**What is the “Moho”? Who Discovered It?**

**What are the Outermost Layers of the Earth?**

How do scientists *know* that there is a boundary called the Moho that separates Earth’s thin crust from the upper mantle? First a little history on one of the greatest contributors to seismology from the early 1900s.

Andrija Mohorovičić was born in Croatia in 1857 and was trained in mathematics and physics. In 1892, while working on his PhD dissertation in meteorology at the University of Zagreb on the study of clouds, he became director of the Zagreb Meteorological Observatory. The following year he became an associate professor of astronomy and geophysics.

*At this time, most scientists believed that the interior of Earth, though hotter inside, has a fairly uniform composition*. As seismometers became widespread, new models were developed. In 1897, German geophysicist Emil Wiechert invented the first seismometer using viscous damping, capable of capturing not just the initial jolt, but a much more useful written recording of earthquake-ground-shaking from worldwide earthquakes. He used these to infer that Earth is layered, comprising a silicate shell surrounding a heavy iron core. This surely intrigued the physicist in Mohorovičić.

By the turn of the century, Mohorovičić had come to the conclusion that it would take about 1000 years of observation to gather enough meteorological data to develop reliable information about the climate, whereas he could make more immediate contributions in the expanding field of seismology. In 1901, he obtained his first horizontal-motion seismograph and the Zagreb (ZAG) seismological station was founded.

Five years later, Mohorovičić talked a colleague into lending him a vertical-component seismograph. It was installed in the basement of the Institute in 1906 and recorded the great San Francisco earthquake of that year. Unsatisfied with the instrument’s performance, compared to the ground motion recorded by Wiechert, Mohorovičić ordered two Wiechert *horizontal* ground motion instruments to be installed at the Zagreb station in 1908 and the second in 1909, fortuitously capturing the Kupa Valley earthquake that struck in October of that year, just 40 km south of Zagreb. The data from this event completely engrossed him.

Curious about the seismograms produced by his two stations, and wanting to study the earthquake in more detail, Mohorovičić asked colleagues all over Europe to send him their seismograms. He received data from 41 stations. As he studied the data, he was puzzled. If the outer layer of the Earth was uniform in composition, he expected the arrivals of the seismic waves to reach distant seismographs at predictable times for the fast compressional P and slower shearing S waves. What he found, however, was that some signals reached seismographs faster than he had thought possible. And some seismographs recorded two different P and S waves that traveled at different speeds. The only way to explain the waves with different speeds was to hypothesize a boundary in the Earth structure deep below the surface.

Snells Law had taught him that as waves strike a boundary between materials with different physical properties, they are reflected or refracted, as light is when striking a prism or water. When seismic waves strike a material with faster velocity at a critical angle, they refract to travel along the boundary between the two layers at the velocity of the lower, faster layer, while sending a series of rays, known collectively as the head wave, back to the surface at the critical angle.

When he combined all of the measured seismic arrival times for this earthquake with earthquake data from previous years,.Mohorovičić noticed that P waves travelling to distant seismometers actually reached those stations before the direct wave traveling a shorter path in the upper layer.  This observation requires a deeper layer that transmits seismic waves faster. Assuming that the lower layer was flat, he calculated the seismic velocities for the direct P waves and the faster velocity, called Pn, for a lower layer. The initials Pn stand for P-normal, meaning Mohorovičić believed that the lower, faster layer was the normal, meaning universal for the Earth.

He had enough data to conclude that the upper 100 km of Earth is not a uniform medium as was previously thought, but that, at a certain depth, there was a sharp increase in seismic velocity.

He was the first to establish the concept that this relatively sharp boundary separates the mantle from an overlying crust of different composition and physical properties. This boundary was called the Mohorovičić discontinuity, now often referred to simply as the Moho. From his data, he estimated the thickness of the upper layer (crust) to be 54 km.

Subsequent studies across the globe would confirm the existence of the Moho under all continents and oceans, although it isn’t always simple.

Rather than regarding the Moho as the base of a homogeneous crustal layer, it is better to view it as a zone where velocities increase rapidly to values above about 7.7 km/sec

Regardless, the Moho is recognized as the boundary zone between Earth's crust and the mantle.

Locating the Moho has helped us understand that basaltic oceanic crust is remarkably uniform in thickness at five to eight km thick, and that continental crust, with an average thickness of 40 km, varies greatly from 70 km thick beneath major mountain systems like the Himalaya where compressional tectonics has stacked wedges of crust on top of one another to only 25 km thick in rift zones (such as the Basin & Range Province where crust has been thinned by extension). Although 70 km sounds thick, the crust is just a thin shell on the outside of the Earth, accounting for less than 1% of Earth's volume. The mantle, sandwiched between the crust and core, is considered to be of fairly uniform high-iron and –magnesium silicate throughout.

The physical *cause* of this abrupt increase in seismic-wave velocity at the Moho is still a topic of continuing research and debate. It is most commonly attributed to a change in rock composition based on rare locations where the Moho has been pushed up and exposed at the Earth’s surface. Locally, where the crust is very thick (70 km), the Moho could also be a phase change within rock whose bulk composition is approximately the same above and below the discontinuity.

The Moho isn’t he only boundary within the Earth. The Moho and the attached lithosphere below is underlain by the relatively weak, ductile layer known as the asthenosphere. Although the presence of the asthenosphere within the mantle was suspected as early as 1926, *its* presence wasn’t confirmed until analyses of seismic waves from the M9.5 Great Chilean earthquake of 1960 indicated a universal seismic slow zone approximately 80 to 200 km (50 to 120 mi) below the surface. The existence of a weak, ductile layer under the rigid lithosphere proved to be an important clue in the Plate-tectonics puzzle about how lithospheric plates are able to move across Earth's surface.

Andrija Mohorovičić wrote: “The goal of seismology is to study the interior of the Earth, and to continue where the geologist stops; it has in modern seismographs a sort of binoculars that enables us to look into the largest of depths