**Structure of the Earth**

By the 1960s scientists had grown sufficiently frustrated by how little they understood of the Earth’s interior that they decided to try to do something about it. Specifically, they got the idea to drill through the ocean floor (the continental crust was too thick) to the Moho discontinuity and to extract a piece of the Earth’s mantle for examination at leisure. The thinking was that if they could understand the nature of the rocks inside the Earth, they might begin to understand how they interacted, and thus possibly be able to predict earthquakes and other unwelcome events.

The project became known, all but inevitably, as the Mohole and it was pretty well disastrous. The hope was to lower a drill through 14, 000 feet of Pacific Ocean water off the coast of Mexico and drill some 17, 000 feet through relatively thin crustal rock. Drilling from a ship in open waters is, in the words of one oceanographer, “like trying to drill a hole in the sidewalks of New York from atop the Empire State Building using a strand of spaghetti.” Every attempt ended in failure. The deepest they penetrated was only about 600 feet. The Mohole became known as the No Hole. In 1966, exasperated with ever-rising costs and no results, the US Congress killed the project.

Four years later, Soviet scientists decided to try their luck on dry land. They chose a spot on Russia’s Kola Peninsula, near the Finnish border, and set to work with the hope of drilling to a depth of fifteen kilometers. The work proved harder than expected, but the Soviets were commendably persistent. When at last they gave up, nineteen years later, they had drilled to a depth of 12,262 meters, or about 12.2 kilometers. Bearing in mind that the crust of the Earth represents only about 0.3 percent of the planet’s volume and that the Kola hole had not cut even one-third of the way through the crust, we can hardly claim to have conquered the interior.

Interestingly, even though the hole was modest, nearly everything about it was surprising. Seismic wave studies had led the scientists to predict, and pretty confidently, that they would encounter sedimentary rock to a depth of 4,700 meters, followed by granite for the next 2,300 meters and basalt from there on down. In the event, the sedimentary layer was 50 percent deeper than expected and the basaltic layer was never found at all. Moreover, the world down there was far warmer than anyone had expected, with a temperature at 10,000 meters of 180 degrees centigrade, nearly twice the forecasted level. Most surprising of all was that the rock at that depth was saturated with water—something that had not been thought possible.

So how much do we know about what’s inside the Earth? Very little. ***Scientists are generally agreed that the world beneath us is composed of four layers—rocky outer crust, a mantle of hot, viscous rock, a liquid outer core, and a solid inner core***. We know that the surface is dominated by silicates, which are relatively light and not heavy enough to account for the planet’s overall density. Therefore there must be heavier stuff inside. We know that to generate our magnetic field somewhere in the interior there must be a concentrated belt of metallic elements in a liquid state. That much is universally agreed upon. Almost everything beyond that—how the layers interact, what causes them to behave in the way they do, what they will do at any time in the future—is a matter of at least some uncertainty, and generally quite a lot of uncertainty.

Even the one part of it we can see, the crust, is a matter of some fairly strident debate. Nearly all geology texts tell you that continental crust is 5 to 10 kilometers thick under the oceans, about forty kilometers thick under the continents, and sixty-five to one hundred kilometers thick under big mountain chains, but there are many puzzling variability’s within these generalizations. The crust beneath the Sierra Nevada Mountains, for instance, is only about nineteen to forty kilometers thick, and no one knows why. By all the laws of geophysics the Sierra Nevada’s should be sinking, as if into quicksand. (Some people think they may be.)

Beneath the crust we plunge into pure mantle. Considering that it accounts for 82 percent of the Earth’s volume and 65 percent of its mass, the mantle doesn’t attract a great deal of attention, largely because the things that interest Earth scientists and general readers alike happen either deeper down (as with magnetism) or nearer the surface (as with earthquakes). We know that to a depth of about 160 kilometers the mantle consists predominantly of a type of rock known as peridotite, but what fills the space beyond is uncertain.

Beneath the mantle are the two cores—a solid inner core and a liquid outer one. Needless to say, our understanding of the nature of these cores is indirect, but scientists can make some reasonable assumptions. They know that the pressures at the center of the Earth are sufficiently high—something over three million times those found at the surface—to turn any rock there solid. They also know from Earth’s history (among other clues) that the inner core is very good at retaining its heat. Although it is little more than a guess, it is thought that in over four billion years the temperature at the core has fallen by no more than 90°C. No one knows exactly how hot the Earth’s core is, but estimates range from something over 4,000°C to 7,200°C—about as hot as the surface of the Sun.

The outer core is in many ways even less well understood, though everyone is in agreement that it is fluid and that it is the seat of magnetism. The theory was put forward by E. C. Bullard of Cambridge University in 1949 that this fluid part of the Earth’s core revolves in a way that makes it, in effect, an electrical motor, creating the Earth’s magnetic field. The assumption is that the convecting fluids in the Earth act somehow like the currents in wires. Exactly what happens isn’t known, but it is felt pretty certain that it is connected with the core spinning and with its being liquid. Bodies that don’t have a liquid core—the Moon and Mars, for instance—don’t have magnetism.

We know that Earth’s magnetic field changes in power from time to time: during the age of the dinosaurs, it was up to three times as strong as now. We also know that it reverses itself every 500,000 years or so on average, though that average hides a huge degree of unpredictability. The last reversal was about 750,000 years ago. Sometimes it stays put for millions of years—37 million years appears to be the longest stretch—and at other times it has reversed after as little as 20,000 years. Altogether in the last 100 million years it has reversed itself about two hundred times, and we don’t have any real idea why. It has been called “***the greatest unanswered question in the geological sciences***.”

We may be going through a reversal now. The Earth’s magnetic field has diminished by perhaps as much as 6 percent in the last century alone. Any diminution in magnetism is likely to be bad news, because magnetism, apart from holding notes to refrigerators and keeping our compasses pointing the right way, plays a vital role in keeping us alive. Space is full of dangerous cosmic rays that in the absence of magnetic protection would tear through our bodies, leaving much of our DNA in useless tatters. When the magnetic field is working, these rays are safely herded away from the Earth’s surface and into two zones in near space called the Van Allen belts. They also interact with particles in the upper atmosphere to create the bewitching veils of light known as the auroras.

A big part of the reason for our ignorance, interestingly enough, is that traditionally there has been little effort to coordinate what’s happening on top of the Earth with what’s going on inside. According to Shawna Vogel: “Geologists and geophysicists rarely go to the same meetings or collaborate on the same problems.”

Perhaps nothing better demonstrates our inadequate grasp of the dynamics of the Earth’s interior than how badly we are caught out when it acts up, and it would be hard to come up with a more salutary reminder of the limitations of our understanding than the eruption of Mount St. Helens in Washington in 1980.