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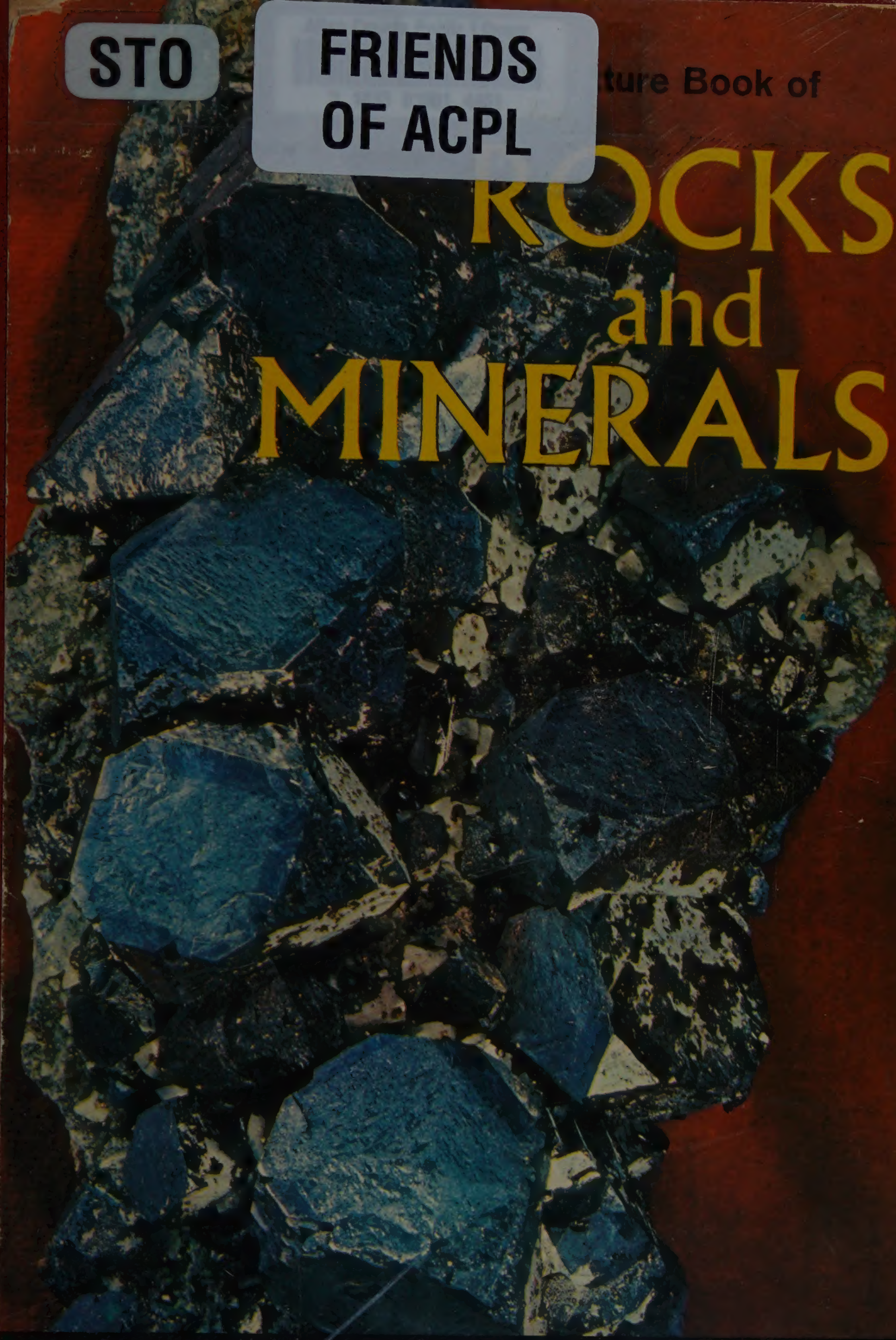

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by FRED REINFELD

Abridged from TREASURES OF THE EARTH

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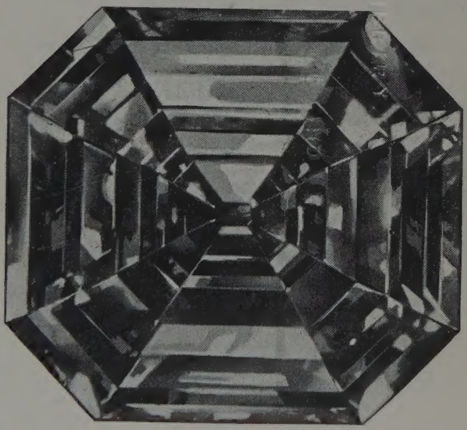

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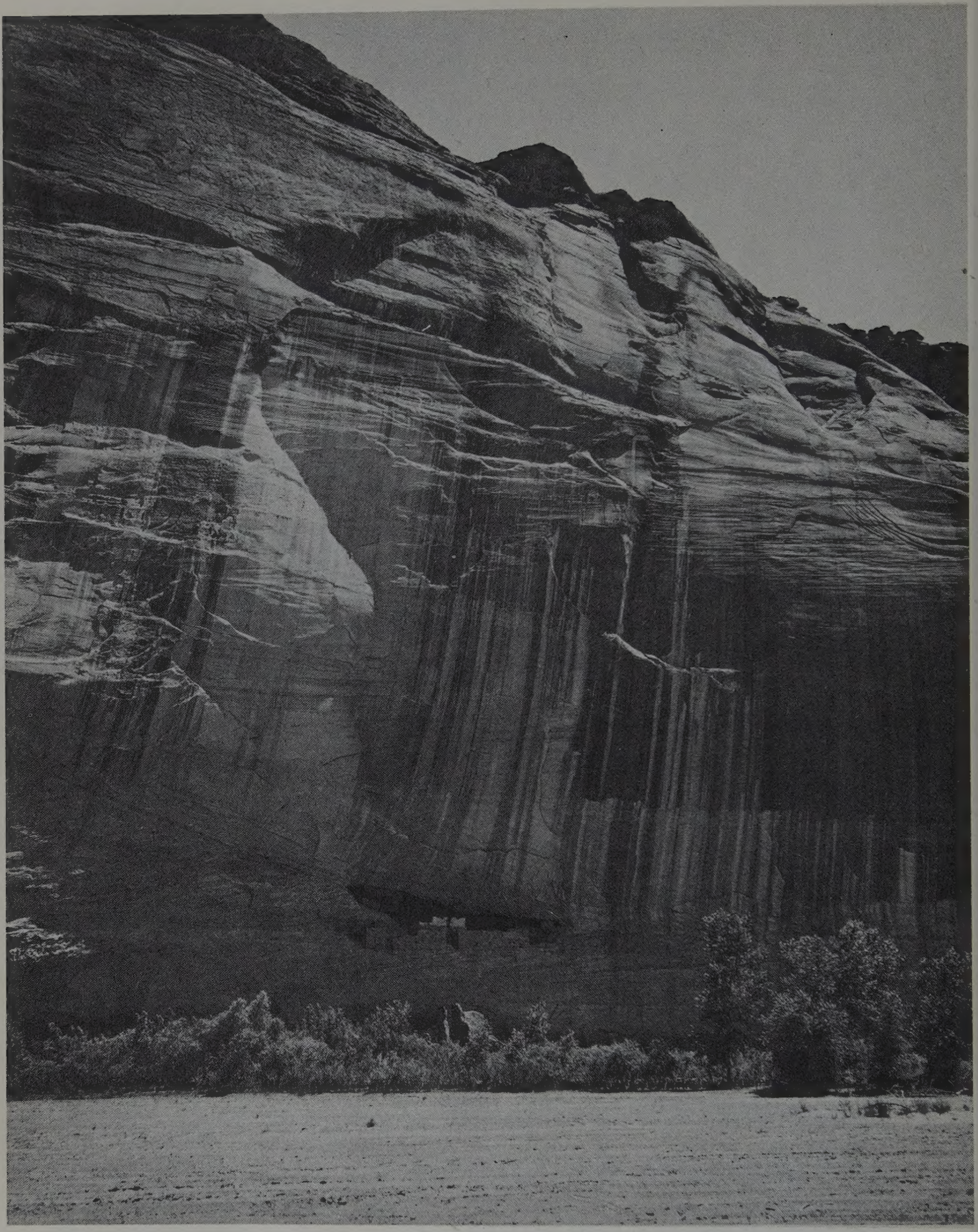
TRILOBITE: One of the earliest animals on earth, the trilobite had amazing features—for example, compound eyes with 15,000 facets.

CONTENTS



ROCK CASTLE: The ruins of Casa Blanca ("White House") in Canyon de Chelly National Monument, Arizona. This picturesque dwelling place cut into the side of a sheer cliff was probably at one time the home of an Indian chief.

1. The Restless Earth

IN OUR everyday conversation we often use such phrases as, "solid as a rock" or "sturdy as a rock." Tacitus, a famous Roman author, wrote two thousand years ago: "The everlasting hills do not change like the faces of men."

The truth about the solidity and permanence of rocks, mountains, the earth's surface, is quite different. The earth's crust has buckled as towering mountains were thrust up by violent underground convulsions. These same peaks have later vanished under the sea.

Again, layers of mud at the bottom of a sea have formed into rock over millions of years. Then, they have been twisted, pushed, crushed, sliced, bent, tilted, and folded. The surface has been worn away by streams, rain, ice, wind, sun. Even plants have "fed" on them by dissolving their minerals and finally cracking them open. The soil, that thin and soft outer part of the earth's crust, is made of crumbled rock and decayed plant and animal matter.

Riddles of the earth

How did oyster shells, seaweed fossils, and skeletons of fish get on top of mountains thousands of feet high and hundreds of miles inland?

How did the skeletons of small sea animals reach the plains of Kansas?

In the Carlsbad Caverns of New Mexico there is a "Big Room"—4,000 feet long, 625 feet wide, 350 feet high. How did this underground structure come into existence?

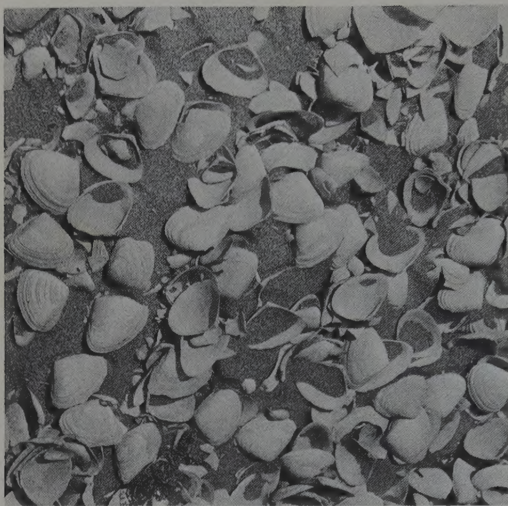
How was the Grand Canyon in Arizona formed?

We'll see in the pages that follow how these and many other puzzling questions have been answered for us by geology, the science which deals with the changes that have taken place on the earth from the earliest times until our own day. The patient and brilliant studies of the geologists have discovered, for example, such wonders as these:

Both the North and South Poles at some time had a tropical climate, and the remains of hundreds of tropical plants have been found in Alaska and Greenland. Elephant bones and the remains of palm trees have been discovered in England.

On the other hand, we have evidence of former glaciers—"rivers of ice"—in Africa, India, and other regions which now have a tropical climate.

The Rocky Mountains were "folded" and uplifted about 70,000,000 years ago in a region that had been a vast inland sea. By way of contrast, the West Indies are the tops of mountains in an area that had been land and has since vanished under the sea. Again by way of contrast, there have been times when much of North America was submerged by the sea. There



GEOLOGICAL UPHEAVAL: Sea shells found far above sea level on an oil field in Peru.

was a time when the highest points of the Appalachians were mere islands in the ocean.

Much of Canada and the northern United States was overlaid by a sheet of ice 2,000 feet thick in some places, almost two miles thick in others. As far as the geologists can determine, this happened at least four times.

The Grand Canyon of the Colorado River, perhaps the most awe-inspiring natural sight in the world, is 217½ miles long, about a mile in depth, and from 4 to 18 miles wide. This fantastic gap was cut through "solid" rock, over a period of some 2,000,000 years, by the silt-laden Colorado River.

Most of our coal deposits were formed from decayed plant remains more than 200,000,000 years ago. Our oil deposits are the remains of tiny sea animals that died 50,000,000 years ago — and more!

Scientific explorers

From even these few examples we can conclude that the reconstruction of geologic events is much more fascinating than the most absorbing mystery or adventure novel. The great geologists have been men who became interested in the story of the rocks during early childhood and kept up that interest for the rest of their lives.

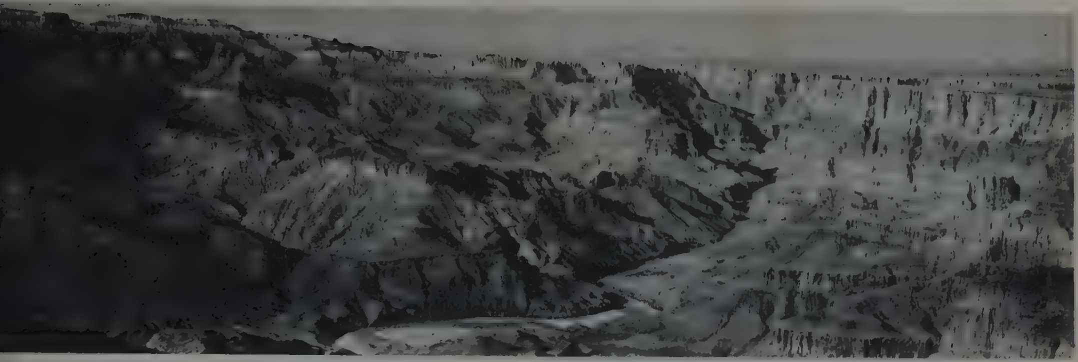
Charles Darwin, for example, decided at the age of 8 that he would study the nature and origin of every pebble on the doorstep of his home. Although Darwin was primarily a naturalist, he did valuable work in geology, based on his observations of the Andes ranges, oceanic islands, and the coral reefs of the Pacific.

Leopold von Buch, a famous German geologist of the early nineteenth century, thought nothing of exploring the Alps through twelve hours of driving rain, and then getting up at five o'clock the next morning to go on with his researches. And he was a man of 73 at the time!

Major John Wesley Powell, a one-armed veteran of the Civil War, became one of the leading field geologists in the United States. He risked his life repeatedly to be the first to shoot the turbulent rapids of the Colorado River at the foot of the Grand Canyon in Arizona. He made the daring trip at the head of a small expedition which used rowboats.

Powell's absorption in scientific matters was so well known that when his men were digging earthworks for the siege of Vicksburg in 1863, they carefully laid aside every fossil for their major. (Fossils, some of them hundreds of millions of years old, are the remains of plants and animals.)

James Dwight Dana, another outstanding American geologist of the nineteenth century, traveled to Hawaii to see a volcano in action. Going down 1,300 feet to the floor of the crater, he reported that he "wandered over the heated lava, through the hot vapors and sulphurous gases, and reached one of the boiling pools. The surface was in constant motion, throwing up



NATURE'S MASTERPIECE: The Grand Canyon was cut by the Colorado River over millions of years from ancient mountains, sea bottoms, and deserts. The rocks are famous for their attractive colors that seem to change with the time of day.

small jets which fell around the sides of the pool. There was no explosion and only a dull grumbling sound."

Rather nonchalantly, considering the circumstances, Dana added that "the deep red glow of the boiling lake, reflected by the walls of the crater, and lighting up the canopy of the clouds which overhung this fiery gulf, made a most awful spectacle at night."

The achievements of these and many other men of science have increased our knowledge of the world and have enriched our lives in a great many ways. But science is a very recent development in man's history. Primitive man, in his first crude, timid attempts to make use of the treasures of the earth, necessarily had to start from the very beginning.

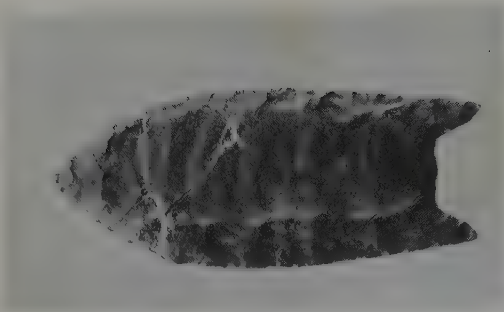
Ancient treasures of the earth

The period in which man learned how to use tools is called the Stone Age. This is divided into the Paleolithic ("Old Stone") Age and the Neolithic ("New Stone") Age.

The men of the Old Stone Age were incapable of building a shelter to protect themselves from the elements and from the beasts that roamed the earth in those days. They had to live in caves. When primitive man started to make tools, he relied on chert (commonly called flint), a variety of quartz. Flint flaked readily; it was therefore easy to shape and yielded sharp points for many purposes. (The use of flint was an important discovery, for Indians were still making fire with it thousands of years later, and white men needed it to light the powder in their flintlocks.)

The earliest weapon was probably a rock sharpened at one end, and rounded at the other to fit the palm. Much later a shaft was added to make this an ax. Other early tools were made for pounding, scraping, and chopping. In time the scraper acquired a handle and became a hoe or shovel. Primitive design branched out to make anvils, planes, drills, awls, fishhooks, and harpoons. Primitive man also needed arrowheads and spear tips for hunting bears, mammoths, reindeer, and other animals of the period.

To get a little ahead of the story, the rough-textured stone used as a missile has undergone considerable improvement in thousands of years. It was eventually replaced by the slingshot, and then by the ballista, an ancient engine for hurling stones into the enemy lines. Then, much later, came the cannon, the aerial bomb, and now the guided missile.



FOLSOM POINT: These points, first found near Folsom, New Mexico, in 1926, are made of chipped flint and may have been used as javelin heads. Remains of bison, camels, and mastodons have been found with the points. Scientists believe Folsom Man reached America by way of the Bering land bridge from Asia, from 7,000 to 25,000 years ago.

In ancient caves scientists have found stone bowls from which the insides were laboriously hollowed out. These were the first lamps; grease was kept burning in them to give a murky light in the caves and scare away wild beasts.

In the caves of Spain, France and other places there are remarkably fine drawings and paintings of bison, mammoths, rhinoceroses, and other animals on the walls and ceilings. Like the Indians thousands of years later, primitive man got his pigments from earth colored by mineral matter.

The man of the Old Stone Age made a living from hunting. In the New Stone Age he learned to raise crops and to get animals to work for him and furnish food and clothing.

Tools became steadily more efficient, more varied, more ingenious. Flint was still the favorite material, but bone was found to be more delicate and versatile for some purposes. There was a good deal of primitive mining for flint with deerhorn picks. Among the new devices were looms, sickles, pulleys, ladders, needles, and hinges.

The neat and serviceable pottery of this period shows primitive man had discovered that soft clay could be shaped into pots, cups, and ladles, and then hardened by heating. These men were fine carpenters, building their dwellings in a variety of styles. The ancient lake-dwellers used clay for their floors and walls.

By 4000 B.C. the stage was set for the first great civilizations — the Egyptian, Babylonian, Assyrian, Sumerian, and others. These peoples had learned to use copper and alloy it into bronze and brass for their tools and weapons. Gold and gems had become prime favorites for adornment. The statues, tombs, palaces, monuments, and temples of Egypt and these other lands show how far man had traveled from the dim caveman days.

One other feature of civilization had appeared — the written word. Writing seems to have started with pictures and designs on pottery and stone tablets. About 3600 B.C. the Egyptians started using hier-

DAWN AGE TOOL: A prehistoric ax discovered near Cedar Lake, Canada.

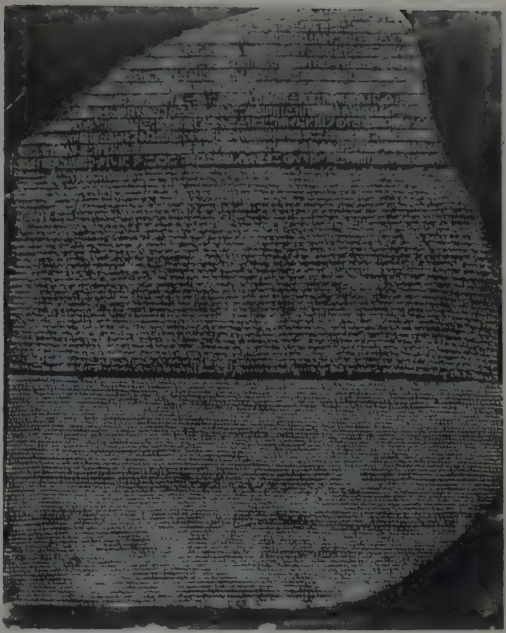
oglyphics — images that became "thought-pictures" and eventually developed into words. From 3000 B.C. on, the Sumerian priests kept records on clay tablets. Such tablets were also used to record business deals.

Modern treasures of the earth

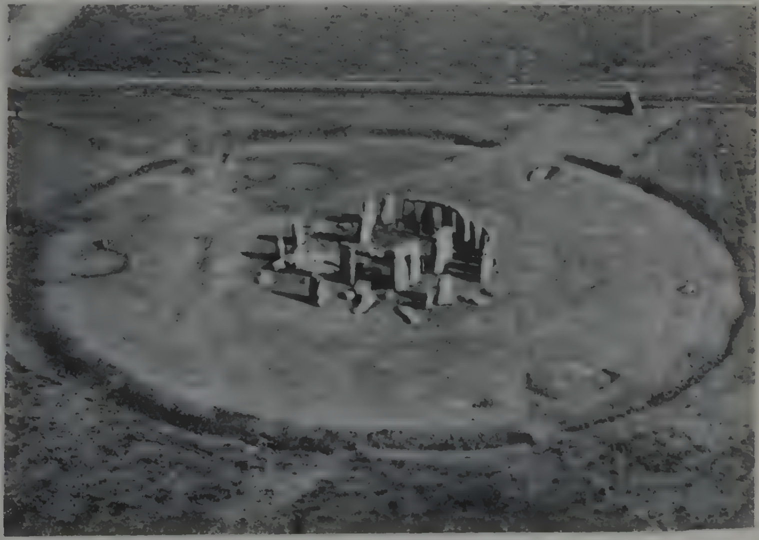
From ancient times to our own, technical skill has increased phenomenally. The list of our uses for the treasures of the earth could easily fill a book of this size.

Let's mention a few of our debts. We owe our skyscrapers and apartment houses, our streets, bridges, and highways to the treasures of the earth. This is equally true of our sleek cars, our crack trains, our superliners, and our transoceanic planes. Our machines, our power and fuel, our coinage and printing type, our watches and scientific instruments, our television sets — all come from the same sources. Mineral products are essential to many processes, such as the making of paper and glass. In fact, rocks — in the form of soil — supply our very food, and so we literally owe our lives to them.

Later on in this book we will get a more detailed picture of the uses to which man has put the treasures of the earth. First, however, let's see what they are and how they came to be at his disposal.



MYSTERIOUS STONE: Ancient Egyptian hieroglyphics ("picture-writing") on the Rosetta stone, shown above, were deciphered by a brilliant French scholar, J. F. Champollion, after the meaning of the writing had mystified men for centuries.



BRONZE AGE MONUMENT: This group of large standing stones at Stonehenge on Salisbury Plain in England is enclosed by a circular ditch 300 feet in diameter. Scholars believe Stonehenge was a shrine for worship and burial thousands of years ago.

2. Cosmic Clocks

ALTHOUGH geology deals with the earliest events on earth, it is a fairly young science. It was not until the middle of the eighteenth century that direct observation began to establish the science of geology.

Nicholas Desmarest, a French scientist of that time, seems to have been the first to show that the English Channel was originally a valley connecting England and France. He was laughed at by the people of his day.

About 1790 James Hutton, a Scottish farmer and amateur student of earth formations, announced that coal was really the remains of ancient plants. He too was ridiculed.

Another pioneer, William Smith (1769-1839) was the founder of geology. As a child on his uncle's farm he was fascinated by the fossils of mollusks. He had very little schooling, but persistent study and sharp observation made him a first-class surveyor and engineer.

In the course of his work, Smith examined coal mines and noted that rock layers always followed a definite order. Later, while employed on the Somerset Canal, he again observed that successive layers of rock were placed on each other like "slices of bread and butter." He was still enormously interested in the fossils he had collected.

Soon Smith realized that certain kinds of fossils were always found above other kinds of fossils. This offered a clue to the time when the rock formations had been laid down.

In 1815 Smith published a map showing the composition of the strata (rock-layers) of the British Isles. The following year he brought out a guide to show how these layers could be identified by the fossils they contained.

Other scientists followed Smith's lead and began to determine the geologic ages that make up the history of the earth. One of these pioneers, Louis Agassiz, startled his contemporaries in 1840 with the then novel theory that much of the earth had been covered by huge ice sheets in former times.

How old is the earth?

Gradually scientists realized that the earth was much older than they had thought. In those days many people still accepted the dictum of Archbishop Ussher, who had announced in 1684 that the world had been created on October 26, 4004 B.C. —at 9 a.m.

Scientists could not accept such a brief figure as 6,000 years or less because they knew that the processes of erosion and mountain-making had taken a much longer time.

And yet attempts to calculate the rate at which rock-layers were formed were tantalizing failures. Different kinds of rocks pile up at varying rates, and the thickness of the layers is not uniform everywhere.

Lord Kelvin, a famous nineteenth-century British scientist, calculated it had taken the earth 40,000,000 years to cool to its present temperature. People were staggered by this figure. Yet it soon turned out

ANCIENT ROCKS: The rocks of the Black Canyon of the Gunnison River date back to Pre-Cambrian times, more than 500,000,000 years ago. The canyon, located in western Colorado, has an average depth of 2,000 feet. The narrowest distance between its rims is 2,000 feet.

to be inadequate. New calculations advanced the age of the earth to 57,000,000 years and then to 90,000,000 years!

In more recent times, however, even this last figure has seemed trifling, as science established the age of the earth as well over 2 billion years! This figure is accepted today as a minimum.

Uranium-lead dating

The modern method of determining the age of the earth and of some extremely ancient rocks is known as "uranium dating" or "lead dating." About 1900 scientists discovered that uranium is radioactive — it gives off particles. (A Geiger counter ticks off the particles as they leave the uranium.) When uranium has emitted its last particle, it turns into lead.

Scientists know the exact length of the radioactive "life" of uranium, and they can find out just how much radioactivity is left in any given specimen of that element. The particles are given off at a rate that never varies. Surrounding conditions, as those of temperature or moisture, do not affect the rate at which the particles are expelled.

The fact that uranium finally turns into lead was crucially important to scientists. They found that the greater the proportion of lead in a mineral deposit, the older that deposit is. By testing different samples of uranium they were able to conclude, from the already expired "life" of the uranium, that the earth's crust is at least 2 billion years old. Similar experiments with the radioactive elements thorium and radium have confirmed these findings.

Scientists have been able to fix with greater certainty the time and length of the geologic ages. They may yet find older uranium deposits and thus prove that the earth is even older — 3 billion years or even as much as 5 billion years.

"A built-in atomic watch"

Discovering the age of uranium deposits by the uranium-lead method is not the only dating method that scientists have devised. The Radiocarbon or Carbon-14 method is effective for objects that are no more than about 28,000 years old.

Carbon-14 differs from other forms of carbon in these ways: it has an atomic weight of 14 and it is radioactive, giving off beta particles. Carbon-14 results from a complicated series of reactions which start with cosmic rays in the earth's outer atmosphere. Science has shown that Carbon-14 remains radioactive for some 28,000 years. All living creatures as well as their remains contain some of this radioactive carbon.

Radiocarbon equipment establishes the loss of carbon radiation in any object it measures. After several further measurements, the age of the object is arrived at.

Carbon-14 dating has given us a great deal of valuable scientific information about primitive man. In Wisconsin there was once a spruce forest that was crushed by a huge icecap of the last Ice Age as it moved southward. The grinding of the mighty ice sheet left only the stumps of the trees, all of them pointing southwest as silent signposts. Most scientists placed this event at about 25,000 years ago, but Carbon-14 dating showed that it was only 10,000 years ago. This has so far been the most important achievement of Carbon-14 dating — the fixing of the end of the Ice Age.

Fluorine dating is still another dating technique that has been developed in recent years. It can go much further back in time than Carbon-14.

During World War II the Geological Survey of England authorized a study of the effect of fluorinated water on tooth decay among children. As a byproduct of this work, scientists discovered that the age of objects buried underground could be gauged by the fluorine they contained.

However, fluorine dating is tricky because the percentage of fluorine in the soil varies from one locality to another. Also the substances containing fossils may have different rates of absorbing fluorine.

Generally speaking, however, the rule holds good that the longer a fossil stays in the earth the more fluorine it contains. Thus scientists now have three valuable dating methods at their disposal: uranium-lead, Carbon-14, and fluorine.

How was the earth formed?

Scientists have worked out their theories about the formation of the earth from indirect evidence. Greatly simplified, the most recently accepted account runs somewhat as follows:

Originally a space much larger than our solar system was filled with hot gases and dust. As they whirled about in space, the force of gravity pressed them together into ever denser masses heated to a glowing hot state. Very slowly they became less hot, and condensed into hot liquid masses. One of these masses was the earth.

Very gradually, as the lengthy cooling process went on, the heavier substances of the earth settled toward the center, the earth's core. Somewhat lighter materials settled further away from the center of the globe. The lightest substances stayed near the outer part of the earth.

Scientists believe that the earth has a core of molten nickel and iron which may be as hot as the *surface* of the sun — in the neighborhood of 10,000 degrees Centigrade. Along the way from the core to the outer crust of the earth, the temperature goes down gradually.

The reason the earth's crust is so varied in appearance is that in some places it has been borne down by the weight of heavy rocks, creating low levels that are filled in with water. In other places we find lighter rocks that are above the crust, often rising to mountain height.

In the earliest times, when the earth's crust was far from firm, fierce volcanic eruptions were incessant, and melted rock spurted up out of the ground. After 100,000,000 years — maybe much longer — the earth's crust hardened as layers of rock were finally formed. As they hardened, water vapor and carbon dioxide were pressed out of them and changed into clouds that brought on torrents of rain.

TILTED COAST: Cormorant Rock, on the coast of Wales, presents a desolate scene. The sharp tilting of these originally horizontal rock beds tells us of geologic activity in bygone times.

For centuries — perhaps for thousands of years — the rains went on without a stop, washing away vast land areas from the desolate earth, and carrying off huge masses of mud for new rock-forming. Thus began the pattern of erosion and mountain-building which is still going on. When the rains stopped, the oceans had been formed. To this day, they take up more of the earth's surface than the land does.

The geologic ages

Geologists have differed considerably in their estimates of the time and duration of the geologic ages. They are agreed on one feature of geologic time — that man has occupied a very tiny portion of it. A famous physicist once compared geologic time to a skyscraper 800 feet high. [The Empire State Building is 1,250 feet high.] A nickel on top of the building would represent man's time on earth. A thin sheet of paper would represent recorded history.

Geologic time is divided into eras. The oldest are the Archeozoic ("ancient age") and the Proterozoic ("beginning age"). Starting at least 2 billion years ago, they lasted about 1½ billion years, or three-quarters of geologic time! A simpler name for this age, about which we know very little, is the Pre-Cambrian Era.

Vast quantities of mud and ooze were sinking into the mighty oceans and (as described in Chapter 4) slowly forming into layers of rock. There were great mountain-building periods, the result of gradual or violent upheavals of the earth's crust. Later on, when life started in the sea, huge quantities of plant and animal remains were added to the rock-forming layers of debris. There was probably considerable volcanic activity, caused by powerful movements and pressure of liquids and gases inside the earth's crust.

The rocks of that far-past time are still deeply imbedded below younger formations, and they have been worked on — "metamorphosed" is the geologist's term — so powerfully and relentlessly by natural forces that scientists have not been able to learn much about them.

The geologists are in reasonable agreement that the continents formed early and went up and down locally but not very far.

The Canadian Shield, a region that extends from north-central Canada and swings south and then east to Nova Scotia, is thought to contain the oldest exposed rocks in the world. The rocks of the Black Canyon of the Gunnison National Monument in Colorado are also considered among the oldest. The bottom gorge of the Grand Canyon of the Colorado River also contains Proterozoic rocks.

Scientists know that simple life-forms existed at least in the latter part of the Pre-Cambrian Era. However, the plants and animals apparently had no hard parts and therefore could not be preserved as fossils.

Scientists do not know how life started but they are in agreement about where it began — in the warm salt sea. Somehow, they say, the sea blended the six necessary elements for living matter: oxygen, carbon, nitrogen, hydrogen, phosphorus, and sulphur. The sun and the earth's outer atmosphere provided the other necessary conditions for maintaining life.

The Paleozoic Era

About 500,000,000 years ago the Paleozoic ("old") Era started, and lasted for about 300,000,000 years. It began with the Cambrian Period, which had a duration of about 80,000,000 years. (The name comes from the old Roman name for northern Wales, where geologists first studied rock formations of this period early in the nineteenth century.)

ROCKS 400,000,000 YEARS OLD: These rugged Ordovician limestone formations of the Archbuckle Mountains in Oklahoma yield petroleum and natural gas.

The characteristic rock of this period, slate, is found in the British Isles in thicknesses thought to be over three miles, in some cases five miles below ground. In the ancient Cambrian slate we may still see the marks of wave ripples and raindrops in the ooze that was once baked by the sun, then sank to the ocean floor, then was pushed up to mountain height, and then worn down (eroded); a cycle that was repeated many times.

In British Columbia there are Cambrian rocks seven miles thick. Cambrian formations are found, sometimes to a thickness of two miles, in various parts of the United States. There are also Cambrian formations in the Adirondacks and in the layers of the Grand Canyon of the Colorado River.

Small sea creatures flourished in Cambrian times, especially the trilobite (page 3), which is our favorite fossil witness, some 500,000,000 years old. Trees and flowering plants were not to appear for hundreds of millions of years, but there were seaweeds, mosses, and lichens in addition to the older algae — the most rudimentary forms of plants.

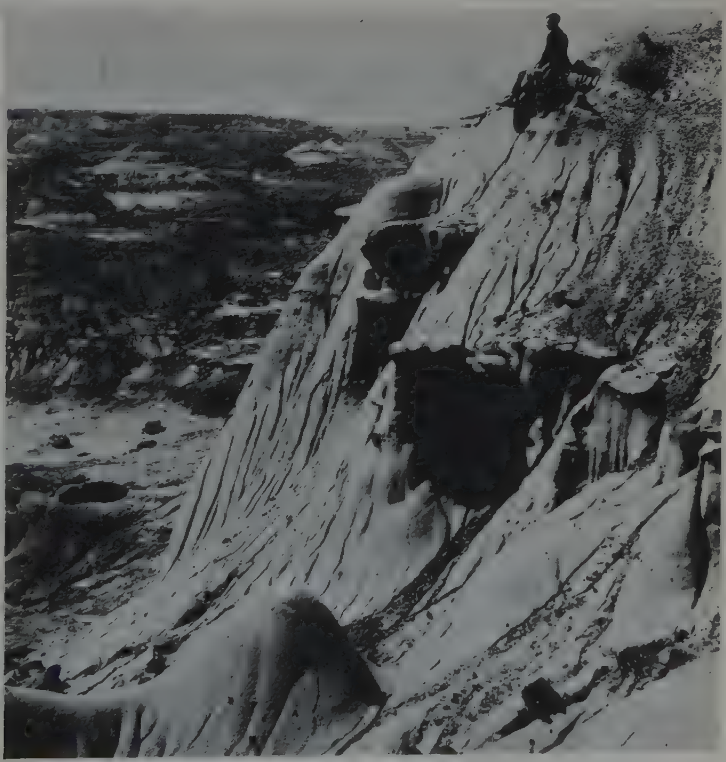
About 420,000,000 years ago the Ordovician Period started, and lasted for about 65,000,000 years. (It is named for an ancient Celtic tribe that lived in Wales, and was given the name of "Ordovices" by the Romans. Ordovician formations were first studied in the area they had inhabited.) During this period, more of North America was submerged than at any other time, over half of it being covered by shallow seas. Toward the end of the Ordovician Period the continents rose above water level and took more or less the shape they now have.

The animal life became more varied. There were many snail-like creatures in the sea, some of them ten feet long. Other animals appeared, all absorbing lime from the sea for their shells. Corals flourished too. All of these, when they died, added their lime to the bottom of the sea to form huge limestone deposits.

Next came the Silurian Period, which started about 355,000,000 years ago and lasted about 35,000,000 years. (This period, like the previous one, was named for an ancient tribe that lived in England and Wales.)

Much of the United States was covered by water during this time. The climate continued warm and moist, sea creatures flourished, and "armored" fishes, the first animals with backbones, made their appearance.

Toward the end of the Silurian Period the waters receded, and much of the



BADLANDS: This area in Alberta, Canada, is often the hunting ground for museum expeditions in search of the remains of prehistoric animals.

NEW AND OLD: A modern automobile highway winds through the desolate rocks of Death Valley. Many of these formations are 50,000,000 years old.

United States became dry land. About this time something very interesting happened: the first amphibians ("double-life" animals) appeared. They were able to live in the sea and also in the boggy muck near the shore lines. We do not know whether they became adapted by venturing forth on land, or whether the drying up of shallow waters brought about this change. In some way the first land plants seem to have gained a hold on the land at this time, too.

The Devonian Period, first studied in the Devonshire region of England, started about 320,000,000 years ago and lasted about 45,000,000 years. Sandstone is characteristic of the Devonian formations. There is a great deal of it in England and in Canada; the Grand Canyon of the Colorado River has some, too. The climate was still warm and moist, but there was a fairly general lowering of sea levels and most of the United States was land.

The first trees, ferns, and "horsetails" appeared in the Devonian swamps. They were not the kind of trees we know, but rather tall, wispy growths. New York State is believed to have the oldest tree remains in the world.

In the Devonian Period the fishes achieved their greatest development and abundance. In fact, the Devonian is known as the "Age of Fishes." Amphibians were becoming more numerous and varied. Scientists have found the first known amphibian footprint in Pennsylvania sandstone.

The Carboniferous Period began about 275,000,000 years ago and continued for about 50,000,000 years. This period gets its name from the fact that a great deal of our coal, which is mostly carbon, dates from this time. The first half of the period is known as the Mississippian, the second half as the Pennsylvanian.

The climate was still moist and warm,

and it was in the Carboniferous swamps, with their rank and luxurious growths, that the insects started. They included a giant cockroach and a 30-inch dragonfly. The amphibians had now become the dominant animals.

Toward the end of the Carboniferous Period the climate began to get cooler and dryer. This was even truer of the succeeding Permian Period (named for Perm, in Russia, where the rocks of this age were first studied.) The Permian Period, which started about 225,000,000 years ago, lasted some 25,000,000 years.

Huge glaciers swept down from the north and covered even the equatorial regions. The swampy American Southwest turned into desert. Shallow inland seas dried up and great beds of salt and gypsum were formed.

During this cold age the trilobites and many of the corals died out. The amphibians began to decline, and the most primitive reptiles appeared. With this Ice Age the Paleozoic Era came to an end.

The Mesozoic Era

The Mesozoic ("middle") Era, which followed, lasted about 130,000,000 years. Remarkable developments succeeded each other rapidly — that is, in comparison with the slow pace of more ancient times. The climate became more moderate, though not so lush and warm as it had been earlier.

The era started with the Triassic Period about 200,000,000 years ago and went on for about 40,000,000 years. (This period got its name from German geologists who broke it up into three subdivisions.) This was a time of great mountain-building and volcanic activity. The Hudson River's Palisades were formed at this time.

Reptiles became more numerous and some of them grew to huge proportions. These are known as dinosaurs ("terrible lizards"). The first mammals appeared —

DINOSAUR EGGS: 18 eggs of the dinosaur Protoceratops — the first dinosaur eggs ever discovered. A scientific expedition from the American Museum of Natural History made this valuable find in Mongolia in 1925.

queer, insignificant creatures, still retaining some reptile characteristics. The earliest remains of cone-bearing trees date from this time.

The Jurassic Period, which began about 160,000,000 years ago, lasted for about 30,000,000 years. It is named for the Jura Mountains of France and Switzerland, where its formations were first studied.

While most of Europe was submerged during this time, most of North America was above water. Severe volcanic disturbances folded and uplifted the Sierra Nevada Mountains toward the close of this period.

The Jurassic is known as the "Age of Dinosaurs" because they reached the height of their power then. The animal life was particularly rich and varied. Many new forms of insect life appeared. The mammals were slowly increasing but were not important. The earliest birds, evolved from the reptiles, date from this time.

The Cretaceous ("chalk") Period, which began about 130,000,000 years ago and lasted for about 60,000,000 years, saw some violent changes. The sea advanced further than it ever has since, covering the southern United States as well as Texas, Oklahoma, Kansas, Wyoming, and part of Canada. Much of Europe was also engulfed. The climate, as we might expect, was once more warm and moist. Chalk beds were formed on both sides of what is now the English Channel and chalk deposits were common in Kansas.

Toward the end of the Cretaceous Period the Rocky Mountains were folded and uplifted. The dinosaurs died out, and the mammals were on the verge of their greatest development. Flowering plants appeared and soon became abundant.

The Cenozoic Era

The Cenozoic ("recent") Era started about 70,000,000 years ago and is still going on. The first part is known as the Tertiary ("third") Period, and is made up of the following epochs, starting with the oldest:

- Paleocene ("oldest recent") about 12,000,000 years
- Eocene ("dawn recent") about 19,000,000 years
- Oligocene ("not very recent") about 11,000,000 years
- Miocene ("fairly recent") about 16,000,000 years
- Pliocene ("more recent") about 11,000,000 years

The second part is known as the Quaternary ("fourth") Period, made up of these two epochs:

- Pleistocene ("most recent") about 1,000,000 years
- Recent about 20,000 years

The Cenozoic Era has seen much mountain-building, for the Alps, Himalayas, Pyrenees, Apennines, and Caucasus ranges all came into existence at this time. There have been several Ice Ages alternating with periods of moderate climate. During these Ice Ages huge, thick sheets of ice covered the earth. The last Ice Age ended only about 10,000 years ago.

The Cenozoic Era is definitely the "Age of Mammals." During this time the horse, pig, camel and other familiar creatures went through millions of years of change.

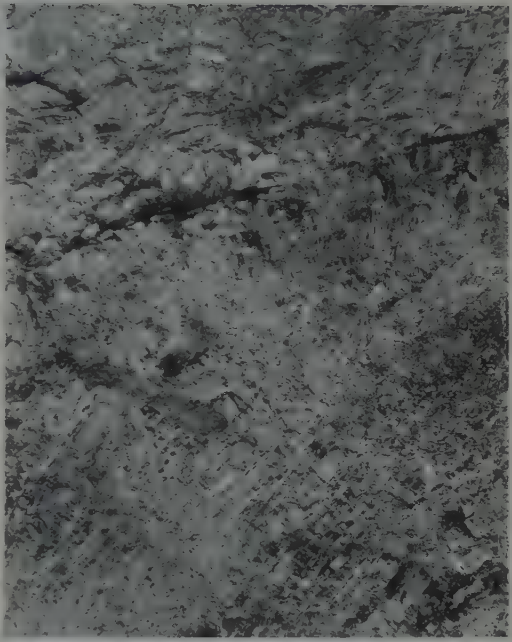
The most recent of the mammals, man, appeared very late in the day. Man's recorded history takes in possibly 5,000 years of the 2,000,000,000 or more years of the earth's existence.

3. How Mountains Are Formed

FOR MANY millions of years various processes have been going on endlessly all over the world, counteracting each other. One, which is very, very gradual and often unnoticeable, is a wearing-down process that eventually produces spectacular results. An opposing tendency, just as gradual, is a building-up process sometimes accompanied by startling, even terrifying, violence.

Erosion is the process which constantly wears away rocks and carries off the crumbled bits to lower levels. At the same time *diastrophism,* the never-ending process of upheaval, is building new mountains.

The mountains we see today were formed millions of years ago. Millions of years from now there will be new mountains which are being formed today, perhaps at the rate of an inch a year or less.



OVERTHRUST FAULT: This break in rock structure will widen over the years.

Mountain-building is caused by disturbances which are not fully understood by scientists. A popular theory is that as the earth's crust cools, it shrinks; this wrinkling process creates movement — sometimes gradual, sometimes violent — among rock formations.

Another theory is that as erosion removes the tops of mountains it lightens the weight pressing down on the earth's crust. The result is that underlying rocks push up and raise the height of the upper rocks.

As described in Chapter 4, mountain-making started with the piling up of mud and debris on the floor of shallow seas. In time this material hardened into layers of rock which often reached a thickness of several miles.

Eventually powerful pressures from alongside the rocky area pushed the rocks together, deforming their shape and buckling them into "folds" and creating "faults." These folds and faults are found in the Rockies, the Alps, and in fact in mountains all over the world. Let's investigate some of them.

ANTICLINE: Rock formations folded upwards like this one are called "anticlines."

Folds

Folds are bends or warps in rock formations. Sometimes rock layers are pushed together to form an upward bend in the shape of an arch. This an "anticline."

Other rock layers are bent downward to form a trough. This is a "syncline."

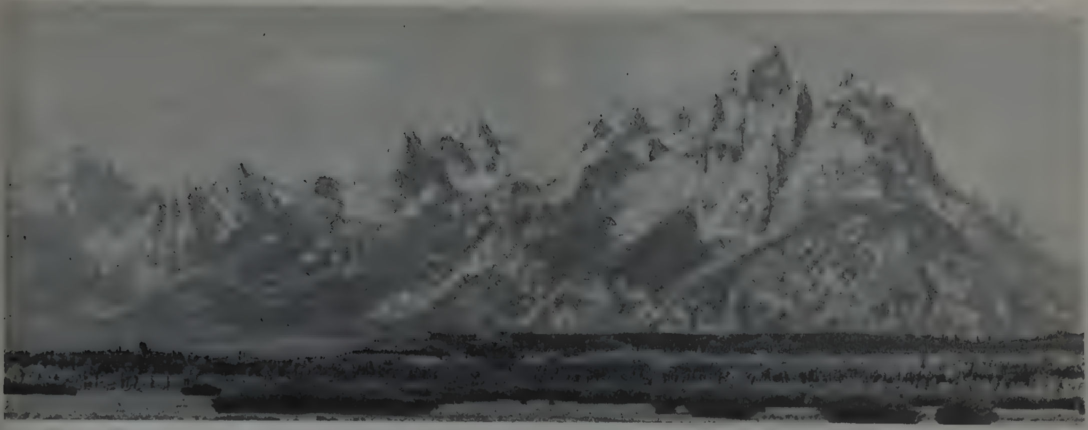
A dip in only one direction is a "monocline."

Sometimes the folds are fairly gentle; other times they show a lot of detailed crumpling. In some fold formations a horizontal layer of rocks has been moved so much that it is again horizontal, but *upside down*. Such folds are found in "old" mountains like the Appalachians.

When later upheavals inside the earth or on the earth's crust lift the rocks to form mountains, the fold formations do not lose their shape. Many mountains are made up of folded anticlines and synclines.

Slow folding, which probably takes place very gradually over a very long period of time, will change the contour of mountains without destructive effect. Such folding gives the "rolling" effect, like the rounded ridges that we see on many mountains.

SYNCLINE: Rock formations folded downwards like this one are called "synclines." (Black Knob Ridge near Atoka, Okla.)



UP AND DOWN: The Teton peaks of Wyoming make up a fault-block range that was uplifted 20,000 feet over a period of many centuries. Millions of years later, the Ice Age glaciers gave these mountains the shape they have today, and left lakes on their lower levels.

Faults

Mountain-building movement often results in cracks in the rocks — fractures known as "joints." Some are on the surface; others are hidden and are gradually revealed by weathering. Once there is movement in any direction, and displacement of rocks on either side, the fracture has become a "fault."

Upward shifts, produced by powerful upward pressures from below, push up one side of the fault while the other side moves much less or remains stationary. Sometimes the higher side may be thrust up thousands of feet over a period of time. In the Arizona-Colorado plateau there are a number of such faults with vertical shifts of several thousand feet. This higher side of the fault is known as a "fault escarpment." The mountain shaped in this way is called a "fault-block" mountain.

Faults vary greatly in both width and length. The famous San Andreas Fault in California is over 500 miles long. Some faults are only a few inches long.

The Sierra Nevada Mountains of California, which are 400 miles long, have a remarkable fault formation. The western side is a gradual slope, whereas the eastern side is a rugged fault escarpment that towers almost three miles above the desert. Mount Whitney, 14,495 feet high, is the tallest peak of this range. Only Mount McKinley in Alaska is higher.

Earthquakes

Today scientists assign two main causes for earthquakes. One is connected with faults, the other with volcanic action.

If the movement of rocks along a fault is too abrupt, or too violent, it produces a tremor or "temblor" — an earthquake. The source or "focus" of an earthquake may be quite near the earth's crust — or it may be as much as 400 miles below the surface. (Earthquakes under the ocean floor, produce tsunamis, what are incorrectly termed "tidal waves."

In early times, when people explained natural events by myths rather than by scientific study, they had a peculiar explanation for earthquakes. They imagined the earth normally stood still, resting on some support. There were Indian tribes in North America who pictured the earth as being held up by a huge tortoise. Certain South American tribes believed the earth was supported by a whale. In Japan a gigantic spider was thought to hold up the earth.

And so each region had its legends. Then, if an earthquake occurred, people explained the terrifying event by saying that the support had temporarily moved, causing a shakiness in some part of the earth.

The powerful pent-up underground forces that produce a volcanic eruption may also cause an earthquake in the vicinity. The explosive effect of the eruption and the movement of magma (see page 28) are bound to disturb nearby rock formations. In addition, the molten rock that spews up out of the ground during an eruption leaves an empty space that will be filled in by other rocks. As the rocks slip into place, some of this movement may cause an earthquake. It may also come about if a part of the earth's crust caves in while deprived of adequate support during the slippage of the rocks.

"It came on suddenly, and lasted two minutes, but the time appeared much longer," Charles Darwin wrote of an earthquake he experienced in South America. "The rocking of the ground was very sensible [noticeable]. There was no difficulty in standing upright, but the motion made me almost giddy."

When a volcano erupted in 1914 on Sakurajima, a Japanese island, there were more than 400 earthquakes of varying intensity in the vicinity during the 30 hours before the eruption. This indicates that the violent underground activity which comes before an eruption and the upward movement of the lava may also cause some earthquakes.

And here is a very significant point: most earthquakes occur more or less in the same regions where volcanic eruptions are most common. About 80 per cent of all earthquakes are in areas bordering on the Pacific. Another 15 per cent occur around the Mediterranean and eastward into Asia. The Caribbean region also has relatively frequent earthquakes.

Effects of earthquakes

When the shock is particularly strong, an earthquake can be very destructive. The shock sets off waves that can hurl heavy objects on the earth's surface for quite a distance and even move roads out of their course as the earth's crust is displaced. Shifts along the San Andreas Fault brought on the California earthquake of 1906, which caused damage for 270 miles. Some roads were "offset" (pushed to the side) as much as 20 feet.

Coastal earthquakes often produce up-and-down effects as well. In the Alaska earthquake of 1899 part of the coast rose over 40 feet.

Chile, a country which has frequent earthquakes, once had one which was felt along a thousand-mile line. In Valparaiso, a city with a fine harbor, a curious incident happened during the earthquake. A ship which had been wrecked many years earlier suddenly appeared on shore, surrounded by the rocks among which it had nestled at the bottom of the harbor. The earthquake had raised the harbor floor so high that Valparaiso and its vicinity had a new coastline.

Earthquakes and fires

The terrifying nature of earthquakes has often resulted in sensational stories. Scientists say there has never been a verified instance of "the earth opening up and swallowing houses and people without a trace."

Reports of fire welling up from the earth are likewise untrue. However, during an earthquake, fire may start from a variety of fire hazards. Once fires do start, they are likely to become unmanageable because the effects of the earthquake often cripple fire-fighting efforts.

In the great San Francisco fire of 1906, firemen were tragically hampered by the earthquake's destruction of the water mains. The fire caused 20 times as much property damage ($400,000,000) as did the earthquake that brought it on, because the city was unprepared for fighting a fire of major proportions.

The Japanese earthquake of 1923 was relatively minor, as far as damage from the shocks was concerned. Yet the destructiveness from fire was appalling. Tokyo, 50 miles from the earthquake, was two-thirds destroyed by fire. Yokohama burned down completely.

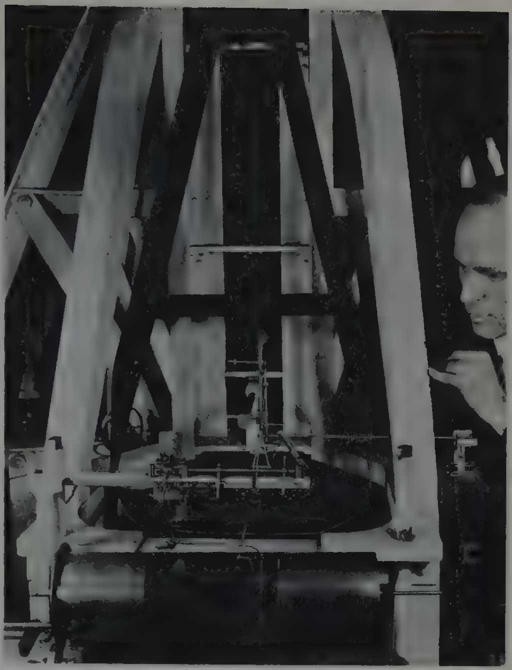
How scientists measure shocks

The vibrations of the earth produced by an earthquake send out several kinds of waves. Two kinds move through the interior of the earth. A "push-pull" wave advances with shaking particles moving back and forth along the line of the wave's movement. These are the fastest-moving waves, covering the first 1,000 miles in a little over three minutes.

A "shake" wave advances with particles moving from one side to the other, of the line of the wave's movement. These waves move somewhat less rapidly than push-pull waves.

There are also several kinds of surface waves that move still less rapidly. All these types of waves radiate in all directions from the source of the earthquake.

Throughout the world, scientists study the action of earthquakes by means of a device known as a seismograph (from two Greek words meaning "shake-writing"). This machine tells the scientists when a disturbance starts, how long it lasts, and how far the waves have traveled. By plotting the distance from different stations, it is possible to establish the source of the earthquake.



SEISMOGRAPH: This instrument is so sensitive to the slightest vibration that it records a light touch of the finger. How the seismograph works is explained below.

The seismograph has weights, one to record vertical motion, another for east-west motion, and a third for north-south motion. Vibrations of the ground are recorded by an electric current which causes a mirror to move back and forth. The mirror reflects a light beam which is focused on photographically sensitized paper. This paper is mounted on a drum that continuously rotates and moves sideways at the same time.

As long as there are no disturbances, the light beams will show a steady line. Should the ground move, the light beam will waver, faithfully reproducing the vibrations. A clock attachment marks off the minutes on the photographed line. Thus the beginning, duration, and end of the disturbance are automatically recorded.

Great care is taken to house seismographs in rooms that are exceptionally solid. Some,

DEAD OR DORMANT? Lassen Peak, located in Lassen Volcanic National Park in California, erupted 300 times between 1914 and 1921. This Park, in its area of 163 square miles, contains some of the most picturesque volcanic remains in the world.

for example, are hewn out of rock. Scientists hope in time to devise a machine that predicts where and when earthquakes will take place.

On the basis of past performance, scientists expect about a million earthquakes a year. This seems an astounding figure, but it is broken down in this way:

Every year, on the average, there is one earthquake of major proportions; about 1,000 that cause some damage; about 100,000 that are felt in a fairly extensive area without any great damage. The other "earthquakes" are very minor shocks that are "felt" only on the scientists' sensitive instruments.

Famous volcanoes

Volcanoes, on the whole, do less damage than earthquakes. But some of them are terrifying spectacles, and some have brought great loss of life. The ancient Romans named the eruptions after Vulcan, the god of fire and metalworking. The fiery glow of the liquid rocks, heated to temperatures in the neighborhood of 1,100 degrees Centigrade, was a fitting setting for the god as he hammered metal at his forge.

As far back as science can trace, there has been a great deal of volcanic activity in many parts of the world. Eruptions have accompanied much mountain-building activity and they have also caused mountains to form.

The classic eruption was that of Mount Vesuvius in 79 A.D. on the Mediterranean coast of Italy (then the center of the Roman Empire). A powerful explosion hurled forth a deadly combination of molten rock and overpowering fumes. For 72 hours cinders and ash rained down on the fertile slopes of Vesuvius and two beautiful and flourishing Roman towns — Pompeii and Herculaneum.

The terror of the people was heightened by thunder and lightning and great waves that lashed the coast. Of the 20,000 people who lived in the two towns, about 2,000 perished. Herculaneum disappeared completely, while Pompeii was buried right up to the rooftops.

With the ruins sealed off from the atmosphere, they remained in a remarkable state of preservation. The uncovering of the two buried towns started 1,600 years later with the discovery that Herculaneum lay under 65 feet of rock. Ever since then more and more of these ancient towns has been revealed, giving us a detailed knowledge of how Romans lived 1,900 years ago.

Vesuvius did not erupt again, by the way, until 1681. Since then there have been frequent eruptions, including one in 1944.

The eruption on Krakatoa in the East Indies in 1883, is outstanding for destructive features. Mount Kobendai in Japan erupted five years later, smashing a billion and a half cubic yards off the sides of the mountain and hurling volcanic matter over an area of 27 square miles.

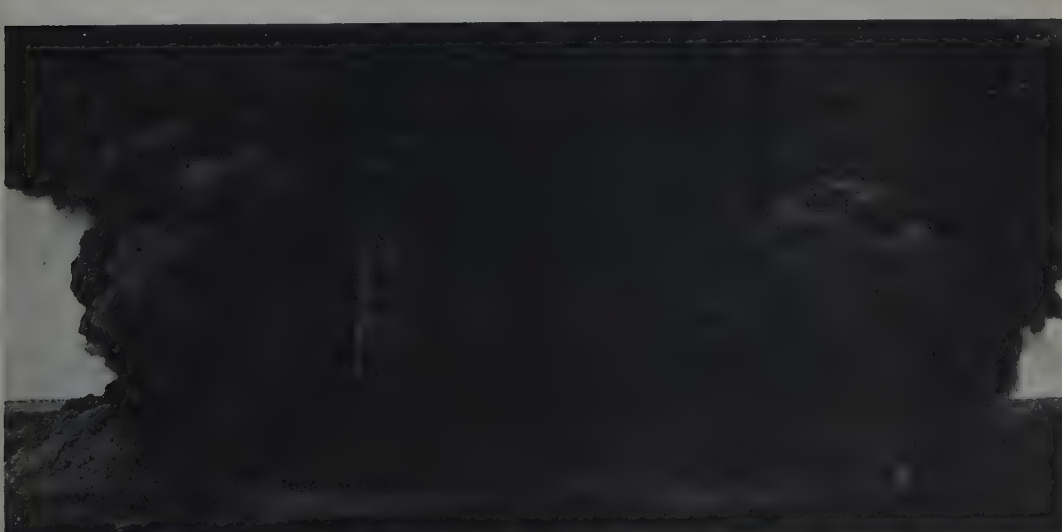
Scientists believe there are about 500 active volcanoes at the present time. The most active one in Europe is Mount Etna in Sicily, which has had 80 eruptions in recorded history. Some of them have created great havoc, killing as many as 10,000 people. Geologists believe Etna has been active for 300,000 years.

Repeated activity by a volcano is far from unusual. Yellowstone National Park has twelve layers of petrified forest (trees turned into stone), one on top of the other, created by successive eruptions. In a canyon of the Snake River in Idaho there are 30 distinct layers of lava.

New volcanoes keep coming into existence every now and then. One of the best-known of recent years is Paricutín in Mexico. In 1943 a series of rumbles was followed by the opening of a crack in the earth's surface. Underground pressures threw up volcanic dust and the crack widened. Soon many tons of hot rock and ash were hurled out. In three days a cone 120 feet high had formed out of the hardened lava. Hot liquid rock continued to shoot out of the hole. In a few years the volcano was 1,600 feet high.

By wiping out forests, lakes, and vegetation, volcanic lava flows have created some of the most desolate landscapes in the world. Perhaps the most remarkable of these bleak lava formations is at Craters of the Moon National Monument in southern Idaho. This site, occupying 74 square

ACTIVE VOLCANO: Kilauea Volcano in Hawaii erupts like this about once a year.



FANTASTIC LANDSCAPE: The aptly-named Craters of the Moon National Monument is a region that has been pitted, scarred, and contorted by countless volcanic eruptions. The National Monument, located about 20 miles west of Arco, Idaho, was once a favorite Indian hunting ground.

miles, contains the world's greatest concentration of volcanic wonders.

Repeated eruptions in this area created a landscape that suggests the surface of the moon as seen through a telescope. The Monument abounds in extinct craters, various types of lava "bombs," natural bridges of lava, cinder cones, and trees twisted and contorted by hardened lava. The profusion of "pahoehoe" (the jumbled type of lava known as "ropy" lava) adds to the eerie impression.

Types of volcanoes

The chief centers of volcanic activity nowadays are in Hawaii, the Philippines, Japan, the Aleutian Islands, Italy, Iceland, South America, and Central America. Eighty per cent of the active volcanoes are in the Pacific area. As we saw, earthquakes are prevalent in the same regions.

By an "active" volcano we mean one that has erupted quite recently and that gives indications of erupting again.

An "extinct" or "dead" volcano is one that has finished erupting. Sometimes people make a very bad mistake in supposing that a volcano is dead when it isn't. Mount Pelée on the West Indies island of Martinique showed no activity from 1852 on, until it erupted in 1902 and killed 30,000 people in the city of St. Pierre. According to some accounts, the only person to escape

HUGE BUT DORMANT: Haleakala, another Hawaiian volcano, rises 10,000 feet above sea level, and has a crater 21 miles in circumference. The volcano has been dormant for over two centuries.

with his life was a prisoner in the local jail, which was not destroyed.

A volcano that has not erupted for a long time, yet gives signs of becoming active some time in the future, is dormant ("asleep").

It is common to speak of volcanoes belching forth flame and smoke. Actually they do neither of these things. The molten rock spurts up glowing red-hot or yellow-hot from the high temperatures. This glow creates an illusion of fire. The "smoke" is steam from vaporized underground water, mixed with volcanic ash and subterranean gases.

The force of an eruption depends on several factors. The explosion will be very fierce where the pressures have accumulated for a long time and have become very powerful; where an opening does not already exist in the earth's crust; and where the opening eventually formed is too narrow for the force and amount of matter being expelled.

When the above conditions apply, the result may well be an eruption so explosive that it literally "blows its top." It was under such conditions that the eruption on Krakatoa took so spectacular a form.

The age of the volcano, the available water, the amount of heat, the nature of the gases — all these are important in determining the force of an eruption.

Still another way to classify volcanoes is by their shape, which in turn depends on the kind of eruption. Where the hot rocks and gases spurt out with great force, the lava spews out fast and falls rapidly, with the result that a fairly steep mountain is formed in time.

This is the familiar cone-shaped mountain, sloping to the sides at an angle of about 35 degrees. This type is known as a "composite volcano." At the top is the crater. Depending on whether the crater is deep or shallow, we speak of it as funnel-shaped, bowl-shaped, or saucer-shaped.

As we have seen, there are cases where the volcanic matter escapes fairly easily from inside the earth. The lava flows out, forming another type known as a "fluid lava dome"—or "shield volcano."

The amount of lava that flows out at one time may be 20 feet thick, or more. Soon there are cracks in the sides of the volcano as well as at the original vent. As the lava comes out of the side fissures, it emphasizes the flat, domelike appearance of the mountain.

Eventually there comes a time when the

"DEVIL'S POST PILE": These six-sided columns of California basalt form a cliff 60 feet high and 300 yards long. They are the remains of lava that cooled off about 200,000 years ago.

pressure upwards can no longer force the molten rock to the original fissure. The remaining volcanic matter flows out at the sides, broadening the mountain but not making it any higher. Sometimes there is an interesting development: several lava flows gradually join up to form a compound volcano. This is the origin of many islands.

The Columbian Plateau in the state of Washington is made up of old lava flows that extend over 200,000 square miles and rest on even older mountains 2,000 feet high. Much of Yellowstone National Park is on a broad plateau built up from many extensive lava flows.

Mount Mauna Loa in Hawaii, consisting of lava from many eruptions, is 200 miles wide with a height of almost 14,000 feet. (The total height from the ocean floor is 34,000 feet.) You can see from these figures that its slope must be very slight.

One exception to the usual process of eruptions on lava domes occurred in 1924. Mount Kilauea, also in Hawaii, erupted with such force that eight-ton boulders were hurled more than a mile.

So, when you see the different mountain shapes you will be able to distinguish between folded mountains, fault-block mountains, lava domes, and composite volcanoes. Each has its distinctive appearance.

What causes eruptions?

Inside the earth, as we know, very high temperatures prevail. The intense heat melts rocks into a half-solid, half-liquid state known as *magma* (the Greek word for "dough"). The hot liquid flows between the rock layers, as it is bound to travel along the line of least resistance.

Since moving toward the earth's crust, away from the center of the earth, means moving to lighter, cooler, and less dense rocks, that is the line of least resistance. Steam and subterranean gases — sulphur, chlorine, carbon dioxide — add to the pressure. As rocks and gases get hotter, they expand in volume, further stepping up the pressure that is driving inexorably for an outlet.

But this is not all. Underground water bubbles and boils and is changed to steam. This adds the incredibly powerful driving force of steam to the pressures that are heading for the earth's crust at temperatures of 1,000 degrees Centigrade or more. At last a weak spot is found and the boiling magma eats its way to the surface. As it pours out, often in great clouds of gas and steam, it soon runs down the sides, hissing and bubbling. Gradually there is a cooling off and hardening of the material and finally it "corks" or "plugs" the mouth of the volcano. Whether the volcano is dead or dormant, time will tell.

Magma is the source of all igneous rocks — rocks that have hardened permanently after cooling off from the molten condition.

The effects of eruptions

Surprising though it may seem, volcanoes help man in a number of ways. Though lava kills vegetation as it spreads over the land, it can also do good. Dark ash, which gets its color from substances containing iron and magnesium, eventually improves the soil to form rich earth. This is true of the most famous of volcanoes, Mount Vesuvius.

In addition, precious stones were formed a long time ago in the rock and volcanic ash. Gold, silver, and other valuable metals were included in the molten material that poured into cracks in the rocks.

The Italian town of Larderello is set in a landscape which gives many signs of earlier volcanic activity. In 1779 someone noticed that the many steam vents which spout out of the ground in this area contain boric acid. After several attempts, engineers devised a method of evaporating the water to obtain the boric acid, a valuable product.

With the development of modern technology, the natural steam was put to other uses as well. Since 1904 the Larderello Company has been taking the steam from the vents in the ground to produce power for dynamos. Gradually this electric power supplied lighting for many towns, and then for railroads and trolley-car systems.

By the 1930's the operation became even more profitable as engineers found ways to separate the impurities and put them to use. The hydrogen sulphide, for example, was drawn off for making sulphuric acid, an important material in many industrial processes. The success of the Larderello venture points to the possibility of large-scale use of the heat inside the earth as a source of energy for operating power plants.

Aside from these economic factors, there are many aspects of volcanic activity about which men of science are eager to learn a

CAVE-IN: About 3,000 years ago Mount Mazama, in Oregon, erupted with such violence that its top 7,000 feet caved in, forming a water-filled crater 2,000 feet deep. This is known as Crater Lake.

"OLD FAITHFUL": This is the most famous of Yellowstone's many geysers because of the regularity with which it spouts. Announced by a great rumble from within the earth, a hissing, boiling column of water and steam shoots up high in the air.

great deal more. One of the most fascinating subjects for study is the distribution of volcanic ash after an eruption.

In 1912 observers in Algeria noted a marked atmospheric haze. It had started, they discovered, with the presence of volcanic particles released by an eruption of Mount Katmai in Alaska. The presence of these particles deprived the earth of 20 per cent of the solar radiation it receives, and it accounted for a marked fall in temperature. Such after-effects of eruptions make some scientists feel that the Ice Ages of the past may have been related to continuous, intense volcanic activity.

Geysers

When underground water comes in contact with hot rock ("magma"), geysers are eventually formed. However, geysers are almost completely limited to Yellowstone National Park, New Zealand, and Iceland. These are areas which in bygone times had a great deal of volcanic activity.

What happens in these regions is that underground hot steam is trapped and unable to escape. It gets superheated. This results in explosions of steam and water from time to time that pierce the surface of the ground.

Yellowstone National Park has about 3,000 geysers and hot springs. The geysers vary a great deal in their activity and the height of their water spouts. Old Faithful, the most famous, sends up a column of water from 120 to 150 feet high about once every 65 minutes. On the other hand, the Giantess spouts no more than twice a year. However, it sends up a column between 150 and 200 feet high and keeps it up anywhere from 12 to 36 hours. Other geysers are even more unpredictable. The Splendid Geyser, for example, failed to spout even once during a period of 39 years.

Hot springs

Hot springs are created by similar causes, but they are different from geysers. Where the quantity of underground water is too great to be turned into steam by the magma, the heated water flows on until it comes out of holes in the ground. This is the origin of such spas as Hot Springs in Arkansas and Warm Springs in Georgia.

Because the hot water underground dissolves many minerals as it flows along, such waters are considered very healthy to bathe in. They are also bottled to be drunk as mineral water.

Centuries ago the Indians knew about the curative properties of the springs, and

they sent wounded warriors there to recover their health. Some scholars believe the "Fountain of Youth" sought by Ponce de León when he came to Florida in 1519 was actually Warm Springs. He undoubtedly heard stories from the Indians, somewhat exaggerated in the telling, about a "fountain" that had marvelous qualities. In modern times the waters of Warm Springs have helped many suffering from polio.

Iceland has 1,500 hot springs. In 1930 the people of this island began drilling wells to make use of this hot water and today it is piped with little loss of heat to hospitals, schools, swimming pools, and private homes. By 1951 Reykjavik, Iceland's capital and largest city, was using this natural hot water for all its public buildings and three-quarters of its homes.

TALL TALE: The first man who brought back a description of Yellowstone's wonders was called a liar. And no wonder—who would believe in the existence of Mammoth Hot Springs without seeing it?

The water from these springs has a high degree of chemical purity. After being pumped up, the water is filtered and then piped to huge containers near Reykjavik. A fascinating use for this water, which leaves the ground at 190 degrees Fahrenheit, is to heat greenhouses. This now enables Iceland to produce tropical fruits in some quantity — despite its nearness to the Arctic Circle!

4. How Mountains Are Worn Down

ROCK is so lasting that it is used for streets and buildings and highways. To break up rock, man must use dynamite and power drills. Yet rock has always been broken by some of the most familiar forces of nature — such as heat and cold, wind and water. The steps in this tearing-down process may not always be obvious to the untrained eye. However, the end-results are often startling enough to impress any beholder, trained or untrained.

We saw in Chapter 3 that millions of years from now there will be mountains that are not in existence today. And due to the process of erosion, mountains that are in existence today will have disappeared, partly or completely, millions of years from now.

How heat and cold wear down rocks

The heat of the sun bakes exposed rocks and boulders day after day. This heat makes the rocks expand. Sooner or later some outside particles crack and drop off.

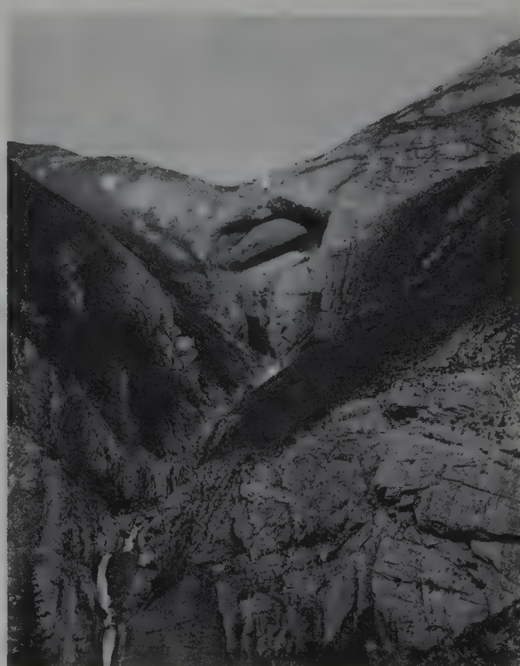
But there is more to this process. When the sunshine heats a rock, it leaves the inside cooler than the surface, so the inside expands much less than the outside does. This unevenness is bound to cause more cracking in the rock.

And what about the cooling-off process? When night comes on, the temperature goes down steadily. But the rate of cooling is also uneven. The outside cools off more rapidly than the inside. The cooling makes the rock shrink in size; and of course the outside, being cooler, shrinks more rapidly than the inside.

All these processes happen again and again, creating strains that cause more and more particles to crack and crumble away.

Ancient peoples were well aware of this

NATURAL ARCH: **This arch in the Canadian Rockies was formed by centuries of erosion.**



NATURAL AMPHITHEATRE: Formed of sandstone and limestone that were eroded by rain and chemical action, Cedar Breaks Natural Monument in Utah is noted for its lavish array of colors.

weathering effect on rocks. When Hannibal, the great general of Carthage, crossed the Alps in 221 B.C. to attack Rome, he relied on this rock-cracking process. He had his men build great fires on the rocks and then pour heaps of snow and ice on them. This alternation of heat and cold cracked the rocks, enabling Hannibal to widen the mountain passes and transport his army of 50,000 men, his elephants, and his supplies, into the land of the enemy.

Across the Atlantic, and perhaps at the very same time, some Indian tribes were mining the plentiful copper deposits on the shores of Lake Superior. Lacking proper tools for getting out the metal, the Indians made clever use of alternately heating and cooling the rocks to break them.

How rain and ice wear down rocks

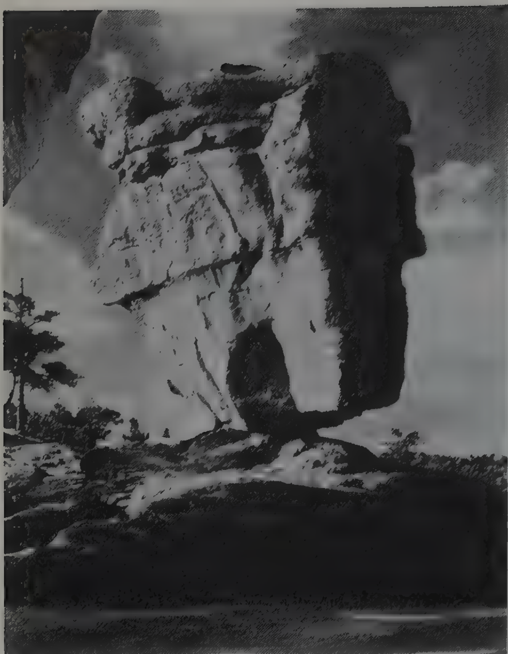
Rain water contains carbon dioxide which helps it to dissolve some of the minerals in rocks. But rain works on rocks in another way too. When rain falls on rocks or snow melts on them, water flows into the cracks and ridges of the rocks. As the weather gets much colder, the water freezes. Unlike most substances, water expands when it freezes. The ice makes room for itself by enlarging the cracks in the rocks.

Here we are describing the effect of ice on rocks on a very small scale. When the ice piles up in huge glaciers on mountaintops, the effects are felt on a much bigger scale.

How plants wear down rocks

Sometimes seeds from plants fall into cracks in rocks. If there is enough soil in the cracks to keep plants alive, the plant roots get into the rocks and get bigger and stronger. They wedge themselves in so powerfully that as they grow their pressure can split a rock.

Lichens, among the oldest of all living things, are plants that are able to grow and flourish on bare rock. Lichens are made up of an alga and a fungus, two of the most primitive plant forms. These two work to-



GROTESQUE: The famous Balanced Rock shows what erosion has accomplished in the Garden of the Gods in Colorado.

gether in one of nature's strangest partnerships.

The fungus in the lichen produces acids that drip over the rock, softening it somewhat and freeing its mineral content. When it rains, the minerals are dissolved into forms that the alga in the lichen can take for nourishment. The alga, in turn, makes organic (living) substances out of the minerals and feeds the fungus on them. And while the lichens flourish, they are breaking down the rock.

How wind wears down rocks

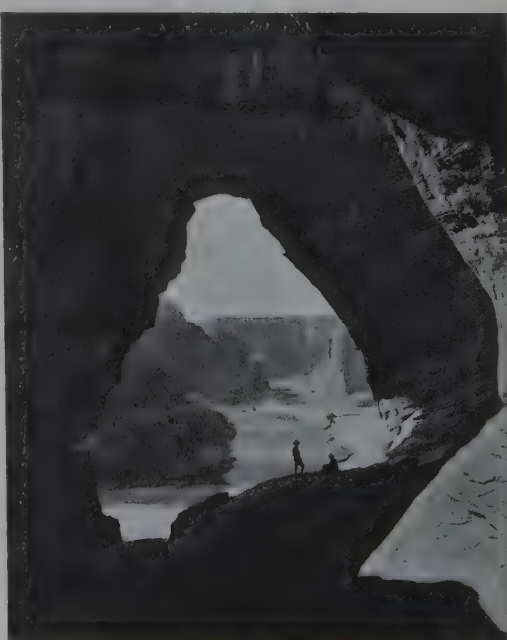
The wind picks up particles of soil and carries them away. If the wind is strong enough, it will whip up a "dust storm." The soil may either get piled up or else be swept along for thousands of miles.

Where trees are abundant, the force of the wind is broken. But where there is little vegetation to begin with, the wind does a particularly destructive job. It strips such areas of any remaining plants. The soil is gradually swept away, too, leaving bare rock. The whims of the wind strew sand over the rock and blow it away again. The desolate surfaces of many parts of Death Valley in California are evidence of the power of the wind.

But what has all this to do with wearing down rock? When the wind breaks up the soil, it carries along innumerable particles of sand. This gives the wind a fine cutting edge against which even rocks are powerless. Over the ages such sand-laden winds wear down towering rock formations and twist them into all sorts of fantastic shapes.

Wind erosion gives rise over the centuries to mysterious holes in a wall of rock, to weird-looking natural bridges and arches in deceptively solid rock structures. The strangely shaped sandstone buttes of Monument Valley on the Utah-Arizona border tell us better than any words what wind and sand can accomplish.

NATURE'S WINDOW: Another example of beautiful effects produced by erosion (Canyon de Chelly, Arizona).



SNOW-WHITE DUNES: The dunes of White Sands National Monument in New Mexico are made of pure-white gypsum sand.

In Death Valley the rocks of the nearby mountains were first weakened by heat and cold and moisture, and then washed away by streams. The rock particles, crumbled into sand, are swept along by the wind, leaving bare rock floor in some parts of the valley and heaping up great sand dunes in other parts.

At the Great Sand National Monument of Colorado the winds pile up dunes as high as 800 feet in the San Luis Valley. The floor of this valley was once a lake-bed covered with silt. This type of soil crumbles very easily and is made to order for dune-building.

Even more impressive is White Sands National Monument, situated between two mountain ranges in New Mexico. Here there are vast deposits of underground gypsum (see page 46), and more gypsum is washed down from the mountains. The resulting sand formations have long shimmering waves of wind ripples that make the area a paradise for photographers.

How water wears down rocks

Erosion starts with "weathering" — the effect of natural forces on rock and soil. Breaking down the rock into small bits is the first step. The second is the removal of these particles from high levels to low levels. This is accomplished mostly by water washing them away. Streams and rain do the trick. The force of gravity makes water run downhill, and thus the crumbled rock is swept off to lower levels.

In one year American rivers carry 800,000,000 tons of mud, silt (sand), and dissolved minerals down to the sea. About half of this is deposited by the Mississippi River.

But even the mightiest river starts somewhere inland as a tiny brook that joins other brooks. Finally a stream is formed. It widens and deepens and becomes a river. Other rivers join it, adding their volume of water and soil.

The movement of water breaks up rock and soil fragments and carries them away. The steeper the slope, and the greater the volume of water, the faster the river flows. The faster it flows, the greater its power to

cut and grind and rub down everything in its way.

As the water wears off bits of rock, it uses them to scrape against the river bed and against the banks, tearing away more rocks and soil and scraping out the bed and pushing back the sides. This is how rivers form valleys. A very deep valley is known as a "canyon."

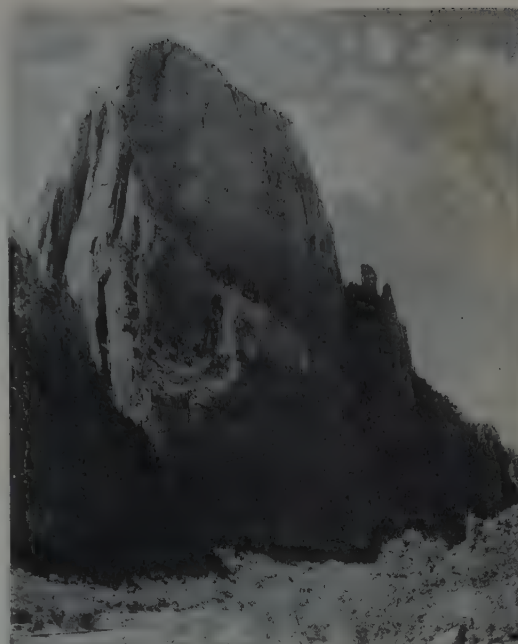
Beautiful Zion Canyon in Utah is a fine example of this process. The Virgin River grinds away about 3,000,000 tons of the canyon's soft sandstone every year. Over the centuries this has created a canyon 15 miles long with steep walls that average about 2,500 feet in depth.

GRAND CANYON: The fast-flowing Colorado River (center) cut through layers of rock to uncover Permian rocks (about 200,000,000 years old). It eventually reached down to Pre-Cambrian formations over 500,000,000 years old.

"THE MITTENS": Here are some of the fantastic shapes carved by erosion in the Monument Valley of Arizona.

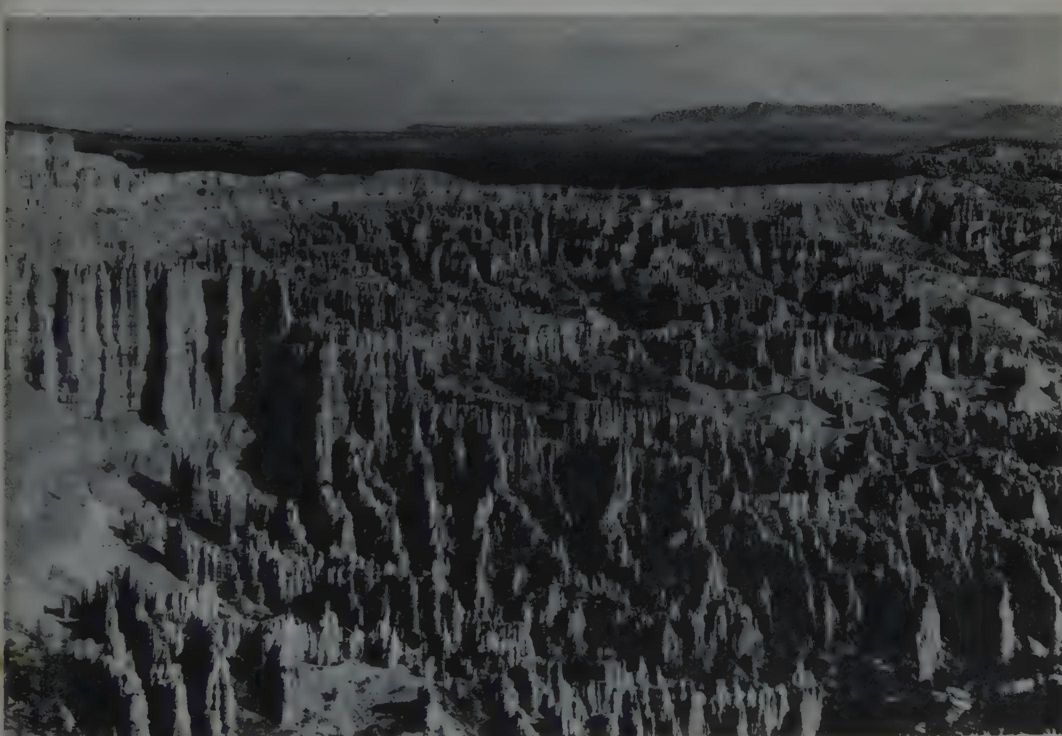
But this canyon, and the even more striking Grand Canyon of the Yellowstone River, are dwarfed by the Grand Canyon of the Colorado River. This canyon's length of 217½ miles is a tribute to erosive activity on a grand scale. It was the Spanish Conquistadores who named the river; in their language the name means "reddish," the color the river takes from all the mud and gravel and rocks that it whirls along in its rapid course. The Colorado River cuts away almost 1,000,000 tons of land every 24 hours. It is precisely this cutting and grinding process that carved out the Grand Canyon over a period of millions of years.

Niagara Falls also presents an erosion problem, but the engineers have a solution



DELICATE STATUES (below): The exquisitely colored pink and white sandstone and limestone of Bryce Canyon in Utah have been eroded by rain and chemical action.

"GREAT WHITE THRONE" (above): This towering rock in Utah's Zion National Park goes half a mile up in the air.



SUBLIME SPECTACLE: The Niagara River (right) flows swiftly through this gorge to Niagara Falls (left), where it drops about 160 feet. The water's rushing and pounding often cause rock breaks.

for it. The Falls were formed toward the end of the last Ice Age by water pouring from Lake Erie over a steep cliff into Lake Ontario via the Niagara River. During thousands of years the Falls have "undercut" an eight-mile length of rock.

Scientists were well aware that if the erosion went on without a stop, the Falls would some day disappear when the undercutting work was fully accomplished. In February, 1954 the United States and Canada began the Niagara Remedial Works Project. This provides for a series of gates and dams that will slow further erosion.

How sedimentary rocks are formed

If you fill a glass with water from a stream, it will look discolored throughout from the particles of earth suspended in it. But after a while the appearance of the water will change. The particles will sink to the bottom of the glass, and the water will look clearer. The bottom will get darker, the top lighter.

This is what happens when the rivers carry their burden of millions of tons of sand, clay, mud, and dissolved mineral matter into the ocean. All the "sediment" gradually sifts out and sinks to the ocean floor. What happens to all these substances when they reach bottom?

First let's see what happens to the sand. For millions of years the sand keeps piling up on the ocean floor. It gets "cemented" together by clay and certain mineral matter in the sea. As layer after layer is formed, the weight of the top layers gets heavier and heavier. Eventually the crushing pressure of the upper layers forces the lower layers together until they become so compact that they harden. The process is helped by the cementing of several kinds of mineral matter. Thus, very, very slowly, sandstone is formed.

The same thing happens to the mud, which forms a thinly layered rock called shale.

There is still a third important type of sedimentary rock. It is limestone, formed from the remains of dead ocean creatures, and calcium carbonate. When fish and countless other kinds of sea animals die, shell sinks to the bottom. Again the same process of pressure takes place. Layer upon layer of these limey remains pile up and eventually they form limestone. Conglomerate, also known as "pudding stone," is another kind of sedimentary rock. As you can guess from the name, it is a mixture of sand and pebbles that happens to be on the ocean bottom.

So we see that erosion, that highly destructive process, leads in the end to the formation of rocks and the rebuilding of mountains. For, in time, the mountain-making pressures described in Chapter 3 will fold and eventually uplift the rocks into towering mountains. (This explains, by the way, how we come to find fossils of sea animals on mountains.) At this point, we are able to get a clear picture of the "rock cycle."

The rock cycle

Let's take the case of some igneous ("fire-formed") rocks which were formed under ground from magma. Eventually this rock is pushed above the earth's crust by volcanic action or by movements caused by folds, faults, and various pressures. Weathering by natural forces breaks the rock down over the years. Water carries the particles off to a river, where they proceed to inland seas. Here they separate from the water and sink to the bottom.

The igneous rock may have started out as granite. Ages later its particles may be formed into sandstone or shale and again much later may be raised to mountain

DINOSAUR HOME: Dinosaur National Monument, located in Colorado and Utah, has proved a rich source of fossil deposits. Though the area today contains some of our barest canyons, it was lush swampland 200,000,000 years ago.

heights once more. And in time this rock will again be subjected to erosion.

This, of course, is a greatly simplified picture of the rock cycle. One other change in rocks should be noted. When sedimentary rocks are raised from the sea bed, the pressure and heat may change them into what are called "metamorphic" rocks. Under these conditions limestone turns into marble; shale turns into slate and schist; and sandstone into quartzite.

This change into metamorphic rock complicates matters for the geologist. Every stage of rock-history has some evidence to offer him. When any of that evidence disappears, his work becomes that much harder.

It seems logical that the rock layers of a certain geologic period should always be found on top of layers of the preceding period. But it doesn't always work out that way. Often, when several layers have formed, the rocks are uplifted. After much of the rock has eroded, the information that the missing layers would have supplied is gone forever.

But this is not all. Suppose the sea level rises again, leaving the top of the mountain below the surface of the water, and new layers begin forming. The geologists, by patient study of evidence from other parts of the locality, are able to piece together what happened.

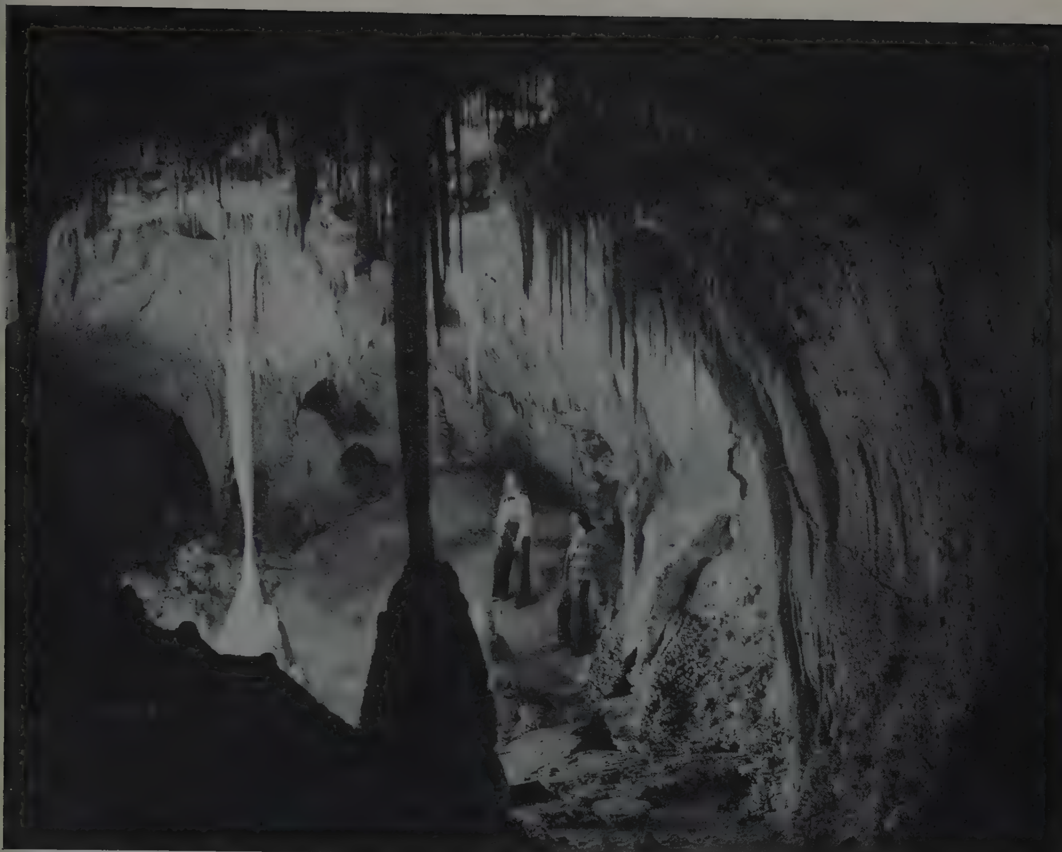
Caves

Some caves have been formed by volcanic action, some by the dashing of waves on rocky coasts. However, most caverns — especially the famous ones — owe their existence to the action of water on limestone. The water seeps down through the soil and rock from rain and from streams. It contains a certain amount of carbon dioxide, which forms an acid.

As the water flows through cracks in limestone, the carbonic acid we spoke of attacks the limestone formations. The limestone dissolves and is carried off by the water. The cracks keep on getting larger and larger, and in thousands or millions of years holes are formed underground and are widened into caverns.

During this process, as water flows through the roof of the cave (the top of the hole), it seeps through the "pores" of the rock. This water carries calcium carbonate in dissolved form. After seeping through the roof, the water drips down. Each drop hangs at the roof before falling, as if it were dripping from a leaky faucet.

"TOOTHPASTE" TUBE: The volcanic formations of Lava Beds National Monument include lava flows that cooled and hardened on the surface while the inner lava continued to flow. This resulted in a hollow inner structure in which the tube-like lava bed caves were formed.



Sometimes it evaporates because of the air which reaches the interior of the cave from outside. Sometimes it falls.

As a drop evaporates, it leaves a particle of mineral matter sticking to the roof. Each time a drop of water reaches the cave roof, the process is repeated, with the water either falling or evaporating. In time a whole icicle-like column of mineral matter hangs down from the roof. This is called a "stalactite."

When the seeping water does not evaporate at once, but drips down to the floor, it carries its mineral content with it. The water stays on the floor, and more water drips down, bringing more mineral matter. Gradually a "stalagmite" (icicle in reverse) rises from the ground. It may happen that eventually a stalactite and a stalagmite meet to form a beautifully shaped solid column from floor to ceiling of the cave. The natural colors of the minerals contribute to the awesome beauty of these fantastic formations.

LARGEST CAVERNS: **Stalagmites join stalactites in the Carlsbad Caverns of New Mexico. They were formed 60,000,000 years ago from limestone.**

Occasionally lava flows have formed caves as the lava hardens on top and continues to flow in molten form on lower levels. The lava caves at Lava Beds National Monument in northeastern California are impressive examples of this type of cave. The Indian writings on the walls ("petroglyphs") and the remains of bighorn sheep and pronghorn antelope indicate these caves were used for human dwellings thousands of years ago.

5. Valuable Rocks and Minerals

WE KNOW that 4,000 years ago and earlier the people of ancient times were using granite, limestone, marble, and other kinds of stone. But how the Egyptians, Mayas, and Incas built their massive structures of great blocks of stone will probably always remain a mystery; they lacked most of the mechanical techniques and devices we have today.

One explanation of the mystery is that ancient peoples used slave labor on a fantastic scale. In order to be able to build the Pyramids, for example, the rulers of Egypt had a magnificent highway built through the desert. This road was constructed of huge blocks, and in some parts was 10 feet wide. It is said that 100,000 slaves were used to transport the material along this road for the Pyramids.

As for the Romans, they constructed 50,000 miles of roads to prove that "all roads lead to Rome." These highways had both military and commercial value. The surface was made of blocks of stone resting on a three-foot-deep bed of smaller stone and cement. Some of these roads, as well as some of the Roman bridges and viaducts, are still in use. Labor was no problem — the Romans had many thousands of war captives.

Massive stone was also used to fortify cities and even borders. The classic example is the Great Chinese Wall, started about 220 B.C. and built up much more extensively some 1,600 years later. In its most elaborate form the wall was 1,500 miles long, 25 feet high, and about 20 feet thick at the base.

The most spectacular construction feats of our own time are doubtless our great dams. Boulder Dam was built of three trillion cubic yards of concrete. It is 1,200 feet long, 660 feet thick, and as high as a 60-story skyscraper. Grand Coulee Dam, the largest concrete structure in the world, is much larger than the Pyramids of Egypt. Grand Coulee contains twice as much concrete as would be needed to build a two-lane coast-to-coast highway.

Quarrying methods

Quarrying is the method used to extract granite, limestone, sandstone, marble, slate, and other kinds of stone in bulk. A quarry is an open pit in the ground, and can be as large as hundreds of feet wide and a hundred feet deep.

The oldest quarrying technique is known as the plug-and-feather method. It was widely used by the Aztecs and other ancient peoples. Holes were chiseled into a layer of rock at intervals. Wooden plugs were inserted into the holes, which were then filled with water. This caused the wood to swell, so that the pressure cracked the layer along a natural and fairly smooth line of cleavage.

In modern quarrying, "feathers" (rounded pieces of steel) are inserted along the sides of the hole, and a plug is driven down by compressed air to achieve the same effect of smooth splitting. This is of course much speedier than the ancient method.

For work on marble, limestone, and sandstone a channeling machine is often used. This is mounted on a truck and delivers about 250 strokes a minute. It is powered by pneumatic (air pressure) machines, or else by rock drills driven by steam or gasoline. Cutting out about 100 square feet of rock in an hour, this machine offers the advantage of extracting massive blocks of stone with the least amount of waste or damage.

Limestone and marble are often cut with wire "saws." Such a saw is an iron-wire rope twisted in three strands, which runs continuously on pulleys. The action of the saw, assisted by sand or some other abrasive, forms deep cuts in the stone.

Where crushed stone is produced for paving, the most efficient method is to use explosives.

GRANITE QUARRY: This view of a granite quarry at Elbertson, Georgia, shows the use of a channeling machine, described on this page.

Useful minerals

The value of certain kinds of rock for building and paving is well known. But there are many other minerals which have a surprisingly wide range of uses in industry. Some of these uses go back to ancient times; others are related to phases of our ultramodern electronics products.

ASBESTOS: Our most valuable fireproofing material.

ASBESTOS is a strange-looking mineral that comes in threadlike slivers. Its ability to resist heat and fire was a lasting source of wonderment to the people of ancient times.

Asbestos is an important ingredient of many fireproof materials, firefighting equipment, plasterboard, and quite a few other products.

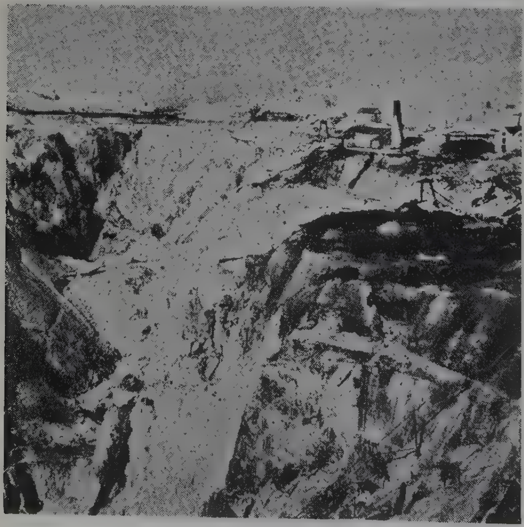
The best kind of asbestos comes from serpentine. Asbestos is either quarried or mined, depending on its location on the surface or underground. The major share of the world supply of asbestos comes from Canada.

Borax gets its name from the Arabic word *buraq*. This white mineral was originally found in ancient lake bottoms of Tibet and imported here by way of China. For about a century we have been getting most of our borax from California, Nevada, and Oregon. Borax Lake in Death Valley is a famous source of this mineral.

Borax is used for several medicines and antiseptics, as well as soaps, tooth powders, and water softeners. It also has valuable industrial uses, for example, in the making of pyrex glass utensils. The "borax bead" test for identifying metals is an important feature of chemical analysis.

Clay, which comes mostly from the breakdown of feldspar, is one of the commonest materials. There are many ancient sources of clay — old swamp formations, mud layers on sea bottoms, and remains of rock fragments left by glaciers. It has a great many varieties and has been useful to man for thousands of years.

The Babylonians, who had very little wood or stone, relied on brick made from clay. Some examples of their use of building clay date back to 3000 B.C. Hardened by exposure to the sun, these clay bricks were suitable only for a dry climate, where they would not be attacked by moisture.



CLAY PIT: The purest form of clay, known as kaolin, is found in pits like this one. Kaolin is easy to work; it resists heat; it hardens after heating; and has an attractive white color.

Adobe is a term used for sun-dried bricks and the clay they were made from. The ancient Babylonians made adobe bricks with straw, and they are fine for use in regions that have little rainfall.

The Romans used clay brick both for public buildings and homes. They fired the bricks in furnaces (kilns), making them resistant to heat and moisture — practically indestructible, in fact. Brick was a great favorite during the Middle Ages and the Renaissance period, and has continued to be popular into our own time.

The use of clay in pottery goes back to prehistoric times. Man learned early to shape clay on a wheel while it was moist. (Potter's wheels 6,000 years old have been found.) To make a shape permanent man learned to bake the clay object; then, to make the surface leakproof and attractive, he glazed the pottery with enamel and baked it again. Examples of clay utensils from early times show that ancient man had mastered the arts of brilliant, sharp enameling and glazing. Cretan, Greek, and Etruscan vases are famous for their artistic beauty.

The Chinese brought the art of pottery-making to such a high degree of skill that we use the term "china" for a whole range of clay products regardless of where they were made. Some collectors believe Chinese craftsmanship in porcelain (a particularly attractive form of processed clay) surpasses anything done in this field anywhere else in the world.

Modern ceramics (pottery) work has to take into account many varying qualities of clays. These include the clay's degree of purity; its ability to be shaped; the amount of shrinkage under firing and air-drying; the color it will take on after firing; the degree of hardness and cohesion ("sticking-together") it will have after baking; and its ability to take ornamentation.

CORUNDUM, which is an aluminum oxide, gets its name from the Sanskrit *kuruvinda*. As the next hardest natural substance after diamond, it is valuable as an abrasive (grinding material) and in wheels for cutting and polishing hard objects. Emery is a form of corundum.

This mineral has several beautiful gem varieties: ruby (red) and sapphire (blue). Sometimes rubies are more highly prized than diamonds. In their less attractive forms, these stones were formerly used in phonograph needles, watches, and precision instruments, and are now made synthetically for these same purposes.

Burma and Ceylon are the leading corundum producers. Some of it comes from the United States — chiefly North Carolina, Georgia, and Montana.

GRANITE, which is so tough it can resist pressures of 15,000 pounds to the square inch, has been a favorite material for building and paving for thousands of years. The Egyptians made their obelisks of granite, and the Romans used this stone a great deal in magnificent public buildings and in bridges that have lasted for 20 centuries.

GRANITE: Despite its coarse appearance in the natural state, some granite can be polished until it takes on a very handsome surface.

CORUNDUM: Source of gem stones.

The choicest granite is selected for monuments and gravestones. This type of granite must have small crystals of more or less uniform size. It must be of the same color throughout and capable of taking a high polish that will give it a smooth, glasslike finish. (Polishing not only gives the stone a very handsome appearance; it also protects it against weathering.) Its texture must be suitable for distinct lettering, which is put on by a special sandblasting process.

Granite for statues and buildings must be of similarly high-grade quality. Some of the most famous buildings in Washington, D.C., such as the Library of Congress, are constructed of granite.

GRAPHITE, like coal and diamond, is a form of carbon. It is black, very soft, greasy to the touch, and an excellent conductor of electricity.

Because graphite is strongly resistant to heat and to burning, it is used to line furnaces, especially for making steel. A very important recent use of graphite is to line the chambers in which atomic reactions are set off, because the graphite slows up the chain reactions.

Graphite is the material in our "lead" pencils. A "hard lead" pencil is made of graphite mixed with quite a bit of clay and makes a light impression on paper. A "soft lead" is made of graphite and very little clay and makes a dark impression on paper. Graphite is also used as a polish, and, in its powdered form, as a dry lubricant in place of oil.

Graphite is found occasionally in granite and other igneous rocks. It also turns up in metamorphic rocks, such as schist, gneiss, and marble.

GYPSUM, a compound of calcium, sulphur, and oxygen, is found in clay deposits or layers of ancient shale. It often appears on the sites of ancient seas, as in New Mexico, in layers that sometimes reach a thickness of 1,000 feet.

Gypsum is mined in many parts of the United States — especially Oklahoma, which is called the "Gypsum State." Some of these deposits go back to Permian and Triassic times, about 200,000,000 years ago. The gypsum may be yellow, gray, or red — depending on the presence of clay, iron oxide, or other impurities.

Gypsum was known to the Egyptians and other ancient peoples. Today it is very important in making Plaster of Paris, which is used for casting in sculpture, and for making casts to help broken limbs knit together properly.

Blackboard "chalk" is made from gypsum. This mineral also is valuable for improving excessively alkaline soil. A massive form, known as "alabaster," is white or slightly tinted. It is used for making statuettes and ornamental vases.

LIMESTONE was originally formed (as we saw) from the remains of sea animals. It is the most popular building stone, and is the source of the cement that goes into our building foundations.

LIMESTONE: Popular building material.

The Romans used considerable limestone in their roads and other durable structures; the Carthaginians also favored it. Limestone is also used extensively in our modern highways; close to 70 per cent of all the crushed rock used for roadbeds is limestone. It also goes into our streets, bridges, and dams.

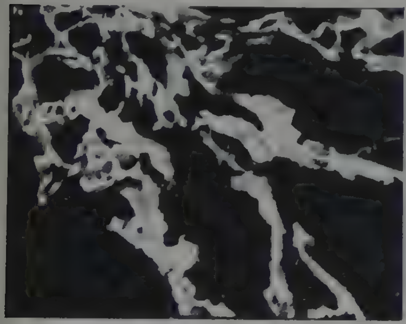
Another of the important uses of limestone is to carry off the impurities in the blast furnaces that extract iron from iron ore. It is also melted to make "rock wool," the valuable insulating material that helps keep houses warm in winter and cool in summer.

Chalk — not to be confused with blackboard "chalk" — is a particularly soft, crumbly form of limestone. Most chalk deposits were laid down in Cretaceous times, 100,000,000 years ago.

Chalk is used in making putty, cement, and plaster, and is useful in farming as a means of checking acidity or excessive clay in soils.

Lime, which is prepared by heating limestone in a kiln, has a fantastically large number of applications. Most important, perhaps, is the making of cement. (See above.) The Romans knew the secret of making concrete and used it for some of their most famous buildings, such as the Forum, the Pantheon, the Baths of Caracalla, and the Circus Maximus, which was constructed to seat 260,000 persons. They also employed concrete for their temples, roads, and notable engineering works. After the fall of Rome the knowledge of concrete-making was lost, and only rediscovered in comparatively modern times.

Industrially and agriculturally, lime is valuable in purifying and as a fertilizer. Stage lighting was once produced by lime-light, which results when a powerful oxy-hydrogen flame is directed against a cylinder of lime.



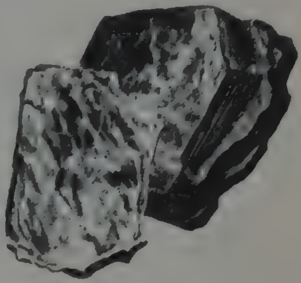
MARBLE: Most beautiful ornamental rock.

MARBLE is a metamorphic form of limestone or dolomite. It comes from the tiny sea animals that were originally deposited on the ocean bottom and turned into stone over a very long period of time. Its beautiful colors and grains are due to the changes in its crystal structure during the metamorphic ("making over") process.

Because of its unusual appearance marble has always been highly regarded as a building and sculptural material. The ancient Greeks excelled in its use, and many of their temples and public buildings were made of marble. The second Temple, which Herod the Great built in Jerusalem, had Corinthian columns of marble 15 feet in circumference. In Italy the famous Carrara and Siena marbles served Michelangelo and other sculptors for some of their outstanding masterpieces.

Marble has kept its popularity in the modern world and is used for a variety of buildings and ornamental purposes. White is considered the best grade for sculpture, but red, pink, yellow, black, and gray all present an attractive appearance in building.

MICA splits into thin sheets, some less than 1/1000th of an inch thick.



MICA is the name of a group of minerals found in long sheets, mostly in pegmatite, a coarse-grained form of granite. Muscovite is commercially the most valuable form of mica because of its resistance to heat and electricity.

Mica is an important insulator in phonographs, loud-speakers, radar detectors, radios, and many other kinds of electrical equipment and appliances. This mineral is also used for insulation and windows in stoves, optical lanterns, and lamp shades. Mica is also essential in making dynamite, paints, tiles, and lubricating oils.

About half the world supply of mica comes from India. There are large deposits of mica in Canada.

QUARTZ CRYSTALS are usually 6-sided with a 6-sided pyramid at one or both ends.

QUARTZ, which is found in all types of rocks, is the commonest of all the minerals.

In the pure state it is colorless. Paradoxically, when it is colored by impurities, it takes on hues that give us many beautiful semiprecious gem stones. In the form of rock crystal (page 56) it has several important industrial uses.

SALT is known to the chemist as sodium chloride and to the geologist as halite; to most of us it is ordinary table salt. This mineral is essential to all plant and animal life, and in earlier times buffaloes and other wild animals wore well-marked trails through the wilderness on their way to the salt "licks." While salt is most abundant in the ocean, it is also plentiful in many areas that were once below sea level and are now dry land.

Salt is obtained by evaporation from sea water; as brine it is pumped from wells; and mined as an underground deposit in the form of rock salt. The remains of ancient seas contain huge salt beds.

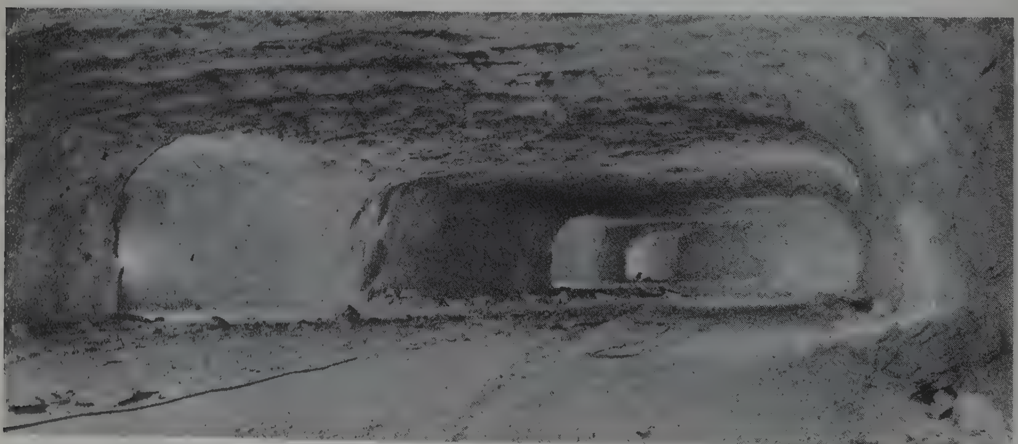
Aside from its dietary value, salt is important as a food preservative. (It was even more important before the days of refrigeration.)

SAND is formed from the weathering and crumbling of igneous, sedimentary, and metamorphic rocks. All the forms of erosion we saw in Chapter 4 contribute to the formation of sand. Where sand is made up of inorganic (nonliving) matter it is all or mostly quartz.

Sand is used in treating metals, filtering water, and in making explosives, pottery, and glass. It is also important in many grinding and polishing processes. Sand is essential in making bricks, mortar, cement, concrete, and plaster.

Glass, which is generally considered the first man-made material, is made from sand. The sand, specially selected for purity, is heated in furnaces at a temperature averaging 2,700 degrees F. This turns the sand into a transparent liquid. It is then allowed to cool, and as it hardens it is blown or molded into various shapes, or rolled into sheets.

"GLASSMAKING": The heat of an atomic-bomb explosion turned sand into these glassy-looking particles.



SALT SUBWAY: Salt mines in Texas are very large, as may be seen from these spacious halls.

Glassmaking apparently was known in prehistoric times, and was developed to a high degree in Egypt, India, and China by 1500 B.C. The Romans were skillful glassmakers; they had glass windowpanes and excellent glassware. The secret of their skill seems to have disappeared with the Empire, for while beautiful glassware and windows continued to be made in the East, the art of glassmaking did not revive in Europe until about 1000 A.D.

Later on, the exquisite stained glass used in cathedrals all over Europe reached the highest levels of artistic skill. For many centuries Venetian glassworkers have been noted for their handsome products. Their specialties are delicate engraving and enameling work.

Glass has always been important in windows and lighting, and is now additionally used for the very structure of buildings, for electrical insulation, scientific instruments, eyeglasses, cooking utensils, and containers. Glass wool makes an excellent insulator; foam glass is used for rafts and life preservers; polarized glass reduces glare. Thus new uses are constantly being found for this ancient product.

GLASS BLOWERS: Shaping red globes for railroad safety signal lanterns. This glass must meet the highest requirements for durability.

SANDSTONE LEDGE: Purest sandstone—the kind seen here—is reduced to quartz grains to be mixed with other raw materials used in glassmaking.

SANDSTONE is sand "cemented" together by such materials as lime and silica. The stone is very popular for building in many regions. The sandstone used for "brownstone" houses in the late nineteenth and early twentieth centuries dates from Triassic times — about 100,000,000 years ago.

Flagstone, which is used a great deal in patios and terraces, is a form of sandstone. Very pure sandstone is sometimes broken down into a powdery form and used instead of sand for glassmaking. The sandstone of the famous St. Peter formation in Illinois, for example, makes optical and plate glass of high excellence.

Sandstone is a porous rock — it contains holes into which liquids can flow. Shale is not porous, and where it is found on top of sandstone we may discover oil deposits that have been trapped by the shale. Sandstone is extremely plentiful in many parts of the United States.

SHALE: This is the rock in which oil is most commonly found.

SHALE, which was once mud, is a sedimentary rock. It sometimes has preserved the tracks of dinosaurs, fossils of corals and other sea creatures, and even the marks of raindrops and wave ripples. Made up mostly of clay particles, shale is sometimes soft and crumbly.

The location of shale often points to the presence of oil and coal deposits. Oil shale can be refined to yield petroleum, but at present the process is too costly to be practical.

SLATE is the metamorphic form of shale. It is generally gray or black but impurities may color it red, yellow, or brown. Slate is often used for roofing because it is easy to process and is highly weather-resistant. It is also used for blackboards.

SOAPSTONE, which has a gray or greenish color, is the impure form of talc. Because soapstone is extremely soft, primitive man used it for cooking utensils before pottery was invented. It is very plentiful in the United States, and the Indians liked to carve ornaments from it.

In modern times the resistance of soapstone to heat and acids has made it ideal for laboratory table tops, laundry tubs, furnace linings, and sinks. Under the name of "French chalk" it is used by tailors for marking alterations on clothes.

SULPHUR, one of the most useful substances in the world, is a golden-yellow powder or solid with no distinctive taste or odor. It is soft, light, and brittle, burning with a blue flame that gives off a stifling odor.

This mineral is necessary to life, and it is found in all protoplasm. Sulphur, the "brimstone" mentioned in the Bible, is one of the substances associated with volcanic eruptions.

The United States leads the world in sulphur production. The great underground sulphur beds of Texas and Louisiana, some of them 120 feet thick, account for 80 per cent of world production. Most commercial sulphur is found near limestone, rock salt, or gypsum deposits. It is also extracted in powdered form from the neighborhood of volcanoes.

This valuable mineral has an extraordinary range of uses. These include the making of drug preparations, gunpowder, and insecticides.

TALC, the softest of all minerals, is greasy to the touch. Its best-known use is in talcum powder, cosmetics and drug preparations. Talc, which is plentiful in the United States, is also used in making paper, linoleum, soaps, and lubricants.

Precious gem stones

COAL, petroleum, and diamond are among the most valuable minerals known to man. Diamond is pure carbon; coal is mostly carbon with some impurities; petroleum is a hydrocarbon, a combination of hydrogen and carbon.

Diamonds are crystallized carbon, form-

DIAMONDS IN THE ROUGH: Note the eight-sided shape of these rough diamonds.

ed a long time ago, it is believed, by volcanic heat and pressure. Mineral crystals come in six different shapes. Most diamonds form a crystal with eight surfaces, or "faces." Some diamonds have twelve faces.

Diamond is the hardest substance known, much harder than corundum, the next hardest natural substance. Acids and alkalis have no effect on diamond. Diamond will not burn until heated to 1600 degrees F.

Though diamonds are noted for their hardness, they can be shattered by a blow, and an expert can split them cleanly. This process is known as cleavage.

The weight of diamonds and other gem stones is measured in carats. A carat is equal to about 1/142nd of an ounce. A round diamond weighing one carat is about a fifth of an inch in diameter.

Diamonds are usually tinged with light yellow, straw, or brown, and occasionally are colorless. The fancy colors (pink, blue, green, orange) are more unusual.

Many of the world's famous diamonds have fascinating histories, and their very names, such as the Great Mogul, the Kohinoor, and the Star of South Africa, have a richly romantic ring about them. Colorful diamonds contributed to the splendor and luxury of the courts of the Moguls and Rajahs of India and all the famous monarchs of Europe. But there is also a somber side to the story of these beautiful gems for some have inspired envy and greed and dreadful crimes.

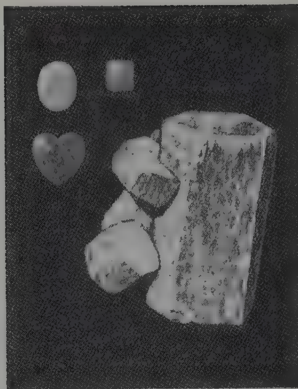
Diamonds, like other gems, have gone up steadily in value as a long-term proposition. In the last hundred years, the price of diamonds has increased many times over. The concentrated wealth represented by diamonds has stimulated efforts to make synthetic gem diamonds. So far, however, man has not mastered nature's secret of making gem stones, though small ones may have been made.

In South Africa, diamonds are mined in a soft rock known as "blue ground." The mines sometimes reach a depth of 3,000 feet, and the whole operation is extremely laborious and costly. Experts say it takes 250 tons of ore to make one finished one-carat diamond.

After the rock is dug out and brought up, it is crushed in several processes, and screened for size. Then comes "jigging"—shaking the crushed rock so that the heavier substances fall to the bottom.

Next, the material is sent down a sloping table in which steps have been cut. The table is covered with grease—a quarter-inch layer of petroleum jelly. The grease holds the diamonds, and lets everything else roll down the table. The grease is now melted, leaving the diamonds at last exposed to view. (They are of course not affected by the melting process.) The diamonds are cleaned with acid and then sorted. They are now ready to be sent to the market, where they will be sold to cutters and finishers.

Gem stones have always been admired for their appearance, and in earlier times they were valued as good-luck charms. In addition to the diamond, there are three other precious gem stones: the ruby, the emerald, and the sapphire. All three have



BERYL: The source of emerald (green) and aquamarine (blue) stones.

certain features in common: they are very beautiful; they are hard enough to be very durable; and they are very rare.

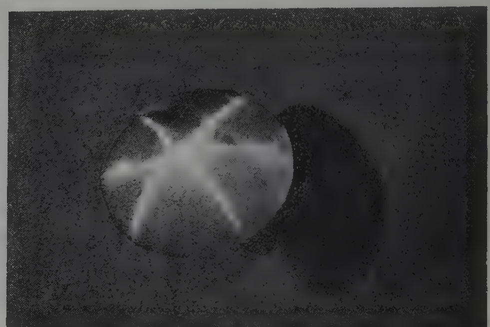
A paradoxical feature of these stones is that their color is the result of "impurities" in what are otherwise rather humdrum minerals. Rubies result from the presence of chromium oxide in corundum, while emeralds are due to the presence of the same substance in beryl. Sapphires depend on titanium and iron impurities in corundum.

Emerald, a beautiful green stone, is generally found with some flaws in the natural state. Gem cutters can remove or minimize the impurities, but a really flawless emerald is almost as valuable as a diamond of comparable size.

The Egyptians discovered emeralds on the west coast of the Red Sea at least as far back as 1600 B.C. To the ancients the emerald was thought to provide clear vision and the ability to prophesy. Cleopatra and Queen Isabella of Spain were among the famous rulers who have been especially fond of these vivid green stones.

The finest emeralds come from Colombia, where they were discovered by Spanish Conquistadors in an abandoned Inca mine in 1558. Emerald mining became a government monopoly in Colombia in recent times.

Ruby, which has been called the "lord of stones" and the "gem of gems," gets its name from the Latin *rubeus* ("red"). In ancient times people believed the gem would protect its wearer from harm. Jehangir, a Mogul emperor of India, saw still another value in the ruby. He had his name carved on one, with the thought that this would preserve his name better than any monument could. He was right.



STAR RUBY: Rounding reveals the pattern.

The finest rubies come from limestone deposits in Burma. They are of the shade known as "pigeon's blood," which has slight tinges of blue. There are also "star rubies," which have internal starlike formations of rays which can be seen when the stone is cut to have a rounded top.

The eroding of some of Burma's limestone deposits has made it possible to find a few rubies in the gravel and clay of streams. Other sources of rubies are Ceylon and Thailand.

Sapphire gets its name from the Greek *sappheiros* ("blue"). The dazzling blue of the sapphire gave rise to a charming Persian legend — that the earth rested on a giant sapphire which was reflected in the sky.

Hebrew tradition held that the Ten Commandments were originally engraved on sapphire, and that the gates of heaven were made of the same stone. In Greek

legend the sapphire was the favorite gem of Cronus, mightiest of the Titans.

As in the case of the ruby, some sapphires also show the six-rayed star. India (Kashmir), Burma, Thailand, and Ceylon are the chief sources of sapphires. Some are found in Australia, and a few in Montana.

But the most beautiful sapphires of all come from Kashmir in India. These sapphires, noted for their soft rich cornflower blue, were unknown until 1875. A number of them in the possession of the Maharajahs of Kashmir have increased in value from $400,000 to $3,000,000.

Semiprecious gem stones

While many of these stones are of striking beauty, they command much lower prices because of their comparative abundance. However, their attractive appearance has made them popular for centuries of use as jewelry and ornament.

AGATE: The finest agates come from Brazil, and the best cutting was done for centuries in Germany.

Agate is a form of chalcedony and therefore belongs to the quartz family. It is distinguished by bands of strongly contrasting colors. When some of the bands are black, the stone is called "onyx." In this form it is used for cuff links, brooches, and rings.

Agate gets its name from the Achates River in Sicily, where the Greeks discovered the stone in ancient times. The agate was once popular as a love-charm and a protection against poison. In the United States, agates are found everywhere, near Lake Superior and in several western states.

Amber, the fossilized resin of trees that died millions of years ago, was valued by ancient peoples for its beautiful appearance. Because of the faint odor of resin that clings to amber, the Arabs named it *anbar* ("perfume" or "incense").

The Egyptians began using amber about 3000 B.C., and it is mentioned in the *Odyssey* and the *Arabian Nights*. The ancient Greeks liked amber as an ornament, and believed it had medicinal value and could cure insanity. The Greeks also observed that rubbing amber created static electricity. That is why they called amber *elektron*, from which we get our modern word "electricity."

The shores and sea bottom of the Baltic have always been the chief source of amber. It has also been found inland in lignite deposits.

Amethyst, a purple variety of quartz, was once as valuable as diamond. After the amethyst became plentiful, its price sank considerably. Thus, an amethyst necklace owned by Queen Charlotte of England about 170 years ago and originally valued at $10,000, would be worth only $500 today.

In earlier times, the amethyst was regarded as a love-charm, protection against thieves and against intoxication. The finest amethysts today come from Brazil and Uruguay.

Aquamarine is a pale-blue or blue-green form of beryl. In Latin it means "sea water." Some aquamarines are found in the United States. However, the choicest aquamarines come from the USSR, Brazil, Ceylon, and Madagascar.

One of the largest, most perfectly cut aquamarines (1425 carats) was presented by the Brazilian government to Franklin Delano Roosevelt.

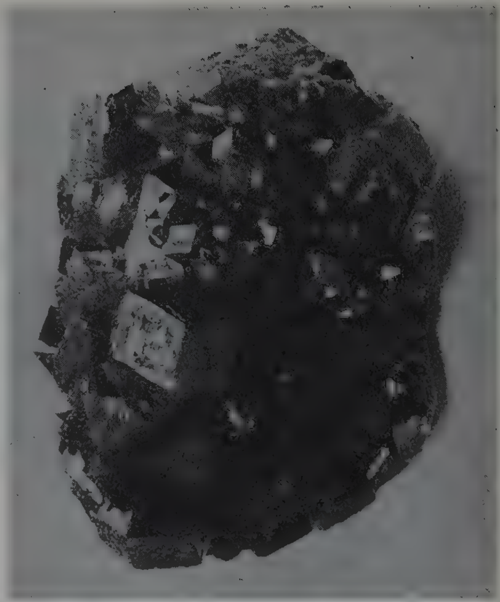
Carnelian is a form of chalcedony and therefore of quartz. Its name comes from the Latin *carneus* ("flesh-colored"), but its color is closer to that of a ripe tomato.

The ancient Egyptians and Assyrians were using carnelian by 2000 B.C. if not earlier. Carnelian was a great favorite in signet rings, and Mohammed is said to have had such a ring. Carnelian is used nowadays in jewelry.

Chalcedony (kal-se-dony), a variety of quartz, is mentioned in the Bible. It lets light through, but has little luster. However, as chalcedony is porous, it can be made more colorful by being placed in a colored solution. Chalcedony makes handsome necklaces, bracelets, and ornaments.

Chrysoberyl, a mineral of the beryllium family, gets its name from a Greek word meaning "golden." In Mohammedan countries the brilliance of this stone is thought to be due to the presence of a genie, or spirit.

One form of the chrysoberyl was not known until 1830, when it was found in Russia. It has the curious property of appearing green by day and red by night. (Red and green were the national colors of imperial Russia.) The chief sources of chrysoberyl are Brazil, the USSR, and Ceylon.



GARNET: This handsome semiprecious stone comes in a variety of forms from a variety of sources.

Garnet, which is a silicate, is generally thought of as having a brilliant crimson color. Actually garnets come in various colors, including emerald-green, orange, and cinnamon-brown. Some garnets are distinguished by starlike arrangements of 4 or 6 rays. Garnet is hard enough to be used industrially for grinding.

The USSR, South Africa, and Mexico have yielded some beautiful garnets.

Jade, though often white, is generally apple-green or dark green. It comes from two metamorphic minerals — jadeite and nephrite. They are found in several parts of the world, with Burma supplying the finest quality, a jadeite.

The use of jade goes back to prehistoric times, when primitive man made axes, knives, and other tools and utensils with it. In the New World the Aztecs carved many beautiful jade objects. A 2,500-pound boulder of nephrite was found some years ago in Wyoming.

But jade is associated above all with the Chinese. Jade-carving goes back at least 5,000 years in China. The Chinese have always been the most skillful craftsmen with this tough mineral that calls for a great deal of loving labor on the carver's part. This is partly due to the rudimentary methods used in China; it is not unusual for a fairly simple carving to take several years in the making.

To the Chinese, jade has mystical medicinal properties, and they associate it with the five traditional virtues: charity, modesty, courage, justice, and wisdom. It is highly valued today. A small jade figure from the Ming Dynasty that sold for $2,300 in 1937 was resold in 1949 for $13,000.

JET, a black, shiny variety of petrified wood, is a form of carbon and really belongs to the coal family. In some regions it was used for ornament as far back as the Old Stone Age. In the Middle Ages, crucifixes were often made of jet.

Because jet, like amber, was first found near the sea, it has often been called "black amber." In later times it was mined in England, Indo-China, and elsewhere. Jet has been used in a wide variety of jewelry and accessories, including earrings, beads, and cigarette holders.

LAPIS LAZULI ("stone of lazurite") is usually deep blue but may also be violet or greenish blue. It was very popular in ancient times, and the mines of Afghanistan date back to about 3500 B.C.

Lapis lazuli was made into bowls, vases, beads, and small ornaments. It was also the source of ultramarine pigments.

MALACHITE (MAL-a-kite), an ore of copper, is a deep green stone striped or banded like agate. In Russia it was used to make strikingly handsome mosaic table tops. In jewelry it is often set in gold to create beautiful effects. The Chinese like to carve in malachite, although they have to get their supply of the stone from Russia or Africa. The Russian Czars often presented gifts of beautifully carved malachite.

The Egyptians are said to have started mining malachite about 4000 B.C. They thought of it as a good-luck charm for children.

OPAL is a beautiful silicate, getting its name from a Sanskrit word that means "precious stone." It comes in several body colors, including milky-white, green, and black. This stone is valued, however, for the remarkable play of shifting colors ("opalescence"). The best opals show reds, oranges and yellows, as well as green and blue.

Opals (or similar stones) are supposed to have been mined as far back as 6,000 years ago in Africa. The Romans set great store by them as good-luck charms. In modern times the finest opals have come from Australia.

MARCASITE: This mineral, which contains iron, was used in earlier times to strike a light.

Peridot is also known as "olivine." It has mainly one color — yellow-green. All of the best peridots come from St. John's Island in the Red Sea, known to the ancients as Topazus. The peridot, which is a magnesium and iron silicate, is occasionally found in meteorites.

(These meteorites are pieces of matter which fall through space onto the earth. There are "stony" meteorites as well as "iron" meteorites — the latter are mostly iron with some nickel and a slight mixture of other substances.)

During the Crusades some exceptionally large and transparent peridots were brought back to Europe. Burma has yielded a few beautiful peridots.

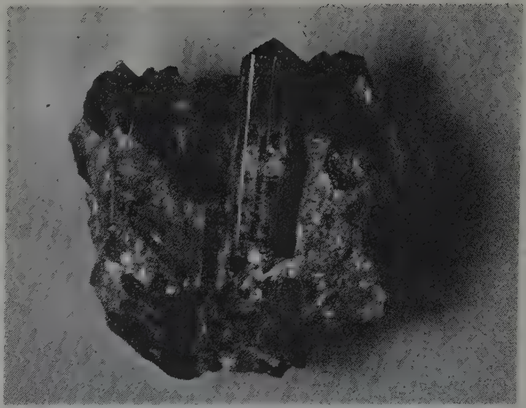
Rock crystal, a form of quartz, is popular in necklaces. It is also the mineral that fortune tellers use for their crystal balls. The largest crystal ball in the United States weighs 107 pounds and is appraised at $250,000. It is kept at the Smithsonian Institution.

Rock crystal also has many industrial uses, in radio, short-wave, and television sets; in radar detectors; in sandpaper and grindstones.

Precious Topaz is a silicate deriving its name from the Greek *topazios* ("to seek"). In ancient times topaz came from a fog-surrounded little island in the Red Sea. It was hard to find, hence the name. The gems on the island were sent to Egypt to be worked on by the royal gem cutters.

Today the finest topaz comes from Brazil. Topaz makes beautiful necklaces and bracelets.

Tourmaline, a member of the silicate family, is generally pink or green, but it comes in a variety of other colors. It was not discovered until 1703, and at first appreciated only as a scientific curiosity. When this gem is heated it acquires an electrical charge which makes it capable of lifting light objects.



TOURMALINE: This semiprecious stone contains such metals as iron, aluminum, and magnesium.

Brazil, Madagascar, and South Africa have yielded beautiful tourmalines, as have California, Connecticut, and Maine. In 1820 two young boys who were interested in geology discovered tourmaline in pegmatite (granite) deposits in Maine. Eventually they are said to have realized $50,000 from their claim.

Turquoise is a compound of copper, aluminum, and phosphate. Its usual color is blue, but green varieties are known. Silver settings give it a very handsome appearance, and turquoise is seen in a variety of jewelry forms. Both the Persians and Pueblo Indians used it as a good-luck charm. Turquoise is found in many parts of the world, and is moderately plentiful in California, Nevada, Arizona, New Mexico, and Colorado.

Zircon, another silicate, is mentioned in the Bible, the Koran, and the *Arabian Nights*. It comes in many colors, and its brilliance is second only to that of the diamond. The chief sources of zircon are gravel deposits in Ceylon, Madagascar, and Indo-China.

6. How to Collect Minerals and Rocks

COLLECTING rocks may give you an absorbing, lifelong interest and will certainly bring you into healthful surroundings out in the open. The lure of new discoveries always provides an attractive goal. If you collect as most people do, in a group or with a person of similar interests, it will foster good companionship and perhaps lasting friendship.

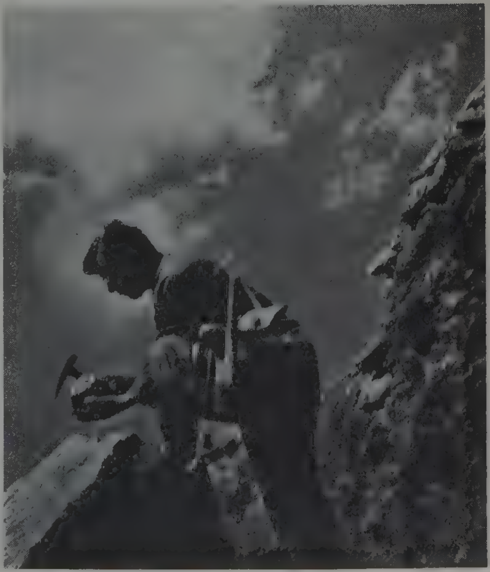
Pictures of rocks and minerals are interesting, but they cannot begin to approach the attractiveness of "the real thing" itself, in its natural surroundings. A visit to the museum is enjoyable, but again it lacks the pleasures of a field trip. And then there is joy and pride of personal ownership in treasured objects that may have cost you a good deal of toil and trouble.

How do people start collecting rocks and minerals? Often such a collection starts with attractive pebbles that happen to catch the eye. This might occur on a hike, on a beach, or on a summer vacation trip — anywhere, in fact, out in the open. You will recall that Charles Darwin's scientific career started with his interest in the pebbles on his father's doorstep. Eventually that interest took shape in a memorable voyage of scientific discovery around the world.

Sometimes people become interested in collecting in the course of school or college field trips in the country, or through seeing a sample collection at a summer camp. (Collecting is a popular activity for winning the Boy Scout merit badge.)

Those who are lucky enough to have a friend or relative or teacher with this hobby may easily become fascinated by the pleasures of collecting. A visit to a museum may inspire a lifelong interest in minerals.

SPLITTING A ROCK: This often provides useful information about a specimen.



FATHER AND SON INSPECTING CRYSTALS

Where to collect

To the beginner the problem of finding specimens may seem to be very difficult, but actually there are many possible sources. Cliffs, ravines, abandoned ore piles or old mining towns, ancient glacier beds, and river banks are ideal for finding minerals.

So are places where roads and railroad tracks have been cut through. The vicinity of mines and quarries is also rich in material for you. Fields often contain boulders and smaller stones that will swell your collection. The seashore, too, is a good place to find attractive specimens.

But even if you don't live near any such areas, your case is far from hopeless! You may visit one of these places or pass them during a vacation trip or excursion, and thus get a chance to do some rewarding collecting.

You can always pick up interesting minerals around excavations, where old houses are being torn down, or where new ones are being built. (That adds a new interest to being a "sidewalk superintendent.")

Even when all these suggestions cannot help you, there are still other sources. You can buy specimens, many of them very reasonably priced, from the dealers who advertise in magazines devoted to natural history hobbies.

Very often collecting takes a specialized turn. You may collect (or buy) rocks containing fossils — a good way to make even more vivid the fascinating story of creatures that lived on this earth millions of years ago. Minerals with beautiful crystals make an absorbing hobby, too.

Some collectors specialize in flint arrowheads, catlinite pipes, obsidian knives, soapstone dishes, and other things made by

OUT HUNTING FOR SPECIMENS

primitive peoples. Collecting minerals for samples of various kinds of cleavage, or luster, is still another fascinating hobby. The more advanced collector may specialize in a classified collection of igneous, sedimentary, and metamorphic rocks.

Your equipment for collecting

To begin with, you need tools for breaking off bits of rock, or for prying them loose. You can get these from a hardware store or from scientific-supply houses which advertise in the hobby magazines.

Most important is a geologist's or prospector's hammer or pick. This type of tool has a broad head for hammering and breaking open rocks, and also a pick with a narrow point for prying out specimens. By using such a tool and a chisel you may often make attractive finds that were not visible on the surface.

HAMMERS

PICK

A chisel, about one inch wide — or a little less — will help you pick out smaller crystals and fragments.

A pocket knife is easy to carry and is helpful in checking "hardness" (page 61) of specimens.

A pocket magnifying glass is also needed; the Coddington Magnifier provides four grades of magnification, the maximum being 20 times, although 8 to 10 is all that will usually be needed.

To carry your specimens you do best to obtain a canvas knapsack which is sold by sporting-goods stores. You can carry your equipment and stones in this bag.

You will find out by experience that it is advisable to number the items you collect. Adhesive tape is very useful for this purpose. Take a strip of adhesive tape before leaving on your trip and cut it up into 20 small pieces. Stick them onto some wax paper (to keep them moist) and number them with black India ink from 1 to 20. On your trip you can then stick a numbered piece of adhesive tape on each specimen.

You will also need a loose-leaf notebook and a pencil. When you find your first specimen, you number it and record the number in the notebook, giving the date, the locality, and a careful description of the stone — including its name and type. Make the entry at the time of discovering the stone. Don't rely on your memory.

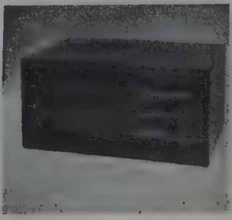
Such descriptions may sometimes be the key to finding something of real value, or to indicating accurately where certain kinds of deposits may be found. You may want to return to search the area, and this information will be valuable to you and to your fellow collectors.

A diameter of about two inches is roughly right for each specimen. If larger, the items will be too heavy and bulky; if smaller, some interesting detail might be lost. There may be special reasons for wanting a stone of a different size. Soft specimens can be cut with a knife; hard ones can be handled with a chisel.

It is a good idea to take along some old newspaper or wrapping paper to wrap each item separately. In this way you will avoid losing the smaller items, and you will pro-

MAGNIFYING GLASS

STORAGE CABINET



CATALOGING AND LABELING

tect the softer ones from getting scratched by the harder rocks and minerals.

Some collectors like to pick up two pieces of each stone. They use the duplicate for swapping or testing. (In that case, they take along a duplicate set of numbers.) However, this has the drawback of limiting the variety of specimens that you can bring home.

How to store your collection

Once you have your stones, you follow through on the idea of keeping them properly numbered and identified.

Offhand the problem of maintaining a collection of stones seems to involve some difficulty and awkwardness. Actually, there are many ways to store a collection — in old cigar boxes, shirt boxes, old dresser drawers, or even trays, shelves, and cabinets. (Egg cartons are fine for smaller items. Cufflink boxes and similar containers of jewelry are likewise suitable.) The space you have can be divided by wooden or cardboard partitions. You can also buy trays from the mineral supply houses.

Where available, an old bookcase or a cabinet with interchangeable drawers is probably the best to use. A good material for the shelves is plywood, which can be bought very reasonably from any retail lumber yard. A two-foot length for the shelves is advisable.

As a matter of fact, you don't need a bookcase in order to use shelves. You can build a very serviceable "bookcase" or cabinet with crates.

Allow plenty of height between shelves so that you can pile one box or tray on another if necessary. Once you paint or varnish the finished job, you will be proud of its appearance.

(It's a good idea to check in advance on the probable size of your trays or other containers, and work out the size of your shelves accordingly.)

The labeling and cataloging of your stones will add greatly to the pleasure and knowledge you derive from your collection. Instead of the adhesive tape technique mentioned before, you can put the information on paper and attach it to the stone with household cement. Still another way is to clean a small part of the stone and paint some white enamel over that section. Then, with a fine camel's hair brush and black enamel or black India ink, you can supply the number and name of the stone.

Near the tray you can pin or paste up a sheet of paper (or an index card) repeating the information in written or typed form. On all such records, you keep using the original number assigned to the stone. If any record is lost, you can check the information in your notebook.

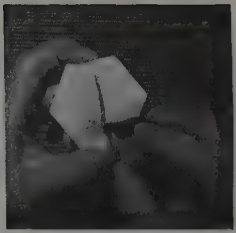
This notebook should be in loose-leaf form because if you find a better specimen of a certain type of rock or mineral, you will want to insert a page for a new description. (You may want to replace the older specimen and set it aside for trading purposes.) Also, a loose-leaf record always allows room for unforeseen expansion — for photographs, for example, of striking formations of column lava, and the like.

Identifying minerals

One of the most useful aids to identifying minerals is the standard hardness scale, which has ten grades of hardness.

A stone of Grade 10 (the hardest) can scratch all the lower grades without their scratching it. A stone of Grade 1 will be scratched by all stones of Grade 2 to 10, without scratching any of them.

Each stone scratches stones belonging to lower grades of hardness, but does not scratch minerals belonging to higher grades of hardness. In the case of two stones be-



HARDNESS POINTS (left) and STREAK PLATES (right) are valuable aids in identifying minerals.

longing to the same grade of hardness, they will scratch each other.

The standard hardness scale uses ten representative minerals, beginning with the softest and ending with the hardest:

1 talc	6 feldspar
2 gypsum	7 quartz
3 calcite	8 topaz
4 fluorite	9 corundum
5 apatite	10 diamond

Here are some examples of how the scale is used, with explanations of the first seven degrees of hardness:

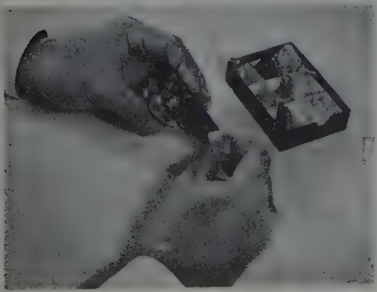
Hardness 1: stones so soft they can be scratched with a fingernail.

Hardness 2: these stones do not feel soft but they can still be scratched with a fingernail.

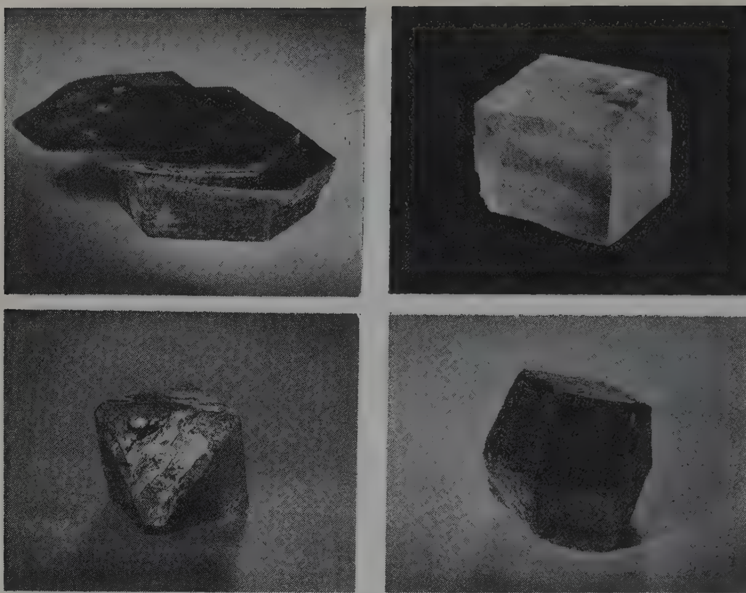
Hardness 3: these stones cannot be scratched by a fingernail, but they are scratched by a penny.

Hardness 4: these stones resist the penny, but a knife will scratch them with no trouble.

Hardness 5: these stones can just barely be scratched by a knife.



TESTING FOR HARDNESS (left) and TESTING FOR STREAK (right)



TYPES OF CLEAVAGE: Mica (top left); halite (top right); fluorite (bottom left); sphalerite (bottom right).

Hardness 6: these stones will scratch the blade of the knife and will just barely scratch glass.

Hardness 7: these stones scratch glass easily and will scratch the vast majority of common minerals.

Hardnesses 8, 9, and 10 are not very common.

Some degrees of hardness may be in between; more than 6, say, and less than 7.

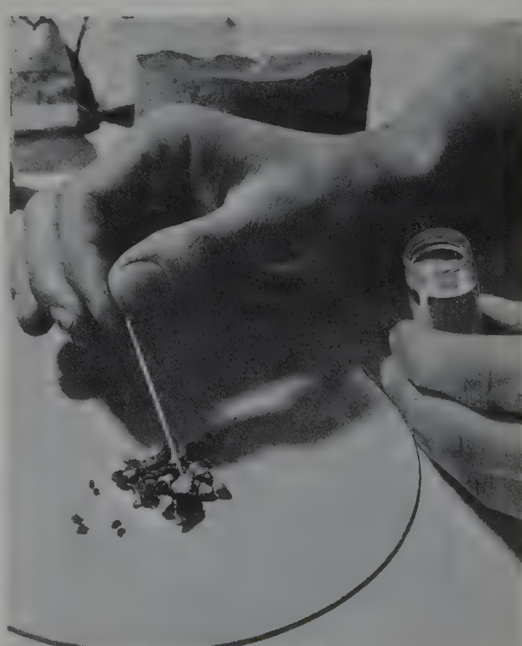
Another help in identifying minerals is to test their cleavage — the way they split. Feldspar, for example, splits cleanly in three directions. If you have a mineral that barely scratches glass (Hardness 6), splits in the manner just described, and has a glassy to dull luster, the mineral you are testing is feldspar. Mica, with a hardness of between 2 and 3, splits into very thin, flat, flexible and elastic layers.

Another common mineral, calcite, may be identified in a number of ways. It bubbles when hydrochloric acid is spilled on it. It scratches a penny and is also scratched by it. This places it in the Hardness 3 group. And finally, calcite breaks cleanly in three ways.

Dealers in mineral supplies sell sets for measuring hardness, which provide all the materials you need for this purpose.

Another help in identifying a mineral is finding out the color of its "streak." The surface color of a mineral specimen is often

ACID TEST: A geologist tests drilling samples for limestone by applying hydrochloric acid to them. (Limestone makes the acid bubble.)



different from the color you find if you scratch the mineral with a piece of bathroom tile. (This is the kind of tile used on bathroom floors. It is also used under hot plates to keep them from damaging a table top.) The color brought out by the tile is the mineral's streak. The table beginning on this page shows the hardness and streak of common minerals.

This table also gives the luster of common minerals. Luster is the quality of reflecting light. In the case of metals and ores, this luster is metallic as a rule. In the non-metals, the most common luster is glassy.

COMMON MINERALS

Mineral	*Hardness*	*Streak*	*Luster*	*Remarks*
AMPHIBOLE	5.5	white to pale green or pale brown	satiny or glassy	group of minerals ranging from white to green, brown, or black, with six-sided long slender crystals; common in metamorphic rocks
APATITE	5	white	glassy	white, green, or brown; found in many igneous or metamorphic rocks
AZURITE	4	light blue	glassy	azure blue; copper ore; bubbles in acid
BERYL	7.5	white	glassy	commonly found in pegmatite; generally green or bluish green
CALCITE	3	colorless	glassy to dull	colorless and transparent in pure state; yellow, brown, green, red or blue from impurities; uniform cleavage in 3 directions; bubbles in hydrochloric acid; clear calcite provides a double image; also known as "Iceland spar"

ICELAND SPAR: This is a name often used for clear calcite, because one of its early discoveries was in Iceland.

DOLOMITE	3.5	white	glassy	white, pink, or gray; contains magnesium; resembles calcite, but bubbles only in warm hydrochloric acid
EPIDOTE	6.5–7	white	glassy	pistachio to very dark yellow-green; found in igneous and metamorphic rock
FELDSPAR	6	white	glassy to dull	feldspar group makes up 60 per cent of the earth's crust; all form crystals with 2 good cleavage planes and 1 imperfect one; mostly white, yellow, pink, but also green, brown, gray
FLUORITE	4	white	glassy	colorless or violet, green, yellow, or rose; cubic system crystals; 4 perfect cleavage directions
GALENA	2.5	lead-gray	metallic	lead-gray color; opaque; brittle; lead ore; perfect cubic cleavage
HALITE	2.5	white	glassy	common salt; colorless to white; test by taste; cubic cleavage
HEMATITE	6	red to dark red	metallic, glassy, or dull	ocher red to black; iron ore; streak test is the definite one

Mineral	*Hardness*	*Streak*	*Luster*	*Remarks*
LIMONITE	5.5	yellow-brown	metallic to dull	yellow-brown to black; iron ore; looks like rust; streak test important
MAGNETITE	6	black	metallic	steel-gray to black; magnetic iron ore; found in igneous or metamorphic rocks
MALACHITE	3.5	light green	silky or dull	vivid green; copper ore; bubbles in acid
MICA	2–3	white	glassy to pearly	group of minerals; white (muscovite), black (biotite), also gray, pink, yellow, green, brown; always crystalline, with some crystals 3 feet in diameter; splits in sheets sometimes less than 1/1000th of an inch thick; these sheets are flexible, elastic, transparent, shiny
PYRITE	6	greenish-black	metallic	brassy yellow, called "fool's gold"; sulphur and iron compound; found in igneous and metamorphic rocks; the hardest metallic mineral
PYROXENE	5.5	white to grayish-green	glassy	group of minerals; common with feldspars in granite, gneiss, and lava
QUARTZ	7	white	glassy	group of most common individual minerals, forming 12 per cent of the earth's crust; crystals usually 6-sided with six-sided pyramid at one or both ends; many varieties are semi-precious; quartz is common in sedimentary, igneous, and metamorphic rocks
SALT				see HALITE
SERPENTINE	2.5–3	white	greasy or waxy	yellowish or green; never occurs in crystals; generally found in metamorphic rocks

SALT CRYSTALS: These crystals were formed by the evaporation of the water in a rock salt solution.