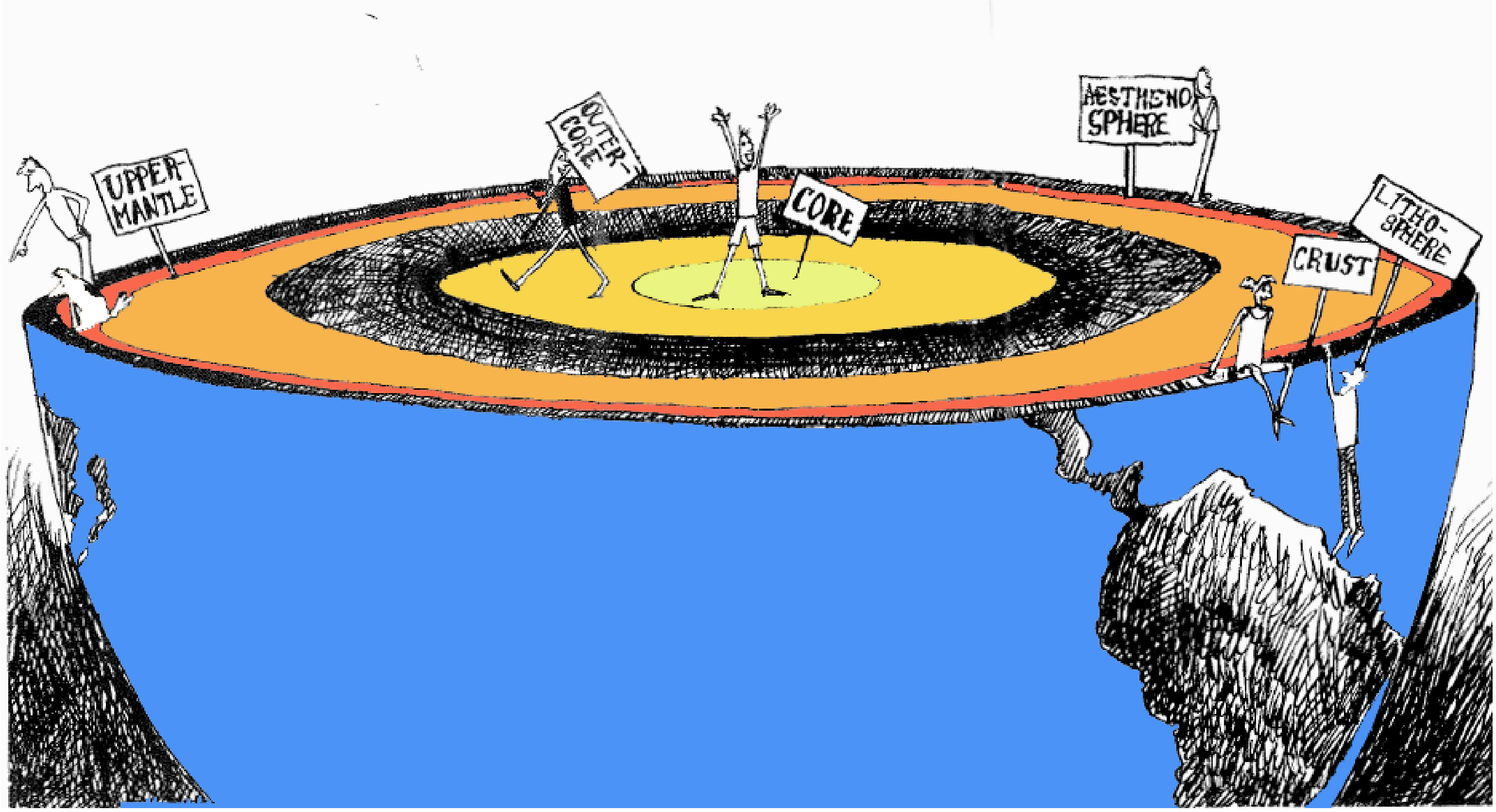
A hands-on and feet-on lesson of Earth's interior structures.

By Eric Muller

Original article is from September 1995 issue of "The Science Teacher"

EARTH WALK

Touring our planet's inner structure



WHEN THE WEATHER IS NICE, I like to take my students on walks of science. These are hands-on, feet-on activities that get people outdoors, moving, and learning.

One walk I recently developed is called "Earth Walk." This excursion effectively helps students visualize our planet's immense size and numerous structures without the usual scale and ratio distortions found in most textbooks. It also allows students to compare their body's height to a scaled-down Earth.

The Earth can be scaled to any convenient ratio you wish to walk. I prefer a stroll of 1 km, but if time or space is limited, a 100-m walk works just fine and can be done on a school's football field. The equation to determine the scaled thickness of each of the Earth's internal layers is a simple proportion based on a planetary radius of approximately 6400 km:

$$\frac{\text{Thickness of layer in km}}{6400\text{ km}} = \frac{x\text{ m}}{1000\text{ m}} \text{ or } \frac{x\text{ m}}{100\text{ m}}$$

The Earth Walk requires a piece of chalk, a 1-km (or 100-m) straightaway, a tape measure, and a good imagination. I highly recommend pacing off your distances because this activity is based on ratios and approximations—extreme accuracy should not be a major concern. To determine the length of an average pace, have students walk 10 paces, measure the total distance traveled, and divide by 10.

Before beginning, it might help to set the following scenario:

Imagine the Earth has been reduced in size 6400 times (or 64,000 times if walking 100 m) and sliced in half by an enormous knife. You and your classmates somehow survived and have landed directly in the center of one of the exposed cross-sections. By walking outward from the center, you will be able to see the various layers that comprise the Earth's internal structure.

Now that the situation has been set, you can take your first steps. Any straight direction you proceed is away from the center of the Earth and is a linear path out toward the crust. As you walk along this radius, have students pace off the scaled distance for each layer of the Earth's internal structure. (See Figure 1 for the appropriate distances.)

TALKING THE WALK

During the walk, it helps to describe the characteristics of each layer. The Earth's *inner core* is a sphere that

BY ERIC P. MULLER

FIGURE 1.

Table of scaled distances.

Layer	Distance from surface (approximate upper and lower limits)	Average approximate thickness	Approximate scaled thickness for 1-km walk	Approximate scaled thickness 100-m walk
Inner core	6400-5200 km	1200 km	190 m	19 m
Outer core	5200-2900 km	2300 km	360 m	36 m
Lower mantle	2900-700 km	2200 km	340 m	34 m
Upper mantle (including asthenosphere and lithosphere)	700-6 km	700 km	109 m	10.9 m
Asthenosphere	225-125 km	100 km	16 m	1.6 m
Lithosphere	125-0 km	125 km	19.5 m	1.95 m
Crust (outer lithosphere)	35-0 km	35 km	5.5 m	0.55 m
Totals	———	6400 km	1000 m	100 m

extends about 1200 km from the center of the Earth. Even though the temperature of the inner core is estimated to be as hot as the Sun's surface (8000° to 10 000°C), enormous pressures keep the core in a solid state. (The surrounding layers of the Earth cause pressures at the core in excess of 3 to 4 million atmospheres.) This solid core is believed to consist primarily of iron and nickel.

The *outer core*, like the inner core, is also composed primarily of iron and nickel, but unlike the inner core, the outer core is thought to be a shell of liquid metal. The fluid motions of this metallic region are thought to be the origin of the Earth's magnetic field.

The next layer, the *mantle* is approximately 2900 km thick and extends from the top of the inner core to the bottom of the Earth's crust. Composed of hot, dense rock, the mantle constitutes the majority of the Earth's volume. The main components of this rock in order of abundance are silicon, oxygen, iron, and magnesium.

The section closest to the core is the *lower mantle*. The interface between the core and the mantle is as pronounced as the interface between the Earth's surface and the atmosphere. Rock at this depth is under substantial pressure and is relatively solid—30 to 100 times the viscosity of the upper mantle.

Above the lower mantle is the *upper mantle*. The pressure and heat in this zone allows molten rock to slowly flow in what is known as a plastic manner. Convection currents cause molten rock to rise, cool, and sink in this layer. These currents are believed to be the driving mechanism for plate tectonics. At the top of the upper mantle is an important layer known as the *asthenosphere*, an area of viscous rock that enables the lithospheric plates above to slide around.

Riding over the top of the asthenosphere is the *lithosphere*. This layer consists of huge plates that migrate over the surface of the globe. The lower portion of this layer, though solid, is still considered part of the mantle. Firmly joined above this lower portion of plate is the layer we live on, the *crust*. The crust is the thinnest, brittlest, and most buoyant of all the layers. During this portion of your talk, it is helpful to have an apple in your hand. When discussing the ratio of average crustal thickness to the planet's size, point out that the crust is actually thinner in comparison than an apple peel is to an apple. At this point, cut the apple for effect.

As you progress farther outward, you finally reach the surface of the crust. At this point, draw a line on the ground with your chalk. This line represents the crust on your 1:6400 scale Earth. Have each student place one grain of sand on the line and tell them that the sand represents their height.

Arrange students and/or the scaled objects listed in Figure 2 at various distances above and below the line, such as 5.5 m below to indicate the bottom of the crust, 2.3 m below to show humankind's deepest subterranean probing (a Russian research bore hole), 6.9 cm above to

FIGURE 2.

Depth and height of various objects and locations from the Earth's surface.

Object or location	Actual height	Height or depth scaled for 1-km walk	Height or depth scaled for 100-m walk	Representative object for 1-km walk	Representative object for 100-m walk
Deepest drill hole (Russia)	-15 km	-2.3 m	-23 cm	—	—
Mariana Trench	-11 km	-1.7 m	-17 cm	—	—
Deepest mine (South Africa)	-3.8 km	-0.6 m	-6 cm	—	—
YOU	1.77 m	0.3 mm	0.03 mm	small sand grain	dust speck
Tallest building (Sears Tower, Chicago)	443 m	6.9 cm	6.9 mm	small stick	pine needle
Tallest mountain (Mt. Everest) 1	8.85 km	1.4 m	14 cm	—	—
Space shuttle's average orbital height	200 km	31 m	3.1 m	small gravel (0.4 cm)	sand grain (0.4 mm)
Moon's distance from Earth	384 000 km	60 km	6 km	—	—

1. The Earth is not a perfect sphere. Because the Earth bulges at the equator, Chimborazo (6.31 km) could be considered the tallest mountain because its summit is about 2.2 km farther from the center of the Earth.

reference the Sears Tower, 1.4 m above to demonstrate the lofty heights of Mount Everest, or 31 m above to show where the space shuttle orbits (see Figure 2 for other size comparisons). This is a great way to illustrate the relative depths and heights of layers and objects with respect to the Earth's thin crust.

OTHER WALKS

A great walk to do when studying our local group of planets is the solar system walk (see "A Stroll through the Solar System," *Science Scope*, Kenneth M. Uslabar, Oct 93: 41–43). This is a very popular walk that takes an interplanetary journey over several kilometers. Beach balls, marbles, and pin heads can be used as props to compare relative planetary sizes and orbital distances.

The Earth's geologic time scale can also be demonstrated via walking. A relation can be made between the immense time span of the Earth and a school's running track. Eras, epochs, and significant evolutionary events can be pointed out by designating spots along a track's perimeter to represent points in time. Numerous fun and pedagogically useful walks can be concocted to convey a variety of facts and concepts. Take a step in the right direction and create your own walks of science. ✧

Eric P. Muller is an H. Dudley Wright Fellow at the Wright Center for Innovation in Science Education at Tufts University, 4 Colby St., Medford, MA 02155.

ACKNOWLEDGMENT

I would like to thank The Wright Center for allowing me the time and support to write this article. The Wright Center can be accessed via the World Wide Web through the Tufts University Departmental home page (http://library.tufts.edu/www/mcdonald/tuftsacprog.html).

FOR FURTHER READING

Most Earth science and geology textbooks contain a lot of information about the interior of the Earth. However, since discoveries and modifications of theories related to the Earth's interior are constantly being updated and published, periodicals are a better source of current information. Almanacs and record books are also great resources. However, you may find subtle, yet conflicting data in these publications. I found the following articles particularly useful:

Doherty, P. 1994. Journey to the Center of the Earth. *The Exploratorium Exploring* series-*Underground*. Fall 1994.

Green, H.W. II. 1994. Solving the Paradox of Deep Earthquakes. *Scientific American*. 271(3): 64.

Larson, R.L. 1995. The Mid-Cretaceous Superplume Episode. *Scientific American*. 272(2): 82.

Wysession, M. 1995. The Inner Workings of the Earth. *American Scientist*. 83(2): 134.

Earth Walk Addendum

For 100 meter scaled Ear

More Facts about Earthly depths and heights:

	Approximate Height or depth (in Km)	Scaled to 100m (in m)
Crust - Oceanic	~6.5	.10
Moon's Radius compared to a 100 m earth	1750	27
Height of atmosphere with less than .1 % sea level air pressure	50	.8
Average ocean depth	-3.8	.06

Circumference related facts for a 100 m radius scaled planet:

	Distance (in Km)	Scaled to 100m (in m)
One Kilometer	64	1
Earth Circumference	40, 075	626
Shanghai to San Francisco	10,238	160
San Francisco to New York	4,200	66
New York to London	5,700	89
Across the state of Rhode Island	~40	.6

Another interesting fact:

The entire surface area of the city and county of San Francisco, ~120 sq. km [45 sq. mi.], would be a little larger then the palms of your hands held together.