R.A.F. Penrose Jr.

EDITOR'S NOTE:

Richard Alexander Fullerton ("R.A.F.") Penrose Jr. (17 Dec. 1863–31 July 1931) was an American mining geologist and entrepreneur. He served as the president of GSA in 1930, but perhaps his greatest contribution to the Society was his generous bequest of nearly US$4 million upon his death in 1931. His bequest continues to support GSA's research grants program and other efforts of the Society. Many say that without this bequest, the Society as we know it would not exist. For example, income from the fund enabled GSA to purchase the land it now occupies on what is aptly named "Penrose Place" in Boulder, Colorado, USA.

Penrose earned a Ph.D. from Harvard in 1885. He performed geological surveys in Texas and Arkansas until 1892, and then traveled the U.S. as a mining surveyor. Most notable was his survey of Cripple Creek, Colorado, for the U.S. Geological Survey.

After his father died in 1908, Penrose made a complete career change, using his knowledge as a mining geologist to succeed as a mining investor and as an entrepreneur in other areas as well. Penrose refrained from purchasing or investing in mines in the Cripple Creek area because of what he saw as his ethical responsibility as a USGS employee, but did purchase and invest in mines elsewhere, including silver and copper mines in Arizona.

Having amassed considerable wealth in these efforts, Penrose established the Penrose Medal of the Geological Society of America (GSA) in 1927, a top honor accompanied by a gold medal. Penrose was very active in GSA: he was elected as a member in 1889, served on GSA Council from 1914 to 1916, was GSA vice president in 1919, a member of the Finance Committee from 1924 to 1929, and GSA president in 1930.

Penrose's 1930 Presidential Address to the Society was published in the 31 March 1931 issue of *GSA Bulletin* (v. 42, p. 393–406) but has not been easily accessible in print and online until now. A transcription of text of that article is reproduced in the following pages.

Note: This information was drawn from the 1982 GSA Memoir, *The Geological Society of America: Life History of a Learned Society*, edited by Edwin B. Eckel (Memoir 155, p. 14–24).

Geology As An Agent In Human Welfare[1]

CONTENTS

INTRODUCTION

From the earliest times in human history the economic and industrial activities of man have been changing the natural features of the earth's surface in many different ways, such as by constructing dams, by diverting tunnels, by mining, by draining oil from the rocks containing it, and in many other ways modifying the natural course of geologic processes.

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Much has been written concerning this material influence of man on the earth, but the opposite effect, that is, the influence of the earth on man, has received much less attention; and yet from primitive times it has been active. It seems proper therefore to note the action of geologic phenomena on man throughout the ages in which he has existed. These influences may be either beneficial or detrimental to man's welfare; they may advance his physical and mental development and his grasp on life, or they may form obstacles in his progress, and at times threaten his very existence. Though periods of slow development and even times of retrogression have occurred in human history, yet throughout the ages as a whole the change, especially in mentality, has been forward, and indicates that man has been able to adapt himself to such geologic surrounds he has had to meet.

RELATION OF GEOLOGY TO PRIMITIVE MAN

The earliest well authenticated remains of human life as yet known are in late geologic times, in the Pleistocene Epoch, during the last Great Ice Age, and in what is known in prehistoric archeology as the Paleolithic Period of the Stone Age; but man or his predecessors may have been active among the animal life of the earth before those times.[2] The Paeolithic [*sic*] Period was characterized by the use of flint, chert, jasper and other materials of a flinty character, susceptible to being chipped into sharp-edged weapons or fashioned into other utensils. Ivory and bone were also used in a similar way, while various hard rocks, such as granite materials, were often used for axes and heavy weapons.

Paleolithic man was a dweller in caves and other shelters formed by geologic action and is often referred to as the cave man. Had it not been for these retreats together with his flint and stone weapons, he might not have found protection from the elements and from his enemies in the form of other animals; and hence some of the early human races might have disappeared on account of the lack of assistance offered by geologic agencies.

In the caves together with the remains of Paleolithic man occur in different places those of the reindeer, the mammoth, the cave bear, the fox, the wild horse, the bison and other animals, mostly of forms now extinct. Drawings and paintings on the walls of caverns, as well as ivory carvings, indicate a degree of art among these primitive men which suggests an advance from a possible former less developed condition.

Previous to the Paleolithic times, in the Prepaleolithic or Eolithic Period, flint and other fragments chipped in a manner to suggest a crude human handicraft, are often found in alluvial or subaerial deposits. Such materials frequently occur in formations much older than the Pleistocene and even the Pliocene Epoch or earlier times. Many archeologists doubt their connection with mankind, while others believe that some of them at least are true artifacts. However this may be, it is a recognized fact that some undoubted artifacts occur in older geologic environments than those in which human bones have yet been found, and this suggests that the bones of remote primitive man who made them have decayed and disappeared, while his more resistant flint and stone implements remain intact.

Among the oldest human remains as yet known is a fragment of a lower jaw found in an alluvial deposit at Mauer near Heidelberg, Germany (*Homo heidelbergensis*) and supposed to belong to the beginning of the Pleistocene Epoch. This fragment as well as parts of a human skull found near Piltdown in Sussex, England (*Eoantrhopus dawsoni*), are usually accepted as the two most ancient evidences of human life as yet discovered. A more complete skull, but vastly later date in the Pleistocene Epoch, was discovered in a cave in the valley of Neanderthal near Düsseldorf, Germany, and represents what is known as the Neanderthal man (*Homo neanderthalensis*). Somewhat later a complete skeleton of a similar human being was found in a cave near le Moustier, France.

[1] Read before the Society on 29 Dec. 1930; manuscript received by the Secretary of the Society on 9 Jan. 1931; originally published in *GSA Bulletin* on 31 Mar. 1931, v. 42, p. 393–406.

[2] The present discussion relates to only distinctly human primates, as distinguished from what in remote times may have partaken of the character of both the anthropoid ape and man, such as the remains of the so-called ape-man (*Pithecanthropus erectus*) found near Trinil in Java.

Human remains and implements resembling those found with the Neanderthal or Mousterian man, have also been discovered in many other places in Europe, North Africa, Arabia, Asia Minor, China and elsewhere. He seems to have thrived particularly during periods of recession in the several alternating advances and retreats of the Glacial Period, when the milder climate favored his development. He did not make pottery and did not use metals; he had no cattle or other domestic herds; he was a hunter living by the chase.

The Neanderthal man was succeeded in the latter part of the Paleolithic Period and the beginning of the Neolithic Period of the archeologist by other races among whom the flint and other stone implements derived from geologic sources were more carefully finished and polished than in the preceding period. The Aurignacian, Solutréan and Magdalenian man thrived in these times. Copper implements made their appearance. Man began to emerge from caves, except where convenience made them desirable, he built shelters in the open, made pottery, and gathered together herds of cattle. Signs of civilization began to appear, and with it came the more and more modern races of man (*Homo sapiens*).

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The caves which gave protection to primitive man depended largely on the character of the geologic formations which permitted the creation of these and other shelters. They were formed in many ways, but mostly in calcareous rocks through which surface waters impregnated with carbonic acid gas from the decay of vegetation percolated into cracks in the rocks, and by their solvent action created openings varying from small cavities to larger caves, and frequently to great caverns. They are common throughout the world wherever limestone or other calcareous rocks exist. They often provide the early man not only with shelter but with water, for many such caves have springs or running streams within them; and sometimes they supplied him with food in the form of other animals which also had sought refuge there.

Caves which may at times have afforded shelter have also been formed by the beating of the sea on the rocks adjacent to the coast. This has occurred not only in limestone but in sandstone, granite, basalt and other materials which during the ages have succumbed in spots to the constant wear of the waters. In later times some of these coastal areas have been elevated, and the caves are found high up on the land. Other less frequent geologic influences may also have provided similar refuge for primitive man.

In North America caves and great caverns occur in many places, but they do not seem to have been used permanently as dwellings to the same extent as in Europe and Asia. The human remains sometimes found in them seem to be there as a result of accident or temporary habitation. This may be due to the fact that the ancestors of the American Indian when they migrated to this continent had reached a stage in civilization that enabled them to construct their own habitations without resorting to the primitive shelters of caves.

The cliff dwellers in the southwestern part of the United States and in Mexico represented in a certain way a class of cave man, inasmuch as their habitat was in the rocky cliffs of canyons, but they were of comparatively recent date, and in no way connected with the cave man of the Stone Age of Europe and Asia. Many archeologists believe that they date back only from several hundred to a few thousand years. They seem to have been an early part of the great family of Pueblo tribes which now inhabit the open country in the same neighborhood as are found the remnants of the old cliff dwellings.

These dwellings were sometimes in caves in the faces of cliffs, or were artificial structures built by man on shelves of rock in similar localities, or were combinations of both. Some of the caves were enlarged by man into capacious dwellings or even underground villages. Flint instruments and utensils are numerous, as well as bows and arrows, pottery, baskets, personal ornaments and other decorations, many of them unlike those made by the modern Pueblo tribes.

The cliff dwellings were used not only as shelters, but also for the storage of corn and other products of the field, as well as for religious ceremonies and for burial places. They are mostly high up on the cliffs, several hundred or a thousand feet above the lowlands, though some are down near the water level. The cliffs themselves consist of a great variety of rocks, including sandstone, various calcareous materials, shale, basalt and eruptive tufa.

Though we thus see that the cliff man had no relationship with the cave man of primitive times, yet his preservation, or at least his protection, was due to similar geologic conditions of environment, which supplied not only a shelter but flint and other materials for his utensils, and rock for the buttressing of his habitations.

EFFECT OF VOLCANOES ON MAN

Volcanic action has always had a marked effect on man and his destiny. It has generally been of tragic character, due to the sudden upheaval of volcanic materials and the destruction of human life and property, but often its after-effects have been beneficial to human welfare in returning desirable materials from great depths to the surface of the earth.

Volcanoes occur in many parts of the world, being particularly abundant in the regions of the Pacific Ocean. In the Malay Archipelago they are so numerous and enormous that it has often been called "the rookery of volcanoes," while elsewhere through the Pacific regions they are abundant not only on the land, but especially on the sea bottom. In Mexico, Central and South America, the West Indies, in Iceland, Europe and many other parts of the world they are among nature's most spectacular manifestations of unrest.

Mount Vesuvius has been studied in its eruptions for almost 2,000 years, and hence its history gives us more enlightenment on the effect of volcanic action on man than other regions where eruptions have only been investigated in later periods. Until the first century of the Christian era Mount Vesuvius had been considered an extinct volcano and had been inactive during historic times, so that the neighborhood with its salubrious climate and wonderful soil had become thickly populated.

About the year 63 A.D. numerous slight earthquake shocks were felt in the vicinity of Mount Vesuvius and these gradually increased until without warning, in the year 79 A.D., Mount Vesuvius itself broke out in a more violent eruption than it has

ever developed in later times. The materials thrown out consisted mostly of volcanic ashes and dense clouds of steam and gases. The ashes overwhelmed the cities of Pompeii and Herculaneum and other places, and so sudden was the upheaval that many of the inhabitants were suffocated and buried in the volcanic materials. It is probable, however, that the loss of life was not so great as first believed, and we know from the letters of Pliny the Younger, that a large part of the population fled to the sea at the first dreadful shock of the outburst, and thus escaped the annihilation which befell those who were more tardy.

The uncle of Piny [*sic*], known as Pliny the Elder, a noted naturalist of his time, was then in command of the Roman fleet in the waters of that region. As soon as the volcanic outburst began he put into shore to rescue the refugees, but was overcome by fumes and ashes and died like many of his countrymen. The younger Pliny describes the occurrence in a letter to the Roman historian Tacitus, and tells how he himself refused to leave the shore because he wished to save his uncle, but when convinced that this was impossible, he led his mother and others out of the danger zone.

In other regions than Mount Vesuvius even greater catastrophes have befallen humanity as a result of volcanic action. In Iceland, in the year 1783, a tremendous eruption of the volcano Skaptar is said to have destroyed about one-fifth of the population of the island by the direct results of the outbreak and the famine which ensued. Even more loss of life and property has occurred in the great volcanic eruptions in the Malay Archipelago and other places, but their historic records are less definite than in the countries which have been longer studied.

The foregoing remarks have described only the disastrous effects of volcanic action on mankind; but there is another and more cheerful side to the problem.

In 1722 the volcano Papandayang in the Malay Archipelago broke out with such force that the upper 4,000 feet of the cone are said to have been blown off and thrown broadcast, destroying over 40 villages. The most enormous eruption known, however, was that of the volcano Tamboro on Sambowa Island, near Java, in 1815, when actually many cubic miles of material are estimated to have been thrown into the air, destroying life and property throughout the region, while the clouds of the ashes and gases obscured the sky for hundreds of miles distant. In 1883 the volcano Krakatoa in the Strait of Sunda, between Sumatra and Java, broke out in an enormous eruption throwing ashes to great heights and over vast areas. The atmospheric disturbance was felt around the whole world, and the seismic waves accompanying the eruption overwhelmed the coasts of Java and Sumatra, causing great loss of life. The volcanoes of the Hawaiian Islands are frequently in active eruption, and the spectacular outbreak of Kilauea in 1924 is well known to all of us, while Mauna Loa, the greatest of all Hawaiian volcanoes in size, is noted for the frequency and vastness of its lava flows.

The foregoing remarks have described only the disastrous effects of volcanic action on mankind; but there is another and more cheerful side to the problem, and that is, the beneficial effects. It has often been asked why the agricultural populations around Mount Vesuvius and Mount Etna, after being driven from their abodes and after their villages and vineyards had been destroyed, have almost always returned when an eruption subsided. One reason for this is the natural reluctance of people, particularly in Europe, to forsake the salubrious climate and rich soil which have in previous days rendered them prosperous and happy; but a particular reason is that the materials composing volcanic ash and lava are remarkably rich in fertilizing substances, such as phosphates and various other salts of calcium, sodium, potassium, iron and other elements important to vigorous plant growth. In the warm, moist climate of southern Italy and Sicily the volcanic ash and lava rapidly disintegrate and the fertilizing constituents are set free, thus creating a soil often far richer than the one that had preceded it, which may have been more or less exhausted by continuous cultivation for generations.

The disintegration of lava on Mount Etna is often artificially assisted by encouraging growth of a large native cactus which rapidly takes root in the cracks and fissures of the rock and by its expansive power tend to disintegrate it and hasten its decay. On both Mount Etna and Mount Vesuvius the stone quarries worked on the hard lava form an additional source of income to the owners of the surrounding vineyards. Hence we find that the inhabitants of these volcanic regions flee in terror when eruptions occur and destroy all they own, but respond to the lure of the old home and return full of hope, with a knowledge that future prosperity awaits them.

Volcanic eruptions also restore enormous quantities of carbonic gas to the atmosphere, and thus replace that which has been absorbed by plant life and certain animal organisms. They also raise from deep-seated sources large quantities of water, often in the form of vapor, and thus return it to the surface.

In early historic times volcanic eruptions were regarded as something mysterious and uncanny, suggesting that the end of the world was approaching, or that the gods were angry, or that something altogether mysterious had occurred. In the flight of the population from Pompeii during the eruption of 79 A.D., the general outcry of the people was that there were no more gods, for they and the earth and its inhabitants were headed direct for everlasting ruin. In later times, however, man began to investigate volcanic eruptions in a more self-composed manner, and the modern scientist who has devoted himself to volcanism has shown that they are purely local manifestations which can even in some cases be anticipated.

EFFECT OF EARTHQUAKES ON MAN

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They occur in many parts of the world, in Europe, Asia, Africa, America and elsewhere, but are most notable in the region of the Pacific Ocean. Though they attract particular attention on the land, yet a far larger number occur on the sea-floors, especially in

the Pacific, the West Indies region of the Atlantic and elsewhere. These submarine earthquakes often give rise to immense waves, popularly known as tidal waves, which however, have no connection with the tides. They are caused by sudden changes in the level of the sea-bottom, which either force vast volumes of water upward, or let similar quantities downward, in either case transmitting their motion to the surface and thus creating immense waves. The so-called tidal waves therefore are well termed seismic waves, as indicating their origin in seismic disturbances. They often roll onto the adjacent land, causing as much devastation as if the earthquake had occurred on shore, and sometimes more.

The destructive aspect of earthquakes has been manifested in many great seismic movements which have become records of horror in the history of human fatality. Among some of those familiar to most of us may be mentioned the great earthquake at Lisbon in Portugal in 1755 followed by an overwhelming seismic wave whereby the city was reduced to ruins, with the loss of 30,000 or 40,000 people. In Japan numerous earthquakes have occurred, and in fact most of that country is in a constant condition of greater or less vibration. The last of its great outbreaks was the terrible catastrophe of 1923 at Tokyo and Yokohama, in which 100,000 lives are supposed to have been lost. Almost equally disastrous earthquakes have occurred in many other places.

In regions closer to our home may be mentioned the series of earthquakes in 1811 in the Mississippi Valley, about 50 miles below where the Ohio River enters the Mississippi. The principal disturbances were near New Madrid, Missouri, but others also occurred on the east side of the river in Kentucky and Tennessee. In places the land sunk many feet, and for brief periods the Mississippi actually flowed backward in its course as a result of the collapse of its bed. The disastrous earthquake at Charleston, South Carolina, in 1886, is well known to many of us, and both it and the Mississippi earthquake were in regions where earth movements of such magnitude did not seem probable.

The great earthquake of California on April 18, 1906, was of all others in America in historic times prominently notable in its extent. The movement followed for some 270 miles or more a great fracture zone extending along the coast. It was mostly horizontal and the displacement varied from a few inches to over 20 feet. Fences, fields and roads were thrown out of line. In San Francisco the water mains were broken, and a large part of the city was burned from lack of water to quell the fires which started in many places. Here, as often in other earthquake disasters, the loss of life and property was due not so much to the earth movements as to the fires which were started as a result of them.

It has generally been found that the greatest destruction by earthquakes occurs in soft ground, either of an alluvial character, or such as is made in cities by filling up hollows with debris of various kinds, and known as made ground; while on the higher land, particularly on the rocky parts, catastrophes are much less severe. This is doubtless due to the fact that the amplitude of vibration in an earthquake movement is much less in solid rock than in loose material, so that a structure built on a mountainside may be only damaged, while one built below on soft material may be reduced to ruins. This feature was particularly noticeable in the earthquake at San Francisco in 1906. The principal destruction was on the water front along the Bay of San Francisco, while higher up on the hills where residences were built on rocky foundations the earthquake itself produced much less damage, but the fire which followed the earthquake spread death and destruction in both the lower and the upper parts of the city.

The earthquake of Valparaiso, Chile, on August 16, 1906, only a few months after the California disaster, extended along the coast for some miles; and as in San Francisco, the greatest destruction was caused in the soft or made ground along the water front of the bay, while the structures on the hills back from the lower city were much less injured. The lower city was almost completely destroyed, and when the speaker visited it shortly after the earthquake, efforts to restore it had only begun. The estimate of the people killed varied from 4,000 to 7,000.

On a hill but little above the lower city in Valparaiso, a large cemetery was located where graves were thrown open and great numbers of coffins hurled down the hillsides into the streets below, causing fear and panic among the people, who thought the time of resurrection had come. The keeper of the cemetery is said to have gone insane at the sight. Rain was falling in deluges at the time, with much thunder and lightning, so that the scene was indeed terrifying to everyone, and even at the time of the visit of the speaker but few people would discuss the situation which had left such a lasting impression on their memories.

Mention might be made of many other earthquakes which have taken their toll of life and property, and have had a lasting and painful effect on those who survived; but just as a volcanic eruption, the scientific study of their nature has to some extent abated the feeling of terror and helplessness which they inspire. In earthquake regions man is learning to reduce the danger by selecting proper locations for buildings, suitable materials for their construction, and above all, by the endeavoring to provide water supplies that may survive earthquake shocks and thus be used to quell the fires which cause more loss of life and property than the seismic disturbances themselves.

EFFECT OF ALLUVIAL DEPOSITS ON MIGRATION OF MAN

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In the upper course of a river the current may be swift enough to keep the channel clear of the lighter sediments, but in its lower parts the waters may move more sluggishly as they pass through a lower country before they enter the sea; and hence the sediments instead of being entirely carried on sink partly to the bottom of the river. This constant accumulation of silt gradually raises the level of the river bed and the waters overflow, often spreading over vast areas and depositing a rich alluvial soil wonderfully adapted to agricultural purposes.

Hence from prehistoric times large communities have grown up along the lower parts of many rivers, especially on the broad deltas

at their mouths, and thus these alluvial regions have often been important geologic influences in the early migrations of man. Among such regions in Europe may be mentioned the thickly inhabited deltas of the River Po, the Danube, the Rhone and other streams, while the enormous delta lands of Africa and Asia are preeminent in size and historic interest, notably those of the Nile in Africa, and of the Euphrates, the Tigris, the Indus, the Ganges and the Brahmaputra in India. The great alluvial region in ancient Mesopotamia and Babylonia, lying between the Euphrates and the Tigris rivers, was once so widely populated that it was known as the cradle of civilization. It supported many ancient cities, such as Nineveh, Babylon, Nippur, Ur, Bagdad and numerous other once prosperous communities.

One of the greatest delta lands in the world is that of the Yellow River, Hoang-ho, in eastern China, which from remote ages has supported a vast population.

Though the streams which have formed great alluvial plains have at times brought happiness and prosperity to the inhabitants, yet they have only too often also brought great loss of life and property. Where agricultural communities and other settlements have grown up embankments have been made to restrain the river floods; but as the sediments continue to settle and the river beds continue to rise, the embankments have to be built higher and higher. Ultimately in time of high water the embankments may be broken down and the surrounding lowlands may be subjected to great floods. Hence the efforts of man to confine rivers to definite channels and thus to reclaim for agricultural purposes the fertile floodplains which were nature's provision to accommodate the excess water when the rivers rose, have often been accompanied by great catastrophes.

When the floods subside, however, the breaches in the embankments are often repaired, the people return and agriculture proceeds as formerly. This process of reconstruction is often repeated time after time as new breaches occur, and thus a somewhat precarious but highly lucrative agriculture is continued often for ages.

The frequent floods in the lower Mississippi River illustrate such occurrences. The first embankments or levees near New Orleans, about 150 years ago, were some 4 feet in height, but as the river bottom rose they had to be built up several times that high. The levees have been extended northward up the Mississippi River for many hundreds of miles and throughout this great distance numerous breaks frequently occur. Hence the disastrous floods and loss of life and property in the Mississippi Valley which shock the country at frequent intervals.

In other lands many similar results have attended attempts to confine rivers to narrow channels and prevent them from overflowing their natural floodplains. The River Po in Italy has been embanked for so many centuries that its bottom is many feet higher than the surrounding lowlands, and disastrous floods have at times followed breaks along its course. In China the Hoang-ho has often broken through its embankments with enormous loss of life, and many of us can remember the great flood of 1887 along this river, in which more than a million, perhaps several millions, of people were lost.

In ancient times in other parts of the world, many of the old embankments were abandoned and are now found only in a condition of decay. Their history of disaster is lost in the vagueness of bygone ages.

INFLUENCE OF MINERAL AND OTHER GEOLOGIC PRODUCTS ON MAN

The mineral products of the earth have probably been of more material benefit to mankind than any other single geologic influence. Even the men of the Stone Age were careful to open quarries where the best flints for their implements could be found. The character of different flints was closely inspected, and in fact this material was in many ways to primitive man what iron and steel are to modern man.

During the latter part of the Stone Age and following it, weapons and utensils of copper made their appearance among prehistoric man. Still later came the use of bronze and this was followed by the Iron Age, in which a greater impetus to human welfare than in all previous times started and still continues to be a dominant factor in man's progress.

The beginning of the use of copper, bronze and even iron is involved in greater or less obscurity in different localities, and doubtless the use of each was dominant at different times in different parts of the world. In fact flint or stone implements were often used by backward races after others had long since begun to make implements of metals. In Neolithic times copper began to be used before flint was discarded. The advent of the use of metals, however, has always supplied the necessary element for rapid human progress; more things, greater things and quicker things were accomplished by the use of metals than by the flint and stone implements of primitive man.

The modern age includes both the use of iron and of many other metals, so that we exist in a time which though preeminently one of iron, is also marked by extensive use of copper, lead, zinc, gold, silver, nickel, aluminum, tin and many other metals, while to these must be added the numerous alloys, such as brass and bronze, which are made from them. Hence the present times are characterized more by human handicraft in fabricating metals than by the use of any one of them, and may well be termed preeminently the age of manufacture.

Present times are characterized more by human handicraft in fabricating metals than by the use of any one of them, and may well be termed preeminently the age of manufacture.

To the metals now used must be added other materials of geologic character which have advanced human welfare, such as natural fuels, including coal, petroleum and gas, without which the efforts of modern man and his accomplishments would have been much retarded. We must also consider the stone for structural and ornamental purposes, and many other geologic materials which have affected human welfare, such as soils, springs and water supply, and the rapidly increasing and enormously important use of waterfalls and other moving waters in generating power.

Space does not permit a full description of the mode of occurrence of these geologic products, nor of the details of many other similar subjects that come close to man, but well can it be said that while the man of primitive ages developed only slowly in great periods of time, yet through the utilization of metals and other geologic products and geologic conditions, mankind in a

vastly shorter time changed from a savage living solely by the hunt to the civilization of ancient historic times, and thence to that of the present day. In the Stone Age his efforts were engrossed in a struggle for existence against the elements and the wild beasts that surrounded him; today, with his actual existence assured against these dangers, his efforts are devoted to constructive endeavors and to defending himself not against the beasts of the forest, but against the ferocious attacks of the hostile elements of his fellow man.

CULTURAL VALUE OF GEOLOGY

A knowledge of at least the general principles of geology is an important part of any liberal education and is essential in many scientific, literary, artistic, engineering and other pursuits of the present day. Nevertheless geology was the last of the great fields of research in natural history to receive scientific attention. Biology was well developed before the basis of geology on which it was founded received recognition. This was doubtless due to the fact that animal and plant life were more immediately noticeable to the casual observer than the nature of the rocks below, and thus scientific study began on the surface objects which attracted most attention; but as the spirit for research increased it tended to seek deeper and deeper below purely superficial manifestations, and thus revealed geology. Until the beginning of the last century the science of geology in its modern interpretation was hardly recognized as more than the vague conception of a few dreamers; today it demands the attention of the world as the basis of all human knowledge of natural history.

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Those who have a knowledge of geology have a vast educational advantage over those who have none, for to them every continent, ocean, river, mountain, valley and even every creek, field or sand bank, has a meaning, which greatly increases their interest in the observation of nature. To the man who has no geologic knowledge continents and oceans mean only land and water, valleys and mountains mean only hollows or elevated spots on the ground, and the various minor details of the earth's surface are looked on indifferently as things that occur as a matter of course, and may be convenient or objectionable, according to his line of thought.

The geologist interprets his science in a form that makes clear the dependence upon the earth of man and his best attainments in civilization, and he realizes the fact that the problems of human life and living are bound up with the problems of geology. Geologic history and the great records of evolutionary processes which it embodies not only in physical and biological aspects, but in psychological, social and economic lines, carries a wealth of instruction unequaled in any other field of learning. As geology becomes rounded out to a still greater fulness [*sic*] it will teach the world profound lessons in the evolution of the highest products of life and thus will have surpassing value in the education of mankind.

R. A. F. Penrose, Jr.

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Christopher Tallackson
at +1-303-357-1007 or
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