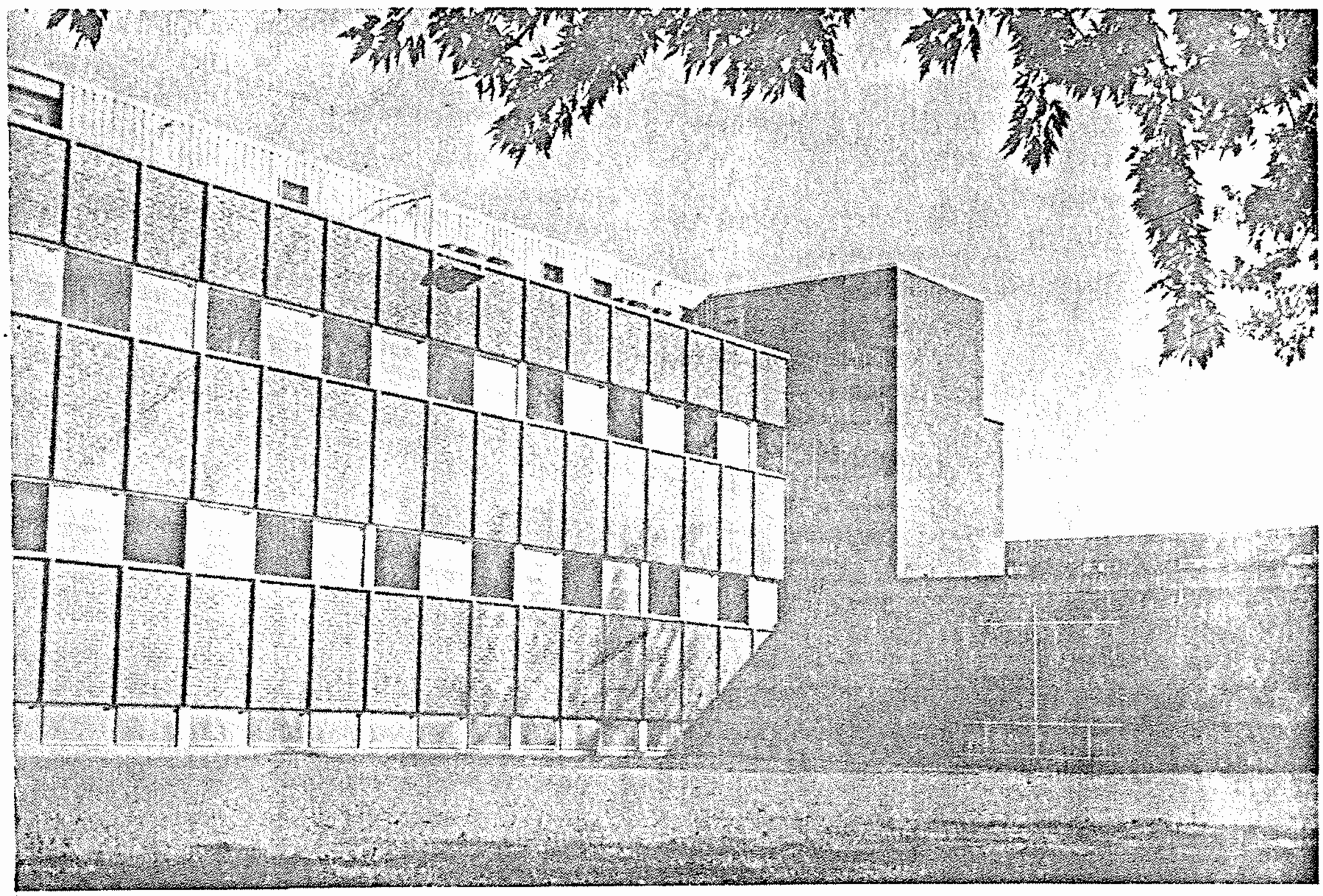
The Place of Geology in American Life

by James Gilluly



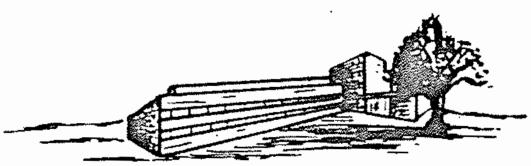
Educational Series — Book One

South Dakota State Geological Survey

STATE OF SOUTH DAKOTA
Archie Gubbrud, Governor
1962

James Gilluly

South Dakota State Geological Survey
Allen F. Agnew, State Geologist



Science Center, University
Vermillion, South Dakota

Cover Photo by R.E. Kucera
Illustrations by Pam Kucera

PREFACE

This publication is the first in a series of reports on different phases of geology, intended primarily for the layman. It is anticipated that the Series will include "popular" handbooks on topics such as minerals and fossils, and guidebooks to the spectacular geologic scenery present in different parts of South Dakota.

It is fitting that the first publication of the new Educational Series contains a philosophic address dealing with the relationship of geology to society, by an eminent geologist whose career as a teacher is exemplified by an outstanding college textbook on geology, of which he is one of the three authors.

On April 27, 1962, the first unit of the new Science Center at the State University of South Dakota was dedicated. This building houses both the State Geological Survey and the Department of Geology of the University, together with their joint library. It also includes the Physics Department, and laboratories for Chemistry and Psychology.

The University and the State Geological Survey were honored to present as the dedicatory speaker Dr. James Gilluly, Senior Research Geologist with the United States Geological Survey. Dr. Gilluly is exceedingly well equipped to deliver such an address, by virtue of his 40 years experience in the field of geology, which includes 12 years of teaching at the University of California in Los Angeles.

Dr. Gilluly's interests in geology cover a broad spectrum, ranging from stratigraphy and structure to the economic geology of copper. In World War II he made significant contributions to the United States' effort in the Southwest Pacific area by his engineering geology studies of the islands.

Dr. Gilluly holds fellowship and membership in many geologic and other scientific societies in the United States, and has been honored by societies both in this country and abroad. Dr. Gilluly received his

Ph. D. degree in geology from Yale University, and was awarded the honorary Doctor of Science degree at Princeton University.

The South Dakota State Geological Survey is pleased to present Dr. Gilluly's address, "The Place of Geology in American Life".

Allen F. Agnew
State Geologist

September 25, 1962

THE PLACE OF GEOLOGY IN AMERICAN LIFE

by

James Gilluly

In considering the place of geology in modern life, I think it best to start at a point that may seen unrelated to the question, but that I believe is the key to a big part of it: the Industrial Revolution.

Our world differs more from that of the Founding Fathers of the Republic than theirs did from the world of Alexander the Great--a greater change in 200 years than in the previous 2000. In 1800, nearly four-fifths of all persons in Great Britain and Italy, the most urbanized countries of Europe, lived on farms, as did more than nine-tenths of those in the rest of Europe. Land transport was by wagons, on roads hardly better than those Caesar used in Gaul; Napoleon's crossing of the Alps was little less of a feat than Hannibal's 2000 years before. Today a Zulu miner travels third class to his labor compound in serfdom on the Rand gold field in greater comfort than Louis XIV rode in his state coach from Paris to Versailles. By our standards, the Zulu's lot is hard and his pay pitiably small; yet he is much better clothed and fed than most people in George the Third's England. He is fortunate indeed, when compared to a slave in the Athenian Mines of Laurium whose life expectancy beneath the supervisor's lash was only four years but whose labors produced the silver that financed the glories of the Greece of Pericles.

Now it is not primarily ethical principles that account for the differences between the ancient and the modern worlds. Material goods are perhaps as unevenly distributed today as under most of the cultures of the past but the whole standard of living, at least of the Western World, is far higher.

The change began with two events of the 18th Century. Neither attracted as much notice at the time as the intrigues of Bonnie Prince Charlie or the campaigns of Frederick the Great. But about 1730 a Shropshire Quaker, Abraham Darby, discovered how to use coke for smelting iron; and in 1768 James Watt invented the steam engine. These men made possible cheap iron, steel, mechanized power, and the industrial age. Without machinery, population would long since have outstripped food supply the world over, as Malthus predicted in 1798, and as indeed it has in China and India, where the industrial revolution has only feeble roots.

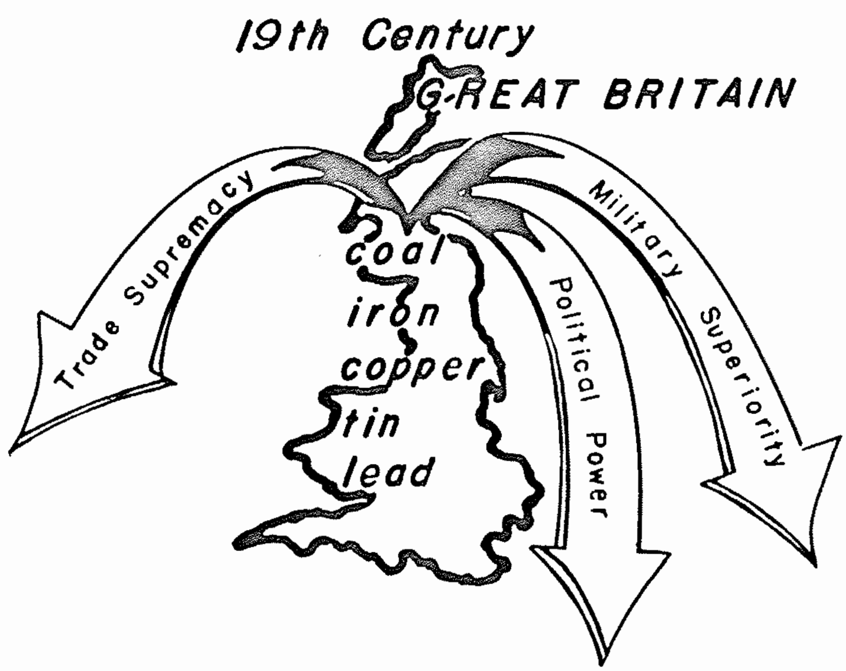
Now, as always, agriculture is the basic industry. But a wholly agricultural economy imposes sharp limits on division of labor and the increased productivity that this allows. As transport improved, first with iron rails and then with locomotives and steam-driven ships, a specialization formerly unknown made possible tremendous savings in labor. By 1830 a 12 year-old girl operating a machine loom in a Lancashire mill could turn out 35 yards of calico daily--in a year enough to clothe about 1200 persons.

Now the facts I have just recited are commonplace and generally accepted. But what is not so widely understood is that all these changes in living standards--the fruits of the division of labor--and the industrial revolution itself depend ultimately upon the world's diminishing and non-replenishable mineral resources.

Throughout history mineral resources have played a much greater role than is usually recognized. Today this role is second only to that of agriculture and, in terms of national power, is often first, as it has repeatedly been even in pre-industrial times, though most historians ignore it. The Greeks who turned back the Persian hosts at Marathon were armed with bronze swords and shields while most of the enemy had only leathern shields and stone weapons. The Greek fleet at Salamis was built and its mercenary crews hired by the Athenian profits from the silver and lead mines of Laurium, discovered only a few years earlier. When Scipio drove the Carthaginians from Spain and won for Rome the gold, iron, copper, silver and mercury of that peninsula, he sealed the fate of Carthage.

These are but a few examples from pre-industrial days. Today, mineral resources and national power and well being are even more closely linked. Gold and silver could hire mercenaries and influence military campaigns, but not many useful goods could be created from them; they merely gave control of the few goods then available from one group to another. They still possess this conventional value, but living standards and national power depend only incidentally on them. Much the greater part of the useful goods of the world depend on the mineral fuels and the industrial metals--iron, copper, aluminum, lead, and a rapidly increasing number of others.

It was no accident that Britain was able to maintain the Pax Britannica through the 19th Century. Her industrial and military supremacy came from the happy fortune that her "tight little island" held a greater known mineral wealth per acre than any similar area in the world, together with a population intelligent and aggressive enough to exploit it. It was no accident either, that Britain was the birthplace of geology as a science dealing with mineral resources.



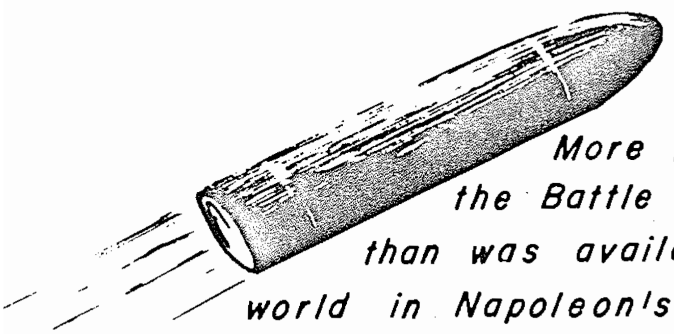
A rise to power following the Industrial Revolution

At one time or another in the 19th Century Britain was the world's largest producer of iron, coal, lead, copper, and tin. From these came her machines, her mills, and the great cities founded on them. Before 1875 she had built more miles of railroad than any of the much larger Continental countries. Her flourishing internal markets and manufactured products carried to all the world by the British merchant marine, brought her the greatest wealth any country in history had ever enjoyed. True, the cheap food stuffs she received in return eventually ruined the island's agricultural economy, but her favorable trade balance enabled British capital to control Malayan tin, Spanish iron, and large segments of the mining industry and oil fields of Mexico, Chile, Iran, Australia, Burma, Venezuela and the United States. These holdings saw her through one World War and maintained her credit through the Second. When her flag followed her mining investments into South Africa and the Boers were defeated, she gained control of more than half the world's production of new gold and diamonds--and ultimately of great deposits of copper, chromite, abestos, and manganese.

Nowhere better than in the United States can be seen the close dependence of living standards and national power upon mineral wealth. Before 1840, manufacturing was inconsequential and only heavy subsidies and tariffs made it possible to compete weakly with the advanced British industries. The small, scattered iron deposits along the eastern seaboard did, it is true, supply enough of the local demand to influence the British Parliament in 1750 to forbid their further exploitation--one of the economic pressures behind our revolution. After independence there was slow growth, but as late as 1850 iron production was only about half a million tons annually. In 1855 the Soo Canal brought the rich Lake Superior iron deposits within economic reach of Pennsylvania coal; by 1860 our iron production had trebled and by 1880 it had passed that of Great Britain.

It was the greater productivity of Northern industry and the weight of arms, supplies and equipment, flowing over its much superior railroad net that were decisive in the Civil War. The Tredegar iron works at Richmond was the only considerable one in the Confederacy--alone it could not begin to compete with the overwhelming output of the Pennsylvania furnaces.

Our huge internal market, our prodigious endowment in all the minerals basic to manufacturing and our favorable agricultural heritage have all contributed to make our country the most powerful in the world at present. During the Battle of the Bulge our troops hurled more metal at the Germans than was available in all the world in Napoleon's day. Cannon and tanks as well as plowshares and tractors, are made of metals and are moved by mineral fuels.



More metal was used during the Battle of the Bulge in World War II than was available in all the mines in the world in Napoleon's time.

It is here that geology becomes important to our economy. Mineral resources are never evenly distributed in the earth's crust. They are sporadic, concentrated in relatively small areas and--most important of all--they are exhaustible. These facts of great social and political implication are often overlooked by economists, historians and politicians.

Mineral deposits of all kinds are essentially freaks of nature. The average rock is no economic source of metals or of fuels. It is the abnormal concentrations that are economic and they are small and commonly difficult to recognize. How small is often ignored. Nearly nine-tenths of the world's nickel comes from less than a score of mines in the Sudbury district of Ontario. A single mine at Climax, Colorado, produces about as large a share of the world's molybdenum from an area of less than one square mile. Nearly 30 percent of the U. S. gold production is from Lead, in this State of South Dakota. Though the mineral fuels are far less localized, they underlie only a trivial part of the continents. Less than 25 percent of Pennsylvania, a leading coal state, is underlain by coal. The East Texas oilfield, the greatest thus far found in the United States, covers an area about 10 X 40 miles--a mere dot on the vast expanse of Texas--yet for several years it yielded about a quarter of the Nation's oil.

The economic implications of this unequal distribution of the mineral fuels are very great. Modern chemistry may be able to make a rayon purse, (perhaps better than a silk one) out of a sow's ear, but only with the expenditure of energy. Today this means mineral fuels, or less importantly, water power. The dreams of many countries of emulating the industrial development of the United States are foredoomed to failure because they lack adequate sources of cheap fuel. It is this fact that explains the tremendous interest of all nations in the prospect of development of cheap atomic power. If such power could be obtained safely--a development still nowhere achieved--the backward economics of many nations might come abreast of that of the United States. Some countries, such as the Scandinavian, have higher educational standards, or, like Argentina, a higher agricultural output per capita than we. But none is so fortunate as the United States in the combination of high average education (and hence a skilled population), great agricultural productivity, and a nearly balanced supply of mineral resources. These give us the greatest industrial development of any free trade area in the world. It will be most interesting to see the effect of the Common Market organization in Western Europe on the production of a like economy in that area, for Western Europe as a whole is well endowed with mineral wealth.

All mineral deposits are limited in extent. They represent unusual associations of geologic factors that have permitted the concentration of one or a few elements to several or many times their average abundance. Once the valuable minerals are extracted from such concentrations by mining, all that is left are holes in the ground. This is the fate of all mines, even of the greatest.

It is true that the mines of Almaden, Spain, have yielded mercury since the days of the Carthaginians and still hold the richest known reserves of this metal. But those great deposits are almost unique. The mines of Cornwall, the Cassiterides of the ancients--supplied tin to the Phoenicians and continued active until a few years ago--in the 19th Century they led the world in production. But now the mines are worked out and the Cornish miners dispersed to spread their traditional mining lore across the earth, far from Britain. The world's greatest single oil well, the Cerro Azul No. 4 in the Tampico field, Mexico, yielded nearly 60 million barrels of petroleum in a few years--then suddenly gave forth only salt water. Neither the old Cornish tin mines nor the Cerro Azul No. 4 will ever yield a new crop--though technical advances may some day permit recovery of some of the lower grade Cornish ores now below the economic limit.

The still fertile valley of the Nile has been the granary of the Mediterranean through most of recorded history, and huge areas in India and China have been farmed nearly or quite as long. The forests of Norway that built the Viking ships still produce lumber. But the mines of Saxony and the Tyrol, where much of economic geology was founded, have long been abandoned. Belgium and Wales, with their cheap coal and metallurgical traditions, are still centers of smelting, but nearly all the metal mines on which these industries were originally based have been exhausted for generations. Potosi, which supplied literally tons of silver to the Viceroyalty of Peru, the fabulous Comstock Lode of Nevada, the Mexican bonanza camp of Pachuca, the copper mines of northern Michigan--none of these are quite dead but they are pale shadows of their former greatness. <u>There is no second crop of minerals</u>. And lest the meaning of this statement--economically, politically and socially--be overlooked, let it be noted that more metal has been mined in the last 35 years than in all of preceding history.

There will be no second crop of minerals; all mines are eventually exhausted.

It seems inevitable that a generation hence the world supply of readily available minerals will be so depleted that lower and lower grade materials will have to be exploited at greater and greater costs in energy.

We are now in the period of the greatest exploitation of mineral wealth in the long sweep of history. That we will be able to maintain our present standard of living is by no means a foregone conclusion. Unless tremendous technological improvements can be made, the inevitable increase in the amount of energy required to win a pound of iron, a gallon of oil or a pound of coal must be reflected in a lower standard of living. This is the inescapable consequence of the localization of mineral resources in the earth's crust. Only technological and scientific improvements of a revolutionary nature--such as may be now developing in the use of nuclear fuels, can postpone such a development for more than a few decades. Here is the driving necessity for geological research in the broadest sense.

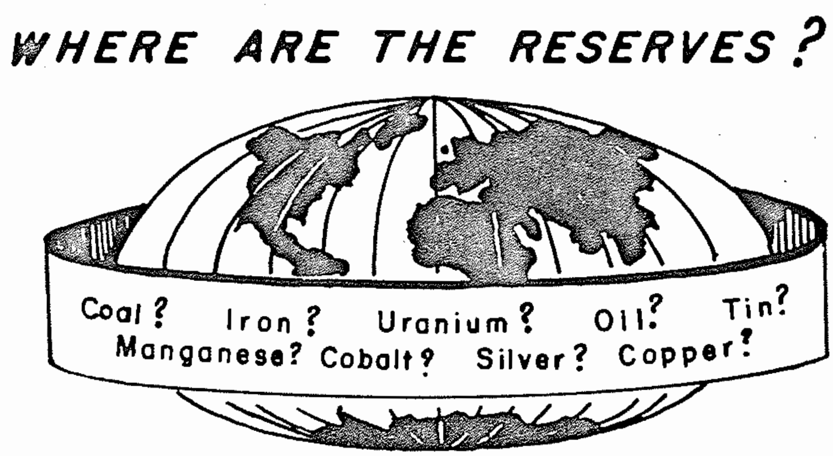
What the exhaustibility of mineral resources means socially can be seen in the long roll of our own Western ghost towns, in which a few families now live where thousands lived before. More dramatically, it is seen in the "distressed" coal areas of England, where although the mines are not, strictly speaking, worked out, the increased costs of deeper mining, of pumping seepage water from greater depths, and of longer hauls from coal face to portal have weakened the competitive position of the mines in world trade. Unemployment, wage-cuts and lower living standards have followed. Only drastic technologic changes can keep costs down.

Although geological conditions make it inevitable that mineral procurement must in the future be more costly <u>in terms of energy</u>, it does not necessarily follow that industrial costs need rise and living standards fall. Many times in the past, technical improvements have made feasible reworking a deposit that had been completely worked out by an outmoded method. Alaskan gold dredges now operate at a profit on placer deposits that contain only a few cents worth of gold per cubic yard--deposits that to the sourdough with his sluice box were exhausted. Similarly most of the world's copper is taken today from deposits that were impossible to exploit by methods in use 60 years ago. We now work copper ores with 14 pounds to the ton at a profit--then we had to have 60 pounds to the ton.

But there are limits to these developments of low grade deposits and it is important to realize that these limitations as well as the sporadic distribution and exhaustibility of mineral resources place upon the mineral industries restrictions that differ <u>in kind</u> from those affecting most other economic activities.

The place of the geologist in this scene is clear. It is our task, as the higher grade deposits are worked out, to locate others, preferably high grade but where these cannot be found, of the next best lower grade. It is our task to locate such deposits, to determine their shapes and character so as to permit plans for their exploitation. The National and State surveys of course do not usually do detailed economic work of this kind, but we did, most successfully, during the uranium shortage--but we have the job of gathering the basic data whose use by industry can lead to such economic developments. Because of past research, when uranium leaped from a mineralogical curiosity to a basic element in national defense, we were able to meet the challenge. No one can be sure when a similar need for another element will arise.

Second, as energy costs are necessarily rising, there is an increasing pressure for substitute materials--for aluminum instead of copper, for example, or magnesium instead of aluminum. It is the geologist's social obligation to locate such deposits of newly demanded substances. We must have a chemical inventory of the earth's crust.



Geologists must make a chemical inventory of the earth's crust.

Third, as technology becomes more complex, wholly new demands are continually arising, elements that formerly were curiosities become essential to industrial use. For example, uranium, thorium, caesium, rhenium, helium, to name only a few of the more than 40 elements now considered essential to our defense effort. They must be found in optimum concentration. To do this job requires much more detailed knowledge than we now have of the geology, mineralogy and chemistry of all parts of the earth's crust. The pegmatites of the Black Hills now yield a half dozen valuable products though on a precarious basis in time of peace. I believe it more than likely that a generation hence they will be exploited for a dozen or perhaps even more products.

Still another aspect of our complex culture demands the economic activity of geologists. With the long history of South Dakota's development of underground water resources it is probably unnecessary to stress the importance of geologic factors in this field. But it is worthy of emphasis that however great we now feel is the pressure on the State's and Nation's water supply, this pressure is certain to become greater still as time goes on. Though many people do not realize it, water, too, is a mineral resource and its effective exploitation demands a thorough grasp of the geologic background.

I could go on at length about the application of geology to our agricultural and industrial life but I turn now to an aspect that I feel is of equal or greater importance: the contribution geology has made and continues to make to the way men think about this world of ours and our place in it.

More than a century and a half ago, when Lewis and Clark made the most important exploration since Magellan--and I have not omitted the much publicized astronaut flights from consideration--Meriwether Lewis collected some bones from a Missouri River bluff about a hundred miles upstream from here. His diary records the bones as those of fish more than 45 feet long. This is the first vertebrate fossil ever recorded from the West. With those dimensions, it was of course not a fish but the first recorded find of one of the great swimming reptiles that ruled the Cretaceous seas that eons ago rolled over the site where we are now meeting.

Lewis' diary records nothing of his thinking about the significance of his find--whether he recognized that the skeleton must have been buried in the soft mud of an ancient sea floor as we now find so easy to accept, or whether he even pondered over the problem. But a few weeks later he found shells which he recognized as those of clams, also embedded in the rocks and in this case specifically interpreted as remnants of marine life.

He did not, of course, call the rocks Cretaceous. In 1804 geology was in its infancy and the name Cretaceous as the designation for rocks formed during a particular geological period was not yet coined. The fact that Lewis' fossil fish and the clams were diagnostic of a time span million of years ago was not recognized for a generation.

The first person to place these South Dakota rocks in the geological time scale was Nicollet, in the early 1840's. He found shells of clams, squid, and other animals in the same rocks and first recognized that their forms were characteristic of those called Cretaceous in Europe.

The patient mapping by thousands of geologists through the past century and a half has placed beyond debate that the rocks record for us an earth history whose gaps are relatively as small as those in most of human history and extending millions upon millions of years into the past.

How many millions of years are recorded in the strata is still a matter of debate, but measurements of radioactive elements such as thorium and uranium and of the daughter products of their disintegration, the various isotopes of lead, are sufficient to prove that some rocks are as much as 3,200 million--more than 3 billion--years old. With more assurance, we can say that Meriwether Lewis' mosasaur was swimming in the salty sea over what is now South Dakota about 80 million years ago, give or take a few million.

The geologic record thus furnishes the strongest support for the most stimulating scientific discovery of the Nineteenth Century and indeed of many centuries: Evolution. Although there are obvious organic remains in much older rocks, the adequate fossil records began about 600 million years ago. Then, in the period geologists call Cambrian, animals with shells of chiton or of calcium carbonate became abundant and the fossil record clearly legible.

From Cambrian time to the present the strata of various parts of the earth when taken all together show a nearly complete record of systematic changes in the fossil assemblages. The trilobites that first appear in the oldest Cambrian became widely diversified in the next hundred million years but then they failed to keep up in the competition. By about 200 million years ago they had died out. The first fossils of back-boned animals are from rocks 500 million years old. These beasts began to live on dry land about 500 million years ago. The first mammals arose about 200 million years ago but the family tree of the primates--the group of which we are the descendants--only about 70 million years ago.

It is of course impossible to draw a sharp line in our ancestral tree and state just where, in the long succession, some of our ancestors became enough different from their contemporaries so that we consider them hominids and their contemporaries protoapes. The best modern information is that the split occurred a million years or so ago, give or take a couple of hundred thousand.

You will note that all the dates I have mentioned are approximate--probably the very best radiometric dating we have should be understood as plus or minus 5 percent. The wider ranges I have given are because our dating is always of specific fossils or of specific events, necessarily singularities in a continuous history. In the nature of inheritance, many generations may have lived and died while racial divergences were developing before these differences became great enough to allow us to distinguish two species.

The fact, then, that our dates are tentative, should not lead to the conclusion that the history is incorrect or uncertain. I think, for example, that if every written record were expunged it would be possible for an archeologist to prove that we had a civil war and that the South lost it, even though the date he deduced from the archeologic remains might be in error by a generation or so. Just such deductions as to Egyptian history have been later confirmed in the records that the Rosetta Stone enables deciphering. So it is with the geologic record. What happened and in what sequence, although it is based on circumstantial evidence, is none-the-less firmly established. As Thoreau said, circumstantial evidence is generally more convincing than other kinds, as for example, when one finds a trout in the milk.

The long succession of changing faunas recorded in the geologic column constitutes the strongest chain of evidence in support of the reality of evolution. When Darwin first offered the suggestion that man, like all other organisms, is the product of evolution, it was possible to consider the proposal as that of a somewhat rash zealot or as a mere statement of faith--so many were the gaps in the record as it then existed. The missing links in the chain were indeed abundant and the gaps in the record very great. In the 90 years since this suggestion, though, continuing research has shrunk the gaps and enriched the evidence. Instead of emphasizing the gaps in the evolutionary progression between man and the other primates, as a result of recent studies in South Africa the paleontologists are embarrassed with riches. Was this small skull associated with tools and with bones that indicate an upright posture, the skeleton of a man or of an ape? Or was that other skull with much greater braincase, the relic of a parallel or of an older race? There are of course still lacunae in the record but where so many gaps have been reduced by the finding of intermediate forms, the old argument about "missing links" in the descent of man no longer has any standing in logic.

We must conclude then that geology teaches important things about the world in which we live: First, it is a very old world indeed, with an age probably as much as five billion years and certainly over three billion. Second, in the last billion years and perhaps longer, the conditions on the earth were not radically different from those of the present day--perhaps a little colder at times, so that the glaciers advanced into lower latitudes (far south of Vermillion), perhaps a little warmer at other times so that the ice caps of Greenland and Antarctica melted, but during all the thousands of thousands of thousands of years there was a sea (even though not always in the same place), the atmosphere had about the same ratio of oxygen, nitrogen and carbon dioxide, and the ozone absorption in the upper atmosphere was about the same as now. Had these conditions varied greatly, life could not have evolved so systematically and the strata would record geologic processes differing in kind--not merely in degree--from those now going on.

It gives one a feeling that perhaps conditions will go on much the same in the near future and even in the far distant future. But I will return to this in a moment.

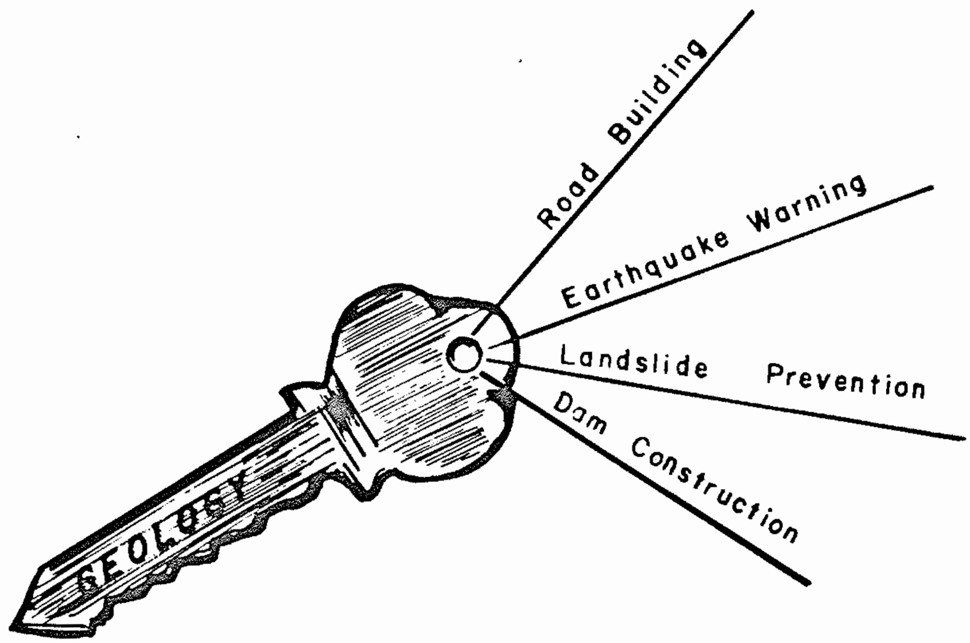
The third lesson of geology is that we are the surviving products of evolution through a tremendous history--a history in which, for every species now living literally thousands have existed in the past, either flourished or maintained precarious livings and then perished, never to reappear. Nature's trials and errors have resulted in the vast variety of today's creatures. There is no reason to believe that man has ended his evolution--perhaps our descendants will evolve into superior humans, perhaps the species will die out as we threaten suicide with hydrogen bombs. The one thing we learn from the geologic record is that the chances of an unchanging racial character are completely negligible. We are part of an evolving organic complex and cannot allow ourselves to think otherwise. If we have descendants a half a million years hence, they will not look like us. Let us hope they can think and live together better.

I return now to my second point. The geologic record of constancy of general earth conditions is unequivocal for the last billion years. But the record of continual change in land and sea, the place and height of mountains, in the location and disappearance of deserts, volcanoes, glaciers, and seas is equally definite. If the present rate of erosion were to persist unchanged on a rigid earth all the lands would be reduced to sea level in about 20 million years. But there have always been streams and storm waves wearing away the lands--obviously some internal process is either continuously or sporadically uplifting new lands, creating new mountains. In other words, we live in a world of constant change, of fluctuating equilibrium between the forces of degradation by rain, ice, wind and running water, and the internal forces in our still energetic globe which act to counteract these leveling agents.

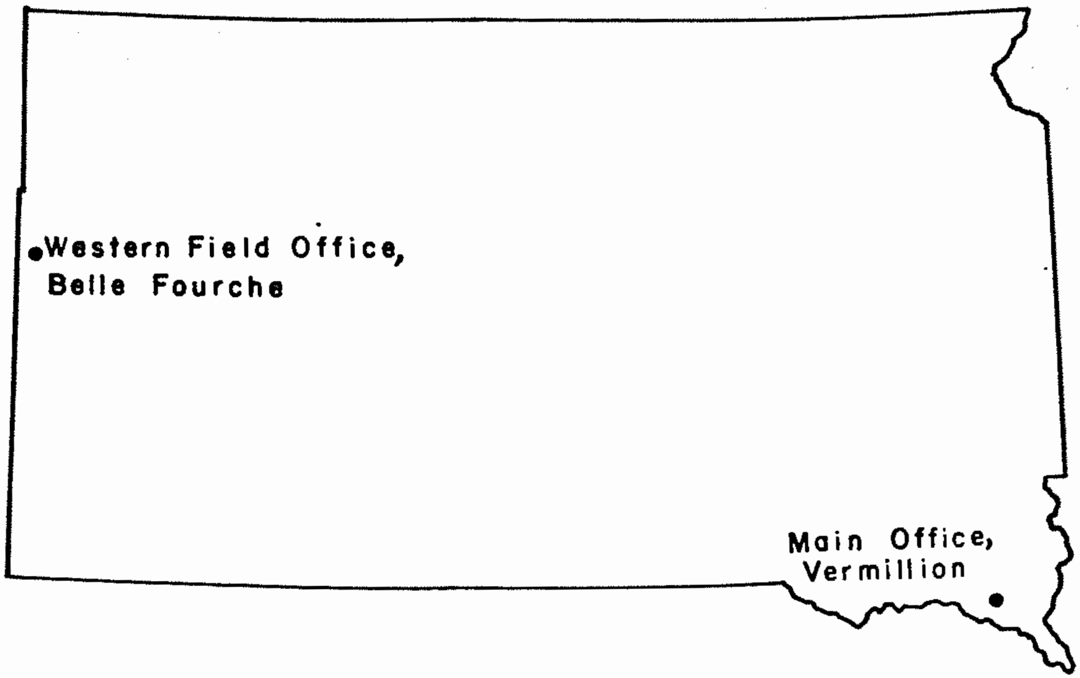
On a shorter time scale, too, we read the geologic record of wide fluctuations--often 10,000 per cent--in stream discharge in a single day, from absolute volcanic quiescence to the explosion of a cubic mile of pumice from a volcano in half an hour. From the quiet uplift of Sweden at a foot per century, to the jump of Disappointment Bay, Alaska, of 42 feet in 10 seconds. In other words, the phenomena we recognize as active are not uniform in rate. The levees that control the ten-year flood may make the destruction of the hundred-year flood almost astronomically larger than it otherwise would have been. The Big Sioux River flood of a few weeks ago, because it did not coincide with one in the Missouri, caused the stream regimen to change more in a few days than it had in a century and a half.

This again is a viewpoint that I feel sure all too few engineers are alive to--the changing world of geologic history is still with us and many of man's works, in attempting to control natural processes, are planned on too short a time scale.

Geology thus teaches us of the great antiquity of our globe and of the life upon it. It teaches of a persistence of conditions much like those of our own day. But quite as insistently, it teaches that the "everlasting" hills are not everlasting, that the mountains wear down to the level of the plains and must be rebuilt either by renewed uplift or in new sites. Ours is a world always much the same but always changing. We cannot hope permanently to preserve the natural scene as it is--it should be the service of geology to make these facts part of the thinking of all who deal with nature and the control of natural forces. Whether the control of soil erosion, of river floods, storage dams, irrigation canals, or water pollution.



It should also be a part of our thinking that on this earth, billions of years old, yet still endowed with the internal energy literally to raise the mountain ranges and to displace the seas, on whose surface the rains, the winds, the waves and the streams are forever carving out new forms, we are the currently dominant product of the stream of life--life that has been evolving for a billion years and of which we are the first species that holds within its power the ability to control the next act in the scene. Can our society evolve quickly enough to prevent our joining the dinosaurs as an extinct species? Or must we fail, as billions of species have done in the past? The placing of man in nature as the culmination of so long a history is the contribution to man's thinking that geology has made in the last three generations. It is a picture that to many of us fires the imagination. It gives us a sense of responsibility to society as it now is, and a dedication to the welfare of the surely different societies of the generations of the future.



Offices of the State Geological Survey of

South Dakota

This booklet is the first in a series included in the educational and public service programs of the State Geological Survey of South Dakota. The staff sponsors field trips and lectures for student groups.

Educational Series Books —— 25 Cents each.
Mail Orders accepted at the Vermillion Office.