upward curve. The initial light of science lit by the Greeks during the Classical Period was nearly extinguished during the Dark Ages by the political changes that ensued and by the repressive dictum of the established Church. And if the events of the prehistorical period could be made known, we might find that the Greek philosophers were by no means the first to possess some of their advanced concepts.

The attainments of the Greeks were preserved apparently by the Arabians through the Dark Ages as a result of their military conquests. In the eleventh century A.D., the Arabian philosopher, Avicenna, the "Prince of Physicians," held to the interpretation that some highlands are due to uplift while many peaks and steep ridges are remnants of hard rocks left by prolonged erosion of soft, weak rocks, and that mountain soil possibly contains material which once was in the sea that formerly overspread the land. Says Fontani: "The age of Arabian learning continued for about five hundred years and was coeval with the darkest and most slothful period of European annals."

The subsequent pace of intellectual progress, when seen against the million years of man's existence, was accelerative. The few centuries that remained for learning to reach the level of modern science was less than one-tenth of one percent of the whole Age of Man. His creative genius has always distinguished him, but because his knowledge of the world started at the animal level and because new concepts suffered a heavy toll until means for preserving them were achieved, advancement was inevitably slow during his early history for millennia upon millennia.

Seneca, Roman philosopher of the first century A.D., said: "Nature does not reveal all her secrets at once. We imagine we are initiated in her mysteries; we are as yet but hanging around her outer courts."

THE RENAISSANCE OF SCIENCE.

For our purpose, however, within the limited scope of this paper, the Renaissance of the 15th century will serve as a practical beginning date for discussing the preparation of modern science for the first geological surveys. There was no prevailing philosophy of natural science. Instead, magic and witchcraft prevailed—the evil children of Ignorance and Superstition. Man had come to believe during the Dark Ages in mysterious and unknown forces and the established Church was intolerant of any scientific pronouncements opposing the orthodox interpretations. There was no scientific climate.

Leonardo Da Vinci, however, possessed great mind and skill. Not only did he produce paintings—*Mona Lisa* and *The Last Supper*—which captured the hearts of the people and were treasured by the Church, but he had a rational approach to the phenomena of nature. To him, as to some of the Greek philosophers, fossil shells in the rocks were the remains of forms that once lived in the seas, when the land was beneath salt water, and that were covered by sediments washed from the lands of that time. From his experience as an engineer, he pointed out that groundwater was not a primitive constituent of the earth but had its origin in rainfall and that it circulated widely through porous strata. Da Vinci also laid some of the groundwork for physics and chemistry by studying falling bodies, developing the concept of work from force, interpreting sound as wave motion in air, finding that air is divisible into combustible and uncombustible constituents, and by other discoveries.

Christopher Columbus, a contemporary of Da Vinci's, upon his return from his voyage to America, taught that the earth was a circumnavigable globe.

Copernicus was born only 22 years later than Da Vinci. He gave mankind a new picture of the world. The earth is not the center of the universe but a member of a family of planets revolving about the sun, rotating on its axis, thereby giving us night and day. The fixed stars, he disclosed, are not set in a firmament enclosing a relatively small sphere but are at such great distances in space that they appear to be fixed.

Thus man approached the overwhelming conception of the infinity of the universe.

Georgius Agricola, a young man when Da Vinci died, made an extensive study of mines and ore deposits, became the world's first mining geologist and metallurgist, and wrote several books on physical geology, subterranean waters and gases, systematic mineralogy, mining and treatment of ores, and a glossary of Latin and German mineralogical and metallurgical terms. He ignored Aristotle's speculations on the influence of the stars on stones, gems, and metals and prepared a fairly rational statement on the part played by mineral-bearing solutions in the deposition of ores and in the cementation of rocks. Unfortunately he could not draw upon modern chemistry and crystallography.

Galileo made his appearance in scientific circles about 40 years later. He confirmed and extended the findings of Copernicus, introduced the use of the telescope, uncovered a new wealth of information on the solar system and the Milky Way, and founded the whole science of motion.

PROGRESS IN THE 17TH CENTURY.

The 17th century had its great disciples of science. Descartes founded analytical geometry. Guericke made the air pump, worked with the phenomena of air and vacuum, and added to knowledge concerning atmospheric pressure and its movement, the nature of propagation of light and sound in air and the relation of air to combustion and to life of animals. He also discovered electrical repulsion.

Boyle discovered his law of gases and helped to lay the foundations of analytical chemistry. Mariotte laid the basis of our knowledge of the distribution of pressure and density in the atmosphere and of measuring altitude by the barometer, initiated the study of hydrology, and explained the origin and nature of clouds.

Nicolaus Steno, after studying medicine at Copenhagen and becoming physician to the Grand Duke of Tuscany, devoted much time to a study of the beaches, quarries, and outcrops in the hills of central Italy, and published what was, for his time, a remarkable treatise on the geologic history of Tuscany in which he recognized successive epochs of submergence, sedimentation, uplift and erosion.

Isaac Newton's revolutionary work also came partly in the 17th century and in the 18th. By observation and mathematics he discovered the laws of universal gravitation—valid, he proclaimed, for all matter in stellar space—and explained the motions of the heavenly bodies, the shape of the earth, the opposite tides of the earth, the relationship between the masses of the earth, moon and sun, the masses and specific gravities of the sun, planets, and some of the satellites, the motions of the earth's axis and the precession of the equinoxes, and discussed the question of the movement of the solar system through space. He also founded differential and integral calculus, the science of acoustics, and developed the fundamental principles of hydrodynamics and aerodynamics. These contributions made by one man are amazing.

EMERGENCE OF GEOLOGY IN THE 18TH CENTURY.

That the science of geology should emerge in the last half of the 18th century following the rationalism already developed was natural. Up to this time the geological features of Italy were the basis for the development of historical geology and stratigraphy. Now the scene shifts to France and the British Isles. About the beginning of the 18th century, Guettard, a physician who was also interested in botany and plant ecology, became intrigued with the habitat relationships of certain plants to certain rocks and eventually devoted his study to the rocks themselves. In his memoir of 1752 upon the rock formations surrounding the Paris basin, he recorded their sequence and he inferred that they once were continuous with similar strata across the English Channel and the Straits of Dover into England. He showed that each formation carried its own mineral resources, which was one of the earliest approaches to a natural resource survey. He later made a map showing the distribution of rocks and minerals from North Ireland to Spain and the Mediterranean, and he also studied their fossils and recognized the erosional processes of streams, groundwater and waves in terms of the past and of the present. He discovered the extinct volcanoes of south central France and identified their products of pumice, scoria and sheet-flows and the inter-bedded soils which he asserted recorded time intervals between episodes of volcanism.

Desmarest followed him in the mapping of the volcanoes and their flows and in 1775 wrote on the theme of streams eroding their own valleys instead of finding them ready-made. This paper, however, was not published until 1806, 18 years before the first American geological survey was established.

Linnaeus, the Swedish botanist, began the renaissance in paleontology about the mid-portion of the 18th century by introducing the binominal system of naming organisms, both living and fossil.

Saussure started the general usage of the terms *geology* and *geologist* in 1779. Being a follower of Werner, who held that the primitive rocks were chemical precipitates in a universal ocean, his love and study of the Alps fell short of contributing all that they might, but it was he who guided Hutton to the summit of the Alps where he gained a tremendous impression of the geologic processes in operation there.

Hutton's presentation of his "Theory of the Earth" to the Royal Society of Edinburgh in 1785 marked a turning point in geology. He, a doctor, scientific farmer, and manufacturing chemist, maintained that the earth changed often and greatly; that conglomerates, sandstones, shales, and limestones could be matched by deposits now being laid down; that a conglomerate was a gravel cemented into stone, a sandstone indurated sand, shale compacted mud, and limestone consolidated fragments of shells and corals; that much rock which now appears on the land was accumulated in the sea; that every age had these sediments; that uplift had caused some rocks to stand on end or be overturned, and many to be folded; that secondary strata were deposited upon tilted strata as is being done today; that some strata had been changed by heat and recrystallization—a concept that foreran the concept of metamorphism announced by Dana 40 years later; and that some rocks were made by lava flows and intrusions into older rocks now eroded away. To him the earth revealed no trace of a beginning, no prospect of an end.

In 1802, Playfair, a more talented writer than Hutton, made a terse, dramatic re-presentation of Hutton's ideas. He emphasized Hutton's principle that the earth's present features and its changes explain its past. His book caused a sensation and helped lead to the rejection of the widely spread Wernerian doctrine.

William Smith, the English civil engineer, brought crowning achievement to 18th-century English geology by his discovery that different fossil faunas distinguish strata of different ages. At the request of Reverend Benjamin Richardson, in 1801, he dictated his "Card of the English Strata" which was distributed to other workers. He published his geological map of England and Wales in 1815.

CHEMISTRY AND PHYSICS BECOME THE HANDMAIDENS OF GEOLOGY.

Not until the latter part of the 18th century did chemistry and physics come to the aid of those working in geology. It must be emphasized, however, that the works of Copernicus, Galileo and Isaac Newton contributed tremendously to rational views of the world as a whole.

The science of chemistry was founded by Black, Scheele, Priestley, and Cavendish in the latter half of the 18th century, but much remained to be done. Electrical and magnetic forces were also explored at this time, together with means for their measurement. Infra-red rays and ultra-violet rays were discovered at the beginning of the 19th century. Dalton discovered the existence of atoms and initiated the Atomic Table in 1808.

GEOLOGICAL WORK IN NORTH AMERICA IN THE 18TH CENTURY.

Geology was brought forth in its swaddling clothes in Europe and not in America. There were no men in America comparable to Guettard, Desmarest, Linnaeus, Hutton, Playfair, or William Smith. A favorable atmosphere for science was generally lacking. Acceptance of the literal teachings of the Bible was general and most of the teaching of science, such as it was, was done in the medical schools.

Following the Revolutionary War, however, the new national spirit gave rise to sentiment for natural resource studies. This interest was increased by the personal contacts and publications of Dr. Johann Schöpf, who had come as a surgeon with the Hessians and remained to tour the East and Southeast after the peace of 1783; Comte de Volney, a learned traveler and historian from France; and William Maclure, an educated businessman and philanthropist from Scotland. It was unfortunate that Maclure brought to America the teachings of Werner rather than of Hutton, the "Father of Geology"!

GEOLOGICAL SCIENCE IN AMERICA AT THE BEGINNING OF THE 19TH CENTURY.

There was no one in America trained in geological observations, no geology was taught as a science, libraries were few and small, to what extent they contained European scientific literature is not known, there were no accurate maps outside of New England and the eastern Atlantic states, most of the continent was still a wilderness, such geological classifications and interpretations as were made were against the background of Wernerism and Biblical teachings, and unfortunately many of the geological initiates were obliged to cut their eyeteeth on some of the most difficult geology in the United States.

At first most of the "scientific" papers were pseudo-scientific and reflect readiness to theorize and respond to personal religious beliefs. The early workers were men of other learned professions, and so erroneous identifications were common. In 1800, although Harvard University was 164 years old, Yale 99, Columbia University and University of Pennsylvania 46, and the state universities of Tennessee and North Carolina had just been started, there were no departments of geology in these American universities.

The first to take the step was Yale University when Benjamin Silliman was appointed Professor of Chemistry and Natural Science in 1802. Being of classical training only, he went to Philadelphia to attend the Medical College. After taking five months of chemistry, anatomy and botany, he gave his first lecture at Yale, April 4, 1804. He soon went to Europe to purchase scientific books and apparatus, to meet scientists and to attend lectures given by followers of both Hutton and Werner. He founded the *American Journal of Science* in 1818.

Parker Cleaveland, a graduate of Harvard, was appointed Professor of Mathematics, Natural Philosophy, Chemistry and Mineralogy in Bowdoin College, Brunswick, Maine, in 1805, with little or no training for the position. Becoming deeply interested in mineralogy, he published the first American treatise on mineralogy and geology in 1816. He emphasized chemical composition as the most important basis of mineral classification.

Papers mainly on local geology also appeared at this time by S. L. Mitchill, J. F. and S. L. Dana, Edward Hitchcock, John H. Kain, Amos Eaton, Henry Schoolcraft, Edwin James, Benjamin Silliman, J. B. Gibson, D. H. Barnes, John Finch and others. These covered various sections of the United States from Massachusetts to the Missouri Ozarks and the headwaters of the Mississippi. Few settled down to exhaustive studies of local areas.

Thomas Say, a biologist, was the first American, according to Schuchert, to point out (in 1819), in his "Observations on Some Species of Zoophytes," that "the progress of geology must be in part founded on a knowledge of different genera and species . . . which the various accessible strata of the earth present."

Rensselaer Institute was established late in 1824 with Amos Eaton as Professor of Chemistry and Experimental Philosophy as well as lecturer on geology, land surveying, and the laws governing town officers. It was here that James Hall graduated in geology and chemistry in 1832 at the age of 21.

THE BEGINNING OF STATE GEOLOGICAL SURVEYS.

It was under these primitive conditions of the science that state geological surveys were established to inform the people of their natural resources. Interest spread from Maine to Michigan, Massachusetts to Tennessee, and south to the Carolinas. The two Carolinas made the initial effort in 1824 and 15 other states during the decade from 1830–1839—Massachusetts in 1830; Tennessee, 1831; Maryland, 1833; Connecticut, New Jersey and Virginia, 1835; Maine, New York, Ohio, and Pennsylvania, 1836; Delaware, Indiana and Michigan, 1837; Kentucky, 1838; and New Hampshire and Rhode Island, 1839.

The more populous area was from Boston to Baltimore; the mountains nearby were a wilderness. Emigration was rapid along the more easily traveled routes to Ohio, Michigan, Indiana, Kentucky, and Tennessee and thence to Illinois, Wisconsin, Iowa, and Missouri.

These were days of expansion and development. The Erie Canal was opened in 1825; nearly 3,000 miles of railroad were laid by 1840. Improvement of existing roads, construction of new ones, promotion of soil fertility, and dreams of finding valuable ores gave impetus to the cause of natural resource surveys.

But state revenues were small and the industrial basis for utilizing the information was slender. There also prevailed the thought that only one, two, or three years were sufficient to make a complete survey of a state. All plans were of a temporary nature. State leaders had no concept of a geological survey as a permanent institution designed to accumulate and disseminate information continuously and to enlarge and preserve collections having future scientific and industrial value. The results, they thought, could be written up and published, wrapped in a package and entrusted to state officers and legislators for distribution and thus the project would be completed and terminated. Henceforward there would be no further need, they thought, for investigation. Any new industrial enterprises or the needs of the rising generation were not in mind.

Consequently the tenure of most of the early geological surveys was ephemeral. Many were re-established, some several times, and their re-establishment bears testimony of renewed interest and faith in the soundness of the principles involved.

There were other aspects of the times that affected these early organizations. The geological profession was small and confined largely to colleges and universities. Therefore it was natural to attach geological surveys to state universities where the chief authority on the science could be found to guide and pursue the investigation. The results of the preceding summer's work could be written up into a report in connection with teaching duties and inquiries could be answered. If appropriations failed there would still be some continuity of service for the public. Likewise there was both economy of operation for the state and enrichment of knowledge for the professor in his teaching of the subject.

Not all of the surveys were given this attachment to universities. The Geological Survey of New York was an outstanding example, but this survey was unique in many respects. Its great leader, James Hall, was inspired by what the geology of New York held for science, in its classic section of the Paleozoic system, and being free to give his chief attention to what he considered to be the Survey's objectives, he pressed forward for continuing support and successfully appealed to the pride of state authorities except for a few years when he carried on indomitably on his own resources. Adhering to fundamental work in stratigraphy and paleontology and convinced of the contribution which the state through him was rendering to science, he made the New York Geological Survey a unique one in the annals of American geology.

The organization of surveys continued decade after decade as the number of states increased. The chronology of those later than the ones mentioned above follows:

1840–49	Alabama, Vermont
1850–59	Arkansas, California, Illinois, Iowa, Mississippi, Missouri, Texas, Wisconsin
1860–69	Kansas, Louisiana, Minnesota, Nevada
1870–79	Colorado, Georgia
1880–89	None
1890–99	Nebraska, North Dakota, South Dakota, West Virginia
1900–09	Florida, Oklahoma, Washington, Wyoming
1910–19	Arizona, Idaho, Montana, Oregon
1920–29	New Mexico
1930–39	Utah

Hall exerted marked influence on many of the surveys that were organized from 1840 to 1870. These emphasized stratigraphy and paleontology but included economic geology. A. H. Worthen, who worked with Hall in Iowa before succeeding J. G. Norwood as State Geologist of Illinois in 1858, believed that the first element in the program of a state geological survey for a state like Illinois was basic stratigraphy and paleontology but that this work should be accompanied by a study of the economic geology. Accordingly in Illinois he employed a staff from time to time consisting of an invertebrate paleontologist, F. B. Meek, a vertebrate paleontologist, J. S. Newberry, a paleobotanist, Leo Lesquereux, several geologists for work on county reports, and a mining geologist, J. D. Whitney, who later became state geologist of California. Although this work was of both a fundamental and economic character and is useful even at the present time, the industrial conditions were inadequate in their demands for geological information and appropriations ceased for field work in 1875 and for publications in 1890. Provision of physical facilities were so meager throughout this period of time that they failed to give the identity to the Survey that it deserved as an institution. This was generally true for the other state surveys of the country during most of the 19th century.

However, there was rapid improvement in the work done as a result of great progress in geology and chemistry, of improvement in field observation and laboratory technique, of extension of detailed studies, and of greater international contact.

Charles Lyell, Charles Darwin, and Louis Agassiz brought to the scientific world penetrating and revolutionary views. They were powerful teachers and lucid writers. The doctrines that the present is the key to the past, that geologic time and changing environments account for the evolution of life, and that continental glaciation had transgressed millions of square miles in Europe and America during the Great Ice Age gave geology a maturity and expansiveness hitherto lacking. New techniques for a penetrating study of crystals, minerals and rocks came from Nicol, Zirkey, and Rosenbusch. The geologic periods of the Paleozoic Era were largely resolved on a stratigraphic basis by Sedgwick, Murchison and Barrande.

In America, J. D. Dana, Sir William Logan, James Hall and others were rising as leaders in physical geology, pre-Cambrian geology, and in paleontology and stratigraphy.

American literature was rapidly growing and European literature was widely available. The mineral industries were showing signs of growth. Manufacturing and commerce were expanding. The Union-Central-Pacific railroad was completed to the Pacific Coast in 1869, and by 1873 railroad mileage in the United States had reached 63,000 miles.

EARLY ACTIVITIES BY THE FEDERAL GOVERNMENT.

Subsidiary geological work was done by the Federal government from 1819 until 1867, in connection with a series of military explorations. These expeditions were sent into the Northwest Territory, the Ozark Mountains, the Great Plains, the Rocky Mountains and Great Basin, and along the Mexican boundary.

"Up to 1867," wrote Director Clarence King in his first annual report of the U. S. Geological Survey, "geology was made to act as a sort of camp follower to expeditions whose main object was topographical reconnaissance. . . . Eighteen hundred sixty-seven, therefore, marks, in the history of national geological work, a turning point, when the science ceased to be dragged in the dust of rapid exploration and took a commanding position in the professional work of the country."

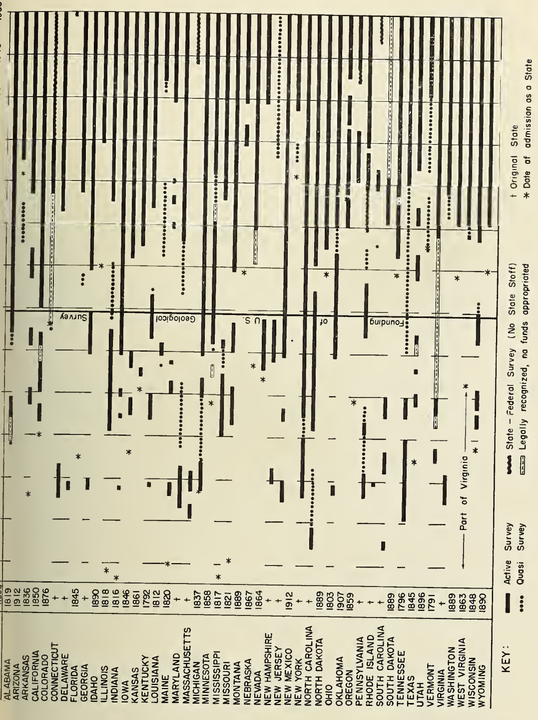
Continued King: "Congress, even then, hardly more than placed the Federal work on a par with that prosecuted by several of the wealthier States. During the years when the Federal geologists were following the hurried and often painful marches of the Western explorers, many States inaugurated and brought to successful issue State surveys whose results are of dignity and value."

In 1867—the turning point in national geological work—Congress authorized the geological exploration of the fortieth parallel by King, geographical and geological survey of the Territories by Hayden, and geographical and geological survey of the Rocky Mountain Region by Powell. In 1879 these were consolidated by Congress into the United States Geological Survey.

Thus the Federal government after fifty years followed the suit of the states. There are obviously national interests as well as state interests to be served. Reports on the public domain, on regional problems, such as the mechanics of Appalachian structure or the clays of the United States east of the Mississippi River, on broad geological subjects such as the Paleozoic fishes of North America or the theory of metamorphism or analyses of rocks and minerals, and on strategic minerals of the nation, are indicative of the need for a national organization.

Since its founding the U. S. Geological Survey has played a large role in the advancement of the geological profession. It has developed specialists in geological subjects who have rendered important service to states, to various branches of the Federal government, and to science.

In the year that the U. S. Geological Survey was founded, only 10 state surveys of 38 states were active—Alabama, Indiana, Illinois, Kentucky, Michigan, New Jersey, New York, North Carolina, Ohio, and Texas. Illinois was active only in the sense that State Geologist Worthen was engaged in prepar


State-hood
ALABAMA 1819
ARIZONA 1912
ARKANSAS 1836
CALIFORNIA 1850
COLORADO 1876
CONNECTICUT †
DELAWARE †
FLORIDA 1845
GEORGIA †
IDAHO 1890
ILLINOIS 1818
INDIANA 1816
IOWA 1846
KANSAS 1861
KENTUCKY 1792
LOUISIANA 1812
MAINE 1820
MARYLAND †
MASSACHUSETTS †
MICHIGAN 1837
MINNESOTA 1858
MISSISSIPPI 1817
MISSOURI 1821
MONTANA 1889
NEBRASKA 1867
NEVADA 1864
NEW HAMPSHIRE †
NEW JERSEY †
NEW MEXICO 1912
NEW YORK †
NORTH CAROLINA †
NORTH DAKOTA 1889
OHIO 1803
OKLAHOMA 1907
OREGON 1859
PENNSYLVANIA †
RHODE ISLAND †
SOUTH CAROLINA †
SOUTH DAKOTA 1889
TENNESSEE 1796
TEXAS 1845
UTAH 1896
VERMONT 1791
VIRGINIA †
WASHINGTON 1889
WEST VIRGINIA 1863
WISCONSIN 1848
WYOMING 1890
1820 1830 1840 1850 1860 1870 1880 1890 1900 1910 1920 1930 1940 1950
Founding of U.S. Geological Survey
Part of Virginia
KEY:
Active Survey
Quasi Survey
State - Federal Survey (No State Staff)
Legally recognized, no funds appropriated
† Original State
* Date of admission as a State

ing his last volume on the *Geology and Paleontology* of Illinois, field surveys having been discontinued in 1875. The surveys of Georgia, New Hampshire, and Wisconsin were discontinued in 1879. T. C. Chamberlin, R. D. Irving, and C. R. Van Hise came into the limelight as a result of their Wisconsin work and soon joined the U. S. Geological Survey. Among others who had had previous state survey experience were Clarence King, G. K. Gilbert, C. A. White, J. S. Newberry, Raphael Pumpelly, Leo Lesquereux, O. C. Marsh, Edw. Orton, and I. C. White. The State geological surveys continued to be a source of strength in the national effort by their fund of detailed information and by their financial cooperation. In 1950 they contributed in excess of $1,000,000 to cooperative funds.

In establishing the U. S. Geological Survey, it seems clear that Congress was simply expressing the sentiment of intelligent, forward-looking citizens that the nation would profit from now on by systematic studies of the geology and mineral resources of the country and by extending and supplementing the efforts of the individual states. The result has justified the innovation. Not only has the nation profited by the Geological Survey's execution of its programs but the activity of the states has increased. As shown in Figure 1, the number of state geological surveys has not only increased since 1890 but their continuity has been greater than ever before. Doubtless the public support given both the Federal survey and the state surveys is a reflection of the common public sentiment.

SCIENCE AND THE ECONOMIC PATTERN.

The earth has always been the mother of mankind, and as the wants and needs of man have grown, this relationship has become more intimate. Science and the economic pattern are mutually reactive. The development of one has stimulated the development of the other.

This audience is familiar with the accelerated rate of change in recent decades and there is no need to review it. Virtually no aspect of our existence has escaped this revolutionary change.

However, I invite attention to two pertinent observations:

(1) Modern geological surveys should not bear any greater resemblance to the early state surveys than does the economic pattern of today to that of the early period.

(2) Geological surveys should command all the power of modern science to meet the needs of the present economic pattern.

These are offered as basic premises for the consideration not only of survey administrators but of the entire profession.

GEOLOGICAL SURVEYS OF THE FUTURE.

Speaking as a state geologist, I trust that it is appropriate to express myself on the matter of state geological surveys of the future, particularly on the principles that should govern their character of organization, the scope of their programs, and policies of operation.

I feel inclined to do this because it is apparent that too many old traditions are being preserved by the states at the sacrifice of meeting the needs of the economic pattern which is ours to serve. Marcus Aurelius once said: "What is not good for the swarm is not good for the bee." A restatement of this might be: "What will help the human economy will help the organization serving it."

It is obvious that no two state geological surveys can be alike. The states all differ in their resources, their economic pattern, their ability to support a survey, their statutory requirements, their institutions, and their customs. These factors in any state provide the environment within which an organization must be oriented, its program determined, and its operations conducted.

Some things, however, are common to every state: (1) the need for geology to serve its industries, its agriculture, its commerce, and its institutions; (2) the availability of modern science to render this service; and (3) knowledge of the policies that are fundamental to fruitful operation and to good public relations.

Inasmuch as it is geological materials and geological conditions with which the human economy is in part concerned and inasmuch as all of the sciences must be marshalled in their study, the personnel of geological surveys, unlike university departments of geology, must include other scientists in addition to geologists. The name "geological survey" should be indicative of the field of study rather than of the personnel composing it.

Nature makes no such distinction between the sciences as we recognize for purposes of university organization and specialization. Therefore, the staff of a geological survey of necessity must include, in addition to specialists in geology, specialists in chemistry, physics and engineering. Furthermore, because we serve the existing economic pattern, there should be provision made for studies in mineral economics.

The geological surveys of the future should be intensive research institutions with laboratories designed for their special purposes. Laboratories of paleontology and petrography are admittedly fundamental but in these days of abundant access to subsurface information laboratories for the study and interpretation of well cuttings and diamond-drill cores are imperative as are also chemical, spectrographic and X-ray laboratories.

The time has passed when the world of technology could depend primarily on information gained from general geologic studies and from empirical engineering tests on samples. The discovery of additional resources requires geophysics and geochemistry. Furthermore, new fundamental information on the physical and chemical nature of materials, including their atomic structure, is required not only to discover additional metallic and petroliferous resources of great urgency but, in the field of industrial minerals, to discover what deposits are adaptable to meet precise specifications and to ascertain what processes of beneficiation are feasible and economic to convert the raw material into a usable product.

The survey organization must likewise maintain adequate technical files, a library of essential information, a clerical staff, help for operation of preparation rooms, mechanics for maintenance of a fleet of motor vehicles, and machinists to design and construct research equipment not available on the open market.

We must lift our sights and recognize new values. A research and service organization of this type will be invaluable to all states in these highly competitive times. Businessmen of vision will lend their support to any such enterprise that is so constructive and helpful to the state's progress.

We see ahead an atomic age. As the changes which it will bring to our economic pattern become clearer we must adjust our programs and our *modus operandi* accordingly.

The administration of sound policies to govern public relationships deserves constant attention by directors and staff members. In addition to matters of integrity in protecting confidential records and in the proper use of information gained at public expense, the survey should insist upon its function as a research institution and avoid becoming a regulatory agency or a service agency, for routine analyses and other work at the sacrifice of research, and in competition with commercial laboratories.

Cooperative relationships should be sought with other organizations to cover inter-areas of research or problems requiring the attention of specialists not possessed by the survey.

State interests should predominate in determining state survey programs and national interests for Federal programs. Except under unusual circumstances the development and control of the resources of a state are the concern primarily of that state, and it is the better part of wisdom that the information concerning its resources should be in the files of the state organization for prompt and convenient reference.

The need for geological surveys of the type which is proposed here is greater than is commonly recognized and deserves careful consideration and action. The circumstances and necessities of the present economic pattern call for a widespread reorganization of existing state surveys into research institutions that will provide the scientific information required both for the present development of our natural resources and for the shaping of sound policies of conservation for the future.

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