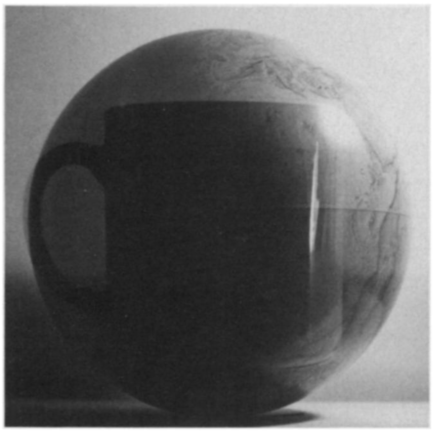
Planetary Coffee

Take a five-minute break inside the Earth


Monastersky

By RICHARD MONASTERSKY

When geophysicist Peter Olson stares into his morning cup of coffee, he sees clear down into the blistering bowels of the planet. It doesn't require bionic vision, just a little insight into the currents of rock oozing beneath Earth's outer shell. You, too, can take a geophysical coffee break in the planet's interior. Just follow these simple instructions.

First, clear your desk and prepare for a scientific experiment. You needn't don a lab coat, although some paper towels could come in handy. Calculator and pocket protector are not necessary.

Assemble the experimental apparatus: a fresh cup of joe and some cream (or milk for the cholesterol-conscious). Don't even think of reaching for that jar of chalky powder; only a liquid creamer will do.

If your supervisor walks by with raised eyebrows, make it known you're conducting a simulation of the utmost importance to understanding the Earth's deep interior. Better yet, put a sign on your door: "Experiment in Progress: Do Not Disturb."

The mug of hot coffee will serve as an analog for the mantle – the great rocky layer that makes up some two-thirds of our planet's mass. Measuring more than 2,800 kilometers thick, the mantle extends from the iron core to within about 30 km of Earth's surface. Rock in this layer remains solid, but it can "creep" because of its extremely high temperatures, registering several thousand degrees centigrade. Over the vast spans of geologic time, the rock actually flows.

This is where the coffee enters the story. A mug of hot liquid resembles the mantle because both stir themselves by a process called convection. As heat escapes at the top of the mug, the upper layer of coffee cools and grows denser, sinking toward the bottom in sheets. The descending currents force warmer liquid to rise.

Convection also occurs in a boiling pot of chicken soup, but it follows a different pattern – one driven by ascending flow. The soup roils in this way because it absorbs heat from the underlying stove, which causes liquid at the bottom of the pot to become warm and buoyant.

The mantle, in contrast, warms mostly from within. Geophysicists estimate that some 80 percent of its heat comes from the decay of radioactive elements distributed throughout the mantle layer. The remaining fraction of heat comes from the core below. At the top of the mantle, heat escapes upward through the tectonic plates that form a thin, broken shell encasing the mantle. These plates continuously rearrange their positions on the surface, bumping and grinding against each other with Earth-shaking consequences.

Although office brew may taste like toxic slurry from the nearest chemical plant, it doesn't have radioactive elements to heat it from within. But because coffee loses heat at its surface, its convection patterns roughly mimic motion in the mantle, says Olson, who conducts convection experiments in oil-filled tanks at Johns Hopkins University in Baltimore.

Armed with that introduction, you're ready to begin your own experiment. Gently pour a bit of cream into the hot coffee and watch closely as the white streams disappear into the depths, then reemerge as chocolate-colored clouds that blossom toward the surface. You might add a little more cream, but resist the temptation to dip a spoon into the cup, or you'll get a uniformly tan liquid that, though tasty, offers little geophysical insight. And don't drink just yet.

Initially, the cream forms swirls and eddies that spin across the surface in a free-form ballet. Then the action settles down and the real show begins as the liquid surface organizes into small blocky segments bounded by dark lines. These lines indicate where currents of cooler coffee crash together head-on, forming liquid sheets that descend toward the bottom of the cup. The cold "sinkers" dominate the coffee convection, forcing liquid aside and causing clouds to rise to the surface.

Now, interpret the data to see whether they reveal anything about the inner Earth. Think about the "Ring of Fire," the chain of volcanoes rimming the Pacific Ocean. These fire-spewing mountains – which include Mount St. Helens in Washington state and Krakatoa in Indonesia – mark places where sheets of cold ocean floor sink into the hot mantle, a process called subduction.

Volcanoes grow over subduction zones because some of the oceanic rock melts as it plows down into the hot mantle, causing molten magma to rise and then erupt at the planet's surface.

In the mug, you have witnessed a miniature imitation of that grand geophysical process. The sheets descending into the coffee depths resemble the seafloor subducting in the mantle.

Olson sees similar sinking features in his internally heated oil tanks, and other researchers have observed the sheet-like downwellings in computer models of convection. These experimentalists conclude that descending sheets are the most important features in the mantle's convection system, providing the engine that powers the movement of tectonic plates across Earth's surface – a continental shuffle that enlarges the gulf between New York and Paris by about 2 centimeters each year.

Of course, java is not lava, and you can carry the mug/mantle analogy only so far. Given that geophysicists have difficulty simulating mantle and plate motion even with complex computer models costing a million dollars, how much can you expect from a 60-cent cup of coffee?

So you might as well take a sip before your desktop model cools completely. Sipping, like stirring, ruins the convection experiment, but it doesn't necessarily end the science lesson. As you remove the cup from your lips, you'll see various shades of brown playing across the coffee surface in a wild and mesmerizing action, providing a glimpse into another scientific realm: the unpredictable world of chaos. □