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GEOLOGY IN NATIONAL AND EVERYDAY LIFE[1]

By Dr. GEORGE R. MANSFIELD

U. S. GEOLOGICAL SURVEY

INTRODUCTION

To a surprisingly large number of people the word geology suggests nothing definite or practical, nothing associated with national or everyday life. Nevertheless, geology is concerned with the materials man uses in building his houses and great industrial plants. It deals with the metals of which his car is composed and with the fuels with which he drives his car or heats his house. It has to do with the seasoning and preservation of his food, with the water he drinks and with the scenery which greets his eyes every morning. It considers the destructive hazards that form part of his environment in many parts of the world, such as floods, earthquakes and volcanic activity, and is concerned as well with the gentler moods of nature that calm his spirit and inspire his imagination.

Minerals enter into all phases of our modern civilization. Geology deals with the occurrence and distribution of minerals and with the laws and forces that tend to create or destroy them. Industry must know where suitable supplies of minerals for its needs may be obtained and what conditions are imposed by nature on their successful recovery and exploitation. Federal, state and local governments must know whether

[1] Address of the retiring vice-president and chairman of the Section on Geology, American Association for the Advancement of Science, Indianapolis, December 31, 1937. Published by permission of the Director, Geological Survey.

mineral supplies, within their respective jurisdictions, are of suitable quality or adequate to meet the needs of their citizens. They must have information on the geologic conditions affecting the sites of constructional works, such as dams, reservoirs, bridges and the foundations of public buildings; on the problems of water supply and sanitation; and on the wise use and conservation of their mineral resources. The individual must earn his living and gain his inspiration amid surroundings from which geology constantly speaks to him. It seems pertinent, therefore, to consider in some detail the relation between geology and our national and everyday life.

RAMIFICATIONS OF GEOLOGY

Geology is concerned with all agencies and phenomena that have affected the earth in the past or are affecting it now. Some agencies, such as the sun's energy, act upon the earth entirely from without. Others act chiefly at the earth's surface. Among them are streams, glaciers, winds and waves. Still others, such as volcanism, earthquakes and mountain-building agencies, act chiefly within the body of the earth, though each of these may have strongly developed surface manifestations. Gravity acts from without the earth as an astronomical agency, but is also associated with every activity at the earth's surface and within its mass.

The geologist reads and interprets the geologic record in the rocks. But this involves consideration of the agencies above mentioned and through them the use of facts and techniques of other sciences, principally chemistry, physics, biology and astronomy. A border zone lies between geology and each of these sciences so that whether an investigation is geological may depend on its view-point or emphasis rather than on the facts or techniques employed.

The borderline sciences, geochemistry and geophysics, have developed to consider problems that fall between the adjacent fields indicated by the names.

Mineralogy may be cited as an example of the dependence of geology on other sciences. Mineralogy has long been dependent on chemistry and optical physics for accurate determinations of mineral species. More recently it has made use of the x-ray. Mineralogy applied to rock study has developed into petrology; similarly applied to the study of useful minerals it has developed into economic geology. Both geochemistry and geophysics are extensively utilized in economic geology, and geophysics has now become an important aid to the petroleum geologist in his search for oil and gas. However, the view-point of geology, the interpretation of the earth's history, is its own, and geology's dependence on other sciences is probably no greater than their dependence on it.

Geology ramifies also into business, national and private life.

GEOLOGY AND THE MINERAL INDUSTRIES

The mineral industries include, generally, those dependent on the discovery and mining of mineral substances and their manufacture into useful products. They give employment to many thousands of our citizens. According to the Minerals Yearbook 1937, published by the Bureau of Mines, the mining industry by itself ranks last among the four primary industries in the United States with respect to capital invested, value of products or number of workers employed. Actually, however, these industries are interdependent. Manufacturing needs minerals both for its machines and for the power to operate them. The products of mines contribute nearly two thirds of the revenue freight handled by the railroads and about one fourth of the ocean-borne traffic. Agriculture requires minerals for fertilizers and farm implements, and minerals serve to link farms and markets. Highways, railroads, trucks and trains are all of mineral origin.

To those who actually mine coal, iron ore and other minerals, the relation of geology to their everyday lives can hardly fail to be evident. The continuity of a vein, the nature of the ground, whether hard or soft, broken or stable, are factors which control the nature and speed of each day's work and the daily risk of personal safety. Similarly, the oil or water driller must keep close watch of the nature and attitude of the rocks through which he is drilling his well. Those who fabricate the product of the mines and wells are farther removed from the direct effects of geology, but they are no less dependent on it, because their employment is contingent on the constant supply of a uniform material suitable for the manufacture of their special product.

Water is as truly mineral as petroleum or other hydrocarbons, and the question of adequate water supply is closely linked with mineral industries. Water is so essential to all phases of human life that no one can escape the consequences of failure, interruption or contamination of his regular supply. An adequate supply of water is contingent on numerous factors, many of which are geological.

The economic geologist is employed to aid in the discovery of mineral resources, to work out their relations in the ground and to obtain quantitative data on which to base estimates of reserves. He must consider grade and accessibility, as these factors ultimately determine whether a given mineral deposit can be exploited at current price ranges. The use of sound geological investigation and advice is essential if waste and suffering are to be avoided by the public when attempts are made to work an unprofitable mining property, to drill for oil in unfavorable places or to unload questionable mining or drilling enterprises on the market.

Metals. The geologist engaged in studying metallic minerals must devote a large share of his time in the field to the available underground workings in such mines as are accessible to him, besides acquainting himself with the surface geology of as much of the region as the limits of his time and funds will permit. He thus gains a better three-dimensional picture of the whole geologic set-up than would be possible from a study of surface relations alone. His maps, sections and laboratory studies serve to control actual mining operations and guide explorations for further supplies of ore. The increasing use of geologists on the staffs of mining companies bears witness to the increasing need of the mining industry for geologic advice and to the growing recognition of that need.

Non-metals. In the field of non-metallic mineral deposits the recognition of the need of geologic advice has grown more slowly and in fact can hardly yet be said to be wide-spread. Non-metallic mineral resources are in general so abundant, lie so near the surface and are so cheap, relatively speaking, that producers have given little thought to their geologic aspects. However, it not infrequently happens that a producer, say, of sand and gravel, locates his plant near a talus pile, which he mistakes for a bedded deposit of suitable thickness and quality. When further work discloses that the actual deposit from which the talus is derived is merely a thin cap at a higher elevation, he is faced with the problem of relocating his plant, changing its layout or abandoning it altogether.

Some industries in the non-metallic field utilize underground methods of mining. For example, mica, feldspar, talc, magnesite, gypsum, fluorite and some phosphates are among the minerals so mined. More recently underground methods have been successfully applied to the mining of limestone, slate, sandstone and even granite at different places. Special processes for recovering salt and sulfur by underground solution or melting and pumping have been devised which differ from ordinary mining methods, but the successful location and development of such an enterprise, as in the other instances, depends fundamentally on knowledge of the geology of the area in which lies the deposit to be mined, or otherwise recovered.

Again supplies of construction materials for building and other activities in the vicinity of large cities or large engineering projects tend to become depleted fairly rapidly and search for such materials has to be extended farther and farther from these centers. Here a good geologic map is of the greatest service whether or not it was originally prepared to serve economic needs. For regional planning, where constructional activities are contemplated, the areal geologic map of the United States has been found a valuable guide for more detailed investigations. Similarly state geologic maps and geologic maps of individual areas, such as those provided in the folios of the Geological Survey, have repeatedly proved their worth in locating supplies of necessary construction materials. For example, the state geologic map of Alabama shows the distribution in the northern part of the state of extensive deposits of gravel in areas mapped as Tuscaloosa formation and large areas of valuable limestone for building in the Bangor limestone. Special economic maps, such as that of the Tennessee Valley, prepared by the Geological Survey, indicate the distribution of a wide variety of mineral deposits. The use of such information may often result in large savings both in time and money, not only by pointing out more favorable areas but also by preventing search in unfavorable areas.

Fuels-coal. Geologists in federal and state surveys, as well as those in private employ, have labored many years to make known the nature and extent of the nation's coal resources. We now know in greater or less detail where the deposits of coal of different ranks, from lignite to anthracite, lie, how extensive they are, how rich in heating value, and which beds among them are best adapted for such purposes as coking and steam production. Some years ago the Geological Survey published a map showing the nature and distribution of the coal fields of the United States, which has proved a very useful summary. Although the number of publications emanating from these sources is large, the work is far from complete because of the wide distribution of the deposits and the refinements of study needed in getting desired information.

Petroleum and Natural Gas. In recent years the search for new supplies of petroleum and natural gas has become increasingly the task of the geologist and the geophysicist. In this task paleontology has acquired greater economic interest and importance than in any other branch of the mineral industry. Fifty years or so ago who would have thought that a matter of prime importance to a great industry would be the stratigraphic position and depth below the surface of certain beds of rock whose chief characteristic is their content of tiny fossils? Yet now in certain oil-bearing regions such beds serve to outline, or help outline, the shape, size and position of oil and gas pools. Our knowledge of subsurface geology, on which the search for oil now largely depends, has been built up by the geologist, patiently gathering and comparing data from well cuttings and cores, identifying fossils—including many of microscopic size—determining mineral particles and preparing the maps and sections on which the collected data are assembled and summarized.

The geophysical prospecting now in wide use in the search for oil and gas derives much of its usefulness from the great body of data assembled and integrated by geologists. The effectiveness of geophysical combined with geologic methods has been well shown in many parts of the United States, especially in Texas and Louisiana near the Gulf of Mexico, where many oil fields and salt domes have been thus located, and more recently in the central Illinois basin. The geologist is indispensable to the oil industry. The literature on geophysical prospecting is increasing at a rapid rate. A quarterly Geological Survey bulletin of about 300 abstracts is now required merely to outline these publications.

The contributions of the petroleum geologist to geologic literature and philosophy have greatly stimulated interest in the deeper rocks and structures of the earth's crust, in problems of sedimentation, ancient shorelines and continental history. In this connection, David White's carbon ratio theory deserves particular mention. The essence of it is that organic substances in sedimentary rocks share in the ordinary metamorphic changes induced by compaction and folding of the deposits. Oils and coals of different ranks are produced and modified by these changes at relatively low temperatures and by a sort of cracking process, whereby the more volatile hydrocarbons are liberated while the fixed carbon remains, thus increasing the ratio of the "fixed" to the volatile carbon. As these metamorphic effects become more intense, the cracking process reaches a "dead line" beyond which no oil or gas pools may be expected. This theory explains many facts regarding the mode of occurrence of petroleum and some of the differences in its character from place to place. By indicating areas where the search for oil would be unprofitable, it has saved producers millions of dollars.

The relationship of geology to the life and interests of a community is nowhere more definitely recognized and more strongly appreciated than among the people living in the oil-producing parts of the country. Even a brief sojourn in such a community suffices to show that the common man has a keen understanding of such geologic terms as anticline, structure, dip and strike, and of the part these features may play in finding oil.

Geology in the Constructional Industries

In recent years the imagination of the public has been stirred by plans involving engineering construction projects on an unprecedented scale. Some of these projects are already in progress and popular attention has been directed to such centers as Norris, Tennessee; Guntersville, Alabama; Boulder Dam, Arizona-Nevada; Bonneville Dam, Oregon-Washington; Grand Coulee Dam, Washington, and Fort Peck, Montana, where construction of large river-control projects is already well advanced.

The geologic conditions at each of these sites presented problems or even hazards that had to be solved and met by special engineering devices before success for the constructional end of the project could be assured. At one site, for example, the difficulties centered in the relative porosity and cavernous character of the limestones on which the dam was to be seated. At another, ground movement, through landslides, introduced serious hazards. At still another the occurrence of large supplies of hot water denoting disturbed structural conditions at the proposed dam site had to be taken into account. The engineers in charge, mindful of previous disasters where work of this sort had been done without sufficient regard to attending geological conditions, called upon geologists for help. As the sites selected have special advantages not easily duplicated, it remained for the geologist and the engineer jointly to work out methods for overcoming these difficulties. This seems in large measure to have been accomplished, and the public has much reason to hope that the structures will prove stable when completed.

Some years ago the government undertook the project of building a large reservoir in a western valley for the purpose of irrigation storage. The site had been selected after a careful investigation by a well-known consulting engineer, who reported that it had several advantages over competing sites and that the construction involved no special problems. When drilling began for the selection of a dam site, trouble arose from drilling water, which disappeared almost as fast as it could be poured into the drill holes. Geological investigation showed that the ground-water table in the vicinity of the proposed dam site was nearly 100 feet below the surface. The rocks on which the dam was to be seated were porous and fractured lavas, resting on thick but poorly consolidated and porous volcanic ash. The proposed dam would surely allow water to flow away beneath and around the dam without providing the desired storage. The site was abandoned, and the resulting saving to the government in avoiding the unwise proposed construction was approximately $2,000,000.

Although the geologist is indispensable in helping to solve problems encountered in great constructional projects, he is even more necessary when it comes to the consideration of the sources of supply and the nature of the mineral substances that enter into any modern constructional project, great or small. At the time the Boulder Dam was under construction, the technical journals and locally the daily newspapers carried accounts of the enormous quantities of sand and gravel, cement, steel, etc., that were needed and used, and of special types of equipment designed to handle these materials. Similarly, for the other projects, much information of this sort is available.

Some years ago E. F. Burchard and G. F. Loughlin compiled construction data, not published, for the Interior Department, North Building, in Washington, D. C. This is a modern office building, completed for occupation in 1917. It occupies an entire city square. According to Burchard and Loughlin's figures, about 8,000 tons of metals, more than two thirds of it structural steel, was utilized. Interesting items in this connection are 20 tons of bronze in locks and 49 miles of wire used in signalling and lighting but not for telephones. The non-metallic minerals used total about 82,500 tons. Of this amount more than a third consisted of sand, gravel and crushed stone; clay products, largely hollow tile and building brick, made up another third. Then came Indiana limestone, plaster and cement and a number of others. These materials came from 28 states and 3 foreign countries.

Oliver Bowles in the magazine, *Stone,* June, 1932, gives an account of the stones used in the Department of Commerce Building in Washington. This building covers a ground area of approximately 8 acres and is one of the largest office buildings in the world. Indiana limestone was the stone most largely used. Of this about 700,000 cubic feet, or 1,100 carloads, was required. Granite from Stony Creek, Connecticut, amounted to 75,000 cubic feet. Other interesting items about this building include 7½ miles of corridor floored with terrazzo chips patterned with small tile; 6 miles of wall base along the corridors covered with polished black Isle La Motte, Vermont, marble, and more than 16 miles of baseboard manufactured from slate obtained in the Pen Argyl district of Pennsylvania. The stones used in this building came from ten states and one foreign country.

The figures cited show something of the nature, diversity and amount of the mineral substances that enter into the construction of large modern buildings. When one considers how many new buildings, both large and small, are being constructed throughout the country each year, and realizes that to obtain an idea of the total quantity of minerals used in their construction, the figures given above must be multiplied enormously, he can better understand the meaning of the statistical summaries of mineral production published each year, formerly by the Geological Survey and now by the Bureau of Mines. These figures, of course, include not only the costs of minerals entering into building construction, usually f.o.b. mine or quarry, but the entire range of industrial and commercial activity in which minerals are used. For 1936, the latest year for which figures have been assembled, the Bureau of Mines shows a grand total of $4,582,000,000 for the value of the output of mineral products in the United States. The greatest contributor was mineral fuels ($2,706,300,000) followed by metallic products ($1,064,000,000), non-metallic products ($789,700,000) and "unspecified" ($22,000,000).

It has been emphasized by geologists and economists, but will bear repetition, that the mineral resources of the country are diminishing assets. When once used they can only in relatively small measure be reclaimed and used again. Periodic mineral inventories, therefore, are essential to provide the best picture of our outlook regarding the future supplies and utilization of minerals, and these inventories are founded on geologic information.

GEOLOGY IN PUBLIC RELATIONS

Governments—federal, state or local—have many problems that involve some relationship with minerals, in the solution of which the geologist may and often does play some important part. The Federal Government and some of the states, for example, Texas, own large tracts of public land, the administration or disposal of which involves a knowledge of the mineral resources that they contain. Many cities and towns own land from which stone may be quarried or sand or gravel be removed.

Geological Survey. The Federal Government, the largest land-holder, early recognized the need of information regarding its public lands. Thus arose the succession of surveys, which finally led to the establishment in 1879 of the Geological Survey, whose director was charged with "the direction of the Geological Survey and the classification of the public lands and examination of the geological structure, mineral resources, and products of the national domain." Though many of its activities relate specifically to the public lands, the scope of the organization is broader, and it may do work for public purposes in any of the states, territories or insular possessions.

Its work has greatly expanded since the early days. The names of its six branches indicate the general scope of its present activities:

Geologic branch (includes wide variety of geologic studies and related chemical and physical work).

Topographic branch (topographic mapping, base maps, etc.).

Water resources branch (surface and ground water divisions).

Conservation branch (land classification, mineral leasing, power sites, etc.).

Alaska branch (geology, topography and mineral resources).

Administrative branch (includes library).

Besides geologists these branches employ many engineers, chemists and physicists, a clerical staff and laborers. The continuous service of one or more legal advisers is also required. Nevertheless, the central purpose about which the entire organization revolves is the extension of geologic knowledge and the application of this knowledge to public problems involving the mineral wealth of the country, especially the public lands, and laws and regulations relating thereto.

Other Governmental Agencies. Other government agencies besides the Geological Survey have need for geologists and geologic advice. Some of them call upon the Survey to do specific pieces of work or carry out special investigations. Thus the Survey has examined many tracts of land for the Forest Service in pursuance of legal obligations placed upon that organization to obtain such examinations prior to the purchase of additional lands for forest reserves. The Indian Service has requested mineral examinations of certain Indian lands prior to opening for settlement or disposal and that organization and the Bureau of Reclamation have asked for damsite investigations. This last organization and some other bureaus originated in the Geological Survey. The Navy Department has asked for geologic aid in selection of sites for special structures and of tracts of land for petroleum reserves. The National Park Service has asked for geologic information for administrative purposes and to further the educational and recreational use of the parks. The Tennessee Valley Authority has asked assistance in the valuation of mineral-bearing lands about to be flooded. The Reconstruction Finance Corporation and the Securities and Exchange Commission have called upon the Survey for advice in their respective fields as to applications for loans of public funds and as to issuing permits to sell securities based on underlying mineral properties.

On the other hand, a number of federal organizations, recognizing the need of geologic information and advice, have attached geologists to their staffs or have built up separate geologic staffs in order to obtain more direct control of such work for their special purposes. Among these are the Army Engineer Corps, the Reclamation Service, National Park Service, the Soil Conservation Service and the Tennessee Valley Authority. The increasing tendency of such organizations to seek geologic advice indicates a growing appreciation of the varied services geology may render.

State Geological Surveys. Before the Federal Government took cognizance of geology as an aid to the better understanding and solution of its problems affecting mineral lands, and resources, some of the states had established geological surveys and published reports. The two Carolinas, North Carolina in 1823, and South Carolina in 1824, were the first to take steps in this direction, followed by Massachusetts in 1830. From that time on more and more states have taken up geologic investigations. Most of the early surveys were discontinued, but many were revived, some of them several times. The New York Survey, however, has been broadly continuous in its activity and name since its inception in 1836. Now the only states that appear to make no specific provision for geologic work within their boundaries are Delaware and Massachusetts. The state surveys, though held within state lines and thus restricted in their fields of operation, have given an excellent account of themselves and have rendered most valuable service to their people and to the country as a whole, as well as to geological science.

Services Rendered by Official Surveys. Besides the applications of geology in the fields of engineering, construction and search for supplies of different minerals, which to a greater or less extent are regular duties of official surveys, its application in land classification, water supply problems, sanitation, legal questions and miscellaneous information service deserve attention.

Land Classification was one of the duties imposed on the Geological Survey by its organic act, but little systematic geologic work was done in this connection until the rise of the conservation movement in the first decade of this century. Attention then was focused on such mineral resources as coal, oil, natural gas, phosphate and salines on public lands, and the interest of the nation as a whole in their proper conservation and use was aroused. Congress passed legislation reserving mineral rights to the government, setting up reserves for special purposes, and providing for the lease and exploitation of public mineral lands. A necessary corollary was the acquirement of more precise information regarding such lands. The Geological Survey thus began and has since continued systematic surveys to show accurately the distribution of such minerals with respect to the established subdivisions of the public land and to measure and sample the deposits for purposes of computing reserves. The acreage withdrawn from or restored to entry and the estimates of reserves have been modified from time to time as new information has become available. They have formed the basis of national planning and legislation. Besides this, land classification data are extensively used by the General Land Office in administering public lands.

Water Supplies. In the better watered parts of the United States and other countries, questions of water supply have not, on the whole, seemed serious until recent years. The situation is different in more arid regions where water is the crux of the question, whether a given area can be used agriculturally or industrially, or perhaps at all. With the rapid expansion of cities in the more thickly settled areas and the increased demands for water in some western states, questions of water supply have assumed national importance. Investigations and measurements must be made both of the available surface water and of water in the ground. These are long-continuing projects because rainfall, which controls both the surface and the ground supply, fluctuates so that investigations, covering only short periods, are likely to be deceptive and undependable.

The problems of proper development and utilization of water involve the cooperation of the engineer, the geologist and the chemist. The engineer is concerned with its production or accumulation, its transportation and handling as a commodity; the geologist with the character (thickness, porosity, etc.) and position of the water-bearing beds, their recharge from available rainfall and their possible contamination by salt water or other undesirable substances. With the engineer he is concerned with the character and stability of rocks affected by tunnels, aqueducts, dams and other structures. The chemist determines the quality of water as regards mineral and organic content. Mineral water, through clogging or staining, may be injurious for industrial use. Mineral substances in solution may also affect health. For example, fluorine detected in the waters of some of the southwestern states has proved injurious to the enamel of human teeth. Organic matter is deleterious to health.

Sanitation. Closely related to the question of water supply is that of sanitation and the disposal of sewage and other wastes. If proper regard is not paid to geological conditions, water supplies otherwise suitable may become contaminated. In some limestone regions where underground channels have been enlarged by solution, water may pass quickly from sources of contamination to places of use without being filtered or purified as they might be by passing through sequences of rocks of normal porosity. Thus the geologist's advice may be valuable to the sanitary engineer.

Legal Questions. Matters in litigation not infrequently hinge on geologic data. The mining industry has been afflicted by litigation in connection with the so-called "apex" law. Many distinguished geologists have participated in these affairs. Frequently the available data have been so incomplete as to allow many differences of opinion among the experts. Boundary disputes between states or individuals, where the position of a stream is involved, have frequently hinged on geologic evidence, as in the case of the Texas-Oklahoma boundary along the Red River some years ago.

Informational and Miscellaneous Services. All the state geological surveys, as well as the Federal Geological Survey, are constantly called upon for a wide variety of information. Letters received at the Geological Survey from people in all walks of life run up into the thousands annually. Many mineral specimens are identified for the public. Work of this kind, including personal interviews, has to be considered a regular function of the geologist in public service. Sometimes the relation of geology to the question raised may at first seem remote, but the answer may reveal an intimate connection. For example, a representative of the United States Fish Commission called at my office one day. He was trying to restock with fish some of the streams in West Virginia. Though he was generally successful, there was one area where the young fish, when released, kept dying and he was not able to obtain satisfactory results. By referring to the county geologic map, a product of the state survey, it was found that the streams that caused the trouble all rose in or crossed a belt of pyrite-bearing shales, and it seemed probable that the unfavorable effects on the young fish were produced by sulfuric acid released by the decomposition and leaching of the pyrite in these shales, and its continual supply to the stream through springs in minute quantities but sufficient to kill the fish.

Another West Virginia problem was brought to my office by an engineer from a telephone company that was having trouble in maintaining its lines. The company, it appeared, had laid these out with regard only to directions of route and mileage. It had not considered the nature of the ground in which its poles must be set. As a consequence disturbance of poles, disarrangement of line and breakage of wires was frequent because of land slips. Recourse to the state geologic map, another product of the state survey, with some further explanations, demonstrated to the engineer the usefulness of such a map in showing the position of the stable rocks that could be safely utilized and of the unstable formations that should be avoided.

GEOLOGY IN DOMESTIC RELATIONS

In the glaciated parts of the country, especially in New England, the land of many farms is stony. In the process of cultivation large numbers of stones, ranging in size from a few inches to as much as a foot in diameter, have been patiently gathered by the farmer and assembled in piles here and there in the fields or built into stone walls. Such walls are a characteristic sight along many New England roads. Successive winter frosts gradually lift other stones in the upper soil within reach of the plough and thus provide the farmer with additional crops of boulders.

Contrasting geologic conditions affecting the lives of whole communities have been called to public attention in the last year or two by the so-called "dust bowl" in the western states and by flooded areas of the Ohio, Mississippi and other rivers. In the dust bowl area cultivation, deficient rainfall and high winds combined to loosen soil and transport it in large quantities to other sites near or far. The farms from which the soil was taken were depleted or ruined, whereas those that received it were improved, if not choked by too much sand or other deleterious material. On the other hand, the flooded areas suffered from the effects of too much rain and from the consequent increase in the transporting power of the rivers. One man's loss was perhaps another's gain in the redistribution of soil that took place during the flood.

An understanding of the effects of heavy rains and run-off on ploughed ground is essential to a farmer if he is to conserve his fields and maintain the productivity of his farm. This is especially true if his fields slope more than a few degrees. The system of contour ploughing now being introduced in many parts of the country, especially in the South, is doing much to prevent soil erosion and the waste of arable land.

My efforts to make a garden in Washington during the World War were directly affected by the geology of my back yard. The upper few inches of soil were derived from gravels of the Columbia group of Pleistocene age and were very stony, the stones ranging from birds egg to football size. They lay on an old deeply weathered and rotted schist of Precambrian age, the contact being beautifully exposed in a cut bank in the alley behind my house. Every square foot of that garden had to be opened by pick and shovel methods. Many wheelbarrow loads of pebbles were taken out and fresh dirt that had been dumped on the hillside behind wheeled in. The rotted schist seemed to have the consistency of lead. Only by persistent effort was the soil lightened and made ready for cultivation.

The practice of insulating houses and office buildings has given rise to a relatively new industry. Some of the more widely used insulating materials are of mineral origin, and locating suitable supplies of them requires geological investigation.

The question of keeping a cellar dry during a wet season, especially where frost and melting snow are involved, is dependent on recognition of the geologic conditions in the immediately underlying or surrounding ground. A ledge protruding into the cellar, or a water-bearing layer in the surrounding ground, if not properly sealed off, may lead water into the house and flood the cellar.

The location of cities, villages, individual dwellings and farms without regard to existing geological conditions, or perhaps in spite of them, has led to many disasters on both a small and large scale. This involves the whole question of disasters due to earthquakes, floods, hurricanes, volcanoes and other geologic agencies. Sometimes the advantages offered by such locations are great and the manifestations of adverse geologic conditions infrequent. Nevertheless, sooner or later they appear and those caught unprepared suffer. Special forms of insurance against disaster are available in some parts of the country. If the cost of protective measures is great, most people prefer to take their chances, but if in such places care is taken to select favorable ground and attention is given to protective types of building construction, the dangers of such disasters in individual cases, at least, may be largely obviated. However, any one who elects to live in such places should realize that potentially disaster-producing agencies are part of his natural environment and if he fails to take these into account he does so at his peril.

GEOLOGY IN EDUCATION

The field of education is broad, embracing all those facts, influences and processes by which the student is made aware of the experience of the past and is prepared to go forward on his own initiative in the business of life and in extending the bounds of knowledge. Naturally many subjects enter into any well-rounded educational program. Some of them, notably geology, quicken observation, broaden understanding, stimulate the love of beauty and cultivate the mind.

One of the greatest contributions of geology to education is the concept of the length of geologic time. This and the astronomical concept of distance in space are among the greatest contributions of science to human knowledge. They serve to put in perspective all happenings on the earth and throughout the universe. The later methods of estimating geologic time, though permitting more exact statement of the lengths of individual periods or eras, emphasize the great age of the earth in contrast with the brevity of recorded history. Thus the age of the earth and the geologic record of the development of life upon it furnish a background for religion, philosophy and social science.

Geography, a subject included in practically every educational program, rests on geology. The progress of life through the ages as shown by the geologic record has depended largely upon geological conditions. Faunas have waxed and waned with the advance and retreat of seas over continents. Floras and vertebrates have responded similarly to the movements of the great ice-sheets. The present distribution of plants and animals shows many peculiarities due to these agencies and to isolation of certain inhabited areas from other corresponding areas by submergence or other geologic causes. The fauna and flora of Australia are well-known examples. The natural conditions that have favored the location of manufacturing or maritime cities, trade routes and transportation lines are generally traceable to geologic causes.

History plays a great part in education. Many historical events from earliest times have had a geological background. Tribes and nations have developed their own customs and habits according to whether they lived in mountain glens or broad alluviated country; in continents or islands. Great civilizations have arisen at the mouths or on the plains of great rivers. These favorable natural features are the products of geologic agencies operating on rocks of different kinds through long ages.

According to trustworthy authorities, the great deluge of Biblical days, as well as the devastating flood of this century at Galveston, Texas, was the result of a chance combination of hurricane and tide in low coastal and estuarine areas. Mountain passes, products of geological agencies, have helped or hindered movements of peoples or armies. The Germans took advantage of the lowlands in Belgium in beginning their first advance in the world war. Accounts of battles have shown that the geological nature of the terrain is always an important factor in any victory or defeat. However, the great underlying causes of wars are economic and depend in large measure upon the distribution of supplies of usable mineral raw materials whose origin and distribution are geological problems.

The observation and study of nature is a prime element in any modern educational program. Nature is so full of geology that one can hardly look in any direction without seeing something of geological interest. Classes in nature study may have different objectives, but geologic materials and processes are always available and may either furnish the major interest or play some subordinate part. Geology lends itself readily to the inculcation of methods of scientific study. Either induction or deduction may be employed. The method of multiple working hypotheses outlined by Gilbert[2] many years ago is a noteworthy contribution to scientific education.

Geologic literature, like that of other sciences, or literature in general, contains much that is commonplace. Nevertheless, in the hands of its masters it has risen to heights worthy of the emulation of any student of English as well as of the sciences. Some years ago I came upon such a passage written by Sir Archibald Geikie.[3] It has lingered in my memory ever since. Discussing stratified rocks of Precambrian age, he writes:

> Few parts of the stratified crust of the earth present greater interest than these earliest remaining sediments. As the geologist lingers among them, fascinated by their antiquity and by the stubbornness with which they have shrouded their secrets from his anxious scrutiny, he can sometimes scarcely believe that they belong to so remote a part of the earth's history as they can be assuredly proved to do.

The shores of the British Isles have suffered severely from marine erosion, fine examples of which may be seen at many places along their coasts. The islands are small enough to enable almost any one who so desires to view the activities of the ocean and the effects that winds, waves, currents and tides have produced. It is therefore not strange that poetic and artistic genius should be stirred by scenes like these. Such may have been the background of Tennyson's poem, "Crossing the Bar," which has brought peace and comfort to vast numbers of people.

Mendelssohn's celebrated overture to Fingal's Cave, still heard in symphony concerts, was composed after his visit to the Island of Staffa off the Scottish coast in 1829. Thus literature and art have been enriched by interested observation of geologic processes and products.

Sometimes art, as well as business, may be promoted by proximity of needed materials. Professor Shaler used to say that the reason Greek sculpture advanced to such heights of excellence was the fact that in the marbles of Attica the Greeks possessed an unrivaled medium for the expression of their art.

In the ordinary prosecution of his work the geologist brings to light facts, principles and ideas of great educational value. His reports, papers and discussions serve as the basis for text-book compilations, classroom studies and field excursions. As a branch of scientific knowledge the cultural value of geology can hardly be overestimated. The literary value of its better products is high, its logic and broad philosophies stimulate the mind, and its factual content has world-wide interest.

Summary

Geology through its bearing on supplies of mineral raw materials, necessary adjuncts to our civilization, enters into many relations of local and national importance. The information it supplies is basic to many great industries. It also enters into more intimate human affairs. Truly it may be said that the relation of human life to geology is as close as that of a fish to water. The earth on which we walk, the air we breathe, the water we drink, the daily events of our lives and even our higher endeavors and aspirations, are ordered or affected by geologic phenomena and principles. Though mystery, in the sense of things we can not explain, enters into geology as it does into life itself, its commoner aspects are so clear, so instructive and so enticing if once sensed, that they can hardly fail to appeal to the imagination and interest of any active mind. Let us each continue striving to extend the knowledge and appreciation of our science.

[2] G. K. Gilbert, *Am. Jour. of Science*, (3), 31: pp. 284–299, 1886.

[3] A. Geikie, "Text Book of Geology," 4th ed., Vol. II, p. 876, New York, 1903.