STATE OF OHIO
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGICAL SURVEY

OUR NATURAL RESOURCES: Their Continuing Discovery And Human Progress

By

MORRIS M. LEIGHTON
Chief, Illinois State Geological Survey

INFORMATION CIRCULAR NO. 12

Columbus, 1953

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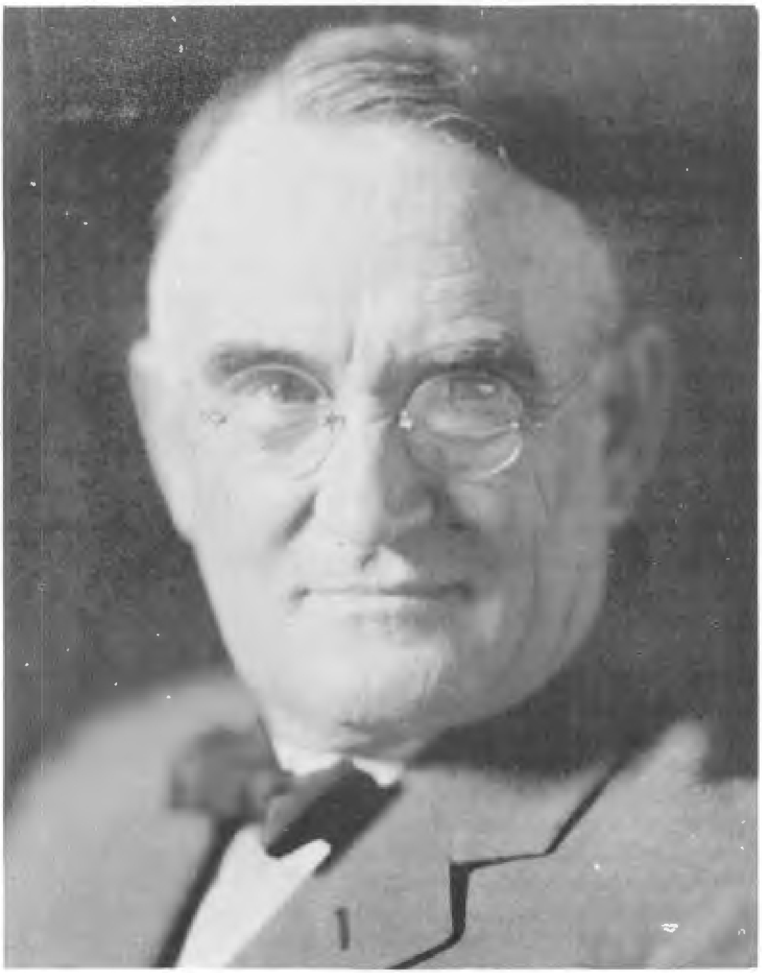


John A. Bownocker

Dr. John Adams

BOWNOCKER

Born near St. Paul, Ohio, in 1865, John Bownocker grew up on the farm and attended the country school. One day he heard Edward Orton, Sr. lecture on geology and he determined, then and there, that he must go to college. He worked, and saved, and in 1883 entered the beginning preparatory class of the Ohio State University. Here, although he lived at the South Dormitory where the students did all their own cooking and housekeeping, and although he worked to earn the money for his expenses, John Bownocker was no dreary grind. He was active in the Horton Literary Society and entertained himself and his many friends with the music of his violin.

After receiving the Bachelor of Science degree from the Ohio State University he spent a year as a Fellow in Geology at the University of Chicago and a year in graduate study at Yale University. He returned to Ohio State as assistant to Dr. Orton and in 1897 his alma mater conferred upon him the degree of Doctor of Science.

Dr. Bownocker rose to become Chairman of the Department of Geology of the Ohio State University and State Geologist of Ohio. Much of his time was devoted to the study of the oil and gas resources of the state and to the building up of the Orton Library of Geology. He was a Fellow of the Geological Society of America, Fellow of the Ohio Academy of Science, honorary member of the Natural Gas Association of America and a member of the Society of the Sigma Xi.

He died on October 21, 1928.

THE BOWNOCKER LECTURES

John Adams Bownocker devoted his life to the service of his native State and to his alma mater, The Ohio State University. His death did not end that devotion. He left his entire estate in trust to his widow with the provision that at her death it should become an endowment fund, the income of which was to be expended in the work of the Department of Geology "in such manner as may seem wise to the proper authorities."

The Bownocker Fellowship and two Bownocker Scholarships were established soon after the creation of the endowment fund, to assist graduate students of outstanding ability in the field of geology.

In 1936 the Bownocker Lectures were inaugurated. Each year an eminent geologist is invited to the campus to present a series of lectures on some topic of geologic interest under the auspices of the Department of Geology and the Society of the Sigma Xi.

BOWNOCKER LECTURERS

1936 - - 1953

1936 - 37	ALFRED LANE
37 - 38	WALTER H. BUCHER
38 - 39	REGINALD A. DALY
39 - 40	CHARLES K. LEITH
40 - 41	ARTHUR L. DAY
41 - 42	GEORGE F. KAY
42 - 43	O. D. VON ENGELN
43 - 44	NO LECTURE
44 - 45	MAX BALL
45 - 46	GEORGE G. SIMPSON
46 - 47	CHESTER B. LONGWELL
47 - 48	HUGH D. MISER
48 - 49	NO LECTURE
49 - 50	HAROLD C. UREY
50 - 51	JAMES GILILLY
51 - 52	SIDNEY PAIGE
52 - 53	MORRIS M. LEIGHTON

The Ohio Division of Geological Survey is publishing the latest of these lectures in the hope that many who were unable to hear the speaker may enjoy reading his words.

Morris M. Leighton

Dr. Morris M.

LEIGHTON

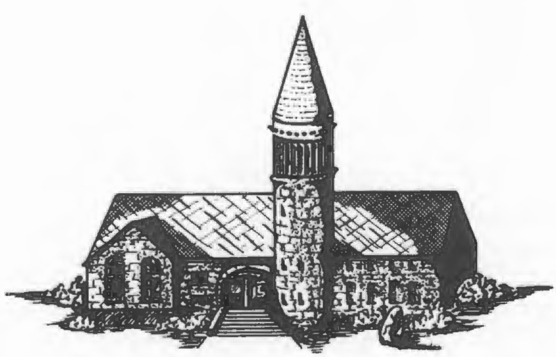
Dr. Morris M. Leighton is a native of the State of Iowa. He was born near Wellman, August 4, 1887, and was a son and grandson of pioneers of that state. He received the degree of Bachelor of Arts from the University of Iowa in 1912, at which time he was awarded the Frank O. Lowden Prize in Geology. He received his Master's degree from that institution in 1913 and his Doctor's degree from the University of Chicago in 1916, where he had been given a Fellowship for two years during his graduate work.

After teaching one year at Iowa State Teachers College, Cedar Falls, and two years at the University of Washington, he was given a leave of absence by the latter institution to serve as Acting Professor of Geology at Ohio State University, 1918-1919, while Dr. J. Ernest Carman was in Europe. Four more years of teaching at the University of Illinois preceded his appointment as Chief of the Illinois State Geological Survey in 1923.

Dr. Leighton is known for his research in Pleistocene geology. With Dr. William C. Alden, member of the U. S. Geological Survey, he established the verity of the Iowan Drift in northeastern Iowa. After some years of research in Illinois he reduced the record of glacial and interglacial stages of the Pleistocene in North America from five to four — a concept that has been generally accepted. He also classified and named the four subdivisions of the Wisconsin stage, developed with Dr. Paul MacClintock the concept of the gumbotil, siltil, and mesotil profiles of weathering of the older glacial drift sheets, and with Dr. Harold B. Willman dated and summarized the history of the widespread loess deposits of the entire Mississippi River Valley region.

Under his leadership the Illinois State Geological Survey has grown from a staff of twenty persons in 1923 to 132 in 1953, this growth being marked by the extension of the Survey's program to include geochemistry and mineral economics and the development of a staff of specialists for comprehensive studies of the State's resources of coal, oil and gas, industrial minerals, clay mineralogy and clay mineral technology, groundwater geology, and engineering geology, and also broad fundamental studies in stratigraphy and paleontology. Numerous publications have brought international attention to the Survey's work. The new Natural Resources Building erected at a cost of nearly $3,000,000 and a separate Applied Research Laboratory costing nearly $200,000, both of these equipped with the latest scientific equipment, are largely due to his leadership. Along with all of this he has kept his interest in and given a place to his research in Pleistocene geology.

Dr. Leighton was President of the Association of American State Geologists from 1931 - 1934, served as a Councillor of the Geological Society of America and as a member of the committee for the reorganization of the American Institute of Mining and Metallurgical Engineers, has been made a Fellow of the American Academy of Arts and Sciences, and has been made an Honorary Member of the American Association of Petroleum Geologists, and Business Editor of Economic Geology. He has also served his state beyond those functions of the Geological Survey as Vice-Chairman of the Post-War Planning Commission and as a member of the State Museum Board.



Dr. Morris M. Leighton presented the following as one of the Bownocker Lecture Series at The Ohio State University, Columbus, Ohio January 20, 1953

OUR NATURAL RESOURCES:

Their Continuing Discovery And Human Progress

Having taught under Dr. J. A. Bownocker, I am happy to give one of the lectures which bear his name. Well do I remember his warm, friendly attitude, his dignified bearing, his honesty, and his sagacious direction of the Department. He made me feel like a colleague rather than a subordinate. This was nearly 35 years ago but it seems like yesterday. This is indeed a highly prized opportunity.

There is facination for me in the statement, "Tell me what your resources are and I will tell you what your society is."

The resources of every region make an impress upon its people. Those regions which have much usually attract men of ability and they in turn develop a progressive society. Those which have little maintain a residual population who live on small margins under relatively primitive conditions.

The mere existence of resources, however, does not insure their development and utilization. The Indians, the first people to inhabit this country, did little in developing them over a period of thousands of years. The attainment of a certain degree of culture is important. Kind of people, kind of government, kind of physical environment, and prowess in science and technology are factors in any economic structure, as well as natural resources. Granting these factors then the state of knowledge of natural resources will determine the relative success of ventures undertaken and the degree of economic progress that can be achieved. My paraphrase of the quotation which I have cited would read: "Tell me what can be done with your resources and I will tell you what your society can become."

Our natural resources deserve the highest and most devoted study. They constitute the foundation for 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 own life changed, his desires increased. His consciousness, his awareness, his vision of a better life widened.

We have resources today that were not regarded as resource yesterday. As science advances and we employ it to discover and disclose other useful substances, our inventory of resources will further grow. It appears that Aurora, the Roman goddess of Dawn, is now strewing the flowers for a new day when all nature will yield its secrets to man.

In the short time that we have tonight, we cannot deal with all segments of the picture of our natural resources and so, being a geologist, I shall invite your attention to one great division of resources, namely, the mineral kingdom.

First, I should like to give thought to that long, early period of struggle when early man was groping to raise himself above the rest of the animal kingdom; secondly, to his intellectual renaissance when he began to lay the foundations of modern science; thirdly, to the birth of geology and the geological profession when the systematic study of our mineral resources began; and fourthly, to certain aspects of the revolution now taking place in our science to meet the new needs already upon us. As Aristotle once said, "He who sees things grow from the beginning will have the best view of them."

Man's Long, Early Period of Struggle

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 obscure records of archeology.

With assurance we can say that man had no knowledge of geology at the close of the geological epoch known as the Pliocene or at the beginning of the Pleistocene. The face of the 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 anticedents 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 advanced concepts.

The attainments of the Greeks were preserved by the Arabians through the Dark Ages as a result of their military conquest. In the eleventh century A. D., the Arabian philosopher, Avicenna, the "Prince of Physicians," held some concepts that are modern, namely, 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 review, the Renaissance of the 15th century will serve as a practical date for discussing the beginnings of modern science. 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. 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.

The 17th century followed with its great co-founders 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 of 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 of 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, and 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.

The Birth of Geology and the Geologic Profession

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.

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 later strata were deposited upon tilted strata as is being done today; that some strata had been changed by heat and recrystallization -- a concept that fore-ran 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 establishment of the modern doctrines of Geology.

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 distated his "Card of the English Strata" which was distributed to other workers. In 1815 he published his geological map of England and Wales.

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.

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.

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 Schopf, who had come as a surgeon with the Hessians and remained to tour the East and Southeast after the peace of 1783; by Comte de Volney, a learned traveler and historian from France; and by William Maclure, an educated businessman and philanthropist from Scotland.

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 deal with some of the most difficult geology in the United States.

At first most of the "scientific" papers were pseudoscientific and reflect readiness to theorize and respond to personal religious beliefs. The early workers were men of other learned professions, and so erroneous indentifications 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 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.

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, later to become famed for his work as State Geologist of New York, graduated in geology and chemistry in 1832 at the age of 21.

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 Ohio, Massachusetts to Tennessee, and south to the Carolinas. The two Carolinas made the initial effort in 1824 and fifteen other states during the decade from 1830 - 1838: Massachusetts in 1830; Tennessee, 1831; Maryland, 1833; Connecticut, New Jersey and Virginia, 1835; Maine, New York, and Pennsylvania, 1836; Delaware, Indiana, Ohio 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, Kentucky, and Tennessee and thence to Indiana, 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 to a new recognition of geology as a developing science and of the fact that information gained in one decade can be improved and extended in the next as a result of the advancement of the science.

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 would 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 were 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 universitites. 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 on the geological framework of the State and convinced of the contribution which his state through him was rendering to science, he gave the New York Geological Survey a lasting place 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

There was rapid improvement in the work done as a result of great progress in geology and chemistry during and after the mid-century, 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 American during the Great Ice Age gave geology a maturity and expansiveness hitherto lacking. New techniques for a penetrating microscopic study of crystals, minerals and rocks came from Nicol, Zirkey, and Rosenbusch, 1850 - 1870. The geologic periods of the Paleozoic Era were largely resolved on a stratigraphic basis by Sedgwick, Murchinson, 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.

Societies for the advancement of science were formed. Ohio's first State Geologist, W. W. Mather, in 1838, addressed a letter to the geologists of the New York Survey in which he stated, in part, "Would it not be well to suggest the propriety of a meeting of the geologists and other scientific men of our country at some central point next fall, say in New York or Philadelphia, There are many questions in our geology that will receive new light from friendly discussion and the combined observations from various individuals who have noted them in various parts of our country. Such a meeting has been suggested by Professor Hitchcock and to me it seems desirable."

This gave impetus to the movement and in 1840 the Association of American Geologists was formed, of which Mr. Mather was a charter member. In 1843, this organization was expanded into "The Association of American Geologists and Naturalists" and in 1847 this body agreed to resolve itself into the American Association for the Advancement of Science which is now one of the largest scientific organizations in the world. In 1867, J. S. Newberry, Ohio's second State Geologist, was made President of this association and in 1899, Ohio's third State Geologist, Edward Orton, was so honored.

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.

For many years geological work by the Federal government had been done only in connection with a series of military explorations. These expeditions were sent into the Northwest Territory, the Ozark Mountains, the 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. Then 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 western public domain, on regional problems that transect state boundaries, 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 the Federal government, and to science.

In the year 1879, when 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. The surveys of Georgia, New Hampshire, and Wisconsin were discontinued that year. T. C. Chamberlin, R. D. Irving, and C. R. Van Hise rose to prominence as a result of their Wisconsin work and soon joined the U. S. Geological Survey. Among others who had had previous state survey experience and who became members of the national survey were Clarence King, G. K. Gilbert, C. A. White, J. S. Newberry, Raphael Pumpelly, Leo Lesquereux, O. C. Marsh, I. C. White, and Edward Orton. The State geological surveys have 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 seens clear the 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. 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. The recent expansion of the Ohio Geological Survey is evidence of this fact.

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

The United States now far exceeds other nations in the production of minerals. Its pre-eminence and its position with nations of second rank are evident from these facts; the United States produces 40 percent of the world's iron ore, an estimated 2 1/2 times as much as Russia; 53 percent of the world's oil, almost four times as much as Venezuela; 37 percent of the world's coal, 1.8 times as much as Russia; 31 percent of the world's copper, almost twice as much as Chile; 42 percent of the world's aluminum, nearly 1 2/3 times as much as Canada; 42 percent of the world's phosphate, nearly three times as much as French Morocco; 32 percent of the world's cement, four times as much as the United Kingdom; and 90 percent of the world's native sulphur, 25 times as much as Italy. There are other things which tell the story of the essentialness of minerals to human progress -- the mechanization of our manufacturing industries and of agriculture, the millions of automobiles, our network of paved highways, our railroad mileage, our communications systems, the mechanization of American homes, and atomic power. Everyone will concede that technology, employing minerals of many kinds, has an importance to our present economic welfare that transcends all government efforts.

To maintain this progress new mineral deposits must be found, new uses discovered for mineral substances already known, and new methods of beneficiation devised to meet more exacting specifications. We need to know more about the origin, occurrence, and detailed nature of minerals.

Our mineral resources are indeed buried treasures. These treasures are not limited to gold, silver and precious gems. In the case of Ohio, its great buried treasures include coal, oil and gas, rock, clays, sands, and that homely commodity so essential to life and progress -- water. There may be others not now known. The maps which help locate these treasures are not old parchments buried under tree roots by pirates of old but geologic maps and cross sections prepared with great care in the course of field and laboratory investigations. These treasures were not buried by human hands centuries ago but were laid down tby natural processes millions and millions of years ago -- before human hands existed. In order to fully and intelligently explore for them, we must learn more and more about the natural processes which produced them.

Modern geological surveys should not bear any closer resemblance to the early state surveys than does the economic pattern of today to that of the early days of this nation. We are in a new world of technology and we can depend no longer on information gained only from general geologic field studies and from empirical engineering tests performed on samples -- the orthodox practice of the past. Geophysics and geochemistry must be employed to discover additional resources. Furthermore the time has arrived when knowledge of the atomic structure of mineral substances opens the way to an understanding of the physical and chemical mechanisms which control the properties of minerals. In some cases, as in the clay minerals, such an understanding enables steps to be taken to modify or improve their properties by physical and chemical means. Trace elements like the new valuable metal, germanium, which two or three years ago was worthless and now has a value of $350 per pound, may be present in some formations in recoverable quantities. The whole field of geology is facing a rebirth of potency. Recovery of more than one product from a mineral resource, like germanium from coal and lead, and uranium and fluorine from phosphate rock, is among the jobs ahead.

Hitherto, geological surveys have been largely organizations of geologists. Nature, however, makes no distinction between the sciences. The mineral resources of the earth have resulted from many physical, chemical, and biological systems of the geological past. Geological surveys, therefore, by their nature must include specialists in chemistry, physics, and engineering, as well as in geology, all working together devotedly to unravel the secrets of nature. Geological surveys of today must have not only research laboratories of paleontology, mineralogy, petrography, sedimentology, and other subjects peculiar to geology, but research laboratories in physical chemistry, organic chemistry, analytical chemistry, spectrometry, and X-ray. These provisions make possible basic research for the growth of the science as well as applied research which aids in the development of the state. As Allen T. Guethmey has said, "Fundamental research is the industrial and intellectual gold mine of the future."

Some of the geological surveys of this country, like your organization, are beginning a reshaping of their programs to meet the new needs in their states. But 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 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 scientific research to serve the State's 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.

Geological surveys must become intensive research institutions equipped with laboratories designed for their special purposes and staffed with scientific specialists who can fully reveal the geological processes of the past which have created our resources, who can devise and direct the techniques for their discovery, and who can extend the possibilites for their utilization in ways that will prevent waste. By doing so geological surveys will the better serve the technology of manufacturing industries and the engineering profession and promote stable industrial development. In the words of Mackenzie, "The science of today is the technology of tomorrow."