MANTLE CONVECTION CELLS

New tools and techniques reveal the inner workings of our planet

Poets and philosophers have celebrated the timelessness of the land around us for eons, but the solid Earth is actually a very dynamic body. Great tectonic plates are in constant motion at Earth's surface.

Earthquakes and volcanic eruptions are manifestations of these movements on human time scales. But over millions of years, the movements of Earth's tectonic plates rearrange the face of the Earth. They cause continents to rift and drift, creating entirely new ocean basins. Collisions between plates squeeze ancient oceans until they disappear and produce majestic mountain ranges such as the Alps and Himalayas.

Like an auto mechanic who has to look "under the hood" to see the engine that powers your car, geologists need to look deep within Earth's interior to understand the tremendous underlying forces that build and shape Earth's surface. We are now beginning to comprehend and describe the role that the Earth's mantle plays in driving changes on the planet we live on.

Hot, flowing rocks

Earth's mantle is the solid, rocky interior of our planet that extends from the base of the crust all the way down to Earth's core, about 2,900 kilometers (1,800 miles) below the surface. Although they are solid, the rocks in Earth's mantle can deform and flow by viscous creep over long time periods. At first glance, this might seem odd; after all, the rocks we find on Earths surface are cold and brittle, and they fracture or break if they are deformed. On a large scale, this same process causes earthquakes.

But as any blacksmith knows, when a hard, brittle material like iron is heated to a temperature just below its melting point, it becomes malleable. Similarly, given enough time, at the high temperatures and pressures found within Earths interior, mantle rocks can deform and flow like a slowly moving fluid, even though they would appear solid to us. (See "Peering into the Crystal

Fabric of Rocks," page 57.) These movements are gradual in human terms (a few centimeters a year), but over a hundred million years, mantle rocks can move thousands of kilometers.

The energy that drives this movement is heat within the Earth, which comes from two main sources. One is the residual heat left over from the formation of our planet 4.6 billion years ago. The radioactive decay of naturally occurring chemical elements in the Earth-most notably uranium, thorium, and potassium-also releases energy in the form of heat.

These two sources of heat warm Earth's mantle and cause it to rise and sink, much like soup in a pot on a stove. Material heated from below gets hotter and rises. It reaches the surface, releases its heat, becomes colder and denser, and sinks again.

Ocean trenches and ridges

The motion of tectonic plates, and all of their associated volcanic and earthquake activity, are believed to be the surface manifestation of similar thermal convection occurring in Earths mantle. The rigid outer layer of our planet, called the lithosphere, is the cold, top boundary of convection cells in the mantle. Two features of the ocean floor are the results of this active process.

At ocean trenches, old, cold, and dense lithosphere sinks back into the hotter mantle below, dragging surface plates along with it. The continents are carried along by these moving surface plates, producing the continental drift that, for instance, rifted and separated Africa and South America.

Beneath ocean spreading centers, two plates are moving apart. Hot, buoyant, solid mantle flows upward. It begins to melt as it reaches shallower areas where pressures are lower. That leads to volcanic activity that forms new ocean crust along the great mid-ocean ridge system.

In addition to this plate-scale flow, plumes of hot material can rise at various places from within the convecting mantle to form ocean island volcanoes or "hot-spots" such as Hawaii.