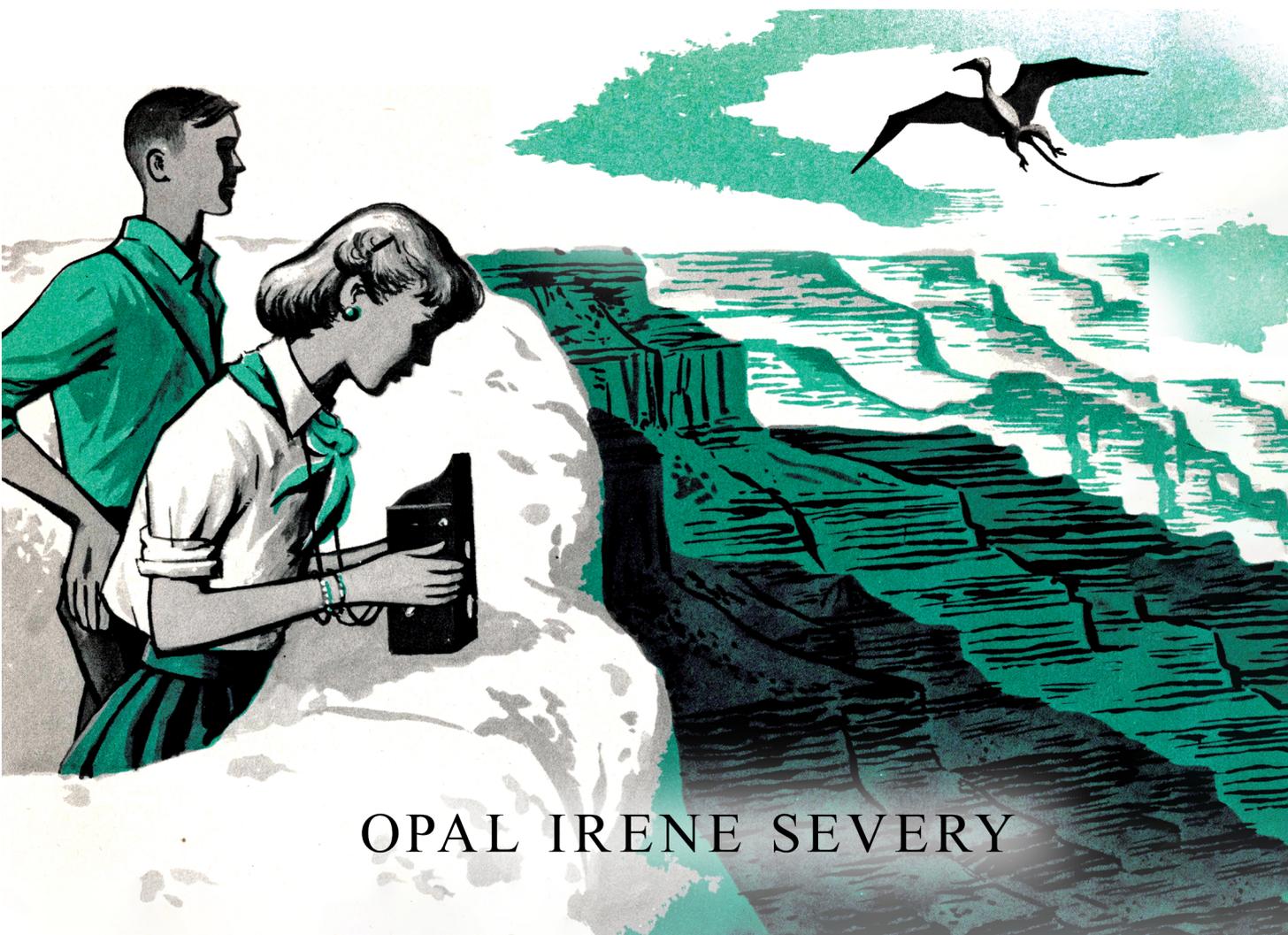


DIVE INTO GEOLOGY'S MARVELS

THE FIRST BOOK — OF THE — EARTH



OPAL IRENE SEVERY

This edition published 2025
by Living Book Press

ISBN: 978-1-76153-941-1 (hardcover)
978-1-76153-953-4 (softcover)

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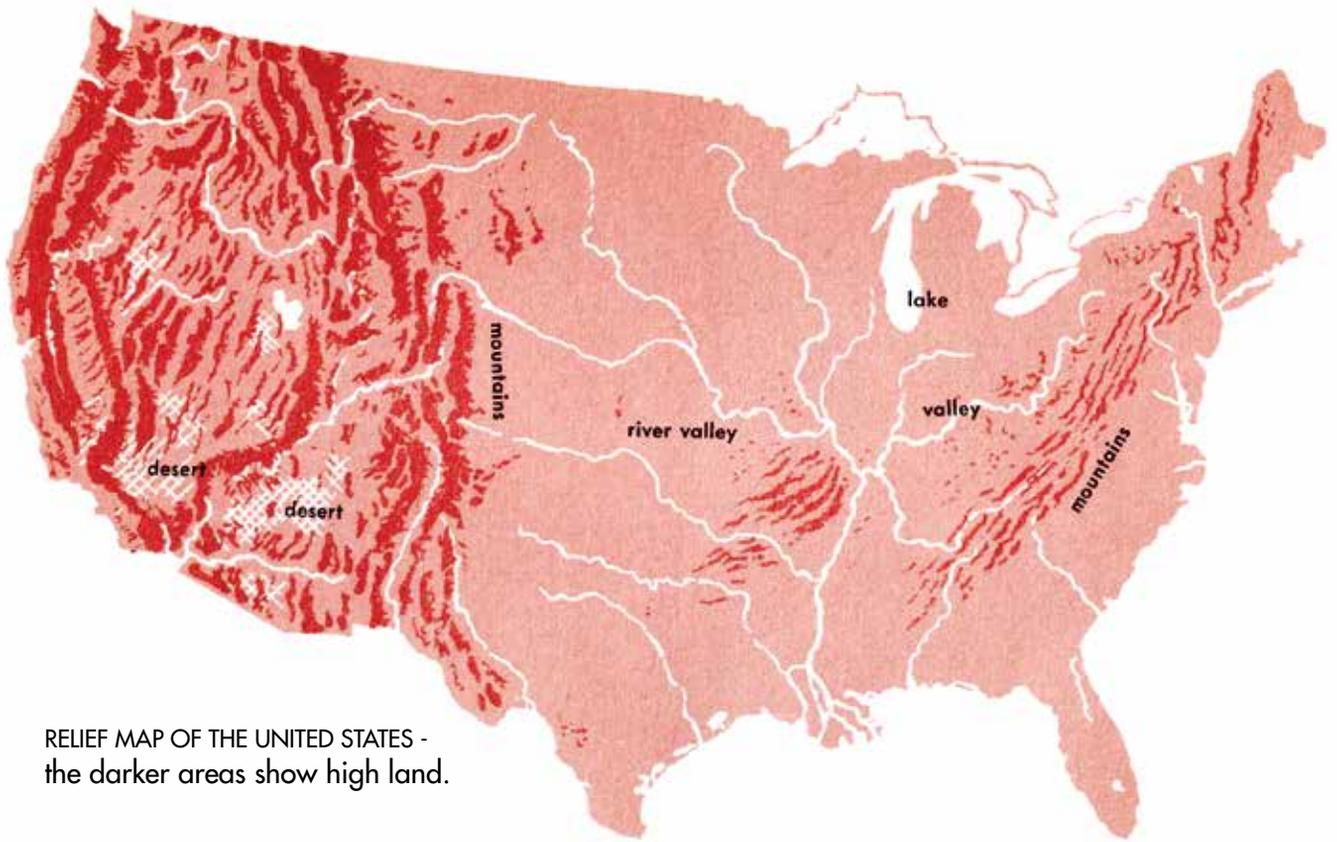
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RELIEF MAP OF THE UNITED STATES -
the darker areas show high land.

our planet

Did you ever look at a map made especially to show the rivers and mountains, the lakes and plains — the “uphills and downdales” of our land? It is called a relief map, and it is quite different from the usual map that shows countries and cities. On it you can really see the hills rising from the flat land. And you can see the rivers beginning as narrow streams and growing wider and wider as they run toward the sea. Some of the land is spotted all over with lakes, large and small. Other parts of the country, the deserts, have no waterways at all.

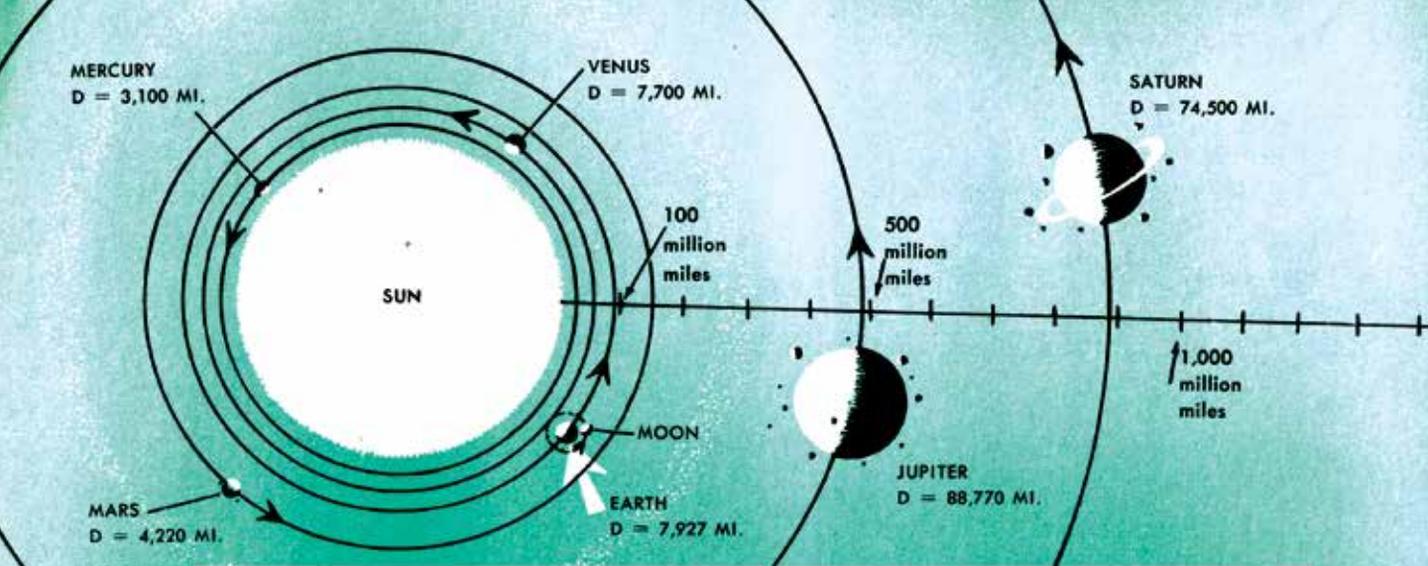
Suppose someone were to ask you to make a quick, very rough map something like this, showing the little hills and valleys, the brooks and ponds of your own small neighborhood. You could probably do it from memory.

“How do you know that’s the way it is, without even looking?” a friend might ask.

“Why, that’s the way it’s always been. I’ve climbed that hill dozens of times,” you might possibly answer, pointing to a hill you had made on your map.

Yet all those hills and valleys, brooks and ponds, and even the earth itself, had a beginning. Did you ever stop to wonder how they all happen to be exactly as they are? Why are there mountains on one part of our earth, plains on another, oceans in another? Why are there rocks, lakes, swamps, and caves?

Men puzzled over questions like these for thousands of years. More and more they looked closely at the earth itself. And there they gradually worked out the answers to many of their questions.



The earth is a picture book that tells much of its story to those who know how to read it.

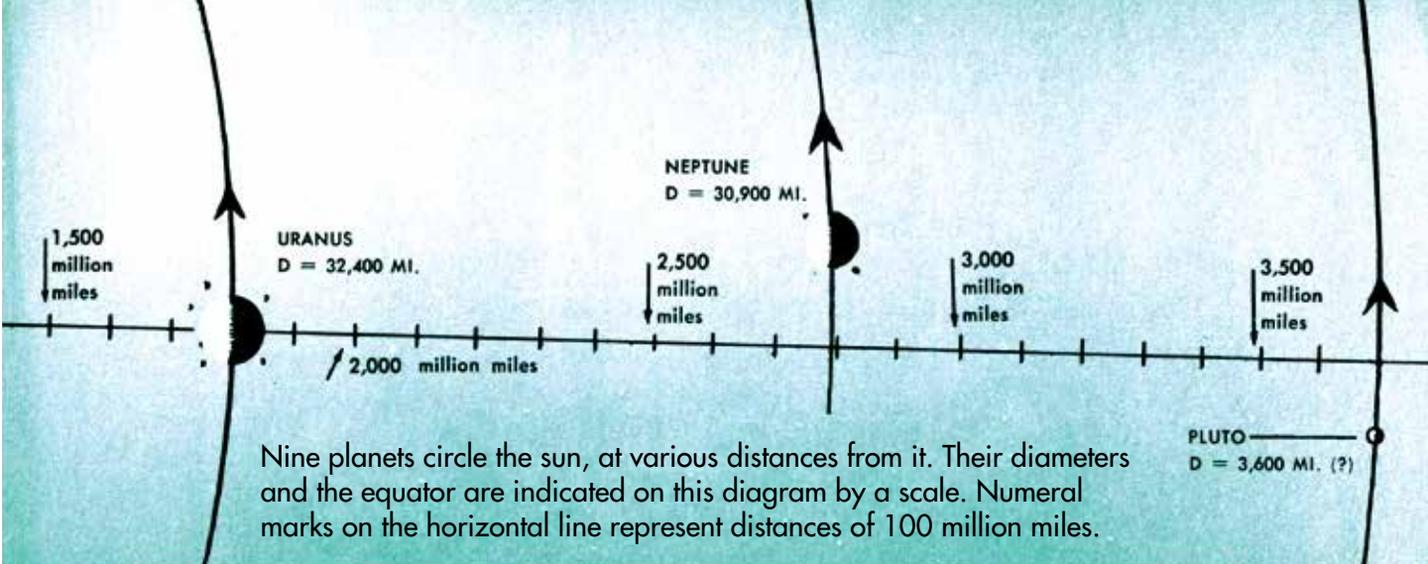
The men who can read our earth best are the geologists. They study the earth. Another group of scientists, the astronomers, tell us about the stars and the earth's place among them. The geologists and the astronomers, between them, have pieced together much of the story of the earth.

They are agreed that the earth is a huge ball of rock moving at great speed around our sun. It is called a *planet*, a name that means "wandering." The sun is circled by nine planets—four that are larger than the earth, three that are smaller, and one, Venus, that is much the same size.

Some of the planets have *moons* — balls of rock that travel with them. The earth has only one moon, while Jupiter, another planet, has twelve¹.

Very small balls of rock, called *asteroids*, journey along with the planets. Thousands of small, broken pieces of rock whirl along with them, too. These are called *meteors*, from a Greek word meaning "high in the sky."

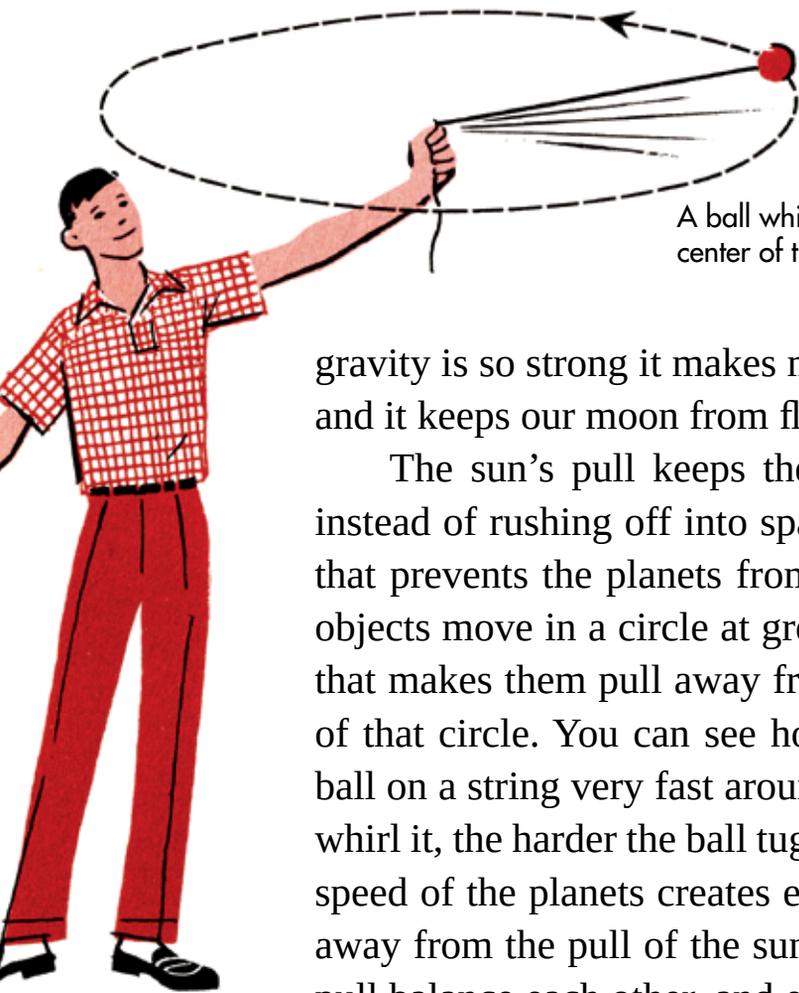
¹ As of April 2025 scientists have identified 97 moons around Jupiter.



Nine planets circle the sun, at various distances from it. Their diameters and the equator are indicated on this diagram by a scale. Numeral marks on the horizontal line represent distances of 100 million miles.

Some astronomers think meteors may have come from a planet that exploded. Meteors which fall into the earth's atmosphere usually become red-hot and burn up before they reach the ground. Often, if you watch at night, you can see them streaking across the sky. Sometimes people call them "shooting stars." But they are not really stars. The real stars are *suns*, or balls of gases that glow by their own light. Our sun is only one of the billions of suns speeding through space.

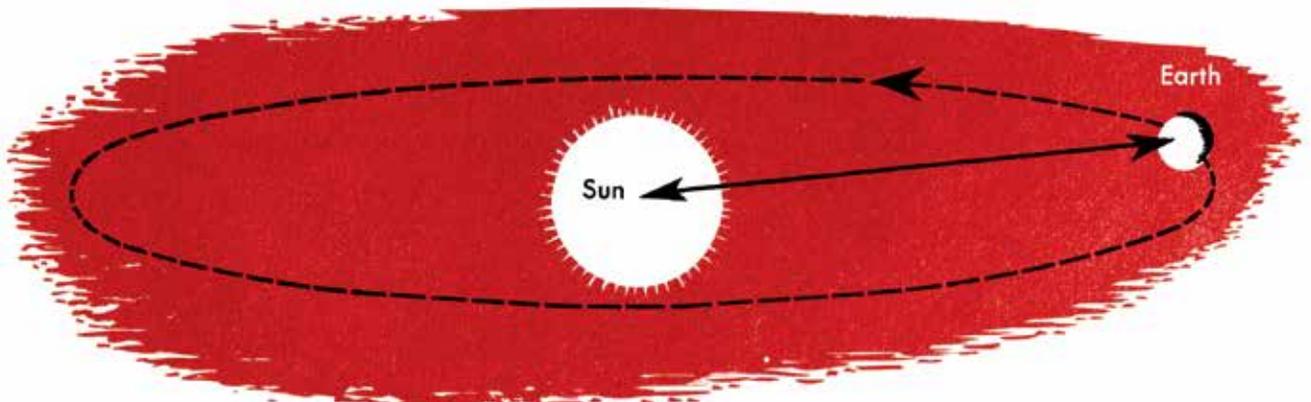
The planets, their moons, the asteroids, and the meteors all circle our sun at great speed. They are the sun's family. They are held together by a terrific force called *gravity*. You have seen gravity at work. It is the "pull" that every object has for every other object — the larger the object and the more matter it has, the greater the pull. When you jump into the air, the earth's gravity tugs you back again. When you throw a ball, gravity finally makes it come down. When fruit drops from a tree, or when raindrops form in clouds, it is gravity that pulls them down to earth. Gravity pulls harder on some objects than on others, and so they are heavier, for the pull of the earth's gravity gives objects their weight. The earth's



A ball whirling on a string tugs away from the center of the circle it travels.

gravity is so strong it makes meteors fall toward the earth, and it keeps our moon from flying off into space.

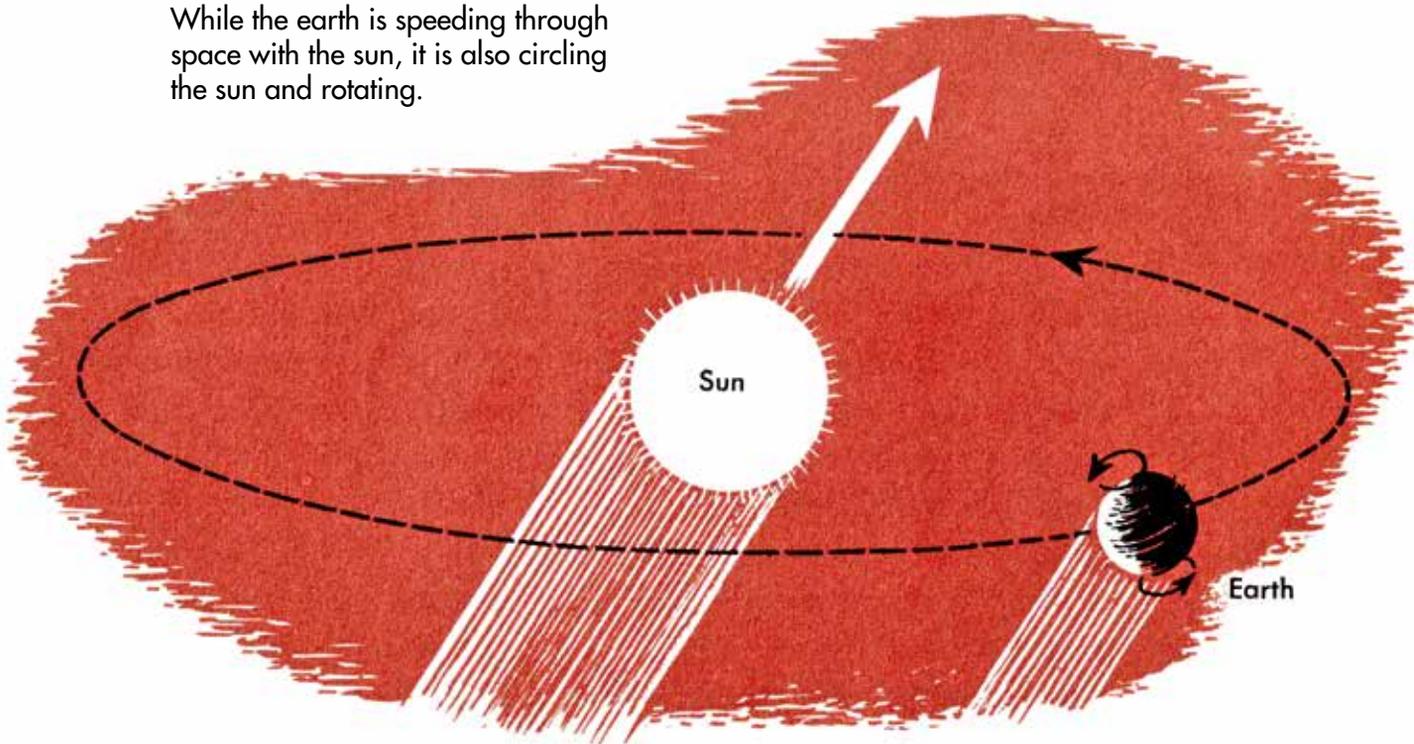
The sun's pull keeps the planets circling around it, instead of rushing off into space. There is something also that prevents the planets from falling into the sun. When objects move in a circle at great speed they gather a force that makes them pull away from whatever is at the center of that circle. You can see how this works by whirling a ball on a string very fast around your head. The faster you whirl it, the harder the ball tugs away. In the same way, the speed of the planets creates enough force so that they tug away from the pull of the sun's gravity. The two kinds of pull balance each other, and each planet is kept moving in a set path around the sun.



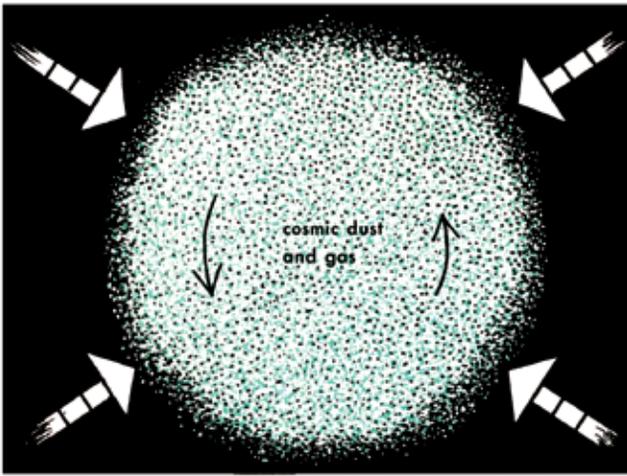
The earth, circling the sun, tugs away from it. Its tug is balanced by the pull of the sun's gravity, and so the earth is kept in its pathway.

Astronomers tell us that our sun *travels* through *space* at the great speed of over 720 miles a minute. It carries our earth and the other planets with it. While the earth is speeding through space with the sun, it is also racing around the sun at more than 1,000 miles a minute. Even at this great speed the earth takes a little more than 365 days to circle the sun completely. We call this length of time a year.

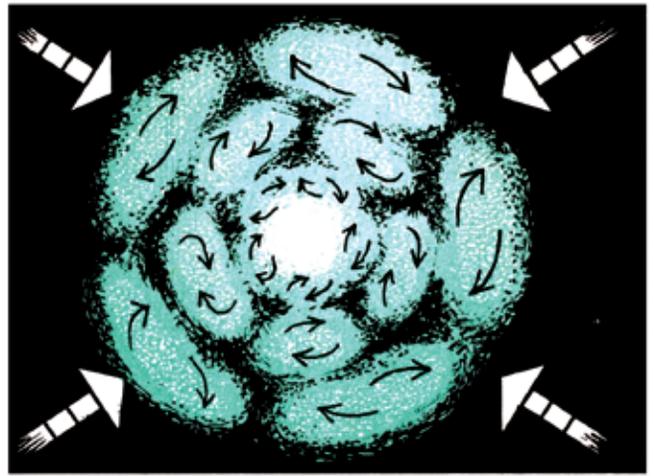
While the earth is speeding through space with the sun, it is also circling the sun and rotating.



While it is traveling through space with the sun and circling the sun, the earth is also spinning like a top. It makes one complete turn every 24 hours — our day. As the earth is 24,902 miles round at the Equator, you can see that it spins, or “rotates,” over 1,000 miles an hour there.



1. Some scientists think the planets may have been formed in the following way. A great cloud of gas and cosmic dust may have been spinning through space.



2. Gradually the cloud began to separate into large and small whirls.

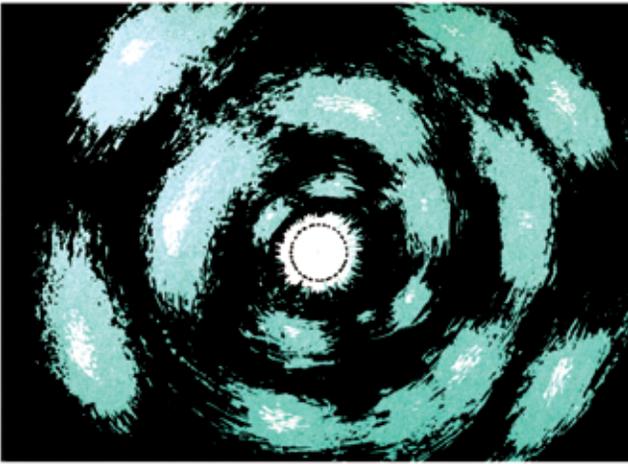
how did it begin?

Scientists know that the earth travels through space, and that it is a planet of the sun. They know many other things about it, too, but they still do not agree on how the earth was made in the first place. Several explanations have been offered, but there is no real way of knowing whether any of them is right.

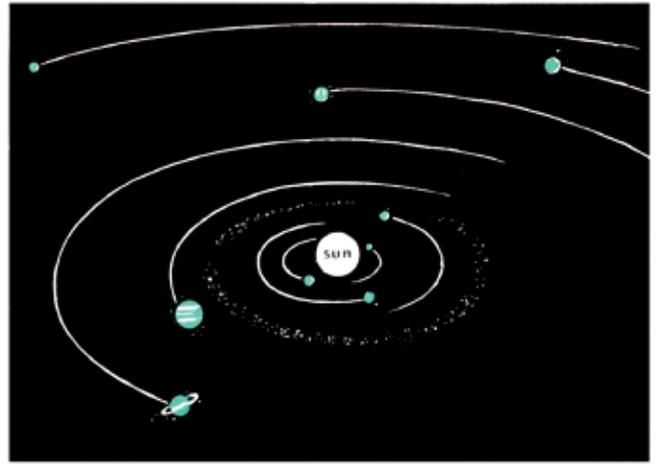
Some scientists have thought that the planets were once part of the sun. Possibly another star passed too close to the sun and pulled away some of its material; this material may then have become the planets, they say.

Other scientists have thought that our sun might once have been one of twin stars. They say the twin may have exploded, and its whirling material may have cooled into the planets.

Astronomers agree, though, that all stars are suns. And most of them agree that suns were formed from clouds of gas and the tiny particles of matter that float around in outer space. These particles are called “cosmic dust.”



3. One of the whirls finally formed the sun.



4. Gradually solid particles in the smaller whirls pressed together to form the planets.

Some astronomers say that if stars were made from gas and cosmic dust, the planets may have been, too. Something like this may have happened, they think. Billions of years ago, a great spinning cloud of gas and cosmic dust may have been traveling through space. Gradually, parts of the cloud began to separate into large and small whirls. They collected more and more material to themselves. One of them spun round and round so rapidly that in time it became white hot. This large, hot ball is our sun. Its gravity made it the center of smaller whirls of gas and dust. Gradually, some of these smaller whirls joined together and collected more and more material from the space around them. In each one, the solid particles pressed tightly together until, in time, these whirls became our planets and their moons. Not all astronomers agree with this explanation. No one is sure.

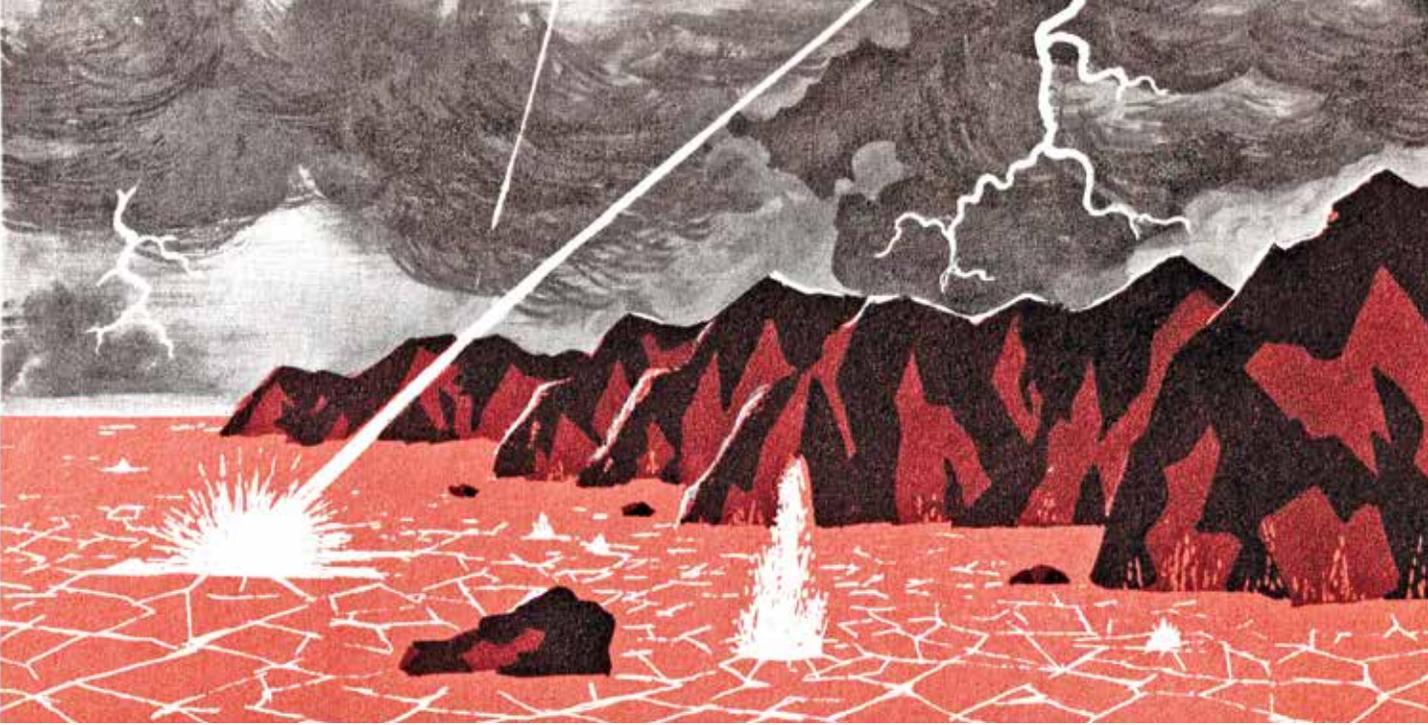
Some astronomers say that in the beginning the earth may have been cold. But in any case, as it spun through the heavens and as its materials squeezed together, it must have become very hot. Its particles slowly formed melted rock, very different from the rock we know today.



As the earth gradually cooled, its crust warped and great masses of rock pushed

Millions of years went by while the earth raced through the icy emptiness of space. Its material began to cool and harden and separate into heavier and lighter portions. The heavier material sank deep into the earth. Great masses of granite floated to the top. Granite is thought to be the lightest of the original rock. As the rock on the surface of the earth cooled, it started to form a thin crust. The earth did not cool quickly, however. Time and again the crust was broken. Underneath it, hot rock pushed and shoved. Wherever there was a gap or a weak place, the hot rock came pouring through to the earth's surface.

In places the crust was so strong that the rock pressing from underneath could not break through. But it could bend the surface upward. It pushed great masses of the outer rock up toward the sky.



upward. Meteorites from outer space fell and added to the earth's size.

Hollows dipped between the high places.

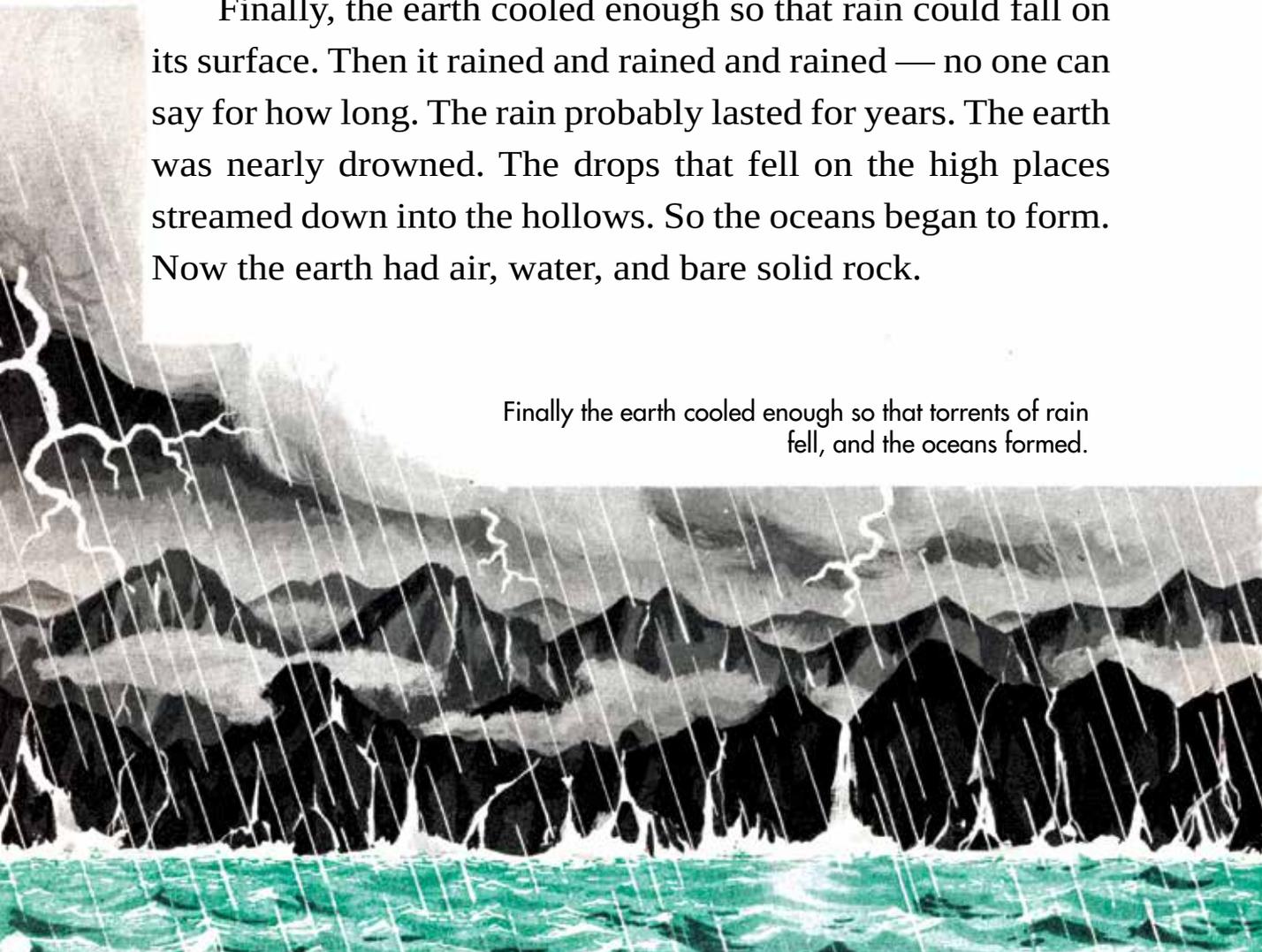
Millions of more years went by. The crust warped and changed and finally became solid. In the meantime, as the rocks cooled and pressed together, gases were squeezed out of cracks and holes. Many scientists think the earth may have been so small at first that its gravity would not hold the gases. They think, however, that many meteorites from outer space fell to the earth and added their material to its size. Finally, it grew large enough to hold around it a layer of gas — its *atmosphere*. In the layer were nitrogen, oxygen, and the other gases that still make up our atmosphere — the air we breathe today.

At first, the gases that escaped from the rock were very hot. When gas is hot, its tiny particles, called *molecules*, have great energy; they are very active. They move farther apart than before, and the gas becomes lighter and rises. This happened to the gas that escaped from the earth in that long-ago time. But as it rose far above the hot

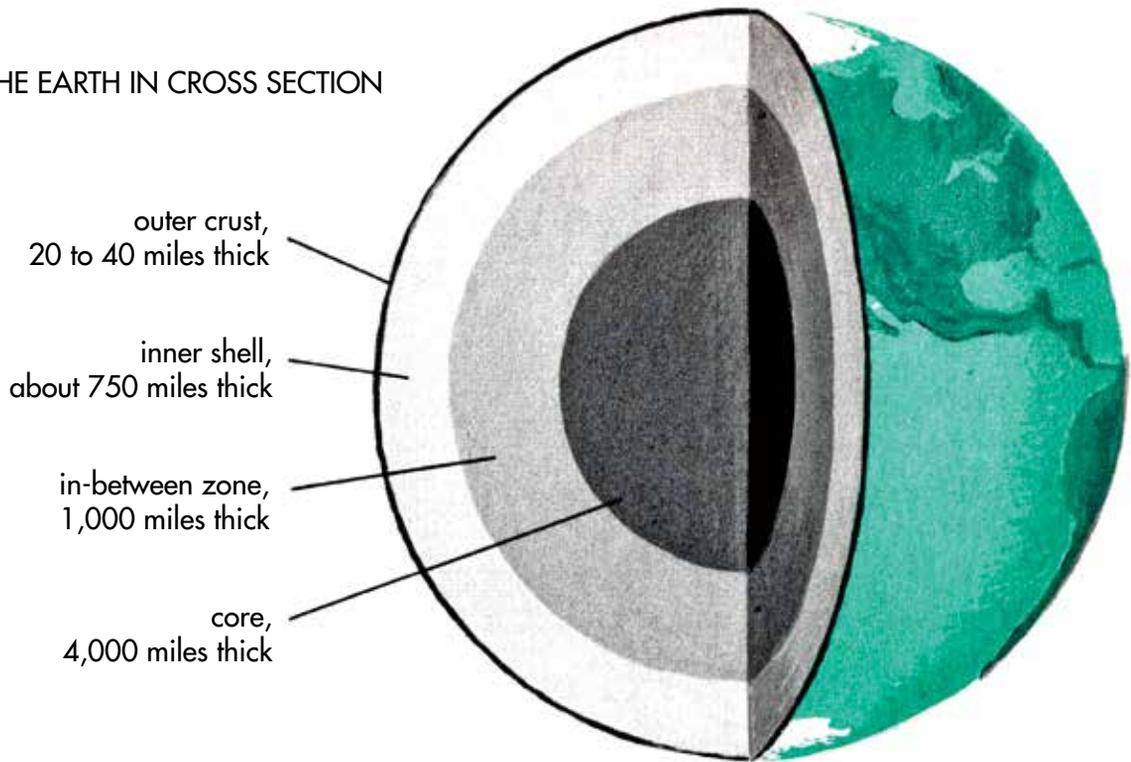
earth's crust, the gas cooled. In it was *water vapor* — water in the form of gas. As the molecules of water vapor cooled and lost their energy, they condensed; that is, they bunched together and formed tiny drops of water. The air became full of moisture, which covered the earth in a thick, dark blanket of clouds. The only light to reach the earth was from the flashing lightning and flames that leaped above the great gaps in the crust. Rain may have fallen from the thick clouds, but for a long time, the earth must have been so hot that raindrops nearing the rocks were changed again to water vapor.

Finally, the earth cooled enough so that rain could fall on its surface. Then it rained and rained and rained — no one can say for how long. The rain probably lasted for years. The earth was nearly drowned. The drops that fell on the high places streamed down into the hollows. So the oceans began to form. Now the earth had air, water, and bare solid rock.

Finally the earth cooled enough so that torrents of rain fell, and the oceans formed.



THE EARTH IN CROSS SECTION



what is the earth made of?

Geologists think the rocky sphere of the earth is made up of the following main parts:

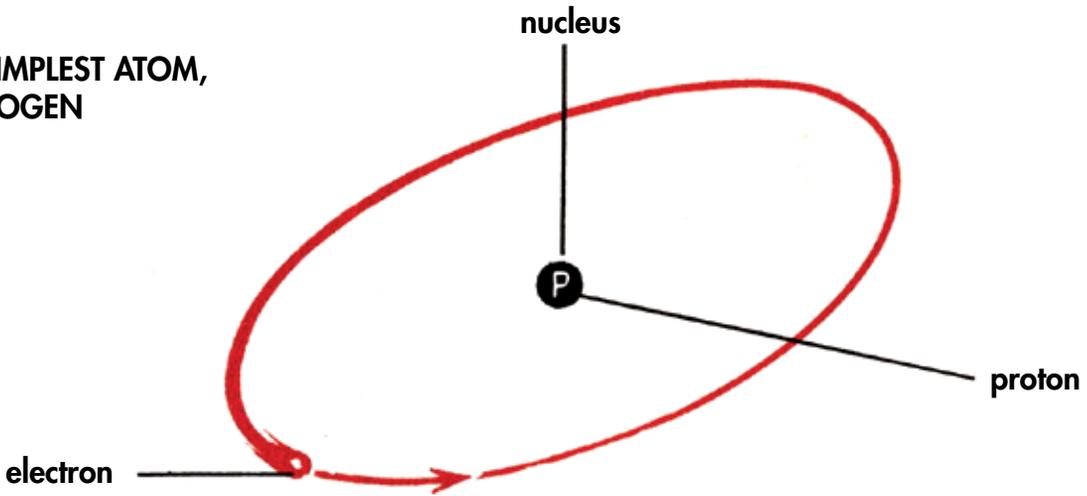
1. The outer crust is probably from 20 to 40 miles thick. Not all its rocks are of the same kind or the same weight. The heavier ones sank to form the basins of our oceans. The lighter blocks of granite rose to make the beginnings of our continents. Underneath the granite, and mixed with it, is a heavy black rock called basalt. Some geologists call this basalt the “basement of the continents and oceans.”

2. An inner shell, or *mantle*, is about 750 miles thick. It is a mixture of very heavy rock.

3. An in-between zone, about 1,000 miles thick, is made of rock and iron.

4. The *core*, or center, of the earth is a sphere, probably about 4,000 miles through. There is still much to be learned about it. It is thought to be a mixture of iron and nickel.

THE SIMPLEST ATOM, HYDROGEN



Scientists in various fields are working to find out more about the inside of the earth. Astronomers try to learn about it by studying the other planets and the meteorites. Geologists study the earth itself and its rocks. Chemists and scientists called physicists study the earth's materials to see what they are made of and how they are put together. The chemists and the physicists have already given us the answers to this question: Why are there so many different kinds of rock in the earth?

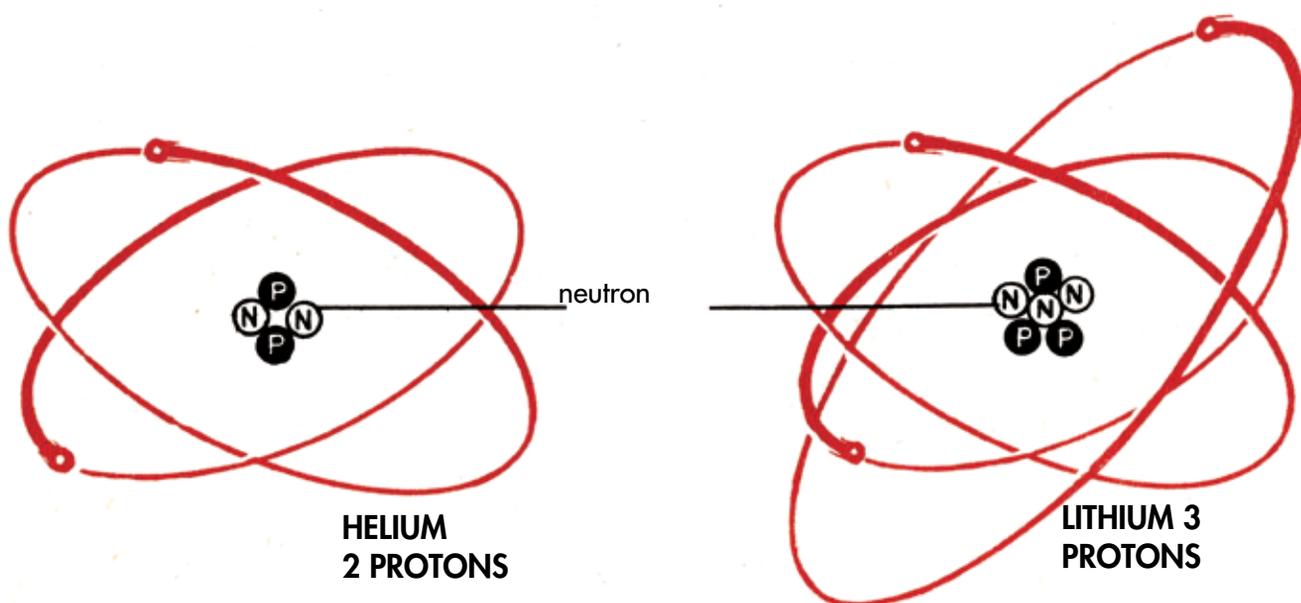
All the materials in the world can be divided into three kinds: *solids*, *liquids*, and *gases*. Rock has length, width, and thickness. It is a solid. Water runs. It is a liquid. Air has no fixed shape, and it can spread out, or take up more space, without any limit. It is a gas.

Solids, liquids, and gases are all made of tiny particles called molecules. They are so small that they cannot even be seen with a microscope. For a long time, scientists thought molecules were the smallest particles there were. After many experiments, however, they found that molecules were made of even smaller particles called *atoms*. Now the scientists have proved that even the atoms are made of something smaller.

Of course, no one has ever seen an atom, but complicated experiments have shown that it is somehow made of electricity. The nearest we can come

to understanding how an atom might look is to compare it with the sun and its planets. The simplest atom of all is that of the gas hydrogen. At its center, or nucleus, is a particle called a *proton*. This has a charge of electricity that is positive — it has a plus value. Outside the nucleus, and circling around it, is another particle, an *electron*. This has a charge of electricity that is negative — it has a minus value. The positive charge of the proton and the negative charge of the electron attract each other, and so the atom is held together. More complicated atoms than hydrogen have particles called *neutrons*, which are like protons but have no electrical charge.

Protons, neutrons, and electrons are the main building blocks of the atoms. Each single positive proton can attract and hold a single negative electron. Because of this, the number of protons in an atom decides its number of electrons, and what kind of atom it is. A nucleus with one proton attracts one electron, and makes an atom of the gas hydrogen. A nucleus with two protons attracts two electrons, and makes something different: an atom of the gas helium. An atom with three protons will, in general, have three electrons. This makes an atom of lithium, a soft,



silver-white material. Of course, each different kind of atom forms a different kind of molecule. And each different kind of molecule makes a different material.

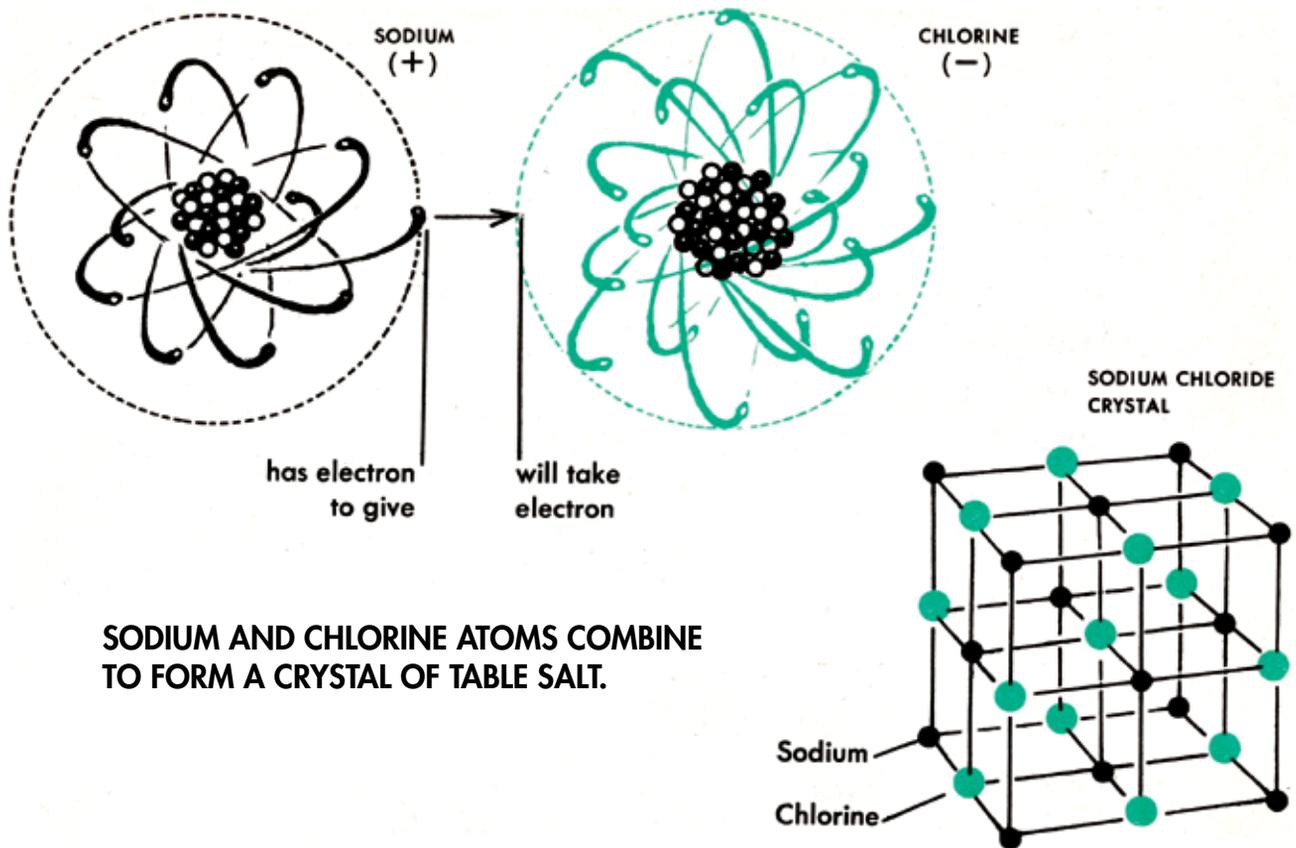
Everything around us is made of various combinations from among the earth's simplest materials, called *elements*. An element is so simple that it cannot be separated by any chemical method into things simpler than itself. There are over 90 natural elements and each is given an atomic number according to the amount of protons it has in its nucleus — that is, from 1 to over 90.

Certain elements have atoms that lose some of their electrons easily. When this happens, the positive protons and the negative electrons in the atom no longer balance. The atom has more protons than electrons and so it becomes positively charged.

Other kinds of atoms gain electrons easily. Then they have more negative electrons than they have positive protons and they become negatively charged.

Negative and positive atoms attract each other. They join together into a new kind of molecule: a combination, or compound, of the original elements. When this happens, the molecules make a new substance. Sodium, a soft silvery element, parts with one of its electrons easily. Chlorine, a green poisonous gas, will not part with an electron, but it will quickly take one from sodium. And what a surprise we have! When these elements combine they become a compound we use every day: our ordinary table salt.

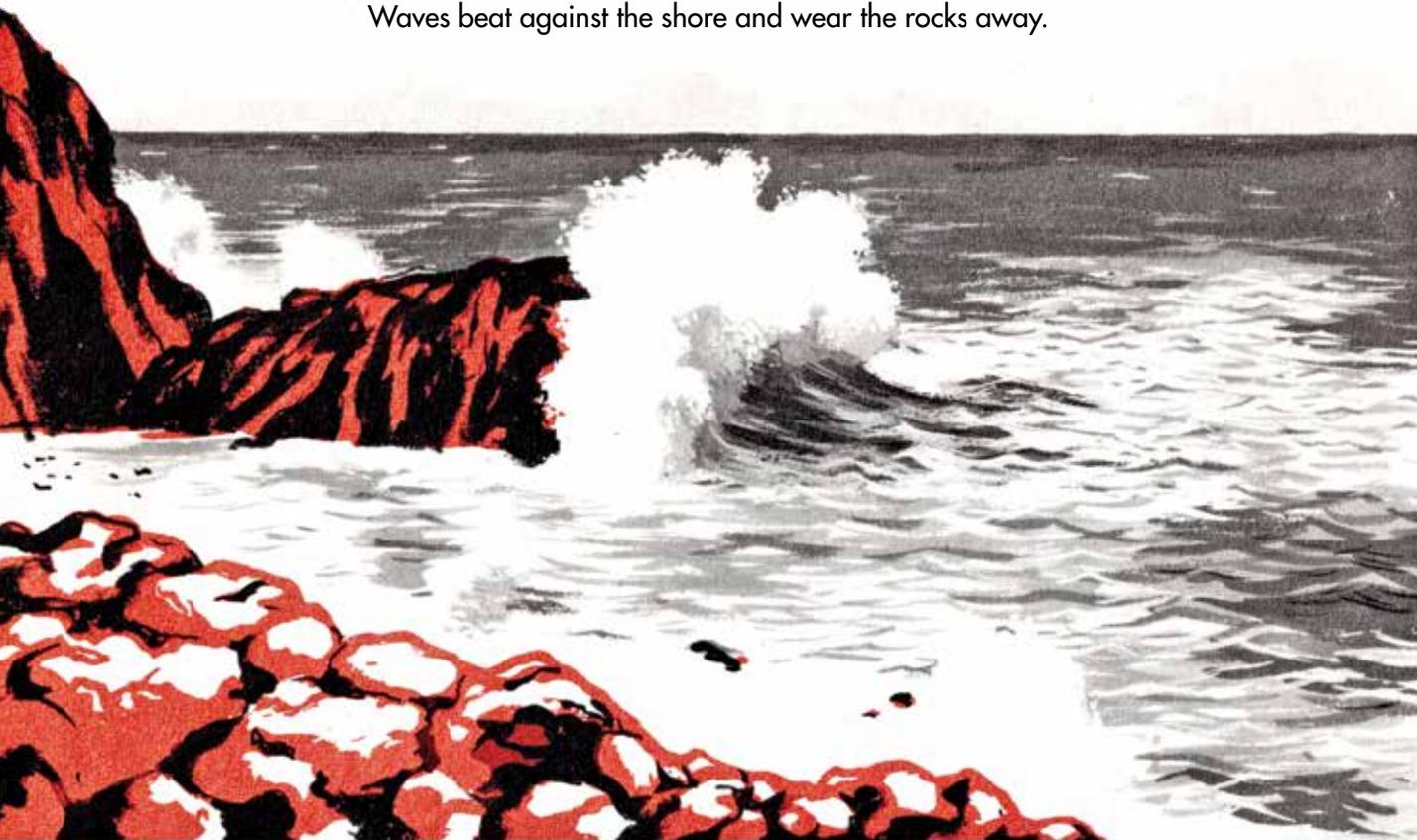
In this way, by gaining and losing electrons, and also, sometimes, by sharing electrons, the elements join together in various combinations, or compounds, to form other substances.



The earth's crust is made up almost entirely of only eight elements in different combinations. While the crust was still hot, the atoms of these elements traveled about easily and joined with one another to make various new substances. How they joined and what they made depended on many things. If the material through which they moved was completely melted, they could travel farther than they could if it was partly cooled and thick as tar. If there was a great deal of water, or if there were many gases, that made a difference, too.

The natural substances that the elements formed in the crust are called *minerals*. Rocks are either simple minerals or, more often, mixtures of minerals.

Waves beat against the shore and wear the rocks away.



the rock families

Geologists put rocks into three large families.

The first family is *igneous* or “fire” rock. (Igneous comes from the Latin word for fire.) Igneous rock forms from hot, melted rock material, as it cools and becomes solid.

There are many different kinds of igneous rock, because of the various combinations of elements and the conditions under which they joined. If the hot materials cooled quickly, they made one kind of rock. If they cooled slowly, they made another. If they cooled deep inside the earth, and very, very slowly, they formed a still different kind of rock.

Probably the most important igneous rocks are granite and basalt, which make up large parts of the earth's crust. Almost everyone has seen granite, and noticed the flecks of the minerals that came together to make it.

Almost half the material in igneous rocks is the mineral feldspar. Feldspar gives rock many of its white, pink, red, and gray colors.

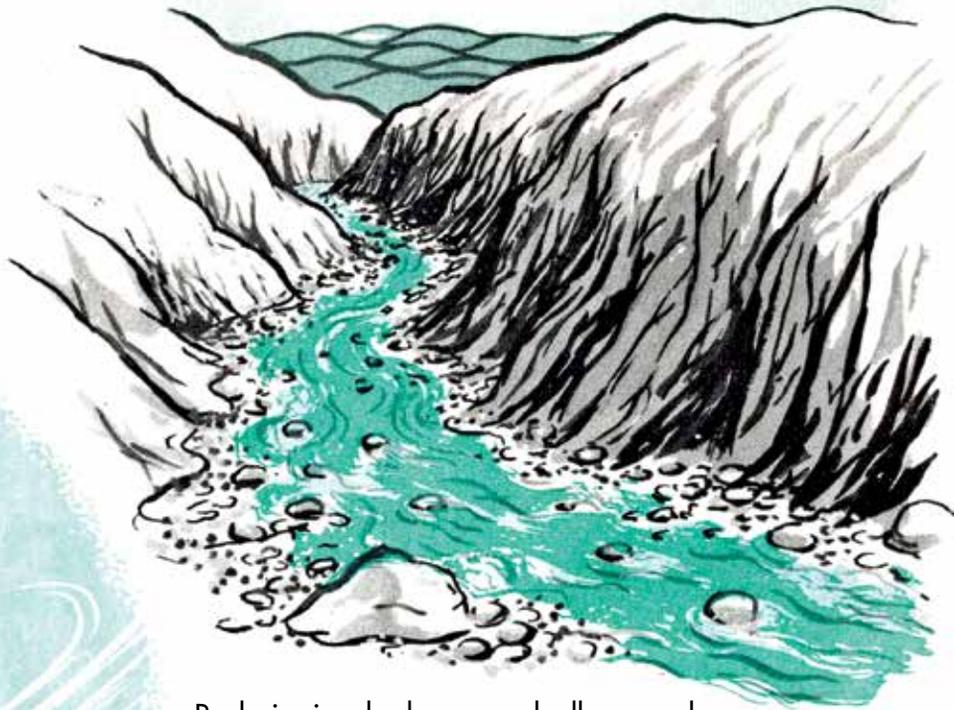
Nearly one-fourth of the remaining material in igneous rocks is the mineral quartz. This appears in many colors, all of which have a somewhat glassy look. Other minerals appear in smaller quantities in igneous rocks.

Igneous rocks were the earth's first ones. Almost at once they began to change. No sooner had the atmosphere been created than it began eating away at the earth's crust. Certain gases in the air attacked some of the minerals in the rocks. This made new substances and helped wear the rocks away.

When at last rain poured down upon the earth, the water joined with minerals to make acids, which ate away more of the rocks. Pieces of them split off. Tons of broken material fell from steep cliffs into the oceans. Here the waves picked up the pieces and pounded them against the cliffs until they were worn into tiny bits of sand, mud, and clay.

You can see for yourself how the rocks are still wearing out, day by day. At the seashore, piles of broken pieces lie at the foot of the cliffs. The waves wash back and forth, scouring the rocks smooth. When there are storms, the breakers hurl pieces of rock against the cliffs and carve out giant holes and caves. The sand and pebbles you find on the beach were once part of the rocks.

**THE ROCKS
WEAR
AWAY**



Rocks in river beds are gradually ground to pieces.



Ice breaks the rocks apart.



Roots pry the rocks apart. →

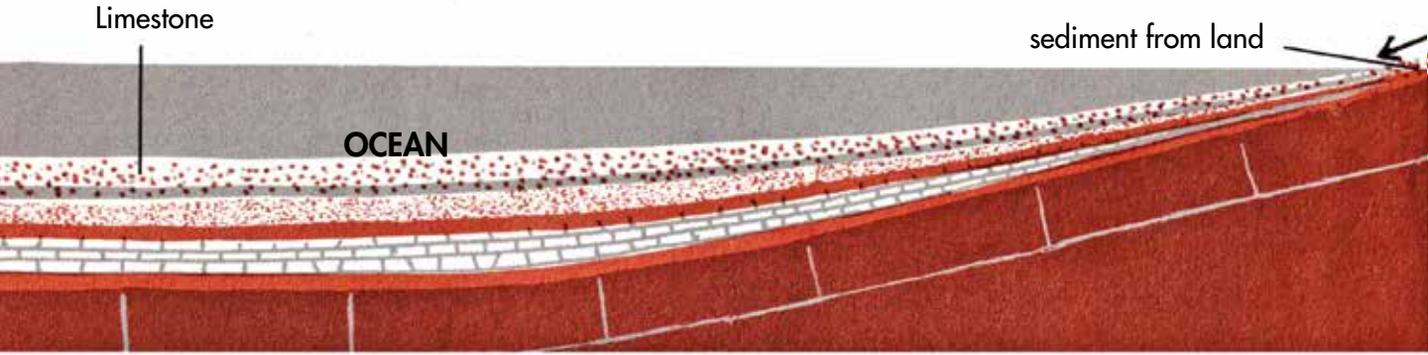
The rocks on the mountains are forever changing, too. The sun heats them in the daytime, and causes them to expand, or swell. At night, when the air grows cold, they contract, or shrink. As this goes on over and over again, the rocks crack. Rainwater creeps into the cracks, and freezes. The ice pushes hard, just as it pushes the cap up from a bottle of milk on a winter morning. All this is called “weathering.” Finally, the rocks fall apart, and pieces tumble down the mountain, breaking more and more as they fall. Piles of their shattered bits spread out like fans from the base of the cliffs. If you look, you may find smaller rockslides like this near your home.

Notice also how plants wear away the rock. The roots of trees and other growing things work their way into cracks. As the roots become larger, they pry the rock apart. Rotting leaves join with rainwater to make acids that decay the rock. Day by day it falls apart. Rotted bits of bark, leaves, and other pieces of once-living plants and animals join with the rock bits to make the soil that covers much of the earth’s crust.

Long, long ago, when the rains poured down upon the mountains, the rushing water picked up pieces of broken rock and carried them along. The water ran where there were natural troughs in the earth’s crust and made creeks and rivers. All along the river bottoms, the rock chunks banged and scraped until even the hard bits of quartz and feldspar were ground into tiny grains of sand. At last, tons and tons of sand, pebbles, mud, and clay reached the lakes or shallow seas and slowly sank to the bottom. Flood after flood dropped more of this material, called *sediment*.

One layer of sediment after another settled on the floor of the quiet lakes and seas. The great weight of the top layers and of the water pressed those underneath until they became hard. The minerals in the water helped cement the tiny particles together, and the sediment became rock. This so-called “sedimentary” rock, formed in layers, is the second big family of rocks. Sedimentary rock is still being made today. Wind, as

Layers of rock are formed from sediment on the ocean floor.

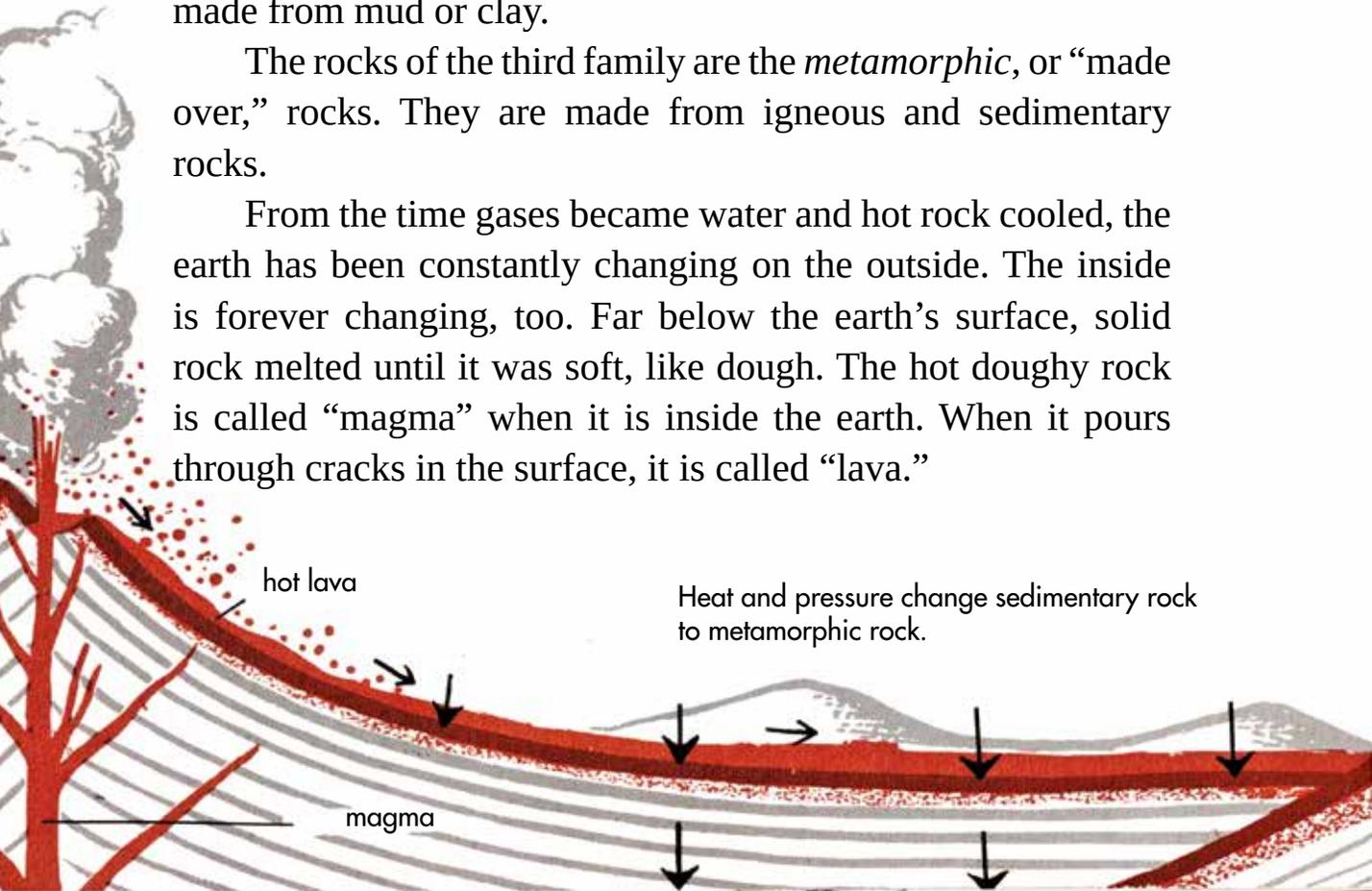


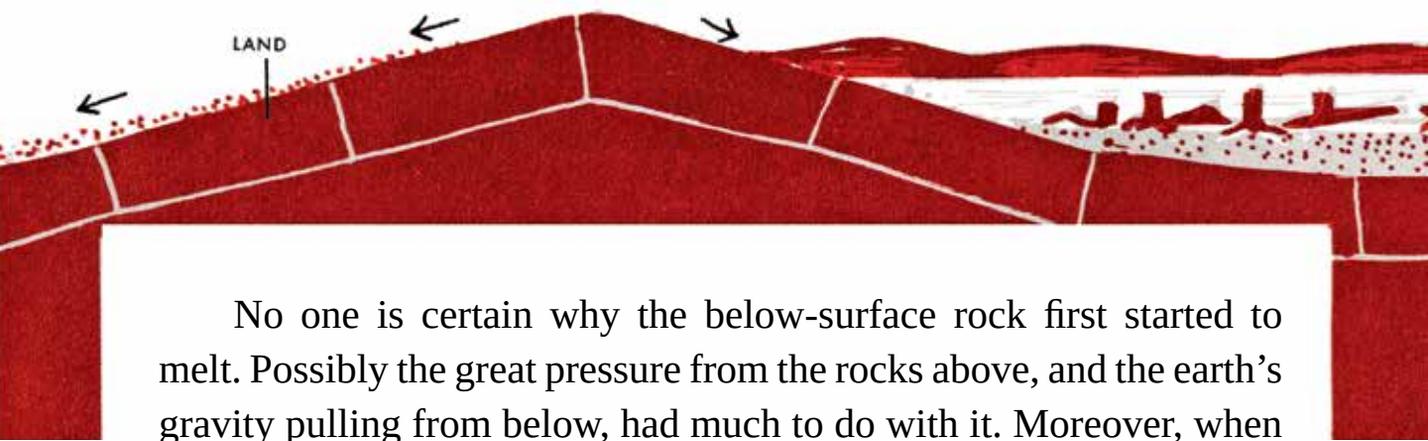
well as water, sometimes piles up sediment that later becomes rock.

You probably know some of the common sedimentary rocks. Sandstone, which looks and feels like sand, is made mostly from quartz sand. Limestone is made from lime in the shells of dead water animals and from lime in the water. Shale is made from mud or clay.

The rocks of the third family are the *metamorphic*, or “made over,” rocks. They are made from igneous and sedimentary rocks.

From the time gases became water and hot rock cooled, the earth has been constantly changing on the outside. The inside is forever changing, too. Far below the earth’s surface, solid rock melted until it was soft, like dough. The hot doughy rock is called “magma” when it is inside the earth. When it pours through cracks in the surface, it is called “lava.”





No one is certain why the below-surface rock first started to melt. Possibly the great pressure from the rocks above, and the earth's gravity pulling from below, had much to do with it. Moreover, when certain gases change into other substances, heat is produced.

Once the rock was heated enough to be doughy, it melted the solid rock around it. Then it began to move. Hot doughy rock is bulkier and lighter than hard rock, so it slowly oozed upward. It squeezed and pushed. Water, gases, and various acids helped it. Slowly it changed the minerals in the rocks it pressed against and heated. They were made over into metamorphic rocks.

Igneous rocks like granite were made over into gneiss (pronounced "nice"). Limestone was changed to marble. Shale was changed to slate or schist (pronounced "shist").

Heat and steady squeezing from above, without any other motion, can make over rocks, too. A layer of shale, pressed long and hard, and mixed with acids and gases, can become slate.

Hot magma, penetrating sedimentary rock, changes it to metamorphic rock.

