

# VOYAGE INTO PLANET EARTH



U.S. National Science Foundation  
Directorate for Geosciences

DO YOU EVER WONDER



## WHAT'S BENEATH YOUR FEET?

You might think Earth is made up of one big solid rock, but it has four layers and lots of moving parts that go miles beneath your feet.

The top layer is the crust, which supports all the people, animals and plants that call Earth home. As you peel back the other layers, you find the mantle, outer core and inner core.

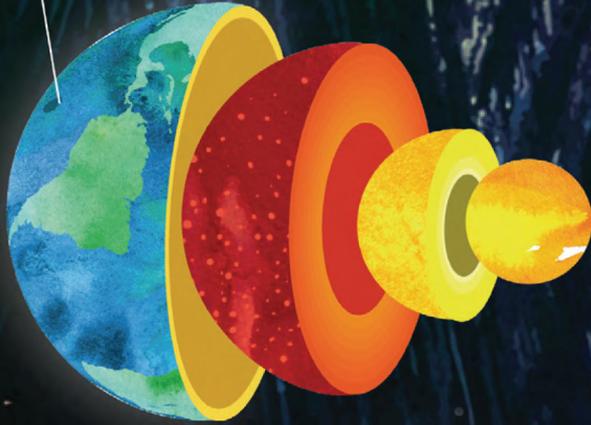
### FUN FACT

Scientists know more about distant galaxies than they do about what lies miles beneath your feet. Although researchers have explored many areas of Earth's crust, they are just scratching the surface of our planet's mysteries.

LET'S  
GO 

ON A VOYAGE INTO PLANET EARTH—  
FROM THE CRUST INTO THE INNER  
CORE—AND EXPLORE EACH LAYER.

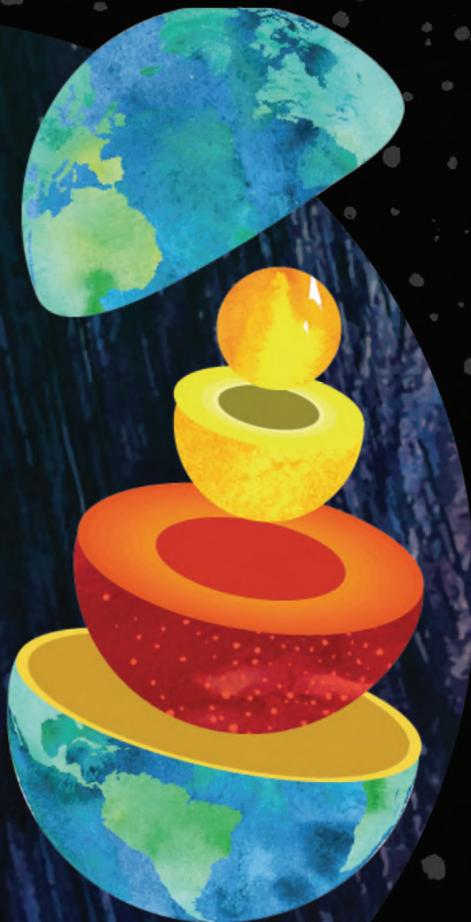
## EARTH'S LAYERS



AS YOU MOVE THROUGH THE EARTH'S LAYERS FROM THE CRUST TO THE CORE, THE PLANET GETS HOTTER. THE RED, YELLOW, AND ORANGE INDICATE CHANGES IN TEMPERATURE.



# THE EARTH'S CRUST



The first stop on our journey is the crust. It is a relatively thin and rocky outer skin that we stand on top of every day. About 30 percent of the crust is covered by solid land and 70 percent by sparkling ocean.

**LOTS OF DIFFERENT KINDS OF ROCKS MAKE UP THE CRUST, WHICH CAN BE FROM 3 TO MORE THAN 43 MILES (4.8 TO 69 KILOMETERS) THICK.**

Although 43 miles of crust sounds thick, it's nothing compared to the other three layers. If the Earth were an apple, the crust would only be as thick as the skin. The crust is the only layer that can be studied using a powerful drill. The other layers are too deep to penetrate, so scientists use more indirect techniques, like measuring seismic waves from earthquakes, to better understand what the hidden layers are made of.



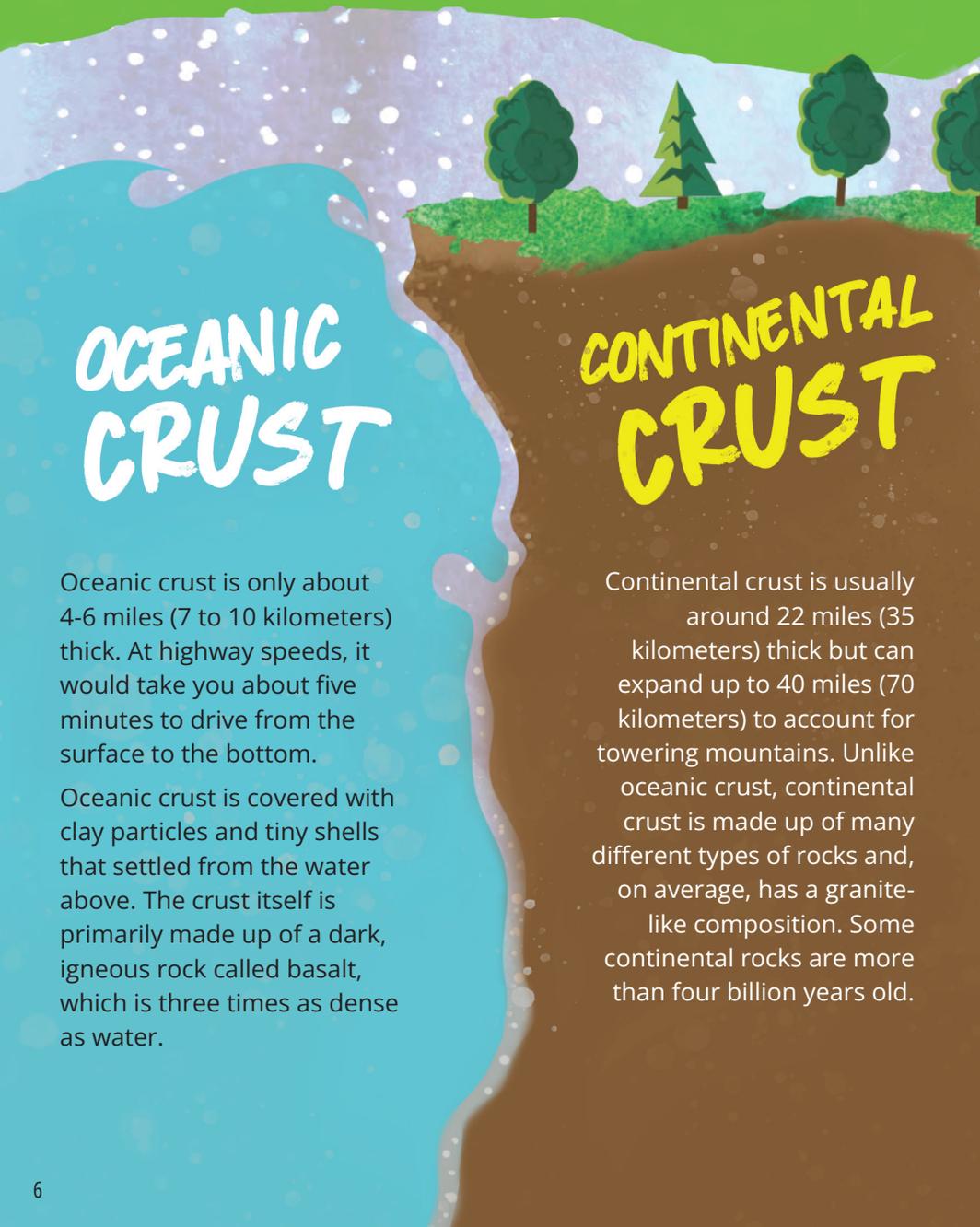
# HOW LOW CAN WE GO?

Just like sending a probe into outer space to observe and bring back pieces of extraterrestrial rocks, we also send a specialized drill deep into the ground to bring back rocks from the Earth's inner layers. Scientists use drill bits as cutting tools to create holes and remove material.

## How Far Down Have Humans Drilled?

The Kola Superdeep Borehole in Russia reached 7.6 miles (12.2 kilometers), the deepest so far. It took almost 20 years to reach that depth, which is only about halfway through the crust. Four miles into digging, scientists discovered interesting fossils of microscopic plankton. They eventually abandoned this drilling borehole when the team encountered higher-than-expected temperatures, which wrecked the drilling equipment.

THERE ARE TWO KINDS OF EARTH'S CRUST — OCEANIC CRUST, WHICH LIES BENEATH THE OCEAN, AND CONTINENTAL CRUST, WHICH FORMS THE GROUND YOU WALK ON EVERY DAY.



## OCEANIC CRUST

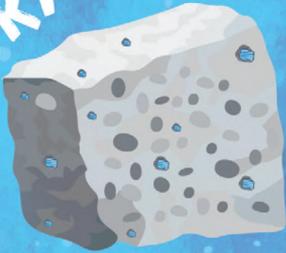
Oceanic crust is only about 4-6 miles (7 to 10 kilometers) thick. At highway speeds, it would take you about five minutes to drive from the surface to the bottom.

Oceanic crust is covered with clay particles and tiny shells that settled from the water above. The crust itself is primarily made up of a dark, igneous rock called basalt, which is three times as dense as water.

## CONTINENTAL CRUST

Continental crust is usually around 22 miles (35 kilometers) thick but can expand up to 40 miles (70 kilometers) to account for towering mountains. Unlike oceanic crust, continental crust is made up of many different types of rocks and, on average, has a granite-like composition. Some continental rocks are more than four billion years old.

# GRANITE



Continental crust contains a lot of the igneous rock granite. The rock's light-colored crystals grow as molten granite deep beneath the surface slowly cools.

# BASALT



Basalt is also an igneous rock, but it's rich in dark minerals. The rock's microscopically small crystals form as its molten form cools at the planet's surface.

# FUN FACT



## **DID YOU KNOW? OXYGEN IS THE MOST ABUNDANT ELEMENT IN THE EARTH'S CRUST.**

There are only a few special places in the world where you can see exposed oceanic crust.

Many of these places are "hot spot" island arcs — including the Galapagos and Hawaiian Islands. Iceland is another example; new oceanic crust forms there very slowly every day.

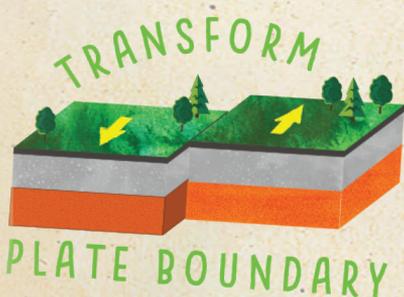
# TECTONIC PLATES



## PLATE BOUNDARIES

Large pieces of oceanic and continental crust, called tectonic plates, slide around on top of the mantle. These plates fit together like a jigsaw puzzle. They move very slowly, usually shifting no more than a couple of inches per year. The plates collide to build mountains or

break apart to form trenches and reveal new seafloor. For example, when two pieces of continental crust push against each other, they don't have anywhere to go but up, making enormous mountains like the Himalayas. Earthquakes and volcanic activity also happen because of movement along plate boundaries.





# FUN FACT

ABOUT 300 MILLION YEARS AGO, EARTH DID NOT HAVE SEVEN CONTINENTS. INSTEAD, THERE WAS ONE MASSIVE SUPERCONTINENT CALLED PANGAEA. BECAUSE TECTONIC PLATES SLOWLY SLIDE AND MOVE, PANGAEA EVENTUALLY BROKE UP INTO THE CONTINENTS YOU SEE TODAY.



## PERMIAN

225 MILLION YEARS AGO



## TRIASSIC

200 MILLION YEARS AGO



## JURASSIC

135 MILLION YEARS AGO



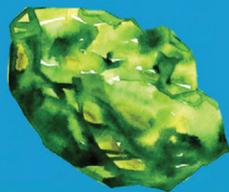
## CRETACEOUS

65 MILLION YEARS AGO



## PRESENT DAY

# MANTLE



**OUR NEXT STOP AS WE JOURNEY TO EARTH'S CORE IS TO THE SECOND AND LARGEST LAYER: THE MANTLE.**

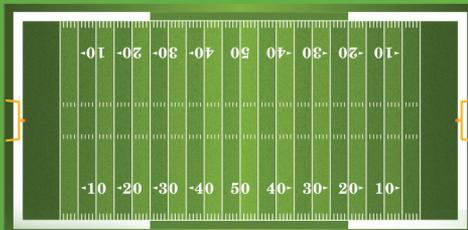
The mantle makes up an estimated 70 percent of Earth's mass and a whopping 85 percent of its volume.

**This layer is 1,800 miles (2,900 kilometers) thick — the equivalent of more than 31,680 football fields lined up end to end.**

**The mantle is divided into two layers: the upper and lower mantle.**

The upper mantle extends from the end of the crust to a depth of 410 miles (660 kilometers) and the lower mantle extends to 1,800 miles (2,900 kilometers). The mantle is very dense because it's under high pressure and contains dense peridotite, among other rocks.

The mantle is so hot that it flows under pressure, like soft road tar. But don't worry. If drillers one day pierce the mantle, hot molten rock will not surge out of the hole like a volcanic eruption. Magma in the mantle flows as slowly as the growth rate of a fingernail — less than 6 inches or 15 centimeters a year. Over long periods, mantle rock can change shape without breaking, like candle wax.



Moving from the crust to the mantle, we see a big shift in composition. Most of the mantle is made up of the rock peridotite, which gives the mantle a green hue.

Overall, the temperature of the mantle increases the deeper you go. However, the temperature across the same depth can vary by density: warmer regions are

less dense and cooler regions are denser. Hot rock creeps up from the depths while cooler rock descends, causing very slow-moving convection currents.

# WHAT'S THE DIFFERENCE BETWEEN MAGMA AND LAVA?



## LOCATION. LOCATION. LOCATION.

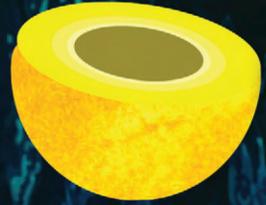
Both lava and magma form when rocks are superheated to the point of becoming viscous and molten. Magma is molten rock within the Earth, but it becomes lava when it reaches the surface and erupts from a volcano .



**FUN  
FACT**

ALTHOUGH OTHER GEMSTONES  
FORM IN EARTH'S CRUST,  
DIAMONDS AND PERIDOTS  
FORM IN THE MANTLE.

# OUTER CORE



**AS YOU CONTINUE YOUR JOURNEY, YOU REACH EARTH'S THIRD LAYER – THE OUTER CORE. THIS LAYER — A SHELL OF LIQUID IRON ALLOY — IS ABOUT 1,400 MILES (2,300 KILOMETERS) THICK.**

The extremely high temperatures between 4,000 to 9,000 degrees Fahrenheit (4,400 to 5,000 degrees Celsius) keep the metals in the outer core in a liquid state.

## **How Do Scientists Know the Outer Core Is Liquid?**

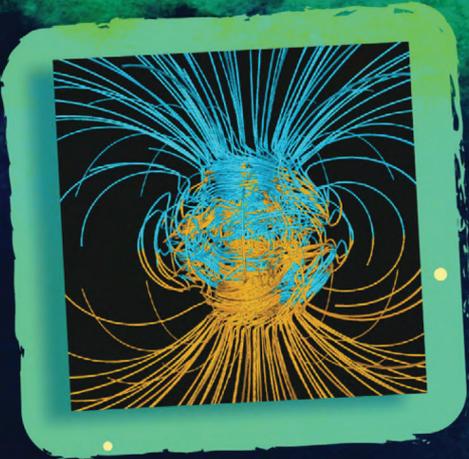
Researchers have never extracted samples directly from the planet's mantle or core. Rather, they analyze seismic waves from earthquakes to "see" those places. Seismic waves change speed and are bent and reflected as they move through different areas or layers with different compositions and properties. Researchers rely on earthquake monitoring stations around the world to detect and record seismic wave activity.

**Seismic waves have revealed the existence of sublayers in the core (outer core and inner core) and the mantle (upper mantle and lower mantle).**

# DID YOU KNOW?

## METALLIC IRON MOVING IN EARTH'S OUTER CORE GENERATES ITS MAGNETIC FIELD.

When the outer core's liquid iron circulates the solid iron of the inner core, a magnetic field forms. This magnetic field protects the planet from the sun's radiation.



NSF-funded researchers have visualized many features of Earth's magnetic field, including magnetic-field reversal, when the North Pole becomes the South Pole and vice versa.

**FUN  
FACT**



Meteorites — metallic remains of meteors — are mostly chunks of nickel and iron, like Earth's core.

# INNER CORE



FINALLY, YOU HAVE REACHED THE CENTER OF EARTH — THE INNER CORE. THE INNER CORE HAS A RADIUS OF APPROXIMATELY 746 MILES (1,200 KILOMETERS), MAKING IT ALMOST AS LARGE AS EARTH'S MOON.

The inner core is even hotter than the outer core. Its metals are squeezed into a solid ball by extreme temperature and pressure. The inner core's immense heat energy makes it Earth's engine room.

Temperatures can reach almost 9,000 degrees Fahrenheit (5,000 degrees Celsius), which is almost as hot as the sun, while pressures are over 3 million times the air pressure you feel when standing at sea level.

Scientists think the inner core spins slightly faster than Earth itself.



## FUN FACT

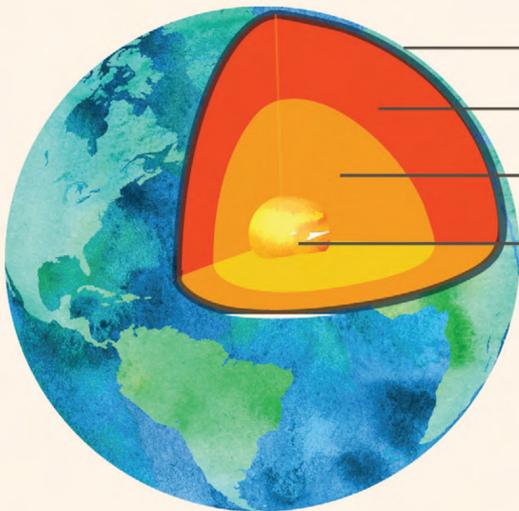
YOU WOULD IMMEDIATELY VAPORIZE IN THE EARTH'S INNER CORE.

# LAYERS OF THE EARTH

As you conclude your voyage to the center of the planet, you might be thinking about how each layer tells a different part of Earth's history, spanning 4.5 billion years.

**NOW YOU KNOW MORE ABOUT WHAT LIES  
BENEATH YOUR FEET.**

Challenge yourself with this quiz to see what you learned.  
Can you name each one of Earth's layers?



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BY FILLING IN THE APPROPRIATE LAYER OF THE EARTH.

THE ..... IS MADE OF MOLTEN MAGMA.

THE ..... IS WHERE WE LIVE, AND WHERE THE CONTINENTS AND OCEANS ARE.

THE INTERACTION BETWEEN THE ..... AND ..... CREATES EARTH'S MAGNETIC FIELD.

THE ..... IS EARTH'S ENGINE ROOM.

THE ..... IS A SOLID METAL BALL.

MOST GEMSTONES FORM IN THE EARTH'S .....

THE PLANET'S THIN, ROCKY OUTER SKIN, IS CALLED THE .....

MOST OF THE EARTH'S VOLUME IS CONTAINED IN THE .....

THE ..... IS A SPHERE MADE OF SOLID IRON.

# EARTH'S LAYERS

## WORD SEARCH

N M T Y Z W O X M E D F X Z X  
H T R A E N V A T X I I R O N  
U K A J S A G Q N S A O W X J  
L L I R D M E E L E M D Q I Z  
M Q L M A K N A W L O J J H J  
J M B B M V D L G O N E E N M  
E R O C R E T U O N D G R Z R  
C R U S T N K B A K A U O M W  
X C D S W C W C Q E C P C A B  
W H M X O L P Z R R G A R N R  
J K J R R T M Q K C Y Q E T J  
T E C T O N I C M C N X N L O  
G M I V B K O E H G U M N E O  
B Q P R R F O T R W B G I F T  
D Z O Y B V O T Q N M B O E E

CRUST

DIAMOND

DRILL

EARTH

INNER CORE

IRON

MAGMA

MANTLE

OUTER CORE

PANGAEA

ROCK

TECTONIC



# NOTES

A large, vertically oriented rectangular area with a cream-colored background and a torn, deckled edge. It contains 18 horizontal black lines, providing a space for writing notes.



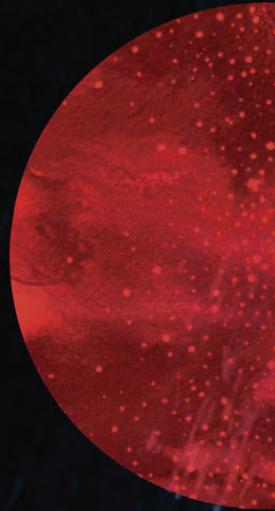
# NOTES

A large, vertically oriented rectangular area with a white background and a torn, ragged edge. It contains 18 horizontal black lines, providing a space for writing notes.



Quiz #1:  
crust, mantle, outer core, inner core

Quiz #2:  
mantle, crust, inner core/outer core,  
inner core, inner core, crust, crust,  
mantle, inner core



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